HYDRAULICS AND FLOODING ANALYSIS
OF
THE 1993 FLOOD ON THE GILA RIVER
IN REGARD TO
THE
BREACH OF GILLESPIE DAM

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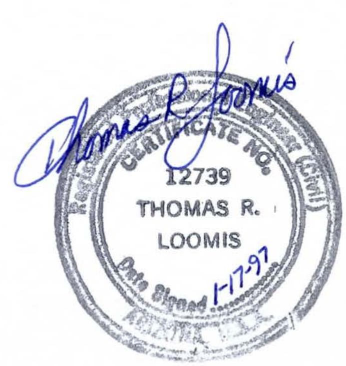
January 1997

TABLE OF CONTENTS

List of Figures

LIST OF TABLES

List of Appendices



1 Introduction

The Gila River experienced a major flood during the months of January and February 1993, with flow in the river continuing until the end of April 1993. The peak discharge occurred about 8:00 a.m. on 9 January 1993 and is estimated to be 132,000 cubic feet per second (cfs) according to Hjalmarson (1997). That estimated peak discharge occurred at Gillespie Dam, located about 17 miles north of Gila Bend, Arizona. A portion of Gillespie Dam reportedly failed at about 12:30 p.m. on 9 January 1993 resulting in an initial breach in the structure that continued to widen over the next one to two days. The Enterprise Canal reportedly failed at two locations downstream of Gillespie Dam at some point during the flood.

The hydraulic analyses done as a part of this report demonstrate the following:

1. The estimated peak discharge of 132,000 cfs at Gillespie Dam is a reasonable value in light of the available data.

2. The limits of flooding on the Gila River between Gillespie Dam and the Gila Bend area as a result of that peak discharge are not unusual or unexpected when compared with previous flood events or the limits of theoretical flood events predicted by others.

3. The farm lands have progressively encroached into the flood plain of the Gila River from 1953 through 1993, thus reducing the available area for conveyance of flood waters. This encroachment results in increased bank erosion, particularly during unusually long periods of sustained flow as occurred during this flood.

4. The breach of Gillespie Dam during the flood did not have a measurable effect on the magnitude of peak discharge, or the extent of flooding on the Gila River downstream of Gillespie Dam.

5. The failure of the Enterprise Canal at two locations downstream of Gillespie Dam was a result of the physical characteristics of the design of the canal (hydraulic capacity of the canal decreases downstream); and how that canal functions during high flow rates in the Gila River. The failures of the canal were not a consequence of the failure of Gillespie Dam.

The various work products used in this report, and referred to extensively in Section 3, are defined and described in Appendix A. Terms such as the "1993 Flood Inundation Limits" and the "1993 Hydraulic Model Riverine Flood Limits" are defined therein.

2 Data Summary and History of Gillespie Dam

2.1 General

The data gathered and used as a basis for this report are listed and described in the following sections. A brief summary of the history of Gillespie Dam is also presented. The work product prepared using this data is described in Appendix A. HEC-RAS work product summaries are contained in Appendices B and C. The Enterprise Canal work product calculations are in Appendix D. Mosaics of historical aerial photographs are in Appendix E.

2.2 Aerial Photography

Aerial photographs of the Gila River are used as a basis for various figures in this report. The photographs used, and their source, are listed in Table 2.1. All are black and white photographs except the 22 February 1993 photographs, which are color. Mosaics of the photographs are contained in Appendix E.

Table 2.1
Aerial photographs used in this study

Flight Date 1	Source 2
31 March 1953	Flood Control District of Maricopa County
6 January 1958	Maricopa County Department of Transportation
20 January 1964	Maricopa County Department of Transportation
29 January 1970	Maricopa County Department of Transportation
2 April 1976	Maricopa County Department of Transportation
February 1978	US Natural Resources Conservation Service
March 1978	US Natural Resources Conservation Service
24 April 1979	Maricopa County Department of Transportation
1 January 1985	Maricopa County Department of Transportation
3 March 1985	Maricopa County Department of Transportation
22 June 1989	Flood Control District of Maricopa County
15 October 1991	Maricopa County Department of Transportation
9 January 1993	Arizona Department of Transportation
22 February 1993	US Army Corps of Engineers
2 March 1993	Flood Control District of Maricopa County

2.3 Existing Hydraulic Model Digital Data Sets

US Army Corps of Engineers HEC-2 computer program data sets for the Gila River have been prepared for flood insurance purposes. Some of those data sets are used in the hydraulic analyses for this study. The available data sets are listed in Table 2.2.

Table 2.2

HEC-2 Models of the Gila River in the vicinity of Gillespie Dam

Company Prepared By 1	Aerial Photo Date 2	Description of Reach 3
Cella Barr Associates	22 June 1989	Gillespie Dam to the Gila Bend area
Dames and Moore	11 May 1984	Upstream from Gillespie Dam
Michael Baker, Jr. Inc.	14 December 1991 13 January 1992 23 January 1992	Upstream from Gillespie Dam, pre-flood (preliminary)
Michael Baker, Jr. Inc.	2 February 1993 (flooded area only)	Upstream from Gillespie Dam, post-flood (preliminary)

2.4 Field Survey

2.4.1 Crest of Dam and Breach Dimension

A field survey of the dam spillway crest was performed on 15 July 1996. The length of the crest of the overflow portion of Gillespie Dam is estimated to be 1657 feet. The overflow area is rectangular in cross section with an available depth of 10 feet before the dam abutments are overtopped. A vertical profile along the center of the spillway crest was surveyed at 21 foot intervals (center of each abutment). The elevation of the remaining crest after the 1993 flood was found to vary a maximum of 0.18 feet (vertically). The average elevation of the crest is about 753.4 feet.

The width of the breach is measured to be about 206 feet. The breach begins about 223 feet west of the east abutment.

2.4.2 Field Survey of the Enterprise Canal

A field survey of portions of the Enterprise Canal was conducted on 27 December 1996. The following physical data were obtained, using the US Geological Survey (USGS) bench mark (USGS Gage Number 09519000) at the east abutment of the SR 80 bridge for reference:

1. Size, invert elevations and length of the existing culvert under the approach road just south of the SR 80 bridge.

2. A profile along the approach road and the levee which forms the east canal bank of the Enterprise Canal south of the approach road.

3. An estimate of the slope of the water surface in the Enterprise Canal downstream of the approach road.

4. A cross section of the Enterprise Canal about 3 miles downstream of the SR 80 bridge, just upstream of the first canal failure location.

5. An estimate of the slope of the water surface in the Enterprise Canal at the cross section in item 4 above.

6. An estimate of the surface velocity of the flow in the Enterprise Canal at the cross section in item 4 above.

7. Photographs of all of the above 6 items.

2.5 Brief History of Gillespie Dam

2.5.1 Description of Gillespie Dam

The construction of Gillespie Dam was completed in 1921. The dam is known as "A Multiple Arch Dam of the Eastwood type" and is a series of reinforced concrete buttresses (21 feet center to center and 2 feet wide) which anchor 81 arches. The length of the buttress-arch structure is about 1701 feet (81 x 21). The dam is about 1800 feet long overall including the abutments. The above data is according to Steele (29 April 1921). The dam height is about 20 feet, from the concrete apron to the top of the buttresses (crest of overflow spillway). The overflow spillway crest is about 1657 feet long (79 arches less the width of ½ buttress on each end) (refer to Section 2.4.1). The dam was designed and constructed as a diversion structure to supply water to the Gila Bend Canal (Steele, 29 April 1921 and Newton, 4 December 1957). It was not intended to function as a dam in the traditional sense of impounding large volumes of water. The dam includes sluice gates at the east end to supply water to that canal. By 1923, sedimentation from the Gila River had essentially filled the entire impoundment upstream from the dam.

2.5.2 Dam failure in 1993

A partial breach reportedly occurred in the dam about 12:30 p.m. on 9 January 1993. The initial breach was reportedly about 20 to 25 feet wide and had a depth of about 10 feet (Stevenson, Cotton, Stephens and Hussain, 11 January 1993) (refer to Figure 2.1). Over the next two hours, the breach apparently continued to widen to a reported width of 135 feet according to Coen, 8 September 1993 (refer to Figure 2.2). Flow was apparently still spread over the entire width of the dam overflow crest at this time, as shown on Figure 2.2.

On 11 January 1993, the breach width was reported to be 135 feet (Hussain and Johnson, 11 January 1993). All flow was concentrated in the breach. On 12 January 1993, the breach width is estimated to be 165 feet (refer to Figure 2.3). That width is estimated by counting the remaining arches using the photographs in Figure 2.3 taken by the USGS on that date. A first generation copy of original photographs was used, which was much clearer than the copy in Figure 2.3. Note that all flow is concentrated in the breach. The final breach width is estimated to be 206 feet, per the field survey done on 15 July 1996 (refer to Figure 2.4). The breach chronology is summarized in Table 2.3.

Table 2.3

Chronology of failure of Gillespie Dam

Date 1	Estimated Time 2	Breach Width, feet 3	Description 4	Source 5
9 Jan 93	12:30 p.m.	20 - 25	Flow over full width of dam crest	Stevenson, et al
9 Jan 93	1 - 2 p.m.	135	Flow over full width of dam crest	Hussain
9 Jan 93	2 - 3 p.m.	135	Flow over full width of dam crest	Coen
11 Jan 93	unknown	135	Flow contained in breach	Hussain
12 Jan 93	unknown	165	Flow contained in breach	USGS photo
15 July 96	-----	206	-----	ASL survey

Figure 2.1
Photograph of Gillespie Dam after the initial breach occurred, on the afternoon of 9 January 1993
(Bates Number 0002051)

Gila River at Gillespie Dam looking upstream at about 1530, By H.H. Schumann 1-9-93

Over Gila River at Gillespie Dam looking toward left-bank (east) side. By H.H. Schumann 1-9-93.

Figure 2.2
Photographs of Gillespie Dam and SR 80 bridge on the afternoon of 9 January 1993

Figure 2.3
Photographs of Gillespie Dam on 12 January 1993
(Bates Number 0015834)

Figure 2.4
Photograph of full 206 feet wide breach in Gillespie Dam, looking upstream on 15 July 1996

3 Analysis of Work Product

3.1 Hydraulic Modeling of the Gila River

The Gila River is a braided alluvial river. An alluvial river is characterized by the bed and banks being composed of sands, gravels and clays (alluvium). Refer to Schumm (1997) for a more detailed description. The Gila River at Gillespie Dam drains a watershed area of about 49,650 square miles. Its bed and banks are typically composed of sand and gravels, and its flow channels are braided (Schumm, 1997). The hydraulics of such a relatively unstable river are therefore difficult to model because the bed and banks are subject to erosion and change during virtually any significant flow event.

Rivers of this type in Arizona and elsewhere are modeled using the US Army Corps of Engineers HEC-2 computer program. The HEC-2 program is a "fixed bed" model, which means that the effects of scour and bank erosion are not estimated. The HEC-2 program can produce reasonable results of flooding limits for alluvial rivers if the average hydraulic characteristics, such as cross sectional area and wetted perimeter, of the cross sections do not change significantly. A cross section may experience cut and fill across the section during the flood event, but the two can average out, resulting in little change in net area. The conveyance, correspondingly, also may not change significantly. This situation, in general, appears to be true for the existing HEC-2 models of the Gila River when used to model the 1993 peak discharge of 132,000 cfs. This is witnessed by the close agreement of flood limits between the 1993 Flood Inundation Limits and the 1993 Hydraulic Model Riverine Flood Limits (refer to Section 3.3).

An additional confidence check is provided by comparison of pre- and post-flood cross sections. Pre- and post-flood HEC-2 cross sections are not available for the Gila River downstream of Gillespie Dam, but are available upstream. Pre-flood and post-flood HEC-2 cross sections for section 172.30 are shown in Figure 3.1. Section 172.30 is about 5.72 miles upstream of Gillespie Dam, and appears to be outside the scour influence of the dam breach. Some of the sediment stored upstream by Gillespie Dam was gradually eroded after the breach occurred (Sabol, 1997). The upstream limit of that erosion is the scour influence of the dam breach. Note the difference in cut and fill across the section as a result of the 1993 flood. Although the channel has shifted location horizontally as a result of the flood, the cut and fill areas are nearly the same. The modeled pre- versus post-flood water surface elevations for section 172.30 are 779.8 and 779.7, respectively; a good agreement. This is certainly not true for every cross section, but appears to be the case on the average, as witnessed by the close agreement between actual and modeled flood limits (refer to Sections 3.2 and 3.3).

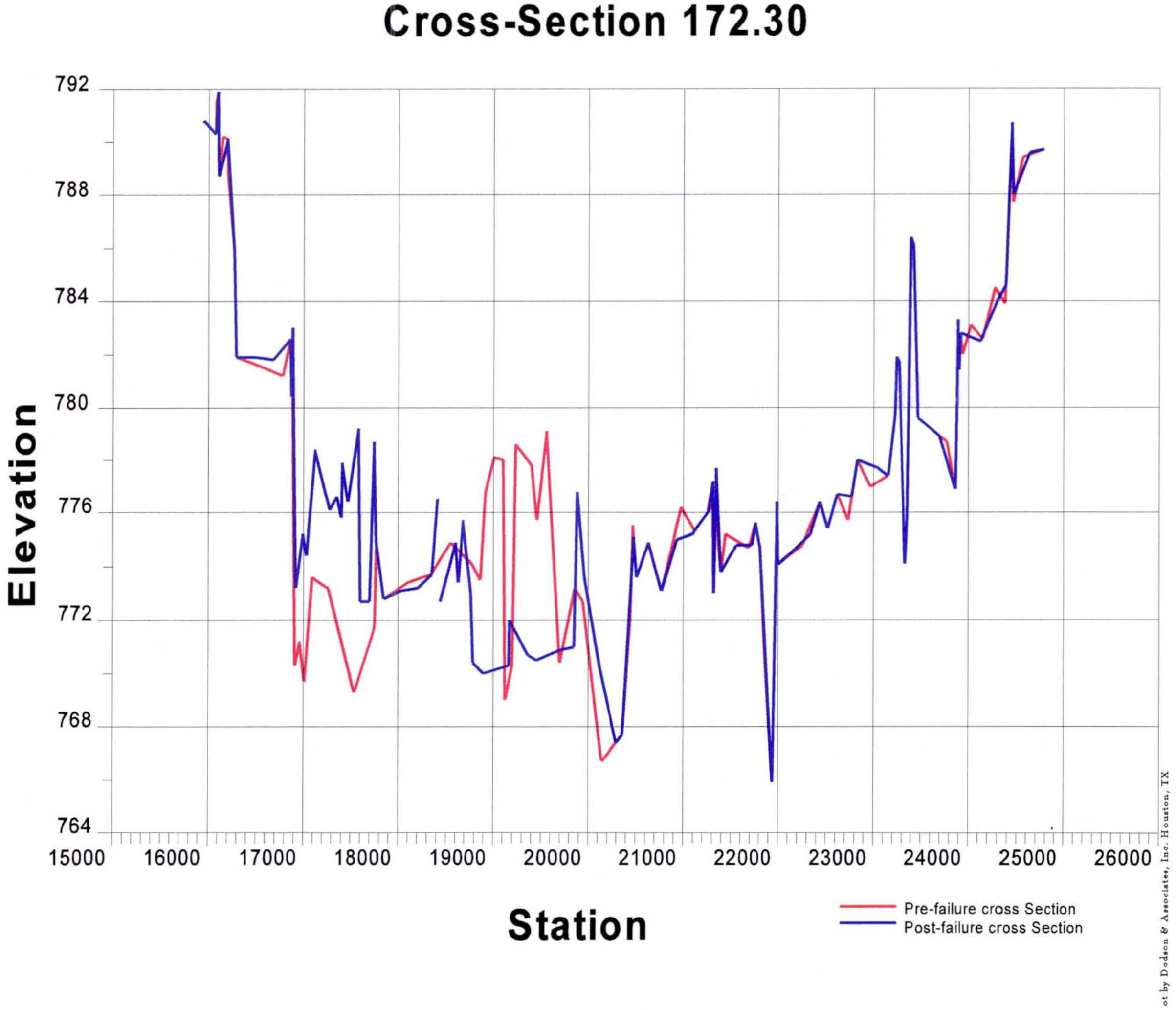


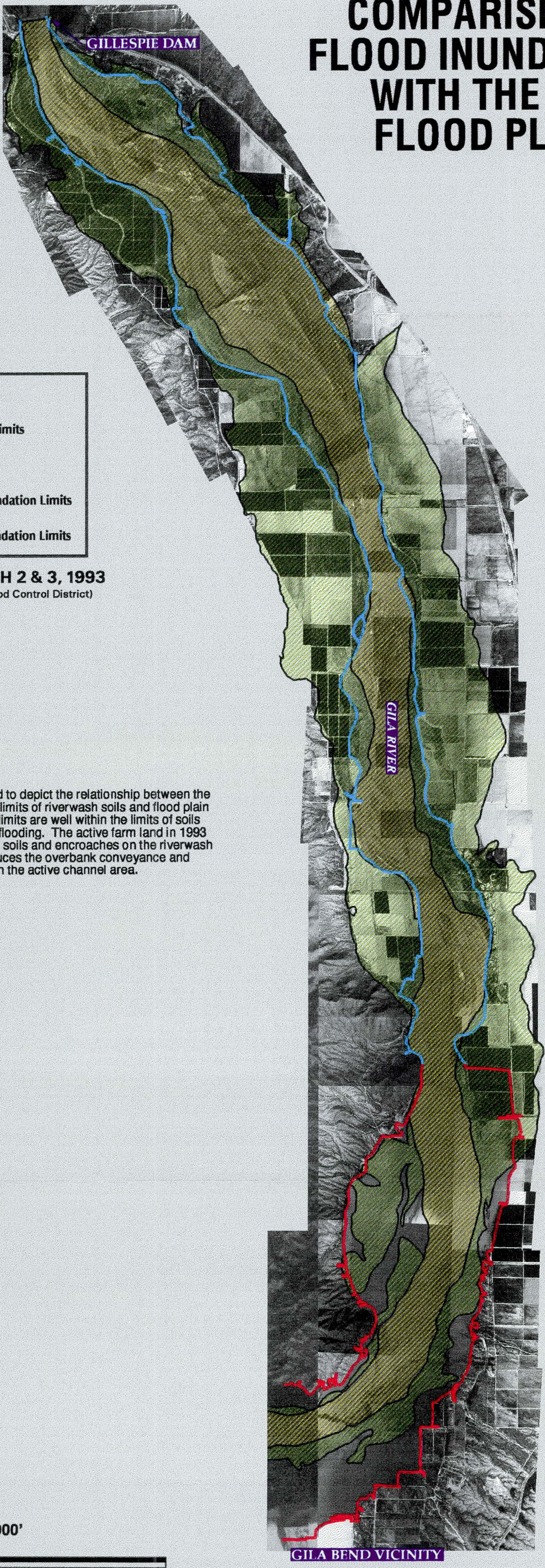
Figure 3.1
Typical pre-flood versus post-flood cross section of the Gila River upstream of Gillespie Dam

The hydraulics of the Gila River are different under low flow and high flow conditions. Under low flow rate conditions the meandering low flow channel path is followed. This results in flatter slopes and lower average velocities of flow. Under high flow conditions, the low flow channels are overtopped and the main flow tends to "short cut" the bends and turns of the low flow channel. The HEC-2 computer program is normally used to model the high flow condition. The HEC-2 models listed in Table 2.2 are representative of high flow conditions.

The Gila River in the vicinity of Gillespie Dam is characterized by heavy tamarisk vegetation in the main conveyance areas and less dense normal desert vegetation on the higher overbanks. The main conveyance area is the active channel areas and associated low overbanks. Several days of high flow rates preceded the peak discharge on 9 January 1993 (Sabol, 1997). This resulted in some removal of the vegetation in the main conveyance areas, and a reduction in the average roughness effect resulting from vegetation being bent over. That is a normal occurrence for high flows in the Gila River. The vegetation is typically reestablished quickly after a large flood (refer to Figures A.2, A.3 and A.4 in Appendix A, Section A.14).

A historic view of the alluvial nature of the Gila River is shown on Figure 3.2. The 1993 Flood Inundation Limits are shown in comparison with the Limits of Flood Plain Soils using the 2 March 1993 aerial photograph background. The Riverwash soils are shown in yellow. This is the current active channel area. The area in green represents the flood plain soils of the Gila River valley. The Gila River, before the encroachments of man, historically was free to migrate back and forth within those limits (Schumm, 1997). Note that the 1993 Flood Inundation Limits are within the Limits of Flood Plain Soils, except in the area of backwater influence from Painted Rock Dam (1993 Ponding Inundation Limits).

COMPARISION OF 1993 FLOOD INUNDATION LIMITS WITH THE LIMITS OF FLOOD PLAIN SOILS



LEGEND

- Flood Plain Soils Limits
- Riverwash Limits
- 1993 Riverine Inundation Limits
- 1993 Ponding Inundation Limits

PHOTO DATES: MARCH 2 & 3, 1993
(Source: Maricopa County Flood Control District)

Description: This figure is used to depict the relationship between the 1993 riverine flooding and the limits of riverwash soils and flood plain soils. The 1993 riverine flood limits are well within the limits of soils historically subject to periodic flooding. The active farm land in 1993 covers most of the flood prone soils and encroaches on the riverwash soils. This encroachment reduces the overbank conveyance and increases the velocity of flow in the active channel area.

Scale 1" = 6000'

0 3000 6000 12000 24000

/hd2/johnhelm/phase1/tom/figure32.aml 01/18/97 16:56:53 Sat

FIGURE 3.2

3.2 Comparison of 1993 Flood Inundation Limits with 1993 Hydraulic Model Riverine Flood Limits

The 1993 Flood Inundation Limits and the 1993 Hydraulic Model Riverine Flood Limits for the Gila River between Gillespie Dam and the Gila Bend area are shown on Figure 3.3 (refer to Appendix A, Sections A.3 and A.4). Note the very good agreement between the modeled riverine limits and the actual riverine limits. The minor differences between the two limits are likely due to the following:

1. The modeled riverine limits are based on the 1989 topography (refer to Section 2.3) which represents the pre-flood hydraulic conditions.

2. The effects of farm land encroachment after 1989 are not reflected in the modeled riverine limits.

3. The n-values used in the hydraulic model may be higher than the actual (refer to Appendix A, Section A.14).

4. There are subtle variations in the elevations of the farm fields which are not reflected in the 1989 topography which had a contour interval of 2 feet.

An additional comparison is made between the 1993 Hydraulic Model Riverine Flood Limits and the USGS gage record at the Enterprise Canal (refer to Appendix A, Section A.15). The HEC-2 model results are found to agree with the peak stage recorded at USGS Gage Number 09519000 on 9 January 1993. That agreement provides further substantiation that the peak discharge of 132,000 cfs estimated by Hjalmarson (1997) is reasonable for the Gila River downstream of Gillespie Dam.

The following conclusions are drawn from these comparisons:

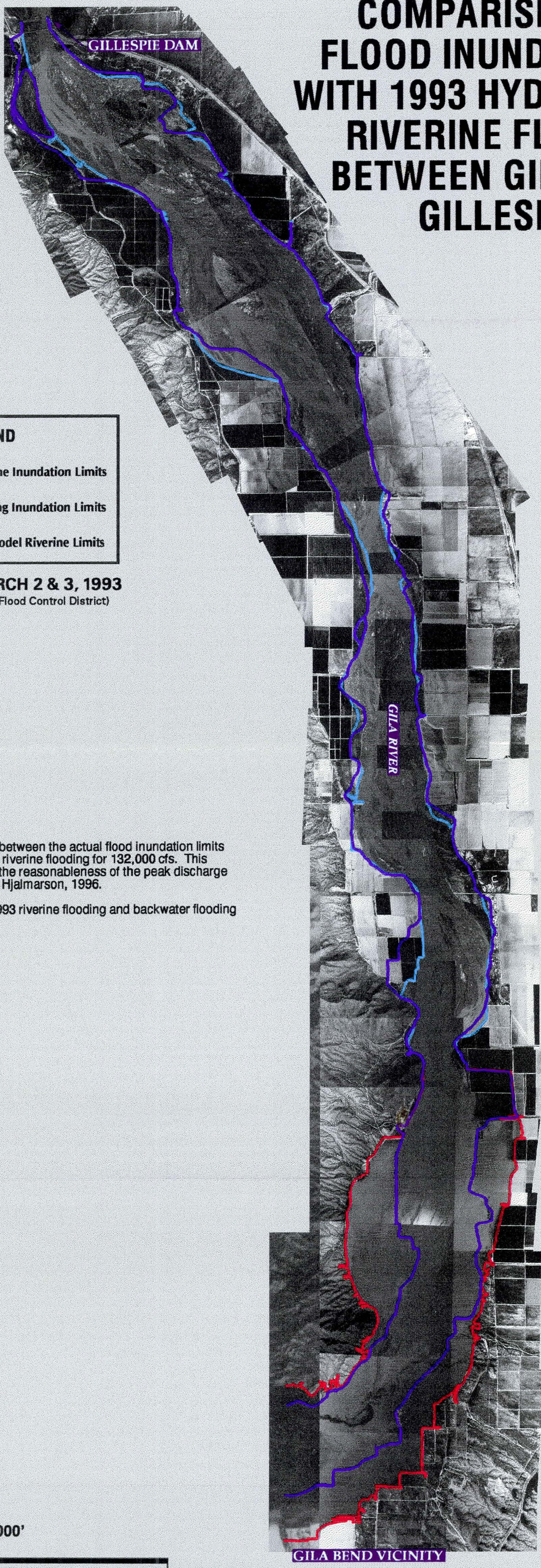
1. The pre-flood hydraulic characteristics of the Gila River between Gillespie Dam and the Gila Bend area did not change significantly as a consequence of the 1993 flood and breach of Gillespie Dam.

2. The flood peak discharge of 132,000 cfs, as estimated by Hjalmarson (1997), is confirmed due to the agreement of the actual flood inundation limits and the modeled flood inundation limits for 132,000 cfs.

3. The breach of Gillespie Dam did not produce flooding in excess of the naturally occurring flood.

4. Differences in the flood inundation limit lines, shown in Figure 3.3, are attributed to normal accuracy limitations that are inherent with this analytic method, and to bank erosion and lateral movement of the river channel that occurred during the 1993 flood. That flood was of exceptionally long duration and magnitude (Sabol, 1997), and such floods are expected to produce bank erosion and lateral movement of the river channel (Schumm, 1997). It is important to note that bank erosion is typically limited to areas adjacent to farm land that have encroached into the active channel of the flood plain as the result of agricultural expansion.

COMPARISION OF 1993 FLOOD INUNDATION LIMITS WITH 1993 HYDRAULIC MODEL RIVERINE FLOOD LIMITS BETWEEN GILA BEND AND GILLESPIE DAM



LEGEND

- 1993 Flood Riverine Inundation Limits
- 1993 Flood Ponding Inundation Limits
- 1993 Hydraulic Model Riverine Limits

PHOTO DATES: MARCH 2 & 3, 1993
(Source: Maricopa County Flood Control District)

Description:

This figure is used to depict:

1. The very good correlation between the actual flood inundation limits and the hydraulic model of riverine flooding for 132,000 cfs. This is supporting evidence for the reasonableness of the peak discharge estimate of 132,000 cfs by Hjalmarson, 1996.
2. The difference between 1993 riverine flooding and backwater flooding from Painted Rock Dam.

Scale 1" = 6000'

0 3000 6000 12000 24000

FIGURE 3.3

3.3 Comparison of the 1993 Upstream Flood Inundation Limits with the 1993 Upstream Hydraulic Model Results

The 1993 Upstream Flood Inundation Limits and the 1993 Upstream Hydraulic Model Flood Limits for the west bank of the Gila River upstream of Gillespie Dam are shown on Figure 3.4 (refer to Appendix A, Sections A.13 and A.14). That figure depicts the area between HEC-2 cross sections 168.01 and 168.95. Also shown on Figure 3.4 is the 9 January 1993 aerial photography, the pre-flood 1992 topography and the Michael Baker Jr., Inc. (Baker) HEC-2 cross section locations. There is very good agreement between the modeled riverine flood limits and the actual riverine flood limits.

