GILA RIVER, GILLESPIE DAM TO YUMA, AZ

RECONNAISSANCE REPORT

US ARMY CORPS OF ENGINEERS
Los Angeles District
South Pacific Division

JANUARY 1995

GILA RIVER, GILLESPIE DAM TO YUMA, AZ
RECONNAISSANCE STUDY REPORT

SUMMARY

This reconnaissance study was directed by Congress as a result of flooding in Arizona in 1993. The Corps of Engineers received Congressional direction in the Senate Supplemental Appropriation on June 8, 1993 to conduct three studies. The three studies are:

Flood Control Studies for Arizona Communities (Construction General),

Arizona Flood Control Study (General Investigations)

Gila River, Gillespie Dam to Yuma (General Investigations)

This report summarizes the Corps response under the Gila River (Gillespie Dam to Yuma) Reconnaissance Study. The report provides an interim response to the overall study authority. The study was initiated in September 1993.

Coordination for this study included Federal, State, and local agencies and authorities. Three public workshops were held in the study area during December 1993. In addition to flood control concerns, input from these meetings identified other issues and opportunities, including water conservation, environmental restoration, and water quality.

This study has concentrated the analysis and recommendations on the following opportunities:

1. Flood Control
2. Water Conservation
3. Environmental Restoration

Water quality is addressed only incidental to the above opportunities.

The study resulted in the recommendation for two separate feasibility phase studies. Feasibility level study is recommended for Water Conservation, and for Environmental Restoration in the study area. No Federal interest was identified with respect to flood control alternatives.

TABLE OF CONTENTS

TABLE OF CONTENTS

Chapter | Page

FIGURES

TABLES

APPENDICES

A. Hydrology
B. Hydraulics
C. Transportation and Utility Crossing Inventory
D. Geotechnical
E. Geomorphology
F. Economics
G. Environmental Restoration
H. Environmental Evaluation
I. Real Estate

CHAPTER 1

AUTHORITY, PURPOSE, AND SCOPE

1. AUTHORITY, PURPOSE, AND SCOPE

1.1 Introduction

Prior to the construction of Painted Rock Dam in 1959, large floods frequently caused extensive damages along the Lower Gila River. Despite the existence of Painted Rock Dam, a major event in 1993 caused over $100 million in estimated damages. Runoff from major storms filled the dam, resulting in emergency spillway flows and damaged agriculture, public infrastructure, and private property.

From late December 1992 through February 1993, a series of winter storms produced record breaking amounts of precipitation and severe weather across Arizona. At this time the state was in its third consecutive year of above average precipitation, upper watersheds were saturated, and record breaking snow packs were recorded statewide.

Heavy rains in January, estimated at 520% above normal, combined with the rapid melting of the snowpack, and caused intense runoff and flooding of streams and rivers throughout the state. The 15 day period of heavy rain and high flood stages in early January 1993 was one of the most damaging and extensive wet winter periods witnessed in recent times.

On January 19, 1993, a Presidential Disaster Declaration was issued for 10 counties in Arizona: Apache, Coconino, Gila, Graham, Greenlee, Maricopa, Navajo, Pima, Pinal, and Yavapai. On January 26, Cochise and Santa Cruz Counties were added, and on February 5, Yuma County was added. The Federal Emergency Response Plan was activated to provide Individual and Public Assistance.

February 1993 storms followed after a brief respite, bringing precipitation of 400% above normal for the month. Streams and rivers statewide, still partially full from January runoff, experienced additional high flows for periods of up to 10 days. In some areas of the state, the additional runoff caused flooding in areas not affected by the January storms.

Damages were widespread and significant. Total public and private damages are estimated to exceed $400 million statewide. Eight deaths and 112 injuries were reported by the Red Cross. Total Federal flood related expenditures exceeded $220 million.

The agriculture industry alone, which accounts for about one-sixth of the Arizona economy, suffered direct damages of approximately $70 million in lost crops, eroded or destroyed land and buildings, and lost income. The consequences of reduced yields on inundated acreage, associated job losses, and reductions in tax basis, will continue for years.

Statewide flooding caused widespread damage to public infrastructure and facilities, impacted people in over 100 communities and on Indian Reservations, and affected the economy of Arizona in numerous ways. Tourism, an important part of the economy, was below normal in many areas during the peak season. The mining industry suffered extensive physical damage, lost production, and increased expenses. Environmental and economic impacts resulted from sewage spills, loss of vegetation and wildlife in floodplains, and sedimentation and debris deposition within Arizona rivers. The ultimate long term effects of the 1993 Arizona Floods will not be known for several years.

1.2 Authority

As a result of the statewide floods, the Corps of Engineers received direction in Public Law 103-50 dated 2 July 1993, Supplemental Appropriations Act of 1993; Senate Report 103-54 FY 93 Supplemental Appropriations dated 8 June 1993. This legislation reads, in part, as follows:

"The area below Gillespie Dam is still extremely vulnerable to any increase in flows in the lower Gila River from drainage and snow melt in the Gila River system. The area will continue to be vulnerable until comprehensive, permanent flood control measures are determined. The existing systems of channels and levees above and below Painted Rock Dam have been severely damaged. For this reason, it is imperative that the Corps conduct a reconnaissance study of the area below Gillespie Dam to determine how to prevent further damage during the current flood event and to expedite permanent flood control measures to prevent future flood problems."

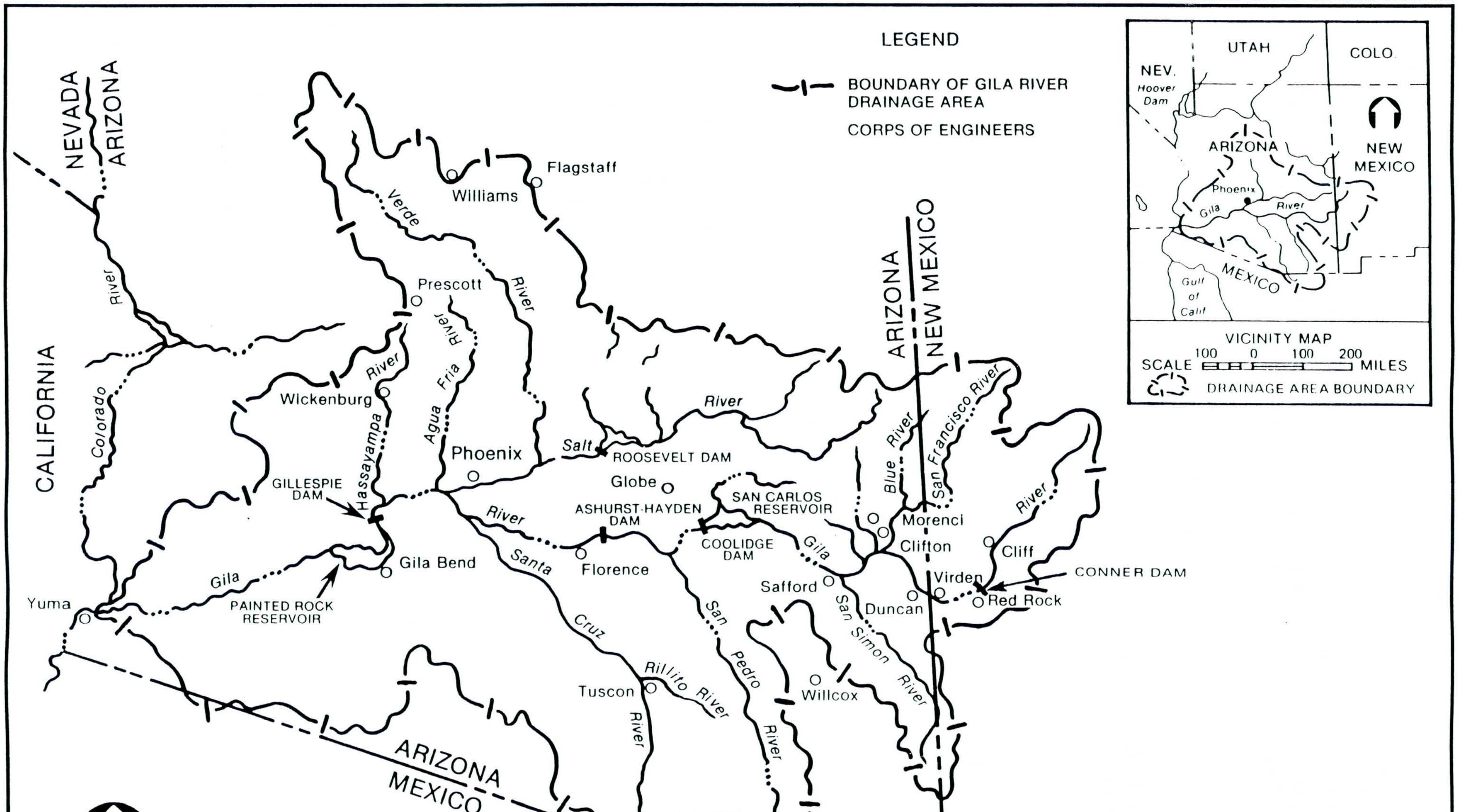
Congress added renewed commitment to providing authority for the Corps to review prior reports in the interest of flood damage reduction, environmental protection and restoration, and related purposes by adopting House Resolution 2425 on May 17, 1994.

This reconnaissance study provides an interim response under Public Law 761, Seventy-fifth Congress, known as the Flood Control Act of 1938. Section 6 of that Act reads in part as follows:

"The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control including floods aggravated by or due to tidal effect at the following-named localities, and the Secretary of Agriculture is authorized and directed to cause preliminary examinations and surveys for run-off and waterflow retardation and soil erosion prevention on the watersheds of such localities;....

Gila River and Tributaries, Arizona and New Mexico ..."

The Gila River and Tributaries Authority area is shown in Figure 1 along with a copy of House Resolution 2425.



GENERAL INVESTIGATIONS · SURVEYS
FLOOD DAMAGE PREVENTION STUDIES

GILA RIVER AND TRIBUTARIES
ARIZONA AND NEW MEXICO

LOS ANGELES DISTRICT
SOUTH PACIFIC DIVISION
1 JANUARY 1986

Figure 1

U.S. House of Representatives

COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION

SUITE 2165 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
(202) 225-4472

COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C.

RESOLUTION

State of Arizona
Docket 2425

Resolved by the Committee on Public Works and Transportation of the United States House of Representatives, That, the Secretary of the Army is requested to review the reports of the Chief of Engineers on the State of Arizona, published as House Document 331, Eighty-first Congress, First Session; Senate Document 116, Eighty-seventh Congress, Second Session; Senate Document 127, Eighty-Seventh Congress, Second Session; House Document 625, Seventy-Eighth Congress, Second Session, House Document 648, Seventy-Eighth Congress, Second Session; Senate Document 63, Eighty-eighth Congress, Second Session; and other pertinent reports, to determine whether modifications of the recommendations contained therein are advisable at the present time, in the interest of flood damage reduction, environmental protection and restoration, and related purposes.

Adopted: May 17, 1994

ATTEST: NORMAN Y. MINETA, Chair

1.3 Purpose and Scope

The study purpose was to accomplish the following four tasks:

1) Define the problems and opportunities; identify possible solutions,

2) Determine Federal interest based on Army policies; cost, benefits, and environmental impacts of the identified potential solutions,

3) Provide an estimate of time and costs for future phases of study,

4) Identify level of interest and support of local sponsor.

The scope of this reconnaissance study consists of identifying problems and needs associated with flooding and related water resources concerns; formulating corrective measures to prevent future flood damages and loss of life throughout the study area; and identifying the role for Corps participation in flood control and related water resources plans.

The Gila River, Gillespie Dam to Yuma, AZ, Reconnaissance Report presents the results of a reconnaissance phase study of flooding problems and alternative solutions for the area. The report outlines the study purpose and scope, provides a presentation of problems and needs, describes the study area, analyzes the problems and opportunities for action, describes alternative solutions, presents results of alternative analyses, and identifies potential Federal interest, and identifies non-Federal partners in more detailed feasibility studies.

An analysis and evaluation of an array of project alternatives is presented. The reconnaissance study will conclude with a recommendation that the study effort continue into the feasibility phase of planning if alternatives are identified which fully comply with the above objectives.

CHAPTER 2

PRIOR STUDIES, REPORTS, AND EXISTING WATER PROJECTS

2. PRIOR STUDIES, REPORTS, AND EXISTING WATER PROJECTS

2.1 Study History

The Gila River, Gillespie Dam to Yuma, AZ, Study (General Investigation) is related to two other Corps studies which were authorized within the same legislation in response to the 1993 floods. These two other ongoing studies are the Flood Control Studies for Arizona Communities (Construction General) and the Arizona Flood Control Study (General Investigation). Los Angeles District coordination of these three study efforts was conducted to avoid any duplication of effort, ensure responsiveness to legislative intent, and provide a more rapid and efficient use of resources (Figure 2).

Large flood flows historically have caused extensive damages in the study area. Painted Rock Dam, located about 40 miles downstream from Gillespie Dam, was constructed by the Corps in 1959 as a flood control structure. Despite the existence of Painted Rock, runoff from a number of major storms in the winter and spring of 1993 filled the dam, overflowed the spillway, and caused major damages to agricultural lands, crops, transportation facilities, homes, and infrastructure. As a result of the severity of the flooding, Congress directed a reconnaissance study start in Fiscal Year 1993. The study commenced 15 September 1993.

The Gila River, Gillespie Dam to Yuma, AZ Reconnaissance study focuses on the section of the Gila River in southwestern Arizona containing Painted Rock Dam. Painted Rock Dam is a Corps of Engineers built and operated flood control structure. As a result of record volumes of inflow to Painted Rock Dam from the 1993 floods, outflow from the dam peaked at approximately 26,000 cubic feet per second (cfs), significantly affecting areas which had previously experienced flood control releases of no more than about 5000 cubic feet per second since the dam was constructed. Although Painted Rock Dam reduced the peak inflow of 204,000 cfs down to 26,000 cfs and prevented an estimated $100 million of additional damages, the floods of 1993 evidenced the need to evaluate the flooding problems and potential solutions on this reach of the Lower Gila River.

The Flood Control Study for Arizona Communities (FCSAC) study was organized to evaluate, at a pre-reconnaissance screening level, the potential for federal interest at 72 damage centers statewide. The evaluations focused on structural and nonstructural alternatives under Section 14 and Section 205 of the U.S. Army Corps of Engineers Continuing Authorities Program (CAP). The CAP was authorized by Congress to delegate authority to the Corps in order to implement projects of limited financial scope without requiring additional Congressional authority. Structural alternatives considered included levees, channelization, detention, and diversion. Nonstructural alternatives considered included floodplain management, floodproofing, and relocation. Each damage center was evaluated to determine appropriate solutions and estimate the likelihood for potential federal interest. Sites showing promise were then recommended for further study under the CAP. The results of the study were summarized in the report dated September 1994.

The Arizona Flood Control Study focused on nonstructural flood warning as one area that the Corps of Engineers may participate in. Specifically in response to numerous public meetings and scoping sessions involving Federal, State, and County interests, flood warning was identified as the primary output of that study effort. The Arizona Flood Control Study report, dated September 1994, recommended implementation of a statewide flood warning system supported by the Arizona Department of Water Resources.

As a result of study coordination and public involvement, the Flood Control Studies for Arizona Communities study deferred the evaluation of 1993 damage centers and sites along the Lower Gila River for inclusion in this Gila River, Gillespie to Yuma reconnaissance study which evaluates those sites from the overall General Investigations standpoint. Conversely, evaluation of non-structural floodwarning alternatives along the Lower Gila River were evaluated under the Arizona Flood Control Study.

**LEGISLATIVE DIRECTION
TO THE
U.S. ARMY CORPS OF ENGINEERS
IN RESPONSE TO
FLOODS OF 1993 IN ARIZONA**

(CG)	(GI)	(GI)
FLOOD CONTROL STUDIES FOR ARIZONA COMMUNITIES	ARIZONA FLOOD CONTROL STUDY	GILA RIVER, GILLESPIE DAM TO YUMA, AZ

FLOOD CONTROL STUDIES FOR ARIZONA COMMUNITIES

- SITE SPECIFIC EVALUATIONS FOR POTENTIAL CONTINUING AUTHORITIES PROGRAM PROJECTS
- EVALUATED STRUCTURAL AND NON-STRUCTURAL ALTERNATIVES, SPECIFICALLY EXCLUDING STATEWIDE FLOOD WARNING
- LIMITED IN SCOPE TO 1993 FLOOD DAMAGE CENTERS

ARIZONA FLOOD CONTROL STUDY

- STATEWIDE FLOOD WARNING

GILA RIVER, GILLESPIE DAM TO YUMA, AZ

- LOWER GILA RIVER INCLUDING PAINTED ROCK DAM

Figure 2

Legislative Direction to the U.S. Army Corps of Engineers in Response to Floods of 1993 in Arizona

2.2 Prior Studies and Reports

The selected studies and reports listed below were conducted by the Corps of Engineers, or other agencies, and have been incorporated, as appropriate, into the study.

1. Geomorphic Assessment of the Lower Gila River West Central Arizona, William L. Graf, et al, July 1994.

2. Wellton-Mohawk Gila River Flood Channel Restoration Project, Draft Environmental Assessment, Bookman-Edmonston Engineering, June 1994.

3. Lower/Middle Gila River Study and Painted Rocks Lake Phase I Diagnostic/Feasibility Study, Arizona Department of Environmental Quality, February 1994.

4. Painted Rock Dam, Report on Inspection, Claude A. Fetzer, Consulting Geotechnical Engineer, February 1993.

5. Painted Rock Dam, AZ, Smart Book, Los Angeles District, COE, February 1993.

6. Report on Flood Damage and Assessment for County Board of Supervisors Meeting, Department of Emergency Management, February 1993.

7. Yuma County Water Resource Management Assessment, Bookman-Edmonston Engineering, January 1992.

8. Arizona Water Quality Assessment 1992, Water Assessment and Groundwater Hydrology Sections, Arizona Department of Environmental Quality, 1992.

9. Wellton-Mohawk Irrigation District, Informational Brochures, 1990 and 1978.

10. Painted Rock Dam and Reservoir, AZ, Information Paper, Arizona COE Real Estate Office, March 1986.

11. Lower Gila South, Resource Management Plan Environment Impact Statement Phoenix District, AZ, May 1985.

12. Final Environmental Assessment, Gila River Channel Enhancement, Wellton-Mohawk Irrigation and Drainage District, U.S. Dept. of Interior Bureau of Reclamation, AZ, July 1984.

13. Painted Rock Dam, Water Quality Study, Wester Technologies, January 1983.

14. Painted Rock Dam, Periodic Inspection Report No. 3, COE, December 1982.

15. Painted Rock Dam, Operation Study, Information Brochure, March 1977.

16. Plan Of Study, Los Angeles District Corps of Engineers, Phoenix Urban Study, November 1975.

17. Release-Salinity Study for Painted Rock Dam, Los angeles District, COE, June 1975.

18. Draft Environmental Study, Gila River from the Confluence of the Salt River Downstream to Gillespie Dam, Jan 73.

19. Painted Rock Dam, Periodic Inspection Report No. 1, COE, May 73.

20. Flood Control Project, Gila River and Tributaries Downstream from Painted Rock Reservoir, Citizens Organization for Protection of the Lower Gila, AZ, May 71.

21. Wildlife Management Plan for Gila River Below Painted Rock Project, COE, Oct 71.

22. Hydrology for Gila River Improvement, D.M. 1 and 2 COE, Dec 70.

23. Infiltration of Painted Rock Reservoir Releases for Gila River Improvement (Texas Hill to Gila Siphon), Design Memorandum No. 2, COE, Sept 70.

24. Environmental Study for the Gila River Below Painted Rock Dam, University of Arizona, School of Earth Sciences, Oct 70.

25. Operations and Maintenance Manual, Painted Rock Reservoir, Gila River, AZ, COE, Jul 63.

26. Gila River and Tributaries Downstream from Painted Rock Reservoir, AZ, Letter from the Secretary of the Arm, Aug 62.

27. Interim Report on Survey for Flood Control, Gila and Salt River, Gillespie Dam to McDowell Dam Site, AZ, Dec 57.

28. Reservoir Regulation Manual, Painted Rock Reservoir Gila River Basin, AZ.

29. Painted Rock Reservoir, Design Memoranda, 1-6, COE, 1955-1956.

30. Flood Damage Report, State of Arizona, Floods of 1993, COE, August 1994.

2.3 Prior Authorized Project

In 1962 a flood control project was authorized for the 58-mile reach of the Gila River from Texas Hill to the Gila Siphon. This project was authorized by the Flood Control Act of 1962, PL 87-874. This authorization was subsequently modified by the Flood Control Act of 1968, PL90-483, to lessen local interest financial responsibility in the project. This project would have provided protection by constructing levee and channel improvements along the Gila River to control a flood of 50,000 cubic feet per second as measured at Dome, AZ.

The improvements would have consisted of 99 miles of compacted earthfill, revetted levee: 49 miles on the right bank and 50 miles on the left bank. The channel would be trapezoidal in shape with a base width of 750 feet. Additional protection for the levees would be provided by permitting a fringe of river-bottom growth such as salt cedar or mesquite, about 100 feet in width, to grow on the river side of the levees on each side of the channel. The remaining 550-foot-wide center portion of the channel would be maintained as a cleared floodway.

In April 1975, the Office of the Chief of Engineers approved reclassification of this project to the inactive category. The project was never constructed, and was de-authorized in 1992 under provisions of Section 1001 of the Flood Control Act of 1986, which limits the time an authorized project may remain inactive.

In accordance with the operation manual and release schedule, in effect prior to 1974, the channel improvement project was economically justified. A revised operation release schedule was proposed in 1974 which, in itself, would minimize downstream damages by about 60 percent. Based on this new operation release schedule, the downstream channel project was no longer justified.

There was also strong opposition to channelization and dredging of the Lower Colorado and Gila Rivers from the following groups:

- Yuma County National Resources Committee
- Yuma Telco Sportsman Club

- Arizona Wildlife Federation
- Arizona Game and Fish Department
- Tucson Wildlife Unlimited

The primary issues included:

- removal of wildlife habitat
- impact of wildlife habitat removal on white-wing dove

2.4 Existing Water Resources Projects

Gillespie dam, built by local interests in 1923 for irrigation diversion, forms the upstream limit of this study. Gillespie dam failed during flooding in January 1993, leaving an approximately 100 foot gap in the center of the embankment. A decision as to repair, demolition, or reconstruction of the dam has not been made at the time of this study. The dam remains in private ownership.

Between Gillespie Dam and Painted Rock Dam downstream, there are no water resource projects. Painted Rock Dam was completed in 1959 and was built and is operated by the Corps of Engineers. The dam is earth filled with a crest length of 4,780 feet with a gross capacity of 2.5 million acre feet at spillway crest (elevation 661). From Painted Rock Dam downstream about to Texas Hill there also are no water resource projects.

From Texas Hill to Dome, lies the Wellton-Mohawk Irrigation and Drainage District (WMIDD). Located within the Gila River valley, the WMIDD is actually a user of Colorado River water. The WMIDD was created by act of the Arizona State Legislature on 23 July 1951. It was organized to provide a legal entity which could enter into a contract with the United States to repay the project cost of providing irrigation and power for the area. The irrigation features were authorized by Congress on 23 July 1947 as the Wellton-Mohawk Division of the Bureau of Reclamation's Gila Project. The irrigation facilities lift the water from the Colorado River eastward into the fertile Gila River valley. The WMIDD now has approximately 378 miles of main canals, laterals, and drainage channels. Additional facilities include three major pumping plants, four minor pump stations on three of the larger irrigation laterals, 10 re-lift pumps at various locations on main and lateral canals, 90 drainage wells, and 480 observation wells.

In 1986, the WMIDD initiated work on a Gila River channel enhancement project. This project included the clearing of brush along the centerline of the channel, construction of a pilot channel, and construction of dikes. The flood channel project had a nominal design flow of 10,000 cfs and was about 95% complete when the flooding began in January 1993. Approximately 65% of this system was damaged during the 1993 floods. Wellton Mohawk intends to restore the flood protection provided by this system under the Federally declared disaster provisions of FEMA. At the time of this report, flood flows in excess of approximately 3,000 cfs could potentially cause significant damages through this reach of the river. Wellton-Mohawk intends to reconstruct the levees to provide the 10,000 cfs pre-disaster capacity.

Downstream from Highway U.S. 95 to the confluence with the Colorado River, the Bureau of Reclamation maintains a levee system under their Front Work and Levee Authority. This system includes existing 50,000 cfs capacity levees along the south side of the Gila River through this reach. Levees along the north side have a capacity limited to approximately 28,000 cfs. The Bureau of Reclamation currently is planning to increase the capacity of this north levee system to 50,000 cfs, starting in about 1997.

CHAPTER 3

PUBLIC AND AGENCY INVOLVEMENT

3. PUBLIC AND AGENCY INVOLVEMENT

3.1 General

Public involvement included notification by mail of study initiation to the Arizona Congressional delegation, Federal, State and local agencies, and known interested individuals.

The Corps of Engineers conducted site visits to the affected areas. Experienced engineers and planners met with County and local officials, viewed 1993 flood problem areas, and obtained locally available information on flood problems and damage history. Local and county officials were consulted regarding their perception of the necessary solutions.

Numerous County and local officials statewide participated fully and integrally in the evaluations through the initial request, participation in the field trips, meetings, provision of background reports and information, and coordination and cooperation with the U.S. Army Corps of Engineers.

3.2 Public Meetings

Public meetings were held at Antelope High School, Wellton, AZ, on 13 December 1993, Arizona Western College, Yuma, AZ on 14 December 1993, and at the Gila Bend Community Center, Gila Bend, AZ, on 14 December 1993. Participants were invited to provide addresses, and all who did so were mailed a summary of the results of all three meetings.

The public workshops were conducted as follows:

1) Initiation of the reconnaissance study was announced.

2) Those in attendance were informed of the goals and objectives of the study, and the study process.

3) An opportunity was provided for all in attendance to provide their comments, issues, and concerns.

3.3 Agency Coordination

Meetings were held throughout the study between Corps staff managers and representatives of Federal, State and local agencies. Agencies that participated included:

U.S. Bureau of Reclamation
U.S. Bureau of Land Management
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Department of Agriculture
Federal Emergency Management Agency
International Boundary and Water Commission
Arizona State Department of Environmental Quality
Arizona State Department of Water Resources
Arizona State Department of Transportation
Arizona State Game and Fish Department
Flood Control District of Maricopa County, AZ
Flood Control District of Yuma County, AZ
Wellton-Mohawk Irrigation and Drainage District

3.4 Synthesis of Meeting and Coordination Comments

Comments from both the public meetings and agency coordination were summarized and distributed to Corps management and technical staff and became part of the Plan Formulation process. A summary of the public comments from the workshops is presented below.

<u>ANTELOPE HIGH SCHOOL WORKSHOP (December 13, 1993) Comments:</u>

1. Need to recognize channel shift, silting.

2. Agricultural damages must also consider sediment damage, eroded fields, loss of real estate values.

3. Address flood control operations of Painted Rock Dam.

4. Who will be the local sponsor for any subsequent feasibility study and project?

5. Corps permit (404) process needs to be expedited.

6. Flood control channels below Painted Rock Dam have enhanced wildlife environment.

7. Is it possible to combine flood control solutions with environmental enhancements?

8. Construction of dams (such as Orme) would have helped minimize flood damages.

ARIZONA WESTERN COLLEGE WORKSHOP (December 14, 1993) Comments:

1. The study should address downstream impacts to Colorado River Below confluence with Gila River (including Yuma, Imperial Co., and Mexico).

2. Investigate any impacts of subbing, high water table, salinity.

3. Ensure all potential benefit categories get included (direct, indirect).

4. Hydraulic designs should include consideration of environmental issues.

5. Hydraulics of the Gila River are complicated, cannot just use designs from higher rainfall areas.

GILA BEND COMMUNITY CENTER (December 14, 1993) Comments:

1. Study should address operations of Painted Rock Dam.

2. Study should include impacts within Painted Rock Reservoir, as well as the area above--up to Gillespie area.

3. Notify meeting attendees of comments from other workshops.

4. Water quality issues should be included in study.

5. Study should not just look at one comprehensive solution. Look at each river reach and see if there are multiple solutions, or if other Corps programs might be applicable.

6. Damages should include loss of real estate and use values.

7. Cropping patterns may now change due to damaged land and channel shifting.

3.5 Environmental Restoration - Public Involvement

Environmental Restoration workshops were held on June 10, 1994, June 23, 1994, October 20, 1994, November 16, 1994, and December 2, 1994. The purpose of the workshops was to bring together environmental expertise from a wide variety of local, state, and federal agencies. The workshops were primarily scoping sessions to assess problems and opportunities for restoration along the lower Gila River and develop an array of alternative solutions and restoration schemes. Participants included representatives from the following agencies:

Arizona State Game and Fish Department
Arizona State Department of Environmental Quality
Arizona State University
Arizona State Riparian Area Advisory Council
Wellton-Mohawk Irrigation and Drainage District
U.S. Bureau of Reclamation
U.S. Bureau of Land Management, Yuma
U.S. Bureau of Land Management, Phoenix
U.S. Fish and Wildlife Service

As a result of the meetings, several alternatives were identified. Problems associated with restoration such as land ownership, water availability, soil conditions, and potential for sustainability were discussed and addressed. Criteria for potential solutions and restoration schemes were developed based upon a wide variety of factors including anticipated requirements for different habitat types, and through a screening process appropriate areas and methodologies were selected for restoration evaluations.

CHAPTER 4

STUDY AREA DESCRIPTION

4. STUDY AREA DESCRIPTION

4.1 Study Area

The study area consists of 164 miles of the Gila River from Gillespie Dam to Yuma, AZ, where the Gila flows into the Colorado River (Figure 3). The area lies within both Maricopa and Yuma Counties, Arizona. Gillespie Dam is located about 60 air miles southwest of Phoenix in south central Arizona. Yuma is located on the Colorado River in extreme southwestern Arizona.

4.2 Gila River Drainage

The Gila River basin is the largest drainage area tributary to the Lower Colorado River, with a total drainage area of 58,200 square miles. Approximately 50,900 square miles of this total lies above Gillespie Dam, and 53,000 above Painted Rock Dam. The Gila River is 654 miles long. The entire Gila drainage is outlined in Figure 1. The major tributaries of the Gila River and their respective drainage areas include the following:

- Salt and Verde Rivers (13,000 square miles)
- Santa Cruz River (8,600 square miles)
- San Pedro River (4,500 square miles)
- San Francisco River (2,800 square miles)
- San Simon River (2,200 square miles)
- Agua Fria River (2,000 square miles)
- Centennial Wash (1,800 square miles)
- San Carlos River (1,027 square miles)
- others include the Hassayampa River and Queen Creek

There are numerous dams within the Gila River basin. The major dams on the Gila River and its tributaries are shown in Table 1. These dams, and their operations, exert an appreciable influence on major floods.

The upper Gila drainage includes the eastern slope of the Mogollon Mountains, and western slope of the Black Mountains in New Mexico. This portion of the watershed remains in its natural state and contains no dams. After the Gila enters Arizona, water is directly pumped from the river for irrigation purposes. The River is then contained in San Carlos Reservoir behind Coolidge Dam, about 80 miles southeast of Phoenix. Below Coolidge Dam, the river flow is diverted by Ashurst-Hayden Dam and the river becomes ephemeral. In the metropolitan Phoenix area the river is joined by major tributaries such as the Salt, Santa Cruz, and Agua Fria Rivers. Effluent from two wastewater treatment plants on the Salt River provides year-round flows that move downstream into the Gila.

At Gillespie Dam, the upper end of this study area, the Gila contains effluent, irrigation return flows, and occasional flood flows. Downstream from Gillespie is Painted Rock Dam, which is the principal flood control structure for the lower Gila River basin.

Below Painted Rock Dam, the Gila River flows approximately 126 miles to the Colorado River at Yuma, Arizona. There is limited use of Gila River surface water flows below Painted Rock Dam. For the first 65 miles downstream of the dam, the terrain is sparsely populated with widely scattered areas of agriculture irrigated by groundwater. The next 45 miles consists of an intensive agricultural area consisting of about 65,000 acres. This land is managed by the Wellton-Mohawk Irrigation and Drainage District and is irrigated with water pumped up from the Colorado River. Immediately upstream of where the Gila River joins the Colorado River, there is a large irrigated agriculture are owned in part by the North Gila Valley Irrigation District, and in part by the Yuma Mesa Irrigation District which extends to the U.S.- Mexico international border. Except during flood releases from Painted Rock, the Gila River contains some return irrigation flows, particularly in the Wellton-Mohawk area. The flows from the Colorado River, occasionally supplemented with Gila River flows, continue to Mexico where water is used primarily for irrigated agriculture on the upper delta and Mexicali Valley.

US ARMY ENGINEER DISTRICT CORPS OF ENGINEERS

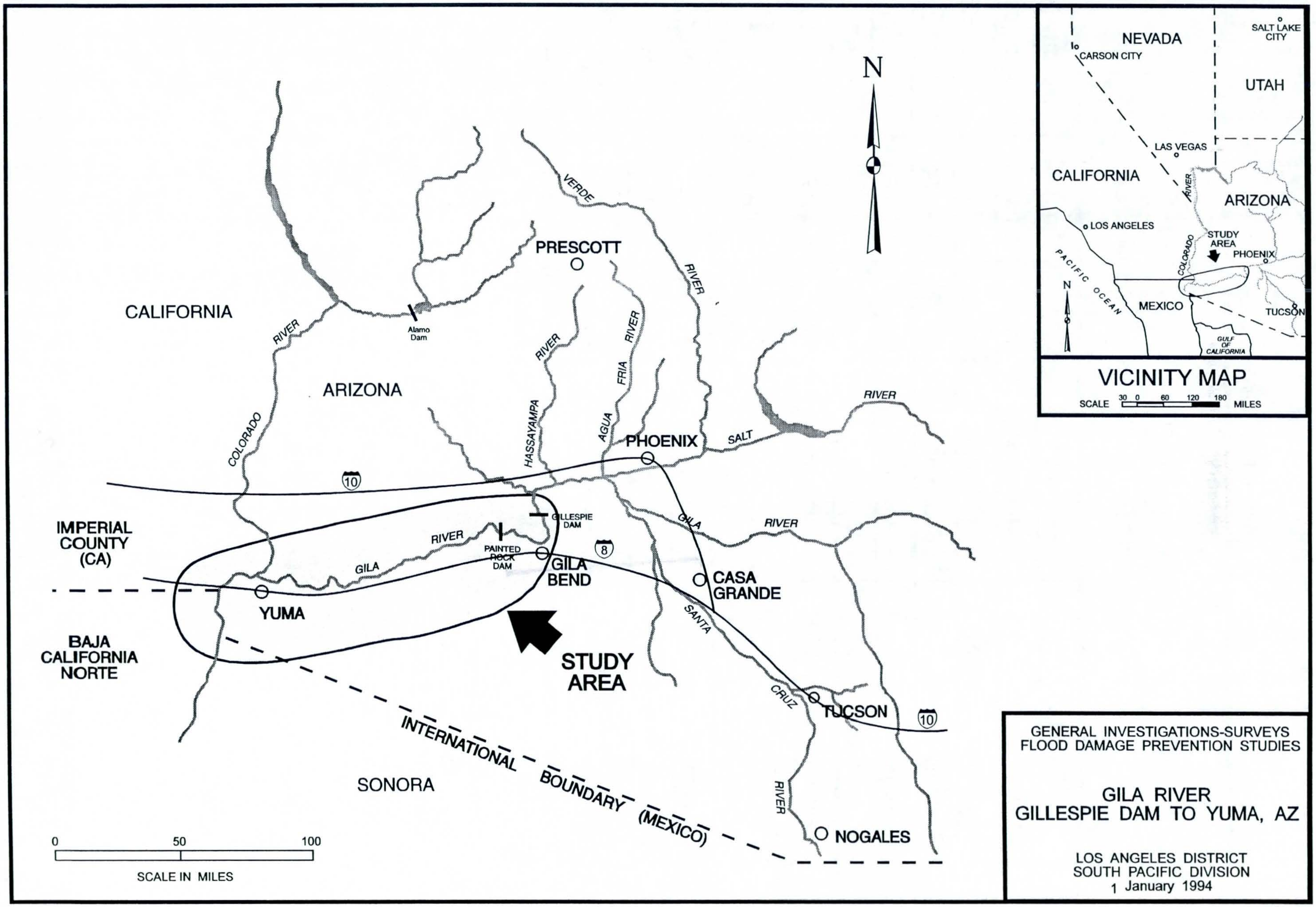


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Figure 3

TABLE 1

Major Dams on the Gila River and Tributaries

Dam (Opr.)[1]	Reservoir	River	Purpose[2]	Capacity (AF)
Coolidge (BIA)	San Carlos	Gila	I & P	1,222,000
New Waddell (BuRec)	Lake Pleasant	Agua Fria	I	902,502
Roosevelt[3] (SRP)	Roosevelt	Salt	I, P, FC	2,100,000
Horse Mesa (SRP)	Apache	Salt	I & P	248,000
Mormon Flat (SRP)	Canyon	Salt	I & P	59,000
Stewart Mountain (SRP)	Saguaro	Salt	I & P	71,000
Horseshoe (SRP)	Horseshoe	Verde	I	141,000
Bartlett (SRP)	Bartlett	Verde	I	182,000
Tat Momolikot (BIA)	St. Clair	Santa Rosa	M	198,000
Gillespie (Pvt)[4]	Gillespie	Gila	I	(N/A)
Painted Rock (COE)	Painted Rock	Gila	FC	2,491,000

1 - Operated by BIA-Bureau of Indian Affairs, BuRec-Bureau of Reclamation, SRP-Salt River Project, Pvt-Private, COE-Corps of Engineers

2 - I-Irrigation, P-Power, M-Multipurpose, FC-Flood Control

3 - Capacity figure includes modifications currently under way.

4 - Gillespie Dam failed in January 1993

Note: In addition to the above there are numerous, mostly smaller, dams such as New River, Adobe, and others. Many of these provide local flood protection.

4.3 Topography

Elevations in the Gila River basin range from more than 12,000 feet in the San Francisco Peaks in the Verde River basin, to 130 feet near Yuma. Much of the northern part of the basin is extremely irregular with elevations ranging from 7,000 feet to 12,000 along the basin boundaries. This part of the basin is mostly drained by the Salt River which flows into the Gila near Phoenix. The eastern half of the basin consists of long desert valleys lying between rugged mountains. Here the elevations are generally lower, but in places are above 10,000 feet.

The study area, from Gillespie Dam to Yuma, is in the southwestern portion of the basin. This area consists of gently rolling desert plains and broad,flat ,low-lying desert valleys ranging in elevation from 130 to 1,500 feet MSL, with a few minor rugged desert mountains reaching elevations of 3,000 to 4,000 feet.

4.4 Climate

The climate in the study area is characteristic of the lower Sonoran desert. The climate is semi-arid, but variations exist depending principally on elevation. The average annual rainfall is 4.0 inches in the lower desert and 30 inches or more in the highest mountains of the basin. The intensity of the precipitation varies widely. Storms on record have produced up to 5 inches of rainfall within a 24 hour period.

Streamflow characteristics vary considerably throughout the basin. Runoff producing storms typically occur during two distinct seasons, the summer monsoon season and during the winter storm season. The monsoon season starts around mid-July and extends in September, while the winter storm season typically begins in late November and extends through April. The streams in the lower desert areas have very little flow other than immediately after the heavier rains. The northern and headwater streams are perennial. Snowmelt is a contributing factor in most winter storms. During major runoff producing storms, streamflow increases rapidly, and in conjunction with steep gradients, snowmelt and sparsely vegetated slopes, results in major floods.

4.5 Geology and Soils

The area is part of the Southern Basin and Range Physiographic Province which is characterized by steep rugged mountain ranges bounded by broad gently sloping alluvium-filled valleys (basins). The mountain ranges have established a general northwest to southeast trend parallel to an extensive system of sub-parallel faults. The mountain ranges were extensively dissected, downdropped and uplifted by this system of northwest to southwest and east to west trending sub-parallel normal faults during the middle to late Cenozoic era. The basins are extremely thick alluvial and colluvial filled valleys, deposited during the late Cenozoic era; they cover the disconnected downdropped portions (grabens) of mountain ranges.

Basins within the project area are made up of Quaternary and upper Tertiary aged sediments (soils) that are almost 5,000 feet thick near valley centers to less than 1 foot thick along mountain fronts. Basin sediment consists mostly of: poorly to well consolidated and unconsolidated inter-layered gravels, sands, clays and caliche, representing a long history of erosion and several environments of deposition. The alluvial fill typically present contributes to sediment loading of flood flows, and patterns of deposition and scouring throughout the system.

Mountain ranges and hills from Gillespie Dam to Yuma consist mostly of younger Tertiary aged sedimentary and volcanic rocks that overlie unconformably on an older Precambrian igneous and metamorphic basement rock complex. The complex is composed predominantly of igneous granite and diorite, schist, gneiss and volcanics. Tertiary rocks consist of volcanic basalt, andesite and rhyolite, sedimentary sandstone, siltstone and conglomerate.

4.6 Vegetation

The vegetation of the study area is characteristic of the Sonoran desert. This vegetation occupies the lowest, most arid regions and extends to elevations of 3,000 feet where terrain is gentle and to 4,500 feet on steep slopes. Native plant life is described to be of three communities: Desert wash or Riparian, Desert outwash plain, and Desert upland. The natural vegetation still exists on the perimeters of the urban areas and within the reservation lands, on steep slopes and mountain tops, and along arroyos, washes and major drainages.

4.7 Population

Immediately upstream from the study area lies the Phoenix metropolitan area with a 1994 estimated population of 2.2 million. This is an increase of 1.0 million from 1970, making Phoenix one of the most rapidly growing urban areas in the country. At the downstream end of the study area, the City of Yuma currently has a population of about 60,000 with a rate of growth similar to Phoenix.

The area from Gillespie to the City of Yuma is largely agricultural or open desert. The largest community in this area is Gila Bend, with a population of 1,800. A number of small farming communities are scattered along the river, or Interstate 8, and include Wellton, Tacna, Dateland, and others, with Populations from 1,500 down to 100.

4.8 Land Use

Agricultural use predominates from Gillespie Dam to Painted Rock. Downstream from Painted Rock to the upper end of the Wellton-Mohawk Irrigation and Drainage District the area is largely undeveloped, and in its natural desert form. The area throughout Wellton-Mohawk is intensively developed into commercial irrigated agricultural uses. This agricultural development extends to Yuma itself. The economy of the area is predominately based on agricultural production, trade, and services.

4.9 Transportation

Transportation routes include Interstate 8, as well as state and local roads. Investigations performed during this study, show 134 transportation or utility crossings of the Gila River in the study area (Appendix C). A mainline Southern Pacific Railroad line transverses the area. Local bridged crossings are critical to movement of people and agricultural products in the area. During the 1993 floods all but one of these crossings were closed due to bridge destruction or damage.

CHAPTER 5

PROBLEM IDENTIFICATION

5. PROBLEM IDENTIFICATION

5.1 Introduction

This chapter presents an overview of the water and related land resources problems specific to the study area. The problems presented are intended to reflect those associated with the Federal objective and identified state and local concerns. It has been attempted to express problems in such a way that meaningful levels of achievement can be identified when evaluating potential solutions to these problems. Problems have been presented for both current and future conditions where sufficient information is available to do so.

5.2 Flood Control

5.2.1 Historical Floods

Historical references to floods on the Lower Gila River extend back to 1833, but continuous records of discharge measurements are not available prior to 1903. Historical accounts indicate that general floods occurred in 1833, 1862, 1869, 1880, 1884, 1886, 1889, 1891, 1893, 1895, and 1903. Records since 1903 show that floods and or storms occurred in March 1905, November 1905, December 1906, December 1914, January 1915, January 1916, October 1916, November 1919, February 1920, December 1923, September 1926, February 1927, February 1937, March 1938, March 1941, September 1946, December-January 1965, March-May 1975, March 1978, December 1978-April 1979, February 1980, October 1983, December 1984-March 1985, February-April 1992, and January-April 1993.

Floods on the lower Gila River, prior to the construction of Painted Rock Dam, were a threat to property in the lower Gila Valley, and along the Colorado River below the confluence with the Gila River. Monetary estimates of damage are not available for floods prior to 1890 and are incomplete for floods since that date. In addition to property damage, loss of life has been reported.

5.2.2 Painted Rock Dam

The flood control project for Painted Rock Dam was authorized by the Flood Control Act approved 17 May 1950, in accordance with the recommendation in the report of the Chief of Engineers, dated 15 August 1949 and printed in House Document No. 331, Eighty-first Congress, first session. Construction on the dam was completed in 1959. A photograph of Painted Rock Dam and the reservoir area is shown on page 28.

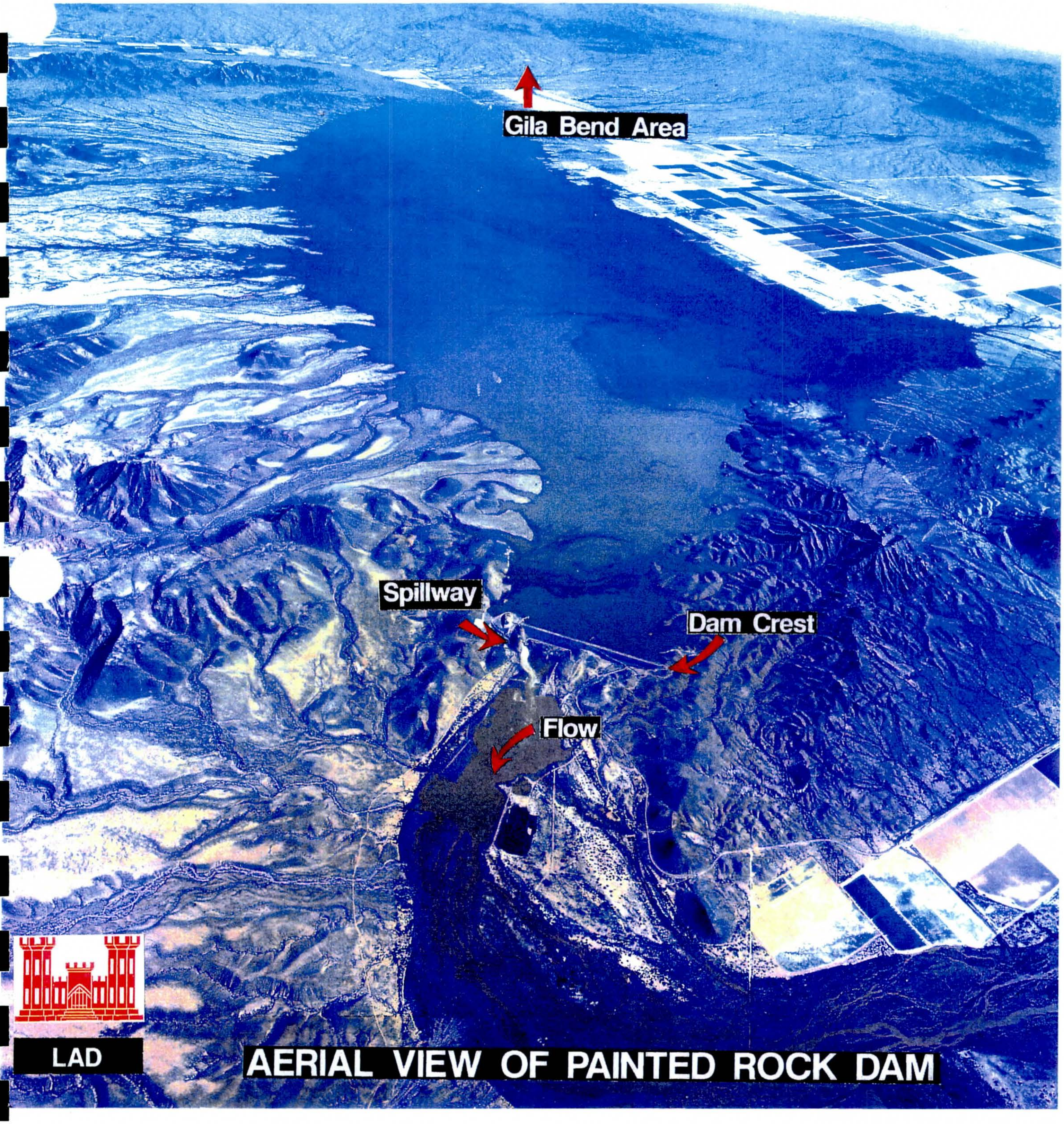
Painted Rock Dam was authorized to provide protection against floods for agricultural lands (1) downstream from Painted Rock Dam in Arizona, (2) along the lower Colorado River in Arizona, California and Mexico, and (3) in the Imperial Valley of California. Flood protection is also provided to residential,commercial, and industrial properties in the city of Yuma and the towns of Gadsen and Somerton, Arizona; to extensive irrigation facilities; and to important defense installations. Painted Rock Dam is vital to the operation of the 1944 Water Treaty with Mexico.

The dam consists of a zoned embankment with a positive cutoff to bedrock. It has a crest width of 20 feet, and a maximum height of approximately 180 feet above the streambed. The spillway is broad crested, detached and unlined with a concrete control sill. The gated outlet is through the right abutment.

PAINTED ROCK DAM RESERVOIR REGULATION MANUAL

Corps of Engineers regulations require preparation of a Reservoir Regulation Manual based on the actual as built design of a flood control project and authorized project purposes. The "Reservoir Regulation Manual for Painted Rock Reservoir," dated June 1962, was approved on November 29, 1962, and is the currently approved Reservoir Regulation Manual for Painted Rock Reservoir. This manual describes the physical characteristics of the project, plan of operation, coordination procedures, hydrologic information of the watershed, emergency procedures, and other information related to the operation of the dam.

There are two basic methods to operate a flood control dam such as Painted Rock during a flood event -- one is to operate on a prediction basis and the second is to operate in accordance with a fixed operation schedule. Operation on a prediction basis establishes the rate of release of floodwaters from the dam based on the upstream and downstream conditions. Relevant factors at Painted Rock Dam include: prior rainfall and runoff, forecasted precipitation (short-term and long-term), ground conditions (e.g., saturation, snowpack, etc.) and forecasted runoff, current level of Painted Rock Reservoir and current inflow to the reservoir, current level of inflow to and outflows from upstream dams, expected operation of upstream dams, the status and expected operation of dams on the main stem of the Colorado River, and the current relationship between reservoir outflow and downstream damages. A fixed operation schedule for a flood control dam merely provides a fixed rate of release for specific water elevations in the reservoir. Such fixed operating schedules ignore the factors described above and usually are designed to control the reservoir



AERIAL VIEW OF PAINTED ROCK DAM

design flood (in this case, the standard project flood). Operation on a prediction basis can provide greater flood control benefits for floods that are smaller than the standard project flood.

The 1962 Reservoir Regulation Manual includes two alternative fixed operation schedules for Painted Rock Dam that are suitable for controlling the standard project flood. Paragraph 64 of the 1962 Reservoir Regulation Manual authorizes the Los Angeles District (LAD) to depart from those fixed operating schedules during floods that are smaller than the standard project flood. Paragraph 65 of the 1962 Reservoir Regulation Manual specifies who may exercise the discretion described in paragraph 64 (i.e., only persons in the LAD office) and addresses operation of the dam in the event of loss of communication between the dam and the LAD office.

PAINTED ROCK RESERVOIR OPERATION

Operation decisions during all flood events at Painted Rock Dam have been in accordance with the authority granted in the 1962 Reservoir Regulation Manual. LAD has operated Painted Rock Dam on a prediction basis.

LAD operates Painted Rock Dam to minimize damage from flood waters in areas downstream of the dam. The major categories of damage that LAD attempts to avoid are: a) damages to the Wellton-Mohawk Irrigation and Drainage District (WMIDD), b) interruption of road crossings (with attendant disruption of transportation and commerce), c) damage to farmlands along the Gila River above Texas Hill, and d) damage to lands adjacent to the lower Colorado River in the United States and Mexico. The WMIDD includes approximately 65,000 acres of irrigated farmlands along the Gila River between Painted Rock Dam and Yuma, Arizona.

Channel capacity has been the most significant factor in the operation of Painted Rock Dam. Large releases from the Painted Rock reservoir cause severe economic and social hardship on the communities downstream of the dam, especially if the improved road crossings are washed out. Prior to the first significant impoundment at Painted Rock dam in 1966, there were no improved vehicle crossings across the Gila River on the entire reach of the river from the dam to the Colorado River. In 1966, when releases were first made, the unimproved crossings were flooded, making them impassible. The loss of these crossings caused severe economic and social hardship to the communities downstream of the dam. In response to this impact, several of the crossings were improved to allow the passage of approximately 1,500 cfs (cubic feet per second). As a result of relatively high releases from the dam for the period of December 1978 to November 1980, the channel capacity was naturally increased due to flows scouring the channel and carrying away brush and vegetation. Over the years, the improved crossings have been enlarged to the point where, by the end of the 1980 impoundment, 5,000 cfs could be released without washing out the improved crossings. During the period following the 1980 flood event, significant improvements were made to a number of Gila River crossings between Painted Rock Dam and the Colorado River. In addition, the WMIDD began construction on a leveed channel system through their District capable of conveying a maximum discharge of 10,000 cfs. Yuma County, Maricopa County, and the WMIDD upgraded the capacity of most of the improved crossings to pass approximately 10,000 cfs. However, many unimproved crossings will still be flooded when releases are made; therefore, substantial social and economic hardships associated with transportation problems will still occur when releases are made from Painted Rock Dam. An inventory of all bridge and utility crossings has been conducted as part of this study. The results are presented in Appendix C. The inventory includes estimation of flow capacities, estimation of scour potential, a description of each crossing, damages from prior flood events, estimated detour routes and mileage, and relationship to existing flood control improvements and repairs.

Two separate "salinity problems" have been considered by LAD in connection with operation of Painted Rock dam: 1) potential salinity damage to lands and crops in the WMIDD caused by high ground water levels, and 2) potential effects of Gila River flows on the United States' obligation to deliver Colorado River water of a specified salinity to Mexico.

Since Painted Rock dam began operation on April 1, 1959, there have been 12 floods that caused the reservoir to rise above Elevation 580 feet. Elevation 580 feet is the elevation in the reservoir in which the Corps owns land in fee title. Above elevation 580 feet the land is in a mix of government owned lands and lands in which the Corps has flowage easements up to the spillway crest elevation of 661 feet. The dates of these 12 flood events is presented below along with a summary of the Painted Rock Dam operation during each of these events.

1. January, 1966
2. March-May, 1973
3. February-March, 1978
4. December, 1978
5. January, 1979
6. March, 1979
7. February, 1980
8. February-May, 1983
9. October, 1983.
10. December, 1984- April, 1985
11. February-April, 1992
12. January-June, 1993

January, 1966 flood. Significant inflow occurred from January 1, 1966 through January 13, 1966. Peak average daily inflow of 30,741 cfs occurred on January 3, 1966. Reservoir elevation peaked at 585.94 feet on January 13, 1966.

March-May, 1973 flood. Runoff from melting of an unprecedented snowpack in central Arizona caused significant inflow to Painted Rock Reservoir from March 18, 1973 to May 22, 1973. Peak average daily inflow of 15,585 cfs occurred on April 4, 1973. Reservoir elevation peaked at 601.25 feet on May 20, 1973. Maximum releases from Painted Rock reservoir were approximately 2500 cfs. From October 5, 1974 to August 17, 1976, LAD stopped releasing water from Painted Rock Reservoir to provide a temporary lake for recreation purposes. During that period, the reservoir was at or below Elevation 558.83. The reservoir was fully drained by August 31, 1976, prior to the next flood.

February-March, 1978 flood. Storms during February 27-March 6, 1978, produced heavy runoff on central Arizona tributaries to the Gila River. Most streams peaked on March 1 or 2. Significant inflow to Painted Rock Reservoir occurred from March 4 through March 31, 1978. Peak average daily inflow of 69,694 cfs occurred on March 4, 1978. Reservoir elevation peaked at 598.13 feet on March 12, 1978. From March 4, 1978 through December 21, 1978, releases were made at a rate equal to the infiltration rate of the Gila River channel between Painted Rock Dam and Texas Hill (approximately 250 cfs) to avoid water reaching WMIDD. Reservoir elevation decreased to a low of 582.75 feet on December 18, 1978 when the next flood arrived.

December, 1978 flood. A storm on December 16-20, 1978, produced heavy runoff throughout most of Arizona and western New Mexico. Moderate snowfall down to elevations below 5,000 feet in early December created a snowpack that contributed significantly to the runoff as it melted during the warm, heavy rain of December 16-20. Most Gila River tributaries peaked on December 18 and 19. Significant inflow to Painted Rock reservoir occurred from December 18, 1978 through January 13, 1979. Peak average daily inflow of 74,724 cfs occurred on December 21, 1978. Reservoir elevation peaked at 612.95 feet on December 31, 1978.

January, 1979 flood. Precipitation during January 16-19, 1979, produced heavy runoff in Arizona. Significant inflow to Painted Rock reservoir occurred from January 16, 1979 through February 20, 1979. Peak average daily inflow of 66,073 cfs occurred on January 20, 1979. Reservoir elevation, which was 611.84 feet at the beginning of the inflow, peaked at 634.66 feet on February 8, 1979.

March, 1979 flood. Rainfall on March 17-22, 1979, produced moderate inflow to Painted Rock reservoir; rainfall during March 28-30, 1979, produced significantly heavier runoff and inflow. Significant inflow occurred from March 17, 1979 through April 18, 1979. Peak average daily inflow of 44,580 cfs occurred on March 30, 1979.

Reservoir elevation, which was 629.63 feet at the beginning of the inflow, peaked at 642.35 feet on April 17, 1979.

December, 1978 - January, 1980 Impoundment. The floods of December, 1978, January, 1979, and March, 1979 produced an impoundment at Painted Rock Reservoir that lasted until January 27, 1980. On December 22, 1978, higher releases were initiated due the unprecedented volume of water (over 600,000 acre-feet) in storage so early in the season. Releases were approximately 1,500 cfs until January 19, 1979. The 1,500 cfs value was the maximum capacity of the crossings downstream of the dam. By January 19, 1979, the capacity of the crossings had been increased to 2,500 cfs, so releases were gradually increased to 2,500 cfs by February 8, 1979. Releases higher than the capacity of the downstream crossings were not made due to the large amount of damage the higher releases would have caused. The 2,500 cfs release was continued from February 8, 1979 until the reservoir was emptied on January 27, 1980.

February, 1980 flood. Above normal precipitation occurred during most of January, 1980, saturating watersheds and causing upstream reservoir levels to rise. Precipitation that occurred on February 13-22, 1980, as a result of six Pacific storms, produced heavy flooding in central Arizona. Inflows to Painted Rock Reservoir rose sharply on February 16, 1980. Significant inflow to the reservoir occurred from February 16, 1980 through March 14, 1980. Peak average daily inflow of 144,658 cfs occurred on February 17. Reservoir elevation peaked at 647.81 feet on March 6, 1980; this was the second highest reservoir pool elevation reached since the dam was constructed in 1959. Releases began on February 3, were progressively increased to 1,000 cfs on February 11, and were further increased to approximately 2,500-2,600 cfs by February 19, 1980. On February 27, 1980, a public meeting was held in Yuma, Arizona, to obtain the views of local interests concerning increased releases. As a result of the meeting, LAD decided to gradually increase releases toward a target of 5,000 cfs. However, based on reports of anticipated downstream damage, judgment decisions were to be made as to what constituted an acceptable sustained release on a given day. Releases were gradually increased from approximately 3,000 cfs at the end of February to approximately 4,300 cfs in mid-June. Starting on June 19, and continuing through July 6, 1980, releases were cut to less than approximately 300 cfs to allow for emergency repair of the downstream Avenue 64E crossing by the Yuma County Highway Department. Releases of about 2,500 cfs were made on July 7, and were gradually increased to a maximum mean daily flow of 5,020 cfs (USGS records). Increasing releases above 3,000 cfs caused the riverbed to gradually scour, expanding downstream channel capacity. Thus, the higher releases in July did not cause a significant increase in river stage or associated damage. Starting on October 21, 1980, releases were gradually reduced to minimize nutrient loading and a potential fish kill in the downstream Borrow Pit Lake. Discharges of nutrients from the bottom of Painted Rock reservoir can cause depletions of oxygen in the Borrow Pit Lake, resulting in fish kills.

Releases were also reduced to lengthen the duration of flow in the Gila River to support a suction dredge operated by the Yuma County Highway Department in conjunction with downstream bridge construction. By December 18, 1980, Painted Rock reservoir was fully drained.

January-May, 1983 flood. The January-May, 1983 flood inflows resulted from release of runoff from the Salt River Project reservoir system upstream of Painted Rock Dam. Significant inflow to Painted Rock reservoir occurred between January 1 and May 30, 1983. Peak average daily inflow of approximately 23,000 cfs occurred on February 12, 1983. Reservoir elevation peaked at 609.40 feet on April 8, 1983. During January and February, Painted Rock dam releases were limited to less than 400 cfs with the objective of infiltrating floodwaters between the dam and Texas Hill, thereby preventing an increase in WMIDD ground water levels. The magnitude of these low releases was also coordinated with modifications underway to certain downstream channel crossings. By March 1, 1983, it became evident that the quantity of water already in storage plus anticipated additional inflows would be greater than could be released by continuing the low releases and still have essentially an empty reservoir at the beginning of the next flood season. Hence, flood releases were gradually increased to about 3,200 cfs by the end of March and further increased to 4,500 cfs by mid-June. In 1983, flooding on the Colorado River reached historic highs -- spillway flow occurred simultaneously at Hoover and Glen Canyon Dams for the first time in history. In mid-June, the need to make large flood control releases from Hoover Dam on the main stem of the Colorado River required a reduction of Painted Rock dam releases to about 500 cfs to avoid aggravating flood damage on the lower Colorado River. Painted Rock Dam releases were limited to about 525 cfs during the second half of June and throughout July. During August, sufficient channel capacity on the lower Colorado River became available to increase Painted Rock dam releases to 1,000 cfs. The 1,000 cfs release was maintained through September 25, 1983 when the reservoir was nearly empty. The remaining 29,000 acre-feet of water (water surface elevation of 558.09 feet) was to be released at 70 cfs so as not to overload the downstream Borrow Pit Lake with decaying organic matter from the upstream lake and cause environmental problems such as fish kills. On October 2, 1983, inflow from the next flood event began.

December, 1984-April, 1985 flood. A series of flood inflows occurred during this flood period with the maximum inflow peak of 27,000 cfs on December 30, 1984. The maximum reservoir pool elevation of 592.31 feet occurred on March 23, 1985. Reservoir releases of about 1,500 cfs in late December were gradually increased to 4,000 cfs in mid-February and sustained until early May. The dam returned to empty in mid-May 1985.

February-April, 1992 flood. During February to April, 1992, three significant flood inflows occurred with the highest peak being about 8800 cfs in mid-February. The maximum reservoir water surface elevation of 583.50 feet occurred on April 3,

1992. Reservoir releases of 1000 cfs in February were increased in a gradual stepwise fashion to a maximum of 3000 cfs in late March through mid-April. In response to a Bureau of Reclamation request, Painted Rock Dam releases were reduced once the reservoir dropped below elevation 580 feet to rates that could be fully utilized for meeting Colorado River water delivery requirements to Mexico. The reservoir returned to empty in mid-June 1992.

January-June, 1993 flood. A series of strong Pacific storms during January and February that picked up tropical moisture from lower latitudes produced record breaking precipitation amounts throughout most of the southern half of Arizona. For example, the January precipitation total at Roosevelt Dam on the Salt River was 11.2 inches, versus a normal January rainfall total of 1.8 inches, and a previous record January precipitation total of 6.4 inches. The record rainfalls filled upstream reservoirs on the Salt, Verde, and Upper Gila Rivers by early January and caused subsequent flood runoff to spill over these facilities and flow downstream to Painted Rock Dam. The resulting runoff produced a new flood of record on the lower Gila River. The runoff volume into Painted Rock Dam during the period 1 January to 9 June was 5.24 (MAF), more than double the 2.5 MAF of flood control storage capacity of the reservoir to spillway crest.

Painted Rock Dam operations began on 4 January with an empty reservoir. When large flood inflow into the reservoir began in the first week of January, reservoir releases were initiated at 2500 cfs on 5 January, and gradually stepped up to 5000 cfs (equal to the previous maximum sustained release) by 14 January. Because of the large magnitude of the projected flood inflow and the existence of channel improvements and upgraded river crossings downstream, reservoir releases were increased to 10,000 cfs on 20 January. Following a coordination meeting with downstream interests on 20 January, releases were further increased to 12,500 cfs, a damaging level that required downstream interests, such as the Wellton-Mohawk Irrigation and Drainage District and Yuma County, to flood fight levees and river crossings in order to maintain sufficient control of the river to prevent large scale flood damages. A 1-week cutback in releases during 30 January to 5 February was necessary to enable downstream interests to retain control of the river which was threatening to break through levees.

Reservoir releases were returned to 12,500 cfs on 9 February and maintained at that level until additional flood events caused the reservoir pool level to rise over the spillway and generate a maximum spillway discharge of about 26,000 cfs on 27 February. The maximum reservoir water surface elevation was 667.01 feet (2.81 MAF of water in storage), which was 6 feet over spillway crest of 661 feet (Figure 6). After the peak of spillway flow, the reservoir releases were initially maintained at 24,000 cfs, utilizing the combination of both spillway outflow and releases from the outlet works, in an effort to regain reservoir storage space as rapidly as possible. Reservoir releases were gradually reduced to 20,000 cfs on 20 March, to 15,000 cfs on 14 April, to 10,000 cfs on 30 April, and to 5,000 cfs on 29 May, in response to diminishing threat of additional flood inflow, and the objective of minimizing downstream flood damages and permitting the recovery of downstream communities.

5.2.3 Without Project Condition Problem Identification

Without Project Condition Damages

Informal estimates by local officials of actual 1993 flood damage to downstream agricultural interests, road crossings, and channel improvements, in addition to transportation delays, flood fighting efforts, etc., are conservatively put at $100 million. The reservoir above Painted Rock Dam inundated some structures, an active Native American burial ground, and agricultural lands in the reservoir area. Photographs that typify some of the damages in the study area from the 1993 event are presented in Figures 5 through 10. The estimated average annual without project flood damages and damages from the 1993 flood are summarized below. This information is presented by study reaches. These study reaches have been established based upon an engineering, environmental, economic, and institutional evaluation of the study area (Figure 4).

Reach 1 - Gillespie Dam to Painted Rock Reservoir

This area consists mainly of farmland. This reach suffered approximately $1.0 million in damages during the 1993 flood. This figure does not include damage to Gillespie Dam itself. The dam is privately owned and under the regulatory authority of the Arizona Department of Water Resources. Damage or repair estimates to the dam were not available. In the 1993 flood, Gillespie Dam failed when a 100 foot section from the center of the structure was washed away. The dam is primarily a diversion structure and provides no flood control benefits. The high discharges downstream of Gillespie Dam caused some lateral migration of the river channel. Portions of farmland were lost to river channelization in 1993 by both erosion and deposition of sediment. The historic U.S. Highway 80 bridge was closed a result of the 1993 flood. This resulted in a temporary 36-mile detour for ranchers, farmers and school buses. The most significant damages in this reach have historically occurred to crops, farm infrastructure, salinization of cropland due to high groundwater, and costs associated with farmland restoration. Smaller damage categories through this reach include damage to structures, content of structures, water pumping and fences. Near Gillespie Dam, the El Paso Natural Gas Company pipeline received damage during the 1993 flood event. The average annual without project damages are currently estimated at $30,600 through this reach.

Reach 2 - Painted Rock Reservoir

During the 1993 flood, the San Lucy Village Sewage Disposal Pond, located north of the town of Gila Bend, was breached causing a limited amount of raw sewage to enter the flood waters being detained behind Painted Rock Dam. A burial ground of the San Lucy Village was also inundated by backwater from Painted Rock Dam during the 1993 event. This burial ground had been protected by levees that were constructed at the time Painted Rock Dam was built. The top of these levees were at the spillway crest elevation of 661 feet. The Corps has flowage easements in the reservoir area up to elevation 661 feet. During the 1993 flood, the maximum water surface elevation was 667 feet. Average annual damage estimates in the reservoir are have not been fully quantified, but are minimal compared to downstream damages.

Reach 3 - Painted Rock Dam to Texas Hill

There are three bridges across the Gila River that were closed from the 1993 flood. They are the Sentinel, Dateland 64E and Agua Caliente bridges. The Corps closed the road crossing over Painted Rock Dam, due to the high water. This forced local residents to use the Agua Caliente Bridge until it was eventually closed due to the approach to the bridge being inundated by the river. This caused residents from the community of Agua Caliente to use detour routes as high as 96 additional miles. A catalog inventory of all transportation and utility crossings is presented in Appendix C. After the flood, the spillway at Painted Rock Dam required reconstruction work to restore it for future emergency spills.

Reach 4 - Texas Hill to Gila Siphon (Dome)

Prior to the 1993 flood, the Wellton-Mohawk Irrigation and Drainage District (WMIDD) had approximately 105 miles of flood control levees in place, which provided a maximum channel capacity of about 10,000 cubic feet per second (cfs) to about 65 river miles. Approximately 65 miles of these levees were damaged during the 1993 event, along with seven bridges and 30,000 acres of irrigated farm land. The flood damaged approximately 65% of the pre-disaster flood control project. Intense flood fighting activities helped the WMIDD maintain most flood control facilities from Avenue 57E to Avenue 52E, and from Avenue 28E to Avenue 11E in the vicinity of the Gila Siphon. The flood control system through the WMIDD suffered heavy damage from Avenue 52E to Avenue 28E. In addition, WMIDD suffered damage to their irrigation and canal system. Approximately seven miles

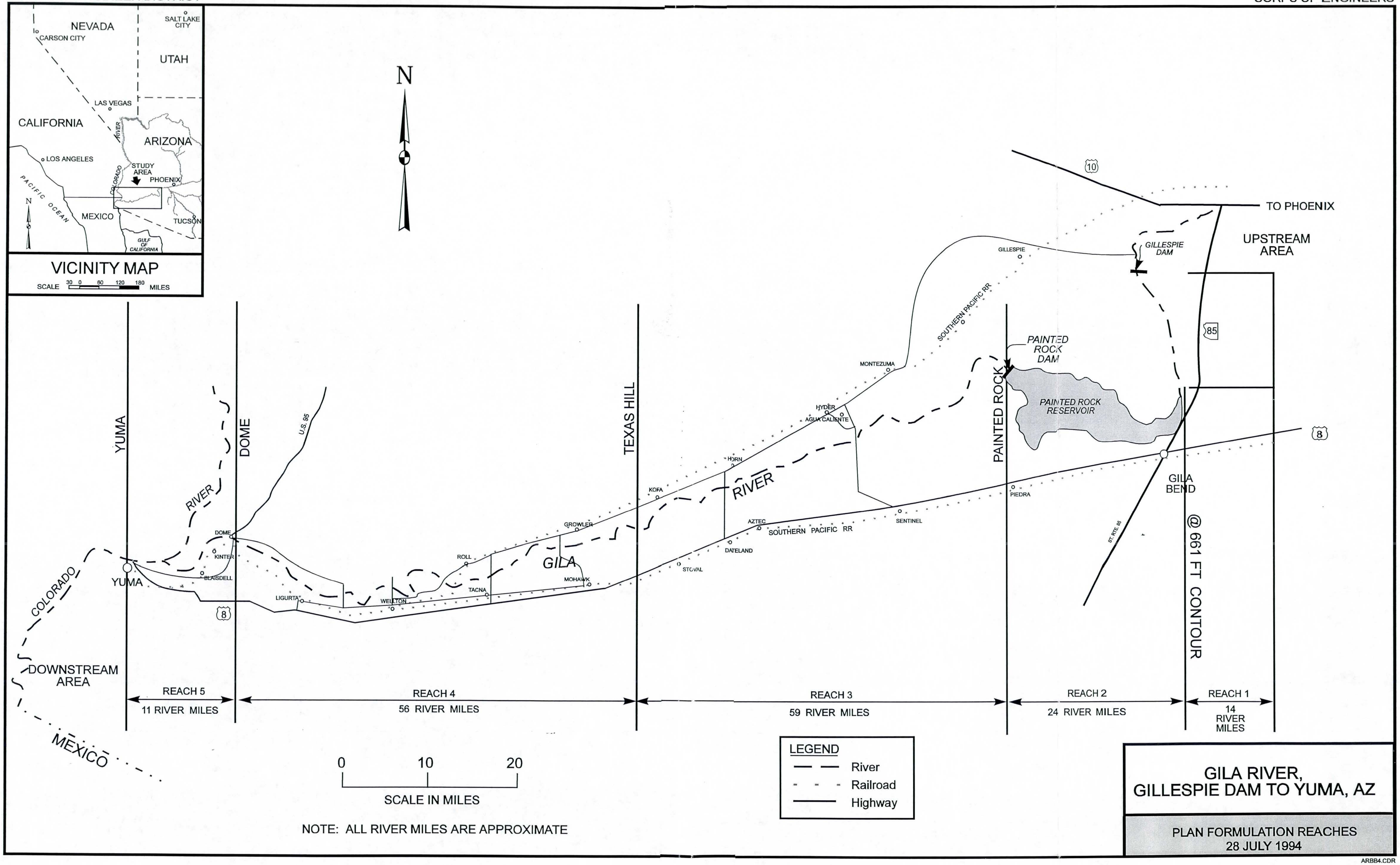

NEVADA
SALT LAKE CITY
CARSON CITY
UTAH
LAS VEGAS
CALIFORNIA
ARIZONA
LOS ANGELES
STUDY AREA
PHOENIX
PACIFIC OCEAN
MEXICO
TUCSON
GULF OF CALIFORNIA
VICINITY MAP
SCALE 30 0 60 120 180 MILES
N
10
TO PHOENIX
UPSTREAM AREA
GILLESPIE
GILLESPIE DAM
SOUTHERN PACIFIC RR
85
PAINTED ROCK DAM
PAINTED ROCK RESERVOIR
MONTEZUMA
HYDER
AGUA CALIENTE
PAINTED ROCK
8
GILA BEND
HORN
RIVER
KOFA
PIEDRA
SENTINEL
AZTEC
SOUTHERN PACIFIC RR
DATELAND
STOVAL
@ 661 FT CONTOUR
GROWLER
GILA
MOHAWK
TACNA
ROLL
WELLTON
LIGURTA
YUMA
DOME
TEXAS HILL
U.S. 95
KINTER
BLAISDELL
COLORADO
DOWNSTREAM AREA
MEXICO
REACH 5
11 RIVER MILES
REACH 4
56 RIVER MILES
REACH 3
59 RIVER MILES
REACH 2
24 RIVER MILES
REACH 1
14 RIVER MILES
0 10 20
SCALE IN MILES
NOTE: ALL RIVER MILES ARE APPROXIMATE
LEGEND
River
Railroad
Highway
GILA RIVER,
GILLESPIE DAM TO YUMA, AZ
PLAN FORMULATION REACHES
28 JULY 1994
ARBB4.CDR

Figure 4

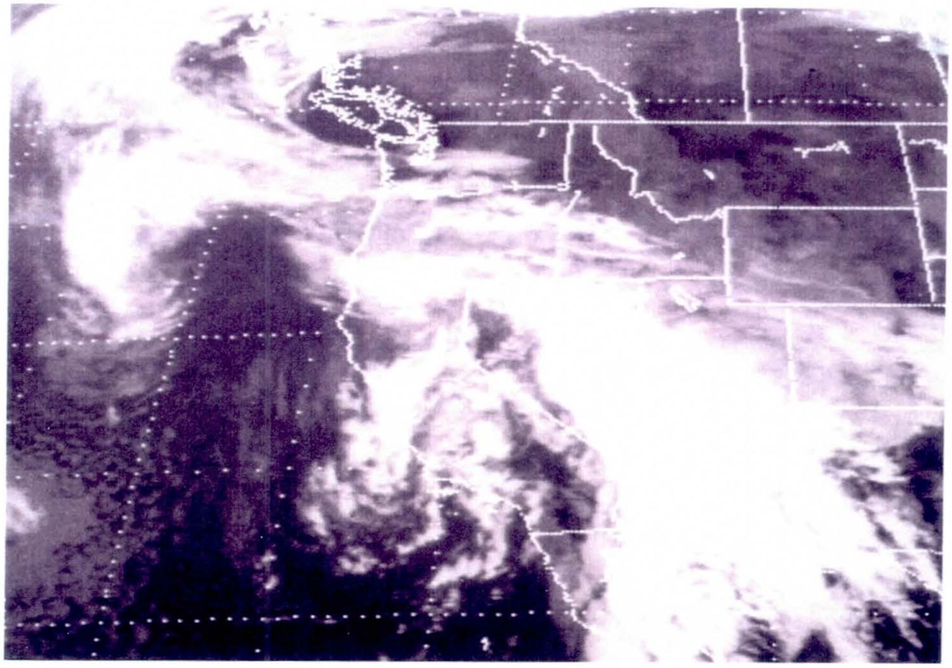


Figure 5. Satellite photo of storm in Jan 93.

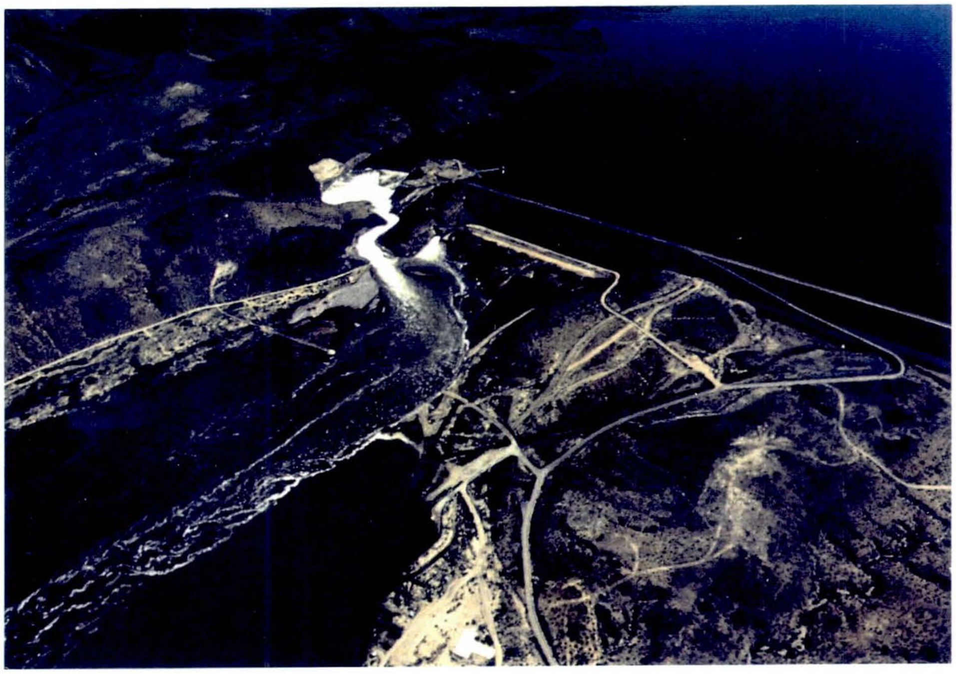


Figure 6. Painted Rock Dam with Spillway flow (Feb 93), view looking ENE.

Figure 7. Gillespie Dam after failure in Jan 93. View looking west.

Figure 8. Avenue 40. Wellton-Mohawk area. Mar 93. View looking north.

Figure 9. Aerial view of submerged agricultural land, Wellton-Mohawk area. Mar 93.

Figure 10. Gila River flood damages. Wellton-Mohawk area. Mar 93.

of irrigation laterals were damaged during the 1993 flood. Total damages exceeded $50 million through this reach. The most significant flood damages in this reach occur to irrigation infrastructure, roads, bridges, transportation impacts, emergency and flood fighting costs, crops, and land restoration. Other quantifiable losses occurred to structures, content of structures, and utilities. Average annual without project flood damages are estimated at $869,540 through this reach. This figure is based on a without project condition assumption that the channelization through the WMIDD will be restored to 10,000 cfs capacity (See Section 5.2.3.2 for details). Until this channel restoration project is constructed, the area is at risk to flood damages from flood flows in excess of about 3000 cfs.

Reach 5 - Gila Siphon (Dome) to Yuma, AZ

From the U.S. 95 Highway Bridge to the confluence with the Colorado River, the Bureau of Reclamation has flood control authority under their Colorado River Front Work and Levee Authority. The Bureau has constructed and maintains levees along the Gila River. The south levee system has 35,000 to 50,000 cfs capacity. The north levee system is limited to about 28,000 cfs capacity. During the 1993 flood, the Bureau of Reclamation spent about $1.5 million in floodfighting and emergency repair activities to the north levee system. There was approximately $700 thousand in damages to a Santa Fe gas line through this reach. Some flood damages have occurred to the Yuma Irrigation and Drainage District and to the North Gila Valley Irrigation and Drainage District. Including reaches 4 and 5, FEMA and the Arizona Division of Emergency Management estimated that they incurred $11,118,449 in flood fighting costs for Federal funding applicants in Yuma County.

Downstream of Study Area

From the Gila confluence to the North International Boundary, there are revetted levees on both sides of the river. The design discharge is 140,000 cfs. The levees are Federal, constructed and maintained by the Bureau of Reclamation. From the North International Border to the South International Border, there are levees on both sides of the Colorado River. The east levee is on U.S. territory and has a design discharge of 140,000 cfs. It is a Federal levee, constructed and maintained by the Bureau of Reclamation. The west levee is on Mexican territory and has an estimated capacity of 28,000 cfs. It has withstood releases of this magnitude for extended periods of time in the past.

The runoff from the Gila River in 1993 carried a large sediment load into the Colorado River, causing significant accumulations in the international boundary segment of the Lower Colorado River from Morelos Dam to the international border. This sediment problem has impacted the ability of the hydraulic system to pass the design flood through the international boundary segment of the Colorado River, which includes the communities of Yuma, Arizona and San Luis, Sonora, Mexico; and inhibits Mexico from receiving full deliveries of Colorado River waters in accordance with the 1944 Water Treaty. This is particularly critical in the area of Mexico's Diversion Dam where the sediment impairs efficient operation of the dam's flood control gates and ability to divert Colorado River waters.

Without Project Condition Assumptions

For the purposes of this reconnaissance study, the following assumptions were made as to existing and future flood control conditions, without a Corps project. These assumptions provide a baseline condition, for analysis purposes, that are considered to be reasonable for helping to define flooding problems in the study area, without any future Corps involvement. These without project condition assumptions are as follows:

Upstream of Study Area

• No new dams would be constructed.

• Flood control storage and additional conservation space would be added consistent with the ongoing modifications being made to Roosevelt Dam. Improvements are currently underway to add approximately 550,000 acre-feet of flood control storage and approximately 270,000 acre-feet of water conservation storage. Hydrology for this study will include Roosevelt Dam modifications for flood control.

Reach 1 - Gillespie Dam to Painted Rock Reservoir

• Gillespie Dam will not be rebuilt, or if it is rebuilt it will provide no significant flood control storage.

• There would be no new flood control structures constructed by others.

Reach 2 - Painted Rock Reservoir and Dam

• Painted Rock Dam will be operated in future floods for its authorized purpose of flood control. Releases from the dam will be made to prevent and minimize downstream damages. This will be largely governed by downstream conditions. Therefore, for the purposes of this study, it will be assumed that the Los Angeles District will continue to operate Painted Rock Dam on a prediction basis and it will not be operated on a permanently fixed operating schedule. The dam will continue to be operated in order to prevent or minimize flood damages downstream of the dam. The assumed baseline flood control (without project condition) is presented in Chapter 7, Table 4. The base conditions presented in Table 4 is representative of Painted Rock Dam with the established without project conditions, and considered to provide the most flood protection for downstream interests. This release schedule is generally reflective of the 1993 flood operation of Painted Rock Dam and consists of a staged increase in reservoir releases to a non-damaging discharge. This was used as the baseline condition for computation of without project flood control damages and for water conservation, specifically in determining incidental water yield realized by this baseline condition.

Reach 3 - Painted Rock Dam to Texas Hill

- No flood control structures will be built by others.

Reach 4 - Texas Hill to Gila Siphon (Dome)

- The WMIDD will restore the river channel to a 10,000 cfs capacity, through the District, in the near future. This channel repair project is in the process of being implemented through provisions of the Federal Emergency Management Agency under the federally declared disaster caused by the 1993 flood (FEMA:977-DR-AZ P.A.NO.027-91000). These provisions provide for Federal financial assistance for the re-establishment of the pre-flood channel and allow for alternative channel alignments to be considered, provided that the new alignments meet environmental requirements, are hydraulically sound, and are cost effective. The WMIDD has contracted with a consulting engineering firm to provide the professional services required to obtain environmental permits, prepare plans and specifications, and to perform construction management, with the objective of restoring the flood control facilities damaged or destroyed during the 1993 flood event. Until these flood control facilities are repaired, the WMIDD faces significant exposure to future flood flows of approximately 3,000 cfs or greater.

Reach 5 - Gila Siphon (Dome) to Yuma, AZ

- The Bureau of Reclamation will be constructing levee improvements along the north side of the Gila River from the U.S. 95 Highway bridge to the confluence with the Colorado River. This will be performed, starting in about 1997, under the Colorado River Front Work and Levee Authority for the Lower Colorado River. This will increase the capacity of the north levee system from its current capacity of about 25,000 cfs to approximately 50,000 cfs, which will match the current capacity of the south levee system through this same reach.

Downstream of Study Area

- Due to the sediment problem caused by the 1993 flood, there is currently a proposed United States-Mexico agreement for an emergency action process and subsequent studies to improve the conveying capacity of the international boundary segment of the Colorado River. The International Boundary and Water Commission, United States and Mexico, and the U.S. Department of Interior Bureau of Reclamation have proposed to engage in a joint effort to remove sediment from the lower Colorado River in an area roughly from the confluence of the Gila River to Moreles Dam.

Summary of Flooding Problems

Based upon the damage estimates and baseline condition assumptions, the primary flood control problems in the study area have been identified to consist of the following:

- Inundation of agricultural land, and damages to the infrastructure that supports the agriculture.

- Inundation damages and problems in the Painted Rock reservoir during detention of large runoff volumes.

- Sedimentation and erosion problems throughout the study area. These problem areas include agricultural locations where the Gila River flows into Painted Rock reservoir, through downstream agricultural areas, and into the lower Colorado River. As a result of the floods of 1993, there was considerable sedimentation, scouring, and channel migration for the Gila River throughout the study area.

- Transportation and utility impacts due to limited capacity bridges and river crossings that close during Gila River events. See Appendix C for a detailed inventory of Gila River transportation and utility crossings in the study area.

- Water table increases through agricultural areas that can negatively impact crop production and contributes to salinization.

5.3 Water Conservation

5.3.1 Historical Perspective

For as long as humans have been living in the Colorado River basin, they have depended on its waters to survive and sustain their lives. Archeological findings indicate that primitive irrigation systems were developed at least 2,000 years ago by the Hohokam Indians. This vanished Indian tribe diverted flows along the Salt and Gila Rivers to irrigate and nourish their lives. It is speculated that drought in the 1200's led to their disappearance. In the 16th century, the Pima Indians in extreme southern Arizona were using Gila River water to irrigate crops.

In modern times, water from the Colorado River Basin is critically important to all seven Colorado River Basin States. Many programs have been established to help manage the river system. As a result, the Colorado River is one of the most physically developed and regulated rivers in the nation. Cities as far away as Tucson and Los Angeles have linked their future to the Colorado River water supplies.

Early in the planning stages for a dam on the lower Gila River, public hearings were held in Yuma, Arizona, on 11 February 1938, and in Phoenix, on 20 October 1938. These public hearings were held in connection with the two preliminary examination reports on the Gila River and tributaries, dated 9 May 1938 and 10 January 1939, respectively. Local interests indicated at these meetings that they wanted a flood control and water-conservation dam at the Sentinel damsite, and channel improvements downstream from the damsite. At that time, studies indicated that there was a lack of justification for water conservation in the reservoir behind the dam.

5.3.2 Problem Identification

• Water Scarcity and Allocation in the Lower Colorado River Basin: In 1922, the seven states of the Colorado River basin adopted a compact which allocated water between the upper and a lower basin at Lees Ferry below Glen Canyon Dam. In addition to the Compact, the so-called "law of the river", is further defined in part by the Boulder Canyon Project Act of 1928 and the landmark 1963 Supreme Court decision in *Arizona v. California*. Under this Compact, the upper basin states had to deliver 75 million acre-feet to the lower states in each ten year period. It was assumed (inaccurately) that the flow of the Colorado River at Lees Ferry consisted of 15 million acre feet each year. This resulted in the upper and lower basins with an average annual entitlement of 7.5 million acre-feet each. Under the law of the river, in the lower basin, the water is divided between the states of Arizona, California, and Nevada. Included in this allocation is 905,000 acre-feet for the five tribes on the mainstem of the lower Colorado River. In addition, the Republic of Mexico is entitled, by treaty, to a fixed annual share of 1.5 million acre-feet of the water. The United States appropriation of the lower Colorado River is presented in Table 2.

Most hydrologists now agree that the annual flow of the Colorado River at Lees Ferry is closer to 14 million acre-feet per year. As a result there does not appear to be enough average annual flow to meet all of the entitlements for Colorado River water. This problem has not yet been fully realized since the upper basin states and Arizona do not currently utilize their full entitlements. This shortfall problem will become increasingly worse in the future as water needs increase. It is not clear where the water will come from in the future. The fastest growing areas of demand are for metropolitan and industrial uses and for the recent assertion of Indian water rights. Colorado River water is the cheapest source of water for most metropolitan areas in southern California and southern Nevada.

TABLE 2

Lower Colorado River Appropriation

State	Quantity (Acre-Feet)
Arizona	2.8 Million
California	4.4 Million
Nevada	0.3 Million
Mexico	1.5 Million

The law of the Colorado establishes a seniority system which is important in understanding water allocation and priorities, shortages, water transfers and exchanges. Agricultural water users typically have more senior, longstanding water rights than the more recent urban water demands. Under the current law, water transfers of Colorado River water between states is not allowed even if both sides are willing to make a deal.

Because demand for this scarce water resource will likely surpass available supplies in the near future, the Department of Interior has recently proposed a revised water policy for the lower Colorado River basin states. This proposed rule would give the federal government an expanded role in defining the uses to which Colorado River water can be put. The intent is to encourage efficient use and to eliminate unauthorized uses. The Department of Interior's proposed rule would have two functions: (1) provide the United States the legal framework to enforce actions to eliminate unauthorized uses; and (2) provide maximum flexibility to entitlement holders for voluntary water transfers for the resolution of local water resource problems and demands.

- <u>Salinity</u>: High concentrations of salt exist in the Colorado River. The concentrations increase downstream. About half of the salinity is from natural sources. The other half of the salinity is from development and use. In the lower Colorado River Basin, high salinity causes millions of dollars in losses each year by agriculture, industrial, and municipal water users. To help alleviate salinity, the

Federal Water Pollution Control Act of 1972 set salinity limits for the lower stem of the Colorado River at 1972 levels. In addition, the Colorado River Basin Salinity Control Act of 1974 authorized control measures to enable the United States to comply with international agreements with Mexico on Colorado River salinity levels. These acts led to construction of the world's largest membrane desalting plant near Yuma, Arizona. This plant, along with agricultural improvements and salinity control measures at the sources, was constructed with the intention to help assure that water delivered to Mexico will meet specified salinity limits.

Over several decades, due to saline irrigation return flows and increased upstream detention on the Colorado River, the salinity of water flowing into Mexico increased from an annual average of about 800 parts per million (ppm) to nearly 1,500 ppm total dissolved solids (tds). Mexico filed a formal protest with the United States which brought about a series of negotiations, agreements, and measures to reduce the salinity of the Colorado river at the border. On 30 August 1973, the two governments incorporated in Minute No. 242 a section entitled "Permanent and Definitive Solution to the International Problem of the Salinity of the Colorado River". This Minute included requirements that the water delivered to Mexico, upstream of Morelos Dam, have an annual average salinity of no more than 115 ppm + 30 ppm over the average salinity of the Colorado River waters which arrive at Imperial Dam (about 850 ppm). Waters from the Gila River, released from Painted Rock Dam, that reach the Colorado River impact the saline balance of the Colorado River at Morelos Dam.

Public Law 92-320, the Colorado River Basin Salinity Control Act of 1974 was passed by Congress which authorized construction, programs, control measures, and further studies to reduce the salinity of water delivered to Mexico. This act also recognized that flood releases from Painted Rock Dam may influence salinity control measures downstream. In times of flooding there are usually wide downward fluctuations in the salinity level of the Colorado River. In addition, flows from the Gila River are usually lower in salinity than those from the Colorado River at the confluence of the two rivers. Therefore, the Salinity Control Act also authorized the acquisition of such lands or interest in lands in Painted Rock Dam reservoir as may be necessary to operate the project to preclude adverse impacts on these measures and to help meet the intent of Minute No. 242. The existing real estate interests at Painted Rock Dam were acquired based on its operation as a single purpose reservoir for flood control. Therefore, at the time Painted Rock Dam was constructed, only flowage easements were acquired for a major portion of the private lands in the reservoir. Section 101 (j) of Title I of the Salinity Control Act recognizes these existing limitations and reads in part as follows:

"The Secretary is authorized to acquire through the Corps of Engineers fee title to, or other necessary interests in, additional lands above the Painted Rock Dam in Arizona that are required for the temporary storage capacity needed to permit operation of the dam and reservoir in times of serious flooding in accordance with the obligation of the United States under Minute No. 242".

5.3.3 Without Project Condition Assumptions

The without project operation for water conservation is critical in determining net water yields and associated benefits. Based on the downstream without project conditions established for flood control, a baseline flood control operation has been established for future operations of Painted Rock Dam which will continue to provide for the minimization of downstream flood damages. Details of this without project condition assumption are presented in Chapter 7 of this report and the Hydrology Appendix.

5.4 Environmental Restoration

5.4.1 Historical Perspective

Prior to human intervention in the natural course of the Gila River from its headwaters, the Gila was a continuous, perennial river. Upstream damming, diversion and downstream flood control features radically modified the fish and wildlife habitats that were historically present. The reach of the Gila below Painted Rock was at one time composed of long, meandering, interconnected cienega like segments that provided considerable habitat values to wildlife. The stream bed and adjacent low flow areas were also periodically inundated with flood flows creating ephemeral saturated conditions. Migratory waterfowl and a variety of other wildlife utilized the availability of these areas.

The operation of the dam has altered and reduced previous habitat values due to radical alteration of the downstream hydrology, silting behind the dam, deprivation of needed sediment downstream, and periodic sustained inundation. Shifting the habitat values along the lower Gila toward a more natural state would provide tremendous environmental benefits.

As part of this reconnaissance study, an assessment of historical conditions was performed. A descriptive evaluation of historical conditions is contained in Appendix E, Geomorphology, and quantitative evaluation of modern historic conditions is contained in Appendix G, Environmental Restoration. Quantitative values for the modern historic conditions are displayed in Section 7.4.3 of this report.

Modern Historic Conditions for this reconnaissance study are defined as the environmental conditions existing during an approximate ten year period immediately prior to construction of the Corps Painted Rock Dam in 1959. The modern historic conditions establish a benchmark against which the impacts of Painted Rock dam can then be assessed.

The modern historic conditions estimate that in the ten year period prior to Painted Rock Dam Construction, there were approximately 72,000 acres of high quality riparian habitat and approximately 4000 acres of low quality saltcedar. Since construction of the dam in 1959, approximately 40,000 acres of riparian habitat have converted and been overrun by non-native low quality saltcedar, a trend which will continue unless actions and management strategies are adopted and pursued.

5.4.2 Without Project Condition Problem Identification

The primary problems causing the loss and degradation of riparian habitat along the lower Gila River are all related to one overriding factor. This factor is the radical alteration of the hydrologic regime by a series of dams which effectively serve to deprive the river of the periodic floods and perennial low flows needed to sustain a wide variety of riparian habitat. This alteration of the hydrologic regime results in other associated problems. Flood control, provided by the Corp's Painted Rock Dam, has resulted in the increased clearing of areas of riparian habitat downstream for conversion to agricultural uses and extended inundation of upstream areas.

From an ecological viewpoint, alteration of the hydrologic regime has resulted in the proliferation of low habitat value exotic species, mainly saltcedar (*Tamarisk chinesis and Tamarix aphylla*), at the expense of high habitat value native species such as cottonwood trees (*Populus fremontii*), desert willow (*Salix goodingii and Salix exigua*), mesquite trees (*Prosopis glandulosa*), paloverde trees (*Cercidium floridum*), smoke tree (*Dalea spinosa*), and canyon ragweed (*Ambrosia ambrosioides*). This conversion of high value habitat to low value habitat means that under existing conditions, even small acreage increases of the now rare native riparian habitat are significant and highly valuable.

All riparian areas in the Gila River basin are linked to the Corps Painted Rock Dam because it is the only dam in the basin which currently provides a singular flood control purpose. This complex legal interrelationship of multiple purposes and federally financed projects has resulted in the degradation or total loss of riparian habitats within the entire Gila basin ecosystem. This study focuses on those areas downstream of Painted Rock Dam which are more directly linked to the Corps built and operated project.

Painted Rock Dam receives flood flows from eight major upstream dams located within the tributary area of the Gila River watershed. With a reservoir capacity of 2,491,700 acre-feet, Painted Rock Dam provides flood protection for extensive agricultural lands along the lower Gila River in Arizona, along the lower

Colorado River in Arizona, California, and Mexico, and the Imperial Valley in California. Flood protection is also provided for residential, commercial, and industrial properties in the city of Yuma and the towns of Gadsden and Somerton, Arizona, and for extensive federally financed irrigation and transportation facilities. Painted Rock Dam operation is vital to the 1944 Water Treaty with Mexico.

Under existing conditions, the native riparian habitat along the lower Gila River will continue to diminish and degrade and be overtaken by exotic saltcedar. Some limited efforts by locals may result in isolated areas of riparian habitat. Without a series of mature riparian areas along the river, exotic species such as salt cedar will continue to outcompete the native riparian vegetation, and periodic floodflows will not serve to reseed or provide germination for emergent riparian vegetation. A more detailed description of this process is presented in Appendix G, Environmental Restoration.

5.5 Water Quality

5.5.1 Without Project Problem Identification

The major water quality concerns in the study area are summarized in Table 3. A discussion of the major problems is presented below.

• Saline Groundwater: The Bureau of Reclamation reports that soon after the delivery of imported water to the WMIDD from the Colorado River in 1952, the saline ground water table in the WMIDD began rising. Wells were installed by the Bureau and the WMIDD to maintain groundwater levels below the root zone. A concrete-lined channel was also constructed to convey this pumped saline water for disposal into the Colorado River.

Gila River flood flows, released from Painted Rock Dam, have an impact on the groundwater levels within the WMIDD. Historical groundwater impacts to the WMIDD, resulting from Gila River flood events, have included increases in percolation, waterlogging of land, build-up of salts on the surface, reduced crop production, and additional pumping costs. This problem has also been identified previously as a flooding related problem.

• Surface Water: Flood flows stored by Painted Rock Dam have historically increased in salinity as a function of storage duration. Initially, the stored water quality is relatively good compared to the Colorado River, but changes depending on the length of detention into the summer months. This problem is due primarily to evaporation. Upstream agricultural return flows can also contribute to the increased salinity. After periods of extended reservoir storage, the last water released from Painted Rock Dam is often of higher salinity than that of the Colorado River which poses a problem as it relates to meeting water quality requirements under Minute 242.

In addition to salinity, the water quality of Painted Rock Reservoir and the downstream Borrow Pit Lake can be degraded by eutrophication (nutrient enrichment) and toxic pollutants. Symptoms of the poor water quality in the lake include: fish and other aquatic organisms contaminated with DDT, toxaphene, and mercury; fish kills; algae blooms; and hydrogen sulfide odors.

The generation of hydrogen sulfide gas has been observed at the outlet works and control room area at Painted Rock Dam during periods of reservoir storage. This has caused damage to electronic equipment in the tower including electrical contacts for the elevator.

- Pesticide and Heavy Metal Contamination: Flood flows through Painted Rock Dam have deposited silt, sand and clay behind Painted Rock Dam and in the Borrow Pit Lake downstream of the dam. This lake has had water depths decrease from 30 feet to about 14 feet due to sedimentation. Sediment and fish tissue sampling during the 1970s and 1980s indicated that organochlorine pesticides (primarily DDT and its decay products) were present at elevated levels. A human health risk assessment was completed by the Arizona Department of Health Services for the Arizona Department of Environmental Quality in 1991. This study indicated that there was a substantial increase in cancer risk in humans if fish and turtles from the Middle Gila River were consumed on a regular basis.

A campground and park facility was operated by Arizona States Parks on the shores of Painted Rock Borrow Pit Lake until 1990 when the state dropped its management and returned it to the U.S. Army Corps of Engineers. A primary factor in the closure of the park and access to the lake was concern about organochlorine pesticide contamination in its sediments and fish.

Movement of this sediment, especially during floods, is a concern within the study area. The failure of Gillespie Dam has increased the opportunity for contaminated sediment to move downstream into the Painted Rock Dam area.

TABLE 3

Potential Water Quality Concerns

Reach	Surface Water	Ground Water	Comment
Upstream Area	Sediment TDS VOC's Mercury, Boron	High Water Table VOC's	
1	Sediment TDS Pesticides VOC's Mercury,Boron	Fluorides	
2	Sediment TDS VOC's H_2S	High Water Table TDS	Painted Rock Borrow Pit Lake Contamination
3	Sediment TDS VOC's		
4	Sediment	High Water Table TDS	Saline Ground Water Impacts to Agriculture.
5	Sediment	High Water Table TDS	
Downstream Area	Sediment	Localized Nitrates Pesticides	Sediment Movement into Colorado River

TDS (Total Dissolved Salts) - Non-organic chlorides (cause salinity problem)
VOC's (Volatile Organic Chemicals) - Solvents such as TCE, benzene, petroleum products
H_2S (Hydrogen Sulfide Gas).

CHAPTER 6

PLANNING OPPORTUNITIES AND CONSTRAINTS

6. PLANNING OPPORTUNITIES AND CONSTRAINTS

6.1 Flood Control Opportunities and Constraints

Planning opportunities that were identified for flood control include the following:

- Reduce flood inundation damages in the study area, above the level to be provided in the without project condition. The primary damage reduction opportunities would be to agriculture and to agriculture supporting infrastructure in the Wellton-Mohawk Irrigation and Drainage District.

- Reduce sedimentation problems downstream of the study area in the lower Colorado River.

- Reduce the flooding induced impacts of high groundwater on agricultural lands.

Planning constraints that were identified for flood control include the following:

- Status of Federal Emergency Disaster relief assistance to downstream areas.

- Land ownership and use.

- Downstream areas in which the Bureau of Reclamation maintains primary flood control authority.

- Environmental impacts could be a significant consideration in participating in any large scale structural flood control solution.

6.2 Water Conservation Opportunities and Constraints

The identified planning opportunities for water conservation at Painted Rock Dam include the following:

- Increase Water for the lower Colorado River Basin System: Gila River water released from Painted Rock Dam could be used to more efficiently satisfy treaty requirements for water deliveries to Mexico. Colorado River could then be saved in upstream reservoirs to provided excess water to the Lower Colorado River system.

• Increase Gila River Surface Water: Capturing flood waters and releasing them from Painted Rock Dam at a rate that could be utilized more efficiently by downstream water users would increase the interest in developing this intermittent Gila River surface water in Arizona, and thus its value.

• Salinity Control: Water in the lower Gila River at the confluence with the Colorado River is generally of lower salinity than that of the Colorado River. Water released from Painted Rock Dam could create an opportunity for Gila River water to be included in developing comprehensive salinity level controls on the Colorado River.

• Hydropower: Excess water in the Colorado System could provide for additional hydropower generation.

The identified planning constraints, relative to water conservation at Painted Rock Dam, include the following:

• Non-Federal Sponsor: The state of Arizona reserves tributary water rights, such as the Gila River, to be adjudicated by the state. As such, it is subject to the Arizona surface water rights rules of prior appropriation. The law of the river considers tributary flow that reaches the Colorado River to become lower Colorado River water which can then be distributed under the existing appropriations and entitlements of the three lower states under the law of the river. This complexity makes it difficult to determine a potential non-Federal sponsor or whether a single non-Federal sponsor is even appropriate.

• Real Estate Costs: Existing flowage easements upstream of Painted Rock Dam are based on temporary inundation for the single purpose of flood control. Flowage easements can be affected by increases in frequency or duration of the inundation.

• Flood Control Impact: The addition of a water conservation purpose at Painted Rock Dam could potentially reduce downstream flood control protection currently provided by the dam and its associated operation. These impacts could include the downstream Gila and Colorado Rivers.

• Salinity/Water Quality: Due to the extended time of impoundment, the last water released from storage at Painted Rock Dam after the 1993 event was of poorer quality and higher salinity than the Colorado River at the confluence with the Gila.

• Water Losses: High evaporation rates during summer months and downstream transmission losses are a problem.

• Service Area: The "law of the river" makes it difficult to identify the service area or final use of additional water in the Lower Colorado System. The use could range from irrigation to municipal and industrial water. The water could potentially be transferred to any one of the three lower Colorado River states. This directly affects the economic analysis.

• Painted Rock Dam Design: Painted Rock Dam was not designed or constructed for permanent or long-term storage.

• Authority: The Corps would likely need new Congressional authority to add a water conservation purpose while continuing to operate Painted Rock Dam for its currently authorized purpose of flood control.

• Groundwater: Long-term releases of flood waters from Painted Rock Dam for water conservation purposes could raise groundwater levels and adversely impact downstream agriculture.

• Maintenance: Revised dam operation to include a water conservation purpose could result in minor increases in operation and maintenance costs to the dam and appurtenances.

6.3 Environmental Restoration Opportunities and Constraints

The entire study reach from Gillespie Dam to Yuma has high potential for environmental restoration activities (Figures 11 and 12). The U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, and Arizona Department of Game and Fish have all expressed interest in such activities. Numerous opportunities exist for environmental restoration consistent with current Corps of Engineers policy and guidance.

Environmental restoration opportunities, to increase environmental outputs in the study area, include the following:

• Opportunity for restoration of a variety of native habitat types

• Augmentation of existing habitat

• Creation of additional riparian areas

• Preservation and maintenance of immature emergent existing habitat which was created by the floods of 1993, but which is projected to sustain an approximately 70% die-off rate if no measures are taken

• A ecosystems approach, in which the combined outputs from a corridor of individual/isolated areas would exceed the outputs of the "stand alone" individual areas

• Use of Painted Rock Dam releases as a potential in-stream water supply source for any restoration alternative.

Identified planning constraints relative to environmental restoration include the following:

• Water source availability at certain sites

• Painted Rock Dam operation and releases

• Land ownership

• Soil suitability for desired vegetation types

• Limitations of non-federal funds for cost sharing purposes that restrict the size of the potential restoration project.

6.4 Water Quality Opportunities and Constraints

The U.S. Army Corps of Engineers regulations (ER 1105-2-100) state that costs for water quality enhancement must be assigned to the appropriate project purposes and shared in the same percentages as the purposes to which the costs are assigned. This limits the opportunities for the Corps to participate in water quality improvement projects. For this reason, water quality opportunities for this study are limited to which are directly linked to existing Corps projects or that relate to other appropriate authorities for which alternatives have been considered under this study. Therefore, water quality opportunities appear to be limited to those problems caused by the detention of flood water behind Painted Rock Dam, and the potential impacts of those identified water quality problems on the other alternatives considered in this report including water conservation and environmental restoration.

Figure 11. Cottonwood-Willow habitat in an area upstream from study area. (No date).

Figure 12. Endangered Yuma Clapper Rail. Photo taken in Lower Gila River area. (No date).

CHAPTER 7

ALTERNATIVE PLANS

7. PLAN FORMULATION AND EVALUATION

7.1 Introduction

This chapter summarizes the plan formulation rationale used during the reconnaissance study to develop, evaluate, compare and select recommended alternative(s) from the array of alternatives identified.

The primary objective of Federal water and related land resource project planning is to contribute to National Economic Development in a manner consistent with protection of the Nation's environment, pursuant to national environmental statutes, applicable Executive Orders, and other Federal planning requirements.

Site visits and meetings with Federal, state, local and private agencies and groups provided key input to issues, concerns and opportunities that existed in the study area. Three public meetings were held subsequent to this visit, and additional analysis provided information for the plan formulation process.

In addition to flood control solutions, it became clear that opportunities existed for water conservation and environmental restoration. Water quality concerns also were sufficient to be included in the formulation process. The planning objectives stated in this chapter are for the relevant identified problems and opportunities. The objectives have been expressed in terms of alleviating the problems and realizing the opportunities.

Key criteria was to develop alternatives that were:

- Complete
- Effective
- Efficient
- Acceptable

7.2 Flood Control

7.2.1 Flood Control Planning Objectives

The specific planning objectives stated herein are intended for direct use in the plan formulation of alternatives considered for solutions to the identified problems. The planning objective(s) specified for flood control are as follows:

- To reduce flood related damages, in an economically justified solution, within the study area. The primary damage reduction objective would be to agriculture and to agriculture supporting infrastructure in the Wellton-Mohawk Irrigation and Drainage District.

7.2.2 Alternatives

The alternative plans considered have been formulated with respect to criteria such as hydrology, hydraulics, design considerations, economics, cost and implementation criteria. Alternative plans considered have been formulated with the intent of meeting the planning objectives while considering the identified opportunities and constraints. The potential for flood control has been considered by study reach as described in Chapter Five of this report.

Reach 1 - Gillespie Dam to Painted Rock Reservoir

No structural alternatives were formulated or analyzed for this reach of the study area. Economic analysis indicated that without project expected annual damages total only $30,600 for this reach. This amount is insufficient for economically justifying a structural solution of the size and scale anticipated to significantly reduce damages.

Reach 2 - Painted Rock Dam and Reservoir

The floods of 1993 caused some inundation damages in the reservoir area. This event was extremely rare with a maximum reservoir water surface elevation six feet over the spillway crest. The Corps has acquired real estate flowage easements up to the spillway crest elevation of 661 feet. There does not appear to be any structural solution that could be economically justified to solve the reservoir inundation problems within flowage easement lands.

Reach 3 - Painted Rock Dam to Texas Hill

This reach suffered minimal damages during the 1993 flood and a structural solution does not appear economically feasible. Maintenance repairs have been made to the Painted Rock Dam spillway to ensure its integrity in the event the emergency spillway is ever needed to be utilized in the future.

Reach 4 - Texas Hill to Dome

This reach includes the Wellton-Mohawk Irrigation and Drainage District (WMIDD). Without project expected annual damages are $869,750. This assumes the 10,000 cfs channel capacity, through the WMIDD, will be restored and in place as part of the without project condition. This without project condition is in the process of being implemented through FEMA provisions. A typical channel cross section of this without project condition through this reach is shown in Figure 13. Additional details are presented in Appendix B. The local project would include 1) channel clearing a 300-foot wide area, 2) construction of seven foot high earthen levees with rip rap armoring at critical areas, 3) approximately 20 grade control structures within the channel, and 4) an operation and maintenance program. This without project condition will effectively eliminate all damages from floods up to the 10,000 cfs design capacity of the channel/levee system. Therefore, alternatives were formulated to determine if higher levels of protection could be economically justified.

The alternatives consist of providing improvements to the restored 10,000 cfs channel/levee system in order to increase the level of protection. The alternative considered increasing the level of protection to the levee/channel system in order to pass discharges of 20,000 cfs. An increase in the levee/channel system capacity to 30,000 cfs was also considered. The improvement was developed for a 56.2 mile reach of the river between Avenue 11E and Avenue 57E. Details of the design analysis are presented in Appendix B.

Reach 5 - Dome to Yuma

Without project expected annual damages total only $8,770. This amount is not sufficient to economically justify a structural solution over such a large area. In addition, the without project condition assumes the Bureau of Reclamation will be constructing channel/levee improvements along the north side of the Gila River, between the U.S. 95 Bridge and the confluence with the Colorado River.

7.2.3 Alternative Evaluation

As discussed in Section 7.2.2, Reach 4 was the only location in the study area in which a flood control alternative was formulated. Results of analysis are presented below.

Reach 4 - Increase Channel/Levee Capacity

The alternative consisted of increasing the level of protection for the levee/channel system from 10,000 cfs to 20,000 cfs. The alternative has an estimated first cost of $34,374,500. The average annual cost is $2,750,000. The average annual expected damages through this entire reach are estimated at $869,540. If it is assumed that the benefits from the alternative eliminates all damages through this reach, the benefit to cost ratio is determined to be as follows:

Alternative Total Cost...........$34,374,500

Alternative Annual Cost..........$ 2,750,000

Alternative Annual Benefits......$ 869,540

Benefit-to-Cost Ratio........... 0.32

Based on the results of this alternative, the 30,000 cfs channel improvement alternative also did not appear to have sufficient damages to support the costs of such an improvement. The Economic Appendix (Appendix F) provides a summary of the flood damage categories.

No Action Plan

The no action plan is identical to the without project condition. The channel/levee system through the WMIDD will be restored to a 10,000 cfs capacity under FEMA provisions. Timely implementation of this project is critical to the operation/release schedule of Painted Rock Dam. Until this project is constructed, the non-damaging discharge will be limited to approximately 3,000 cfs. With this project in place, the non-damaging discharge is 10,000 cfs. This larger downstream capacity, will provide significantly greater protection for downstream areas and allows the Corps greater opportunity to carry out its mandated flood control mission in the operation of Painted Rock Dam.

Non-structural measures may include floodproofing of structures, relocation of equipment, structures, or people out of the floodplain, localized flood warning implementation, and proper implementation of floodplain regulations. No federal interest in any non-structural measures was identified during this reconnaissance study, however, a separate Corps study, the Arizona Flood Control Study, evaluated flood warning in the study area (See Section 2.1 of this report). The recommendations from that study are pending certification.

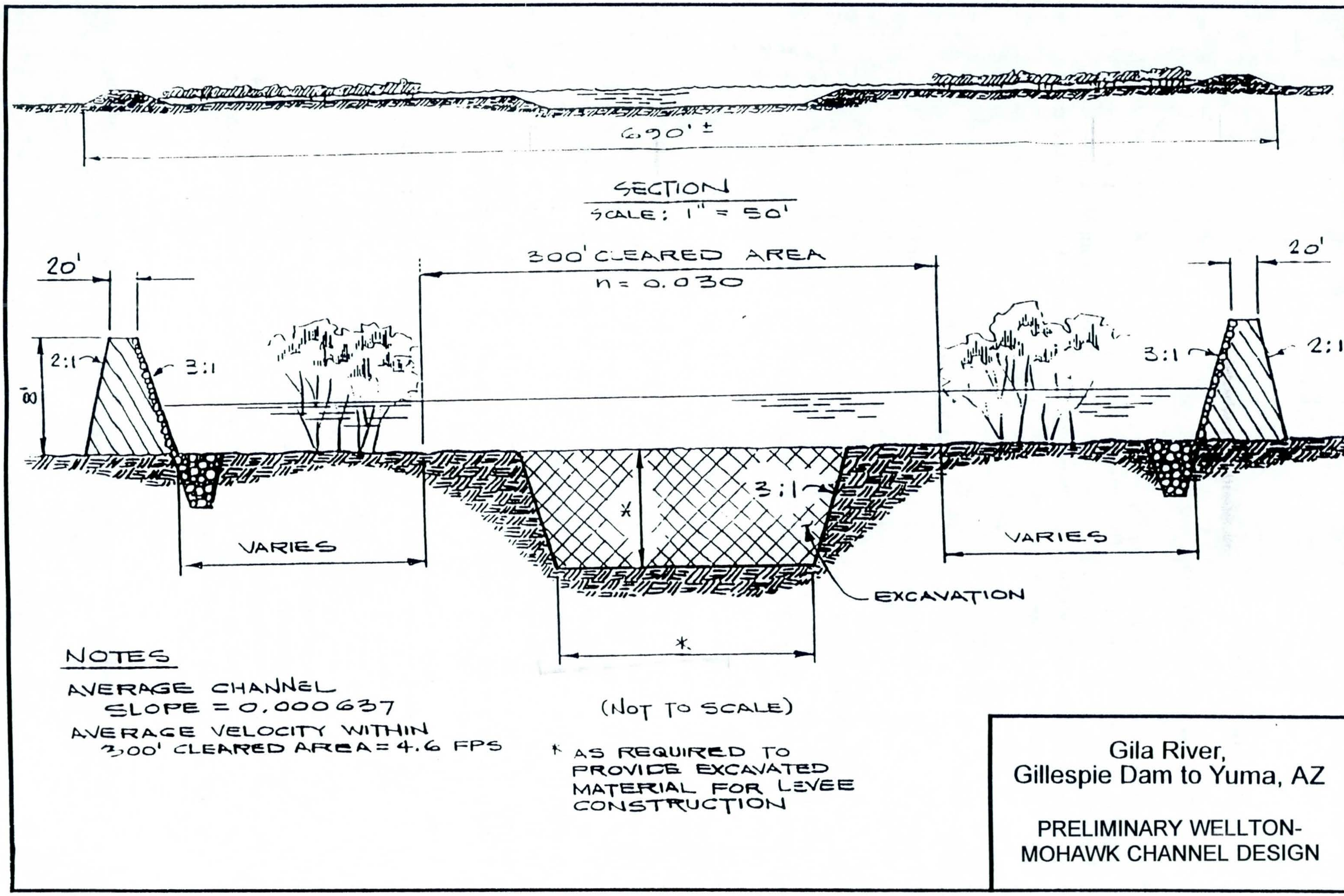

690' ±
SECTION
SCALE: 1" = 50'
300' CLEARED AREA
n = 0.030
20'
20'
2:1
3:1
3:1
2:1
8'
3:1
*
VARIES
VARIES
EXCAVATION
*
NOTES
AVERAGE CHANNEL SLOPE = 0.000637
AVERAGE VELOCITY WITHIN 300' CLEARED AREA = 4.6 FPS
(NOT TO SCALE)
* AS REQUIRED TO PROVIDE EXCAVATED MATERIAL FOR LEVEE CONSTRUCTION
Gila River,
Gillespie Dam to Yuma, AZ
PRELIMINARY WELLTON-MOHAWK CHANNEL DESIGN

FIGURE 13

7.3 Water Conservation

7.3.1 Water Conservation Planning Objectives

The water conservation objective in this study effort is to add a water supply purpose to Painted Rock Dam. The intent of this objective would be to increase the beneficial use of releases from Painted Rock Dam, for water supply purposes downstream, including the Colorado River system, while continuing to operate the dam for its currently authorized purpose of flood control.

7.3.2 Alternatives

Two water conservation alternatives at Painted Rock Dam have been considered as part of this reconnaissance study. Due to the identified planning constraints associated with identifying a specific service area and non-Federal sponsor, the alternatives have been formulated with the intent of providing additional water for the lower Colorado River system. The additional water could be allocated under the rules of the existing legal framework that exists for the lower Colorado River system.

The formulated alternatives involve adding a seasonal water conservation storage with outflow to downstream users along the Gila River or to the Colorado River. The intent of the seasonal water supply pool is to retain floodwater after the threat of flooding has diminished. For this report, the analysis assumes that seasonal joint use (water conservation and flood control) begins on March 1st and extends through November of each year. The remainder of the year is the historical flood season in which operation for the single purpose of flood control is given priority. No seasonal water is assumed to be carried over in the reservoir to the next flood season, therefore, the reservoir is assumed to be nearly empty on December 1st of every year. More specific details are presented in the Hydrology Appendix (Appendix A).

The alternatives are intended to represent two extremely different, but reasonable scenarios in considering the possibility of utilizing Painted Rock Dam as an integral element of a water supply system. The analyses results in the determination of how much surplus water remains in the reservoir, that could potentially be utilized downstream, after the flood season has passed each year. This surplus or excess water is then assumed to be delivered downstream, during the non-flood season, to more efficiently satisfy downstream water demands. In either alternative, the excess water is assumed to supply or replace water needs that are currently being supplied by Colorado River water.

The quantity of excess water made available by seasonal storage, beyond the incidental yield resulting from flood control releases, is defined in this study as "water yield". Therefore, it is critical to this analysis that a baseline flood control release operation be definitized. The baseline flood control operation is the assumed operation of Painted Rock Dam, for its authorized single purpose of flood control, with downstream channel improvements in place which provide a minimum channel capacity of 10,000 cfs. The assumed baseline flood control (without project condition) for the water conservation analysis is presented in Table 4. The base conditions presented in Table 4 is representative of Painted Rock Dam with the established without project conditions, and considered to provide the most flood protection for downstream interests. This release schedule is generally reflective of the 1993 flood operation of Painted Rock Dam and consists of a staged increase in reservoir releases to a non-damaging discharge. This was used as the baseline condition for computation of water yield, specifically in determining incidental yield realized by this baseline condition.

The average annual yield is the average yield for each alternative calculated over the period of simulation divided by the number of years in that period (35 years). The water yielded, by the Painted Rock Dam water conservation alternatives, is assumed to result in additional water that could be stored in facilities on the mainstem lower Colorado River. These facilities such as Imperial Dam and Parker Dam, would allow the additional yielded water to replace Colorado River water, increase storage, and be used at a later time. In addition, the lower Colorado River diversion projects, could provide for a wider distribution of water users and uses that could benefit from any additional water to the system. The major water projects on the lower Colorado River are shown in Figure 14.

Alternative 1 - Seasonal Storage

This alternative was formulated with the intent of providing a constant release of 500 cfs from Painted Rock Dam for downstream use, during the non-flood season. This water might be diverted from the Gila River by Arizona water users such as the WMIDD, or possibly delivered to Mexico, in partial satisfaction of Minute No. 242, while not adversely impacting groundwater problems through the WMIDD. This alternative provides 371,000 acre-feet of seasonal water conservation storage, up to elevation 598 feet, starting on March 1st. This space could then be utilized for water conservation storage or releases during the non-flood season, when waters are available. Yields for this alternative have been determined based on historical runoff and storage data over the 35 year period of record since the dam was completed. Based on the simulation of the without project operation, there would have been significant water behind Painted Rock Dam, on March 1st or afterwards, seven times over this 35 year period. The seasonal water control plan for this alternative is presented in Table 5. Under this alternative, the average annual yield is 27,500 acre-feet.

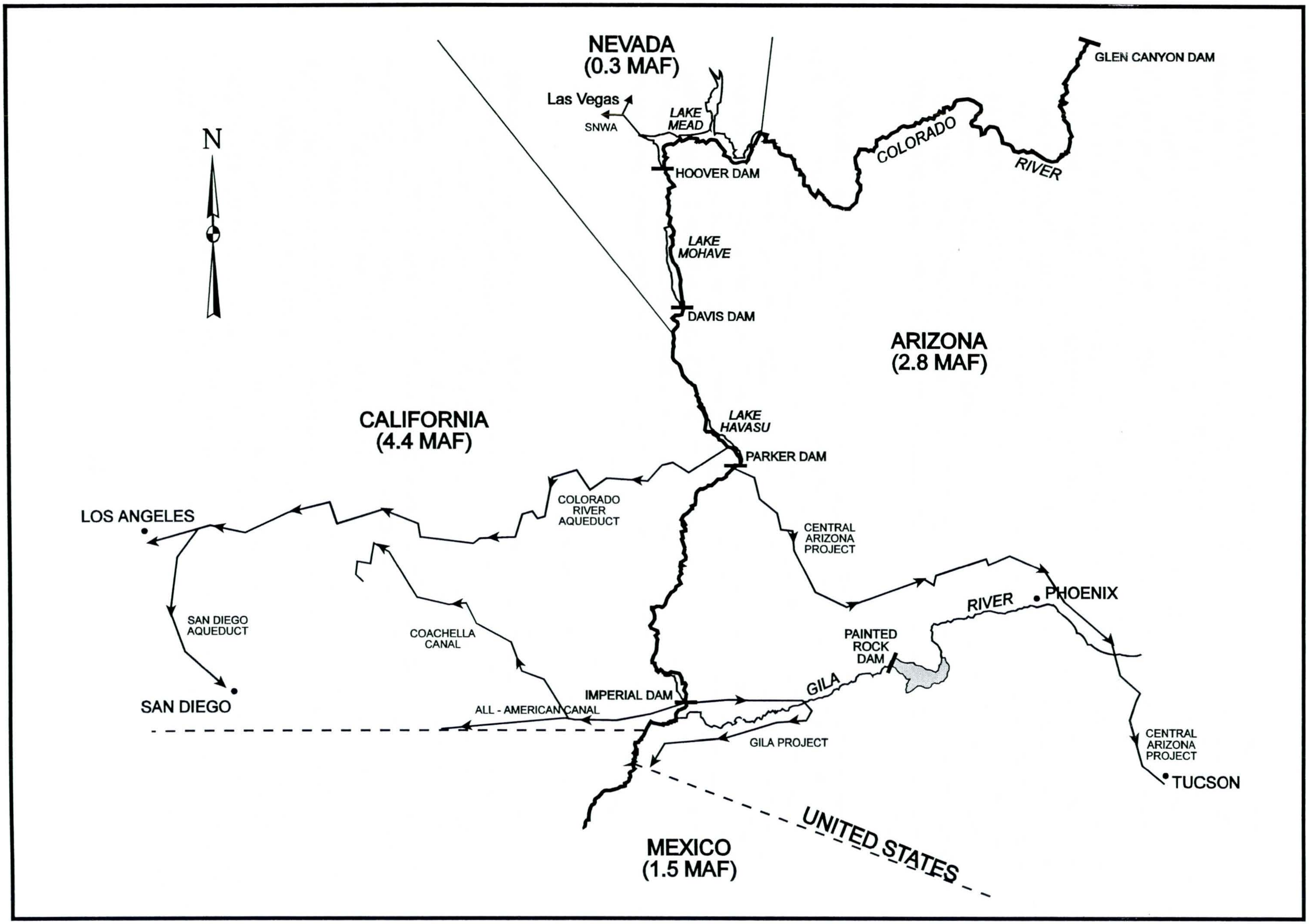


FIGURE 14 LOWER COLORADO RIVER WATER SUPPLY PROJECTS

TABLE 4 Painted Rock Dam Baseline Condition for Flood Control Operation		
Elevation (Ft NGVD)	W/O Project Discharge (cfs)	Comment
530	0	Invert Elevation
532	0	Gates Open 0.5 ft.
550	0	Top of Debris Pool
550.1	2,500	Begin Flood Pool
591	2,500	End Step 1 Release
591.1	5,000	Begin Step 2
603	5,000	End Step 2 Release
603.1	10,000	Begin Step 3
661	10,000	Spillway Crest
664.4	10,000	All Gates Closed
666	20,000	Spillway Flow Only
667.6	30,000	Spillway Flow Only
676	108,000	Spillway Flow Only
690	298,000	Spillway Flow Only
705	564,000	Top of Dam

Alternative 2 - Seasonal Matching

This alternative is based on releases from Painted Rock Dam intended to match the historical average monthly deliveries of water to Mexico after March 1st. This alternative provides 1,265,000 acre-feet of allocated storage space for water conservation up to elevation 634 ft in Painted Rock Dam starting on March 1st. Water would be released to more efficiently match Mexico's delivery schedule, when flood waters are available to do so. The release rate has been established to vary between 1,115 and 2,872 cfs, during the non-flood season, as required to match Mexico's historical monthly demand schedule. The seasonal water control plan for this alternative is presented in Table 5. Under this alternative, the average annual yield is 47,900 acre-feet.

7.3.3 Alternative Evaluation

Water Conservation Assumptions and Results:

- Results are based upon the additional yielded water being incorporated with Colorado River system water.

- There is no evidence that in the more than 100-year record of the Gila River basin that flood control will be compromised by a seasonal water supply operation as assumed in either of these two alternatives. Based upon the historical record, implementation of the alternative does not appear to increase the frequency or duration of damaging releases from Painted Rock Dam.

