CDM

SALT-GILA INTERIM FLOOD CONTROL WORKS

HOLLY ACRES AREA

DRAFT FINAL REPORT

Camp Dresser & McKee

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For

Flood Control District
of Maricopa County, Arizona

By

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Walnut Creek, CA

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

BACKGROUND AND AUTHORIZATION

In February-March 1978, December 1978-January 1979 and again in February of 1980, major flooding occurred along the Salt and Gila Rivers in and around Phoenix in Maricopa County, Arizona (see Figure 1). The residential subdivision called Holly Acres and the surrounding area suffered heavy damage as a result of these floods.

In April of 1980, the Arizona Legislature passed Senate Bill 1163, which appropriated funds to several agencies to study and construct flood control projects throughout the State. The Bill also established the Holly Acres Flood Relief Commission for the purpose of evaluating the feasibility of different alternatives for providing flood control along the Salt and Gila Rivers between 91st Avenue and the Agua Fria River. This reach, bounded on the north by Broadway Road and on the south by Baseline Road, is considered to be the Holly Acres area (see Figures 1 and 2). It covers approximately twelve square miles, most of which is irrigated farmlands. Residential acreage is mostly concentrated in five major subdivisions, one of which is the Holly Acres subdivision. There are approximately 400 total residential units in the area, with a population of approximately 1,500 people.

The Final Report of the Holly Acres Flood Relief Commission was released in July, 1980. This report presents a more detailed description of the area and the historical damages due to flooding than is included above. Several possible programs to provide structural and non-structural flood control measures were reviewed and their applicability to the Holly Acres area was assessed by the Commission. The programs considered were the Corps of Engineers' Central Arizona Water Control Study or Small Projects Authority,