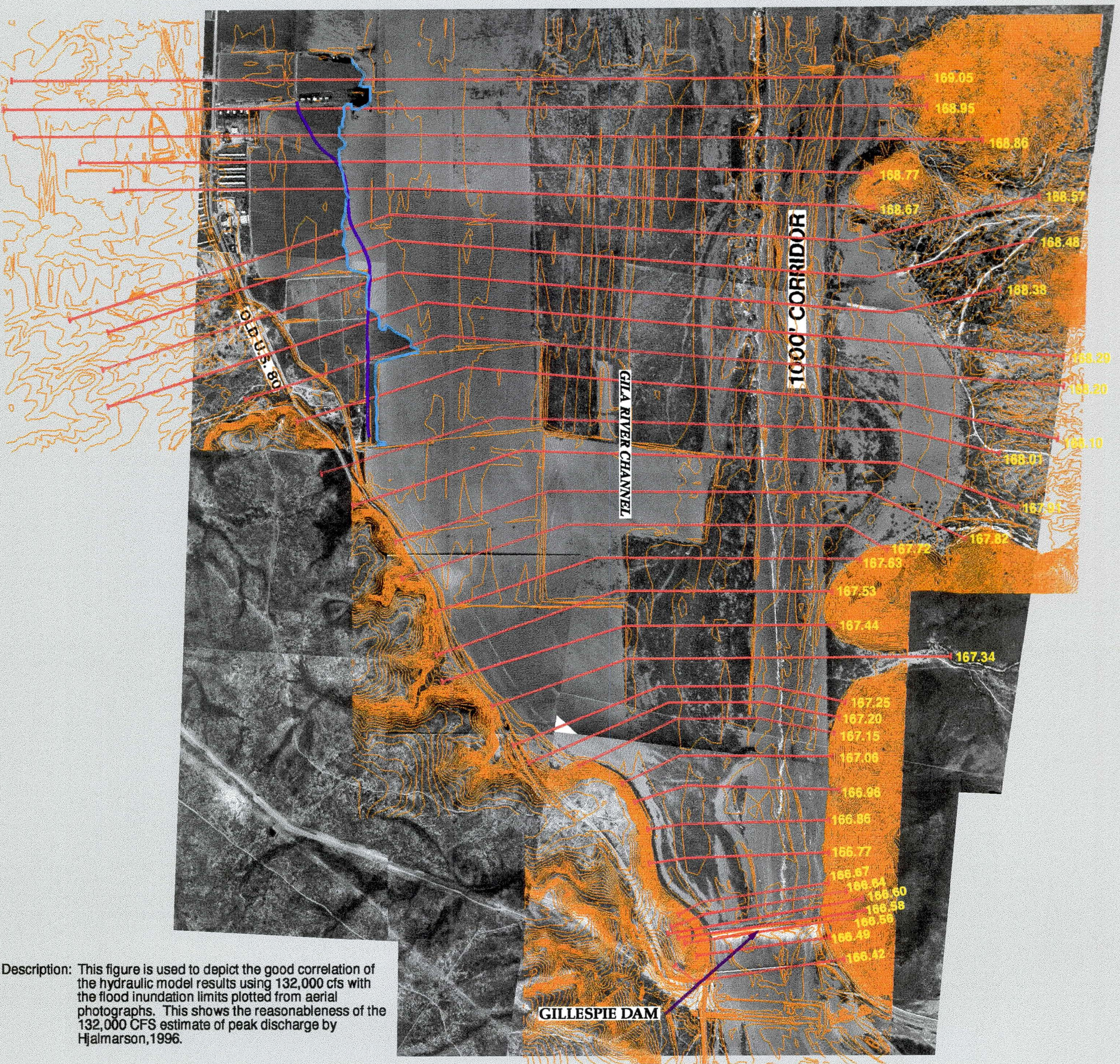
The following conclusions are drawn from this comparison:

1. The resistance to flow caused by vegetation in the flood plain was reduced due to the sustained high discharges. Much of that reduction in flow resistance had taken place by the time the flood peak discharge occurred. The reduction of flow resistance factors in the Baker HEC-2 model are appropriate (refer to Appendix A, Section A.14).

2. The flood peak discharge of 132,000 cfs, as estimated by Hjalmarson (1997), is confirmed for the Gila River upstream of Gillespie Dam.

3. The flood peak discharge is the same (132,000 cfs) both upstream and downstream of Gillespie Dam. Therefore, the breach of Gillespie Dam did not increase the flood inundation downstream of Gillespie Dam over that which resulted from the naturally occurring flood.

COMPARISON OF 1993 UPSTREAM FLOOD INUNDATION LIMITS WITH 1993 UPSTREAM HYDRAULIC MODEL RESULTS ALONG THE WEST BANK OF THE GILA RIVER UPSTREAM OF GILLESPIE DAM



Description: This figure is used to depict the good correlation of the hydraulic model results using 132,000 cfs with the flood inundation limits plotted from aerial photographs. This shows the reasonableness of the 132,000 CFS estimate of peak discharge by Hjalmarson,1996.

Topography: Michael Baker Jr. Engineers, 1992, Contour Interval = 4 feet
HEC-2 Cross Sections: Michael Baker Jr. Engineers, 1992, Pre-flood HEC-2 Model

LEGEND

- 1993 Upstream Flood Inundation Limits
- 1993 Upstream Hydraulic Model Riverine Flood Limits
- HEC-2 Cross Section

PHOTO DATE: JANUARY 9, 1993
(Source: Maricopa County Flood Control District)

Flood Control District of Maricopa County — Geographic Information System

Scale 1" = 1650'

0 825 1650 3300 6600

FIGURE 3.4

/hd2/johnhelm/phase1/uppergila/figure34.aml 01/20/97 14:13:38 Mon

3.4 Effects of the Breach of Gillespie Dam on the Downstream Flood Plain Hydraulics

The breach of Gillespie Dam on 9 January 1993 did not occur rapidly. Instead, the breach reportedly occurred gradually over a 2 to 3 hour period, stabilized, and then continued to widen over a period of days (refer to Section 2.5). There was an insignificant volume of water impounded upstream of the dam (less than 50 acre-feet, refer to Appendix A, Section A.11), in comparison to the 258,000 acre-feet which passed over the dam on 9 January 1993 (Sabol, 1997). Flow apparently continued over the entire length of the dam spillway crest for some time after the initial breach (refer to Figures 2.1 and 2.2). The breach apparently began on the receding limb of the hydrograph, 4 to 5 hours after the time of peak flow which occurred about 8:00 a.m. on 9 January 1993 (Hjalmarson, 1997).

The breach resulted in an increase in flow velocity through the breach itself. The increase in velocity through the breach can be assumed to dissipate and return to normal flow conditions using a 4:1 expansion factor. The 4:1 expansion factor is an empirical rule that is often used in the analysis of flow constrictions on a river (Hoggan, 1989 and US Army Corps of Engineers, 1995). A second method of estimating the expansion factor is to use available photographic evidence. The upper photograph in Figure 2.2 is used to estimate the actual expansion ratio which occurred at about 3:30 p.m. on 9 January 1993. The limits of turbulence downstream of the breach are estimated to expand at about a 4.6:1 ratio on the west side and a ratio of 4.4:1 on the east side of the breach. The width of the breach at 3:30 p.m. was estimated to be about 135 feet (refer to Table 2.3). That width is supported by the upper photograph in Figure 2.2. The encroachment width on the west side of the breach is estimated to be 1300 feet, assuming the 135 feet wide breach begins a distance of 223 feet from the east abutment (refer to Figure 3.5). The encroachment width on the east side of the breach is estimated to be 223 feet. These estimates are conservative because a significant amount of flow was still overtopping the entire length of the dam spillway crest so there was not a full contraction into the breach under high flow rates. The effects on velocity and turbulence from the breach are estimated to extend about 6000 feet downstream along the west side of the flow expansion and about 1000 feet downstream along the east side of the flow expansion using the estimated expansion ratios. The 4:1 estimate of expansion ratio yields a 5200 feet long expansion length. The worst case limit of hydraulic effects of the dam breach downstream from Gillespie Dam is estimated to be about 6000 feet. The first farm land parcels adjacent to the Gila River start about 10,000 feet downstream of Gillespie Dam, almost twice the distance of hydraulic effects from the breach.

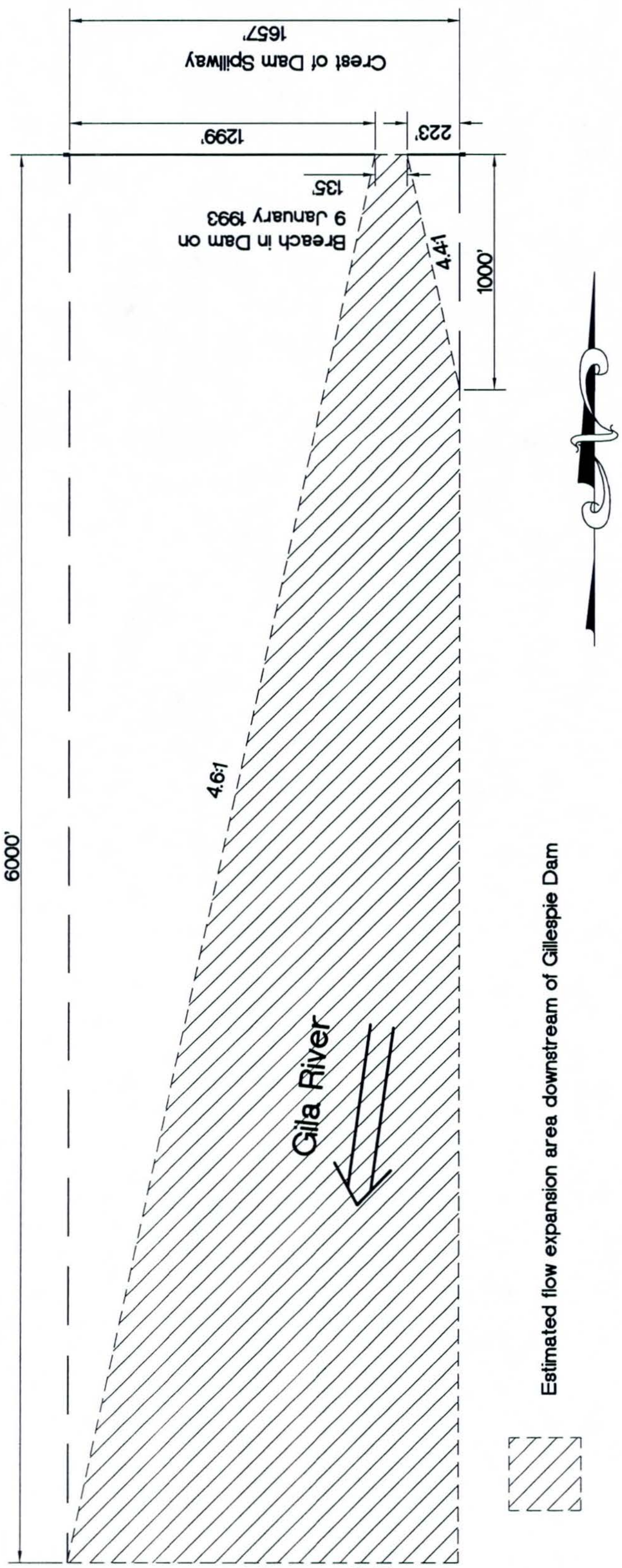
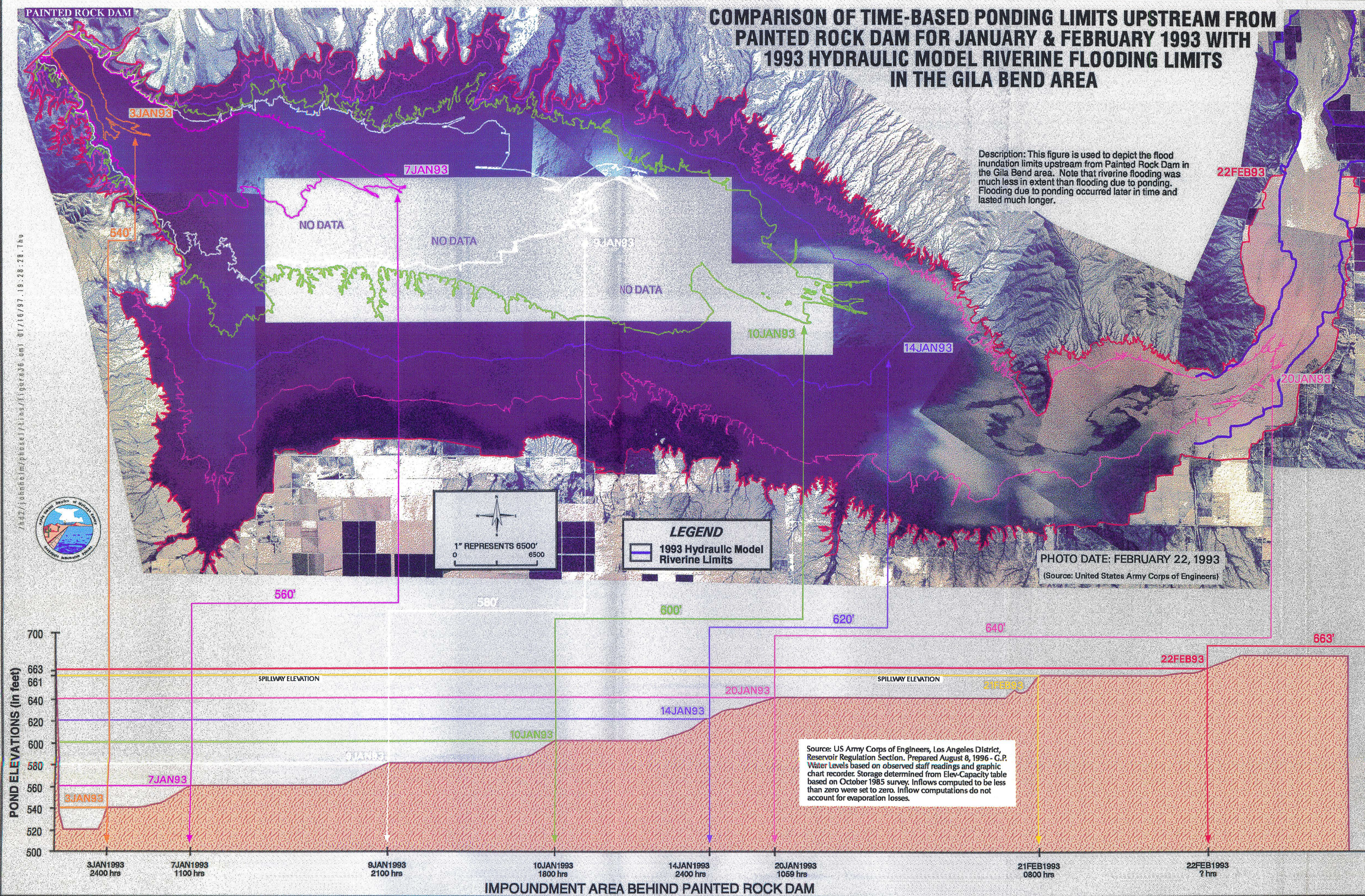


Figure 3.5
Diagram of estimated flow expansion downstream of the breach in Gillespie Dam

3.5 Comparison of Riverine Flooding Limits and Ponding Limits Upstream from Painted Rock Dam in the Gila Bend Area

The 1993 Hydraulic Model Riverine Flood Limits and a time-based series of ponding limits upstream from the Painted Rock Dam in the Gila Bend area are shown on Figure 3.6 (refer to Appendix A, Section A.6). The modeled flood limits are representative of the actual riverine flood limits which occurred on 9 January 1993 because of the comparison discussed in Section 3.2. The area shown on Figure 3.6 clearly experienced two separate types of flood as a result of the 1993 event, riverine and ponding. Riverine flooding is that produced by flow in the Gila River. Flooding due to ponding is caused by waters stored upstream of Painted Rock Dam. Peak riverine flooding limits occurred on 9 January 1993, affecting only the areas within the limits shown on Figure 3.6. The flooding due to ponding behind Painted Rock Dam gradually re-inundated the areas of riverine flooding after the riverine flood receded, and then the area of inundation due to ponding increased outside the limits of riverine flooding as shown.



COMPARISON OF TIME-BASED PONDING LIMITS UPSTREAM FROM PAINTED ROCK DAM FOR JANUARY & FEBRUARY 1993 WITH 1993 HYDRAULIC MODEL RIVERINE FLOODING LIMITS IN THE GILA BEND AREA

FIGURE 3.6

3.6 Comparison of 1993 Flooding Limits with known Flood Hazard Areas

There are three limits of flood hazard areas for the Gila River between Gillespie Dam and the Gila Bend area that define flood limits typically broader than the 1993 Flood Inundation Limits. Those are, in order of the most severe flood condition:

1. Limits of Flood Plain Soils;
2. USGS Flood Prone Limits; and
3. 1989 FEMA 100-year Flood Plain Limits.

Those three sets of flood hazard areas are shown on Figure 3.7, in addition to the 1993 Flood Inundation Limits (refer to Appendix A, Sections A.7, A.9 and A.10). The Limits of Flood Plain Soils are representative of the historic limits of flooding in the Gila River valley for recent geologic time. The USGS Flood Prone Limits are representative of the 1951 topography and the highest peak discharge of record for the Gila River (250,000 cfs). The 1989 FEMA 100-year Flood Plain Limits are representative of the farm land encroachments as of 1989, and a peak discharge of about 230,000 cfs. Note that in general the 1993 Riverine Flood Inundation Limits lie within the FEMA limits, which lie within the USGS limits, which lie within the soils limits. The 1993 Ponding Flood Inundation Limits are greater than the other three limits because of the extreme magnitude of the volume of runoff from the 1993 flood (Sabol, 1997).

The conclusions drawn from this figure are:

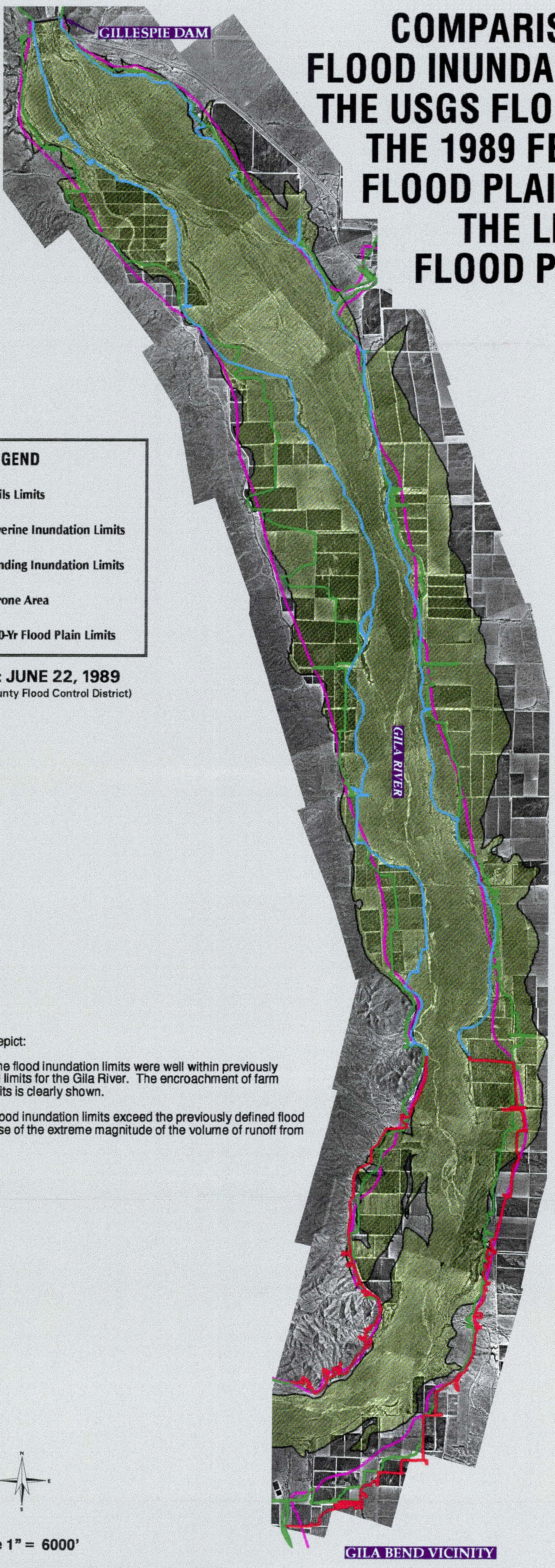
1. The 1993 Riverine Flood Inundation Limits are contained within the three other flood limit lines. This indicates that the 1993 flood was less than the 100-year flood.

2. There was information of record as early as 1972 which defined riverine flooding limits more severe than what occurred in 1993.

3. The 1989 FEMA 100-year Flood Limits exhibit a decrease in flooding width in some areas when compared with the USGS Flood Prone Limits. That decrease is apparently due to the encroachment of farm land into the flood plain.

4. Lands lying within the Limits of Flood Plain Soils, the USGS Flood Prone Limits, and the 1989 FEMA 100-year Flood Plain Limits are expected to be subject to flooding.

COMPARISION OF 1993 FLOOD INUNDATION LIMITS WITH THE USGS FLOOD PRONE AREA, THE 1989 FEMA 100-YEAR FLOOD PLAIN LIMITS, AND THE LIMITS OF FLOOD PLAIN SOILS



LEGEND

- Flood Plain Soils Limits
- 1993 Flood Riverine Inundation Limits
- 1993 Flood Ponding Inundation Limits
- USGS Flood Prone Area
- 1989 FEMA 100-Yr Flood Plain Limits

PHOTO DATE: JUNE 22, 1989
(Source: Maricopa County Flood Control District)

Description:

This figure is used to depict:

1. That the 1993 riverine flood inundation limits were well within previously defined flood hazard limits for the Gila River. The encroachment of farm land within those limits is clearly shown.
2. The 1993 ponding flood inundation limits exceed the previously defined flood hazard areas because of the extreme magnitude of the volume of runoff from the flood.

Flood Control District of Maricopa County — Geographic Information Systems

Scale 1" = 6000'

0 3000 6000 12000 24000

FIGURE 3.7

/hd2/johnhelm/phase1/tom/figure37.aml 01/18/97 20:54:28 Sat

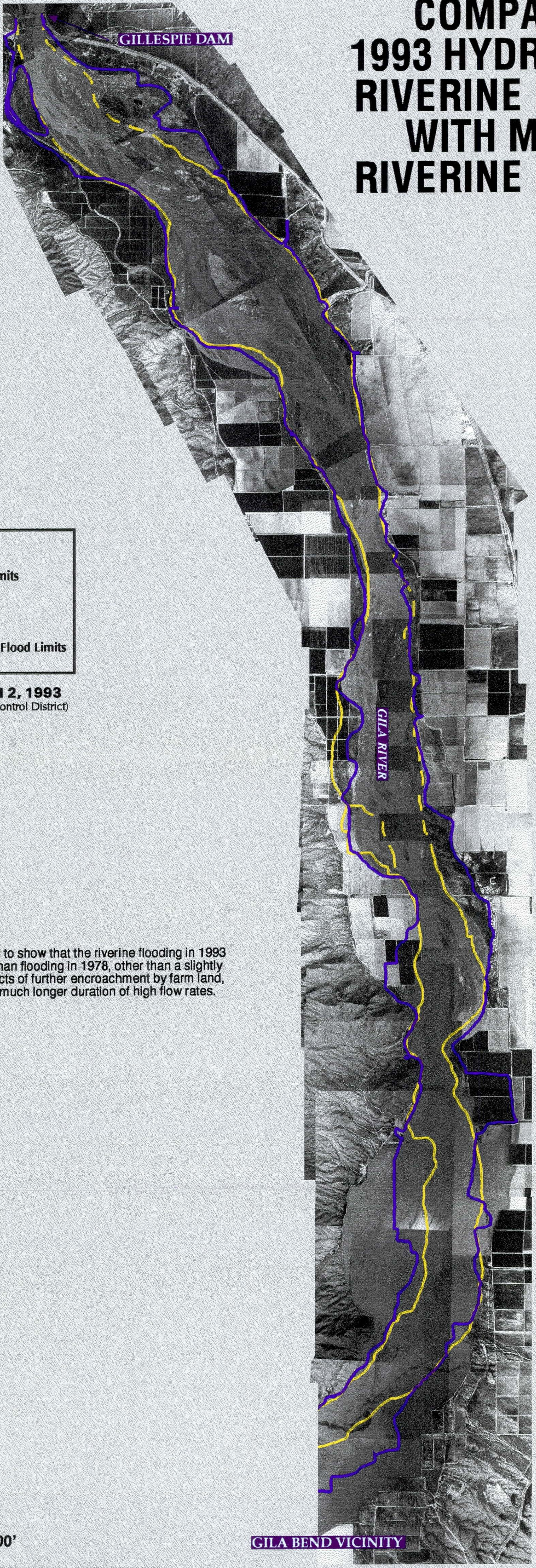
3.7 Comparison of the 1993 Hydraulic Model Riverine Flood Limits with the March 1978 Riverine Flood Limits

The 1993 Hydraulic Model Riverine Flood Limits and the March 1978 Riverine Flood Limits are shown on Figure 3.8 for the Gila River between Gillespie Dam and the Gila Bend area (refer to Appendix A, Section A.5). Note that the March 1978 Riverine Flood Limits (peak discharge of 92,900 cfs) lie within the 1993 Hydraulic Model Riverine Flood Limits (132,000 cfs) for most of the reach between Gillespie Dam and the Gila Bend area. The exceptions are typically where farm land has encroached into the river after 1978. Those encroachments appear to force the constrictions where the 1993 limits are inside the 1978 limits. The conclusions drawn from Figure 3.8 are:

1. The 1993 Hydraulic Model Riverine Flood Limits are reasonable in comparison to the March 1978 Riverine Flood Limits. The 1993 Riverine Flood Inundation Limits are also reasonable in comparison to the March 1978 Riverine Flood Limits because of the close agreement with the 1993 Hydraulic Model Riverine Flood Limits described in Section 3.2.

2. Farm land encroachment into the Gila River flood plain between 1978 and 1993 apparently forced a noticeable constriction in the 1993 flood limits, particularly along the west bank, looking downstream.

COMPARISION OF 1993 HYDRAULIC MODEL RIVERINE FLOOD LIMITS WITH MARCH 1978 RIVERINE FLOOD LIMITS



LEGEND

- 1978 Riverine Flood Limits
- 1978 Bank Limits
- 1993 Hydraulic Model Flood Limits

PHOTO DATE: MARCH 2, 1993
(Source: Maricopa County Flood Control District)

Description: This figure is used to show that the riverine flooding in 1993 was not significantly different than flooding in 1978, other than a slightly larger peak discharge, the effects of further encroachment by farm land, and bank scour caused by the much longer duration of high flow rates.

Scale 1" = 6000'

0 3000 6000 12000 24000

FIGURE 3.8

/hd2/johnhelm/phase1/tam/figure38.aml 01/18/97 20:00:45 Sat

3.8 Effects of Agriculture Related Encroachments on Flood Plain Hydraulics

The Limits of Farm Land History are compared with the 1993 Flood Inundation Limits and the USGS Flood Prone Limits on Figure 3.9 (refer to Appendix A, Section A.8). The farm land occupied between the photography date of a given year and the previous photography date, such as between 1958 and 1953, is color coded to distinguish that intrusion into the Gila River flood plain.

A typical bank erosion location at a bend in the Gila River is shown in Figure 3.10. The location is shown for three periods in time: 1953, 1978 and 1993. Examining the 1953 photograph, note the limits of farm land encroachment in 1953 compared with the estimated active channel bank of the Gila River. Switching to the 1978 photograph, note that the farm land encroachment in 1978 has extended past the 1953 bank limit, probably using fill to construct the level farm fields. The Gila River was constricted by the extended bank encroachment constructed to form the farm field. Note that the peak flow limits in 1978 were contained by that bank. Switching to the 1993 photograph, note that the 1993 flood, which had a higher peak flow rate and much longer duration of high flows than occurred in 1978, attacked that bank and eroded it. The bank which was eroded is defined by the difference between the 1993 Hydraulic Model Riverine Flood Limits and the 1993 Riverine Flood Inundation Limits. The hydraulic model limits from the HEC-2 computer program do not include bank erosion because it is a fixed bed model (refer to Section 3.1).