- Gila River water is generally of higher quality and less salinity than Colorado River water. An exception to this is the last water released from Painted Rock Dam after large flood storage. As a result, it has been assumed that the last 30,000 acre-feet of water in Painted Rock Dam is not useable due to historic observations of poor quality in this range. This amount is not included in the yield calculations.

- Water losses have been included in the analysis for evaporation from the reservoir area only. Downstream channel losses have not been included in this analysis. Additional losses could be accounted for by modifying the seasonal rule curve to permit additional seasonal storage as required to realize the demand, including losses, whenever sufficient water is available to do so.

Water Conservation Alternative Costs:

Each alternative has an estimated annual cost of $24,500 for operation and maintenance. This cost is based on two components. The first component is additional labor costs which have been estimated in administration and operating Painted Rock Dam for water conservation for each event in which significant water is available. The second cost component consists of maintenance costs to the dam itself. A summary of these estimated annual costs is presented in Table 6.

Quantifiable first costs include the real estate acquisition costs to purchase lands in the seasonal storage pool for each of the alternatives that is not currently in fee title by the government. The seasonal storage alternative (Elevation 598 feet) has total estimated identifiable real estate acquisition cost of $1,860,000, or on an annual basis, $144,200. Including operation and maintenance, the total annual cost for the seasonal storage alternative is $168,700. The seasonal matching alternative (Elevation 634 feet) has total estimated identifiable real estate acquisition costs of $5,600,000, or $434,200 annually. Including operation and maintenance costs, the total annual costs for the seasonal matching alternative is $458,700. Adequate

TABLE 5 Monthly Seasonal Water Control Plan for Painted Rock Dam Water Supply Alternatives

MONTH	RULE CURVE DEVELOPMENT						
	EVAPORATION inches	SEASONAL STORAGE Demand = 500 ft^3/s			SEASONAL MATCHING Demand = NIB		
		Starting Storage ac-ft	Elevation ft,NGVD	Demand ft^3/s	Starting Storage ac-ft	Elevation ft,NGVD	Demand ft^3/s
JANUARY	2.11	3515	550.0	0	3515	550.0	0
FEBRUARY	3.09	3515	550.0	0	3515	550.0	0
MARCH	4.96	371,000	598.3	500	1,265,000	633.5	2666
APRIL	7.42	334,000	596.1	500	1,082,000	628.0	2872
MAY	10.05	300,000	593.5	500	899,000	622.0	1592
JUNE	12.26	255,000	590.5	500	778,000	617.5	2343
JULY	11.52	213,000	587.2	500	614,000	610.8	2508
AUGUST	10.53	170,000	583.6	500	441,000	602.3	2470
SEPTEMBER	8.53	131,000	579.6	500	276,000	592.2	1574
OCTOBER	5.66	95,000	575.4	500	174,000	584.2	1115
NOVEMBER	3.23	61,000	570.3	500	101,000	576.3	1163
DECEMBER	2.04	30,000	563.0	500	31,000	563.3	500

Notes:
1) Evaporation represents net evaporation, i.e. evaporation minus precipitation; source:LAD Reservoir Regulation Section
2) Storage of 3515 ac-ft (elevation=550) is buffer pool
3) Elevations are rounded to nearest tenth of a foot
4) Seepage unaccounted for
5) Channel losses=0
6) Whenever seasonal storage allocations/elevations described by this rule curve are exceeded, the regulation plan reverts to the flood control release schedule presented in table 8 as the without project water control plan.

capability has been assumed to be available in existing distribution systems along the Colorado River. These would include systems such as the Colorado River Aqueduct, All American Canal, and the Central Arizona Project canal.

Benefits:

Benefits have been estimated to be the value of the additional yielded water. This assumes that water released from Painted Rock Dam on the Gila River is directly interchangeable with Colorado River water for the same uses. Based on historical occurrences to date, the expected return interval for water conservation is seven times in 34 years (a 20.5% chance event per year). The value of the yielded water is assumed to range from $50 per acre-foot for irrigation water to $200 per acre-foot for municipal and industrial water. The costs are assumed to include any pumping and transportation costs, and infrastructure required. The M&I rate is based on the typical surplus water rate for the Metropolitan Water District (MWD), and represents the resource cost of the water to MWD's service area including power purchased from the Bureau of Reclamation. A specific identification of water use was not performed during this reconnaissance study. Therefore, benefit calculations assume a mid-range value of irrigation and municipal/industrial water provided. The resulting value of the water used in this analysis is $125 per acre foot. The net benefits and the benefit-to-cost ratios for the two alternatives are presented below.

Alternative 1 - Seasonal Storage

Benefit-to-Cost Ratio	20.4 to 1
Net Benefits	$3,268,800

Alternative 2 - Seasonal Matching

Benefit-to-Cost Ratio	13.1 to 1
Net Benefits	$5,528,800

Additional details of the economic analysis for water conservation are presented in the Economic Appendix (Appendix F).

No Action Plan:

Under the no action plan, this valuable water resource would not be formally developed. The Corp's single purpose flood control operation of Painted Rock Dam would not take advantage of the opportunity to provide this additional water supply to benefit the nation and the region. It is anticipated that reasonable future demands will be placed upon the Corp's to operate Painted Rock Dam to help solve the identified water supply and salinity problems. The current Painted Rock Dam authority will inhibit the Corp's ability to comply with these requests unless a new authority is obtained which will add water conservation to the existing flood control authority. This will allow the Corps to operate the dam in a more efficient multipurpose manner.

TABLE 6

Estimated Costs for Water Supply Alternatives

With Project Operations & Maintenance: The costs presented have been estimated to be separable from flood control O&M costs and applicable for water conservation only. The costs shown below are for each occurrence. The occurrence interval is assumed to be seven out of 34 years. Costs are estimated at 1994 values.

Water Conservation Operation Labor Costs			
Reservoir Regulation	Manhours	Cost	Total
Supervisory & Admin.	80 Hrs	$80/Hr	$ 6,400
Technical & Field Personnel	300 Hrs	$50/Hr	$15,000
Operations			
Supervisory & Admin.	40 Hrs	$80/Hr	$ 3,200
Technical & Field	320 Hrs	$40/Hr	$12,800
Water Conservation Maintenance Costs			
Dam Costs (Benching, Stone,Gate/Outlet)	1 Job	L/S	$25,000
D/S Channel Maintenance	1 Job	L/S	$25,000
TOTAL WATER CONSERVATION O&M COSTS PER OCCURRENCE			$87,400
ANNUAL WATER CONSERVATION O&M COST			$24,500
Real Estate Costs			
Seasonal Storage Real Estate Acquisition Cost			$1,860,000
Seasonal Storage Real Estate Annual Cost			$ 144,200
Seasonal Matching Real Estate Acquisition Cost			$5,600,000
Seasonal Matching Real Estate Annual Cost			$ 434,200

7.4 Environmental Restoration

7.4.1 Environmental Planning Objectives

The general objective of environmental restoration in the study area is to restore the habitat and its environmental functions and values along the lower Gila River between Painted Rock Dam and the Colorado River towards a more natural state. Specific objectives are as follows:

Preserve and maintain new riparian habitat which was created by the 1993 flood events,

Restore riparian habitat in appropriate areas, and

Provide a corridor of riparian habitat along the lower Gila River from Painted Rock Dam to Yuma, Arizona.

Riparian habitat along the lower Gila River is defined as consisting primarily of three vegetative community types: Cottonwood-Willow, Leguminous short trees (Mesquite), and Wetland-marsh. Alternatives are formulated to include an appropriate mix of vegetative types dependent upon the area under consideration.

7.4.2 Alternatives

Alternative Development Criteria

With respect to the identified opportunities and constraints, the alternatives were considered with respect to the following:

- Require minimal development of new sources of water
- Be compatible with existing soil conditions
- Be compatible with existing land ownership and uses
- Be relatively low cost to implement and relatively simple to maintain,
- Be sustainable over the long term, either through natural processes or through maintenance,
- Provide environmental outputs closer to modern historic conditions.

Alternatives Considered

Several approaches to restoration alternatives were considered and screened according to the criteria in Section 7.4.2.1 above. A brief description of these alternatives follows.

Corridor Approach: This alternative consists of a distributed restoration approach, wherein numerous areas downstream of Painted Rock Dam were evaluated for mixed habitat creation, augmentation which would lead to additional habitat growth, and connection with one another by the ability of wildlife to move between these areas. A distributed site location corridor approach increases the combined outputs such that higher efficiency and greater benefits could be achieved. The corridor consists of the entire reach of the Gila River below Painted Rock Dam.

Stand Alone Areas: Another alternative consisted of evaluating areas for separate stand alone projects, potentially under the Section 1135 small projects authority.

Upstream of Painted Rock Dam: The area upstream of Painted Rock was considered for environmental restoration in two distinct areas. The first area considered was from Gillespie Dam to the upstream end of the Painted Rock Dam reservoir. The reservoir area itself was also considered for environmental restoration potential.

Alter Painted Rock Dam Operation: This alternative was strictly composed of altering the operations of Painted Rock Dam to be more compatible with native vegetation needs and a return to a more natural hydrologic condition downstream of the dam.

Off Stream Storage: Another alternative was offstream storage potential at Agua Caliente. The alternative calls for the creation of offstream diversion and storage basins which would recharge the aquifer to enhance survivability of the existing vegetation, including the relic mesquite stands.

No Action: A No Action alternative is discussed below.

Alternative Screening

Corridor Approach: With the distributed restoration approach, environmental outputs from all of the components, if implemented, would be enhanced through multiplier, synergistic type of effects. This alternative best met the overall criteria and planning objectives. This alternative additionally addresses restoration more from an ecosystem and watershed perspective, consistent with emerging Corps policy. For these reasons, this alternative was selected for further evaluation and analysis under this reconnaissance study. Details and evaluation of this alternative are presented in Section 7.4.2.4 and 7.4.3 of the report.

Stand Alone Areas: Numerous opportunities exist, however, the result would be piecemeal solutions to an overall river ecosystem problem. Increases in the environmental outputs are greater with a broad based ecosystem approach, additionally, it is expected that there will always be a potential for isolated projects in numerous areas along the lower Gila. Pursuit of multiple, separate stand alone alternatives would not be as efficient or effective as the broad based approach.

Upstream of Painted Rock Dam: Riparian habitat already exists in much of this upstream area from Gillespie Dam to the Painted Rock reservoir area. The opportunity for restoration is less in this area than that in the more damaged areas downstream from Painted Rock Dam. The increase in environmental outputs relative to the cost was qualitatively judged less than could be developed downstream of the dam. Although the potential for future study should not be dismissed, restoration in this area was not evaluated any further in order to focus on more serious problem areas downstream of Painted Rock Dam.

In addition, the Corps has previously pursued environmental restoration within the reservoir inundation pool. Alternatives in this area would have high operation and maintenance (groundwater pumping) costs to provide a needed source of outside water. Since the alternative criteria calls for minimal development of outside water sources, and it is anticipated that a significant outside source of water would again need to be developed for this area, no reservoir alternatives were carried forward for this reconnaissance study.

Alter Painted Rock Dam Operation: The authorized purpose of Painted Rock Dam for flood control constrains any significant changes in the operation and release schedule. Therefore, this alternative was not carried forward for further analysis. In addition, it was determined that minor operational changes alone might not ensure development and survivability of habitat below the dam. Efforts to replace or create habitat would still be required. Releases from Painted Rock Dam may provide a complementary, but not a sole, source of water for other downstream alternatives.

Off Stream Storage: This alternative was formulated to enhance the environmental quality and wildlife habitat of the Agua Caliente area. The alternative allows recharge of the groundwater, upstream of the Agua Caliente crossing. This alternative will create riparian, wetlands, and open water habitat. Flood flows will be directed to extend into the riparian areas. This alternative was eventually incorporated as a component of the corridor approach.

No Action Alternative: The No Action alternative would result in an approximately 70% die-off rate of the emergent habitat created by the 1993 floods, and would result in the continued degradation of habitat along the lower Gila River (Also see Section 5.4.2, Without Project Problem Identification). Additionally, no action precludes the opportunities associated with restorative measures that could be taken in other areas. The floods of 1993 have created a unique opportunity for riparian habitat restoration along the lower Gila River. Considering the high value of rare riparian habitat in Southwestern Arizona, the No Action alternative was not considered further in this reconnaissance study.

Selected Alternative

One purpose of reconnaissance level investigations is to determine if at least one alternative warrants the federal interest. The corridor restoration approach alternative meets this criteria.

The corridor alternative would restore habitat in key component areas existing along a corridor downstream of Painted Rock Dam. A water source for the riparian habitat is provided by the existing groundwater table in selected areas, and development of a minimal water source in other areas. Existing wells and periodic floodflows can be utilized to augment the water availability. The restored areas would provide key components of migratory habitat, including open water and emergent riparian vegetation. The areas would be used as a resting site and wintering habitat for migratory waterfowl including ducks and geese, and as habitat for wildlife and listed and proposed threatened & endangered species (Figure 15).

The corridor restoration alternative consists of several key components. Each component is a part of an overall corridor approach wherein the combined environmental outputs exceed the environmental outputs of the individual components.

Within each component area, appropriate restoration strategies were selected to provide long term increases in environmental values based upon the experience and professional judgement of members of the technical team. Restoration strategies are discussed in detail in Appendix G, Environmental Restoration, and are briefly described below for the corridor component areas.

Dendora Valley Component

The Dendora Valley is located downstream from Painted Rock Dam (Figure 16), and contains critical habitat for the Federally listed threatened and endangered Yuma Clapper Rail. The restoration plan would include land acquisition, potentially at no cost through letters of agreement with other agencies in regard to land owned by those agencies. Restoration strategies developed for the Dendora Valley are as follows:

(1) Preservation of Existing Native Riparian Vegetation: The area currently contains approximately 240 acres of mesquite habitat, considered a critical component of riparian ecosystems. The long term trend is for the mesquite communities to eventually be overtaken by exotic salt cedar. Without project conditions estimate a projected decrease of 20% of this habitat. An additional 85 acres of 1993 flood created wetland-marsh habitat is also at long term risk, with a projected die-off rate of 70%.

(2) Revegetation with Native Riparian Species: The area directly downstream of Painted Rock Dam in the Dendora Valley and Agua Caliente areas, historically supported about 1300 acres of cottonwood-willow, and 5700 acres of mesquite. Based upon the presence of Painted Rock Dam and other factors, it is estimated that in addition to the existing habitat described above, an additional 50 acres of sustainable cottonwood-willow, an additional 500 acres of mesquite, and an additional 200 acres of marsh-willow habitat could be restored through the combination of measures proposed.

(3) Removal of Saltcedar: Approximately 750 acres of initial and then periodic saltcedar removal would be needed to allow the natural growth and maturing of native riparian communities to a point that they could outcompete the saltcedar over the long term.

(4) Alteration of Channel Form: Consists of deepening of side swales to create an incoming channel and construction of temporary off channel berms to back water up to create marsh/wetland conditions when water is present. Earthwork would be located and performed to minimize destructive effects of future floods while maximizing the potential for water to reach vegetative communities.

(5) Creation of Open Water Sites through Excavation: In conjunction with altering the channel form, some areas would be excavated further to create areas of shallow (<1 ft.) open water. This strategy would be dependent upon an available, albeit minimal, source of water.

(6) Allow the River to Seek its own Path: This strategy recognizes the dynamic nature of the river system and is incorporated into the above measures to enhance the potential for long term survivability by allowing a more natural hydrologic and geomorphologic state to prevail over the long term.

(7) Alteration of Painted Rock Dam Releases: The Dendora Valley area is directly downstream of Painted Rock Dam. Large releases during late March to early

April could coincide with seed dissemination of native riparian species, allowing seeds from the restoration projects to be spread downstream to other areas.

Agua Caliente Offstream Storage Component

The Agua Caliente offstream storage/recharge alternative was incorporated as a key component connected area into the corridor approach (Figure 17).

The area around Agua Caliente has historically been an area of native vegetation with areas of agriculture occurring adjacent to the north-south transportation routes. The prime areas of agriculture have been at the Agua Caliente crossing where extensive citrus orchards had been cultivated on the bluffs overlooking the Gila River. The irrigation practices that were employed for these orchards (now diminished) caused a rising in the groundwater table, which allowed extensive areas of riparian habitat, including mesquite bosque, to grow and survive the otherwise adverse impacts that upstream dams have had in changing the hydrologic regime of the river. The alternative calls for the creation of offstream storage basins which would recharge the aquifer to enhance the existing vegetation, including the relic mesquite stands, and potentially enable the local farmers to draw water from shallower depths than currently available. The restoration strategies developed for the Agua Caliente area are as follows:

(1) Preservation of Existing Native Riparian Vegetation: The Agua Caliente area currently contains approximately 930 acres of mesquite habitat, 190 acres of cottonwood-willow, and 158 acres of marsh-wetland. The long term trend is for the continued degradation of these habitats and conversion of many areas to saltcedar. Measures to allow this existing native riparian vegetation to survive is considered a critical aspect of any restoration project in the area.

(2) Revegetation with Native Riparian Species: The area directly downstream of Painted Rock Dam in the Dendora Valley and Agua Caliente areas, historically supported about 1300 acres of cottonwood-willow, and 5700 acres of mesquite. In the Agua Caliente area, active revegetation strategies are estimated to restore, in addition to the existing habitat described above, an additional 300 acres of mesquite, an additional 40 acres of critical cottonwood-willow, and an additional 100 acres of marsh-wetland, through the combination of measures proposed.

(3) Removal of Saltcedar: Approximately 340 acres of initial and then periodic saltcedar removal would be needed to allow the natural growth and maturing of native riparian communities to a point that they could outcompete the saltcedar over the long term.

(4) Alteration of Channel Form: This measure involves excavation of offstream areas, and diversion of floodflows and possibly irrigation return flows through the

areas which would retain the water behind constructed berms for more extended periods of time to allow the groundwater table in the area to rise (the currently estimated depth to groundwater is 35 feet). During the times when water would be in these areas, an ephemeral open water condition would prevail, which would support the cottonwood-willow and marsh-wetland vegetative communities.

(5) Allow the River to Seek its own Path: This strategy would be incorporated into the above measures to the degree practicable to allow a more natural hydrologic and geomorphologic state to prevail over the long term.

(6) Alter Painted Rock Dam Releases: Large releases during late March to early April could be beneficial to providing an enhanced ability for propagation of riparian communities.

U.S. Bureau of Land Management Lands

Proceeding downstream from the Dendora Valley and Agua Caliente areas, are large parcels of land owned/managed by the U.S. Bureau of Land Management (BLM) (Figure 17). Riparian habitat restoration in these areas would be in accord with agency objectives and has received strong support from that agency. The agency expects to be fully able under existing authority to set aside lands for any restoration project which the Corps of Engineers would pursue. BLM lands help to form the connected corridor of riparian habitat along the lower Gila River. Restoration strategies developed for this area consist of the following:

(1) Preservation of Existing Native Riparian Vegetation: The area currently supports approximately 1725 acres of mesquite-type habitat, about 100 acres of cottonwood-willow (1993 flood-created), and about 50 acres of marsh-wetland habitat (1993 flood-created). Preservation of these unique areas is critical to maintaining riparian environmental values along the lower Gila River corridor.

(2) Revegetation with Native Riparian Species: The BLM lands historically supported an estimated 1540 acres of mesquite, 600 acres of cottonwood-willow, and 400 acres of wetland-marsh type habitats. In addition to preserving the existing and flood-created communities as described above, restoration strategies are estimated to result in an additional 300 acres of mesquite, an additional 40 acres of critical cottonwood-willow, and an additional 75 acres of marsh-wetland.

It is noted that restoration strategies are not designed to exactly reproduce the modern historic conditions (acreages), but instead are intended to shift total of the riparian habitat functions and values toward a more natural state than which currently exists, based upon an existing (non-historic) hydrologic regime.

(3) Removal of Saltcedar: Approximately 340 acres of initial and then periodic saltcedar removal would be needed to allow the natural growth and maturing of native riparian communities to a point that they could outcompete the saltcedar over the long term.

(4) Allowing the River to Seek its own Path: In the BLM area, maximum advantage would be taken of this strategy. Riparian preservation and revegetation efforts would take into account the full floodplain width and geomorphological terraces upon which the riparian vegetation resides. No alteration to the channel form or other constructive measures would be taken.

(5) Alteration of Painted Rock Dam Releases: This strategy would be incorporated, in conjunction with the other strategies above, as appropriate within the authorized flood control purpose.

Wellton Mohawk Irrigation & Drainage District Component

The Wellton-Mohawk Irrigation and Drainage District (WMIDD) is a State entity comprising approximately 60,000 acres of Colorado-River-water-irrigated farmland producing a gross of over $100 million per year as a result of an approximate total $500 million investment by the federal government since its inception, primarily from the U.S. Bureau of Reclamation.

In the interest of Environmental Restoration, the area is unique due to the availability of a potentially substantial source of water from irrigation return flows and from groundwater pumping which is required to keep the water table and associated soil saline level low. The waste water is returned to the Gila/Colorado system. In this area, flows in the Gila River are near-perennial due to these factors.

During the 1993 flood events, the WMIDD suffered extensive damages to their protective levee system which had been under construction since 1986. Current proposals for rehabilitation of the levees, under FEMA provisions, include mitigation proposals on lands owned by the WMIDD. The restoration strategies developed for the area are additional to and beyond currently proposed levee rehabilitation mitigation proposals.

It is noted that at this time, for the purposes of this reconnaissance study, no proposed WMIDD mitigation is included in the without project condition due to the currently indeterminate nature of both the levee rehabilitation and associated mitigation. In the event that any mitigation is performed or agreed to prior to the conclusion of any Corps Environmental Restoration Feasibility Study, then that specific mitigation would be incorporated into the without project conditions of any such feasibility study.

Restoration strategies developed for the WMIDD Valley are as follows:

(1) Preservation of Existing Native Riparian Vegetation: The WMIDD Valley currently supports an estimated 2743 acres of mesquite, 2000 acres of critical cottonwood-willow (majority 1993 flood-created), and nearly 1100 acres of marsh-wetland habitat (majority 1993 flood-created). These resources are very significant in light of the rarity of native riparian communities along the lower Gila River, and measures to prevent their eventual degradation are considered a critical component to any environmental restoration project.

(2) Revegetation with Native Riparian Species: Restoration strategies for the WMIDD Valley are estimated to restore (in addition to the existing riparian habitat, much of which was created by the 1993 flood events but which is not currently sustainable over the long term) an additional 100 acres of mesquite, an additional 100 acres of critical cottonwood-willow, and an additional 400 acres of wetland-marsh habitats.

The area historically supported an estimated 845 acres of cottonwood-willow, 12,000 acres of mesquite, and 400 acres of wetland-marsh riparian habitats. It is noted that restoration strategies are not designed to exactly reproduce the modern historic conditions (acreages), but instead are intended to shift the total of riparian habitat functions and values toward a more natural state than which currently exists, based upon an existing (non-historic) hydrologic regime.

(3) Removal of Saltcedar: Approximately 200 acres of initial and then periodic saltcedar removal would be needed to allow the natural growth and maturing of native riparian communities to a point that they could outcompete the saltcedar over the long term.

(4) Periodic Flooding of Dedicated Agricultural Fields: Many fields were taken out of production after being damaged by the floods of 1993, and are currently experiencing the emergence of native riparian, especially cottonwood-willow, vegetation. Irrigation supply canals already exist to these lands. Periodic flooding of such areas could result in the continued survival of the riparian species, and additional native riparian vegetation could also provided.

(5) Rehabilitating Dedicated Farmlands

The donation or provision by a local sponsor of recently abandoned farmlands is also a component area for the restoration of Cottonwood/Willow habitat along the Gila. These farmlands became abandoned after the 1993 flood when the farmers determined that damages to their fields were such that they were not economically repairable. This component would also allow for the planting of native grains.

(6) Enhance Oxbows and Sloughs: This component takes advantage of the impact of the 1993 flood on the WMIDD levees. This would call for the selective removal of salt cedar, the lowering of the current river channel portion of the oxbow to approach or be below the existing groundwater level, and the planting of Cottonwood, Willow, and potentially Mesquite trees on appropriate terraces, which are prime habitat for the Threatened & Endangered proposed Federally listed Southwestern Fly catcher, and other species (Figure 18). These areas would be protected from future floods by the WMIDD proposed levee rehabilitation project.

(7) Create Open Water Spaces through Excavation: This strategy would be incorporated within the above strategies in appropriate areas to provide excavated areas down to shallow groundwater suitable for marsh type conditions in low lying areas to complement and enhance the environmental diversity of all riparian restoration strategies.

7.4.3 Evaluation of the Selected Alternative

Federal Interest and Linkage to Existing Corps Project

"The Federal Interest in environmental quality is supported in law, Executive Order, and treaty. A number of these general statements declare it National Policy that full consideration be given to the opportunities which projects afford to ecological resources. In addition, authorities for new individual studies and projects to restore ecological resources, as well as regional restoration programs, have been provided in legislation, which collectively demonstrate Federal interest. For the Corps Civil Works Program, the Federal interest in the quality of environmental resources is broadly supported by legislation.......Sections 306 and 307 of WRDA 90 support the Corps pursuit of opportunities to protect and restore existing ecological resources and their values in conjunction with planning for new projects and in the operation of existing projects, within the limits expressed elsewhere in law and administration policy". (Paraphrased from Draft EC 1105-2-206, pp. 5, 7 March 94).

The areas selected for environmental restoration are directly downstream and are affected and impacted by the Corps owned and operated Painted Rock flood control Dam. Therefore, environmental restoration along the lower Gila River warrants the Federal Interest.

NED Benefits

Monetary benefits attributable to the recommended plan exist and should be evaluated during the feasibility phase. For the purposes of this reconnaissance study, consistent with prior guidance, the benefits are at least considered equal to the costs.

Habitat Analysis

An assessment was performed for riparian habitat in the lower Gila River Corridor. The assessment evaluated the acreages and estimated habitat units for appropriate riparian habitat components in the Southwestern Sonoran Desert area of the United States based upon accepted methodologies and performed by personnel with professional experience with Arizona riparian ecosystems analysis.

A complete description of the habitat analysis conducted for this study is included in as Appendix G, Environmental Restoration. The analysis estimated modern historic conditions, existing conditions, future without project conditions, and future with project conditions assuming all of the restoration strategies described above are implemented. Table 7, Environmental Restoration Evaluation, summarizes the material contained in the technical appendix, and displays the difference between the future without and future with project conditions, both in terms of acreage and habitat units.

The selected alternative is estimated to result in an increase of approximately 7000 riparian acres and 5000 riparian habitat units based upon the strategies selected and analysis methodology. **No comparison can be made between habitat units in the Southwest Sonoran Desert and elsewhere in the U.S.** However, the restoration strategies proposed would result in a 32% acreage increase of all riparian vegetative community types, and an over 500% increase in the wetland-marsh component. Due to the rare nature of riparian, and especially wetland-marsh, in the southwestern United States, these increases are more valuable and significant than habitat values elsewhere. See Table 7 for a complete summary breakdown of the habitat analysis and evaluation.

Cost Estimate

A cost estimate was developed for the restoration strategies proposed for the lower Gila River. The cost estimate was based upon extensive previous experience by others in environmental restoration projects similar to those proposed. In particular, the local sponsor, the Arizona Game and Fish Department, has experience with these types of projects, and additionally, cost data was obtained from a variety of other sources, including the Corps of Engineers Los Angeles District.

The costs presented reflect the cost of restoration measures based upon the types of restoration in the identified component areas, the estimated costs of operation and maintenance (monitoring and periodic saltcedar removal), and valuation of the lands upon which the restoration would be performed (see Real Estate Memorandum in Appendix G, Environmental Restoration, Cost Estimate Addendum).

The total cost of the proposed environmental restoration alternative includes an initial period for maintenance, monitoring, and salt cedar control until the riparian vegetation becomes self sustaining. Also included within the costs are estimated total costs per acre for provision of a water source where required. The total project cost is estimated to be $26,748,839. The average annual cost, based upon a 50 year project life and 7-3/4% interest rate is $2,123,900.

Cost Effectiveness Analysis

Cost Effectiveness is based upon the assumption that once environmental values are established, they remain, continuing to provide the benefits (habitat units). The benefits result from the habitat units which accrue after the initial establishment period of approximately 5 years. The cost effectiveness is expressed in terms of annual cost compared to the annual increase in habitat units.

Based upon an estimated annual average cost of $2,123,900 and an average annual net habitat unit increase of 3569, the aggregate average annual cost per annual habitat unit provided is approximately $595. Based upon total increased riparian habitat units of approximately 5000, the average annual cost per riparian habitat unit is $425. Based upon a net increase of 7000 riparian acres, the average annual cost per riparian acre is $303. Evaluation of the additional outputs of the combined components into the corridor approach to provide future germination and dispersement potential should be evaluated during the feasibility phase. See Table 8 for a display of cost effectiveness, and Appendix G, Environmental Restoration, Cost Estimate Addendum for additional information.

TABLE 7

ENVIRONMENTAL RESTORATION EVALUATION

Area	Vegetative Community	Modern Historic Condition		Existing Conditions (3)		Future Without Project		Future With Project		Difference	
		Acres	HU	Acres	HU	Acres	HU	Acres	HU	Acres	HU
DENDORA VALLEY & AGUA CALIENTE	Cottonwood Willow (4)	1302	1172	190	179	57	54	280	263	223	210
	Leguminous Short Tree (5)	5730	2808	1170	562	936	449	1970	946	1034	496
	Wetland-Marsh (4)	292	292	243	231	73	69	543	516	470	447
	Open Space (6)	15754	5987	5139	2055	4625	1850	4839	1936	214	86
	Saltcedar	153	30	12156	3343	13207	2641	11266	2253	-1941	-388
WELLTON-MOHAWK	Cottonwood Willow (4)	845	683	2080	1956	624	587	2180	2049	1556	1463
	Leguminous Short Tree (5)	11959	5860	2743	1317	2194	1053	2843	1365	649	311
	Wetland-Marsh (4)	400	400	1095	1040	329	312	1495	1420	1167	1108
	Open Space (6)	16102	6118	7698	3079	6928	2771	7298	2919	370	148
	Saltcedar	3687	700	21450	5899	24991	4998	21250	4250	-3741	-748
BLM LANDS	Cottonwood Willow (4)	599	539	99	93	30	28	139	131	109	103
	Leguminous Short Tree (5)	1539	753	1727	829	1382	663	2027	973	645	310
	Wetland-Marsh (4)	34	34	50	48	15	14	125	119	110	105
	Open Space (6)	17035	6474	5387	2155	4848	1939	5312	2125	464	185
	Saltcedar	68	17	12112	3331	13100	2620	11772	2354	-1328	-266
TOTALS	Desirable Communities	71591	31120	27621	13544	22041	9790	29051	14761	7010	4971
	Saltcedar (Undesirable)	3908	747	45718	12572	51298	10260	44288	8858	-7010	-1402
	All Communities	75499	31867	73339	26116	73339	20050	73339	23618	NA	3569

NOTES:

1. Lower habitat value saltcedar areas are replaced with higher habitat value cottonwood-willow and leguminous short tree vegetative communities through selective clearing and revegetation strategies.
2. Lower habitat value open spaces are replaced with higher value wetland-marsh vegetative communities through selective provision of minimal supplies of water.
3. Existing Conditions are primarily a result of the 1993 floods, but include previous restorative measures by locals. The long term survivability of these immature emergent vegetative communities, which were created by the floods, is questionable. Therefore, existing conditions are unique and are expected to deteriorate over time. See notes 4 through 7.
4. For future without project conditions it is projected that 70% of 1993 flood-created cottonwood-willow and wetland marsh habitat will die off and be replaced with saltcedar.
5. For future without project conditions it is projected that 20% of leguminous short tree habitat will be outcompeted by proliferating saltcedar.
6. For future without project conditions it is projected that 10% of open space will be replaced with saltcedar.

TABLE 8 Cost Effectiveness Analysis

TABLE 8. Cost Effectiveness for Habitat Restoration Along the Lower Gila River (Initial Implementation Costs).

Riparian Community	Area Preserved (Acres)	Initial Preservation Cost	Net Gain in Habitat Units	Cost/ Habitat Unit	Area Restored (Acres)	Initial Restoration Cost	Net Gain in Habitat Units	Cost/ Habitat Unit	Total First Cost	Total Net Gain in Habitat Units	Total First Cost/Habitat Unit
DENDORA VALLEY AND AGUA CALIENTE											
Leguminous Short Tree	1,170	$1,287,000	66	$19,643	800	$7,680,000	224	$34,286	$8,967,000	290	$30,972
Cottonwood-Willow	190	$209,000	98	$2,124	90	$864,000	67	$12,973	$1,073,000	165	$6,502
Wetland-Marsh	243	$267,300	128	$2,096	300	$2,880,000	225	$12,800	$3,147,300	353	$8,929
Open Space	4,839	NA[3]	43	NA	NA	NA	NA	NA	NA	43	NA
Subtotal	6,442	$1,763,300	334	$5,276	1,190	$11,424,000	516	$22,157	$13,187,300	850	$15,517
Contingencies		$264,495[1]	NA	NA	NA	$2,970,240[2]	NA	NA	$3,234,735	NA	NA
Total		$2,027,795	334	$6,067		$14,394,240	516	$27,917	$16,422,035	850	$19,324
BLM LANDS											
Leguminous Short Tree	1,727	$1,899,700	97	$19,666	300	$2,880,000	84	$34,286	$4,779,700	181	$26,466
Cottonwood-Willow	99	$108,900	51	$2,133	40	$384,000	30	$12,973	$492,900	81	$6,111
Wetland-Marsh	50	$55,000	26	$2,095	75	$720,000	56	$12,800	$775,000	83	$9,394
Open Space	5,312	NA	93	NA	NA	NA	NA	NA	NA	93	NA
Subtotal	7,188	$2,063,600	267	$7,737	415	$3,984,000	170	$23,456	$6,047,600	437	$13,853
Contingencies		$309,540[1]	NA	NA	NA	$1,035,840[2]	NA	NA	$1,345,380	NA	NA
Total		$2,373,140	267	$8,888		$5,019,840	170	$29,528	$7,392,980	437	$16,935
WELLTON-MOHAWK											
Leguminous Short Tree	2,743	$877,760	154	$5,710	100	$100,000	28	$3,571	$977,760	182	$5,381
Cottonwood-Willow	2,080	$665,600	1077	$618	100	$100,000	74	$1,351	$765,600	1151	$665
Wetland-Marsh	1,095	$350,400	575	$610	400	$400,000	300	$1,333	$750,400	875	$858
Open Space	7,298	NA	74	NA	NA	NA	NA	NA	NA	74	NA
Subtotal	13,216	$1,893,760	1880	$1,008	600	$600,000	402	$1,493	$2,493,760	2282	$1,093
Contingencies		$284,064[1]	NA	NA	NA	$156,000[2]	NA	NA	$440,064	NA	NA
Total		$2,177,824	1880	$1,159		$756,000	402	$1,881	$2,933,824	2282	$1,286
Project Total	26,846	$6,578,759	2481	$2,652	2,205	$20,170,080	1088	$18,545	$26,748,839	3568	$7,497

[1] Assumed 20% of total cost.
[2] Assumed 31% = 20% contingencies, 5% engineering and design and 6% supervision and administration.
[3] Not Applicable. Note: Preservation of some open space is expected to occur as an indirect result of project-related activities. There is no direct cost associated with this item.

Overall Evaluation

The selected alternative would restore riparian habitat, including significant marsh-wetlands, a very limited and highly valuable component of the Sonoran desert ecosystem. The restored areas provide a habitat corridor capable of supporting migratory waterfowl and a variety of wildlife species. Numerous intangible benefits include 1) contribution to habitat and biodiversity in the desert southwest, 2) providing habitat for the Yuma Clapper Rail, an endangered species, and the Southwestern Willow Flycatcher, a proposed listed species, 3) re-establishing resting sites and wintering areas for migratory waterfowl and habitat for other wildlife. Tangible benefits are derived from increases in waterfowl and other wildlife populations (i.e., the condition and quality of habitat influences subsequent reproductive and survivability success) as wildlife oriented recreation, consumptive and non-consumptive use, is expected to increase; the result of which is positive economic effect on the waterfowl sporting goods industries, tourist trade, and increased revenue to Arizona Game and Fish Department. Intangible benefits result from the increases in the functions and values and other environmental outputs the restored habitat provides, and are evaluated from a cost effectiveness standpoint.

The 1993 flood events in Arizona have created a unique opportunity to maintain riparian communities created by the flood events, and to provide additional riparian habitat along an approximate 164 mile long corridor below the Corps of Engineers Painted Rock Dam.

The costs of preserving the existing riparian habitat and restoring riparian habitat in conjunction with any restoration project is expected to increase over time as these vegetative communities experience gradual die-off and increased susceptibility to the trend of exotic low habitat value saltcedar domination of the corridor.

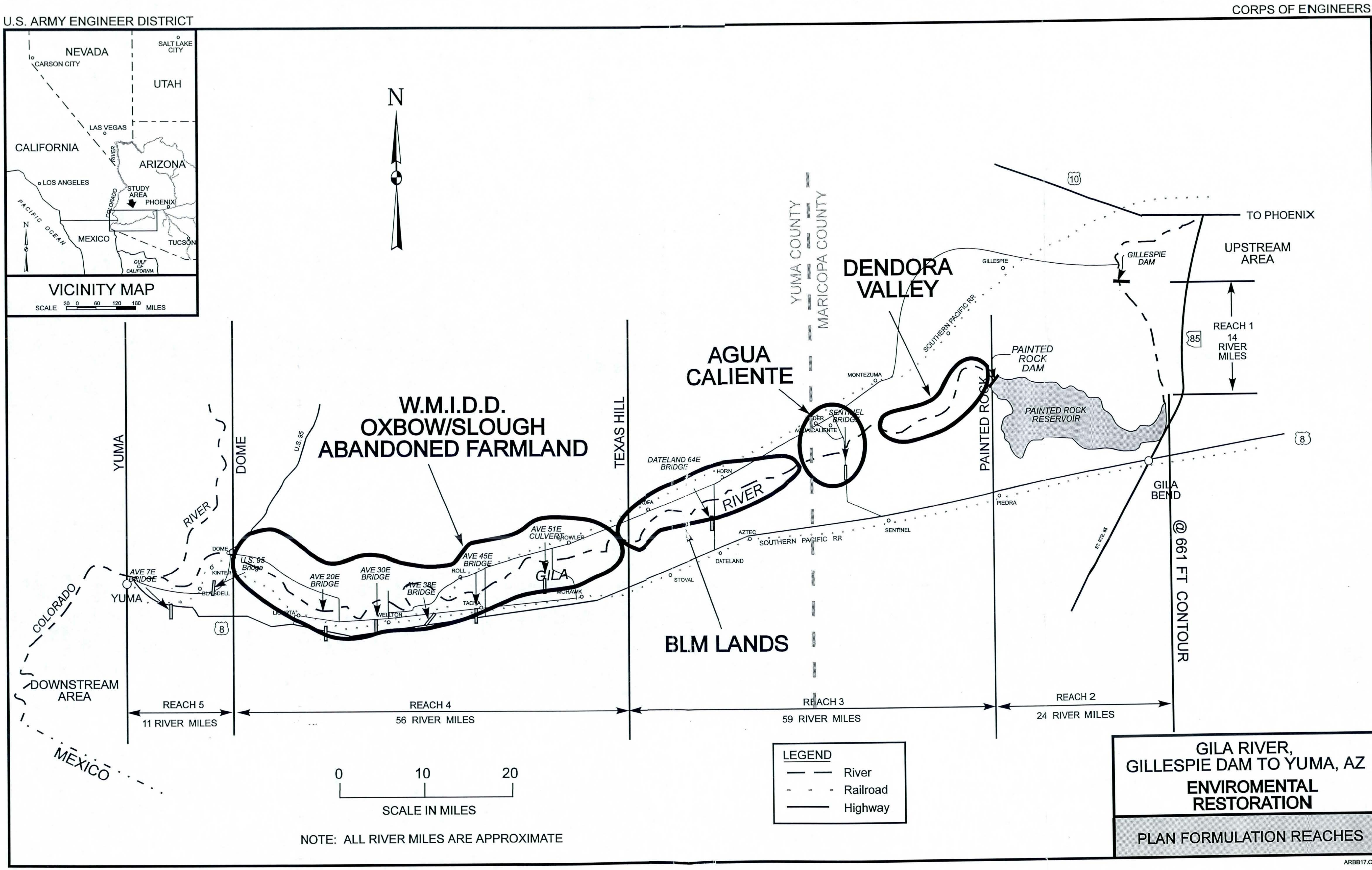


FIGURE 15 ENVIRONMENTAL RESTORATION, GENERAL AREAS

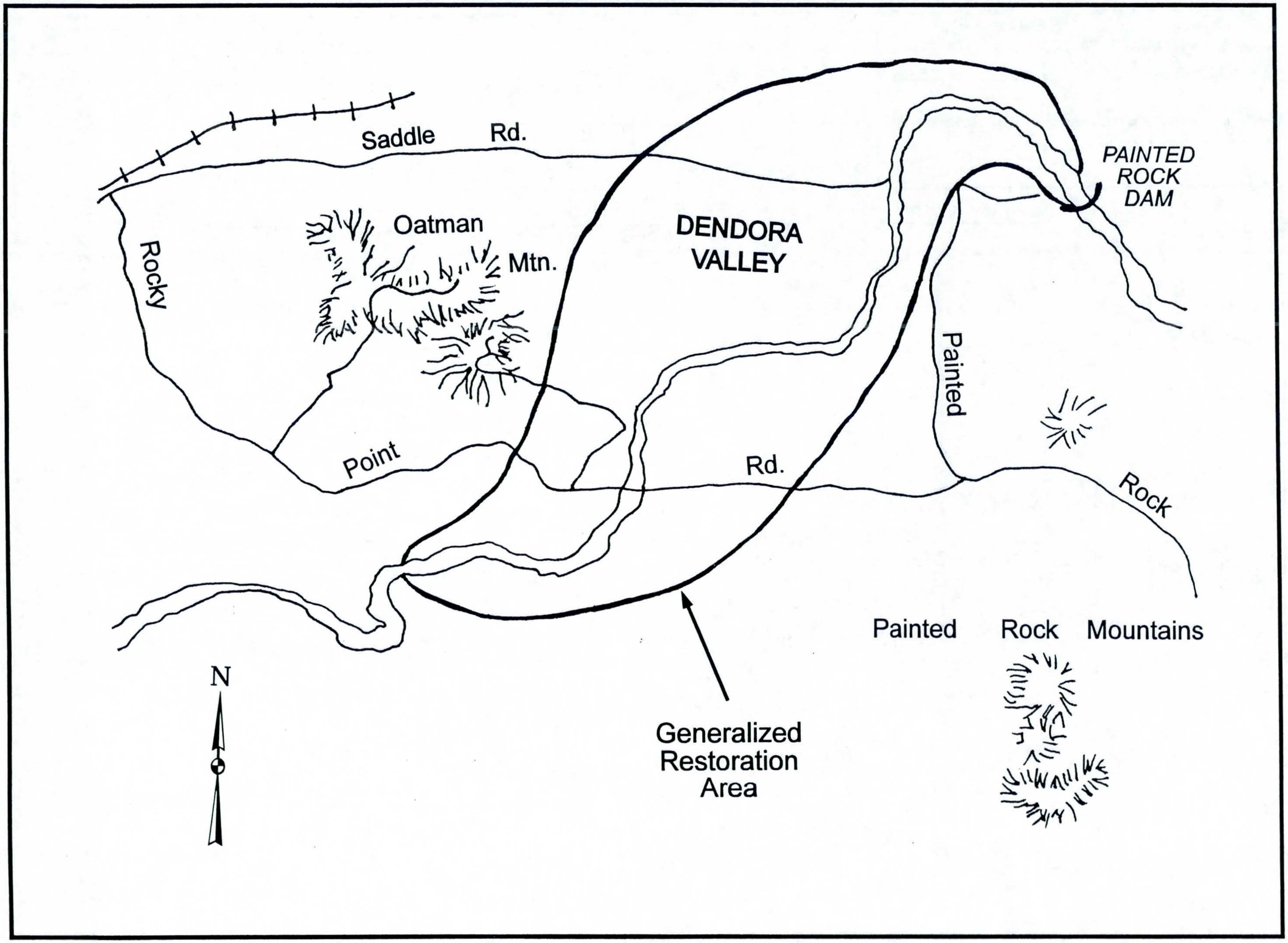


FIGURE 16 DENDORA VALLEY RESTORATION PROJECT

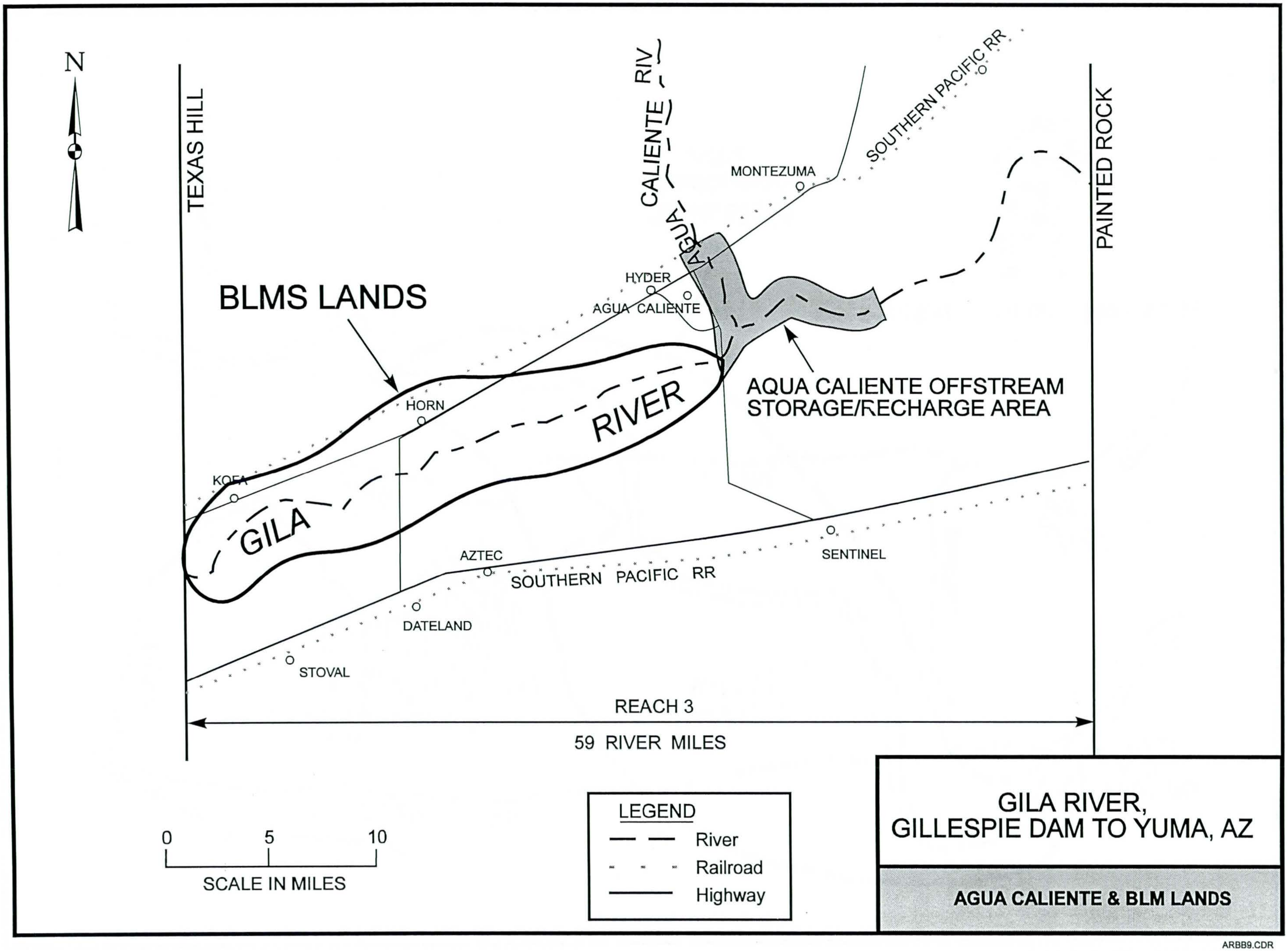


FIGURE 17 AGUA CALIENTE & BLM LANDS RESTORATION AREAS

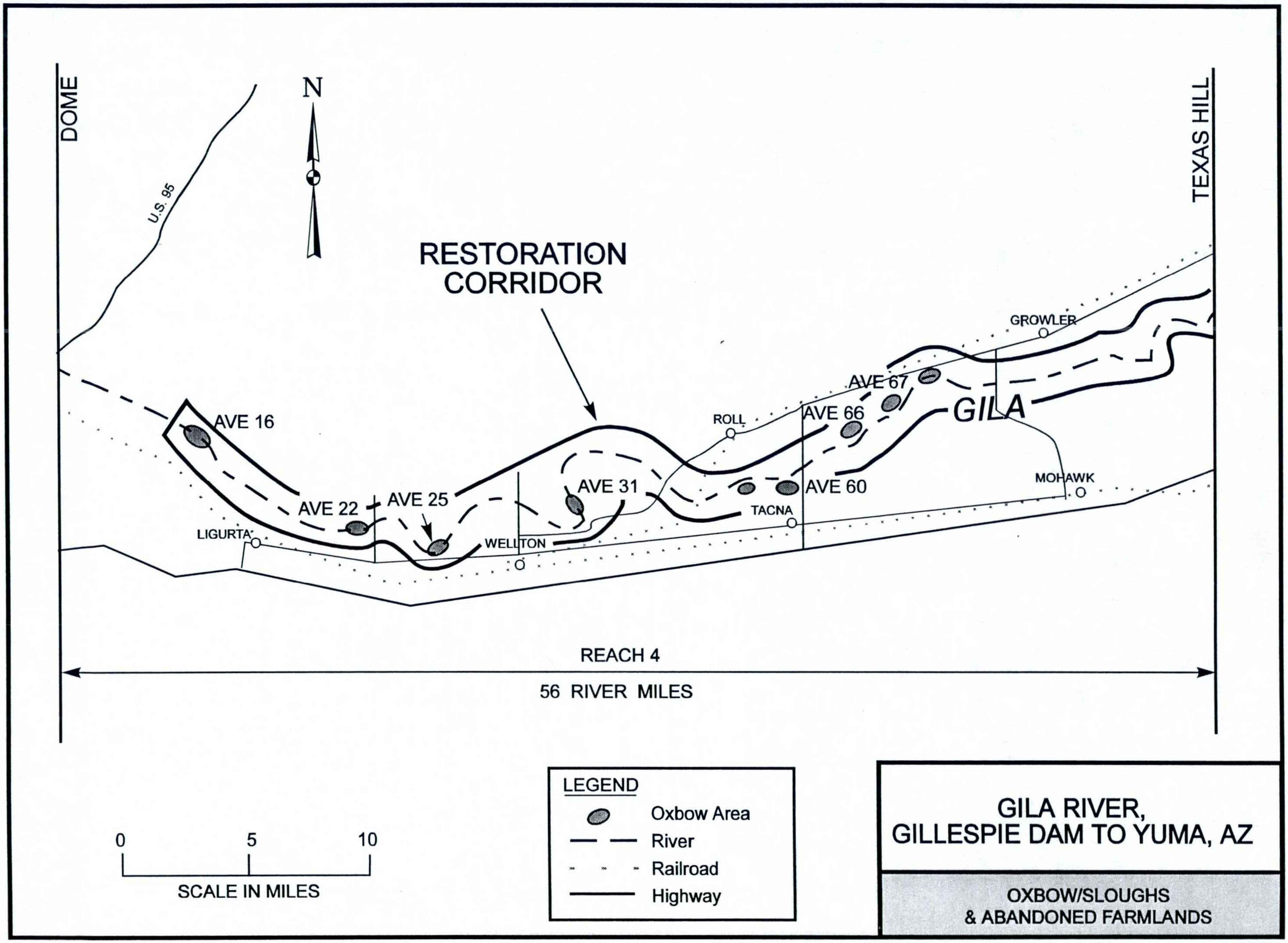


FIGURE 18 OXBOWS ALONG THE LOWER GILA

7.5 Water Quality

7.5.1 Water Quality Objectives

For the purpose of this report, water quality objectives are limited to those problems and opportunities directly caused by or related to existing Corps projects and the potential water quality impacts of any alternatives considered in this study. The planning objective for water quality is to improve the quality of stored water behind Painted Rock Dam for purposes related to safety, savings in operation and maintenance costs, and the ability to release the last stored water without impacting flood control or water conservation alternatives.

7.5.2 Actions to Date

The Corps currently participates in water quality monitoring. Annual operation and maintenance funds are provided to the Arizona Department of Environmental Quality to perform water quality monitoring at the Painted Rock Dam Borrow Pit Lake. An annual water quality report is put out each year by the Reservoir Regulation Section of the U.S. Army Corps of Engineers, Los Angeles District.

The Arizona Department of Environmental Quality's (ADEQ) 1992 water assessment concluded that toxaphene, DDT, and methylmercury contaminants in fish tissue from Painted Rock Borrow Pit Lake exist at toxic levels harmful to human health if long-term consumption occurred. As a result, a fish advisory was issued for the Gila River, from the Salt River to Painted Rock Dam. A public health risk assessment was completed in 1991 by the Arizona Department of Health Services determined that human health risk associated with exposure to lake water or sediment was deemed insignificant. In 1992, additional warning signs against the consumption of fish were posted along the Middle Gila River, Painted Rock Lake and the Borrow Pit Lake Ongoing investigations will continue through the use of the ADEQ Water Quality Assurance Revolving Fund.

The hydrogen sulphide problem at Painted Rock Dam has been addressed by providing forced ventilation to the control tower by the installation of a large electric fan in 1974. This fan blows through the gate shaft to one of the vent systems. Recently, all of the elevator electrical equipment has been sealed from the gas to prevent damages and electrical failure. Based on the results of maintenance inspections, there has been no apparent damage to the concrete in the dam.

7.5.3 Alternatives and Evaluation

No Action Plan

It is expected that continued monitoring efforts will be conducted by the combined efforts of local, state and federal agencies. This monitoring is necessary for resource management, environmental and public health purposes, and to assess trends in contaminant concentrations in the environment.

A 1994 report by the ADEQ presented the results of a study that evaluated the potential of restoring the Painted Rock Dam Borrow Pit Lake for traditional recreational values and other related alternatives. This study concluded that restoration of the lake was not feasible at this time. The costs of these alternatives and the uncertainty about their success were the primary factors in this conclusion. The identification and examination of specific pollutant sources upstream were cost prohibitive due to the size of the upstream watershed.

CHAPTER 8

PRELIMINARY FINANCIAL ANALYSIS

8. PRELIMINARY FINANCIAL ANALYSIS

Further project planning, engineering, design, and construction would be conducted in accordance with the cost-sharing principles provided by the Water Resources Development Act of 1986, as amended. The next phase would consist of a cost-shared feasibility study, if recommended and supported by a non-Federal sponsor. The scope, schedule and cost of the feasibility study, is determined based on a Study Management Plan (SMP) negotiated with the sponsor. The feasibility study is required to be cost-shared 50/50 between the Federal government and the sponsor. At least one-half of the sponsor's share of the feasibility study must be provided in cash and up to one-half of the of the sponsor's share may be provided by in-kind services as part of the study.

For flood control, potential non-Federal sponsors include the Wellton-Mohawk Irrigation and Drainage District, Yuma County and the Flood Control District of Maricopa County. No SMP has been prepared for flood control since the results of this study did not identify an economically justified flood control alternative.

Potential cost sharing sponsors for water conservation are being coordinated in conjunction with the primary custodian of lower Colorado River waters, the Bureau of Reclamation. The current water policy of the Colorado River makes it difficult to determine whether participation with a specific non-federal sponsor is appropriate. Corps of Engineers guidance and regulations with respect to the non-federal cost sharing for water allocation and conservation projects are not readily implementable with the current body of law and developing water rights for the mainstem lower Colorado River system. The potential non-Federal interest in additional lower Colorado River water is evidenced by the tremendous water supply demands placed on the river. The lower Colorado River provides water to five major southwest cities including Las Vegas, Los Angeles, San Diego, Phoenix, and Tucson; 10 smaller cities along the river; five Indian Reservations; three large wildlife areas; and 11 irrigation districts. A "draft" SMP has been prepared for a water conservation follow-on study. Due to the strong Federal interest that has been identified for water conservation, efforts will continue to identify a non-Federal sponsor under traditional General Investigations programs. If special institutional circumstances that exist in the lower Colorado River system preclude identification of a non-Federal sponsor, a one hundred percent federally funded special study could be initiated for water conservation at Painted Rock Dam. The authority for the special study would be based on direct language to be included in the Legislative Initiatives Program.

The identified non-Federal sponsor for an environmental restoration feasibility study is the Arizona Game & Fish Department. They have provided a letter of support for a feasibility study and an interest in cost sharing (attached). A "draft" SMP and Feasibility Cost Sharing Agreement has been prepared for an Environmental Restoration feasibility study and is currently being developed and revised in coordination with the identified non-Federal sponsor.

THE STATE OF ARIZONA

GAME & FISH DEPARTMENT

2221 West Greenway Road, Phoenix, Arizona 85023-4399 (602) 942-3000

October 31, 1994

Mr. Joe Dixon
US Army Corps of Engineers
3636 North Central Avenue Suite 740
Phoenix, Arizona 85012-1936

Re: Gila River Reconnaissance Study

Dear Mr. Dixon:

I am writing in reference to our conversations and participation in the Gila River Reconnaissance Study, and future participation in a potential feasibility study. The Corps has done an excellent job in preparing the Reconnaissance Study, and we are particularly impressed with the attention that the Corps has given to riparian restoration. The Department has been pleased to participate and contribute in-kind efforts to that undertaking.

You inquired about the Department's willingness to be a potential cost-share partner in a potential Gila River Feasibility Study. The Department is very interested in participating in riparian restoration aspects of any future studies. As you are aware, our mission is solely directed to wildlife resources and wildlife associated recreation. Because of the significant value of riparian wildlife habitats in the southwest, we could justify participation in restoration portions of any project. We would, however, not be able to justify financial participation in aspects of the project that relate to activities outside of our mission.

The total cost of the feasibility project we discussed is perhaps small on a federal scale, but by our standards it is quite large. We are uncertain that we could bear the cost-share burden entirely, however we are anxious to explore financing opportunities with you. There may be opportunities to seek financing from the Game and Fish Department's Heritage funds, but we would certainly hope to find other partners in addition to the Department to bear the expense. Please be aware that Heritage monies that might be made available for feasibility studies, not unlike Corps funds, are subject to prioritization by the Arizona Game and Fish Commission. We would need to jointly submit a proposal for Heritage monies. Certainly, the Department would be most interested and willing to offer in-kind service assistance and participation in any future feasibility studies.

I would very much like to keep our dialog open on this subject, and I look forward to continuing to work with your office on continuing Reconnaissance and potential Feasibility projects.

Sincerely,

For BDT

Bruce D. Taubert
Assistant Director

BDT:lr

cc: Sam Spiller, US Fish and Wildlife Service, Phoenix, Arizona

United States Department of the Interior

BUREAU OF RECLAMATION
Yuma Area Office
P.O. Box D
Yuma, Arizona 85366

IN REPLY REFER TO:
YAO-2540
PRJ-13.00

JAN - 9 1995

U.S. Army Corps of Engineers
One Columbus Plaza
Attention: Joe Dixon
3636 North Central Avenue,
Suite 740
Phoenix AZ 85012-1936

Subject: Reconnaissance Study - Gila River, Gillespie Dam to Yuma, Arizona
Dated: October 1994

Gentlemen:

We have reviewed the United States Army Corp of Engineers reconnaissance study on the Gila River from Gillespie Dam to Yuma, Arizona. We concur with the report's findings that the Painted Rock Reservoir has storage capability and agree with the technical results of the report.

The Bureau of Reclamation, Yuma Area Office, would be interested in participating in further investigations of Painted Rock's storage potential. We would also be happy to assist in researching any non-Federal cost sharing opportunities.

Our point of contact regarding this study will be Mr. Gary Taylor (602-343-8163). Please contact him at your convenience.

Sincerely,

Gary L. Bryant
Area Manager

CHAPTER 9

CONCLUSIONS

9. CONCLUSIONS

The District Engineer, Los Angeles District, U.S. Army Corps of Engineers, has reviewed and evaluated, in light of overall public interest, the data, information and alternatives for water resources development pertaining to the Gila River (Gillespie Dam to Yuma) area of Arizona. The data and information presented in this report include the results of investigations and studies prepared by Los Angeles District staff, documents and information provided by local interests, and the stated views of these interests and agencies relative to the various possible alternatives for achieving the stated objectives of providing flood control and related water resources features along the lower Gila River. This report constitutes interim compliance with the overall Gila River and Tributaries study authority, Public Law 103-50 dated 2 July 1993, and Senate Report 103-54 dated 8 June 1993 and House Resolution 2425.

The results of the Gila River, Gillespie Dam to Yuma, AZ, Study, are based upon a thorough analysis and evaluation of various practical alternatives for achieving the stated objectives for flood control, water conservation and environmental restoration. Conclusions with respect to flood control, water conservation and environmental restoration are as follows:

1. Flood Control: No alternative was identified which was deemed to warrant the Federal interest at this time, due to insufficient flood damages prevented in relation to the cost of providing such protection. Several transportation and utility crossing locations have been identified that will continue to be impacted by Gila River flooding under current conditions.

2. Water Conservation: The study results indicate a high Federal interest in water conservation potential, as it relates to the storage, operation and release schedule of Painted Rock Dam. This interest is motivated by the scarcity of water in the Colorado River and the immense water needs placed upon it. The water needs cover a large regional area and a wide range of uses. Almost all of the Colorado river water is put to a beneficial use to the nation. Shortages will increase in the future as more entities utilize their full allotments or during times of drought. Alternatives have been identified in this study, at Painted Rock Dam, that can provide a significant increase in the quantity of this valuable resource. There appears to be strong Federal and non-Federal interest and support for continuing Federal efforts with respect to a formal water conservation output recommendation to be included in a more detailed feasibility study. The alternatives evaluated in this report have

economic benefits much greater than costs. The implementation of such an alternative could help solve serious national and regional problems by developing this currently undeveloped water resource.

3. Environmental Restoration: This report identifies an environmental restoration alternative that warrants continued federal participation towards an environmental restoration feasibility study. There is strong local multi-agency support for the alternative plan evaluated during this reconnaissance study. The environmental outputs that would result from implementation are expected to be relatively high for the cost (investment). Authority for the feasibility study exists under Public Law 103-50 dated 2 July 1993, Supplemental Appropriations Act of 1993; Senate Report 103-54 FY 93 Supplemental Appropriations dated 8 June 1993; Resolution 2425 dated May 17, 1994; and the Gila River and Tributaries Study Authority in accordance with the Flood Control Act of 1938. The objective of the feasibility study will be to recommend a general construction authority be established by Congress that would allow for the implementation of an identified environmental restoration plan within the Gila River watershed, from Painted Rock Dam to the confluence of the Gila River with the Colorado River.

4. Water Quality: Based on recent study efforts by state agencies, water quality restoration measures do not appear to be practical at this time due to the extent of the upstream watershed contributing to the problem and the cost of undertaking such measures. Continued water quality monitoring is important for public health purposes, and to assess trends in contaminant concentrations in the environment.

CHAPTER 10

RECOMMENDATIONS

10. RECOMMENDATIONS

I recommend that no Federal action be taken at this time towards a cost shared feasibility study for flood control along the Gila River, between Gillespie Dam and Yuma, Arizona.

As a result of the reconnaissance level investigations into water conservation, there appears to be a very strong Federal interest in pursuing more detailed studies. It is in the best interest of the Federal government, and I recommend, that the Los Angeles District continue to pursue a Non-Federal sponsor under traditional feasibility study guidelines. I further recommend that if special institutional circumstances that exist in the lower Colorado River system preclude identification of a Non-Federal sponsor, a one hundred percent Federally funded special study be initiated for water conservation at Painted Rock Dam. The authority for this special study will be based on direct language to be included in the Legislative Initiatives Program.

It is recommended that a cost-shared environmental restoration feasibility study be initiated for the Gila River, between Painted Rock Dam and the confluence with the Colorado River.

It is recommended that operation and maintenance funding be continued with respect to water quality monitoring at Painted Rock Dam and vicinity.

Michal R. Robinson
Colonel, Corps of Engineers
District Engineer

APPENDIX A

HYDROLOGY

GILA RIVER RECONNAISSANCE STUDY

GILLESPIE DAM TO YUMA, ARIZONA

HYDROLOGIC ANALYSIS

WITH AND WITHOUT PROJECT

U.S. ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

JANUARY 1995

GILA RIVER RECONNAISSANCE STUDY

GILLESPIE DAM TO YUMA, ARIZONA

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF PLATES

No. Title

GILA RIVER RECONNAISSANCE STUDY

GILLESPIE DAM TO YUMA, ARIZONA

I. INTRODUCTION

A. PURPOSE

This hydrologic documentation presents with and without project frequency relationships for the Gila River downstream of Gillespie Dam to Yuma, Arizona. Included among these frequency relationships are inflow, elevation-duration, and outflow at Painted Rock Dam. These results are intended to provide input for determination of the without project damages and the ensuing benefits of alternative reservoir regulation plans.

In addition, a water supply analysis for two distinct demand scenarios is presented for seasonally implemented joint use of Painted Rock Dam storage. Average annual yields for both alternative demand schedules are developed based upon the increase in deliverable water above the without project operation plan. Joint use of the flood pool must not reduce the downstream level of protection.

B. SCOPE

1. Flood Control Analysis.

The hydrologic analysis of streamflow and the impact of Painted Rock Dam on streamflow was performed at the Reconnaissance level, making use of readily available data. Without project conditions inflows were based upon the presumed completion of modifications to Roosevelt Dam on the Salt River (see figure 1 for location and figure 2 for modifications), and operation, as described within this report, according to Plan 9[1]; in addition, the existence and continued operation in the current manner of all the other major storage facilities listed within this report is anticipated. Gillespie Dam, a diversion structure on the Gila River upstream of Painted Rock Dam was breached by the 1993 runoff in January and has

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[1] Plan 9 operation refers to a maximum release of 25,000 ft3/s from the flood pool at Roosevelt Dam. Plan 9 results are used for two reasons:
a) there is no approved regulation plan for the new flood control allocation currently being constructed at Modified Roosevelt Dam;
b) Plan 9 operation is the only existing regulation plan with documented results, and the impact on Painted Rock Dam of variations in this plan, to be determined within the ongoing Section 7 Study of Modified Roosevelt Dam, are not anticipated to be significant as far as the effects on Painted Rock Dam and downstream environs.

not been rebuilt. As a diversion structure it had no impact on flood inflow to Painted Rock Dam. Hence, whether it is rebuilt for its former purpose or remains breached, it will not impact runoff to Painted Rock Dam. Without project outflows and elevation relationships were developed based upon the simulated regulation of Painted Rock Dam, in a manner similar to the 1993 flood regulation. The downstream channel was presumed to be capable of containing a flow of 10,000 ft^3/s, in conjunction with the ongoing efforts of the Wellton-Mohawk Irrigation and Drainage District (WMIDD) and other downstream agencies to improve the carrying capacity of the Gila River. Consequently, the maximum release from Painted Rock Dam under without project conditions, has been established as 10,000 ft^3/s.

Since the flood control project alternatives to be evaluated within this study were changes in the regulation schedule at Painted Rock Dam combined with subsequent downstream channel modifications, the reservoir inflows for with project conditions are unaffected by the alternatives, and thus are identical to those for without project conditions. With project outflows and elevations were determined in a similar manner to those for without project conditions - simulated reservoir routing. The alternative regulation plans evaluated allowed for the sustained release of either 20,000 ft^3/s or 30,000 ft^3/s through the flood outlets. The cost of the increase in the downstream channel capacity to accommodate these increased flows will offset the project benefits resulting from a higher level of protection below the dam, and decreased frequency and duration of inundation for agricultural lands within the reservoir pool.

Reservoir inflows were developed based upon observed inflow to Painted Rock Dam since its closure in January 1960, computed using the Continuity equation,

$dS/dT = I_{ave} + O_{ave}$, where

S = reservoir storage

T = computation time interval

I = reservoir inflow

O = reservoir outflow,

and adjusted to account for the impact of modified Roosevelt Dam upstream. The adjusted observed inflows were augmented by synthetic flood flows in order to obtain a wider range of frequencies than would be provided by the available record since 1960. The synthetic flood flows were generated from

Balanced Hydrographs developed for the Salt River Project (SRP) reservoir system for use in the Section 7 Study of Modified Roosevelt Dam, currently underway and scheduled for completion in 1995. The Balanced Hydrographs were routed through the SRP system simulating the Plan 9 operation for Modified Roosevelt Dam, while adjusting the starting storage in the system reservoirs in order to produce downstream peak discharges at the confluence of the Salt and Verde rivers similar to those from the 1988 Cliff Dam Alternatives Study, which contains the most recent evaluation of the impacts of Plan 9 on the outflow from the SRP system. The next step was to route these synthetic outflow hydrographs from the SRP system to Painted Rock Dam using the "developed channel" model data that the Los Angeles District (LAD) provided to the Flood Control District of Maricopa County in 1989. Finally, Gila River flows above the confluence with the Salt River were added to the synthetic hydrographs, based on ratios of the 1993 Gila River at Kelvin streamflow. The ratios varied from 0% for the 5-year synthetic flood to 100% for the 200- and 500-year synthetic floods. These ratios were determined by comparing a statistical analysis of the observed 90-day inflow volumes at Painted Rock Dam to the synthetic flood 90-day inflow volumes, and adjusting the synthetic flood volumes upward to account for the increasing likelihood of runoff downstream from the SRP system entering the reservoir at Painted Rock Dam during more rare floods (such as the flood of 1993). The systematic inclusion of ratioed Gila River flows was done to provide a quantifiable process for addressing the runoff downstream of the Salt River which appears as Painted Rock Dam inflow. Sources of this inflow, in addition to the upper Gila River (the Gila River upstream of the Salt River confluence), are the Agua Fria River, the Hassayampa River, and Centennial Wash. Offsetting these inflows, channel losses reduce the streamflow which reaches Painted Rock Dam. Since the majority of runoff which reaches the dam emanates from either the Salt River (the primary source) or the upper Gila River (the secondary source), the additional inflow from other sources and the channel losses were considered to cancel each other out.

Reservoir elevations and outflows were produced as a result of the reservoir simulation procedure. By comparing these pairs of elevation-outflow data, consistent interpretations of the frequency relationships were made. In addition to the maximum elevation-frequency relationship, elevation-duration frequency relationships were evaluated for periods up to 90-days. The need for evaluating longer durations (the reservoir design flood is only 18 days in duration) was documented during the flood of 1993, which produced a maximum spillway flow approximately 1 1/2 months after the beginning of inflow to Painted Rock Dam. Finally, it should be noted that water supply alternatives for Painted Rock Dam, if implemented (see following discussion and the remainder of the report) would impact the elevation frequency relationships for longer durations and for smaller floods. No attempt was made to quantify this effect within the framework of this study.

2. Water Supply Analysis.

While Painted Rock Dam is normally empty, during some years excessive inflows to upstream reservoirs - the Salt River Project on the Salt and Verde Rivers, Coolidge Dam on the Gila River, and New Waddell Dam on the Agua Fria River - produces large and/or long duration releases to the Salt and Gila River, which results in the buildup of a lake behind Painted Rock Dam. At other times, or coincident with releases from the upstream reservoirs, runoff downstream from these reservoirs may be sufficient to also reach Painted Rock Dam. At these times releases from Painted Rock Dam are limited to a maximum of 10,000 ft^3/s due to channel capacity limitations below the Dam. Consequently surplus water may remain in the flood pool even after the threat of high inflows has passed. During this non-flood season, attention has been given to maintaining a joint use flood pool and delivering the water in reduced quantities to satisfy downstream demands.

For purposes of this analysis, seasonal joint use begins on 1 March of each year and extends through November of each year. At that time water in storage, if less than indicated from an estimated seasonal Rule Curve, is automatically converted to water supply. Seasonal Rule Curves are established based on the normal reservoir drawdown from evaporation and demand. The first demand scenario, a constant seasonal demand of 500 ft^3/s (March - November), is predicated on diversion of the flow for use by WMIDD. The other demand scenario (variable for each month, from March through November), is based on the average monthly delivery of water to Mexico at the NIB. As such, the Seasonal Rule Curve developed for this alternative represents an extreme of possible use in considering Painted Rock Dam as a water supply facility.

Yield is determined by computing the difference between water released from Painted Rock Dam under the two demand scenarios and under the without project conditions. Flood releases which exceed the demand are not counted toward the incidental yield of the without project conditions. Average annual yield is simply the average of the yield for each demand scenario over the period of simulation divided by the number of years in that period - 35. As a check on the validity of the average annual yield developed for the two demand scenarios based on the relatively short length of record used, a probabilistic approach was also employed. To do this, synthetic inflow hydrographs to Painted Rock Dam, which were developed to augment the flood frequency analysis, were routed through the dam using the two seasonal demand scenarios and the applicable rule curves. The resulting "frequency yields", determined in the same manner as yields from specific flood events, were integrated over the range of probabilities to estimate an average annual yield.

C. RESULTS.

1. Flood Control

Inflow-, outflow-, elevation-, and elevation-duration frequency relationships for Painted Rock Dam were developed for without project and with project conditions, and the results are summarized in tables 1 and 2, and displayed on plates 1-12. Although the study limits extend from Gillespie Dam (a diversion structure on the Gila River which was breached during the January 1993 runoff) to the city of Yuma at the mouth of the Gila River, no separate analysis was done for these upstream and downstream limits. The inflow frequency relationships established in this study for Painted Rock Dam are applicable to the upstream study reach. Likewise, because of the extended duration of most reservoir releases from Painted Rock Dam, little attenuation results between Painted Rock Dam and the downstream study limits at Yuma, except during releases of small magnitude. Hence, outflow frequency relationships at Painted Rock Dam are appropriate for use in the downstream study reach.

2. Water Supply

Annual yield for both demand scenarios is presented in table 11 along with average annual yield. As might be expected, the higher demand (referred to as NIB) required a greater allocation of seasonal water supply space, and produced a higher average annual yield than the lesser demand (referred to as

500 ft^3/s), 47,900 ac-ft/year compared to 27,500 ac-ft/year. However, the lower demand alternative produced more yield in two of the seven years, due to the method by which yield is defined in this study, i.e. flow which is less than or equal to demand is counted as yield, and flow which exceeds demand is wasted. These results were determined by simulation of without project and with project[2] reservoir operation for the seven floods in the period-of-record since Painted Rock Dam was completed which resulted in stored water during the seasonal period. Graphical depictions of these simulated routings are displayed in figures 10 to 13. Rule curves, established by iteratively evaluating the magnitude of storage on 1 March of each year and withdrawing the monthly demand through 1 December of each year while also allowing for evaporation, are displayed on figure 10, and in table 10. The 1 March storage required to satisfy the monthly demand scenarios is 371,000 ac-ft for the 500 ft^3/s plan and 1,265,000 ac-ft for the NIB plan. The invert elevation for Painted Rock Dam is at 530 ft, NGVD, and the spillway crest is at elevation 661 ft, NGVD. By comparison, the maximum seasonal water supply pool allocations are at approximate elevations 598 and 634, respectively. Of the years since closure of Painted Rock Dam in 1960, only the year 1983 resulted in 1 December storage greater than the rule curve target. This storage was the result of the unprecedented October flood of that year. For purposes of comparison the 1 December storage is compared below:

1983 FLOOD - STORAGE ON 1 DECEMBER, AC-FT

W/O PROJECT	5OO FT^3/S	NIB
136,000	173,000	142,000

As evident from this comparison, very little flood control space would have been compromised by either water supply alternative. In no instance did the simulated outflow from the water supply alternatives exceed that of the without project conditions. Rather, during large floods the operation for water supply is minimized and flood control dominates. See flood routings, figures 12 and 13 for more information.

D. BACKGROUND

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[2] With project conditions for water supply analysis refers to the two demand scenarios - a constant 500 ft3/s and a monthly variable demand.

The flood of 1993, which produced the first ever spillway flow at Painted Rock Dam, and unprecedented downstream damage, has resulted in this congressionally authorized study of the Gila River, from Gillespie Dam Yuma, Arizona, to evaluate various combinations of modified regulation plans in conjunction with downstream channelization for economic viability.

II. **DESCRIPTION OF AREA**

A. DRAINAGE AREA

The drainage area of the Gila River (see figure 1) covers approximately 58,000 sq. mi. and extends from the Continental Divide in southwestern New Mexico to the Colorado River at Yuma, Arizona, including practically all the southern half of the State of Arizona. The Gila River, which is 654 miles long, rises in an area of high mountains and plateaus and flows westward in a generally central course through the basin. The Gila River includes the following major tributaries:

- the Salt and Verde Rivers, combined drainage area of 13,000 sq. mi.
- the Santa Cruz River, drainage area of 8,600 sq. mi.
- the San Pedro River, drainage area of 4,500 sq. mi.
- the San Francisco River, drainage area of 2,800 sq. mi.
- the San Simon River, drainage area of 2,200 sq. mi.
- the Agua Fria River, drainage area of 2,000 sq. mi.
- the Centennial Wash, drainage area of 1,800 sq. mi.
- the San Carlos River, drainage area of 1,027 sq.mi.
- others, including Queen Creek, the Hassayampa River, and Waterman Wash.

Elevations in the basin range from more than 12,000 feet in the San Francisco Peaks in the Verde River basin, to 130 feet in the vicinity of Yuma. Much of the northern part of the basin is extremely irregular and rugged with elevations ranging from 7,000 feet to 12,000 feet along the basin boundaries. This portion of the basin is mostly drained by the Salt River, which joins the Gila River at mile 198, near Phoenix. The eastern half of the southern part of the basin consists largely of long desert valleys lying between north-south ranges of rugged mountains; here the elevations are generally lower but in places are above 10,000 feet. The southwest third of the basin consists essentially of broad, flat, low-lying desert valleys and isolated mountains of relatively low relief; comparatively few localities are more than 4,000 feet in elevation, and a large part is below 1,000 feet; the elevation of the river mouth near Yuma is about 130 feet. The major streams are also delineated in figure 1. The climate of the Gila River Basin is semiarid as a whole, but, depending principally upon elevation, ranges from hot and arid to cool and humid. The average annual precipitation ranges from less than 4 inches in the lower desert to 30 inches or more in the highest mountains. Streamflow characteristics vary considerably throughout the basin. The streams in the southern deserts have very little flow other than immediately after the heavier rains, while the northern and headwater streams are perennial. During major storms, such as those used for analysis in this report, streamflow increases rapidly, and in combination with steep gradients and often-barren slopes, results in major floods. Snowmelt is a contributing factor in most winter floods.

Within the Gila River Basin are numerous dams, but only a few of these will exert an appreciable influence on major floods:

- Roosevelt Dam on the Salt River, currently in the process of modification to increase the total storage (including an added flood pool of 565,000 ac-ft) to 2,100,000 ac-ft.
- Horse Mesa on the Salt River, with a storage of approximately 245,000 ac-ft.
- Mormon Flat on the Salt River, with a storage of approximately 58,000 ac-ft.
- Stewart Mountain on the Salt River, with a storage of approximately 70,000 ac-ft.
- Horseshoe on the Verde River with a storage of approximately 131,000 ac-ft.
- Bartlett on the Verde River with a storage of approximately 178,000 ac-ft.
- Coolidge on the Gila River with a storage of approximately 1,100,000 ac-ft (currently storage is restricted due to dam safety issues).
- New Waddell on the Agua Fria River, recently enlarged, with a total storage of approximately 1,000,000 ac-ft.
- Painted Rock on the Gila River, with a flood control pool of approximately 2,500,000 ac-ft.

The locations of these water impoundment facilities are shown on figure 1.

B. PAINTED ROCK DAM

Painted Rock Dam is located in the southwest part of Maricopa County in the State of Arizona about 20 miles northwest of the town of Gila Bend. The dam is on the Gila River, and controls a drainage area of 50,800 sq. mi. Construction of Painted Rock Dam began in July 1957 and closure was made in April 1960. The dam has a rolled-fill earthen embankment with a crest length of 4,780 feet and crest width of 20 feet. The dam crest is at elevation 705 feet NGVD, which is 181 feet above the original streambed. The area and capacity of the reservoir formed by Painted Rock Dam are 53,200 acres and 2,476,300 ac-ft at spillway crest (elevation 661), respectively; the area and capacity at the top of the dam (elevation 705) are 90,100 acres and 5,575,000 ac-ft. An allocation diagram for Painted Rock Dam is shown on figure 3. The dam has gated flood outlets which are capable of releasing 30,000 ft^3/s at spillway crest - the maximum scheduled gated release is 22,500 ft^3/s - and which are connected to a 925 foot long, 25 foot diameter concrete-lined outlet conduit which discharges to an unlined trapezoidal rock channel 330 feet long. For purposes of this study, the maximum scheduled gated release for without project conditions has been restricted to 10,000 ft^3/s, the maximum flow which can be safely conveyed through the downstream damage reaches after expected improvements have been completed. The spillway is a detached broad-crested weir, located 600 feet beyond the right abutment. The spillway crest is 610 feet in length at elevation 661 feet NGVD, and empties into a small canyon which enters the Gila River about 800 feet below the downstream toe of the embankment. Repairs due to damage resulting from the sustained spillway flow during the 1993 flood have recently been completed (January 1994).

1. Project background

Painted Rock Dam was built by the Corps of Engineers for its congressionally authorized purpose of flood control. Completed in January 1960, Painted Rock Dam is located on the Gila River, approximately 126 miles from its confluence with the Colorado River (see figure 1). The drainage area above Painted Rock Dam is 50,800 sq mi. The reservoir has a total storage of 2,476,339 ac-ft at spillway crest (based on computations made in 1985 from available survey data). Figure 4 shows the project's pertinent data. The approved flood control plan for Painted Rock Dam calls for a maximum reservoir release of 22,500 ft^3/s, as stated in the Painted Rock Dam water control manual dated June 1962; however, the downstream channel has a limited capacity, lower than the maximum flood control releases, as discussed previously.

There are numerous reservoirs in the Gila Basin above Painted Rock Dam. However, only eight influence the regulation of major floods at the dam (see figure 1 for the location of these reservoirs). These reservoirs will have a combined usable storage space below spillway crests of approximately 4.9 million ac-ft, and intercept runoff from an area of 26,742 sq. mi, or approximately 53 percent of the total drainage area above Painted Rock Dam.

2. Downstream development

Below Painted Rock Dam, the Gila River flows approximately 126 miles to the Colorado River at Yuma. South of the River, Interstate Highway 8 runs the entire distance from Gila Bend to Yuma. There are nine bridges across the Gila River that connect the communities downstream of the dam (see table 3), and only six of these nine crossings were designed to handle as much as 10,000 ft^3/s. With only an estimated 5,000 to 7,000 residences scattered throughout the area, there is no major urban development that exists along the Lower Gila River between the dam and the City of Yuma. For 65 miles downstream of the dam, the terrain is sparsely inhabited, with widely scattered pockets of agriculture. The next 45 miles consists of WMIDD, which is an intensive agricultural area consisting of about 65,000 acres of land. Existing improvements include irrigation canals, pump stations, transmission lines, and flood control structures. In addition to the nine bridge crossings shown on Table 3, there are other bridges that are affected in the overflow area created when releases are in excess of current channel capacities.

Where the Gila River joins the Colorado River east of Yuma, there is a large irrigated agriculture area owned in part by the North Gila Valley Irrigation District, and in part by the Yuma Irrigation District. To the east and south of Yuma, The Yuma Mesa Irrigation District extends to the US - Mexico International Border. The combined flows from the Colorado River and the Gila River continue to Mexico where water is used primarily for irrigated agriculture on the upper delta and Mexicali Valley.

3. Operating constraints at Painted Rock Dam

The currently approved water control plan for Painted Rock Dam calls for a maximum flood control release of 22,500 ft^3/s. As discussed previously, releases in excess of 10,000 ft^3/s could produce devastating social and economic impacts to the downstream areas, especially to the Wellton-Mohawk's intensive improvements. Hence, for purposes of this study the without project conditions have been formulated based upon a maximum release of 10,000 ft^3/s. Table 3 lists the major bridge crossings that connect communities downstream of the dam. Releases in excess of 15,000 ft^3/s would result in closure of all these river crossings and isolation of the north and south sides of the river. According to the local sheriff department's estimate, approximately 3,500 area residents would be isolated on the north bank when all bridges are closed. Travel to schools, work and hospitals would be impossible, except for 120 mile long alternate route.

III. **RUNOFF**

A. STREAMFLOW RECORDS

Within the study reach from Gillespie Dam to Yuma, Az., there are streamgages at the following locations:

a) Gillespie Dam, since 1921, destroyed in January 1993 and replaced with the gage near Estrella Road (Drainage Area=49,650 mi^2);

b) below Painted Rock Dam, since 1959, removed in January 1993 due to high releases from Painted Rock Dam (Drainage Area=50,910 mi^2); as yet, repairs have not been initiated;

c) near Mohawk, since 1973 (Drainage Area=55,430 mi^2); and

d) near Dome, since 1903 (Drainage Area=57,850 mi^2).

There are numerous other gaging stations upstream of the study reach which were utilized to develop synthetic flood flows for the purpose of evaluating the alternative regulation plans for Painted Rock Dam. At some of these gaging stations or their vicinity, streamflow record is available from August 1888. Discharge frequency relationships developed for inflow to the SRP system are based on an adjusted record length of 105 years.

B. FLOOD HISTORY

Since the completion of the dam in 1960, significant inflows occurred in December 1965-January 1966, March-May 1973, March 1978, December 1978-April 1979, February 1980, February-May 1983, October 1983, December 1984-March 1985 , and February- April 1992, and January-April 1993. Figure 5 presents the flood history of Painted Rock Dam since its completion; hydrographs depicting mean daily inflow and outflow, along with elevation, are provided therein.

IV. DEVELOPMENT OF PAINTED ROCK RESERVOIR INFLOWS

A. OBSERVED INFLOWS

Computations of reservoir inflow are made whenever water is stored in the reservoir. The basis for these computations is the continuity equation, which states that the difference between reservoir inflow and outflow is stored in the reservoir (when the outflow is less than the inflow), or released from the reservoir storage (when the outflow is greater than the inflow). Since the change in storage can be estimated from the change in water surface elevation during any computational interval, and the outflow is known from the discharge elevation relationships for specified gate openings (in addition to information usually available from the downstream gage), the inflow during any computational period can be determined. Painted Rock Dam inflow hydrographs based on these computations are available since completion of the dam in 1960. However, these flows represent the reservoir inflow for a condition which does not include the modifications to Roosevelt Dam scheduled for completion in 1996, nor does it include the regulation plan which is currently being developed for the flood control pool. In the absence of an approved regulation plan for Modified Roosevelt Dam, Plan 9, which limits releases from the flood control pool to 25,000 ft^3/s, has been adopted as an interim plan for evaluation of impacts to Painted Rock Dam and the Gila River downstream from the dam. Since spillway flow at Painted Rock Dam results from long duration inflows, and since the Verde River is not impacted by the addition of flood control space at Roosevelt Dam, the variation between the regulation plan developed during the Section 7 Study of Modified Roosevelt Dam and Plan 9 should not have a significant impact on frequency relationships developed for Painted Rock Dam. In addition, these observed inflows do not include the effects of the recently completed New Waddell Dam on reservoir inflows.

To account for these upstream effects, the sources of Painted Rock Dam inflows were examined: based on the differences between regulated flood control releases from Roosevelt Dam under the Plan 9 concept, and the actual releases, the impact on Painted Rock Dam inflows was determined. Accordingly, the February 1980 maximum one-day inflow to Painted Rock Dam was reduced by approximately 40,000 ft^3/s, which reduced the maximum simulated water surface elevation by 0.9 feet (based on the without project regulation plan for the dam). The inflow volume to Painted Rock Dam was adjusted over time such that any additional water stored at Modified Roosevelt Dam due to the reduction in outflow to 25,000 ft^3/s, was released when the actual outflow from the Salt River (Salt River below Stewart Mountain Dam) became less than 25,000 ft^3/s. Table 4 presents more details for the February 1980 flood adjustment. Since Painted Rock reservoir routings were simulated for a 24-hour computation period, and releases from Stewart Mountain Dam for most observed events did not exceed 25,000 ft^3/s for periods of that duration or longer, no other adjustments to observed inflows were necessary. Observed maximum 6-hour inflows to Painted Rock Dam used in the simulation of without and with project conditions are shown in table 5.

B. SYNTHETIC FLOOD INFLOWS

The pre-existing volume-frequency relationships for inflow to the SRP system were developed from runoff record for the period through 1980. Since there have been significant inflow years since that time (especially the 1993 Water Year), and since it has become apparent that longer duration flows than 10-days, which were generated for the Central Arizona Water Control Study (CAWCS), are critical in determining the releases to the Salt River as well as the impacts on the Gila River, those volume-frequency relationships for inflow to the SRP system were inadequate. During the initial phase of the Section 7 Study for developing a flood control regulation plan for Modified Roosevelt Dam, the runoff record since 1980 was incorporated into the data base, and additional duration relationships for 30-, 60-, and 90-days were developed. The revised set of volume-frequency relationships was then used in the evaluation of the without project and with project frequency relationships within this study. Figures 6-1 through 6-7 display the synthetic flood hydrographs, used in the evaluation of Painted Rock Dam alternatives, routed from the Salt-Verde River confluence to Painted Rock Dam.

To determine the volume of inflow to Painted Rock Dam during long duration events, the following approach was taken: a) The maximum 90-day inflows since the completion of the dam were computed; these events were then ranked and ordered and plotted on log-discharge frequency paper using Median plotting positions, and a 90-day frequency curve was developed.

b) The SRP system Balanced Hydrographs were routed through the SRP reservoir system, iteratively adjusting the starting storage. The objective was to adjust the starting storage within the SRP system reservoirs in a logical and consistent manner, in order to reproduce the pre-existing peak discharges at the confluence of the Salt and Verde rivers. These pre-existing peak discharges were presented in the Cliff Dam Alternatives Study prepared for the Bureau of Reclamation (BOR) by the Los Angeles District of the Corps of Engineers (COE, 1988). (See table 6 for a presentation of the final starting storage and a comparison of simulated peak discharges to Plan 9 discharges.) The combined Salt and Verde river outflows from the simulated reservoir routings of the Balanced Hydrographs were then routed to Painted Rock Dam using the storage-discharge relationships for the Salt and Gila river channels developed by the COE for the Flood Control District of Maricopa County in 1989 - this model included development and channelization of the Salt River floodplain, along with a channel percolation rate of 0.2 ft^3/s/wetted acre (equivalent to 0.2 inches per hour).

c) The maximum 90-day flow for each of the routed SRP system "Balanced Hydrographs" was then plotted on the same frequency paper as the adjusted observed 90-day inflows, using the nominal return period (e.g., the 500-year Balanced Hydrograph plotting position is 0.2 exceedances per 100-years). See figure 7 for a comparison. The difference between the observed inflow 90-day frequency curve and the SRP system outflows could be characterized in this manner: for smaller floods, i.e. more frequent events, runoff is typically represented by flow released or spilled through the SRP system; for larger floods, i.e. more rare events, runoff from the SRP system releases or spills is augmented by downstream sources such as the Gila River (above the confluence with the Salt River and the Agua Fria River). To distribute the additional Gila River volume and combine it with the Salt River runoff required information concerning the following:

(1) the temporal distribution of the 90-day Gila River contribution was unknown, and

(2) the magnitude of the 90-day Gila River contribution was unknown.

d) These problems were resolved by using the observed streamflow from the Gila River at Kelvin gage during the 1993 flood event as the basis for additional downstream inflow; because the pattern hydrographs used to develop the SRP system inflows were the 1993 floods on the Salt and Verde rivers, using the 1993 flood on the Gila River preserved not only the overall temporal distribution of the event, but also the relative magnitude of the Gila river contribution; indeed, this event is known to be the largest inflow event to Painted Rock Dam for which record is available (105 years), and thus represents a valid basis for development of more rare synthetic hydrographs. Therefore, to supplement the inflows from the Balanced Hydrographs, ratios of the Gila River at Kelvin 90-day runoff were added to the routed Balanced Hydrographs in proportions which would reproduce the observed inflow 90-day frequency relationship. These ratios ranged from 0% for the 5-year flood to 100% for the 200- and 500-year floods.

FREQUENCY	% GILA RIVER	90-DAY GILA VOLUME	90-DAY PAINTED ROCK VOLUME
5-YEAR	0	0	443,000
10-YEAR	14	233,900	1,090,000
20-YEAR	23	384,200	1,880,000
50-YEAR	44	735,000	3,140,000
100-YEAR	61	1,019,000	4,280,000
200-YEAR	100	1,670,000	5,820,000
500-YEAR	100	1,670,000	7,118,000

The synthetic hydrographs for each of the above frequencies were then evaluated to determine the maximum duration flow for each flood event, and the results are presented in table 7.

V. **FREQUENCY ANALYSIS**

While streamflow record is available at Gillespie Dam since 1921, the record is non-homogeneous because of the construction of upstream reservoirs during that period. Balanced Hydrographs representing a base condition, i.e. the condition existing at that time, were developed for the Salt-Gila rivers during the CAWCS study. These have since been modified to include the recently completed re-evaluation of discharge frequency relationships for the SRP system, and to include the completion of Modified Roosevelt Dam. Because there is little impact on streamflow due to local intervening inflow between Gillespie Dam and Painted Rock Dam, inflow frequency relationships established herein for Painted Rock Dam are adequate for representing discharge frequency relationships at Gillespie Dam.

Likewise, streamflow records for the Gila River at Dome are available since 1903, but are also non-homogeneous. For purposes of this reconnaissance study, outflows from Painted Rock Dam are not considered to be attenuated due to the typically long duration of reservoir releases. Releases of small magnitudes (or short duration releases) may be severely attenuated, but releases for large flood events, which may result in downstream damage are less affected. For example, the peak outflow from Painted Rock Dam during the 1993 flood arrived at the Dome gage without any reduction in discharge. Therefore, outflow frequency relationships developed within this study are considered to be unaffected by routing. Intervening local inflow between Painted Rock Dam and Yuma was examined durıng this study by eliminating the peak flows which resulted from releases from Painted Rock Dam (since 1960) or would have been intercepted by Painted Rock Dam (prior to its existence). Analysis of the resulting set of discharges indicated that the 100-year local intervening runoff between Painted Rock Dam and Yuma is approximately 10,000 ft^3/s. Runoff emanating from the uncontrolled drainage area downstream of Painted Rock Dam results from high intensity rainfall during the months of June through October. Most of the runoff is flashy in nature and either occurs during the period when flood releases from Painted Rock Dam have been curtailed or when their is no release from Painted Rock Dam. Because this runoff is typically non-contemporaneous with significant reservoir releases, and because it is also non-damaging, combining the reservoir releases and local intervening runoff into a probabilistic relationship is unnecessary. To put this more simply:

- Downstream local intervening runoff is essentially non-damaging;

- Painted Rock Dam releases are non-contemporaneous with downstream local intervening runoff;

- Thus the only damages remaining affected by the project result from reservoir releases and can be analyzed separately.

All frequency relationships developed within this study framework are based upon observed inflows to Painted Rock Dam during the period since 1960, adjusted to reflect the existing or without project conditions, along with synthetic flood hydrographs developed from upstream gages, generally representing the runoff period since 1888. When sufficient information is available, the adjusted observed event results have been ranked as being the largest event in a time period which may exceed the 1960 - 1993 period. Previous hydrologic studies performed during the Central Arizona Water Control Study (CAWCS) resulted in development of streamflow data for the period beginning in 1888. As a consequence, it is possible to estimate the relative magnitude of some of the systematic record events (i.e. inflow, outflow, or elevation) within the 1960 - 1993 period, compared to those simulated for the period from 1888 based upon existing conditions. Accordingly, the five largest peak inflows within the systematic record were judged to be greater than any event since the simulated January 1916 flood (77 years). However, the largest single event, in terms of its impact on Painted Rock Dam, was the January 1993 event. Therefore the relative plotting position assigned to the water surface elevation and resulting outflow were the largest for the entire period (105 years). Not enough information was available to make further judgements concerning the relative plotting positions for the remaining systematic elevation-outflow events in the context of the period outside of the systematic record. When no assignment of a relative plotting position outside of the systematic record could be made, the events were assigned plotting positions within the 35-year systematic period which corresponded to their overall rank within that period.

A. WITHOUT PROJECT

1. Reservoir inflow

The magnitude and frequency of reservoir inflows are not affected by the regulation plan for Painted Rock Dam. Hence, reservoir inflow frequency relationships are identical for both without and with project conditions.

a. *combination of synthetic floods and adjusted observed inflows.* The adjusted observed inflows (representing 6-hour maxima, to be consistent with the synthetic hydrograph computation interval) were ordered and ranked. Comparison of these inflows to the simulated period of record results for Plan 9, developed by the COE in 1983, revealed that the 5 largest inflows to Painted Rock Dam in the period from 1960 - 1993 were also probably the 5 largest inflows since the flood of January 1916 (under the simulated conditions representing without project, i.e., with all the existing upstream impoundments in-place). Thus, median plotting positions were assigned to these 5 largest inflows based upon an historic period of 77 years, while the remainder of the inflows were assigned plotting positions based upon the systematic period of 35 years. The synthetic flood hydrograph peak inflows were plotted according to their nominal value on the same discharge frequency paper.

b. *construction of combined frequency curve.* Since more than half of the basin upstream of Painted Rock Dam is controlled by reservoirs, an analytical approach to developing inflow-frequency is not applicable. Graphical procedures were employed to produce a best-fit curve which balanced the observed and synthetic inflows. The results are listed in table 1, and shown on plate 1.

2. Reservoir elevation/reservoir outflow

a. *HEC-5 model development.* A reservoir simulation data set representing Painted Rock Dam was developed for the HEC-5 program. Key elements in the data set are the elevation-discharge-storage relationships (defined in table 8), the downstream channel capacity (10,000 ft^3/s), and the rate of change of flood control releases (1250 $ft^3/s/day$). Since each flood was evaluated from the beginning of reservoir inflow, the starting storage in each case

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(2) elevation/duration - in addition to the frequency curve presenting maximum elevations, the duration which is exceeded for various frequencies of floods was determined in the following steps:

(a) The elevation hydrographs for each observed and synthetic flood were examined to determine the highest elevation equalling or exceeding a series of discrete

durations, i.e. 1-, 2-, 3-, 5-, 10-, 30-, 60-, and 90-day.

(b) The results for the observed events were ranked, ordered, and plotted on frequency paper using a systematic record length of 35 years for each event with the exception of the 1993 flood. The 1993 flood was assigned a plotting position corresponding to the largest event in 105 years.

(c) In addition, the results for the synthetic flood hydrographs were tabulated and plotted at their nominal frequency.

(d) Elevation-duration frequency curves were constructed in the same manner as the maximum elevation frequency curve. Because there was little differentiation between the varying duration curves, only the peak, 10-day, and 90-day have been displayed. The results are presented in table 2 and on plate 4.

B. WITH PROJECT FLOOD CONTROL ALTERNATIVES

The project alternatives consist of two reservoir regulation plans with scheduled releases in excess of the without project improved channel capacity of 10,000 ft^3/s. Each alternative requires an improvement in the Gila River capacity downstream of the dam, commensurate with the maximum scheduled release.

In addition to the increased maximum release, the rate-of-change of reservoir releases was doubled (from 1250 $ft^3/s/day$ to 2500 $ft^3/s/day$) to take advantage of the increased downstream channel capacity . Delaying the time to reach maximum release by using the without project criterion, reduces the beneficial aspects of these alternatives, i.e. the increased level-of-protection, reduced water surface elevation, and decrease in duration of upstream and downstream flooding, which are the product of higher release capability. To fully utilize the 30,000 ft^3/s improved channel concept required discontinuance of the stepped release approach; for this alternative, the flood control releases are continuously incremented at the rate of 2500 $ft^3/s/day$ as the pool elevation rises. Table 8 presents the elevation-discharge-storage relationships for both alternative regulation plans.

1. <u>Alternative A - 20,000 ft^3/s d/s channel</u>

a. *HEC-5 model development.* The HEC-5 data model for Painted Rock Dam representing without project conditions was modified to allow a maximum release of 20,000 ft^3/s and an accelerated schedule of outflows (see table 8). As in the previous model, the gated flood control releases were curtailed when the pool elevation exceeded spillway crest (elevation 661 ft.,NGVD); however, since the maximum allowable release was increased to 20,000 ft^3/s, the flood release gates were not completely closed until the pool elevation reached 666 ft., NGVD, at which point the uncontrolled spillway flow was 20,000 ft^3/s. Simulated reservoir routings for the 500- and 100-year synthetic floods and the 1993 flood are shown on figure 8-1 to 8-3. Simulated reservoir routing results for the systematic record as well as for the synthetic floods are displayed in Table 9.

b. *development of combined frequency curves.* The approach used to combine the results of the simulated reservoir routing of observed inflows and synthetic flood hydrographs was identical to the without project procedure, but the elevation-duration analysis was limited to the 10-day and 90-day durations. Plates 5 through 7 present the resulting frequency curves and plates 11 and 12 compare the alternative to the without project results. Tables 1 and 2 summarize these relationships.

2. <u>Alternative B - 30,000 ft^3/s d/s channel</u>

a. *HEC-5 model development.* The HEC-5 data model was modified to allow a maximum gated flood control release of 30,000 ft^3/s at spillway crest (elevation 661 ft., NGVD). To ensure that this additional release capacity is utilized, the rate-of-change of reservoir releases was increased to 2500 $ft^3/s/day$ and the steps were eliminated, resulting in continuously increasing reservoir releases as the pool elevation rises, until the maximum release of 30,000 ft^3/s is attained. The flood release gates are then systematically closed as the pool elevation continues to rise to maintain a total of regulated and uncontrolled outflow of 30,000 ft^3/s. At a pool elevation of 667.6 ft., NGVD, the flood gates are completely closed and the uncontrolled spillway outflow is 30,000 ft^3/s. Simulated reservoir routings for the 500- and 100-year synthetic floods and the 1993 flood are shown on figure 8-1 to 8-3. Simulated reservoir routing results for the systematic record as well as for the synthetic floods are displayed in Table 9.

b. *development of combined frequency curves.* The approach used to combine the results of the simulated reservoir routing of observed inflows and synthetic flood hydrographs was identical to the procedures for without project and Alternative A (the elevation-duration analysis was limited to 10-day and 90-day durations). However, because the outflows were continuously increased as the pool elevation increased, the resulting frequency relationships were interpreted as continuous relationships, rather than as a stepped outflow-frequency relationship along with a parallel elevation-frequency relationship; as was the case for without project and Alternative A, elevation-outflow pairs have identical frequencies. Plates 8 through 10 present the resulting frequency curves and plates 11 and 12 compare the alternative to the without project results. Tables 1 and 2 summarize these relationships.

VI. **WATER SUPPLY ANALYSIS**

The basis for determination of the average annual yield for the seasonal joint use of the flood control space behind Painted Rock Dam is simulation of period-of-record inflows (adjusted for Plan 9 Roosevelt, see Chapter IV, Observed Inflows) for the without project conditions as well as the with water supply project conditions. Increases in water delivered to potential users downstream of Painted Rock Dam for the with water supply project conditions are quantified for each year of simulation, and the accumulated yield is divided by the number of years since construction of the dam was completed - 35 years - to obtain the average annual yield for with water supply project conditions.

A. WITHOUT PROJECT

The flood history used to define the discharge frequency relationship for Painted Rock Dam was used to determine which flood years produced enough inflow to the dam to be candidates for water supply analysis. As a result, the floods of 1973, 1978, 1979, 1980, 1983, 1992, and 1993 were determined to retain enough stored water by the beginning of the water supply season (1 March) to be capable of developing some yield. Yield is defined to be the quantity of deliverable outflow produced by maintaining a seasonal water supply pool. As such it represents the difference between usable water supplied during without project operation (incidental yield resulting from downstream usage of normal flood control releases) and with water supply project operation. Hence, without project simulations using the without project regulation plan (table 8) were used as the baseline for computation of yield.

B. WITH WATER SUPPLY PROJECT

1. 500 ft^3/s demand

The first supply scenario considered was a constant delivery of 500 ft^3/s which might be diverted for use at WMIDD, or delivered to Mexico while minimizing groundwater problems throughout WMIDD. A seasonal rule curve was established (see table 10 and figure 9) by determining how much water supply space set aside on 1 March of each year would be depleted by 1 December of that same year, based upon average monthly evaporation along with the 500 ft^3/s demand. As a result, a seasonal water supply pool allocation of approximately 371,000 ac-ft (pool elevation approximately 598 ft NGVD) beginning 1 March of each year was established. Whenever the pool elevation exceeds the elevation established by the rule curve, the regulation plan reverts to the without project release schedule. If the pool elevation is less than or equal to the rule curve elevation for the appropriate time period, the regulation plan requires a water supply release of 500 ft^3/s . If existing storage is inadequate to deliver 500 ft^3/s , the maximum release possible will be made. A nominal amount of storage (the last 30,000 ac-ft) was set aside as being non-usable based upon the history of water quality problems associated with long term storage at Painted Rock Dam.

2. NIB demand

An alternative demand schedule, based upon the average monthly delivery of water to Mexico at the Northerly International Boundary (NIB), was developed and the resulting yield determined. As for the 500 ft^3/s demand schedule, a monthly rule curve was established using the variable monthly delivery schedule and average monthly evaporation to determine the seasonal storage allocation for 1 March at Painted Rock Dam. The 1 March seasonal pool was determined to be approximately 1,265,000 ac-ft (elevation 634 ft, NGVD). The monthly demand schedule and evaporation rates used to determine this storage are shown in table 9. The seasonal rule curve is also shown in table 9 and on figure 9. As in the previous discussion concerning the application of the rule curve, the regulation plan reverts to the without project plan whenever the elevation exceeds the seasonal rule curve elevation.

3. Simulation results

Painted Rock Dam operation for each of the seven water years (1973, 1978, 1979, 1980, 1983, 1992, and 1993) was simulated for without project and with project plans. The period from 1 March to 1 December was examined to determine when the water supply space was depleted for without project conditions. Any scheduled water supply release which was made after this time (or which was in excess of the without project release during the seasonal period) was considered to be yield. These quantities are displayed on an annual basis in table 11 and the simulations are compared on figures 10 to 13. Average annual yield for the 35 year period, based on the accumulated yield for each of the seven contributing water years, is approximately 27,500 ac-ft for the 500 ft^3/s demand alternative and 47,900 ac-ft for the NIB alternative.

VII. **ADEQUACY OF RESULTS**

Although this study was performed at the Reconnaissance level, all the hydrologic information used was the best available: the observed inflow data set for Painted Rock Dam was the complete set of inflows since the dam was constructed; the reservoir characteristics represent the results of the most recent survey; the without project regulation plan is based on a concept currently being formally evaluated by the COE and includes channel improvements underway or completed; the impact of Modified Roosevelt Dam on inflow to Painted Rock Dam has been incorporated into the data set; the most recent synthetic flood hydrographs, developed for the Section 7 Study for Modified Roosevelt Dam, and which have been extended to a duration of 90-days, were used in the development of frequency relationships for Painted Rock Dam; and the only regulation plan which has been evaluated from an engineering basis (Plan 9) has been utilized in developing the downstream inflow data base. Therefore, the results are satisfactory for a Reconnaissance study. However, the development of a water control plan for Modified Roosevelt Dam will result in a modified set of downstream runoff data for the period from 1888 - 1993. Because the Painted Rock Dam inflow set will be altered, the elevation/outflow frequency relationships for Painted Rock Dam will also be altered. The impact of these changes on project formulation and relative benefits is not expected to be significant.

Average annual yield is based upon the same period-of-record as the flood control analysis. The period examined contained both dry and wet periods and was considered representative of the long term inflow variations to Painted Rock Dam. No weighting was given to any of the events in determining the average annual yield. An investigation into the yield determined through a stochastic process, by evaluating the yield for discrete frequency floods, indicated that the results of the 35 year period were reasonable.

While evaporation was accounted for, both in the development of the rule curves and the flood simulations, channel percolation was not. It is likely, based upon experience, that long duration releases made during the hottest months of the year, would result in reduced delivery of water at the point of takeoff, especially if it is the NIB. Further refinement of yield considering percolation losses and evaporation in transit should be made in Feasibility level studies if they are conducted (or in whatever further study is authorized). It should be noted, however, that losses in transmission can be offset in-whole or in-part by allocating an increased volume of seasonal space for water supply storage and utilizing that space to make deliveries large enough to offset the transmission losses.

In addition water quality problems which arise from long duration storage at Painted Rock Dam during hot weather months should be addressed in Feasibility (or follow-up) studies. It is important to note that the water quality problems are pre-existing. While they may be aggravated by storing water on a seasonal basis for delivery at a reduced rate, water has been retained during normal flood operations in previous years and will continue to be held over in the future when reservoir inflow requires. The problem is inherent to surface water in the desert southwest. Oxygen depletion and the effects of anaerobic decomposition on water stored behind Painted Rock Dam are well-documented, and are not relegated to seasonal water supply storage. It is not apparent that such problems will affect the quality of the water as delivered. However, measures to improve the upstream situation should include the costs to alleviate existing problems as well as induced problems resulting from seasonal storage. Salinity increases resulting from holding water for increased periods of time, especially in the hot, dry summer months are a more serious handicap to water supply. Again, these impacts must be addressed for both incidental yield and the water supply alternatives during later studies.

The effect of long-term seasonal storage on flood control may not be evaluated adequately within any period of record. The future magnitude and timing of inflow events may not be represented by historical records. However, the record examined in this analysis did not result in identification of any negative impact on the level of flood protection provided to downstream interests.

TABLE 1. INFLOW, OUTFLOW, AND ELEVATION PROBABILITY VALUES FOR PAINTED ROCK DAM

PROBABILITY (%)		WITHOUT PROJECT		ALTERNATIVE A		ALTERNATIVE B	
	INFLOW (ft^3/s)	OUTFLOW (ft^3/s)	ELEVATION (ft)	OUTFLOW (ft^3/s)	ELEVATION (ft)	OUTFLOW (ft^3/s)	ELEVATION (ft)
.2	260,000	55,000	671.5	55,000	671.5	55,000	671.5
.3	241,000	52,000	671.0	52,000	671.0	30,000	667.6
.5	213,000	42,000	670.0	39,000	668.0	29,700	658.0
.7	198,000	30,000	668.5	20,000	659.0	28,000	642.5
1.0	179,000	15,000	666.0	20,000	645.0	27,300	638.0
1.1	175,000	10,000	664.4	20,000	641.5	27,000	636.5
1.6	154,000	10,000	661.0	20,000	637.0	26,600	632.5
2.0	140,000	10,000	658.0	20,000	636.0	26,100	629.0
5.0	87,000	10,000	626.0	20,000	623.5	23,000	614.0
7.0	71,000	10,000	612.0	10,000	612.0	20,500	606.0
10.0	53,000	10,000	603.0	10,000	603.0	18,000	597.0
10.9	49,000	10,000	602.0	10,000	602.0	17,200	594.0
11.0	49,000	5000	602.0	5000	602.0	17,200	594.0
20.0	24,500	5000	591.0	5000	591.0	10,000	572.0
21.4	21,500	5000	589.0	5000	589.0	8800	569.5
21.5	21,500	2500	589.0	2500	589.0	8800	569.5
28.0	12,000	2500	566.0	2500	566.0	5000	555.0
30.0	9500	2000	550.0	2000	550.0	3800	550.0
36.0	4500	700	550.0	700	550.0	1400	550.0
40.0	2500	150	---	150	---	150	---

TABLE 2. ELEVATION-DURATION PROBABILITY VALUES FOR PAINTED ROCK DAM

PROBABILITY (%)	ELEVATION[1] (ft)								
	WITHOUT PROJECT			ALTERNATIVE A			ALTERNATIVE B		
	PEAK	10-DAY	90-DAY	PEAK	10-DAY	90-DAY	PEAK	10-DAY	90-DAY
.2	671.5	668.0	665.0	671.5	668.0	659.5	671.5	668.0	643.0
.5	670.0	667.0	663.5	668.0	661.0	652.5	658.0	640.0	631.0
1	666.0	664.0	653.0	645.0	639.0	623.0	638.0	631.5	589.5
2	658.0	654.0	628.0	636.0	633.0	607.0	629.0	621.5	565.0
5	626.0	618.0	598.5	623.5	616.0	591.0	614.0	603.5	550.0
10	603.0	600.0	585.5	603.0	600.0	584.0	597.0	587.0	550.0
20	591.0	586.0	562.0	591.0	584.0	559.0	572.0	563.0	550.0

[1] Elevations in feet, NGVD, represent the elevation which is exceeded for the given duration and frequency.

TABLE 3. MAJOR GILA RIVER CROSSINGS DOWNSTREAM OF PAINTED ROCK DAM

NAME	LOCATION FROM DAM (miles)	DESIGN CAPACITY (ft^3/s)
1. Sentinel	35	5,000
2. Dateland (Ave 264)	49	10,000
3. Ave 51E	66	7,000
4. Ave 45E	83	10,000
5. Ave 38E	98	10,000
6. Ave 30E	120	10,000
7. Ave 20E	104	10,000
8. US Highway 95	115	25,000
9. Ave 7E	125	7,000

TABLE 4. FEBRUARY 1980 OBSERVED INFLOW TO PAINTED ROCK DAM ADJUSTED FOR PLAN 9
(all discharge values in ft³/s)

DATE	PAINTED ROCK INFLOW[1]	DATE	STEWART MOUNTAIN OUTFLOW[2]	PLAN 9 OUTFLOW[3]	CHANGE	ACCUM. CHANGE	ADJ. PAINTED ROCK INFLOW[4]
16 FEB	76,098	15 FEB	38,200	25,000	13,200	13,200	62,898
17	146,545	16	64,000	25,000	39,000	52,200	107,545
18	80,263	17	57,200	25,000	32,200	84,400	48,063
19	90,468	18	43,200	25,000	18,200	102,600	72,268
20	91,023	19	33,300	25,000	8,300	110,900	82,723
21	90,126	20	32,800	25,000	7,800	118,700	82,326
22	96,134	21	43,600	25,000	18,600	137,300	77,534
23	77,529	22	46,500	25,000	21,500	158,800	56,029
24	53,584	23	39,600	25,000	14,600	173,400	38,984
25	45,974	24	29,200	25,000	4,200	177,600	41,774
26	35,708	25	21,400	25,000	-3,600	174,000	39,308
27	16,550	26	13,300	25,000	-11,700	162,300	28,250
28	9797	27	10,500	25,000	-14,500	147,800	24,297
29	10,875	28	10,500	25,000	-14,500	133,300	25,375
1 MAR	7873	29	8410	25,000	-16,590	116,710	24,463
2	8267	1 MAR	8600	25,000	-16,400	100,310	24,667
3	7839	2	8520	25,000	-16,480	83,830	24,319
4	7478	3	7300	25,000	-17,700	66,130	25,178
5	7046	4	6420	25,000	-18,580	47,550	25,626
6	4821	5	2370	25,000	-22,630	24,920	27,451
7	1896	6	51	24,971	-24,920	0	26,816

[1] Observed inflow based on COE calculations from changes in storage.

[2] Observed releases, USGS gaged data, lagged 1-day for computational purposes based upon variation between outflow from SRP and Painted Rock inflow.

[3] Adjusted outflow based on Plan 9 - Roosevelt Dam operated such that outflow from Stewart Mountain Dam equals the lesser of inflow or 25,000 ft3/s on the rising limb, and remains at the maximum release on the falling limb until the flood pool is empty.

[4] Adjusted Painted Rock inflow = Painted Rock inflow - change in Stewart Mountain outflow attributable to Plan 9.

TABLE 5. MAXIMUM OBSERVED INFLOWS TO PAINTED ROCK DAM, ADJUSTED FOR MODIFIED ROOSEVELT DAM

Event	Maximum Inflow (ft^3/s) (based on 6-hour time interval)
October 1964	1460
January 1966	54,000
December 1967	8100
September 1970	5870
August 1971	3900
April 1973	16,300
October 1975	1040
March 1978	108,000
December 1978	89,900
February 1980	151,000
February 1983	26,800
October 1983	86,600
March 1985	17,300
December 1985	1370
March 1992	9000
January 1993	186,000

TABLE 6. SYNTHETIC FLOOD ROUTING, MAXIMUM DISCHARGES, SALT RIVER TO PAINTED ROCK DAM

FREQUENCY (YRS)	SALT/VERDE CONFLUENCE		SALT/GILA CONFLUENCE		PAINTED ROCK DAM	
	CLIFF 1988	GILA RECON	CLIFF 1988	GILA RECON	CLIFF 1988	GILA RECON
5	45,000	45,600	40,000	39,200	28,300	23,100
10	85,000	66,900	85,000	64,300	54,800	46,700
20	115,000	107,000	120,000	92,600	79,200	69,400
50	145,000	155,000	175,000	138,000	115,000	103,000
100	175,000	203,000	210,000	175,000	148,000	130,000
200	210,000	224,000	240,000	221,000	191,000	171,000
500	275,000	261,000	290,000	280,000	268,000	256,000

NOTES:

Starting Storage for simulations in SRP system - Roosevelt Dam, 1,609,000 ac.ft.
Other Salt River dams, 90% full
Verde River dams, full

Bartlett Dam release lagged 6 hrs

Local Inflow - 8 % of Roosevelt inflow on Salt, 8 % of Horseshoe inflow on Verde
% of Gila River at Kelvin for the Gila u/s of Salt as follows -
- 5-yr, 0%
- 10-yr, 14%
- 20-yr, 23%
- 50-yr, 44%
- 100-yr, 61%
- 200-yr, 100%
- 500-yr, 100%

All discharges represent maximum 6-hour values in ft^3/s

TABLE 7. VOLUME FREQUENCY INFLOWS TO PAINTED ROCK DAM

FLOOD FREQUENCY	DURATION[1]							
	1-DAY	2-DAY	3-DAY	5-DAY	10-DAY	30-DAY	60-DAY	90-DAY
5-yr	22,300	20,400	18,300	14,700	11,100	5270	3710	2550
10-yr	46,000	44,000	41,700	36,300	25,600	12,700	8840	6390
20-yr	66,300	59,600	54,600	47,300	39,900	20,900	14,700	11,100
50-yr	98,200	86,600	75,300	63,000	52,200	34,600	24,600	18,700
100-yr	124,000	109,000	93,700	75,800	61,500	46,000	32,900	25,100
200-yr	161,000	141,000	121,000	97,500	78,600	61,100	44,300	34,100
500-yr	245,000	210,000	177,000	139,000	99,200	73,300	54,500	41,500

[1] Duration discharges represent maximum average inflow in ft3/s. All flows are computed from synthetic inflow hydrographs only.

TABLE 8. ALTERNATIVE FLOOD CONTROL REGULATION PLANS FOR PAINTED ROCK DAM

ELEVATION (ft NGVD)	DISCHARGE (ft^3/s)			STORAGE[1] (ac-ft)	COMMENT
	W/O PROJECT[2]	ALT. A[2]	ALT. B[2]		
530	0[3]	0[3]	0[3]	0	Sill Elevation
532	0[3]	0[3]	0[3]	31.2	See Footnote 3
550	0	0	0	3515	Top of Debris Pool
550.1	2500	2500	3750	3516	Begin Flood Pool
591	2500	2500	17,000	258,500	End Step 1 Release, w/o project & Alt. A
591.1	5000	5000	17,100	258,600	Begin Step 2 Release, w/o project & Alt. A
603	5000	5000	21,600	454,700	End Step 2 Release, w/o project & Alt. A
603.1	10,000	10,000	21,700	454,800	Begin Step 3 Release, w/o project & Alt. A
618	10,000	10,000	24,200	791,136	End Step 3 Release, Alt. A
618.1	10,000	20,000	24,300	793,773	Begin Step 4 Release, Alt. A
661	10,000	20,000	30,000	2,476,339	Spillway Crest
664.4	10,000	20,000	30,000	2,661,400	All Flood Gates Closed - w/o project
666	20,000	20,000	30,000	2,751,270	All Flood Gates Closed - Alt. A
667.6	30,000	30,000	30,000	2,842,992	All Flood Gates Closed - Alt. B
676	108,000	108,000	108,000	3,353,800	Uncontrolled Spillway Flow
690	298,000	298,000	298,000	4,323,000	Uncontrolled Spillway Flow
705	564,000	564,000	564,000	5,562,000	Top of Embankment

[1] Surveyed October 1985, computed by Ray Nickless.

[2] Flood control releases will be incremented in amounts of 1250 ft3/s/day, w/o project - 2500 cfs/day, with project, throughout the flood pool (to elevation 661 ft, NGVD).

[3] Gates may be open 1/2 foot between elevation 530 and 535 to pass low flows.

TABLE 9. RESERVOIR ROUTING, PAINTED ROCK DAM, OBSERVED ADJUSTED AND SYNTHETIC INFLOWS - MAXIMUM INFLOW, OUTFLOW, AND ELEVATION

FLOOD EVENT	MAX INFLOW (ft^3/s)	WITHOUT PROJECT[1]		ALTERNATIVE A[2]		ALTERNATIVE B[3]	
		OUTFLOW	ELEVATION	OUTFLOW	ELEVATION	OUTFLOW	ELEVATION
	OBSERVED INFLOWS ADJUSTED FOR MODIFIED ROOSEVELT DAM (DAILY FLOW ROUTINGS)						
Jan 1966	54,000	2500	585.20	2500	584.98	10,500	575.91
Apr 1973	16,300	5000	593.30	5000	593.29	8890	569.65
Mar 1978	108,000	5000	595.63	5000	595.59	16,700	590.56
Dec 1978	89,900	10,000	614.39	10,000	613.90	19,900	599.43
Feb 1980	151,000	10,000	641.41	20,000	633.89	25,800	628.65
Oct 1980	920	1200	550.87	1250	550.78	1650	550.09
Mar 1982	756	417	550.03	417	550.03	417	550.02
Feb 1983	26,800	5000	598.92	5000	598.91	10,000	574.94
Oct 1983	86,600	5000	597.89	5000	597.86	17,500	593.24
Mar 1985	17,300	5000	597.05	5000	597.01	11,300	576.88
Dec 1985	1370	1480	550.08	1480	550.08	1480	550.06
Mar 1992	9000	2500	575.45	2500	575.45	6110	560.46
Jan 1993	186,000	27,600	667.20	20,000	652.61	27,600	640.91
	SYNTHETIC FLOOD HYDROGRAPHS (6-HOUR PERIOD ROUTINGS)						
5-year	23,100	2500	589.91	2500	589.69	10,500	574.33
10-year	46,700	10,000	609.01	10,000	608.41	18,800	595.68
20-year	69,400	10,000	623.40	20,000	621.70	23,300	613.03
50-year	103,000	10,000	648.76	20,000	636.94	26,000	629.86
100-year	130,000	19,300	665.95	20,000	649.79	27,400	639.55
200-year	171,000	44,300	669 02	39,400	668.49	29,700	658.10
500-year	256,000	52,100	669.87	52,100	669.87	51,500	669.91
Note: all outflows represent maximum values in ft^3/s, and elevations represent maximum values in ft, NGVD							

[1] Maximum gated release = 10,000 ft3/s.

[2] Maximum gated release = 20,000 ft3/s.

[3] Maximum gated release = 30,000 ft3/s.

TABLE 10. MONTHLY SEASONAL RULE CURVE DEVELOPMENT FOR PAINTED ROCK DAM WATER SUPPLY ALTERNATIVES

MONTH	RULE CURVE DEVELOPMENT						
		Demand = 500 ft³/s			Demand = NIB		
	EVAPORATION inches	Starting Storage ac-ft	Elevation ft,NGVD	Demand ft³/s	Starting Storage ac-ft	Elevation ft,NGVD	Demand ft³/s
JANUARY	2.11	3515	550.0	0	3515	550.0	0
FEBRUARY	3.09	3515	550.0	0	3515	550.0	0
MARCH	4.96	371,000	598.3	500	1,265,000	633.5	2666
APRIL	7.42	334,000	596.1	500	1,082,000	628.0	2872
MAY	10.05	300,000	593.5	500	899,000	622.0	1592
JUNE	12.26	255,000	590.5	500	778,000	617.5	2343
JULY	11.52	213,000	587.2	500	614,000	610.8	2508
AUGUST	10.53	170,000	583.6	500	441,000	602.3	2470
SEPTEMBER	8.53	131,000	579.6	500	276,000	592.2	1574
OCTOBER	5.66	95,000	575.4	500	174,000	584.2	1115
NOVEMBER	3.23	61,000	570.3	500	101,000	576.3	1163
DECEMBER	2.04	30,000	563.0	500	31,000	563.3	500

Notes:
1) Evaporation represents net evaporation, i.e. evaporation minus precipitation; source:LAD Reservoir Regulation Section
2) Storage of 3515 ac-ft (elevation=550) is buffer pool
3) Elevations are rounded to nearest tenth of a foot
4) Seepage unaccounted for
5) Channel losses=0
6) Whenever seasonal storage allocations/elevations described by this rule curve are exceeded, the regulation plan reverts to the flood control release schedule presented in table 8 as the without project water control plan.

TABLE 11. WATER SUPPLY STUDY RESULTS - SEASONAL STORAGE ALTERNATIVES

WATER YEAR	DEMAND=500 ft^3/s			DEMAND=NIB	
	STORAGE 1 MARCH ac-ft	YIELD ac-ft		STORAGE 1 MARCH ac-ft	YIELD ac-ft
1973	2359 (383,000 on 26 Apr)	142,000		2359 (359,000 on 21 May)	120,000
1978	0 (372,000 on 11 Mar)	201,000		0 (349,000 on 11 Mar)	64,600
1979	364,000 (599,000 on 3 Apr)	156,000		571,000 (935,000 on 17 Apr)	534,000
1980	1,405,000[1] (1,656,000 on 7 Mar)	141,000		1,534,000[1] (1,735,000 on 7 Mar)	473,000
1983	282,000 (458,000 on 3 Apr)	96,000		283,000 (564,000 on 8 Apr)	301,000
1992	93,100 (322,000 on 10 Apr)	189,000		93,100 (171,000 on 4 Apr)	81,200
1993	2,804,000[1]	37,500		2,804,000[1]	101,000
TOTAL		962,500			1,674,800
AVERAGE[2]		27,500			47,900

NOTE:
All storages within parentheses refer to maximum seasonal storage after 1 March, the beginning of joint use.

[1] Exceeds seasonal allocation of water supply space. Scheduled flood control releases will be made until the pool is drawn down to that elevation shown on the rule curve.

[2] Average annual results since 1960, i.e. total yield/35 years.