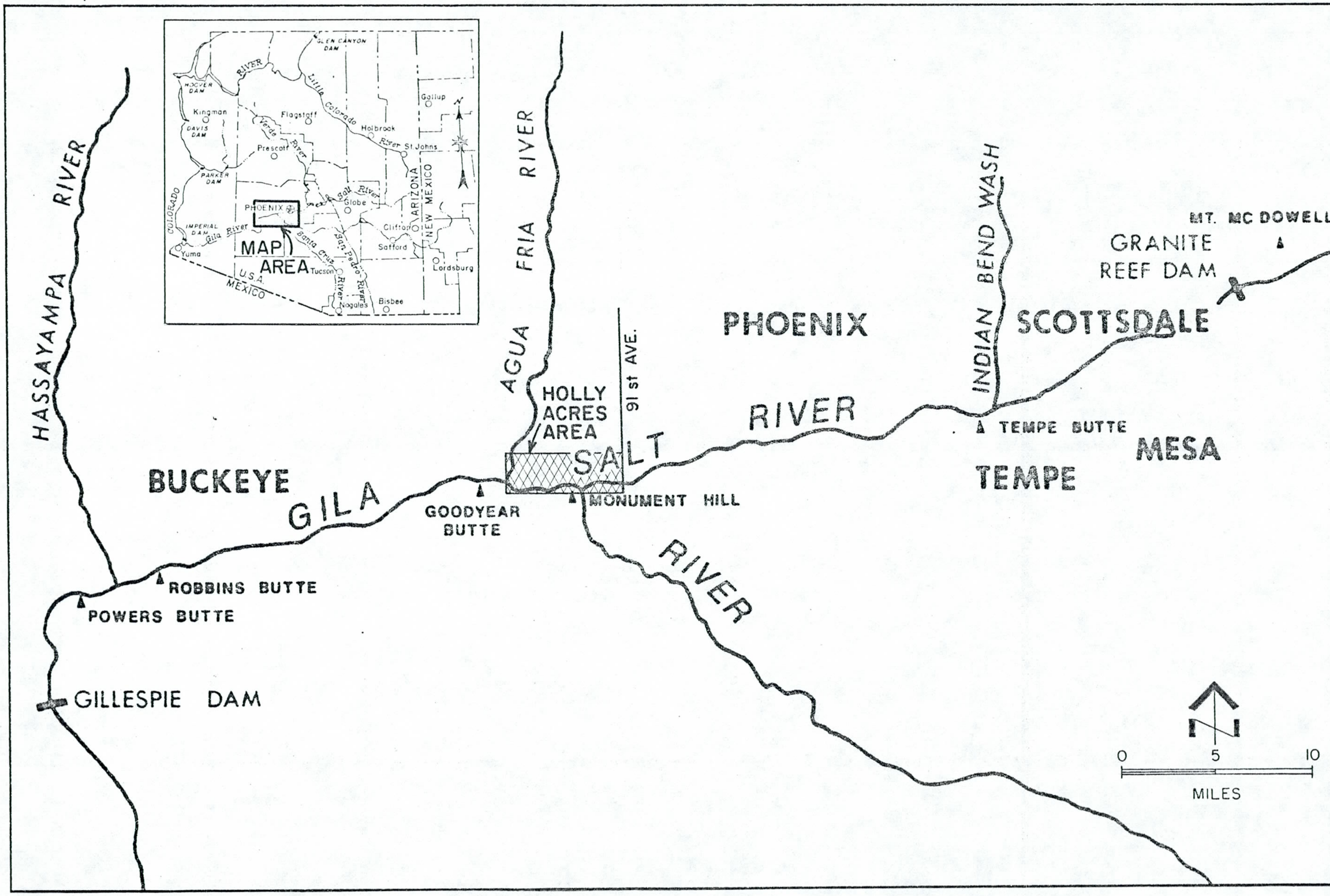

FIGURE 1

HOLLY ACRES AREA LOCATION MAP

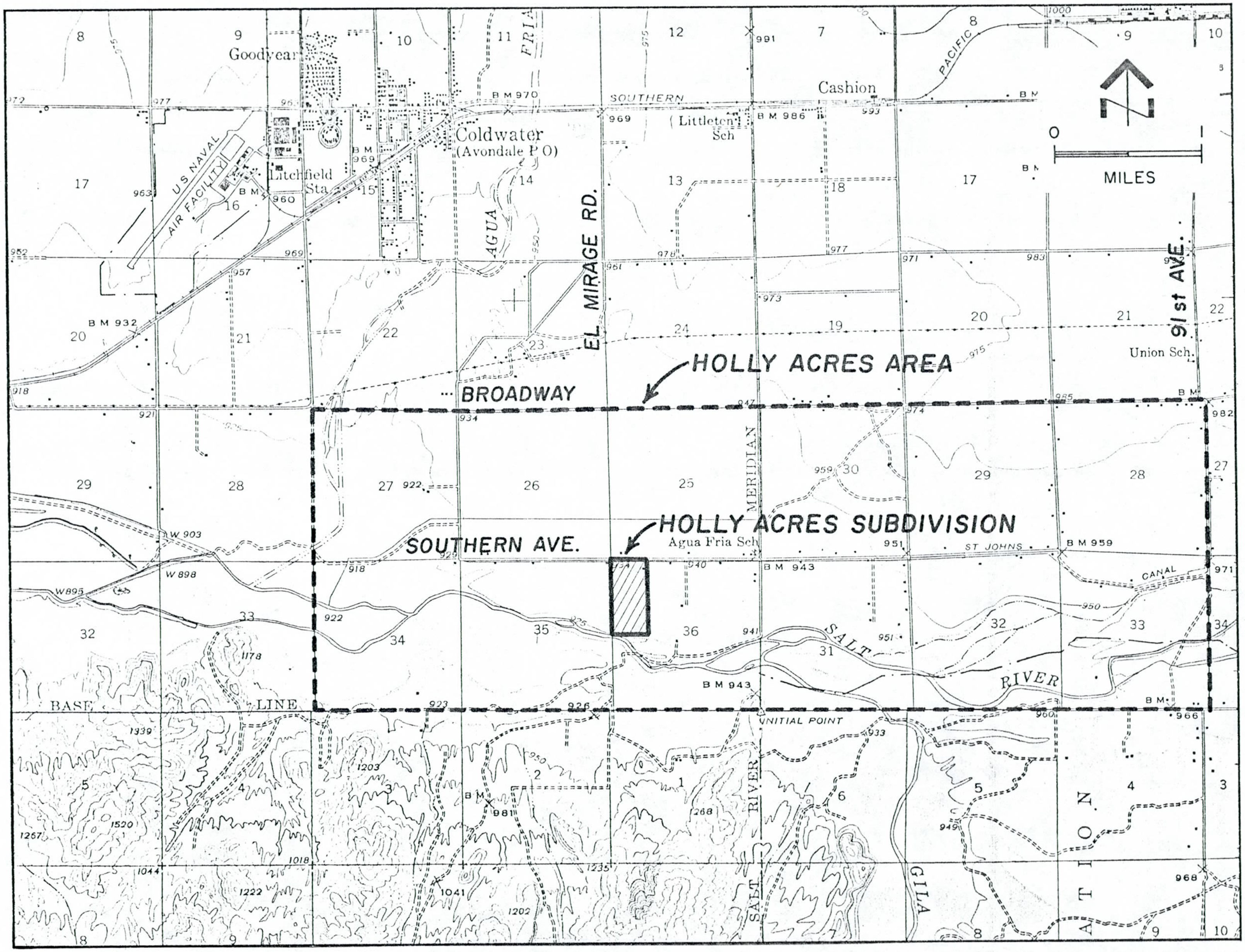

FIGURE 2

HOLLY ACRES AREA SITE MAP

the Flood Control District of Maricopa County's Salt-Gila River Clearing Project, the Arizona Department of Water Resources Alternative Flood Control Assistance Program, and relocation programs administered by the State government and coordinated by the Arizona Division of Emergency Services.

The major findings of the Commission were that relocation was not appropriate until it can be determined that there is no possibility of structural protection for the area. The Commission held that structural solutions should be studied with reference to the Arizona Alternative Flood Control Assistance Program. By law, this study must be performed by the Flood Control District of Maricopa County. The Commission therefore entered into an inter-governmental agreement with the Flood Control District and provided funds for such a study from their own allocation. This report presents the preliminary results of that study.

SCOPE OF STUDY

This report presents the preliminary results of a study of alternative structural flood control measures for the Holly Acres area. The study consisted of data collection and review (including site inspections and meetings with affected residents), qualitative analysis of flood problems, hydrologic and hydraulic analyses, development of alternative measures, benefit/cost analyses and report preparation. The chapters in this report correspond to the major tasks.

This study of the Holly Acres area is being performed in conjunction with a study of interim flood control measures for several other areas between Holly Acres and Gillespie Dam on the Gila River. Much of the data collected, methodology developed, and analyses performed is applicable to all these areas. This report, however, is specific to work performed for the Holly Acres area.

II. DATA COLLECTION AND REVIEW

A list of data items collected in the study is contained in the Appendix. It includes maps, photographs, reports, documents and numerical data (hydrology, surveys, costs, etc.). In addition, meetings were held with the Holly Acres Flood Control Association (homeowners) and various governmental agencies as noted on the list. A detailed review of this data and the findings from the meetings provided the basis for the qualitative analysis of flood problems as well as raw data for the analysis of hydrology, hydraulics, and economics of potential flood control measures. No new raw data such as surveys, flow measurements, damage surveys, etc. was developed for this study. More detailed discussions of the quality and limitations of the available data are included at appropriate places in this report.

III. QUALITATIVE ANALYSIS OF FLOOD PROBLEMS

This chapter presents a general discussion of the factors that influence flooding in the Holly Acres area. It is based on previous studies of this and other comparable areas, information from locally knowledgeable individuals, and the observations and engineering experience of the authors. It should be noted that some parts of this analysis are are subjective in nature and may be subject to alternative interpretations by others.

The Salt and Gila Rivers are typical of the rivers of the Great Basin geomorphic province of the American Southwest. These rivers are basically dry except during seasonal floods, are marked by high width to depth ratios and are often braided into several channels across their floodplains. The flows in the Salt and Gila Rivers are largely controlled by upstream water conservation dams except during large floods. Therefore, the Rivers tend to be nearly dry all year (or for several years) except for those rare flood periods, at which time the flow is very high. The critical flood events in the study area originate on the Salt River, with the Gila contributing only a small additional flow.

When flooding occurs, flow is initially confined to a meandering low-flow channel that is much narrower than the river. This condition is stable to the extent that this confined flow is capable of transporting its sediment load. As the flow rises, it begins to spread out rapidly across the river in various smaller channels. The flow tends to be concentrated in channels since this allows more sediment to be carried. The flow is concentrated in areas of least resistance, and deposition occurs in areas of higher resistance where velocities are lower. Through a process called channel avulsion, sediment deposition in parts of the river cause the flow to seek new routes, leading to substantial changes in the location of the low-flow channel and in the braiding pattern of the river in the course of one or more floods. This process of continual shifting of the low-flow channels in the Salt and Gila Rivers is well documented by historical aerial photographs.

A factor that further increases the instability of the Salt and Gila Rivers in the study area and downstream therefrom is the presence in the river of phreatophytes (water-loving plants), mostly salt cedar. These plants tend to grow rapidly following a flood and are often concentrated in the low flow channel. The next flood cannot easily flow in the low-flow channel due to the resistance created by the plants. Flow velocities are low, deposition occurs in the low-flow channel, and the flow seeks another location. Areas of phreatophytes may be washed away and new channels scoured out while others are reinforced by deposition at their bases. The instability of the river is thus increased further by the phreatophytes.

In addition to increasing instability, the phreatophytes also have the effect of generally increasing flow resistance. This causes the depth of flow for a given discharge to be higher than it would be in a clear river. This also means that flooding will occur at a lower discharge and more frequently. Once the river banks are topped, flood waters spread out over large areas of the relatively flat floodplain, causing damages to agricultural and residential acreage.

A recently completed study performed by William L. Graf for the Corps of Engineers documents via aerial photos the presence and extent phreatophytes in the study area since 1937. There have been fluctuations over the years, due largely to flood events, but phreatophytes have been widespread throughout this period. A second report by Graf shows that the low-flow channel has been historically very unstable. The low-flow channel has occuppied several different positions in the river over the years 1868 to 1980.

These interesting findings by Graf tend to indicate that the existing phreatophyte coverage and recent low-flow channel shifts are not extraordinary in the historical perspective. Recent flooding problems seem to have only a minor relationship to man-induced changes in the river, such as the discharge of sewage effluent. Structures in the river such as dikes and road crossings were not of sufficient size or strength to substantially influence flood levels in the study area. Trapping in salt cedars of debris washed out of upstream landfills could have increased flow resistance in certain areas enough to raise the flood levels upstream somewhat.

The photograph shown in Figure 3 was taken near the time of peak discharge (170,000 cfs) during the February 1980 flood. This photograph can tell us several things about the flooding in the Holly Acres area. First, we can see that flow first beings to leave the river to cause substantial damages around 103rd Avenue. This point corresponds to a large resistant growth of phreatophytes upstream of the Gila confluence, which constricts the river to a narrow channel and forces much flow into the north overbank. Downstream from the Gila confluence, most of the flow appears to be concentrated on the south side, but dense phreatophytes obstruct much of the channel and force the flow to the north overbank, through fields and the Holly Acres subdivision. Some of the flow is able to return to the river through breaks in the phreatophytes, but some is carried all the way to the Agua Fria River. It is apparent that a good deal of the river is rendered ineffective in transporting flow due to the phreatophytes.

The photograph also shows that St. John's Canal, which runs parallel to and south of Southern Avenue and is elevated above ground level, serves to restrict the flood waters from progressing farther north in several places and provides a good deal of flood protection. Note, however, that the Canal passes under El Mirage Avenue (west side of Holly Acres subdivision) and flow crosses Southern Avenue to flood a limited area. This area is

FIGURE 3

HOLLY ACRES AREA - AERIAL PHOTO OF FEBRUARY 1980 FLOOD drained by an irrigation tailwater ditch running west. Finally, we can see that the south bank of the river is abrupt and there is little development on that side.