The conclusions drawn from examination of Figures 3.9 and 3.10 are:

1. A significant area of land lying within the 1972 USGS Flood Prone Limits has been converted to farm land since 1953.

2. The majority of that land lies between the farm land developed as of 1953 and the active portion of the Gila River.

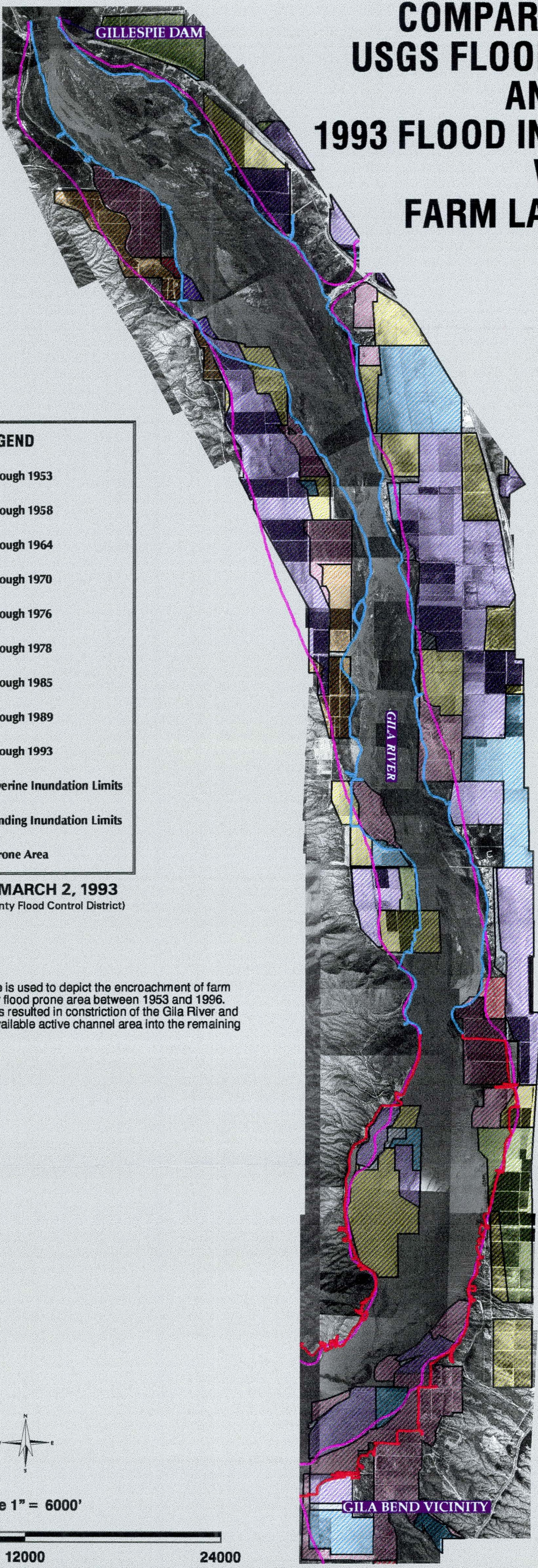
3. Many of the encroachments are significant in that the encroachment extends into the river at a bend where scour and bank migration (both natural processes) would be expected to occur.

4. Encroachment of the 1993 Riverine Flood Inundation Limits into farm land typically occurs at a bend in the river.

5. The farms have constricted the Gila River to a narrower width than it historically has occupied.

6. The bank erosion which occurred during the 1993 flood was a result of natural river processes and encroachments into the historic flow path of the Gila River by farm land.

COMPARISION OF THE USGS FLOOD PRONE LIMITS AND THE 1993 FLOOD INUNDATION LIMITS WITH FARM LAND HISTORY



LEGEND

- Farm Land Through 1953
- Farm Land Through 1958
- Farm Land Through 1964
- Farm Land Through 1970
- Farm Land Through 1976
- Farm Land Through 1978
- Farm Land Through 1985
- Farm Land Through 1989
- Farm Land Through 1993
- 1993 Flood Riverine Inundation Limits
- 1993 Flood Ponding Inundation Limits
- USGS Flood Prone Area

PHOTO DATE: MARCH 2, 1993
(Source: Maricopa County Flood Control District)

Description: This figure is used to depict the encroachment of farm land into the Gila River flood prone area between 1953 and 1996. This encroachment has resulted in constriction of the Gila River and concentration of the available active channel area into the remaining un-farmed areas.

Flood Control District of Maricopa County
Geographic Information Systems

Scale 1" = 6000'

0 3000 6000 12000 24000

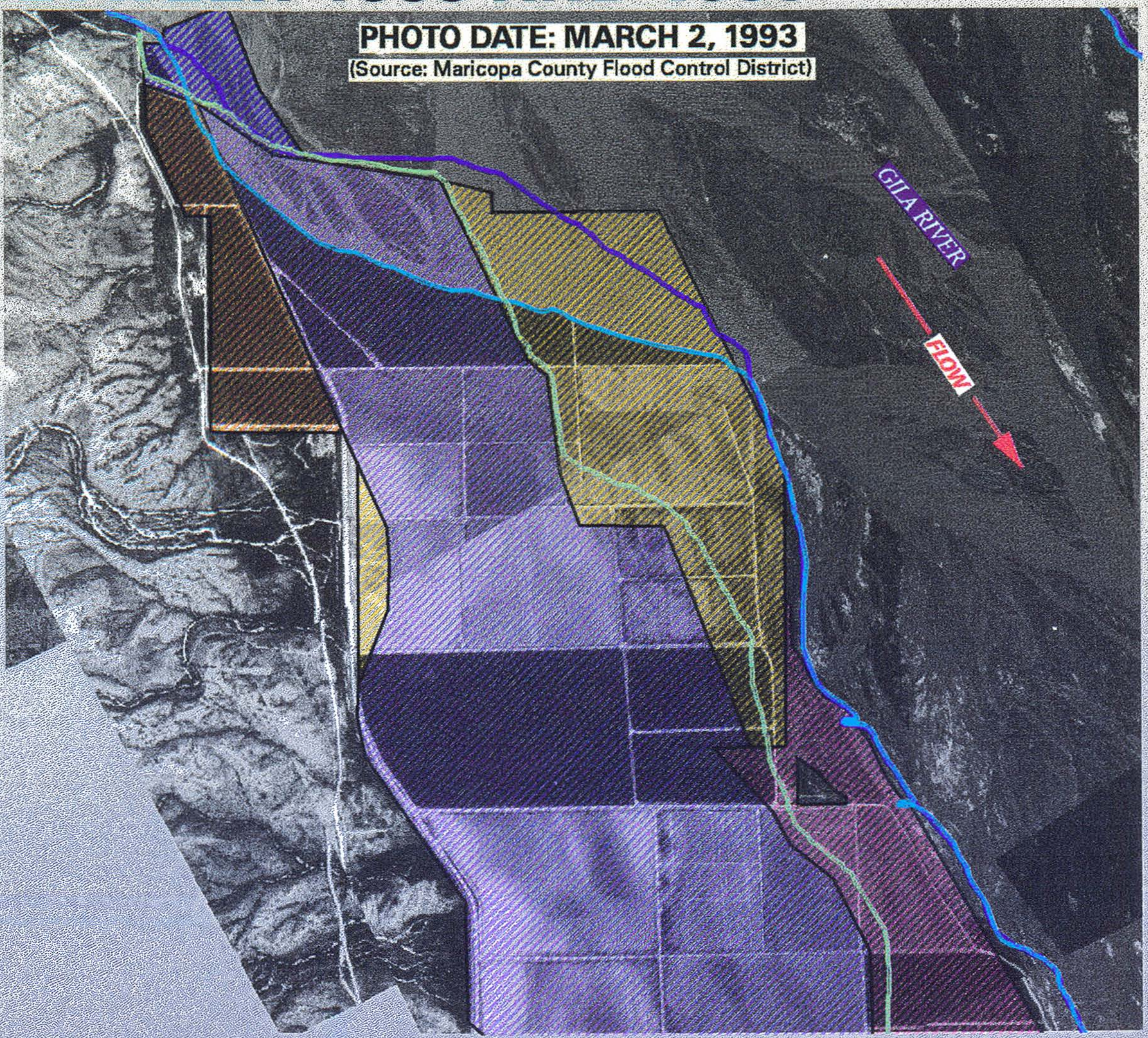
FIGURE 3.9

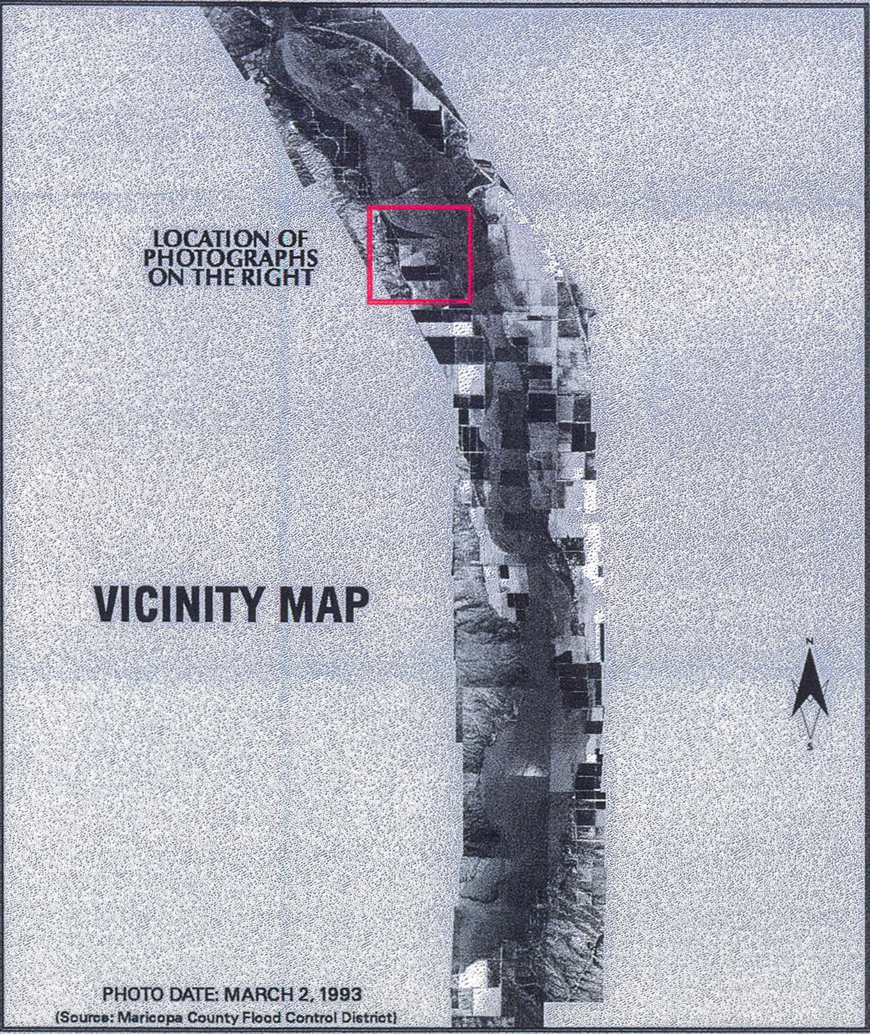
/hd2/johnheim/phasel/tom/figure39.aml 01/18/97 20:30:48 Sat

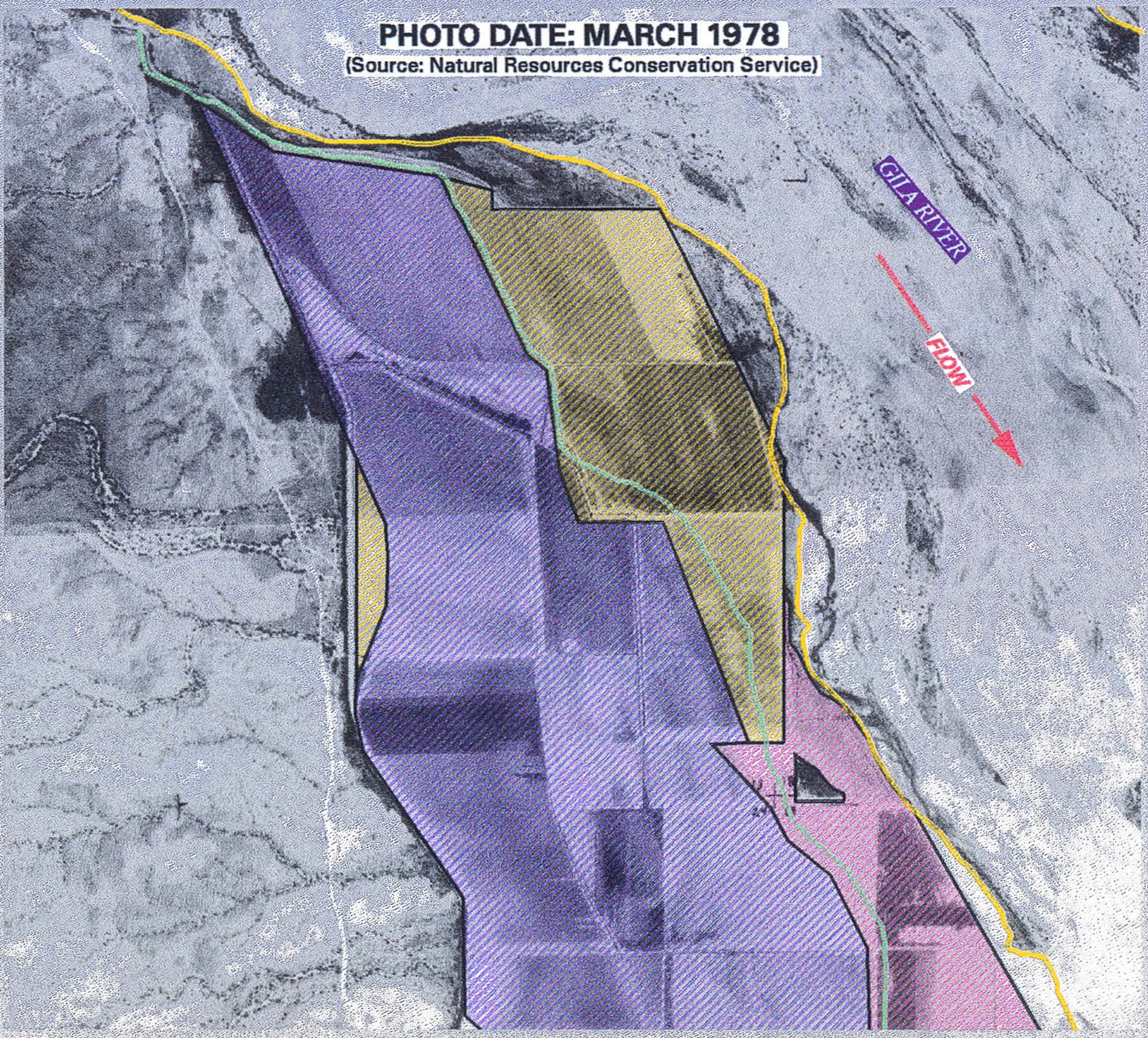
EXAMPLE OF FARM LAND ENCROACHMENT AND BANK EROSION BETWEEN 1953 AND 1993

LEGEND

- Farm Land Through 1953
- Farm Land Through 1958
- Farm Land Through 1964
- Farm Land Through 1970
- Farm Land Through 1976
- Farm Land Through 1978
- Farm Land Through 1985
- Farm Land Through 1989
- Farm Land Through 1993
- USGS Flood Prone Limits
- March 1978 Riverine Flood Limits
- 1993 Flood Inundation Limits
- 1993 Hydraulic Model Riverine Flood Limits
- Approximate West Bank of Gila River in 1953







Description:

This figure is used to depict:

1. Typical farm land encroachment over time at a bend in the river.
2. The Gila River attempting to regain lost conveyance area through bank erosion.

Flood Control District of Maricopa County Geographic Information Systems

Scale 1" = 1700'

0 850 1700 3400 6800

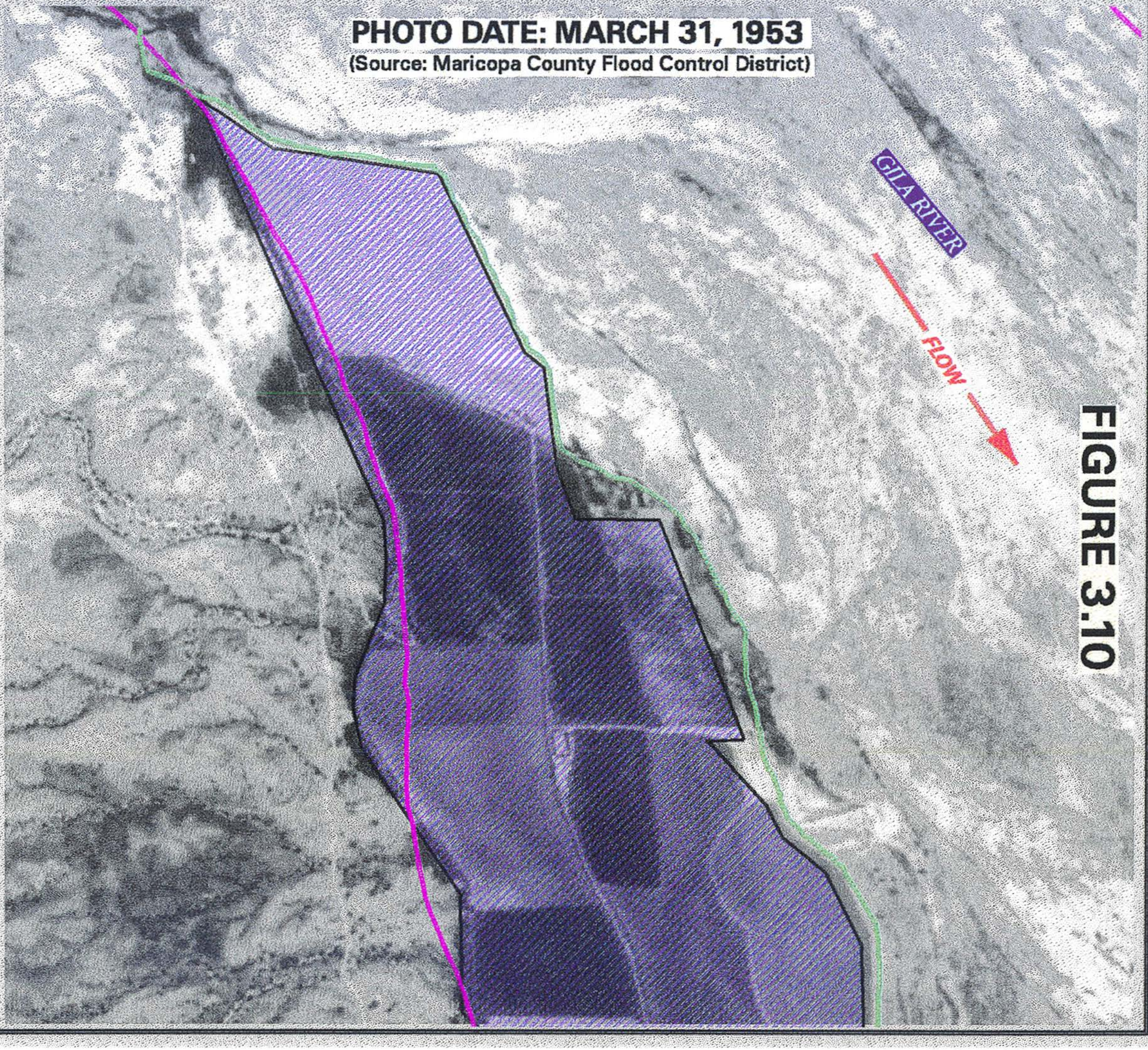


FIGURE 3.10

3.9 Enterprise Canal Capacity and Breakouts

The reach of the Enterprise Canal of interest lies between Gillespie Dam and a location about 3.6 miles downstream of the SR 80 bridge. That reach is shown on Figure 3.11. The Enterprise Canal is only directly affected by flooding in the Gila River between Gillespie Dam and the approach road crossing just downstream of the SR 80 bridge. The canal in that reach is typically completely inundated by high flows in the Gila River. Approximately 345 cfs was discharged into the Enterprise Canal at the time of peak in the Gila River on 9 January 1993 at the approach road crossing (refer to Appendix A, Section A.16). That flow drained in the canal to the two points of failure, 3 and 3.6 miles downstream, as shown on Figure 3.11.

The two locations of canal failure are shown in more detail on Figure 3.12. Note the two types of flooding which occurred at the first location, 3 miles downstream. The first type of flooding was bank overflow upstream from a farm road crossing as shown on Figure 3.12. Based on physical evidence found at the site, it is likely that a culvert existed to pass the canal flow under the farm road. The farm road no longer crosses the canal at that point, but the road approaches to the canal are still in place, and the remains of a culvert are present in the canal and scattered about on the west bank. The overflow was apparently resultant from backwater from the culvert, lack of hydraulic capacity in the canal, or a combination of both. The second type of flooding at location one is flooding of the field located south of the canal and downstream of the canal farm road crossing. It is likely that flooding was caused by flow overtopping the canal farm road crossing. The canal bends to the left at that location. Flow overtopping the farm road crossing would tend to continue in a straight line into that field.

The second failure location, 3.6 miles downstream, exhibits only one type of failure. Apparently the east canal bank either failed or was overtopped. The downstream farm field was flooded as shown in Figure 3.12.

The inlet of the culvert under the approach road just downstream of the SR 80 bridge, described previously, is shown in Figure 3.13. That culvert inlet was flooded to just under the top of the bank located to the left of the pipe in the photograph, forcing about 345 cfs through the culvert. The Enterprise Canal downstream of that culvert is shown in Figure 3.14. The Enterprise Canal at that point has a full flow hydraulic capacity of about 3600 cfs (refer to Appendix A, Section A.16).

The hydraulic capacity of the Enterprise Canal decreases as it proceeds downstream. This is normal design for an irrigation supply canal because as canal water is delivered, less hydraulic capacity is necessary to convey the reduced irrigation flow. The Enterprise Canal has a full flow hydraulic capacity at failure point one of about 260 cfs (refer to Appendix A, Section A.16). The reach of the canal upstream of the farm road crossing at failure point one is shown in Figure 3.15. The reduced hydraulic capacity of the canal in that reach is visibly apparent. The canal banks along both sides of the canal shown in Figure 3.15 were overtopped during the 1993 flood, the limits of which are shown on Figure 3.12. The farm field at the top right of Figure 3.15 was flooded, the limits of which are also shown on Figure 3.12. Overbank flooding would have occurred whether or not a culvert constriction was present at failure point one because of the inadequate hydraulic capacity of the canal at that location.

A canal head gate structure just downstream of failure point two is shown in Figure 3.16. The hydraulic constriction caused by that structure would be sufficient to cause a backwater effect in the vicinity of the failure point, particularly if the gate was not fully open, as was the case on the date this photograph was taken. The bank failure at location two was likely the result of overtopping and scour resultant from backwater from the head gate.

The conclusions drawn from the hydraulic analysis of the failures along the Enterprise Canal are as follows:

1. The Gila River flows which entered the Enterprise Canal just downstream of the SR 80 bridge are a normal consequence of high flow rates in the Gila River. It is a natural result of the structure design necessary to divert water from the Gila River into the Enterprise Canal.

2. The failure of the Enterprise Canal at the two locations downstream, and the subsequent damage to the canal and farm fields, resulted from the reduction in hydraulic capacity of the Enterprise Canal as it drains downstream. That reduction in capacity is a characteristic of irrigation delivery canals.