PAINTED ROCK RESERVOIR

GILA RIVER BASIN, ARIZONA

REVISED: April 1993

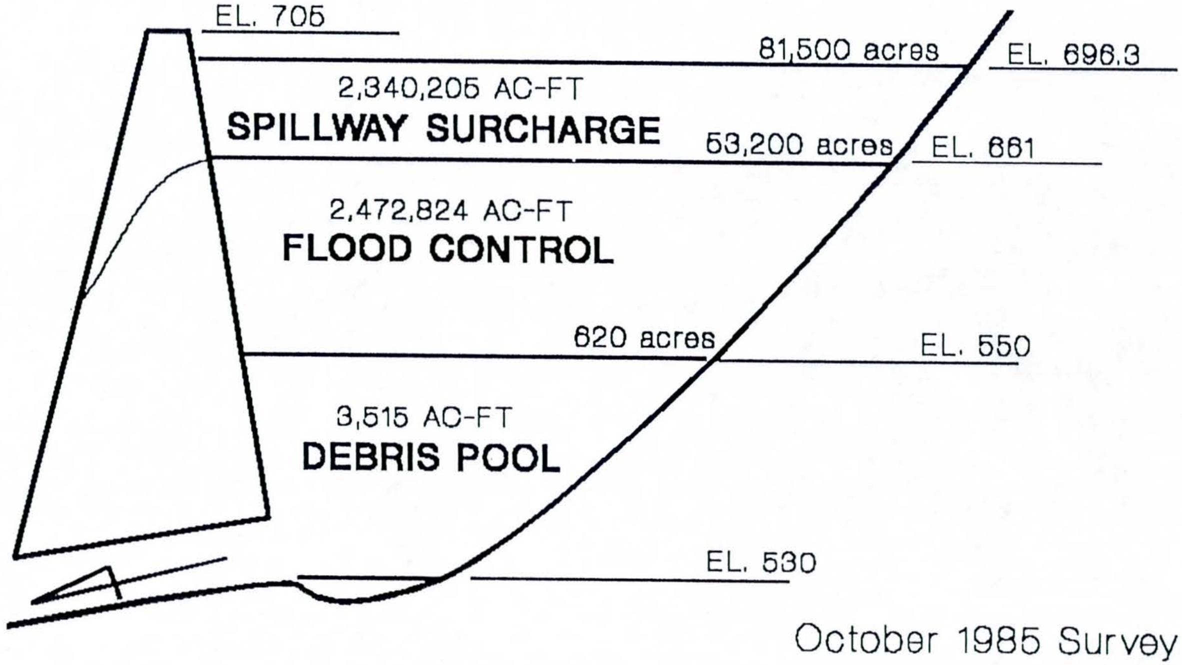

FIGURE 3 ALLOCATION DIAGRAM - PAINTED ROCK DAM

Painted Rock Dam and Reservoir
Maricopa County, Arizona
PERTINENT DATA
APRIL 1993

Stream System		Gila River
Drainage Area	sq. mi.	50,800
Reservoir:		
Elevation		
Streambed	ft., msl	524
Debris Pool	ft., msl	550
Flood Control Pool (Spillway Crest)	ft., msl	661
Spillway Design Surcharge level	ft., msl	696.3
Top of Dam	ft., msl	705
Area*		
Debris Pool	acres	620
Flood Control Pool (Spillway Crest)	acres	53,200
Spillway Design Surcharge Level	acres	81,500
Top of Dam	acres	89,600
Capacity*		
Debris Pool	ac-ft	3,515 (0.00**)
Flood Control Pool (spillway crest)	ac-ft	2,476,339 (.91**)
Spillway Design Surcharge Level	ac-ft	4,816,544 (1.79**)
Top of Dam	ac-ft	5,561,470 (2.05**)
Allowance for Sediment (50-yr)	ac-ft	200,000 (0.07**)
Dam: - Type		Earthfill
Height Above Original Streambed	ft	181
Top of Length (excluding saddle dike and spillway)	ft	4,780
Top Width	ft	20
Freeboard	ft	8.7
Spillway: - Type		Ungated, Broad-crested
Crest Length	ft	610
Design Surcharge	ft	35.3
Design Discharge	cfs	401,700
Outlets:		
Gates - type		Tainter
Number and Size		3 - 10'W X 18'H
Gate and Sill Elevation	ft., msl	530
Conduits		
Number and Size - Inside Diameter	ft	1 - 25
Length	ft	925
Maximum Capacity at Spillway Crest	cfs	30,480
Regulated Capacity at Spillway Crest	cfs	23,000
Reservoir Design Flood:		
Duration (Inflow)	days	18
Total Volume	ac-ft	2,800,000 (1.03**)
Inflow Peak	cfs	300,000
Spillway Design Flood		
Duration (Inflow)	days	18
Total Volume	ac-ft	7,680,000 (2.83**)
Inflow Peak	cfs	620,000
Historic Maximums		
Maximum Release	cfs	26,000
Date		2/27/93
Maximum Water Surface Elevation	ft., msl	667.00
Date		2/27/93

* Based on October 1985 survey **Inches of runoff

FIGURE 4 PERTINENT DATA - PAINTED ROCK DAM

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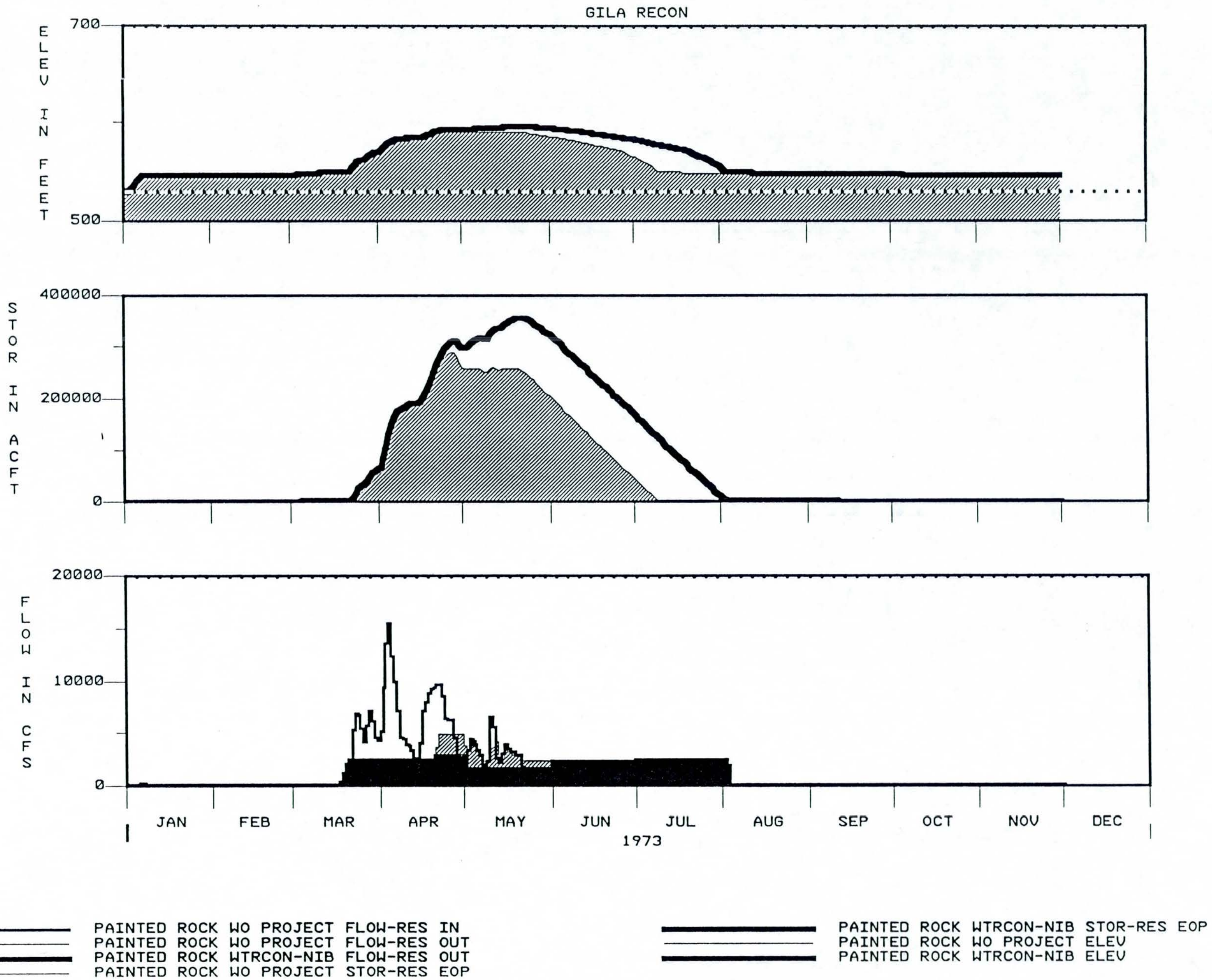


FIGURE 13-1 RESERVOIR ROUTING - w/and w/o project (NIB)
1973 - PAINTED ROCK DAM

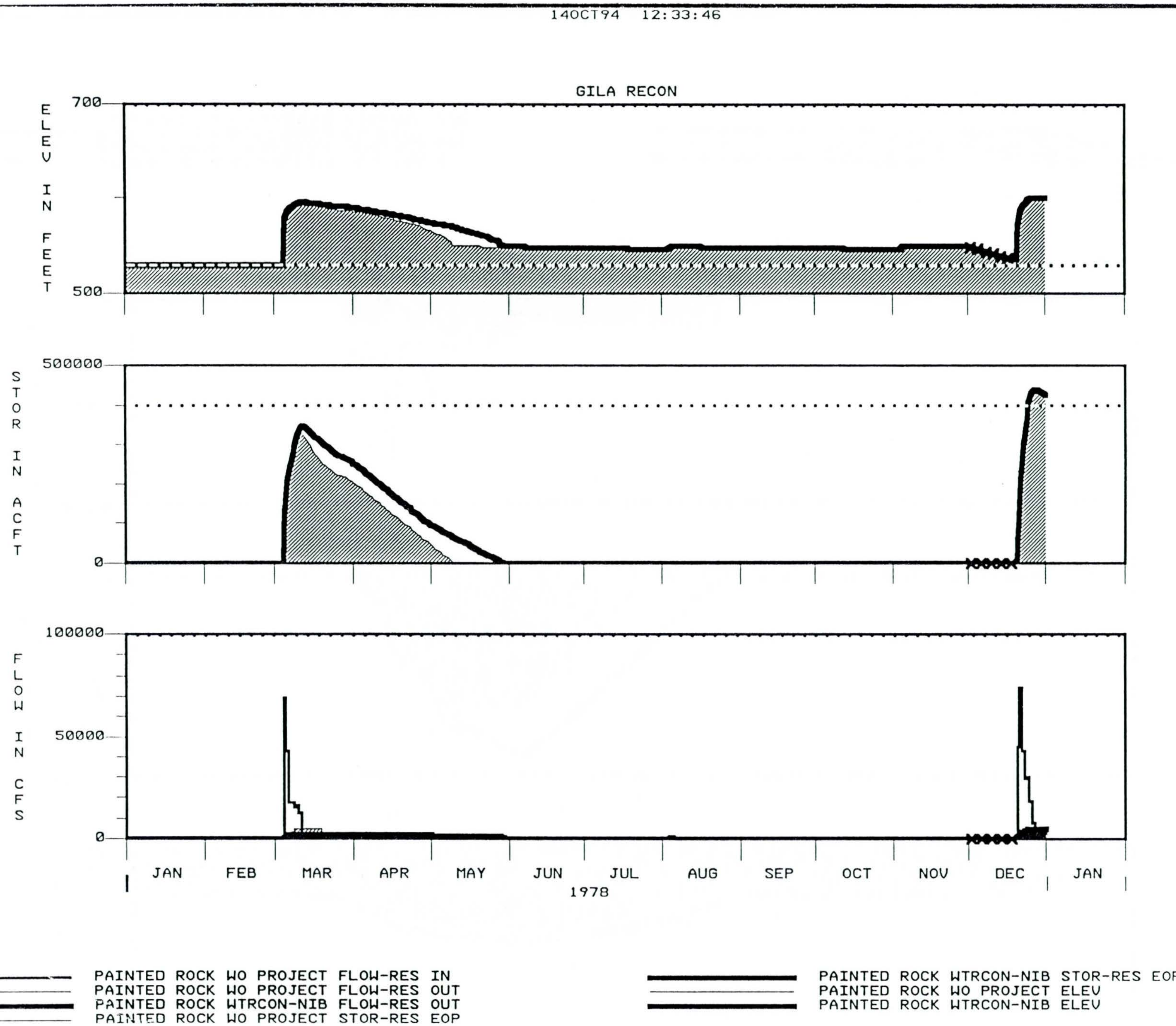
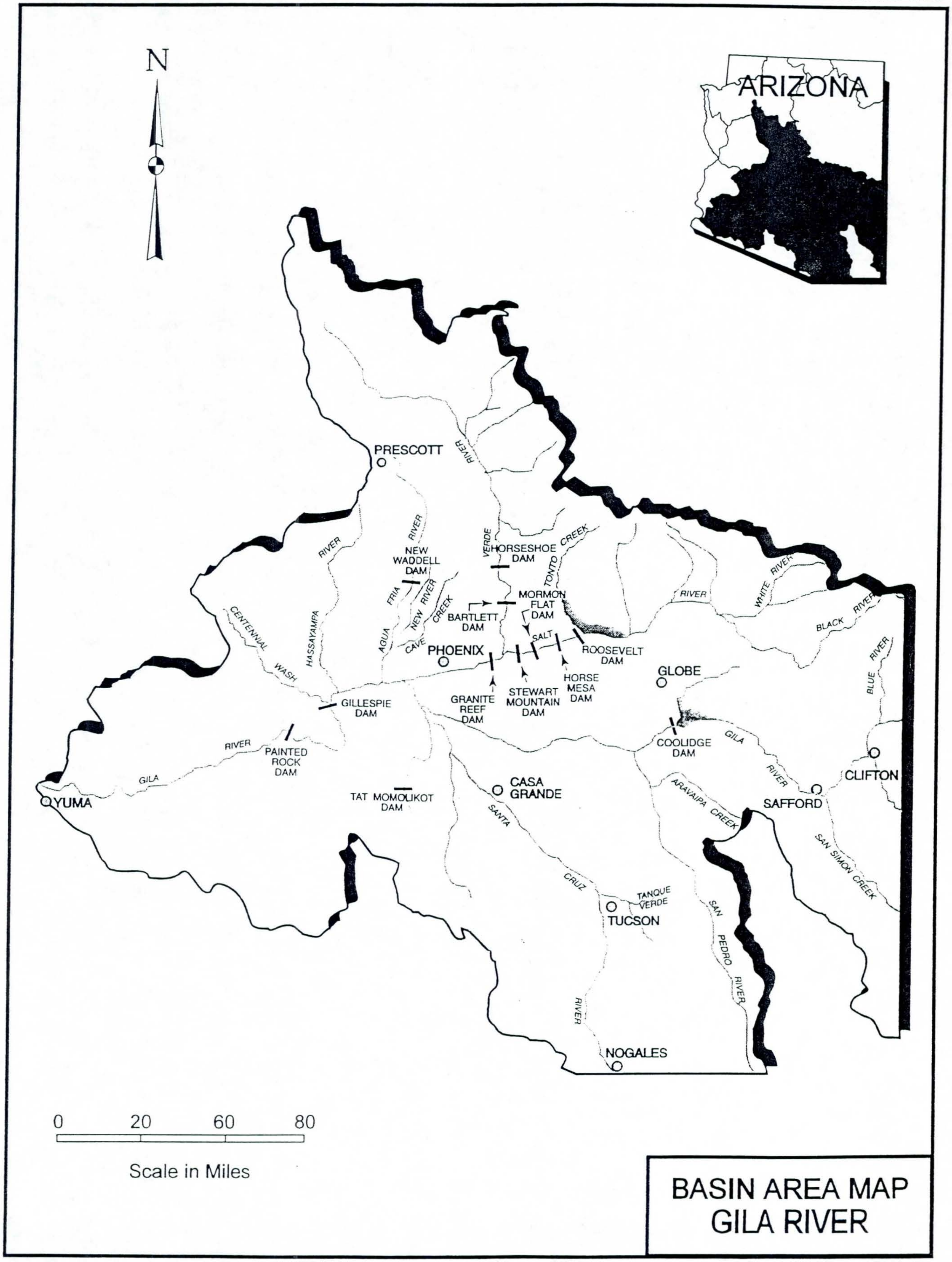


FIGURE 13-2 RESERVOIR ROUTING - w/and w/o project (NIB)
1978 - PAINTED ROCK DAM



BASIN AREA MAP
GILA RIVER

Figure 1

Modified Roosevelt Dam

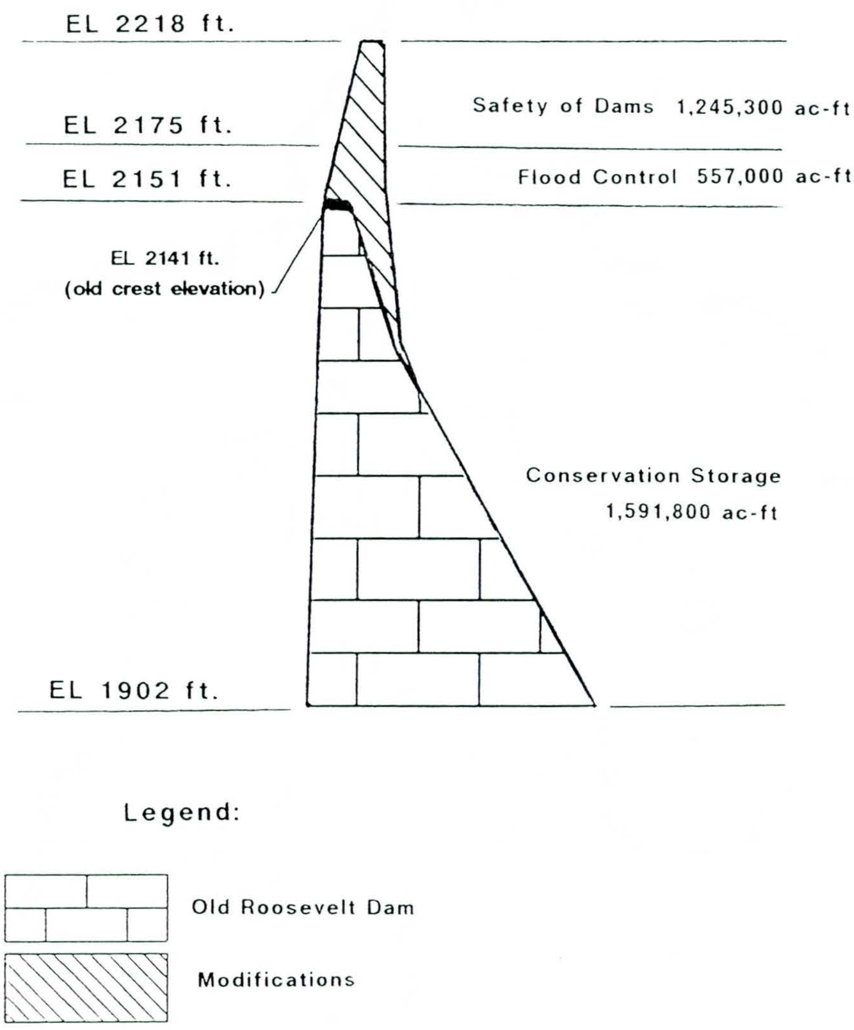


FIGURE 2 ALLOCATION DIAGRAM - MODIFIED ROOSEVELT DAM

Source: US Bureau of Reclamation

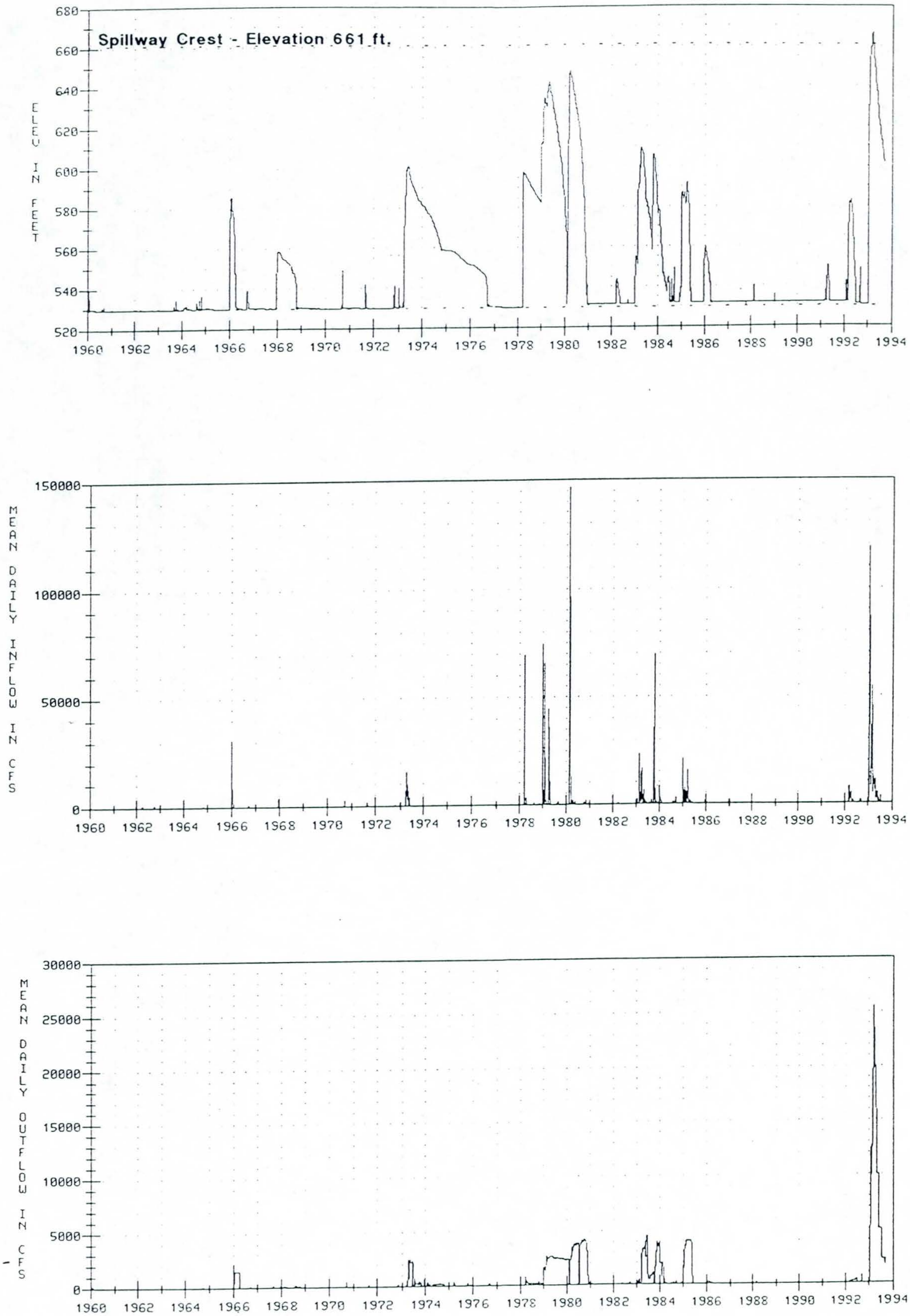
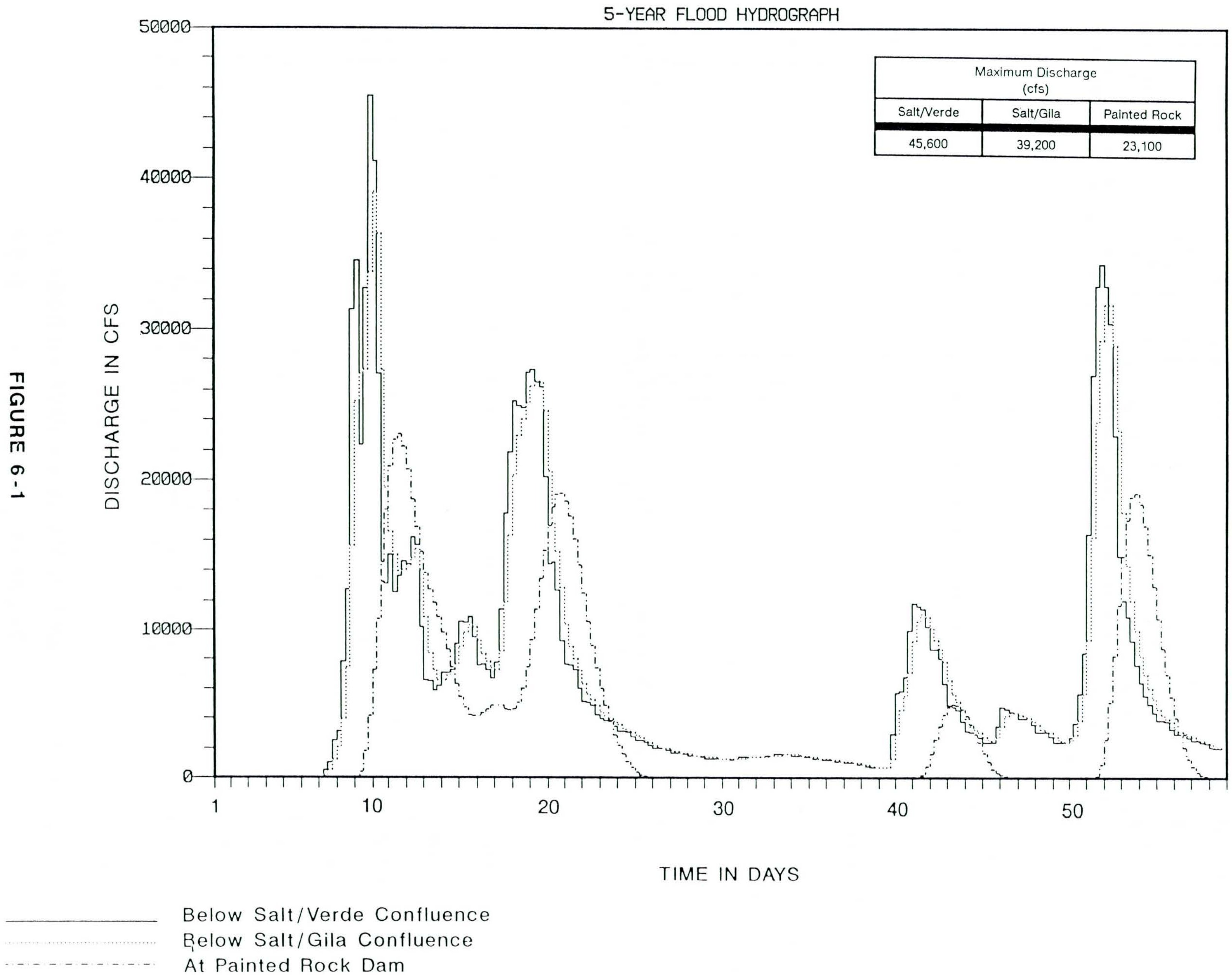


FIGURE 5 FLOOD HISTORY OF PAINTED ROCK DAM

01 January 1960 - 10 June 1993

FIGURE 6-1



SYNTHETIC FL[illegible] HYDROGRAPHS
ROUTED FROM THE SALT-VERD[illegible] [illegible]FLUENCE TO PAINTED ROCK DAM

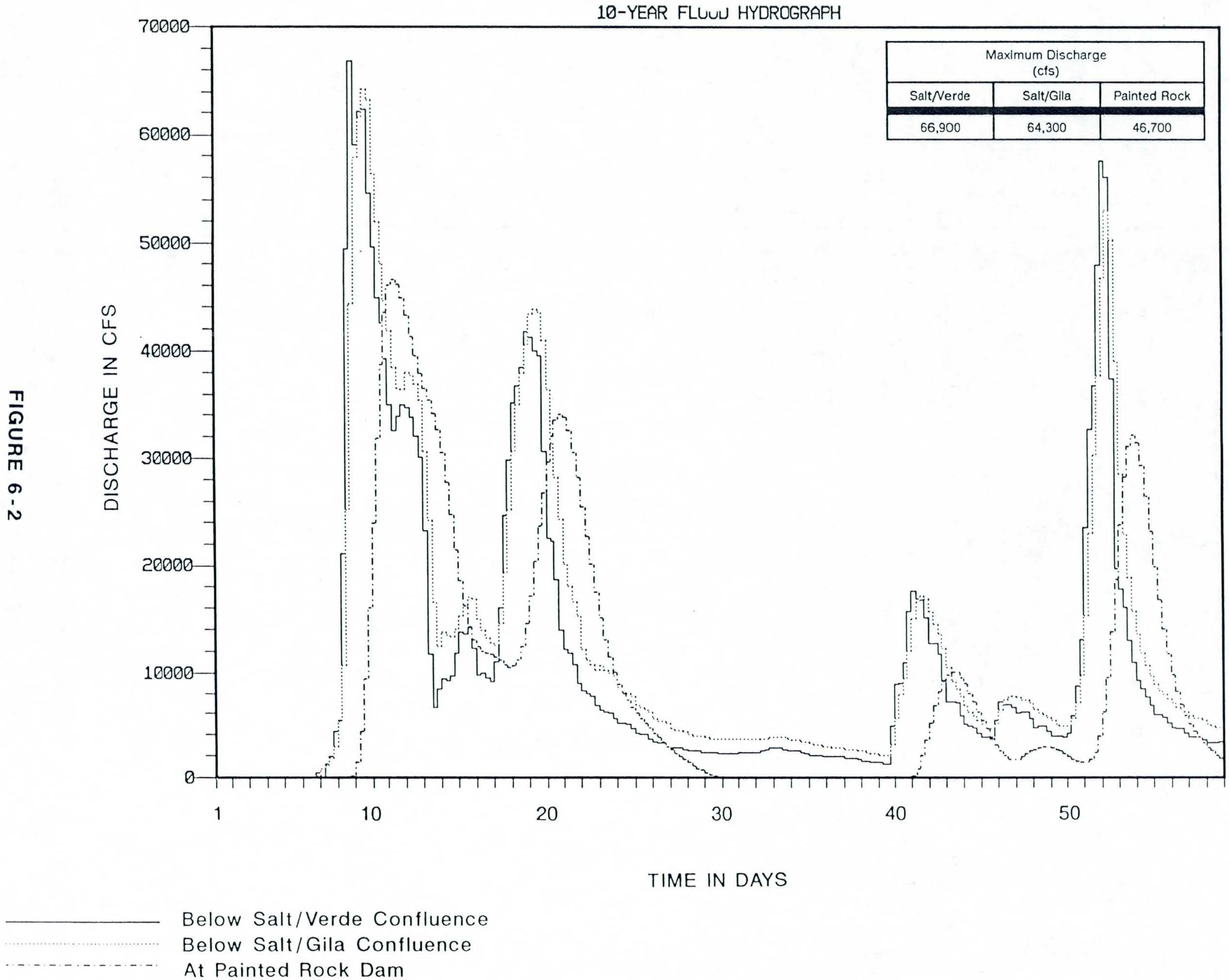


FIGURE 6-2

SYNTHETIC FLOOD HYDROGRAPHS
ROUTED FROM THE SALT-VERDE CONFLUENCE TO PAINTED ROCK DAM

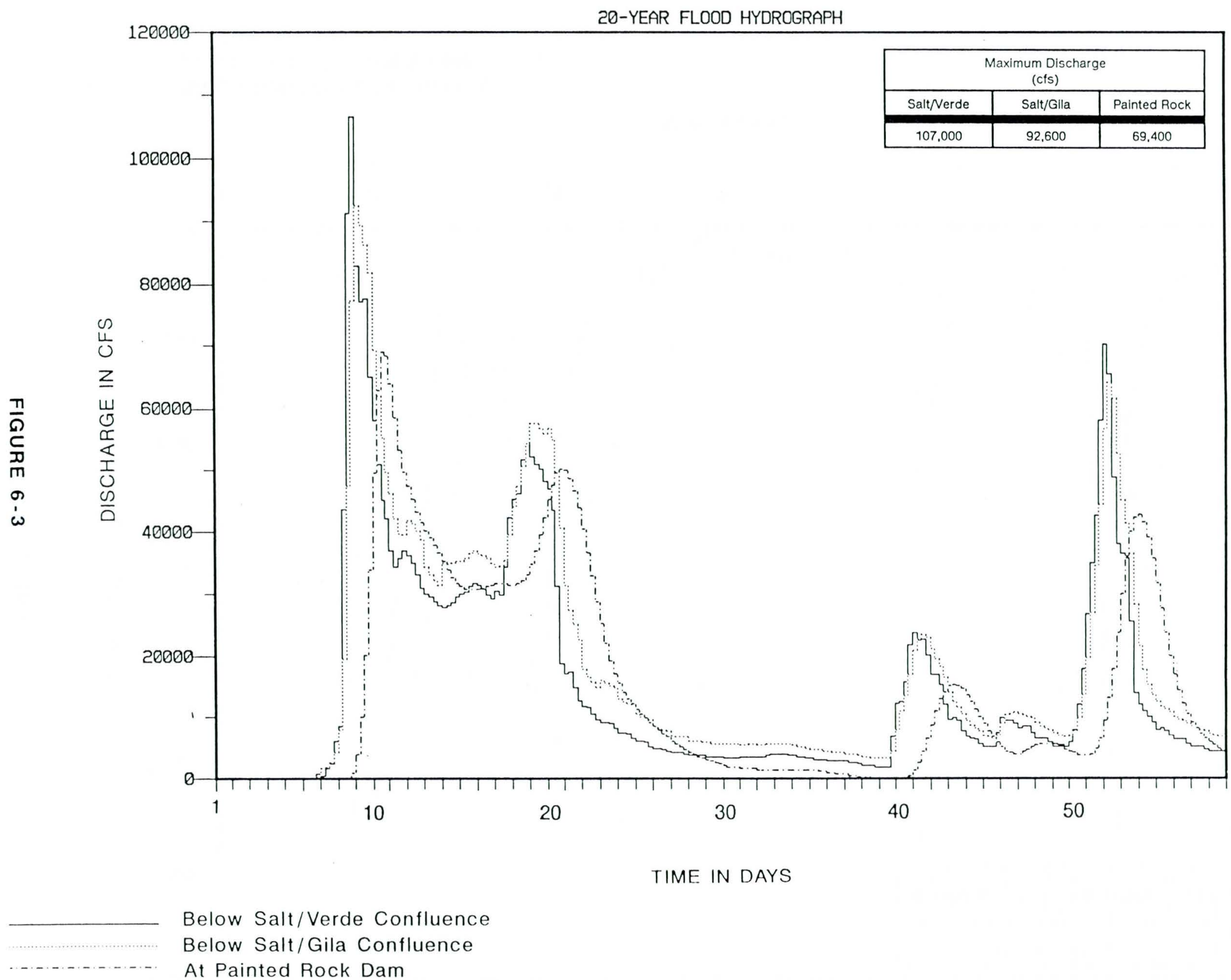


FIGURE 6-3

SYNTHETIC FL HYDROGRAPHS
ROUTED FROM THE SALT-VERDE FLUENCE TO PAINTED ROCK DAM

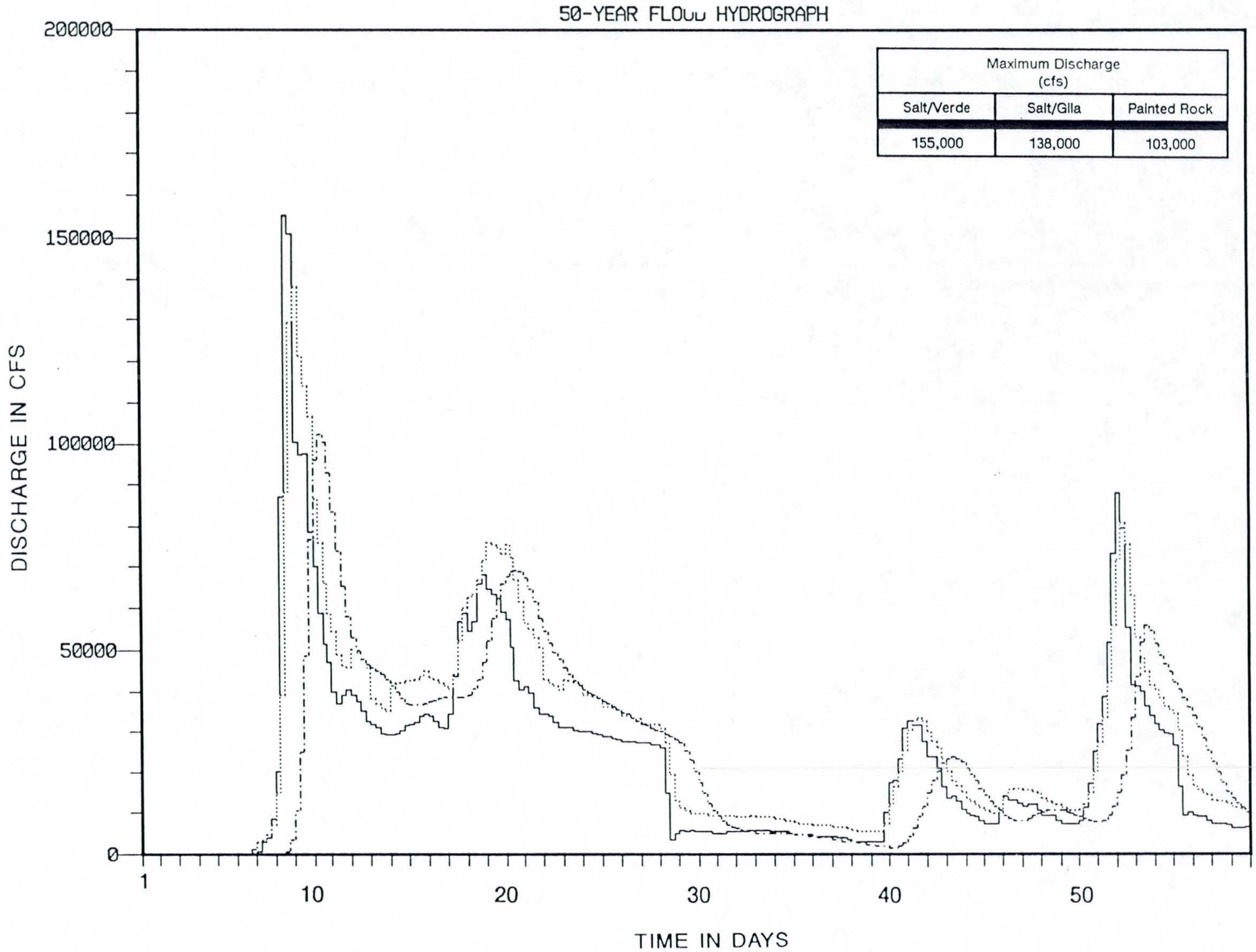
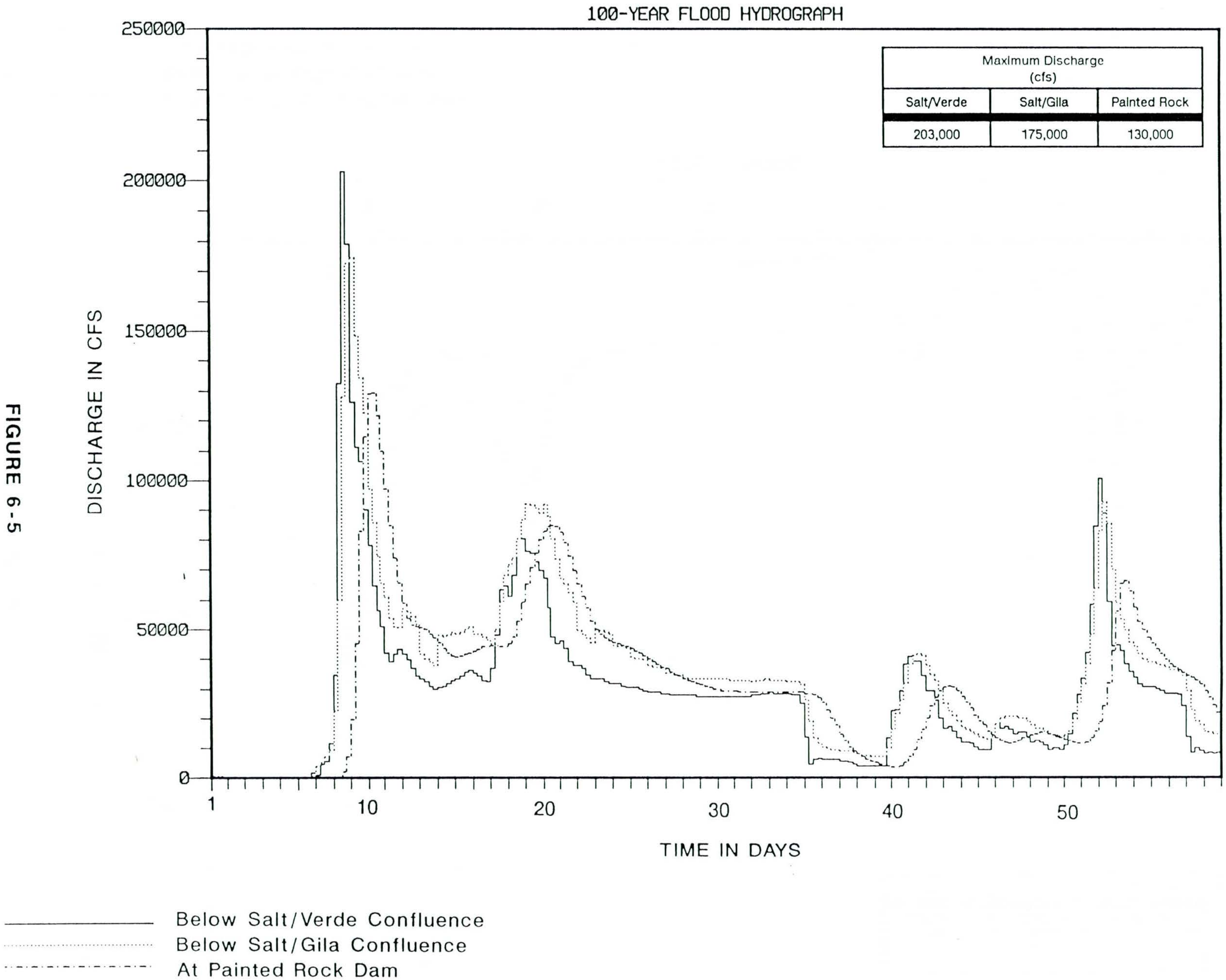


FIGURE 6-4

Below Salt/Verde Confluence
Below Salt/Gila Confluence
At Painted Rock Dam

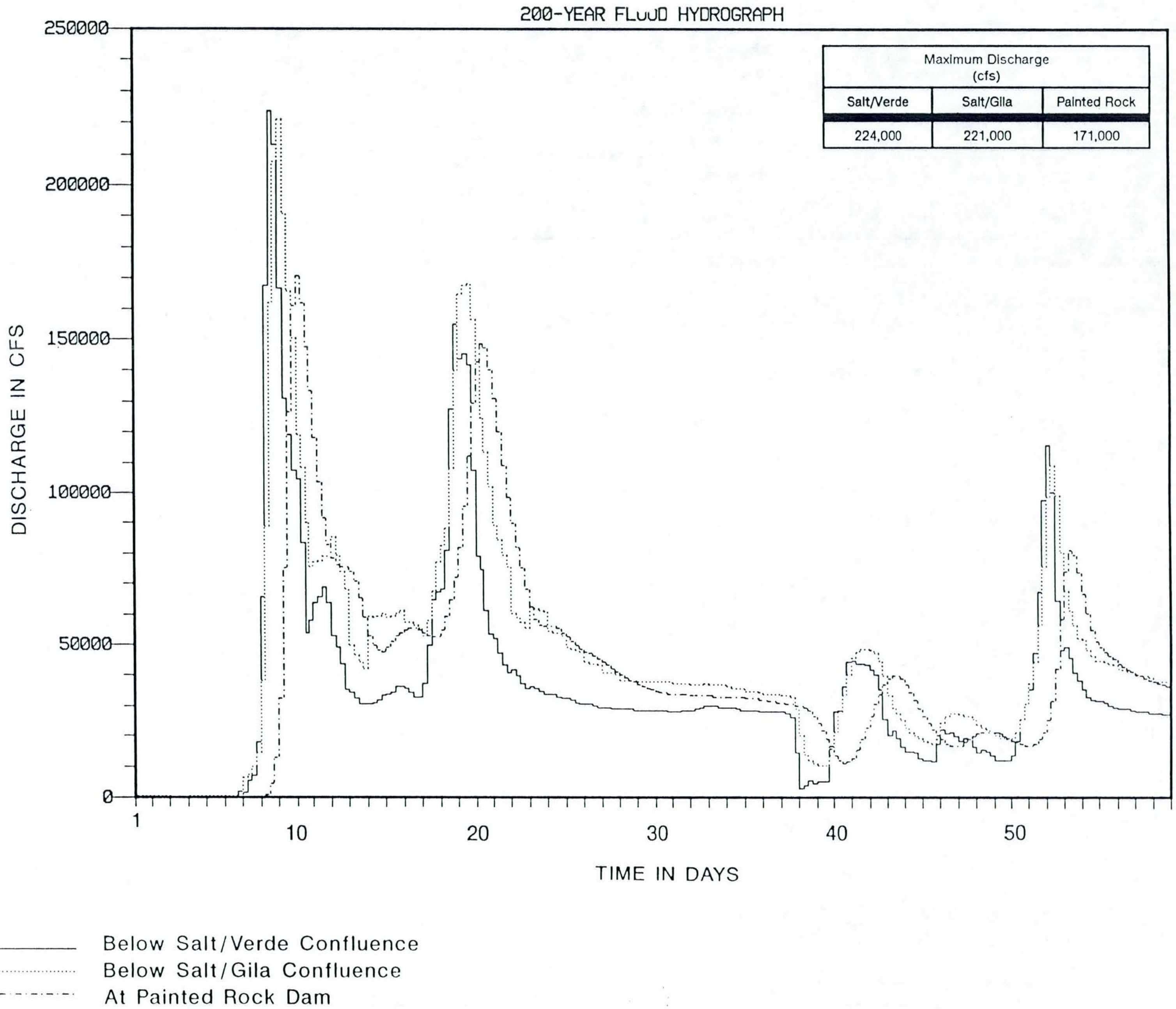
SYNTHETIC FLOOD HYDROGRAPHS
ROUTED FROM THE SALT-VERDE CONFLUENCE TO PAINTED ROCK DAM

FIGURE 6-5



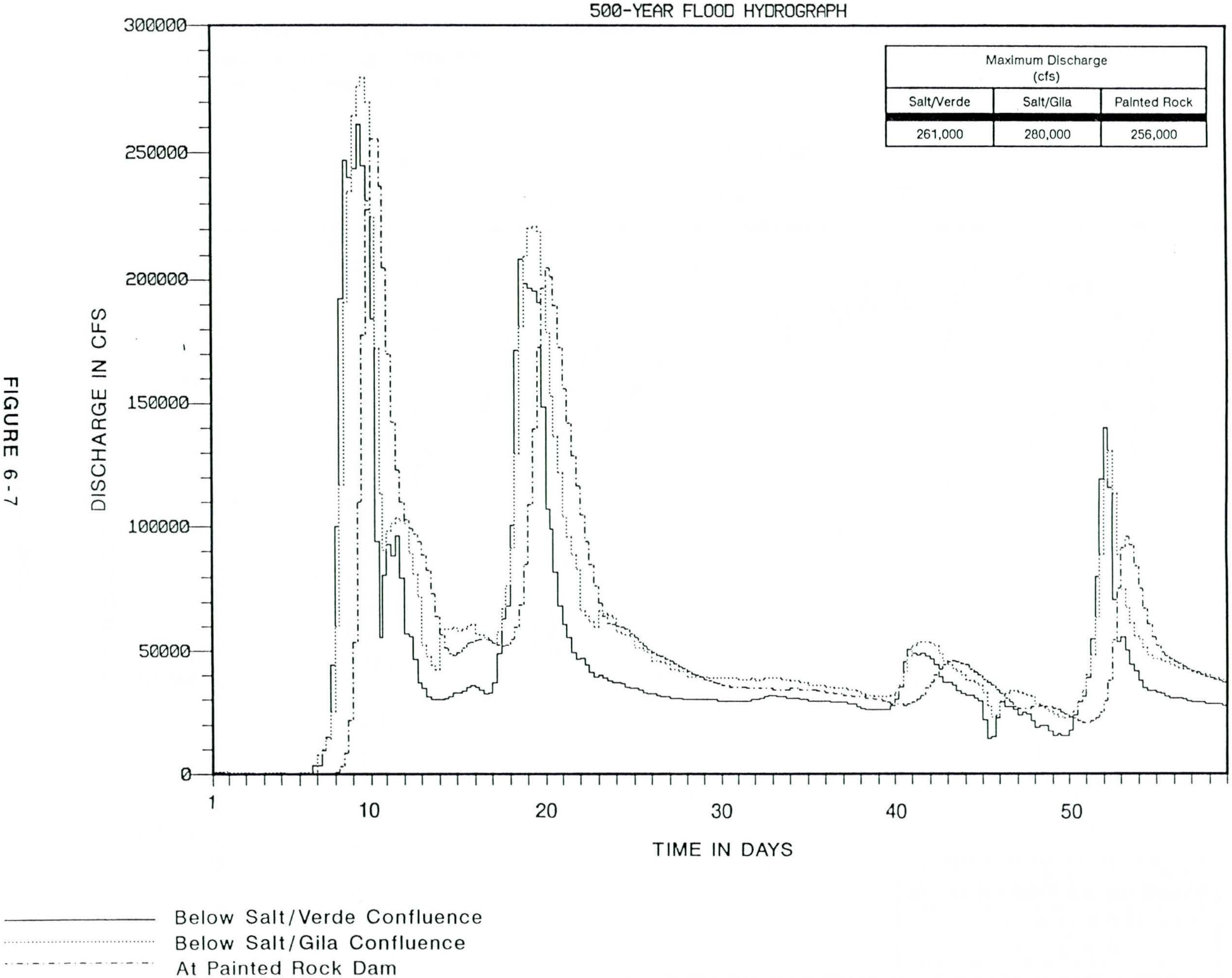
SYNTHETIC FLO[illegible] HYDROGRAPHS
ROUTED FROM THE SALT-VERDE [illegible]LUENCE TO PAINTED ROCK DAM

FIGURE 6-6



SYNTHETIC FLOOD HYDROGRAPHS
ROUTED FROM THE SALT-VERDE CONFLUENCE TO PAINTED ROCK DAM

FIGURE 6-7



SYNTHETIC FI ˥ HYDROGRAPHS
ROUTED FROM THE SALT-VERDI ˥FLUENCE TO PAINTED ROCK DAM

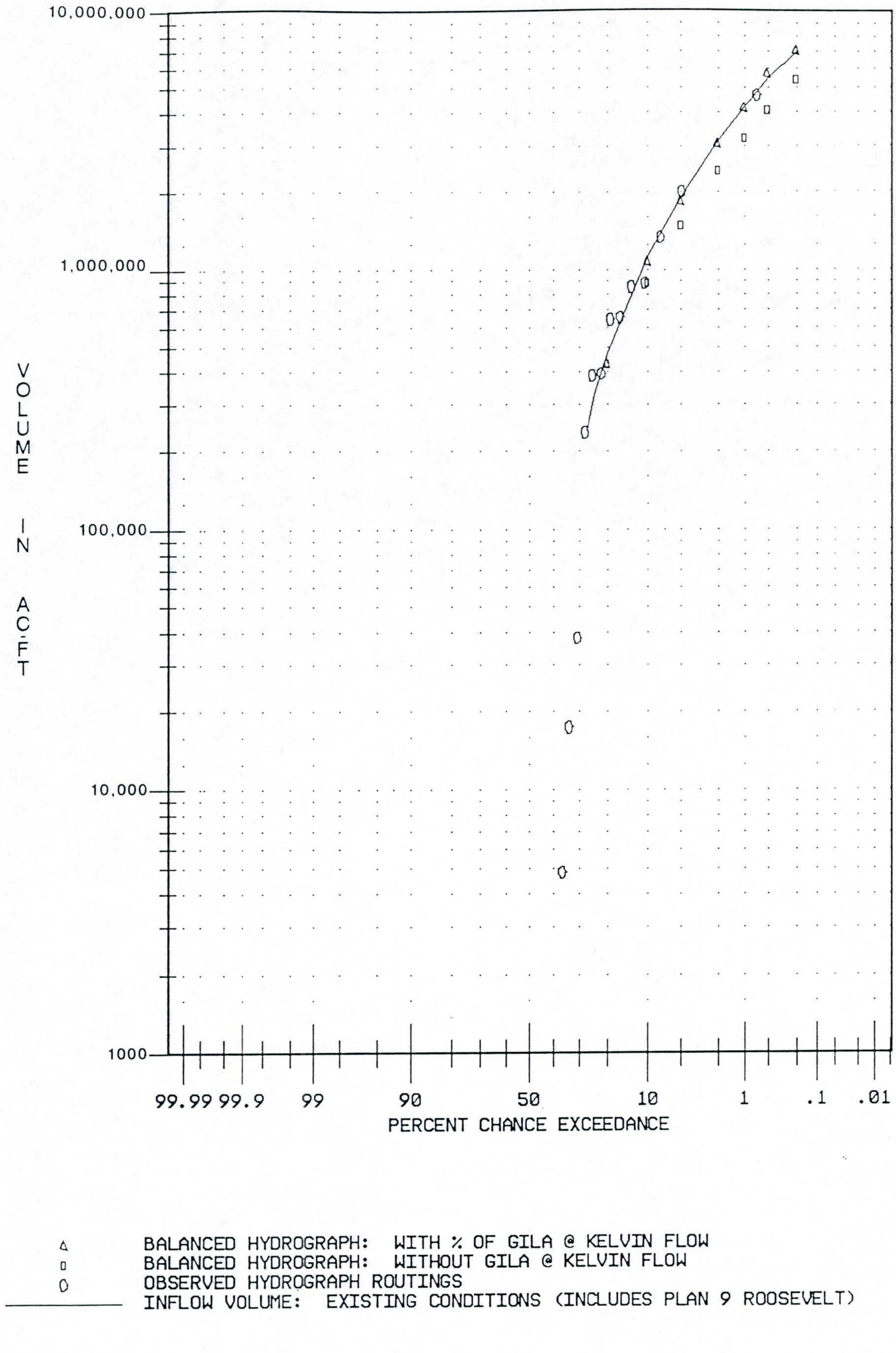


FIGURE 7 90-DAY INFLOW FREQUENCY CURVE - PAINTED ROCK DAM

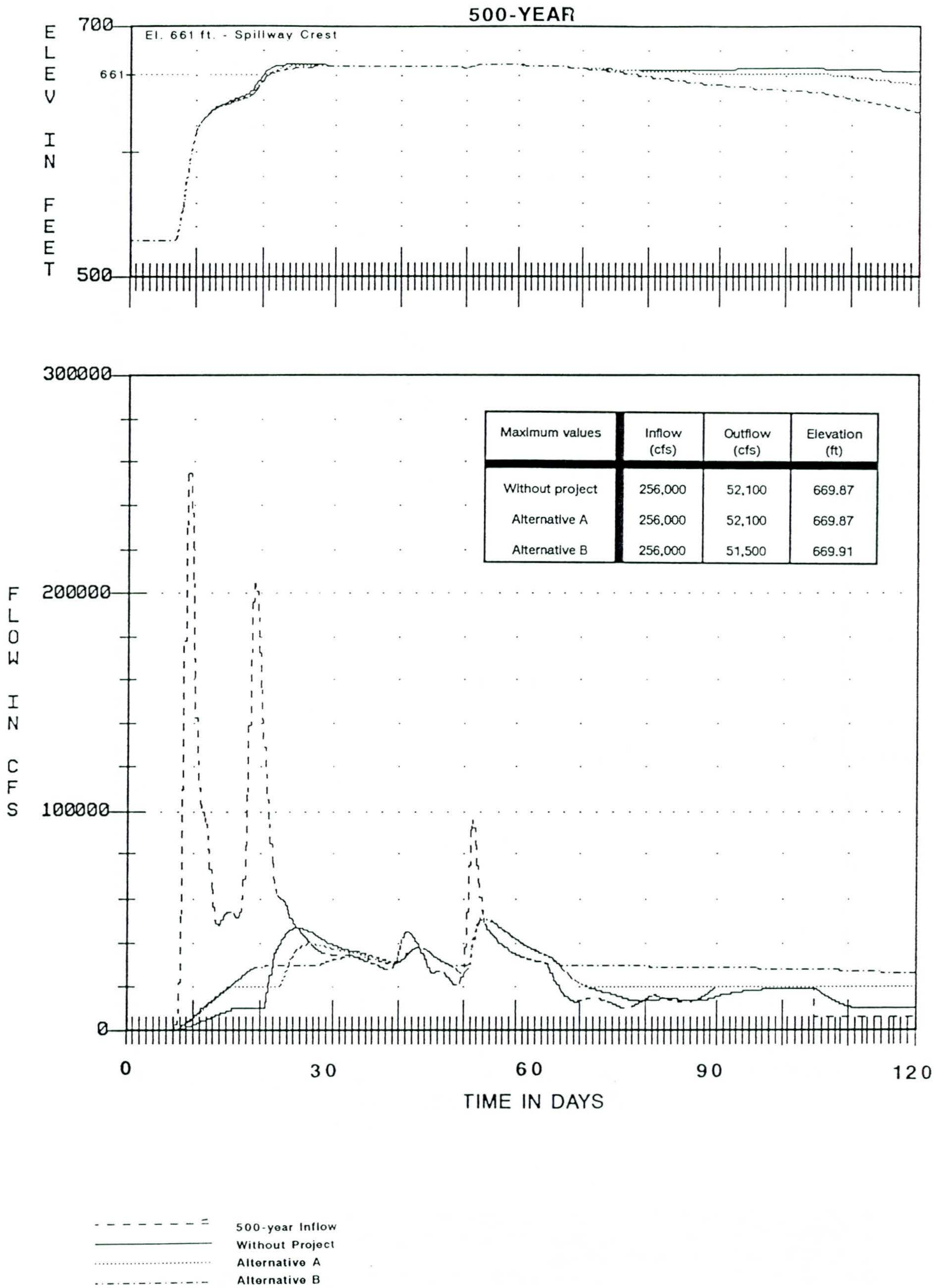
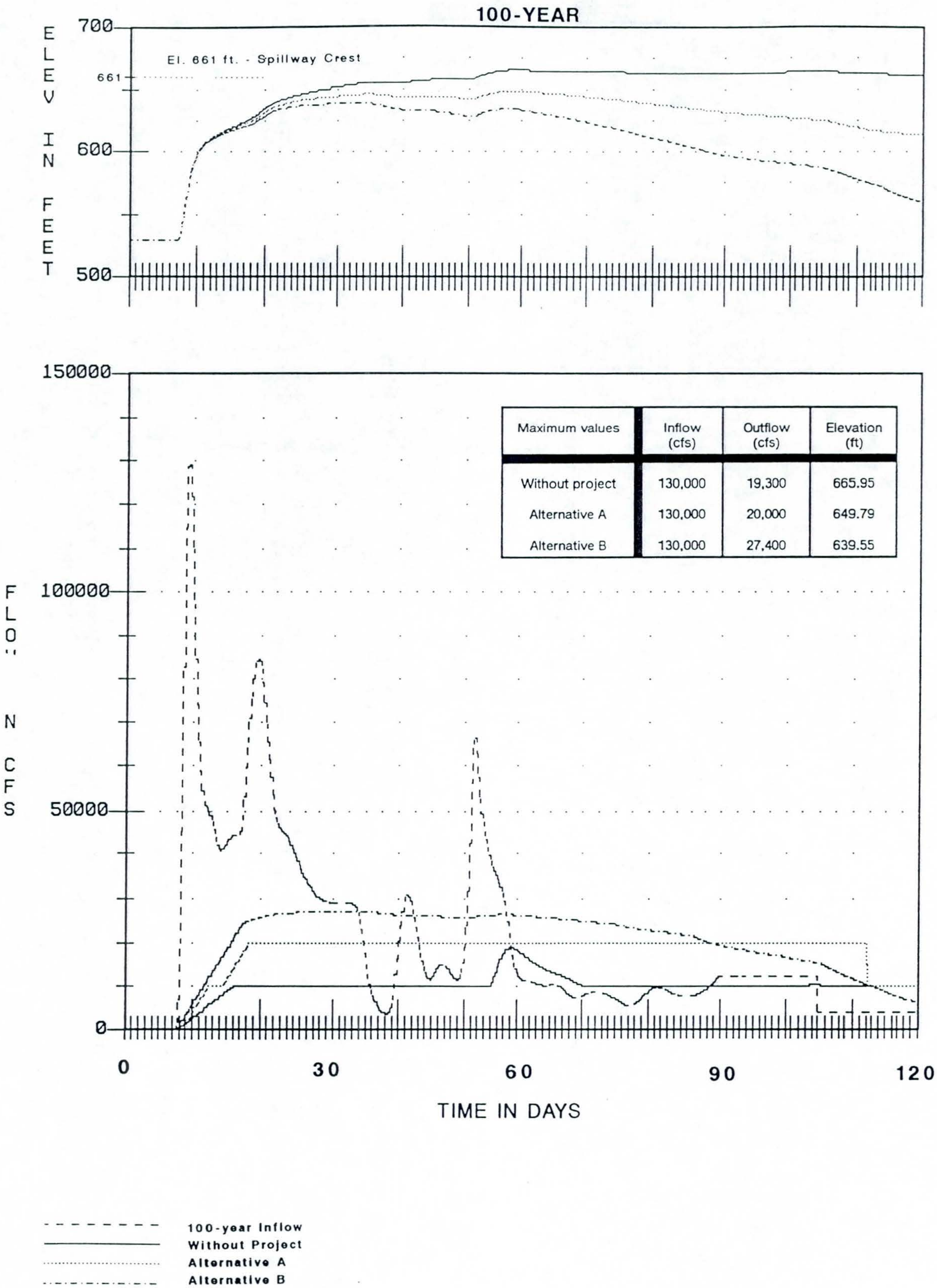
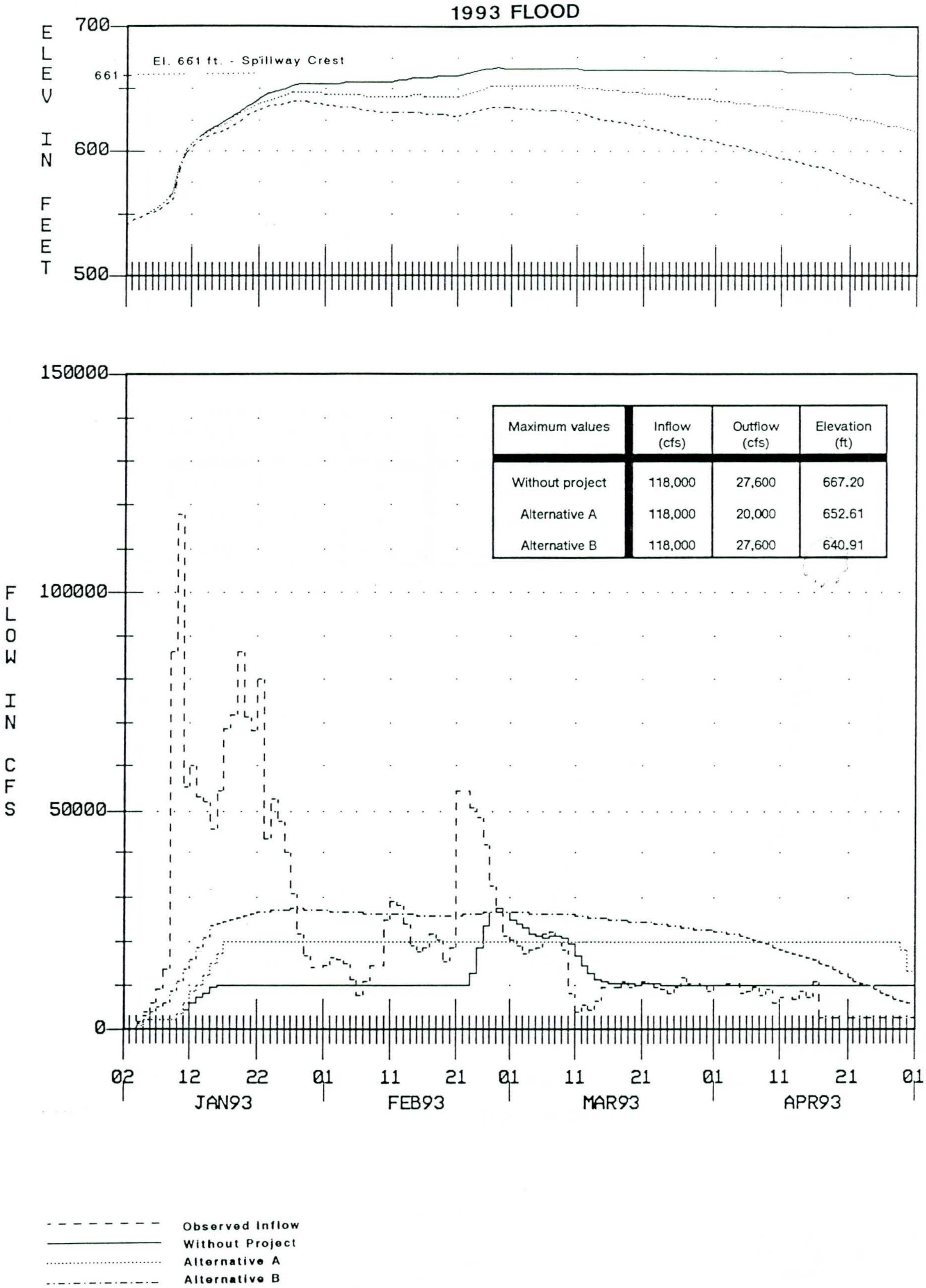


FIGURE 8-1 RESERVOIR ROUTING HYDROGRAPHS - PAINTED ROCK DAM



Maximum values	Inflow (cfs)	Outflow (cfs)	Elevation (ft)
Without project	130,000	19,300	665.95
Alternative A	130,000	20,000	649.79
Alternative B	130,000	27,400	639.55

FIGURE 8-2 RESERVOIR ROUTING HYDROGRAPHS - PAINTED ROCK DAM



Maximum values	Inflow (cfs)	Outflow (cfs)	Elevation (ft)
Without project	118,000	27,600	667.20
Alternative A	118,000	20,000	652.61
Alternative B	118,000	27,600	640.91

FIGURE 8-3 RESERVOIR ROUTING HYDROGRAPHS - PAINTED ROCK DAM

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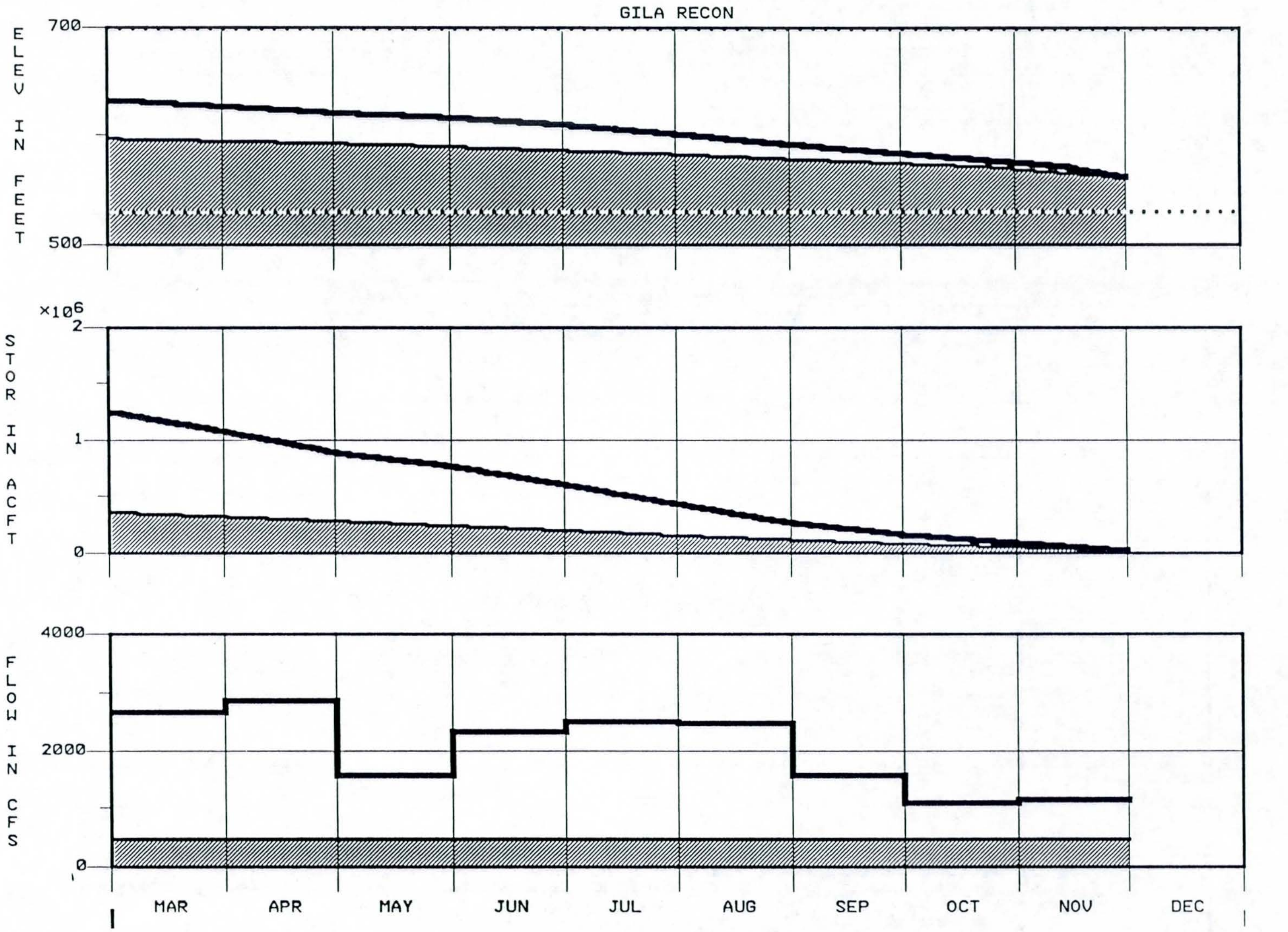

PAINTED ROCK RULE CURVE-500CFS FLOW-RES OUT
PAINTED ROCK RULE CURVE-NIB FLOW-RES OUT
PAINTED ROCK RULE CURVE-500CFS STOR-RES EOP
PAINTED ROCK RULE CURVE-NIB STOR-RES EOP
PAINTED ROCK RULE CURVE-500CFS ELEV
PAINTED ROCK RULE CURVE-NIB ELEV

FIGURE 9 RULE CURVES - PAINTED ROCK DAM

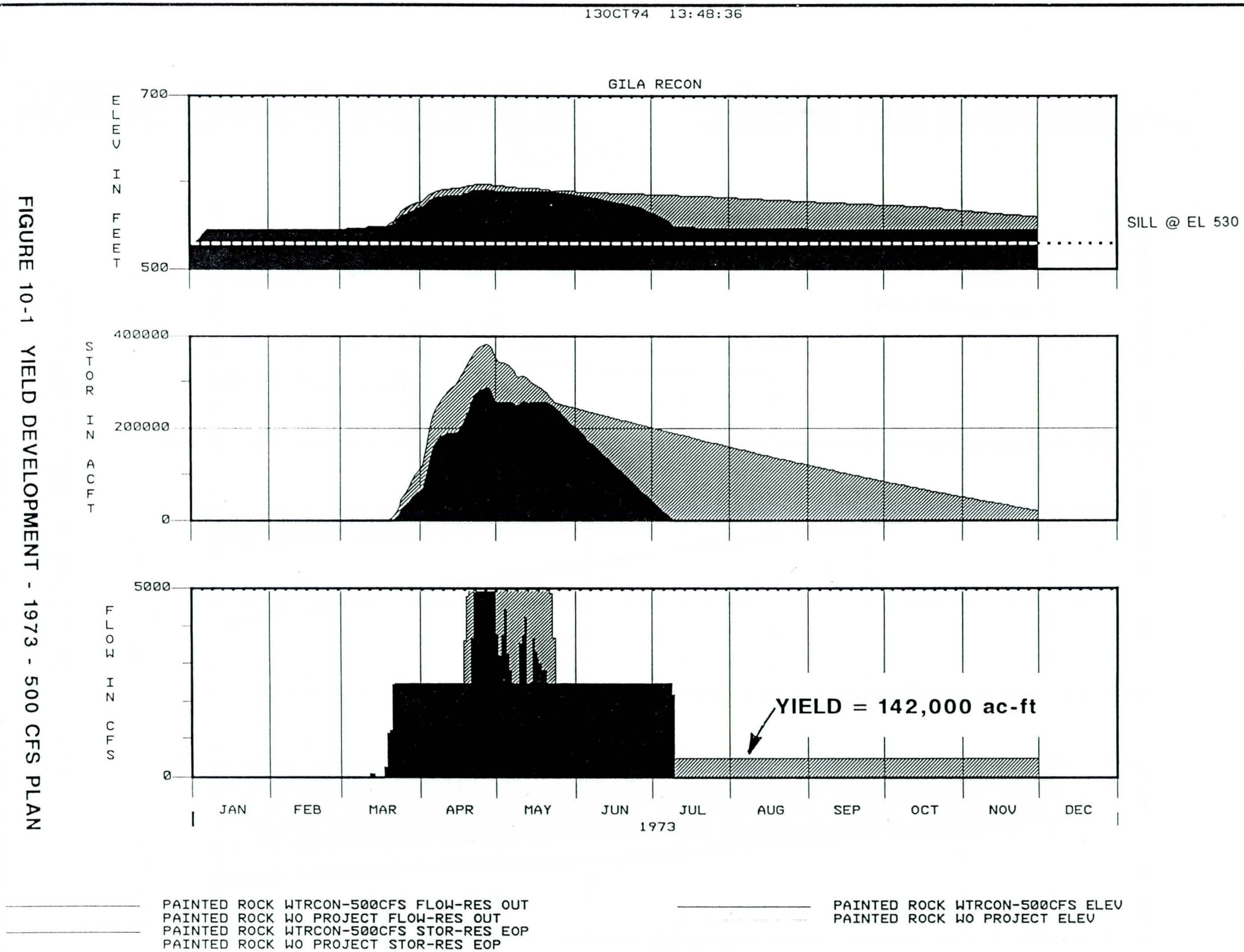

FIGURE 10-1 YIELD DEVELOPMENT - 1973 - 500 CFS PLAN

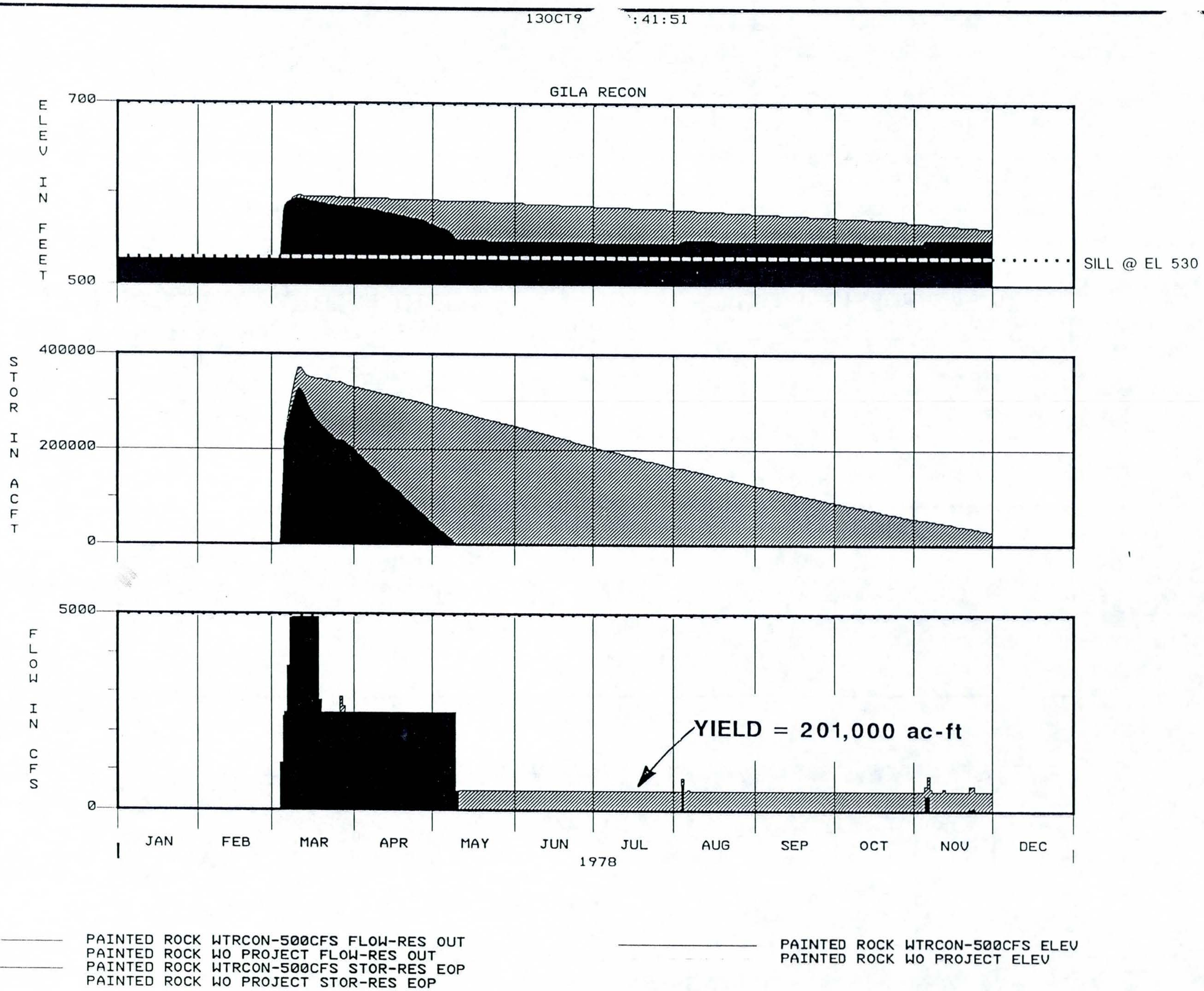

FIGURE 10-2 YIELD DEVELOPMENT - 1978 - 500 CFS PLAN

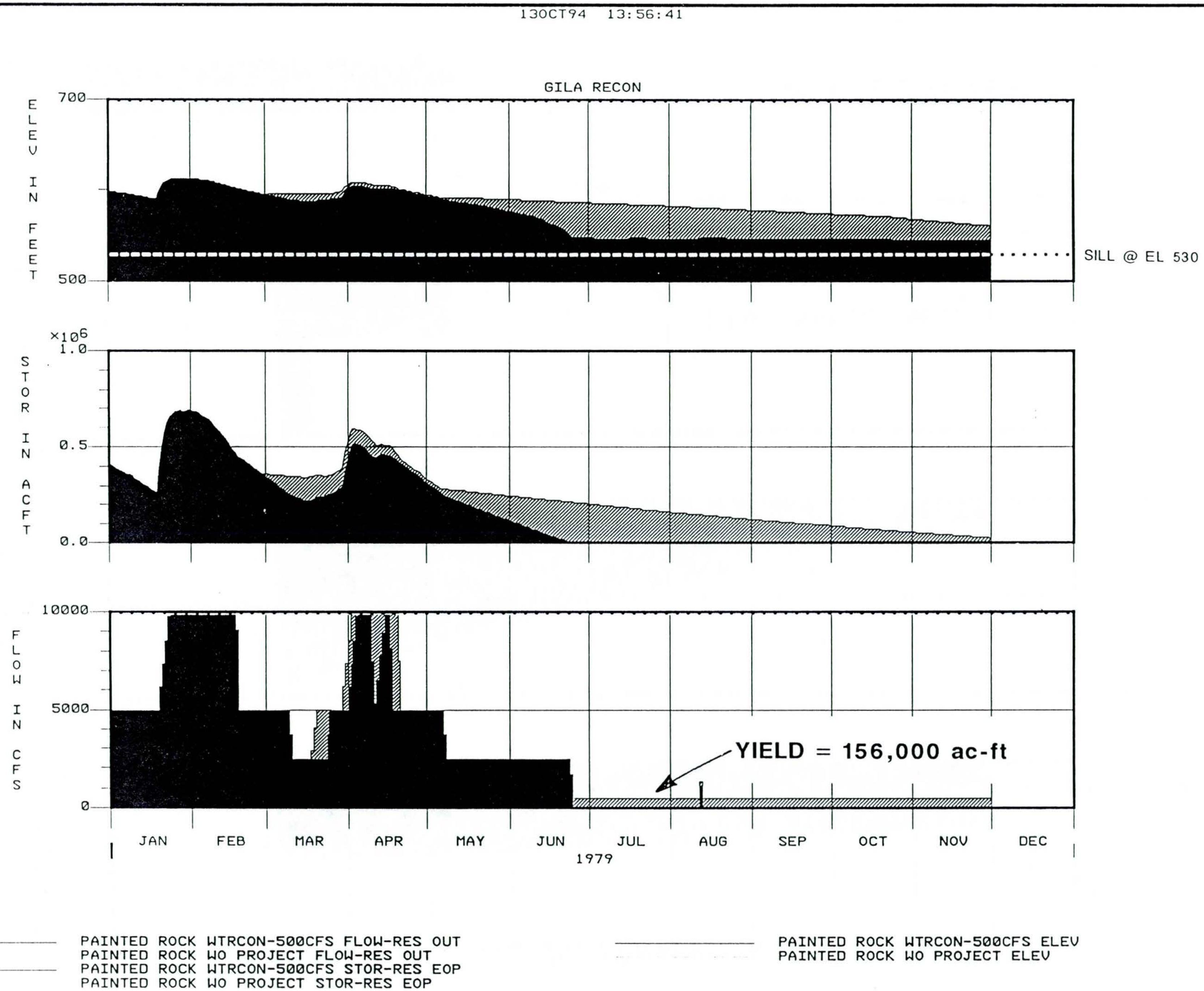

FIGURE 10-3 YIELD DEVELOPMENT - 1979 - 500 CFS PLAN

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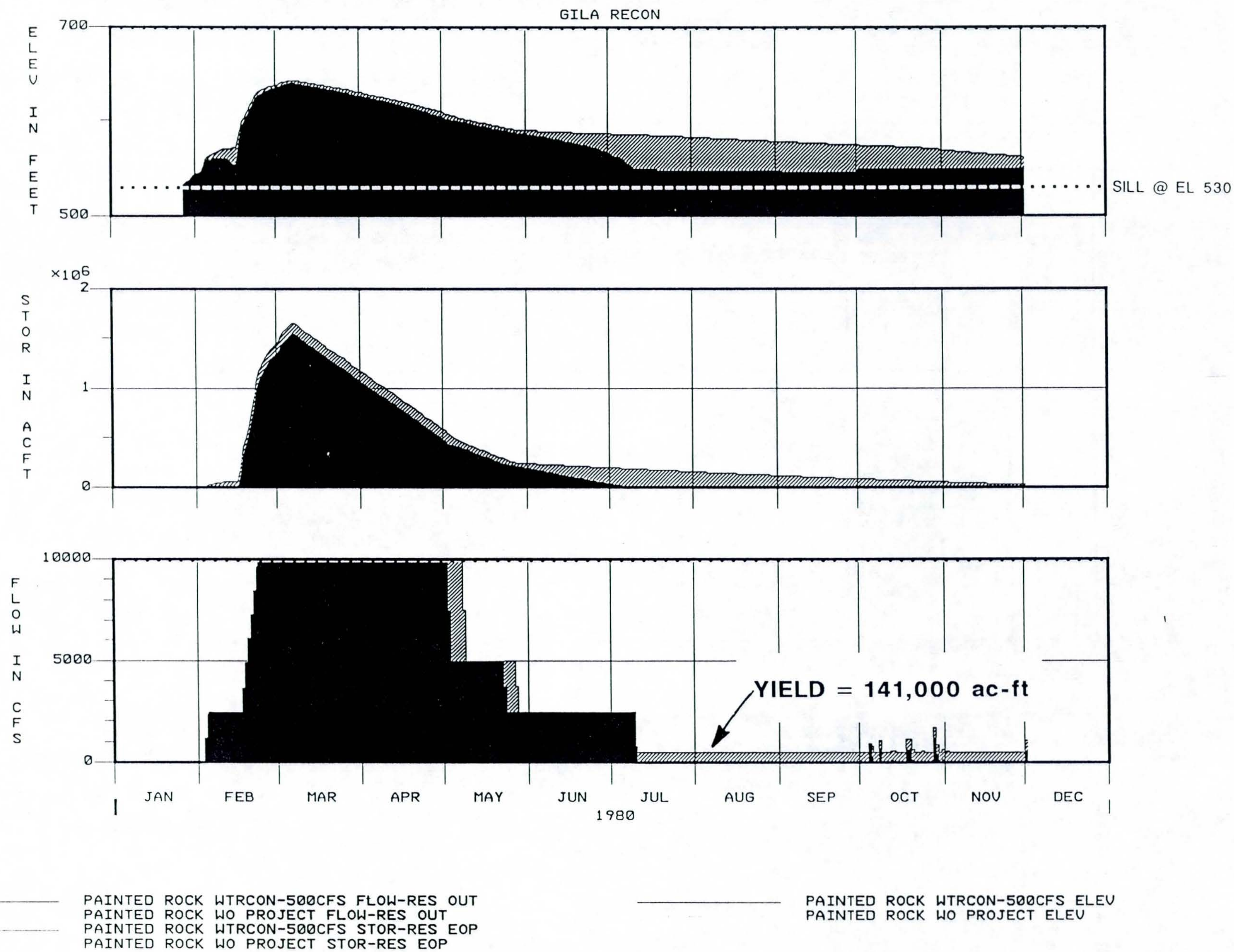

FIGURE 10-4 YIELD DEVELOPMENT - 1980 - 500 CFS PLAN

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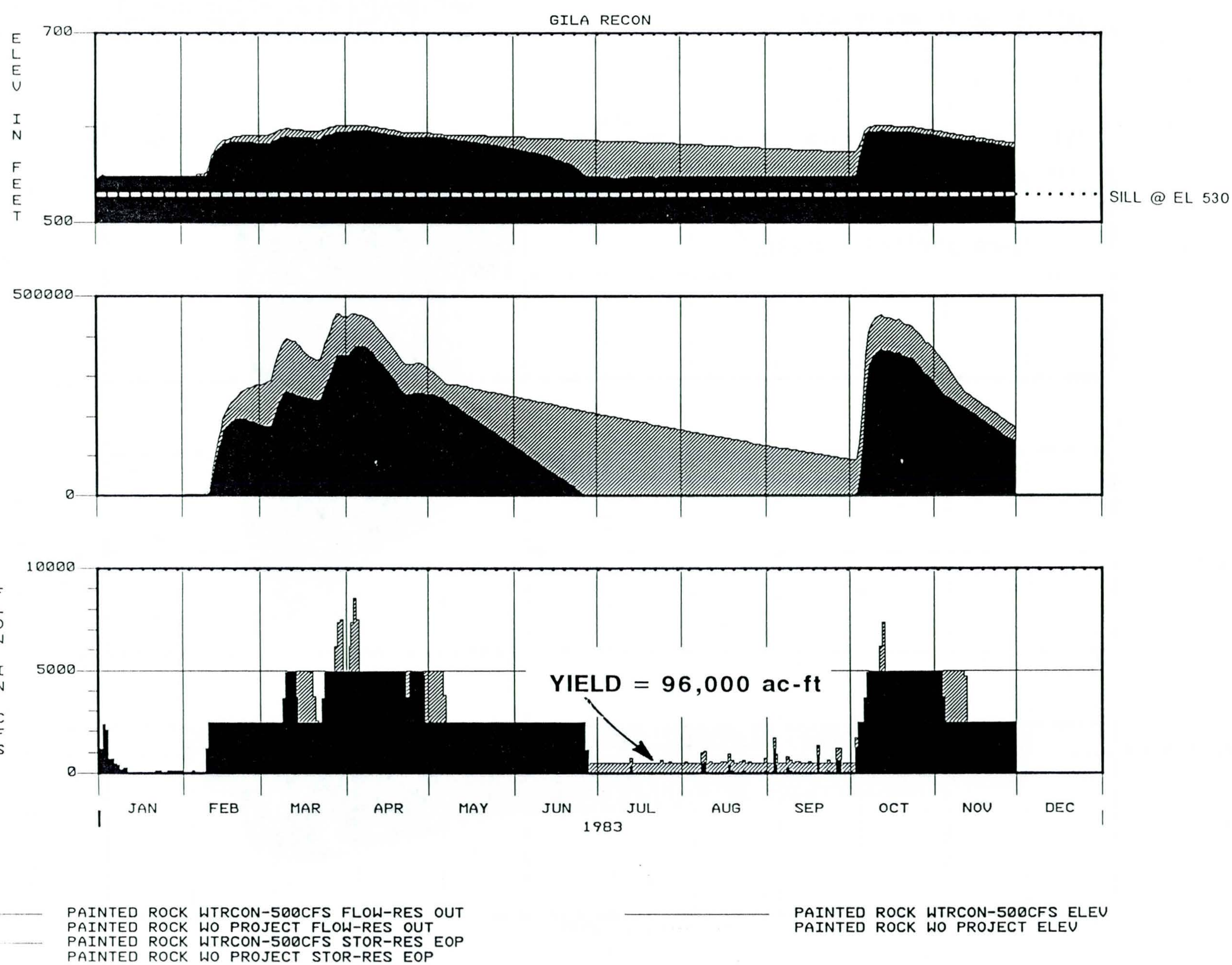

FIGURE 10-5 YIELD DEVELOPMENT - 1983 - 500 CFS PLAN

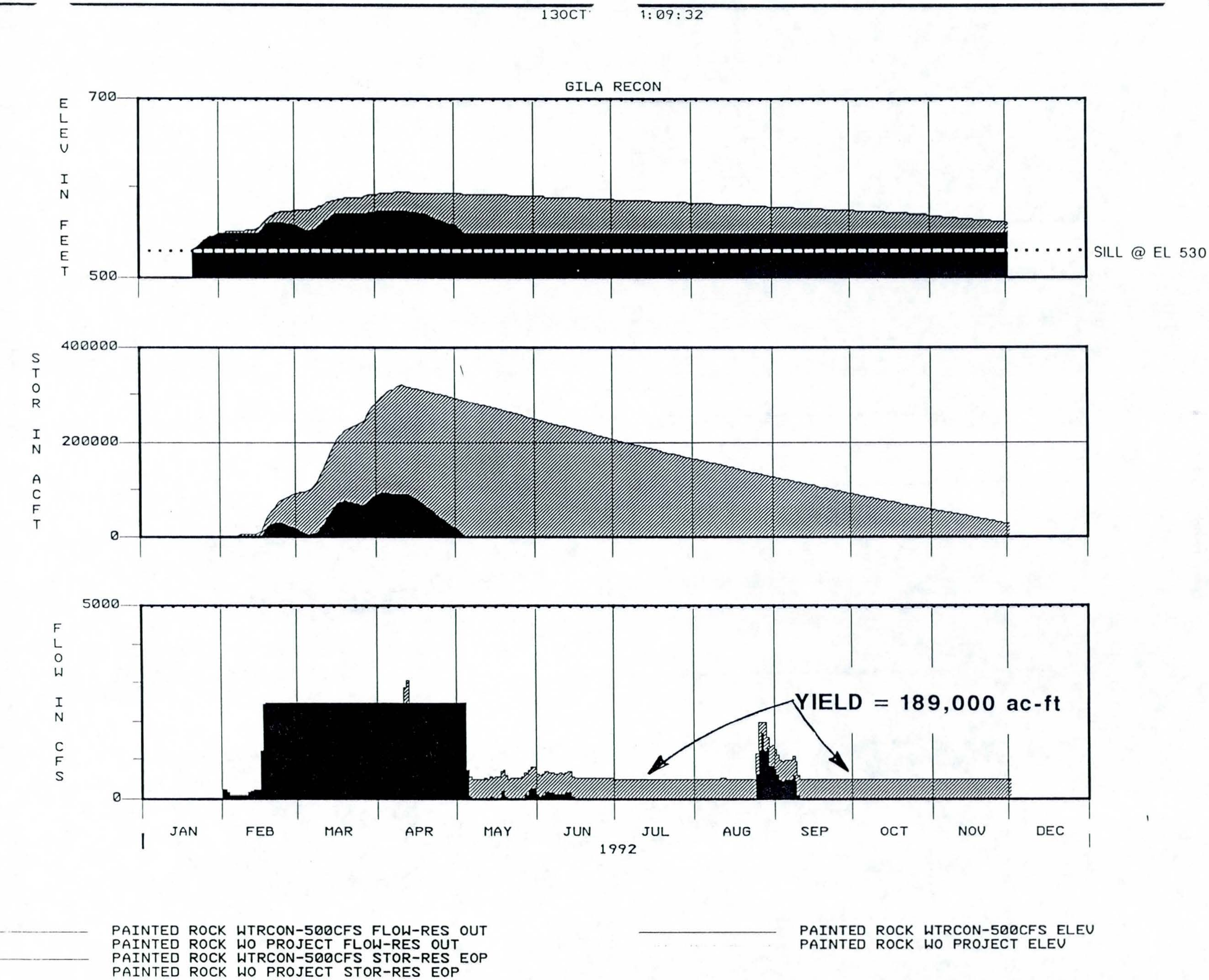

FIGURE 10-6 YIELD DEVELOPMENT - 1992 - 500 CFS PLAN

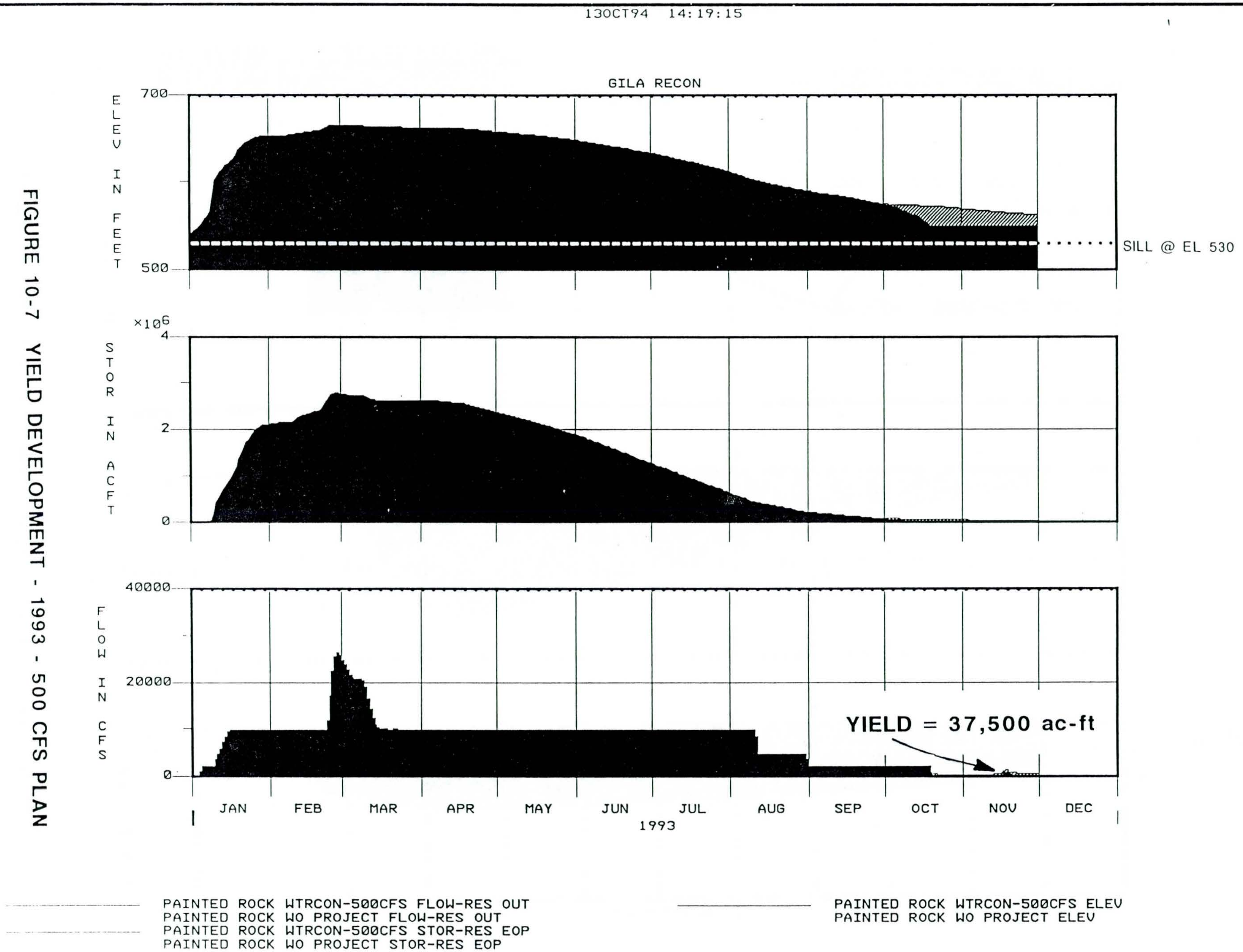

FIGURE 10-7 YIELD DEVELOPMENT - 1993 - 500 CFS PLAN

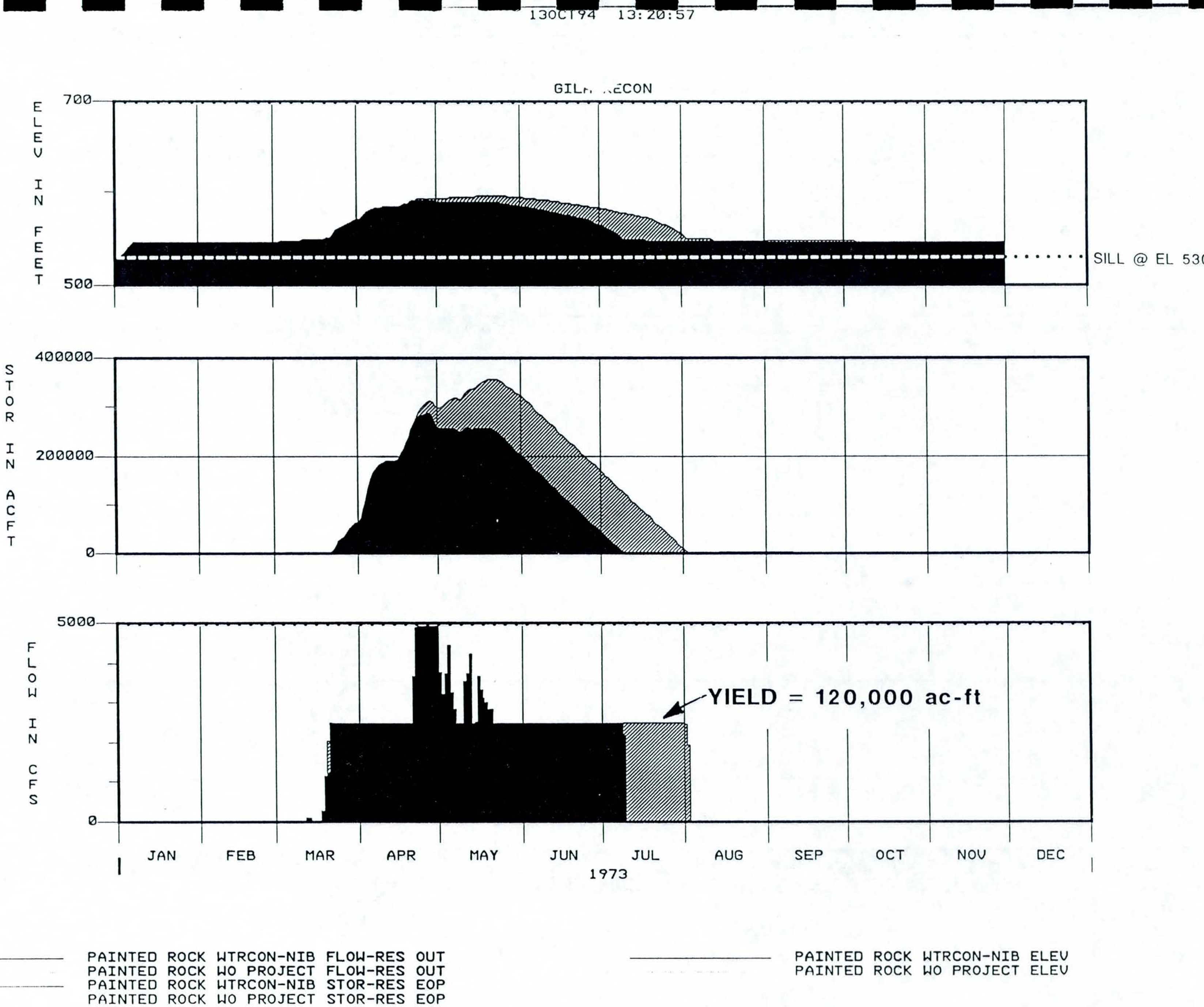

FIGURE 11-1 YIELD DEVELOPMENT - 1973 - NIB PLAN

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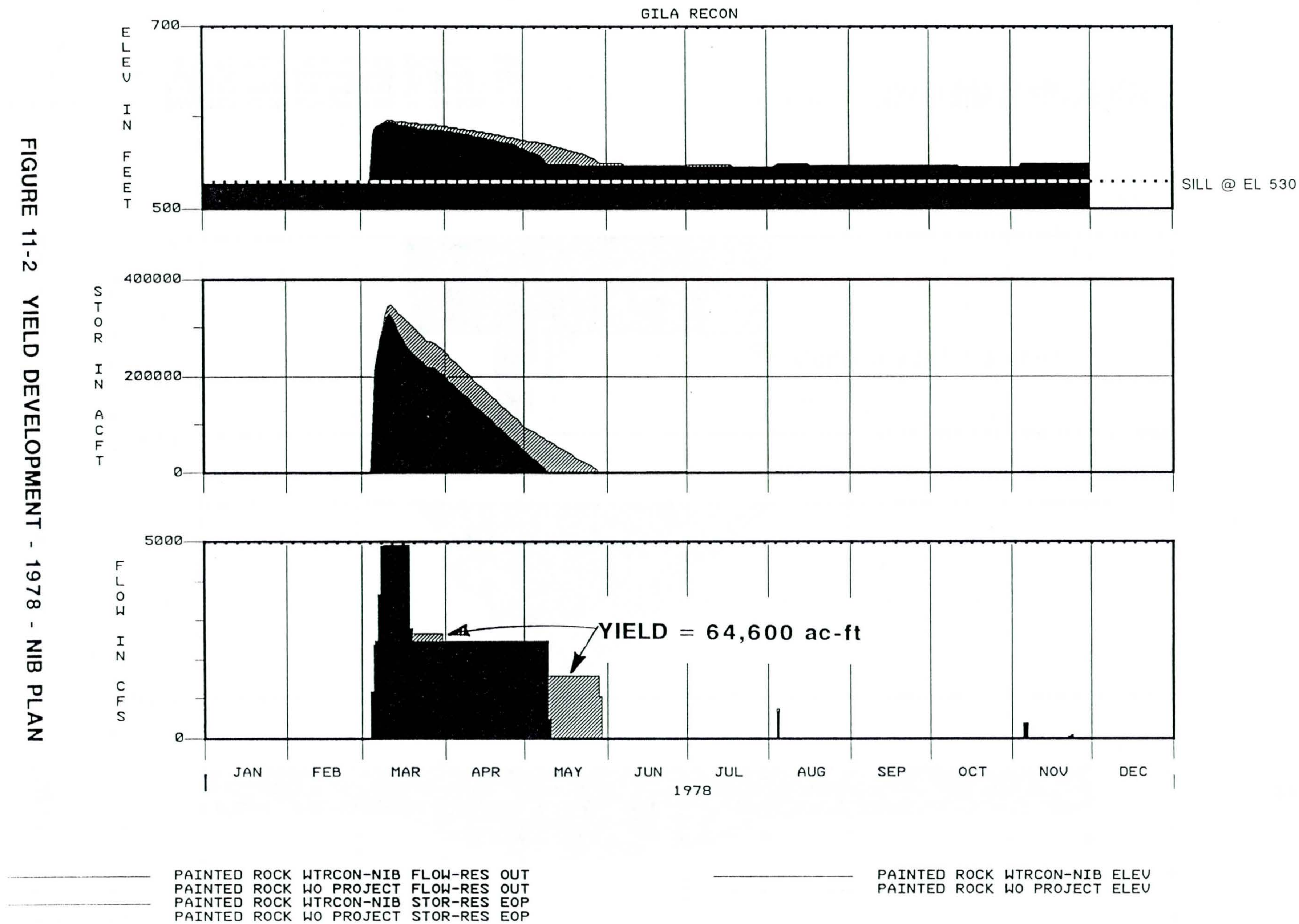


FIGURE 11-2 YIELD DEVELOPMENT - 1978 - NIB PLAN

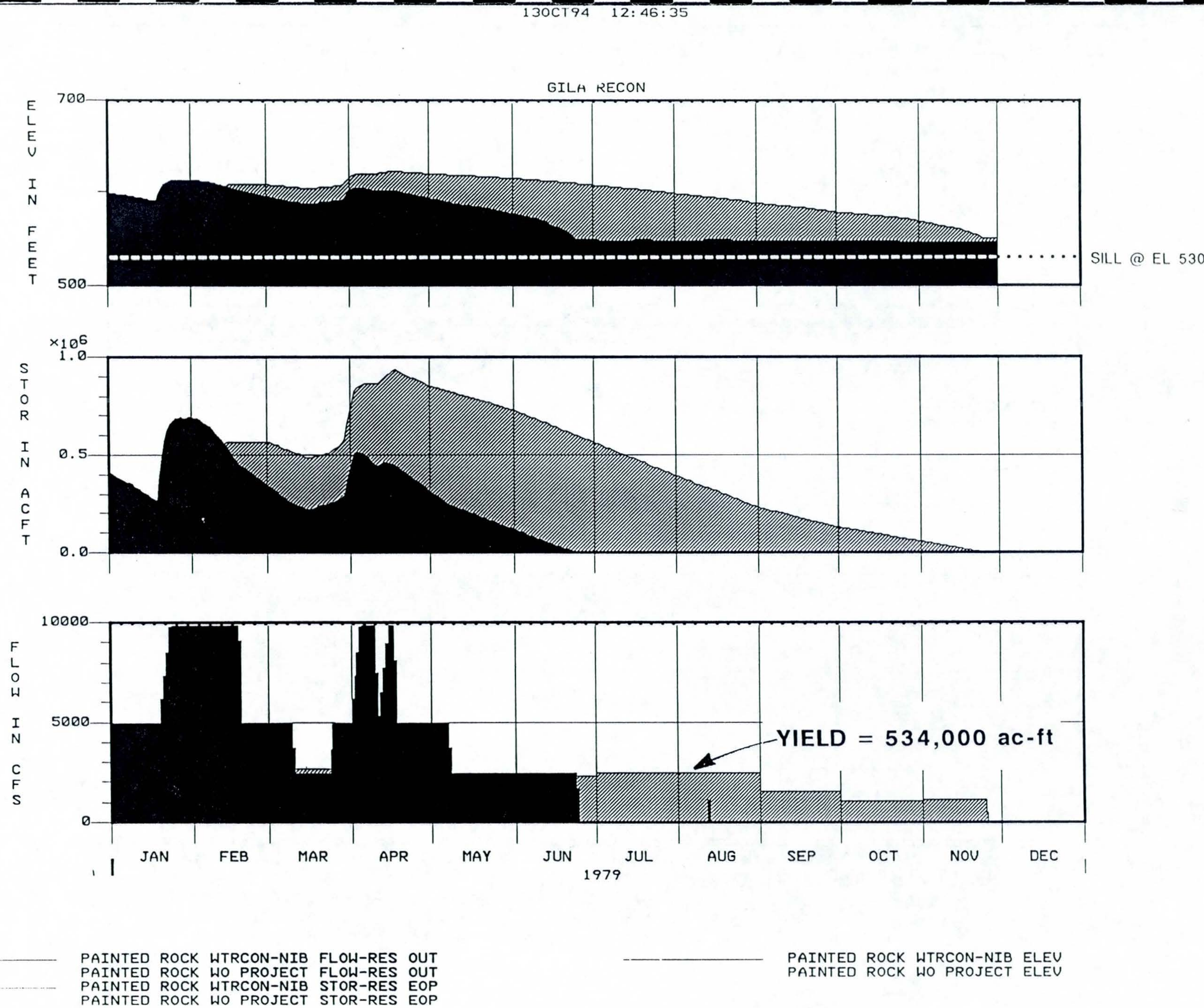
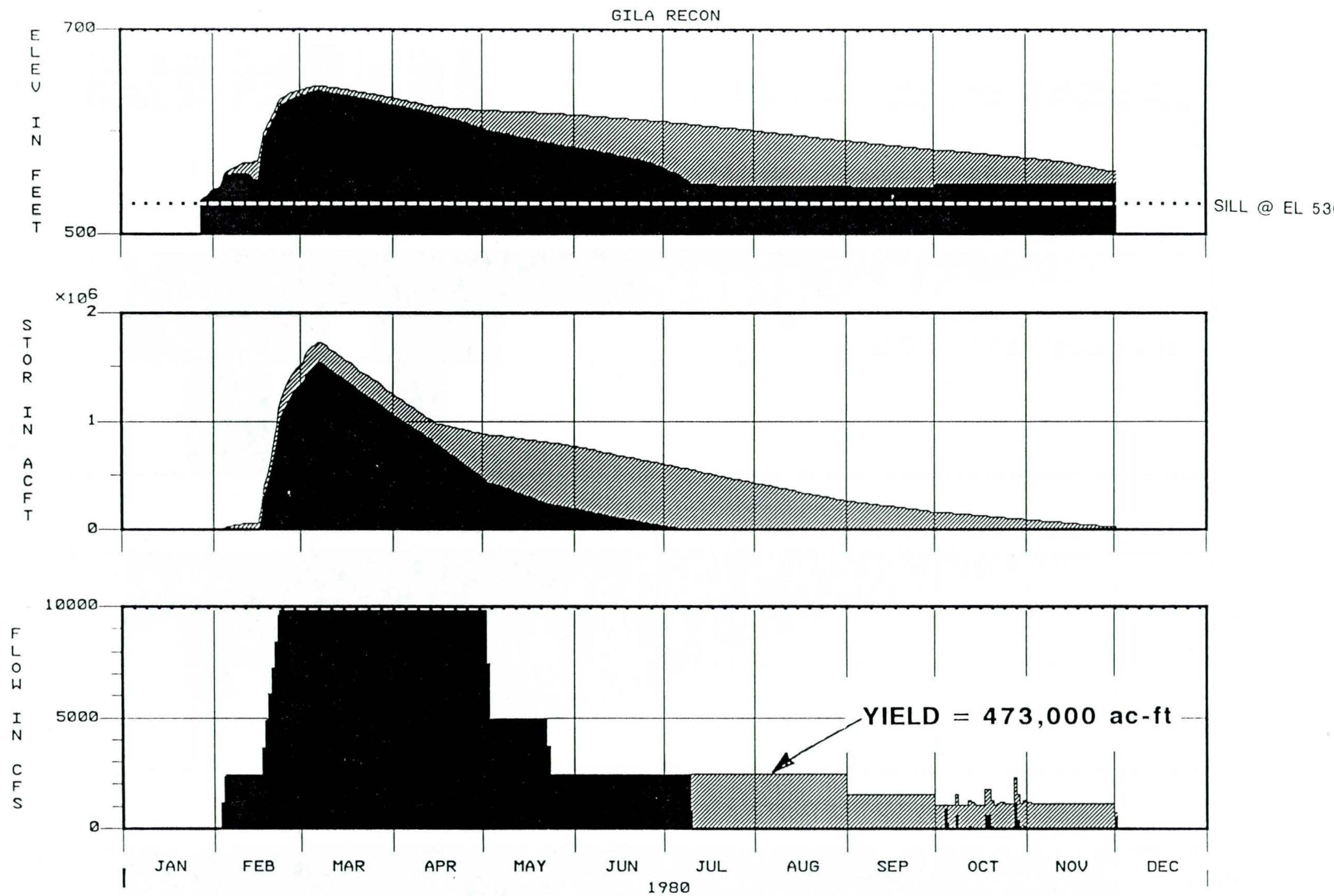


FIGURE 11-3 YIELD DEVELOPMENT - 1979 - NIB PLAN

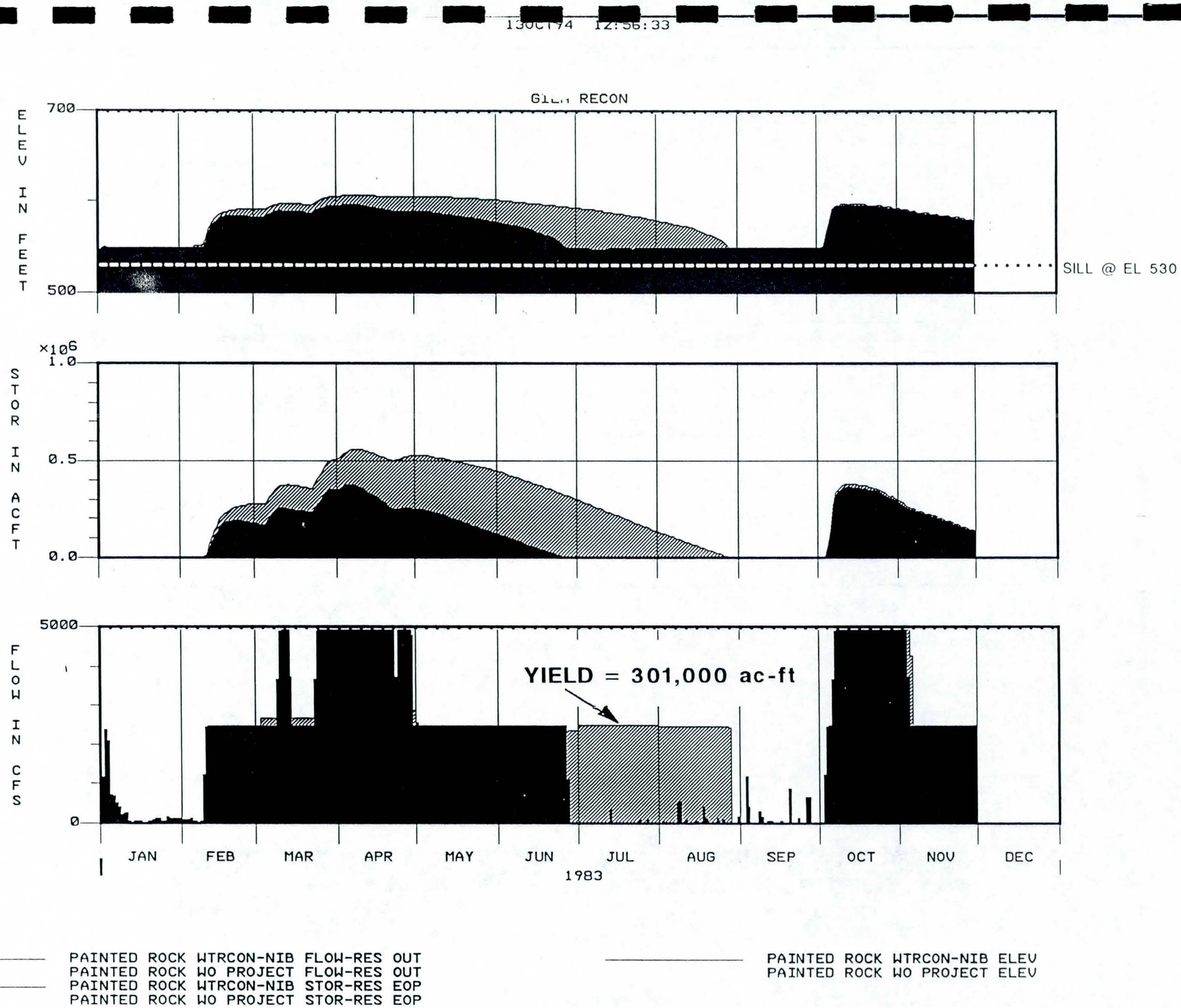


PAINTED ROCK WTRCON-NIB FLOW-RES OUT
PAINTED ROCK WO PROJECT FLOW-RES OUT
PAINTED ROCK WTRCON-NIB STOR-RES EOP
PAINTED ROCK WO PROJECT STOR-RES EOP

PAINTED ROCK WTRCON-NIB ELEV
PAINTED ROCK WO PROJECT ELEV

FIGURE 11-4 YIELD DEVELOPMENT - 1980 - NIB PLAN

FIGURE 11-5 YIELD DEVELOPMENT - 1983 - NIB PLAN



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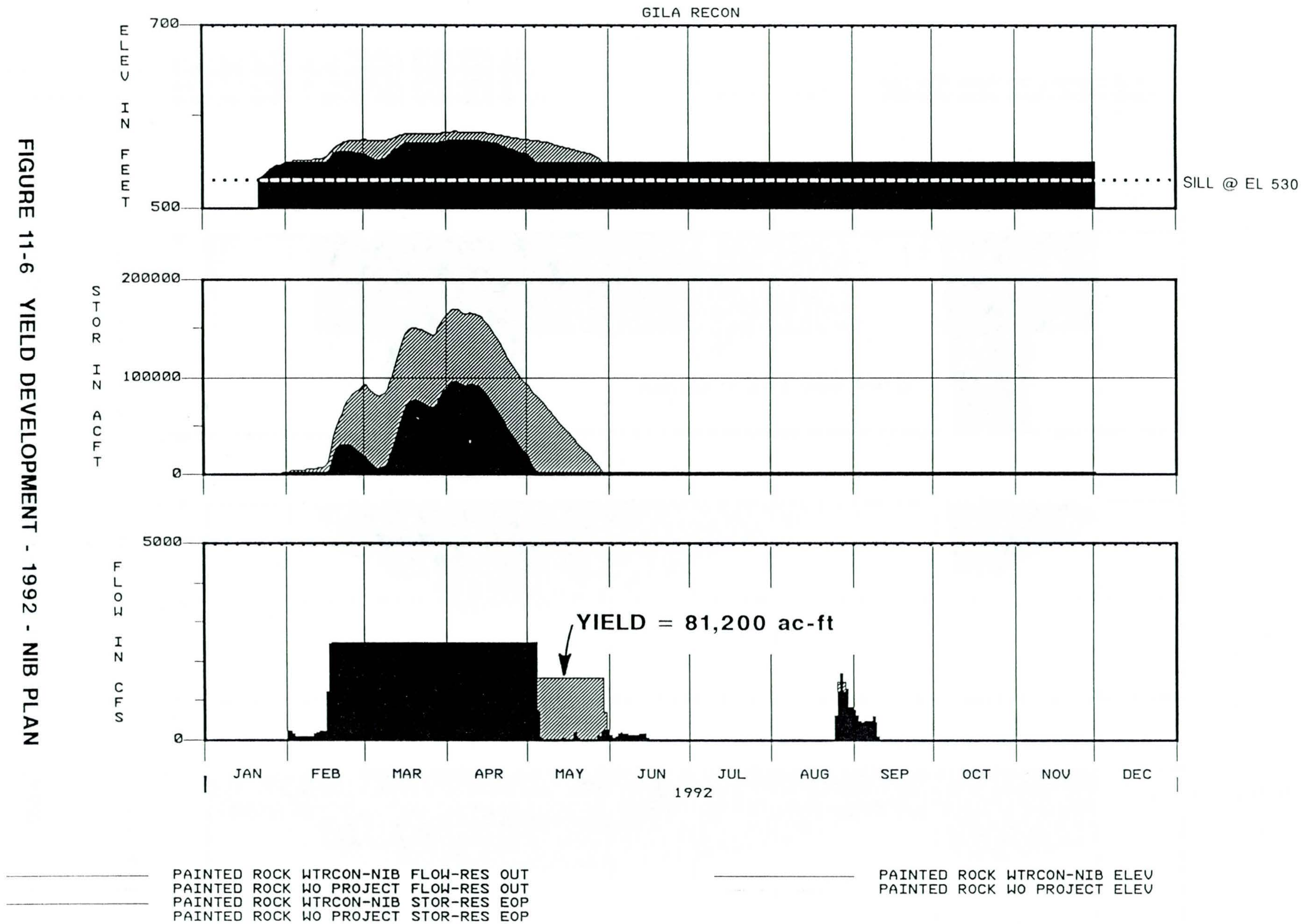

FIGURE 11-6 YIELD DEVELOPMENT - 1992 - NIB PLAN

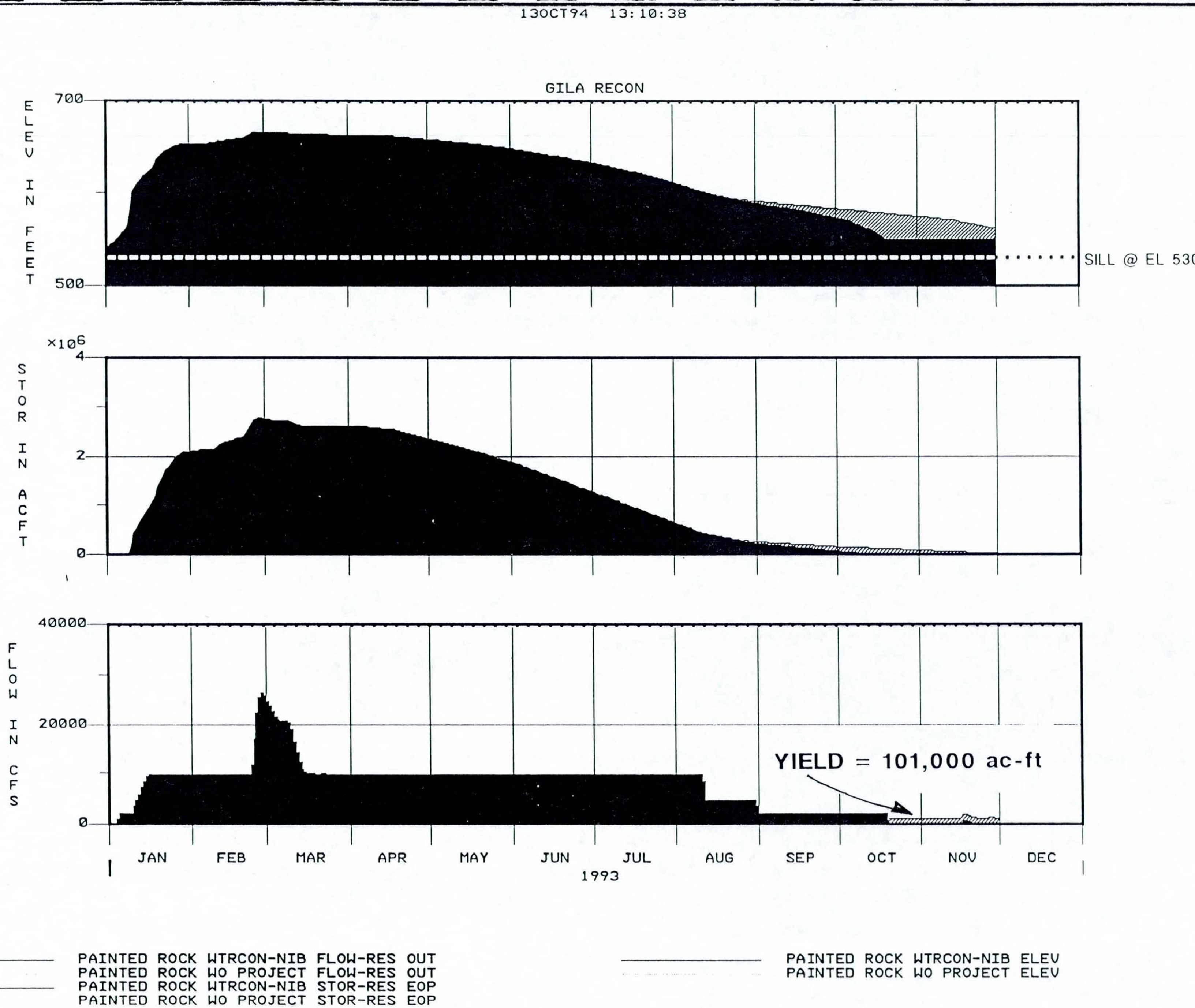

FIGURE 11-7 YIELD DEVELOPMENT - 1993 - NIB PLAN

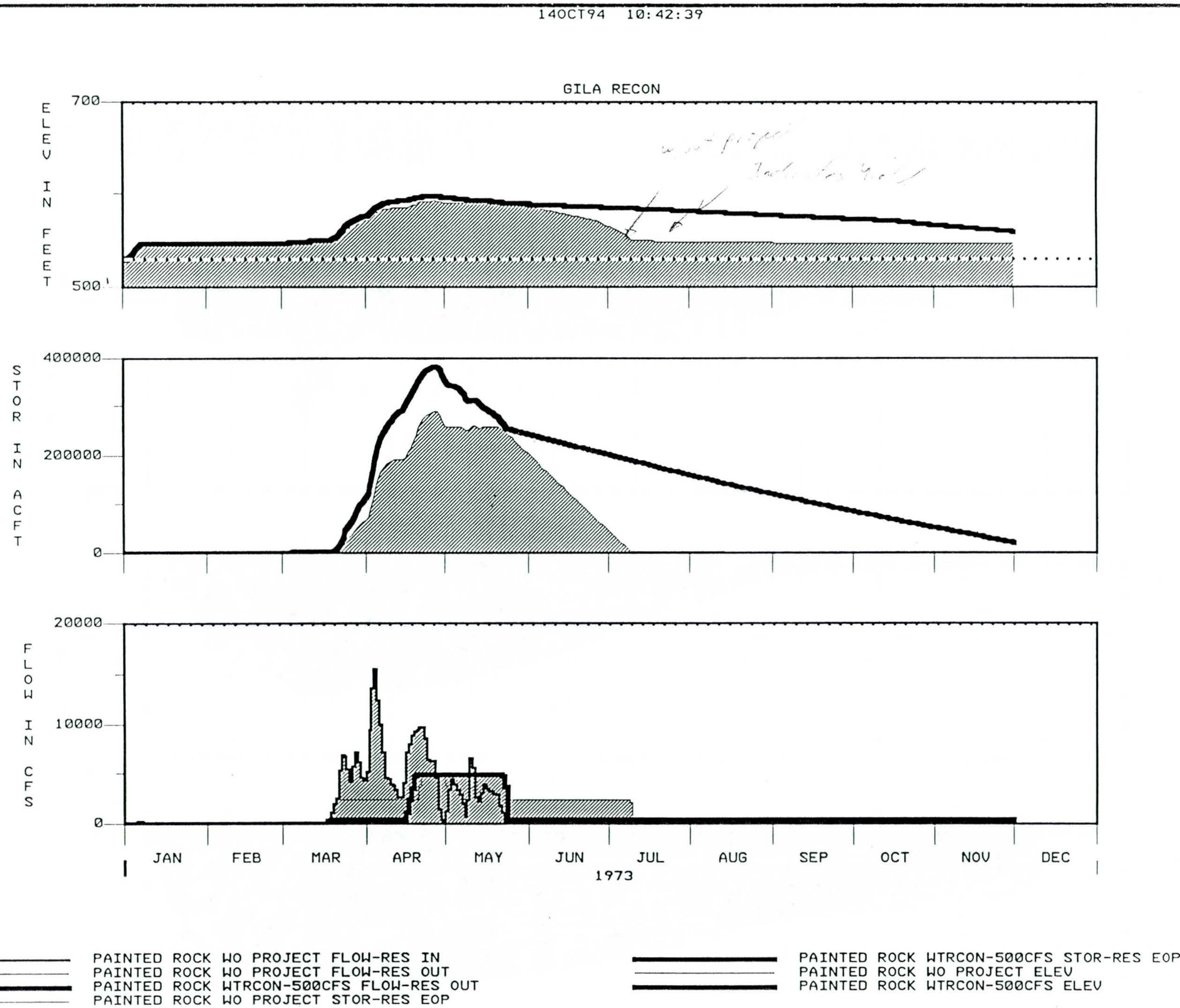

FIGURE 12-1 RESERVOIR ROUTING - w/and w/o project (500 cfs)
1973 - PAINTED ROCK DAM