These observations of flooding characteristics led to the identification of several alternative flood control measures that will be described in a later chapter. First, however, the hydrologic and hydraulic analyses were performed to quantify the extent and frequency of flooding.

IV. HYDROLOGIC ANALYSIS

The hydrology of the Salt and Gila Rivers has been analyzed several times over the years by different parties. These studies are based on long-term flow gauging records available at Gillespie Dam and Granite Reef Dam (see Figure 2), among others. However, because flows are controlled by upstream dams except during large floods, the historical gauge records must be corrected for the effects of storage behind several dams.

It is generally accepted that the peak flows in the Holly Acres area originate from the Salt River and its largest tributary, the Verde River. The contribution of the Verde River is especially significant since there are no flood control dams on the Verde River, but Roosevelt Dam on the Salt River provides some flood control. The contribution of the Gila River to the flood peaks at Holly Acres is relatively small compared with the Salt River flows.

Figure 4 shows the Flood Frequency Curve for the Gila River downstream from the Salt River and the Salt River upstream from the Gila. The flows in the Salt River just upstream of the Gila River are some 10 to 30 percent lower than the Gila River flows. The curve marked "FIA" was developed in 1977 for the Federal Insurance Administration and served as a basis for floodplain delineations. The curve marked "Corps" was developed in June, 1980 by the Corps of Engineers for use in the evaluation of flood control alternatives in the Central Arizona Water Control Study. The Corps study incorporated the floods of 1978-1980 and, as expected, predicts more frequent occurrence of any given discharge. The differences between the FIA and Corps studies is especially great for the smaller floods and is probably attributable to different analysis methodology and assumptions as well as the use of recent flood data.

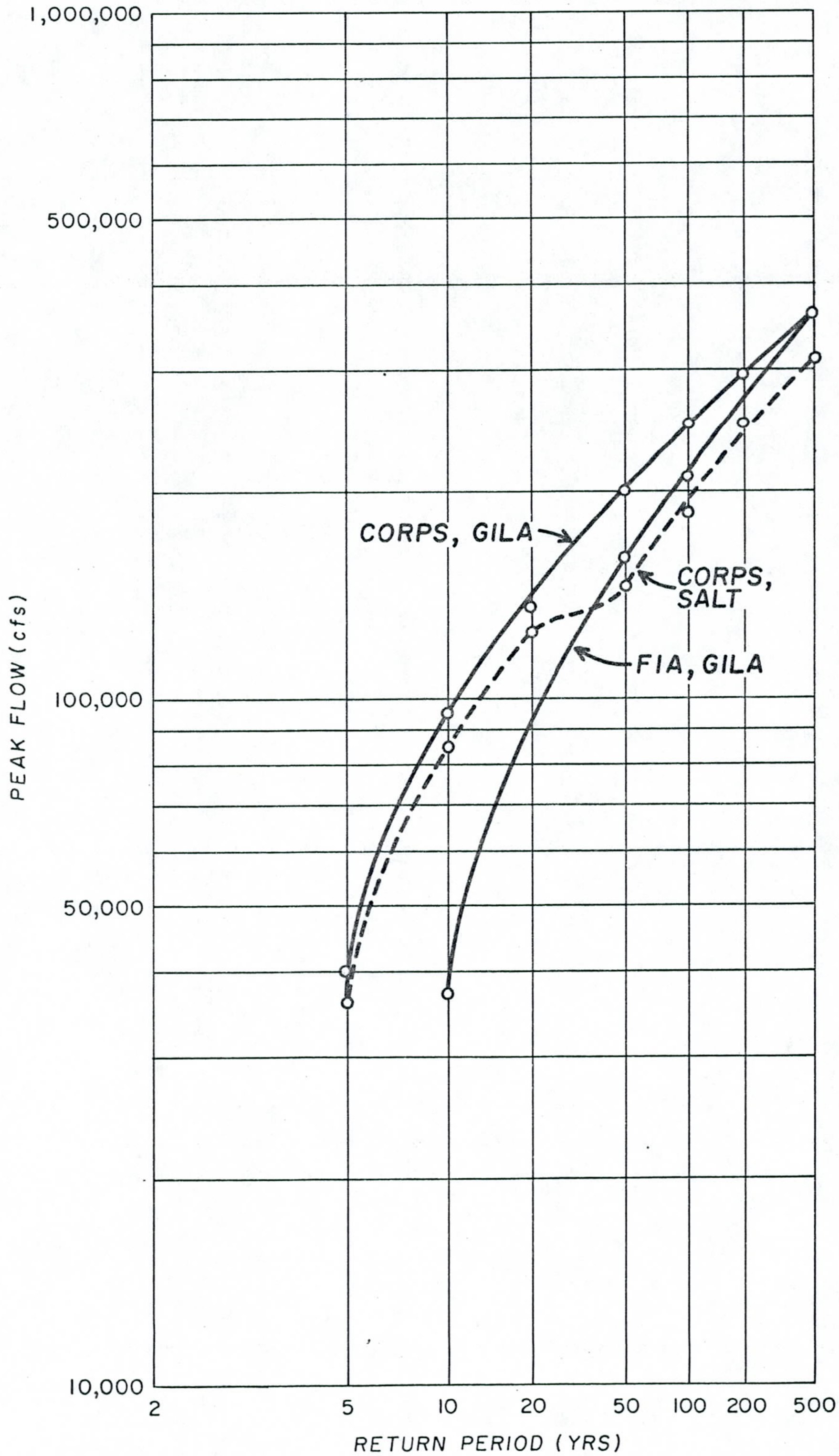

FIGURE 4

FLOOD FREQUENCY CURVES
GILA RIVER BELOW SALT RIVER - SALT RIVER ABOVE GILA RIVER

For this study the Corps hydrology was used as the basis for determining flood damages with and without flood control measures. The use of the Corps hydrology results in project benefits that are much greater than those calculated using the FIA hydrology.

V. HYDRAULIC ANALYSIS

The hydraulic analysis consisted of computation of water surface profiles through the Holly Acres area for flows of 50,000, 100,000 200,000 and 320,000 cfs. The computer program HEC-2 Water Surface Profiles, developed at the U.S. Army Corps of Engineers Hydrologic Engineering Center, was used to perform the backwater calculations.

The cross-sections utilized to define the river geomeetry were surveyed in 1976 for use in the Federal Insurance Administration's flood insurance program. It is recognized that the three major floods that have occurred since that survey was made have altered the riverbed substantially. However, as noted earlier in this report, the riverbed of the Salt and Gila Rivers changes substantially after every flood event. Therefore, it was judged that the time and expense required to re-survey the rivers could not be justified for this study.

This is further supported by the fact that the Manning "n" friction factors, as affected by phreatophyte growth and wash-out, is also highly variable. Given the natural variability of the bed configuration and resistance, the condition in 1976 is likely to be as representative of the condition during future floods as is the condition in 1981. Furthermore, the Manning "n" friction factors were recently adjusted or "calibrated" by the Corps of Engieners such that the model roughly matched observed areas of inundation during 1978 and 1980 floods when run for those discharges. These calibrated "n" values were used for the first set of HEC-2 runs.

A second set of HEC-2 runs for the same discharges (50,000,100,000, 200,000 and 320,000 cfs) was made after modifying the Manning "n" values in a 1,000-foot wide strip to simulate the phreatophyte clearing performed by the Maricopa County Flood Control District. This involved utilizing the horizontal variation in Manning "n" option (NH cards) of the HEC-2 program.

Manning "n" values outside the 1,000-foot strip were unchanged. The phreatophyte clearing was computed to have a rather small effect, however. The clearing decreased water surface elevations by less than 1 foot, and generally less than half a foot. The computed water surface profiles are plotted on Figure 5 (in back packet) along with the river invert (1976), the ground elevation at the north bank (above which damages begin to occur) and the elevation of the top of the banks of the St. John's Canal.