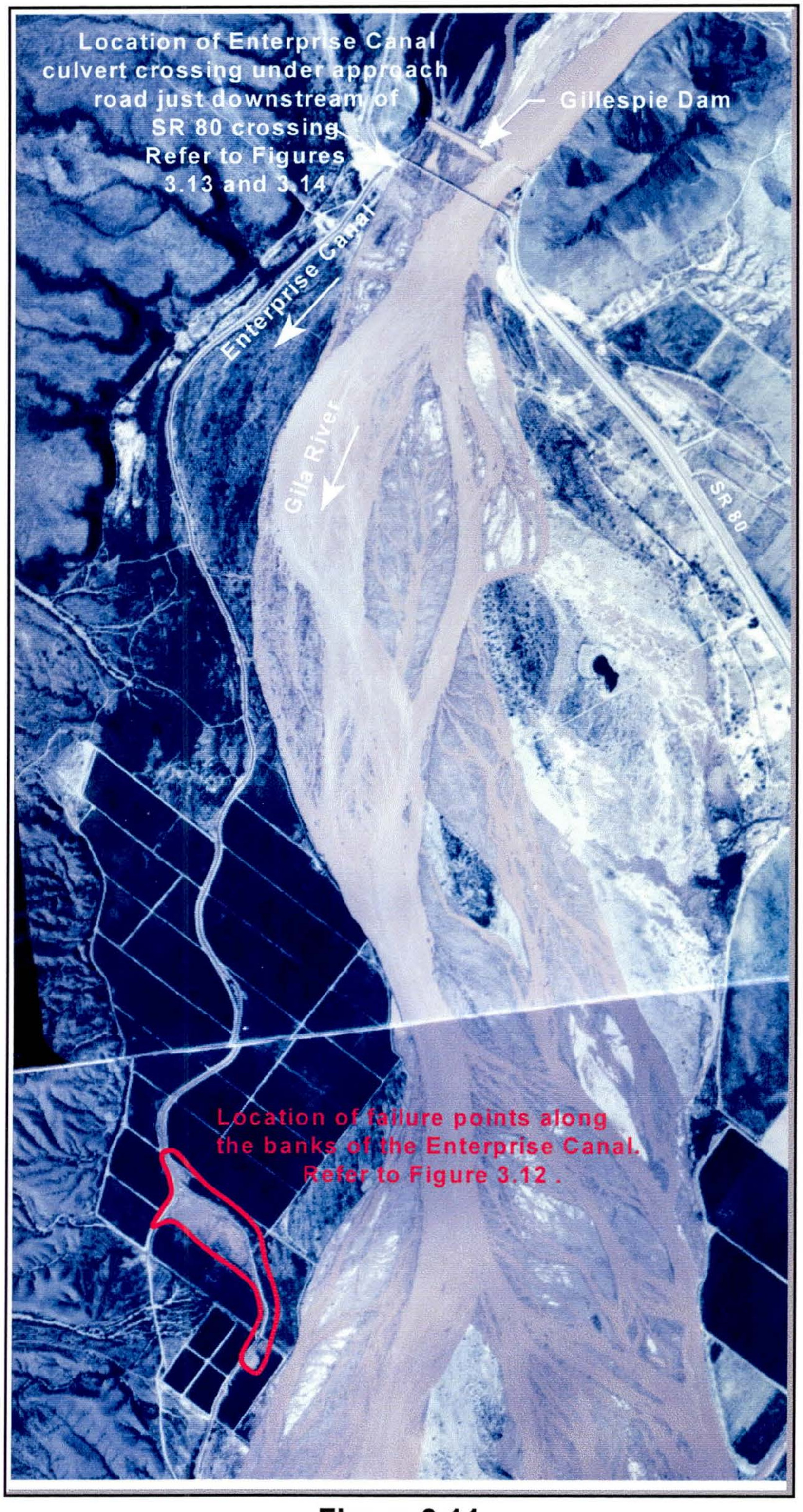


Figure 3.11
Aerial photograph of the Enterprise Canal and Gila River, from Gillespie Dam to the two sites of canal failure
Photo Date: 22 February 1993

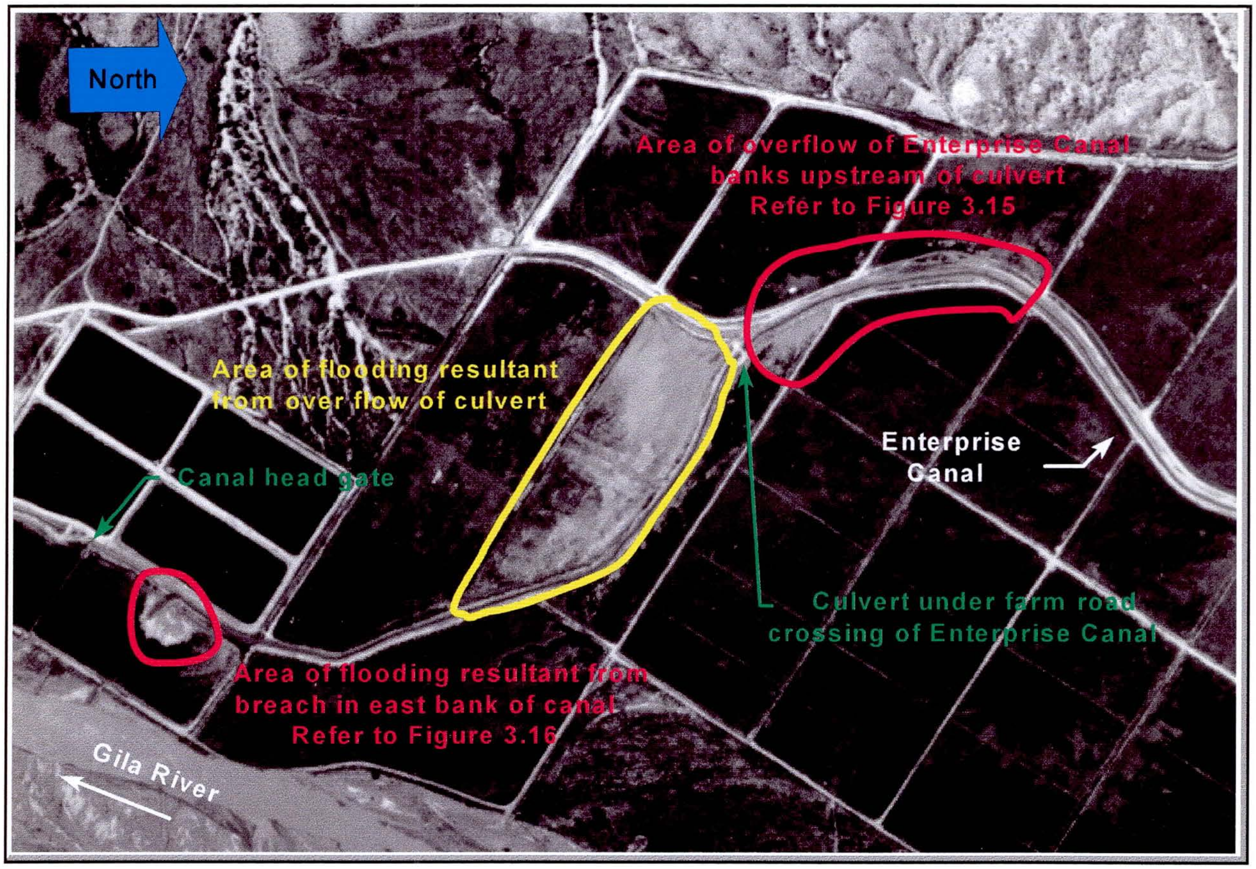


Figure 3.12
Aerial photograph of the Enterprise Canal at the two sites of canal failure 3 and 3.6 miles downstream of the SR 80 bridge
Photo Date: 2 March 1993

Figure 3.13
Photograph of Enterprise Canal looking downstream at inlet of culvert constriction just downstream of SR 80 (December 1996)

Figure 3.14
Photograph of Enterprise Canal looking downstream from outlet of culvert constriction just downstream of SR 80 (December 1996)

Figure 3.15
Photograph of Enterprise Canal about 3 miles downstream of the SR 80 bridge looking downstream at area of canal failure (December 1996)

Figure 3.16
Photograph of Enterprise Canal about 3.6 miles downstream of the SR 80 bridge looking downstream at canal head gate structure (December 1996)

4 Summary of Opinions

The following is a summary of the opinions resulting from my analysis of the hydraulic characteristics of the 1993 flooding of the Gila River between the Gillespie Dam and the Gila Bend area:

1. It is my opinion that the magnitude of the peak discharge in the Gila River upstream of Gillespie Dam, estimated to be 132,000 cfs by Hjalmarson (1997), is reasonable and substantiated by the available data and analyses of that data.

2. It is my opinion that the breach of Gillespie Dam did not have a measurable effect on the magnitude of peak discharge, or the extent of flooding in the Gila River between Gillespie Dam and the Gila Bend area.

3. It is my opinion that the effects of the breach in Gillespie Dam on the Gila River flood hydraulics were limited to a maximum reach length of about 6000 feet downstream from the dam. That location is substantially upstream (about 4000 feet, or close to 3/4 mile) from the first farm fields affected by flooding in the Gila River in 1993.

4. It is my opinion that the limits of riverine flooding along the Gila River between Gillespie Dam and the Gila Bend area are not unusual or unexpected for a flood caused by the magnitude of the peak discharge on 9 January 1993, or the unusually long duration of sustained high flow rates.

5. It is my opinion that the farm land encroachment into the flood plain of the Gila River has reduced the available conveyance area of the river, in particular the overbank conveyance areas. That encroachment has

restricted the ability of the active channel area of the Gila River to migrate back and forth within the historic flood plain.

6. It is my opinion that the restrictions in the Gila River flood plain due to farm land encroachment resulted in bank erosion, in particular where encroachments occurred at bends in the river. That bank erosion was intensified by the unusually long duration of sustained flow in the Gila River.

7. It is my opinion that two separate flooding incidents occurred within the impoundment area of the Painted Rock Dam. The first was due to riverine flooding from the peak discharge on 9 January 1993. The limits of that flood were less than the second flood and were of much lesser duration. The second flood was caused by backwater from the Painted Rock Dam. The maximum flooding limits from that flood did not occur until 26 February 1993. The duration of inundation was much longer than the first flood.

8. It is my opinion that the two failures along the Enterprise Canal, and subsequent flooding, were a result of the innate design of the canal delivery system. It is also my opinion that the canal has been flooded in a similar manner by previous record flows in the Gila River. I found no evidence to suggest that the failures of the canal were related in any way or manner to the failure of Gillespie Dam.

9. The farm lands flooded in 1993 lie within flood prone areas that were defined and of public record prior to the 1993 flood (as early as 1972). The owners of those properties had access to the records. In my opinion, it is reasonable that the property owners should have expected flooding on their properties from a storm of the magnitude that occurred in 1993.

REFERENCES

Arizona Department of Water Resources (ADWR), 9 July 1991, Inspection of Operational Dam.

Bookman - Edmonston Engineering, Inc., 12 November 1978, Letter to the Arizona Water Commission regarding Gillespie Dam structural stability.

Bookman - Edmonston Engineers, Inc., 12 July 1979, As-Built plans of Gillespie Dam Sluice Gates.

Coen, S., 8 September 1993, Summary Report for Gillespie Dam Failure, Maricopa County, Arizona.

Hjalmarson, H. W., January 1997, Flow Routing and Miscellaneous Hydrology, Gila River at Gillespie Diversion Dam, Flood of January, 1993.

Hoggan, D. H., 1989, Computer Assisted Floodplain Hydrology and Hydraulics, pg. 389.

Holmquist and King, Consulting Engineers, Inc., 21 December 1973, Modifications to Gillespie Dam prepared for the Arlington Canal Company.

Hussain and Johnson, 11 January 1993, ADWR memorandum to Bill Jenkins.

Natural Resources Conservation Service (NRCS), April 1996, Soil Survey of the Gila Bend - Ajo Area.

Newton, C. T., 4 December 1957, Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona, US Army Corps of Engineers.

Sabol, G. V., January 1997, Flood Hydrology and Sediment Analyses of the 1993 Flood on the Gila River in regard to the breach of Gillespie Dam.

Schumm, S., January 1997, Geomorphology of the Gila River Near Gillespie Dam.

Steele, W. M., 19 April 1921, Report on Gillespie Dam, Gila Bend, Arizona, by the Foundation Company of America.

Thomsen, B. W., and Hjalmarson, H. W., 1991, Estimated Manning's roughness coefficient for stream channels, and flood plains in Maricopa County, Arizona, Figure 7.

US Army Corps of Engineers, July 1995, HEC-RAS River Analysis System Hydraulic Reference Manual, pg. 5-2.

US Department of Transportation, Federal Highway Administration, September 1985, Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5.

ASL SIERRA
CONSULTING ENGINEERS

APPENDIX A

APPENDIX A

LIST OF FIGURES

LIST OF TABLES

A.1 General

The following sections list and describe work product prepared by ASL Sierra Consulting Engineers, Inc. and others.

A.2 Photomosaic Coverage of the Available Aerial Photographs

The aerial photographs described in Section 2.2 were scanned into the Flood Control District of Maricopa County's (FCDMC) Geographic Information System (GIS) computer system and then photomosaiced to provide strip coverage of the Gila River between Gillespie Dam and the Gila Bend area. The FCDMC's GIS software is UNIX based ArcInfo. The photographs were mosaiced and registered against existing digital data, such as the centerline of roads, section corners, section lines, township and range lines and natural features. These photograph mosaics are used as a base for many of the figures produced in this report.

A.3 9 January 1993 Flooding Limits Between Gillespie Dam and the Gila Bend Area

The limits of actual riverine flooding caused by the peak flow on 9 January1993, and the ponding upstream of Painted Rock Dam, are estimated using the aerial photographs dated 22 February 1993 and 2 March 1993 (refer to Section 2.2). The limits were defined using the photographs and then transferred onto the topographic mapping from the 1989 flood insurance study produced by Cella Barr Associates. Those limits were then transferred into the FCDMC's GIS computer system. The results reflect riverine flooding and bank scour limits upstream of the backwater influence from Painted Rock Dam, and ponding limits in the backwater influence area.

These limits are referred to herein as the 1993 Flood Inundation Limits. The 1993 Flood Inundation Limits are plotted on the available aerial photographs, except for 1993, on Figures E-1 through E-7 in Appendix E. Those limits are also used on many of the figures in Section 3.

A.4 Modeled Riverine Flooding Limits Between Gillespie Dam and the Gila Bend Area

The 1989 Cella Barr Associates HEC-2 hydraulic computer model data set was used to model the effects of the estimated 132,000 cfs peak discharge in the Gila River between Gillespie Dam and the Gila Bend area. The resultant limits of flooding are valid for riverine conditions only. The ponding limits caused by Painted Rock Dam are not modeled. The HEC-2 digital data set was imported into the US Army Corps of Engineers HEC-RAS computer program. The modeled limits from HEC-RAS were plotted on the 1989 Cella Barr Associates flood insurance study mapping and then transferred into the FCDMC's GIS computer system. Those limits are referred to herein as the 1993 Hydraulic Model Riverine Flood Limits.

HEC-RAS was used because it is easier to view and interpret the results with that program. HEC-RAS and HEC-2 produce nearly identical results with the Cella Barr data sets, except upstream from the SR 80 bridge. The HEC-2 output was used for that reach because the HEC-RAS bridge data records would require revisions. The HEC-2 emulation settings were used with the HEC-RAS model. Output summary tables from HEC-RAS are included in this report as Appendix B.

A.5 4 March 1978 Riverine Flooding Limits Between Gillespie Dam and the Gila Bend Area

The limits of actual riverine flooding caused by the peak flow in the Gila River between Gillespie Dam and the Gila Bend area on 4 March 1978 are estimated using the aerial photographs dated February 1978 and March 1978 (refer to Section 2.2). There is not complete coverage of the river reach on the post-flood March 1978 photographs. The February 1978 photographs are used to supplement the March 1978 photographs. The flood limits were located on the March 1978 photographs, and the river bank limits on the February 1978 photographs. Those limits were then transferred onto scaled copies of the photographs and transferred into the FCDMC's GIS computer system. Separate line styles are used to distinguish between the actual flood limits from the March 1978 photographs, and the bank limits from the February 1978 photographs. The results represent riverine flooding only, as the backwater from Painted Rock Dam did not intrude as far upstream in 1978 as occurred in 1993. The peak discharge for 4 March 1978 is estimated to have been 92,900 cfs by the USGS (Sabol, 1996). Those limits are referred to herein as the March 1978 Riverine Flood Limits. The March 1978 Riverine Flood Limits are plotted on the 1978 aerial photography on Figure E-8 in Appendix E.

A.6 Reservoir Ponding Limits Upstream from Painted Rock Dam

The reservoir ponding limits for various days during the flood event were plotted by FCDMC staff using the peak stage from the US Army Corps of Engineers data for representative days, and available topographic mapping (USGS quadrangle maps). The results were transferred into the FCDMC's

GIS computer system and are referred to herein as the Time-Based Ponding Limits Upstream from Painted Rock Dam.

A.7 Limits of Soils Subject to Periodic Flooding

The limits of the historic flood plain of the Gila River can be estimated by studying the soils along the river. Various soil types, as defined by the Natural Resource Conservation Service (NRCS), present along the Gila River between Gillespie Dam and the Gila Bend area are listed in Table A.1.

Table A.1

NRCS soil types present in the Gila River Valley between Gillespie Dam and the Gila Bend area

Soil Type 1	Description 2
55	Riverwash, present in the channel and adjacent low flood plain and is subject to frequent flooding
1, 43	Soils on flood plains along the Gila River which are regularly flooded
2, 27, 28, 29, 30, 41, 42, 43 and 63	Soils on flood plains along the Gila River subject to occasional flooding
13, 15	Soils on terraces and not subject to flooding

The boundaries from the NRCS are from the Soil Survey of Gila Bend-Ajo Area, Parts of Maricopa and Pima Counties, Arizona. Those boundaries were transferred into the FCDMC's GIS computer system. The exterior limits of all soil types, excluding 13 and 15, are referred to herein as the Limits of

Flood Plain Soils. The boundary of the Type 55 soils is referred to as the Active Channel of the Gila River. The aerial photography used for the definition of the soil boundaries by the NRCS was dated 1972. The field soil sampling was done between 1979 and 1985, (B. Johnson, personal communication). The soils limits represent pre-1993 flood conditions.

A.8 Farm Land Development from 1953 to 1993

The aerial photographs from Section 2.2 are used to delineate the progressive increase in developed farm land along the Gila River from Gillespie Dam to the Gila Bend area between 1953 and 1993. Boundaries were developed for the years 1953, 1958, 1964, 1970, 1976, 1985, 1989 and 1993. Those boundaries were then transferred into the FCDMC's GIS computer system. Those limits are referred to herein as the Farm Land History. Refer to Appendix E for plots of the historical aerial photographs used to define the Farm Land History boundaries (Figures E-1 through E-7). The plaintiff farm land ownership boundaries are shown on Figure E-9.

A.9 USGS Flood Hazard Area Limits

The US Geological Survey (USGS) was requested by the 89th Congress to prepare flood-prone area maps for various areas of the United States for use by administrators, planners and engineers concerned with future land developments. The Gila River was one such mandated area. Flood hazard area limits for the Gila River between Gillespie Dam and the Gila Bend area were prepared by Mr. Hjalmar W. Hjalmarson in 1972 while employed by the USGS. The flood-prone area limits for that reach of the Gila River were developed using the 1951 USGS 15-minute Quadrangle Maps of the area and the record peak discharge of 250,000 cfs for the flood of February 1891

(H. W. Hjalmarson, personal communication). The USGS flood hazard area limits were adopted as regulatory 100-year flood plain limits in July 1979 by the Federal Emergency Management Agency.

USGS flood hazard area limits for the Gila River between Gillespie Dam and the Gila Bend area were transferred into the FCDMC's GIS computer system. Those limits are referred to herein as the USGS Flood Prone Limits, and reflect the effects of the topography in the Gila River valley as of 1951.

A.10 FEMA Regulatory 100-year Flood Plain Limits

The Federal Emergency Management Agency (FEMA) published 100-year flood plain limits for the Gila River between Gillespie Dam and the Gila Bend area in 1979 and revised the limits in 1989. The boundaries were prepared for flood insurance purposes under the mandate of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. The source of the 1979 limits was the USGS Flood Prone Limits using the record peak discharge of 250,000 cfs. The hydraulic computer model used to define the 1989 limits was prepared by Cella Barr Associates (refer to Table 2.2). The 100-year peak discharge used in the 1989 Cella Barr Associates model varied from 231,000 to 233,000 cfs. The 100-year peak discharge is the discharge value which has a one percent (1%) chance of being met or exceeded in any given year. The 100-year flood plain limits are used, in addition to flood insurance purposes, as a regulatory area where development is either prohibited (floodway areas), or only allowed under certain conditions (flood plain areas).

The FCDMC maintains the current 100-year flood limits for major washes in Maricopa County in the FCDMC's GIS computer system. Those limits are referred to herein as the 1989 FEMA 100-year Flood Plain Limits.

A.11 Level Pool Impoundment Storage Volume Upstream of Gillespie Dam

The total volume of runoff water held in storage upstream from Gillespie Dam, and level with the top of the dam prior to the 1993 flood, is important for estimating the hydraulic effects of the failure of the dam. The best available topographic data for that purpose is the 4 foot contour interval mapping prepared by Michael Baker, Jr. Engineers (Baker) in 1992 (refer to Section 2.2). It is obvious from an inspection of that mapping that the retained volume is very small and can not be estimated accurately using that mapping. This is because the mapping was prepared at a scale (1 inch equals 400 feet) commensurate with the size of the river. The majority of the area upstream of Gillespie Dam is silted to, or above, the top of dam elevation. The only area available for storage of water is the area of low flows or where sediment was removed to facilitate operation of the diversion structures for the Enterprise Canal (west end of dam) and the Gila Bend Canal (east end of dam). The pre-failure storage volume at an elevation level with the dam spillway crest is estimated to be less than 50 acre-feet. That volume is too small to be more accurately estimated using the available mapping. The storage capacity was estimated to be zero by Newton (1957) which further substantiates that the actual volume was negligible.

A.12 Field Survey Data

Two field surveys were performed to obtain the following data:

1. A post-failure profile of the overflow spillway crest of Gillespie Dam, and the horizontal dimensions of the dam breach (refer to Section 2.4.1).

2. Cross sections, and other topographic information, of the Enterprise Canal (refer to Section 2.4.3).

A.13 1993 Riverine Flooding Limits Upstream of Gillespie Dam

The limits of flooding at peak on 9 January 1993 along the west bank of the Gila River upstream of Gillespie Dam were estimated using aerial photographs taken on 9 January 1993, shortly after the initiation of the breach. This area is of importance because the west overbank in that reach is relatively flat and the elevation of flooding can therefore be estimated using available topographic mapping. That information is useful for validation of the estimate of peak discharge in the Gila River at that point. The reach of interest lies between cross sections 168.01 and 168.95 of the Baker HEC-2 model. Gillespie Dam lies at cross section 166.58. The cross section numbers are the distance in miles upstream from the confluence of the Gila River and the Colorado River at Yuma, Arizona. The area of interest is therefore 1.43 to 2.37 miles upstream of Gillespie Dam.

The flood limits were defined on the aerial photographs and then transferred onto the pre-flood Baker topographic mapping. The limits were then transferred into the FCDMC's GIS computer system. Those limits are referred to herein as the 1993 Upstream Flood Inundation Limits. Refer to Appendix C for HEC-RAS output summary tables between Gillespie Dam and section 169.05.

A.14 1993 Modeled Riverine Flooding Limits Upstream of Gillespie Dam

The pre-failure 1992 Baker HEC-2 data set was used to model the hydraulics of the estimated 132,000 cfs peak discharge in the Gila River upstream of Gillespie Dam. The HEC-2 data set was imported to the US Army Corps of Engineers HEC-RAS computer program. HEC-RAS was used for this task because it is easier to view and interpret the results with that program. HEC-RAS and HEC-2 produce nearly identical results with the Baker data set. The HEC-2 emulation settings were used with the HEC-RAS model.

The following are modifications made to the Baker data set:

1. Cross sections 166.42, 166.49 and 166.56 were deleted from the data set. These are the first three cross sections downstream of the Gillespie Dam. Those cross sections are not necessary for this model because a fixed starting condition is used at cross section 166.58 at the dam.

2. The starting condition for the model at cross section 166.58 (Gillespie Dam) was changed to a fixed water surface elevation. That elevation, 760.6, is the stage which corresponds to 127,300 cfs on the rating curve for USGS Gage Number 09519502 located on the east, upstream, end of Gillespie Dam (refer to Figure A.1). That curve was provided by H. W. Hjalmarson, who received the data from the USGS. The evidence available indicates that the sluice gates at the east end of the dam were open at the time of peak discharge (H. W. Hjalmarson, personal communication). A rating curve for the sluice gates by Bookman-Edmonston (1979) indicate that as much as 4,700 cfs was going through the sluice gates at peak. The total

hydraulic capacity of Gillespie Dam at stage 760.6 is therefore about 132,000 cfs.

3. Cross sections 166.61, 166.64 and 166.67 were deleted from the data set. These are the first three cross sections upstream of the Gillespie Dam. The cross sections were deleted because they do not accurately reflect the area immediately upstream of the dam. The inaccuracy is the cross sections were derived from aerial photography and there was ponded water upstream of the dam at the time of the flight, which would have obstructed the actual ground below the water surface.

4. The Manning's n-values (roughness coefficients) for the heavily vegetated areas upstream of the dam were revised from 0.15 in the Baker model, to 0.04 for cross sections 166.77 through 167.06, and to 0.08 for cross sections 167.15 through 169.05. The value of 0.15 is appropriate for the tamarisk vegetation upstream from Gillespie Dam, assuming it is there at the time of peak. The 0.15 value is used for flood insurance purposes because it provides conservative water surface elevations. Since the model is being used in this case to simulate actual conditions during the peak flow rate of the flood, the n-values are reduced to reflect the average actual vegetation conditions that were likely to exist at the time of peak flooding.

   There is evidence that much of the tamarisk vegetation was either removed by the flood, or crushed down as a result of the force of the water, particularly in the high velocity reaches immediately upstream and downstream of Gillespie Dam (refer to Figures 4.2 and 4.3). Those photographs clearly show the vegetation removal which occurred as a result of the 1993 flood, immediately downstream of Gillespie Dam. A similar condition is assumed for the reach upstream of Gillespie Dam and n-values were selected accordingly. The tamarisk vegetation quickly reestablishes itself, as demonstrated by Figure A.4, taken in 1996.

The modeled flood limits were plotted on the Baker pre-failure topographic mapping and transferred into the FCDMC's GIS computer system. Those limits are referred to herein as the 1993 Upstream Hydraulic Model Riverine Flood Limits.

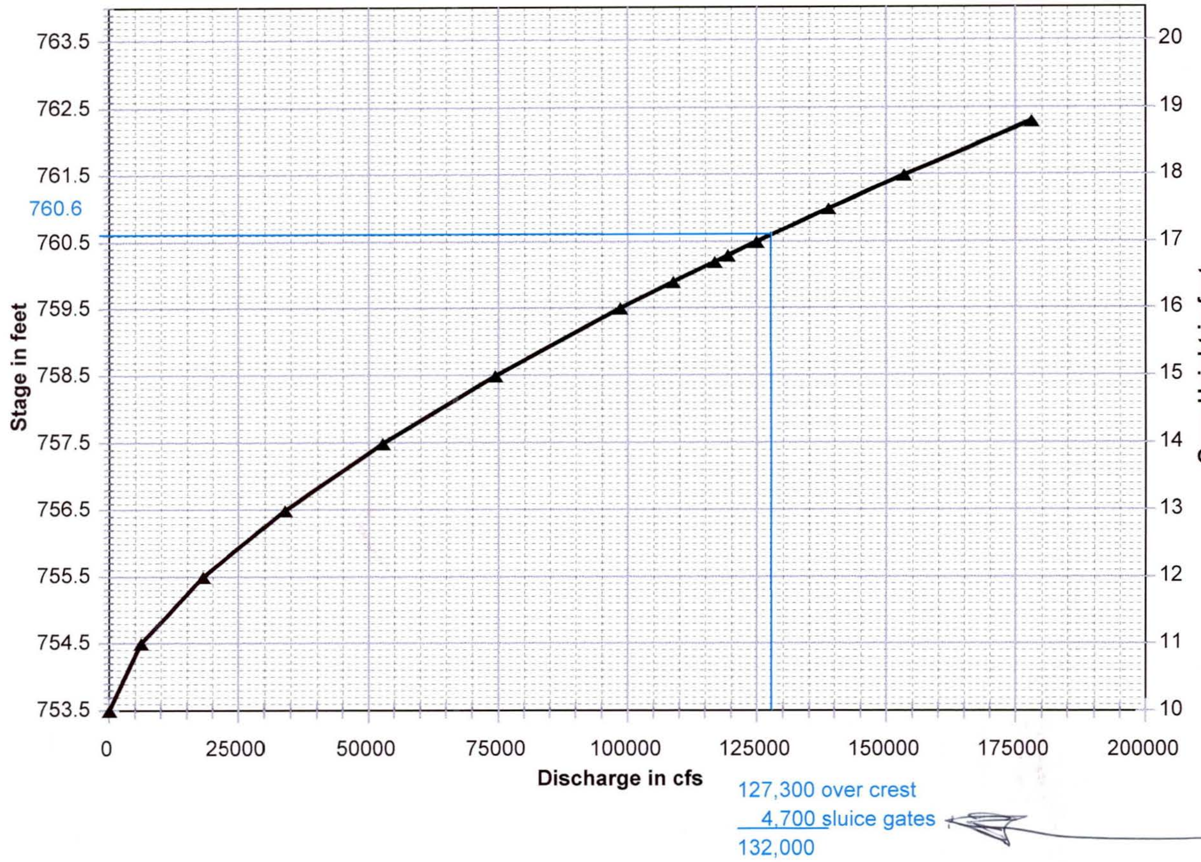
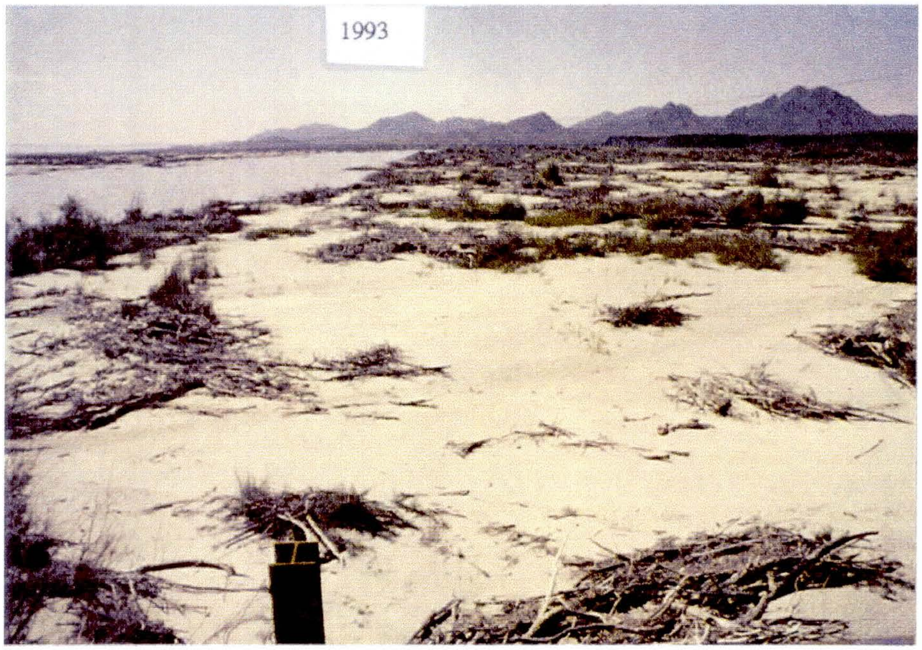


Figure A.1
Hydraulic Rating curve for USGS Gage 09519502 at Gillespie Dam

1990



1993 Post-flood

Figure A.2
Photographs of the Gila River looking downstream from the SR 80 Bridge, pre- and post-flood