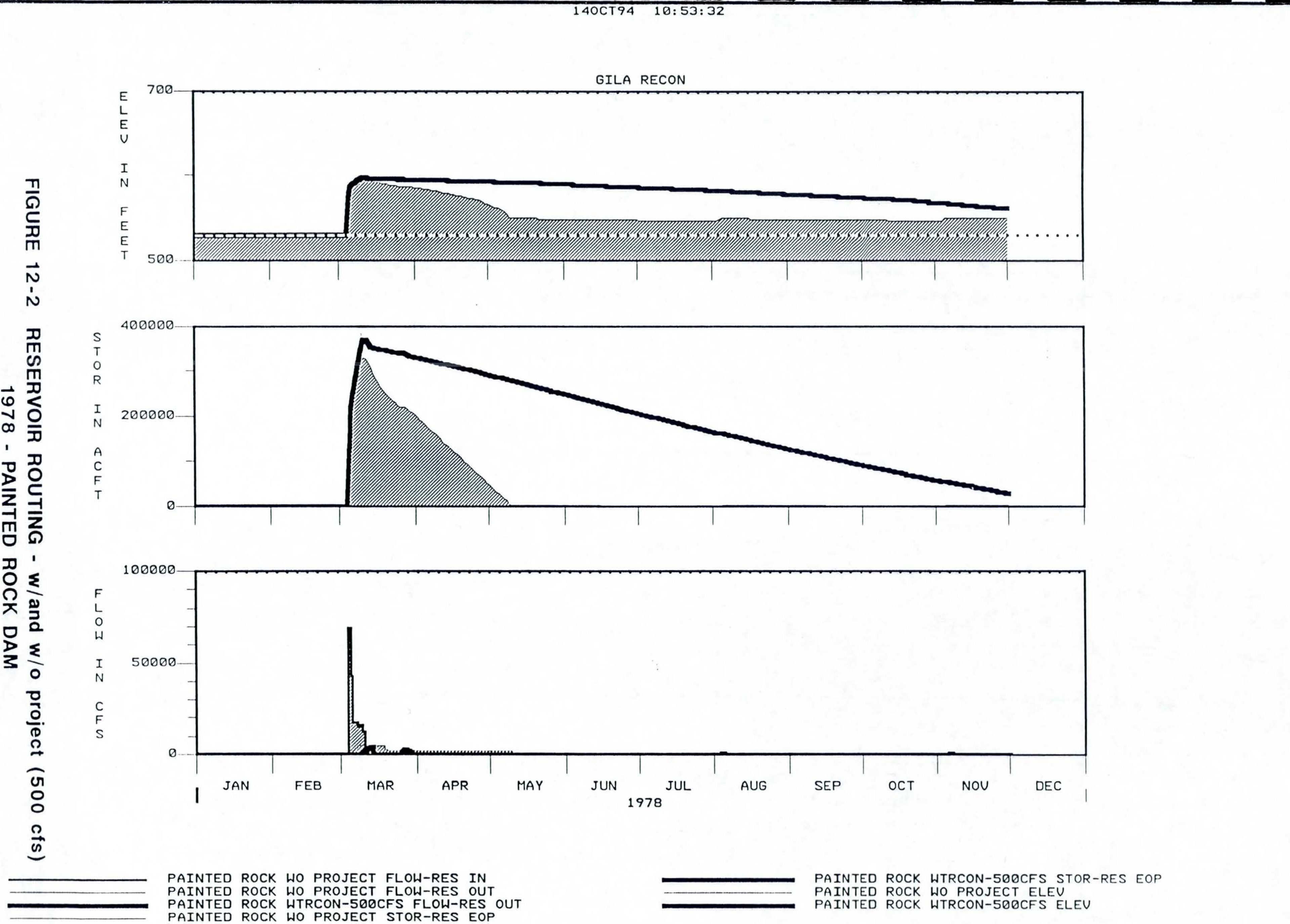

FIGURE 12-2 RESERVOIR ROUTING - w/and w/o project (500 cfs)
1978 - PAINTED ROCK DAM

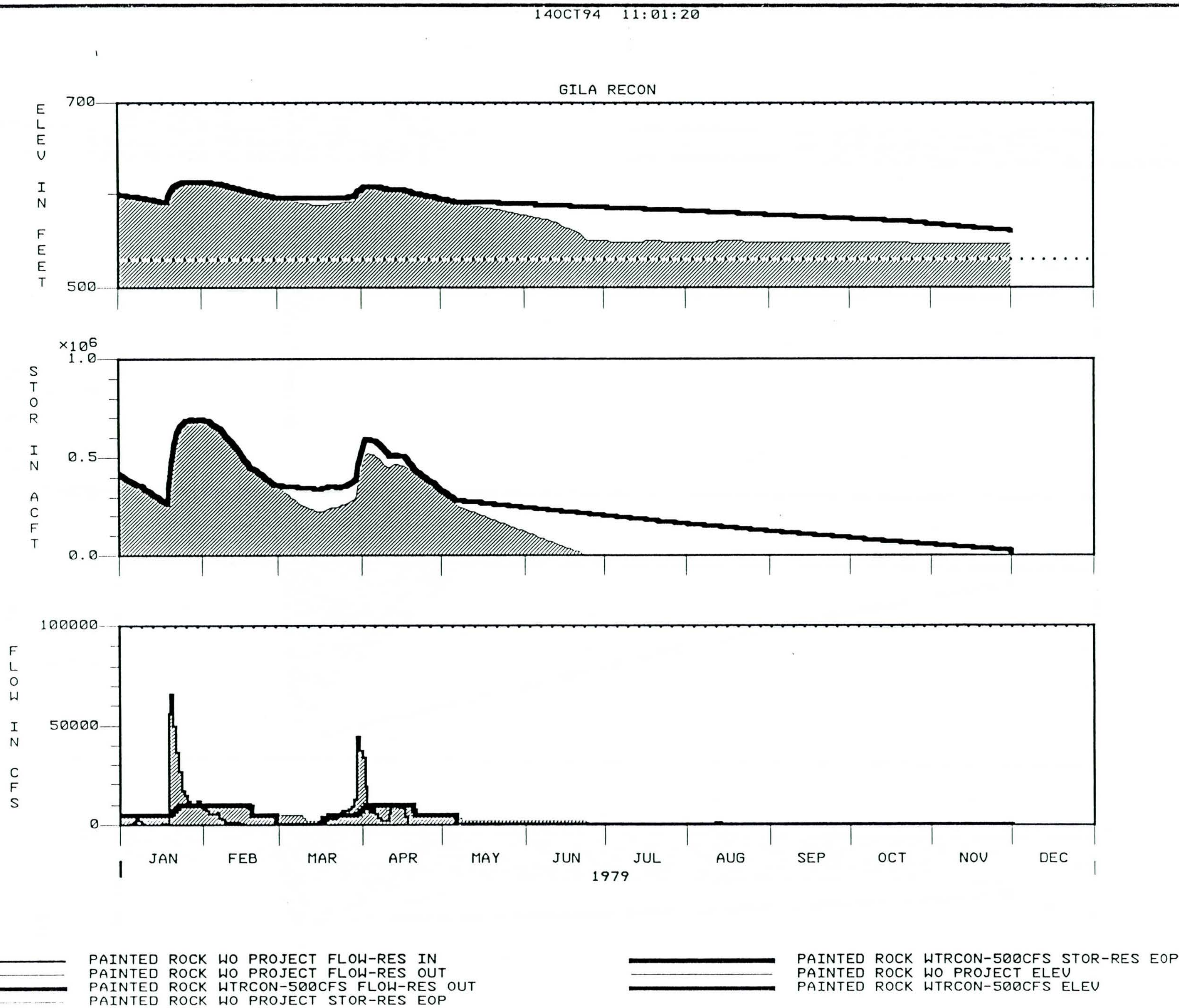

FIGURE 12-3 RESERVOIR ROUTING - w/and w/o project (500 cfs)
1979 - PAINTED ROCK DAM

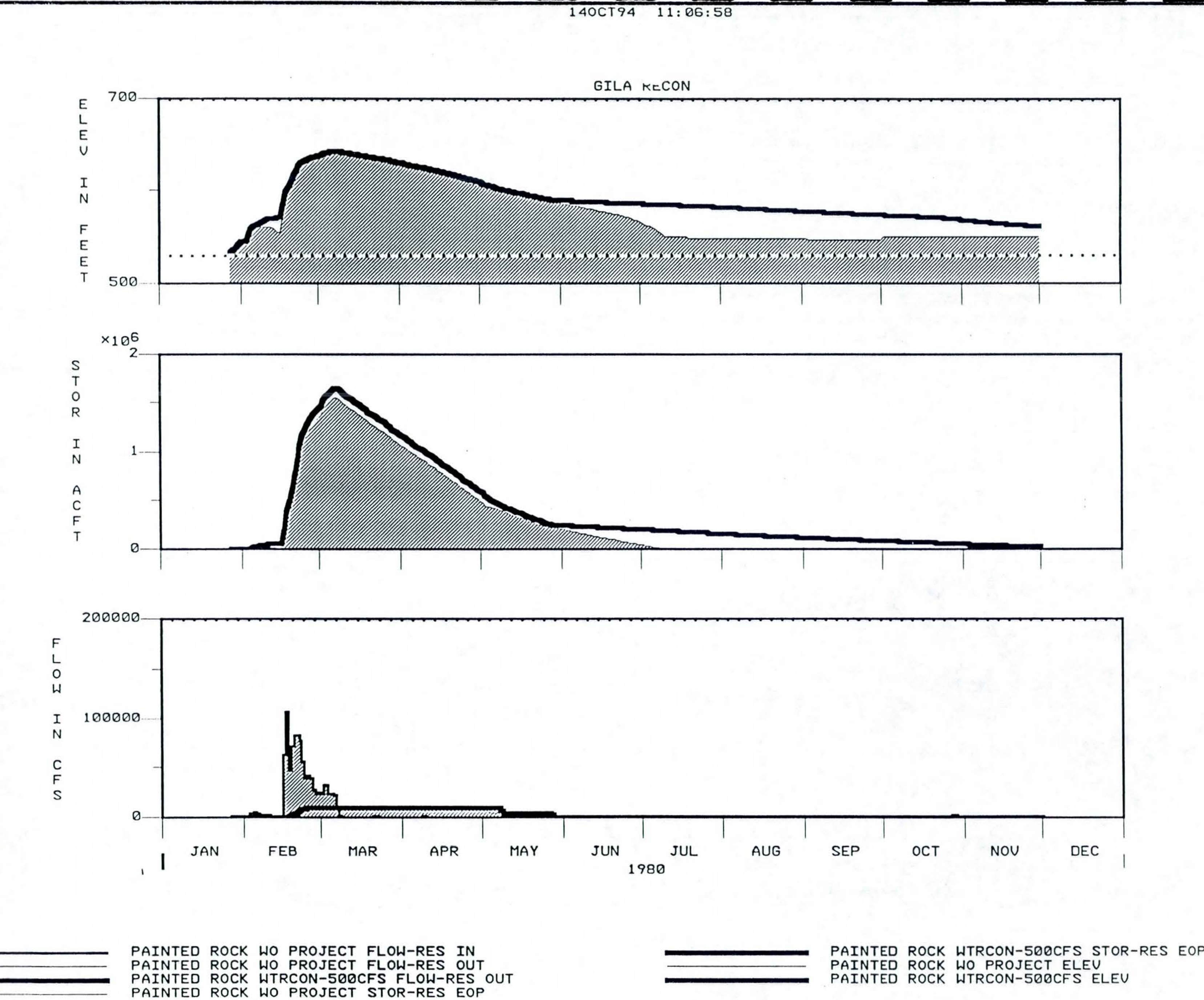

FIGURE 12-4 RESERVOIR ROUTING - w/and w/o project (500 cfs)
1980 - PAINTED ROCK DAM

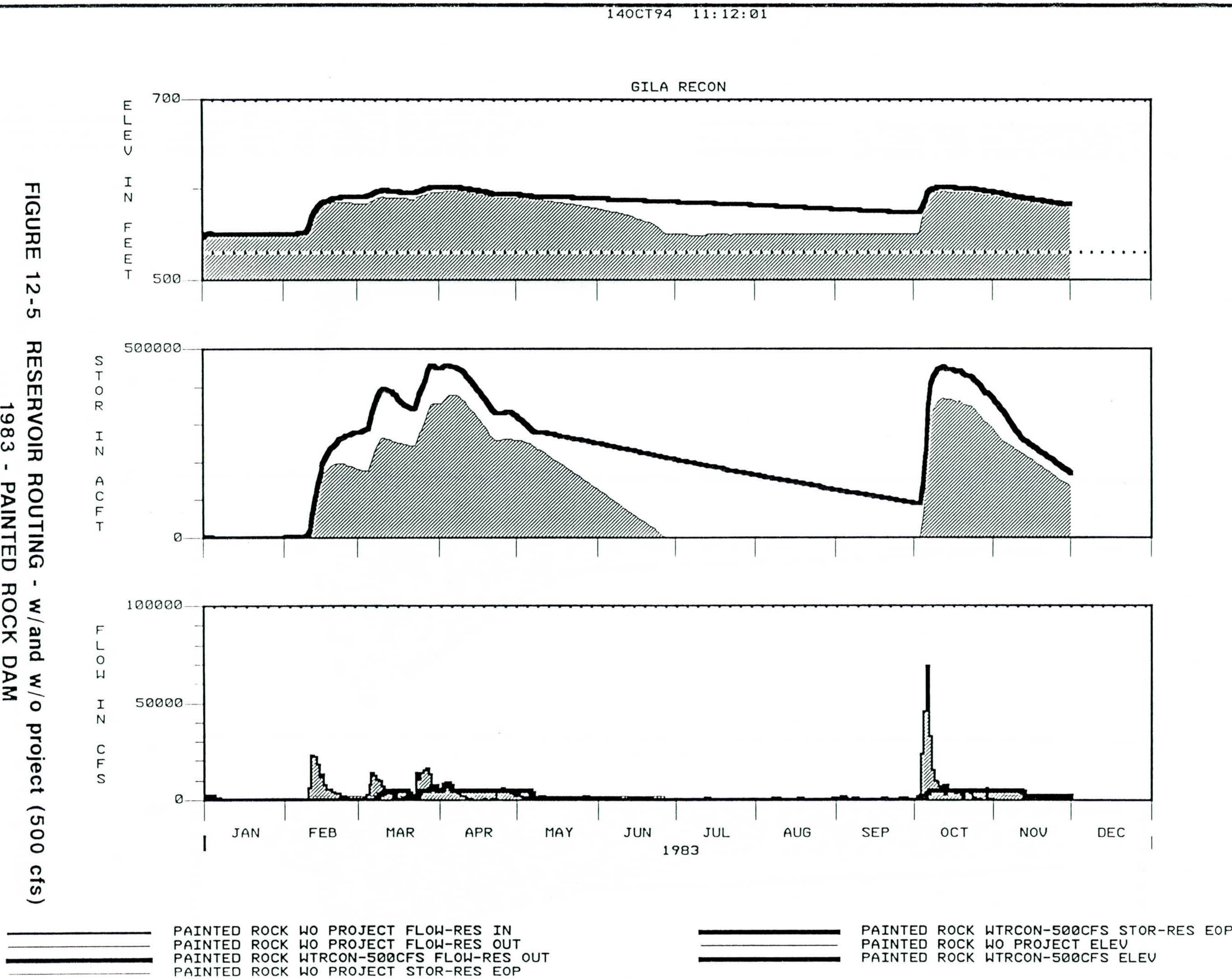

FIGURE 12-5 RESERVOIR ROUTING - w/and w/o project (500 cfs)
1983 - PAINTED ROCK DAM

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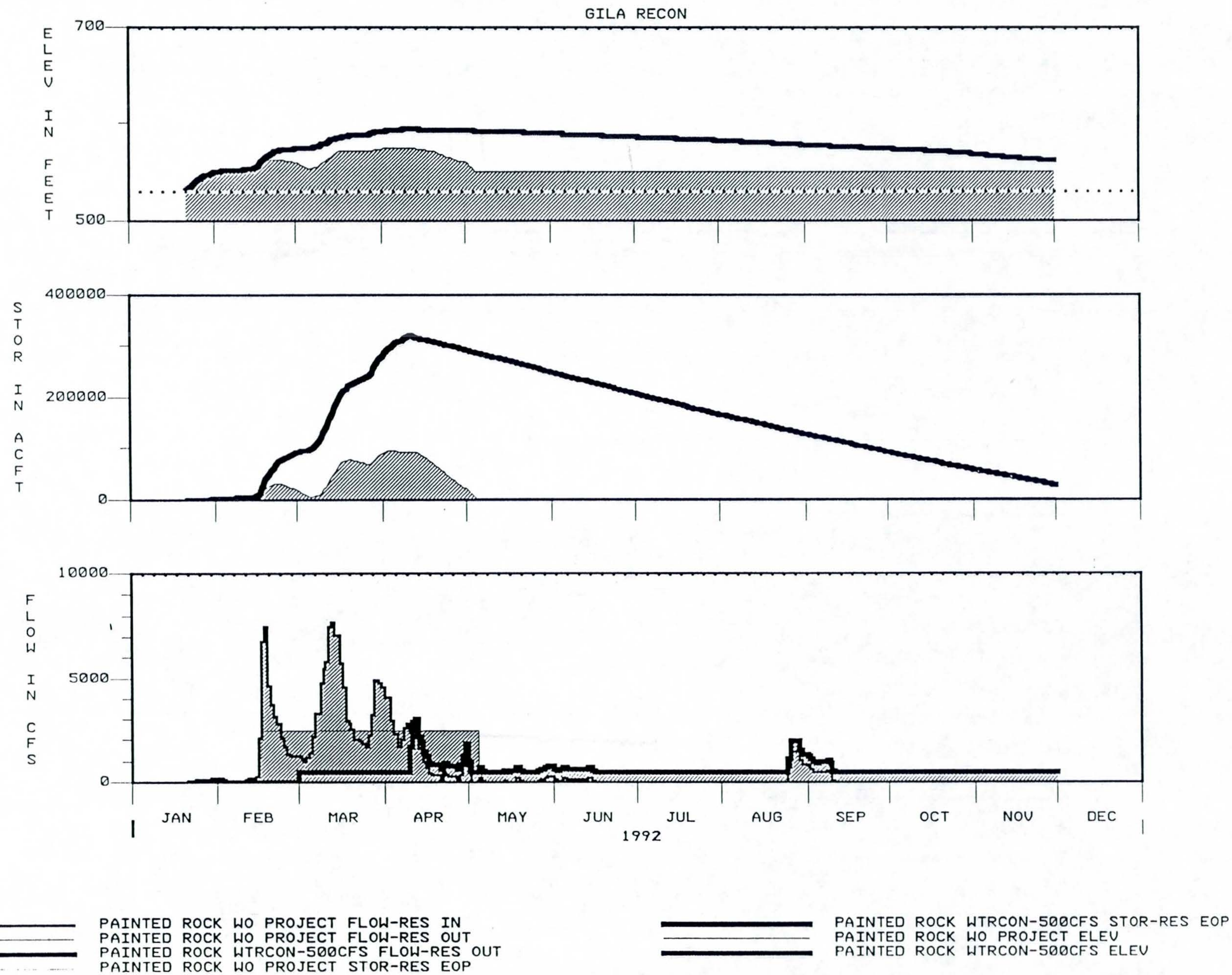


FIGURE 12-6 RESERVOIR ROUTING - w/and w/o project (500 cfs)
1992 - PAINTED ROCK DAM

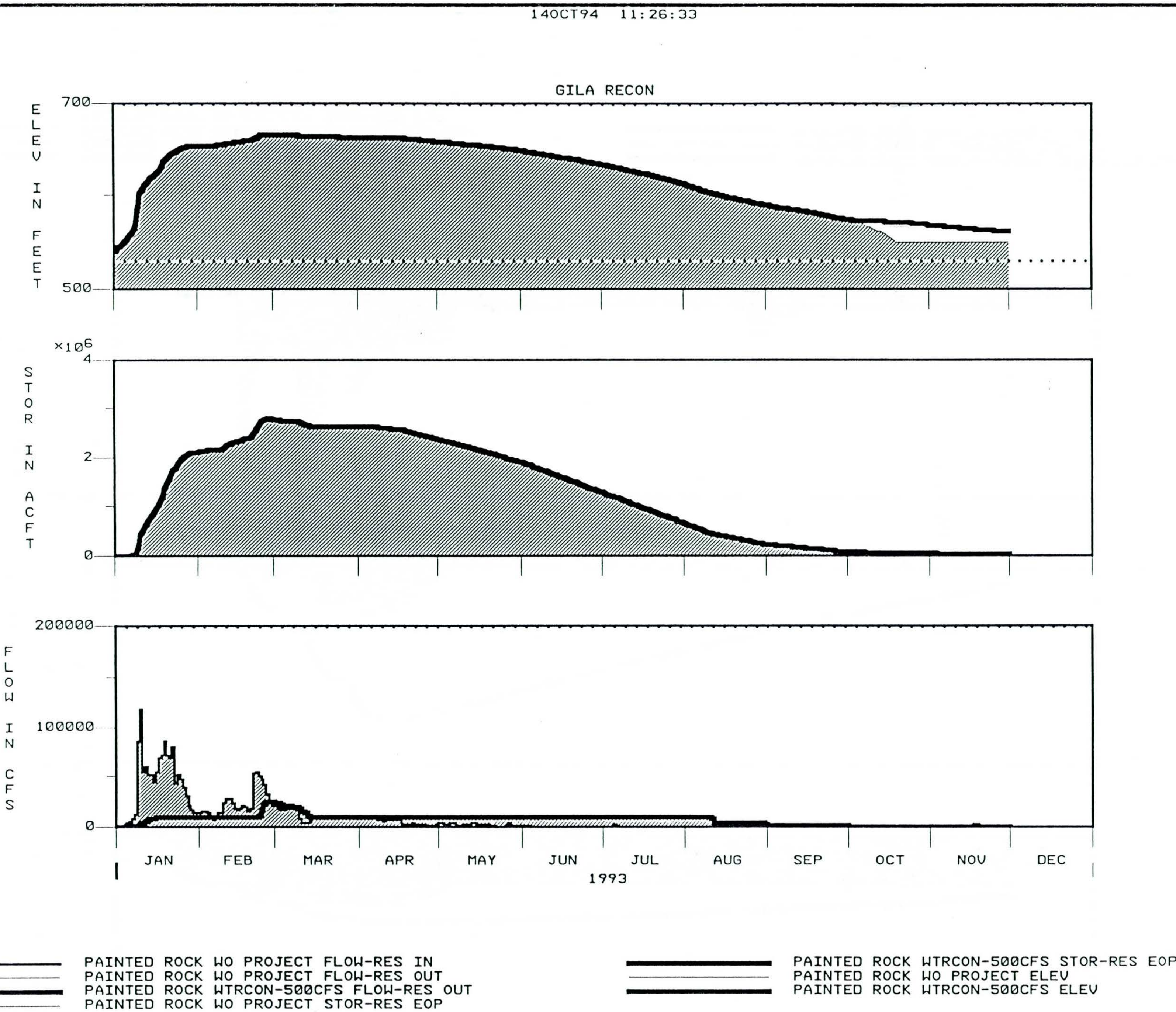


FIGURE 12-7 RESERVOIR ROUTING - w/and w/o project (500 cfs)
1993 - PAINTED ROCK DAM

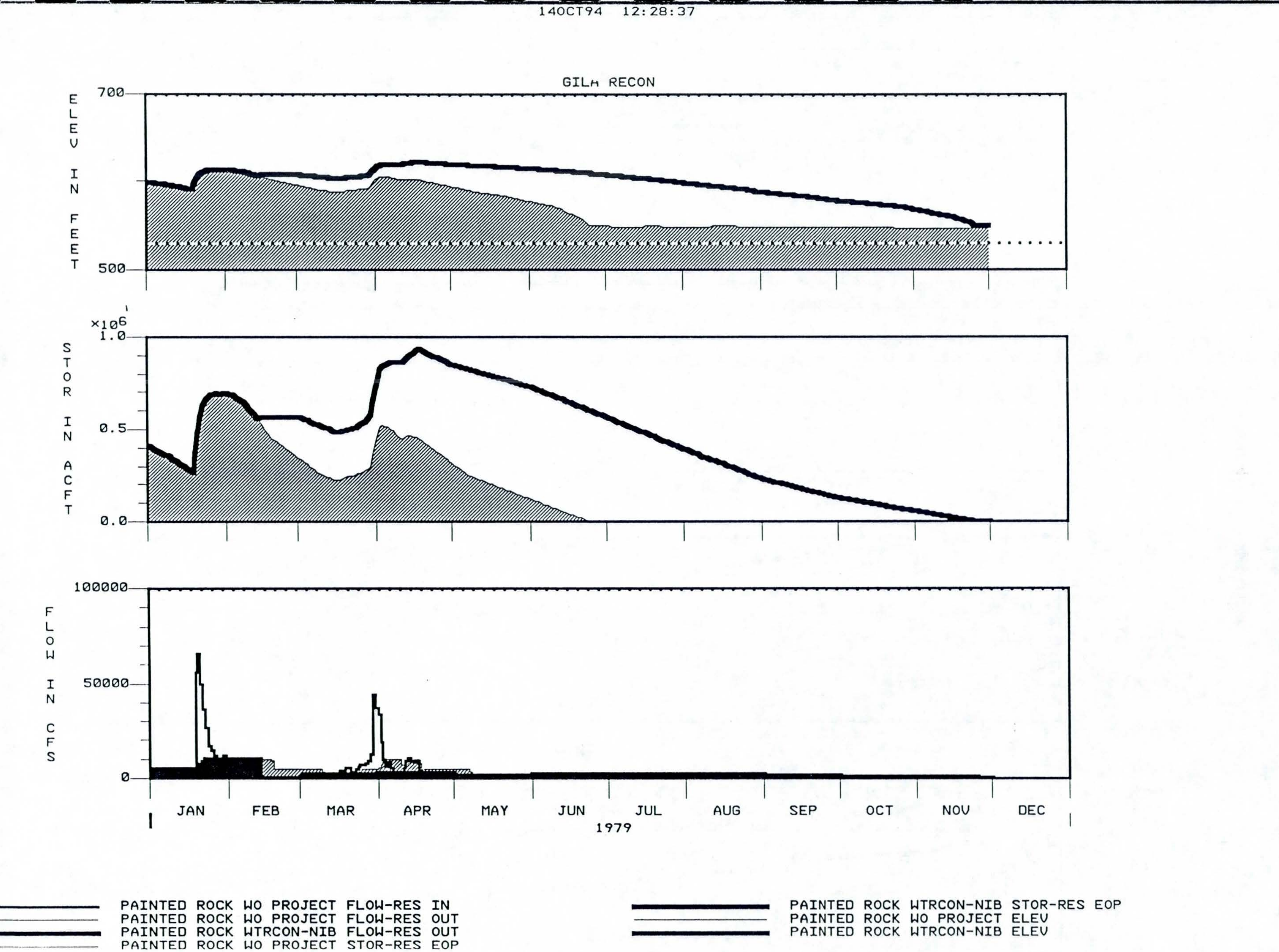
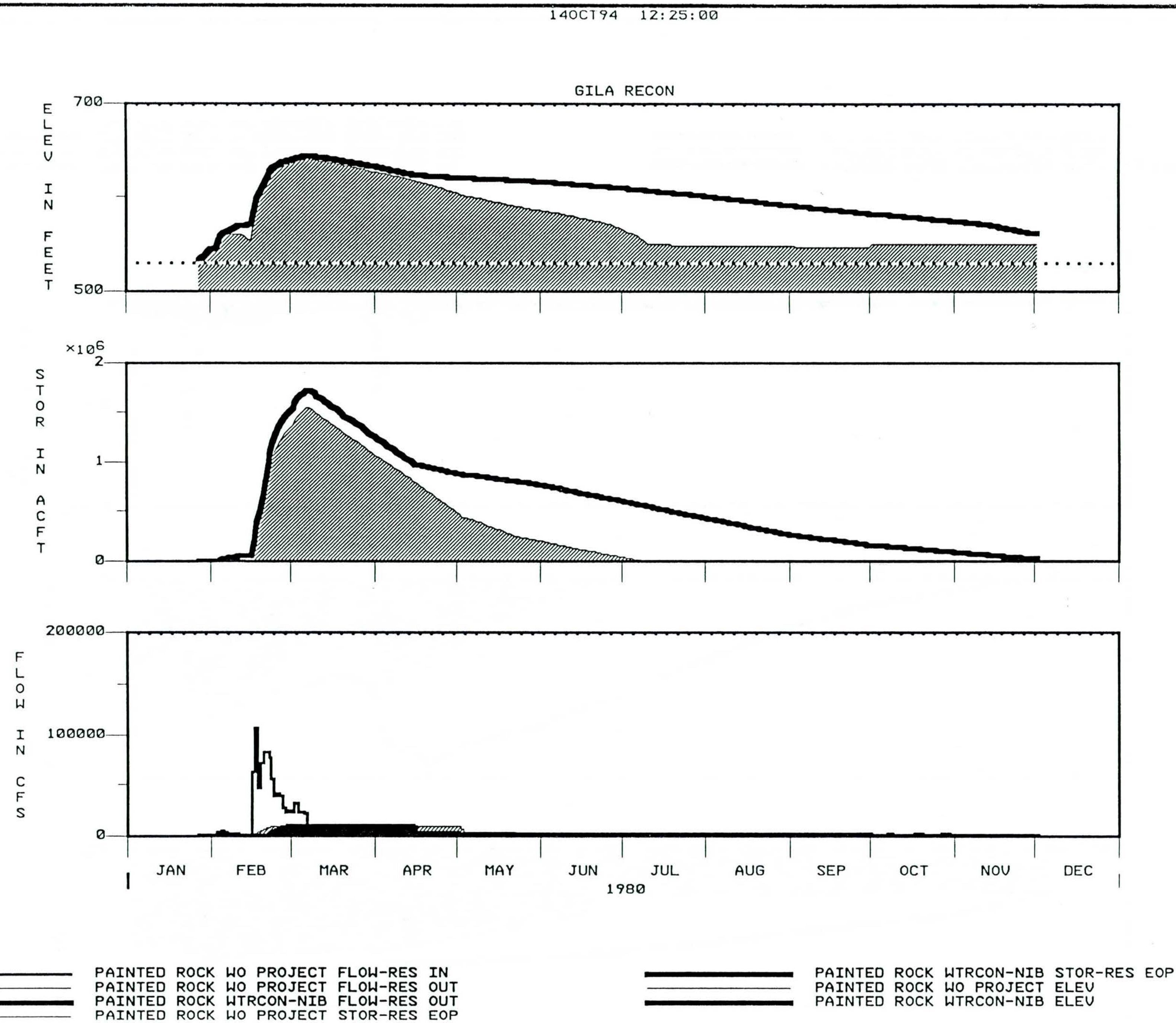


FIGURE 13-3 RESERVOIR ROUTING - w/and w/o project (NIB)
1979 - PAINTED ROCK DAM

FIGURE 13-4 RESERVOIR ROUTING - w/and w/o project (NIB)
1980 - PAINTED ROCK DAM



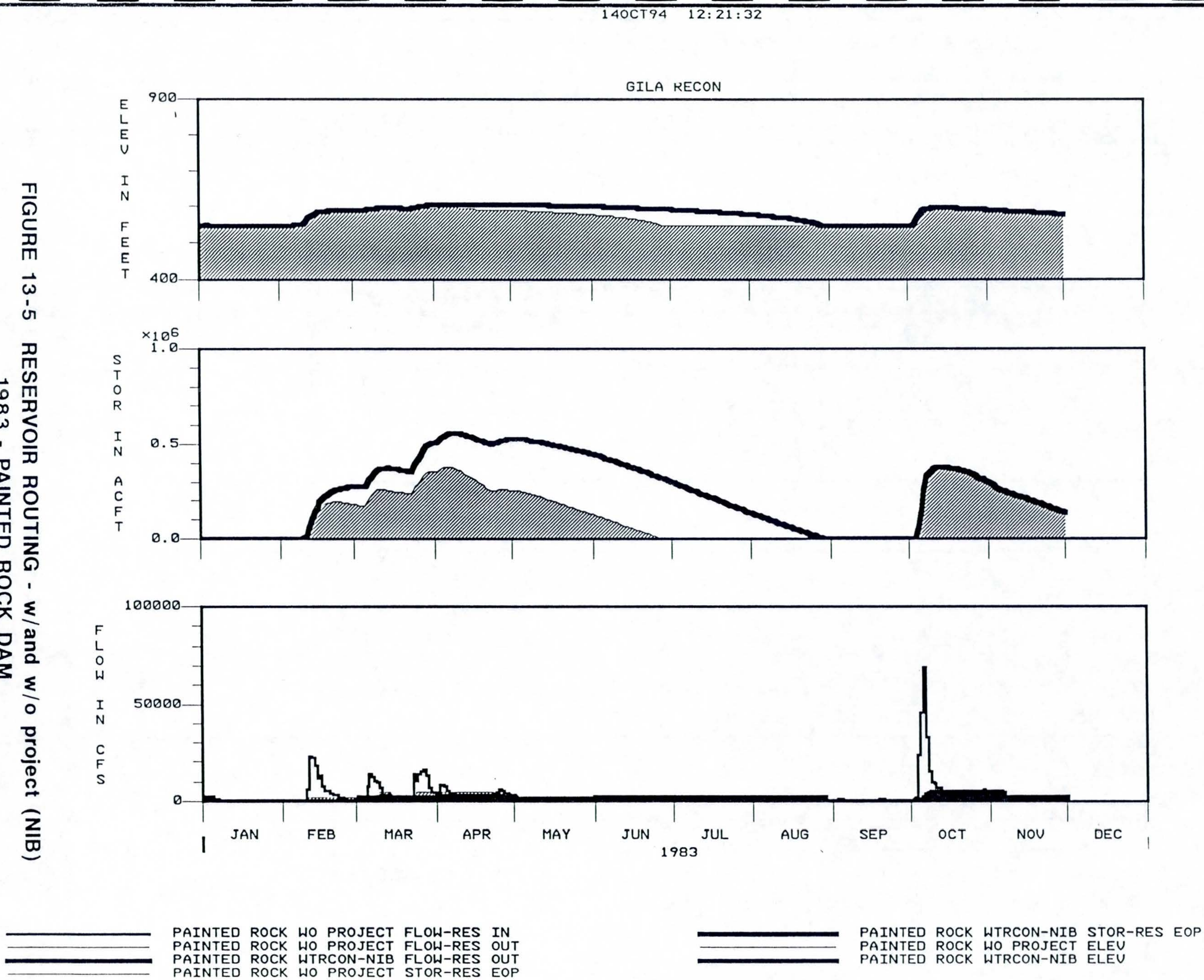


FIGURE 13-5 RESERVOIR ROUTING - w/and w/o project (NIB)
1983 - PAINTED ROCK DAM

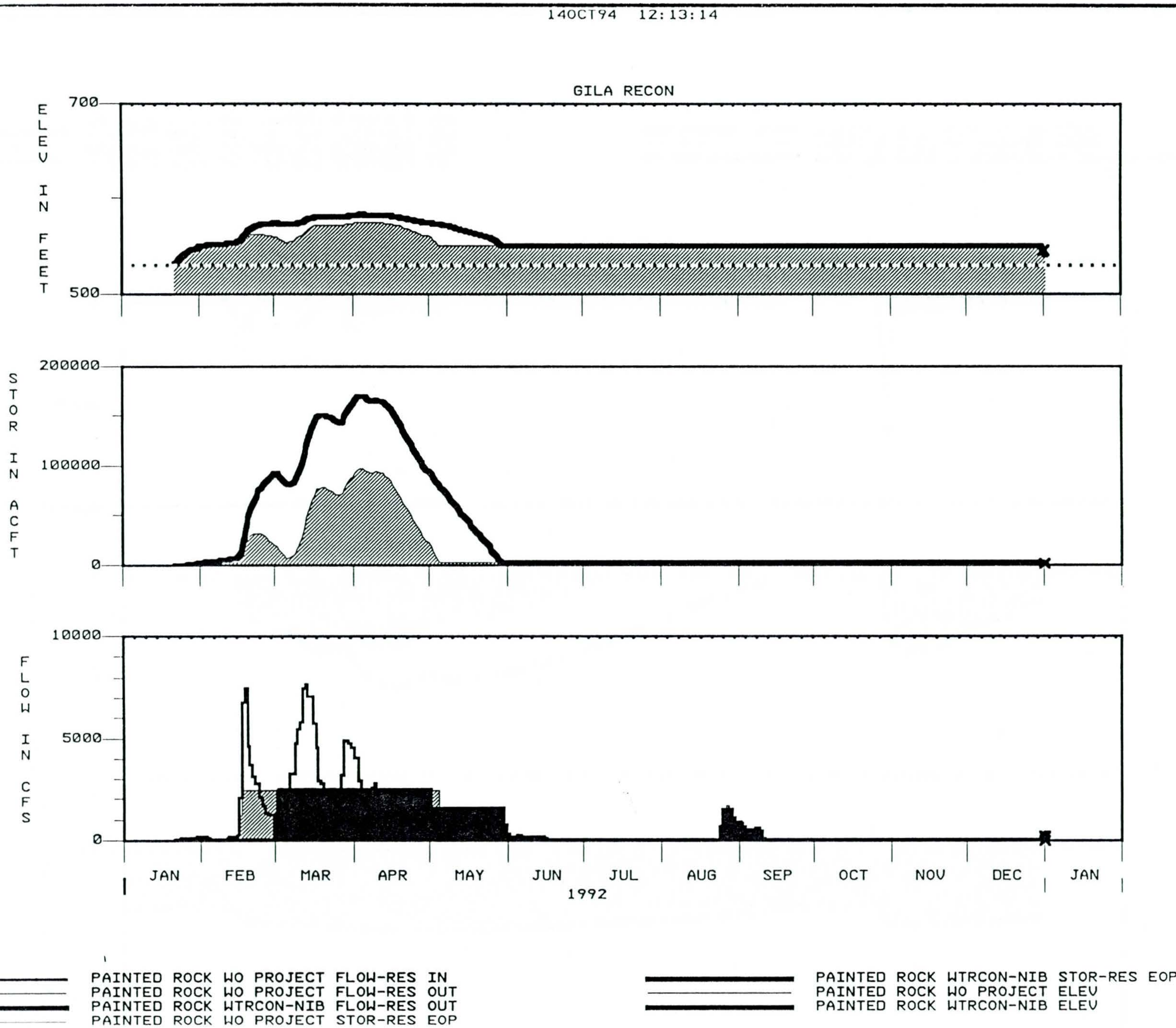


FIGURE 13-6 RESERVOIR ROUTING - w/and w/o project (NIB)
1992 - PAINTED ROCK DAM

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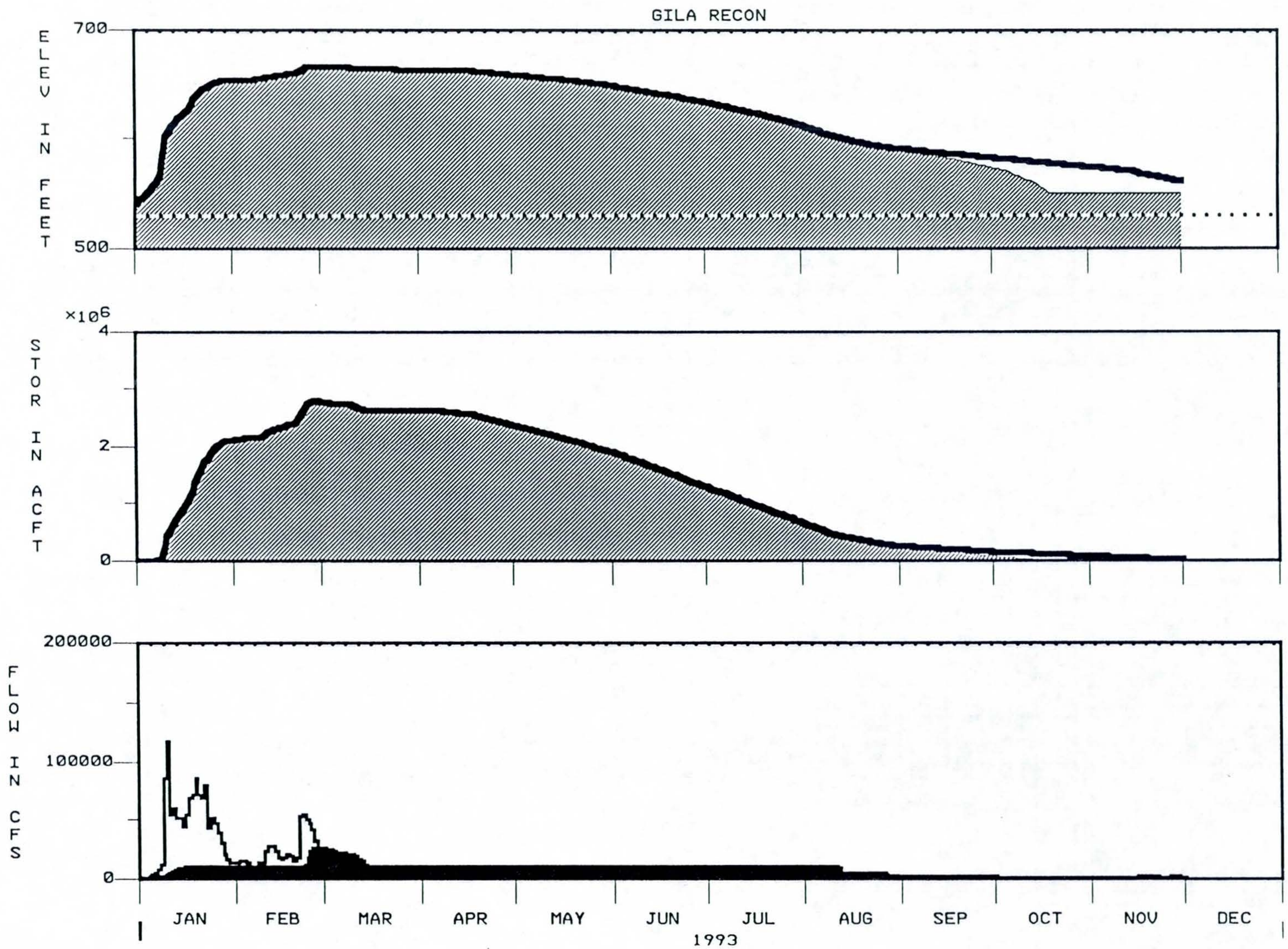

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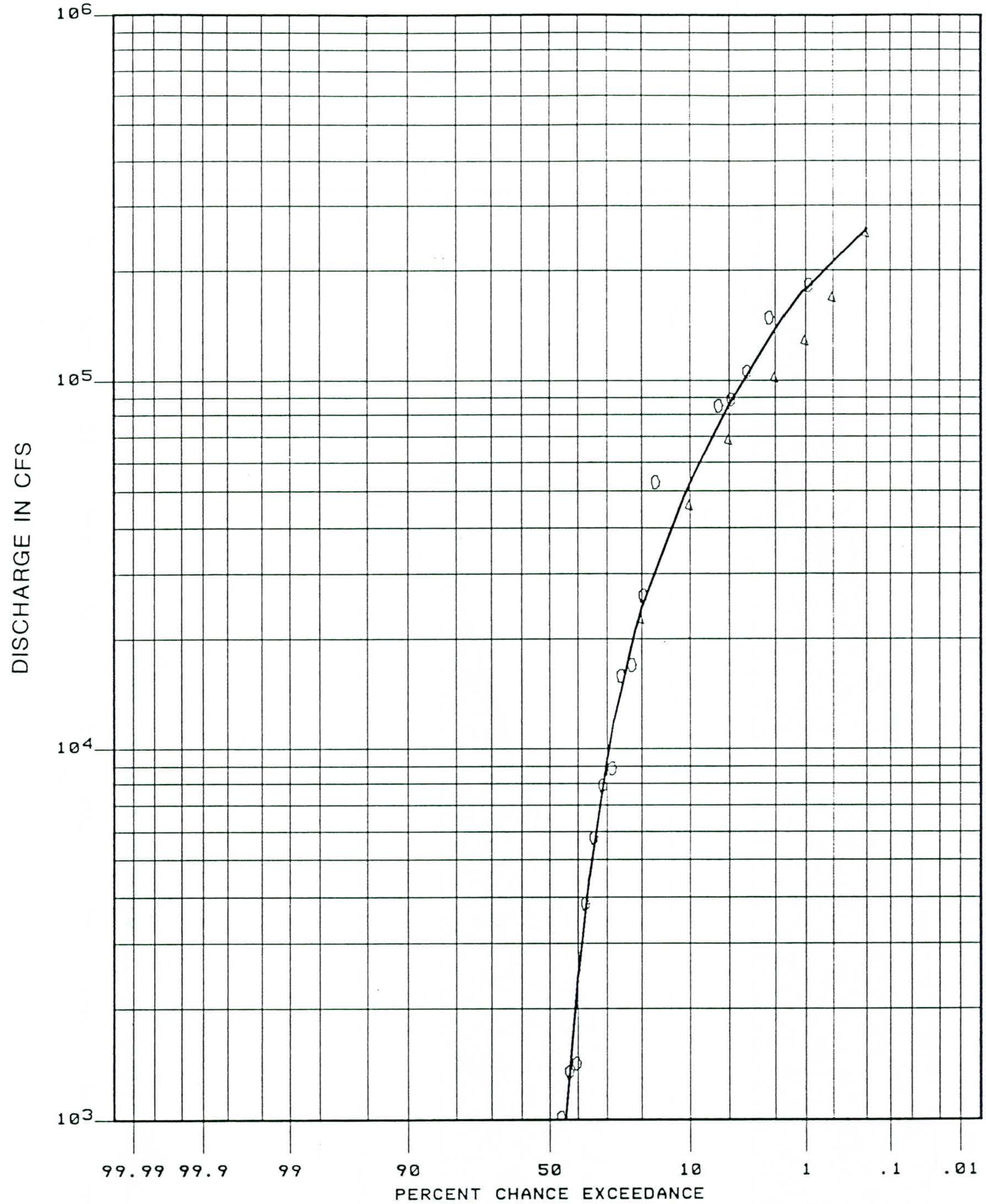
PAINTED ROCK WO PROJECT FLOW-RES OUT
PAINTED ROCK WTRCON-NIB FLOW-RES OUT
PAINTED ROCK WO PROJECT STOR-RES EOP
PAINTED ROCK WTRCON-NIB STOR-RES EOP
PAINTED ROCK WO PROJECT ELEV
PAINTED ROCK WTRCON-NIB ELEV

FIGURE 13-7 RESERVOIR ROUTING - w/and w/o project (NIB)
1993 - PAINTED ROCK DAM



Includes Plan 9 Roosevelt Dam

0 Observed inflows, adjusted for Modified Roosevelt Dam:
Median Plotting Positions
H=77, m=1-5(1993,1980,1978,1979,1984)
N=35, m=6-16

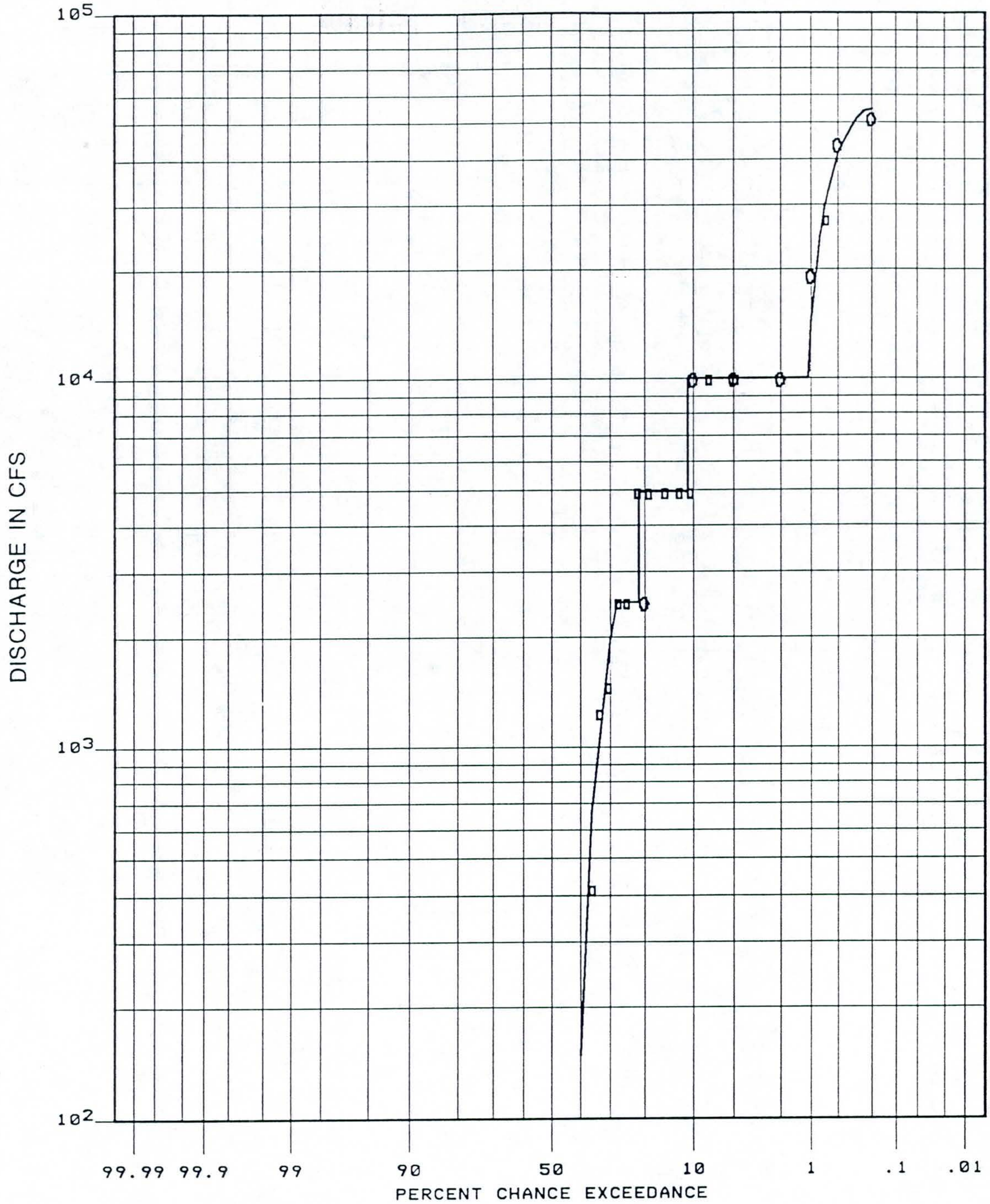
Δ Balanced Hydrographs

Note: Inflows based on 6-hour time interval

GILA RIVER RECON STUDY

INFLOW FREQUENCY CURVE
PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



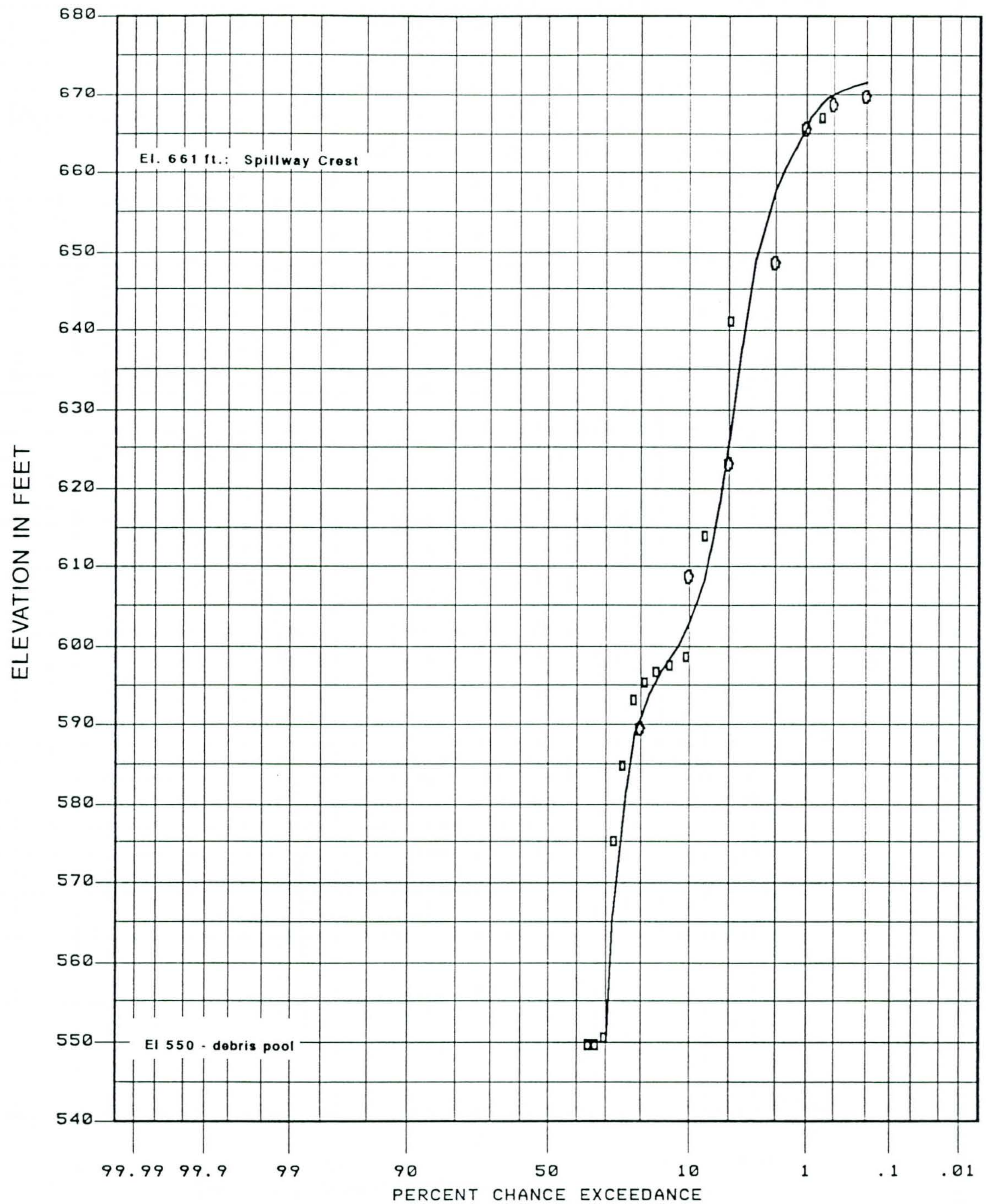
□ Simulated outflows, based on observed inflows adjusted for Modified Roosevelt Dam
Median Plotting Positions
H=105, m=1 (1993)
N=35, m=2-13
O Balanced Hydrographs

Includes Plan 9 Roosevelt Dam

GILA RIVER RECON STUDY

OUTFLOW FREQUENCY CURVE
WITHOUT PROJECT
PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



▯ Simulated elevations, based on observed inflows adjusted for Modified Roosevelt Dam
Median Plotting Positions
H=105, m=1(1993)
N=35, m=2-13

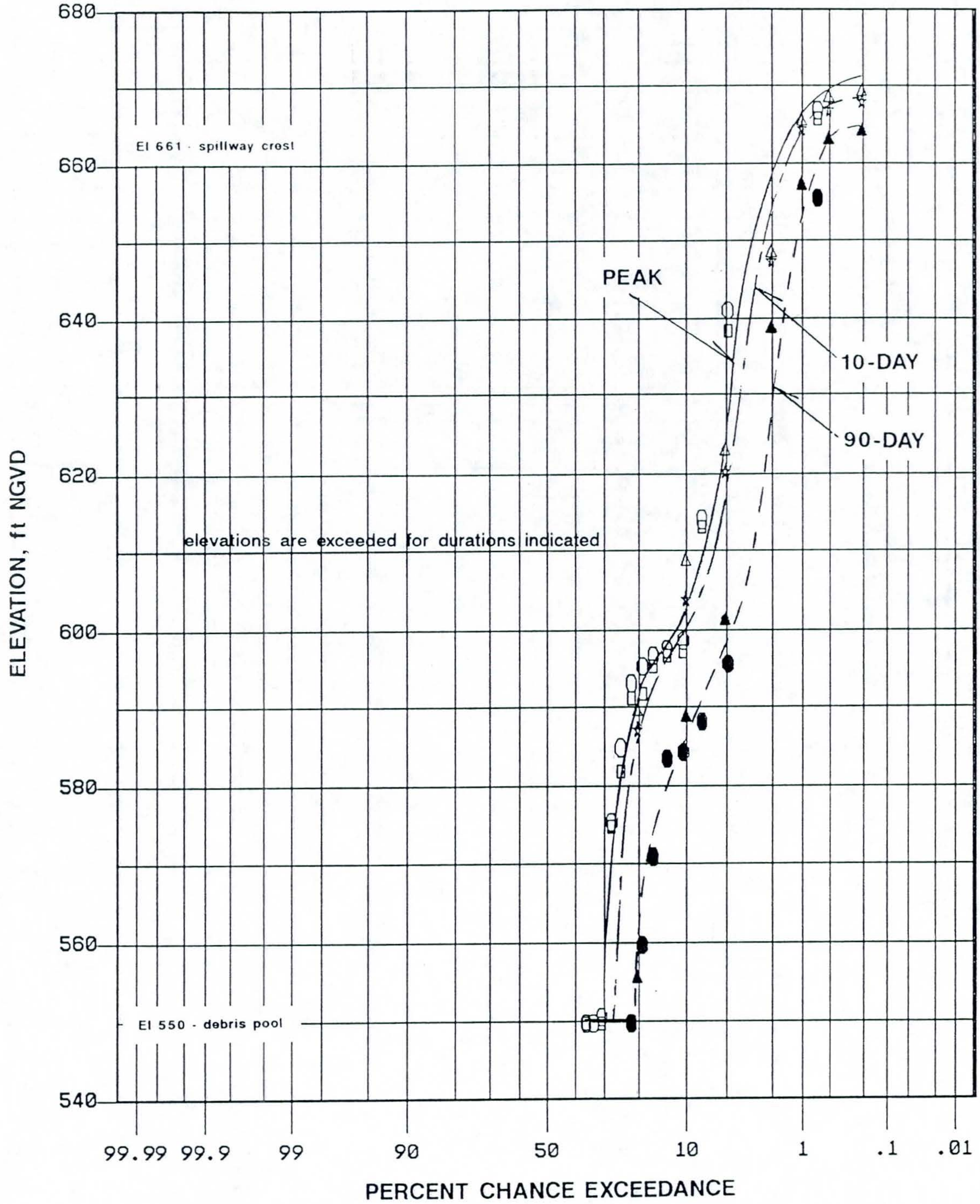
○ Balanced Hydrographs

Includes Plan 9 Roosevelt Dam

GILA RIVER RECON STUDY

ELEVATION FREQUENCY CURVE
WITHOUT PROJECT
PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



WITHOUT PROJECT CONDITIONS
(includes Plan 9 Roosevelt Dam)

Simulated elevations, based on observed inflows adjusted for Modified Roosevelt Dam

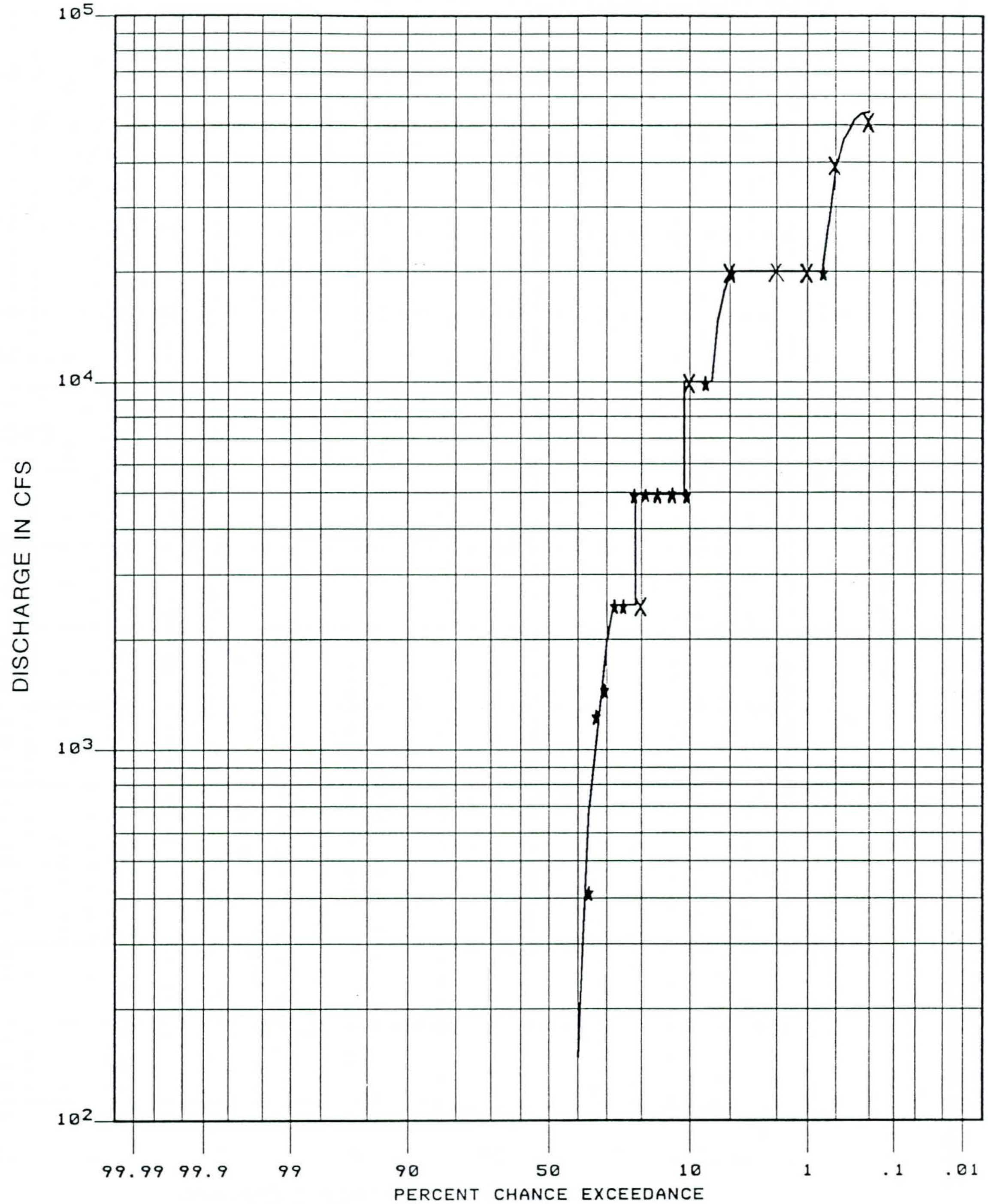
Median Plotting Positions
H=105, m=1 (1993)
N=35, m=2-13

Symbol	Median Plotting Positions	Symbol	Balanced Hydrographs
○	Peak	△	Peak
□	10-day	☆	10-day
●	90-day	▲	90-day

GILA RIVER RECON STUDY

PAINTED ROCK DAM
ELEVATION-DURATION
FREQUENCY CURVES

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



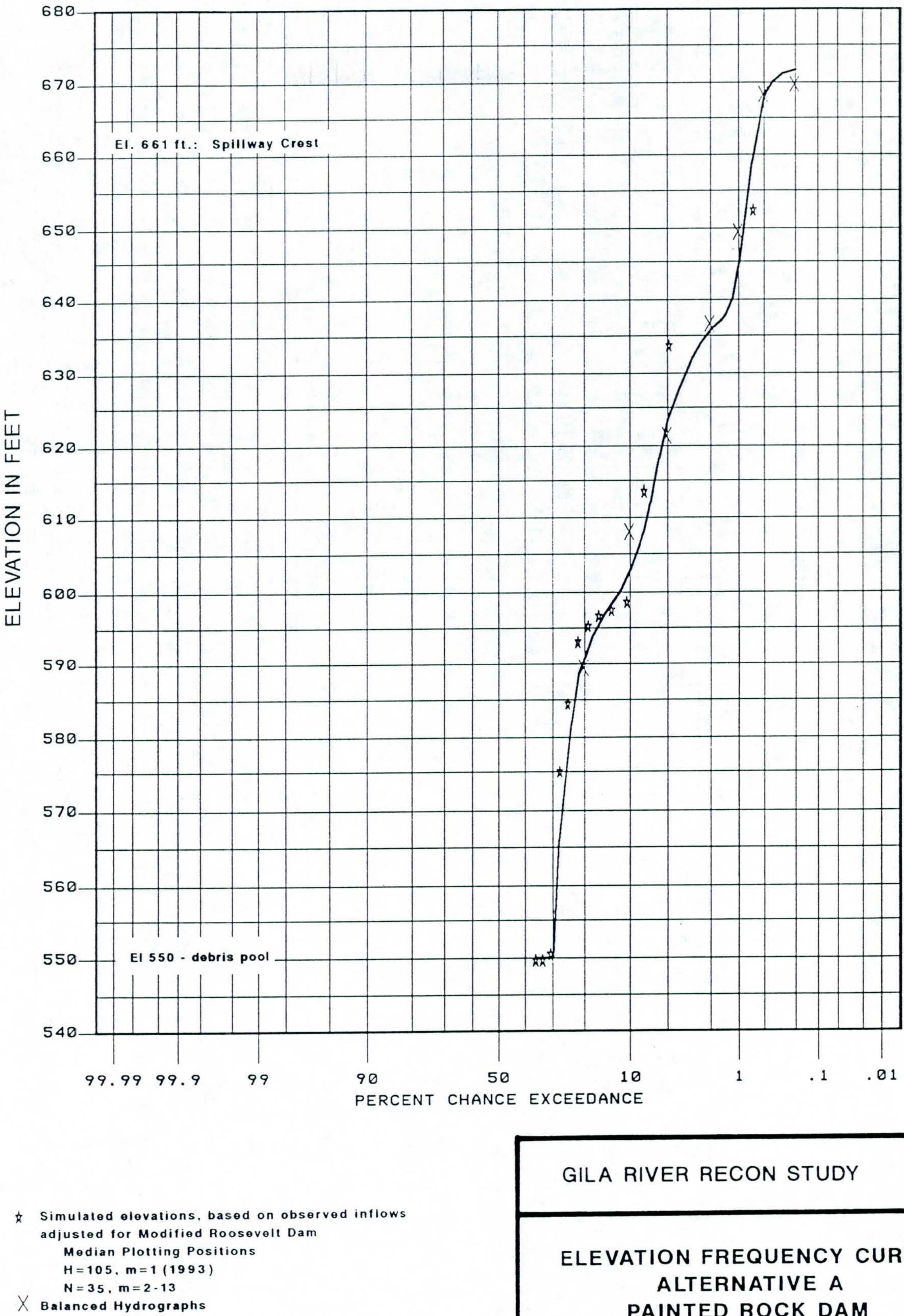
★ Simulated outflows, based on observed inflows adjusted for Modified Roosevelt Dam
Median Plotting Positions
H=105, m=1(1993)
N=35, m=2-13

X Balanced Hydrographs

GILA RIVER RECON STUDY

OUTFLOW FREQUENCY CURVE
ALTERNATIVE A
PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

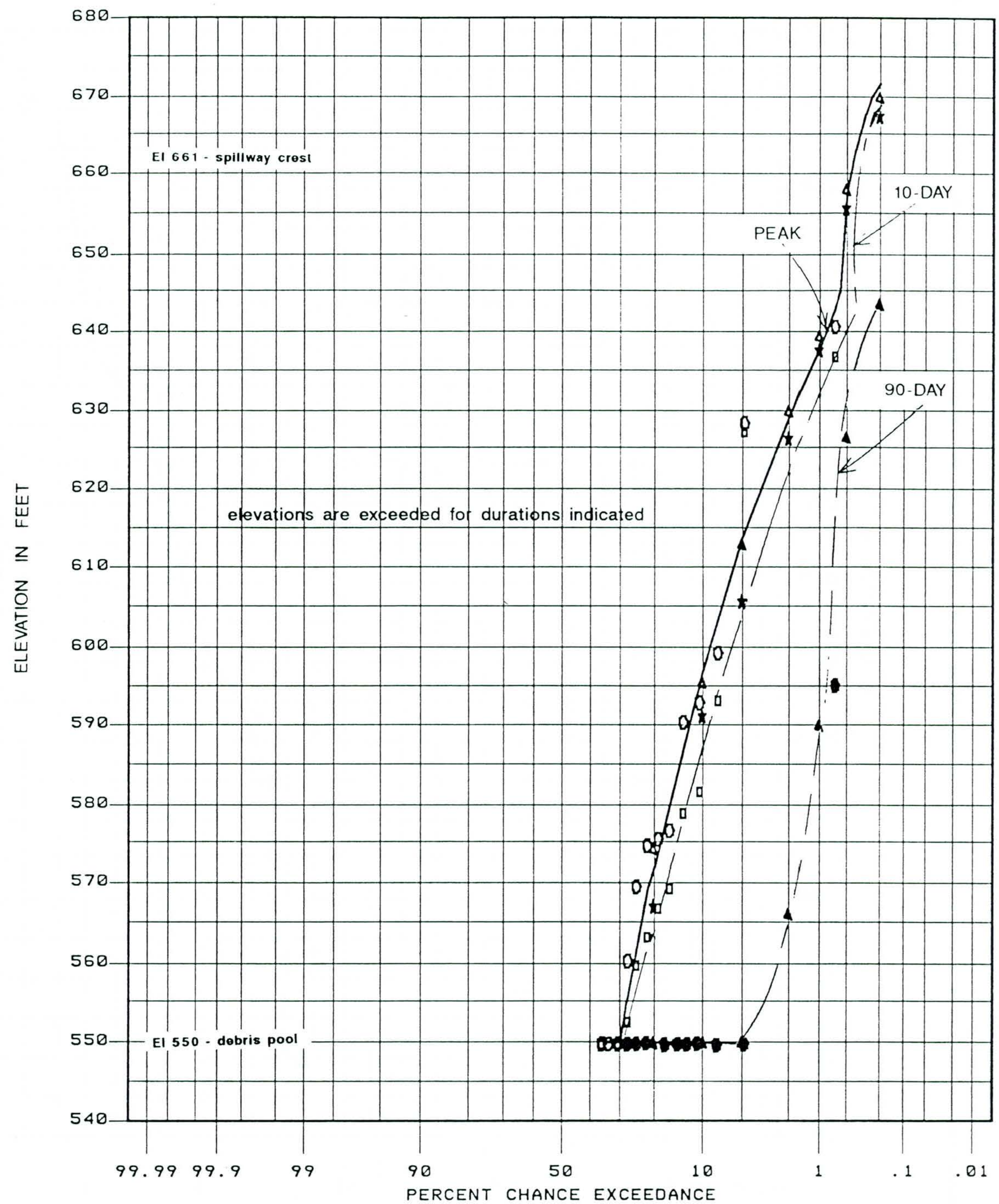


GILA RIVER RECON STUDY

ELEVATION FREQUENCY CURVE
ALTERNATIVE A
PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 6



Simulated elevations, based on observed inflows adjusted for Modified Roosevelt Dam

Median Plotting Positions

H=105, m=1 (1993)

N=35, m=2-13

- Peak
- 10-day
- 90-day

Balanced Hydrographs

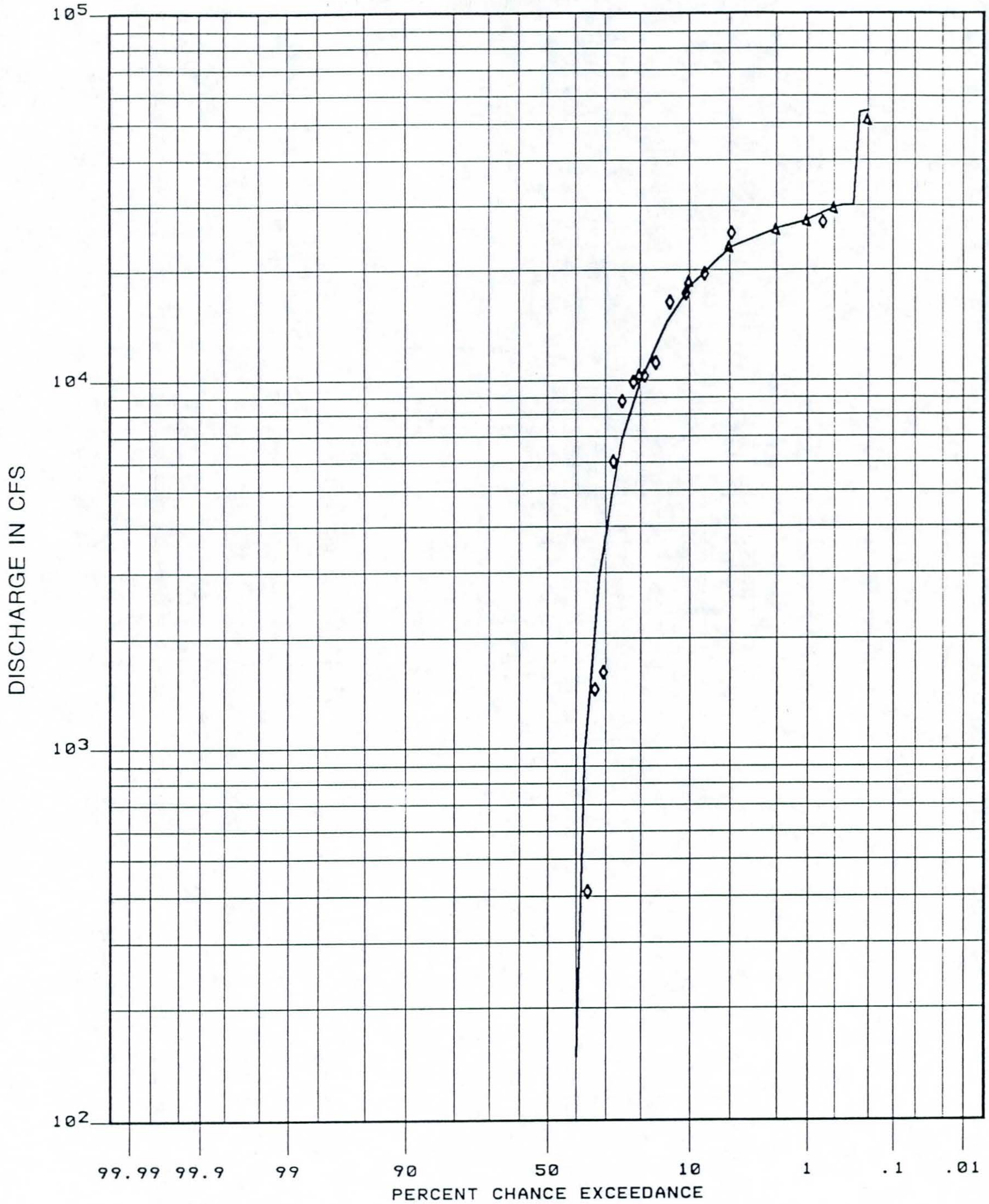
- Peak
- 10-day
- 90-day

GILA RIVER RECON STUDY

PAINTED ROCK DAM ELEVATION-DURATION FREQUENCY CURVES

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

ALTERNATIVE A



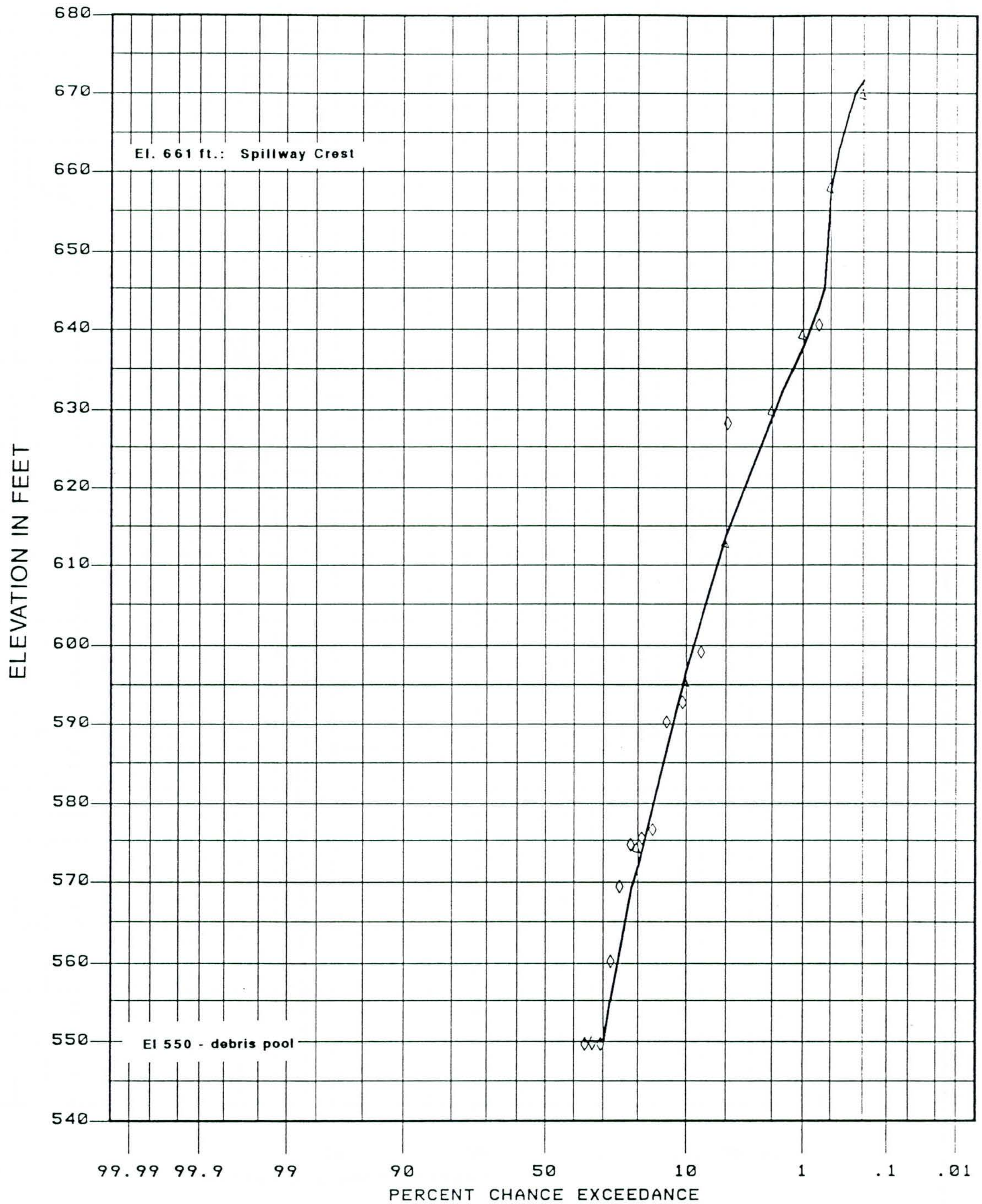
◊ Simulated outflows, based on observed inflows adjusted for Modified Roosevelt Dam
Median Plotting Positions
H=105, m=1 (1993)
N=35, m=2-13

Δ Balanced Hydrographs

GILA RIVER RECON STUDY

OUTFLOW FREQUENCY CURVE
ALTERNATIVE B
PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

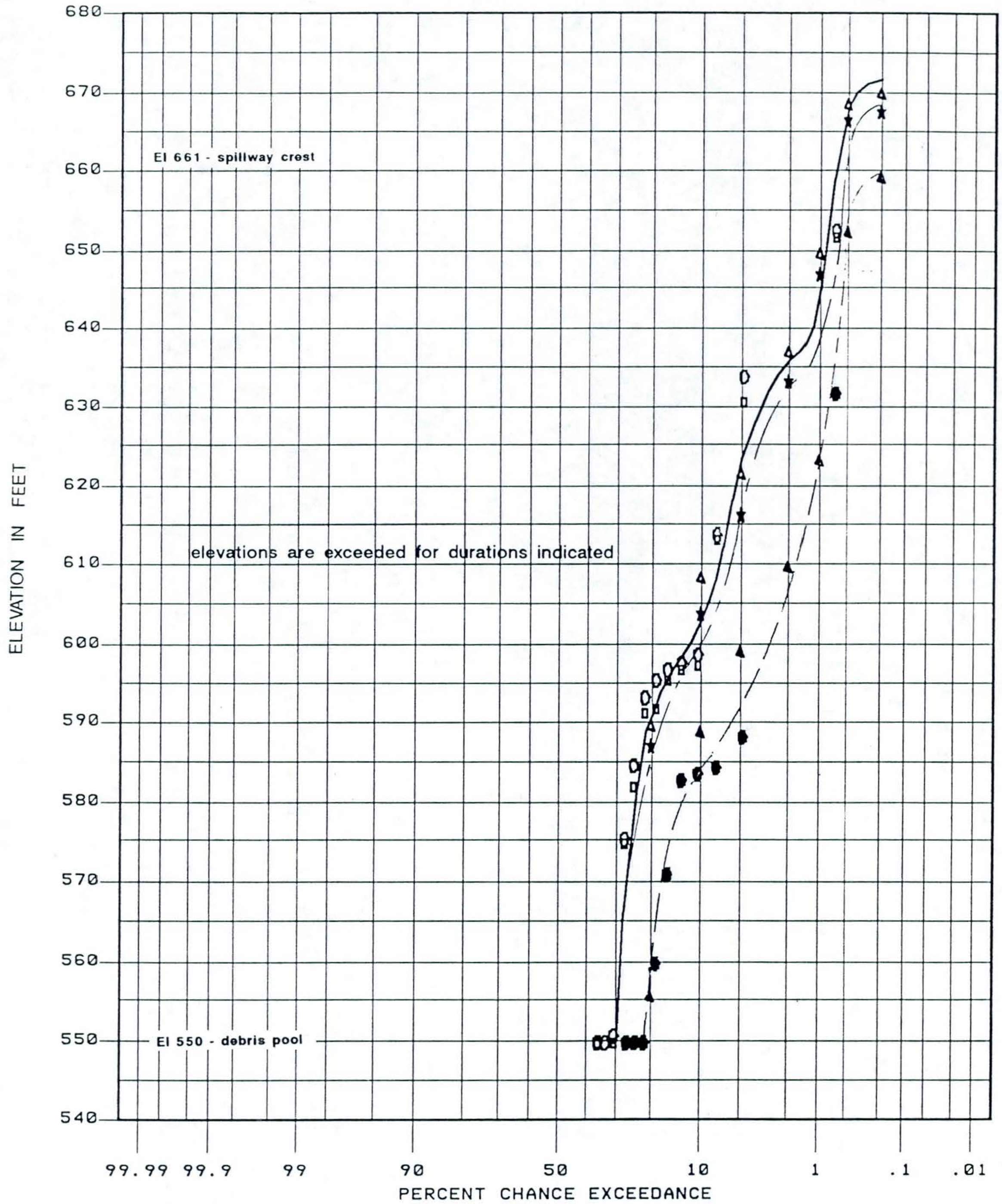


◊ Simulated elevations, based on observed inflows adjusted for Modified Roosevelt Dam
Median Plotting Positions
H=105, m=1 (1993)
N=35, m=2-13
△ Balanced Hydrographs

GILA RIVER RECON STUDY

ELEVATION FREQUENCY CURVE
ALTERNATIVE B
PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



Simulated elevations, based on observed inflows
adjusted for Modified Roosevelt Dam

Median Plotting Positions
H=105, m=1 (1993)
N=35, m=2-13

Peak
10-day
90-day

Balanced Hydrographs

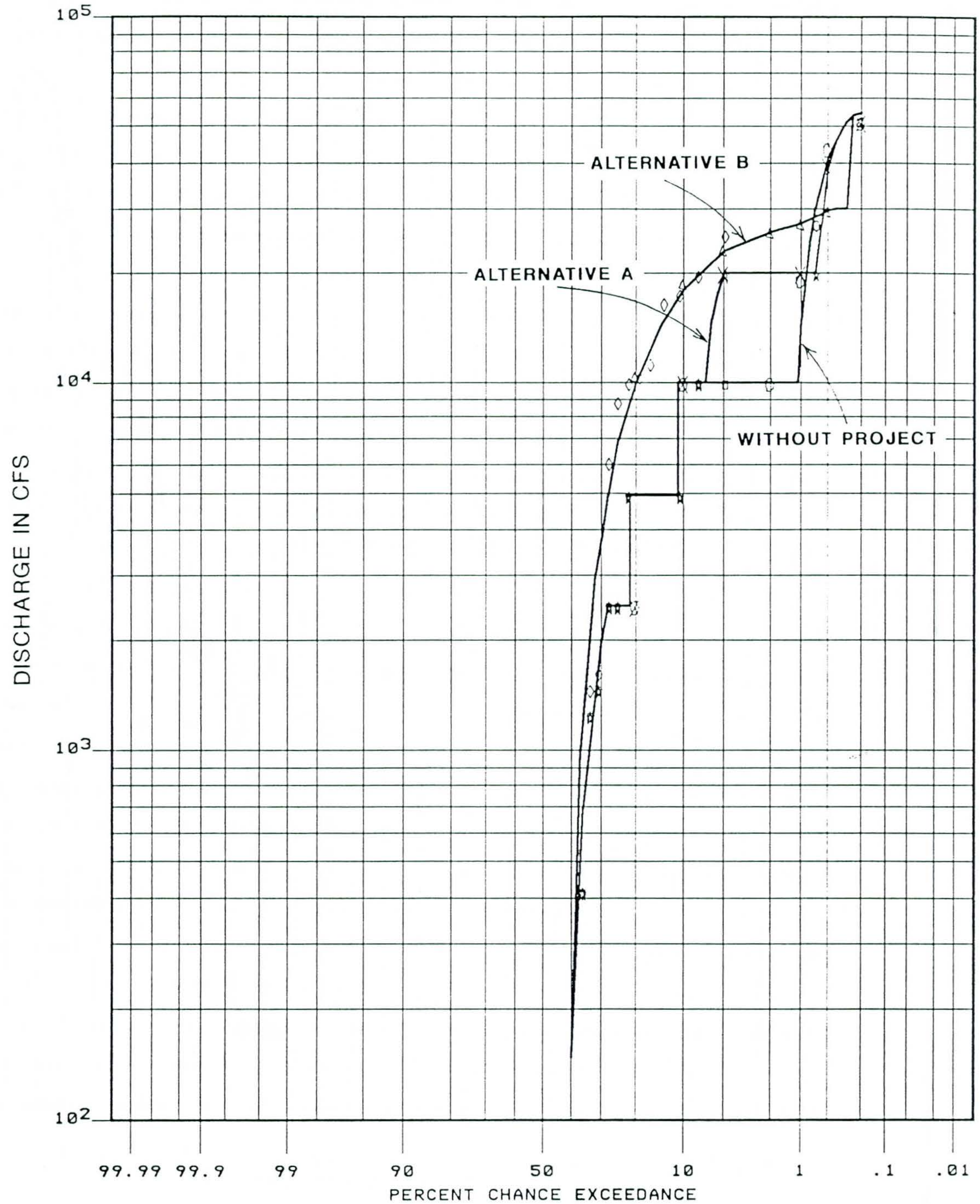
Peak
10-day
90-day

GILA RIVER RECON STUDY

PAINTED ROCK DAM
ELEVATION-DURATION
FREQUENCY CURVES

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

ALTERNATIVE B



Includes Plan 9 Roosevelt Dam

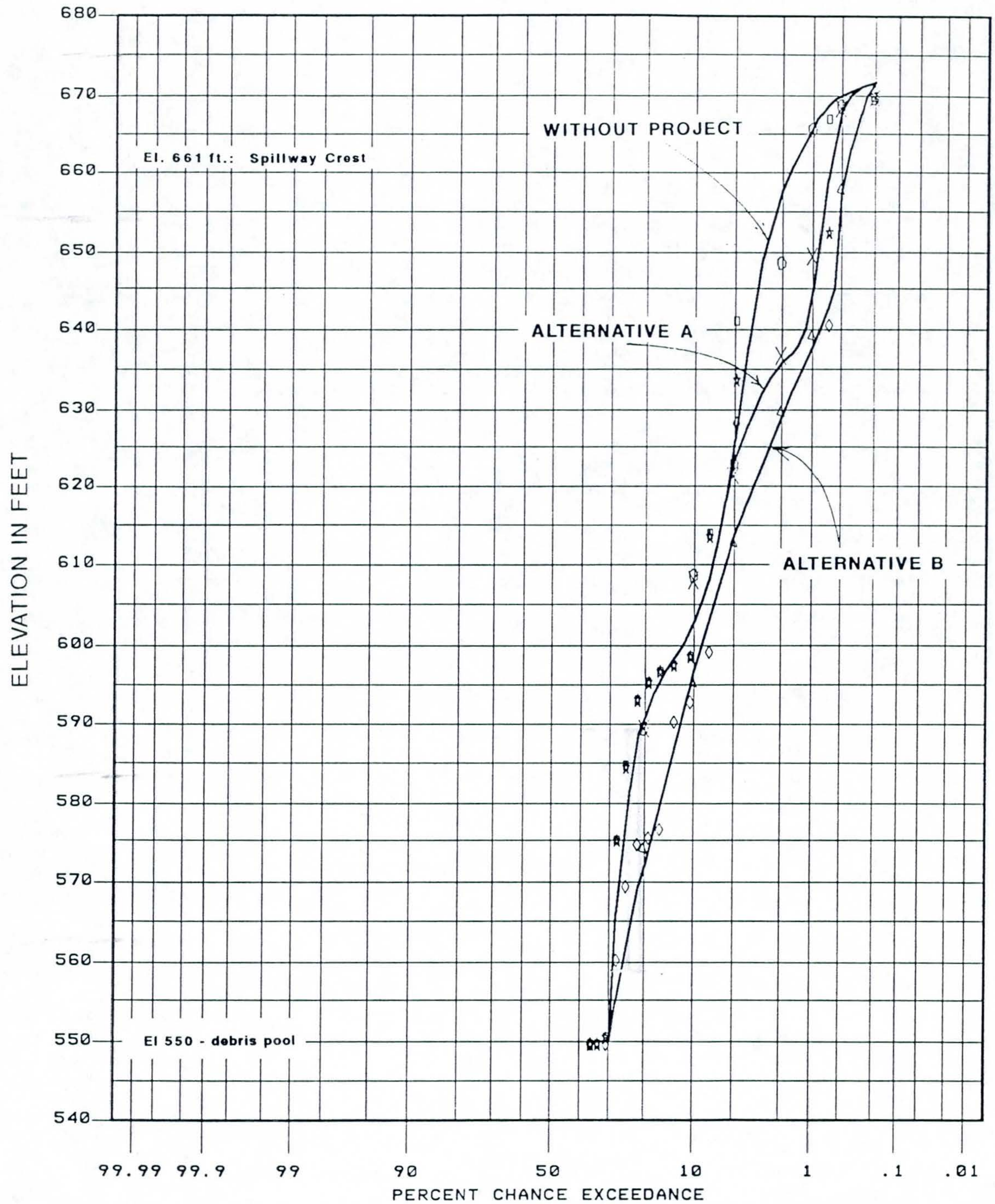
OBSERVED INFLOW HYDROGRAPH ROUTINGS:
- ▯ WITHOUT PROJECT
- ★ ALTERNATIVE A
- ◊ ALTERNATIVE B

BALANCED HYDROGRAPH ROUTINGS:
- O WITHOUT PROJECT
- X ALTERNATIVE A
- ᐃ ALTERNATIVE B

GILA RIVER RECON STUDY

OUTFLOW FREQUENCY CURVE COMPARISON PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



Includes Plan 9 Roosevelt Dam

OBSERVED INFLOW HYDROGRAPH ROUTINGS:

- ▯ WITHOUT PROJECT
- ★ ALTERNATIVE A
- ◊ ALTERNATIVE B

BALANCED HYDROGRAPH ROUTINGS:

- O WITHOUT PROJECT
- X ALTERNATIVE A
- Δ ALTERNATIVE B

GILA RIVER RECON STUDY

ELEVATION FREQUENCY CURVE COMPARISON PAINTED ROCK DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

APPENDIX B

HYDRAULICS

CESPL-ED-HH (335-2-5C) 30 August 1994

MEMORANDUM FOR CESPL-PD-WC, ATTN: Bill Burton

SUBJECT: Hydraulic Support for the Gila River from Gillespie to Yuma, Arizona Area Reconnaissance Study

1. References:

a. ESR No. RH-94-6001, dated 6 December 1993 from CESPL-PD-WC (Study Manager-Bill Burton).

b. Topographic USGS Quadrangle maps of Arizona, dated 1982 (approximate) with a scale of 1"=2000 feet and 10 foot contour intervals. A listing of the quad maps used are: Texas Hill, Growler, Roll, Tacna, Red Bluff Mtn. East, Wellton Mesa, Red Bluff Mtn. West, Wellton, Dome, Lugurta, Laguna Dam, Fortuna, Yuma East, and Yuma West.

c. Photo Mapping of the Gila River, dated 10 January 1994, from Avenue 57E (near Texas Hill) to Avenue 11E (Gila Siphon), by Bookman-Edmonston Engineering Inc.

d. Fax transmission (Levee construction and channel clearing), dated 5 July 1994, to Glenn Mashburn (CESPL-ED-HH) from Bill Burton (CESPL-PD-WC).

e. Typical channel cross section (assumed without project condition) entitled "Theoretical Channel Cross Section" found in the Draft Environmental Assessment for the Welton-Mohawk Gila River Flood Channel Restoration Project, dated 1994 (Enclosure 1).

2. This memorandum documents the hydraulic analysis used in developing reconnaissance level improvements to the "existing" 10,000 cfs levee/channel system so that it will pass two design discharges of 20,000 cubic feet per second (cfs) and 30,000 cfs. Both distinct levee/channel improvements designs were developed for a 56.2 mile reach between Avenue 11E and Avenue 57E.

3. The design analysis incorporated the following:

a. The HEC-2 computer program was used to perform normal depth computations at selected design cross sections.

b. n values - An average channel Manning's Equation coefficient of friction of 0.03, was used for the 300 foot wide cleared area (low flow channel) in the center of the channel. This area of the channel would be maintained and periodically cleared of all vegetation as stipulated in ref. 1.d. Between the levees, a roughness coefficient of 0.07 was applied to the uncleared areas on the left and right sides of the cleared area.

The selection of these coefficients was based on prior flood studies done in the area and field inspection.

c. Channel slope - A relatively constant slope of 0.0005 was used for the entire study reach based on preliminary information provided by one of the potential local project sponsors (Welton-Mohawk Irrigation District).

d. Cross Sections - Based on information contained in ref. 1.a. and 1.e, cross sections that were used in the analysis were of trapezoidal configuration, and incorporated a trapezoidal low flow channel at the center. Specific features of these cross sections included the following: (1) The levees' inside and outside side slopes were 3:1 and 2:1, respectively; (2) The width (distance separating the levees) of each cross section was determined through the use of aerial photographic maps (ref. 1.c.); (3) The levee top width was limited to 20 feet; and (4) The low flow channel was constrained to a constant top width of 200 feet with side slopes of 2:1, and a variable depth figure that was dependent on the amount of fill material that was transferred from the low flow channel and placed in both levees.

e. Levee Reach Length - The river study reach length is 56.2 miles. However, since 15% of the length is escarpment, only 47.8 miles of levee reach needed to be raised to meet the criteria of the two design capacities.

f. Without Project Channel - As stipulated by the Study Manager, the existing channel, for without project conditions would correspond to the trapezoidal channel configuration noted in ref. 1.d. This channel has not yet been constructed, but is expected to be in place at some point in the not-too-distant future. Typically, the "existing" channel would consist of a flat natural bottom, a 7 foot high levee (3:1 inside riprap slope and 2:1 outside slope), and a low flow channel. The channel was assumed to convey a flood discharge of 10,000 cfs with 2.5 feet of freeboard. The interior sides of the levees, were assumed to be faced with riprap 24 inches thick and extend over the full interior slopes of the levees to three feet below ground level. In critical channel bends areas (over an estimated total of 8.6 miles) larger rock was specified at an increased layer thickness of 72 inches. These areas were assumed to also include the placement of a 6 foot toe trench. Finally, the without project designed channel plan includes approximately 20 grade control stabilizers. Each of these structures consists of a rock-filled trench that extends the full width of the channel (levee to levee).

4. Particular details of the 20,000 cfs and 30,000 cfs levee designs are discussed in the following:

a. Specific component features of both levee designs incorporate the following: (1) a requirement of 2.5 feet of freeboard; (2) a larger low flow channel equivalent to the amount of excavated material being added to the existing condition levees to accommodate the higher design flood discharge; and (3) continuation of the riprap protection features described in 3.f. above.

b. At eleven representative locations along the 56.2 mile study reach, cross section information was developed based on criteria stated above. Then a subsequent normal depth analysis was applied through the use of the HEC-2 computer program for determination of the approximate design depths.

5. The results of the balanced cut and fill levee/channel, in terms of levee heights, levee volumes, and depths and volumes of excavation of the low flow channel, are presented in Enclosure 2. Subsequent to our hydraulic analysis, details of our design results were delivered to John Karakawa on 20 July 1994 so that he could develop his cost analysis. Finally all original maps and details of the design are contained in CESPL-ED-HH files.

6. If you have any questions or need further assistance, please contact Theodore Yee at X6993.

Encl

BRIAN TRACY, PE
Chief, Hydraulic Section

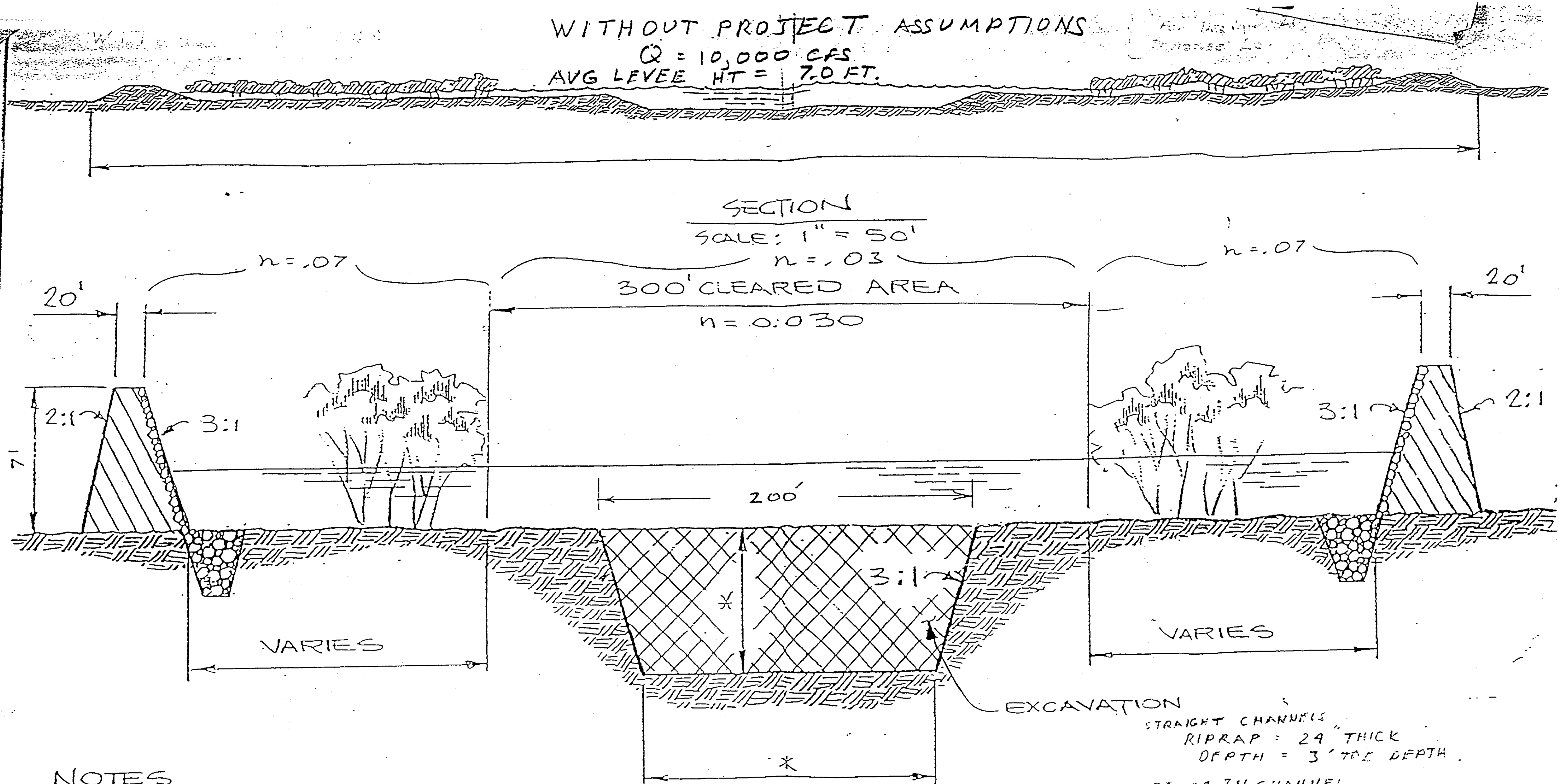
CF (w/encl):

CESPL-ED-HH
CESPL-ED-HE
CESPL-ED-DB
CESPL-ED-WC
CESPL-ED-GD

TRACY
CESPL-ED-HH

MASHBURN
CESPL-ED-HH

YEE
CESPL-ED-HH



NOTES

AVERAGE CHANNEL SLOPE = 0.0005

AVERAGE VELOCITY WITHIN 300' CLEARED AREA = 4.6 FPS

(NOT TO SCALE)

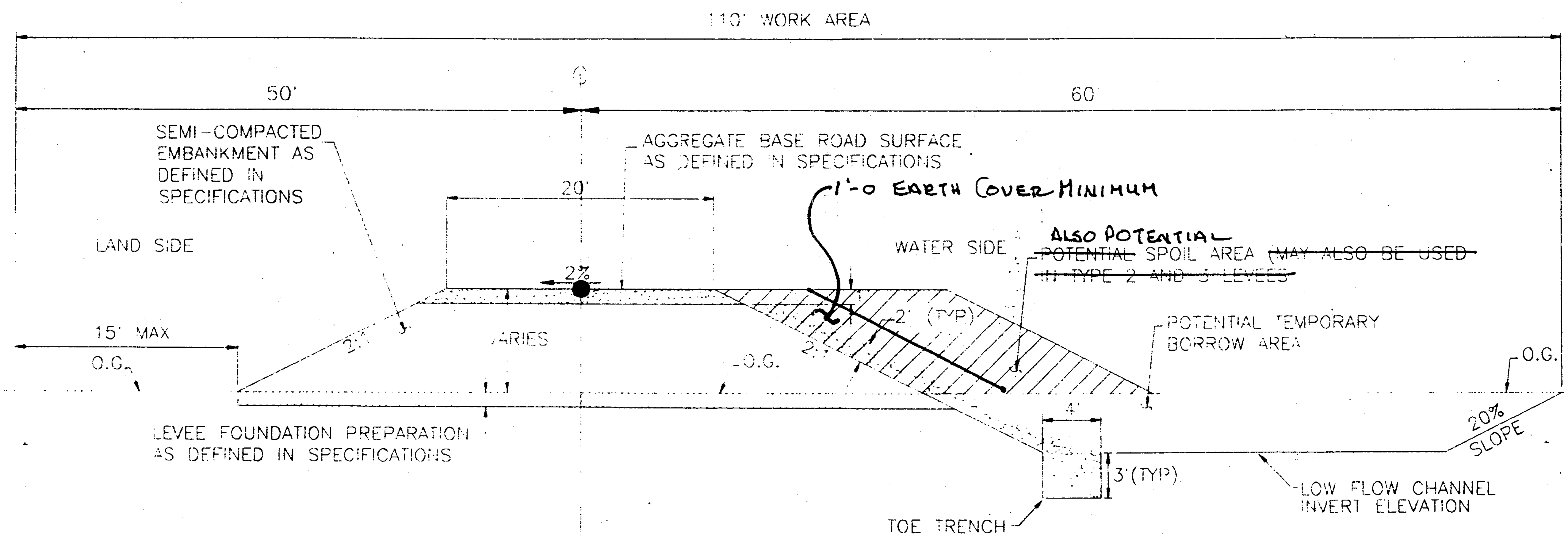
* AS REQUIRED TO PROVIDE EXCAVATED MATERIAL FOR LEVEE CONSTRUCTION

THEORETICAL CHANNEL CROSS SECTION

GILA RIVER FLOOD CHANNEL RESTORATION

RED LINE ALIGNMENT ALTERNATIVE

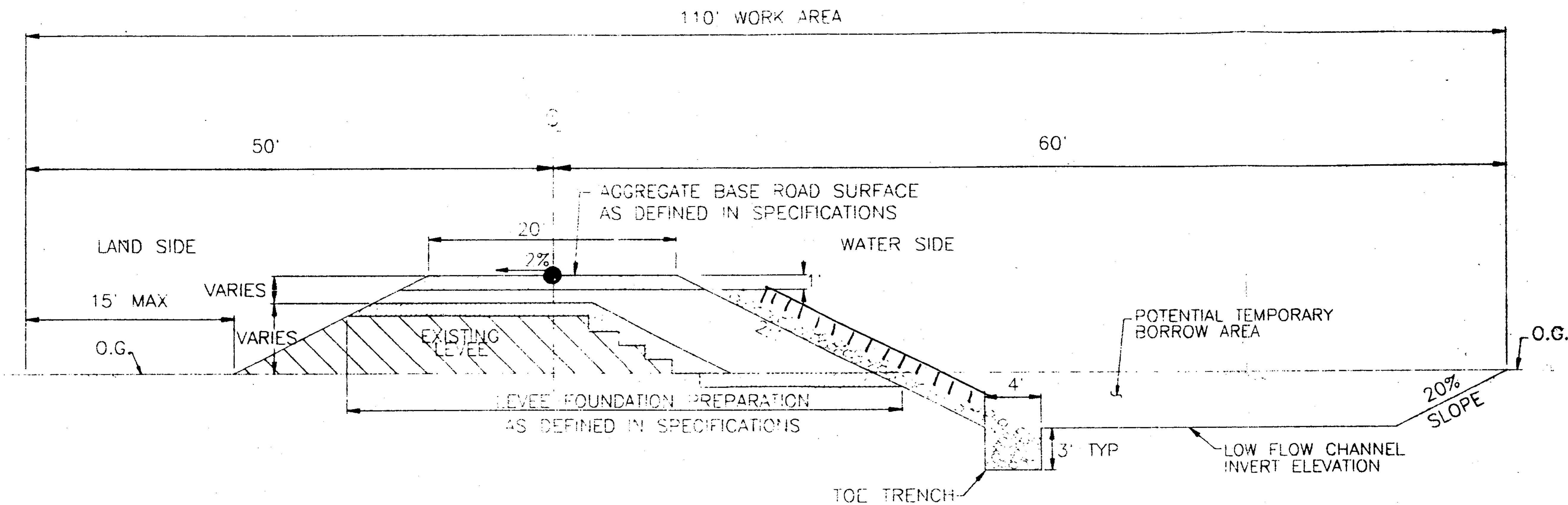
REF:



TYPE 1 -TYPICAL LEVEE SECTION

N.T.S.

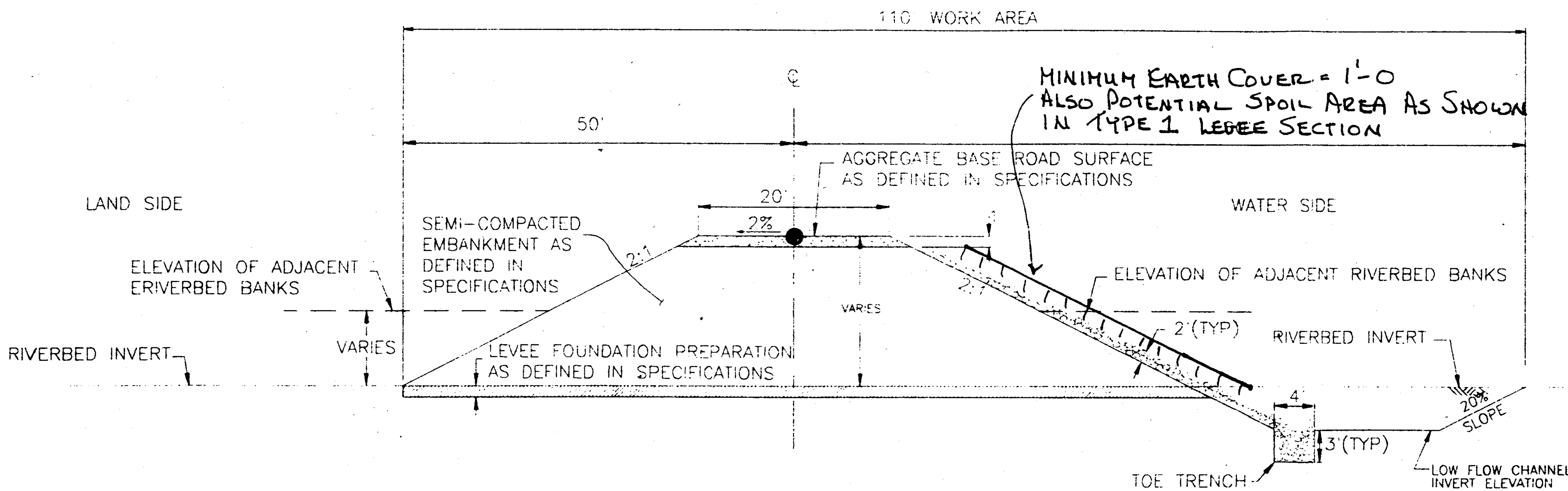
Enclosure 2



TYPE 2 -TYPICAL IMPROVEMENT OF AN EXISTING LEVEE

N.T.S.

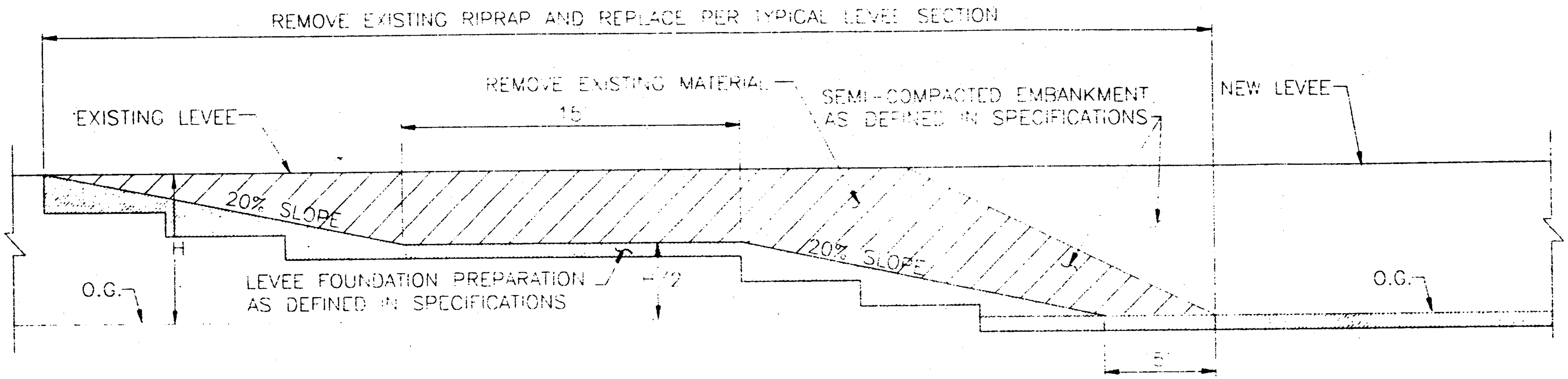
Enclosure 3



TYPE 3 -TYPICAL LEVEE SECTION AT RIVERBED CROSSINGS

N.T.S.

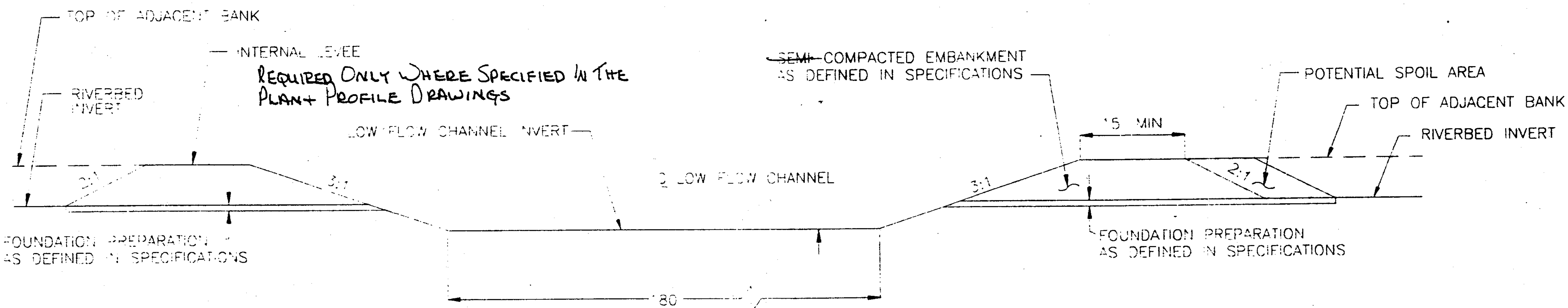
Enclosure 4



TYPE 4 -TYPICAL LEVEE TIE-IN WITH EXISTING LEVEE

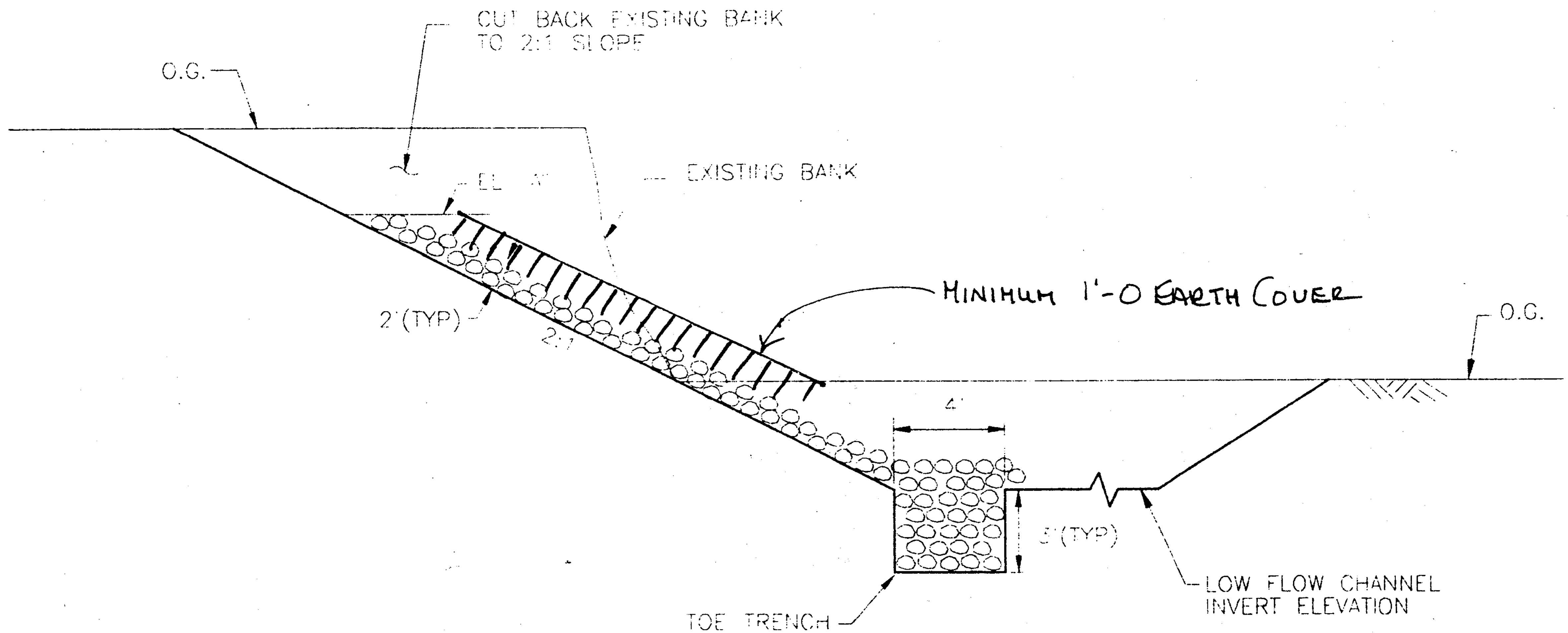
N.T.S.

Enclosure 5



TYPE 5 - LOW FLOW CHANNEL CROSSING OF EXISTING RIVERBED

Enclosure 6



TYPE 6 - EXISTING BANK PROTECTION

Enclosure 7

CESPL-ED-HH (335-2-5C) 4 May 1994

MEMORANDUM FOR CESPL-PD-WE

SUBJECT: Hydraulic Support Channel Capacity Information for the Lower Gila River Study

1. Per oral request by CESPL-PD-WE (Ron Conner) on 15 April 1994, CESPL-ED-HH agreed to provide preliminary channel capacity information for the reach of the Gila River between Gillespie Dam and Texas Hill (Reaches 2 and 3). Our results are summarized in the enclosed Hydraulic Memorandum dated 3 May 1994. Note, the actual location of the memorandum's referenced cross sections are shown on a workmap which was made available to Ron on 3 May 1994.

2. If you have any questions or need further assistance, please contact Ted Yee at X6993.

Encl

Brian Tracy

BRIAN TRACY, PE
Chief, Hydraulic Section

CESPL-ED-HH (335-2-5C) 3 May 1994

MEMORANDUM FOR CESPL-PD-WE

SUBJECT: Hydraulic Support Channel Capacity Information for the Lower Gila River Study from Gillespie Dam to Texas Hill

1. References:

a. Topographic USGS Quadrangle maps of Arizona with a scale of 1"= 2000 feet and 10 foot contour intervals, are listed as follows: Citrus Valley West, 1986; Spring Mtn, 1978; Cotton Center NW, 1973; Cotton Center 1973; Dendora Valley, 1986; Oatman Mountain, 1986; Hyder SE,1982; Aqua Caliente, 1982; Aztec NW, 1982; Horn, 1982; and Texas Hill, 1982.

b. Aerial photos (colored) belonging to the Los Angeles District, with a scale of 1"=3000 feet and dated 9 March 1993.

2. This memorandum documents the analysis used in developing approximate channel capacity information for the reach of the Gila River between Gillespie Dam to Texas Hill (Reaches 2 and 3). The results of the analysis are shown on the attached table.

3. The analysis was based on the following assumptions:

a. The computer program, PCOMP (which is Mannings equation-normal depth based) was used in the channel capacity analysis.

b. n value - An average channel Manning's Equation coefficient of friction value of 0.045 was used for this study. This value was determined by field observations and engineering judgment.

c. Cross Sections - Cross sections were approximated to conform to a rectangular configuration and based on the following assumptions: (1) vertical side slopes; (2) the invert elevations were determined from USGS maps (ref. 1.a.); (3) the estimated depth of flow at each cross section was approximated as the difference between the average invert elevation and the top of adjacent bank elevation; (4) the effective flow width for each section was estimated by summing the flow width segments (brown color on the aerial photos, reference 1.b.) within each cross section (yellow line drawn on the aerials); and (5) the location of the cross sections were initially selected in areas of commercial or agricultural development (ref. 1.b.). The location of these aerially selected cross sections were then transferred to USGS maps (ref. 1.a.) for detailed cross section parameter development.

d. Channel slopes - The information was determined from USGS maps (ref. 1.a).

CESPL-ED-HH
SUBJECT: Hydraulic Support Channel Capacity Information for the Lower Gila River Study from Gillespie Dam to Texas Hill

4. Enclosed is a summary table of channel capacities entitled "Lower Gila River" dated 21 April 1994. References 1.a. and 1.b. located in the Hydraulic Section files.

5. If you have any questions or need further assistance, please contact Theodore Yee at X6993.

Encl

Brian Tracy
BRIAN TRACY, PE
Chief, Hydraulic Section

21, April 1994

LOWER GILA RIVER

Reach: Gellespie Dam to Texas Hill
Subject: Determine Channel Capacities

LOCATION	SECTION NO.	Q CFS (CHANNAL CAPACITY)
0.9 MI. downstream from Gillespie Dam	1	13,200
3.8 MI. downstream from Gillespie Dam	2	9,440
6.6 MI. downstream from Gillespie Dam	3	12,355
9.1 MI. downstream from Gillespie Dam	4	7,140
11.3 MI. downstream from Gillespie Dam	5	12,900
1.9 MI. downstream from Painted Rock Dam	6	10,500
3.8 MI downstream from Painted Rock Dam	7	6,650
6.1 MI. downstream from Painted Rock Dam	8	2,600
1.3 MI upstream of Sentinel Ave.	9	5,200
7.5 MI. downstream of Sentinel Ave.	10	2,700
1.0 MI upstream of Dateline Ave.	11	4,200
Ave. 56	12	1,650

APPENDIX C

TRANSPORTATION AND UTILITY CROSSING INVENTORY

Table of Contents

List of Figures

List of Tables

I. INTRODUCTION

This document is a catalog inventory of transportation and utility crossings of the Gila River, from Gillespie Dam to Yuma, Arizona. The inventory includes estimation of flow capacities, estimation of scour potential, a description of each crossing, a qualitative evaluation of the effects of river flows on each crossing, damages from prior flood events, estimated detour routes and mileage, and relationship to existing flood control improvements and repairs. The inventory was based primarily on the field investigation and available information.

II. DESCRIPTION OF STUDY AREA

2.1 General Description

The study reach extends 166 miles along the Gila River from Gillespie Dam to the Colorado River in Maricopa and Yuma counties, Arizona (See Figure 2.1). Approximately 60 miles and 106 miles of the study reach is located within Maricopa County and Yuma County, respectively.

The study reach can be divided into two distinct subreaches based upon hydrology. The first reach, between Gillespie dam and Painted Rock Dam for approximately 40 miles, the Gila River is an unregulated stream with high peak flow rates. Gillespie Dam is an irrigation diversion dam with little flood-control capacity. This dam was breached in the 1993 flood and has not been repaired. The second reach, downstream of Painted Rock Dam, is regulated by controlled releases from Painted Rock Dam. Painted Rock Dam is a flood-control dam operated by the Corps of Engineers for the purpose of preventing flood damages in the Wellton-Mohawk agricultural area and in Yuma.

The Gila River in the study reach is naturally a meandering channel occupying a flat floodplain bottomland ranging from approximately 500 to 8,000 feet wide. The channel slope is approximately 0.0005 ft/ft. Most of the reach, particularly the lower 90 miles, have been extensively converted to agriculture. Aside from agriculture and a few scattered structures related to agriculture, there is very little development. Levees have been constructed along the lower 68 miles to protect agricultural land from flooding. These levees are designed for a discharge of 10,000 cfs, and were partially destroyed in the 1993 flood. These damaged levees are currently being reconstructed and redesigned to provide more effective flood protection.

The study reach from Gillespie Dam to Yuma consists of mostly agricultural land with very little urban development. For approximately 45 miles downstream of the Painted Rock Dam, from Avenues 11E to 57E in the County of Yuma, Wellton-Mohawk Irrigation and Drainage District (WMIDD) serves approximately 65,000 acres of agricultural land. Improvements within this reach owned and operated by WMIDD

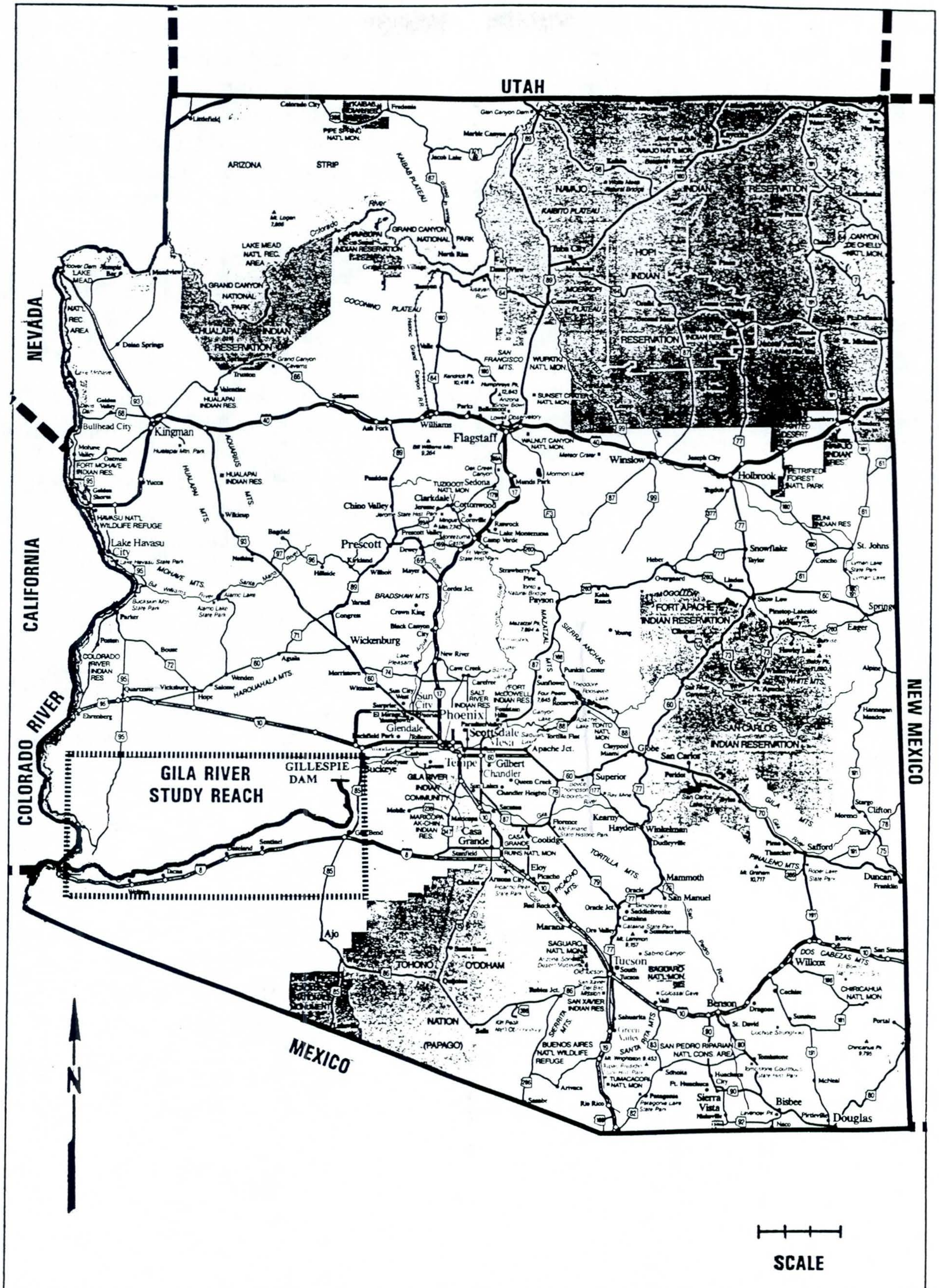


Figure 2.1 Location Map

consist of irrigation canals, siphons, pump stations, overhead transmission lines and flood control structures. Flood control structures implemented by the District include earth levees, training dikes and river bank protection. Bridge crossing in this reach were originally built by WMIDD and turned over to the County of Yuma for maintenance. Further downstream along the Gila River is a large agricultural area served by the North Gila Valley Irrigation District and Yuma Irrigation District. The Gila River joins the Colorado River east of Yuma. The Gila River from the U.S. Highway 95 (upstream of Avenue 11E) to the confluence of the Colorado is managed by the Bureau of Reclamation.

2.2 Flood History

Prior to 1959, large floods on the Gila River were fairly frequent. According to the WMIDD, there were damaging floods in 1862, 1891, 1932 and 1941. Lesser flood flows were experienced in 1921, 1923, 1931, 1932 and 1941. Painted Rock Dam was constructed in 1959 and from then until 1993, all Gila River flows originating upstream of the dam were regulated to a level below that which would cause significant damage. The 1993 flood was of sufficient magnitude and duration to overtop the emergency spillway for the first time. This flood breached Gillespie dam and caused significant damage to crops, levees and road crossings throughout the study reach.

All but one of the bridge crossings of the Gila River were closed during the 1993 flood. Only the Avenue 7E bridge remained open. The Avenue 38E bridge was the only bridge that was completely inundated, but this bridge suffered little damage. The U.S. Highway 95 bridge and the Coast-to-Coast bridge (See Figure 2.2) suffered severe damage due to excessive scour at, and collapse of, the bridge piers. The Coast-to-Coast bridge is a historical bridge that is no longer used for traffic.