The above described HEC-2 runs (with and without clearing) were also performed prior to this study by the Corps of Engineers to analyze the effects of channel clearing. In the previous study, the floodplain boundaries at each discharge (with and without clearing) were plotted on topographic maps. The changes in inundated areas, and the structures and farm land included in these areas, were then identified and quantified to determine the flood damages that would be eliminated by the clearing project. For the most part, the inundated areas and structures previously identified were used to estimate project benefits in this study, but the water surface profiles shown in Figure 5 were also used to refine the estimates in certain areas. This is further discussed in the chapter on Benefit Estimation.

A few comments are in order on the limitations of the hydraulic analysis. As was previously pointed out, the Salt and Gila Rivers are highly unstable and this instability is compounded by the growth and wash-out of phreatophtes in the rivers. The water surface elevation at any given discharge in the future depends not only on the discharge, but on a number of unpredictable circumstances, including the level of phreatophyte growth, the sequence of preceeding flows and their effectiveness in washing out phreatophytes, and the amount of sediment and debris carried into the reach from upstream. For these reasons; the actual water surface elevations experienced in the future may vary substantially from those computed. Nevertheless, the computed elevations are a reasonable estimate, based on the best data available and observations of recent floods.

Another important consideration in the hydraulic analysis is the restriction of overbank flooding by natural and man-made structures such as levees. The Holly Acres area is marked by natural levees along the north bank. There is low ground about a mile north of the river, while the highest ground follows Southern Avenue and the St. John's Canal, which runs alongside it. St. John's Canal is some 3 feet or so above the surrounding ground, as well.

Because of these conditions, determining the inundated areas for a given discharge is not straightforward. Below a certain discharge, flow will be contained by the river banks. Higher discharges will overflow but will be generally restricted to the north by the banks of St. John's Canal. Some waters may find their way north of the Canal via drainage culverts under the Canal or at points where the canal passes under a road crossing that is lower than the Canal levees (see Figure 3). Once the discharge gets high enough, flow will occur north of the Canal as a result of the Canal being overtopped and/or outflanked by overflows upstream of 91st Avenue. At that point, the flow will spread out over a large area around the low ground previously noted and drain into the Agua Fria River. The discharge at which this overtopping/outflanking occurs is of primary importance because of the large amounts of residential development north of Southern Avenue. One of the key products of the hydraulic analysis was the estimation of this discharge (200,000 cfs) and the refinement of previously estimated floodplains. Another important product was the approximate depth of flooding in each developed area. These findings are described in the Benefit Estimation chapter and were instrumental in estimating flood damages and project benefits.

VI. FLOOD CONTROL ALTERNATIVES

Six flood control measures to reduce or eliminate flood damages in the Holly Acres Area were considered. These measures vary widely in approach, scale, degree of protection provided and areas protected. As will be seen in subsequent chapters, they also vary widely in economic justification (dollars of damages prevented [benefits], versus dollars to build the project [costs]). The purpose of this discussion is to describe the alternatives with emphasis on their key features. An evaluation of each measure from engineering and economic standpoints is contained in a later chapter.

Alternative 1 - Channel Clearing

Based on the preceeding discussion of the effects of phreatophytes on flood levels, clearing of phreatophytes from at least some portion of the river is a potentially promising method of reducing flood damages. By removing phreatophytes, flow resistance is lowered, resulting in lower water surface elevations and reduction of inundated areas for any given discharge. The concentration of flow in the cleared strip could also encourage scour of bed sediments and increase the cross-sectional flow area of the river, further reducing water levels. If the flow is concentrated away from the river banks, bank erosion damages could also be reduced.

When the U.S. Army Corps of Engineers first studied the Salt and Gila Rivers in 1957, they recommended clearing a 2,000-foot wide strip from Gillespie Dam to Granite Reef Dam. The clearing was estimated to have a favorable benefit-cost ratio. Water conservation benefits, as well as flood control benefits, were assumed. Subsequent to that study, changes in floodplain development have occurred and more information has become available about hydrology, observed flood levels, costs of phreatophyte removal and of maintenance of the cleared channel, and the potential water conservation benefits of clearing.

The Flood Control District of Maricopa County recently studied the environmental impacts and costs and benefits of channel clearing from the Holly Acres area to Gillespie Dam, with the assistance of the Corps of Engineers and Benham-Blair Affiliates, Inc., a consultant. Figure 6 (A and B), taken from the Draft Environmental Assessment Report, shows the alignment of the clearing project in the Holly Acres area. The proposed project consists of clearing and grubbing phreatophytes from a 1,000-foot wide strip as shown on the plans, minor grading of the cleared area, and maintenance clearing every two years. The clearing has been completed from 91st Avenue to El Mirage Road (west side of Holly Acres subdivision) with the remaining clearing planned for after completion of an Environmental Impact Report in mid-1981.

A cost-benefit analysis had not been previously performed specifically for the Holly Acres portion of the clearing project. For this report, a cost-benefit study was performed based on data collected in the previous County study, but revised to consider the most recent hydrologic findings, the hydraulic analysis preformed for this study, the special local flooding and damage considerations in the Holly Acres area, and the use of consistent, generally accepted economic evaluation methods. The clearing project was not examined in this study from the standpoint of alignment, width of clearing or clearing methods. A more detailed description of the proposed clearing project is contained in the Draft Environmental Assessment Report by Benham-Blair & Affiliates, Inc.

Alternative 2 - Channel Excavation

This alternative would involve excavation of a uniform channel through the Holly Acres area. The channel could vary in width, depth, alignment and type of bank protection. The result would be reduction of water surface elevations, inundated areas and river bank erosion. Since phreatophytes

N

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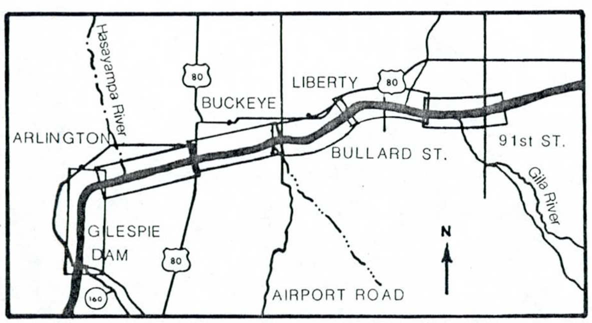
SCALE IN MILES



Legend

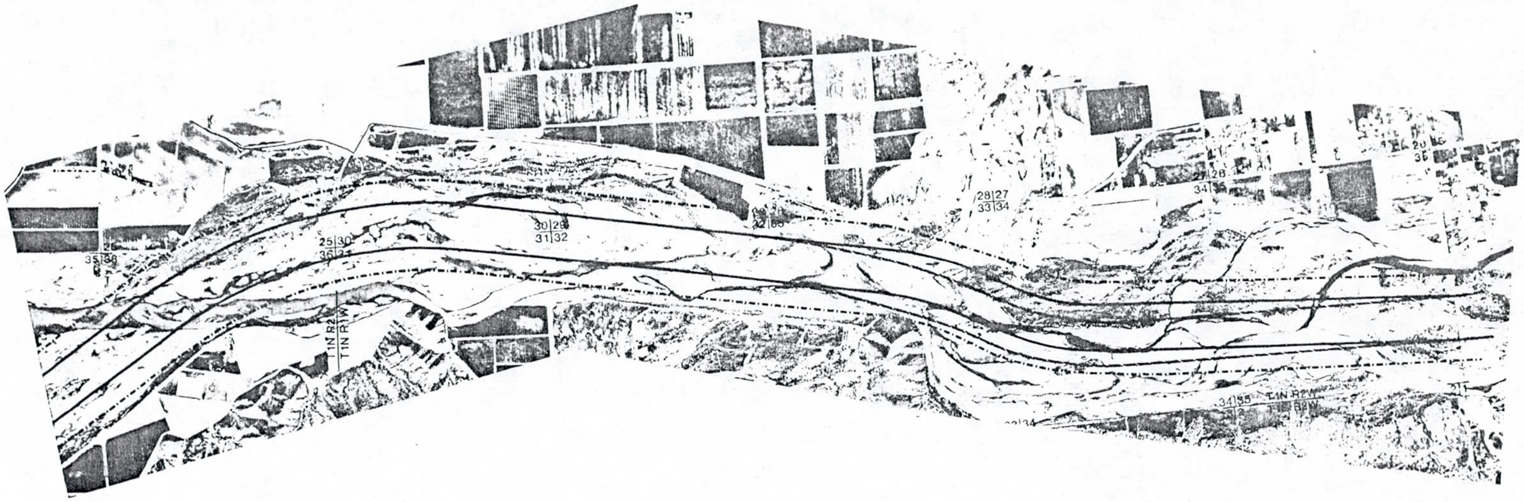
Proposed action (1,000-foot COE alignment)	▬▬▬
Alternative 1 (1,000-foot FWS alignment)	▬ ▬ ▬
Alternative 2 (2,000-foot COE alignment)	▬ · ▬ · ▬