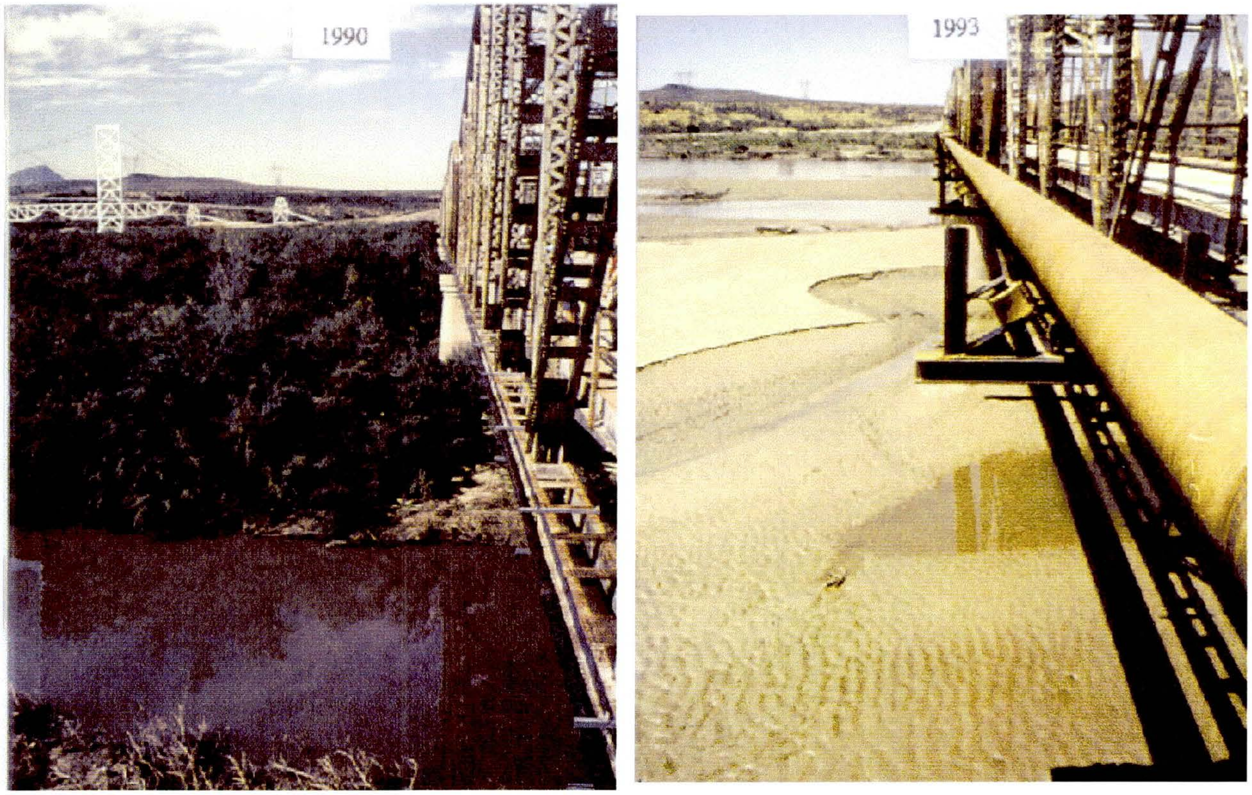


Figure A.3
Photographs of the Gila River looking west along the south side of the SR 80 bridge, pre- and post-flood

Figure A.4
Photograph of Gillespie Dam looking west from the east side of the breach
(15 July 1996)

A.15 Comparison of 1993 Hydraulic Model Riverine Flood Limits with the USGS Gage Record at the Enterprise Canal

The USGS flow gage at the Enterprise Canal on the south side of the SR 80 bridge (USGS Gage Number 09519000) was not reported as damaged during the 1993 flood and yielded a continuous record. The peak gage height recorded was 11.55 feet per Hjalmarson (1996). The USGS bench mark at that gage is at elevation 745.47 which equates to a gage height of 13.32 feet (J. Phillips, personal communication). The peak stage recorded by the USGS on 9 January 1993 on the west end of the south side of the SR 80 bridge was 743.65. The water surface elevation from the HEC-2 model described in Section A.4 for that same location (HEC-2 section 166.41) was 745.1. The recorded elevation is therefore about 1.5 feet lower than the modeled elevation. This is an acceptable difference. The difference is explainable by the roughness coefficients used in the HEC-2 model. The n-values in the HEC-2 model reflect the heavy tamarisk vegetation normally present immediately downstream of Gillespie Dam. That vegetation was stripped away by the flood as shown on Figures A.2 and A.3. The use of a lower n-value, such as 0.025 suggested by Thomsen and Hjalmarson (1991) for the cleared Gila River channel, would bring the modeled elevation much closer to the recorded elevation.

A.16 Enterprise Canal Hydraulic Analysis

The Enterprise Canal begins at the west end of Gillespie Dam and flows south along the west side of the Gila River. That canal is used to deliver irrigation water to the farm land along the west bank of the Gila River. The canal failed at two locations during the flood of 1993. The two locations are about 3 and 3.6 miles downstream of the SR 80 bridge across the Gila River. Refer to Section 3.9 for more detail and figures.

This work task consists of a hydraulic analysis to estimate the cause of the canal failures downstream. The Enterprise Canal is subject to inundation by flood waters in the Gila River between Gillespie Dam and a crossing of the canal just downstream of the SR 80 bridge. That road is an approach road for the old dip section crossing of the Gila River used for a period of time while the SR 80 bridge was closed. Historically, the canal receives flood water in that reach any time Gillespie Dam experiences flows which overtop the west end of the dam spillway crest. A levee provides protection of the canal from flood waters downstream of the approach road crossing, and did so in 1993. However, that levee will not fully protect the canal from flow in the Gila River during the 100-year event. There is an existing culvert under the approach road to convey irrigation water. The amount of flood water which can discharge into the Enterprise Canal downstream of the approach road crossing is limited by the hydraulic capacity of that culvert.

The hydraulic analysis consisted of the following:

1. Estimation of the peak flow rate discharged into the Enterprise Canal downstream of the approach road under the hydraulic head on the culvert inlet at the time of peak discharge in the Gila River.

2. Estimation of the hydraulic capacity of the Enterprise Canal immediately downstream of the approach road crossing.

3. Estimation of the hydraulic capacity of the Enterprise Canal at the first canal failure location about 3 miles downstream of the SR 80 bridge.

The physical data used in the hydraulic analyses were obtained during the field survey described in Section 2.4.3. The peak stage in the Gila River at the culvert inlet was estimated using the peak stage recorded by USGS Gage Number 09519000 (refer to Section A.15). The water surface elevation used is 743.7 feet.

The hydraulics of the culvert under the approach road were estimated using the methods set forth in Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5 (HDS-5), dated September 1985, by the US Department of Transportation, Federal Highway Administration. The HDS-5 methodology was applied using the HY8 computer program. Version 4.0 of HY8 dated April 1992, as published by the McTrans Center for Microcomputers in Transportation at the University of Florida was used.

The hydraulic capacity of the Enterprise Canal was estimated using the Manning's equation for open channel flow. That equation was applied by use of the Flow Master computer program produced by Haestad Methods, version 5.12.

The following are the findings of the hydraulic analysis. Refer to Appendix D for supporting documentation.

1. The culvert under the approach road just downstream of SR 80 is estimated to have discharged about 345 cfs into the canal at the time of peak in the Gila River on 9 January 1993.

2. The hydraulic capacity of the Enterprise Canal immediately downstream of the approach road crossing is estimated to be about

3600 cfs before the levee on the east canal bank is overtopped, assuming no downstream backwater effects.

3. The hydraulic capacity of the Enterprise Canal about 3 miles downstream of the SR 80 bridge is estimated to be about 260 cfs before the canal banks are overtopped, and assuming no downstream backwater effects.

APPENDIX B

ASL SIERRA
CONSULTING ENGINEERS

HEC-RAS Plan: r1-3runs Reach: 1 12/26/96 1:02:42 PM

River Sta.	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
146.55	132000.00	631.10	639.52	639.52	641.73	0.006137	12.12	11841.54	3131.55	0.91
146.65	132000.00	632.40	642.40		643.51	0.002089	9.28	17911.15	3296.38	0.56
146.74	132000.00	632.10	643.69		644.31	0.001080	6.74	24305.71	5121.57	0.41
146.78	132000.00	632.70	644.14		644.57	0.000789	5.75	28935.38	5104.01	0.35
146.83	132000.00	633.00	644.40		644.83	0.000797	5.67	28109.46	4811.92	0.34
146.93	132000.00	633.30	644.82		645.32	0.000946	6.01	25945.02	4793.10	0.37
147.02	132000.00	633.70	645.29		645.81	0.000971	6.23	24379.98	3711.53	0.37
147.12	132000.00	635.10	645.73		646.47	0.001499	7.36	21129.76	4179.03	0.47
147.21	132000.00	634.00	646.50		647.04	0.000852	6.44	25168.05	3885.40	0.35
147.31	132000.00	632.70	646.95		647.46	0.000839	6.37	25899.63	4027.34	0.37
147.4	132000.00	631.70	647.41		647.76	0.000423	5.20	31285.49	4186.28	0.27
147.5	132000.00	631.70	647.54		648.07	0.000686	6.76	27002.07	4083.36	0.34
147.59	132000.00	631.50	648.01		648.35	0.000411	5.44	32663.76	4201.15	0.27
147.69	132000.00	633.70	648.24		648.53	0.000354	4.81	33275.41	4000.54	0.25
147.78	132000.00	634.60	648.45		648.67	0.000268	4.11	37535.77	4179.58	0.21
147.88	132000.00	635.00	648.54		648.84	0.000370	4.47	31449.55	3265.28	0.25
147.97	132000.00	635.70	648.72		649.04	0.000420	4.50	29452.04	3280.42	0.26
148.07	132000.00	635.70	648.92		649.28	0.000493	4.76	27806.81	3196.92	0.28
148.16	132000.00	636.60	649.19		649.51	0.000420	4.52	29276.10	3200.00	0.26
148.26	132000.00	633.50	649.43		649.70	0.000355	4.16	31719.65	3375.82	0.24
148.35	132000.00	635.60	649.61		649.89	0.000394	4.30	31542.49	3687.07	0.25
148.44	132000.00	636.30	649.81		650.10	0.000435	4.34	30954.46	3731.97	0.26
148.54	132000.00	636.10	650.04		650.31	0.000402	4.23	32369.43	4070.90	0.25
148.63	132000.00	636.40	650.25		650.51	0.000369	4.17	33639.33	4363.98	0.24
148.73	132000.00	637.50	650.41		650.74	0.000490	4.64	30623.31	4366.04	0.28
148.82	132000.00	638.20	650.61		651.07	0.000703	5.53	26400.78	4207.21	0.33
148.92	132000.00	639.10	650.96		651.41	0.000654	5.49	26862.55	4574.42	0.32
149.01	132000.00	639.70	651.28		651.76	0.000724	5.78	25679.16	3674.00	0.34
149.11	132000.00	640.00	651.62		652.18	0.000919	6.13	23622.39	3509.66	0.38
149.2	132000.00	640.80	652.11		652.64	0.000954	6.04	24370.84	4012.61	0.37
149.3	132000.00	641.50	652.64		653.08	0.000883	5.62	26907.29	4539.03	0.36
149.39	132000.00	640.50	653.05		653.45	0.000738	5.27	27988.91	4341.78	0.32
149.49	132000.00	640.30	653.39		653.78	0.000692	5.32	28628.83	4325.26	0.32
149.58	132000.00	641.30	653.72		654.21	0.000920	5.87	25671.21	4268.66	0.36
149.68	132000.00	641.60	654.20		654.66	0.000820	5.80	26939.98	4139.85	0.35
149.77	132000.00	642.70	654.53		655.18	0.001034	6.91	24025.51	4471.77	0.40
149.87	132000.00	643.40	655.13		655.68	0.000933	6.26	25259.11	4637.18	0.37
149.96	132000.00	643.50	655.54		656.26	0.001170	7.16	22972.54	4736.66	0.43
150.05	132000.00	643.30	656.20		656.84	0.001157	6.83	24159.27	5125.68	0.41
150.15	132000.00	644.70	656.70		657.40	0.001047	6.91	22620.99	4917.39	0.41
150.24	132000.00	644.80	657.35		657.82	0.000633	5.65	27217.67	4879.04	0.32
150.34	132000.00	645.20	657.71		658.13	0.000603	5.41	29053.60	6803.54	0.31
150.43	132000.00	646.90	658.03		658.43	0.000624	5.25	29589.65	6849.00	0.31
150.53	132000.00	646.30	658.35		658.77	0.000737	5.30	26859.78	5376.06	0.33
150.62	132000.00	646.90	658.74		659.14	0.000709	5.19	27708.04	6382.40	0.33
150.72	132000.00	642.60	659.07		659.49	0.000660	5.33	27390.95	5515.00	0.32
150.81	132000.00	649.50	659.45		659.78	0.000591	4.62	28611.85	4711.44	0.30
150.91	132000.00	649.80	659.68		660.21	0.001163	6.23	23833.76	4536.94	0.41
151	132000.00	649.40	660.28		660.99	0.001775	7.39	21524.66	5080.78	0.50
151.1	132000.00	650.70	661.21		661.73	0.001117	5.96	23283.33	4542.43	0.40
151.19	132000.00	650.70	661.80		662.24	0.000864	5.52	25898.67	4922.01	0.36
151.29	132000.00	651.00	662.23		662.70	0.000947	6.10	25877.74	4819.66	0.38
151.38	132000.00	650.80	662.68		663.14	0.000913	5.61	25738.72	4707.81	0.37
151.48	132000.00	652.00	663.13		663.66	0.001100	5.93	23500.38	4397.65	0.40
151.57	132000.00	652.00	663.66		664.24	0.001219	6.37	23761.13	4805.40	0.42
151.66	132000.00	652.60	664.25		664.84	0.001159	6.18	22253.15	3675.62	0.41

HEC-RAS Plan: r1-3runs Reach: 1 12/26/96 1:02:42 PM

River Sta.	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
146.55	641.73	639.52	2.21	0.00	0.00	3693.29	127720.10	586.65	3131.55
146.65	643.51	642.40	1.11	1.67	0.11	27427.88	103126.10	1446.01	3296.38
146.74	644.31	643.69	0.63	0.76	0.05	13224.31	115829.00	2946.74	5121.57
146.78	644.57	644.14	0.43	0.23	0.02	21010.23	104549.50	6440.33	5104.01
146.83	644.83	644.40	0.42	0.26	0.00	25648.94	104977.00	1374.05	4811.92
146.93	645.32	644.82	0.50	0.47	0.02	19026.65	112672.60	300.72	4793.10
147.02	645.81	645.29	0.53	0.49	0.01	11425.55	99795.90	20778.55	3711.53
147.12	646.47	645.73	0.74	0.59	0.06	9729.21	106572.00	15698.76	4179.03
147.21	647.04	646.50	0.54	0.55	0.02	9109.89	104275.20	18614.94	3885.40
147.31	647.46	646.95	0.52	0.42	0.00	13848.74	99887.70	18263.56	4027.34
147.4	647.76	647.41	0.35	0.29	0.02	11845.39	102852.10	17302.57	4186.28
147.5	648.07	647.54	0.54	0.26	0.06	11683.69	90626.79	29689.53	4083.36
147.59	648.35	648.01	0.34	0.25	0.02	10258.11	79790.26	41951.63	4201.15
147.69	648.53	648.24	0.29	0.18	0.00	1543.07	91339.32	39117.62	4000.54
147.78	648.67	648.45	0.22	0.13	0.01	1330.83	96077.84	34591.33	4179.58
147.88	648.84	648.54	0.29	0.14	0.02		122672.40	9327.62	3265.28
147.97	649.04	648.72	0.31	0.19	0.01		131918.90	81.12	3280.42
148.07	649.28	648.92	0.35	0.23	0.01		131939.30	60.74	3196.92
148.16	649.51	649.19	0.32	0.23	0.00		131931.30	68.71	3200.00
148.26	649.70	649.43	0.27	0.19	0.00	0.02	131999.10	0.88	3375.82
148.35	649.89	649.61	0.28	0.19	0.00		129988.20	2011.78	3687.07
148.44	650.10	649.81	0.29	0.21	0.00	1812.24	130187.80		3731.97
148.54	650.31	650.04	0.27	0.21	0.00	3300.05	128651.40	48.54	4070.90
148.63	650.51	650.25	0.26	0.19	0.00	5418.54	126397.60	183.84	4363.98
148.73	650.74	650.41	0.32	0.21	0.02	4166.81	126424.10	1409.12	4366.04
148.82	651.07	650.61	0.45	0.29	0.04	6241.03	124982.60	776.41	4207.21
148.92	651.41	650.96	0.45	0.34	0.00	5342.66	125380.50	1276.86	4574.42
149.01	651.76	651.28	0.48	0.34	0.01	10720.87	121142.90	136.27	3674.00
149.11	652.18	651.62	0.55	0.39	0.02	8809.44	123190.10	0.47	3509.66
149.2	652.64	652.11	0.53	0.46	0.00	9068.12	122931.90		4012.61
149.3	653.08	652.64	0.44	0.43	0.01	17540.52	114459.50		4539.03
149.39	653.45	653.05	0.40	0.37	0.00	11837.98	120161.00	1.00	4341.78
149.49	653.78	653.39	0.39	0.33	0.00	17015.85	114865.10	119.05	4325.26
149.58	654.21	653.72	0.49	0.40	0.03	13501.92	118476.90	21.19	4268.66
149.68	654.66	654.20	0.46	0.45	0.00	19895.76	112088.80	15.46	4139.85
149.77	655.18	654.53	0.64	0.46	0.06	13164.26	111426.10	7409.65	4471.77
149.87	655.68	655.13	0.55	0.49	0.01	11941.41	116784.20	3274.35	4637.18
149.96	656.26	655.54	0.72	0.53	0.05	6559.27	118597.30	6843.46	4736.66
150.05	656.84	656.20	0.64	0.57	0.01	6997.48	114474.30	10528.20	5125.68
150.15	657.40	656.70	0.70	0.55	0.02	5436.15	123440.70	3123.20	4917.39
150.24	657.82	657.35	0.47	0.39	0.02	3770.46	123596.50	4633.00	4879.04
150.34	658.13	657.71	0.42	0.30	0.00	3308.54	120764.70	7926.74	6803.54
150.43	658.43	658.03	0.40	0.30	0.00	2117.37	121710.50	8172.13	6849.00
150.53	658.77	658.35	0.43	0.34	0.01	1661.94	129052.00	1286.08	5376.06
150.62	659.14	658.74	0.40	0.36	0.00	9436.55	121382.10	1181.39	6382.40
150.72	659.49	659.07	0.41	0.34	0.00	10181.25	121209.60	609.14	5515.00
150.81	659.78	659.45	0.33	0.29	0.01	61366.04	70569.06	64.89	4711.44
150.91	660.21	659.68	0.52	0.37	0.06	33980.16	97259.27	760.58	4536.94
151	660.99	660.28	0.71	0.73	0.06	30021.39	100120.90	1857.75	5080.78
151.1	661.73	661.21	0.52	0.72	0.02	39559.00	92323.77	117.23	4542.43
151.19	662.24	661.80	0.44	0.50	0.01	16005.53	114537.90	1456.57	4922.01
151.29	662.70	662.23	0.47	0.44	0.01	43721.94	85606.71	2671.35	4819.66
151.38	663.14	662.68	0.46	0.44	0.00	6243.25	121990.20	3766.55	4707.81
151.48	663.66	663.13	0.53	0.50	0.02	1847.42	128946.40	1206.16	4397.65

HEC-RAS Plan: r1-3runs Reach: 1 12/26/96 1:02:42 PM (continued)

River Sta.	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
151.57	664.24	663.66	0.58	0.57	0.02	8897.07	121021.00	2081.89	4805.40
151.66	664.84	664.25	0.58	0.59	0.00		129496.90	2503.08	3675.62

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River Sta.	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
151.66	132000.00	652.60	664.25	661.12	664.83	0.001161	6.18	22242.83	3675.29	0.41
151.76	132000.00	652.30	664.80		665.54	0.001499	6.92	19994.38	5657.03	0.48
151.85	132000.00	652.20	665.50		666.28	0.001419	7.24	20969.33	5643.54	0.47
151.95	132000.00	653.20	666.18		666.96	0.001306	7.23	20077.76	3905.45	0.45
152.04	132000.00	653.30	666.85		667.63	0.001402	7.38	22837.34	5486.99	0.46
152.14	132000.00	654.10	667.53		668.35	0.001461	7.54	22398.96	5173.08	0.47
152.23	132000.00	654.50	668.16		669.04	0.001305	7.72	19400.81	4896.85	0.45
152.33	132000.00	655.90	668.46		670.31	0.003242	11.03	13377.24	3468.34	0.70
152.42	132000.00	655.80	670.53		671.09	0.000710	6.14	26306.16	5670.32	0.34
152.52	132000.00	657.00	671.01		671.40	0.000500	5.13	31042.38	5806.94	0.29
152.61	132000.00	658.00	671.26		671.64	0.000499	5.05	28026.13	5005.72	0.28
152.71	132000.00	658.90	671.50		671.95	0.000656	5.43	25722.90	4359.81	0.32
152.8	132000.00	657.40	671.89		672.23	0.000468	4.73	31509.70	5757.77	0.27
152.9	132000.00	658.70	672.15		672.48	0.000518	4.60	29117.04	4191.01	0.28
152.99	132000.00	659.00	672.46		672.75	0.000602	4.47	30789.85	4855.75	0.30
153.09	132000.00	660.10	672.78		673.06	0.000622	4.37	31540.89	5080.50	0.30
153.18	132000.00	659.30	673.10		673.34	0.000486	4.04	34158.17	5453.49	0.27
153.27	132000.00	658.30	673.34		673.62	0.000549	4.37	32847.35	5730.81	0.28
153.37	132000.00	657.20	673.61		673.84	0.000350	3.88	36436.02	5440.75	0.23
153.46	132000.00	655.80	673.81		673.99	0.000252	3.46	41770.71	6030.14	0.20
153.55	132000.00	658.20	673.93		674.12	0.000271	3.54	38960.30	5429.34	0.21
153.65	132000.00	657.70	674.08		674.26	0.000257	3.48	40640.76	5683.29	0.20
153.75	132000.00	658.00	674.20		674.39	0.000284	3.59	39432.97	5510.21	0.21
153.84	132000.00	659.70	674.33		674.58	0.000388	4.08	34832.12	5008.78	0.25
153.94	132000.00	660.00	674.51		674.81	0.000489	4.47	32083.62	4770.71	0.27
154.03	132000.00	662.00	674.71		675.19	0.000956	5.67	25347.21	4186.50	0.37
154.13	132000.00	662.80	675.09		675.92	0.001603	7.31	18705.24	3856.61	0.48
154.22	132000.00	662.80	675.82		676.79	0.001722	7.90	17082.67	2958.65	0.51
154.27	132000.00	668.20	676.16		677.56	0.003205	9.53	14235.46	3057.04	0.67
154.32	132000.00	663.50	677.07	674.40	678.16	0.002005	8.50	16117.23	2528.00	0.54
154.41	132000.00	665.20	678.05		679.22	0.002163	8.76	15281.29	2059.96	0.56
154.51	132000.00	665.80	679.25		680.08	0.001297	7.29	18428.73	3103.39	0.44
154.6	132000.00	666.80	680.11		680.57	0.000669	5.46	25169.96	4622.97	0.32
154.69	132000.00	667.00	680.55		680.86	0.000462	4.45	30753.19	4774.69	0.27
154.79	132000.00	667.40	680.81		681.17	0.000803	4.94	28378.26	5231.24	0.34
154.88	132000.00	669.00	681.23		681.52	0.000565	4.41	31628.99	5497.01	0.29
154.98	132000.00	670.30	681.53		682.02	0.001471	6.00	25305.94	6165.61	0.45
155.07	132000.00	669.20	682.24		682.55	0.000744	5.00	34409.36	6146.71	0.33
155.17	132000.00	670.80	682.59		682.90	0.000653	4.85	33942.70	6118.11	0.31
155.26	132000.00	672.00	682.92		683.28	0.000836	5.07	29415.05	5824.76	0.34
155.36	132000.00	673.00	683.32		683.78	0.001122	5.60	26771.48	5398.92	0.39
155.45	132000.00	674.00	683.92		684.45	0.001525	6.06	25921.24	6433.20	0.45
155.55	132000.00	673.40	684.61		684.94	0.000622	4.56	30732.21	4981.73	0.30
155.64	132000.00	675.00	684.92		685.44	0.001381	5.84	24277.34	5121.93	0.43
155.74	132000.00	672.90	685.60		686.02	0.000938	5.21	26955.54	5761.60	0.36
155.83	132000.00	674.30	686.08		686.60	0.001317	5.85	24712.84	6011.55	0.43
155.93	132000.00	674.80	686.76		687.28	0.001417	5.85	25140.20	6377.44	0.43
156.02	132000.00	676.30	687.44		687.90	0.001082	5.51	25877.52	6167.01	0.38
156.12	132000.00	674.10	687.96		688.37	0.000794	5.19	26927.41	5387.95	0.35
156.21	132000.00	676.80	688.33		688.76	0.000753	5.25	26213.92	4771.17	0.33
156.3	132000.00	676.20	688.70		689.21	0.000959	5.75	23913.62	3691.54	0.37
156.4	132000.00	678.00	689.15		689.85	0.001443	6.81	20312.34	3262.48	0.46
156.49	132000.00	677.50	689.89		690.52	0.001230	6.36	21059.31	3361.30	0.42
156.59	132000.00	677.70	690.53		691.02	0.000783	5.60	23849.42	3510.20	0.35
156.68	132000.00	677.30	691.02		691.38	0.000645	4.87	28121.85	4463.14	0.29
156.78	132000.00	677.40	691.37		691.68	0.000517	4.46	30955.17	4463.91	0.27
156.87	132000.00	675.80	691.64		691.91	0.000397	4.14	32405.06	4009.80	0.24
156.97	132000.00	680.00	691.79		692.26	0.000922	5.53	24562.59	3607.78	0.37
157.06	132000.00	680.80	692.24		692.79	0.001128	6.00	22409.46	3363.79	0.40
157.16	132000.00	680.90	692.77		693.56	0.001791	7.19	18596.73	3016.77	0.50
157.25	132000.00	681.50	693.57		694.48	0.001742	7.69	17606.79	2725.08	0.51
157.35	132000.00	680.20	694.54		695.16	0.001003	6.33	21079.28	2731.33	0.39
157.44	132000.00	680.90	695.01		695.65	0.000958	6.50	20819.36	2736.93	0.39
157.54	132000.00	682.20	695.48		696.19	0.001143	6.90	20181.47	2862.67	0.42
157.63	132000.00	681.80	696.05		696.75	0.001110	6.84	20401.47	2913.17	0.41
157.72	132000.00	680.80	696.55		697.50	0.001688	7.95	17572.33	2836.16	0.49
157.82	132000.00	685.40	697.35		698.57	0.002413	8.90	15177.35	2450.47	0.59

HEC-RAS Plan: R2-3RUNS Reach: 1 12/24/96 10:45:30 AM (continued)

River Sta.	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
157.91	132000.00	683.30	698.62		699.33	0.000943	6.91	20772.68	3062.87	0.39
158.01	132000.00	682.80	699.03		699.84	0.000964	7.35	19960.35	4400.77	0.40
158.1	132000.00	682.30	699.51		700.34	0.001023	7.41	19327.69	3296.64	0.41
158.2	132000.00	683.70	700.10		700.77	0.000696	6.63	21366.90	3423.88	0.35