2.3 Gila River Hydrology

The Gila River 100-year discharge at Gillespie Dam is 235,000 cfs. Downstream of Painted Rock Dam, the regulated 100-year discharge is reduced to 15,000 cfs. Other return period discharges are listed in Tables 2.1 and 2.2. Tributary flow downstream of Painted Rock dam increases the discharge until the estimated 100-year discharge is 23,000 cfs at Yuma.

An estimated peak flow of 25,845 cfs occurred downstream of the Painted Rock Dam on February 28, 1993. Figure 2.3 illustrates the release rates from Painted Rock Dam from January to June of 1993.

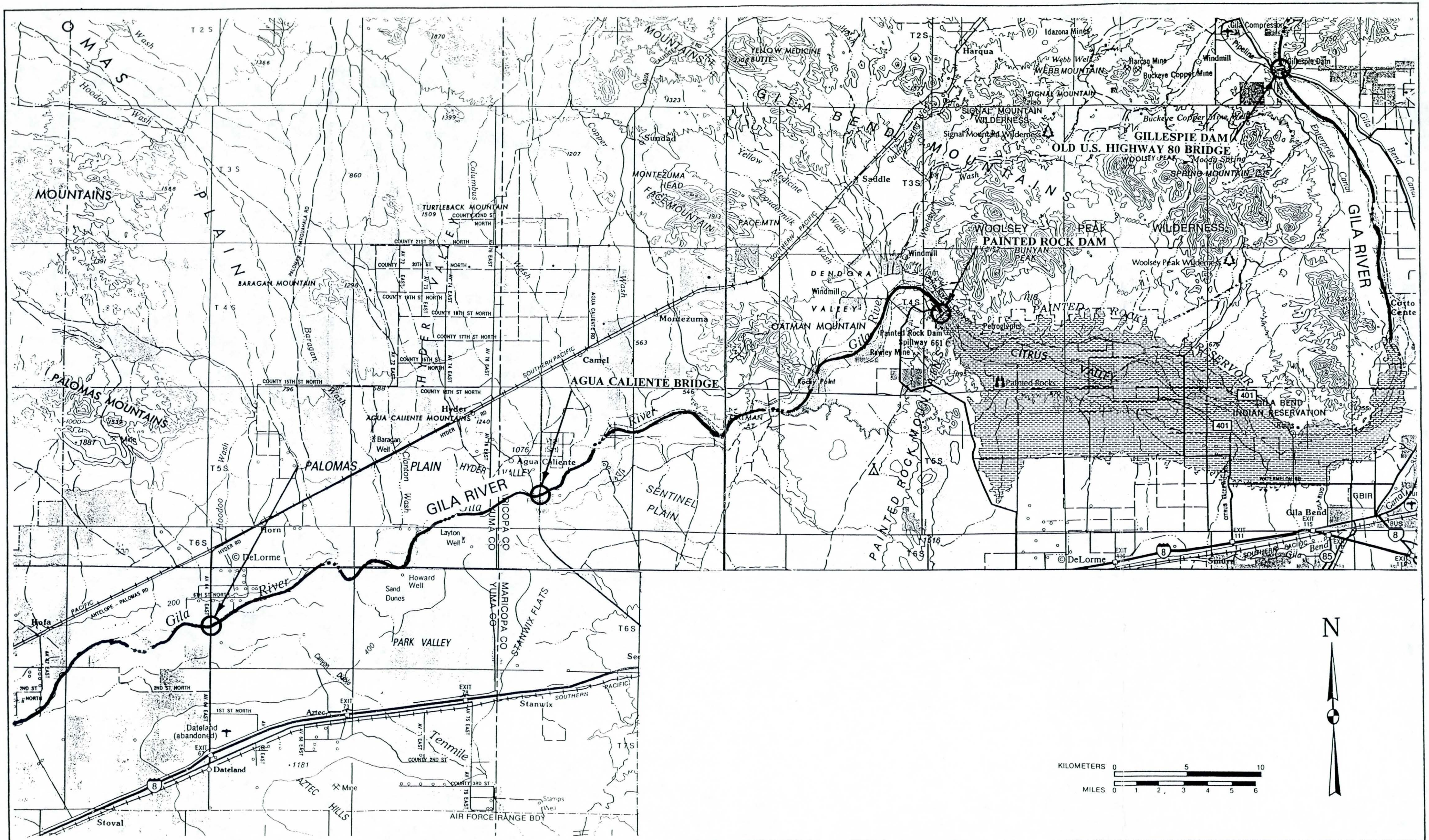


Figure 2.2a Study Reach Vicinity Map

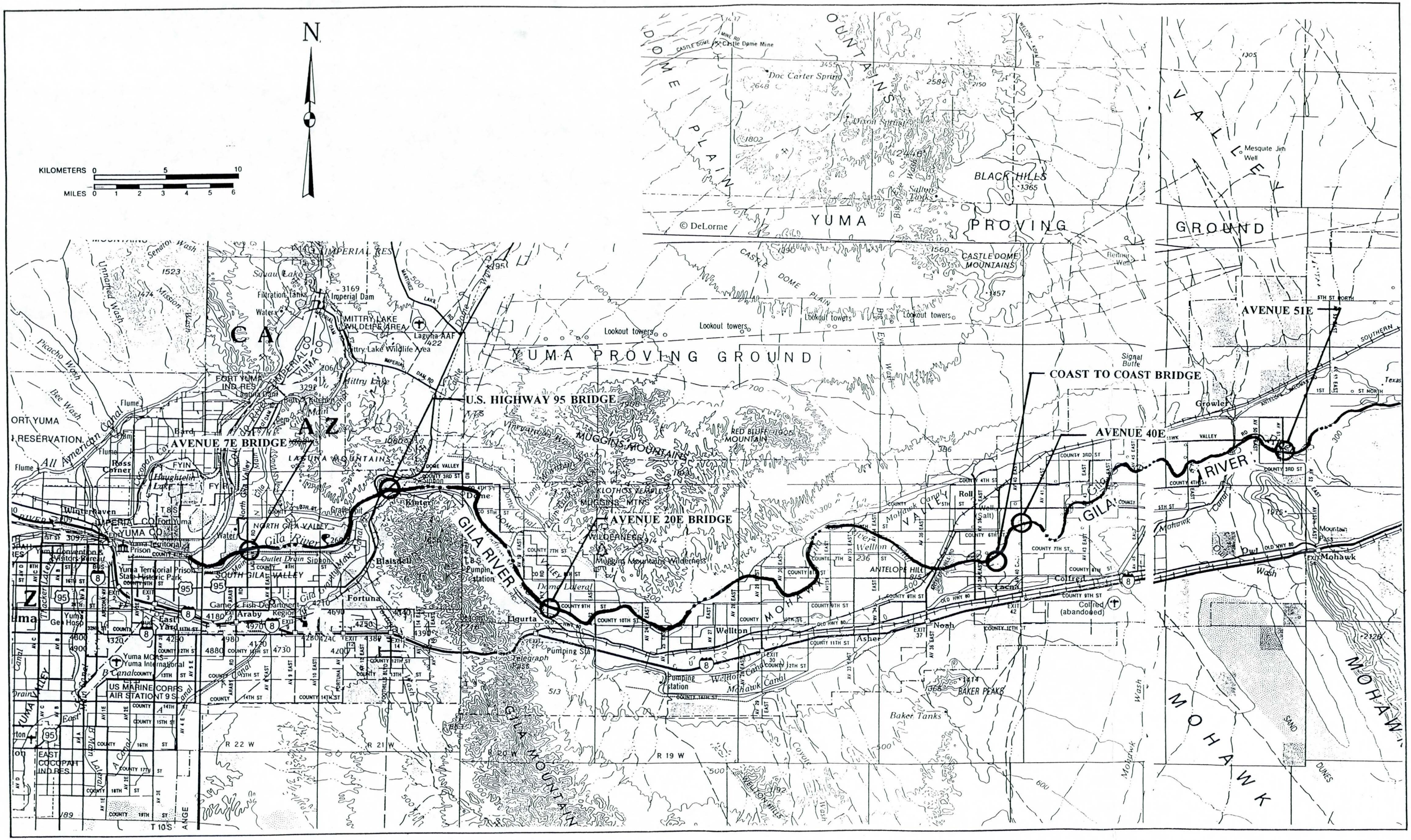


Figure 2.2b Study Reach Vicinity Map

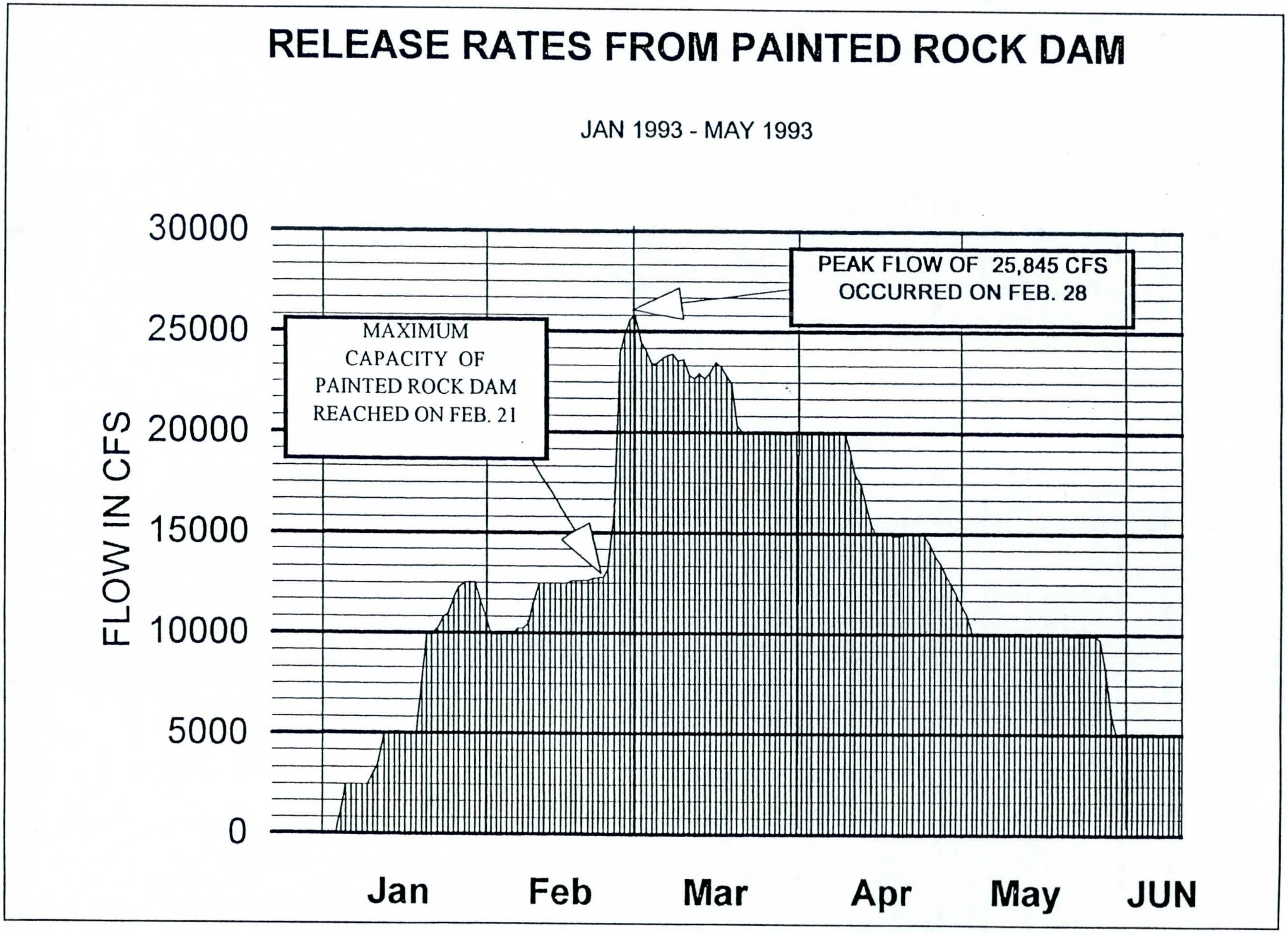


Figure 2.3 Release Rates From Painted Rock Dam

Table 2.1.Summary of Gila River Discharges at Gillespie Dam (Upstream of Painted Rock Dam)	
Return Period Floods	**Discharges**
100-year	179,000 cfs
50-year	140,000 cfs
10-year	53,000 cfs
5-year	24,500 cfs (est)

Table 2.2.Summary of Gila River Discharges Downstream of Painted Rock Dam	
Return Period Floods	**USCOE Estimated Dam Release Discharges**
100-year	15,000 cfs
50-year	10,000 cfs
25-year	10,000 cfs
10-year	10,000 cfs
5-year	5,000 cfs

2.4 River Crossing Summary

A total of 134 river crossings have been identified along the Gila River between Gillespie Dam and the Colorado River. Table 2.3 lists the crossing location, type, and ownership (responsible agency) of each crossing. Crossing locations are shown on in the Appendix.

Table 2.3. List of Crossings From Gillespie Dam to Yuma, Arizona							
XING NO.	DISTANCE TO COLORADO RIVER, IN MILES	LOCATION	FACILITY	RESPONSIBLE AGENCY	USGS QUAD	TOWN RANGE	SECTION NUMBER
1	166.0	1000' u/s of Hwy 80	Gillespie Dam		Spring Mountain	T2S R5W	28
2	165.9	US Hwy 80	Old U.S. Highway 80	County of Maricopa	Spring Mountain	T2S R5W	28
3	165.8	200' d/s of Hwy 80	El Paso Gasline	El Paso Natural Gas	Spring Mountain	T2S R5W	28
4	165.6	1000' d/s of Hwy 80	High Voltage Line	SRP	Spring Mountain	T2S R5W	27,28
5	154.8	Pierpoint Road	Dip Crossing	County of Maricopa	Cotton Center	T4S R4W	8,17
6	151.6	Fornes Road	Dip Crossing	County of Maricopa	Cotton Center	T4S R4W	29,32
7	139.4	363 Avenue	Dip Crossing	County of Maricopa	Citrus Valley East	T4S R6W	35,36
8	135.0	395 Avenue	Dip Crossing	County of Maricopa	Citrus Valley West	T4S R6W	31,32
9	128.0	Painted Rock Dam	Flood Control Dam	US COE	Dendora Valley	T4S R7W	--
10	128.0	PR Dam Road	Dip Crossing	US COE	Dendora Valley	T4S R7W	--
11	125.2	Saddle/Poco Dinero	Dip Crossing	County of Maricopa	Dendora Valley	T4S R8W	14
12	122.0	Hansen Crossing	Hansen Crossing	County of Maricopa	Dendora Valley	T4S R8W	32
13	120.0	Rocky Point Road	Dip Crossing	County of Maricopa	Dendora Valley	T4S R8W	32,5
14	118.1	Oatman Crossing	Oatman Crossing	County of Maricopa	Oatman Mountain	T5S R9W	12
15	106.5	Ag. Caliente/Sentinel	Agua Caliente Bridge	County of Maricopa	Agua Caliente	T5S R10W	28
16	106.5	Sentinel	Sentinel	County of Maricopa	Agua Caliente	T5S R10W	29
17	89.5	Avenue 64 E	Dateland Bridge	County of Maricopa	Horn	T6S R12W	25,30
18	81.2	Avenue 57 E	Power Distribution Line	WMIDD	Texas Hill	T7S R14W	11,12
19	78.2	Avenue 55 E	Dip Crossing	County of Yuma	Texas Hill	T7S R14W	15,16

Table 2.3. List of Crossings - Gillespie Dam to Colorado River (Continued)							
Xing No.	**Distance to Colorado River, In Miles**	**Crossing**	**Type**	**Responsible Agency**	**USGS Quadrangle**	**Township Range**	**Section Number**
20	74.4	Avenue 52 E	Dip Crossing	County of Yuma	Texas Hill	T7S R15W	25,30
21	74.4	Avenue 52 E	San Cristobal Wash	WMIDD	Texas Hill	T7S R15W	25,30
22	73.4	Avenue 51E	Power Distribution Line	WMIDD	Growler	T7S R15W	25,26
23	73.4	Avenue 51E	Unpaved road w/ culverts	County of Yuma	Growler	T7S R15W	25,26
24	72.2	Avenue 50	Drain Pipe undercrossing	WMIDD	Growler	T7S R15W	22,23
25	72.2	Avenue 50	Dip Crossing	County of Yuma	Growler	T7S R15W	22,23
26	70.8	Avenue 49 1/2 E	Drain Pipe Undercrossing	WMIDD	Growler	T7S R15W	22
27	70.8	Avenue 49 1/4 E	Growler Wash Confluence	WMIDD	Growler	T7S R15W	22
28	70.8	Avenue 49E	Mhwk Canal'Norton' siphon	WMIDD	Growler	T7S R15W	27,28
29	70.8	Avenue 49E	Power Distribution Line	WMIDD	Growler	T7S R15W	27,28
30	70.8	Avenue 49E	Dip Crossing	County of Yuma	Growler	T7S R15W	27,28
31	68.7	Ave 47E-47 1/4	Power Distribution Line	WMIDD	Growler	T7S R15W	29
32	68.7	Avenue 47E	Dip Crossing	County of Yuma	Growler	T7S R15W	29,30
33	66.0	Avenue 45E	Tyson Wash Floodway	WMIDD	Growler	T7S R16W	35,36
34	66.0	Avenue 45E	Avenue 45E bridge	County of Yuma	Growler	T7S R16W	35,36
35	65.0	Avenue 44E	Power Transmission Line	WMIDD	Roll	T7S R16 W	34,35
36	65.0	Avenue 44E	Dip Crossing	County of Yuma	Roll	T7SR16W	34,35
37	63.8	Ave 43 3/4 & 4th	Drain Pipe undercrossing	WMIDD	Roll	T7S R16W	3,34
38	63.8	Ave 43 3/4 & 4th	Dip Crossing	County of Yuma	Roll	T7S R16W	3,34

Table 2.3. List of Crossings - Gillespie Dam to Colorado River (Continued)							
Xing No.	Distance to Colorado River, In Miles	Crossing	Type	Responsible Agency	USGS Quadrangle	Township Range	Section Number
39	63.6	Avenue 43 1/2 E	Snyder Floodway	WMIDD	Roll	T7S R16W	3
40	63.1	Avenue 43E	Power Transmission Line	WMIDD	Roll	T7S R16W	3,4
41	63.1	Avenue 43E	Dip Crossing	County of Yuma	Roll	T7S R16W	3,4
42	62.2	Ave 42 1/4 & 5th1/2	Snyder Drain	WMIDD	Roll	T7S R16W	4,5
43	62.0	Ave 42 & 5th 1/2	Drain Pipe undercrossing	WMIDD	Roll	T8S R16W	4,5
44	62.0	Avenue 42 & 5th	Telephone Line	US West	Roll	T8S R16W	4,5
45	62.0	Avenue 42 & 5th	Power Distribution Line	WMIDD	Roll	T8S R16W	4,5
46	62.0	Avenue 42 & 5th	Dip Crossing	County of Yuma	Roll	T8S R16W	4,5
47	61.8	Avenue 41 3/4 E	Colfred Floodway	WMIDD	Tacna	T8S R16W	17
48	51.5	Avenue 40E	Telephone Line	US West	Tacna	T8S R16W	7,12
49	51.5	Avenue 40E	Power Distribution Line	WMIDD	Tacna	T8S R16W	7,12
50	51.5	Avenue 40E	Avenue 40E bridge	County of Yuma	Tacna	T8S R16W	7,12
51	50.6	Avenue 39 1/2 E	Dip Crossing	County of Yuma	Tacna	T8S R17W	13
52	50.4	Ave 39 1/4 E & 6th	Davidson Drain Crossing	WMIDD	Tacna	T8S R17W	13
53	50.2	Ave 39 1/2 E & 7th	Quigley Pond	Game & Fish	Tacna	T8S R17W	14,23
54	48.1	Avenue 38E	Power Distribution Line	WMIDD	Tacna	T8S R17W	22,23
55	48.1	Avenue 38E	Avenue 38E bridge	County of Yuma	Wellton Mesa	T8S R17W	22,23
56	46.9	Avenue 36 5/8 E	Coast to Coast Bridge	See Remarks	Wellton Mesa	T8S R17W	21
57	46.7	Avenue 36 1/2 E	Dip Crossing	County of Yuma	Wellton Mesa	T8S R17W	21

Table 2.3. List of Crossings - Gillespie Dam to Colorado River (Continued)							
Xing No.	**Distance to Colorado River, In Miles**	**Crossing**	**Type**	**Responsible Agency**	**USGS Quadrangle**	**Township Range**	**Section Number**
58	46.7	Avenue 36 1/2 E	Telephone Cable	US West	Wellton Mesa	T8S R17W	21
59	46.7	Avenue 36 1/2 E	High Pressure Gas Line	EL Paso Natural Gas	Wellton Mesa	T8S R17W	21
60	46.7	Avenue 36 1/2 E	Fiber Optics Cable	MCI	Wellton Mesa	T8S R17W	21
61	46.7	Avenue 36 1/2 E	Petroleum Lines	SFPPL	Wellton Mesa	T8S R17W	21
62	46.7	Avenue 36 1/2 E	Signal Line	SPTC	Wellton Mesa	T8S R17W	21
63	46.7	Avenue 36 1/2 E	SPRR bridge	SPRR	Wellton Mesa	T8S R17W	21
64	46.2	Avenue 36E	Power Transmission Line	WMIDD	Wellton Mesa	T8S R17W	20,21
65	43.6	Avenue 34	WM Main Conv. Channel	WMIDD	Wellton Mesa	T8S R18W	13,18
66	43.6	Avenue 34	Power Distribution Line	WMIDD	Wellton Mesa	T8S R18W	13,18
67	43.6	Avenue 34	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	13,18
68	42.9	Ave 33 1/4 & 6th	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	12,13
69	42.9	Ave 33 1/4 & 6th	Telephone Line	US West	Wellton Mesa	T8S R18W	12,13
70	42.7	Ave 33 & 6 1/2	Power Distribution Line	WMIDD	Wellton Mesa	T8SR18W	12,13
71	42.6	Ave 33 1/2	Radium Hot Spr. Fldwy	WMIDD	Wellton Mesa	T8S R18W	11,12
72	42.5	Avenue 33	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	11,12
73	40.7	Avenue 31 & 6 1/2	Wellton Dike No. 2 Floodway	WMIDD	Wellton Mesa	T8S R18W	15,16
74	40.7	Ave 31 & 6 1/2	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	15,16
75	40.7	Ave 31 & 6 1/2	Wellton Canal Siphon	WMIDD	Wellton Mesa	T8S R18W	15,16
76	40.2	Ave 31 1/2 & 7 1/2	Drain Pipe undercrossing	WMIDD	Wellton Mesa	T8S R18W	16

Table 2.3. List of Crossings - Gillespie Dam to Colorado River (Continued)							
Xing No.	**Distance to Colorado River, In Miles**	**Crossing**	**Type**	**Responsible Agency**	**USGS Quadrangle**	**Township Range**	**Section Number**
77	32.5	Ave 31 & 8th	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	22,27
78	32.0	Ave 31 & 8 1/2	Drain Pipe undercrossing	WMIDD	Wellton Mesa	T8S R18W	21,22
79	30.0	Avenue 30E	Drain Pipe undercrossing	WMIDD	Wellton Mesa	T8S R18W	28
80	30.0	Avenue 30E	Telephone Line	US West	Wellton Mesa	T8S R18W	28
81	30.0	Avenue 30E	Power Distribution Line	WMIDD	Wellton Mesa	T8S R18W	28
82	30.0	Avenue 30E	Avenue 30E bridge	County of Yuma	Wellton Mesa	T8S R18W	28
83	29.5	Ave 29 1/2 & 8th	Sump Pipeline		Wellton	T8S R18W	20,29
84	29.0	Avenue 29E	Power Distribution Line	WMIDD	Wellton	T8S R18W	20,29
85	29.0	Avenue 29E	Drain Pipe undercrossing	WMIDD	Wellton	T8S R18W	20,29
86	29.0	Avenue 29E	Dip Crossing	County of Yuma	Wellton	T8S R18W	19,20,29,30
87	26.8	Avenue 27 E	Dip Crossing	County of Yuma	Wellton	T8S R19W	25,26
88	26.3	Ave 26 1/2 & 9th	Coyote Wash Confluence	WMIDD	Wellton	T8S R19W	26,35
89	26.3	Ave 26 1/2 & 9th	Gas Line	SWG	Wellton	T8S R19W	26,35
90	25.8	Ave 26 - 26 1/2 E	Power Transmission Line	WMIDD	Wellton	T8S R19W	35
91	25.5	Ave 25 3/4 E & 10th	Power Transmission Line	WMIDD	Wellton	T8S R19W	34,3
92	25.5	Ave 25 3/4 E & 10th	Dip Crossing	County of Yuma	Wellton	T8S R19W	34,3
93	25.3	Avenue 25 1/2 E	WM Main Conv. Channel	WMIDD	Wellton	T9S R19W	3
94	24.8	Avenue 25E	Dip Crossing	County of Yuma	Wellton	T9S R19W	3,4
95	24.3	Ave 24 3/4 E	Grout Wash	WMIDD	Wellton	T9S R19W	4

Table 2.3. List of Crossings - Gillespie Dam to Colorado River (Continued).							
Xing No.	Distance to Colorado River, In Miles	Crossing	Type	Responsible Agency	USGS Quadrangle	Township Range	Section Number
96	24.1	Ave 24 1/2 E & 10th	Power Transmission Line	WMIDD	Wellton	T9S R19W	4,33
97	24.1	Ave 24 1/2 E & 10th	Dip Crossing	County of Yuma	Wellton	T9S R19W	4,33
98	23.3	Avenue 24 E	Power Distribution Line	WMIDD	Wellton	T8S R19W	32,33
99	23.3	Avenue 24 E	Telephone Line	US West	Wellton	T8S R19W	32,33
100	23.3	Avenue 24 E	Dip Crossing	County of Yuma	Wellton	T8S R19W	32,33
101	22.8	Avenue 23 E	WM Conv. Channel Siphon	WMIDD	Wellton	T8S R19W	32
102	22.8	Avenue 23 E	Gomez Wash	WMIDD	Wellton	T8S R19W	32
103	22.4	Avenue 22 1/2 E	Ligurta Wash	WMIDD	Ligurta	T8S R19W	31
104	22.2	Avenue 22E	Dip Crossing	County of Yuma	Ligurta	T8S R20W	31,36
105	21.5	Avenue 21 1/2 E	Red Top Wash	WMIDD	Ligurta	T8S R20W	36
106	20.2	Avenue 20 1/2 E	Unnamed Floodway	WMIDD	Ligurta	T8S R20W	35
107	19.7	Avenue 20E	Avenue 20E bridge	County of Yuma	Ligurta	T8S R20W	34,35
108	18.5	Avenue 18 3/4 E	Floodway Chute over WM	WMIDD	Ligurta	T8S R20W	34
109	19.0	Avenue 19 1/2 E	Dome Canal Siphon	WMIDD	Ligurta	T8S R20W	27,34
110	18.5	Avenue 18 3/4 E	Floodway Chute over WM	WMIDD	Ligurta	T8S R20W	16
111	18.3	Ave 18 3/4 E & 8th	Power Distribution Lines	WMIDD	Ligurta	T8S R20W	21,28
112	18.3	Ave 18 3/4 E & 8th	Dip Crossing	County of Yuma	Ligurta	T8S R20W	21,28
113	18.0	Avenue 18 1/4 E	Dome Floodway	WMIDD	Ligurta	T8S R20W	16
114	17.8	Avenue 18E	Power Transmission Line	WMIDD	Ligurta	T8S R20W	16,17

Table 2.3. List of Crossings - Gillespie Dam to Colorado River (Continued)							
Xing No.	Distance to Colorado River, In Miles	Crossing	Type	Responsible Agency	USGS Quadrangle	Township Range	Section Number
115	14.5	Avenue 17E & 5th	Dip Crossing	County of Yuma	Dome	T8S R20W	7,8
116	14.5	Avenue 17E & 5th	Power Distribution Line	WMIDD	Dome	T8S R20W	7,8
117	14.2	Avenue 17E	Dome Wash	WMIDD	Dome	T8S R20W	5
118	12.8	Avenue 16E	Dip Crossing	County of Yuma	Dome	T8S R20W	6
119	12.8	Avenue 16E	Telephone Line	US West	Dome	T8S R20W	6
120	12.5	Avenue 15 1/2 E	Floodway Chute over WM	WMIDD	Dome	T8SR21W	1
121	12.1	Avenue 15E	Power Distribution Line	WMIDD	Dome	T8S R20W	1
122	11.5	Avenue 14-15 3/4	High Voltage Line	WAPA	Dome	T8S R21W	1
123	11.1	Avenue 14E	Floodway Chute over WM	WMIDD	Laguna Dam	T8S R21W	2
124	11.1	Avenue 14E	WM Main Conv. Channel	WMIDD	Laguna Dam	T8S R21W	2
125	10.8	Avenue 13 3/4 E	Castle Dome Floodway	WMIDD	Laguna Dam	T8S R21W	2,3
126	10.5	Avenue 13 1/2 E	Power Transmission Line	WMIDD	Laguna Dam	T8S R21W	3
127	10.5	Avenue 13 1/2 E	High Voltage Line	WAPA	Laguna Dam	T8S R21W	3
128	10.4	Avenue 13 3/8 E	High Pressure Gas Line	El Paso Gas Line	Laguna Dam	T8S R21W	3
129	9.8	Avenue 12 1/4	U.S. Highway 95	ADOT	Laguna Dam	T8S R21W	4
130	9.1	Avenue 12 1/2 E	McPhaul Bridge	See Remarks	Laguna Dam	T8S R21W	4
131	8.6	Avenue 12E	High Pressure Gas Line	El Paso Natural Gas	Laguna Dam	T8S R21W	8,9
132	7.4	Avenue 11 1/4	Gila Gravity Main Canal	WMIDD	Fortuna	T8SR21W	8,17
133	7.4	Avenue 11 1/4	Ave 11 1/4 Dip Crossing	County of Yuma	Fortuna	T8S R21W	8,17
134	2.0	Avenue 7E	Avenue 7E bridge	County of Yuma	Yuma East	T8S R22W	21,22

III. RIVER CROSSING INVENTORY

3.1 Transportation Crossings

Transportation crossings along the Gila river consists of 37 on-grade (dip) crossings and 10 bridges (See Appendix for location). Bridge crossings are discussed in detail in Section 3.1.1. On-grade (dip) crossings are discussed in detail in Section 3.1.2. Traffic detour for all transportation crossings is described in Section 3.1.3.

3.1.1 Bridges

Flow Capacities

Bridge flow capacities were estimated based on three methods as described below:

1. Because the Gila River floodplain can be up to 8,000 feet wide, it is not practical for most bridges to span the entire floodplain. The U.S. Highway 80 bridge is one exception to this. Most bridges span only the narrow low-flow channel which may only have capacity for 10,000 cfs (a 10 to 50-year flood). Larger flows leave the low-flow channel, travel overland along the floodplain, and flow over the bridge approaches as shown in Figure 3.1, taken from an aerial photograph of the overflow of the approach to the Agua Caliente bridge during the 1993 flood. When the overflows occur the roadway is rendered impassable and is generally closed by the agency with maintenance authority. By correlating the time at which the crossings were closed during the 1993 flood with the discharge released from Painted Rock Dam shown in Figure 2.3, it is possible to estimate the discharge above which the road crossing becomes impassable. This is referred to in this study as the road closure capacity or the bridge approach capacity.

2. The bridges are all designed to pass a certain discharge through the open area beneath the bridge low chord and between the bridge abutments. Normal depth calculations were used to estimate this capacity using information from the bridge plans and river slope and estimated roughness. The maximum-capacity depth of flow was assumed to be at the elevation of the bridge low chord. This is referred to in this study as the bridge design capacity. If design capacity information was available from the design agency, this discharge was used as the design capacity.

3. The channel bed elevation frequently changes as deposition or scour occur during floods. When this occurs, the conveyance capacity of the bridge can be different from the design capacity. Field measurements were made on September 17-21, 1994 to determine the actual height of the open area beneath

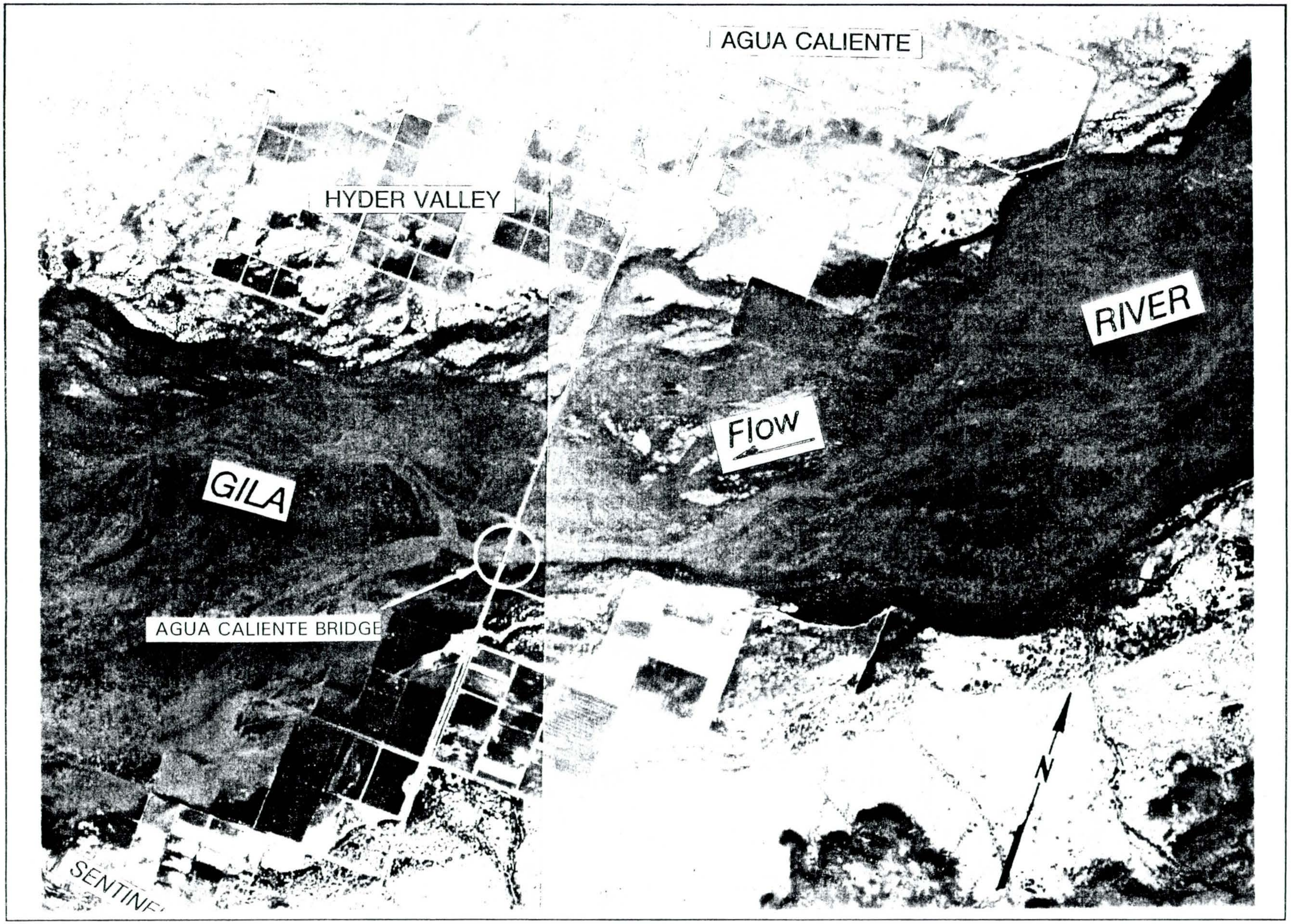


Figure 3.1 Aerial Photograph of Agua Caliente Bridge Taken on March 6, 1994

each bridge. Actual capacities were then estimated using normal depth methods. This is referred to in this report as the bridge opening capacity.

Table 3.1 provides a summary of the estimated bridge capacities computed by the three methods. The existing bridge capacities listed in Table 3.1 , as defined by Method 1 is consistently larger than the design discharge with the exception of Avenue 40 E and U.S. Highway 95 bridges, both of which were reconstructed after the flood. These are recorded discharges at the time the road was closed to traffic. At these discharges, the bridge approaches becomes impassable.

Maximum bridge capacity was obtained as defined by Method 2. Avenues 45 E, 38 E, 30 E and 20 E bridge maximum capacities are less than the road closure capacities. These bridges have design capacities of only 10,000 cfs. At these maximum discharges, the water surface reaches the bridge low chord.

Table 3.1. Summary of Bridge Capacities.			
Bridge	Design Capacity (cfs)[1]	Existing Capacity[2] (Discharge at Bridge closure) cfs	Maximum Capacity[3] (cfs)
OLD US HWY 80	235,000 cfs	200,000	276,000
AGUA CALIENTE	10,000	12,500	18,200
AVENUE 64 E	10,000	12,500	16,500
AVENUE 45 E	10,000	25,120	15,500
AVENUE 40 E	50,000	Not Available	50,000
AVENUE 38 E	20,000	25,120	7,900
AVENUE 30 E	10,000	21,910	11,800
AVENUE 20 E	10,000	25,530	12,100
US HWY 95	50,000	24,400	26,600
AVENUE 7E	7,000	18,000	18,000

Note:

1. Design capacities were obtained from As-Builts, provided by WMIDD, Bookman-Edmonston or the County.

2. See Method 1 Description (Sec. 3.1.1).

3. See Method 2 Description (Sec. 3.1.1).

Scour and Erosion Potential

Scour

Vertical scour at bridge piers is one of the primary causes of bridge failure. During the 1993 flood, two of the bridges, the U.S. Highway 95 bridge and the Coast-to-Coast bridge, suffered severe damage due primarily to structural failure related to excessive scour of the river bed. The U.S. Highway 80 bridge was also damaged, but not severely. One of the piers on this bridge was cracked, but the bridge remained standing and is still in use.

Although it is not possible without a detailed structural analysis at what point a bridge will fail due to scour, it is possible to obtain an indication of the potential threat by comparing estimated scour depths with pier depth, as is done in Tables 3.2 and 3.3.

Table 3.2 lists the estimated total scour at the bridges based on several return periods and maximum bridge capacity. These computed scour depths do not assume the presence of debris at the piers. The computed scour is the total of the bridge pier scour, bed form scour and low flow thalweg.

The U.S. Highway 80 bridge is the only bridge that appears to be in danger of damage from vertical scour. Assuming that there is no accumulation of debris on the piers, this bridge is in danger on a 50-year flood, which is approximately the return period of the 1993 flood which caused pier cracking.

Debris accumulation on bridge piers can significantly increase the pier scour depth. An additional 4 feet of width (or twice the pier width, whichever was greater), was added to each bridge pier in the scour analysis presented below. However, it was observed in the field trip that debris accumulation can be as much as 25 feet in width at one pier as shown in the photograph taken of the Agua Caliente bridge (top photograph) and Avenue 64 E (bottom photograph) shown in Figure 3.2. Table 3.3 lists the total scour at bridge crossings assuming the presence of debris at the bridge piers.

The U.S. Highway 80 bridge is the only bridge that would be adversely affected by the debris accumulation, which could cause failure at discharges as low as a 5-year flood. Although there have been some recent repairs to prevent this from happening, the repairs do not cover all of the piers. Furthermore, the rupture of Gillespie dam may result in higher debris loads in the future than have occurred in the past.

Figure 3.2 Photographs of Agua Caliente Bridge (top) and Avenue 64 E Bridge (bottom) Showing Debris at the Bridge Piers

Table 3.2. Summary of Total Scour at Bridges (Assuming No Debris at Piers).									
BRIDGE LOCATION	PIER DEPTH (ft)	100-YEAR FLOOD		5O-YEAR FLOOD		5-YEAR FLOOD		MAXIMUM DISCHARGE	
		Q (cfs)	TOTAL SCOUR	Q (cfs)	TOTAL SCOUR	Q (cfs)	TOTAL SCOUR	Q (cfs)	TOTAL SCOUR
OLD US HWY 80	20	235,000	21.7	186,000	20.6	48,000	15.5	126,500	22.4
AGUA CALIENTE	91.6	15,000	11.6	10,000	10.8	5,000	9.7	18,200	12.0
AVENUE 64E	31	15,000	8.2	10,000	7.7	5,000	7.0	16,500	8.3
AVENUE 45E	50	15,000	8.2	10,000	7.7	5,000	7.0	15,500	8.2
AVENUE 40E	45	15,000	7.0	10,000	7.1	5,000	6.2	50,000	8.4
AVENUE 38E	37.8	15,000	8.2	10,000	7.7	5,000	7.0	7,900	7.5
AVENUE 30E	55	15,000	8.1	10,000	7.4	5,000	7.0	11,800	7.9
AVENUE 20E	50	15,000	8.1	10,000	7.6	5,000	7.0	12,100	7.8
US HWY 95	80	15,000	8.6	10,000	8.1	5,000	7.5	26,600	9.5
AVENUE 7E	75	15,000	8.0	10,000	7.6	5,000	6.9	18,000	8.2

Note:

1. Bridge and channel information is based on as-built bridge plans.

2. Hydraulics are estimated by normal depth method with manning n=0.03 and slope=0.0006 and 0.0005 for upstream and downstream reaches of Ave 38E, respectively.

3. Total Pier scour was estimated by the relationship recommended in ADWR 1985.
Note that other scour components, such as general and long-term scours, or additional safety factor were not included.
Total scour consists of bridge pier scour, bed form scour and low flow thalweg.

4. Discharges obtained from USCOE September 1994, Gila River Reconnaissance Report (Painted Rock Dam Outflow)

Table 3.3. Summary of Total Scour at Bridges (Assuming Debris Presence at Piers).

BRIDGE LOCATION	PIER DEPTH (ft)	100-YEAR FLOOD		50-10-YEAR FLOOD		5-YEAR FLOOD		MAXIMUM DISCHARGE	
		Q (cfs)	TOTAL SCOUR	Q (cfs)	TOTAL SCOUR	Q (cfs)	TOTAL SCOUR	Q (cfs)	TOTAL SCOUR
OLD US HWY 80	20	235,000	31.7	186,000	29.9	48,000	22.2	126,500	32.4
AGUA CALIENTE	91.6	15,000	15.7	10,000	12.4	5,000	13.0	18,200	16.4
AVENUE 64E	31	15,000	13.2	10,000	12.3	5,000	10.9	16,500	13.4
AVENUE 45E	50	15,000	13.2	10,000	12.3	5,000	10.9	15,500	13.3
AVENUE 40E	45	15,000	11.2	10,000	10.5	5,000	9.5	50,000	14.1
AVENUE 38E	37.8	15,000	13.2	10,000	12.3	5,000	10.9	7,900	11.7
AVENUE 30E	55	15,000	13.2	10,000	12.3	5,000	10.9	11,800	12.6
AVENUE 20E	50	15,000	13.1	10,000	12.2	5,000	10.8	12,100	12.5
US HWY 95	80	15,000	12.8	10,000	11.9	5,000	10.6	26,600	14.2
AVENUE 7E	75	15,000	12.9	10,000	12.0	5,000	10.6	18,000	13.3

Note:

1. Bridge and channel information is based on as-built bridge plans.

2. Hydraulics are estimated by normal depth method with manning n=0.03 and slope=0.0006 and 0.0005 for upstream and downstream reaches of Ave 38E, respectively.

3. Total Pier scour was estimated by the relationship recommended in ADWR 1985.
Note that other scour components, such as general and long-term scours, or additional safety factor were not included.
Total scour consists of bridge pier scour, bed form scour and low flow thalweg.

4. Discharges obtained from USCOE September 1994, Gila River Reconnaissance Report (Painted Rock Dam Outflow)

5. The "with debris" condition assumes debris presence at the bridge piers. Pier + Debris, Pier width + 4 feet or twice the Pier width, whichever is greater was included as a debris factor to estimate total scour at the bridges

3.1.2 On-Grade (Dip) Crossings

On-grade dip crossings are generally unpaved roads. Many have circular pipe culverts underneath for the passage of low flows. The pipe culverts are sometimes located in fill, as is the case with the Poco Dinero crossing shown in Figure 3.3, or along one bank of the river as shown in Figure 3.4 for the Avenue 49E (top photograph) and Avenue 31E (bottom photograph) dip crossings. In most cases where the culvert is located along the channel bank, the roadway surface in the middle of the river bed is below the culvert soffit (See Figure 3.4). This reduces the culvert capacity. Table 3.4 provides a list of dip crossing information. Majority of the dip crossings are owned and maintained by Maricopa or Yuma Counties.

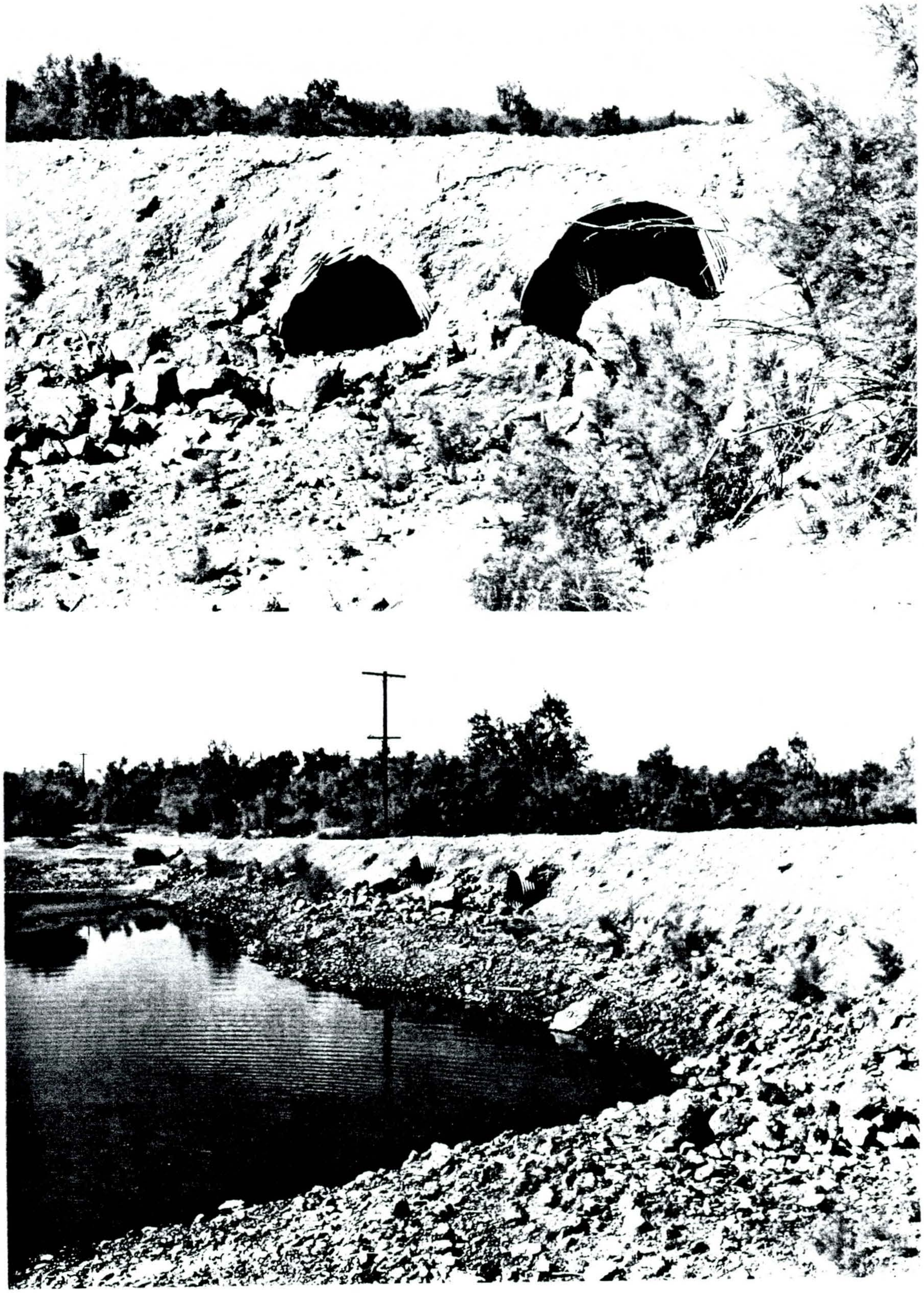


Figure 3.3 Photographs of Poco Dinero Low Flow On Grade (Dip) Crossing

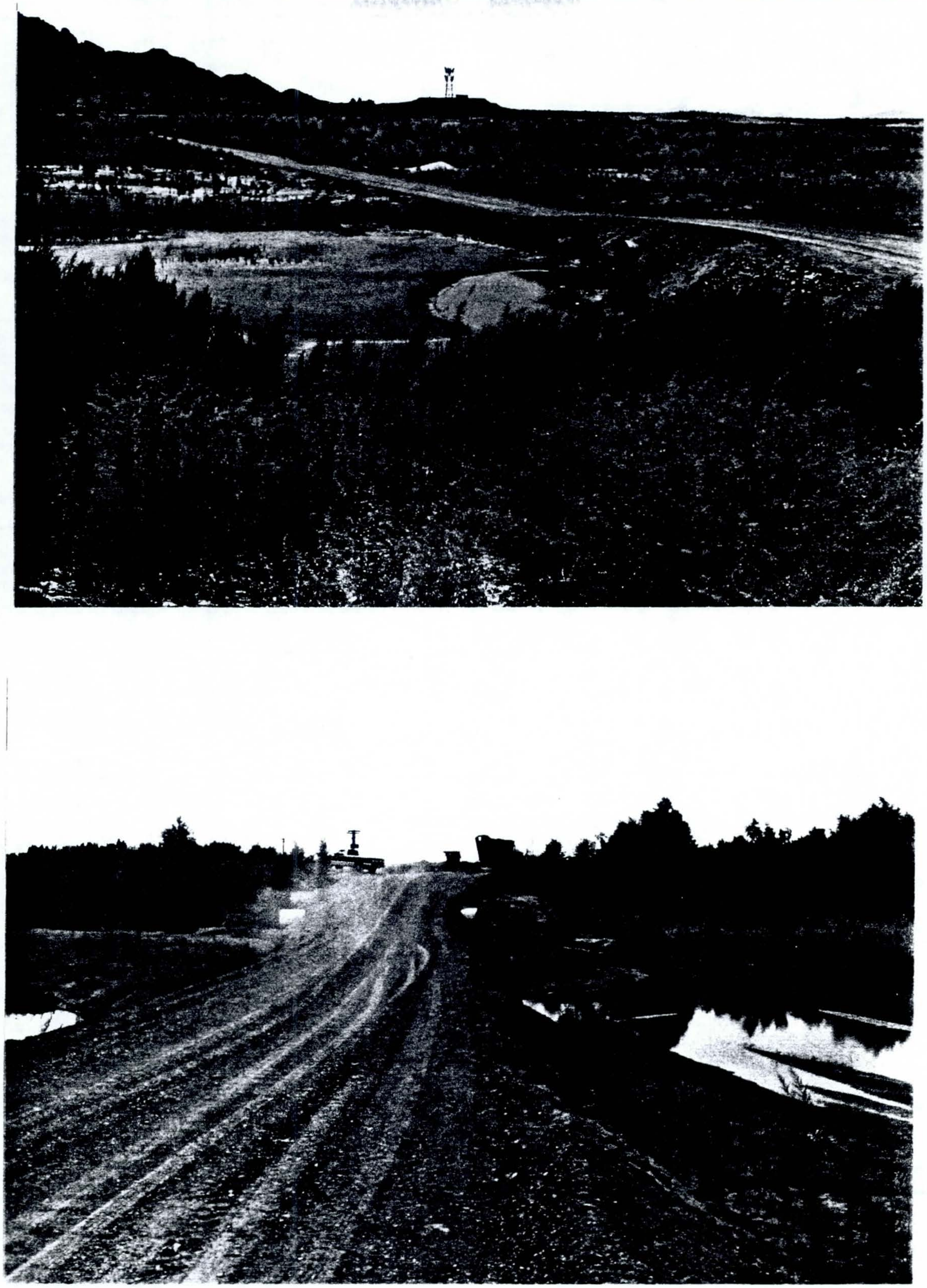


Figure 3.4 Photographs of Avenue 49 E and Avenue 31 E Dip crossings

Table 3.4. List of Dip Crossings - Gillespie Dam to Yuma, Arizona.					
Crossing Number	Approximate Distance from Colorado River (In Miles)	Location	Culvert Size	Culvert Capacity	Crossing Condition
5	154.8	Pierpoint Road	Unknown	Unknown	Operable
6	151.6	Fornes Road	Unknown	Unknown	Abandoned
7	139.4	363 Avenue	Unknown	Unknown	Abandoned
8	135.0	395 Avenue	Unknown	Unknown	Abandoned
10	128.0	PR Dam Road	Unknown	Unknown	Closed
11	125.2	Saddle/Poco Dinero	4, 4-ft Pipe	520 cfs	Operable
12	122.0	Hansen Crossing	None	None	Unknown
13	120.0	Rocky Point Road	4, 4-ft Pipe	520 cfs	Operable
14	118.1	Oatman Crossing	Unknown	Unknown	Operable
19	78.2	Avenue 55 E	None	None	Washed out
20	74.4	Avenue 52 E	None	None	Washed out
23	73.4	Avenue 51E	8, 14-ft pipes	8,000 cfs	Operable
25	72.2	Avenue 50	None	None	Operable
30	70.8	Avenue 49E	1, 7-ft pipe	90 cfs	Operable
32	68.7	Avenue 47E	1, 7-ft pipe	90 cfs	Operable
36	65.0	Avenue 44E	None	None	Operable
38	63.8	Ave 43 3/4 & 4th	1, 5-ft pipe	110 cfs	Operable
41	63.1	Avenue 43E	None	None	Washed out
46	62.0	Avenue 42 & 5th	1, 5-ft Pipe	110 cfs	Washed out
51	50.6	Avenue 39 1/2 E	None	None	Operable
57	46.7	Avenue 36 1/2 E	1, 5-ft pipe	160 cfs	Operable
67	43.6	Avenue 34	1, 5-ft Pipe	110 cfs	Washed out
68	42.9	Ave 33 1/4 & 6th	1, 5-ft Pipe	110 cfs	Washed out
72	42.5	Avenue 33	None	None	Washed out
74	40.7	Ave 31 & 6 1/2	1, 2-ft Pipe	22 cfs	Washed out
77	32.5	Ave 31 & 8th	1, 5-ft Pipe	50 cfs	Operable
86	29.0	Avenue 29E	1, 7-ft Pipe	260 cfs	Operable
87	26.8	Avenue 27 E	1, 2-ft Pipe	22 cfs	Operable

Table 3.4. Summary of Dip Crossings - Gillespie Dam to Colorado River (Continued)					
Crossing Number	Approximate Distance from Colorado River, In Miles	Location	Culvert Size	Culvert Capacity	Crossing Condition
92	25.5	Ave 25 3/4 E & 10th	1, 5-ft Pipe	110 cfs	Washed out
94	24.8	Avenue 25E	1, 5-ft Pipe	110 cfs	Washed out
97	24.1	Ave 24 1/2 E & 10th	1, 5-ft Pipe	110 cfs	Washed out
100	23.3	Avenue 24 E	1, 5-ft Pipe	110 cfs	Operable
104	22.2	Avenue 22E	1, 7-ft Pipe	260 cfs	Operable
112	18.3	Ave 18 3/4 E & 8th	1, 7-ft Pipe	260 cfs	Operable
115	14.5	Avenue 17E & 5th	None	None	Operable
118	12.8	Avenue 16E	1, 5-ft Pipe	190 cfs	Operable
133	7.4	Avenue 11 1/4	2, 3-ft Pipe	60 cfs	Operable

3.1.3 Traffic and Detour Analysis

As roads are shut down by flooding, the traffic that the roads normally carry is interrupted or is forced to take detour routes. Dip crossings with no culverts will be affected first, then dip crossings with culverts, then bridges. Table 3.5 provides a probable scenario of what would occur to road crossings on the lower Gila River below the Painted Rock Dam with increasing discharge released from Painted Rock Dam.

Table 3.5.Summary of Probable Traffic Interruptions with Increasing Discharge from Painted Rock Dam.					
Discharge from Painted Rock Dam	**Impassable Road Crossings[1]**	**Total Traffic Affected[2] Trips**	**Total Detour Miles**	**Detour Cost Per Day[3]**	**Description**
< 50 cfs	Painted Rock Dam Road	100	11	578	A total of 13 dip crossings have capacities less than 50 cfs. Detour route and mileage are based on the nearest dip crossing or bridge with capacities greater than 50 cfs. The dip crossing detour routes range from 4 miles for Avenue 44 E crossing to 40 miles for Hansen crossing. The daily detour cost ranges from $210 to $2,100 per crossing. The total delay cost for these 13 dip crossings is estimated at $7,900 per day.
	Hansen Crossing	100	40	2,100	
	Oatman Crossing	100	36	1,890	
	Avenue 55E	100	4	210	
	Avenue 52E	100	4	210	
	Avenue 50E	100	4	210	
	Avenue 44E	100	4	210	
	Avenue 43E	100	6	315	
	Avenue 39 1/2 E	100	12	630	
	Avenue 33E	100	3	158	
	Avenue 31E & 6 1/2	100	5	263	
	Avenue 27 E	100	6	315	
	Avenue 17 E	100	15	788	
Total	13 Crossings	1,300 trips	150 Miles	$7,900	
50 to 100 cfs	Avenue 49 E	100	14	735	A total of 17 crossings have capacities less than 100 cfs. The total delay cost for these 17 crossings is approximately $10,100 for 192 detour miles.
	Avenue 47 E	100	8	420	
	Avenue 31E & 8th	100	6	315	
	Avenue 11 1/4 E	100	14	735	
Total	17 Crossings	1,700 trips	192 Miles	$10,100	
100 to 200 cfs	Avenue 43 3/4 & 4th	100	4	210	A total of 27 crossings have capacities less than 200 cfs. The total delay cost for these 27 crossings is approximately $16,300 for a total of over 300 detour miles
	Avenue 42E & 5th	100	16	840	
	Avenue 36 1/2 E	100	15	788	
	Avenue 34 E	100	18	945	
	Avenue 33 1/4 &6th	100	19	998	
	Avenue 25 3/4 & 10th	100	8	420	
	Avenue 25 E	100	9	473	
	Avenue 24 1/2 &10th	100	8	420	
	Avenue 24 E	100	6	315	
	Avenue 16 E	100	15	788	
Total	27 crossings	2,800 trips	310 Miles	$16,300	

Table 3.5. Summary of Probable Traffic Interruptions with Increasing Discharge at Painted Rock Dam (Continued)

Discharge from Painted Rock Dam	Impassable Road Crossings[1]	Total Traffic Affected[2]	Total Detour Miles[3]	Detour Cost Per Day[3]	Description
200 to 500 cfs	Avenue 29 E	100	5	263	70 percent of the crossings have capacities less than 500 cfs. Total delay cost is estimated at approximately $17,300.
	Avenue 22 E	100	6	315	
	Avenue 18 3/4 E & 8th	100	9	473	
Total	30 crossings	3,100 trips	330 Miles	$17,300	
500 to 3000 cfs	Saddle/Poco Dinero	100	80	4,200	Vehicles using Poco Dinero Crossing would have to drive to Agua Caliente to cross the river. Detour route is as much as 80 miles.
	Rocky Point	100	40	2,100	
	Avenue 51 E	100	24	1,260	
Total	33 Crossings	3,500 trips	474 Miles	$24,900	
3,000 to 20,000	Agua Caliente	236	96	11,894	Residents from the community of Agua Caliente will have detour routes as much as 96 miles. Avenue 40 E bridge will be the only way to access the Interstate 8.
	Avenue 64 E	695	56	20,433	
	Avenue 7 E	4,558	14	33,501	
Total	36 Crossings	8,989 trips	640 Miles	$90,700	
20,000 to <50000 cfs	Avenue 45 E	900 (est)	23	10,868	A total of 40 crossings have capacities less than 50,000 cfs. A total delay cost is estimated at $150,600 per day.
	Avenue 38 E	900 (est)	11	5,198	
	Avenue 30 E	900 (est)	30	14,175	
	Avenue 20 E	1,660	34	29,631	
Total	40 Crossings	13,349 trips	738 Miles	$150,600	
>=50,000 cfs	U.S. Highway 80	326	38	6,504	There are only three bridge crossings with capacities at or greater than 50,000 cfs. Should these bridges fail, access north and south of the river would be require detour routes greater than 100 miles.
	Avenue 40 E	893	76	35,631	
	U.S. Highway 95	6,100	84	269,010	
Total	43 crossing	20,668 trips	936 Miles	$461,700	

1 It is assumed that any discharge above 10 cfs flowing outside of a culvert in a dip crossing renders the dip crossing impassable.

2 It is assumed that dip crossings with no counts available have 100 ADTs on the average.

3 It is assumed that detour traffic flows at a rate of 40 miles per hour on the average, that each vehicle is occupied by one person, and that detour travel time is valued at $7.00/hour/person. Vehicle mileage costs are also included at $0.35/mile.

3.2 Utility Crossings

Table 3.6 list the utility crossings from Gillespie Dam to the Colorado River. Utility crossings consists primarily of power distribution lines, telephone lines, high voltage power, and high pressure gas lines. The location of these utility crossings are shown in the Appendix. Power distribution lines along the dip crossings were rebuilt after the floods of 1993. During the floods of 1993, a gasline explosion occurred just downstream of the U.S. Highway 80 bridge. This gas line has been repaired and reburied 35 feet below the channel invert.

Table 3.6. List of Utility Crossings - Gillespie Dam to Colorado River										
XING NO.	MILES FR COLORADO RIVER	LOCATION	FACILITY	RESPONSIBLE AGENCY	USGS QUAD	TOWN RANGE	SECTION NUMBER	FACILITY SIZE	CAPACITY	PRESENT CONDITION
3	165.8	200' d/s of Hwy 80	El Paso Gasline	El Paso Natural Gas	Spring Mountain	T2SR5W	28			Operable
4	165.6	1000' d/s of Hwy 80	High Voltage Line	SRP	Spring Mountain	T2SR5W	27,28			Operable
18	81.2	Avenue 57 E	Power Distribution Line	WMIDD	Texas Hill	T7SR14W	11,12	2-WIRE	12 1/2 KV	washed out
22	73.4	Avenue 51E	Power Distribution Line	WMIDD	Growler	T7SR15W	25,26	4-wire	12 1/2 kv	Operable
29	70.8	Avenue 49E	Power Distribution Line	WMIDD	Growler	T7SR15W	27,28	4-wire	12 1/2 kv	Operable
31	68.7	Ave 47E-47 1/4	Power Distribution Line	WMIDD	Growler	T7SR15W	29	4-wire	12 1/2 kv	Operable
35	65.0	Avenue 44E	Power Transmission Line	WMIDD	Roll	T7S R16 W	34,35	8-wire	34 1/2 kv	Operable
40	63.1	Avenue 43E	Power Transmission Line	WMIDD	Roll	T7S R16W	3,4		34 1/2 kv	Operable
41	63.1	Avenue 43E	Dip Crossing	County of Yuma	Roll	T7S R16W	3,4	No pipe		Washed out
44	62.0	Avenue 42 & 5th	Telephone Line	US West	Tacna	T8S R16W	4,5			
45	62.0	Avenue 42 & 5th	Power Distribution Line	WMIDD	Tacna	T8S R16W	4,5		12 1/2 kv	
49	51.5	Avenue 40E	Power Distribution Line	WMIDD	Tacna	T8S R16W	7,12	4-wire	12 1/2 kv	Operable
58	46.7	Avenue 36 1/2 E	Telephone Cable	US West	Wellton Mesa	T8S R17W	21			Unknown
59	46.7	Avenue 36 1/2 E	High Pressure Gas Line	EL Paso Natural Gas	Wellton Mesa	T8S R17W	21			Operable
60	46.7	Avenue 36 1/2 E	Fiber Optics Cable	MCI	Wellton Mesa	T8S R17W	21			Operable
61	46.7	Avenue 36 1/2 E	Petroleum Lines	SFPPL	Wellton Mesa	T8S R17W	21	1-20 inches; 1-12 inches		Operable
62	46.7	Avenue 36 1/2 E	Signal Line	SPTC	Wellton Mesa	T8S R17W	21			Operable
64	46.2	Avenue 36E	Power Transmission Line	WMIDD	Wellton Mesa	T8S R17W	20,21		34 1/2 kv	
66	43.6	Avenue 34	Power Distribution Line	WMIDD	Wellton Mesa	T8S R18W	13,18	2-wire	12 1/2 kv	Washed out

Table 3.6. List of Utility Crossings - Gillespie Dam to Colorado River.										
Xing No.	**Miles to Colo.River**	**Location**	**Facility**	**Responsible Agency**	**USGS Quadrangle**	**Township Range**	**Section Number**	**Facility Size**	**Capacity**	**Present Condition**
69	42.9	Ave 33 1/4 & 6th	Telephone Line	US West	Wellton Mesa	T8S R18W	12,13			Washed out
70	42.7	Ave 33 & 6 1/2	Power Distribution Line	WMIDD	Wellton Mesa	T8SR18W	12,13		12 1/2 kv	Washed out
80	30.0	Avenue 30E	Telephone Line	US West	Wellton Mesa	T8S R18W	28			Operable
81	30.0	Avenue 30E	Power Distribution Line	WMIDD	Wellton Mesa	T8S R18W	28	4-wire	12 1/2 kv	Operable
84	29.0	Avenue 29E	Power Distribution Line	WMIDD	Wellton	T8S R18W	20,29		12 1/2 kv	
89	26.3	Ave 26 1/2 & 9th	Gas Line	SWG	Wellton	T8S R19W	26,35	6" steel	330 psi	Unknown
90	25.8	Ave 26 - 26 1/2 E	Power Transmission Line	WMIDD	Wellton	T8S R19W	35		34 1/2 kv	Operable
91	25.5	Ave 25 3/4 E & 10th	Power Transmission Line	WMIDD	Wellton	T8S R19W	34,3		34 1/2 kv	Operable
96	24.1	Ave 24 1/2 E & 10th	Power Transmission Line	WMIDD	Wellton	T9S R19W	4,33		34 1/2-69kv	Operable
98	23.3	Avenue 24 E	Power Distribution Line	WMIDD	Wellton	T8S R19W	32,33	4-wire	12 1/2 kv	Operable
99	23.3	Avenue 24 E	Telephone Line	US West	Wellton	T8S R19W	32,33			Operable
111	18.3	Ave 18 3/4 E & 8th	Power Distribution Lines	WMIDD	Ligurta	T8S R20W	21,28		12 1/2 kv	
114	17.8	Avenue 18E	Power Transmission Line	WMIDD	Ligurta	T8S R20W	16,17		34 1/2 kv	
116	14.5	Avenue 17E & 5th	Power Distribution Line	WMIDD	Dome	T8S R20W	7,8		12 1/2 kv	
119	12.8	Avenue 16E	Telephone Line	US West	Dome	T8S R20W	6			Operable
121	12.1	Avenue 15E	Power Distribution Line	WMIDD	Dome	T8S R20W	1		12 1/2 kv	Operable
122	11.5	Avenue 14-15 3/4	High Voltage Line	WAPA	Dome	T8S R21W	1		161 kv	
126	10.5	Avenue 13 1/2 E	Power Transmission Line	WMIDD	Laguna Dam	T8S R21W	3		34 1/2 kv	
127	10.5	Avenue 13 1/2 E	High Voltage Line	WAPA	Laguna Dam	T8S R21W	3		161 kv	Operable
128	10.4	Avenue 13 3/8 E	High Pressure Gas Line	El Paso Gas Line	Laguna Dam	T8S R21W	3	10 inches	800 psi	Operable
131	8.6	Avenue 12E	High Pressure Gas Line	El Paso Natural Gas	Laguna Dam	T8S R21W	8,9	5 inches		Abandoned

3.3 Irrigation Siphons

Table 3.7 lists irrigation siphons crossing the Gila River downstream of the Painted Rock Dam. These siphons are owned and maintained by WMIDD. Major siphon crossings listed are the Norton siphon near Growler, siphon near Wellton, Dome and the Gravity Main Canal Siphon downstream of Highway 95. The location of these siphon crossings are shown in the Appendix.

Table 3.7. List of Siphon Crossings - Gillespie Dam and Colorado River.									
XING NO.	MILES FR COLORADO RIVER	LOCATION	FACILITY	RESPONSIBLE AGENCY	USGS QUAD	TOWN RANGE	SECTION NUMBER	FACILITY SIZE	PRESENT CONDITION
28	70.8	Avenue 49E	Mhwk Canal'Norton' siphon	WMIDD	Growler	T7SR15W	27,28	8'ft dia. pipe	Operable
65	43.6	Avenue 34	WM Main Conv. Channel	WMIDD	Wellton Mesa	T8S R18W	13,18	5ft dia. pipe	Operable
75	40.7	Ave 31 & 6 1/2	Wellton Canal Siphon	WMIDD	Wellton Mesa	T8S R18W	15,16		Operable
93	25.3	Avenue 25 1/2 E	WM Main Conv. Channel	WMIDD	Wellton	T9S R19W	3		Operable
101	22.8	Avenue 23 E	WM Conv. Channel Siphon	WMIDD	Wellton	T8S R19W	32	2-54 or 60"	Operable
109	19.0	Avenue 19 1/2 E	Dome Canal Siphon	WMIDD	Ligurta	T8S R20W	27,34		Operable
124	11.1	Avenue 14E	WM Main Conv. Channel	WMIDD	Laguna Dam	T8S R21W	2	2-54 or 66" pipes	Operable
132	7.4	Avenue 11 1/4	Gila Gravity Main Canal	WMIDD	Fortuna	T8SR21W	8,17		Operable

3.4 **Description of Crossings**

Old U.S. Highway 80 bridge

The Old U.S. Highway 80 bridge is the first bridge crossing downstream of the Gillespie Dam. It is located approximately 500 feet downstream of the dam. The 70-year old bridge is a steel, high truss structure with tow ten-foot wide lanes. The metal bridge has 9 spans and 12 foot long rectangular piers. The failure of the Gillespie Dam during the 1993 flood scoured the river bed south of the bridge to the base of the bridge footings. Maricopa County closed the bridge for 10 months requiring 36-mile detour for ranchers, farmers, school buses and delivery vehicles. The bridge pier has been repaired. Minor local erosion was observed at the west abutment. The distance from low chord to the channel invert is approximately 19 feet. According to Maricopa County, a channel scour for 250 feet of the 1900 feet bridge caused damage and a crack to one of the piers. Maricopa County's possible solution to the problem is to install a cutoff wall for 1900 feet and repair one pier at a cost of approximately $1.1 million. The bridge is maintained by Arizona Department of Transportation (ADOT).

El Paso Gasline

A 30-inch gasline is located approximately 300 feet downstream of the Old Highway 80 bridge. The gasline is owned by El Paso Natural Gas Company. The pipeline is buried 35 feet below the channel invert (Maricopa County, 1994). The floodplain is very wide at this location (approximately 1000 feet wide).

Overhead Power Lines

A 500kV power line crosses the Gila River approximately 100 feet downstream of the El Paso gasline. One tower is located within the channel bed and another tower located within the floodplain. The tower located within the channel is stabilized by a concrete foundation. The tower is owned and operated by the Salt River Project (SRP).

Gila Bend Canal and Enterprise Canal

Two canals parallels the Gila River at the Old Highway 80 vicinity. The Gila Bend Canal is located along the east side of the Gila River. The Enterprise Canal is located long the west side of the river.

Pierpoint Road

Pierpoint Road is a dip crossing at the community of Cotton Center. This crossing is mainly used by farm workers. The crossing consists of unstructured fill approximately 30 feet wide and approximately 2,000 feet long. There is one 4-foot corrugated metal pipes placed at each end of the dip crossing. This crossing is maintained by Maricopa County Department of Transportation (MCDOT).

Fornes Road

Fornes Road received significant damages during the 1993 floods. The dip crossing was abandoned and is no longer maintained by Maricopa County Department of Transportation (MCDOT).

363rd Avenue

363rd Avenue received significant damages during the 1993 floods. The dip crossing was abandoned and is no longer maintained by MCDOT.

395th Avenue

395th Avenue received significant damages during the 1993 floods. The dip crossing was abandoned and is no longer maintained by MCDOT.

Painted Rock Dam/ Painted Rock Dam Road

The Painted Rock Dam is a flood-control dam owned and maintained by the U.S. Army Corps of Engineers. Painted Rock Dam Road was not accessible during the field survey.

Saddle Road/Poco Dinero Road

Poco Dinero Road is a dip crossing consisting of non-compacted fill with four 4-foot corrugated metal pipes for low flows. The unpaved crossing is raised approximately five feet higher than the channel invert. There is an overhead telephone/utility crossing on the upstream side of the road. The road is maintained by MCDOT. The main use for this road is access to farming area west of the river in the vicinity of Dendora Valley.

Rocky Point Road

Rocky Point is an unpaved dip crossing used mainly for access to farming area west side of the river in the vicinity of Oatman Mountain. The dip crossing is maintained by MCDOT.

Agua Caliente Bridge (571st Avenue)

The Agua Caliente (571st Avenue) is the shortest paved access from State Highway 8 to the communities of Agua Caliente, Hyder and Camel and Montezuma. The floodplain is very wide (5,000 feet to 7,000 feet) at this location. The Gila River meanders and consists of several low flow braids at the vicinity of the bridge. The bridge may not have 100-year flow capacity. Both approaches to the bridge are lower than the bridge and may experience inundation and access loss during high flows. Spur dikes may have been damaged during the 1993 floods. Replaced spur dike bank protection consisting of riprap may not be adequate for higher flows (i.e. 100-year flows). Large amounts (25 feet in width) of debris have collected at the bridge piers. The Agua

Caliente Bridge is 257 feet long and 55 feet wide. It has three spans of 86 feet each and has piers each 4 feet in diameter. During the 1993 flooding, channel scouring and roadway erosion occurred north of the bridge. The estimated damaging flow was 45,000 cfs (Maricopa County). The bridge experienced scour for 260 feet of the bridge with a 500-foot roadway erosion and three 36-inch corrugated metal pipes. Maricopa County's possible solution is to install a cutoff wall downstream of the bridge and rebuild 500 feet of 28 feet wide, 3-inch thick asphalt with a 6-inch cement treated base for slope protection to the scour depth. The cost for improvements is estimated at $400,000. The bridge was constructed in 1987 and is maintained by MCDOT. Overhead telephone/utility lines are present at the upstream side of the bridge.

Sentinel Road

Sentinel Road merges with the Agua Caliente Road south and north of the bridge. This road is used as access to the community of Sentinel. This is the downstream most river crossing in Maricopa County.

Avenue 64 E

Avenue 64 E bridge crosses the Gila River near the community of Dateland. This road is defined as a major collector by FHWA. Avenue 64 E connects the State Highway 8 to the Antelope-Palomas Road and is mainly used as access to the communities of Horn and Kofa. The bridge consists of 4 spans of 60 feet each. This bridge was completely inundated on both approaches during the flood. It was estimated that about 400 feet of one approaches and 100 feet of another approach were inundated. Three of the spans were added after the original construction of the bridge. The bridge is 244 feet long, 32 feet wide, and is supported by round-nose piers. Spur dikes protect the approaches to the bridge. At the time of the field survey, the south and north approaches were protected by a spur dike consisting of non-structured fill without bank protection. The original bridge span is protected by old smaller spur dikes consisting of riprap. A telephone cable is buried upstream of the bridge. Overhead utility poles exist on the downstream side of the bridge. Avenue 64E bridge was built by Wellton Mohawk Irrigation and Drainage District (WMIDD) and is maintained by Yuma County. The design discharge of the bridge is 10,000 cfs according to Yuma County.

Oatman Crossing

Oatman Crossing is a dip crossing access road at Oatman Flat to the Oatman Mountain. This dirt road is mainly used by farm workers.

Hansen Crossing

Hansen Crossing is a dip crossing/access road to the Hansen Ranch. This road is mainly used by Hansen Ranch residences and farm workers.

Avenue 57 E

This dirt road is located in the vicinity of Texas Hill. This road does not cross the Gila River but a large portion of it was damaged by the 1993 flooding. The road is currently abandoned and no signs of repair were observed during the field survey. Overhead utility lines exist on the downstream side of the road. The utility lines may be buried across the river.

Levees in the vicinity of Texas Hill

Levees are present along the north bank just downstream of Avenue 57 E road alignment. These levees continue several miles downstream to the San Cristobal Wash confluence. The levees were under construction during the field survey. The levees are approximately five to ten feet above the ground, 20 feet top width with bank protection through most of the reach. The levee bank protection consisted of riprap with D_{50} of approximately 6 inches. The levees do not appear to be designed to large floods (100-year discharge). Bank protection toe-down were observed to have the maximum depth to the thalweg of the river. Per Bookman-Edmonston (WMIDD Contracted Engineers), the levees were designed to 10,000 cfs.

Avenue 55 E

Avenue 55 E is an abandoned graveled dip crossing. This crossing was damaged during the 1993 flooding. It is unknown at this time whether the County will rebuild this crossing.

Avenue 52 E

Avenue 52 E is an abandoned graveled dip crossing. This crossing was damaged during the 1993 flooding. This crossing was closed to traffic and not accessible during the field survey. It is unknown at this time whether the County will rebuild this crossing.

San Cristobal Wash Confluence

The San Cristobal Wash confluences with the Gila River just upstream of Avenue 52 E. San Cristobal Wash is a natural channel with bank protection along the west side. The bank protection was built to protect several square miles of agricultural land south of the Gila River and west of San Cristobal Wash.

Avenue 51 E

The Gila River floodplain is very wide at this location. Avenue 51 E has two separate dip crossing sections. The southern dip crossing is approximately 10 feet higher than the existing channel grade. The upstream side of this dip crossing is protected by large riprap. There were no culverts found in this section. Large scour holes were observed upstream and downstream of this crossing section. It was observed during the field survey that the Gila River flow is diverted away from the southern crossing and directed to the northern crossing by construction of a riprap-protected levee. The north dip crossing consists of compacted fill approximately 10 feet higher than existing channel grade. Eight circular metal projecting culverts are used to convey flows through this dip crossing. These 14-foot diameter circular culverts are half buried in the channel. The WMIDD stated that these culverts were designed to convey 9,000 cfs. According to Larry Killman of WMIDD, the 8 pipes handled a flow of 11,000 cfs until the road washed out during the flood. There were no dike breaks upstream of Avenue 51 E. Existing capacity is estimated at 2,800 cfs. An overhead utility crossing exist along the upstream side of Avenue 51 E crossing. This crossing was originally built by WMIDD and turned over to Yuma County for maintenance. An abandoned USGS station exists on the west side of the road. The gaging station was moved to Avenue 64.

Avenue 50 E

Avenue 50 E is an graveled dip crossing. This road was washed out during the 1993 flood. This crossing is maintained by Yuma County.

Growler Wash Confluence

Growler Wash confluences with the Gila River in the vicinity of Avenue 49 1/4 E road alignment. WMIDD estimates the capacity of Growler Wash at 40,000 cfs. The Texas Hill Wash flows into Growler Wash. The wash is contained with bank-protected levee along the west and east sides of the channel.

Mohawk Canal 'Norton' Siphon

The Mohawk Canal siphon crosses the Gila River near the Avenue 49 E alignment. Mohawk Mountains is located south of the Gila River and the community of Growler to the north. At the siphon crossing vicinity, there are lined irrigation canals north and south of the Gila River, a pump house at the north bank, bank protection upstream of the crossing and the pump house, overhead utility crossing upstream of the siphon and an unpaved dip crossing downstream of the siphon. According to WMIDD, approximately $1 million was spent protecting this crossing. Gila River bends and meanders just upstream of the siphon crossing. There are several areas upstream of the crossing where the low flow channel impinges to the levee. This levee is protected by medium-sized riprap. It is unknown whether this levee was built to withstand the design discharge of 10,000 cfs. This levee was built to protect agricultural land, the Mohawk canal and the pump house. The Avenue 49 E unpaved dip crossing downstream of the siphon is used as access for the farm workers. There is a single 4-ft corrugated metal pipe at the north end of the dip crossing. The irrigation canal, siphon crossing, utility lines and the dip crossing are maintained by WMIDD.

Avenue 47 E

Avenue 47 E is an unpaved dip crossing located in the vicinity of the community of Growler. The road is mainly used by farm workers. The Gila River floodplain is approximately 1,000 feet wide at this location. This crossing was completely damaged during the 1993 flood. The road has been rebuilt by the County. An 12 1/2 kV overhead power distribution line exist along the upstream side of the dip crossing from Avenue 47 to 47 1/4 E. The river eroded southeast and undermined the power poles.

Tyson Wash Confluence

The Tyson Wash originates from the Castle Dome Mountains and terminates at the Gila River just upstream of Avenue 45 E alignment. The Tyson Wash has been channelized at the Gila River confluence. Tyson Wash is maintained by WMIDD.

Avenue 45 E Bridge

The Avenue 45 E bridge crosses the Gila River near the towns of Colfred and Growler. The bridge is 244 feet long and the deck is 32 feet wide. It has four 60 foot long spans and has two round-nose piers, one of which experienced pier scour during the flood. Both bridge abutments were washed out during the 1993 flood. The spur dikes were under construction during the field survey. The spur dikes are protected by loose gravel and may not have been designed to withstand high flows. During the 1993 floods, Gila River split approximately one mile upstream of Avenue 45 E and rejoined one mile downstream of the bridge. There is a large volume of sediment upstream of the bridge and the channel appears to have aggraded approximately 5 feet. The bridge is primarily used as access to agricultural areas north of the river. Avenue 45 E road has riprap protection on the upstream side for a distance of approximately 1,500 feet north and 300 feet south.

Avenue 44 E

Avenue 44 E is an unpaved dip crossing located near the Town of Colfred. The road and dip crossing experienced severe damages during the 1993 flood. This is the narrowest point of the river. The entire flow width is only 100 feet. The dip crossing has been reconstructed by Yuma County. An overhead utility crossing exist along the upstream side of the dip crossing.

Avenue 43 3/4 & 4th

Avenue 43 road is an unpaved dip crossing located near the Town of Colfred. Approximately 8,000 feet of roadway was washed out or damaged during the flood. The dip crossing has been reconstructed by Yuma County.

Avenue 43 E

Avenue 43 E is an unpaved dip crossing located near the Town of Colfred. The road and dip crossing experienced severe damages during the 1993 flood. The dip crossing has been reconstructed by Yuma County. A relocated 34 1/2 kV overhead powerline exist along the upstream side of the dip crossing.

Avenue 42 E and 5th

There is an unpaved dip crossing at the Avenue 42 E and 5th intersection located near the Town of Colfred. The river has shifted considerably and bends at this location. The road and dip crossing experienced severe damages during the 1993 flood. The dip crossing has been reconstructed by Yuma County. An overhead utility crossing exist along the upstream side of the dip crossing.

Avenue 40 E bridge

Avenue 40 E was formerly an unbridged crossing. To prevent long detours for Wellton and Dome Valley residents, a pre-fabricated bridge was installed at this crossing. Detour routes would have to be as much as 80 miles round trip to access areas north or south of the Gila River. Avenue 40 E is now a paved road north and south of the bridge. The County has reconstructed and enlarged the bridge. Emergency work by the County or WMIDD also include reconstruction of the spur dikes and bank protection upstream of the bridge. An overhead power distribution line exist along the upstream side of the bridge. The bridge is approximately 600 feet in length with a 32 feet wide bridge deck. The bridge has 15 spans and the piers consist six 16 inch diameter round-nose piers. The bridge was designed to convey 50,000 cfs. Avenue 40 E is primarily used to access agricultural land from the Town of Tacna. The approaches to the bridge are lower than the bridge deck, and it is apparent from the 1993 flood that these approaches will be inundated during high Gila River flows. An overhead power distribution line exists along the upstream side of the bridge.

Levee at Avenue 40 E

An earthen levee exists along the north bank of the river beginning just upstream of Avenue 40 E bridge and extending approximately three miles downstream to Avenue 38 E. The levee downstream of the Avenue 40 E bridge breached for approximately one-half mile long during the 1993 flooding. The levee consists of fine material and had very little or no bank protection. No repairs have been made to this levee. This levee was built to protect agricultural land north of the levee. Several square miles of agricultural land were inundated and damaged by sediment deposits at this location. The Mohawk Valley School is located along the north bank from Avenue 38 E and Avenue 40 E. Yuma County is requesting the construction or reconstruction of the levees along the north bank to protect the school from future flooding.

Avenue 39 E & 1/2

Avenue 39 E road, also known as Davidson Lane is an unpaved dip crossing. There are no culverts at this dip crossing. The dip crossing was washed out during the 1993 flooding. The road is maintained by WMIDD.

Quigley Pond

Quigley pond is a 20-acre pond protected by Arizona Game & Fish Department. It is an isolated oxbow preserved outside of the channel dikes. The area was not damaged during the 1993 flooding.

Avenue 38 E bridge

Avenue 38 E bridge crosses the Gila River in the vicinity of the communities of Roll and Tacna. This bridge is approximately 220 feet in length with a 33 feet wide bridge deck. The bridge has three spans with 18-inch diameter piers. Vertical scour has affected this bridge. Gabions at the base of one of the piers was exposed by the 1993 flooding. The breaching of the levee upstream of Avenue 39E caused a majority of the Gila River flow to split and be diverted away from this bridge crossing. The bridge is located on a secondary channel south of the former river channel location. Three breakouts occurred in the roadway. The bridge was built on H piles with 45 feet of riprap. During the flood, a large amount of rock was dumped to protect the bridge. The levee along the north bank of the river terminates at the upstream side of the bridge. The levee is protected by grouted riprap for a short distance just upstream of the bridge. An overhead power distribution line exists along the upstream side of the bridge. The bridge was originally constructed by WMIDD and turned over to the County for maintenance.

Coast to Coast Bridge

The Coast to Coast bridge is a historical concrete bridge structure just upstream of the Roll Road north of the Antelope Hill. Two bridge decks have fallen in the past and the remaining portions of the bridge still exists in the channel. This bridge is not used for transportation because it is a historical bridge.

Avenue 36 1/2 E (Roll Road) at Antelope Hill

Roll Road crosses the Gila River at Avenue 36 1/2 E road alignment north of Antelope Hill near the community of Noah. Roll Road is an unpaved dip crossing with a single 5-ft corrugated metal pipe. The dip crossing was inundated and damaged by the 1993 flood. This road was an old Federal highway maintained by the county with Federal Highway Administration funds. There is a U.S. West telephone cable overhead line along the downstream side of the dip crossing. The Southern Pacific Railroad crosses the Gila River approximately 50 feet downstream of the dip crossing. The railroad bridge was design to withstand 200,000 cfs (pre-Painted Rock Dam condition). There were no damages to the railroad bridge during the 1993 flood. MCI's fiber optics cable, Santa Fe petroleum pipeline and a SPTC signal line are suspended to the railroad bridge. On overhead utility line crosses the Gila River approximate 1,500 feet downstream of the railroad bridge.

Wellton Mohawk Conveyance Channel Siphon

The 5-foot diameter siphon crosses the river at the Avenue 34 E road alignment. The siphon is located on the east side of the road. The siphon was extended by WMIDD from 1/4 to 1/2 mile in length under the river. The siphon is owned and operated by WMIDD.

Avenue 34 E

Avenue 34 E is an unpaved dip crossing near the communities of Wellton and Asher. The dip crossing was washed out during the 1993 flooding. The dip crossing has single 5-foot corrugate metal pipe for low flows. The road crossing is inaccessible and it is uncertain when or whether the County will reconstruct this road crossing. An overhead utility crossing exist along the upstream side of the dip crossing.

Avenue 33 1/4 & 6th

An unpaved dip crossing at Avenue 33 1/4 & 6th was washed out during the 1993 flood. The dip crossing has a single 5-foot corrugated metal pipe for low flow. Reconstruction of this dip crossing is pending. This road was used as access to agricultural land at the Radium Hot Springs area. Overhead utility poles cross the Gila River along the downstream side of the dip crossing. These utility lines may have been abandoned.

Avenue 32 E

Avenue 32 E is an unpaved dip crossing with two 4-foot corrugated metal pipes one at each end of the dip crossing. This dip crossing has no cross drain pipe for low flows. The dip crossing was severely damaged during the 1993 flooding. The dip crossing has been reconstructed by Yuma County.

Levee at Avenue 32 E Vicinity

An earthen levee exists along the south side of the river from Avenue 33 E and extends two miles downstream to Avenue 32 E dip crossing. The levee does not have bank protection for this reach.

Avenue 31 E & 6 1/2

Avenue 31 E is an unpaved dip crossing with a single 5-foot corrugated metal pipe. The dip crossing was severely damaged during the 1993 flood. The dip crossing was reconstructed by the County. The road crossing is made of unprotected fine uncompacted material which can be damaged during high flows.

Wellton Canal Siphon

The Wellton canal siphon crossing is located near the community of Wellton. The siphon sustained damages during the 1993 flood. The damages have been repaired and is currently operating. The Wellton Canal siphon is owned and operated by WMIDD.

Avenue 30 E Bridge

Avenue 30 E bridge crosses the Gila River north of the community of Wellton. The bridge is 243 feet and length and has a bridge deck of 32 feet. The bridge has four spans of 60 feet each and has 18-inch diameter metal piers. The river bends at this location. Overhead power distribution lines exist along the downstream side of the bridge. The bridges south abutment was washed out during the flood. Both approaches to the bridge were inundated during the flood and the road was impassable. The abutment has been restored since the flood.

Avenue 29 E

Avenue 29 E is an unpaved dip crossing with a single 7-foot corrugated metal pipe for low flows. The dip crossing was severely damaged during the 1993 flood. The County was in the process of reconstructing the dip crossing and closed to traffic during the field survey. Overhead utility lines exist along the upstream side of the road.

Avenue 27 E

Avenue 27 E is an unpaved dip crossing with a single 2-foot corrugated metal pipe for low flow. The dip crossing was inaccessible at the time of the field survey. Reconstruction of the dip crossing is currently pending.

Coyote Wash Confluence

Coyote Wash confluences with the Gila River at the Avenue 27 E alignment north-west of the community of Wellton. Coyote Wash channel has an estimated capacity of 2,000 cfs. The Coyote Wash channel is maintained by WMIDD. A 6-inch steel gasline belonging to Southwest Gas Company (SWG) crosses the Gila river along the 9th Street alignment in the vicinity of the Coyote Wash - Gila River confluence. It is unknown how deep the gasline is buried below the channel invert.

High Voltage Power Lines

Two high voltage power lines cross the Gila River downstream of the Coyote Wash confluence. One overhead line is a 34 1/2 kV power line following the old dike alignment paralleling the river from Avenue 26 to 26 1/2 E. The power line is currently operable and damages to the towers have been repaired. The second overhead line is a 69 kV power line crossing the river at the vicinity of Avenue 25 3/4 E and 10th Street. This line is also currently operable and flood damages to the towers have been repaired. These power lines are maintained by WMIDD.

Wellton Mohawk Main Conveyance Canal

The Wellton-Mohawk main conveyance canal experienced extensive damage to the canal lining and the embankment. Damages to the canal have been repaired but the embankment do not appear to have any bank protection. The canal is owned and maintained by WMIDD.

Avenue 25 E

Avenue 25 E is an unpaved dip crossing. This dip crossing was severely damaged during the 1993 flooding. The road is mainly used by farm workers to access a small agricultural area north of the river and south of the Muggins Mountains. The river makes an abrupt bend at the Avenue 25 E crossing. The road was impassable during the field survey. Reconstruction of the dip crossing is pending. A levee is present upstream and downstream of the Avenue 25 E crossing along the south bank. These levees are approximately 6 feet high with riprap bank protection on both sides of the levee.

Grout Wash Confluence

Grout Wash confluences with the Gila River in the vicinity of Avenue 24 3/4 E alignment. WMIDD estimates the capacity of Grout Wash to be approximately 1,000 cfs. The Grout Wash channel is maintained by WMIDD.

Avenue 24 E

Avenue 24 E is an unpaved dip crossing with a single 5-foot corrugated metal pipe. This crossing was severely damaged during the 1993 flood. The road crossing was impassable during the field survey. Reconstruction of the dip crossing is pending. On overhead U.S West telephone line is located along the downstream side of the dip crossing. A separate 12 kV overhead power distribution line located on double poles crosses the river downstream of the dip crossing. Both utility lines are currently operating and flood damages to these lines have been repaired.

Wellton Mohawk Conveyance Channel Siphon

The Wellton Mohawk conveyance channel siphon is double 60-inch siphon is located in the vicinity of the Avenue 23 E alignment. The siphon outlet and approximately 600 feet of the canal was destroyed during the 1993 flood. WMIDD has installed riprap-protected berm along the south side existing channel to access and repair the outlet. Damages to the siphon have been repaired. The canal and siphon is owned and operated by WMIDD.

Gomez Wash Confluence

Gomez Wash confluences with the Gila River from the north side at the vicinity of the Avenue 23 E alignment. Gomez Wash is a natural channel with riprap protected levees along the east and west sides of the channel. WMIDD estimates the capacity of Gomez Wash channel to be approximately 5,000 cfs. The channel is maintained by WMIDD.

Ligurta Wash Confluence

Ligurta Wash confluences with the Gila River from the south side in the vicinity of the Avenue 22 1/2 E alignment. Ligurta Wash is a natural channel with bank protection along the east and west sides of the channel. WMIDD estimates the capacity of Ligurta Wash to be approximately 15,000 cfs. The channel is maintained by WMIDD.

Avenue 22 E

Avenue 22 E is an unpaved dip crossing with a single 7-foot corrugated metal pipe. The dip crossing was washed out during the 1993 flood. The County was reconstructing the dip crossing at the time of the field survey. The channel braids in this area and there are two district dip crossings at this location. The road crossing consists of fine uncompacted material. This crossing may continue to sustain damages during future high flows.

Red Top Wash Confluence

Red Top Wash confluences with the Gila River from the south side of the river in the vicinity of the Avenue 21 E alignment. The Red Top Wash has been channelized at the confluence. The levees at the confluence sustained damages during the 1993 flood. WMIDD estimates the capacity of Red Top Wash to be approximately 8,000 cfs. Red Top Wash channel is maintained by WMIDD.

Unnamed Wash Confluence

An unnamed wash confluences with the Gila River approximately one mile downstream from the Red Top Wash confluence in the vicinity of Avenue 20 E alignment. WMIDD estimates the capacity of the unnamed wash at 1,000 cfs. WMIDD maintains this unnamed wash channel.

Avenue 20 E Bridge

Avenue 20 E bridge crosses the Gila River near the community of Ligurta. The bridge is approximately 240 feet in length and has a 33 feet wide bridge deck. The bridge has 4 spans with 18-inch diameter metal piers. The bridge south abutment was washed out during the 1993 flood. The bridge abutments have been reconstructed and are protected by newly constructed spur dikes with inadequate bank protection. A levee downstream of the bridge was recently reconstructed from Avenue 20 to approximately Avenue 18 1/4. This north bank levee was reconstructed to approximately one foot higher than the previous levee. Utility/power lines exist upstream and downstream of the bridge along the north bank. The levees have riprap bank protection which may have been placed as part of the emergency work during the flood to save the bridge abutments. The bank protection placed along the levees do not appear to have been designed to 10,000 cfs. The bridge was originally constructed by WMIDD and turned over to the County for maintenance. A telephone cable is suspended on the bridge along the east barrier. The telephone cable continues on overhead telephone poles north and south of the bridge.

Dome Canal Siphon

The Dome Canal siphon crosses the Gila River at the vicinity of Avenue 19 1/2 E roadway alignment. The siphon is currently operating and damages to the siphon crossing have been repaired. The siphon is owned and operated by WMIDD.

Avenue 18 1/4 E

Avenue 18 E is an unpaved dip crossing with a single 7-foot corrugated metal pipe for low flows. The dip crossing was washed out during the 1993 flood. The reconstruction of this crossing is pending. An 12 kV overhead power line crosses the river along the downstream side of the road.

Dome Wash Confluence

Dome Wash confluences with the Gila River along the north bank of the river. Dome Wash originates from the Yuma proving grounds and is channelized through agricultural land. WMIDD estimates the capacity of Dome Wash at approximately 15,000 cfs. Levees beginning from the Dome Wash confluence to Avenue 20 E has been reconstructed. It is unknown whether the levee was designed to 10,000 cfs or placed as part of emergency work along the Gila River during the flood. A high voltage (34 1/2 kV) power line crosses the river a quarter mile downstream of the Dome Wash confluence.

Avenue 17 E and 5th

Avenue 17 E is an unpaved dip crossing without culverts for low flow. This crossing was washed out during the 1993 flooding. It is unknown whether this crossing will be reconstructed. A high voltage (12 1/2 kV) power distribution line crosses the river along the downstream side of the dip crossing.

Dome Wash Confluence

Dome Wash, identified as Dome 6.4 (B-E, 1994) confluences with the Gila River in the vicinity of Avenue 17 E road alignment. Dome Wash enters the river from northeast bank. The channel has levees on the north and south sides of Dome Wash at the confluence. WMIDD estimates the Dome Wash design discharge as 15,000 cfs.

Avenue 16 E

Avenue 16 E is an unpaved dip crossing with a single 5-foot corrugated metal pipe for low flows. This crossing was washed out during the 1993 flood. A scour hole is present downstream of the dip crossing. Gila River bends to the south at this location. The river runs along the Wellton Mohawk canal. A levee along the south bank protects the canal from Gila River flows. Short training dikes exist in this reach. An overhead telephone line crosses the river along the downstream side of the dip crossing. An high voltage (12 1/2 kV) power distribution line crosses the river approximately one mile downstream of Avenue 16 E (power line crossing at Avenue 15 E alignment).

High Voltage WAPA Powerline

A high voltage overhead power distribution line crosses the river in the vicinity of Avenue 14 to 15 3/4 E. The 161 kV line was originally constructed by WMIDD and turned over to WAPA. WAPA is currently redesigning the line and is awaiting the completion of the channel alignment design proposed by WMIDD. The power line is currently operable.

Wellton Mohawk Main Conveyance Channel Siphon

The Wellton Mohawk Main Conveyance Channel Siphon consists of two 60-inch pipes crossing the river. The siphon is currently operable and flood damages to the siphon have been completely repaired. The siphon is operated and maintained by WMIDD.

Castle Dome Wash Confluence

The Castle Dome Wash confluences with the Gila River at the vicinity of the Avenue 13 3/4 E roadway alignment. Castle Dome Wash capacity is estimated by WMIDD as 35,000 cfs. Castle Dome enters the river from the north side of the river just upstream of the U.S. Highway 95 bridge crossing.

Utility Crossings Upstream of Highway 95

A 34 1/2 kV overhead power distribution line crosses the river in the vicinity of Avenue 13 1/2 E. A high voltage 161 kV powerline also cross the river in a northeast to southwest direction. This line was originally constructed by WMIDD and turned over to WAPA. WAPA is redesigning the line and is currently awaiting the completion of the proposed channel alignment design. Both lines are currently operable.

El Paso Gasline

A high pressure gasline, 10 inches in diameter crosses the river in the vicinity of Avenue 13 3/8 E. The gasline is currently operable and is owned and maintained by El Paso Gas Company.

U. S. Highway 95 Bridge

U.S. Highway 95 is a major north-south route through Western Yuma County. The bridge failed around April 11, 1993 due to bridge scouring. The U.S. Highway 95 crosses the Gila River south of the Laguna Mountains and north of the Gila Mountains. This paved highway bridge was washed out during the 1993 flooding and caused access problems to the area north of the river. The bridge has been rebuilt and is designed to convey 50,000 cfs. The bridge has 16 spans and the largest depth from bridge low chord to the channel invert is approximately 25 feet. Half of the bridge opening is blocked with sediment (low chord to invert approximately 8 feet). The US Highway 95 bridge is approximately 685 feet long and has a 48 foot wide bridge deck. The bridge is supported by 5 piers of 30 inch diameter. Levees exist on both sides of the river. The levee along the north bank is protected by riprap. The extent of toe down at this location is unknown. The bridge south abutment is protected with gabions. The bridge was opened to traffic shortly after the flood and is maintained by the Arizona Department of Transportation.

Mc Phaul Bridge

The Mc Phaul bridge crosses the Gila River at the vicinity of Avenue 12 1/4 E road alignment. The Mc Phaul bridge is no longer used for traffic. The bridge is listed in the National Register as a historical bridge. It was the first suspension bridge in the United States (B-E, 1994). The bridge was designed to a capacity of 100,000 cfs. A high pressure El Paso Gas Company gas line crosses the river a quarter mile downstream of the Mc Phaul bridge. The 5-inch gas line has been abandoned.

Avenue 11 1/4 E

Avenue 11 1/4 E is an unpaved dip crossing with two 3-foot corrugated metal pipe for low flows. This dip crossing was washed out during the 1993 flood. The road parallels the Gila siphon. The reconstruction of this dip crossing may have been finished or currently pending.

Gila Gravity Main Canal

The Gila Gravity Main canal siphon crosses the river in the vicinity of Avenue 11 1/4 E. The siphon is currently operable. There were no damages to this siphon and no improvements to this crossing have been made. Approximately 60 percent of the water is diverted into the Wellton Mohawk canal and the remainder is conveyed to Yuma. There are two Southern Pacific Pipeline petroleum lines crossing the river approximately one quarter mile downstream of the siphon.

Fortuna Wash Confluence

Fortuna Wash confluences with the Gila River in the vicinity of Avenue 10 E road alignment. Fortuna Wash is heavily vegetated at the confluence area. Agricultural areas west of Fortuna Wash is protected by a levee with riprap bank protection.

Avenue 7 E Bridge

Avenue 7 E bridge is the downstream-most transportation crossing in Yuma County along the Gila River. The bridge is approximately 300 feet in length with a bridge deck width of 36 feet. The bridge has 5 spans with 18 inch diameter metal piers. The existing depth from the bridge low chord to the channel invert is approximately 15 feet. The bridge abutments are protected by spur dikes with riprap bank protection. A levee extends for a distance of approximately 1,000 feet along the south side of the river downstream of the bridge. Based on conversations with Yuma County, this was the only bridge in the area that remained open during the 1993 flood. The Gila River is very narrow at this location compared to the upstream reaches. The County would like to extend this bridge. The bridge was designed to a capacity of 10,000 cfs.

Colorado / Gila River Confluence

The Gila River terminates at the Colorado River approximately 2 1/2 miles downstream of the Avenue 7 E bridge crossing. The Bureau of Reclamation place emergency riprap banks along the north bank of the Colorado River to prevent damages to agricultural land. The Bureau of Reclamation manages the Colorado River and Gila River confluence for a distance of 10 miles upstream along the Gila to just upstream of the U.S. Highway 95 bridge. The bureau is currently preparing a channelization/levee plan for the Gila river south of the Highway 95 crossing. Only conceptual levee alignment and environmental assessment of the study area was prepared. The bureau stated that funds are currently not available to continue the study and construct the channel and levees.

IV. SECTION 14 EVALUATIONS

The Section 14 Authority of the Corps of Engineers Continuing Authorities Program pertains to emergency bank protection. Potential for streambank erosion at the bridge crossings were evaluated to determine whether the crossing has the potential to warrant Federal interest after further, more-detailed study.

The pre-reconnaissance preliminary Section 14 evaluation of the bridges was based upon the following assumptions: 1) the Painted Rock Dam outflow discharge at the time of the crossing closure is the non-damaging discharge (with the exception of the U.S. Highway 80 bridge located upstream of the Painted Rock Dam), and 2) the 100-year discharge at 15,000 cfs is the current 100-year outflow discharge at the dam. Future detailed studies could include an evaluation of the rate of streambank erosion at the bridge crossings to properly determine whether the bridge and its approaches are in danger of bank erosion. Preliminary screening of the bridge crossings are discussed in the following paragraphs.

U.S. Highway 80 Bridge Crossing

The U.S. Highway 80 bridge crossing is located just downstream of the Gillespie Dam. The Dam is supported on both sides of the river by high bluffs. These bluffs continue downstream near the bridge protecting the approaches. From field observation, it was determined that the bridge and bridge approach do not appear to be in imminent danger of bank erosion. Further study of this bridge under the Section 14 Authority is not recommended.

Agua Caliente Bridge Crossing

Figure 4.1a shows an aerial view of the bridge crossing looking downstream. Based upon field observations and preliminary evaluation of the crossing, it was determined that there is a potential for erosion of the bridge approaches. During the floods of 1993, traffic through this crossing was closed due to inundation of the approaches. The bridge was closed to traffic for 10 weeks when the outflow discharge at the dam exceeded 12,500 cfs (approximately a 75-year flood). The volume of average daily trips at the bridge crossing is estimated at 236 trips with a detour route of approximately 96 miles. The total delay cost is estimated at $820,700, an annualized cost of $10,940.

A potential solution to this site is to construct levees with soil cement bank protection extending upstream for a distance of approximately 500 feet from the bridge along both sides of the river. The total cost for this solution is approximately $300,000. The estimated annualized cost is $24,500 (based on 8 percent annual rate and 50-year life of the project). The benefit/cost ratio for this solution is 0.45. Other solutions could be devised which could result in a favorable benefit/cost ratio. It is recommended that a pre-reconnaissance-level study be conducted to further investigate Section 14 potential at this location.

Figure 4.1a Aerial Photograph of Agua Caliente Bridge

Figure 4.1b Aerial Photograph of the Avenue 45 E Bridge Looking from the South

Avenue 45 E Bridge Crossing

Figure 4.1b is an aerial view of Avenue 45 E bridge crossing. This bridge crossing is located at a mild river bend. Based on field observations and preliminary analysis, the south bridge approach may be subject to bank erosion. This bridge crossing was closed to traffic for 5 months during the floods of 1993 when the Gila River estimated discharge was approximately 25,120 cfs. The discharge at bridge closure exceeded the current 100-year dam-released discharge of 15,000 cfs. The volume of average daily trips at the bridge crossing is estimated at 900 trips with a detour route of approximately 23 miles. The total delay cost is estimated at $1,662,800, an annualized cost of $13,260.

A preliminary solution to this site is to construct levees with soil cement bank protection extending upstream for a distance of 2,000 feet from the bridge along south side of the river. The total cost for this solution is $600,000. The estimated annualized cost is $49,000 (based on 8 percent annual rate and 50-year life of the project). The preliminary benefit/cost ratio is 0.27. Further detailed study of this site should be conducted on a pre-reconnaissance level and include an evaluation of the rate of erosion along the south bank to determine whether the bridge approach is subject to erosion and consequently qualifies under Section 14 Authority.

Avenue 40 E Bridge Crossing

Figure 4.2a shows an aerial photograph of the Avenue 40 E bridge crossing. Based upon field observations and a preliminary evaluation, the bridge structure and approaches do not appear to be imminent danger of bank erosion. Furthermore, the non-damaging discharge, based on the discharge at bridge closure during the 1993 flood, is greater than the 100-year discharge. Further study under the Section 14 Authority is not recommended.

Avenue 38 E Bridge Crossing

Figure 4.2b shows an aerial view of the Avenue 38 E bridge crossing. From field observations and preliminary evaluation, the bridge structure and the bridge approaches do not appear to be imminent danger of bank erosion. Furthermore, the non-damaging discharge, based on the discharge at bridge closure during the 1993 flood, is greater than the 100-year discharge. Further study under the Section 14 Authority is not recommended.

Avenue 30 E Bridge Crossing

The Avenue 30 E bridge crossing is located at a mild river bend (See illustration on Figure 4.3). Based upon field observations and a preliminary evaluation, there may be a potential for eventual erosion of the south bridge approach. This bridge crossing was closed to traffic for 3 months during the floods of 1993, at a discharge exceeding the 100-year discharge from Painted Rock

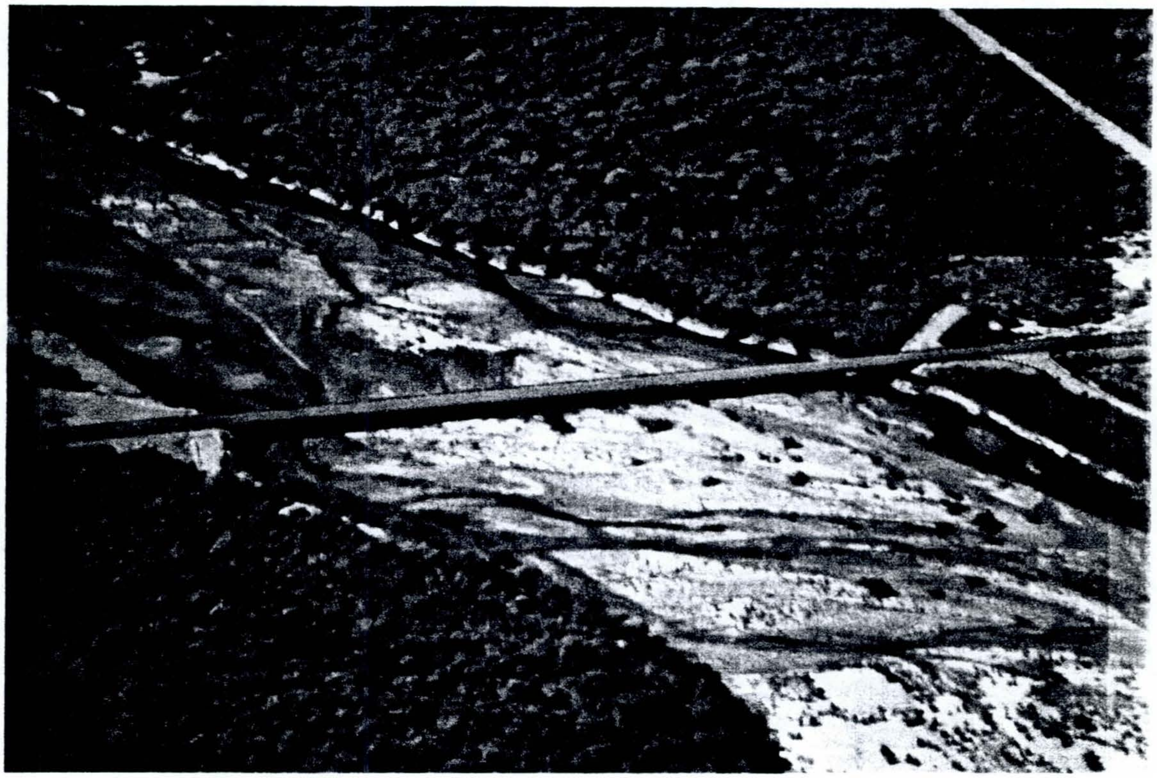


Figure 4.2a Aerial Photograph of the Avenue 40 E Bridge

Figure 4.2b Aerial Photograph of the Avenue 38 E Bridge

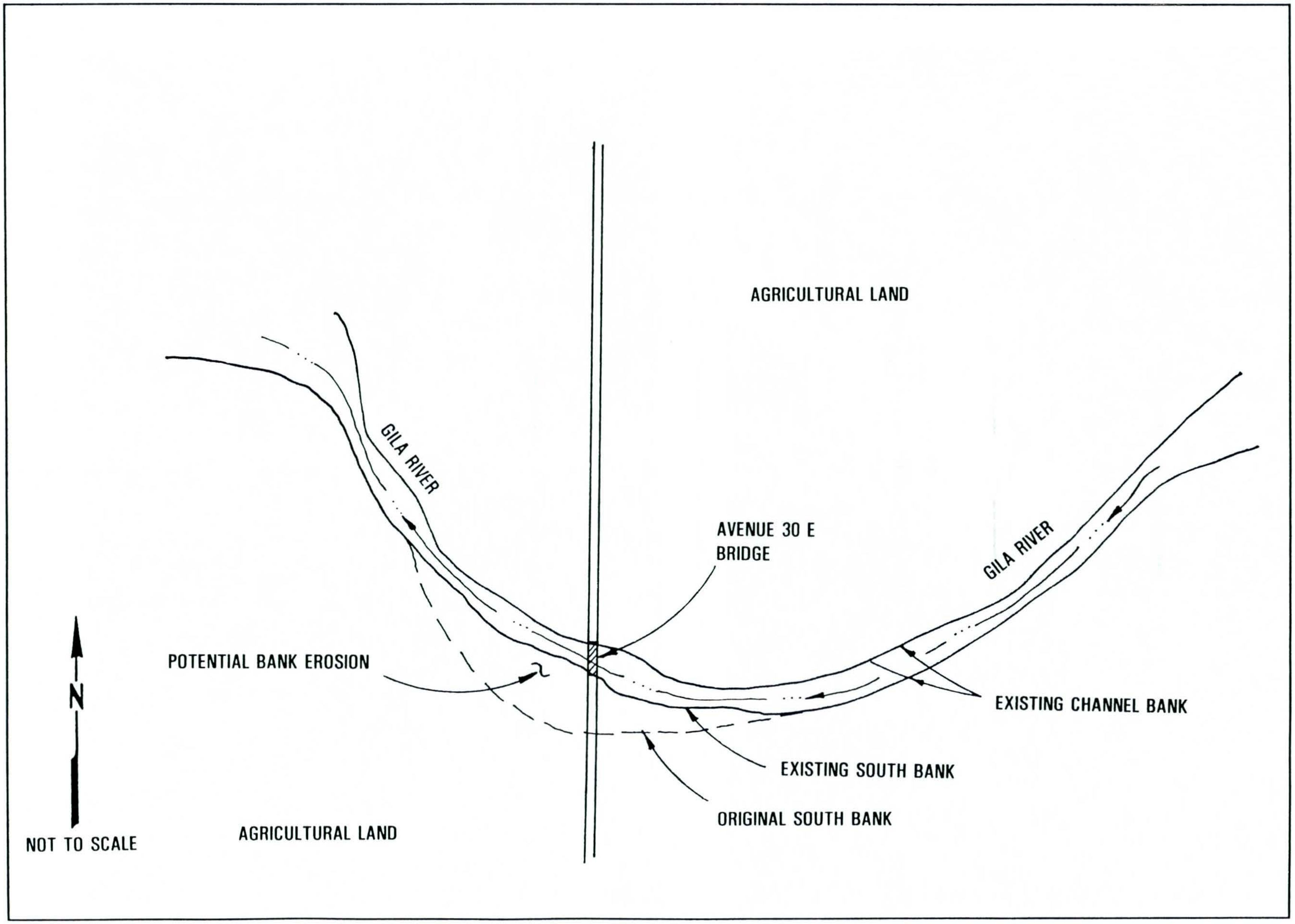


Figure 4.3 An Illustration of the Avenue 30 E Bridge Crossing

dam. The volume of average daily trips at the bridge crossing is estimated at 900 trips with a detour route of approximately 30 miles. The total three-month delay cost is estimated at $1,148,200.

A solution to this site is to construct levees with soil cement bank protection extending upstream for a distance of 1,200 feet from the bridge along south side of the river. The total cost for this solution is $360,000. The benefit to cost ratio, comparing single-event damage to construction cost, is 3.2. Further detailed study of this site should be conducted on a pre-reconnaissance level under Section 14 Authority.

Avenue 20 E Bridge Crossing

Based upon field observations and preliminary evaluation, the bridge structure and the bridge approaches do not appear to be imminent danger of bank erosion. Furthermore, the non-damaging discharge, based on the discharge at bridge closure during the 1993 flood, is greater than the 100-year discharge. Further study under the Section 14 Authority is not recommended.

U.S. Highway 95 Bridge Crossing

The U.S. Highway 95 bridge structure failed during the floods of 1993. The bridge was closed to traffic for approximately 4 months due to bridge approach inundation and emergency reconstruction of the bridge. The bridge has been reconstructed and is designed to withstand flows of 50,000 cfs. Based upon field observations and preliminary evaluation, the bridge structure and the bridge approaches do not appear to be imminent danger of bank erosion. Furthermore, the non-damaging discharge, based on the discharge at bridge closure during the 1993 flood, is greater than the 100-year discharge. Further study under the Section 14 Authority is not recommended.

Avenue 7 E Bridge Crossing

The Avenue 7E bridge remained open during the 1993 floods when flows were exceeding the 100-year discharge. Levees exist along the north and south banks upstream of the bridge. Based upon field observations and preliminary evaluation, the bridge structure and the bridge approaches do not appear to be imminent danger of bank erosion. Further study under the Section 14 Authority is not recommended.

Mohawk Canal 'Norton' Siphon Crossing (Vicinity of Avenue 48E)

Figure 4.4 illustrates the Mohawk Canal 'Norton' siphon crossing near the community of Growler. Field observations show that several braids of the Gila River low flow channel impinge directly onto existing riprap-protected levees upstream of the siphon. The levees were constructed to protect the canal and the pump house which operates the siphon. The siphon crossing may have potential for Corps of Engineers involvement under the Section 14 Authority since preliminary evaluation of the site show that the siphon and associated structures may be in danger of bank erosion. Further, reconnaissance-level study of this siphon is recommended provided that the Wellton-Mohawk Irrigation District qualifies as a public entity under the Section 14 Authority

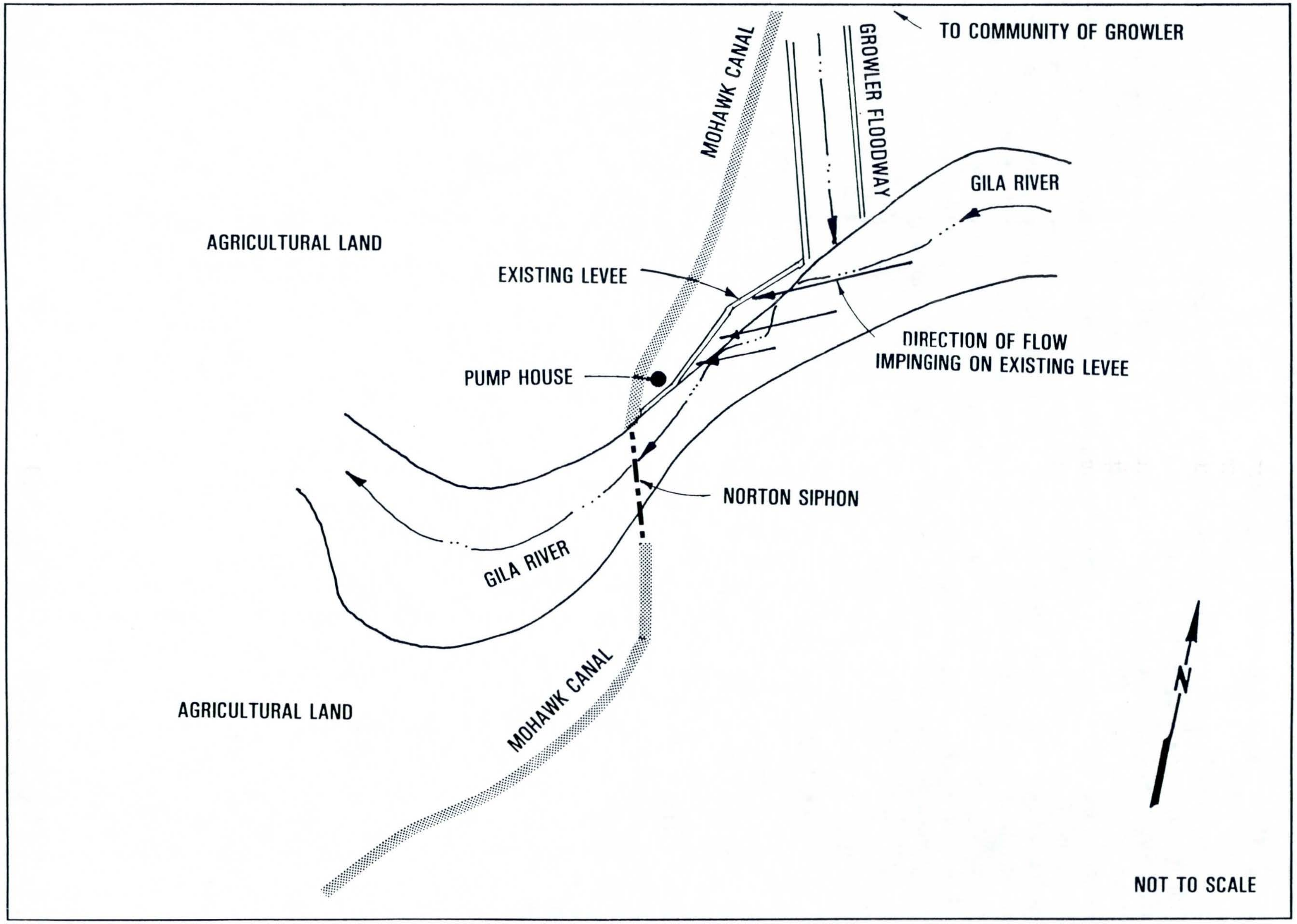


Figure 4.4 An Illustration of the Mohawk Canal 'Norton' Siphon Crossing Near the Community of Growler

V. PROPOSED CHANNELIZATION

5.1 Wellton-Mohawk Channelization Plan

Wellton-Mohawk Irrigation and Drainage District (WMIDD) is currently conducting a Gila River flood control restoration project. The project is prepared in three phases. Phase 1 is currently in draft form. WMIDD proposes channel improvements on Gila River between Avenue 11 E and Avenue 57 E crossings. The proposed work went beyond the repairs of flood control facilities damaged by the 1993 floods. The proposed design concept (conducted by Bookman-Edmonston Engineering, Inc. in September 1994) entails excavation of a low flow channel within a 250-foot-wide cleared area, bordered by levees faced on the water side slope with riprap bank protection. The levee to levee distance varies between approximately 600 feet to 2,600 feet. Additional proposed improvements consist of seven grade-control structures and turn-out structures. Bookman-Edmonston, under contract with the district is currently obtaining environmental permits, preparing plans and specifications and managed construction to restore portions of the flood control facilities to the preflood capacity of 10,000 cfs.

5.2 Bureau of Reclamation

The Bureau of Reclamation, in conjunction with Wellton-Mohawk Irrigation and Drainage District is in the process of preparing a channelization plan for the Gila River from the U.S. Highway 95 bridge to the Colorado River confluence. The river plan consists of channelization of the river and construction of levees along the north and south bank. The river plan is currently in the conceptual planning stages. A total levee distance of 10 miles is included in the river plan and 10 miles of Gila River channelization. The channel ranges in width from 250 feet to 600 feet.

VI. CONCLUSION/RECOMMENDATIONS

There are 134 crossings along the 166-mile reach of the Gila River from Gillespie Dam at Maricopa County to the Colorado River confluence in Yuma County. These crossings consist of 10 bridges, 37 on-grade dip crossings, 40 utility crossings, 8 siphons and 23 tributary confluences. The remaining 16 crossings are irrigation-type structures.

Potential for streambank erosion at the bridge crossings was evaluated to determine whether the crossing has the potential to warrant Federal interest under Section 14 after further, more-detailed study. The Section 14 Authority of the Corps of Engineers Continuing Authorities Program pertains to emergency bank protection. Based upon this preliminary screening, further, pre-reconnaissance-level study under Section 14 is recommended for the Agua Caliente Bridge, the Avenue 45E bridge, the Avenue 30E bridge, and the Norton Siphon. The Mohawk canal and siphon are owned and operated by Wellton-Mohawk Irrigation District which provides services to privately owned farmland. Section 14 Authority requires that a public structure or facility be in danger of streambank erosion to qualify.

VII. REFERENCES

1. Arizona Water Commission, Prepared by Johannessen & Girand, January 11, 1980. Flood Control Study for the Gila River, Yuma County, Arizona.

2. Federal Emergency Management Agency, September 30, 1988. Flood Insurance Study Yuma County, Arizona.

3. Federal Emergency Management Agency. Flood Insurance Study Maricopa County, Arizona.

4. The Flood Control District of Maricopa County, March 1, 1994. Salt-Gila River Land Use and Structures Inventory.

5. U.S. Army Corps of Engineers Los Angeles District, June 1994. Gila River Reconnaissance Study Gillespie Dam to Yuma, Arizona. Hydrologic Analysis with and without Project.

6. U.S. Army Corps of Engineers Los Angeles District, July 1994. Reconnaissance Report Gillespie to Yuma, Maricopa and Yuma Counties, Arizona. Economic Appendix

7. U.S. Army Corps of Engineers Los Angeles District, August 1994. Gila River, Gillespie Dam to Yuma, Arizona, Reconnaissance Study R3 Documentation.

8. U.S. Army Corps of Engineers Los Angeles District, July 1994. Geomorphic Assessment of the Lower Gila River, West Central Arizona.

9. U.S. Army Corps of Engineers Los Angeles District, December 1970. Design Memorandum No.1 Hydrology for Gila River Improvement (Texas hill to Gila Siphon).

10. U.S. Department of the Interior Bureau of Reclamation, July 1994. Final Environmental Assessment Gila River Channel Enhancement Wellton-Mohawk Irrigation and Drainage District.

11. United States Geological Survey Quadrangles.

12. Wellton-Mohawk Irrigation and Drainage District, September 1994. Prepared by Bookman-Edmonston Engineering, Inc. Gila River Flood Channel Restoration Project Design Memorandum - Draft.

13. Wellton-Mohawk Irrigation and Drainage District, September 1994. Prepared by Bookman-Edmonston Engineering, Inc. Hydraulic Analyses for the Gila River Flood Channel Restoration Project, Technical Memorandum

14. Wellton-Mohawk Irrigation and Drainage District, March 1994. Prepared by Bookman-Edmonston Engineering, Inc. Alternative Alignment Cost Comparison Restoration of Gila River Flood Channel Avenue 57E to the Gila Siphon.

15. Wellton-Mohawk Irrigation and Drainage District, March 1994. Prepared by Bookman-Edmonston Engineering, Inc. Draft Environmental Assessment

16. Wellton-Mohawk Irrigation and Drainage District, June 1994. Prepared for the U.S. Army Corps of Engineers, Prepared by Bookman-Edmonston Engineering, Inc. Section 404 Alternatives Analysis.

17. Wellton-Mohawk Irrigation and Drainage District, September 1994. Prepared by Robert I. Strand. Analysis of Potential Scour at Grade Control Structures, Bridges and Levees Gila River Flood Channel Restoration Project Technical Memorandum - Draft.

18. Wellton-Mohawk Irrigation and Drainage District, September 1994. Prepared by Robert I. Strand. Analysis of Sediment Transport Capability in the Gila River Flood Channel Restoration Project, Technical Memorandum.

19. Wellton-Mohawk Irrigation and Drainage District, September 1994. Prepared by Bookman-Edmonston Engineering, Inc. Gila River Drainage and Utility Linelist - Draft.

20. Yuma City/County Division of Emergency Management. Yuma County Floods 1993 Summary Report.

21. Yuma County, Inventory of Yuma County Road Damage From Gila River Flood As of May 12, 1993.

22. Yuma Metropolitan Planning Organization. 1993 24 Hour Quarterly Traffic County Report.

23. Yuma County Flood Control District, June 1980. Prepared by the Arizona Water Commission. Reconnaissance Report Lower Gila River Flood Control Project.