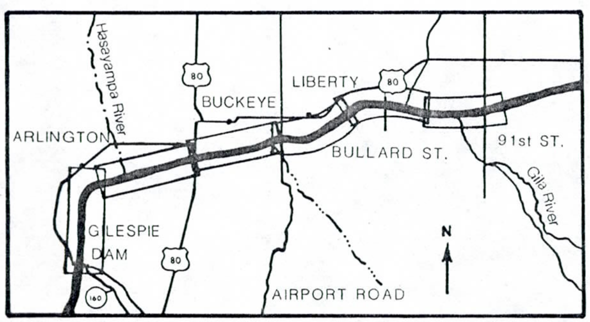
Source: Arizona Department of Transportation 1980.

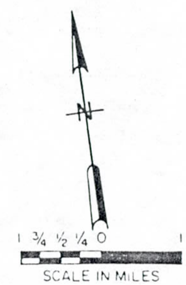
FIGURE 6A

SALT-GILA RIVER CLEARING PROJECT IN HOLLY ACRES AREA

SOURCE: Draft Environmental Assessment Report, Benham-Blair & Affiliates, Inc. Oct., 1980







Legend

Proposed action (1,000-foot COE alignment)

Alternative 1 (1,000-foot FWS alignment)

Alternative 2 (2,000-foot COE alignment)

Source: Arizona Department of Transportation 1980.

FIGURE 6B

SALT-GILA RIVER CLEARING PROJECT IN HOLLY ACRES AREA

SOURCE: Draft Environmental Assessment Report, Benham-Blair & Affiliates, Inc. Oct.,1980 must be cleared for initial channel excavation and regularly removed from the channel to insure maximum efficiency, this alternative would require Alternative 1 to be carried out in some fashion as a prerequisite.

No detailed plans for channel excavation were developed in this study. This is because the concept was rejected after preliminary engineering and economic feasibility evaluations. These evaluations are described in later chapters.

Alternative 3 - Levee Along North Bank

The constriction of a levee along the north bank from 91st Avenue to the Agua Fria River would protect virtually the entire Holly Acres area from the design flood on the Salt and Gila Rivers. By tying into high ground along the east side of the Agua Fria River, protection from floods on that river would also be provided. The levees would roughly follow the existing north bank where development abuts the river. They would be composed of compacted local soils. Bank protection would be required and would need to extend roughly 10 feet below the river invert to prevent levee erosion or undermining during floods. The top of levee elevation would be the predicted water surface elevation during the 100-year discharge (250,000 cfs) plus a freeboard allowance of 3 feet. An elaborate interior drainage system consisting of collection channels, gated gravity outlets and pump stations would be required to convey runoff to the river during local rainstorms.

As part of the Central Arizona Water Control Study (CAWCS), the Corps of Engineers and their consultant, Camp Dresser & McKee, studied north bank levees on the Salt and Gila Rivers. One of the projects studied corresponds exactly with the Holly Acres area levee plan described above. A plan and profile and typical section for the levee plan is shown in Figure 7 (A and B) contained in the back packet. The design discharge for the levee is 300,000 cfs.

The basic levee design and quantities were not altered from the Corps' design for this study. However, the cost estimate was revised to account for such factors as differences in the County's cost estimation criteria and design discharge, and price inflation since January, 1980. Benefits were calculated based on the best available information and compared to project costs. These calculations and project evaluation are discussed in later chapters.

Alternative 4 - Levee Along Southern Avenue

A large portion of the cost of the north bank levee plan is attributable to bank protection required to resist erosive flow velocities against the north bank during floods. At Southern Avenue, however, flow velocities are much lower and a levee at this location would need minimal bank protection (see Figure 3). The cost savings of this revised alignment would need to be compared with the benefit reduction of not protecting development between the river and Southern Avenue.

No detailed plans were developed for this alternative because preliminary economic feasibility evaluations led to rejection of this concept. These evaluations are described in subsequent chapters.

Alternative 5 - Ring Levee Around Holly Acres Subdivision

The Holly Acres subdivision, consisting of some 77 acres of irrigated low density residential development, is located between Southern Avenue and the Gila River, just east of El Mirage Road (Figure 2). During recent floods, this subdivision suffered the most concentrated damages within the Holly Acres area and the entire Gila River. Hydraulic and hydrologic analyses indicated that the subdivision (as well as other residents south of Southern Avenue) is likely to be flooded at much more frequent intervals than are other subdivisions and lands north of Southern Avenue. This suggests the possibility of achieving a high degree of flood damage reduction with a limited levee project confined to the Holly Acres subdivision.

A ring levee around the subdivision was designed as part of this study. No detailed design had been developed previously by others. Preliminary plans for the levee are shown in Figures 8 and 9 in the back packet. The key features of the plan include raising El Mirage Road south of Southern Avenue, raising the intersection of Southern Avenue and El Mirage Road, raising the existing north side bank of the St. John's Canal and constructing levees around the east and south sides of the subdivision using compacted local soils. The top of levee elevation would be the water surface elevation during the 100-year discharge (250,000 cfs) plus a freeboard allowance of 3 feet. Extensive protection would be provided only along the south side levee and tapered off along the east side levee. A pumping station with a gravity outlet and flapgate would be located at the southwest corner to handle interior drainage. Gates on the St. John's Canal and on drainage culverts would be installed to prevent entry of floodwaters into the subdivision when the surrounding area is flooded. Access to the subdivision would be restricted only during the largest floods when depths of water on Southern Avenue and/or El Mirage Road north of Southern Avenue would prohibit travel. This would probably occur only above the 100-year flood discharge.

The area protected from flood damages includes an area northwest of the intersection of Southern Avenue and El Mirage Road. The level of protection to this area is somewhat less than 100-year, however. Details of the cost and benefit analyses are described in later chapters.

Alternative 6 - Southern Avenue - El Mirage Road Improvements

Figure 3 shows an area northwest of the intersection of Southern Avenue and El Mirage Road that is being flooded during the February 1980 flood. Waters enter this area via a culvert along El Mirage Road and over the Southern Avenue-El Mirage Road intersection, which is lower in elevation than the St. John's Canal bank (the Canal siphons under El Mirage Road). Once the floodwaters cross Southern Avenue, they enter irrigation and drainage ditches and can cause local flooding before the waters can be drained to the west. At sufficiently high discharges, the area would be flooded by overtopping and/or upstream bypassing of the St. John's Canal.

The flooding that occurs prior to overtopping and/or upstream bypassing could be eliminated by raising the intersection of Southern Avenue and El Mirage Road to the height of the St. John's Canal banks and installing a gate on the drainage culvert along El Mirage Road that passes under Southern Avenue. The location and details of the gate depend on whether the Holly Acres subdivision ring levee is built and the normal operation of the culvert. This alternative is included as part of the ring levee plan and is shown on Figures 8 and 9. The costs and benefits have been separated from the ring levee plan.