HEC-RAS Plan: R2-3RUNS Reach: 1 12/24/96 10:45:30 AM

River Sta.	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
151.66	664.83	664.25	0.58	0.00	0.00		129500.00	2500.05	3675.29
151.76	665.54	664.80	0.73	0.66	0.04	63.87	129552.50	2383.68	5657.03
151.85	666.28	665.50	0.78	0.73	0.01	3427.73	124965.30	3607.02	5643.54
151.95	666.96	666.18	0.78	0.68	0.00	4652.28	126401.10	946.66	3905.45
152.04	667.63	666.85	0.78	0.67	0.00	10129.52	121545.30	325.21	5486.99
152.14	668.35	667.53	0.82	0.70	0.01	9451.60	122548.40		5173.08
152.23	669.04	668.16	0.88	0.67	0.02	6445.70	125538.20	16.08	4896.85
152.33	670.31	668.46	1.85	0.98	0.29	2816.59	129182.60	0.82	3468.34
152.42	671.09	670.53	0.56	0.65	0.13	5738.96	125256.50	1004.51	5670.32
152.52	671.40	671.01	0.39	0.29	0.02	5740.44	125407.10	852.43	5806.94
152.61	671.64	671.26	0.39	0.25	0.00	1034.12	126961.90	4003.98	5005.72
152.71	671.95	671.50	0.45	0.29	0.02	760.40	127351.90	3887.72	4359.81
152.8	672.23	671.89	0.34	0.27	0.01	2509.71	129359.90	130.40	5757.77
152.9	672.48	672.15	0.33	0.25	0.00	76.02	128273.90	3650.08	4191.01
152.99	672.75	672.46	0.30	0.27	0.00	66.99	117954.40	13978.60	4855.75
153.09	673.06	672.78	0.28	0.30	0.00	0.32	113553.50	18446.20	5080.50
153.18	673.34	673.10	0.24	0.28	0.00	0.00	108727.50	23272.47	5453.49
153.27	673.62	673.34	0.27	0.26	0.01	111.09	118197.50	13691.42	5730.81
153.37	673.84	673.61	0.22	0.22	0.00	65.48	125631.70	6302.78	5440.75
153.46	673.99	673.81	0.18	0.15	0.00	48.04	122657.00	9294.99	6030.14
153.55	674.12	673.93	0.19	0.13	0.00		129569.60	2430.44	5429.34
153.65	674.26	674.08	0.18	0.13	0.00	832.16	127198.10	3969.74	5683.29
153.75	674.39	674.20	0.19	0.13	0.00	3495.35	123665.80	4838.84	5510.21
153.84	674.58	674.33	0.25	0.17	0.02	3957.39	126599.50	1443.09	5008.78
153.94	674.81	674.51	0.30	0.22	0.01	4283.09	126339.30	1377.60	4770.71
154.03	675.19	674.71	0.48	0.33	0.05	5838.84	126161.20		4186.50
154.13	675.92	675.09	0.82	0.62	0.10	943.96	131031.80	24.21	3856.61
154.22	676.79	675.82	0.96	0.83	0.04	471.10	131528.90		2958.65
154.27	677.56	676.16	1.40	0.64	0.13	535.28	131464.70	0.00	3057.04
154.32	678.16	677.07	1.09	0.57	0.03	607.09	126522.20	4870.72	2528.00
154.41	679.22	678.05	1.17	1.04	0.02		128699.20	3300.77	2059.96
154.51	680.08	679.25	0.82	0.82	0.04	225.69	131774.30		3103.39
154.6	680.57	680.11	0.46	0.45	0.04	609.42	131195.70	194.89	4622.97
154.69	680.86	680.55	0.31	0.28	0.02	830.45	131165.00	4.53	4774.69
154.79	681.17	680.81	0.37	0.30	0.02	2238.29	126177.80	3583.89	5231.24
154.88	681.52	681.23	0.29	0.34	0.01	762.08	114861.00	16376.97	5497.01
154.98	682.02	681.53	0.49	0.44	0.06	5825.18	100971.00	25203.77	6165.61
155.07	682.55	682.24	0.31	0.52	0.02	7314.35	98136.95	26548.71	6146.71
155.17	682.90	682.59	0.31	0.34	0.00	4704.92	106319.60	20975.50	6118.11
155.26	683.28	682.92	0.36	0.36	0.02	2026.02	110911.10	19062.90	5824.76
155.36	683.78	683.32	0.46	0.48	0.03	1057.02	123085.60	7857.37	5398.92
155.45	684.45	683.92	0.53	0.65	0.02	4476.86	121930.70	5592.42	6433.20
155.55	684.94	684.61	0.32	0.46	0.02	32.88	131761.70	205.47	4981.73
155.64	685.44	684.92	0.53	0.44	0.06	49.03	130967.80	983.12	5121.93
155.74	686.02	685.60	0.42	0.56	0.01	295.19	130833.50	871.28	5761.60
155.83	686.60	686.08	0.52	0.55	0.03	1457.62	130315.20	227.21	6011.55
155.93	687.28	686.76	0.52	0.68	0.00	2092.50	129107.10	800.39	6377.44
156.02	687.90	687.44	0.46	0.62	0.01	658.01	129857.60	1484.36	6167.01
156.12	688.37	687.96	0.41	0.46	0.01	3796.86	127638.00	565.16	5387.95
156.21	688.76	688.33	0.43	0.39	0.01	404.73	131569.40	25.84	4771.17
156.3	689.21	688.70	0.51	0.42	0.02	1548.18	130451.80		3691.54
156.4	689.85	689.15	0.69	0.58	0.06	6406.57	125593.40		3262.48
156.49	690.52	689.89	0.63	0.66	0.01	135.30	131422.70	442.02	3361.30
156.59	691.02	690.53	0.49	0.48	0.01	47.71	131769.60	182.71	3510.20

HEC-RAS Plan: R2-3RUNS Reach: 1 12/24/96 10:45:30 AM (continued)

River Sta.	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
156.68	691.38	691.02	0.37	0.35	0.01		130932.70	1067.32	4463.14
156.78	691.68	691.37	0.30	0.29	0.01		128938.50	3061.47	4463.91
156.87	691.91	691.64	0.27	0.23	0.00	1.62	131238.90	759.48	4009.80
156.97	692.26	691.79	0.47	0.29	0.06	1098.47	130078.30	823.20	3607.78
157.06	692.79	692.24	0.55	0.51	0.02	1416.07	130338.60	245.36	3363.79
157.16	693.56	692.77	0.79	0.70	0.07	1904.53	130095.40	0.04	3016.77
157.25	694.48	693.57	0.91	0.88	0.03	1063.91	130774.30	161.77	2725.08
157.35	695.16	694.54	0.62	0.65	0.03	99.33	131380.90	519.74	2731.33
157.44	695.65	695.01	0.65	0.49	0.01		129743.00	2257.04	2736.93
157.54	696.19	695.48	0.72	0.52	0.02	2433.68	127162.50	2403.83	2862.67
157.63	696.75	696.05	0.71	0.56	0.00	965.30	128163.60	2871.12	2913.17
157.72	697.50	696.55	0.95	0.67	0.07	35.20	126900.60	5064.21	2836.16
157.82	698.57	697.35	1.22	1.00	0.08	32.49	130207.60	1759.94	2450.47
157.91	699.33	698.62	0.72	0.71	0.05	1375.82	126877.70	3746.52	3062.87
158.01	699.84	699.03	0.81	0.48	0.03	2671.15	126600.40	2728.48	4400.77
158.1	700.34	699.51	0.83	0.49	0.01	1413.53	127794.20	2792.27	3296.64
158.2	700.77	700.10	0.67	0.41	0.02	848.56	128572.20	2579.23	3423.88

HEC-RAS Plan: R3-3RUNS Reach: 1 12/30/96 4:11:54 PM

River Sta.	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
158.2	132000.00	683.70	700.09	694.33	700.75	0.000693	6.61	21328.96	3406.08	0.34
158.29	132000.00	684.60	700.41		701.11	0.000725	6.85	20857.27	2625.86	0.36
158.39	132000.00	685.60	700.73		701.56	0.000950	7.41	18690.28	2226.95	0.40
158.48	132000.00	686.50	701.13		702.22	0.001474	8.44	15970.49	2049.59	0.49
158.58	132000.00	687.10	701.95		702.92	0.001285	7.92	16918.92	2035.36	0.45
158.67	132000.00	688.30	702.72		703.57	0.001241	7.44	18213.06	2228.56	0.42
158.77	132000.00	688.10	703.38		704.14	0.001052	7.06	19133.20	2167.03	0.40
158.86	132000.00	688.10	703.99		704.62	0.000812	6.38	21304.58	2435.52	0.35
158.96	132000.00	688.60	704.49		705.00	0.000692	5.78	23047.50	2509.24	0.32
159.05	132000.00	690.20	704.92		705.37	0.000760	5.46	24598.97	2834.54	0.32
159.15	132000.00	689.80	705.28		705.75	0.000720	5.49	24051.55	2714.01	0.32
159.24	132000.00	690.30	705.68		706.03	0.000442	4.80	27558.02	3124.03	0.27
159.34	132000.00	688.20	705.93		706.25	0.000387	4.51	29810.02	4322.28	0.25
159.43	132000.00	689.90	706.12		706.49	0.000535	4.89	27194.55	3663.29	0.28
159.52	132000.00	690.70	706.39		706.75	0.000528	4.88	27991.35	4120.56	0.29
159.62	132000.00	691.40	706.67		707.03	0.000594	4.99	28032.55	3510.61	0.29
159.71	132000.00	691.80	706.96		707.36	0.000706	5.28	26929.37	3665.89	0.33
159.81	132000.00	693.30	707.32		707.71	0.000715	5.11	27130.14	3771.31	0.32
159.9	132000.00	695.00	707.68		708.08	0.000793	5.18	27199.42	4059.34	0.33
160	132000.00	695.60	708.05		708.51	0.000853	5.59	25323.24	3959.61	0.36
160.09	132000.00	695.90	708.49		708.95	0.000903	5.58	25555.09	4257.29	0.37
160.19	132000.00	695.50	708.92		709.38	0.000844	5.62	26146.64	4468.77	0.36
160.28	132000.00	695.50	709.34		709.91	0.001173	6.47	24241.52	4556.60	0.42
160.38	132000.00	695.20	709.91		710.51	0.001216	6.43	23108.51	4337.72	0.42
160.47	132000.00	695.10	710.55		711.02	0.000847	5.80	26060.23	4398.78	0.36
160.57	132000.00	695.80	710.96		711.48	0.000946	5.92	24995.55	4556.16	0.38
160.66	132000.00	696.40	711.48		711.89	0.000702	5.41	28283.45	4765.35	0.33
160.76	132000.00	698.80	711.83		712.23	0.000684	5.29	28706.23	4832.07	0.32
160.85	132000.00	699.70	712.17		712.60	0.000815	5.38	26500.00	4788.65	0.35
160.95	132000.00	700.00	712.62		712.93	0.000591	4.49	30320.41	5079.82	0.29
161.04	132000.00	701.00	712.87		713.24	0.000877	5.01	27368.25	4729.69	0.35
161.13	132000.00	701.80	713.30		713.67	0.000969	4.99	27064.00	4982.27	0.36
161.23	132000.00	702.60	713.77		714.13	0.000991	4.85	27542.63	5124.72	0.37
161.32	132000.00	704.30	714.30		714.62	0.000963	4.68	29194.28	5863.53	0.35
161.42	132000.00	704.10	714.65		715.03	0.000996	4.89	26458.45	5351.67	0.38
161.51	132000.00	704.70	715.03		715.43	0.001381	5.17	26052.93	6381.34	0.42
161.61	132000.00	703.80	715.70		715.99	0.000984	4.56	30721.57	7124.11	0.35
161.7	132000.00	704.40	716.04		716.41	0.001125	4.55	27197.52	6199.14	0.39
161.8	132000.00	702.60	716.50		716.77	0.000693	4.16	32179.93	6996.96	0.32
161.89	132000.00	703.00	716.80		717.15	0.001222	4.99	27987.26	6542.80	0.40
161.99	132000.00	702.30	717.26		717.52	0.000692	4.41	33498.77	7401.27	0.31
162.08	132000.00	703.80	717.57		717.91	0.000958	4.94	28840.57	6087.97	0.37
162.17	132000.00	706.40	718.01		718.40	0.001294	5.04	26483.01	6183.75	0.40
162.27	132000.00	706.20	718.50		718.83	0.000890	4.68	28552.08	6190.33	0.34
162.36	132000.00	705.00	718.89		719.30	0.001082	5.45	25924.53	5749.46	0.39
162.46	132000.00	706.30	719.38		719.83	0.001317	5.51	24629.82	5533.14	0.40
162.55	132000.00	706.70	719.90		720.33	0.000978	5.45	25487.12	4867.99	0.37
162.65	132000.00	710.00	720.37		720.75	0.000879	5.20	27363.44	6776.31	0.35
162.74	132000.00	710.10	720.80		721.39	0.001683	6.33	21613.74	4530.88	0.47
162.84	132000.00	708.70	721.59		721.91	0.000669	4.81	29175.88	4996.38	0.31
162.93	132000.00	712.50	721.94		722.36	0.001098	5.13	25660.56	4588.82	0.37
163.03	132000.00	712.60	722.58		723.03	0.001315	5.11	24792.86	5159.54	0.39
163.12	132000.00	712.80	723.27		723.68	0.001236	4.81	26034.76	5112.74	0.37
163.22	132000.00	714.30	723.83		724.20	0.001118	4.94	27106.53	5438.91	0.36
163.31	132000.00	714.90	724.32		724.70	0.001107	4.87	26783.72	4926.65	0.36
163.41	132000.00	714.50	724.83		725.22	0.001108	4.97	26303.19	4695.65	0.36
163.5	132000.00	714.30	725.39		725.83	0.001415	5.32	24798.17	4449.64	0.40
163.6	132000.00	714.20	726.02		726.42	0.000994	4.80	26479.08	4537.02	0.35
163.69	132000.00	713.30	726.52		727.02	0.001343	5.81	23709.55	4346.36	0.42
163.79	132000.00	714.10	727.12		727.52	0.000824	5.24	26800.26	4356.11	0.34
163.88	132000.00	713.00	727.53		727.97	0.000964	5.39	24683.77	4059.30	0.36
163.97	132000.00	712.30	727.96		728.55	0.001194	6.21	21389.65	3257.35	0.42
164.07	132000.00	713.90	728.59		729.16	0.001247	6.10	21653.15	3320.87	0.42
164.16	132000.00	713.80	729.15		729.81	0.001244	6.51	20499.50	3217.89	0.42
164.26	132000.00	713.80	729.76		730.46	0.001313	6.76	20052.66	3242.45	0.43
164.35	132000.00	714.50	730.49		731.02	0.000915	5.86	22739.59	3356.11	0.37
164.45	132000.00	715.30	731.03		731.46	0.000809	5.27	25439.79	3953.64	0.34

HEC-RAS Plan: R3-3RUNS Reach: 1 12/30/96 4:11:54 PM (continued)

River Sta.	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
164.54	132000.00	716.50	731.47		731.85	0.000714	4.98	27112.18	4294.72	0.31
164.64	132000.00	717.10	731.90		732.32	0.001229	5.18	25578.06	3546.29	0.33
164.73	132000.00	717.10	732.57		732.89	0.001020	4.54	29698.12	4761.99	0.27
164.83	132000.00	717.70	733.09		733.48	0.001298	5.00	26848.15	4211.07	0.31
164.92	132000.00	717.10	733.73		734.05	0.000974	4.53	29410.17	3846.55	0.27
165.02	132000.00	718.00	734.18		734.43	0.000620	4.07	33558.26	4247.72	0.23
165.11	132000.00	721.10	734.51		734.83	0.000953	4.55	29581.22	4245.11	0.28
165.21	132000.00	720.30	734.97		735.27	0.000805	4.46	30501.06	4310.79	0.27
165.3	132000.00	720.80	735.39		735.74	0.001044	4.76	28065.43	4063.24	0.30
165.4	132000.00	721.00	735.92		736.17	0.000671	4.02	33501.00	4886.85	0.24
165.49	132000.00	722.50	736.32		736.63	0.001214	4.44	30303.30	4623.15	0.28
165.58	132000.00	722.90	736.91		737.22	0.001153	4.49	29525.46	4044.77	0.28
165.68	132000.00	724.50	737.42		737.77	0.001016	4.76	27811.18	3548.27	0.30
165.77	132000.00	724.90	737.86		738.20	0.000721	4.70	28458.33	3376.20	0.27
165.87	132000.00	725.70	738.23		738.66	0.001074	5.28	25114.49	2865.88	0.31
165.96	132000.00	726.00	738.75		739.22	0.001121	5.53	23927.37	2602.96	0.32
166.06	132000.00	725.90	739.26		740.00	0.001817	6.92	19172.00	2309.69	0.41
166.15	132000.00	726.90	740.68		741.33	0.004161	6.51	20588.25	2214.57	0.36
166.25	132000.00	727.40	742.40		743.04	0.002865	6.47	20747.91	2270.65	0.35
166.34	132000.00	728.10	743.91		744.56	0.003251	6.56	21428.54	2309.59	0.34
166.41	132000.00	728.00	745.12		745.72	0.002815	6.25	21104.91	1651.70	0.30
166.414	Bridge									
166.42	132000.00	728.00	745.16	737.82	745.77	0.002622	6.23	21184.67	1652.36	0.30
166.49	132000.00	728.00	746.21		747.07	0.004302	7.43	17783.18	1676.23	0.40
166.56	132000.00	727.00	747.64		748.08	0.001762	5.29	24970.15	1724.21	0.24
166.58	132000.00	752.80	759.86	759.86	762.63	0.023581	11.42	11162.13	1736.59	0.79

HEC-RAS Plan: R3-3RUNS Reach: 1 12/30/96 4:11:54 PM

River Sta.	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
158.2	700.75	700.09	0.66	0.00	0.00	1001.64	128067.20	2931.17	3406.08
158.29	701.11	700.41	0.70	0.35	0.01	1260.15	126939.80	3800.07	2625.86
158.39	701.56	700.73	0.84	0.41	0.04	459.04	129439.70	2101.30	2226.95
158.48	702.22	701.13	1.09	0.58	0.08		130129.30	1870.70	2049.59
158.58	702.92	701.95	0.97	0.69	0.01	1.25	131630.00	368.72	2035.36
158.67	703.57	702.72	0.85	0.63	0.01	233.59	130646.00	1120.42	2228.56
158.77	704.14	703.38	0.77	0.57	0.01	28.27	130410.10	1561.58	2167.03
158.86	704.62	703.99	0.63	0.46	0.01	794.23	130436.70	769.12	2435.52
158.96	705.00	704.49	0.52	0.37	0.01	2.22	131659.10	338.70	2509.24
159.05	705.37	704.92	0.46	0.36	0.01	2787.87	129128.10	84.05	2834.54
159.15	705.75	705.28	0.47	0.37	0.00		131999.30	0.66	2714.01
159.24	706.03	705.68	0.36	0.28	0.01		131997.10	2.95	3124.03
159.34	706.25	705.93	0.32	0.21	0.00		131852.00	148.01	4322.28
159.43	706.49	706.12	0.37	0.23	0.02		131948.70	51.29	3663.29
159.52	706.75	706.39	0.36	0.26	0.00		126192.60	5807.44	4120.56
159.62	707.03	706.67	0.36	0.28	0.00		119967.20	12032.83	3510.61
159.71	707.36	706.96	0.40	0.32	0.01		112556.00	19443.96	3665.89
159.81	707.71	707.32	0.39	0.35	0.00		120840.10	11159.92	3771.31
159.9	708.08	707.68	0.40	0.37	0.00	724.40	125468.30	5807.30	4059.34
160	708.51	708.05	0.46	0.41	0.02	4907.87	124327.30	2764.88	3959.61
160.09	708.95	708.49	0.46	0.43	0.00	4264.24	123124.30	4611.47	4257.29
160.19	709.38	708.92	0.46	0.43	0.00	6231.40	120988.10	4780.48	4468.77
160.28	709.91	709.34	0.56	0.50	0.03	18409.39	106659.90	6930.69	4556.60
160.38	710.51	709.91	0.60	0.59	0.01	4960.49	120939.90	6099.58	4337.72
160.47	711.02	710.55	0.47	0.50	0.01	7779.08	115863.80	8357.06	4398.78
160.57	711.48	710.96	0.51	0.45	0.01	5259.40	123402.50	3338.16	4556.16
160.66	711.89	711.48	0.41	0.40	0.01	7266.90	117026.80	7706.28	4765.35
160.76	712.23	711.83	0.40	0.34	0.00	7251.83	119821.00	4927.16	4832.07
160.85	712.60	712.17	0.43	0.37	0.01	1979.93	127010.50	3009.63	4788.65
160.95	712.93	712.62	0.31	0.32	0.01	1341.08	92740.83	37918.09	5079.82
161.04	713.24	712.87	0.37	0.29	0.02	834.96	93258.61	37906.43	4729.69
161.13	713.67	713.30	0.38	0.43	0.00	329.05	102634.80	29036.13	4982.27
161.23	714.13	713.77	0.36	0.46	0.00		98131.05	33868.95	5124.72
161.32	714.62	714.30	0.33	0.49	0.00	1889.56	90428.85	39681.59	5863.53
161.42	715.03	714.65	0.39	0.39	0.02		78064.99	53935.00	5351.67
161.51	715.43	715.03	0.40	0.40	0.00		80447.19	51552.82	6381.34
161.61	715.99	715.70	0.29	0.54	0.01	23.29	77169.94	54806.77	7124.11
161.7	716.41	716.04	0.37	0.40	0.02		67690.78	64309.22	6199.14
161.8	716.77	716.50	0.26	0.35	0.01		70469.74	61530.25	6996.96
161.89	717.15	716.80	0.35	0.36	0.03		80534.59	51465.41	6542.80
161.99	717.52	717.26	0.26	0.36	0.01	5.27	91429.84	40564.89	7401.27
162.08	717.91	717.57	0.34	0.36	0.02	0.01	88469.05	43530.94	6087.97
162.17	718.40	718.01	0.39	0.47	0.02		79824.95	52175.05	6183.75
162.27	718.83	718.50	0.33	0.43	0.01		89406.77	42593.23	6190.33
162.36	719.30	718.89	0.42	0.45	0.03		99494.41	32505.59	5749.46
162.46	719.83	719.38	0.45	0.52	0.01		93490.30	38509.69	5533.14
162.55	720.33	719.90	0.43	0.50	0.00		100205.70	31794.28	4867.99
162.65	720.75	720.37	0.38	0.41	0.00		98573.51	33426.50	6776.31
162.74	721.39	720.80	0.58	0.58	0.06		93810.95	38189.05	4530.88
162.84	721.91	721.59	0.33	0.50	0.03	244.71	94101.36	37653.93	4996.38
162.93	722.36	721.94	0.41	0.42	0.03		84805.16	47194.84	4588.82
163.03	723.03	722.58	0.44	0.66	0.01		87924.31	44075.69	5159.54
163.12	723.68	723.27	0.41	0.65	0.00		84508.28	47491.72	5112.74
163.22	724.20	723.83	0.37	0.52	0.00		100857.80	31142.17	5438.91

HEC-RAS Plan: R3-3RUNS Reach: 1 12/30/96 4:11:54 PM (continued)

River Sta.	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
163.31	724.70	724.32	0.38	0.50	0.00	139.96	103083.40	28776.61	4926.65
163.41	725.22	724.83	0.40	0.52	0.00	193.81	107881.00	23925.19	4695.65
163.5	725.83	725.39	0.44	0.60	0.01		122220.20	9779.82	4449.64
163.6	726.42	726.02	0.40	0.59	0.00	334.25	104358.90	27306.82	4537.02
163.69	727.02	726.52	0.50	0.57	0.03	823.72	110226.80	20949.50	4346.36
163.79	727.52	727.12	0.40	0.49	0.01	100.37	113501.80	18397.86	4356.11
163.88	727.97	727.53	0.45	0.44	0.02	83.96	121934.90	9981.14	4059.30
163.97	728.55	727.96	0.60	0.53	0.04	18.83	131225.00	756.15	3257.35
164.07	729.16	728.59	0.58	0.61	0.00		132000.00		3320.87
164.16	729.81	729.15	0.66	0.62	0.02	188.82	131801.90	9.24	3217.89
164.26	730.46	729.76	0.70	0.64	0.01	1484.91	130514.80	0.29	3242.45
164.35	731.02	730.49	0.53	0.54	0.02	153.12	131845.60	1.27	3356.11
164.45	731.46	731.03	0.43	0.43	0.01	284.59	131707.80	7.63	3953.64
164.54	731.85	731.47	0.38	0.38	0.00	416.78	131576.30	6.97	4294.72
164.64	732.32	731.90	0.42	0.46	0.01	77.28	131918.40	4.34	3546.29
164.73	732.89	732.57	0.32	0.56	0.01	405.73	131584.80	9.53	4761.99
164.83	733.48	733.09	0.39	0.57	0.02	412.75	131421.60	165.70	4211.07
164.92	734.05	733.73	0.32	0.56	0.01	0.55	131673.70	325.78	3846.55
165.02	734.43	734.18	0.25	0.38	0.01	1483.48	129703.40	813.14	4247.72
165.11	734.83	734.51	0.32	0.38	0.02	108.25	131132.60	759.10	4245.11
165.21	735.27	734.97	0.30	0.44	0.00	249.70	128572.90	3177.43	4310.79
165.3	735.74	735.39	0.35	0.46	0.01	160.10	130832.20	1007.74	4063.24
165.4	736.17	735.92	0.25	0.41	0.01	426.88	130180.00	1393.08	4886.85
165.49	736.63	736.32	0.30	0.44	0.02	1024.37	130640.10	335.52	4623.15
165.58	737.22	736.91	0.31	0.59	0.00	68.89	131598.60	332.54	4044.77
165.68	737.77	737.42	0.35	0.54	0.01		131818.20	181.82	3548.27
165.77	738.20	737.86	0.34	0.42	0.00		131392.10	607.93	3376.20
165.87	738.66	738.23	0.43	0.44	0.03		131702.30	297.65	2865.88
165.96	739.22	738.75	0.47	0.55	0.01		131789.00	210.98	2602.96
166.06	740.00	739.26	0.74	0.70	0.08	3.67	131625.70	370.68	2309.69
166.15	741.33	740.68	0.65	1.32	0.01	1138.80	130167.20	694.04	2214.57
166.25	743.04	742.40	0.64	1.71	0.00	4069.74	126834.10	1096.15	2270.65
166.34	744.56	743.91	0.65	1.51	0.00	5179.63	126395.70	424.68	2309.59
166.41	745.72	745.12	0.61	1.16	0.00		129709.50	2290.50	1651.70
166.414	Bridge								
166.42	745.77	745.16	0.60				129764.60	2235.40	1652.36
166.49	747.07	746.21	0.86	1.22	0.08		131971.20	28.80	1676.23
166.56	748.08	747.64	0.43	0.97	0.04		131999.10	0.88	1724.21
166.58	762.63	759.86	2.77	0.41	0.70	11920.72	97023.88	23055.40	1736.59