List of Crossings From Gillespie Dam to Yuma, Arizona							
XING NO.	DISTANCE TO COLORADO RIVER, IN MILES	LOCATION	FACILITY	RESPONSIBLE AGENCY	USGS QUAD	TOWN RANGE	SECTION NUMBER
1	166.0	1000' u/s of Hwy 80	Gillespie Dam	US COE	Spring Mountain	T2S R5W	28
2	165.9	US Hwy 80	Old U.S. Highway 80	County of Maricopa	Spring Mountain	T2S R5W	28
3	165.8	200' d/s of Hwy 80	El Paso Gasline	El Paso Natural Gas	Spring Mountain	T2S R5W	28
4	165.6	1000' d/s of Hwy 80	High Voltage Line	SRP	Spring Mountain	T2S R5W	27,28
5	154.8	Pierpoint Road	Dip Crossing	County of Maricopa	Cotton Center	T4S R4W	8,17
6	151.6	Fornes Road	Dip Crossing	County of Maricopa	Cotton Center	T4S R4W	29,32
7	139.4	363 Avenue	Dip Crossing	County of Maricopa	Citrus Valley East	T4S R6W	35,36
8	135.0	395 Avenue	Dip Crossing	County of Maricopa	Citrus Valley West	T4S R6W	31,32
9	128.0	Painted Rock Dam	Flood Control Dam	US COE	Dendora Valley	T4S R7W	--
10	128.0	PR Dam Road	Dip Crossing	US COE	Dendora Valley	T4S R7W	--
11	125.2	Saddle/Poco Dinero	Dip Crossing	County of Maricopa	Dendora Valley	T4S R8W	14
12	122.0	Hansen Crossing	Hansen Crossing	County of Maricopa	Dendora Valley	T4S R8W	32
13	120.0	Rocky Point Road	Dip Crossing	County of Maricopa	Dendora Valley	T4S R8W	32,5
14	118.1	Oatman Crossing	Oatman Crossing	County of Maricopa	Oatman Mountain	T5S R9W	12
15	106.5	Ag. Caliente/Sentinel	Agua Caliente Bridge	County of Maricopa	Agua Caliente	T5S R10W	28
16	106.5	Sentinel	Sentinel	County of Maricopa	Agua Caliente	T5S R10W	29
17	89.5	Avenue 64 E	Dateland Bridge	County of Maricopa	Horn	T6S R12W	25,30
18	81.2	Avenue 57 E	Power Distribution Line	WMIDD	Texas Hill	T7S R14W	11,12
19	78.2	Avenue 55 E	Dip Crossing	County of Yuma	Texas Hill	T7S R14W	15,16
20	74.4	Avenue 52 E	Dip Crossing	County of Yuma	Texas Hill	T7S R15W	25,30
21	74.4	Avenue 52 E	San Cristobal Wash	WMIDD	Texas Hill	T7S R15W	25,30
22	73.4	Avenue 51E	Power Distribution Line	WMIDD	Growler	T7S R15W	25,26
23	73.4	Avenue 51E	Unpaved road w/ culverts	County of Yuma	Growler	T7S R15W	25,26
24	72.2	Avenue 50	Drain Pipe undercrossing	WMIDD	Growler	T7S R15W	22,23
25	72.2	Avenue 50	Dip Crossing	County of Yuma	Growler	T7S R15W	22,23
26	70.8	Avenue 49 1/2 E	Drain Pipe Undercrossing	WMIDD	Growler	T7S R15W	22
27	70.8	Avenue 49 1/4 E	Growler Wash Confluence	WMIDD	Growler	T7S R15W	22
28	70.8	Avenue 49E	Mhwk Canal'Norton' siphon	WMIDD	Growler	T7S R15W	27,28
29	70.8	Avenue 49E	Power Distribution Line	WMIDD	Growler	T7S R15W	27,28
30	70.8	Avenue 49E	Dip Crossing	County of Yuma	Growler	T7S R15W	27,28
31	68.7	Ave 47E-47 1/4	Power Distribution Line	WMIDD	Growler	T7S R15W	29
32	68.7	Avenue 47E	Dip Crossing	County of Yuma	Growler	T7S R15W	29,30
33	66.0	Avenue 45E	Tyson Wash Floodway	WMIDD	Growler	T7S R16W	35,36
34	66.0	Avenue 45E	Avenue 45E bridge	County of Yuma	Growler	T7S R16W	35,36
35	65.0	Avenue 44E	Power Transmission Line	WMIDD	Roll	T7S R16 W	34,35
36	65.0	Avenue 44E	Dip Crossing	County of Yuma	Roll	T7SR16W	34,35
37	63.8	Ave 43 3/4 & 4th	Drain Pipe undercrossing	WMIDD	Roll	T7S R16W	3,34
38	63.8	Ave 43 3/4 & 4th	Dip Crossing	County of Yuma	Roll	T7S R16W	3,34
39	63.6	Avenue 43 1/2 E	Snyder Floodway	WMIDD	Roll	T7S R16W	3
40	63.1	Avenue 43E	Power Transmission Line	WMIDD	Roll	T7S R16W	3,4
41	63.1	Avenue 43E	Dip Crossing	County of Yuma	Roll	T7S R16W	3,4
42	62.2	Ave 42 1/4 & 5th1/2	Snyder Drain	WMIDD	Roll	T7S R16W	4,5
43	62.0	Ave 42 & 5th 1/2	Drain Pipe undercrossing	WMIDD	Roll	T8S R16W	4,5
44	62.0	Avenue 42 & 5th	Telephone Line	US West	Roll	T8S R16W	4,5
45	62.0	Avenue 42 & 5th	Power Distribution Line	WMIDD	Roll	T8S R16W	4,5
46	62.0	Avenue 42 & 5th	Dip Crossing	County of Yuma	Roll	T8S R16W	4,5
47	61.8	Avenue 41 3/4 E	Colfred Floodway	WMIDD	Tacna	T8S R16W	17
48	51.5	Avenue 40E	Telephone Line	US West	Tacna	T8S R16W	7,12
49	51.5	Avenue 40E	Power Distribution Line	WMIDD	Tacna	T8S R16W	7,12
50	51.5	Avenue 40E	Avenue 40E bridge	County of Yuma	Tacna	T8S R16W	7,12
51	50.6	Avenue 39 1/2 E	Dip Crossing	County of Yuma	Tacna	T8S R17W	13
52	50.4	Ave 39 1/4 E & 6th	Davidson Drain Crossing	WMIDD	Tacna	T8S R17W	13
53	50.2	Ave 39 1/2 E & 7th	Quigley Pond	Game & Fish	Tacna	T8S R17W	14,23
54	48.1	Avenue 38E	Power Distribution Line	WMIDD	Tacna	T8S R17W	22,23
55	48.1	Avenue 38E	Avenue 38E bridge	County of Yuma	Wellton Mesa	T8S R17W	22,23
56	46.9	Avenue 36 5/8 E	Coast to Coast Bridge	See Remarks	Wellton Mesa	T8S R17W	21
57	46.7	Avenue 36 1/2 E	Dip Crossing	County of Yuma	Wellton Mesa	T8S R17W	21

List of Crossings - Gillespie Dam to Colorado River (Continued)							
Xing No.	Distance to Colorado River, In Miles	Crossing	Type	Responsible Agency	USGS Quadrangle	Township Range	Section Number
58	46.7	Avenue 36 1/2 E	Telephone Cable	US West	Wellton Mesa	T8S R17W	21
59	46.7	Avenue 36 1/2 E	High Pressure Gas Line	EL Paso Natural Gas	Wellton Mesa	T8S R17W	21
60	46.7	Avenue 36 1/2 E	Fiber Optics Cable	MCI	Wellton Mesa	T8S R17W	21
61	46.7	Avenue 36 1/2 E	Petroleum Lines	SFPPL	Wellton Mesa	T8S R17W	21
62	46.7	Avenue 36 1/2 E	Signal Line	SPTC	Wellton Mesa	T8S R17W	21
63	46.7	Avenue 36 1/2 E	SPRR bridge	SPRR	Wellton Mesa	T8S R17W	21
64	46.2	Avenue 36E	Power Transmission Line	WMIDD	Wellton Mesa	T8S R17W	20,21
65	43.6	Avenue 34	WM Main Conv. Channel	WMIDD	Wellton Mesa	T8S R18W	13,18
66	43.6	Avenue 34	Power Distribution Line	WMIDD	Wellton Mesa	T8S R18W	13,18
67	43.6	Avenue 34	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	13,18
68	42.9	Ave 33 1/4 & 6th	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	12,13
69	42.9	Ave 33 1/4 & 6th	Telephone Line	US West	Wellton Mesa	T8S R18W	12,13
70	42.7	Ave 33 & 6 1/2	Power Distribution Line	WMIDD	Wellton Mesa	T8SR18W	12,13
71	42.6	Ave 33 1/2	Radium Hot Spr. Fldwy	WMIDD	Wellton Mesa	T8S R18W	11,12
72	42.5	Avenue 33	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	11,12
73	40.7	Avenue 31 & 6 1/2	Wellton Dike No. 2 Floodway	WMIDD	Wellton Mesa	T8S R18W	15,16
74	40.7	Ave 31 & 6 1/2	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	15,16
75	40.7	Ave 31 & 6 1/2	Wellton Canal Siphon	WMIDD	Wellton Mesa	T8S R18W	15,16
76	40.2	Ave 31 1/2 & 7 1/2	Drain Pipe undercrossing	WMIDD	Wellton Mesa	T8S R18W	16
77	32.5	Ave 31 & 8th	Dip Crossing	County of Yuma	Wellton Mesa	T8S R18W	22,27
78	32.0	Ave 31 & 8 1/2	Drain Pipe undercrossing	WMIDD	Wellton Mesa	T8S R18W	21,22
79	30.0	Avenue 30E	Drain Pipe undercrossing	WMIDD	Wellton Mesa	T8S R18W	28
80	30.0	Avenue 30E	Telephone Line	US West	Wellton Mesa	T8S R18W	28
81	30.0	Avenue 30E	Power Distribution Line	WMIDD	Wellton Mesa	T8S R18W	28
82	30.0	Avenue 30E	Avenue 30E bridge	County of Yuma	Wellton Mesa	T8S R18W	28
83	29.5	Ave 29 1/2 & 8th	Sump Pipeline		Wellton	T8S R18W	20,29
84	29.0	Avenue 29E	Power Distribution Line	WMIDD	Wellton	T8S R18W	20,29
85	29.0	Avenue 29E	Drain Pipe undercrossing	WMIDD	Wellton	T8S R18W	20,29
86	29.0	Avenue 29E	Dip Crossing	County of Yuma	Wellton	T8S R18W	19,20,29,30
87	26.8	Avenue 27 E	Dip Crossing	County of Yuma	Wellton	T8S R19W	25,26
88	26.3	Ave 26 1/2 & 9th	Coyote Wash Confluence	WMIDD	Wellton	T8S R19W	26,35
89	26.3	Ave 26 1/2 & 9th	Gas Line	SWG	Wellton	T8S R19W	26,35
90	25.8	Ave 26 - 26 1/2 E	Power Transmission Line	WMIDD	Wellton	T8S R19W	35
91	25.5	Ave 25 3/4 E & 10th	Power Transmission Line	WMIDD	Wellton	T8S R19W	34,3
92	25.5	Ave 25 3/4 E & 10th	Dip Crossing	County of Yuma	Wellton	T8S R19W	34,3
93	25.3	Avenue 25 1/2 E	WM Main Conv. Channel	WMIDD	Wellton	T9S R19W	3
94	24.8	Avenue 25E	Dip Crossing	County of Yuma	Wellton	T9S R19W	3,4
95	24.3	Ave 24 3/4 E	Grout Wash	WMIDD	Wellton	T9S R19W	4
96	24.1	Ave 24 1/2 E & 10th	Power Transmission Line	WMIDD	Wellton	T9S R19W	4,33
97	24.1	Ave 24 1/2 E & 10th	Dip Crossing	County of Yuma	Wellton	T9S R19W	4,33
98	23.3	Avenue 24 E	Power Distribution Line	WMIDD	Wellton	T8S R19W	32,33
99	23.3	Avenue 24 E	Telephone Line	US West	Wellton	T8S R19W	32,33
100	23.3	Avenue 24 E	Dip Crossing	County of Yuma	Wellton	T8S R19W	32,33
101	22.8	Avenue 23 E	WM Conv. Channel Siphon	WMIDD	Wellton	T8S R19W	32
102	22.8	Avenue 23 E	Gomez Wash	WMIDD	Wellton	T8S R19W	32
103	22.4	Avenue 22 1/2 E	Ligurta Wash	WMIDD	Ligurta	T8S R19W	31
104	22.2	Avenue 22E	Dip Crossing	County of Yuma	Ligurta	T8S R20W	31,36
105	21.5	Avenue 21 1/2 E	Red Top Wash	WMIDD	Ligurta	T8S R20W	36
106	20.2	Avenue 20 1/2 E	Unnamed Floodway	WMIDD	Ligurta	T8S R20W	35
107	19.7	Avenue 20E	Avenue 20E bridge	County of Yuma	Ligurta	T8S R20W	34,35
108	18.5	Avenue 18 3/4 E	Floodway Chute over WM	WMIDD	Ligurta	T8S R20W	34
109	19.0	Avenue 19 1/2 E	Dome Canal Siphon	WMIDD	Ligurta	T8S R20W	27,34
110	18.5	Avenue 18 3/4 E	Floodway Chute over WM	WMIDD	Ligurta	T8S R20W	16
111	18.3	Ave 18 3/4 E & 8th	Power Distribution Lines	WMIDD	Ligurta	T8S R20W	21,28
112	18.3	Ave 18 3/4 E & 8th	Dip Crossing	County of Yuma	Ligurta	T8S R20W	21,28
113	18.0	Avenue 18 1/4 E	Dome Floodway	WMIDD	Ligurta	T8S R20W	16
114	17.8	Avenue 18E	Power Transmission Line	WMIDD	Ligurta	T8S R20W	16,17

List of Crossings - Gillespie Dam to Colorado River (Continued)							
Xing No.	**Distance to Colorado River, In Miles**	**Crossing**	**Type**	**Responsible Agency**	**USGS Quadrangle**	**Township Range**	**Section Number**
115	14.5	Avenue 17E & 5th	Dip Crossing	County of Yuma	Dome	T8S R20W	7,8
116	14.5	Avenue 17E & 5th	Power Distribution Line	WMIDD	Dome	T8S R20W	7,8
117	14.2	Avenue 17E	Dome Wash	WMIDD	Dome	T8S R20W	5
118	12.8	Avenue 16E	Dip Crossing	County of Yuma	Dome	T8S R20W	6
119	12.8	Avenue 16E	Telephone Line	US West	Dome	T8S R20W	6
120	12.5	Avenue 15 1/2 E	Floodway Chute over WM	WMIDD	Dome	T8SR21W	1
121	12.1	Avenue 15E	Power Distribution Line	WMIDD	Dome	T8S R20W	1
122	11.5	Avenue 14-15 3/4	High Voltage Line	WAPA	Dome	T8S R21W	1
123	11.1	Avenue 14E	Floodway Chute over WM	WMIDD	Laguna Dam	T8S R21W	2
124	11.1	Avenue 14E	WM Main Conv. Channel	WMIDD	Laguna Dam	T8S R21W	2
125	10.8	Avenue 13 3/4 E	Castle Dome Floodway	WMIDD	Laguna Dam	T8S R21W	2,3
126	10.5	Avenue 13 1/2 E	Power Transmission Line	WMIDD	Laguna Dam	T8S R21W	3
127	10.5	Avenue 13 1/2 E	High Voltage Line	WAPA	Laguna Dam	T8S R21W	3
128	10.4	Avenue 13 3/8 E	High Pressure Gas Line	El Paso Gas Line	Laguna Dam	T8S R21W	3
129	9.8	Avenue 12 1/4	U.S. Highway 95	ADOT	Laguna Dam	T8S R21W	4
130	9.1	Avenue 12 1/2 E	McPhaul Bridge	See Remarks	Laguna Dam	T8S R21W	4
131	8.6	Avenue 12E	High Pressure Gas Line	El Paso Natural Gas	Laguna Dam	T8S R21W	8,9
132	7.4	Avenue 11 1/4	Gila Gravity Main Canal	WMIDD	Fortuna	T8SR21W	8,17
133	7.4	Avenue 11 1/4	Ave 11 1/4 Dip Crossing	County of Yuma	Fortuna	T8S R21W	8,17
134	2.0	Avenue 7E	Avenue 7E bridge	County of Yuma	Yuma East	T8S R22W	21,22

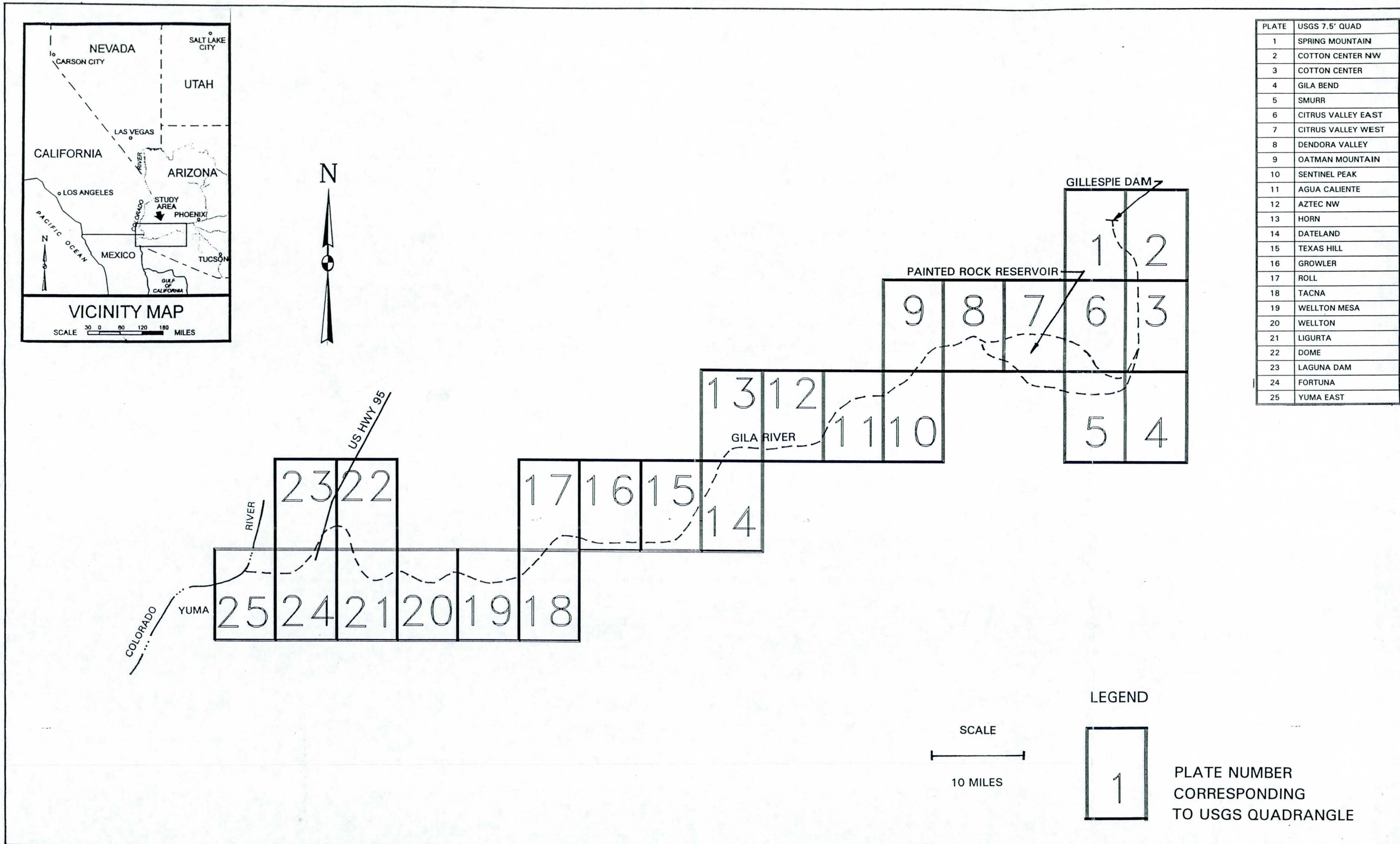


PLATE	USGS 7.5' QUAD
1	SPRING MOUNTAIN
2	COTTON CENTER NW
3	COTTON CENTER
4	GILA BEND
5	SMURR
6	CITRUS VALLEY EAST
7	CITRUS VALLEY WEST
8	DENDORA VALLEY
9	OATMAN MOUNTAIN
10	SENTINEL PEAK
11	AGUA CALIENTE
12	AZTEC NW
13	HORN
14	DATELAND
15	TEXAS HILL
16	GROWLER
17	ROLL
18	TACNA
19	WELLTON MESA
20	WELLTON
21	LIGURTA
22	DOME
23	LAGUNA DAM
24	FORTUNA
25	YUMA EAST

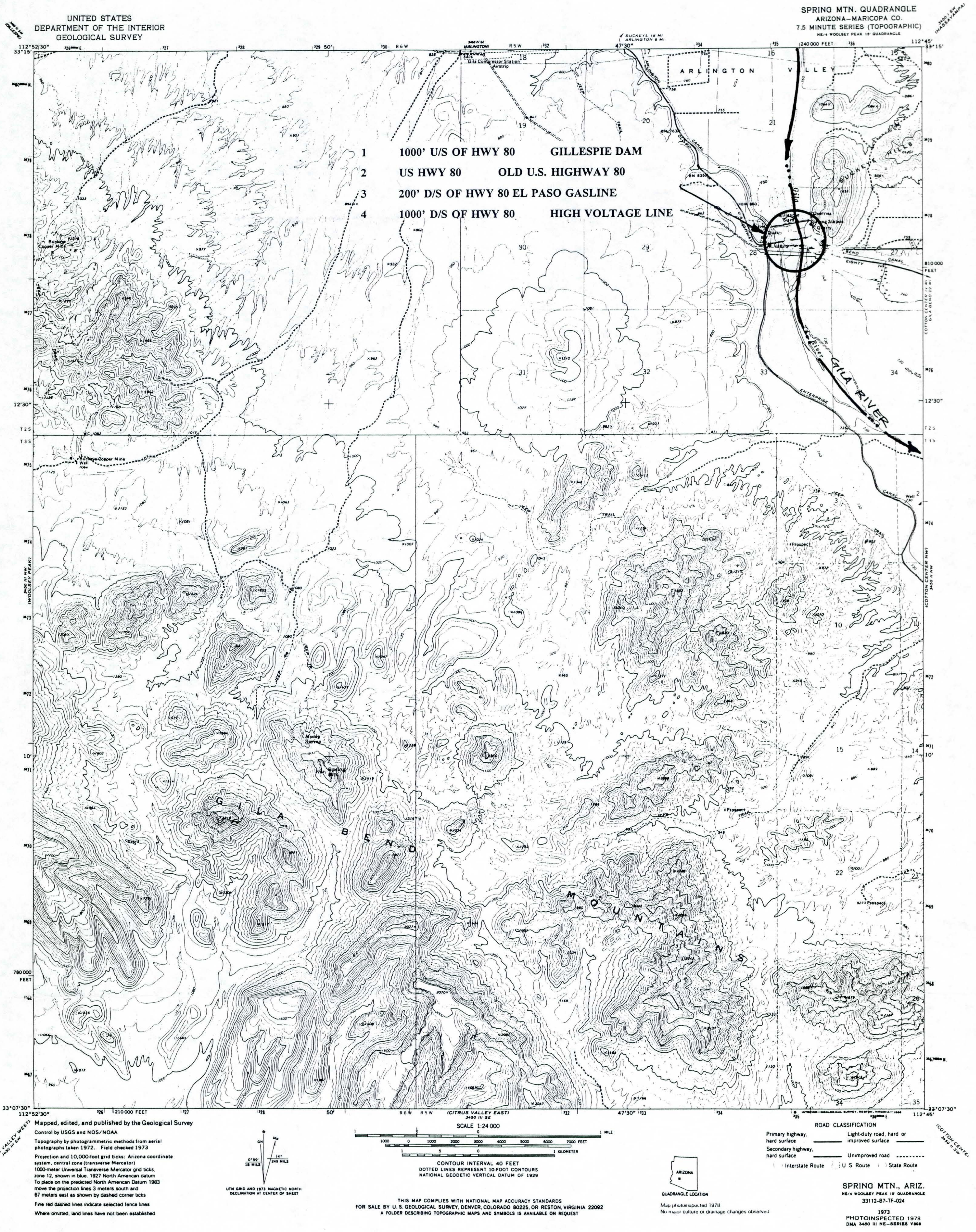

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SPRING MTN. QUADRANGLE
ARIZONA–MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
1 1000' U/S OF HWY 80 GILLESPIE DAM
2 US HWY 80 OLD U.S. HIGHWAY 80
3 200' D/S OF HWY 80 EL PASO GASLINE
4 1000' D/S OF HWY 80 HIGH VOLTAGE LINE
ARLINGTON VALLEY
GILA RIVER
GILA BEND MOUNTAINS
Gila Compressor Station
Airstrip
ENTERPRISE
CANAL
Buckeye Copper Mine
Woody Spring
Spring Mtn
Prospect
TRAIL
Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA
Topography by photogrammetric methods from aerial photographs taken 1972. Field checked 1973
Projection and 10,000-foot grid ticks: Arizona coordinate system, central zone (transverse Mercator)
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American datum
To place on the predicted North American Datum 1983 move the projection lines 3 meters south and 67 meters east as shown by dashed corner ticks
Fine red dashed lines indicate selected fence lines
Where omitted, land lines have not been established
UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
QUADRANGLE LOCATION
Map photoinspected 1978
No major culture or drainage changes observed
ROAD CLASSIFICATION
Primary highway, hard surface
Light-duty road, hard or improved surface
Secondary highway, hard surface
Unimproved road
Interstate Route
U S Route
State Route
SPRING MTN., ARIZ.
NE/4 WOOLSEY PEAK 15' QUADRANGLE
33112-B7-TF-024
1973
PHOTOINSPECTED 1978
DMA 3450 III NE–SERIES V898

PLATE 1

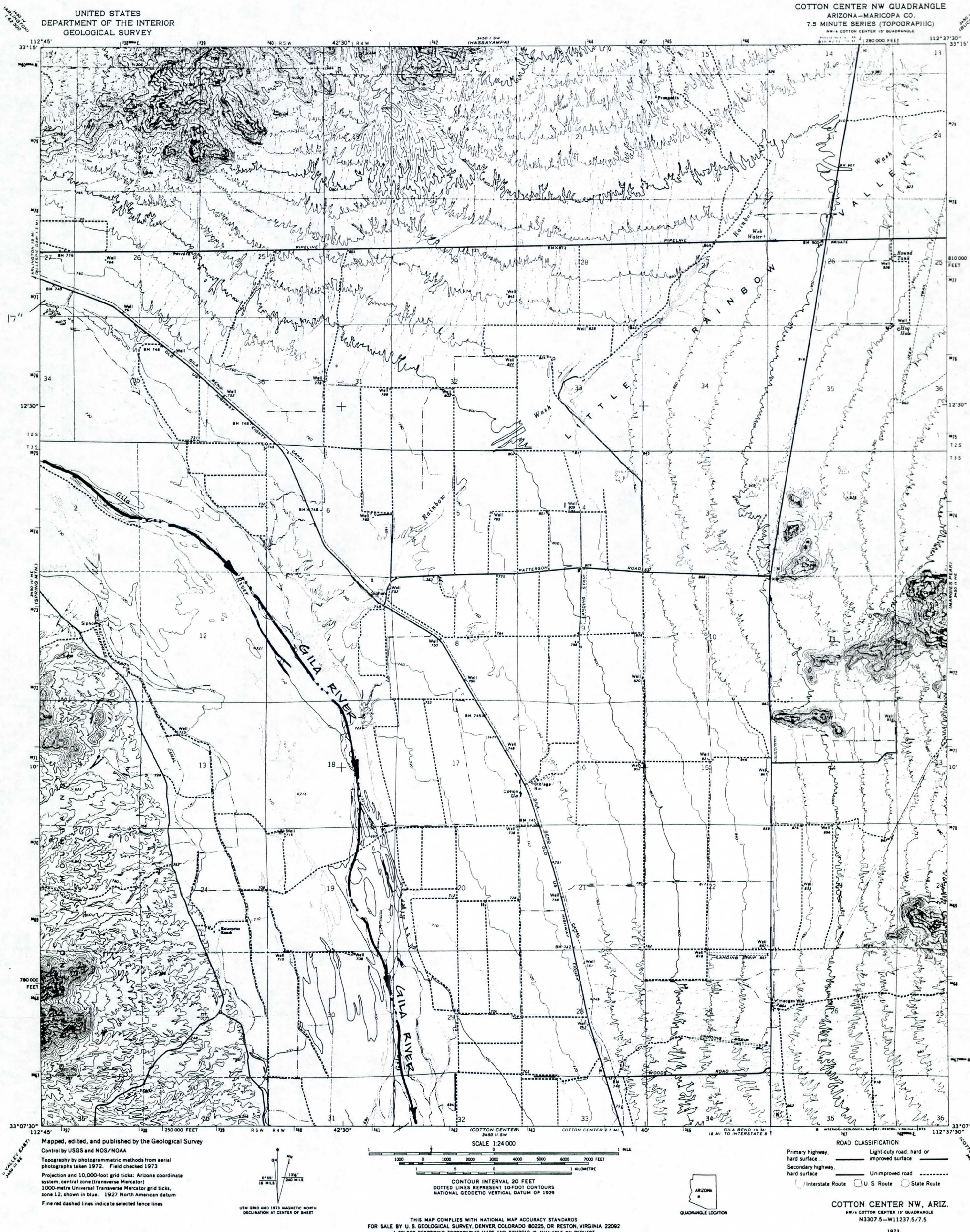

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
COTTON CENTER NW QUADRANGLE
ARIZONA–MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
NW/4 COTTON CENTER 15' QUADRANGLE
GILA RIVER
LITTLE RAINBOW VALLEY
PATTERSON ROAD
WOODS ROAD
PIPELINE
Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA
Topography by photogrammetric methods from aerial photographs taken 1972. Field checked 1973
Projection and 10,000-foot grid ticks: Arizona coordinate system, central zone (transverse Mercator)
1000-metre Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American datum
Fine red dashed lines indicate selected fence lines
UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
QUADRANGLE LOCATION
ROAD CLASSIFICATION
Primary highway, hard surface
Light-duty road, hard or improved surface
Secondary highway, hard surface
Unimproved road
Interstate Route
U. S. Route
State Route
COTTON CENTER NW, ARIZ.
NW/4 COTTON CENTER 15' QUADRANGLE
N3307.5—W11237.5/7.5
1973
AMS 3450 II NW—SERIES V898

PLATE 2

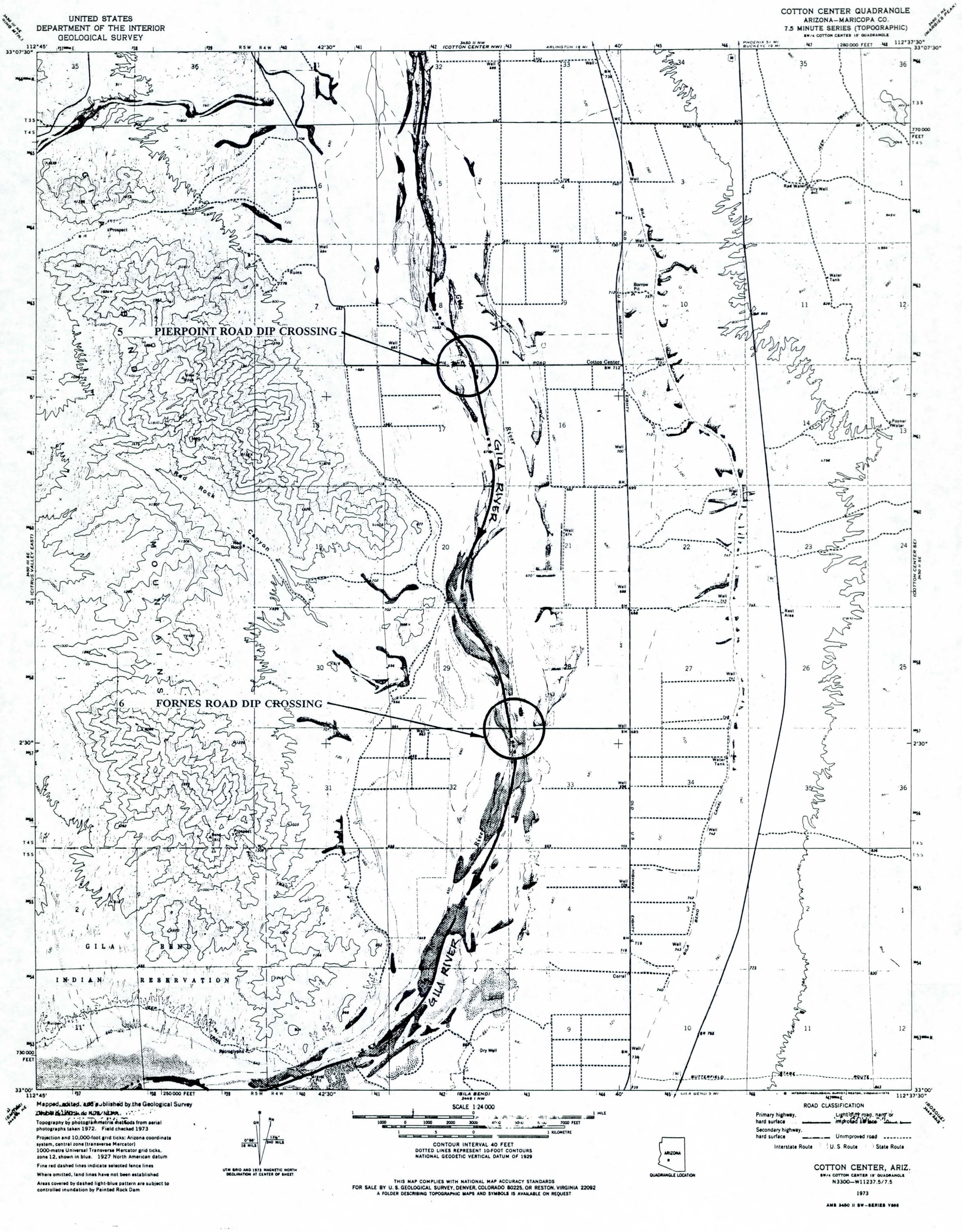

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
COTTON CENTER QUADRANGLE
ARIZONA—MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
PIERPOINT ROAD DIP CROSSING
FORNES ROAD DIP CROSSING
GILA RIVER
GILA RIVER
Red Rock Canyon
GILA BEND INDIAN RESERVATION
Cotton Center
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
QUADRANGLE LOCATION
COTTON CENTER, ARIZ.
1973

PLATE 3

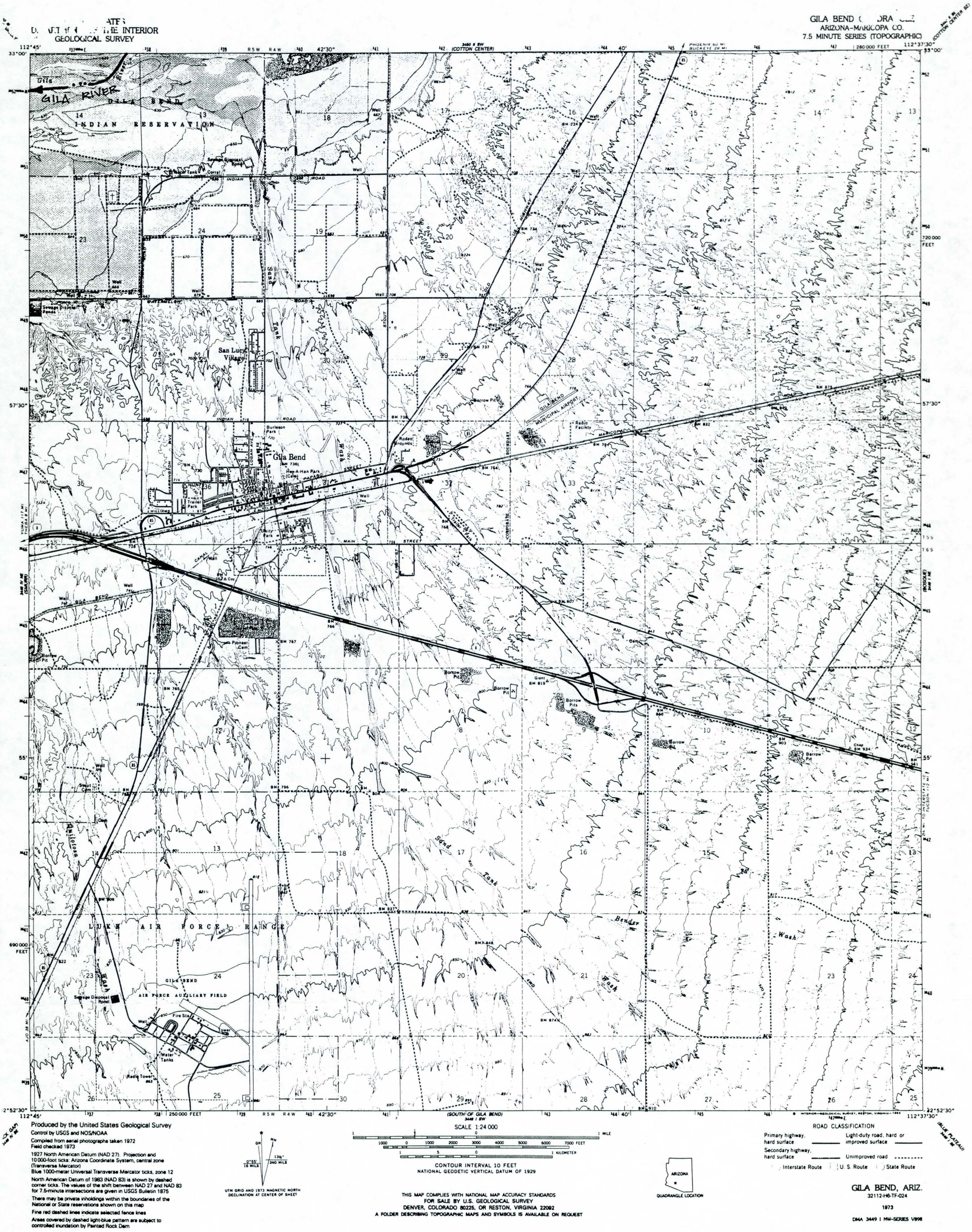

GEOLOGICAL SURVEY
GILA BEND
ARIZONA-MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
GILA RIVER
GILA BEND INDIAN RESERVATION
San Lucy Village
Gila Bend
MUNICIPAL AIRPORT
LUKE AIR FORCE RANGE
GILA BEND AIR FORCE AUXILIARY FIELD
Sand Tank
Bender Wash
Produced by the United States Geological Survey
Control by USGS and NOS/NOAA
Compiled from aerial photographs taken 1972
Field checked 1973
1927 North American Datum (NAD 27). Projection and 10 000-foot ticks: Arizona Coordinate System, central zone (Transverse Mercator)
Blue 1000-meter Universal Transverse Mercator ticks, zone 12
North American Datum of 1983 (NAD 83) is shown by dashed corner ticks. The values of the shift between NAD 27 and NAD 83 for 7.5-minute intersections are given in USGS Bulletin 1875
There may be private inholdings within the boundaries of the National or State reservations shown on this map
Fine red dashed lines indicate selected fence lines
Areas covered by dashed light-blue pattern are subject to controlled inundation by Painted Rock Dam
UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY
DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
QUADRANGLE LOCATION
ROAD CLASSIFICATION
Primary highway, hard surface
Light-duty road, hard or improved surface
Secondary highway, hard surface
Unimproved road
Interstate Route
U. S. Route
State Route
GILA BEND, ARIZ.
32112-H6-TF-024
1973
DMA 3449 I NW-SERIES V898

PLATE 4

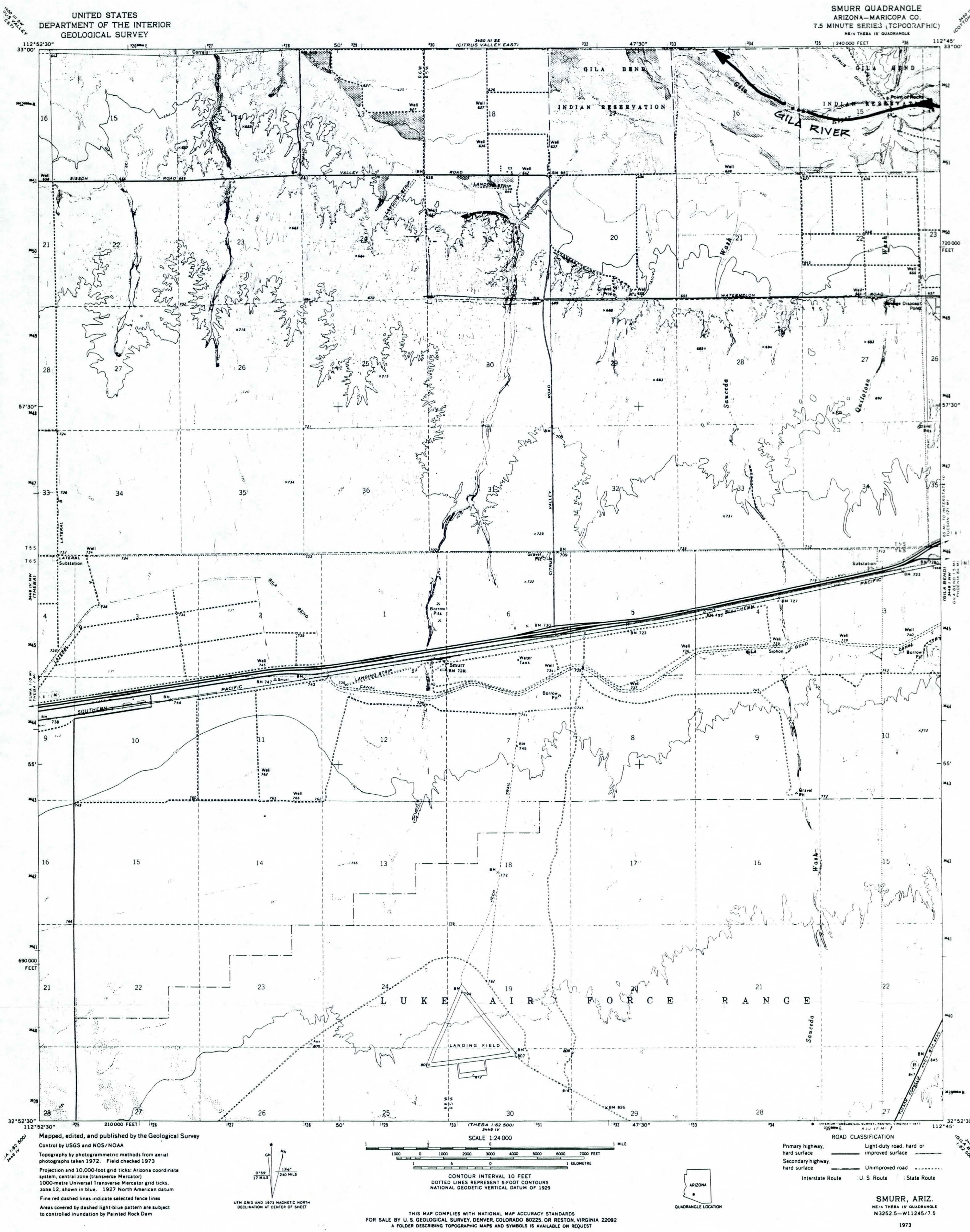

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SMURR QUADRANGLE
ARIZONA–MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
GILA RIVER
GILA BEND INDIAN RESERVATION
LUKE AIR FORCE RANGE
LANDING FIELD
Mapped, edited, and published by the Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
SMURR, ARIZ.
N3252.5—W11245/7.5
1973

PLATE 5

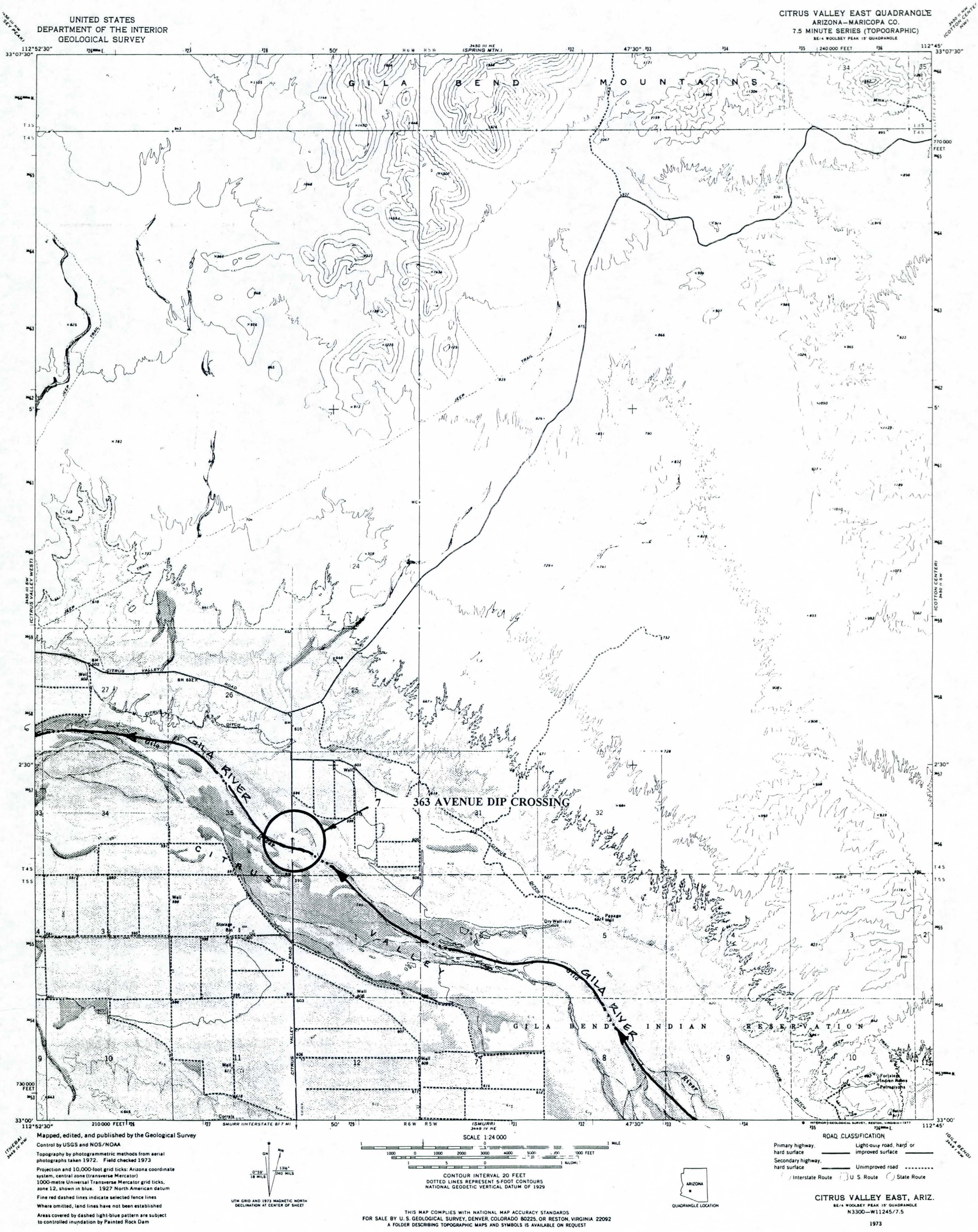

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CITRUS VALLEY EAST QUADRANGLE
ARIZONA—MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
GILA BEND MOUNTAINS
363 AVENUE DIP CROSSING
GILA RIVER
CITRUS VALLEY
GILA BEND INDIAN RESERVATION
Mapped, edited, and published by the Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
CITRUS VALLEY EAST, ARIZ.
N3300—W11245/7.5
1973

PLATE 6

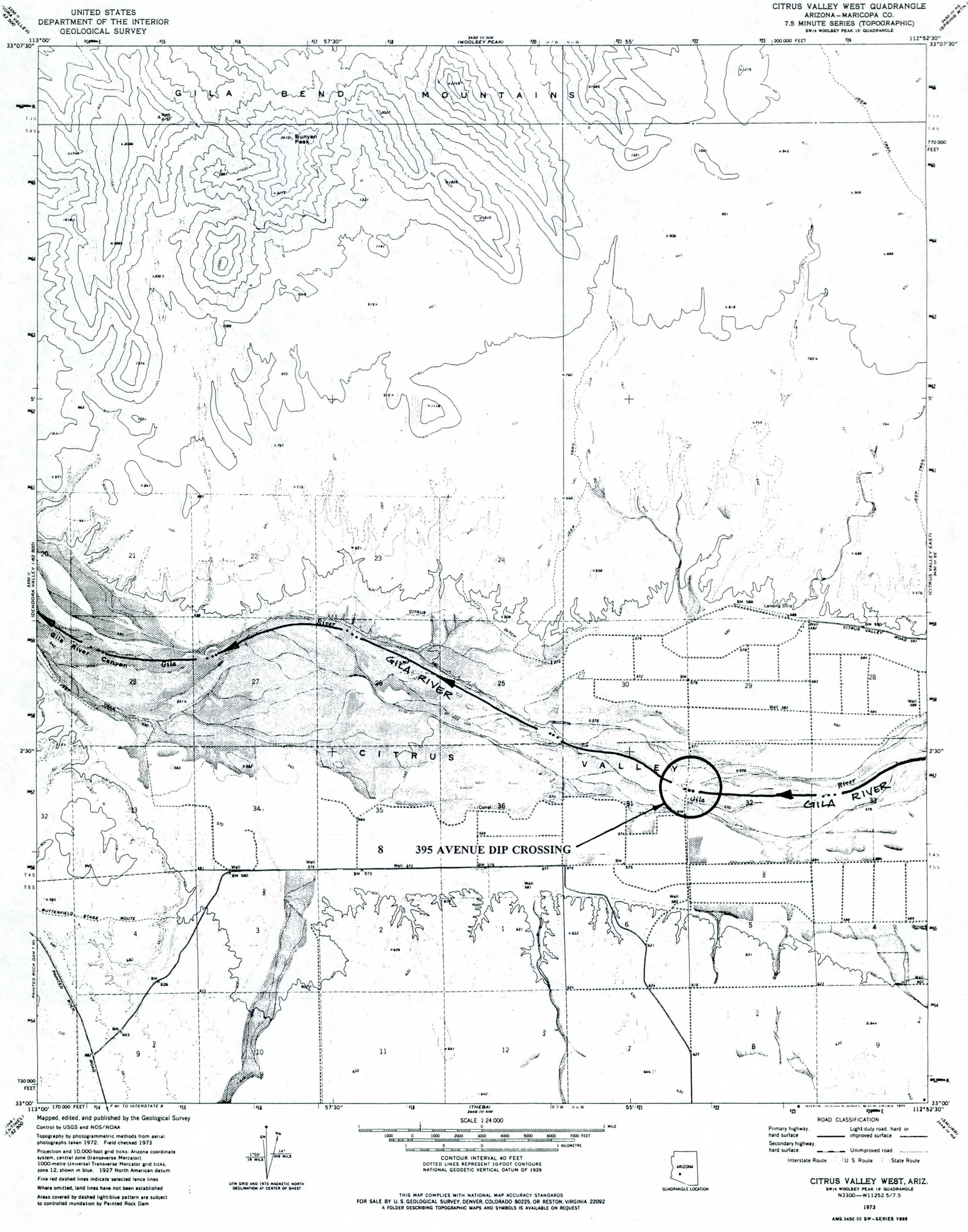
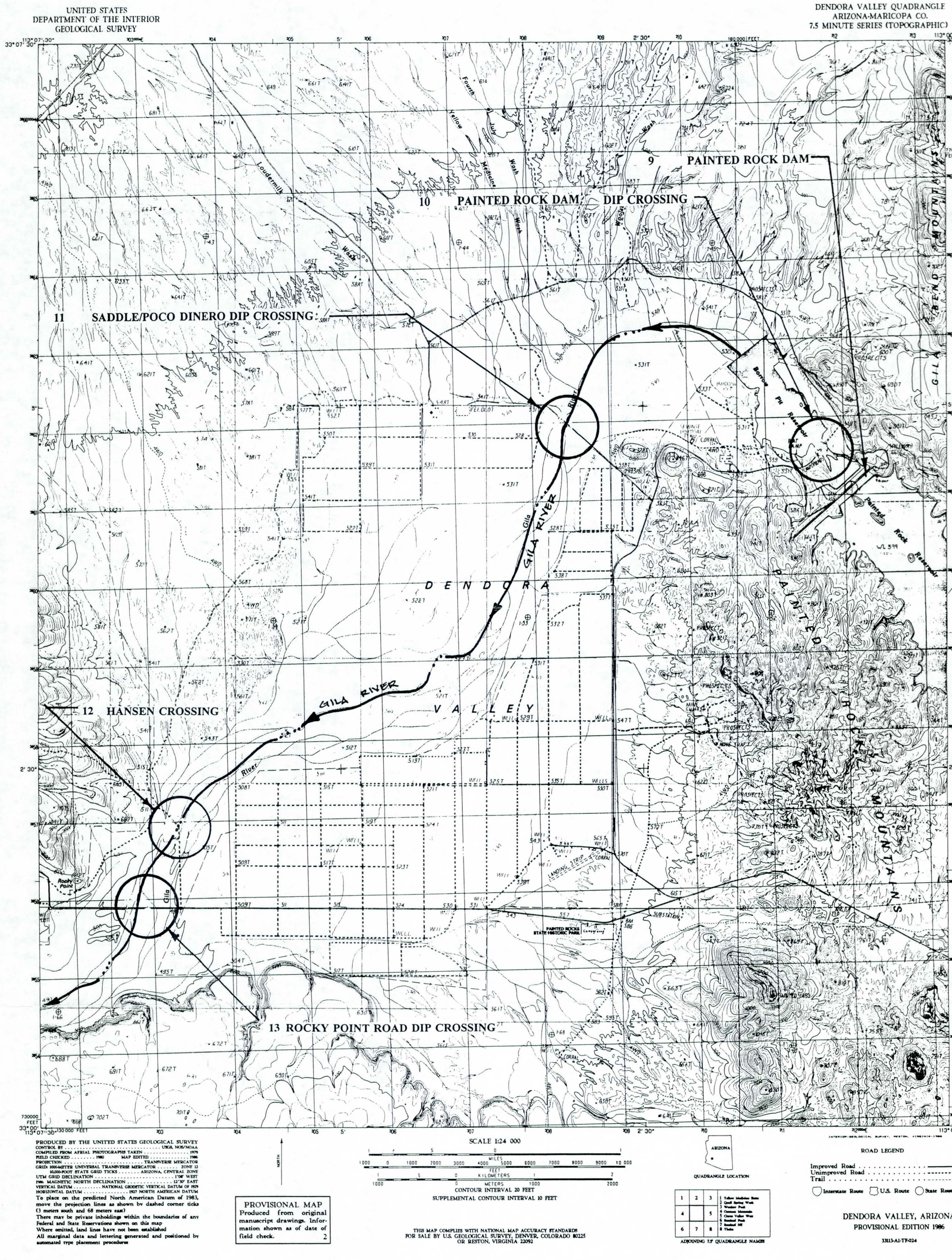

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CITRUS VALLEY WEST QUADRANGLE
ARIZONA–MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 WOOLSEY PEAK 15' QUADRANGLE
GILA BEND MOUNTAINS
Bunyan Peak
GILA RIVER
Gila River Canyon
CITRUS VALLEY
395 AVENUE DIP CROSSING
BUTTERFIELD STAGE ROUTE
Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA
Topography by photogrammetric methods from aerial photographs taken 1972. Field checked 1973
Projection and 10,000-foot grid ticks: Arizona coordinate system, central zone (transverse Mercator)
1000-metre Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American datum
Fine red dashed lines indicate selected fence lines
Where omitted, land lines have not been established
Areas covered by dashed light-blue pattern are subject to controlled inundation by Painted Rock Dam
UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
QUADRANGLE LOCATION
ROAD CLASSIFICATION
Primary highway, hard surface
Light-duty road, hard or improved surface
Secondary highway, hard surface
Unimproved road
Interstate Route
U. S. Route
State Route
CITRUS VALLEY WEST, ARIZ.
SW/4 WOOLSEY PEAK 15' QUADRANGLE
N3300—W11252.5/7.5
1973
AMS 3450 III SW—SERIES V898

PLATE 7

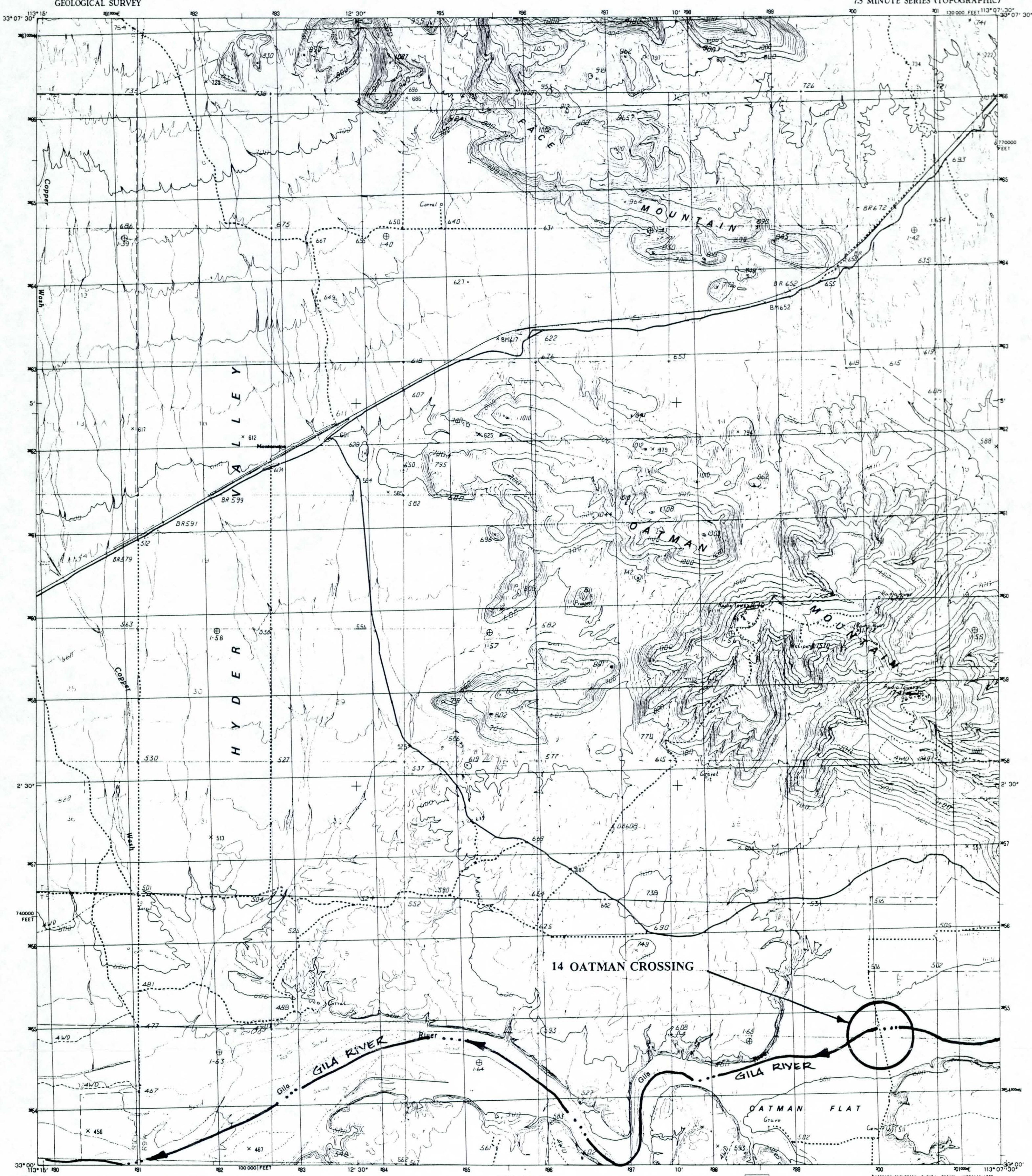


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
DENDORA VALLEY QUADRANGLE
ARIZONA-MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
9 PAINTED ROCK DAM
10 PAINTED ROCK DAM DIP CROSSING
11 SADDLE/POCO DINERO DIP CROSSING
12 HANSEN CROSSING
13 ROCKY POINT ROAD DIP CROSSING
GILA RIVER
DENDORA
VALLEY
PAINTED ROCK MOUNTAINS
GILA BEND MOUNTAINS
Painted Rock Reservoir
Loudermilk Wash
Yellow Medicine Wash
Borrow Pit Reservoir
PAINTED ROCKS STATE HISTORIC PARK
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
SUPPLEMENTAL CONTOUR INTERVAL 10 FEET
PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check.
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092
ROAD LEGEND
Improved Road
Unimproved Road
Trail
Interstate Route
U.S. Route
State Route
QUADRANGLE LOCATION
ADJOINING 7.5' QUADRANGLE NAMES
DENDORA VALLEY, ARIZONA
PROVISIONAL EDITION 1986

PLATE 8

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OATMAN MOUNTAIN QUADRANGLE
ARIZONA-MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY .... USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1979
FIELD CHECKED .... 1980 MAP EDITED 1986
PROJECTION .... TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR .... ZONE 12
10,000-FOOT STATE GRID TICKS .... ARIZONA, CENTRAL ZONE
UTM GRID DECLINATION .... 1°12' WEST
1986 MAGNETIC NORTH DECLINATION .... 12°30' EAST
VERTICAL DATUM .... NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM .... 1927 NORTH AMERICAN DATUM

To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks (3 meters south and 68 meters east)

There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map

Where omitted, land lines have not been established

All marginal data and lettering generated and positioned by automated type placement procedures

NORTH

SCALE 1:24 000

MILES — FEET — KILOMETERS — METERS

CONTOUR INTERVAL 20 FEET

PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check. 2

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092

ARIZONA

QUADRANGLE LOCATION

ADJOINING 7.5' QUADRANGLE NAMES

ROAD LEGEND

Improved Road
Unimproved Road
Trail

Interstate Route — U.S. Route — State Route

OATMAN MOUNTAIN, ARIZONA
PROVISIONAL EDITION 1986

33113-A2-TF-024

PLATE 9

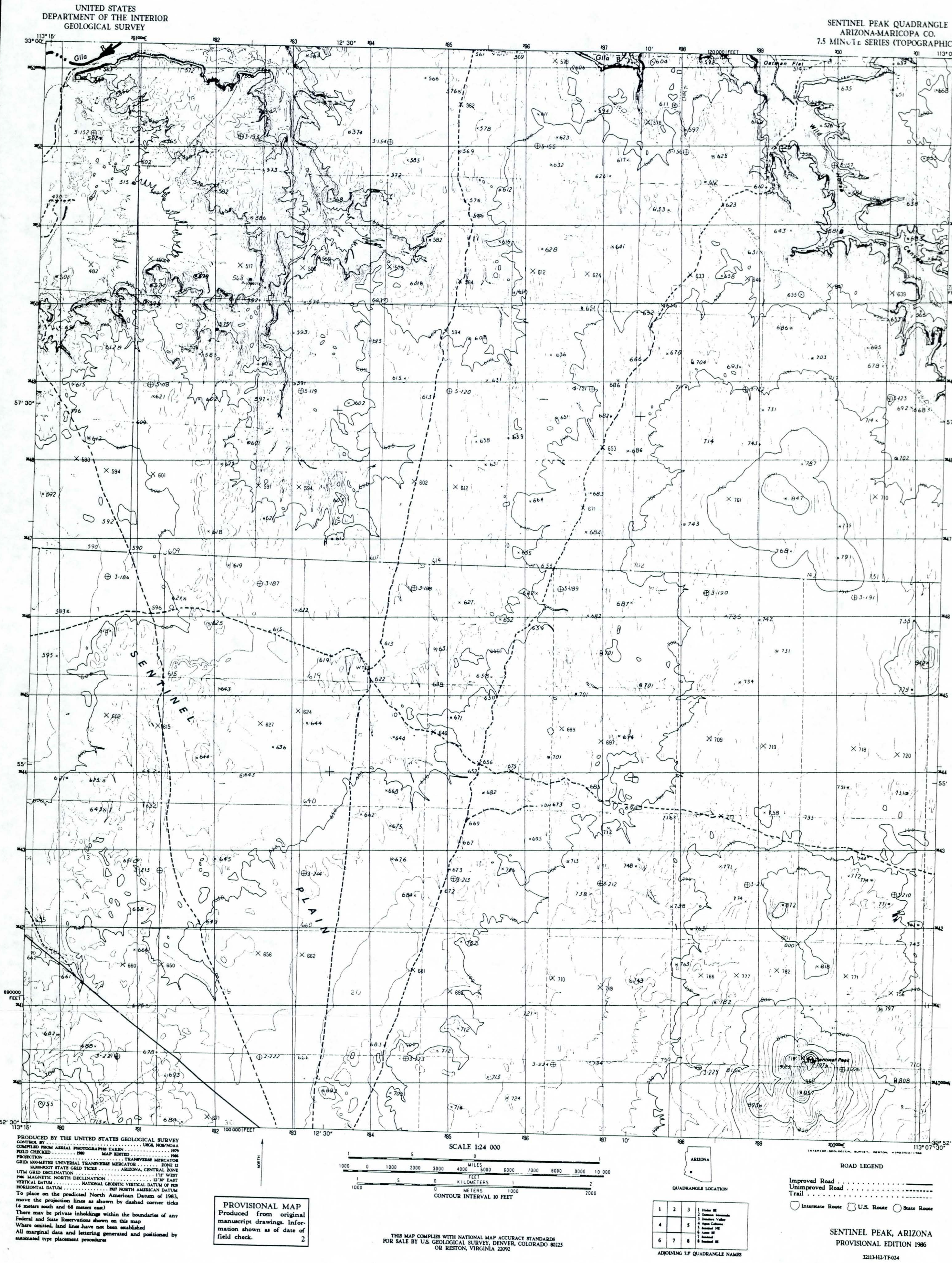
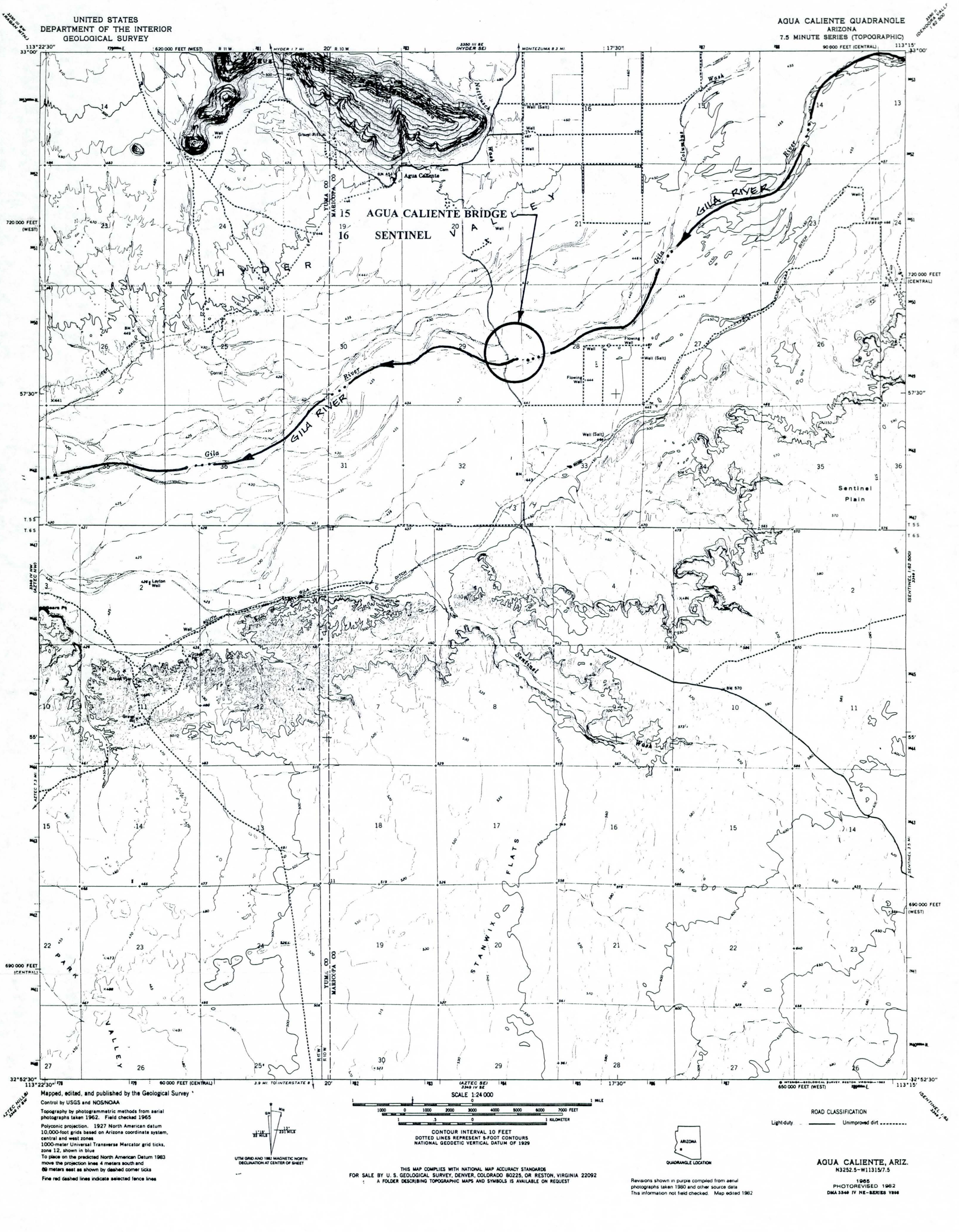

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SENTINEL PEAK QUADRANGLE
ARIZONA-MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
Gila
Oatman Flat
SENTINEL
PLAIN
Sentinel Peak
PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY .... USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1979
FIELD CHECKED .... 1980 MAP EDITED 1986
PROJECTION .... TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR .... ZONE 12
10,000-FOOT STATE GRID TICKS .... ARIZONA, CENTRAL ZONE
UTM GRID DECLINATION .... 1°11' WEST
1986 MAGNETIC NORTH DECLINATION .... 12°30' EAST
VERTICAL DATUM .... NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM .... 1927 NORTH AMERICAN DATUM
To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks (4 meters south and 68 meters east)
There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map
Where omitted, land lines have not been established
All marginal data and lettering generated and positioned by automated type placement procedures
NORTH
PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check. 2
SCALE 1:24 000
MILES
FEET
KILOMETERS
METERS
CONTOUR INTERVAL 10 FEET
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092
ARIZONA
QUADRANGLE LOCATION
ADJOINING 7.5' QUADRANGLE NAMES
ROAD LEGEND
Improved Road
Unimproved Road
Trail
Interstate Route
U.S. Route
State Route
SENTINEL PEAK, ARIZONA
PROVISIONAL EDITION 1986
32113-H2-TF-024

PLATE 10



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
AGUA CALIENTE QUADRANGLE
ARIZONA
7.5 MINUTE SERIES (TOPOGRAPHIC)
AGUA CALIENTE BRIDGE
SENTINEL
GILA RIVER
Gila River
Agua Caliente
HYDER VALLEY
Sentinel Plain
STANWIX FLATS
PARK VALLEY
Sentinel Wash
Columbus Wash
YUMA CO
MARICOPA CO
Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA
Topography by photogrammetric methods from aerial photographs taken 1962. Field checked 1965
Polyconic projection. 1927 North American datum
10,000-foot grids based on Arizona coordinate system, central and west zones
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue
To place on the predicted North American Datum 1983 move the projection lines 4 meters south and 69 meters east as shown by dashed corner ticks
Fine red dashed lines indicate selected fence lines
UTM GRID AND 1982 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
Light-duty
Unimproved dirt
QUADRANGLE LOCATION
Revisions shown in purple compiled from aerial photographs taken 1980 and other source data
This information not field checked. Map edited 1982
AGUA CALIENTE, ARIZ.
N3252.5—W11315/7.5
1965
PHOTOREVISED 1982
DMA 3349 IV NE—SERIES V898

PLATE 11

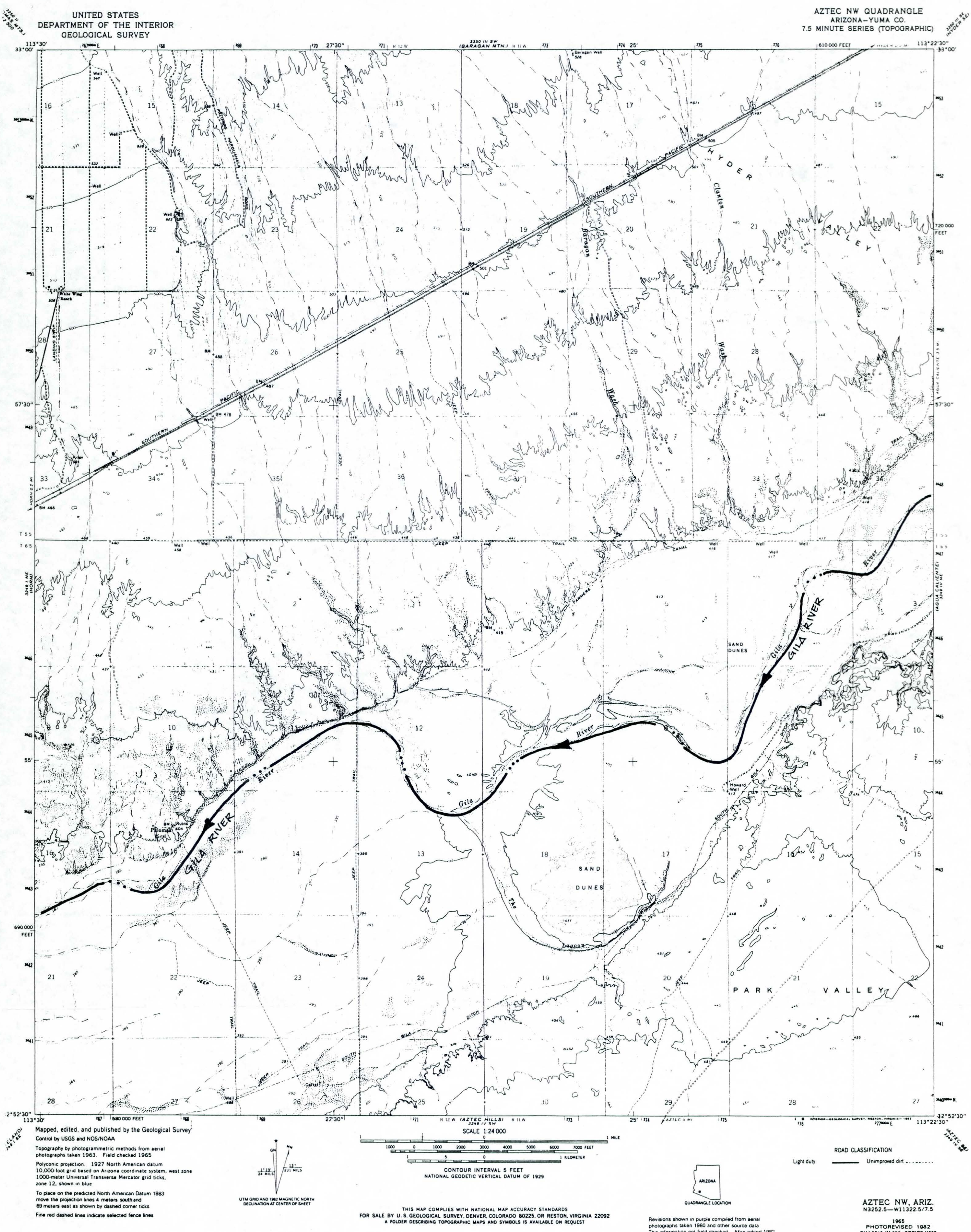

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
AZTEC NW QUADRANGLE
ARIZONA–YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
(BARAGAN MTN.)
HYDER VALLEY
SOUTHERN PACIFIC
Clanton Wash
Baragan Wash
GILA RIVER
Gila River
SAND DUNES
The Lagoon
PARK VALLEY
Paloma
Howard Well
(AZTEC HILLS)
Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA
Topography by photogrammetric methods from aerial photographs taken 1963. Field checked 1965
Polyconic projection. 1927 North American datum
10,000-foot grid based on Arizona coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue
To place on the predicted North American Datum 1983 move the projection lines 4 meters south and 69 meters east as shown by dashed corner ticks
Fine red dashed lines indicate selected fence lines
UTM GRID AND 1982 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ARIZONA
QUADRANGLE LOCATION
Revisions shown in purple compiled from aerial photographs taken 1980 and other source data
This information not field checked. Map edited 1982
ROAD CLASSIFICATION
Light-duty
Unimproved dirt
AZTEC NW, ARIZ.
N3252.5—W11322.5/7.5
1965
PHOTOREVISED 1982
DMA 3349 IV NW—SERIES V898

PLATE 12

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HORN QUADRANGLE
ARIZONA–YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 STOVAL 15' QUADRANGLE

Mapped, edited, and published by the Geological Survey
Control by USGS and USC&GS
Topography by photogrammetric methods from aerial photographs taken 1962 and 1963. Field checked 1965
Polyconic projection. 1927 North American datum
10,000-foot grid based on Arizona coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue
Fine red dashed lines indicate selected fence lines

UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Light-duty ——— Unimproved dirt - - - - - -

HORN, ARIZ.
NE/4 STOVAL 15' QUADRANGLE
N3252.5—W11330/7.5
1965
AMS 3249 I NE–SERIES V898

PLATE 13

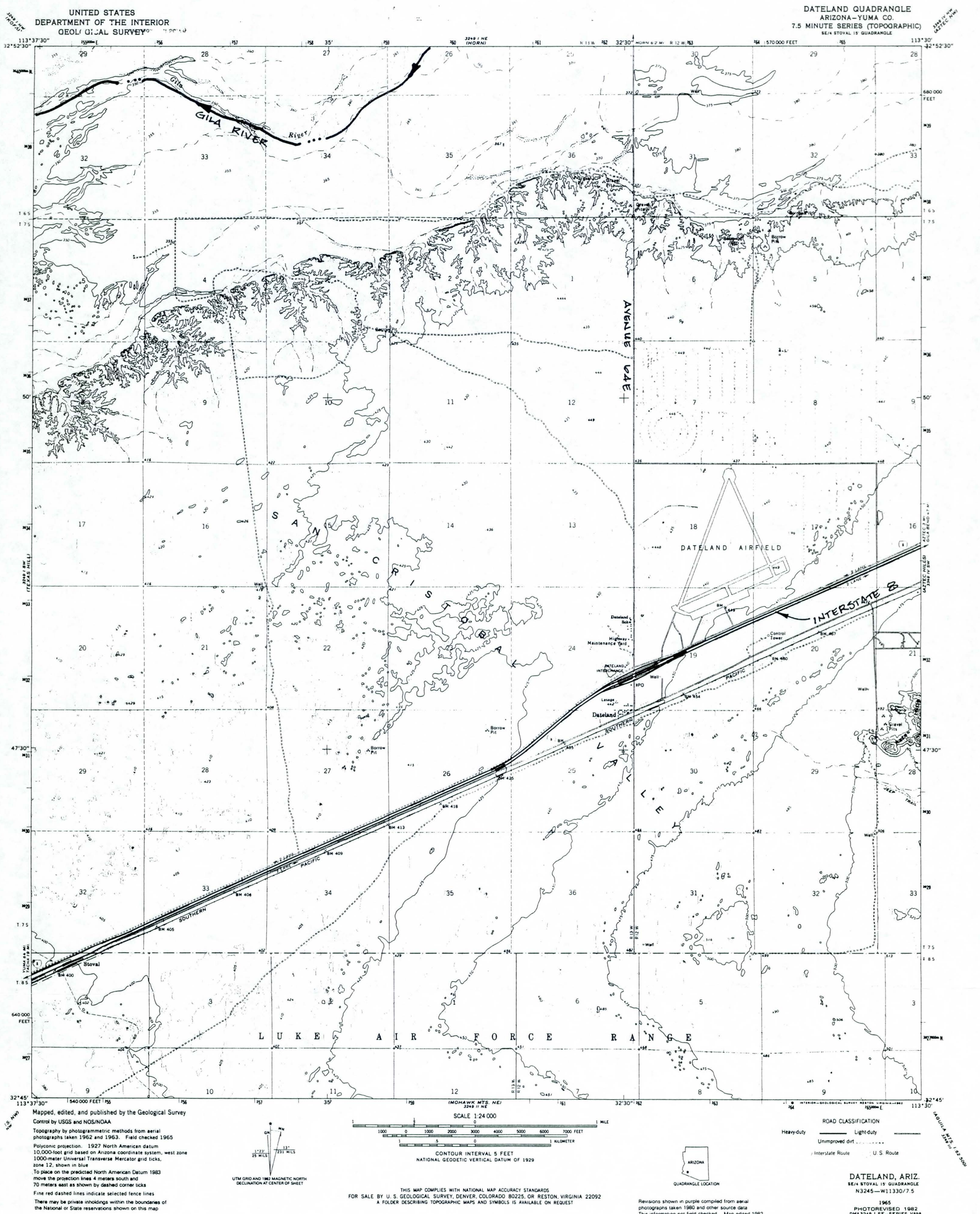

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
DATELAND QUADRANGLE
ARIZONA–YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SE/4 STOVAL 15' QUADRANGLE
GILA RIVER
Gila
River
AVENUE 64E
SAN CRISTOBAL VALLEY
DATELAND AIRFIELD
INTERSTATE 8
SOUTHERN PACIFIC
Dateland
Stoval
LUKE AIR FORCE RANGE
Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA
Topography by photogrammetric methods from aerial photographs taken 1962 and 1963. Field checked 1965
Polyconic projection. 1927 North American datum
10,000-foot grid based on Arizona coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue
To place on the predicted North American Datum 1983 move the projection lines 4 meters south and 70 meters east as shown by dashed corner ticks
Fine red dashed lines indicate selected fence lines
There may be private inholdings within the boundaries of the National or State reservations shown on this map
UTM GRID AND 1982 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ARIZONA
QUADRANGLE LOCATION
Revisions shown in purple compiled from aerial photographs taken 1980 and other source data
This information not field checked. Map edited 1982
ROAD CLASSIFICATION
Heavy-duty
Light-duty
Unimproved dirt
Interstate Route
U. S. Route
DATELAND, ARIZ.
SE/4 STOVAL 15' QUADRANGLE
N3245—W11330/7.5
1965
PHOTOREVISED 1982
DMA 3249 I SE—SERIES V898

PLATE 14

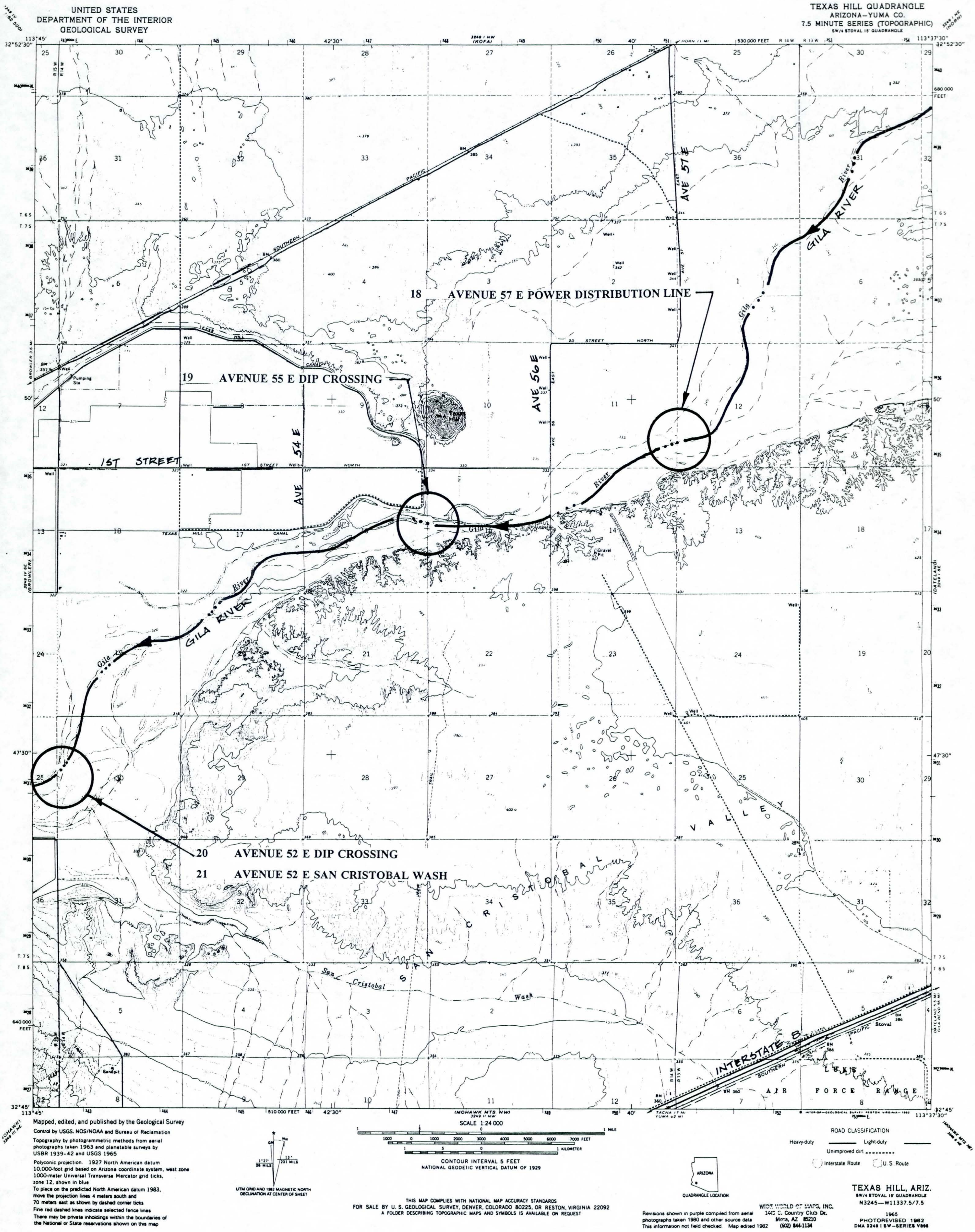

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
TEXAS HILL QUADRANGLE
ARIZONA–YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 STOVAL 15' QUADRANGLE
18 AVENUE 57 E POWER DISTRIBUTION LINE
19 AVENUE 55 E DIP CROSSING
20 AVENUE 52 E DIP CROSSING
21 AVENUE 52 E SAN CRISTOBAL WASH
AVE 57 E
AVE 56 E
AVE 54 E
1ST STREET
GILA RIVER
SAN CRISTOBAL VALLEY
INTERSTATE 8
Mapped, edited, and published by the Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
TEXAS HILL, ARIZ.
SW/4 STOVAL 15' QUADRANGLE
N3245—W11337.5/7.5
1965
PHOTOREVISED 1982
DMA 3249 I SW—SERIES V898

PLATE 15

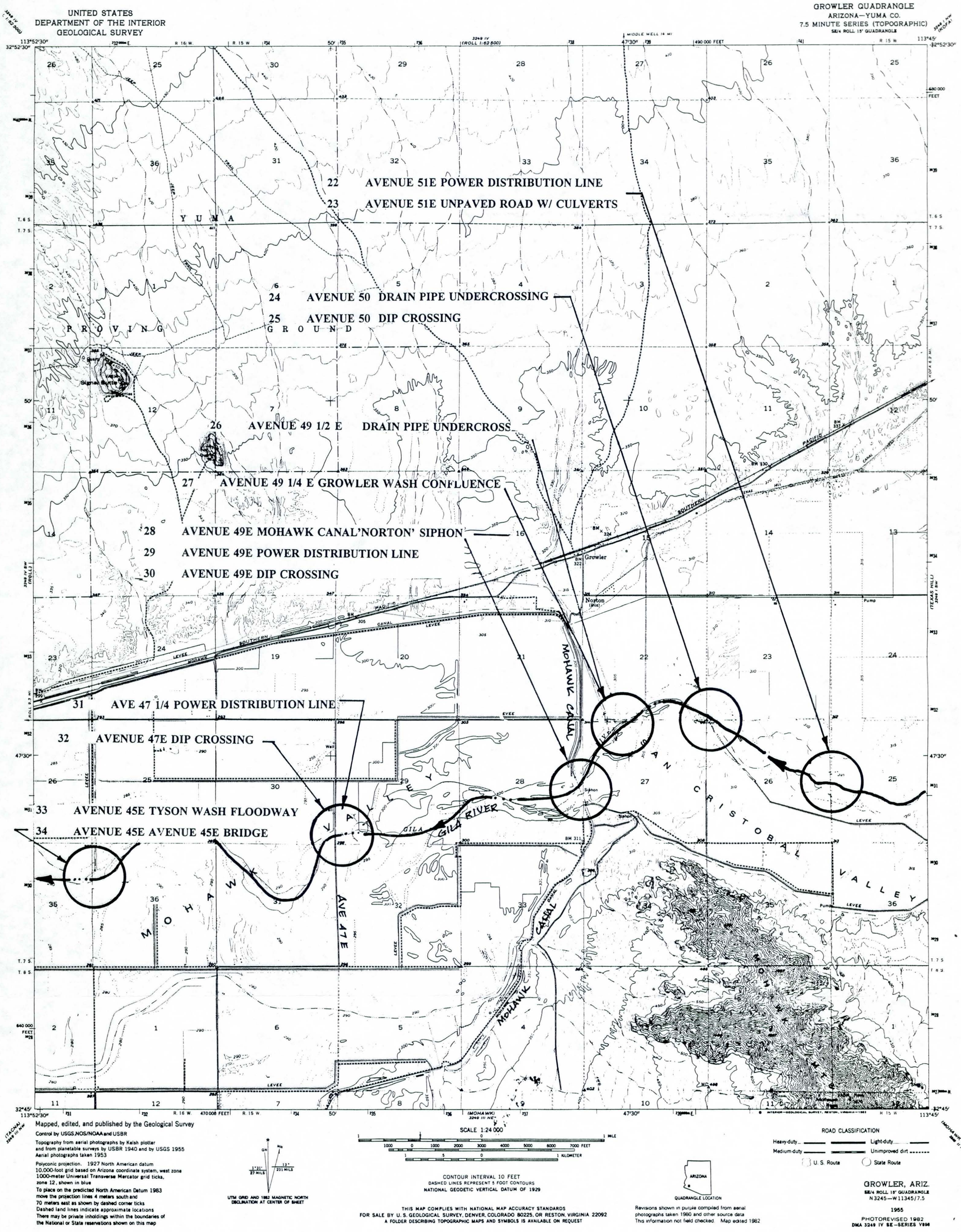
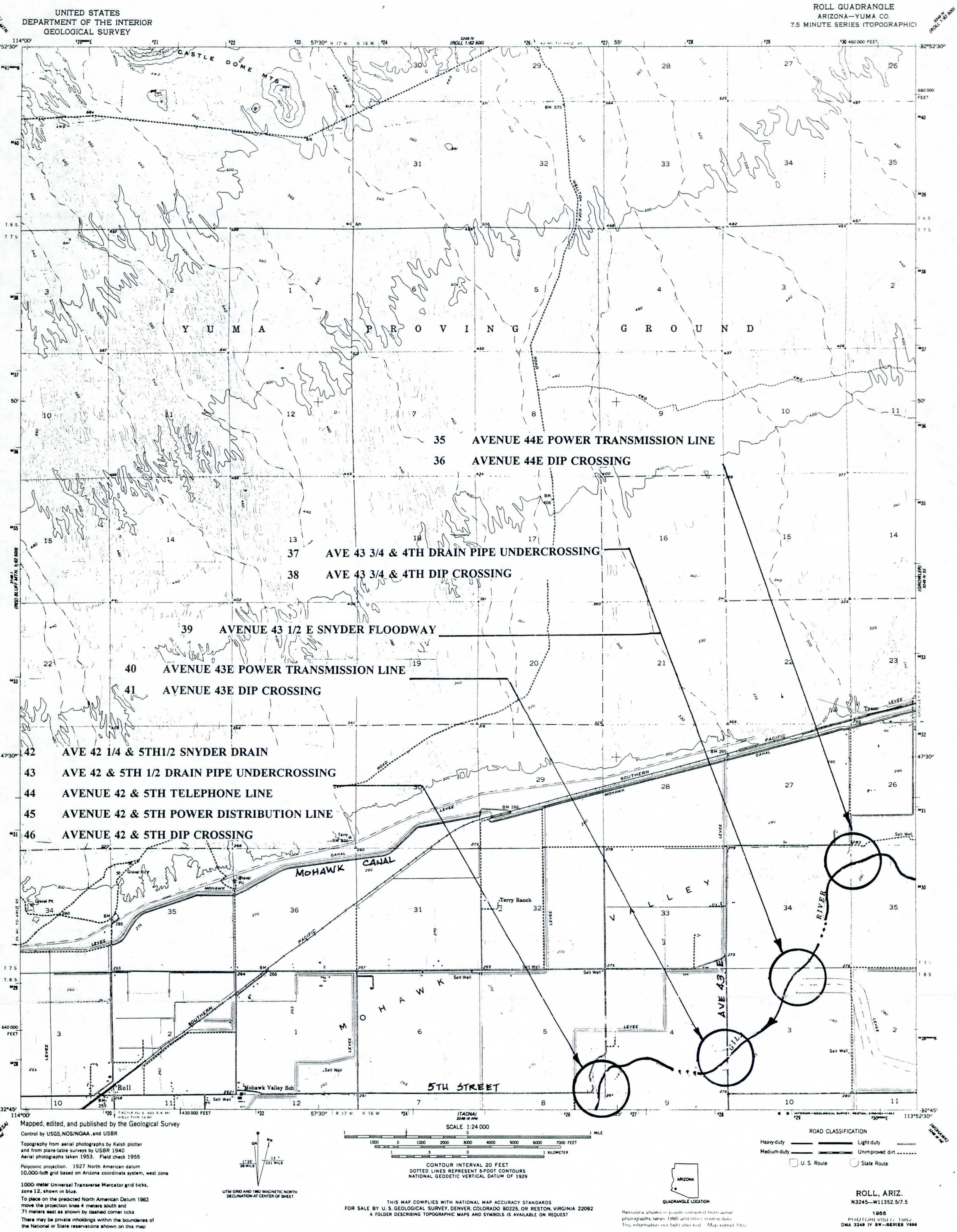

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
GROWLER QUADRANGLE
ARIZONA—YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
22 AVENUE 51E POWER DISTRIBUTION LINE
23 AVENUE 51E UNPAVED ROAD W/ CULVERTS
24 AVENUE 50 DRAIN PIPE UNDERCROSSING
25 AVENUE 50 DIP CROSSING
26 AVENUE 49 1/2 E DRAIN PIPE UNDERCROSS
27 AVENUE 49 1/4 E GROWLER WASH CONFLUENCE
28 AVENUE 49E MOHAWK CANAL'NORTON' SIPHON
29 AVENUE 49E POWER DISTRIBUTION LINE
30 AVENUE 49E DIP CROSSING
31 AVE 47 1/4 POWER DISTRIBUTION LINE
32 AVENUE 47E DIP CROSSING
33 AVENUE 45E TYSON WASH FLOODWAY
34 AVENUE 45E AVENUE 45E BRIDGE
YUMA
PROVING GROUND
MOHAWK CANAL
GILA RIVER
AVE 47E
MOHAWK VALLEY
SAN CRISTOBAL VALLEY
Growler
Norton
Signal Butte
SOUTHERN PACIFIC
Mapped, edited, and published by the Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
DASHED LINES REPRESENT 5 FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
GROWLER, ARIZ.
N3245—W11345/7.5
1955
PHOTOREVISED 1982

PLATE 16



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
ROLL QUADRANGLE
ARIZONA—YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
CASTLE DOME MTS
Y U M A P R O V I N G G R O U N D
35 AVENUE 44E POWER TRANSMISSION LINE
36 AVENUE 44E DIP CROSSING
37 AVE 43 3/4 & 4TH DRAIN PIPE UNDERCROSSING
38 AVE 43 3/4 & 4TH DIP CROSSING
39 AVENUE 43 1/2 E SNYDER FLOODWAY
40 AVENUE 43E POWER TRANSMISSION LINE
41 AVENUE 43E DIP CROSSING
42 AVE 42 1/4 & 5TH1/2 SNYDER DRAIN
43 AVE 42 & 5TH 1/2 DRAIN PIPE UNDERCROSSING
44 AVENUE 42 & 5TH TELEPHONE LINE
45 AVENUE 42 & 5TH POWER DISTRIBUTION LINE
46 AVENUE 42 & 5TH DIP CROSSING
MOHAWK CANAL
SOUTHERN PACIFIC
M O H A W K V A L L E Y
GILA RIVER
AVE 43 E
5TH STREET
Terry Ranch
Mohawk Valley Sch
Roll
Tyson
Mapped, edited, and published by the Geological Survey
Control by USGS, NOS/NOAA, and USBR
Topography from aerial photographs by Kelsh plotter and from plane-table surveys by USBR 1940
Aerial photographs taken 1953. Field check 1955
Polyconic projection. 1927 North American datum
10,000-foot grid based on Arizona coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue.
To place on the predicted North American Datum 1983 move the projection lines 4 meters south and 71 meters east as shown by dashed corner ticks
There may be private inholdings within the boundaries of the National or State reservations shown on this map
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
QUADRANGLE LOCATION
ROAD CLASSIFICATION
Heavy-duty
Medium-duty
Light-duty
Unimproved dirt
U. S. Route
State Route
ROLL, ARIZ.
N3245—W11352.5/7.5
1955
PHOTOREVISED 1982
DMA 3249 IV SW—SERIES V898

PLATE 17

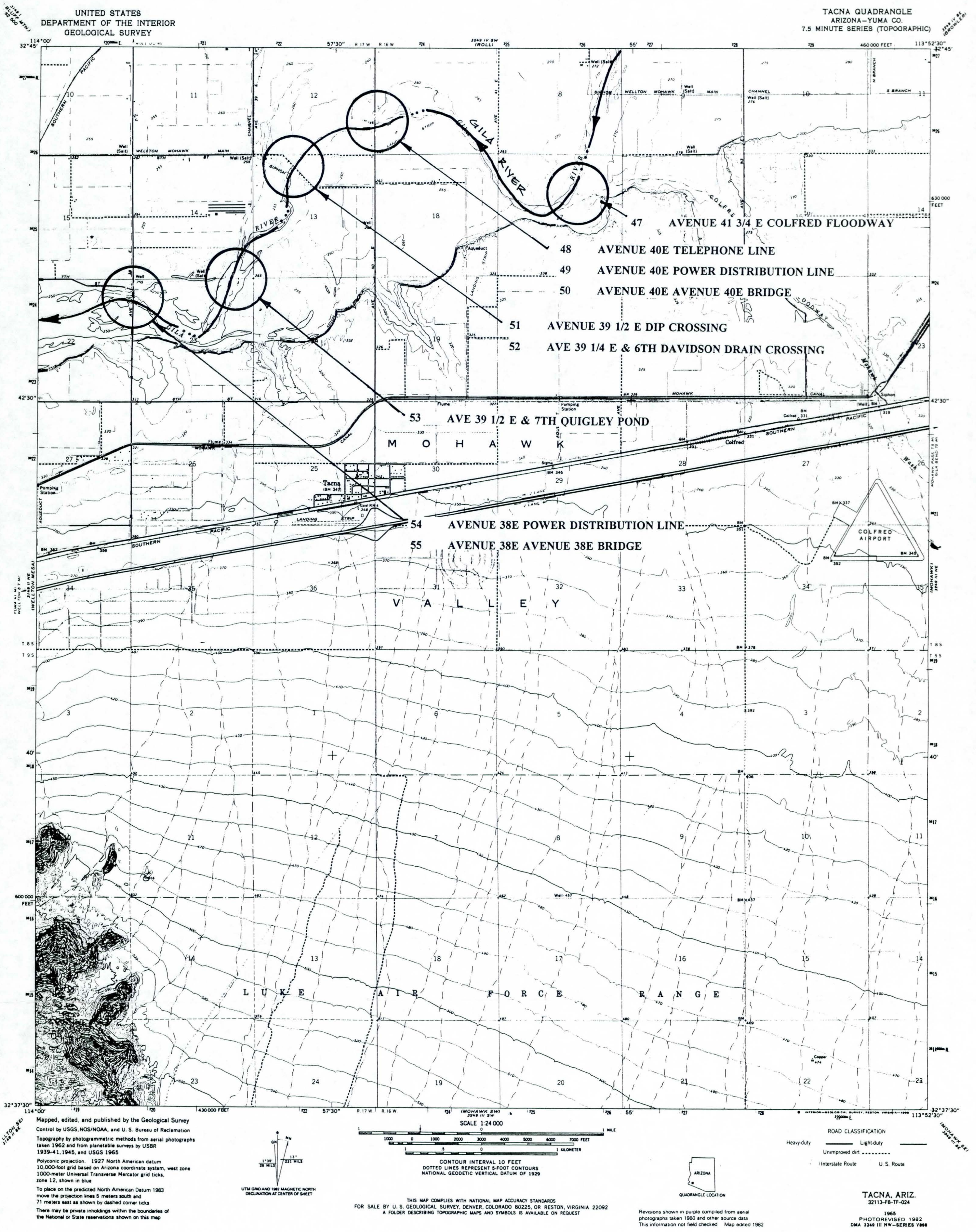

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
TACNA QUADRANGLE
ARIZONA–YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
47 AVENUE 41 3/4 E COLFRED FLOODWAY
48 AVENUE 40E TELEPHONE LINE
49 AVENUE 40E POWER DISTRIBUTION LINE
50 AVENUE 40E AVENUE 40E BRIDGE
51 AVENUE 39 1/2 E DIP CROSSING
52 AVE 39 1/4 E & 6TH DAVIDSON DRAIN CROSSING
53 AVE 39 1/2 E & 7TH QUIGLEY POND
54 AVENUE 38E POWER DISTRIBUTION LINE
55 AVENUE 38E AVENUE 38E BRIDGE
GILA RIVER
M O H A W K
V A L L E Y
L U K E A I R F O R C E R A N G E
Tacna
COLFRED AIRPORT
Mapped, edited, and published by the Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
TACNA, ARIZ.
1965
PHOTOREVISED 1982

PLATE 18

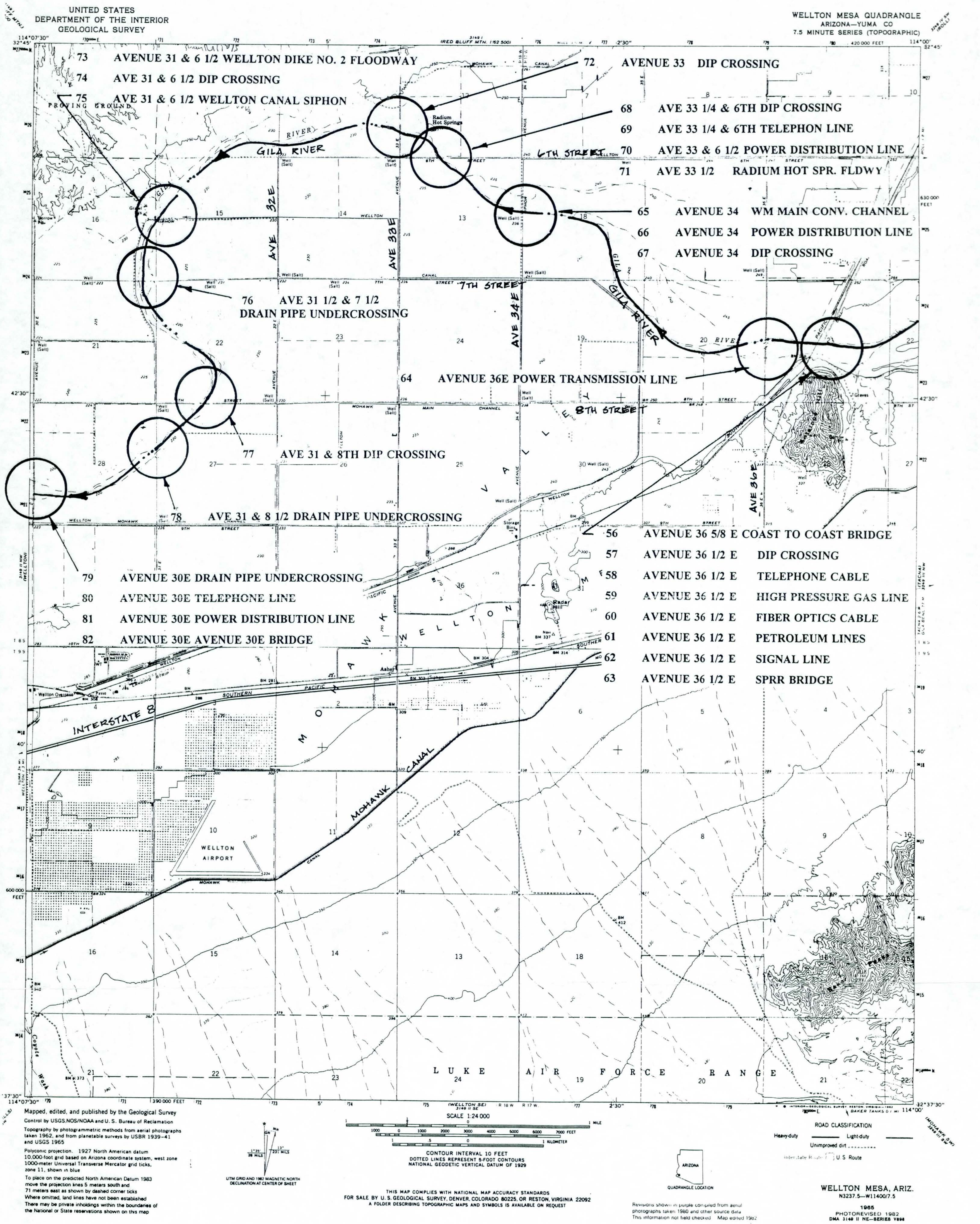

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WELLTON MESA QUADRANGLE
ARIZONA—YUMA CO
7.5 MINUTE SERIES (TOPOGRAPHIC)
73 AVENUE 31 & 6 1/2 WELLTON DIKE NO. 2 FLOODWAY
74 AVE 31 & 6 1/2 DIP CROSSING
75 AVE 31 & 6 1/2 WELLTON CANAL SIPHON
72 AVENUE 33 DIP CROSSING
68 AVE 33 1/4 & 6TH DIP CROSSING
69 AVE 33 1/4 & 6TH TELEPHON LINE
70 AVE 33 & 6 1/2 POWER DISTRIBUTION LINE
71 AVE 33 1/2 RADIUM HOT SPR. FLDWY
65 AVENUE 34 WM MAIN CONV. CHANNEL
66 AVENUE 34 POWER DISTRIBUTION LINE
67 AVENUE 34 DIP CROSSING
76 AVE 31 1/2 & 7 1/2 DRAIN PIPE UNDERCROSSING
64 AVENUE 36E POWER TRANSMISSION LINE
77 AVE 31 & 8TH DIP CROSSING
78 AVE 31 & 8 1/2 DRAIN PIPE UNDERCROSSING
56 AVENUE 36 5/8 E COAST TO COAST BRIDGE
57 AVENUE 36 1/2 E DIP CROSSING
58 AVENUE 36 1/2 E TELEPHONE CABLE
59 AVENUE 36 1/2 E HIGH PRESSURE GAS LINE
60 AVENUE 36 1/2 E FIBER OPTICS CABLE
61 AVENUE 36 1/2 E PETROLEUM LINES
62 AVENUE 36 1/2 E SIGNAL LINE
63 AVENUE 36 1/2 E SPRR BRIDGE
79 AVENUE 30E DRAIN PIPE UNDERCROSSING
80 AVENUE 30E TELEPHONE LINE
81 AVENUE 30E POWER DISTRIBUTION LINE
82 AVENUE 30E AVENUE 30E BRIDGE
GILA RIVER
6TH STREET
7TH STREET
8TH STREET
AVE 32E
AVE 33E
AVE 34E
AVE 36E
INTERSTATE 8
MOHAWK CANAL
WELLTON AIRPORT
M O H A W K V A L L E Y
W E L L T O N
L U K E A I R F O R C E R A N G E
Mapped, edited, and published by the Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
WELLTON MESA, ARIZ.
N3237.5—W11400/7.5
1965
PHOTOREVISED 1982

PLATE 19


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WELLTON QUADRANGLE
ARIZONA–YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
88 AVE 26 1/2 & 9TH COYOTE WASH CONFLUENCE
89 AVE 26 1/2 & 9TH GAS LINE
90 AVE 26 - 26 1/2 E POWER TRANSMISSION LINE
87 AVENUE 27 E DIP CROSSING
83 AVE 29 1/2 & 8TH SUMP PIPELINE
84 AVENUE 29E POWER DISTRIBUTION LINE
85 AVENUE 29E DRAIN PIPE UNDERCROSSING
86 AVENUE 29E DIP CROSSING
101 AVENUE 23 E WM CONV. CHANNEL SIPHON
102 AVENUE 23 E GOMEZ WASH
98 AVENUE 24 E POWER DISTRIBUTION LINE
99 AVENUE 24 E TELEPHONE LINE
100 AVENUE 24 E DIP CROSSING
91 AVE 25 3/4 E & 10TH POWER TRANSMISSION LINE
92 AVE 25 3/4 E & 10TH DIP CROSSING
93 AVENUE 25 1/2 E WM MAIN CONV. CHANNEL
94 AVENUE 25E DIP CROSSING
95 AVE 24 3/4 E GROUT WASH
96 AVE 24 1/2 E & 10TH POWER TRANSMISSION LINE
97 AVE 24 1/2 E & 10TH DIP CROSSING
MUGGINS MOUNTAINS
YUMA PROVING GROUND
GILA RIVER
AVE 29E
AVE 28E
AVE 27E
AVE 25E
AVE 24 E
10TH STREET
DOME VALLEY
MOHAWK VALLEY
Wellton
INTERSTATE 8
MOHAWK CANAL
Mapped, edited, and published by the Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
WELLTON, ARIZ.
N3237.5—W11407.5/7.5
1965
DMA 3149 II NW—SERIES V898

PLATE 20

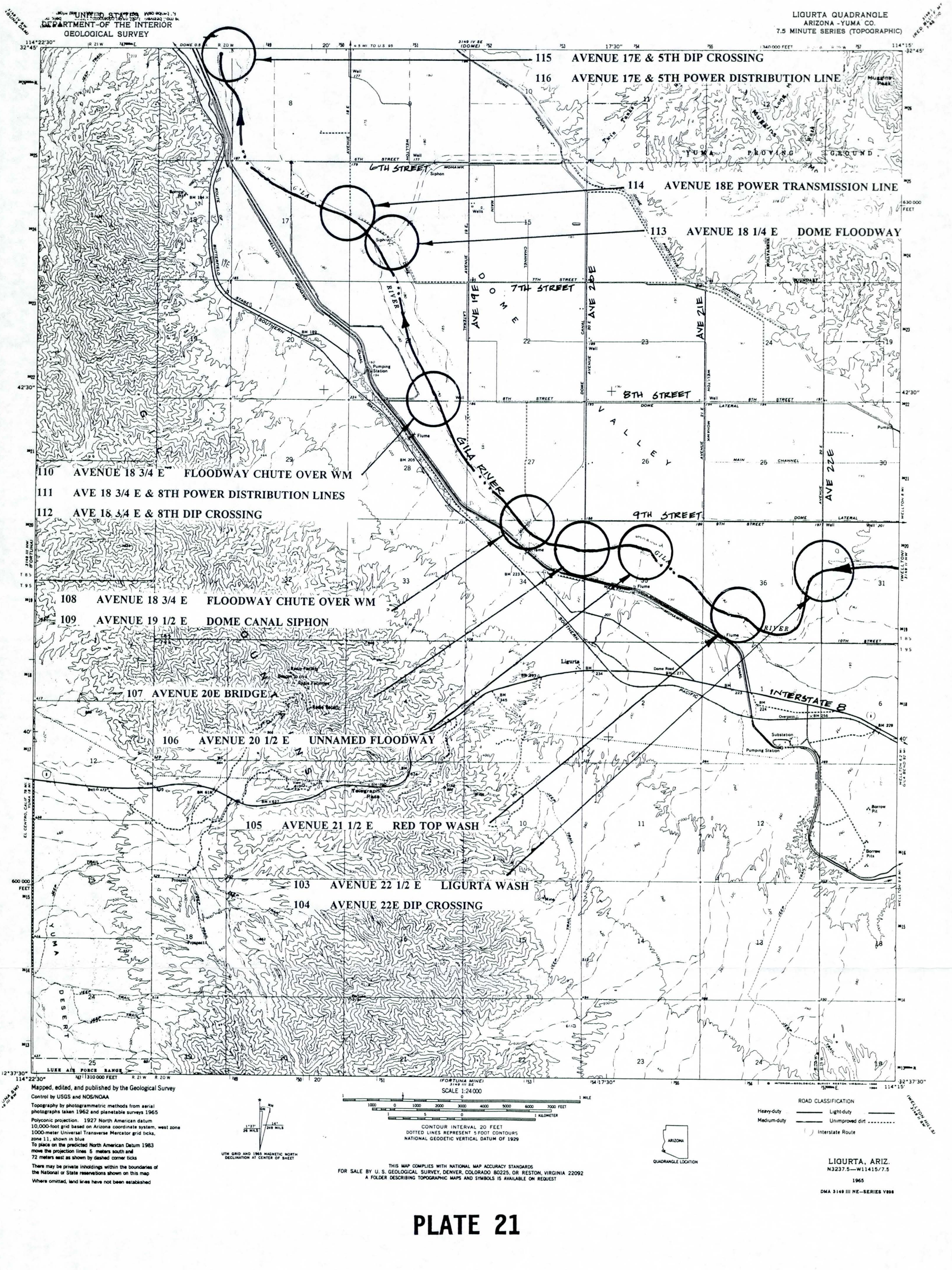

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
LIGURTA QUADRANGLE
ARIZONA - YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
115 AVENUE 17E & 5TH DIP CROSSING
116 AVENUE 17E & 5TH POWER DISTRIBUTION LINE
114 AVENUE 18E POWER TRANSMISSION LINE
113 AVENUE 18 1/4 E DOME FLOODWAY
110 AVENUE 18 3/4 E FLOODWAY CHUTE OVER WM
111 AVE 18 3/4 E & 8TH POWER DISTRIBUTION LINES
112 AVE 18 3/4 E & 8TH DIP CROSSING
108 AVENUE 18 3/4 E FLOODWAY CHUTE OVER WM
109 AVENUE 19 1/2 E DOME CANAL SIPHON
107 AVENUE 20E BRIDGE
106 AVENUE 20 1/2 E UNNAMED FLOODWAY
105 AVENUE 21 1/2 E RED TOP WASH
103 AVENUE 22 1/2 E LIGURTA WASH
104 AVENUE 22E DIP CROSSING
6TH STREET
7TH STREET
8TH STREET
9TH STREET
AVE 19E
AVE 20E
AVE 21E
AVE 22E
GILA RIVER
DOME VALLEY
INTERSTATE 8
YUMA PROVING GROUND
Ligurta
Mapped, edited, and published by the Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
LIGURTA, ARIZ.
N3237.5—W11415/7.5
1965

PLATE 21

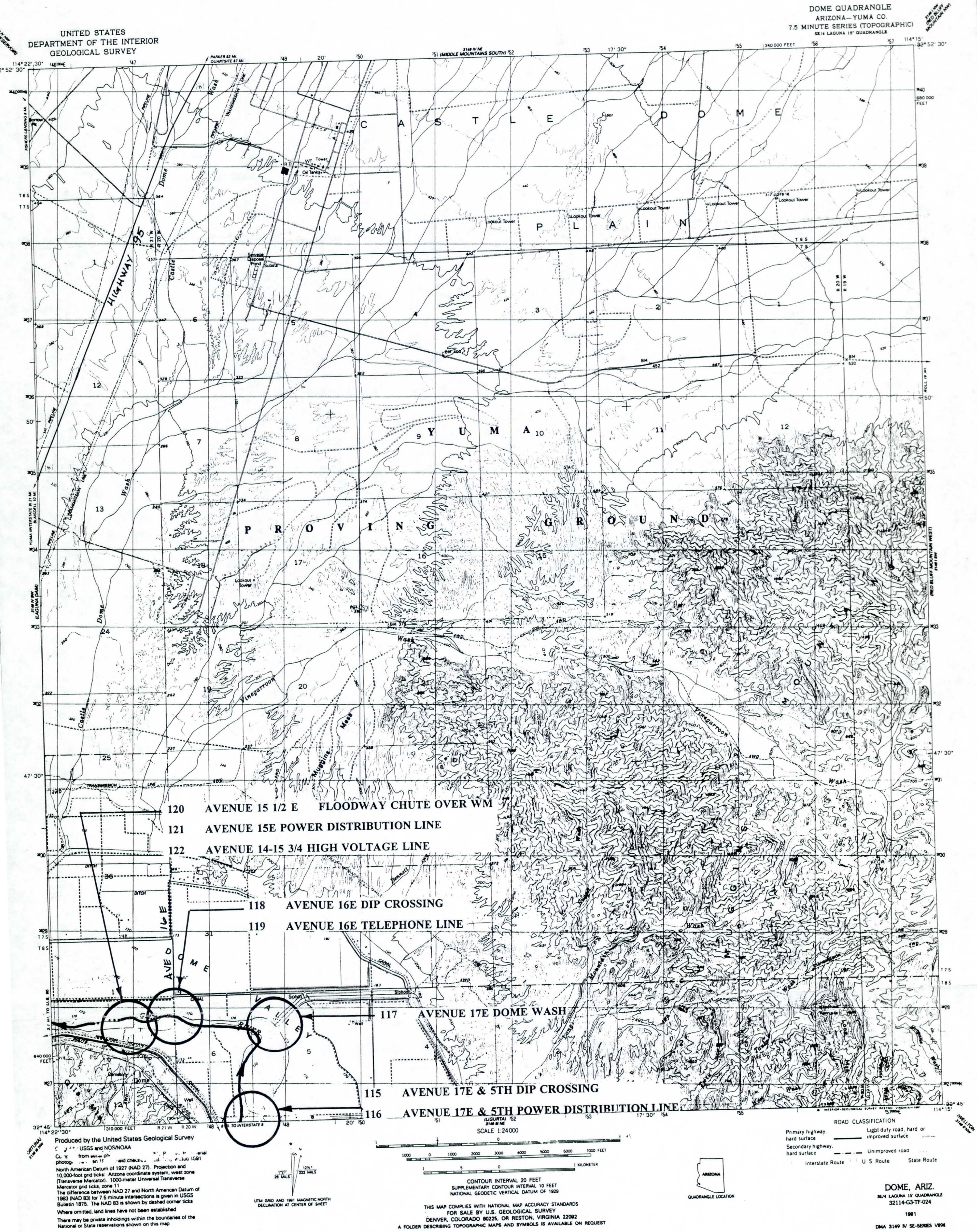
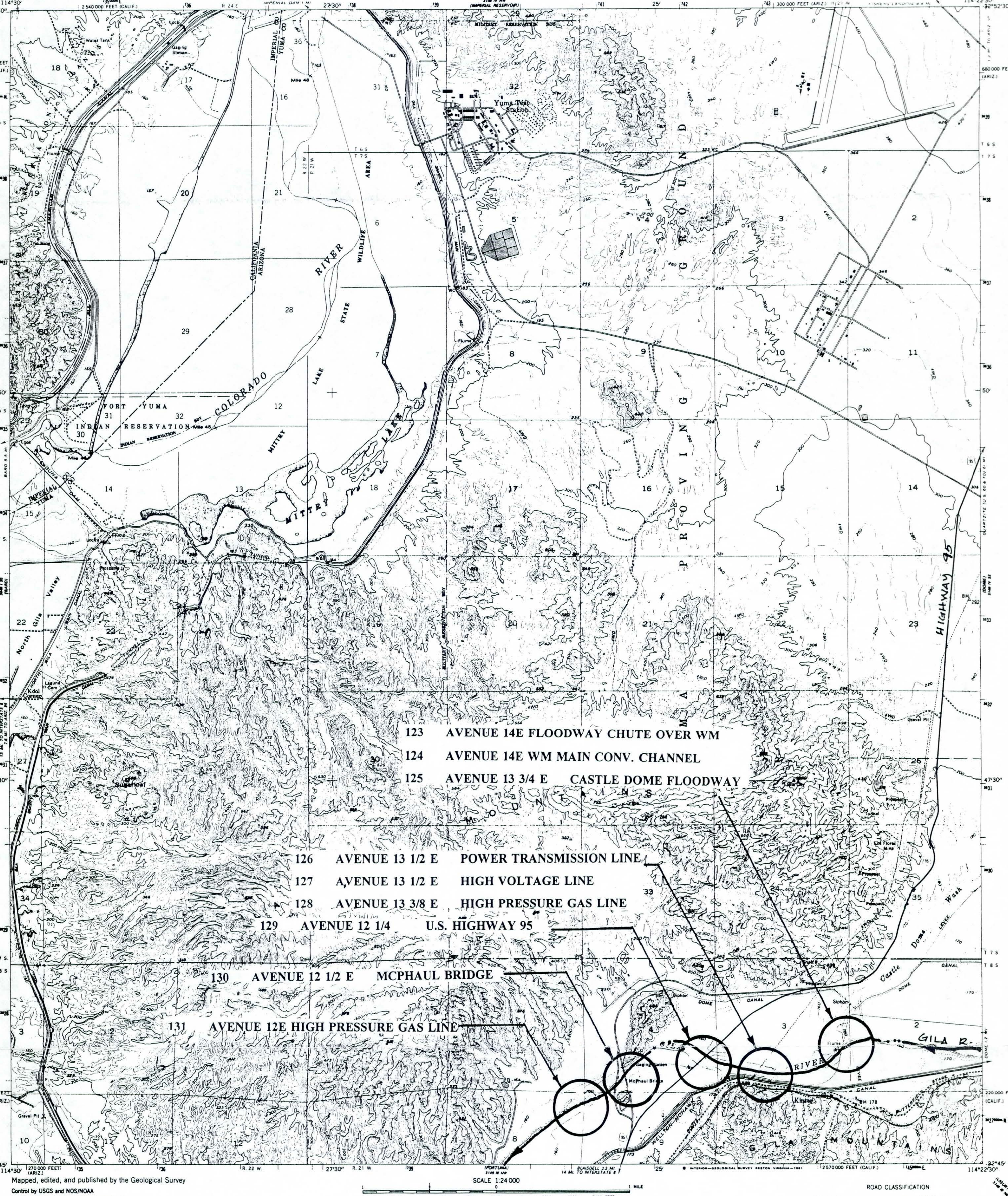

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
DOME QUADRANGLE
ARIZONA—YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
C A S T L E D O M E
P L A I N
Y U M A
P R O V I N G G R O U N D
HIGHWAY 95
120 AVENUE 15 1/2 E FLOODWAY CHUTE OVER WM
121 AVENUE 15E POWER DISTRIBUTION LINE
122 AVENUE 14-15 3/4 HIGH VOLTAGE LINE
118 AVENUE 16E DIP CROSSING
119 AVENUE 16E TELEPHONE LINE
117 AVENUE 17E DOME WASH
115 AVENUE 17E & 5TH DIP CROSSING
116 AVENUE 17E & 5TH POWER DISTRIBUTION LINE
AVE 16E
D O M E
V A L L E Y
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
SUPPLEMENTARY CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY
DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
Produced by the United States Geological Survey
ROAD CLASSIFICATION
DOME, ARIZ.
1991

PLATE 22

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LAGUNA DAM QUADRANGLE
ARIZONA—CALIFORNIA
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography from aerial photographs by Kelsh plotter
Aerial photographs taken 1953. Field check 1955

Polyconic projection. 1927 North American Datum
10,000-foot grids based on Arizona coordinate system, west zone
and California coordinate system, zone 6

1000-meter Universal Transverse Mercator grid ticks,
zone 11, shown in blue
To place on the predicted North American Datum 1983,
move the projection lines 4 meters south and
72 meters east as shown by dashed corner ticks

There may be private inholdings within the boundaries of
the National or State reservations shown on this map

UTM GRID AND 1979 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

Revisions shown in purple and woodland compiled from
aerial photographs taken 1976 and other source data
This information not field checked. Map edited 1979

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U.S. Route — State Route

LAGUNA DAM, ARIZ.—CALIF.
32114-G4-TF-024
1955
PHOTOREVISED 1979
DMA 3149 IV SW—SERIES V898

PLATE 23

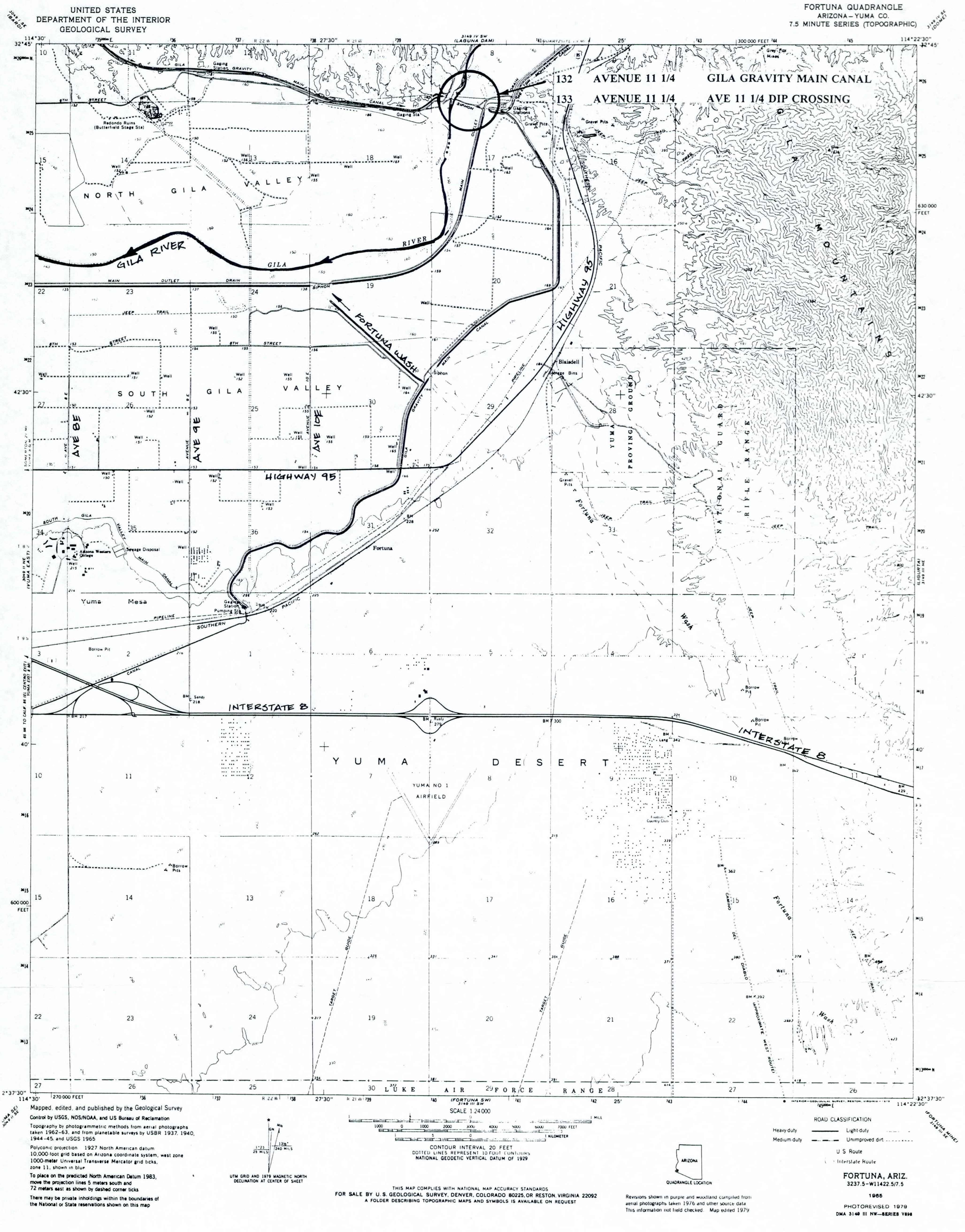

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
FORTUNA QUADRANGLE
ARIZONA—YUMA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
132 AVENUE 11 1/4 GILA GRAVITY MAIN CANAL
133 AVENUE 11 1/4 AVE 11 1/4 DIP CROSSING
NORTH GILA VALLEY
GILA RIVER
FORTUNA WASH
HIGHWAY 95
SOUTH GILA VALLEY
AVE 8E
AVE 9E
AVE 10E
GILA MOUNTAINS
YUMA PROVING GROUND
NATIONAL GUARD RIFLE RANGE
Blaisdell
Fortuna
Yuma Mesa
INTERSTATE 8
YUMA DESERT
YUMA NO 1 AIRFIELD
LUKE AIR FORCE RANGE
Mapped, edited, and published by the Geological Survey
Control by USGS, NOS/NOAA, and US Bureau of Reclamation
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
QUADRANGLE LOCATION
FORTUNA, ARIZ.
1965
PHOTOREVISED 1979

PLATE 24

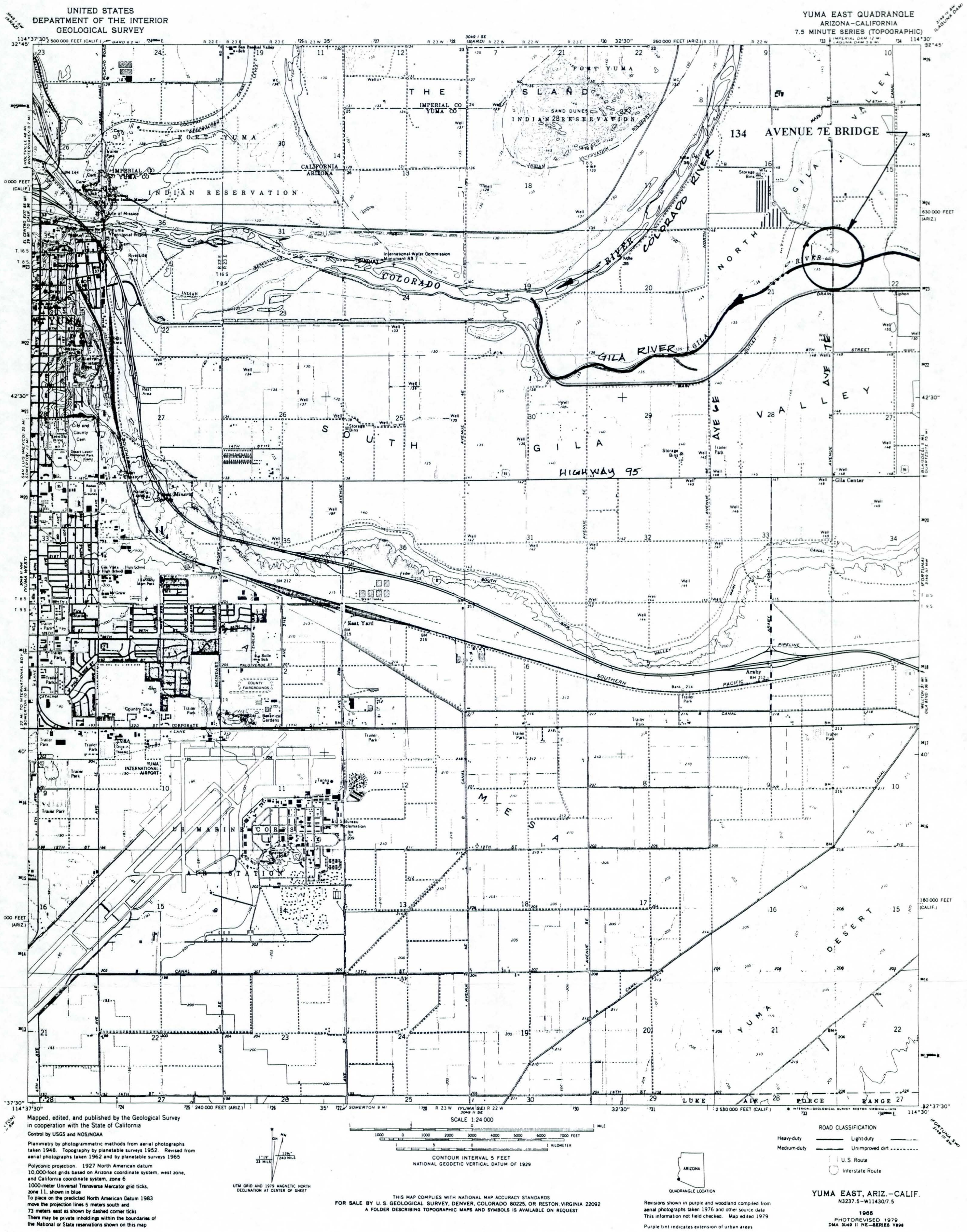

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
YUMA EAST QUADRANGLE
ARIZONA–CALIFORNIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
134
AVENUE 7E BRIDGE
FORT YUMA
THE ISLAND
SAND DUNES
INDIAN RESERVATION
IMPERIAL CO
YUMA CO
CALIFORNIA
ARIZONA
COLORADO RIVER
COLORADO
GILA RIVER
NORTH GILA VALLEY
SOUTH GILA VALLEY
HIGHWAY 95
AVE 7E
YUMA
Gila Center
East Yard
Araby
SOUTHERN PACIFIC
YUMA INTERNATIONAL AIRPORT
U S MARINE CORPS AIR STATION
MESA
YUMA DESERT
LUKE AIR FORCE RANGE
Mapped, edited, and published by the Geological Survey
in cooperation with the State of California
Control by USGS and NOS/NOAA
Planimetry by photogrammetric methods from aerial photographs taken 1948. Topography by planetable surveys 1952. Revised from aerial photographs taken 1962 and by planetable surveys 1965
Polyconic projection. 1927 North American datum
10,000-foot grids based on Arizona coordinate system, west zone, and California coordinate system, zone 6
1000-meter Universal Transverse Mercator grid ticks, zone 11, shown in blue
To place on the predicted North American Datum 1983 move the projection lines 5 meters south and 73 meters east as shown by dashed corner ticks
There may be private inholdings within the boundaries of the National or State reservations shown on this map
UTM GRID AND 1979 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
QUADRANGLE LOCATION
ARIZONA
Revisions shown in purple and woodland compiled from aerial photographs taken 1976 and other source data
This information not field checked. Map edited 1979
Purple tint indicates extension of urban areas
ROAD CLASSIFICATION
Heavy-duty
Light-duty
Medium-duty
Unimproved dirt
U.S. Route
Interstate Route
YUMA EAST, ARIZ.–CALIF.
N3237.5–W11430/7.5
1965
PHOTOREVISED 1979
DMA 3049 II NE–SERIES V898

PLATE 25

APPENDIX D

GEOTECHNICAL

Gila River
Gillespie Dam to Yuma, Az.