VII. COST ESTIMATION

Cost estimation consisted of three major tasks: unit costs determination, rough cost estimates and preliminary cost estimates. The rough cost estimates, in conjunction with benefit estimates, served to indicate which alternatives would not be cost-effective and should not be given detailed design or cost-consideration. The preliminary cost estimates are approximate in that the quantities were developed using topography that is not very detailed (1976 topography, 1" = 400', 4' contours) for this type of work. A new survey would be required, and the design and costs for a selected project would need to be refined, before final plans could be developed.

Unit costs were based on several recent bid summaries for construction projects in the Phoenix area. Among the projects considered were:

- RWCD Floodway-Reach 1, Soil Conservation Service, June 1980
- Saddleback Floodwater Retarding Structure, Soil Conservation Service, August 1980
- Indian Bend Wash Interceptor Channel, U.S. Army Corps of Engineers, October 1980
- Tuthill Road Bridge, Maricopa County Highway Department, July 1980
- Additional information on channel clearing and other local projects, Flood Control District of Maricopa County.

The cost of each alternative described in Chapter VI was considered. Some of the alternatives were not designed or costed out in detail because they were not considered to be justifiable from an engineering and/or a cost-effectiveness standpoint following initial analysis. The more promising alternatives were studied in greater detail. Annual costs were computed by amortizing the first cost over a 25-year analysis period at 3 percent interest (as per Arizona DWR criteria) and adding estimated annual operation and maintenance costs. The following paragraphs describe briefly the cost analysis performed for each alternative and the results. Back-up details are contained in the Appendix.

Alternative 1 - Channel Clearing

The costs of channel clearing were based on information supplied by the Flood Control District of Maricopa County for their 1,000 ft. wide clearing project. The initial cost includes clearing and grubbing to a depth of 2 feet below the surface, disposal of cuttings and minor grading work. Maintenance would take place every two years to control re-growth. The estimated costs are $1,000/acre for initial clearing work and $300/acre for maintenance work. Clearing a six mile long strip 1,000 ft. wide would cost $727,000 plus $109,000 per year. The annual cost is $150,000 per year. It is noteworthy that even if initial clearing costs would be much different due to site-specific conditions, the effect on the annual cost would be slight, since maintenance is the dominant cost.

Alternative 2 - Channel Excavation

Channel excavation costs were developed on a per foot of depth for a 1,000 foot wide channel per mile. The cost includes only excavation and disposal of the excavated material. No bank protection, land purchase, overhaul or other costs are included. The initial cost is $342,000 per foot per mile. The annual cost is $23,000 per foot per mile, including maintenance. This is approximately the same cost as clearing and maintaining the same surface area free of phreatophytes.

Alternative 3 - Levee Along North Bank

The costs for this alternative were previously estimated by CDM for the Corps of Engineers' Central Arizona Water Control Study. The estimate used in this study was determined by adjusting the Corps estimate for differences in design and cost criteria and inflation. The projected cost for the levees is $43,857,000. With a 1 percent O&M allowance, the annual cost is $2,956,000 per year.

Because this project could be considered to be a longer term solution than the other alternatives, with a project life of 100 years, the annual cost was also computed using a 100-year amortization. That cost is $1,824,000 per year.

Alternative 4 - Levee Along Southern Avenue

This alternative was not designed. However, by inspecting the cost breakdown for the north bank levee, it was possible to roughly estimate the cost of this alternative. By eliminating bank protection, toe excavation and fill, and reducing levee quantities and interior drainage areas, it is reasonable to expect a cost reduction of 60 percent. Therefore, this alternative was estimated at roughly 40 percent of the cost of the north bank levee, or $17,500,000 first cost and $1,180,000 annual cost.

With these cost reductions, the interior drainage cost would be the largest single cost item. A more detailed study of local drainage facilities and options for providing interior drainage at a reduced cost would be appropriate if it appeared that this alternative were reasonably close to being cost-effective. This was not done.

Alternative 5 - Ring Levee Around Holly Acres Subdivision

This alternative was designed and a fairly detailed cost estimate was developed. Table VII-1 presents the cost estimate item by item. The Appendix contains the back-up for this estimate, including design considerations and quantity calculations.

TABLE VII-1

HOLLY ACRES RING LEVEE COST ESTIMATE

QUANTITY TAKE-OFF		________ ESTIMATE
		JOB NO.
MARICOPA COUNTY FLOOD CONTROL DISTRICT		
SALT-GILA INTERIM FLOOD CONTROL WORKS	COMPUTED BY SWJ	PREPARED BY
HOLLY ACRES AREA	CHECKED BY PRG	CHECKED BY
RING LEVEE AROUND HOLLY ACRES SUBDIVISION	DATE 1/14/81	DATE

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	TOTAL COST
	FIRST COST				
1	Diversion and Control of Water	1	JOB	L.S.	1,400
2	Clear Site and Remove Obstructions	7.5	ACRE	300	2,250
3	Excavation				
	A. For Levee Fill	53,400	CY	1.50	80,100
	B. Toe	75,700	CY	2.50	189,300
4	Compacted Fill				
	A. Levees	46,500	CY	1.00	46,500
	B. Toe	75,700	CY	1.30	98,400
5	Vegetation Erosion Protection	3.5	ACRE	200	700
6	Filter Material	3,850	CY	18.00	69,300
7	Rock Rip-Rap	15,400	CY	18.00	277,200
8	Slide Gates	3	EA	2000	6,000
9	Interior Drainage				
	A. Collection	1	JOB	L.S.	11,000
	B. Pump Station	1	JOB	L.S.	100,000
10	Road Work				
	A. Excavation and Fill	3,540	CY	2.50	8,900
	B. Remove Pavement	93,400	SF	0.60	56,000
	C. Aggregate Base	1,355	CY	18.00	24,400
	D. Asphaltic Concrete	73,000	SF	1.00	73,000
	Total Construction Costs				1,044,500
	Contingencies, 15%				156,700
	Engineering and Design, 10%				120,100
	Supervision and Administration, 10%				120,100
11	Land Acquisition	6.6	ACRE	8000	52,800
	TOTAL FIRST COST				1,494,000

The total first cost is $1,494,000. The annual cost, including 1 percent for O&M, is $101,000 for 25-year amortization.

Alternative 6 - Southern Avenue-El Mirage Road Improvements

This alternative was designed as part of the ring levee plan. The costs are broken out in Table VII-2. The total first cost is $72,000. The annual cost excludes any O&M costs, which are assumed to be negligible. For 25-year amortization, the cost is $4,100 per year.

Table VII-3 presents a summary of the estimated project costs.

TABLE VII-3

SUMMARY OF ESTIMATED COSTS
OF ALTERNATIVE FLOOD CONTROL MEASURES

Alternative	First Cost	Annual O&M Cost	Total Annual Cost 25 yrs @ 3%	Total Annual Cost 100 yrs @ 3%
1. Channel Clearing	$ 727,000	$109,000	$ 150,000	
2. Channel Excavation	--------------------Not Computed--------------------			
3. North Bank Levee	$43,857,000	$438,600	$2,956,000	$1,824,000
4. Southern Avenue Levee	$17,500,000	$175,000	$1,180,000	
5. Ring Levee	$ 1,494,000	$ 14,900	$ 101,000	
6. Road Improvements	$ 72,000	--	$ 4,100	