APPENDIX C

HEC-RAS Plan: BE prefall Reach: 1 1/17/97 12:02:20 PM

River Sta.	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
166.58	132000.00	753.43	760.60	759.24	762.52	0.000920	11.11	11884.25	1657.50	0.73
166.77	132000.00	755.32	762.87	762.87	765.01	0.013874	11.41	11254.48	2606.76	1.00
166.86	132000.00	756.71	766.53		767.14	0.001762	6.20	21133.88	2692.17	0.39
166.96	132000.00	757.10	767.46		767.88	0.001102	4.96	25441.35	3019.89	0.31
167.06	132000.00	756.78	768.09		768.41	0.001103	5.69	32250.25	3219.47	0.32
167.15	132000.00	758.22	768.65		768.88	0.000773	4.61	36857.39	3928.92	0.27
167.2	132000.00	757.10	768.88		769.01	0.000301	2.83	44510.83	4766.02	0.17
167.25	132000.00	756.67	768.98		769.10	0.000323	2.96	47658.99	4975.66	0.17
167.34	132000.00	755.63	769.18		769.25	0.000188	2.33	63972.25	6510.62	0.13
167.44	132000.00	755.60	769.27		769.36	0.000241	2.14	55204.07	5722.24	0.12
167.53	132000.00	753.62	769.40		769.48	0.000211	1.99	57539.17	6007.21	0.11
167.63	132000.00	754.48	769.52		769.60	0.000201	2.00	62920.36	6467.12	0.11
167.72	132000.00	754.19	769.63		769.69	0.000123	1.43	71252.05	7329.80	0.08
167.82	132000.00	753.98	769.70		769.74	0.000107	1.31	80963.94	8778.13	0.07
167.91	132000.00	752.61	769.76		769.80	0.000091	1.40	85045.86	9334.20	0.08
168.01	132000.00	754.90	769.83		769.87	0.000238	2.14	79197.01	9600.66	0.12
168.1	132000.00	752.80	769.97		770.02	0.000253	2.38	75379.36	9279.03	0.13
168.2	132000.00	752.96	770.09		770.14	0.000274	2.25	74817.98	9229.91	0.13
168.29	132000.00	753.13	770.20		770.25	0.000188	2.60	80697.16	9310.68	0.13
168.38	132000.00	753.59	770.29		770.35	0.000206	2.77	75898.21	8592.25	0.14
168.48	132000.00	755.24	770.41		770.47	0.000288	2.98	68805.43	8370.39	0.16
168.57	132000.00	755.40	770.55		770.62	0.000343	3.31	64632.17	8136.79	0.18
168.67	132000.00	755.50	770.72		770.79	0.000326	2.68	68023.94	7837.94	0.14
168.77	132000.00	756.40	770.89		770.95	0.000381	2.36	64739.96	8236.14	0.13
168.86	132000.00	756.90	771.05		771.09	0.000230	1.61	77840.75	9513.89	0.09
168.95	132000.00	753.60	771.16		771.21	0.000254	2.10	74909.90	9421.89	0.11
169.05	132000.00	755.05	771.27		771.32	0.000241	2.20	74636.45	8998.67	0.12

w D A
2600 7.5' 19,500

$V = \frac{132000}{19500} \approx 6.8'/sec$

$Slope = \frac{4.82}{.19(5280)} = 0.0037$

SP = 62.4(.0037) RV
= .2309 RV

HEC-RAS Plan: BE prefail Reach: 1 1/17/97 12:02:20 PM

River Sta.	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
166.58	762.52	760.60	1.92	0.00	0.00		132000.00		1657.50
166.77	765.01	762.87	2.14	2.41	0.07		53253.38	78746.61	2606.76
166.86	767.14	766.53	0.61	1.98	0.15	474.46	88020.66	43504.88	2692.17
166.96	767.88	767.46	0.42	0.72	0.02	779.15	55383.90	75836.94	3019.89
167.06	768.41	768.09	0.32	0.51	0.01	590.70	58633.03	72776.27	3219.47
167.15	768.88	768.65	0.22	0.46	0.01	12747.46	42277.00	76975.55	3928.92
167.2	769.01	768.88	0.14	0.13	0.01	11363.66	29358.08	91278.26	4766.02
167.25	769.10	768.98	0.12	0.09	0.00	12805.12	33169.25	86025.63	4975.66
167.34	769.25	769.18	0.07	0.14	0.01	22510.29	28569.33	80920.38	6510.62
167.44	769.36	769.27	0.09	0.11	0.01	213.72	24450.21	107336.10	5722.24
167.53	769.48	769.40	0.08	0.12	0.00		23110.31	108889.70	6007.21
167.63	769.60	769.52	0.07	0.12	0.00	6204.58	21819.79	103975.60	6467.12
167.72	769.69	769.63	0.06	0.09	0.00	8634.07	17672.01	105693.90	7329.80
167.82	769.74	769.70	0.05	0.06	0.00	15314.10	14747.43	101938.50	8778.13
167.91	769.80	769.76	0.04	0.06	0.00	13755.62	23036.42	95207.96	9334.20
168.01	769.87	769.83	0.05	0.07	0.00	19044.84	31852.50	81102.67	9600.66
168.1	770.02	769.97	0.05	0.14	0.00	26179.17	30121.84	75698.98	9279.03
168.2	770.14	770.09	0.05	0.13	0.00	26719.39	26786.20	78494.41	9229.91
168.29	770.25	770.20	0.05	0.11	0.00	35502.07	29070.28	67427.66	9310.68
168.38	770.35	770.29	0.06	0.09	0.00	33130.47	26669.02	72200.50	8592.25
168.48	770.47	770.41	0.07	0.12	0.00	26009.56	21773.62	84216.82	8370.39
168.57	770.62	770.55	0.08	0.15	0.00	10651.62	27135.54	94212.84	8136.79
168.67	770.79	770.72	0.06	0.16	0.00	11002.68	28622.83	92374.50	7837.94
168.77	770.95	770.89	0.07	0.17	0.00	8300.99	30557.87	93141.14	8236.14
168.86	771.09	771.05	0.05	0.14	0.00	17316.80	23476.79	91206.41	9513.89
168.95	771.21	771.16	0.05	0.11	0.00	6272.32	38554.85	87172.82	9421.89
169.05	771.32	771.27	0.05	0.11	0.00	2822.18	42141.52	87036.30	8998.67

APPENDIX D

ASL/SIERRA
CONSULTING ENGINEERS

SHEET NO. 1 OF 1

ENGINEER ____ DATE 12/31/96 JOB NO. 1137.003 BY TRL

SUBJECT Enterprise Canal CHECKED BY ____

OFFICE ____ TELEPHONE ____

Summary of Findings:

1. Enterprise Canal at culvert just downstream of SR 80:

Headwater stage at culvert inlet for 132,000 cfs in Gila River

CBA Model results:	166.34	743.9
	166.41	745.1

Culvert inlet is at about 166.40, stage = 745.1
Flow in Gila River did not overtop canal levee downstream of culvert; therefore, maximum stage at culvert inlet is 745.1.
Stage measured at Enterprise Canal gage by USGS = 743.7. Use
That stage will force about 345 cfs through culvert.
The Enterprise Canal downstream of culvert has a maximum capacity of 3600 cfs before levee is overtopped.

2. Enterprise Canal about 3.0 miles downstream of SR 80:

Canal maximum capacity before overtopping banks is about 260 cfs.
The canal capacity was restricted by a culvert under a field access road crossing of the canal. The reduced canal hydraulic capacity of the cross section, combined with backwater from the culvert, caused the canal banks to be exceeded. This resulted in flooding of the fields and probably failure of the culvert.

Backwater from the head gate downstream of the canal failure caused overtopping of the east canal bank.

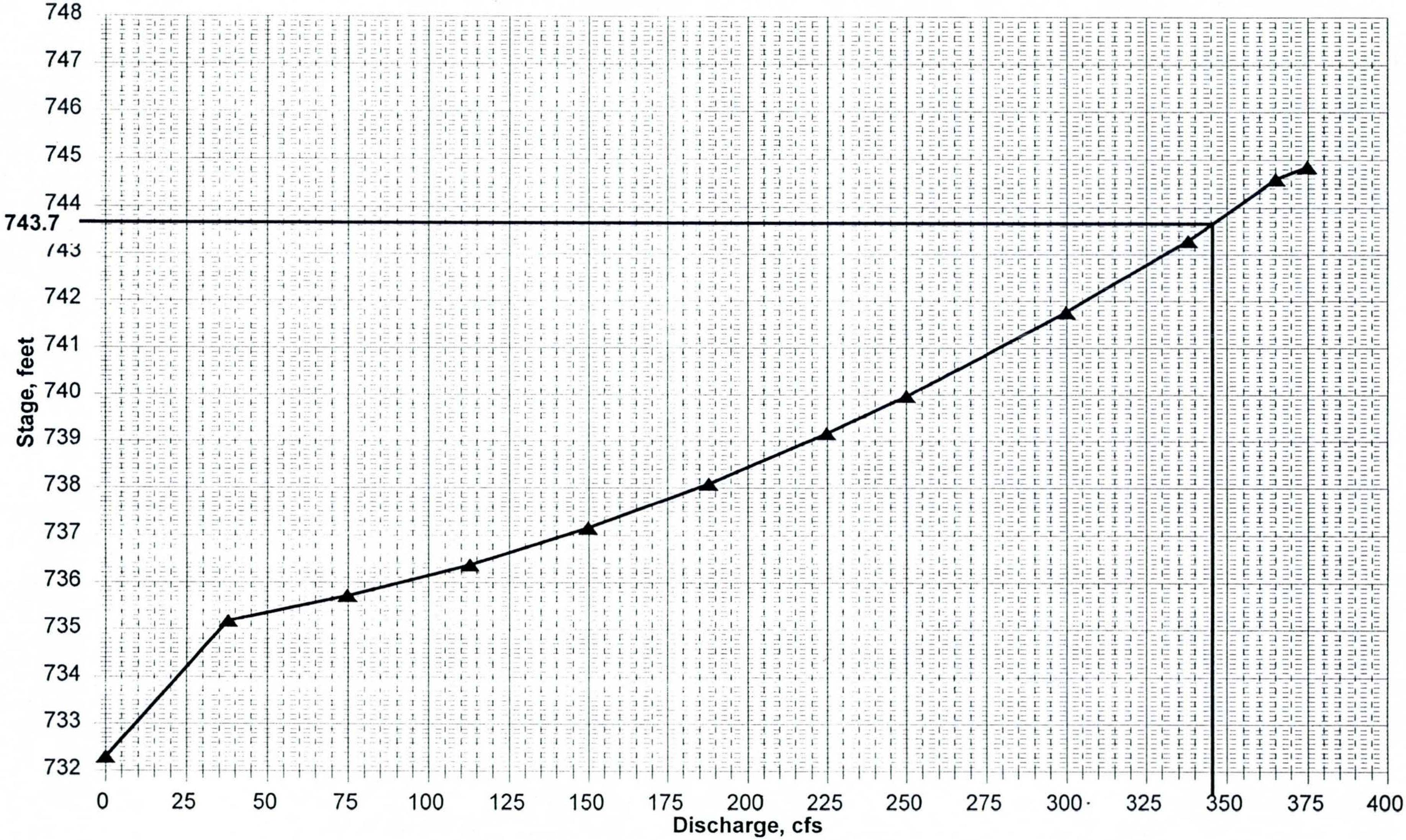

Figure C-1

Stage versus discharge curve for Enterprise Canal culvert just downstream of SR 80

Enterprise Canal Culvert just downstream from SR80:
Existing 85"x54"x70' CMPA

Headwater Elevation for 132,000 cfs = 743.7
From Enterprise Canal USGS Gage Number 09519000 record for 9 January 1993

CURRENT DATE: 12-30-1996
CURRENT TIME: 16:30:28

FILE DATE: 12-30-1996
FILE NAME: ENTRPRSE

FHWA CULVERT ANALYSIS
HY-8, VERSION 4.0

CULV #	SITE DATA: INLET ELEV. (FT)	OUTLET ELEV. (FT)	CULVERT LENGTH (FT)	CULVERT SHAPE, MATERIAL, INLET: BARRELS SHAPE MATERIAL	SPAN (FT)	RISE (FT)	MANNING n	INLET TYPE
1	732.30	732.29	70.00	1 CMPA	7.08	4.50	.026	CONVENTIONAL
2								
3								
4								
5								
6								

SUMMARY OF CULVERT FLOWS (CFS) FILE: ENTRPRSE DATE: 12-30-1996

ELEV (FT)	TOTAL	1	2	3	4	5	6	ROADWAY	ITR
732.30	0	0	0	0	0	0	0	0	1
735.19	38	38	0	0	0	0	0	0	1
735.72	75	75	0	0	0	0	0	0	1
736.37	113	113	0	0	0	0	0	0	1
737.16	150	150	0	0	0	0	0	0	1
738.09	188	188	0	0	0	0	0	0	1
739.17	225	225	0	0	0	0	0	0	1
739.97	250	250	0	0	0	0	0	0	1
741.77	300	300	0	0	0	0	0	0	1
743.29	338	338	0	0	0	0	0	0	1
744.85	375	369	0	0	0	0	0	5	7
744.60	365	365	0	0	0	0	0	OVERTOPPING	

SUMMARY OF ITERATIVE SOLUTION ERRORS FILE: ENTRPRSE DATE: 12-30-1996

HEAD ELEV(FT)	HEAD ERROR(FT)	TOTAL FLOW(CFS)	FLOW ERROR(CFS)	% FLOW ERROR
732.30	0.00	0	0	0.00
735.19	0.00	38	0	0.00
735.72	0.00	75	0	0.00
736.37	0.00	113	0	0.00
737.16	0.00	150	0	0.00
738.09	0.00	188	0	0.00
739.17	0.00	225	0	0.00
739.97	0.00	250	0	0.00
741.77	0.00	300	0	0.00
743.29	0.00	338	0	0.00
744.85	-0.01	375	1	0.18

<1> TOLERANCE (FT) = 0.010 <2> TOLERANCE (%) = 1.000

Enterprise Canal Culvert just downstream from SR80:
Existing 85"x54"x70' CMPA

Headwater Elevation for 132,000 cfs = 743.7
From Enterprise Canal USGS Gage Number 09519000 record for 9 January 1993

CURRENT DATE: 12-30-1996 FILE DATE: 12-30-1996
CURRENT TIME: 16:30:28 FILE NAME: ENTRPRSE

PERFORMANCE CURVE FOR CULVERT # 1 - 1 (7.083333 BY 4.5) CMPA

DIS-CHARGE FLOW (cfs)	HEAD-WATER ELEV. (ft)	INLET CONTROL DEPTH (ft)	OUTLET CONTROL DEPTH (ft)	FLOW TYPE <F4>	NORMAL DEPTH (ft)	CRITICAL DEPTH (ft)	OUTLET VEL. (fps)	OUTLET DEPTH (ft)	TAILWATER VEL. (fps)	TAILWATER DEPTH (ft)
0	732.30	0.00	0.00	0-NF	0.00	0.00	0.00	0.00	0.00	0.00
38	735.19	1.80	2.89	6-FFn	4.50	1.13	1.49	4.50	2.63	1.34
75	735.72	2.75	3.42	6-FFn	4.50	1.70	2.98	4.50	3.23	1.95
113	736.37	3.55	4.07	6-FFn	4.50	2.16	4.47	4.50	3.62	2.42
150	737.16	4.32	4.86	6-FFn	4.50	2.56	5.96	4.50	3.92	2.81
188	738.09	5.14	5.79	6-FFn	4.50	2.91	7.45	4.50	4.17	3.15
225	739.17	6.09	6.87	6-FFn	4.50	3.23	8.94	4.50	4.37	3.45
250	739.97	6.82	7.67	6-FFn	4.50	3.42	9.93	4.50	4.50	3.64
300	741.77	8.51	9.47	6-FFn	4.50	3.73	11.92	4.50	4.72	3.98
338	743.29	10.00	10.99	6-FFn	4.50	3.93	13.41	4.50	4.87	4.21
369	744.85	11.41	12.55	6-FFn	4.50	4.09	14.68	4.50	5.01	4.44

El. inlet face invert 732.30 ft El. outlet invert 732.29 ft
El. inlet throat invert 0.00 ft El. inlet crest 0.00 ft

***** SITE DATA ***** CULVERT INVERT **************

INLET STATION (FT)	0.00
INLET ELEVATION (FT)	732.30
OUTLET STATION (FT)	70.00
OUTLET ELEVATION (FT)	732.29
NUMBER OF BARRELS	1
SLOPE (V-FT/H-FT)	0.0001
CULVERT LENGTH ALONG SLOPE (FT)	70.00

***** CULVERT DATA SUMMARY ************************

BARREL SHAPE	PIPE ARCH
BARREL SPAN	7.08 FT
BARREL RISE	4.50 FT
BARREL MATERIAL	STEEL OR ALUMINUM
BARREL MANNING'S N	0.026
INLET TYPE	CONVENTIONAL
INLET EDGE AND WALL	HEADWALL
INLET DEPRESSION	NONE

Enterprise Canal Culvert just downstream from SR80:
Existing 85"x54"x70' CMPA

Headwater Elevation for 132,000 cfs = 743.7
From Enterprise Canal USGS Gage Number 09519000 record for 9 January 1993

CURRENT DATE: 12-30-1996
CURRENT TIME: 16:30:28

FILE DATE: 12-30-1996
FILE NAME: ENTRPRSE

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*******************************************************************************
*************************          TAILWATER          *************************
*******************************************************************************

******* REGULAR CHANNEL CROSS SECTION ****************
        BOTTOM WIDTH (FT)                              8.00
        SIDE SLOPE  H/V (X:1)                          2.0
        CHANNEL SLOPE V/H (FT/FT)                      0.002
        MANNING'S N (.01-0.1)                          0.025
        CHANNEL INVERT ELEVATION (FT)                732.29
        CULVERT NO.1 OUTLET INVERT ELEVATION         732.29 FT

******* UNIFORM FLOW RATING CURVE FOR DOWNSTREAM CHANNEL
```

FLOW (CFS)	W.S.E. (FT)	FROUDE NUMBER	DEPTH (FT)	VEL. (FPS)	SHEAR (PSF)
0.00	732.29	0.000	0.00	0.00	0.00
37.50	733.63	0.400	1.34	2.63	0.16
75.00	734.24	0.407	1.95	3.23	0.23
112.50	734.71	0.410	2.42	3.62	0.29
150.00	735.10	0.412	2.81	3.92	0.33
187.50	735.44	0.414	3.15	4.17	0.37
225.00	735.74	0.415	3.45	4.37	0.41
250.00	735.93	0.416	3.64	4.50	0.43
300.00	736.27	0.417	3.98	4.72	0.47
337.50	736.50	0.418	4.21	4.87	0.50
375.00	736.73	0.419	4.44	5.01	0.53

```
*******************************************************************************
*************************  ROADWAY OVERTOPPING DATA  *************************
*******************************************************************************

      ROADWAY SURFACE                               GRAVEL
      EMBANKMENT TOP WIDTH (FT)                      40.00
***** USER DEFINED ROADWAY PROFILE
```

CROSS-SECTION COORD. NO.	X (FT)	Y (FT)
1	0.00	746.20
2	5.00	746.00
3	10.00	745.80
4	15.00	745.60
5	20.00	745.30
6	25.00	745.00
7	35.00	744.80
8	45.00	744.70
9	55.00	744.70
10	65.00	744.60
11	65.00	746.20

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*******************************************************************************
```
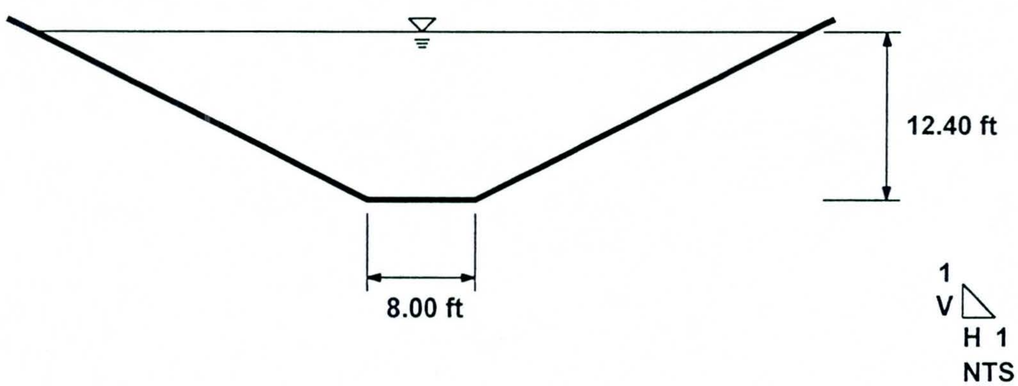

Cross Section
Cross Section for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal d/s of SR80.
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Section Data		
Mannings Coefficient	0.025	
Channel Slope	0.001900	ft/ft
Depth	12.40	ft
Left Side Slope	2.000000	H : V
Right Side Slope	2.000000	H : V
Bottom Width	8.00	ft
Discharge	3,635.94	cfs



Enterprise Canal d/s of SR80, d=4.4'
Worksheet for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal d/s of SR80.
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coefficient	0.025	
Channel Slope	0.001900	ft/ft
Depth	4.40	ft
Left Side Slope	2.000000	H : V
Right Side Slope	2.000000	H : V
Bottom Width	8.00	ft

Results		
Discharge	368.65	cfs
Flow Area	73.92	ft²
Wetted Perimeter	27.68	ft
Top Width	25.60	ft
Critical Depth	3.11	ft
Critical Slope	0.007725	ft/ft
Velocity	4.99	ft/s
Velocity Head	0.39	ft
Specific Energy	4.79	ft
Froude Number	0.52	
Flow is subcritical.		

Enterprise Canal d/s of SR80, d=12.4'
Worksheet for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal d/s of SR80.
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coefficient	0.025	
Channel Slope	0.001900	ft/ft
Depth	12.40	ft
Left Side Slope	2.000000	H : V
Right Side Slope	2.000000	H : V
Bottom Width	8.00	ft

Results		
Discharge	3,635.94	cfs
Flow Area	406.72	ft^2
Wetted Perimeter	63.45	ft
Top Width	57.60	ft
Critical Depth	9.75	ft
Critical Slope	0.005773	ft/ft
Velocity	8.94	ft/s
Velocity Head	1.24	ft
Specific Energy	13.64	ft
Froude Number	0.59	
Flow is subcritical.		

Curve
Plotted Curves for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal d/s of SR80.
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Constant Data		
Mannings Coefficient	0.025	
Channel Slope	0.001900 ft/ft	
Left Side Slope	2.000000 H : V	
Right Side Slope	2.000000 H : V	
Bottom Width	8.00	ft

Input Data	Minimum	Maximum	Increment
Depth	0.00	12.40	0.10 ft

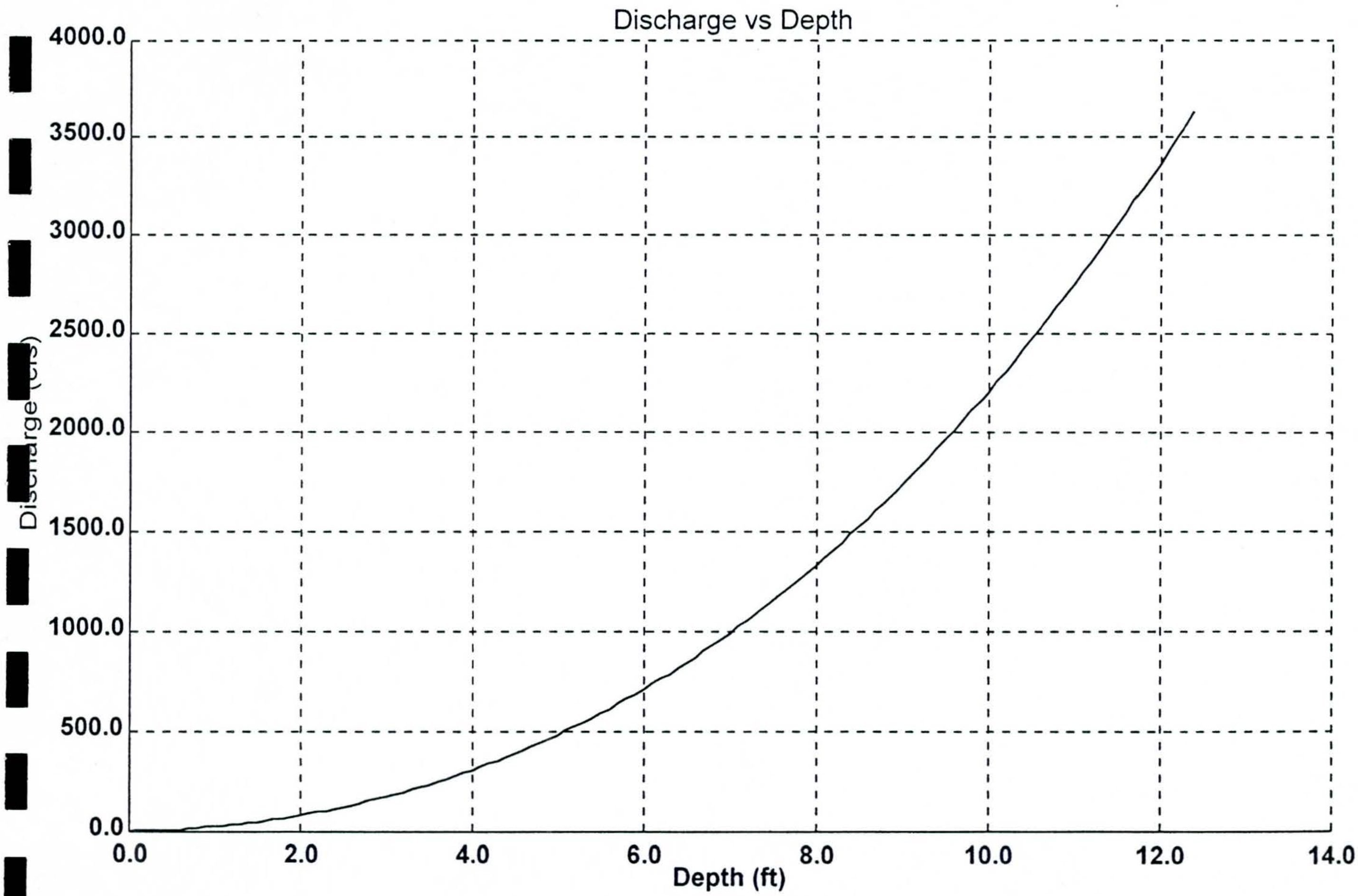


Table
Rating Table for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal d/s of SR80.
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Constant Data	
Mannings Coefficient	0.025
Channel Slope	0.001900 ft/ft
Left Side Slope	2.000000 H : V
Right Side Slope	2.000000 H : V
Bottom Width	8.00 ft

Input Data	Minimum	Maximum	Increment
Depth	0.00	12.40	0.50 ft

Rating Table

Depth (ft)	Discharge (cfs)	Velocity (ft/s)
0.00	0.00	0.00
0.50	6.74	1.50
1.00	22.36	2.24
1.50	46.15	2.80
2.00	78.42	3.27
2.50	119.67	3.68
3.00	170.48	4.06
3.50	231.44	4.41
4.00	303.15	4.74
4.50	386.20	5.05
5.00	481.17	5.35
5.50	588.63	5.63
6.00	709.16	5.91
6.50	843.30	6.18
7.00	991.60	6.44
7.50	1,154.59	6.69
8.00	1,332.81	6.94
8.50	1,526.78	7.18
9.00	1,736.99	7.42
9.50	1,963.97	7.66
10.00	2,208.20	7.89
10.50	2,470.17	8.11

Table
Rating Table for Trapezoidal Channel

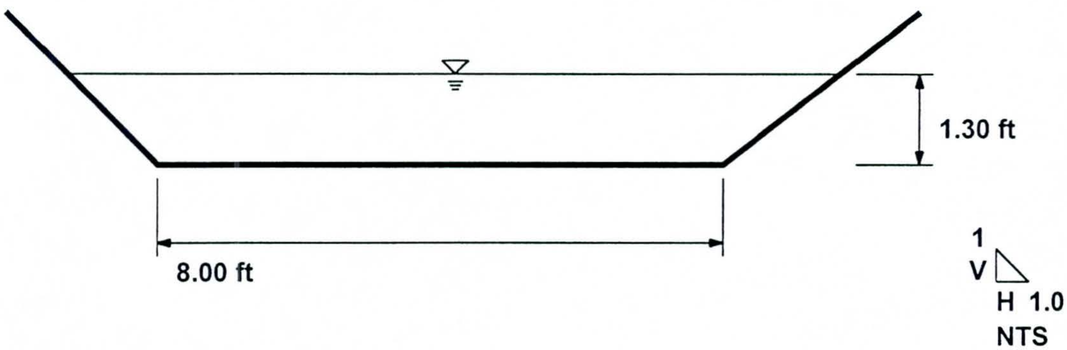
Rating Table

Depth (ft)	Discharge (cfs)	Velocity (ft/s)
11.00	2,750.37	8.33
11.50	3,049.27	8.55
12.00	3,367.35	8.77
12.50	3,705.07	8.98

Cross Section
Cross Section for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal 13000 ft downstream
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Section Data		
Mannings Coefficient	0.027	
Channel Slope	0.001000	ft/ft
Depth	1.30	ft
Left Side Slope	1.000000	H : V
Right Side Slope	1.300000	H : V
Bottom Width	8.00	ft
Discharge	21.93	cfs



Enterprise Canal 13000 ft d/s d=1.3'
Worksheet for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal 13000 ft downstream
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coefficient	0.027	
Channel Slope	0.001000	ft/ft
Depth	1.30	ft
Left Side Slope	1.000000	H : V
Right Side Slope	1.300000	H : V
Bottom Width	8.00	ft

Results		
Discharge	21.93	cfs
Flow Area	12.34	ft²
Wetted Perimeter	11.97	ft
Top Width	10.99	ft
Critical Depth	0.60	ft
Critical Slope	0.013770	ft/ft
Velocity	1.78	ft/s
Velocity Head	0.05	ft
Specific Energy	1.35	ft
Froude Number	0.30	
Flow is subcritical.		