Geotechnical Appendix

1. Topography. The Gila River and its tributaries drain the southern half of the State of Arizona. The river, which is about 650 miles long, drains into the Colorado River near Yuma and has its headwater in western New Mexico near the Continental Divide. In the reach under investigation in this study, the river flows through a valley that is about 1 mile wide at the downstream end and more than 5 miles wide at the upstream end. However, the stream, which is meandering, is confined within a 3-mile width. Painted Rock Dam, an earthfill flood control structure, is located at a narrows on the river downstream from Gillespie Dam. The river has an average gradient of 3 feet per mile in the project reach.

2. Geology. Through the reach, the Gila River is an aggrading stream, flowing over unconsolidated silts, sand, and gravels varying in thickness from 2 feet near rock outcrops to over 1,700 feet in deeper portions. During explorations conducted in 1959 along the river, ground water was found in the stream at numerous locations and in nearly all test holes. As distance from the channel increased, the water table was at slightly greater depths. The alluvial materials found in the streambed and terraces are principally medium dense silts, silty sands, and fine sand. Occasionally, lenses of stiff clay or gravelly sand occur. Alluvial fans at the mouths of canyons on the north side of the valley consist of gravelly silts and gravelly clays. The alluvial fans on the south side of the valley consist of gravelly sands and some gravelly silts. There are no subsidence concerns related to groundwater withdrawal in the study area.

3. Faulting and Seismicity. The project reach falls almost entirely within Zone 2 of the Seismic Risk Map of the United States. A moderate damage potential exists for structures within this zone. The boundary with Zone 4 (highest seismic risk) is at the downstream end of the reach at Yuma, AZ. This is due to the proximity of the northwest trending faults associated with the San Andreas fault system. An earthquake with an estimated magnitude of 5.9 occurred near Yuma in 1872 and major earthquakes generated on the San Andreas or associated faults could occur as close as 25 miles from the downstream end of the project. A major event could cause accelerations in excess of 0.2g near Yuma. Because the river course is normal to the zone of high seismic potential, the felt effects of a major earthquake would diminish upstream.

4. Potential HTRW Sites. From the city of Yuma, AZ to near city limits, a high potential for the discovery of HTRW contaminated sites located within future project construction boundaries exists. Most of HTRW contamination encountered could likely be traced to various types of sources related to operations of active and abandoned semi-heavy to light manufacturing, service and/or agricultural industries

and landfills. The management and operation practices of these types of industries typically cause soil and/or ground water and surface water contamination related to hydrocarbon chemicals, metals, pesticides and inorganic chemicals. HTRW contamination could be released into the environment from a variety of sources such as: a). Active and abandoned leaking underground storage tanks (USTs) and above ground tanks (ASTs). b). Active and abandoned leaking waste pits and ponds. c). Unknown or abandoned industrial waste sites consisting of drums, containers and irregular masses. d). Agricultural waste/pesticide and/or industrial waste point source runoff. e). Leaching and leaking landfills.

A high potential for HTRW contamination related to agricultural, landfill and sewage related activities exists for future construction boundaries existing along a 160 mile stretch of the Gila river, between Yuma city limits and Gillespie Dam. A low potential for HTRW pollution exists for activities related to heavy and light manufacturing/service industries within these boundaries. Contamination caused by agriculture is well documented throughout the project area. Sediments beneath the Gila river's water surface are heavily polluted with pesticide derived DDT, Toxaphene and fertilizer derived selenium. The most seriously contaminated areas along the Gila are located at Painted Rock reservoir, Gillespie reservoir and Borrow Pit Lake just below Painted Rock Dam. The majority of pesticide and selenium contaminants have been transported to the Gila river via groundwater infiltration and irrigation runoff from nearby farms and ranches. Plants and aquatic life within the Gila contain heavy absorbed concentrations of metals and organic hydrocarbon chemicals derived from landfill leachate and sewage effluent. Most of the contaminants released from landfills and sewage treatment plants have been traced upstream to sources in metropolitan Phoenix.

The Arizona Department of Environmental Quality (ADEQ) and U.S. Environmental Protection agencies are responsible for monitoring and protection of the surface/ground waters and soils in the project area. In October of 1991, the Surface Water Monitoring Unit of the ADEQ and Arizona Department of Health Services issued an aquatic animal consumption warning for all waters of the Salt and Gila rivers, including Borrow Pit lake.

5. <u>Previous Explorations.</u> In 1959, conditions along the river were explored by drilling 33 bucket auger test holes and carefully examining the ground surface, stream terraces, cut banks, existing quarries, and fills. Test holes were spaced at intervals of 1 to 3 miles. Samples were tested for moisture content, Atterberg limits, mechanical analysis, and compaction data.

6. <u>Hydraulic Fracturing.</u> Water conservation involving long term storage at Painted Rock Dam is an alternative being considered in this study. Concerns regarding seepage and the flood control design intent for the structure as constructed were raised during an evaluation of water storage at the dam in the early 1980's. A concern that has developed recently is the potential for hydraulic fracturing of the core. The following conclusions are made based on review of the design and

construction data, limited research, and a qualitative evaluation of the potential for hydraulic fracturing at the dam.

(1) The central core zone is narrow and is made of erodible materials.

(2) The steeper than designed core cut-off trench contributes to the cracking potential.

(3) Load transfer from the core to the adjacent Zone II material may occur and would promote cracking.

(4) Available geotechnical data is not sufficient to fully evaluate the potential and extent of the hydraulic fracturing at the dam.

Based on the above and the fact that open joints in the foundation rock required treatment with concrete and mortar during construction and the reservoir fills quickly, the hydraulic fracturing of the embankment at high reservoir pool is likely.

7. Seepage at Painted Rock Dam. The seepage paths through the bedrock fracture systems in which observed seepage at the dam is thought to occur are very complex. Piezometer data indicated high hydrostatic pressures in the bedrock with rapid response to reservoir pool fluctuations and no indication of significant headloss or lag time. There is no evidence of migration of fines either from the embankment core, the rock foundation or the alluvium under the embankment shell.

However, since seepage is occurring outside the limits of the embankment and Seepage Control Measures Areas, the possibility of erosion through the embankment toe and/or the toes of the surcharge berms still exists at reservoir pool levels higher than 667.

A large system of underseepage through the bedrock does exist. Reservoir water enters fractured rock upstream of the dam, passes under the shallow grout curtain, and exits downstream of the embankment and surcharge berms. Some TDS data also suggested that dissolution may be occurring either from seepage passing through calichified material or mineral deposits being dissolved along bedrock fractures.

Based on measurements and observations made during the 1993 filling of Painted Rock Dam, the Seepage Control Measures constructed in 1980 were not completely effective in reducing the uplift pressures and collecting the seepage and that without the construction of additional measures, the safety of the structure could be compromised if the reservoir level was allowed to exceed elevation 670.

APPENDIX E

GEOMORPHOLOGY

GEOMORPHIC ASSESSMENT OF THE LOWER GILA RIVER, WEST CENTRAL ARIZONA

by

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for

U.S. Army Corps of Engineers, Los Angeles District
Arizona Area Office, Planning Section C
3636 N. Central Avenue, Suite 740
Phoenix, Arizona 85012-1936

Contract DACW09-94-M-0494

July 1994

DISCLAIMER

This report was done under contract to the Los Angeles District, U.S. Army Corps of Engineers. The report was intended for internal plan formulation purposes and reflects the findings and opinions of the Contractor, not necessarily those of the Corps of Engineers. Any questions concerning this report should be directed to Mike Ternak or Bill Burton of the Corps' Planning Office in Phoenix at (602) 640-2003.

EXECUTIVE SUMMARY

The purpose of this report is to assess the geomorphology and related physical systems of the Lower Gila River between Gillespie Dam and Yuma, Arizona. This report was prepared in a 30-day time frame. it is therefore at the reconnaissance level of detail. The report includes data sources for historical information and photography about the river when it was in a nearly natural state, as well as sources for hydrologic, geologic, and ecologic information. The report provides historical descriptions of the channel from eyewitness accounts of the river in its nearly natural state.

The application of a geomorphologic naturalness scale to the river shows that there is considerable variability along the channel in the degree of naturalness, and that there are some limited reaches where the geomorphology of the river is somewhat similar to its original condition. After the 1993 flood, even some reaches of the channel in the Wellton-Mohawk Irrigation and Drainage District are surprisingly natural. The geomorphic characteristics of the channel are also variable from place to place, including classic braided conditions in the aggrading Cotton Center reach, to compound channel forms in much of the system.

Sediment is an emerging management problem in the Lower Gila River system. Sedimentation in the river is accelerated by restricted flows from Painted Rock Dam and continuing contributions from tributary streams below the dam. The movement of sediments contaminated by DDT and related chemicals from the western Salt River Valley into the Lower Gila River is beginning in noticeable proportions, perhaps enhanced by the breach of Gillespie Dam in 1993.

Constraints on environmental restoration in the Lower Gila River are related to the lack of surface water that is so severe no large scale (extending over tens of miles) projects are likely to succeed. However, there are numerous opportunities for numerous small scale projects likely to return substantial benefits in terms of enhancement of wildlife habitat. Environmental restoration project worthy of further investigation include extensive restoration in Dendora Valley immediately below Painted Rock Dam, enhanced habitat in the Basalt Gorge immediately below the Oatman Grave site, excavation and planting in several major oxbow or slough areas, reconstruction of several bridge crossings to tap runoff from approach roads and develop artificial marshes, modification to develop lines of cottonwoods along ramps that conduct tributary stream through the irrigated lands to the main river channel, and modifications to the operating rules of Painted Rock Dam to more closely mimic natural flows that once existed in the river.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 The Lower Gila River

The Gila River, extending from the mountains of southwestern New Mexico across Arizona to the Colorado River at Yuma, drains 57,850 square miles of arid and semi-arid terrain. Its sinuous, often braided channel across basin floors has nurtured human lives and commerce for thousands of years, and its course has been the site of riparian habitats unique to its otherwise sparsely vegetated desert setting. During the twentieth century, the construction of numerous dams within the Gila River Basin has radically altered the character of the river by storing water in its upper and middle reaches and depriving the channel of its natural flows in the lower reaches. Development of water delivery systems have given rise to extensive irrigation and drainage networkds, and flood-control works have altered the form and processes of its channel. After immense floods in 1993 in the lower reaches of the river, environmental managers have sought a clearer understanding of the lower river. With increased interest in environmental quality and preservation of wildlife, managers now consider restoration of the lost riparian habitats as a social goal alongside the tradition objectives of flood control and water resource development. This report is an assessment of the geomorphology of the Lower Gila River, including potential for flood control and environmental restoration investments. For the purposes of this report, the "Lower Gila River" is the stream between Gillespie Dam and Yuma (Figure 1).

1.2 The Institutional Setting

A variety of governmental agencies, including the Bureau of Reclamation, Bureau of Indian Affairs, and the Salt River Project, operate dams in the Gila River Basin that have downstream effects on the Lower Gila River (Table 1). These structures usually store waters at mid-basin locations, but during a few years their storage capacity is exceeded, and releases cause high flows in the Lower Gila River. In the Phoenix metropolitan area, the Maricopa County Flood Control District constructs and maintains improved channel systems on the Salt and Gila Rivers that enhanced the through-flow of flood waters, probably increasing downstream discharges. Along the lower Gila River, two agencies are the primary actors in flood control efforts: the U.S. Army Corps of Engineers and the Welton-Mohawk Irrigation and Drainage District.

The U.S. Army Corps of Engineers has a long history of river engineering and construction. Its legislative mandate for flood-related work appeared in U.S. House of Representatives Document 308 in 1927. This formal authorization coupled with catastrophic floods on the Mississippi River in 1928 stimulated the first major flood control work by the Corps (Black, 1987, p. 22). Subsequent major flooding on the Susquehanna River in the middle 1930s prompted the passage of the Omnibus Flood Control Act of 1936, which was the beginning of a nation-wide flood control program (Leopold and Maddock, 1954). Omnibus flood control and public works project bills were enacted by congress in many years thereafter. Two of these omnibus acts, 1944 and 1954, had significant policy implications. After planning difficulties in dealing with work on the

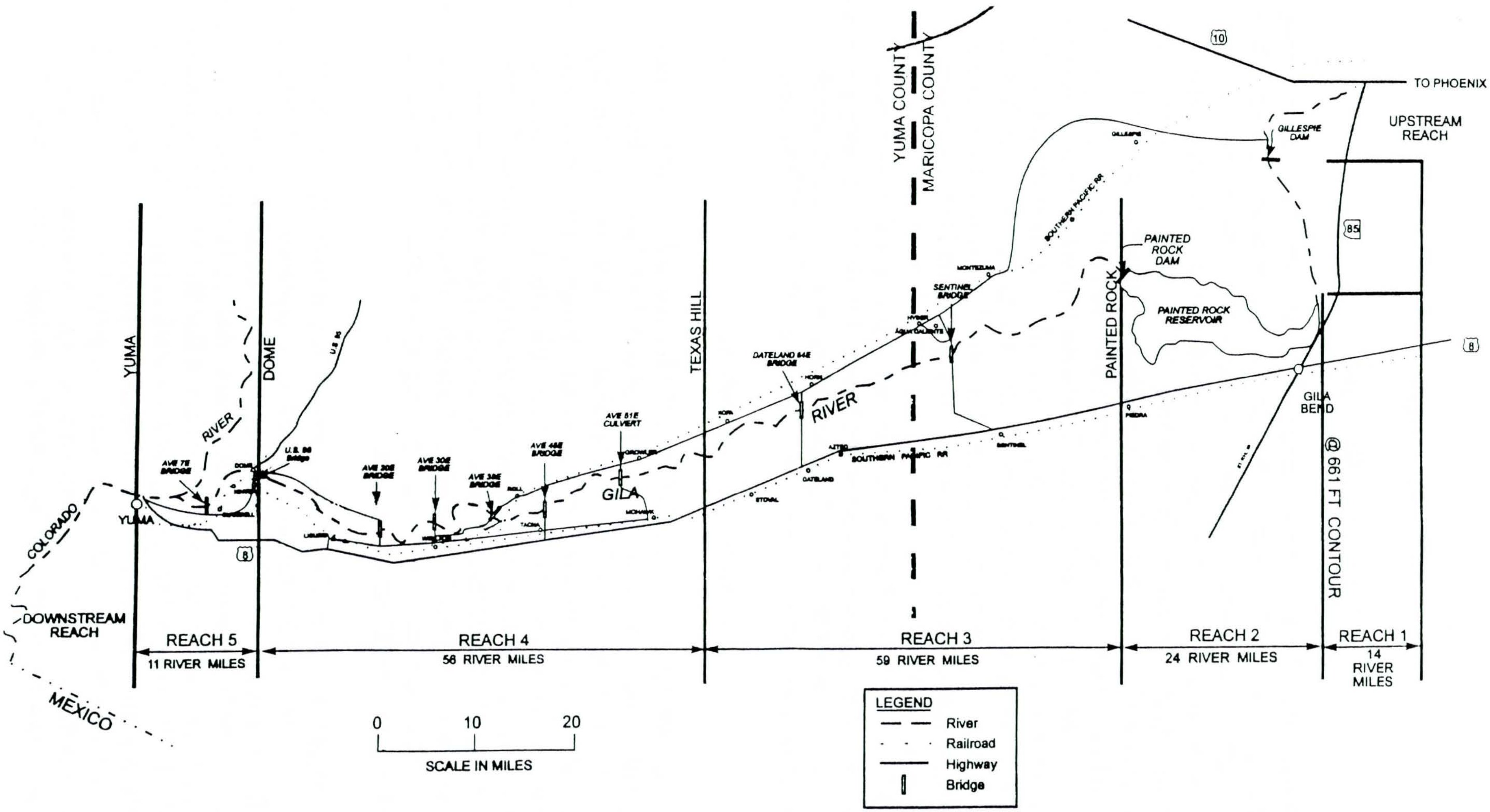


Figure 1. General features of the Lower Gila River, with north to the top (U.S. Army Corps of Engineers Draft Map, 1994).

Table 1. Major dams and reservoirs in the Gila River Basin.

Dam	River	Reservoir	Date of Origin	Storage (ac ft)
Waddell	Agua Fria	Lake Pleasant	1927	165,000*
Bartlett	Verde	Bartlett Lake	1939	182,000
Horseshoe	Verde	Horseshoe Lake	1949	141,000
Stewart Mountain	Salt	Saguaro Lake	1930	71,000
Mormon Flat	Salt	Canyon Lake	1938	59,000
Horse Mesa	Salt	Apache Lake	1927	248,000
Roosevelt	Salt	Roosevelt Lake	1911	1,398,000*
Coolidge	Gila	San Carlos Lake	1928	1,222,000
Painted Rock	Gila	Painted Rock Lake	1959	2,500,000

Note: * indicates original storage capacity before modifications that are presently under way to expand capacity. Data from International Commission on High Dams (1973).

Missouri River in the early 1940s, the 1944 Omnibus Flood Control Act further defined the role of the Corps as the nation's primary flood control engineering agency. While the Corps has dealt with flooding in downstream channels, the Soil Conservation Service has dealt with upstream watersheds as the origin of flood waters (Bennett, 1955). The 1954 omnibus bill began the process of requiring cost sharing with the federal government for flood control efforts, with later legislation increasing the degree of participation by local interests (Heft, 1984). Reflecting general trends in federal agencies that have heightened interest in environmental quality (Feldman, 1991), the Corps has recently taken on an expanded mission that combines habitat management and restoration with its long established mission of flood control.

As a result of this history, the Corps has significant responsibility for flood control and related efforts on the Lower Gila River. Though the Corps has not built local channel facilities along the Lower Gila River, but the agency has constructed Painted Rock Dam to protect irrigation works on the Lower Gila River from inundation and channel erosion. The dam, begun in 1957 and completed in 1960, can store 2.5 million acre feet of water, with controlled releases up to 22,000 cubic feet per second (Bureau of Reclamation, 1984).

The Bureau of Reclamation has primary responsibility for the development and delivery of water resources. The Bureau's organic act is the 1902 Reclamation Act which was intended to provide federal investment (with subsequent repayment by users) and expertise in the development of water resources, primarily in the West (Sax, 1978). The Act was designed by Congress to provide irrigation water to individual farmers with limited land holdings, and did not adequately recognize the need for land leasing and the management of large land holdings. The Bureau does not deal with individual land owners, but operates in cooperation with organized irrigation districts, with the districts operating maintaining the distribution systems. The Reclamation Reform Act of 1982 brought about significant adjustments in the Bureau's operating methods, recognized leasing, and changed payment procedures (Goldfarb, 1988, p. 78).

In the Lower Gila River, the Bureau has had a major hand in dealing with water resources. Under authority of the Gila Reauthorization Act of 1947, the Bureau constructed the Wellton-Mohawk Division of the Gila Project. Completed in 1952, the project initially irrigated about 75,000 acres through a system of more than 300 miles of lined canals and laterals, and established 90 wells converted to drainage. Application of river water to the partially closed basin resulted in rising saline ground waters, and the project converted wells to lower the ground-water levels for efficient agricultural production. The Wellton-Mohawk Irrigation and Drainage District assumed control in the late 1950s (Bureau of Reclamation, 1984).

The Wellton-Mohawk Irrigation and Drainage District has also played a significant role in channel changes through the construction and maintenance of levees constructed during the 1980s and maintained in the early 1990s. Despite the presence of Painted Rock Dam upstream, the District suffered $6.1 million in flood damage in 1966, $9.1 million in 1979, $8.0 million in 1980, and several million more in 1983. Recent floods in 1993 also caused damages of $50-60 million and the destruction of many of the levees.

1.3 Purpose and Scope of this Report

This report was commissioned under the provisions of Contract DACW09-94-M-0494, S. Army Corps of Engineers, Los Angeles District, Arizona Region, Phoenix Planning Section C. The report provides the Corps with a physical science perspective on a series of broad ranging policy issues related to the geomorphology, hydrology, and riparian ecology of the Lower Gila River. The following pages contain a philosophical perspective that might be used by the Corps in assessing its institutional position with respect to the geomorphic condition of the channel. The report uses historical data to reconstruct geomorphic and riparian conditions prior to extensive development, and the assesses the subsequent adjustments of the channel in response to dam construction, river engineering, and vegetation management. The report collates relevant data related to hydrology, geology, ecology, and human history, as well as defining sources of information for further exploration. This report also explores the potential and constraints for environmental restoration. Brief comments are included pertaining to flood control, especially the relationship between flood control and environmental restoration. The report is at a *reconnaissance* level and represents a general starting point for considering Federal involvement in further activities on the Lower Gila River (Table 2).

1.4 The Study Area

1.4.1 General Conditions

The study area for this report consists of the channel and near-channel environment of the Lower Gila River in southwest Arizona from Gillespie Dam in Maricopa County the Colorado River at Yuma. This 164-mile reach includes the course of the river through Cotton Center Valley, the Gila or Great Bend, the Painted Rock Dam and Reservoir, and the Wellton-Mohawk Irrigation District (Figure 1, Appendix 11.1). In this reach, the river flows through the warmest and driest region of Arizona: temperatures in the coldest month (January) average well above freezing, and annual precipitation less than 10 inches. The potential evapotranspiration is greater than precipitation every month, and the soil-moisture budget is deficient throughout the year (Hendricks, 1985, p. 41).

The soils in the vicinity of the channel throughout the study area are of the hyperthermic torrifluvents association, a group of soils that are well-drained to excessively well-drained (Hendricks, 1985, p. 74-75). They are often sandy to gravelly, but may include lenses of finer particles. They are often redistributed by water flows associated with nearby active channels.

1.4.2 Geology

The physiography of this region of the Gila River is typical Basin and Range

Table 2. General Corps of Engineers project process.

	Step	Notes
1	Congressional Authorization for a Reconnaissance Report	Local community and local officials contact the Corps of Engineers, expressing concern that water and land resource problems are beyond local means for solution; Congressional recognition of possible federal interest
2	Congressional Appropriation for Reconnaissance Report	Federally funded, exploratory effort, if authorization is not funded within 8 years, authorization ceases
3	Reconnaissance Report Preparation	Directed by District Engineer, determines federal interest, costs, benefits, environmental consideration **(role of the present report in the Corps process)**
4	Feasibility Report Preparation	Does not proceed without identification of a local, cost-sharing partner to work with the Corps, report for the use of Congress, includes environmental impact assessment and cost-benefit analysis
5	Corps Review	Review by Division Engineer, Board of Engineers for Rivers and Harbors of the Corps, Chief of Engineers, state governor, and Secretary of Interior.
6	Final Project Report	Chief of Engineers of the Corps sends final feasibility report to Secretary of the Army; review by Office of Management and Budget; then transmitted to Congress
7	Congressional Authorization of Project	Some or all of the proposed work may be authorized, no project may be authorized if more than 5 years have elapsed since the submission of the reconnaissance report
8	Congressional Appropriation for Project	A substantial backlog of authorized but unfunded projects exists
9	Planning	Engineering design work and development of specifications
10	Construction	Execution of the engineering work and final development of the physical project

Source: Goldfarb, 1988, p. 80-82.

Province. The geologic units, ages, and interpretation are from Reynold's geologic map of Arizona (1988), a portion of which is shown in Figure 2. The region of the Lower Gila River in this study covers the river's course from Gillespie Dam to Yuma, Arizona. The dam is situated between the Gila Mountains to the southwest and the Buckeye Hills to the northeast.

The Buckeye Hills are composed of granitic rocks of early to middle Proterzoic age. The Gila Bend Mountains region where the dam is located is composed of basaltic rocks of Holocene to late Pliocene age. Other parts of the Gila Bend Mountains along the river's course are made of granitoid rocks, metamorphic rocks composed of undifferentiated metasedimentary, metavolcanic, and gneissic rocks. These rocks are of early Proterozoic age.

Near Painted Rock Dam the Gila River is bounded by volcanic rocks with compositions ranging from silicic to mafic flows along with pyroclastic rocks of Miocene to Oligocene age. The Dendora Valley immediately downstream from Painted Rock Reservoir is composed of alluvium, eolian deposits, and sedimentary rocks of mid Pleistocene to late Pliocene age. These sedimentary rocks are from the Bidahochi and Bouce Formations. The southern margin of the Gila River along this reach is composed of basaltic rocks covering the Sentinel Plain. From Sentinel Plain to Wellton the Gila River flows through surficial deposits of alluvium and eolian deposits in present day dry valleys and piedmonts. These deposits are Holocene to middle Pleistocene age.

North of Wellton the river is bounded by volcanic and sedimentary rocks (fluvial and lacustrine) of the Muggins Mountains which are middle Miocene to Oligocene age. West of the Muggins Mountains, near Dome, the Gila River floodplain is two miles wide. The river flows around sedimentary rocks deposited during the mid Tertiary orogenic episode in the Basin and Range Province. Jurassic granitoid rocks composed of granite, diorite, and alkaline rocks are also exposed along this reach of the river near Dome. Westward from Dome toward Yuma the Gila River flows through Holocene to mid Pleistocene surficial deposits composed of eolian deposits and present day dry valley alluvium (silt, sand, gravel, and conglomerates).

The intermontane regions outside the modern flood plain are primarily composed of Tertiary volcanics, Pleistocene lavas, fans, river terrace deposits, and playa sediments. Local dunes and wash deposits are also found here. Slopes in this region are less than 15°, and the area is only locally dissected. Small late Quaternary volcanic constructs are also observed in the area. There are no significant mineral deposits of any economic value found in this region.

1.4.2 Riparian Ecology

"Riparian" is defined as relating to, living on, or located on the banks of a natural water course (river) or sometimes a lake or tidewater (Ohmart and Anderson, 1986). Lowe (1964) defined riparian ecosytems as riparian associations of any kind (excluding marshes)

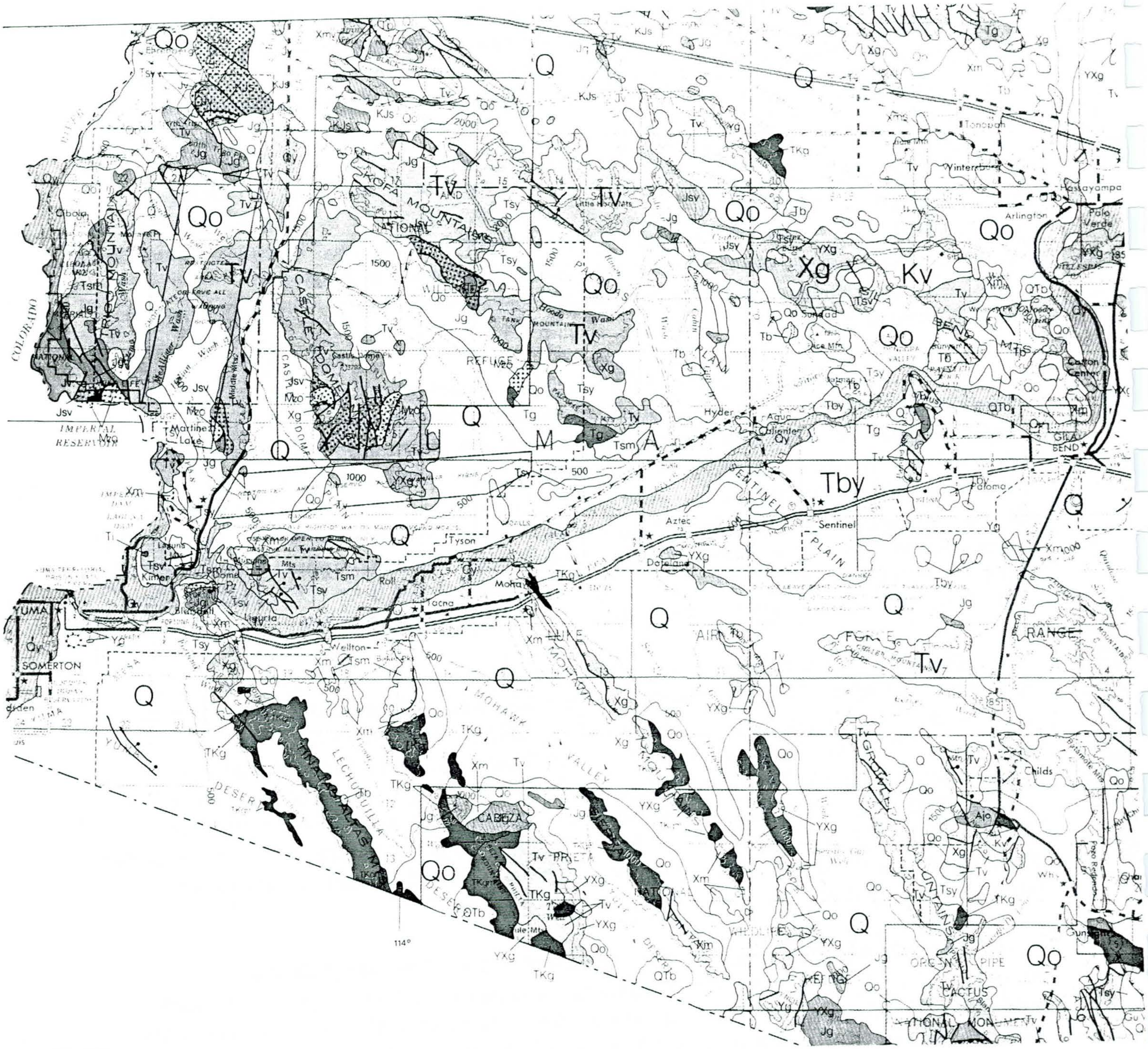


Figure 2. Portion of the geologic map of Arizona showing the Lower Gila River region. Key to various units given on the following two pages.

Qy	Young alluvium (Holocene to latest Pleistocene)—Deposits in present-day river and stream channels, flood plains, and playas
Q	Surficial deposits (Holocene to middle Pleistocene)—Alluvium in present-day valleys and piedmonts, eolian deposits, and local glacial deposits.
Qo	Older surficial deposits (middle Pleistocene to latest Pliocene)—Alluvium with less abundant talus and eolian deposits.
QTb	Basaltic rocks (Holocene to late Pliocene; 0 to 4 Ma).
QTv	Volcanic rocks (Quaternary to late Pliocene)—Rhyolitic to andesitic rocks associated with unit QTb.
Tsy	Sedimentary rocks (Pliocene to middle Miocene)—Units deposited during and after late Tertiary normal faulting, sedimentary parts of the Bidahochi Formation, and the Bouse Formation; commonly capped by patches of Quaternary surficial deposits.
Tby	Basaltic rocks (Pliocene to late Miocene; 4 to 8 Ma).
Tvy	Volcanic rocks (Pliocene to middle Miocene; 4 to 15 Ma)—Rhyolitic to andesitic rocks associated with units Tby and Tb.
Tb	Basaltic rocks (late to middle Miocene; 8 to 16 Ma)—Units, such as the Hickey Formation, erupted after most mid-Tertiary volcanism and tectonism.
Tsm	Sedimentary rocks (middle Miocene to Oligocene; 15 to 38 Ma)—Deposited during mid-Tertiary orogenic activity in the Basin and Range Province and southwestern Transition Zone.
Tv	Volcanic rocks (middle Miocene to Oligocene; 15 to 38 Ma)—Silicic to mafic flows and pyroclastic rocks; includes some subvolcanic intrusions.
Tsv	Volcanic and sedimentary rocks (middle Miocene to Oligocene).
Ti	Subvolcanic intrusive rocks (middle Miocene to Oligocene).
Tg	Granitoid rocks (early Miocene to Oligocene; 18 to 38 Ma).
Tso	Sedimentary rocks (Oligocene to Eocene or locally Paleocene)—Units deposited on the Colorado Plateau and Transition Zone prior to or during the initial phases of mid-Tertiary volcanism; many units were deposited by drainages flowing north and east onto the Colorado Plateau; includes "rim gravels" and associated finer grained rocks along the Mogollon Rim; also includes Chuska Sandstone; some units, especially those in the Transition Zone, may overlap in age with unit Tsm.
TKgm	Granitic rocks (early Tertiary to Late Cretaceous; 45 to 75 Ma)—Commonly muscovite-garnet-bearing peraluminous granite and associated pegmatite.
TKg	Granitoid rocks (early Tertiary to Late Cretaceous; 55 to 85 Ma)—Generally metaluminous granite to diorite and subvolcanic porphyry.
Kv	Volcanic rocks (Late Cretaceous; early Tertiary near Safford)—Rhyolitic to andesitic volcanic rocks and locally associated sedimentary and subvolcanic intrusive rocks.
Kmv	Mesaverde Group (Late Cretaceous)—Yale Point Sandstone, Wepo Formation, and Toreva Formation.
Ks	Sedimentary rocks (Cretaceous)—Dakota Sandstone, Mancos Shale, and related rocks near Show Low, Morenci (Pinkard Formation), and Deer Creek.
KJs	Sedimentary rocks with local volcanic units (Cretaceous to Late Jurassic)—Bisbee Group (largely Early Cretaceous) and related rocks, Temporal, Bathtub, and Sand Wells Formations, rocks of Gu Achi, McCoy Mountains Formation, and Upper Cretaceous Fort Crittenden Formation and equivalent rocks.
Jm	Morrison Formation (Late Jurassic)—Locally mapped with San Rafael Group.
Js	San Rafael Group (Late to Middle Jurassic)—Bluff and Cow Springs Sandstones, Summerville Formation, Todilto Limestone, Entrada Sandstone, and Carmel Formation.
Jgc	Glen Canyon Group (Early Jurassic)—Navajo Sandstone, Kayenta and Moenave Formations, and Wingate Sandstone.

Unit	Description
Jg	Granitoid rocks (Jurassic)—Granite to diorite, with local alkaline rocks; includes Triassic(?) granitoids in Trigo Mountains.
Jsv	Sedimentary and volcanic rocks (Jurassic)—Sil Nakya, Ali Molina, and Pitoikam Formations, Cobre Ridge tuff, Rudolfo Red Beds, Recreation Red Beds, Gardner Canyon Formation, and part of the Canelo Hills Volcanics in southern Arizona; Harquar formation and rocks of Slumgullion in western Arizona.
Jv	Volcanic rocks (Jurassic; locally latest Triassic)—Mount Wrightson Formation, part of Canelo Hills Volcanics, Mulberry Wash Volcanics, Black Rock Volcanics, and equivalent rocks.
JTR	Sedimentary and volcanic rocks (Jurassic and Early Triassic)—Buckskin Formation, Vampire Formation, and Planet Volcanics in west-central Arizona.
TRc	Chinle Formation (Late Triassic)—Shinarump Conglomerate Member (TRcs) mapped separately in most areas.
TRm	Moenkopi Formation (Middle[?] and Early Triassic).
Mzo	Orocopia Schist (Jurassic protolith; Cretaceous metamorphism).
MzPz	Mesozoic and Paleozoic rocks—Structurally complex Jurassic, Triassic, and Paleozoic rocks in west-central Arizona.
Pz	Paleozoic rocks, undifferentiated.
P	Sedimentary rocks (Permian)—Kaibab Limestone, Toroweap Formation, Coconino Sandstone, San Andres Formation, and Glorieta Sandstone on the Colorado Plateau; age-equivalent rocks in the Basin and Range Province and Transition Zone are included with unit PIP.
PIP	Sedimentary rocks (Permian and Pennsylvanian)—Hermit Shale, Supai Group, Naco Group, De Chelly Sandstone, Cutler Group, Pakoon Limestone, Callville Limestone, and Queantoweap Sandstone.
MЄ	Sedimentary rocks (Mississippian to Cambrian)—Redwall Limestone, Temple Butte Limestone, and Tonto Group in northern Arizona; Escabrosa Limestone, Percha Shale, Martin Formation, El Paso Limestone, Abrigo Formation, and Bolsa Quartzite in southern Arizona.
Ys	Sedimentary rocks (Middle Proterozoic)—Grand Canyon Supergroup (locally Late Proterozoic), Apache Group, Troy Quartzite, and local basalt flows and diabase.
Yd	Diabase (Middle Proterozoic; 1100 Ma).
Yg	Granitoid rocks (Middle Proterozoic; 1400 Ma).
YXg	Granitoid rocks (Middle or Early Proterozoic; 1400 Ma or 1650 to 1750 Ma).
Xg	Granitoid rocks (Early Proterozoic; 1650 to 1750 Ma)—Granite, granodiorite, tonalite, quartz diorite, diorite, and gabbro; commonly foliated.
Xq	Quartzite (Early Proterozoic; 1700 Ma)—Mazatzal Group and similar rocks.
Xm	Metamorphic rocks (Early Proterozoic; 1650 to 1800 Ma)—Undifferentiated metasedimentary, metavolcanic, and gneissic rocks.
Xms	Metasedimentary rocks (Early Proterozoic; 1650 to 1800 Ma).
Xmv	Metavolcanic rocks (Early Proterozoic; 1650 to 1800 Ma).

MAP SYMBOLS

- Contact
- Fault
- Low-angle normal fault
- Detachment fault
- Thrust or reverse fault
- Middle Tertiary mylonitic fabric; lined pattern is approximately parallel to lineation.
- Mesozoic to early Tertiary metamorphic fabric in Proterozoic to Mesozoic sedimentary rocks

which is in or adjacent to drainageways and or their flood plains and which is further characterized by species and or life forms different from that of the immediately surrounding non-riparian climax. This also includes plant communities located along drainageways either permanently or intermittently flowing.

Riparian habitats should be afforded a high priority status in any land planning or management efforts because of their importance to fish, wildlife, and recreational activity. For instance, it has been observed that 64 wildlife species presently listed as endangered and an additional 47 more species being considered for listing are dependent on riparian habitats (Johnson, 1978). Past treatment of these habitats as sewage transport systems, and refuse landfill sites must be re-evaluated, and special attention needs to be paid to these ecosystems. The U.S. Council on Environmental Quality (1978) estimated that between 70 - 90% of the natural riparian ecosystems in the U.S. have been destroyed by human induced activities. In Arizona alone, 85-95% have been lost (Warner, 1979). Riparian habitat studies (Carothers et al. 1974; Ohmart and Anderson, 1976; Ohmart and Anderson, 1986) found that more than 60% of the vertebrates in the Southwest were obligate to riparian ecosystems. These studies also found that the highest densities of breeding birds in North America were found in riparian habitat regions. If these habitats were lost or continued to be destroyed then 60-80% of our native wildlife species could be lost in the western U.S. (Ohmart and Anderson, 1986).

Riparian vegetation is important for several reasons: as a food source, shade source for smaller order streams, bank stabilizer by preventing excessive sedimentation, and intercepting pollutants (Mahoney and Erman, 1984; Asmussen et al. 1977). Vegetation may also improve water quality in agricultural watersheds (Karr and Schlosser, 1977, 1978). Riparian vegetation is also important as a means of flood control by reducing flow velocity and its erosive energy during flood events (Chaimsson, 1984; Li and Shen, 1973).

Gallery forests of *Populus fremontii* Wats. and *Salix goodingii* Ball are found along the flood plains of low elevation rivers, like the Gila, in the desert southwest. Historically these forests covered hundreds of miles along the lower reaches of rivers, like the Salt and Gila (Stromberg, 1993). In modern times these Sonoran cottonwood and willow forests are one of the most endangered forests in the U.S. (Swift, 1984).

Optimal conditions for cottonwood - willow forests are found in depositional environments where fine grained alluvial substrates are located on flood plains (Stromberg, 1993). These forests commonly occur with other riparian assemblages because fluvial processes (floodplain aggradation and channel meandering) create environmental gradients and mosaics (e.g., water table depth, inundation frequency) which favor diverse riparian species assemblages (Lacey et al. 1975; Brown, 1982) including : Sonoran interior marshlands dominated by *Typha spp.* (cattail), *Scirpus spp.* (bulrush), or other emergents; Sonoran riparian scrubland dominated by *Bacchariss Salicifolia* (R&P) Pers. (seepwillow), *Hymenoclea spp.* (burro brush), *tessaria sericea* (Nutt.) Shinners (arrowweed), *Suaeda torreyana* Wats. (seepweed), or *Atriplex spp.* (saltbush); and *Prosopis spp.* (Sonoran riparian mesquite) forests (Stromberg, 1993). The mature cottonwoods and willows reach 90 feet in height and 10 feet in diameter (Stromberg, 1993).

Cottonwood and willow forests normally are composed of spatially separate, same age cohorts which grow in linear bands parallel to the primary or secondary channels (Stromberg et al., 1991). The bands represent the previous locations of channel-edge environments that have subsequently been abandoned by shifting channgel positions. The oldest trees are located on the flood plains up to 600 feet from the primary channel and the youngest cohorts closest to the channel (Stromberg, 1993). The lifespans of these trees are from 100 to 150 years (Stromberg et al. 1991; Stromberg, 1993).

Threats to cottonwood and willow forests are primarily from human activities such as groundwater pumping, damming, surface flow diversion and regulation, and interbasin groundwater and or surface water flow transfers (Stromberg, 1993). Although dams and large scale diversions have not increased in numbers recently (Beaumont, 1978), riparian ecosystems still are threatened. Artificial inputs of water occasionally support riparian communities similar to natural assemblages, particular in areas with waste water effluent (Tellman, 1992). Diversion of this effluent is being contemplated by numerous cities as an alternative to meeting stringent water quality standards, but diversion could result in the decline or elimination of the riparian vegetation (Jones and Snyder, 1984). Instead of diverting the effluent the authorities could decide to construct artificial wetlands at the effluent release point. These wetlands are excellent filtering mechanisms for removing heavy metals and nutrients that often occur in effluent water (Sullivan, 1991).

Riparian ecosystems along regulated river reaches are impacted in subtle ways. For example, since impoundments decrease water velocity and this consequently reduces the transport capability of suspended material, sediment and nutrients are deposited in the impoundment area rather than being released into the below-dam system. These sediment depleted flows have an increased erosive power which causes channel downcutting and a decline in riparian water tables (Bradley and Smith, 1984; Williams and Wolman, 1984). These changes impact cottonwoods, willows, and any other riparian trees dependent on shallow water tables and on the deposition of alluvial recruitment areas, and can lead to the loss of gallery forests (Stromberg, 1993). Since the age of some dams (less than 50 years) is young in comparison to the forests lifespans (100 to 200 years), impending forest decline may be hidden by the apparent vigor of the mature forests (Petts, 1985). Furthermore, summer or fall high flows tend to favor tamarisk. Tamarisk has the ability to establish itself after floods that occur during any part of the growing season unlike cottonwoods and willows (Horton et al. 1960). Tamarisk forests have low habitat value because they have low plant species diversity, low canopy height, and low vertical and horizontal complexity (Rosenberg et al. 1991).

Large dense *Prosopsis spp.* (mesquite) forests or bosques are found along abandoned lakes, lake edges and river flood plains (Jarrell and Virginia, 1990). Mesquite bosques were once the most abundant riparian type in the Southwest (Klopatek et al. 1979; Brown, 1982) but are now reduced to remnant status. Most mesquite bosques are large (one mile long and 600 feet wide), but these are small compared to pre-settlement bosques which spanned widths of 5 to 10 miles and extended for hundreds of miles along reaches of the Gila River (Minckley and Clark, 1984; Minckley and Rinne, 1985).

Mesquite bosques often occur with associations that include *Populus Salix* (cottonwood-willow) forests, *Tamarix supp.* (exotic tamarisk) forests, shrub associations, and emergent herbaceous associations (Brown, 1982). Within such complexes, bosques often cover more area than any other types, as much as 56% on the Gila River (Lacey et al. 1975). Bosques usually are found on the drier habitat types within the riparian continuum. The locations for this setting are flood plains several meters above the streambed, and up to 45 feet above the water table (Brown, 1982; Turner, 1983; Stromberg et al. 1992). Most bosques are made up of high densities (200-800/ha) of young or second growth multi trunked trees (Minckley and Clark, 1984). The tallest trees are up to 50 feet high, but most of the tree diameters are less than 1.5 feet (Minckley and Clark, 1981).

Prosopis pubescens Benth. (screwbean mesquite) is a distinct species that is found along the Gila River. Less than 25% of the trees in bosques are composed of species which can include: *Acacia gregii* Gray (catclaw acacia), *Celtis reticulata* Torr. (netleaf hackberry), *Cercidium floridum* Benth. (blue palo verde), *Chilopsis linearis* (Cav.) Sweet (desert willow), *Fraximus pennsylvanica* Marsh. spp. velutina (Torr.) G.N. Miller (velvet ash), *Juglans major* (Torr.) Heller (arizona walnut), *Morus microphylla* Buckl. (Texas mulberry), *Populus fremontis* Wats. (Fremont cottonwood), *Salix goodingii* Ball (Gooding willow), *Sambucus mexicana* Presl. (Mexican elder), and *Sapindus saponaria* L. var. *drummondi* (H. & A.) Benson (soapberry) (Minckley and Clark, 1981, 1984; Szaro, 1989; Stromberg et al. 1992).

Mesquite bosques go through cycles of formation and destruction on timescales that range from decades to centuries (Minckley and Clark, 1984). Dynamic fluvial processes are required to serve as recruitment sites for young mesquite, specifically flood plains. These may be formed by sediment deposition on streamside areas by silt laden floodwaters, lateral movement of the stream channel away from the floodplain, or entrenchment of the channel and subsequent lowering of the water table (Lacey et al. 1975). Floods also destroy bosques. An example occurred on the Gila River when a bosque was destroyed in 1978 as a result of prolonged flooding. The flood waters undercut and collapsed the flood plain, thus wiping out the mesquite located on the surfaces. Minckley and Clark (1984) believe that most of the bosques in Arizona are relatively young, less than 100 years old based on observations that massive flooding around the turn of the century concurrently destroyed existing bosques and created habitats for new bosque development.

The native vegetation along the lower Gila River floodplain has changed dramatically over the last century (Haas, 1972). Most of the changes occurred with the arrival of Anglo-American settlers. Riparian forests of mesquite, cottonwoods, and willow were replaced with slat cedar or tamarisk. Salt cedar is a phreatophyte native to Eurasia, and was probably introduced into the U.S. in the 19th century (Robinson, 1965). In 1846 cottonwoods along the lower Gila River were described as 25 to 30 feet high and the bottom land was thickly overgrown with willow (Emory, 1848). Emory also mentioned that many signs of waterfowl, deer, and beaver were present. The river bottom also had areas covered with salt and had many salt lakes located within the flood plains. The Gila River was a very popular route to California, and consequently had many miners and farmers passed through the region. They removed riparian trees for fuel, buildings, fence posts, and to clear the land for crops. This clearance provided conditions favoring the later incursion of tamarisk by decreasing competition from native species (Harris, 1966). Tamarisk spread through Southwestern river systems at a rate of almost 15 miles per year (Graf, 1978). Tamarisk was also used for windbreaks and erosion control. This practice resulted in the tamarisk seeds being widely distributed over the region (Robinson, 1965). An additional aid to tamarisk establishment was the construction of dams and the changes this caused in drainage patterns and flow frequency. As a result the lower Gila River bottoms were described as desolate areas of sand and silt with thickets of arrowweed by Ross in 1923. Over time various efforts have been directed toward the elimination of tamarisk along the lower Gila River region. The largest clearing effort took place between January 1958 and September 1959 when a swath 400 feet wide and 50 miles long was cleared by bulldozers (Frost and Hamilton, 1960). Localized clearing efforts continue.

1.5 Significance of the Lower Gila River

1.5.1 Agricultural Significance

The primary economic significance of the Lower Gila River is its agricultural productivity. The Lower Gila River has been cultivated periodically since prehistoric times. Until the late 1800's all agriculture was conducted by Indians who inhabited small enclaves along the river banks, growing maize, beans, calabashes (gourds) and watermelons (WMIDD, 1978). Even in these early periods irrigation from the Gila River was needed in order to sustain crop development. Farming in this region was more or less a feast or famine operation. The early farmers battled with irrigation water problems, flood problems and many other problems that hindered the development of farming in its early years. Farming in the region was not generally productive until the municipal water districts were established. Today the agricultural lands of the Lower Gila River are highly dependent on irrigation water from a variety of sources: the Colorado River, Central Arizona Project, and pumped groundwater.

The Wellton-Mohawk Irrigation and Drainage District (WMIDD) is the largest agricultural area along the Lower Gila, with all other agricultural areas above it and below it producing similar crops. The WMIDD consists of approximately 125,000 acres, of which roughly 63,000 acres is irrigable land. In 1994, 97% of the irrigable land is privately owned, while the remaining 3% is either state or federal land (RMI, 1994). The principal crops grown in the WMIDD in 1990 have been compiled in Table 3. One of the advantages of the climate and the water availability (Colorado River) in the WMIDD is that in many cases there is double-cropping of the principal crops (barley, wheat, grain sorghum, lettuce, and cantaloupe) and in some cases even triple-cropping. In 1990 these principal crops were

Table 3. Agricultural produce of the Wellton-Mohawk Irrigation and Drainage District

WMIDD Crops	Acres	Value	Tot. Az. Acres (1978)	Tot. U.S. Acres (1990)	Tot. U.S. Value (1990)
Barley	165	$46,113	350000	8201000	$905,923,000
Sorghum	108**	$19,441**	73000	10535000	$1,201,581,000
Wheat	10272	$4,025,704	138000	77286000	$7,298,833,000
Alfalafa & Other Hay	29185	$22,207,762	206000	26750000	$11,138,492,000
Beans (dry)	452	$92,931		2178600	$609,334,000
Cotton (upland)	12188	$12,028,337	538000	12196800	$4,923,943,000
Cotton Seed		$1,823,325			$739,238,000
Cotton (Pima)	1046	$818,809	34200	231700	$182,650,000
Cotton Seed		$85,354			
Broccoli	160	$315,177	900	110800	$268,220,000
Cabbage	26	$72,540			
Carrots	9	$10,799	2000	94440	$272,743,000
Cauliflower	512	$1,721,750	1300	65800	$190,350,000
Lettuce	12793	$31,975,733	38500	231300	$846,973,000
Cantaloupe	334	$1,899,796	9900		
Honeydew	338	$1,551,043	1620	26500	$81,636,000
Watermelon	317	$922,555	3800		
Tomatoes (Can'g)	179	$373,537		134290	
Grapefruit	81	$366,821	10830	133400	$380,764,000
Lemons	556	$3,362,088	20890	62100	$294,534,000
Oranges	746	$1,801,985	20930	612700	$1,671,990,000
Peaches	5	$9,625		185500	$365,443,000
Pecans	582	$1,340,898			
Peanuts	130	$163,192		1809500	$1,260,174,000
Totals	70076	$87,023,885	1449870	140845430	$32,632,821,000

**1989 figures.

Sources: Wellton-Mohawk Irrigation and Drainage District

Agricultural Statistics 1991

Arizona Statistical Abstracts 1979

planted on 70,076 acres in the WMIDD. The 1990 principal crops generated a total of $87,023,885, producing a gross yield per acre of land of $1242 (This figure does not account for any other costs leading to the production of the crop, for example cost of irrigation water, farm equipment, herbicides, pesticides, and employment of workers). During the 1960's, this region enjoyed the highest income per farm in the nation, with the bulk of the income coming from the sale of crops (OALS, 1970). In 1990 the four crops bringing the largest revenue as well as covering the greatest acreage were (in descending order) lettuce, alfalfa and other hay, cotton and wheat. The order of importance of these crops is subject to change with the changing consumer needs and market prices.

The acreage in the WMIDD represents about 0.05% of the total U.S. acreage in these principal crops, and the production value of the WMIDD crops represents 0.27% of the total U.S. production value for these crops. In 1978 the principal crops (Table 1) covered 74,000 acres in the WMIDD which is approximately half of the total acreage covered by these crops throughout the state of Arizona.

1.5.2 Environmental Significance

In general the Lower Gila River is a typical desert southwest ephemeral stream, although it has been drastically altered by damming upstream. For most of the year a large portion of the stream remains dry, however in some areas when the water table is high the stream does receive some baseflow. There are some riverine wetland and marsh areas that are a direct result of the nearness of groundwater (in most cases the high groundwater levels are in response to excess irrigation water that has percolated into the aquifer) to the surface, these may persist throughout the year. In an attempt to examine the environmental significance of the Lower Gila River, this section will address: (1) the geomorphic environment of the river, (2) riparian vegetation associated with the river, (3) wetlands that exist along the margin of the river and (4) the animal and bird species that are associated with each of these environments.

The river consists of a low flow channel that meanders in some places and is abraded in others (for details, see Section 4.3 below). Adjacent to the low flow channel is a series of terraces. The form of the river is in direct response to the numerous high flow events that have taken place throughout its history and have culminated with the most recent flood of 1993. One of the most prominent features associated with the flooding events are shifts in the location of channel flow which leave numerous meander scars and oxbows, common features along the Lower Gila River. Channel shifts have also been important in the formation of the floodplain that consists mostly of alluvial sediments carried during the flood events.

Observations from aerial photos, historical ground photos, and field reconnaissance have shown that the Lower Gila River has consistently had high levels of sedimentation. The bulk of these sediments is provided from the numerous tributary streams, with some contribution from the older alluvial fill as the river cuts through these deposits and minor contributions aeolian transport (sand and dust particles). High levels of sedimentation further reduce the stability of the channel, causing aggradation, downcutting and further impetus for channel shifting. Presently, the river from Gillespie Dam to Dome appears to be in an aggradational phase, with numerous large bar deposits evident along the stretch from below Painted Rock Dam to Antelope Hill (east of Mohawk) from the 1993 flood. John Laird, a local resident of Gila Bend also explained that the stretch of the river north of the town filled 3-4 feet with sediment (Figure 3).

The riparian vegetation consists of nine associated types: cottonwood-willow, salt cedar, salt cedar-honey mesquite, salt cedar-screwbean mesquite, honey mesquite, arroweed, Atriplex, creosote and salt cedar-willow-arrow weed complexes (USBR, 1984). Like the sediment transport and the channel configuration, the riparian vegetation is greatly effected by the high water flows. In many cases the riparian vegetation is located on the surfaces that have been created during flood events. At present most of the consist almost exclusively of salt cedar-willow-arrow weed complexes. In the past this was not always the case. There has been a series of successional changes, where the original climax vegetation (cottonwood, willow, mesquite and arrow weed communities) have been mostly destroyed by human disturbances and the tamarisk-willow-arrow weed complexes have filled the niche created by human disturbances. In most reaches of the river the tamarisk-willow-arrow weed complexes make-up approximately 95-100% of the riparian vegetation (RMI, 1994). The most prominent species in the tamarisk-willow-arrow weed complexes is the exotic invader salt cedar (*Tamarix chinensis*), which appeared around the turn of the century and since its introduction has spread rapidly in the riparian corridor. At present the U.S. Fish and Wildlife Service has not identified any riparian plants in this section of the river that would be considered endangered species.

Most of the wetland areas are located along old riverine oxbow and meander scars or low lying areas in the floodplain of the river. The wetland areas are to some extent dependent on irrigation water that has percolated into the aquifer, especially in the WMIDD. Still other wetland areas are associated with the standing waters that are in response to the two diversion dams on the upper section of the Lower Gila River (Gillespie and Painted Rock dams). All of the wetland environments consist of some or all of the aforementioned riparian vegetation, there are also two species of emergent marsh species, cattail (*Typha latifolia*) and bulrushes (*Scirpus spp.*). Most of the water in the Gila River is too turbulent or its flow is too undependable for submergent species to exist (Brown, 1985).

The fish and wildlife species have been cataloged in Table 4. This is not a complete listing of all the species that live in the area, nor does it cover all of the migratory species that are often found along the Lower Gila River. It does however, give the scope of the species that inhabit the different ecosystems that are associated with the study area. The riparian vegetation and the wetland areas support most of wildlife species. In some cases the migratory birds also use agricultural fields to rest and eat, especially fields where grasses are grown. In all cases, except for the pronghorn sheep, the endangered species reside in the riparian vegetation or the wetland areas associated with the river. The candidate species are those species that may warrant either a listing of endangered or threatened at the state or federal level. These creatures have more of a diversified habitat,

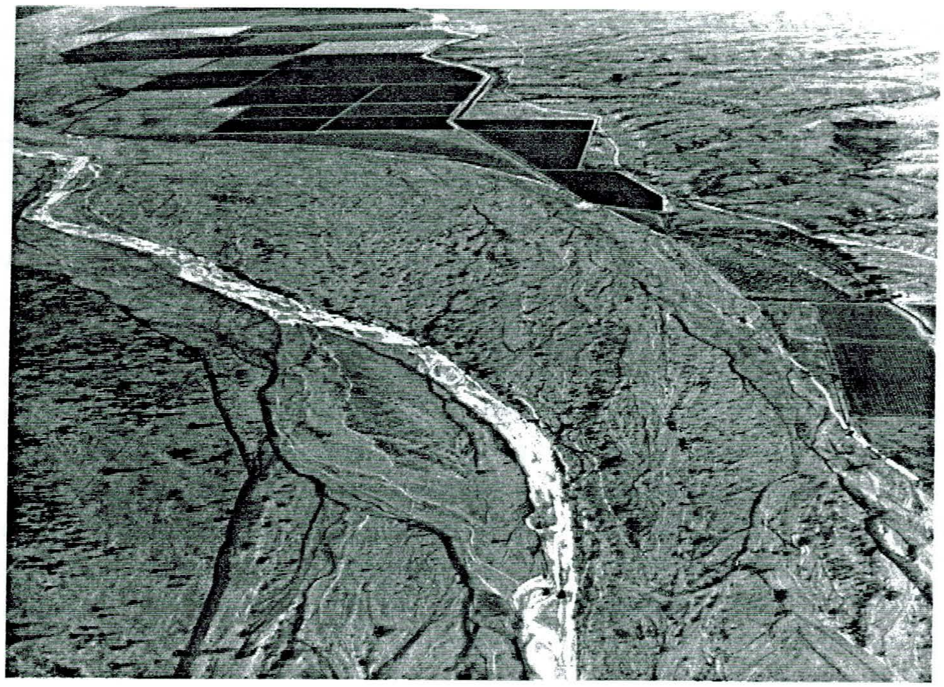


Figure 3. The Gila River channel near Cotton Center, below Gillespie Dam and above Gila Bend, in an area with extensive aggradation (Graf Photo 120-3, June 26, 1994).

Table 4. Fish and wildlife along the Lower Gila River.

Common Names	Scientific Names	Common Names	Scientific Names
Mammals		Amphibians and Reptiles	
cottontail rabbits	Sylvilagus audoboni	bullfrog	Rana catesbiana
striped skunk	Mephitis mephitis	lowland leopard frog	Rana yavapaiensis
badger	Taxidea taxus	spiny softshell turtle	Trionyx spiniferus
raccoon	Procyon lotor	Woodhouse's toad	Bufo woodhousei
beaver	Castor canadensis	common jingsnake	Lampropeltis getulus
bighorn sheep	Ovis canadensis	gopher snake	Pituophis melanoleucus
numerous rodents		western diamondback rattlesnake	Crotalus atrox
		western whiptail	Cnemidophorus tigris
Birds			
		Fish (introduced species)	
Osprey	Pandion haliaetus		
lesser nigthawk	Chordeiles acutinpennis	Tilapia	Tilapia mossambica
ash-throated flycatcher	Myiarchus cinerascens	sailfin mollie	Mollienisia latipinna
black pheobe	Sayornis nigricans	Mexican mollie	Poecilia mexicana
marsh wren	Cistothorus palustris	carp	Cyprinus carpio
blue grosbeak	Guiraca caerulea	red shiner	Richardsonius balteatus
summer tanager	Piranga rubra	goldfish	Carassius auratus
Gila woodpecker	Melanerpes uropygialis	channel catfish	Ictalurus punctatus
verdin	Auriparus flaviceps	flathead catfish	Pylodictus olivaris
Bewick's wren	Thryomanes bewickii	largemouth bass	Micropterus salimoides
loggerhead shrike	Lanius ludovicianus		
mourning dove	Zenaida macroura	Endangered and Threatened Species	
white-winged dove	Zenaida asiatica		
Gambel's quail	Callipepla pambelii	Yuma clapper rail	Rallus longirostris yumanesis
black-crowned night heron	Nycticorax nycticorax	yellow-billed cuckoo	Coccyzus americanus
least bittern	Ixobrychus exilis	southwestern willow flycatcher	Empidonax trailii extimus
green heron	Butorides virescens	Sonoran pronghorn	Antilocapra americana sonoriensis
wood storks	Mycteria americana		
Gadwall	Anas strepera	Candidate Species	
mallard	Anas platyrhynchos		
green-winged teal	Anas crecca	Cowles fringe-toed lizard	Uma notata rufopunctata
bald eagle	Haliaeetus leucocephalus	white-faced ibis	Plegadis chihi
		western snowy plover	Charadrius alexandrinus nivosus
		long-billed curlew	Numenius americanus
		spotted bat	Euderma maculatum

but are still closely associated with the river ecosystems, especially with the wetland areas found in the meander scars.

A recent survey by the Arizona Game and Fish Department demonstrates the importance of wetlands and their wildlife to the general public. The Behavior Research Center of Phoenix interviewed 1,500 people in the state, asking about their priorities for wildlife and land management, in preparing the survey results entitled *Wildlife 2000* (Burkhart, 1994). Of those surveyed, 89 percent said that wetlands are important for wildlife and should be protected vigorously, and 63 percent said that wetlands should be protected even at the expense of other uses that might produce more jobs or economic income. In Arizona, these results send the clear signal that the public is sensitive to the ecological value of wetlands, and that governmental agencies enhancing wetlands can expect substantial public support.

2 PRIMARY PHILOSOPHICAL ISSUES

For the U.S. Army Corps of Engineers, planning and managing engineering works for rivers takes place within a well-developed philosophical framework that has developed over more than a century and a half of American engineering practice. Any evaluation or assessment of conditions on the Lower Gila River takes place within this framework. Similar considerations of environmental restoration, however, lack a similar widely accepted philosophy within the Corps. In fact, river management using engineering structures and strategies for environmental enhancement is an emerging ethic that is generally not yet formalized, though the Bureau of Reclamation has explored the issue in philosophy and in practice on the Colorado River below Glen Canyon Dam for the past decade (National Research Council, 1987). The purpose of the following paragraphs is to address a series of general questions with broadly defined answers that can serve as a philosophical foundation for decision-making regarding environmental restoration by the Corps. Decisions about the fate of individual sites might be governed by this general background.

This strategic development by the Corps fits within a broad national strategy advocated by the National Academy of Sciences for the federal government. The Academy's recent report, which is widely considered the state of the art statement on environmental restoration, defines four elements for a national environmental restoration strategy (National Research Council, 1992, p. 3):

1. A set of restoration goals and assessment strategies for each ecoregion of the nation..

2. Principles for priority setting and decision making.

3. Policy and program redesign for federal and state agencies to emphasize restoration.

4. Innovation in financing and use of land and water markets.

The present report is the product of only a 30-day contract effort, so that it cannot explore in depth the implications of all these elements for the Lower Gila River. This report can, however, identify particular problem issues and offer preliminary solutions as a foundation for the Los Angeles District as it begins to participate in the national process envisioned by the Academy.

2.1 What is Environmental Restoration?

In the abstract, environmental restoration implies that present ecosystems that have been radically altered from their previous natural states can be returned to those conditions but replicating the original physical and biological systems. In reality, such wholesale turning back of the environmental clock is simply not possible, at least in large river systems. Instead, it is more realistic to think about ecosystems as resting along a continuum ranging from completely natural to completely artificial. Most modern American rivers fall somewhere between these two extremes. Restoration might be thought of as an effort to move an ecosystem through intentional management and engineering efforts along this continuum to a position closer to the natural end of the scale.

In this discussion, "environment" and "ecosystem" are synonymous. They refer to a dynamic system containing interactive physical, chemical, and biological elements, including the air, water, earth, flora, fauna, and people of a particular area. There is logical debate about whether or not people are part of the natural system, but generally natural systems are considered by the federal government to be those without substantial human impacts. Environmental restoration is the "reestablishment of predisturbance aquatic functions and related physical, chemical, and biological characteristics" (Cairns, 1988; Lewis, 1989). Restoration is different from habitat creation, reclamation, rehabilitation, or improvement in that restoration is a holistic process that involves reestablishment of an entire system with all of its elements. The habitat creation, reclamation, rehabilitation, and improvement usually involve the manipulation of one or a few of the components of the ecosystem. It is impossible to return systems to their exact pre-disturbance condition, so that all restorations are "exercises in approximation and in the reconstruction of naturalistic rather than natural assemblages of plants and animals with their physical environments" (Berger, 1990).

Restoration of streams and rivers in a general sense includes several components as recognized by the National Academy of Sciences (National Research Council, 1992, p. 8):

1. Upland erosion control to prevent sedimentation.

2. Grazing controls to minimize damage to riparian vegetation.

3. Channel erosion controls by "soft engineering" for bank stabilization in preference to "hard engineering" such as levees, dams, channelization, and riprap.

4. Removal of ineffective dikes and levees to connect riparian environments with flood plains.

5. Classification of land use and wetlands to explicitly designate riparian environments and flood plains that retain their periodic connections to the channel.

The application of these general concepts to the Lower Gila River is at once good news and bad news. The good news is that the dryland river has a less complex biological system associated with it than a humid river, so that few species of plants and animals are involved. The dryland system is also simpler from a chemical perspective because in the high pH environment of the dryland system, many potential contaminants are precipitated from solution and are strongly adsorbed onto sedimentary particles. The bad news is that water, the critical connective component in ecosystem manipulation, is not only in short supply, its delivery is often in flashy, high volume discharges that are difficult to manage and use. The channel and bank systems are also more unstable in the Lower Gila River than in humid region systems because the dryland river sediments are poorly consolidated and do not contain large amounts of cohesive fines. Bank stability is an abstract idea more than it is a fact.

2.2 What is Natural?

If environmental restoration has as its goal the recreation of a pre-disturbance, natural condition, how does one define that natural condition? More importantly, how does one define the most common systems, those that are partly natural and partly artificial? If a continuum of natural-to-artificial systems were to be constructed, the first necessary ingredient is the definition of the end points; the second task is to define the intermediate states between the extremes. The following paragraphs briefly consider these tasks with respect to ecosystems in their entirety, and then from a specifically geomorphological perspective for rivers.

Specification of completely artificial ecosystems is relatively easy because they are comprised of engineered or completely disrupted systems. The River Walk along the San Antonio River in downtown San Antonio, Texas, is a famous example of such a system. With its water flows controlled by gates, its channel defined by cement walls, its vegetation consisting of imported plants, and its built landscape, the River Walk is completely unlike the ecosystem it replaced. The natural end of the spectrum for ecosystems is also relatively easy to define, with some attempts now established in law. Section 2 of the 1964 Wilderness Act defines a natural system in the formal sense of wilderness: "A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain" (Hendee et al., 1978, p. 68). In the past three decades, about 100 million acres of federal land have received legislative designation as wilderness (completely natural) by Congress (Graf, 1991). Intermediate parts of the classification of naturalness for ecosystems would be difficult to quantify, but such increments as partly natural and mostly artificial are easily envisioned.

The 1968 Wild and Scenic Rivers Act also codified definitions of naturalness specifically for rivers. Section 16(a) of the act defines a river as "a flowing body of water or estuary or a section, portion, or tributary thereof, including rivers, streams, creeks, runs, kills, rills, or small lakes." The law contains a scale, ranging from wild through scenic to recreational for defining the naturalness of river segments. The scale is based mostly accessibility, degree of disruption, and the presence of control structures on the river (American Rivers, 1988, p. 13-15). Section 2(b) of the 1968 act specifies:

> "1. **Wild** river areas: those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds and shorelines essentially primitive and water unpolluted. They represent vestiges of

primitive America.

2. **Scenic** rivers areas: those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads.

3. **Recreational** river areas: those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines and that may have undergone impoundment or diversion in the past."

The Wild and Scenic Rivers Act defines for the purposes of the present report one of the end members of the scale: the completely natural river channel is analogous to the wild river as defined by the Act. The references to impoundments in the original act have been interpreted by Congress to mean that no impoundments are acceptable within the reach of river to be designate wild, scenic, or recreational. Many river reaches now included in the Wild and Scenic River System have impoundments upstream, outside the boundaries of the designated reaches. The Lower Gila River in the study area for this report has no reaches that are candidates for wild status, and few that would fit the formal "scenic" designation, but there are some reaches that should not be summarily rejected for "recreational" consideration, especially if environmental restoration is modestly successful.

The Wilderness Act and the Wild and Scenic Rivers Act define their classifications based on holistic ecosystems. The classification of the subdivisions of ecosystems, the physical, chemical, and biological components, on a naturalness scale is also possible, and perhaps more useful from a management and policy standpoint than very general approaches. In the case of fauna, for example, estimates might be made of the species and their populations prior to human disturbance, and those numbers might then be compared to post-disturbance species and populations in a quantitative fashion. Such assessments also have spatial dimensions, and the mapping of ecosystems or their subcomponents showing the distribution of naturalness would provide useful input to environmental management. Since the purpose of this report is a geomorphic assessment, the following paragraphs outline only a geomorphic scale for naturalness, with a few remarks related to a hydrologic scale.

The geomorphic scale of naturalness for river channels presented here was designed with the following criteria and objectives.

1. The scale applies only to geomorphology and sedimentology of the channel. It does not pertain to the flood plain or other near-channel forms, and it does not account for directly for hydrology, flora, fauna, or other subsystems.

2. The scale is general enough to apply to the full range of rivers found in the earth environment, but detailed enough to provide specific information about dryland rivers on a reach-by-reach basis.

3. The geographic unit of application of the scale is about one mile or one kilometer of channel length. Thus, one mile of channel might be completely natural, while the next mile downstream might be partly natural and partly artificial. The scale does not apply directly to river networks or basins.

4. The various parts of the scale are useful for planning and management purposes, but they are couched in terms understandable to the educated lay person.

5. The scale as used in this report is both qualitative and in some respects quantitative to facilitate unbiased application.

6. The scale is to be used with aerial photography as a primary data source, with field checks as a secondary data source; application of the scale does not require detailed field mapping.

7. The classification is straight forward and objective, using objective reality as its base. The scale does not have social or other values attached to its various designations, and it does not purport to identify good or bad geomorphic environments.

Table 5 contains the geomorphic naturalness classification developed for this report. Application of the classification to the Lower Gila River demonstrates the spatial variability of the condition of the channel between Gillespie Dam and Yuma. Note that the classification refers only to the geomorphic state of the channel and does not include assessment of the vegetation. Note too that this evaluation was for channel conditions in June 1994 after substantial floods in 1993 destroyed many channel engineering works and reestablished some semblance of a natural channel.

Gillespie Dam to the eastern boundary of the Gila Bend Indian Reservation: 2. Essentially Natural.

Eastern Boundary of Gila Bend Indian Reservation to Painted Rock Dam: 4. Substantially Modified.

Painted Rock Dam to the Barrow Pit Lake: 7. Completely Artificial.

Barrow Pit Lake to lower end of Dendora Valley: 3. Partly Modified.

Lower end of Dendora Valley to Texas Hill: 2. Essentially natural.

Texas Hill to Dome: 3. Partly Modified.

Dome to the Colorado River: 5. Mostly Modified.

The geomorphic condition of the river and its degree of naturalness from a geomorphic perspective are largely the products of the hydrology of the stream. The

Table 5. Geomorphic "naturalness" classification for river channels.

Channel Type	1. Completely Natural	2. Essentially Natural	3. Partly Modified	4. Substantially Modified	5. Mostly Modified	6. Essentially Artificial	7. Completely Artificial
Pattern, X-Section Shape	No obvious evidence of human activities--same forms and processes as existed prior to human occupation	No obvious evidence of human activities--same forms and processes as existed prior to human occupation	Altered channel patterns or x-sectional shapes, as a result of human activities	Altered channel patterns or x-sectional shapes as a result of human activities	Altered channel patterns or x-sectional shapes as a result of human activities	Altered channel patterns or x-sectional shapes as a result of human activities	Completely engineered and/or built channel with altered processes and sediment
Minor Landforms	Same forms and processes as those found prior to human occupation	Altered by human activities or changes in sediment supply	Altered by human activities or changes in sediment supply	Altered by human activities or changes in sediment supply	Altered by human activities or changes in sediment supply	Altered by human activities or changes in sediment supply	Altered by human activities or changes in sediment supply
% Channel Area Engineered or Disturbed	0 %	< 10%	< 10%	> 10%, < 50%	> 50%, < 90%	> 90%, < 100%	100%
Descriptive Notes	Completely undisturbed channel, could be a "wild river" in the Wild and Scenic River System	Minor modifications by human, through flow regulation or by scattered structures on an otherwise undisturbed channel	Obvious modifications by flow regulation or altered sediment supply resulting in channel metamorphosis, scattered structures	Major modifications to channel forms and processes, with up to half the channel area disturbed by mining, development, or structures	Major modifications to channel forms and processes, with most of the channel area disturbed by mining, development, or structures	Largely artificial channel due to engineered bed and/or banks; in some cases including dredging; a few natural forms or processes remain	Channel completely determined by design and manipulation with no natural forms or processes
Example	Middle Verde River, Arizona	Colorado River in Grand Canyon, Arizona	Platte River in Western Nebraska	Potomac River near Georgetown, Maryland	Santa Cruz River near Santa Cruz, California	Illinois River in Central Illinois	Los Angeles River in Los Angeles, or Indian Bend Wash, Arizona

Note: Shaded cells indicate the most important diagnostic characteristic for each channel type.

controlling position of hydrology in the system comes about because the water in the channel represents the energy available for geomorphic work. If that energy is delivered at rates, in amounts, or at times different from the natural conditions, changes are bound to occur in the physical channel. In many respects, although the physical form of the channel is obviously disrupted by engineering works and other mechanical means, the geomorphology of the channel system is natural only to the degree that the hydrologic regime is natural. The installation and management of dams represent the most direct disruption of the hydrologic regime, though land management also may have pervasive, far-reaching effects that alter channel geomorphology downstream.

Through their storage capacity, outlet works, spillway capacity, and operating rules dams alter four fundamental discharge properties, listed here in increasing order of their temporal scale (Petts, 1984, p. 26): short-term fluctuations; magnitude of high, low, or mean flows; timing of extreme events; and mean annual water yield. The operating rules for a given dam depend on the ultimate purpose of the structure. For instance, hydroelectric produce daily fluctuations in releases, for example, in response to demands for discharges to produce electricity, demands which typically have a daily cycle. Taken together, the four general flow characteristics permit the construction of a naturalness classification for river hydrology similar to the geomorphic classification described above. In such a classification scheme (Table 6), the flow of the Lower Gila River below Painted Rock Dam would be defined as completely artificial.

2.3 What are Possible Corps Projects in the Lower Gila River?

Given the interests and abilities of the U.S. Army Corps of Engineers, along with the significantly altered geomorphology and completely artificial hydrology of the Lower Gila River, what sort of projects and priorities are appropriate for the agency? Detailed exploration of potential responses to this question are in section 7 of this report. Generally from the flood control perspective, however, the answer is that a reinvestigation of the operating rules for Painted Rock Dam may be in order. The present rules are clearly established in published Corps documents, but in practice, the dam has been operated almost exclusively to keep flows through the Wellton-Mohawk Irrigation and Drainage District at an absolute minimum. This strategy has resulted in reservoir filling and an uncontrolled spillway release once since the closure of the dam in 1960. The 1993 flood was probably a 500-year event, and resulted in maximum inflows to the reservoir of 186,000 cfs. Maximum outflows at the dam, including controlled release and overtopping of the spillway by about 6 feet of uncontrolled flow, were 24,000 cfs.

Environmental restoration projects in the Gila River between Gillespie Dam and Yuma represent limited but definite possibilities. The Corps of Engineers has a direct federal interest in environmental restoration in the river downstream from Painted Rock because of the Corps' responsibility in operating the dam. As outlined above, dam operations have a direct and overriding significance in channel processes, including channel change or stability that might impact restoration efforts.

Table 6. Hydrologic naturalness classification for river discharges.

Hydrologic Type	1. Completely Natural	2. Partly Modified	3. Mostly Modified	4. Completely Artificial
Short-term Fluctuations	Unchanged	Increased, usually due to hydroelectric power production at an upstream dam	Increased, usually due to hydroelectric power production at an upstream dam	No flow in the channel most of the time due to diversions
Magnitude of High, Low, and/or Mean Flows	Unchanged	Modest changes, usually increased low flows and decreased high flows	Substantial changes, particularly in mean flows: decreases due to withdrawals or increases due to injection of pumped waste water	No flow in the channel most of the time, flood peaks higher than previous annual maximum
Timing of Extreme Events	Unchanged	Unchanged	Some extreme events added or subtracted from the annual hydrograph	All but most extreme flood flows eliminated
Annual Water Yield	Unchanged	Unchanged	Substantial changes, decreases due to withdrawals or increases due to injection of pumped waste water	Annual flow from local tributary and waste water sources only
Example	Rouge River, Oregon, a "wild" river without dams	Elwha River, Washington, downstream from hydroelectric plant at Glines Canyon Dam	Gunnison River, Colorado, downstream from Blue Mesa Dam	Salt River, central Arizona, below Salt River Project dams

The general philosophical question facing the Corps is not "can we return the river to its natural, pre-disturbance condition?" because that goal is not possible given the influences of the other dams in the middle and upper portions of the Salt and Gila system. The real question facing the Corps in the Lower Gila River is "given the present controls exerted by other dams, how natural can we make some limited reaches of the river through mechanical means and operations of Painted Rock Dam?" Section 7.2 of this report provides some specific indications of potential projects that the Corps might undertake, but they all have the commonalities of limited spatial extent, some mechanical manipulation of the local landscape, and altered operations of Painted Rock Dam.

2.4 What is the Probable Without-Project Future?

The without-project future for the Lower Gila River is likely to be similar to conditions that have evolved within the last three decades, after the closure of Painted Rock Dam. The major components of this future are periodic moderate floods, occasional large floods, sedimentation within the river channel, and a vegetation community dominated by salt cedar that grows to significant densities in post-flood periods unless clearing operations are maintained.

Periodic moderate flooding is likely to continue in the Lower Gila River as the Corps operates Painted Rock Dam to issue moderate-level releases. Presumably the Corps would continue to attempt to minimize downstream flood damage by maintaining releases below 10,000 cfs. Discharges of this magnitude are likely to be sufficient to cause channel erosion and migration of the thalweg, so that erosion damage will result. At those places where dikes or levees constructed by the Wellton-Mohawk Irrigation and Drainage District intersect the course of the migrating thalweg, levee damage should be expected. While the 1993 flood was probably a one in five-hundred year event, other events of a lesser magnitude by greater than the one-hundred year event are expectable and likely to be damaging in terms of erosion and inundation, partly depending on operational discharges.

Because Painted Rock Dam prevents periodic low and moderate flows that might mobilize sediment in the main channel, sediment accumulation is likely under the no-project scenario. Sedimentation will occur because energy to move the materials will be lacking with the dam in place, but contributions from tributary streams will continue. These streams drain extensive areas of poorly vegetated surfaces of alluvial valley and basin fill, and as they occasionally flood, they will continue to conduct large quantities of sediment to the main channel. The materials will remain in the main channel of the Gila River until the rare high discharge event evacuates it. Accumulation of this sediment is likely to increase flood hazards because it will reduce channel capacity and increase the likelihood of overbank flooding. Unless vegetation is continually cleared from the surface of this accumulating sediment, plant roots and stems will increase the stability of channel fill, and accentuate the problem of lost channel capacity.

Vegetation communities in the main flow channel were probably at a minimum in early 1994. As barren sediment accumulations, bars, and channel surfaces are colonized, mostly by salt cedar, they will become the sites of monotypical riparian forests similar to those seen previously on this and other parts of the Gila River (Robinson, 1965). Because of the relatively shallow depth to ground water throughout much of the Lower Gila River, these phreatophytes are likely to survive in dense growths unless they are cleared. Clearing and maintenance of cleared channels will be likely requirements of a prudent flood control strategy, with the costs borne by local land owners.

2.5 How Can the Corps Evaluate Environmental Restoration?

The U.S. Army Corps of Engineers has extensive experience in evaluating benefits from flood control projects, but less experience in dealing with environmental restoration. While this report is primarily a geomorphic assessment, some observations about the evaluation of environmental restoration using geomorphologic techniques are in order. Sculpturing of the landscape and development of riparian communities that are more natural than the ones existing at present will produce economic benefits of significance, in terms of both use and non-use. Use values would be directly connected to users of the improved environments in the form of wildlife watching and touring, especially during the winter months. If a fairly large restoration effort is made in Dendora Valley, the potential economic impact on the town of Gila Bend is likely to be measurable by normal economic evaluation techniques that account for user days and local expenditures in pursuit of the outdoor activity. Quantification of these benefits appears to be a straight-forward exercise in the evaluation of recreation use as has often been accomplished for water resources projects (Walsh et al., 1987; Harpman et al., 1993).

The restoration of Dendora Valley or a similar large area (several hundred acres) might also be designed with temporary residents in mind. Seasonal residents in other areas of central Arizona often make use of informal camping areas on Bureau of Land Management lands. If reasonably attractive areas could be maintained along the Lower Gila River, they would offer an attractive and economically definable alternative to use of other public lands.

Environmental restoration also generates non-use values, social and economic values that are held by people who do not visit the area in question. The intrinsic value of the area as a component of the general environment, and especially as a place that nurtures wildlife, can be defined through broad-gauge public surveys after suitable scoping meetings. Such approaches have been used successfully in defining the non-use economic value of wilderness areas (Walsh et al., 1982), and might reasonably be applied to restoration areas. The Bureau of Reclamation is beginning to investigate and quantify non-use values in its projects on some western rivers, and the Corps, through the services of professional economists, should explore similar techniques for potential restoration efforts on the Lower Gila River.

3 ENVIRONMENTAL HISTORY OF THE LOWER GILA RIVER

3.1 Pre-Development Conditions--Prior to About 1900

Analysis of the environmental history of the Lower Gila River by the use of historical ground photographs focused mainly on the riparian vegetation and geomorphology of the area (see Appenix 11.3 for sources of photographs, Appendix 11.4 for descriptions of individual photographs). Prior to 1900 (pre-development), the riparian vegetation appeared to be dominated by the cottonwood, willow and the different species of mesquite (some areas more so than others). There were more emergent plant species (i.e. reeds, bulrushes and cattails) in some reaches of the river, located at or near the margin of the low flow channel. The emergent species were hard to identify because the researcher was not familiar with the species and in many cases they appeared in the background of many of the pictures. The post-development photos (1910-1994) showed a gradual change from the cottonwood, willow and mesquite species to a salt cedar-willow-arrow weed complex. The more recent photos lend support to the dominance of this complex as previously mentioned in Section 1.5. There was also a drastic decline in the number of emergent species as the photos became more recent. No observations could be made of the submergent species associated with the river, as they were not evident in any of the historical photographs, and at present they are generally only found near the mouth of the Gila River.

From the photos that were examined, there were no discernible changes in the geomorphology of the river from the pre-development era to the post-development. However, there did seem to be a more constant flow of water in the older pictures. Irregardless of the time of year many of the pre-development pictures had some flowing water in the stream bed, while the post-development river only had water during high flow events. In the post-development photos water was present in areas where the groundwater table had artificially risen and intersected the river bed (especially the WMIDD). This change was expected, because although flows were reduced by diversion, extensive irrigation of porous soils stimulated rises in the groundwater table.

It was evident that sediment transport in the river has historically been in high amounts, an arrangement that continues to the present. In almost all of the pictures that were viewed there were large bedforms and a low flow channel. A great deal of the sediment transported by the river occurred during the high flow events. Water during the high flow events was usually very turbid and laden with sediment. In some of the older photos, where there were smaller, more consistent flows, the water did not seem as sediment laden. Aggradation and degradation episodes have occurred throughout the history of the stream based upon what was seen in the historical photographs. In the 1993 event, the system seemed to be aggrading more than it was degrading.

The channel configuration in both periods (pre-1900 and post-1910) showed evidence that during the same year some reaches of the stream were abraded and then further downstream it was meandering, probably in response to variations in sediment supply, bank erosion, and discharge. The shifts in the river channel were not evident in the photographs, but they were evident in the numerous meander scars that were visible on the maps and in our reconnaissance flight. The channel shifts are partially in response to the high amounts of sediment that would make the channel unstable. Many of the meander scars still support some small amounts of water. This is probably in response to their proximity to groundwater, as these areas tend to be low lying.

Literary sources also provide useful descriptions of the pre-development conditions. Written accounts of conditions along the lower Gila River provide a general picture of the hydrologic regime of the river, the geomorphology of the channel, and the natural vegetation and wildlife along the river (see Appendix 11.5 for direct quotes from historical eyewitness accounts). Historical accounts of the Gila River begin in the 1540s with the reports of Francisco Vasquez de Coronado and his party as they traveled through central Arizona and up the Colorado River. These accounts describe the middle Gila River, but do not provide any information on the lower Gila River. Accounts written by 18th century missionaries, such as Eusebio Francisco Kino (1919), Jacobo Sedelmayr (1955), and Francisco Garces (1965), describe the groves of cottonwood, alder, willow, and mesquite along the river, and note the lack of grass suitable for pasturage. During the mid-1800s, the Gila River became a major trail for trappers, miners, and those traveling to California, as well as the site of Federal government exploration. Some disparity notwithstanding, the written accounts present a general picture of the river before damming and development.

According to historical accounts, the Gila River was hydrologically similar to other dryland rivers, including the Salt River, but carried notably more dissolved salts. While the channel apparently contained water throughout the year, the amounts were usually small. At its confluence with the Colorado River near Yuma, Arizona, Bartlett (1854, 160) described the Gila as a "diminutive stream," its lowest 20 miles strongly influenced by the flow of the Colorado River (Figure 4). Observations of debris and sediment on the flood plain suggest that high flows occurred irregularly, perhaps every two or three years. Both traveling in 1849, Harris (1960, p. 85) noted "flood-drift several feet high on trees and brush," and Clarke (1988, p. 76) concluded that the "volume of water at times must be immense, as there is brush and other substances lodged in the mesquites from ten to twenty feet high, through the adjoining plain." Although it contained little suspended sediment, the Gila carried sufficient dissolved salts to give the water a striking blue-green color and a salty taste (Emory, 1987). Shallow pools of water on the floodplain left behind salt deposits when they evaporated.

Geomorphically, the natural Lower Gila River typified braided streams, variable in channel configuration and dimensions, and overwhelmed with sediment along its course. The river was broad and shallow, ranging in width from 50 - 150 feet at its mouth to 1200 feet west of Gila Bend, and in depth from less than one to three feet (Bartlett 1854; Browne 1951; Clarke 1988; Emory 1987). Of these spatial variations, Cooke (1938, p. 197) lamented: "The river, where I have wanted it as a barrier to the mules, has always been but a few inches deep; here, where I must cross it, it is swimming." The river varied between a single channel and multiple channels along its course, at low flow occupying less than half

Figure 4. Woodcut print of the confluence of the Gila and Colorado Rivers near Yuma, Arizona, looking up the Gila River, from 1850-1853. Note the small size of the Gila compared to the Colorado River in the foreground. From John Russell Bartlett, Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua, Connected with the United States Boundary Commission, during the Years 1850, '51, '52, and '53 (New York, 1854), facing p. 158.

of the flood plain. The presence of lagunas, or small lakes, presumably abandoned oxbows or overflow channels, attests to the frequent shifting of the main channels of the river. One account suggests that radical changes in channel position occurred over short periods of time: Barlett (1854, p. 208) described "a sluice, which a year before was the main branch of the river, the stream having since found another channel." Often decribed as quicksand or a serious impediment to travel, sand covered the beds of the channels, formed bars in the wider and shallower sections of the channel, and blanketed large areas along the river.

The historical accounts provide extensive descriptions of the vegetation and wildlife along the river. In contrast to the barren uplands, the Gila River valley supported thick groves of trees, abundant bushes and reeds, and a variety of waterfowl and mammals. Sand and weeds dominated the areas along and in channel; grass for fodder was difficult for travelers to find, seeming to occur only where the water had recently overflowed the channel. Cottonwoods, willows, and alders marked the boundary of the channel (Figures 5 and 6). According to Bartlett (1854, p. 198), "we could trace [the river's] course from the bright green line of cotton-woods and willows, as it wound away through the desert." Thickets of mesquite covered the lower terrace, or "upper stratum of the Gila bottom" (Browne 1951, p. 75), making travel to the water difficult (Figure 7). The lagunas (oxbow lakes) created by channel shifting provided water and shade for birds and mammals, including duck, geese, swan, quail, dove, crane, raven, hawk, owl, beaver, deer, wolf, panther, wildcat, and possibly bear. The lack of animals, waterfowl particularly, noted by some writers along certain parts of the river emphasizes the importance of these lagunas. Fish also lived in the waters of the Gila, but writers' of the accounts did not consider them fit to eat.

In addition to observations on the natural environment, many historical accounts contain speculation on the ability of the Lower Gila River flood plain to support livestock and agriculture. Generally, all accounts that mention ranching agreed with Reid's (1935, 230) judgment that the bottomland offers no "inducements to the stock raiser." Writers of the accounts differed widely in their assessments of the potential for agriculture, their tones suggesting that their opinions on agriculture largely related to personal attitudes about their journey, and not to objective consideration of the land. For example, Couts (1961) effusively praised the fertility of the Gila Valley while noting the barrenness of the flood plain. Cooke (1938, 1964, p. 168) gave the most astute statement on agriculture in two accounts, concluding that the lack of precipitation, "salty efflorescences," and clay-rich soils on the floodplain made the land unsuitable for agriculture (168). Clearly, others saw the lack of rainfall as the only limitation on agriculture, a limitation erased by irrigation. The transformation of the Gila River valley by development became obvious as early as 1909-1910: "Any one who has seen the marvellous changes brought about in the arid regions of the Gila River through irrigation will easily understand the unusual opportunity presented here for agriculture on a large scale" (Lumholtz 1971, p.162).

3.2 Post-Development Conditions

Post-development conditions are described in considerable detail in sections 4, 5,

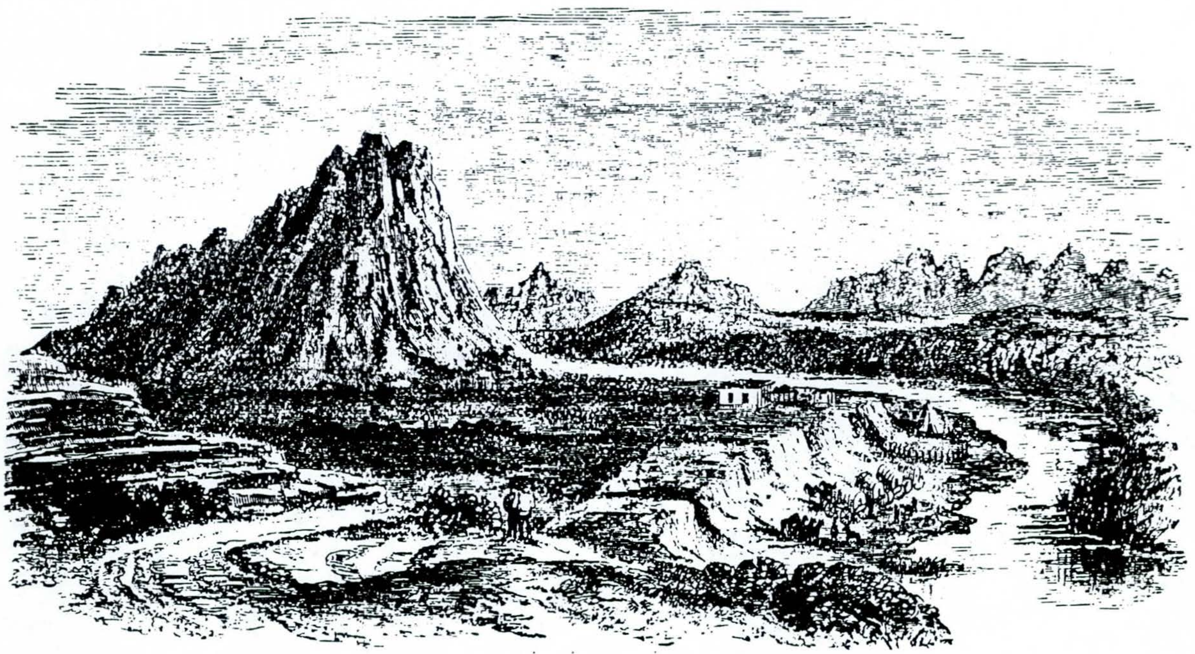


Figure 5. Woodcut print of the Gila River near Antelope Peak, looking west (downstream) August 1864. Note the line of trees bordering the channel on the north. From J. Ross Browne, A Tour through Arizona 1864, or, Adventures in the Apache Country (Tucson, Ariz., 1951), facing p. 83.

Figure 6. Illustration of the Gila River below "The Great Bend," near the city of Gila Bend, Arizona, 1853-56. Note the line of trees bordering the left side of the channel and the wide, shallow nature of the river. From U. S. Pacific Railroad Exploration and Surveys, Explorations for a Railroad Route from the Mississippi River to the Pacific Ocean -- General Report (Washington, D. C., 1853-6), plate VI.

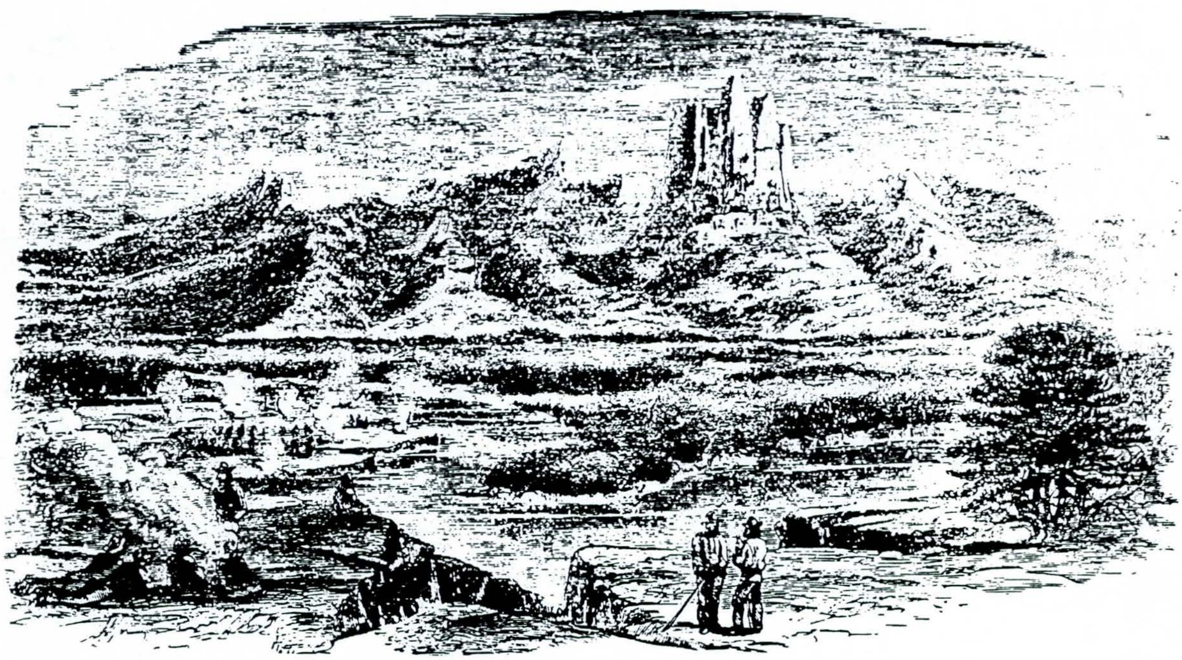


Figure 7. Woodcut print of the Gila River near "Corunnacion Peak," identified as a peak in the Muggins Mountains east of Dome, Arizona, looking north, 1864. Note the thick growth of trees and shrubs on the low terrace on the north side of the river. From J. Ross Browne, A Tour through Arizona 1864, or, Adventures in the Apache Country (Tucson, Ariz., 1951), facing p. 78.

and 6 in this report. However, a few general observations about the geomorphic/ecologic associations in the study area may be appropriate as a counter point to the preceding descriptions of pre-development conditions. The elimination of annual floods and nearly continuous low flows in the channel have produced obvious changes in the processes and forms of the channel, as well as in the riparian vegetation. The low flow channel of the river today may look remarkably like the one that existed a century ago, but the low flow channel is a minor component of the entire system. The braided, high flow channel is much less active now than it was previously because of the lack of annual floods. Previously, these floods caused annual, small changes in the braiding configuration, but now such adjustments occur only occasionally in floods resulting from dam releases or spillway flow. Sediment storage is occurring in the high flow part of the channel at greater rates now than in the past as a result of these hydrologic changes. Overflow of the lowest terrace was a common phenomenon before the construction of upstream dams, a fact recognized by the first surveyors of the region. Overflow of the first, or lowest, terrace now occurs only during the infrequent large flood, but it may become more common as the active channel fills with sediment.

The post-development riparian vegetation is drastically different from the pre-development conditions. Mesquite bosques have been cut as a source of fuel and posts, and they are generally lacking throughout the study area. Cottonwood and willow gallery forests along the margins of the active channel have also been removed, partly by cutting and partly by the hydrologic changes brought about by the imposition of dams. The once barren, sandy braided high flow channel is in many places now completely colonized by tamarisk. In those places where the 1993 flood flow destroyed the tamarisk, it is rapidly reseeding and regrowing. In sum, the present conditions are very much unlike the essentially natural ones that existed as recently as a century and half ago.

4 THE LOWER GILA RIVER GEOMORPHIC SYSTEM

4.1 Hydrology

4.1.1 Surface Water Hydrology

The operations of nine dams (Table 1) have significantly impacted the hydrologic regime of the Gila River. These dams include eight major dams upstream of the study reach and Painted Rock Dam within the reach. The annual peak discharges and monthly mean daily discharges for the Gila River near Dome, Arizona, illustrate the nature of these changes in the timing and magnitude of flows. The streamflow record for the Dome station covers the years 1906 and 1930 to present. This record contains three periods of time distinguished by dam operations. Flows in the pre-1938 period represent natural flow before major dams controlled the movement of water to the lower Gila. The second period, 1939-1959, begins with the closure of Bartlett Dam on the Verde River, the last of the free-flowing major tributaries on the Gila River. During this time, major flows on the lower Gila River relied on releases from upstream dams. In the third period, 1960 - present, flows largely exhibit a pattern determined by operations at Painted Rock Dam superimposed on releases from dams upstream. Comparisons of the records from the Dome station with records from stations below Painted Rock Dam and below Gillespie Dam suggest that operations at Painted Rock Dam reduce peak flows and on average increase flow in the naturally drier summer months (Appendix 11.6 contains the information sources for hydrologic information, while Appendix 11.7 contains basic hydrologic data).

The magnitude of annual peak discharges and frequency of high flows at the Dome station, near the downstream end of the study reach, strongly reflect the influence of dams upstream (Figures 8 and 9). Prior to the closure of Bartlett Dam in 1938, annual peak discharges exceeded 5,000 cfs (cubic feet per second) in approximately half of the years of record. The highest flow on record, 95,000 cfs, occurred in 1906. Between 1939 and 1959, dams upstream reduced flood peaks so that the maximum discharge in all years was less than 5,000 cfs. Peak flows significantly decrease downstream, as illustrated by comparison with the record for the station below Gillespie Dam, at the upstream end of the study reach. Painted Rock Dam, a factor in the third period of the record 1960-1992, reduced peak flows when significant discharges were released from upstream dams. Again, the highest flows did not exceed about 5,000 cfs. Notably, peak flows at the Dome station exceeded flows below Painted Rock Dam in eight out of 24 years since the dam closed, suggesting that water contributions from tributary streams and groundwater in the lower basin provide relatively significant flow in about one-quarter of the years.

Dam operations also impact the seasonal pattern of mean flows on the lower Gila River. During the nearly natural flow period, prior to 1938, mean daily discharge was higher in the late winter months, peaking in February, at the Dome station (Figure 9). Flows were low (less than 100 cfs) in the summer and early fall months. Upstream dams in the period 1938-1959 substantially reduced the mean daily discharge and shifted the month

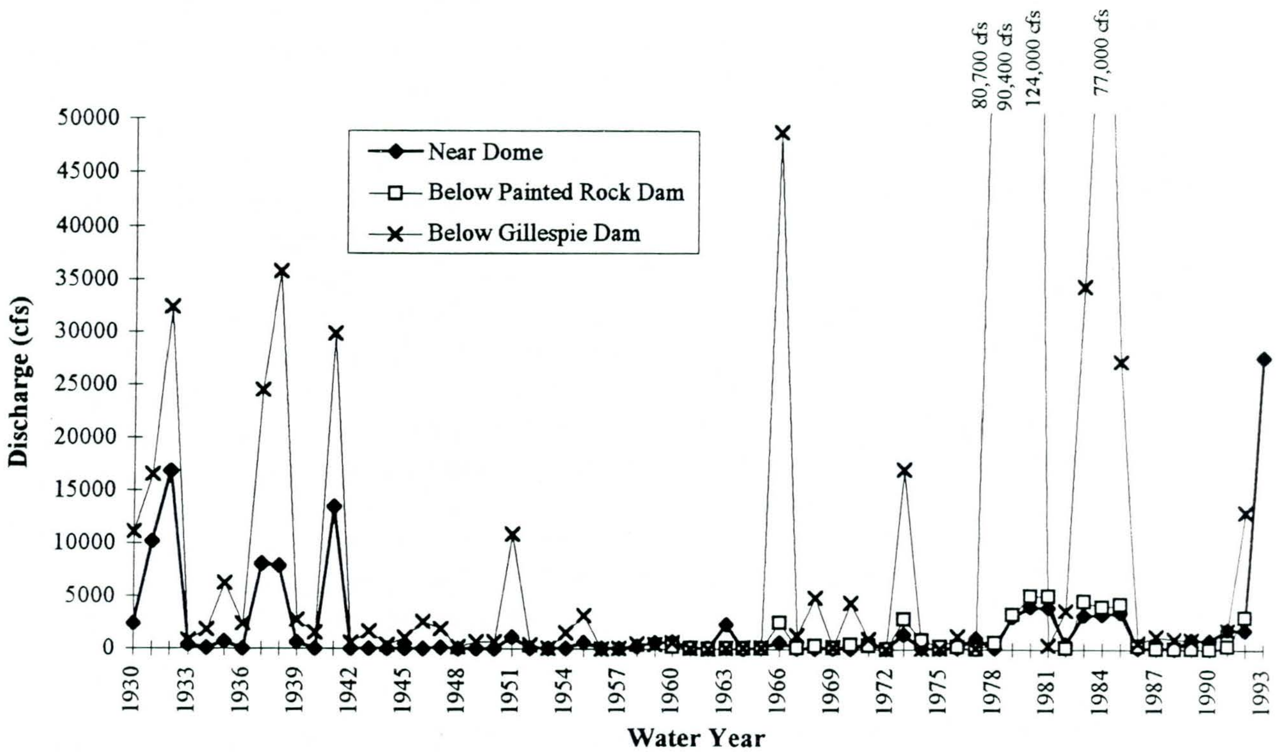


Figure 8. Annual peak discharge for three stations on the lower Gila River: (a) below Gillespie Dam 1930-1992, and (b) below Painted Rock Dam 1960-1992, and (c) near Dome, 1930-1992. Data from U. S. Geological Survey, Water Resources Data Arizona, U.S. Geological Survey Water-Data Report (Washington, D. C., various years).

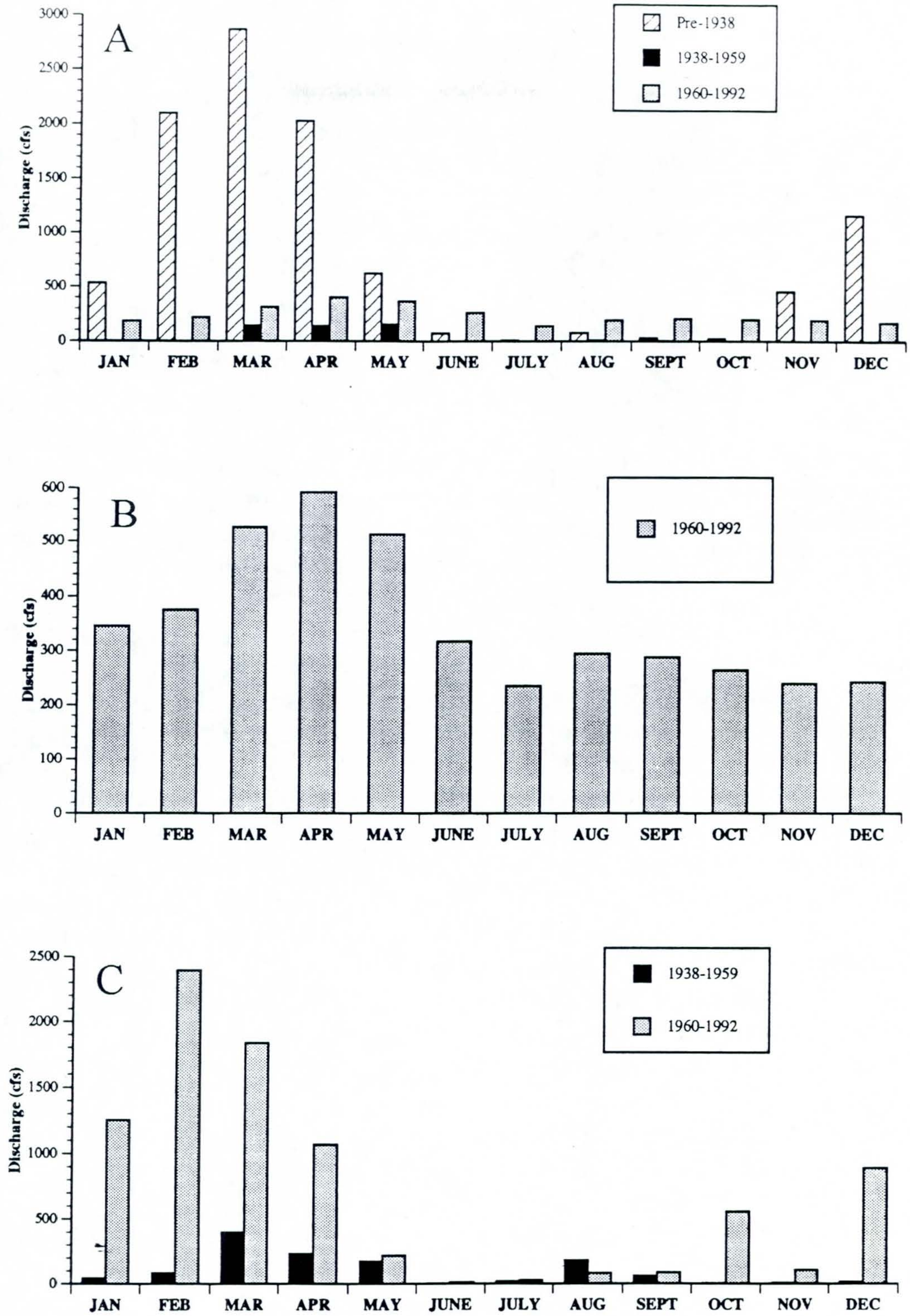


Figure 9. Mean daily discharge by month for three stations on the lower Gila River: (a) below Gillespie Dam 1930-1992, for each of the three periods of differing control by dams, (b) below Painted Rock Dam 1960-1992, and (c) near Dome 1930-1992, for each of the three periods of differing control by dams. Data from U. S. Geological Survey, Water Resources Data Arizona, U. S. Geological Survey Water-Data Report (Washington, D. C., various years).

of maxiumum discharge to March. Month-to-month variation is much less than it was previously. While upstream dams reduce and delay high mean flows, Painted Rock Dam significantly impacts flow during the naturally drier months, June through October. By storing and slowly releasing flows from upstream dams, Painted Rock Dam extends flow into the summer and fall months, reducing the striking seasonal pattern apparent in the records prior to 1960 and upstream in the basin.

4.1.2 Ground Water Hydrology

This section presents a brief overview of depth to groundwater and fluctuations in the water table based on limited well data and information from reports on discreet portions on the area. Groundwater levels with the lower Gila River valley respond to both natural processes and human activities. In general, natural processes, such as rainfall-runoff infiltration and floods, tend to raise the water table, while human activities, mainly irrigation and pumping, both raise and lower the water table.

Spatially, depth to groundwater varies due to local factors, including the thickness of the alluvium and the presence of bedrock sills, hills, or mountain ranges (Bryan 1925; Bookman-Edmonston Engineering, Inc., 1992). Pumping of water, whether for irrigation in the Gila Bend area or for drainage in the Wellton-Mohawk Irrigation and Drainage District, strongly controls the level of the water table in some areas. Table 7 presents data for six wells along the lower Gila River, representing groundwater levels in general areas. Depth to groundwater is greatest near the reach of the Gila River from Gillespie Dam to Painted Rock Reservoir: depth to groundwater beneath the channel averages 47.6 - 57.6 feet (Well A). Data for Wells B, D, E, and F, indicate that on average, groundwater is at or within a few feet of the channel bed in Painted Rock Reservoir and between Texas Hill and Dome. Between Painted Rock Dam and Texas Hill, as suggested by Well C, groundwater remains deeper, between 10 and 15 feet below the river channel. Groundwater is at a similar depth near Yuma (10 to 14 feet), where the Colorado River strongly influences the position of the water table (Mock et al., 1988).

On a small timescale, the level of the water table does not change drastically along the Gila River. The Texas Hill to Dome area (Wells D, E, and F) experienced the smallest fluctuations in the water table over the past five years, with an average fluctuation of less than two feet per year (Table 7). Drainage wells in the Wellton-Mohawk Irrigation and Drainage District largely control the depth to groundwater on the floodplain, and thus keep variations to a minimum (Ligner et al. 1969). Fluctuations upstream of Texas Hill (Wells A, B, and C) tend to be greater, ranging from two to five feet per year.

In contrast, well records extending as far back as the 1940s indicate water table fluctuations as great as 82 feet near Cotton Center and 15 feet in the Wellton-Mohawk area (see Appendix 11.7). These large fluctuations appear to be related to two separate factors: flooding and the use of water for agriculture. For example, depth to groundwater increased in the Wellton-Mohawk area until about 1952, when farmers began to use Colorado River water rather than groundwater for irrigation (Halpenny et al., 1952).

Table 7. Depth to ground water in the Lower Gila River region.

Well #	Represented period	Elevation of well (ft)	Elevation of river channel near well (ft)	Average DTGW in well (ft)	Range in DTGW during period (ft)	Average amount of fluctuation in DTGW (ft/yr)
A	1988-1992	705	660-670	92.6	20.3	5.02
B	1988-1992	580	540-550	30	5.36	2.37
C	1983-1992	383	365-370	26.1	8.98	2.13
D	1987-1992	280	275-280	5.6	2	0.65
E	1987-1992	248	250-255	10.7	1.1	0.82
F	1987-1992	208	195-200	13.7	3.6	1.98

In subsequent years, the water table rose drastically as flood irrigation added to natural groundwater recharge and pumping stopped (University of Arizona, School of Earth Sciences, Office of Arid Land Studies, 1970). Floods, specifically releases from Painted Rock Dam, contribute to rapid, significant rises in the water table as well (Ligner et al. 1969). During the 1973-75 releases, the water level within the Gila River floodplain rose two to six feet as releases from Painted Rock Dam seeped into the bed of the channel (U.S. Army Corps of Engineers, 1975). While such changes do not greatly affect the Gila River above Texas Hill, this magnitude of increase in the elevation of the water table below Texas Hill causes irrigation drainage and salinity problems for agriculture.

4.2 Sediment Transport and Deposits

On a geologic time scale, the Lower Gila River is the site of sediment storage. The fault-block valleys through which the Gila River flows are immense valleys filled with fluvial sediments deposited there over a period of more than 20 million years (Figure 10, Peirce, 1984). The depth of unconsolidated sediments is not known with great accuracy, but it is 10,000 feet or greater in many areas. For some periods of geologic time, the structural basins may have had closed drainage, without outlets, an arrangement that accelerated sedimentation. During geologically recent time (the last 10,000 years or so), through-flowing drainage has always existed, but the extremely low gradients of the channel have resulted in large amounts of deposition and internal storage. No matter what engineering or environmental management options are ultimately selected for the Lower Gila River, continued sedimentation will be a fact of life.

In historical times, the deposition has continued, with large amounts of sediment leaving the downstream end of the system only during flood events. Two such events illustrate the consequences of this sediment mobility from the Gila River to the Colorado River. In the most recent example, in the 1993 floods as outlined above, sediment flushed from the Gila system entered the Colorado River and posed management problems for diversion works on the Colorado. However, this event was not particularly unusual from a larger perspective. In 1905, a large flood on the Gila River cause elevated discharges on the Colorado, but also deposited large amounts of sediment in the channel of the Colorado. The result was the breaching of the intake gates for the canal system serving the Imperial Valley, and the diversion of nearly the entire flow of the Colorado into the canal system and the Alamo River terminating in the Salton Sink (Howe and Hall, 1910; Freeman, 1923). After nearly two years of effort, the breach was closed and the Colorado was restored to its present course, but the flow into the Imperial Valley had created the Salton Sea. The episode demonstrated the importance of sediment processes in the Gila for dynamics on the Colorado.

Within the the Lower Gila River system, sediment transport and storage are important keys to understanding the instability of the river. Sediment enters the system from upstream, from tributaries, and from bank erosion. Sediment entering the system from upstream is carried directly by the waters of the Gila River, and is variable in size, though sand is the largest component of the material. The breach of Gillespie Dam

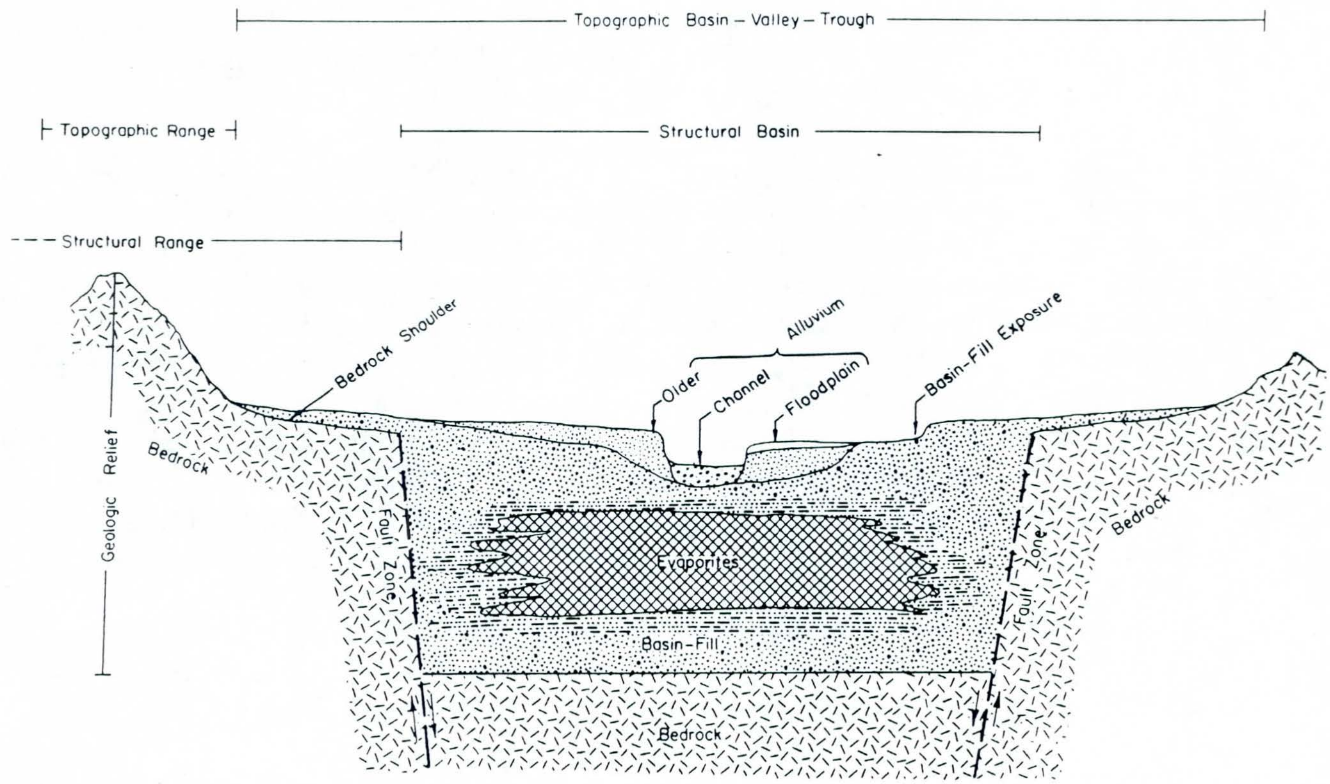


Figure 10. Diagrammatic representation of surfaces and subsurface features in a typical Basin and Range valley similar to the Lower Gila River Valley (Figure 10.2, p. 171, Peirce, 1984).

contributed unknown but significantly greater than normal amounts of fine materials to the Lower Gila River. These silts and clays were carried in suspension during the 1993 flood event, and some were transported through the outlet works and over the spillway of Painted Rock Dam. Some of the fines were deposited in Dendora Valley, immediately downstream from the dam, while perhaps some of this fine material was carried the length of the lower river. The sand component of the upstream input is presently being deposited in and near the channel through Cotton Center Valley between Gillespie Dam and Gila Bend, a zone of deposition before the dams (Figure 11).

Sedimentation in the channel of the Gila River below Painted Rock Dam now comes from upstream contributions derived from erosion near the dam. Water released from the dam has relatively less sediment than it would if the dam were not present because sediment settles out in the reservoir. The released water therefore entrains some material below the dam, redepositing it in shallow-gradient reaches. This sediment is greatly augmented by tributary contributions, additions from streams draining valleys along the length of the Lower Gila (Figure 12). These additions are large over a period of several decades as uncontrolled floods in the tributaries empty sediment into the main channel, where reduced flows are unable to develop sufficient power to move the materials. The channel sediment load is also augmented by bank erosion when lateral migration of the active channel impinges on the first terrace or on dune deposits along the channel (Figure 13). During several flood events since the closure of Painted Rock Dam, terrace edges have been eroded, with the resulting material added to total load of the channel. During the 1993 flood, substantial erosion of the dune field on the south side of the channel in Mohawk Valley contributed to the sand load of the river system.

The accumulation of sediment in the channel results in loss of channel capacity and instability. Channel side bars, mid-channel bars, and re-attachment bars downstream from obstructions and bridges or their approach levees are common. Channel macro-forms also occur in the reach upstream from Texas Hill and in more limited reaches in the Texas Hill to Dome portion of the river. These macro-forms are large sand sheets, up to half a mile in width and length, with sharply defined downstream edges. The sheets are 3 to 10 feet thick, and contain large amounts of material moving through the system. First described in detail on the Missouri River (Karlinger et al., 1983, p. 5-6), they are indicative of a stream in which the amount of sediment available for transport exceeds the transport capacity. Even large floods are unlikely to evacuate all the materials, so that aggradation occurs on a multiple-century scale.

4.3 Channel Reaches and Systems

4.3.1 Channels

The channel of the Lower Gila River between Gillespie Dam and Yuma has a variety of geomorphologically defined segments, with each segment having distinctive characteristics. Taken together, all the channel reaches fall into two broadly defined categories: braided and compound. Those segments that are braided channels have more

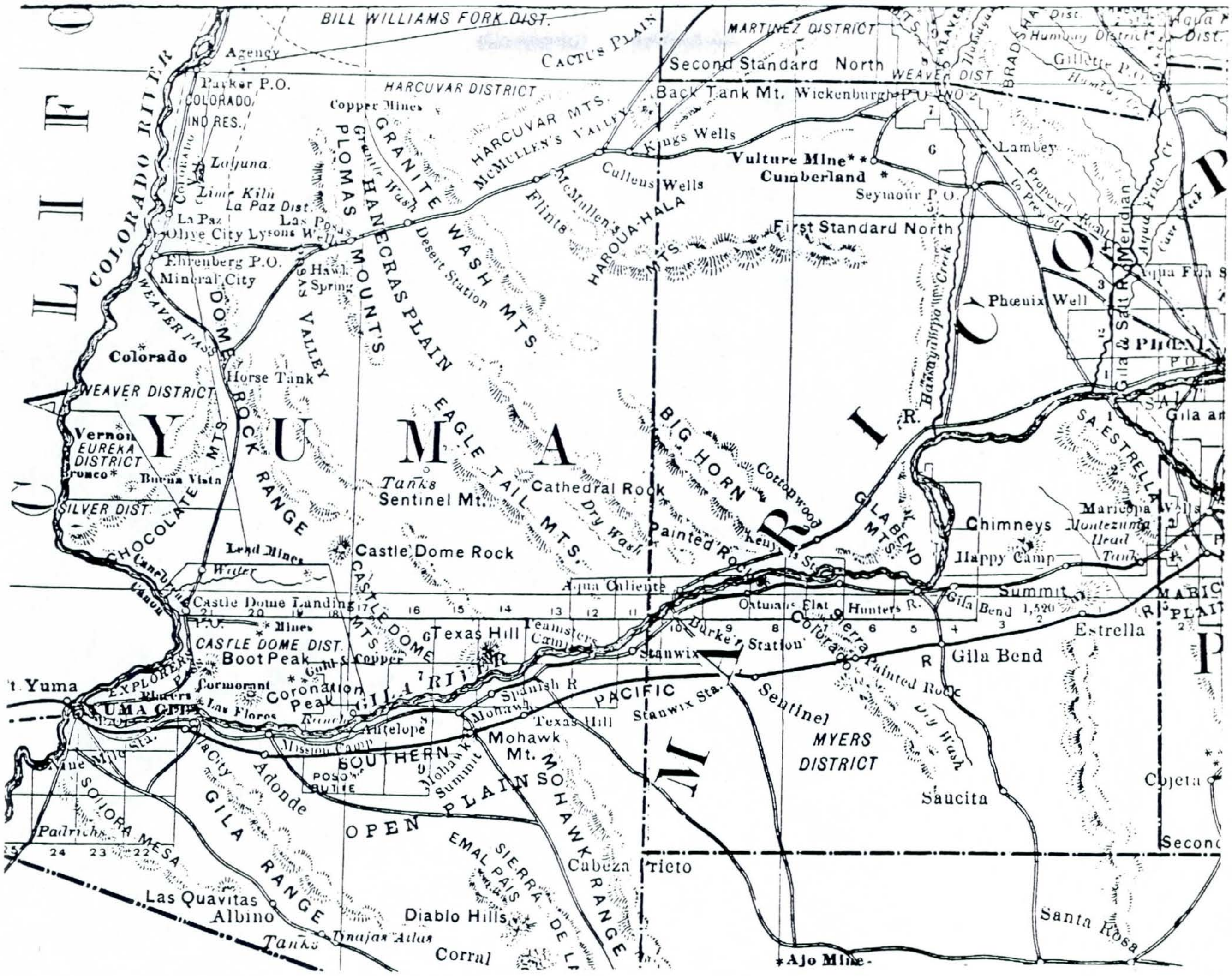


Figure 11. Section of an 1868 general map of Arizona. Note how the cartographer depicted the Gila River immediately north of Gila Bend, with broad two channels separated by an island, an arrangement typical of an aggrading stream drawn at this general scale (Rand McNally, 1868).