TABLE VII-2

SOUTHERN AVE.-EL MIRAGE RD. IMPROVEMENTS COST ESTIMATE

QUANTITY TAKE-OFF					________ ESTIMATE
MARICOPA COUNTY FLOOD CONTROL DISTRICT				JOB NO.	
SALT-GILA INTERIM FLOOD CONTROL WORKS		COMPUTED BY SWJ		PREPARED BY	
HOLLY ACRES AREA		CHECKED BY PRG		CHECKED BY	
SOUTHERN AVE.-EL MIRAGE RD. IMPROVEMENTS		DATE 1/14/81		DATE	
ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	TOTAL COST
	FIRST COST				
1	Diversion and Control of Water		JOB	L.S.	
2	Clear Site and Remove Obstructions		ACRE	300	
3	Excavation				
	A. For Levee Fill		CY	1.50	
	B. Toe		CY	2.50	
4	Compacted Fill				
	A. Levees		CY	1.00	
	B. Toe		CY	1.30	
5	Vegetation Erosion Protection		ACRE	200	
6	Filter Material		CY	18.00	
7	Rock Rip-Rap		CY	18.00	
8	Slide Gates	1	EA	2000	2,000
9	Interior Drainage				
	A. Collection		JOB	L.S.	
	B. Pump Station		JOB	L.S.	
10	Road Work				
	A. Excavation and Fill	1,390	CY	2.50	3,500
	B. Remove Pavement	26,200	SF	0.60	15,700
	C. Aggregate Base	430	CY	18.00	7,700
	D. Asphaltic Concrete	23,000	SF	1.00	23,000
	Total Construction Costs				51,900
	Contingencies, 15%				7,800
	Engineering and Design, 10%				6,000
	Supervision and Administration, 10%				6,000
11	Land Acquisition		ACRE	8000	--
	TOTAL FIRST COST				72,000

VIII. BENEFIT ESTIMATION

Average annual benefits attributable to each alternative flood control project were estimated in terms of changes occurring to national income due to the project. Only benefits related directly or indirectly to flood control were included. The existing development in the Holly Acres Area was assumed in computing the differences in flood damages with and without the projects. The without-project condition for Alternatives 2 through 6 assumed a 1,000 ft. wide channel clearing project was already implemented. The without-project condition for Alternative 1, channel clearing, was the river condition before clearing was performed.

The average annual flood damages in the Holly Acres Area have been estimated independently within the last year by the Corps of Engineers as part of the CAWCS and by the Flood Control District of Maricopa County as part of the Draft Environmental Assessment Report for channel clearing. The County study was performed by Great Western Research, a subcontractor to Benham-Blair & Affiliates. The Corps study was generally more detailed and rigorous in approach than the County study, but results and data from the Corps study were not available prior to this writing. It is expected that this information will become available shortly and will be used to revise the benefits calculated in this study if appropriate. The economic data collected for the County study therefore served as the basis for damage estimates. The estimates of inundated areas and structures from the County study were also utilized. However, both the economic data and inundated areas were refined to take into account the special local flooding and damage considerations in the Holly Acres Area (both previous studies covered much larger areas than Holly Acres). Also, more recent hydrologic data and generally accepted economic evaluation methods were employed.

The procedures and assumptions used to compute benefits were as follows:

1. Based on the hydraulic analysis and the previous channel clearing study, inundated areas and depths of flooding were determined on a section (1 square mile) by section basis for flows of 50,000, 100,000, 200,000 and 320,000 cfs. It was determined that below 200,000 cfs most of the development north of Southern Avenue would not flood due to the banks of the St. John's Canal. Localized flooding north of Southern Avenue would occur northwest of the El Mirage-Southern Avenue intersection (flow over the road and through a culvert) and also near the Agua Fria River (backwater outflanking the Canal). This is supported by the computer water surface profiles (Figure 5) and by observations during the February 1980 flood of 170,000 (Figure 3). At higher discharges, upstream outflanking of the Canal and localized overtopping would inundate low-lying areas north of Southern Avenue.

2. Unit damage values were estimated in each of 14 categories. For the most important categories (residential and agricultural), the damages were estimated on a section by section and flow by flow basis. Recent flood damages experienced and the estimated flood depths and exposure to high flow velocities were considered in arriving at the estimates. For other categories a constant unit damage value was applied to inundated areas regardless of location or flood discharge. These unit damages were taken from the Great Western Research study, as was recent flood damage survey information. The unit damages assumed were:

   1. Frame Homes:

South of Southern Avenue	50,000 cfs:	$12,000 ea.
	100,000 cfs:	$20,000 ea.
	200,000 cfs:	$30,000 ea.
	320,000 cfs:	$45,000 ea.

	North of Southern Avenue	50,000 cfs: no damages
		100,000 cfs: $ 8,000 ea.
		200,000 cfs: $12,000 ea.
		320,000 cfs: $16,000 ea.
2.	Block Homes:	Same as frame homes
3.	Mobile Homes:	$ 4,000 ea.
4.	Farmsteads:	$23,000 ea.
5.	Cultivated Land:	
	South of Southern Avenue	50,000 cfs: $200/ac.
		100,000 cfs: $300/ac.
		200,000 cfs: $500/ac.
		320,000 cfs: $750/ac.
	North of Southern Avenue	50,000 cfs: no damages
		100,000 cfs: $150/ac.
		200,000 cfs: $200/ac.
		320,000 cfs: $250/ac.
6.	Pasture Land:	$ 100/ac.
7.	Dairies and Feedlots:	$50,000 ea.
8.	Farm Ditches:	$23,760/mile
9.	Canals:	$ 5,000/mile
10.	Commercial Buildings:	$10,000 ea.
11.	Public Buildings:	$76,000 ea.
12.	Paved Roads:	$18,000/mile
13.	Dirt Roads:	$ 6,000/mile
14.	Crop Losses:	
	South of Southern Avenue	50,000 cfs: $250/ac.
		100,000 cfs: $300/ac.
		200,000 cfs: $400/ac.
		320,000 cfs: $600/ac.

North of Southern Avenue	50,000 cfs:	no damages
	100,000 cfs:	$200/ac.
	200,000 cfs:	$250/ac.
	320,000 cfs:	$300/ac.

All other damages were considered to be indirect damages amounting to 15 percent of computed direct damages.

3. Numbers of units in each category for each flow both with and without channel clearing were enumerated on a section by section basis. For the most part, unit counts were taken from the County channel clearing study as determined by Great Western Research based on Corps of Engineers hydraulic computations and floodplain boundaries. These values were modified substantially, however, to be consistent with the hydraulic findings described in 1. above. Also, in key damage areas, actual finished floor elevations were estimated to determine whether homes should be included in the damage estimates. Numbers of units for 100,000 cfs were only roughly estimated since the previous study had not considered this discharge explicitly. Also, units in areas smaller than a section were enumerated where necessary (e.g., Holly Acres subdivision protected by ring levee). Results are tabulated in the Appendix.

4. Total direct damages for each flow were computed on a section by section basis (or smaller) by multiplying units in each category by the appropriate unit damage values and summing over the 14 damage categories. Results are tabulated in the Appendix.

5. Average annual damages were computed by multiplying the average damage in each flow range by the probability of a flood in that flow range occurring in a year. Probabilities were based on the latest Corps hydrology as shown in Figure 4. Separate frequency

values were used for Salt and Gila River areas. The average annual damages were computed for the following areas assuming the following conditions:

- Entire Holly Acres area with no channel clearing
- entire Holly Acres area with 1,000 ft. wide channel clearing
- areas north of Southern Avenue
- areas protected by the Holly Acres subdivision ring levee
- areas protected by the Southern Avenue-El Mirage Road improvements

The computations and results are found in the Appendix.

6. Based on the annual expected flood damages in selected areas and under certain project construction assumptions, average annual direct benefits of several of the alternative flood control measures were computed. Channel clearing was assumed to be completed in evaluating other alternatives. Indirect benefits were assumed to be 15 percent of direct benefits. Table VIII-1 summarizes the results.