Enterprise Canal 13000 ft d/s d=4.3'
Worksheet for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal 13000 ft downstream
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coefficient	0.027	
Channel Slope	0.001000	ft/ft
Depth	4.30	ft
Left Side Slope	1.000000	H : V
Right Side Slope	1.300000	H : V
Bottom Width	8.00	ft

Results		
Discharge	184.76	cfs
Flow Area	55.66	ft^2
Wetted Perimeter	21.13	ft
Top Width	17.89	ft
Critical Depth	2.27	ft
Critical Slope	0.010229	ft/ft
Velocity	3.32	ft/s
Velocity Head	0.17	ft
Specific Energy	4.47	ft
Froude Number	0.33	
Flow is subcritical.		

Table
Rating Table for Trapezoidal Channel

Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal 13000 ft downstream
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Constant Data		
Channel Slope	0.001000	ft/ft
Depth	1.30	ft
Left Side Slope	1.000000	H : V
Right Side Slope	1.300000	H : V
Bottom Width	8.00	ft

Input Data	Minimum	Maximum	Increment
Mannings Coefficient	0.020	0.040	0.001

Rating Table

Mannings Coefficient	Discharge (cfs)	Velocity (ft/s)
0.020	29.60	2.40
0.021	28.19	2.28
0.022	26.91	2.18
0.023	25.74	2.09
0.024	24.67	2.00
0.025	23.68	1.92
0.026	22.77	1.84
0.027	21.93	1.78
0.028	21.14	1.71
0.029	20.41	1.65
0.030	19.73	1.60
0.031	19.10	1.55
0.032	18.50	1.50
0.033	17.94	1.45
0.034	17.41	1.41
0.035	16.91	1.37
0.036	16.44	1.33
0.037	16.00	1.30
0.038	15.58	1.26
0.039	15.18	1.23
0.040	14.80	1.20

Range for n : 0.021 → 0.027

Rating Curve for Enterprise Canal 13000' d/s
Plotted Curves for Trapezoidal Channel

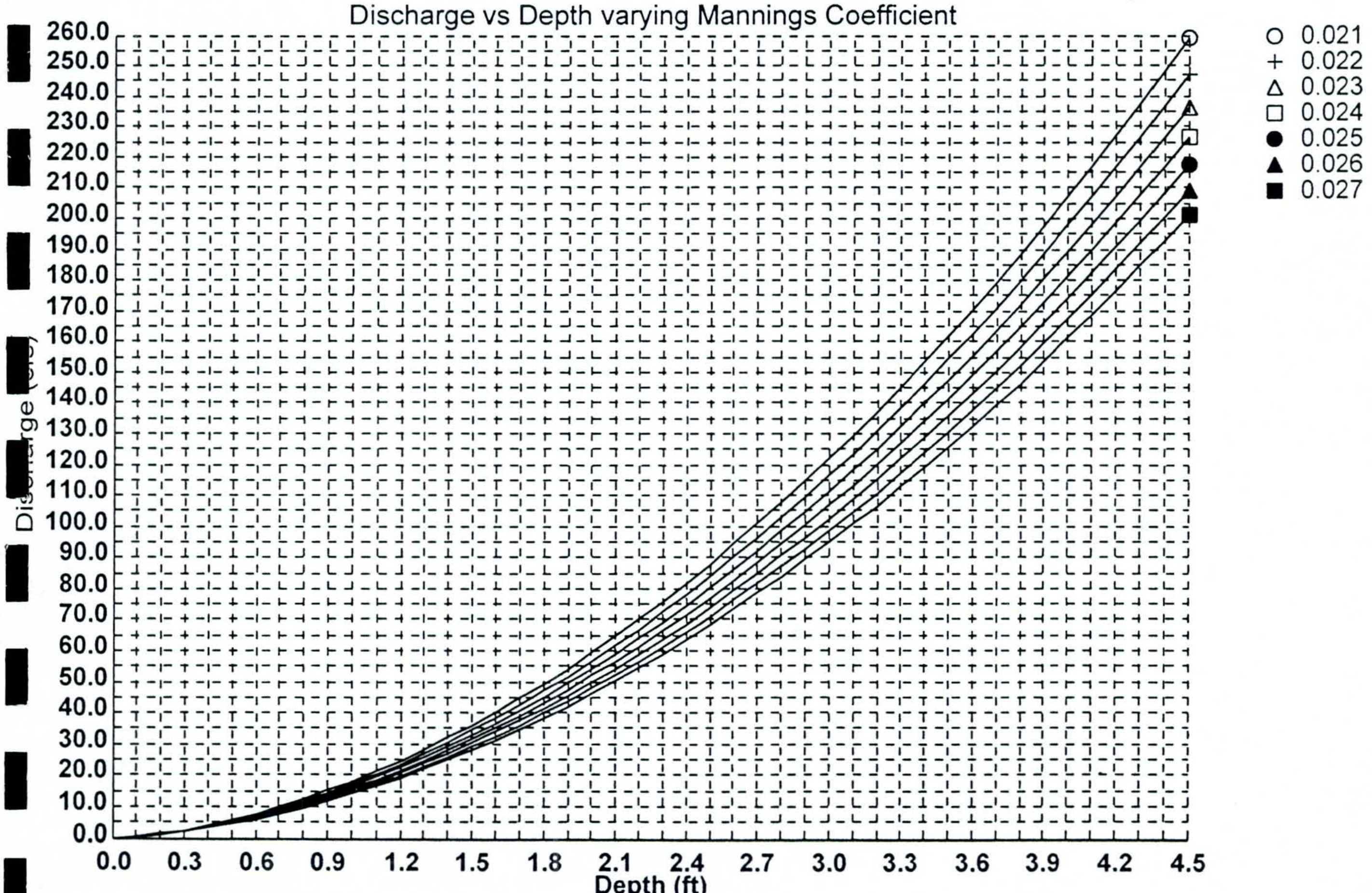
Project Description	
Project File	h:\sdskproj\1137003\fmw\1137003.fm2
Worksheet	Enterprise Canal 13000 ft downstream
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Q varies from 200-260 cfs

Constant Data		
Channel Slope	0.001000	ft/ft
Left Side Slope	1.000000	H : V
Right Side Slope	1.300000	H : V
Bottom Width	8.00	ft

Input Data	Minimum	Maximum	Increment	
Depth	0.00	4.50	0.10	ft
Mannings Coefficient	0.021	0.027	0.001	

Discharge vs Depth varying Mannings Coefficient



APPENDIX E

LIST OF FIGURES

PHOTO MOSAIC OF THE GILA RIVER LANDSCAPE IN 1953

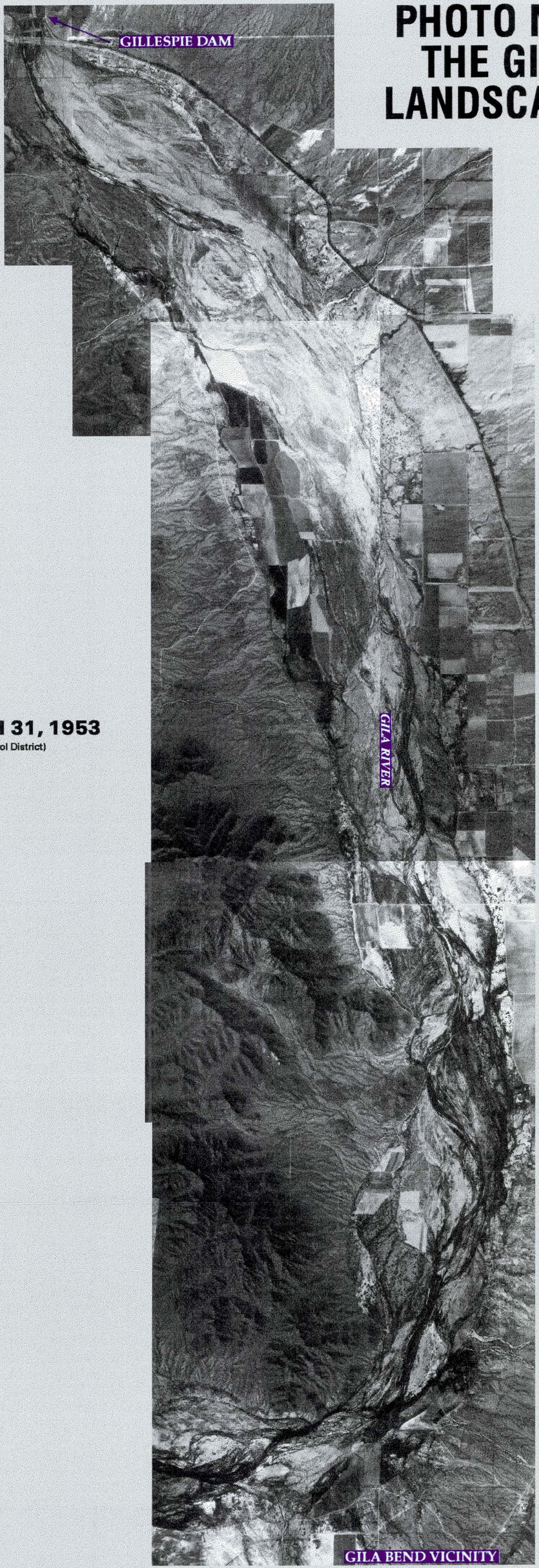


PHOTO DATE: MARCH 31, 1953
(Source: Maricopa County Flood Control District)

Flood Control District of Maricopa County
Geographic Information Systems

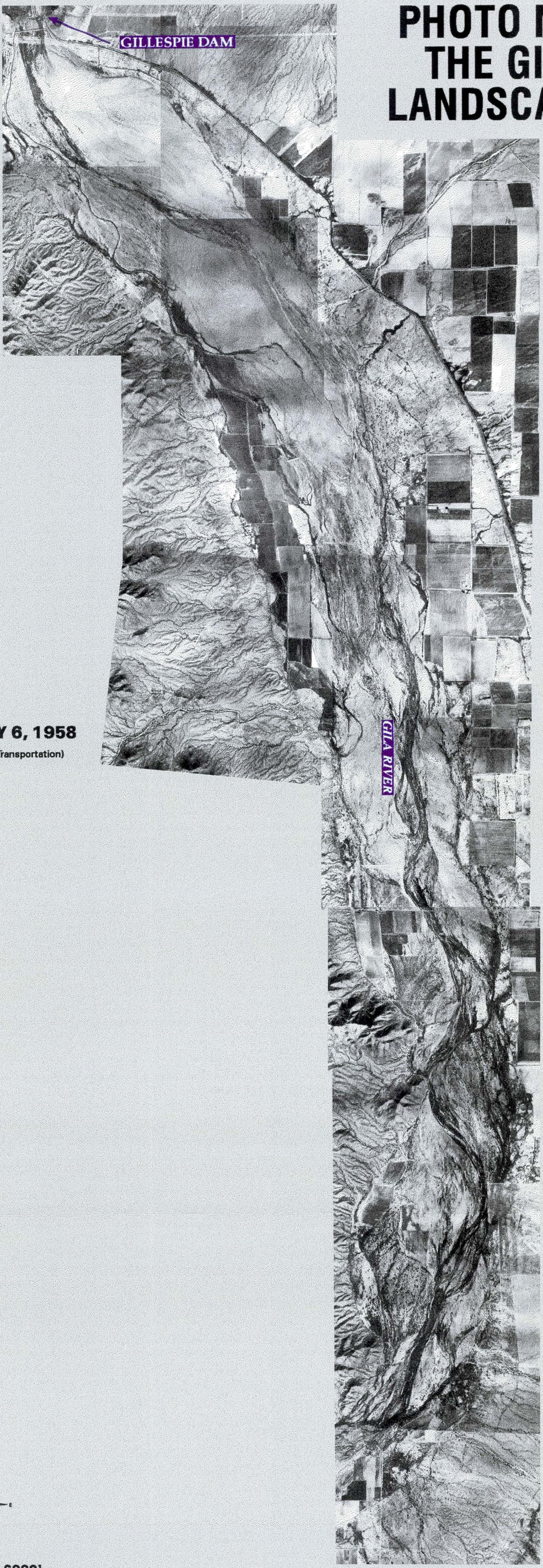
Scale 1" = 6000'

0 3000 6000 12000 24000

/hd2/johnhelm/phasel/tam/e53.aml 01/18/97.14:25:21.Sat

FIGURE E-1

PHOTO MOSAIC OF THE GILA RIVER LANDSCAPE IN 1958



GILA BEND VICINITY

PHOTO DATE: JANUARY 6, 1958

(Source: Maricopa County Department of Transportation)

Scale 1" = 6000'

0 3000 6000 12000 24000

FIGURE E-2

/hd2/johnheim/phase1/tom/e58.aml 01/18/97 14:32:07 Sat

PHOTO MOSAIC OF THE GILA RIVER LANDSCAPE IN 1964

PHOTO DATE: JANUARY 20, 1964

(Source: Maricopa County Department of Transportation)

Scale 1" = 6000'

0 3000 6000 12000 24000

FIGURE E-3

PHOTO MOSAIC OF THE GILA RIVER LANDSCAPE IN 1970

PHOTO DATE: JANUARY 29, 1970

(Source: Maricopa County Department of Transportation)

Scale 1" = 6000'

0 3000 6000 12000 24000

/hd2/johnhelm/phasel/tom/e70.aml 01/17/97 22:05:40 Fri

FIGURE E-4

PHOTO MOSAIC OF THE GILA RIVER LANDSCAPE IN 1976

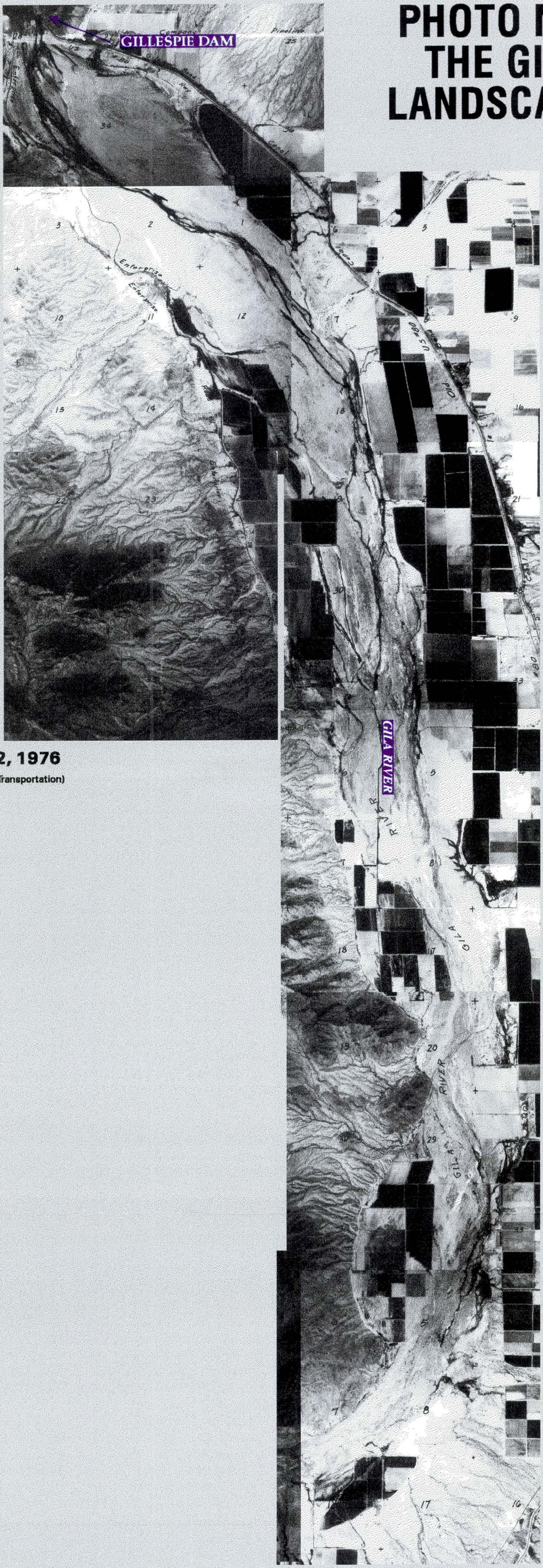


PHOTO DATE: APRIL 2, 1976

(Source: Maricopa County Department of Transportation)

Flood Control District of Maricopa County
Geographic Information Systems

Scale 1" = 6000'

0 3000 6000 12000 24000

FIGURE E-5

PHOTO MOSAIC OF THE GILA RIVER LANDSCAPE IN 1985/1991

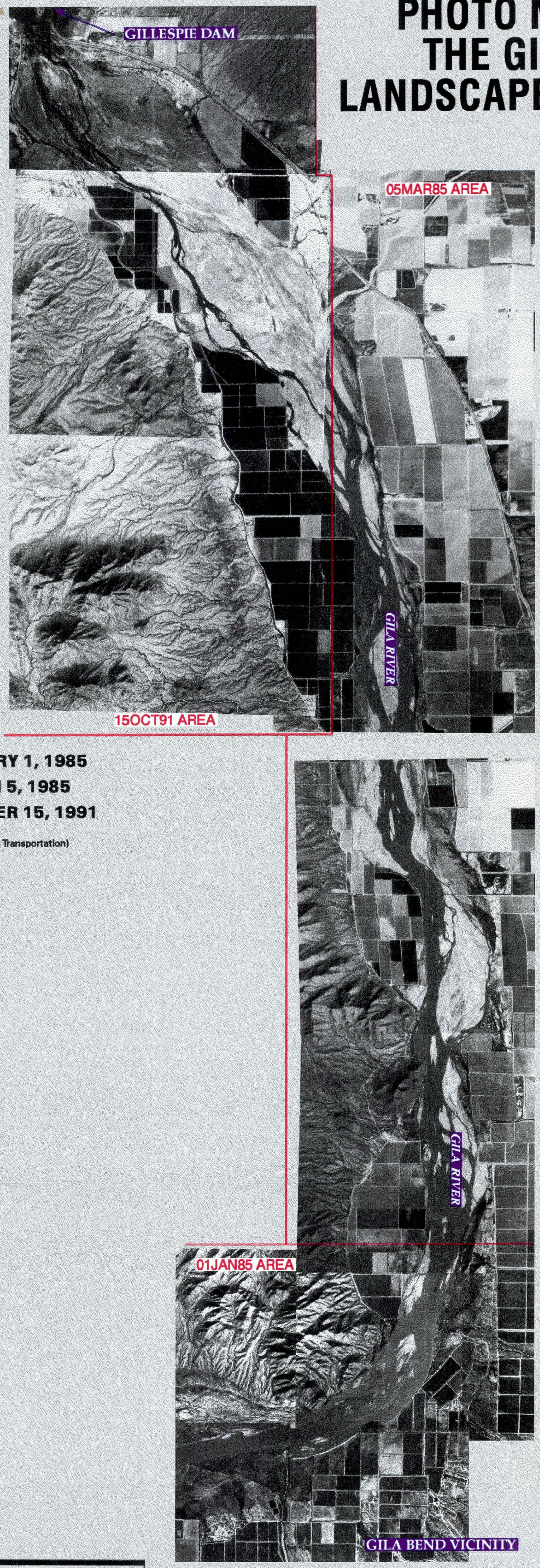


PHOTO DATES: JANUARY 1, 1985
MARCH 5, 1985
OCTOBER 15, 1991

(Source: Maricopa County Department of Transportation)

Scale 1" = 6000'

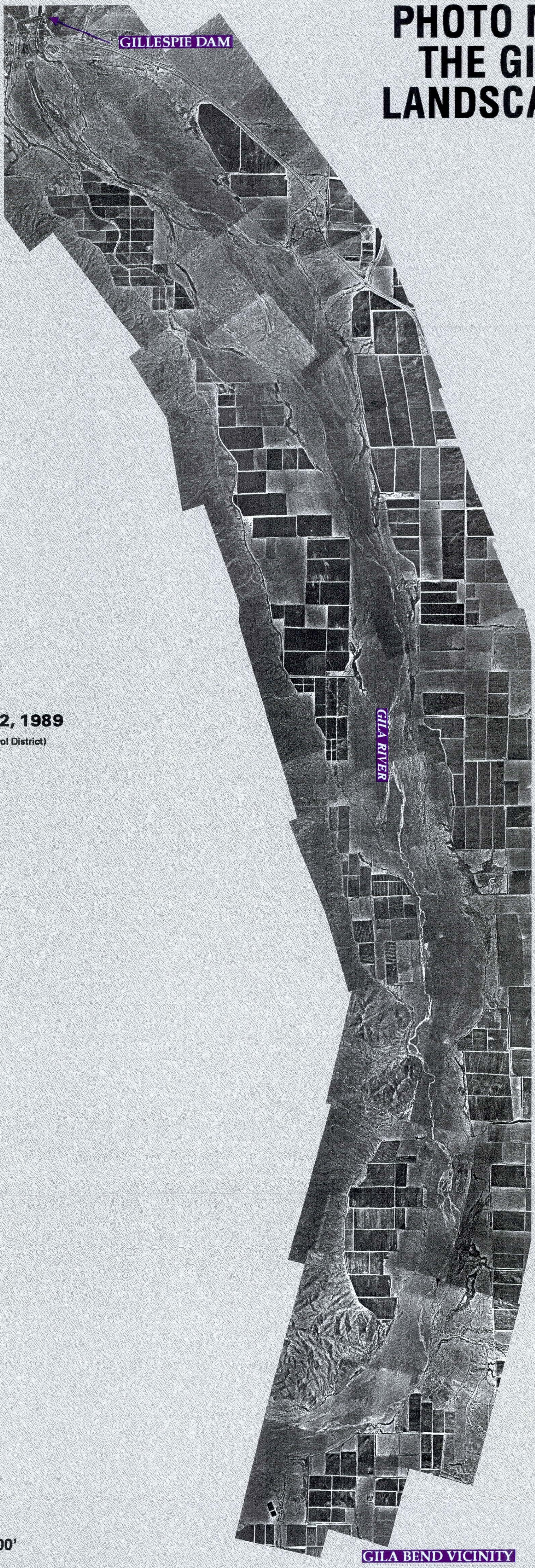
0 3000 6000 12000 24000

FIGURE E-6

PHOTO MOSAIC OF THE GILA RIVER LANDSCAPE IN 1989

PHOTO DATE: JUNE 22, 1989

(Source: Maricopa County Flood Control District)



Scale 1" = 6000'

0 3000 6000 12000 24000

FIGURE E-7

/hd2/johnhelm/phase1/tom/e89.aml 01/18/97 14:45:31 Sat

COMPARISION OF 1978 FLOOD INUNDATION LIMITS WITH 1978 LANDSCAPE

LEGEND

- 1978 Riverine Inundation Limits
- 1978 Bank Limits

PHOTO DATE: FEBRUARY 1978
(SOURCE: Natural Resources Conservation Service)

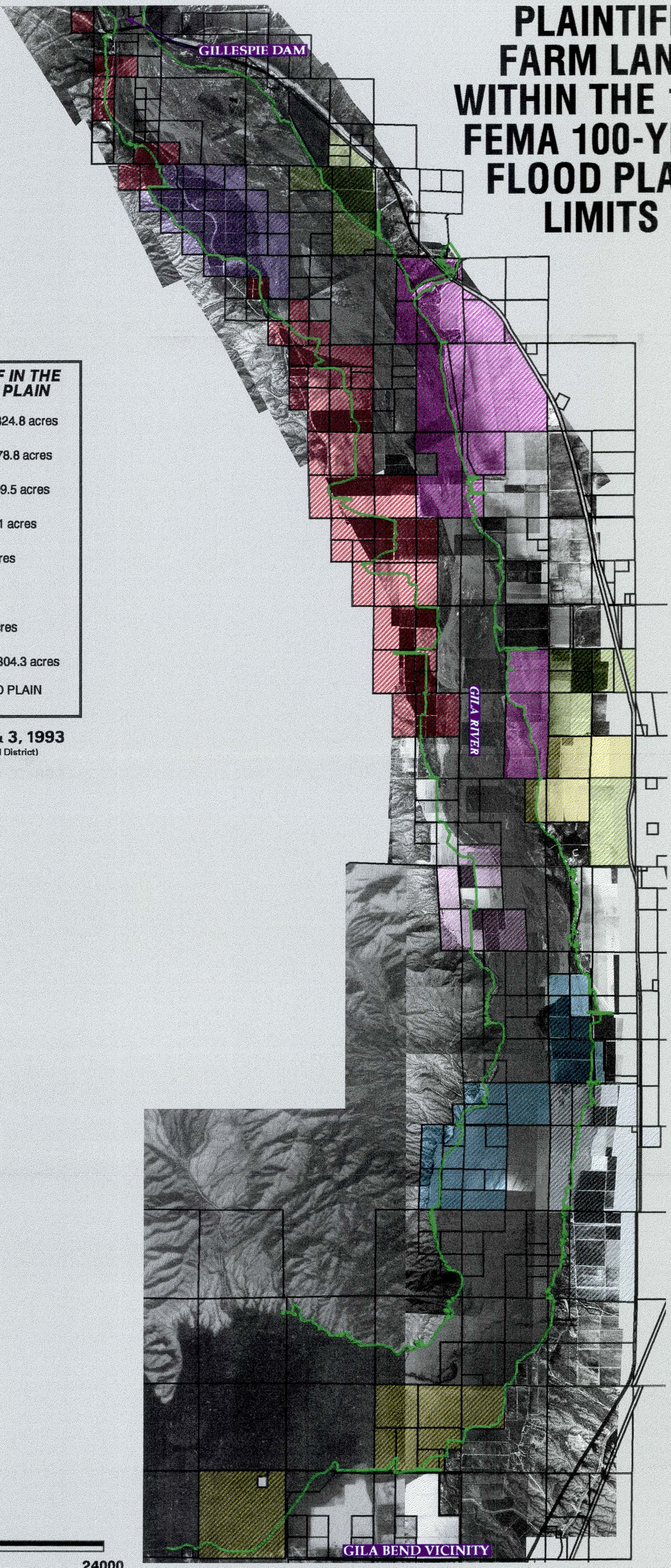
Scale 1" = 6000'

0 3000 6000 12000 24000

/hd2/johnhelm/phasel/tom/e78.aml 01/18/97.13:00:25.Sat

FIGURE E-8

PLAINTIFF FARM LAND WITHIN THE 1989 FEMA 100-YEAR FLOOD PLAIN LIMITS



ACREAGE PER PLAINTIFF IN THE 100 YEAR FEMA FLOOD PLAIN

- A TUMBLING T RANCHES: 1324.8 acres
- ROSEMARY L. EDWARDS: 878.8 acres
- RUSSEL BADLEY FARMS: 209.5 acres
- DELMAR JOHN FARMS: 943.1 acres
- PIERPOINT FARMS: 312.5 acres
- BDJ FARMS: 1289 acres
- FORNE & PJ FARMS: 1115 acres
- WOOD BROTHERS FARMS: 304.3 acres
- 1989 FEMA 100-YEAR FLOOD PLAIN LIMITS

PHOTO DATES: MARCH 2 & 3, 1993
(Source: Maricopa County Flood Control District)

Flood Control District of Maricopa County — Geographic Information Systems

Scale 1" = 6000'

0 3000 6000 12000 24000

FIGURE E-9