TABLE VIII-1

SUMMARY OF AVERAGE ANNUAL BENEFITS
OF ALTERNATIVE FLOOD CONTROL MEASURES

Alternative	Damages Without Project	Damages With Project	Direct Benefits	Total Benefits (1.15 Times Direct)
1. Channel Clearing	$542,400	$518,100	$ 24,300	$ 28,000
2. Channel Excavation	-------------------	Not Computed	-------------------	
3. North Bank Levee	$518,100	$ 0	$518,100	$595,800
4. Southern Avenue Levee	$518,100	$405,600	$112,500	$129,400
5. Ring Levee	$518,100	$329,700	$188,400	$216,700
6. Road Improvements	$518,100	$493,200	$ 24,900	$ 28,600

The following observations are in order:

1. Channel clearing appears to have very little effect on flood damages, reducing without-project damages by only 4 percent. This is attributable to three major factors. First, the area to be cleared already had been calibrated to have a fairly low Manning "n", presumably because the phreatophytes had already been washed away in that area when the observations were made. Thus, the predicted change in water surface elevation was small. Secondly, the levee along St. John's Canal serves to limit the extent of the inundated area below 200,000 cfs. Therefore, significant benefits of channel clearing occur only at very low flows (before the levee is reached) and at very high flows (after the levee is overtopped/bypassed). It is true the clearing results in slightly lower flood depths at all flows and delays the overtopping/bypassing somewhat, but the

effects were too small to be considered. Finally, even at high flows, the effects of the clearing are mostly confined to eliminating inundation at the outer boundary of the floodplain, where flooding is very shallow and very few homes are located. Thus, benefits are minimal.

To the extent that the clearing might have a greater impact than predicted at lower flows (before phreatophytes are washed out) and also might increase the cross-sectional area of the river via scour and reduce damages due to bank erosion, the benefits could be higher. Unfortunately, it is not possible to accurately estimate these additional benefits.

2. Channel excavation benefits were not computed. This is discussed in the next chapter.

3. The north bank levee would provide total protection. The freeboard allowance of 3 feet for the 100-year flood would be reduced to a little under 2 feet for the 500-year flood. Residual damages are negligible.

4. The Southern Avenue levee would only reduce average annual flood damages by about 20 percent. This is largely because the existing levee along St. John's Canal provides a considerable amount of flood protection at this time. Most of the benefits of this levee would be at the downstream end of the area near the Agua Fria River, where backwaters flood some areas north of Southern Avenue at the lower discharges.

5. The Holly Acres subdivision ring levee would provide an impressive 40 percent reduction in average annual damages despite its rather limited coverage. This, of course, is because the project surrounds the highest damage area, an area that is not currently protected by the St. John's Canal levee.

6. El Mirage-Southern Avenue road improvements would reduce damages by some 5 perent. These are mostly damages that occur at discharges between 100,000 cfs and 200,000 cfs. Although the benefits are rather small, the improvements required to achieve them are fairly minor. These benefits are also included in the ring levee benefits.

IX. EVALUATION OF ALTERNATIVES

The primary evaluation criteria considered in evaluating the alternatives at this stage were effectiveness and efficiency (as measured by the benefit/cost (B/C) ratio). Table IX-1 presents a summary of the annual benefits and costs for each alternative. Data for this table comes from Tables VII-3 and VIII-1. An evaluation of each alternative follows:

TABLE IX-1

SUMMARY OF ANNUAL BENEFITS
AND COSTS OF ALTERNATIVE FLOOD CONTROL MEASURES

Alternative	Average Annual Benefits	Total Annual Cost 25 yrs. @ 3%	Benefit/Cost Ratio
1. Channel Clearing	$ 28,000	$ 150,000	0.19
2. Channel Excavation	---------------Not Computed----------------		
3. North Bank Levee	$595,800	$2,956,000	0.20*
4. Southern Avenue Levee	$129,400	$1,180,000	0.11
5. Ring Levee	$216,700	$ 101,000	2.2
6. Road Improvements	$ 28,600	$ 4,100	7.0

*0.33 for 100-year amortization

Alternative 1 - Channel Clearing

Channel clearing appears to be an inefficient flood control measure in this reach. The reasons for the low benefits and the limitations on the hydraulic analysis were previously discussed. The major environmental consideration is the destruction of wildlife habitat. The Draft Environmental Assessment Report by Benham-Blair & Affiliates contains more information on the potential impacts of this measure.

Alternative 2 - Channel Excavation

Channel excavation was considered as a concept only and no plans were developed. The concept was rejected for lack of both effectiveness and efficiency. The effectiveness of channel excavation is considered poor because the natural forces of the river could easily lead to shifts in alignment and sedimentation that would greatly reduce the effectiveness of the excavation over time. Furthermore, channel clearing alone will tend to concentrate the flow and scour out the river in that area. Any more than a small pilot channel through a cleared area would likely be wasted effort.

Despite the above argument, a sufficient amount of excavation in the river could reduce flood depths, at least until the sediment carried by the river could replace the excavated material. However, the rough cost calculations performed indicated that an excavation of only 1 foot in depth would cost as much as clearing and maintaining the same surface area free of phreatophytes. Clearing must be performed as part of any excavation as well. Simple hydraulic calculations show that clearing a strip of the river that is covered with phreatophytes would lower the water surface much more than excavating a 1 foot deep channel in a cleared area, yet would cost about the same. Excavation is less efficient than clearing, yet clearing is not efficient in the Holly Acres area. Channel excavation was therefore not considered further.

Alternative 3 - Levee Along North Bank

This alternative would be very effective in preventing flood damages over the entire Holly Acres area. However, as can be seen, its efficiency is very low. Even if significant cost reductions were identified by further study and a 100-year amortization period were used, the project would not be cost-effective. The possibility of incorporating other objectives into this plan has been mentioned, but the benefits derived from these other uses would have to be much larger than the flood control benefits to justify the project.

Alternative 4 - Levee Along Southern Avenue

This project would cost roughly 40 percent as much as the north bank levee, yet it would produce only 20 percent of the benefits. Its efficiency is thus only half that of the north bank levee. The benefit/cost ratio is so low that even if interior drainage costs were reduced to almost nothing, this alternative would still not be cost effective. For this reason, this alternative was not considered further.

Alternative 5 - Ring Levee Around Holly Acres Subdivision

The benefits of this project are considerably greater than its costs - this appears to be a cost-effective solution to some of the flood problems in the Holly Acres area. The cost and benefit calculations must now be reviewed in more detail to insure that the damage values, unit costs, and design assumptions and criteria are appropriate.

The possibility of local financing appears good since the project has a moderate cost. Federal involvement may be a possibility if the cost estimate of $1.5 million is reasonably accurate (this is less than the Corps of Engineers' $3 million limit for the Small Projects Authority). Environmental impacts should be minor.

Local support for the project should be reasonably good. In the June 1980 survey of the Holly Acres Flood Control Association membership, only 5 percent picked levees as their first choice, but only 8 percent picked levees as their least preferred choice for flood relief. Channelization was by far the most popular choice and relocation was by far the least popular. The ring levee, however, will likely be acceptable to many residents, if the only alternative for flood relief is relocation. The major objection will likely be the limited scope of this project that fails to protect many of the area's residents.

<u>Alternative 6 - Southern Avenue-El Mirage Road Improvements</u>

This project is cost-effective, but extremely limited in scope. The hydraulic analysis for this project was highly approximate since the available topographic data was not very detailed and the flooding of this area is a rather complex dynamic phenomenon. More data collection and analysis needs to be performed on this alternative before it can be recommended, although it appears at this time that the project is a good one. Adverse environmental impacts should be negligible. Public support may be lacking due to the very limited scope of the project.

X. CONCLUSIONS

Alternatives 2 through 4, channel excavation and levees along the north bank of the river or along Southern Avenue, are not cost-effective alternatives and should not be studied further. Alternative 1, channel clearing, has been partially implemented already, but will involve a high cost every year if it is to be maintained. Although the benefits of the clearing do not appear to justify the cost, there are potential benefits that were not quantified in this study. Initial clearing should be completed and the project re-evaluated after observing actual effects on flood stages and recording actual maintenance costs.

Alternative 5, ring levee around Holly Acres subdivision, should be further studied. A topographic survey of the area should be conducted, and cost and benefit data and analyses should be refined. A meeting with the Holly Acres homeowners should be held and their views on the project should be incorporated into future planning. The minor improvements of Alternative 6 should also be refined and discussed as part of the ring levee plan, or separately if the ring levee plan is rejected for some reason.