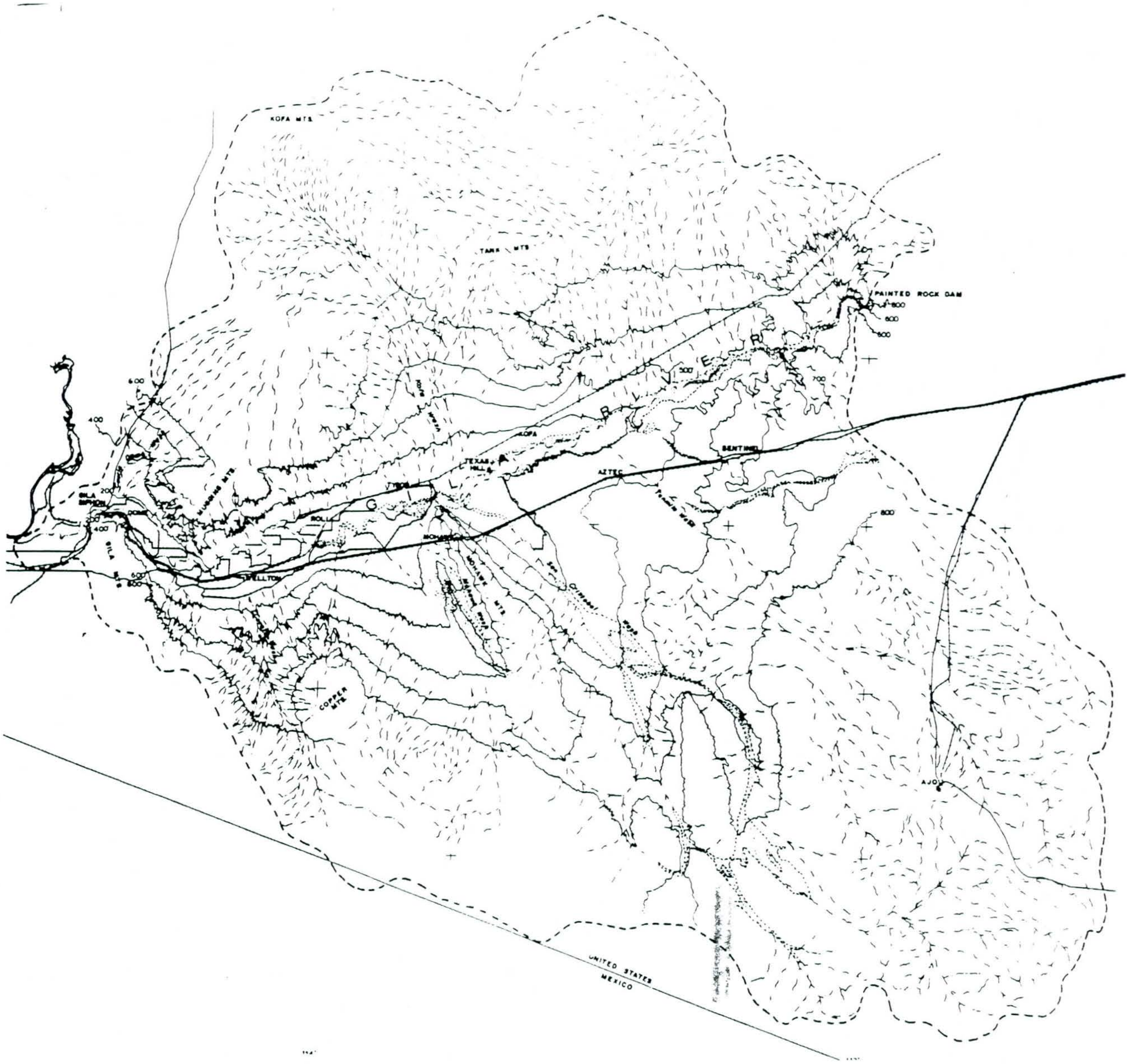


Figure 12. Map showing tributary drainages of the Lower Gila River downstream from Painted Rock Dam, showing the sources of sediment contributed to the main channel of the stream (map by University of Arizona, Office of Arid Lands Studies, 1970).

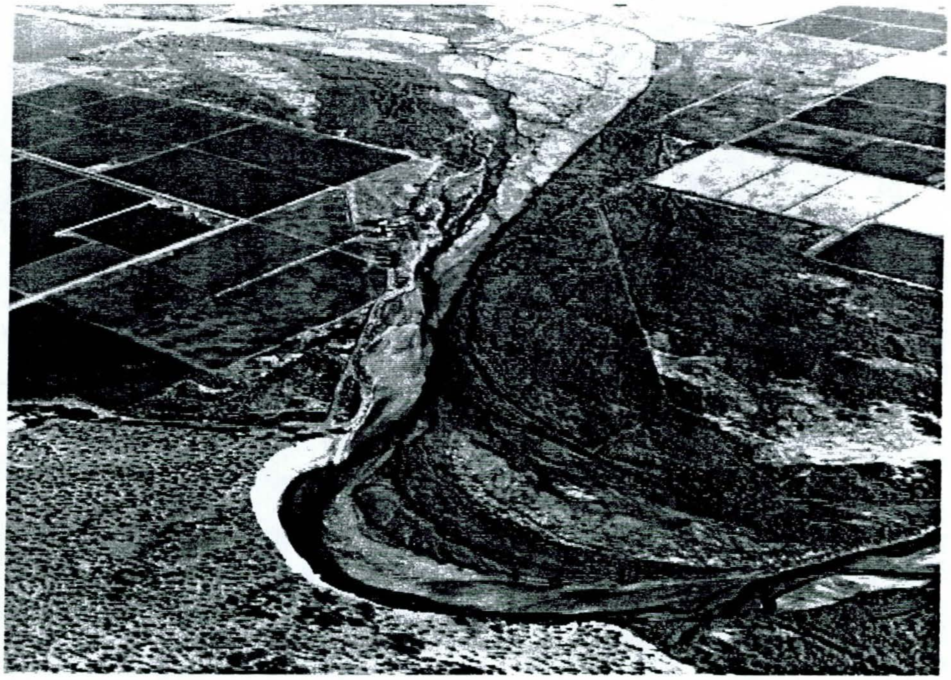


Figure 13. Bank erosion by the main channel of the Lower Gila River near Mohawk, excavating inactive sand dunes and adding sediment to the main channel (W. L. Graf Photo 120-26, June 26, 1994).

than one low flow channel, usually one that is clearly the thalweg plus additional channels that are occupied only at moderate or high flows. These channels are separated from each other by sand bars, sand sheets, or "mid-channel" bars (Wolman and Leopold, 1957). In general, the braided configuration is the natural product of four controlling factors, all of which occur in the Lower Gila River. First, braided channels typically carry large amounts of sediment compared to the capacity of the stream, and the Lower Gila appears to be "overloaded" with sediment in some reaches. Second, such streams also have gradients that are relatively steep or they generate high amounts of stream power. The Lower Gila has a relatively shallow gradient, but during flood flows, those discharges that shape the channel and accomplish sediment transport on a large scale, stream power is likely to be high. Third, braided channels have erodible banks, a condition common on the Lower Gila. Finally, braiding usually results from highly variable discharges such as those found in glacial or dryland rivers such as the Gila. For these reasons, braiding of at least parts of the Lower Gila River channel is the natural tendency of the system, a tendency that may be viewed by river engineers as undesirable.

The second general channel type found in the Lower Gila River is the compound form (Figure 14; also referred to as "channel in channel," Gregory and Park, 1974). Compound channels function with two modes of operation: one at low flow when water occupies a single, meandering channel, and the other at high flow when water occupies a much broader "braided" channel (Graf, 1988, p. 202-203). Compound channels are common in dryland settings downstream from dams, irrigation areas, and urban areas because waste water (and occasional natural low flows) maintain the low flow meandering channel. If this low flow channel has sufficient discharge, it becomes unstable and is an erosion hazard. When meanders are abandoned, they are known locally as sloughs or oxbows. The are the sites of standing water for a period, and eventually they fill with sediment. Upstream dams prevent moderate flows, but occasional catastrophic floods (perhaps accompanied by spills from the dam) make the broad, braided part of the channel functional. Natural channels of this type occur downstream from desert mountain areas that generate some low flow and large floods, but few moderate flows. The Lower Gila River has compound channels in several segments.

4.3.2 Geomorphic Divisions of the Lower Gila River

An assessment of channel segments in the Lower Gila shows that in 1994 the following definable reaches have internally consistent conditions.

Gillespie Dam to Painted Rock Dam

1. Gillespie Dam to the eastern edge of the Gila Bend Indian Reservation, Cotton Center Valley: single and multiple thread braided channel with substantial sedimentation; almost no standing water, sparse vegetation in the active channel area.

2. Eastern edge of the Gila Bend Indian Reservation to Painted Rock Dam: the pool area of the dam, single thread channel through sedimentation area, several sites with standing

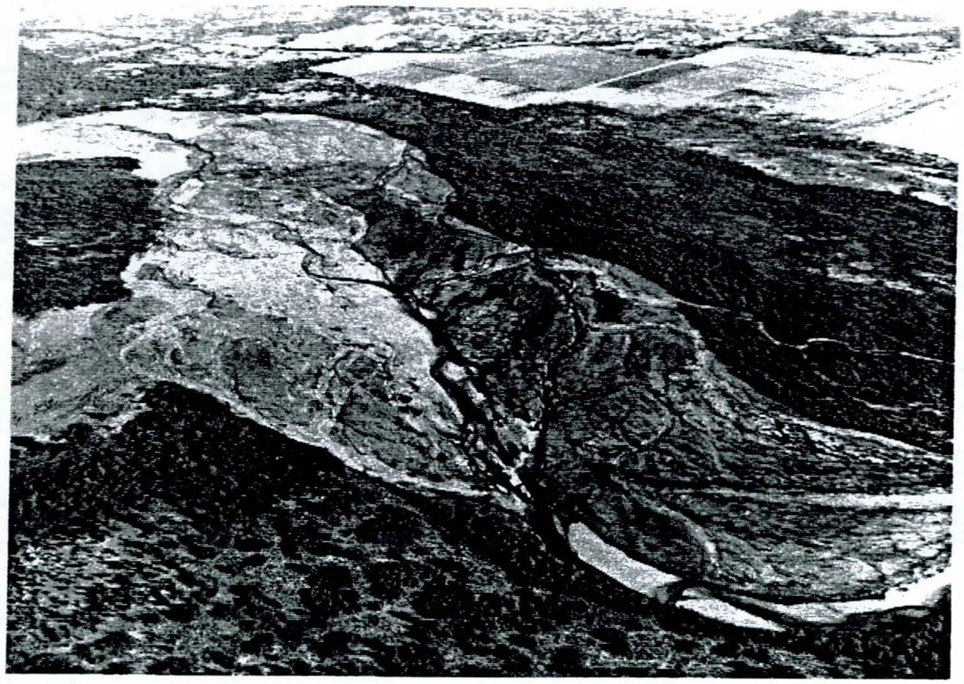


Figure 14. The Lower Gila River channel above Texas Hill, showing a typical compound channel with a single thread low flow channel (near the bottom of the view, black ribbon with light sand bars) within a broad, braided high flow channel (gray, mottled area, darker tamarisk forest occupies additional portions of the high flow channel). The first terrace appears at the bottom of the view and at the top (W. L. Graf Photo 120-17, June 26, 1994).

water, considerable vegetation cover, some dead cottonwood trees, especially on the north edge of the channel in Painted Rocks Wildlife Area.

Painted Rock Dam to Texas Hill

3. Painted Rock Dam to Oatman Grave, Dendora Valley: much sediment storage in a structural valley, compound channel with two low flow components in some places, some standing water, includes the "Barrow Pit Lake," a scour zone with some sediment refilling below the dam.

4. Oatman Grave three miles downstream to a point near East Mill Well: constricted channel zone where the river has excavated a narrow canyon through a Tertiary basalt flow, single thread, slightly meandering channel with defined banks and flood-plain-like surfaces on either side.

5. East Mill Well to Agua Caliente: single thread low flow channel in a relatively narrow braided high flow channel, standing water in some sites.

6. Agua Caliente to Texas Hill: typical compound channel with a broad high flow, braided zone, generally no water in the low flow channel, but standing water in some abandoned oxbows or sloughs.

Texas Hill to Dome

7. Texas Hill to Growler: a more narrow braided high flow channel with a single thread low flow channel, little water in the low flow channel, entire compound channel is relatively straight.

8. Growler to confluence with Mohawk Wash, about 7 river miles upstream from Antelope Hill: similar to the previous upstream reach, except the entire compound channel has a more meandering course, a more shallow gradient, more sedimentation, and considerable sediment input from Mohawk Wash and Owl Wash.

9. Confluence with Mohawk Wash, about 7 miles upstream from Antelope Hill, to Avenue 33 East Crossing, about 6 river miles east of Mohawk: sediment filled zone with a broad, barren braided channel.

10. Avenue 33 East Crossing to the alignment of Avenue 25 East: a more narrow compound channel with an overall meandering configuration and some abandoned sloughs, less sediment storage than above or below.

11. Avenue 25 East alignment to Avenue 20 East: broad diverging flow zone with considerable sedimentation, with a meandering low flow channel, water in the channel.

12. Avenue 20 East to Dome: a relatively narrow braided channel with a relatively broad

low flow channel meandering from one side of the high flow zone to the other, relatively little sediment storage.

Dome to the Colorado River

13. Dome to the Colorado River: similar to previous segment, but with additional engineering constraints and influence of Colorado River flood plain, not generally a sediment storage area.

4.3.3 Terraces

The channel of the Lower Gila River lies at the foot of a series of relatively flat surfaces that rise, stair step fashion, on either side. These terraces are graded to previous elevations of the river channel, and along the Lower Gila there are usual two or three terraces above channel level (Figure 15). Although they are obvious landscape features, their expression is sometimes subtle, with only a couple of feet in vertical separation. In some cases, drains for irrigation tail waters are located at the downslope (toward the river) edge of terraces, and sometimes laterals or main delivery canals occupy the upslope edge. The lowest terrace is subject to flooding in extreme events, and usually has some fine-grained soils that reflect minor deposition during floods. This lowest terrace does not function as a flood plain, however, because the bulk of its materials are not part of the modern active river regime. The earliest surveyors in the region understood and platted the channel and terrace forms, sometimes correctly labeling surfaces that were in the high flow active channel as "overflow land," separate from terraces (Figures 16 and 17).

Thus, in moving from the channel center outward the following sequence of landforms is common along the Lower Gila: low flow channel (often meandering), high flow channel (often braided), first terrace (occasionally flooded), second terrace (usually not flooded in the present hydrologic regime), third terrace (sometimes), piedmont slopes (unrelated to river processes in the channel). There is no flood plain in the sense of the term as it is applied to humid region streams.

4.4 Implications for Flood Control and Environmental Restoration

Although the application of engineering-based mathematical models such as HEC-2 may treat some parts of the channel cross section as "flood plain," in a functional geomorphologic sense, the form is absent from this system. Land owners construct fields outside the low flow channel, assuming that they are on the flood plain, but in fact they are located in the braided portion of the active channel, and hence they sustain significant damage at surprisingly low discharges. The construction of flood control levees within this braided portion of the compound channel is risky business, because in fact the levees are constructed within the geomorphic channel rather than at its margin. Agricultural activities on the first terrace are subject to inundation hazards during high flows, and are not isolated from channel processes. Engineering works on the edge of the terrace are also subject to erosion hazards if the meandering low flow channel impinges on the terrace edge.

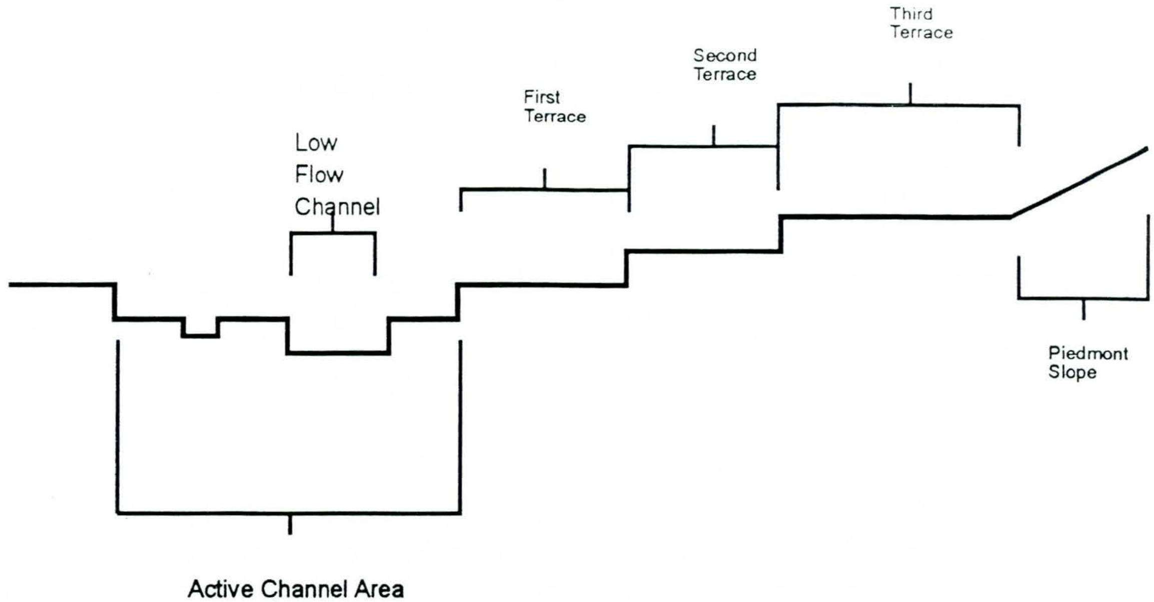


Figure 15. Sketch of surfaces across the Lower Gila River.

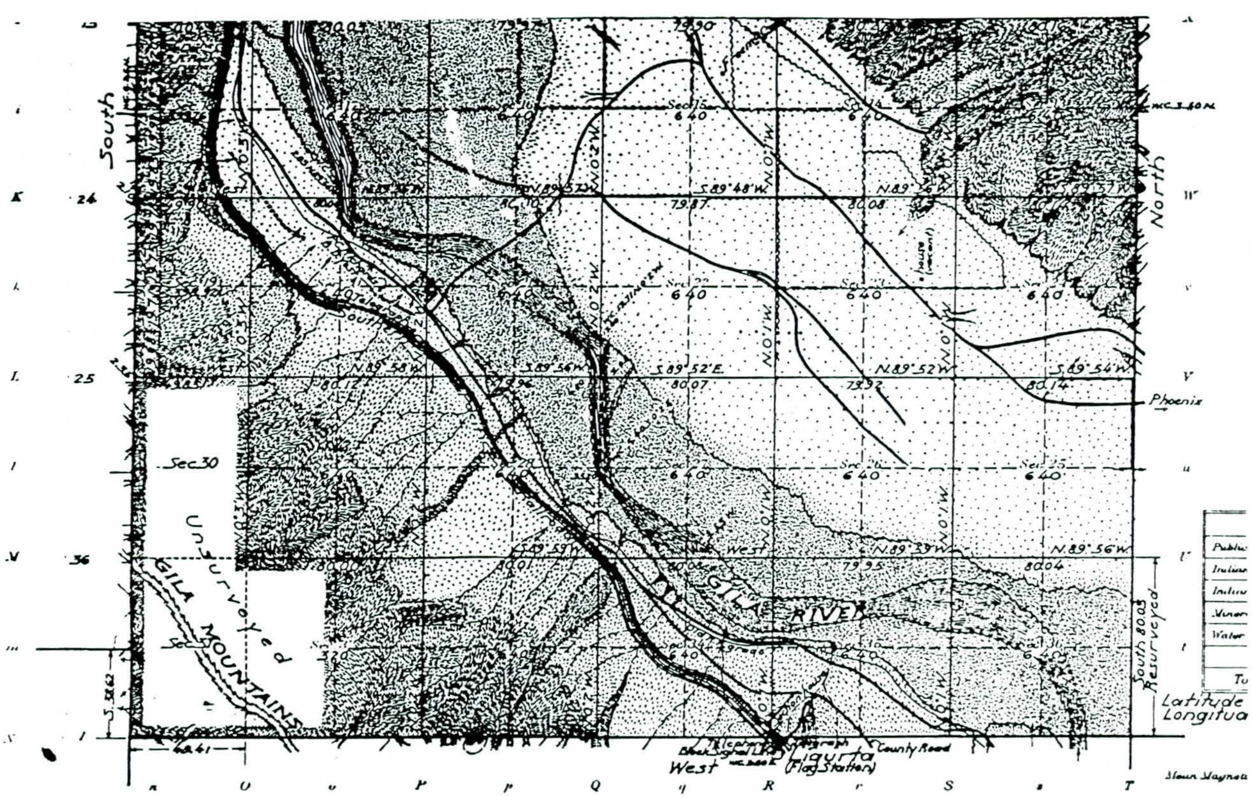


Figure 16. Portion of the General Land Office Plat Map for Township 8, Range 20 West, an area near Ligurta, showing the channel of the Lower Gila River as it appeared in 1919. The map shows a compound channel with a low flow area with the label "Gila River," the high flow braided area of the active channel as gray stippled pattern, and the higher terraces as white with dots (copy of original map on file at the Bureau of Land Management Office, Phoenix, Arizona).

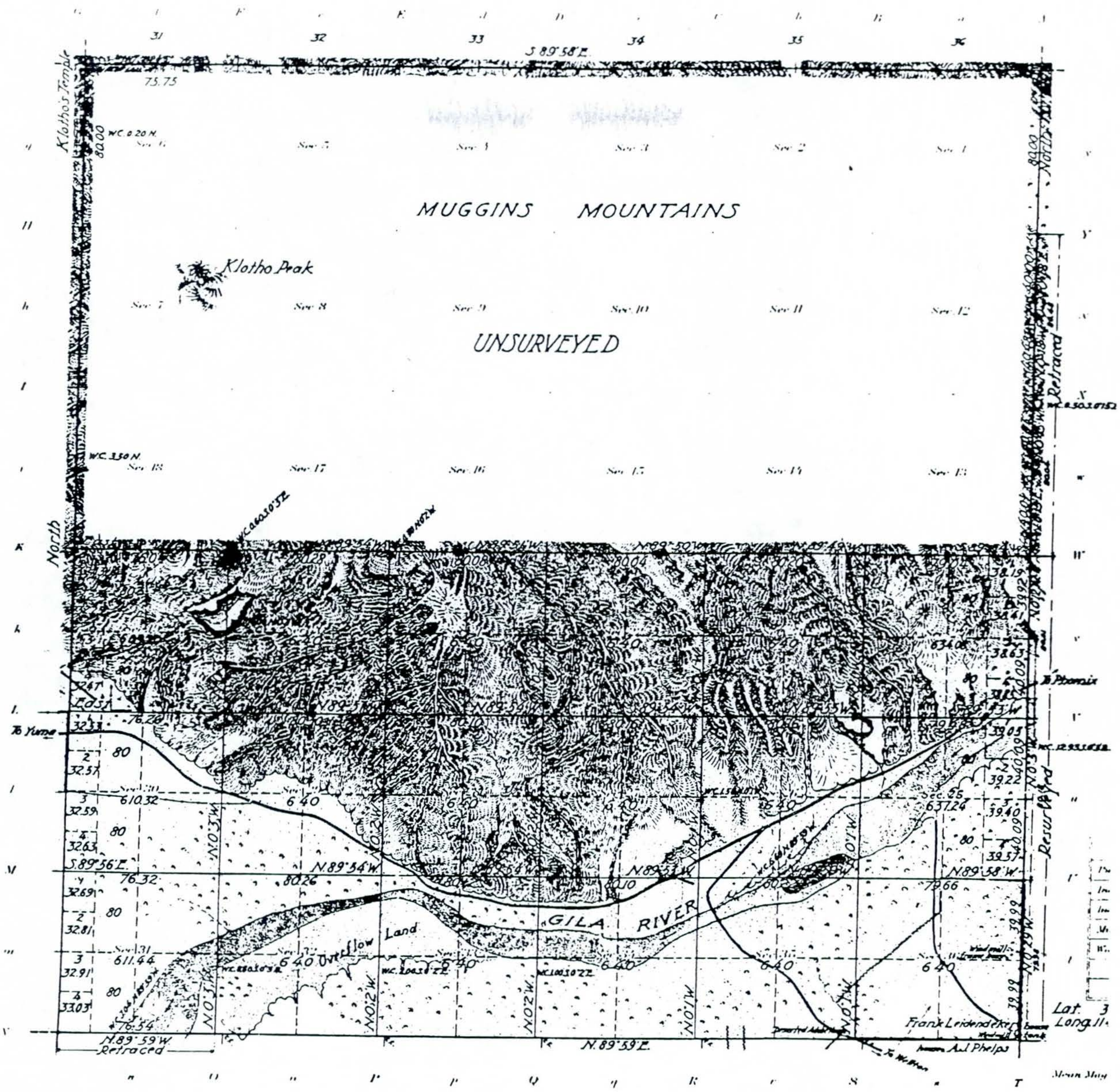


Figure 17. Portion of the General Land Office Plat Map for Township 8, Range 19 West, an area near Wellton, showing the channel of the Lower Gila River as it appeared in 1915. The map shows a compound channel with a low flow area with arrows showing direction of flow, the high flow braided area of the active channel labeled as "Overflow Land," and the higher terraces as white with dots (copy of original map on file at the Bureau of Land Management Office, Phoenix, Arizona).

There is considerable variation along the length of the Lower Gila River with respect to sediment storage and channel instability, with instability at a maximum in those segments characterized by active sediment storage. Control of erosion damage from migration of the low flow channel, and of innundation damage resulting from loss of channel capacity through sedimentation may be easier if sediment influxes from tributary streams are controlled. Primary candidates for the installation of sediment trapping basins or other similar measures include Owl Wash, Mohawk Wash, Coyote Wash, Castle Dome Wash, small drainages from the Muggins and Gila Mountains, and King Valley or Growler Wash.

From a restoration perspective, the cross sectional sequence of landforms is important because it is directly related to vegetation communities. Under entirely natural circumstances, the low flow channel and the braided channel in which it is situated were mostly without vegetation. Cottonwood and willow grew along the margins of the braided channel, where they adjusted to moderately frequent floods. Mesquite bosques were found on the first terrace, where they grew in relatively fine soils, their roots tapped shallow ground water, and they were occasionally subject to innundation that was not forceful enough to destroy them. Any successful restoration effort will need to take this landform-botanical system connection into account, and should seek to replicate the arrangement.

Management. Warner, R.E. and K.M. Hendrix, eds. Berkeley: University of California Press. Pp. 168-176.

Lumholtz, Carl. 1971. *New Trails in Mexico: An Account of One Year's Exploration in North-Western Sonora, Mexico, and South-Western Arizona 1909-1910*. Glorieta, N. Mex.: Rio Grande Press.

Meyers, C. J., and Tarlock, A. D. 1980. *Water Resource Management: A Coursebook in Law and Public Policy.* Mineola, N.Y.: Foundation Press.

Minckley, W.L. and J.N. Rinne, 1985, Large woody debris in hot desert streams: An historical review, Desert Plants, 7:142-153.

Minckley, W.L. and Clark, T.O. 1981, Vegetation of the Gila River resource area, eastern Arizona. *Desert Plants* 3:124-140.

Minckley, W.L. and Clark, T. O. 1984. Formation and destruction of a Gila River mesquite bosque community. *Desert Plants* 6:23-30.

Mock, Peter A., Burnett, Earl E., and Hammett, B. A. 1988. Digital Computer Model Study of Yuma Area Groundwater Problems Associated with Increased River Flows in the Lower Colorado River from January 1983 to June 1984. Arizona Department of Water Resources Open-File Report no. 6. Phoenix, AZ: Arizona Department of Water Resources.

National Research Council. 1992. *Restoration of Aquatic Ecosystems*. Washington, D.C.: National Academy Press.

National Research Council. 1987. *River and Dam Management: A Review of the Bureau of Reclamation's Glen Canyon Environmental Studies*. Washington, D.C.: National Academy Press.

Office of Arid Lands Studies. 1970. *Emvironemental study for the Gila River below Painted Rock Dam*. Contract # DacW09-70-C-0079.

Ohmart, R.D., and Anderson, B. W. 1974. Vegetation management: Annual report. U.S. Dep. Inter., Bureau of Reclamation. Boulder city, Nevada.

Ohmart, R.D. and B.W. Anderson, 1986, Riparian habitat. In *Inventory and Monitoring of Wildlife Habiatat*, Cooperrider, A.Y., R.J. Boyd, and H.R. Stuart, eds. Denver, Colo.: U.S. Bureau of Land Management Serive Center. Pp. 169-200.

Petts, G.E. 1985. Time scales for ecological concern in regulated rivers. In: J.F. Craig, J.B. Kemper (eds.). Regulated Streams: Advances in Ecology, J. F. Craig and J. B. Kemper, eds. New York: Plenum Press, New York. Pp. 257-266.

Petts, G. E. 1984. *Impounded Rivers: Perspectives for Ecological Management.* Chichester: John Wiley & Sons.

Rand McNally. 1868. *Arizona.* Map. Chicago: Rand McNally and Company, Engineers.

Reid, John C. 1935. *Reid's Tramp, or a Journal of the Incidents of Ten Months Travel Through Texas, New Mexico, Arizona, Sonora, and California*. Austin, Tex.: Steck.

Resource Managment International Inc. 1994. Wellton-Mohawk Gila River flood channel restoration project. unpublished, 1994.

Reynolds, S.J. 1988. *Geologic Map of Arizona.* Arizona Geological Survey Map 26.

Robinson, T. W., 1965. *Introduction, Spread, and Areal Extent of Saltcedar (Tamarix) in the Western States.* U.S. Geological Survey Professional Paper 491-A, Washington, D.C.: U.S. Government Printing Office.

Rosenberg, K.V., Ohmart, R. D., Hunter, W. C., and Anderson B. W. 1991. *Birds of the Lower Colorado River Valley*. University of Arizona Press, Tucson.

Ross, C.P. 1922. T*he lower Gila region, Arizona - A Geographic, Geologic, and Hydrologic Rreconnaissance with a Guide to Desert Watering Places*. U.S. Geological Survey Water Supply Paper. 498. Washington, D.C.: Government Printing Office.

Sittig, M., ed. 1980. *Priority Toxic Pollutants: Health Impacts and Allowable Limits.* Park Ridge, N. Jer.: Noyes Data Corporation.

Stromberg, J.C. 1993a. Fremont cottonwood-goodding willow riparian forests: A review of their ecology, threats, and recovery potential. *Journal of the Arizona - Nevada Academy of Science* 26:97-110.

Stromberg, J.C. 1993b. Riparian mesquite forests: A review of their ecology, threats, and recovery potential. *Journal of the Arizona - Nevada Academy of Science* 27:111-124.

Stromberg, J.C., Patten D. T., and Richter B. D. 1991. Flood flows and dynamics of Sonoran riparian forests. *Rivers* 2:221-235.

Stromberg, J.C., Tress, J. A., Wilkins, S. D., and Clark, S. D. 1992. Response of velvet mesquite to groundwater decline. *Journal of Arid Environments* 23:45-58.

Sax, J. L. 1978. "Federal Reclamation Law." In *Waters and Water Rights*, R. E. Clark, ed., Indianapolis, Ind.: Allen Smith Co., p. 118-132.

Sebenik, P. G. 1981. Maps Showing Ground-Water Conditions in the Gila Bend Basin Area, Maricopa County, Arizona -- 1979. Arizona Department of Water Resources

Table 8. Specifications for Painted Rock Dam.

Height at highest point:	55.2 meters (181 feet)
Length:	457 meters (4780 feet)
Drainage area above dam:	131,515 square kilometers (50,800 square miles)
Capacity at the spillway crest:	3.1 million cubic meters (2.5 acre-feet)
Reservoir area at capacity:	215 square kilometers (53,200 acres)
Streambed elevation:	159.7 meters (524 feet)
Top elevation:	214.9 meters (705 feet)
Spillway crest elevation:	201.5 meters (661 feet)
Number of outlet gates:	3
Land ownership:	
up to water level 177 meters (580 feet):	Army Corps of Engineers
up to water level 201.5 meters (661 feet):	flowage easements on private, state, and reservation lands

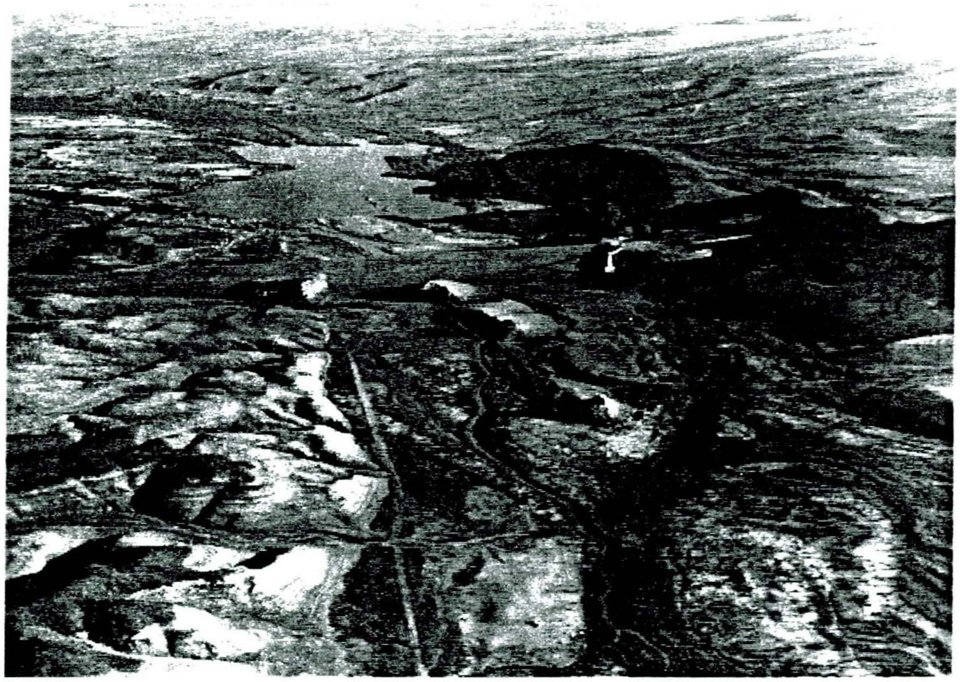


Figure 18. The vicinity of Painted Rock Dam, showing the dam from upstream. The reservoir pool is dry in this view, with some water occupying the Barrow Pit Lake immediately downstream from the structure (W. L. Graf Photo 120-14, June 26, 1994).

5.3 Levees

The construction of Painted Rock Dam eased fears of truly large floods on the Lower Gila River, but additional protection from moderate flows was needed. The irrigation and drainage district authorized the construction of flood control devices that consisted of levees and incidental works with a 10,000 cfs capactiy from the Gila Gravity Main Canal upstream to Texas Hill. The channelization of the river would involve removing a 250 foot wide swath of vegetation along the centerline of the channel. Dikes were then emplaced so that their height was no more than ten feet above the river bottom (most of the installations in this plan were wiped out in the 1993 flood event.

Currently the U.S. Army Corps of Engineers is working on an environmental assessment for WMIDD, examining the potential for a flood channel restoration project. The project calls for the re-establishment of the 10,000 cfs flood through the WMIDD. The proposed action calls for the establishment of a 300-foot wide low flow channel and the construction or reconstruction of the earthen dikes on one or both sides of the low flow channel as containment structures for flood flows and releases from Painted Rock Dam. The dikes would be constructed to a height of seven feet and the distance between dikes would be 500 feet. The dikes would be a minimum width of 20 feet at the top and 60 feet wide at the bottom. The material for dike construction would be obtained from the channel. A riprap facing of two feet thick would extend down the interior slope and three feet below the surface. This depth is not likely to protect the structures from erosion damage, however, because bed sediments are likely to be mobilized to a depth equal to two times the depth of water flow (Graf, 1979).

The levees that are proposed are not large enough to support the size of the controlled releases that can occur from Painted Rock Dam. The flood channel restoration would be built to support a 10,000 cfs flow, but the Painted Rock Dam can release flows of 22,000 cfs. Based on the potential releases from Painted Rock Dam it would seem that the proposed flood channel restoration would not be adequate to support this amount of water. It is not likely that enough water would dissipate by infiltration prior to reaching this area and the end result would be that the levees would be overtopped and potentially destroyed. This scenario would be similar to what occurred in the 1993 flood, when dam releases and spillway flows combined to produce a discharge of 25,000 cfs.

5.4 Bridges

Table 9 is a compilation of the bridges that are located on the Lower Gila River from Gillespie Dam to Yuma. A total of 24 bridges were identified for this stretch of the river, with most occurring from Texas Hill to Yuma. Bridges are important to the geomorphology of the river because they confine the width of the channel and focus the flow downstream of the bridge. This may result in increased the bank erosion directly above the bridge structure as a result of reverse eddy flows. The increased bank erosion would increase the amount of sediment in transport, and promote channel instability.

located along the reservoir.

The U.S. Army Corps of Engineers wrote the first operation schedule for the dam upon completion of the dam in late 1959. The current operation schedule, written in 1962, established a fixed release schedule based on modeling of the standard project flood (300,000 cfs). This schedule specifies a fixed rate of release based on the elevation of the water level in the reservoir. Releases in 1966 and 1973 proved that this schedule does not satisfy either flood control or water quality concerns. The releases set by the operation schedule caused damage to farm land in the Wellton Mohawk district. In response to this problem the Corps reduced releases and stored water in the reservoir. However, this water storage caused concerns to be raised about water quality and violations to the agreement made with the government of Mexico. These failures stimulated interests in revising the operation schedule of the dam. In 1974, a study by the Corps, suggested that flood damages did not necessitate the construction of more than 100 miles of levees downstream of the dam. Instead, reassessment of dam operations would improve both flood control and water quality. As of July 1994, the Corps has not revised the 1962 operation schedule, but instead emphasizes that the fixed schedule may be altered for floods smaller than the standard project flood.

5.2 Welton Mohawk Irrigation and Drainage District Works

Construction of the Wellton-Mohawk Irrigation and Drainage District (WMIDD) began in 1949. The district became a formal legal entity July 23, 1951, and the first water delivery was in 1952. The WMIDD extends from Texas Hill to the Gila Gravity Main Canal, covering 60 river miles. WMIDD is actually a political subdivision of the state of Arizona, a municipal corporate entity that operates very similarly to a city or county. Water for the WMIDD is diverted from the Imperial Dam, on the Colorado River, through the Gila Gravity Main Canal. At mile 15 on the Gila Gravity Main Canal, water is then diverted into the District's Wellton-Mohawk Canal. WMIDD is allotted a consumptive use of 300,000 acre-feet of Colorado River water. This allotment of water is one of the most senior of any on the lower Colorado River. All irrigation water is delivered through a series of flow measuring devices (constant head orifices, propeller meter or broad-crested weirs) to monitor the amount of water that is being received. Monitoring is performed by the Soil Conservation Service.

The WMIDD has approximately 378 miles of main canals, lateral and drainage canals. In addition the District has 3 major pumping stations along the main canal, 4 minor pumping stations on the 3 larger lateral canals and 10 re-lift (side delivery) pumps on the main and lateral canals. There are also 90 drainage wells (converted irrigation wells) that are on the average about 100 feet deep. The wells are used to control the water table, pumping out groundwater with 40 to 75 horsepower motors. Drainage well operation is guided by a computer monitoring system of 480 observational wells that are evenly spaced throughout the District. The return flow from this system is carried all the way back to the Colorado River. In all cases the canals and laterals are concrete lined to reduce the seepage of water into the aquifer.

The end result of the increase in the velocity could be significant changes in the channel configuration.

Alternatively, some bridge locations may experience increased deposition, especially downstream from the structures. The bridge supports and riprap protecting the bridges may increase turbulence and cause the deposition of reattachment bars on the downstream sides of the abutments. The newly deposited areas could serve as potential sites for vegetation establishment after the water subsides (either naturally or with human intervention). The large deposits would also be sediment storage areas that could be eroded, with the sediments moving downstream in the next high flow event. This arrangement would further complicate the sediment transport within the channel.

Table 9. Bridges across the Lower Gila River.

Location	Bridge
Gillespie Dam to Painted Rock Dam	U.S. Highway 80
Painted Rock Dam to Texas Hill	Paco Dinero Crossing
	Oatman Crossing
	Rocky Point Crossing
	Hansen Crossing
	Sentinel Crosssing
	Dateland Crossing-Ave 84E
Texas Hill to Yuma	Ave 50E
	Ave 49E
	Ave 47E
	Ave 45E
	Ave 44E
	Ave 43E
	Ave 40E
	Ave 36E
	Ave 33E
	Ave 30E
	Ave 29E
	Ave 25E
	Ave 22E
	Ave 20E
	Ave 16E
	U.S. Highway 95
	Ave 7E

6 WATER QUALITY AND SEDIMENT QUALITY

6.1 Water Quality

6.1.1 Types and Sources of Contaminants

Contaminants of surface water and ground water include naturally occurring and artificial (human-made) substances. Technically, to be considered contaminants, they must be present in concentrations greater than some established level, which varies by substance. Federal and State agencies use these standards, but do not necessarily explain the basis for hazard levels. Types of substances contaminating both surface and ground water in Arizona include inorganic chemicals (nitrates, sulfates, metals), volatile organic compounds, BTEX (Benzene, Toluene, Ethylbenzene, Xylene), petroleum products, pesticides, and radiological substances. Some substances may naturally occur in contaminant concentrations. However, most contaminants have their source in human-related activities, such as landfill, mining, hazardous waste sites, water impoundments and agriculture (Water Assessment Section and Groundwater Hydrology Section, Office of Water Quality, Arizona Department of Environment Quality 1990). On the lower Gila River, inorganic chemicals, specifically total dissolved solids (TDS), pose the greatest threat to water quality. A 1991 water quality assessments for Arizona found contaminant levels of boron in the water of the Gila River near Dome (Water Quality and Waste Programs, Arizona Department of Environmental Quality 1992).

6.1.2 Total Dissolved Solids

The concentration of TDS in water in the lower Gila River valley creates the greatest water quality problems for both natural and human processes. Historical accounts (see section 3.1) indicate that water in the Gila River naturally contains high concentrations of dissolved salts, but these levels were not high enough to prevent the establishment of vegetation and use of the river by animals. Human activity --specifically agriculture and impoundment of water by dams-- has exacerbated the natural conditions. For example, percolation of irrigation return flows in the Wellton-Mohawk area increased the average salinity of groundwater to over 6,000 milligrams per liter (mg/l) in the 1960s (Bookman-Edmonston Engineering, Inc. 1992). Impoundment of water behind dams, especially Painted Rock Dams, increases TSD concentrations by enhancing and prolonging evaporation. As a result, impoundments in Painted Rock Reservoir dominate the water quality of not only the reservoir, but water quality in the lake below the reservoir (called Borrow Pit Lake), the Gila River channel, and groundwater (Western Technologies, Inc. 1983).

In the 1990s, the TDS concentration in the water of the lower Gila River ranges between 850 to over 5,000 mg/l (Water Quality and Waste Programs, Arizona Department of Environmental Quality 1992). TDS in the groundwater ranges from 3,000 to over 10,000 mg/l (Arizona Department of Environmental Quality 1993).

While no investigations into the sources of this contamination in the study area have been accomplished, one possible origin seems more likely than any other. During the decades after World War II, applications of DDT on cotton in the western Salt River Valley, the agricultural area west of Phoenix, were among the highest in the nation. Although its application was later banned by federal regulation, the DDT already in the area continues to be a source of concern. DDT in dissolved form may move southward in the ground water, until it surfaces along the Gila River in the reach from the confluence with the Salt River to Robbins Butte, west of Buckeye. As the DDT comes to the surface at the Gila River channel, the DDT is adsorbed onto sedimentary particles, in part because of the presence of calcium, salt, and other chelating agents. Once precipitated, the DDT tends not to dissolve again until it is in relatively low pH environments such as lakes with some organics present.

The DDT enriched sediments have been moving down the Gila River during flood events, and considerable amounts may have been included in the sediments behind Gillespie Dam. When the 1993 flood flows breached the dam, about a third of the stored sediments moved downstream, with some of them reaching Painted Rock Reservoir. Because fine particles contain proportionately greater amounts of adsorbed contaminants, and because during flood events fine particles are carried in suspension, some DDT bearing sediment is likely to have been carried through the outlet works of the dam and over the spillway. Deposition in the Barrow Pit Lake is the fate of some of these materials.

The only other major contaminant related to sediment in the study area may be selenium. Concentrations of selenium in water are often in the range of about 2 ppm. If this is the case, concentrations in sediment are likely to be much higher, because for heavy metals (similar to selenium), concentrations in western river sediments are usually two to three orders of magnitude greater than concentrations in water. The selenium occurs naturally in the region in low concentrations, but leaching by irrigation waters increases concentrations in water and sediment.

Congressional action is not yet complete on the approval of a reauthorization of the Clean Water Act, but all indications are that the revised Act will classify sediment as a pollutant. If this designation materializes in law, the major pollutant in the Lower Gila River (in addition to dissolved solids) will be sediment. Therefore, any attempts at flood control or environmental restoration should be evaluated in terms of the impact potential projects might have on the transport or storage of sediment.

6.2.2 Temporal Trends

There are no reliable data on temporal changes in sediment quality in the Lower Gila River, but based on the physical evidence, some reasonable speculation may be in order. If the explanation for DDT and related contaminants outlined above is correct, the near future is likely to bring an increased amount of pollution to the Lower Gila River from this source. Sediments from the Gila River in the western Salt River Valley will continue to move downstream. Additional injections of contaminated sediment from the

6.1.3 Temporal Trends

Fluctuations in water quality largely depend on a combination of human activity and natural events, namely agriculture and river impoundment, and flow events. The level of TDS in the groundwater in the Wellton-Mohawk Irrigation and Drainage District presents a major limitation on agricultural activities. Thus, the District has worked to reduce the concentrations of TDS in the groundwater, lowering the level to around 3,000 mg/l in 1992 (Bookman-Edmonston Engineering, Inc. 1992). Surface water quality, as represented by TDS for a station on the Gila River near Dome, varies considerably over a period of a few months (Figure 19). The fluctuations show no relationship to the mean daily discharge at the site, although flows during the period of record were very low. The lack of a clear relationship emphasizes that trends in water quality result from the complex interaction of surface and ground water, irrigation and drainage, and evaporation and precipitation.

6.2 SEDIMENT QUALITY

6.2.1 Types and Sources of Contaminants

Contaminants in sediments of the Lower Gila River have not been extensively investigated, except for some samples from the Barrow Pit Lake that were analyzed for the Arizona Department of Environmental Quality, Clean Lakes Program. The primary contaminant in the samples was DDE, a breakdown product of DDT. Levels of DDE in sediment were among the highest values reported for sediment from anywhere in the United States (reports not yet published; stated by ADEQ researcher Thomas Trend, U.S. Army Corps of Engineers Environmental Restoration Meeting, Phoenix, June 15, 1994).

The significance of DDT and its daughter products, DDE and DDD, is that all these compounds negatively impact wildlife reproduction, and fish in the lake have levels of these chemicals above safe standards for human consumption. DDT is the short expression for the chemical dichlorodiphenyltrichloethane, a water soluble pesticide used extensively in the United States beginning in the early 1940s. It was virtually banned in the United States in 1972, and concentrations in wildlife tissues has generally declined since that time as the chemical has dissipated or been buried in river and estuary sediments (Associated Press, 1994). While mammals generally are not adversely affected by normally encountered concentrations of DDT, aquatic and avian wildlife are exceptionally sensitive. The present exposure limits (set by the U.S. Environmental Protection Agency in 1978) are 0.41 micrograms per liter (acute value) and 0.00023 micrograms per liter (chronic value) for freshwater aquatic life (Sittig, 1980, p. 123). Concentrations for DDE of 10 to 40 milligrams per kilogram in dry food impairs reproduction of migratory birds, concentrations that are readily exceeded in fish from polluted waters and sediment areas. Biamplification of DDT and its associated chemicals in the food chain ranges from 100,000 to 2 million (U.S. Environmental Protection Agency, 1976), so that minor values in sediments may become major problems in the life system.

remaining deposits behind the breached Gillespie Dam is nearly a certainty. Much of this material might be expected to come to rest in Painted Rock Reservoir, but because some of the sediment is fine enough to be suspended easily, especially in flood discharges, some will also reach deposition sites below Painted Rock.

Selenium concentrations are not likely to change because the Lower Gila is a through-flowing system. As long as an outlet is maintained for flows from the system, and as long as major impoundments of water without throughput are avoided, selenium is unlikely to increase in the system. Flood control environmental restoration projects should be designed with this through-flow requirement in mind, however, in order to avoid a miniature version of the debacle at Kesterson Wildlife Refuge in California. Irrigation drainage waters containing selenium were trapped there, and through evaporation the selenium concentrations increased to damaging levels.

The amount of sediment entering the Lower Gila River is likely to remain generally constant with only minor changes as assessed by decade averages (there is a great deal of year-to-year variation). Some increase in sediment loading should be expected as the sediments behind Gillespie Dam are excavated by flood flows. Land management may increase or decrease inputs from the tributaries to the river below Painted Rock Dam, but given the large amount of sediment involved and the relatively sparse vegetation cover in the low deserts, changes in sediment yield from the tributaries are not likely without engineering control efforts such as sediment retention basins.

These comments regarding sediment, DDT, and selenium have implications for the Wellton-Mohawk Irrigation District and for restoration efforts generally in the lower river system. The District has had flooding problems that are partly related to the reduction of channel capacity. The growth of exotic vegetation, primarily tamarisk, serves as an effective roughness element in the channel, stimulating deposition through turbulence. The extensive root systems stabilize the deposits. If sediment continues to enter the system in large quantities, build-up of that material will almost certainly continue in the channel. If some clearing of the channel is undertaken, the sediment will move downstream to the Colorado River where it poses problems for the management of Morelos Dam. Thus, even though the district is not the origin of the sediment, it will have to contend with its implications.

Likewise, the irrigation and drainage istrict must contend with the downstream flux of DDT and its daughter products. As these materials pass from the District to the Colorado River, the WMIDD may be erroneously identified as the "source" of these contaminants instead of simply a pass-through system. It would serve the best interests of the District and the best interests of environmental restoration if the exact source and pathways of DDT, DDE, and DDD were to be defined by research. Control measures would then be more likely to be effective. If the origin of these contaminants proves to be the western Salt River Valley, reconstruction of Gillespie Dam becomes more desirable as a means of stabilizing and burying the contaminated materials before they move further. Pump and treat approaches to cleansing the groundwater in the Gillespie area might then

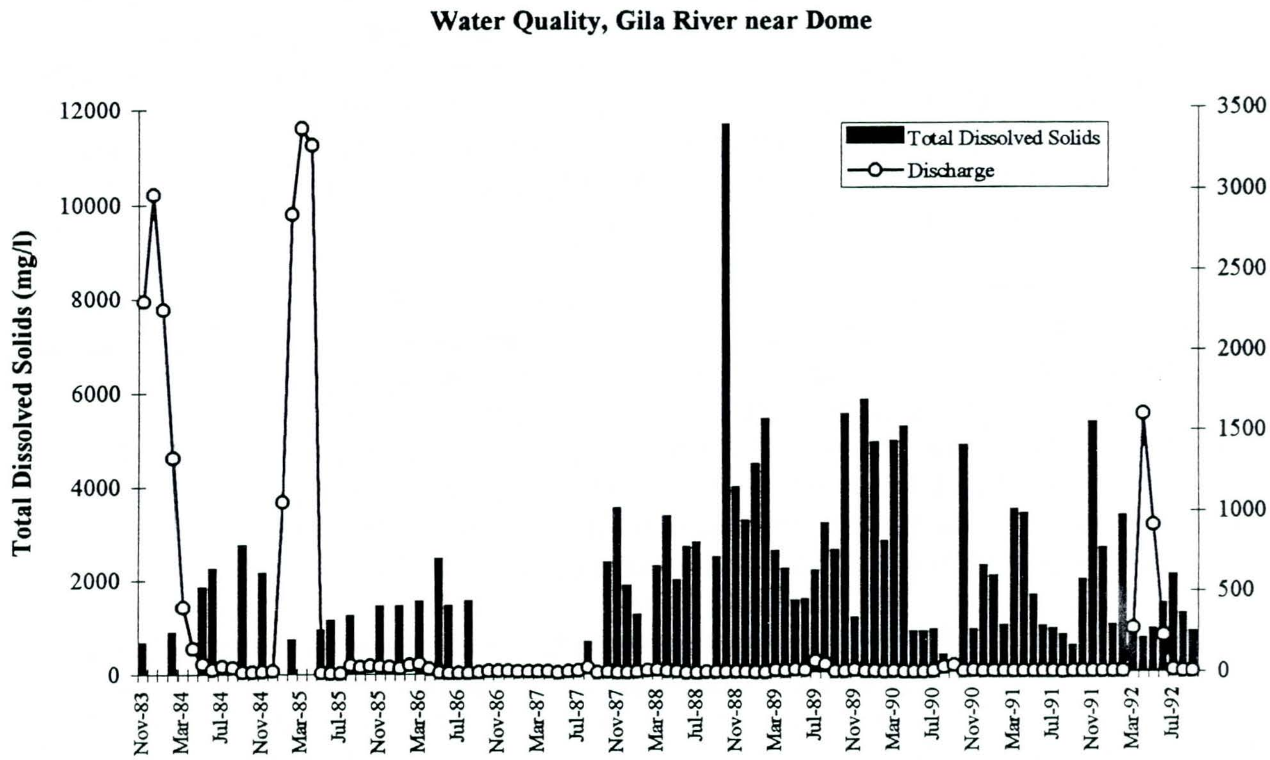


Figure 19. Mean daily discharge and water quality for the Gila River near Dome as represented by Total Dissolved Solids (TSD). Data from U. S. Geological Survey, Water Resources Data Arizona, U. S. Geological Survey Water-Data Report (Washington, D. C., various years).

7 OPPORTUNITIES AND CONSTRAINTS FOR POTENTIAL USCOE PROJECTS

7.1 Opportunities and Constraints for Flood Control Projects

Opportunities for major flood control projects by the U.S. Army Corps of Engineers appear to be limited in the Lower Gila River to two obvious possibilities: sediment control and erosion control. The control of sediment flows into and through the river are of great importance to the stability of the river environment. The development of sediment control basins on tributary streams (see section 4.2 above) would substantially improve stability of the main channel system. The construction of as many as six large basins (at the mouths of the largest tributaries) and up to ten smaller ones would have wide-ranging benefits for the Wellton-Mohawk Irrigation and Drainage District, and would improve the likelihood of success for environmental restoration projects in the area.

Control of sediment flows from the Gillespie Dam area is also a primary concern. The dam is privately owned, and present deliberations about its possible reconstruction focus mostly on questions related to irrigation diversions at the site for the Enterprise and Gila Bend canals. However, the downvalley movement of sediments that are likely to contain contaminants should also be a consideration. Gillespie Dam was probably the storage site of sediments containing herbicides and pesticides that originally were applied to field in the western Salt River Valley beginning in the 1950s. Those contaminants are likely to have moved in ground water to the channel of the Gila River, where they were adsorbed onto sediments. The sediment then moved into the Gillespie Dam sedimentation area, where their movement virtually ceased. When the dam was breached, they were remobilized, and made their way downstream to Painted Rock Reservoir, and in some cases the finest materials passed over or through the dam to reaches further downstream. The containment of the remaining sediments upstream from Gillespie Dam, and the interception of additional possibly contaminated sediments that continue to enter the area from upstream offer challenges for engineers and environmental managers.

The Corps might also consider raising Painted Rock Dam. Because the water surface area of the reservoir is so large, small increments in increased elevation of the dam result in dramatic increases in storage capacity. Though it is often dry, a reservoir with enlarged capacity for storage would provide a greater latitude for protection and management. It would also allow for enhanced long-term sediment control by trapping materials eroded from Arlington Valley, the Salt River (which continues to degrade), and the middle Gila River. The trapping of these sediments is significant because such a strategy would provide protection for Bureau of Reclamation structures on the Colorado river a short distance downstream from the mouth of the Gila River at Yuma. Sediment eroded from the Gila downstream from Painted Rock already poses some concern, as evidenced by the 1993 event, and elimination of additional loadings from the upper basin would be beneficial. Other flood control works involving the channel downstream from the dam have been considered by the Corps in the past, but cost-benefit analyses did not prove favorable.

remove the contaminants.

Irrigation drainag water from the WMIDD is the source of a continuing salinity problem for downstream flows, and sediments play a role in that situation. Sediments are temporary, concentrated storage sites for salts, so that any further attempts to deal with salinity problems must take into account the channel sediments.

water tables are common. This source is not available in Cotton Center Valley where water table depths approach 100 feet. Any such excavations are likely to be either in the low flow or high flow channel, and in both cases, sedimentation during floods is likely to occur. Filling by sediment is the natural fate of such features in undisturbed and uncontrolled streams, and it would occur in the Lower Gila as well.

6. **Maintain high water tables.** To a certain degree this is already the case, so that a continuation of present pumping practices actually provides opportunities for environmental restoration. High water tables do not occur in Cotton Center Valley.

7.2.2 Dendora Valley

Opportunities for large-scale environmental restoration projects on the Lower Gila River are severely limited by lack of surface water. With upstream dams in place and no recognized instream flow rights for the lower river, large-scale restoration seems unlikely. Instead, a series of more limited opportunities might be pursued. The largest potential restoration area is Dendora Valley, immediately downstream from Painted Rock Dam (Figure 20). The valley is somewhat self-contained, and ground water appears to partially dammed by the basalt flows immediately downstream from the Oatman Grave site. Useful vegetation already exists in the area, though investment would be required to improve it. The Borrow Pit Lake provides standing water, but it also provides the constraint that its sediments are heavily polluted by DDE. These sediments must be removed and disposed of, and upstream controls imposed on potential injections of new, contaminated sediments. If operating rules were changed for Painted Rock Dam so that it could store water for longer periods and release it periodically, a more natural surface flow might result (outlined below). Treatment of these releases is almost certainly required, so that the installation of water treatment facilities at the outlet works would be needed.

7.2.3 Basalt Gorge

Immediately downstream from Dendora Valley is a narrow reach of the river about 3 miles long where the stream passes through a basalt flow (Figure 21). A small canyon conducts the river between rock walls, and on the canyon floor there is enough space for one or more terraces. The basalt appears to force groundwater, which is migrating down valley through the Dendora area, to the surface. This basalt gorge offers a nearly natural environment with respect to vegetation, geomorphology, and hydrology (especially with the addition of "trickle flows" from the dam as outlined below). The establishment of cottonwood and willow along the banks, perhaps with mesquite bosques on the fine-grained soils of the terraces, should be further investigated.

7.2.4 Oxbows and Sloughs in the High Flow Channel

Smaller investments in environmental restoration might include the excavation of a variety of oxbows and sloughs, abandoned low flow channel segments that are close to the level of ground water (Figure 22). Lowering the floors of these features by excavation

At the present time, calculations of the benefits from preventing flood damages for the Corps of Engineers includes only determination of inundation damages. If those calculations were to include erosion damages and agricultural damages, there would be significant potential for involvement on the Lower Gila River in the control of the meandering low flow channel as well as control of the expansion of the braided high flow channel. The protection of agricultural properties and irrigation and drainage works located on the first terrace from erosion by the active channel is not possible on a long term basis with unconsolidated levees built to contain the 10,000 cubic foot discharge event (the present effort of the irrigation and drainage district). Larger, more sophisticated structures along with "soft engineering" through vegetation management might be an avenue for Corps involvement if erosion prevention were included in the calculated benefits.

7.2 Opportunities and Constraints for Environmental Restoration Projects

7.2.1 Summary of Potential Water Sources

Whatever the opportunities for environmental restoration in the Lower Gila River, there are only six potential sources of water.

1. **Colorado River water.** Some 300,000 acre feet per year flow into the Wellton-Mohawk Irrigation and Drainage District, but this water is critical to the overall operation of the system. Not only does it water crops, but when mixed with water high in salt content, it can be returned to the Colorado River for use by Mexico. International treaty agreements require the water crossing the border be of a certain quality, and the Colorado River water is critical for that purpose.

2. **Pumped water from conveyance channels.** This water is generally of low quality, at least with respect to salinity. It might provide local sources for environmental restoration, however.

3. **Pumped water from the groundwater table.** Although fairly close to the surface and therefore relatively inexpensive to obtain, this pumped water is high in dissolved solids. Again, it might provide a source for localized environmental restoration, in oxbows or sloughs, for example. It would not serve to sustain channel flow.

4. **Seepage from fields to the adjacent river channel.** The magnitude of this source is not known, but it is probably small. Localized use of this seepage for the maintenance of lines of cottonwood and willow along banks may be possible, thus providing enhanced bank stability as well as providing environmental restoration. The desirable tree species would have to be planted and nurtured until they became large enough to compete effectively with tamarisk.

5. **Excavate to reach the water table.** Excavations in oxbows and sloughs may reach high water tables fairly easily, and throughout the irrigation and drainage district, high

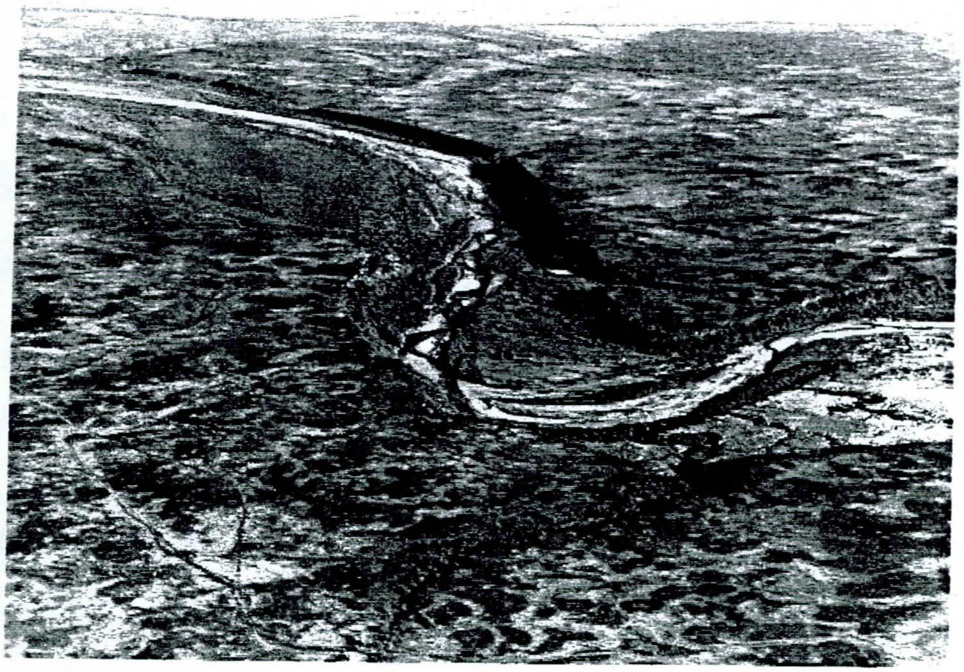


Figure 21. The upper end of the Basalt Gorge (shown at the center right) at the downstream end of Dendora Valley. The basalt rises by steep slopes from the alluvial valley floor that includes minor terraces, point bars, and channels (W. L. Graf Photo 120-18, June 26, 1994).

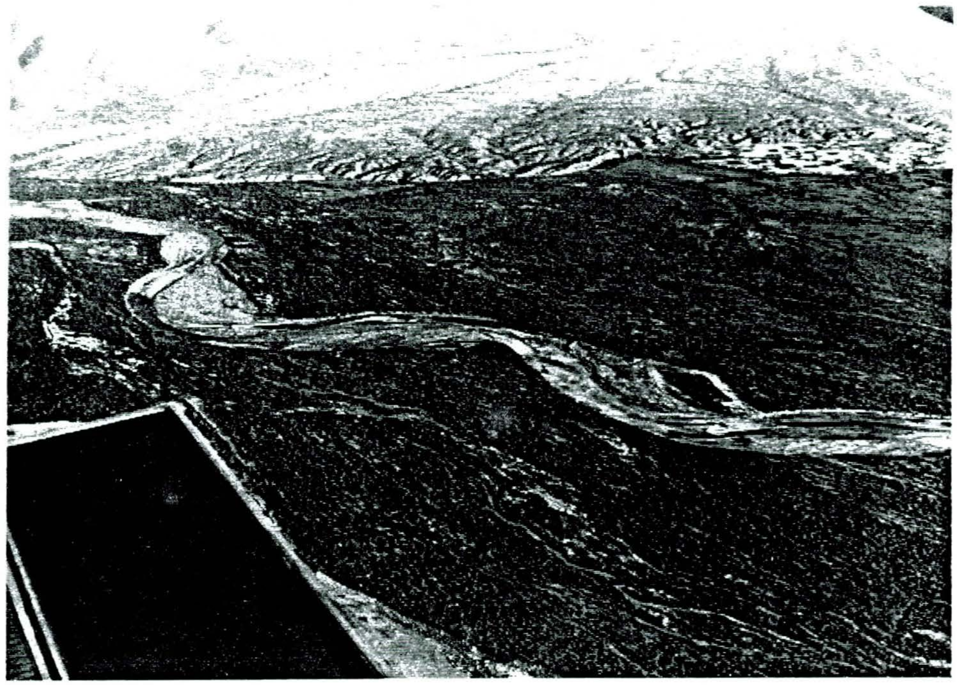


Figure 20. A portion of Dendora Valley downstream from Painted Rock Dam, showing a relatively narrow active channel area through a dense riparian forest. A desert piedmont slope appears at the top, with a cultivated and irrigated field at the lower left. Note the density of vegetation (W. L. Graf Photo 120-15, June 26, 1994).

might result in the creation of additional and enlarged wetlands. An advantage of this approach is that the ground water level is closely controlled through pumping by the irrigation and drainage district, so some external control on water would be available. This is especially important, because it would be desirable to facilitate the movement of water through restored systems. Standing water that is allowed to evaporate in place is likely to concentrate contaminants in the remaining water, especially dissolved solids. These smaller excavated features would also have to have berms or dikes to protect them from filling by sedimentation during moderate flow events. Filling is the natural fate of oxbows and sloughs, an engineering steps would be required to slow the process. Some prime candidates for these attempts include the following:

1. Upstream from Pierpoint Road, near Cotton Center

2. Immediately north of Gila Bend near the eastern edge of the Gila Bend Indian Reservation.

3. Upstream of the road crossing at Agua Caliente.

4. The "lagoon" near the site of Palomas, 8 river miles downstream from Agua Caliente.

5. Outside meander north of Tacna.

6. Abandoned low flow channel segments immediately northwest of Wellton.

7. Abandoned low flow segment, outside meander, immediately east of Dome.

Artificial oxbows might also be constructed for environmental restoration, especially upstream from bridge crossings. These excavations could be outside the lowflow channel area, and separated from the low flow by a low levee (perhaps constructed from material from the excavation). During flood periods, these artificial oxbows would be filled with water and could deflect energy from scouring bridge structures by creating slack water upstream.

7.2.5 Bridge and Road Crossings

Additional opportunities are available for possible environmental restoration where paved roads intersect the channel at bridge crossings (Figure 23). Because the roads slope gently downward to the channel, the drainage ways on each side of the roadway conduct some water to the channel. This arrangement might be enhanced significantly by lining the ditches, insuring that as much water falling on the road surface is captured and conducted to the side ditches, which then conduct it to the river. The ditches on the downstream side of the road should connect by pipe under the road to place all the runoff on the upstream side of the bridge abutments or approaches. On the upstream side of each abutment or approach might be located a wetland area of a few acres to several tens of acres in extent

Figure 22. A slough or oxbow lake area on the south side of the active channel near Mohawk with an extensive riparian forest. The active channel, including a meandering low flow alignment and a broader, braided component appears across the upper part of the photo. A terrace crosses the bottom portion of the photo (W. L. Graf Photo 120-28, June 26, 1994).

(Figure 24). These areas are erosion zones during flood events, and are naturally scoured to some degree when reverse eddies are established as flow exceeds capacity of the channel under the bridge. Extensive infillng of these areas is not likely because of the persistence of these reverse eddies, and marsh-like areas would lose vegetation during the flood event. If cottonwood and willows were to be nurtured along the road bank, approaches, or abutment areas, they would serve as erosion protection and as edge vegetation for the marshes.

In areas such as these road-fed marshes, loss of precious surface runoff to percolation is a major issue. Such vertical loss could be controlled by the installation of artificial perched water tables. The area beneath the marsh must be excavated and lined with clay, and then capped with channel materials to serve as a substrate for marsh vegetation and the trees along the road or approach. While some experimentation may be required to determine the optimum size of the perched water table to sustain the marsh, it would prevent raising the general water table in those areas where it is close to the surface.

7.2.6 Tributary Ramps

Tributary streams join the Lower Gila River in the Wellton-Mohawk Irrigation and Drainage District through artificially constructed flow ways (Figure 25). These broad, shallow channels are often lined with berms and cross canals and drains by way of bridges. They form confined ramps, sometimes two or miles in length. These tributary ramps should be explored as locations for artificial environments that might replace some lost environments on the main stream. With occasional floods and high water tables, the edges of these ramps are prime candidates for cottonwood restoration. During those years when a surface flow is needed but none is forthcoming naturally, some water might be emptied into the ramps from highline canals or drains. Water quality will probably be the limiting factor in these efforts, but the viability of the approach is demonstrated by lines of cottonwoods along ramps on the southern edge of the Muggins Mountains. Candidate areas for ramp enhancement include Owl Wash, Mohawk Wash, Coyote Wash, Castle Dome Wash, small drainages from the Muggins and Gila Mountains, and King Valley or Growler Wash. The enhancement might be conducted in association with flood control measures related to the construction of sediment basins as discussed above.

7.2.7 Dam Operations

Dam operations hold one key to environmental restoration in the Lower Gila River. Releases from dams in general are highly variable depending on the management objectives (Figure 26). The present strategy comes into play when the reservoir stores water from inflows. Operators draw down reservoir waters as quickly as possible using 5,000 cfs releases. The low-level releases minimize damage to the Wellton-Mohawk irrigation and drainage works. This arrangement might be altered to retain as much water for as long as possible, subject to the following constraints.

Figure 23. Rail and road (two) bridge crossing at Antelope Hill, with the Hill in the lower left foreground (W. L. Graf Photo 120-29, June 26, 1994).

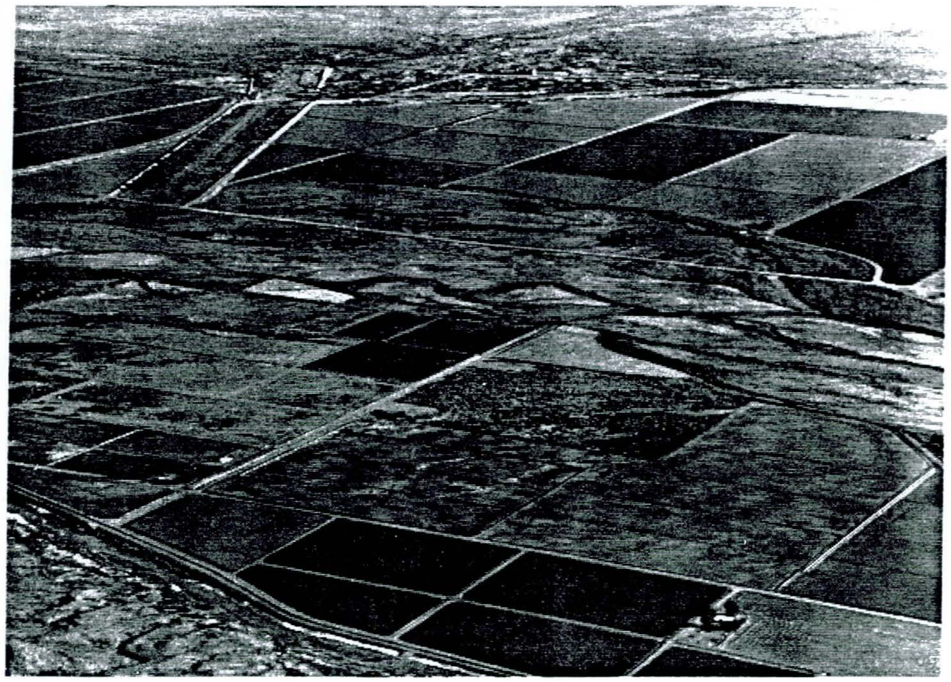


Figure 25. The Lower Gila River below Texas Hill, showing a tributary ramp (in the upper left corner) crossing the irrigated and cultivated terraces to the channel (W. L. Graf Photo 120-24, June 26, 1994).

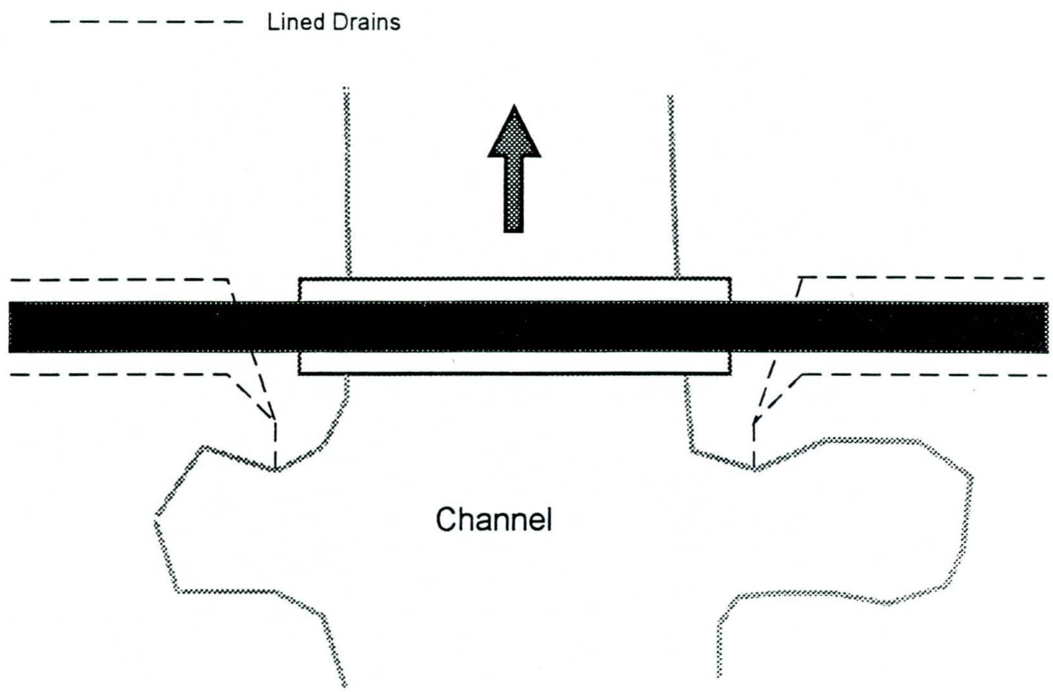


Figure 24. Sketch showing a vertical view of a hypothetical bridge crossing arranged to improve habitat upstream of the structure by using runoff control structures to harvest water discharging from the approach roads.

1. **Discharges are kept in the 250-500 cubic feet per second range.** Such a trickle flow would nourish a true cycling nutrient system in Dendora Valley and the basalt gorge area, but would not be large enough to reach the irrigation and drainage works downstream from Texas Hill. Peculation losses deplete releases of this magnitude to zero when they reach that distance. A trickle flow also maintains the channel system in a system of processes and forms faintly resembling its pre-development condition, at least in the Painted Rock to Texas Hill reach. Benefits to wildlife are likely to be substantial.

2. **One spring flood of several thousand cubic feet per second is released from the dam but that is within the capacity of the levees and protective works in Wellton-Mohawk.** This would simulate natural annual floods in the river and provide a boost to sprouting cottonwoods if released in March, before the major flowering season of tamarisk. The flow would also clear some vegetation from the maintained channel through the irrigation and drainage district, and would replenish the Borrow Pit Lake with less polluted water. Although district farmers might prefer no discharges at all, these flows would stimulate protective vegetation at the foot of the levee system while maintaining a clear channel between levees.

3. **The reservoir is drawn down before the following winter**, in accordance with the overall Corps objective of having the reservoir serve as a major flood control capacity in winter and spring months.

7.2.8 General Perspectives

Improvement of wildlife habitat along rivers in western Arizona means by definition an increase in riparian woodlands as sources of cover and nesting places. Irrespective of the size or location of restoration efforts seeking to establish cottonwood, willow, or mesquite along the Lower Gila River, two prerequisite conditions must be met. First, seasonal flows of water are required in most years, including periodic flooding of the restored environment. Additional water is required in the form of high water tables to sustain growth during non-flood periods. Second, a suitable substrate consisting of particular materials arranged on particular surfaces is required. Along the Lower Gila, cottonwood and willow were essentially edge species growing in a band along the active high flow channel. In any given restoration area of the river, this high flow edge must be identified and mapped. In 1994, this edge sometimes was at the margins of the barren portion of the channel, but in other cases it was obscured, abandoned under cover of tamarisk or other growth. Mesquite bosques, under natural circumstances, grew on the fine soils of the first terrace, and if managers desire restoration of the bosques, that restoration will have the highest probability of success if the effort is made on the same substrate in the same geomorphologic position. In 1994, the first terrace in some places is under irrigation and cultivation, while in other places the terrace is the site of abandoned fields or has not been cultivated.

Competition with other vegetation will inevitably play a role in restoration efforts. Periodic maintenance will be required for restored natural vegetation until it is mature

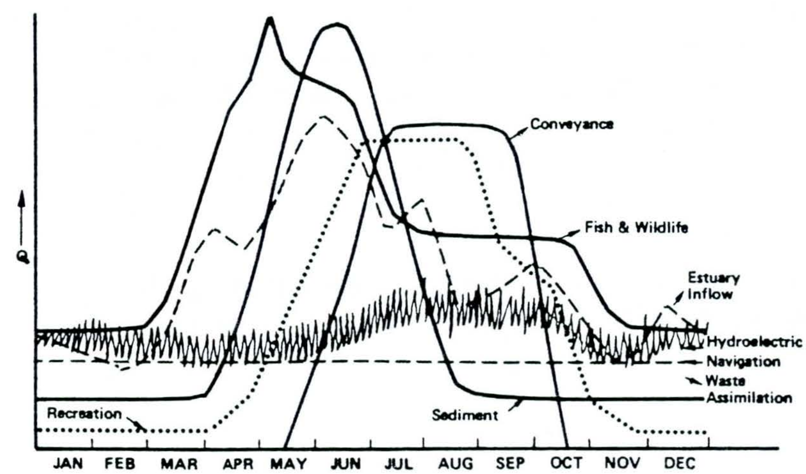


Figure 26. Hypothetical discharges under a variety of policy objectives from controlled releases from a dam (Unnumbered figure from Meyers and Tarlock, 1980, p. 26).

8 INFORMATION RESOURCES

8.1 Hydrology

Data for surface hydrology were obtained from U. S. Geological Survey Water-Data Reports for Arizona for water years 1990-1992, from the U. S. Geological Survey Office in Tucson, Arizona, for 1993, and from the U. S. Geological Survey Hydrodat 2.2 compact disc for all other water years. Daily discharge records are available for the lower Gila River for the following stations for the specified periods of record:

Gila River above Diversions, at Gillespie Dam, 1973-present
*Gila River below Gillespie Dam, 1921-present
*Gila River below Painted Rock Dam, 1960-present
Gila River near Mohawk, 1973-present
*Gila River near Dome, 1906, 1930-present

Figures in section 4.1.1 and tables in appendix 11.2 contain data from the marked (*) stations. Data on surface water quality of the Lower Gila River are available for the Gila River above Diversions, Gillespie Dam, and Gila River near Dome stations. Section 6.1.2. and 6.1.3 and appendix 11.2 contain data from the Dome station.

Data for groundwater conditions is available from various sources; the following list is not exhaustive. Data for the six representative wells were obtained from U. S. Geological Survey Water-Data Reports for Arizona and are presented in section 4.1.2 and appendix 11.2. These reports contain depth to groundwater and water quality data for as many as 41 wells in the groundwater basins of the lower Gila River Valley. The published well information, suggesting that the records for some wells extend back to the 1940s and 1950s, conflicts with examination of the records from the mid-1980s: either the data for specific wells was not included in the published report or data from different wells in close proximity compiled to create the longer records. Other sources of information include reports and maps published by Federal and State agencies and reports commissioned by the U. S. Army Corps of Engineers (see appendix 11.2).

8.2 Geology

The primary sources of geologic information are the offices of the U.S. Geological Survey in Phoenix and Tucson, with the Tucson office serving as the best source because of its bureaucratic position as the Arizona District Office--it also has a major library. Additional geologic data, especially for specific topics and specific regions, may be found in the dissertation and thesis collections of Arizona State University and the University of Arizona. The relevant literature is reviewed in section 1.4.1 above.

8.3 Riparian Ecology

The primary source of riparian ecology information is the Center for Environmental enough to shade invading tamarisk. Experience on the Salt and Gila Rivers elsewhere suggests that cottonwood and willow compete well with tamarisk, but only once the natives are well established. Tamarisk and perhaps knotweed will always colonize and grow in the barren portions of the low flow channel and the barren high flow braided component, because under natural conditions those parts of the channel cross section were not occupied by native vegetation. Clearing of the exotic plants is probably the only control available.

In many cases on the Lower Gila River, environmental restoration should be viewed as an attempt to improve habitat for wildlife. Without the reinstitution of continuous surface flows and areas of standing water, the restoration of truly functional, naturalistic ecosystems is not possible. This does not mean that the projects outlined above are so limited that they are worthless. It does mean that the Corps and its constituents should have reasonable expectations of the outcomes.

librarian and for this reason all of the photos located here are not accessible.

There are also two agencies that have more recent photos. The Arizona Dept. of Transportation have photos from the 1957 to the present. Along similar lines the Arizona Game and Fish Dept. has photos from the 1950's to present.

8.6 Aerial Photography

Aerial photographs are also considered to be part of the recent photographs section and it would appear that the best possible source for air photos is the Soil Conservation Service Irrigation and Power (Soil Conservation Service) in Wellton. They have aerial photographs from 1958 to 1993. In order to get access to the photos, the researcher has to go the SOIL CONSERVATION SERVICE in Wellton. To a lesser extent, there are also aerial photos available at the U.S. Army Corps of Engineers, but not anywhere near the coverage that the SOIL CONSERVATION SERVICE in Wellton. The U.S. Army Corps of Engineers has very good coverage of the Wellton-Mohawk Irrigation and Drainage District (1994, 1:400 scale coverage from Texas Hill to Dome). Additional aerial photography is available from the EROS Data Center of the U.S. Geological Survey at Souix Falls, South Dakota. This data center, which operates largely through mail queries, maintains a collection of all the photography taken by the Survey for mapping purposes, as well as older photographs taken by the U.S. Air Force, U.S. Army, and newer ones by NASA, including photos taken from orbital altitudes. Photos from the early 1940s may be available from the Fairchild Aerial Survey Collection, maintained by the Department of Geology at Whittier College, Whittier California.

Studies at Arizona State University. As with the geologic data, there are several important documents stored in the dissertation and thesis collections of Arizona State University and the University of Arizona. The files and offices of the Arizona Game and Fish Department in Phoenix and Yuma, as well as the U.S. Department of Fish and Wildlife in Phoenix contain numerous relevant documents not explored in this brief report.

8.4 Historical Accounts

Historical accounts of the Lower Gila River prior to development, summarized in section 3.1, are contained in various published diaries, reports, letters, and journals available from Hayden and Noble Libraries at Arizona State University in Tempe, Arizona, and Fletcher Library at Arizona State University West in Phoenix, Arizona. Appendix 11.3 provides these accounts, their sources, and secondary sources used to locate them. The list of sources is not exhaustive.

8.5 Historical Ground Photographs

In an attempt to evaluate the continuously changing environmental and geomorphological history of the Lower Gila River , a series of historic and recent photographs were examined. Because of the short time frame involved with this reconnaissance study, our group used only photos from local sources within the state of Arizona. Undoubtedly, there are other sources, such as California historical societies and repositories, the National Archives (Washington D.C.) and numerous agencies that sell aerial photos. However, with this in mind, this section of the report will directly address the sources, accessibility and usefulness of historic and recent photographs that were discovered in the Arizona repositories.

The sources of photographs have been compiled in the table entitled 'References for Historical Photographs'. The reference list has been annotated, so that the type of photos available at each site are recorded. Also included in the annotation is a phone number and name of the person to contact at each one of the repositories. From this list there are really three main sources of historical photographs to be found in the state of Arizona. The first place to start would be the State Lands Dept. (Navigable Stream Adjudication). This department has compiled there own list of historical photographs which could point a future researcher in the right direction. The two other sources that have the best quantity and quality photographs are the Arizona Heritage Center and the Arizona State University Dept. of Archives and Manuscripts. In both cases a list of relevant photos for this project has been compiled, with the earliest photos dating from the 1880's in both places (Appendix 11.2). In either case order forms are available for reprints of the photos. Reprints can be attained for a nominal cost. Also included on the photo list are other photos that were found in various locations (Appendix 11.3). Note that Arizona State University Archives does not permit photocopies of their pictures and the Az. Heritage center has an antiquated photocopying machine that produces poor photocopies, it is best to purchase reprints. A fourth potentially invaluable source of historical photographs is the Arizona Historical Society in Tempe. However, at present there is no

9 CONCLUSIONS

In conclusion, there may be Federal interest in flood control and environmental restoration in the Lower Gila River because the system is dominated by the federal dam at Painted Rock. Opportunities for enhancing flood protection are fairly limited, but worthy of consideration. Opportunities for flood protection include efforts related to increased channel capacities by flood-plain and soft-engineered levees, with associated growth of riparian vegetation providing both recreational and erosion-control benefits. Detailed evaluation of erosion control benefits and of the entire range of agricultural benefits, including those derived from reductions in salinity and contaminants, should be pursued.

There are substantial opportunities for small to moderate scale projects related to environmental restoration. The most promising potential projects include significant restoration and development of Dendora Valley, development of numerous naturally occurring oxbows and sloughs, growth of vegetation along the foot slopes of levees, and the use of road and bridge locations for marshes. These projects would not restore the river to its original condition even in short reaches, but it would measurably shift environmental conditions in some places toward more naturalist arrangements than exist at present. The potential benefits are most obvious for wildlife enhancement, direct recreation, and indirct non-use values.

10 REFERENCES

American Rivers. 1988. *The American Rivers Guide to Wild and Scenic River Designation: A Primer on National River Conservation.* Washington, D.C.: American Rivers, Inc.

Arizona Department of Environmental Quality. 1993. Arizona Water Quality Assessment 1992. Phoenix, AZ: Arizona Department of Environmental Quality.

Asmussen, L.E., A.W. White,Jr., E.W. Hanson, and J.M. Sheridan. 1977. Reduction of 2,4-d load in surface runoff down a grassed waterway. *Journal of Environmental Quality*. 6:159-162.

Associated Press. 1994. Falcons fail to take flight from DDT's lasting dangers. *Arizona Republic,* July 4, 1994.

Brown, D.E. 1982. Biotic communites of the American Southwest - U.S. and Mexico, *Desert Plants*, 4:1-342.

Bartlett, John Russell. 1854. *Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua, Connected with the United States Boundary Commission, during the Years 1850, '51, '52, and '53.* Vol. 2. New York: D. Appleton.

Bennett, H. H. 1955. *Elements of Soil Conservation*. New York: McGraw-Hill.

Berger, J. J. 1990. Evaluating Ecological Protection and Restoration Projects: A Holistic Approach to the Assessment of Complex, Multi-Attribute Resource Management Problems. Unpublished PhD Dissertation, University of California, Davis.

Black, P. E. 1987. *Conservation of Water and Related Land Resources*. 2nd Ed. Totowa, N.Jer.: Rowman and Littlefield.

Bookman-Edmonston Engineering, Inc. 1992. Yuma County Water Resource Management Assessment. Yuma, AZ: City of Yuma, Arizona.

Brown D.E. 1985. *Arizona Wetlands and Waterfowl*. Tucson.: University of Arizona Press.

Browne, J. Ross. 1951. *A Tour through Arizona 1864, or, Adventures in the Apache Country*. Tucson: Arizona Silhouettes.

Bryan, Kirk. 1925. *The Papago Country, Arizona: A Geographic, Geologic, and Hydrologic Reconnaissance with a Guide to Desert Watering Places*. U. S. Geological Survey Water-Supply Paper 499. Washington, D. C.: U. S. Government Printing Office.

Bureau of Reclamation. 1984. *Draft Environmental Assessment, Gila River Channel Enhancement, Wellton-Mohawk Irrigation and Drainage District, Yuma County, Ariozna.*

floodplain. *American Journal of Science* 266:417-439.

Fenner, P., Brady, W. W., and Patton, D. R.. 1985, Effects of regulated water flows on regeneration of Fremont cottonwood. *Journal of Range Management* 38:135-138.

Frost, K.R. and K.C. Hamilton. 1960. *Report on the Wellton Mohawk salt cedar clearing studies*. Arizona Agriculture Experiment Station. Report 193.

Haase,E.F. 1972. Survey of floodplain vegetation along the lower Gila River in southwestern Arizona. *Journal of the Arizona Academy of Science* 7:75-81.

Harris, D.R. 1966. Recent plant invasions in the arid and semiarid Southwest of the U.S. *Annals of the Association of American Geographers* 56(3):408-422.

Horton, J.S., F.C. Mounts, and J.M. Kraft. 1960. Seed Germination and Seedling Establishment of Phreatophyte Species. U.S. Forest Service Rocky Mt. Forest and Range Experiments Station Paper 48. Ft. Collins, Colo.: U.S. Forest Service.

Jarrell,W.M. and R.A. Virginia. 1990. Soil cation accumulation in a mesquite woodland, *Journal of Arid Environments* 18:51-58.

Feldman, D. L. 1991. *Water Resources Management: In Search of An Environmental Ethic*. Baltimore: Johns Hopkins University Press.

Garces, Francisco. 1965. *A Record of Travels in Arizona and California 1775-1776.* Translated by John Galvin. San Francisco: John Howell Books.

Goldfarb, W. 1988. *Water Law*. Chelsea, Mich.: Lewis Publishers.

Graf, W. L. 1978. Fluvial adjustments to the spread of tamarik in the Colorado Plateau region. *Geological Society of America Bulletin* 89:1491-1501.

Graf, W. L. 1983. Flood-related change in an arid region river. *Earth Surface Processes and Landforms* 8:125-139.

Graf, W. L. 1988. *Fluvial Processes in Dryland Rivers*. Berlin: Springer-Verlag.

Graf, W. L. 1991. *Wilderness Preservation and the Sagebrush Rebellions*. Totowa, N. Jer.: Rowan and Littlefield.

Halpenny, L. C., et al. 1952. Groundwater in the Gila River basin and adjacent areas, Arizona -- a summary. U. S. Geological Survey Open-File Report. Tucson, Ariz.: U. S. Geological Survey.

Harris, Benjamin Butler. 1960. *The Gila Trail: The Texas Argonauts and the California*

Yuma, Ariz.: Lower Colorado Region, Yuma Projects Office, U.S. Bureau of Reclamation.

Burkhart, B. 1994. Survey Says: Wetlands are Priority for State's Wildlife. *Arizona Republic*, Outdoors Notes, June 26, 1994.

Cairns, J., Jr. 1988. Increasing Diverstiy by Restoring Damaged Ecosystems. In *Biodiversity*, ed. by E. O. Wilson, Washington, D.C.: National Academy Press, p. 333-343.

Carothers, S.W., R.R. Johnson, and S.W. Aitchison. 1974. Population structure and social organization of southwest riparian birds. *American Zoologists*. 14:97-108.

Chaimson, J.F. 1984. Riparian vegetation planting for flood control. In *Califronia Riparian Systems: Ecology, Conservation, and Productive Management.* Warner, R.E. and K.M. Hendrix, eds. Berkeley: University of California Press. Pp. 120-123.

Corbett, E.S. and J.A. Lynch. 1985. Management of streamside zones on municipal watersheds. In *Riparian Ecosystems and their Management: Reconciling Conflicting Uses*. Proceedings of 1st North American Riparian Conference, Johnson, R.R., C.D. Ziebell, D.R. Patton, R.F. Folliott, and R.H. Hamre, eds. U.S. Department of Agriculture and Forest Service General Technical Report RM-120. Pp. 187-190.

Clarke, Asa Bement. 1988. *Travels in Mexico and California: Comprising a Journal of a Tour from Brazos Santiago, through Central Mexico, by Way of Monterey, Chihuahua, the Country of the Apaches, and the River Gila, to the Mining Districts of California*. Edited by Anne M. Perry. College Station: Texas A&M University Press.

Cooke, Philip St. George. 1964. *The Conquest of New Mexico and California in 1846 - 1848*. Chicago: Rio Grande Press.

Cooke, Philip St. George. 1938. "Cooke's Journal of the March of the Mormon Battalion, 1846-1847," in *Exploring Southwestern Trails 1846-1854*, Southwestern Historical Series, vol. 7, ed. Ralph P. Bieber. Glendale, Calif.: Arthur H. Clark.

Couts, Cave Johnson. 1961. *Hepah, California! The Journal of Cave Johnson Couts from Monterey, Nuevo Leon, Mexico to Los Angeles, California during the Years 1848-1849.* Edited by Henry F. Dobyns. Tucson, Ariz.: Arizona Pioneers' Historical Society.

Emory, William H. 1987. *Report on the United States and Mexican Boundary Survey Made under the Direction of the Secretary of the Interior*. Vol. 1. Austin, Texas: Texas State Historical Assocation.

Emory, W.H. 1848. *Notes of a Military Reconnaissance from Fort Leavenworth in Missouri to San Diego in California.* 30th Congress, 1st Session. Senate document 167. Pp 614.

Everitt, B.L. 1968, Use of the cottonwood in an investigation of the recent history of a

Management. Warner, R.E. and K.M. Hendrix, eds. Berkeley: University of California Press. Pp. 168-176.

Lumholtz, Carl. 1971. *New Trails in Mexico: An Account of One Year's Exploration in North-Western Sonora, Mexico, and South-Western Arizona 1909-1910*. Glorieta, N. Mex.: Rio Grande Press.

Meyers, C. J., and Tarlock, A. D. 1980. *Water Resource Management: A Coursebook in Law and Public Policy.* Mineola, N.Y.: Foundation Press.

Minckley, W.L. and J.N. Rinne, 1985, Large woody debris in hot desert streams: An historical review, Desert Plants, 7:142-153.

Minckley, W.L. and Clark, T.O. 1981, Vegetation of the Gila River resource area, eastern Arizona. *Desert Plants* 3:124-140.

Minckley, W.L. and Clark, T. O. 1984. Formation and destruction of a Gila River mesquite bosque community. *Desert Plants* 6:23-30.

Mock, Peter A., Burnett, Earl E., and Hammett, B. A. 1988. Digital Computer Model Study of Yuma Area Groundwater Problems Associated with Increased River Flows in the Lower Colorado River from January 1983 to June 1984. Arizona Department of Water Resources Open-File Report no. 6. Phoenix, AZ: Arizona Department of Water Resources.

National Research Council. 1992. *Restoration of Aquatic Ecosystems*. Washington, D.C.: National Academy Press.

National Research Council. 1987. *River and Dam Management: A Review of the Bureau of Reclamation's Glen Canyon Environmental Studies*. Washington, D.C.: National Academy Press.

Office of Arid Lands Studies. 1970. *Emvironemental study for the Gila River below Painted Rock Dam*. Contract # DacW09-70-C-0079.

Ohmart, R.D., and Anderson, B. W. 1974. Vegetation management: Annual report. U.S. Dep. Inter., Bureau of Reclamation. Boulder city, Nevada.

Ohmart, R.D. and B.W. Anderson, 1986, Riparian habitat. In *Inventory and Monitoring of Wildlife Habiatat*, Cooperrider, A.Y., R.J. Boyd, and H.R. Stuart, eds. Denver, Colo.: U.S. Bureau of Land Management Serive Center. Pp. 169-200.

Petts, G.E. 1985. Time scales for ecological concern in regulated rivers. In: J.F. Craig, J.B. Kemper (eds.). Regulated Streams: Advances in Ecology, J. F. Craig and J. B. Kemper, eds. New York: Plenum Press, New York. Pp. 257-266.

Gold Rush. Edited by Richard H. Dillon. Norman: University of Oklahoma Press.

Heft, F. E., 1984. The Dilemma of Conservation. *Journal of Soil and Water Conservation* 39:291.

Hendee, J. C., Stankey, G. H., and Lucus, R. C. 1978. *Wilderness Management*. Forest Service Miscellaneous Publication No. 1365. Washington, D.C.: U.S. Department of Agriculture.

International Commission on Large Dams. 1973. *World Registry of Dams*. Paris: International Commission on Large Dams.

Johnson, R.R. 1978. The lower Colorado River: A western system. In *Strategies for Protection and Management of Floodplain Wetlands and O her Riparian Ecosystems*. Johnson, R.R. and J.F. McCormick, eds. U.S. Department of Agriculture, Forest Service General Techical Paper WO-12. Washington, D.C.: Department of Agriculture. Pp. 41-45.

Karr, J.R. and I.J. Schlosser. 1977. *Impact of Nearstream Vegetation and Stream Morphology on Water Quality and Stream Biota*. Environmental Research Laboratory EPA-600/37-77-097,. U.S. EPA, Athens, Georgia: U.S. Environmental Protection Agency.

Kino, Eusebio Francisco. 1919. *Kino's Historical Memoir of Pimeria Alta*. Vol. 1. Edited by Herbert Eugene Bolton. Cleveland, Ohio: Arthur H. Clark.

Lacey, J.R., P.R. Ogden, and K.E. Foster. 1975. Southern Arizona riparian habitat: Spatial distribution and analysis. *University of Arizona Office of Arid Lands Bulletin* 8:1-148.

Leopold, L. B., T. Maddock, T. 1954. *The Flood Control Controversy: Big Dams, Little Dams, and Land Management*. New York: Ronald Press.

Lewis, R. R., III. 1989. "Wetlands Restoration, Creations, and Enhancement Technology: Suggestions for Standardization." *Wetland Creation and Restoration: The Status of the Science*, Vol. II EPA 600/3/89/038B. Washington, D.C.: U.S. Environmental Protection Agency.

Li, R.M. and W.H. Shen. 1973. Effects of tall vegetation and flow sediment. *Journal Hydraul. Div*ision, American Society of Civil Engineers Vol 9(HY5) Proc. Paper 9748.

Ligner, J. J., White, Natalie D., Kister, L. R., and Moss, M. E. 1969. *Water Resources. Arizona Bureau of Mines Bulletin* 180: 471-570.

Lowe, C.H., (ed.). 1964. *The Vertebrates of Arizona*. Tucson: University of Arizona Press.

Mahoney, D.L. and D.C. Erman. 1984. The role of streamside buffer strips in the ecology of aquatic biota. In Califronia Riparian Systems: Ecology, Conservation, and Productive

Hydrologic Map Series Report no. 3. Phoenix, AZ: Arizona Department of Water Resources.

Sedelmayr, Jacobo. 1955. Jacobo Sedelmayr, Missionary, Frontiersman, Explorer in Arizona and Sonora: Four Original Manuscript Narratives 1744-1751. Translated by Peter Masten Dunne. Tucson, Ariz.: Arizona Pioneers' Historical Society.

Stulik, R. S., and Moosburner, Otto. 1969. Hydrologic Conditions in the Gila Bend Basin, Maricopa County, Arizona. Arizona State Land Department Water-Resources Report no. 39. Phoenix, Ariz: Arizona State Land Department.

Sullivan, M.E. 1991. Heavy metal concentration in riparian vegetation exposed to wastewater effluent. M.S. Thesis. Arizona State University. Tempe.

Szaro, R.C. 1989. Riparian scrubland and community types of Arizona and New Mexico. *Desert Plants* 9(3-4):1-138.

Tellman, B. 1992. Arizona's effluent dominated riparian areas: Issues and opportunities. University of Arizona Water Resources Research Center Issue Paper 12: 1-45.

U.S. Army Corps of Engineers. 1962. Reservoir Regulation Manual for Painted Rock Reservoir. L.A.D.M. 1130-2-43. Los Angeles.

U.S. Army Corps of Engineers. 1970. Infiltration of Painted Rock Reservoir releasing for Gila River improvement (Texas Hill to Gila Siphon). Draft of design memorandum no.2. Los Angeles.

U. S. Army Corps of Engineers. 1975. Report on Release-Salinity Study for Painted Rock Dam. Los Angeles: U. S. Army Corps of Engineers.

U. S. Geological Survey. [various years]. *Water Resources Data - Arizona.* U. S. Geological Survey Water-Data Reports. Washington, D. C.: U. S. Government Printing Office.

U.S. Army Corps of Engineers. 1993. Painted Rock Dam (Smart Book).

U.S. Army Corps of Engineers. 1974. Report on Gila river and tributaries, downstream from Painted Rock Reservoir, Arizona. Los Angeles.

U.S. Army Corps of Engineers. 1977. Painted Rock Dam Operation Study Information Brochure. Los Angeles.

U.S. Army Corps of Engineers. 1986. Painted Rock Dam and Reservoir, Arizona: Information paper. Los Angeles.

U.S. Council on Environmental Quality. 1978. Environmental quality. The 9th report of the

Council on Environmental Quality. U.S. Govt. Printing Office, Washington D.C. (stock number 041-011-00040-8).

U.S. Environmental Protection Agency. 1976. *Quality Criteria for Water*. Washington, D.C.: U.S. Environmental Protection Agency.

University of Arizona, School of Earth Sciences, Office of Arid Land Studies. 1970. Environmental Study for the Gila River below Painted Rock Dam. A report prepared for the U. S. Army Corps of Engineers. October, 1970.

Water Assessment Section and Groundwater Hydrology Section, Office of Water Quality, Arizona Department of Environmental Quality. 1990. State of Arizona Water Quality Assessment Report for 1990 (Water Years 1988-89) Clean Water Act Section 305(b) Report. Phoenix, AZ: Arizona Department of Environmental Quality.

Water Quality and Waste Programs, Arizona Department of Environmental Quality. 1992. 1991 Annual Report. Phoenix, AZ: Arizona Department of Environmental Quality.

Weist, W. G., Jr. 1965. Geohydrology of the Dateland-Hyder Area, Maricopa and Yuma Counties, Arizona. Arizona State Land Department Water-Resources Report no. 23. Phoenix, AZ: Arizona State Land Department.

Western Technologies, Inc. 1983. Painted Rock Dam Water Quality Study Final Report. Phoenix, AZ: U. S. Army Corps of Engineers.

Wilkins, D. W. 1978. Maps Showing Ground-Water Conditions in the Yuma Area, Yuma County, Arizona -- 1975. U. S. Geological Survey Water-Resources Investigations Open-File Report 78-62. Tucson, AZ: U. S. Geological Survey.

Williams, G.P., and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers. U.S. Geological Survey Professional Paper 1286:1-64.

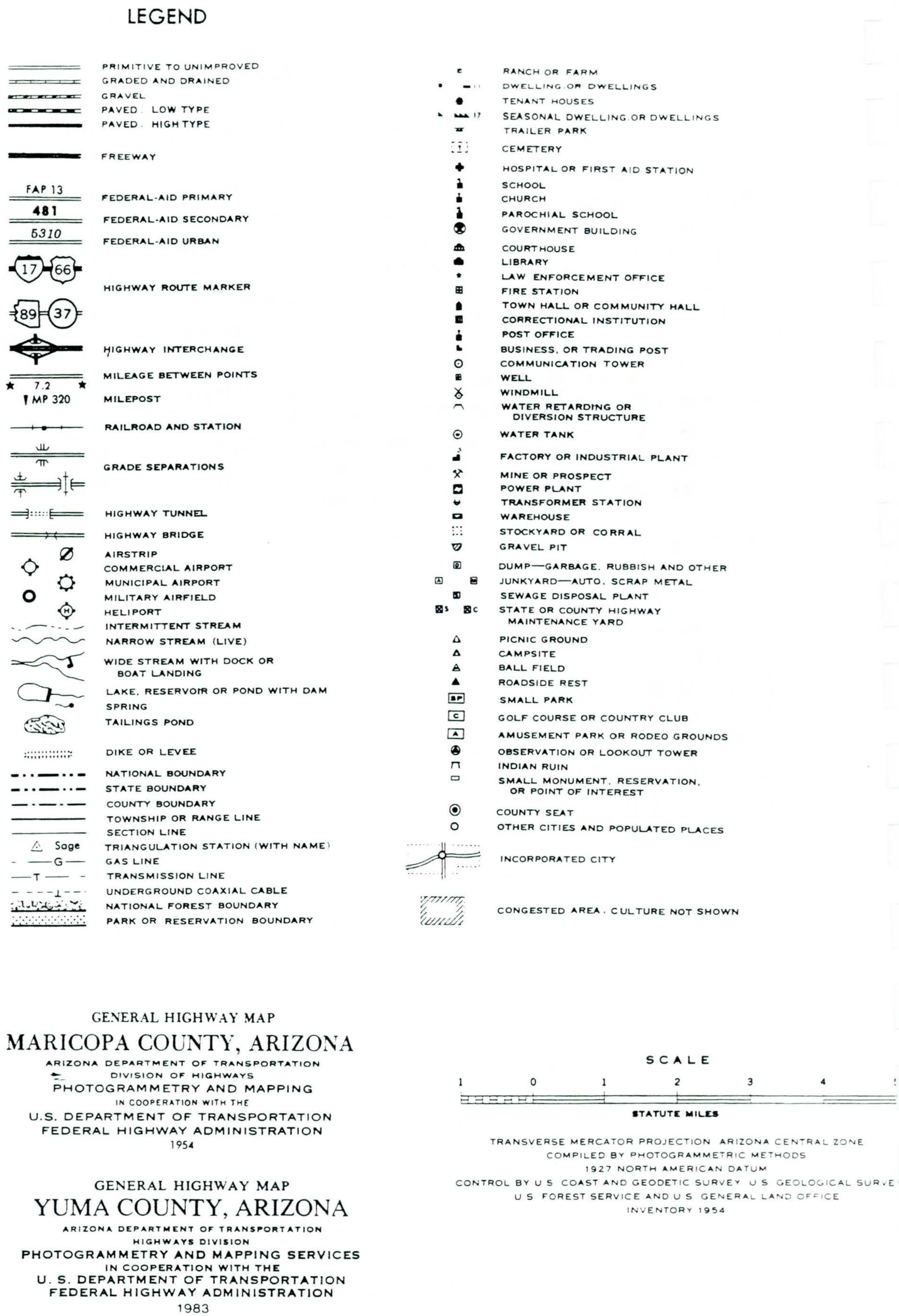
11 APPENDICES

APPENDIX 11.1 GENERAL LOCATION MAPS

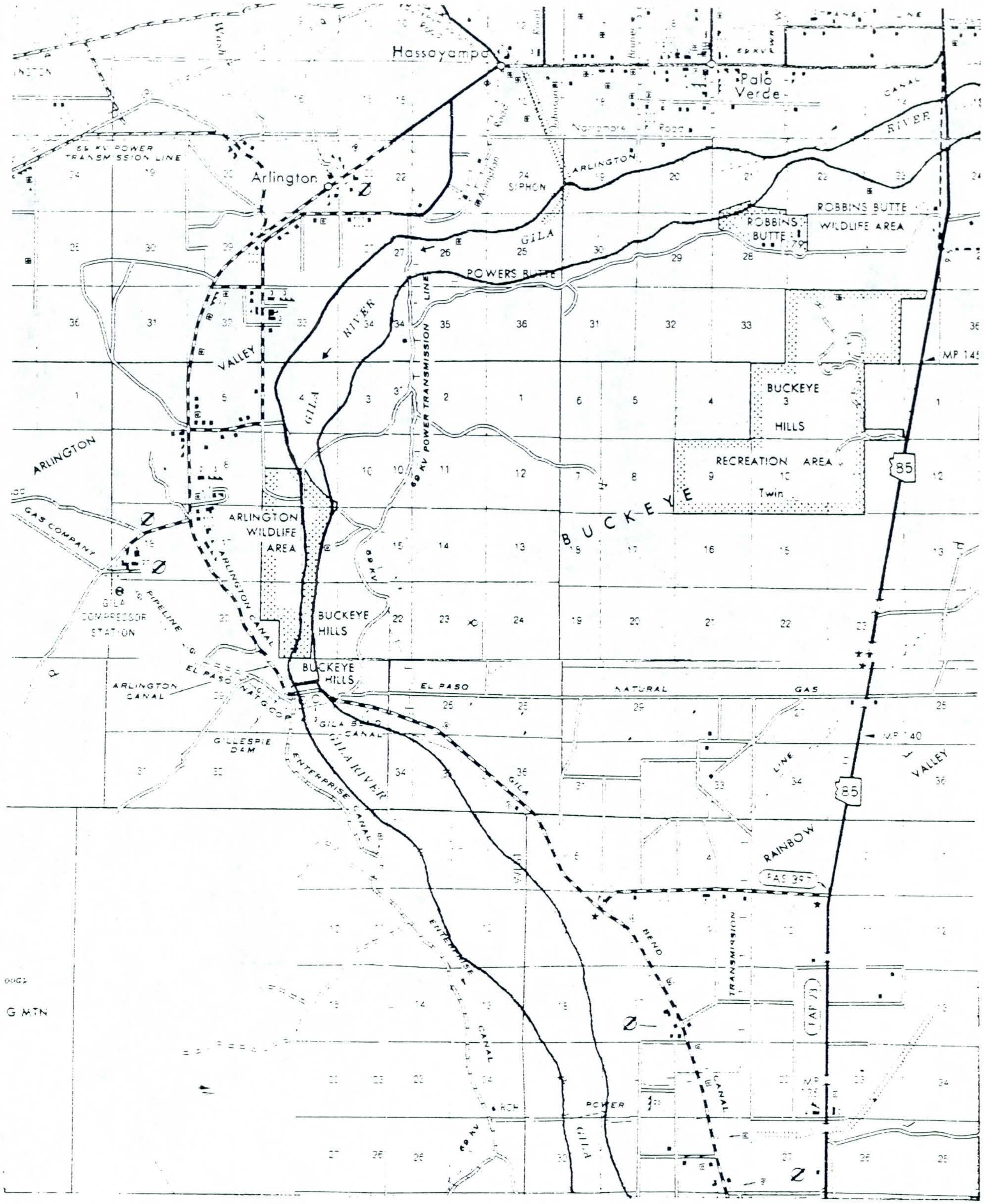
The following pages contain general location maps derived from publish maps of the Arizona Department of Transportation. The first page of this appendix contains the standard legend showing symbols used on the various sheets. The original cartographic representation of the Gila River channel is outlined in black line. For Maricopa County areas this outline shows 1954 conditions, while for Yuma County it shows 1983 conditions. Channel configurations in 1994 vary considerably from these earlier arrangements.

The first page in Appendix 11.1 contains the legend used for ADOT maps, along with the scale and the identication blocks for the maps. The subsequent pages contain portions of the larger maps that show the zone along the Lower Gila River. In some cases, these views consist of parts of two or more maps rearranged for convenience. The map segments identified by the vicinity they depict are as follows.

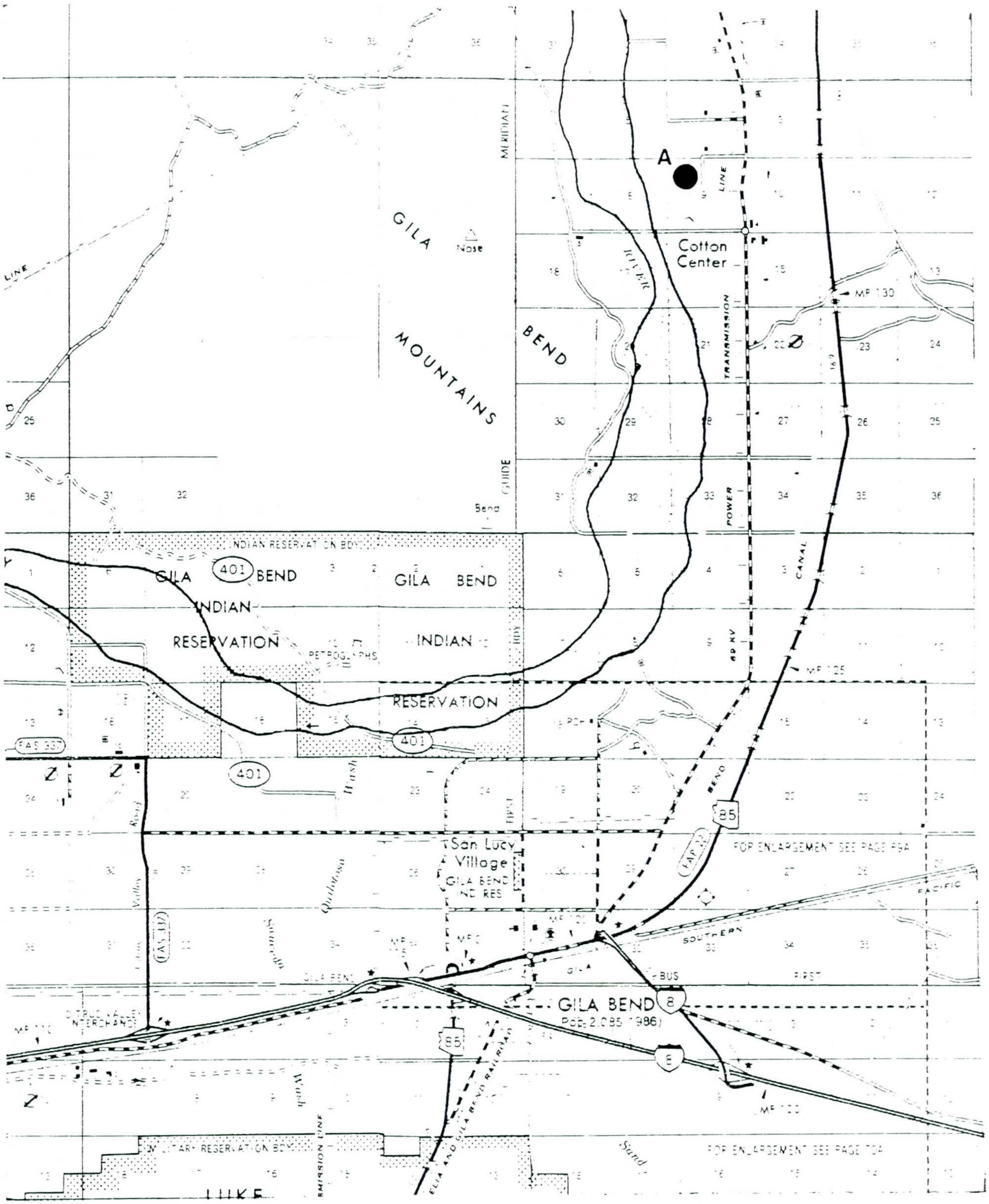
11.1.1 Legend
11.1.2 Arlington
11.1.3 Gila Bend
11.1.4 Painted Rock
11.1.5 Oatman
11.1.6 Agua Caliente
11.1.7 Dateland
11.1.8 Growler
11.1.9 Antelope Hill
11.1.10 Ligurta
11.1.11 Yuma



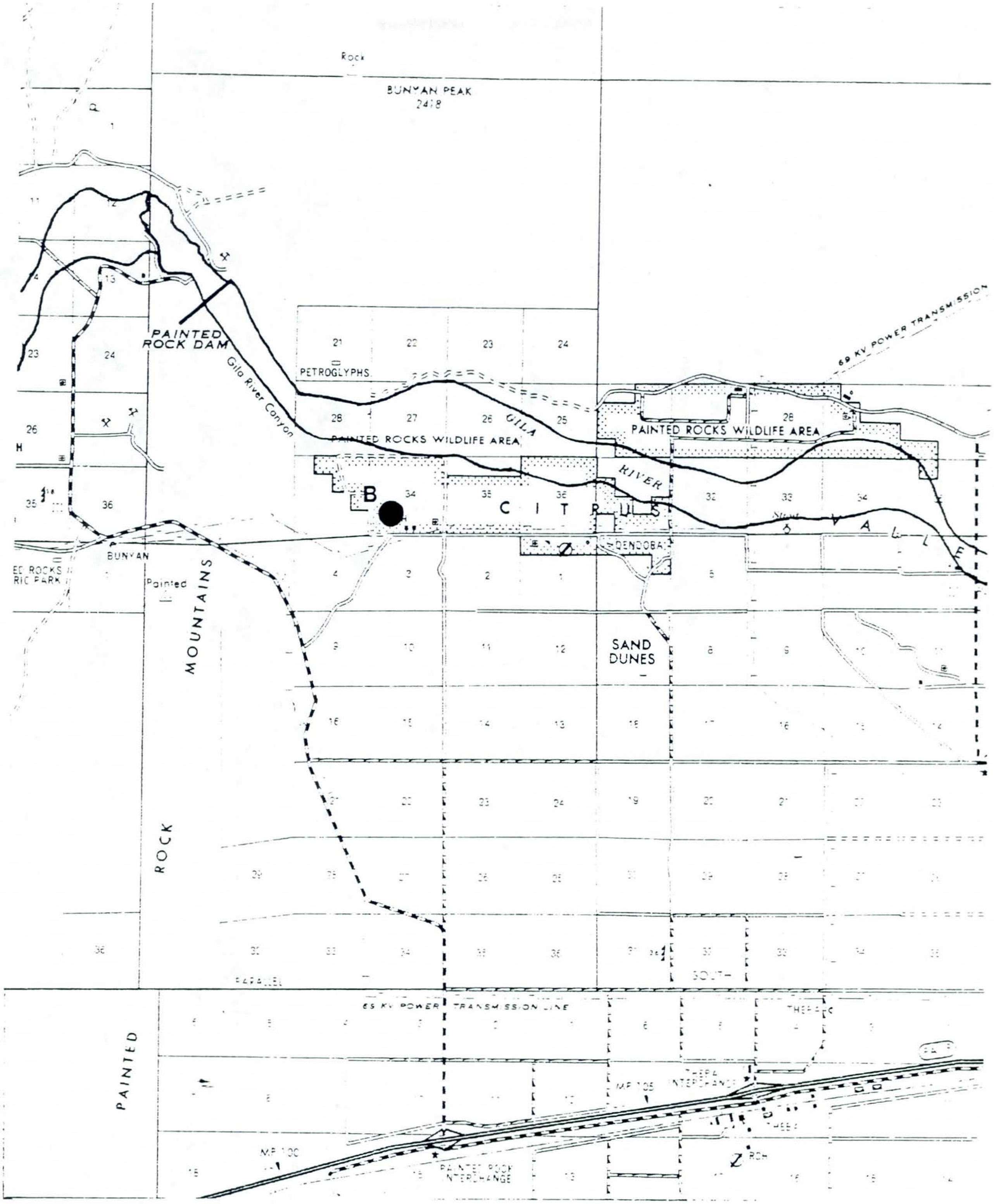
Appendix 11.1.1 Legend for ADOT county highway maps.



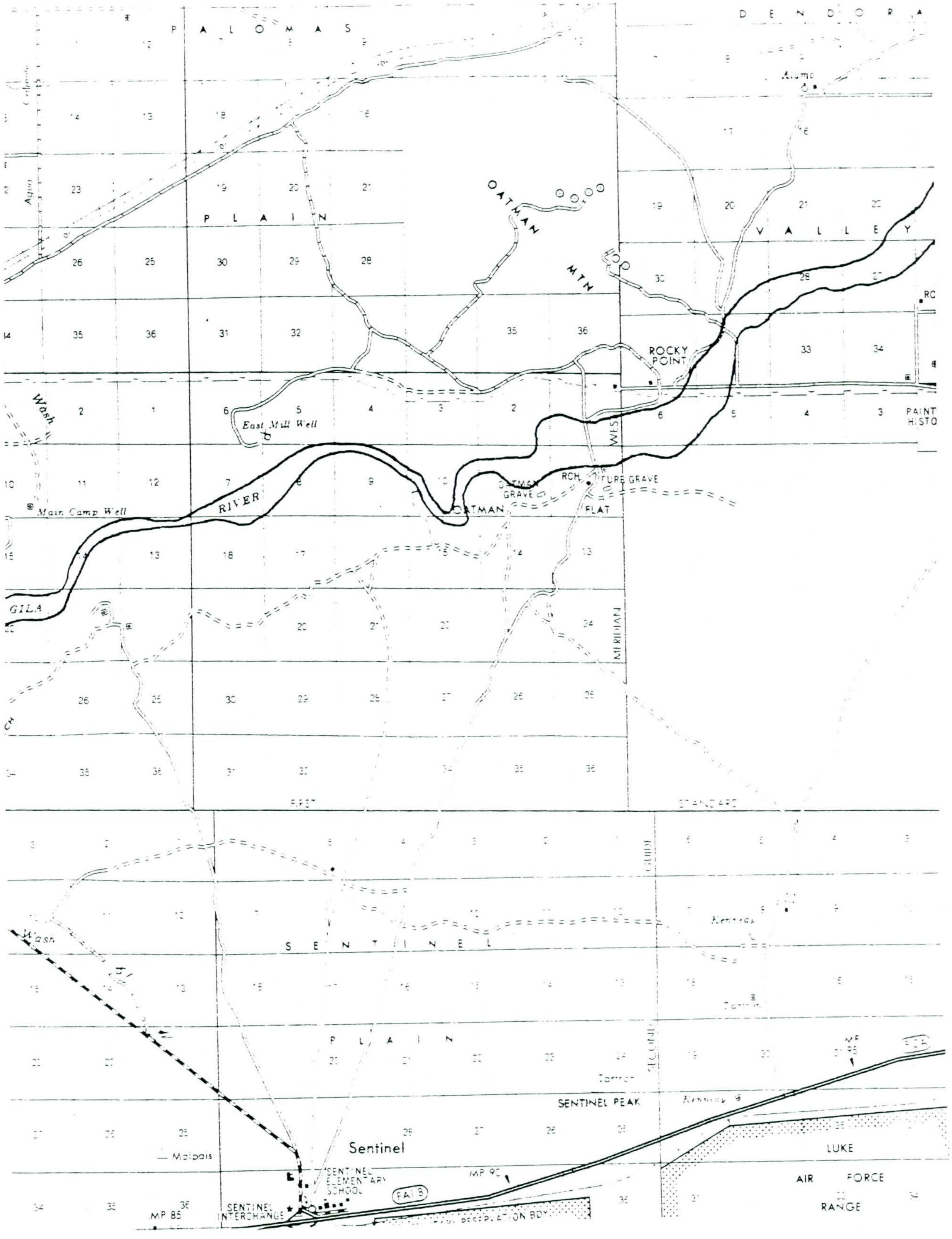
Appendix 11.1.2 Arlington vicinity (ADOT county map series).



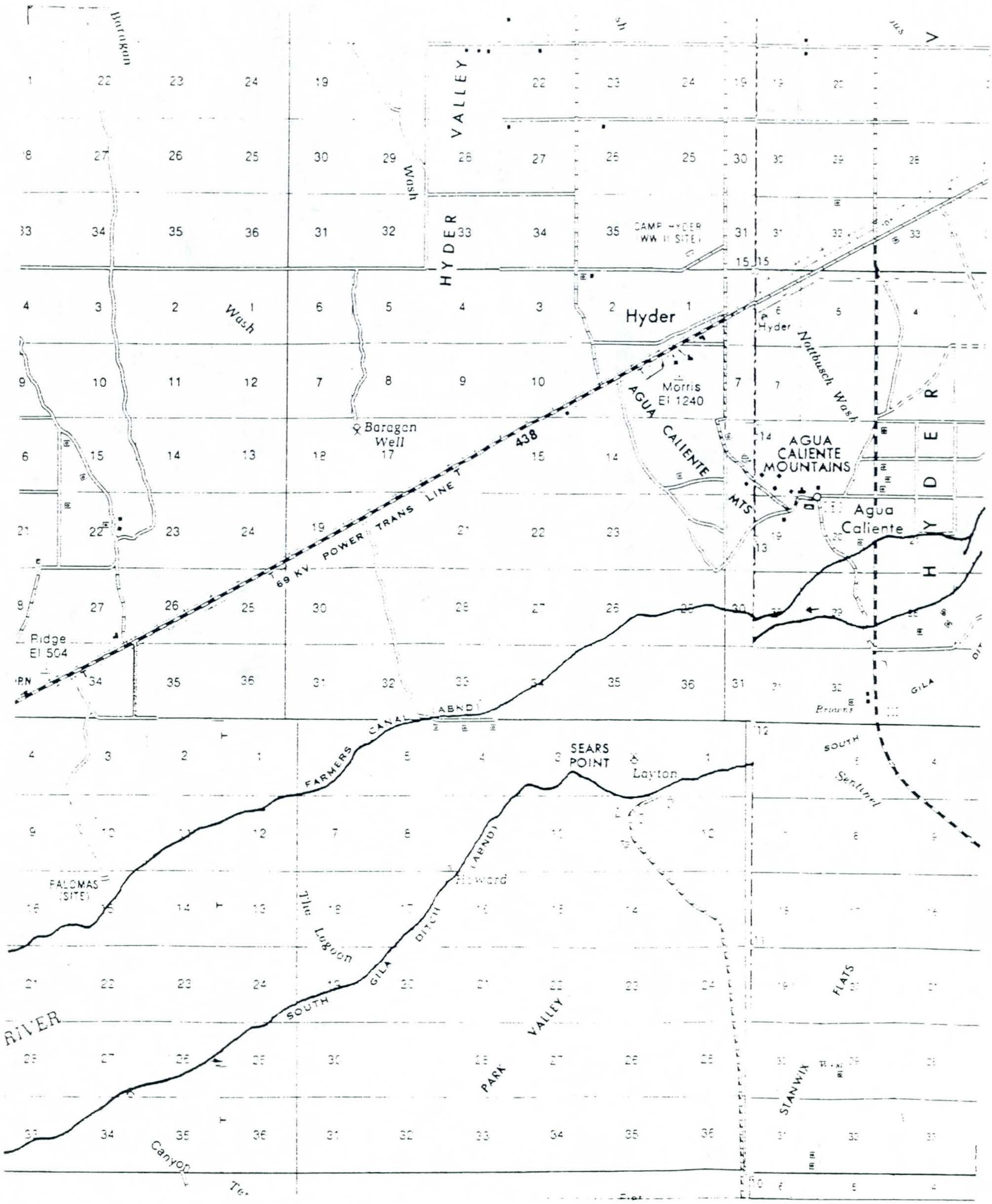
11.1.3 Gila Bend vicinity (ADOT county map series).



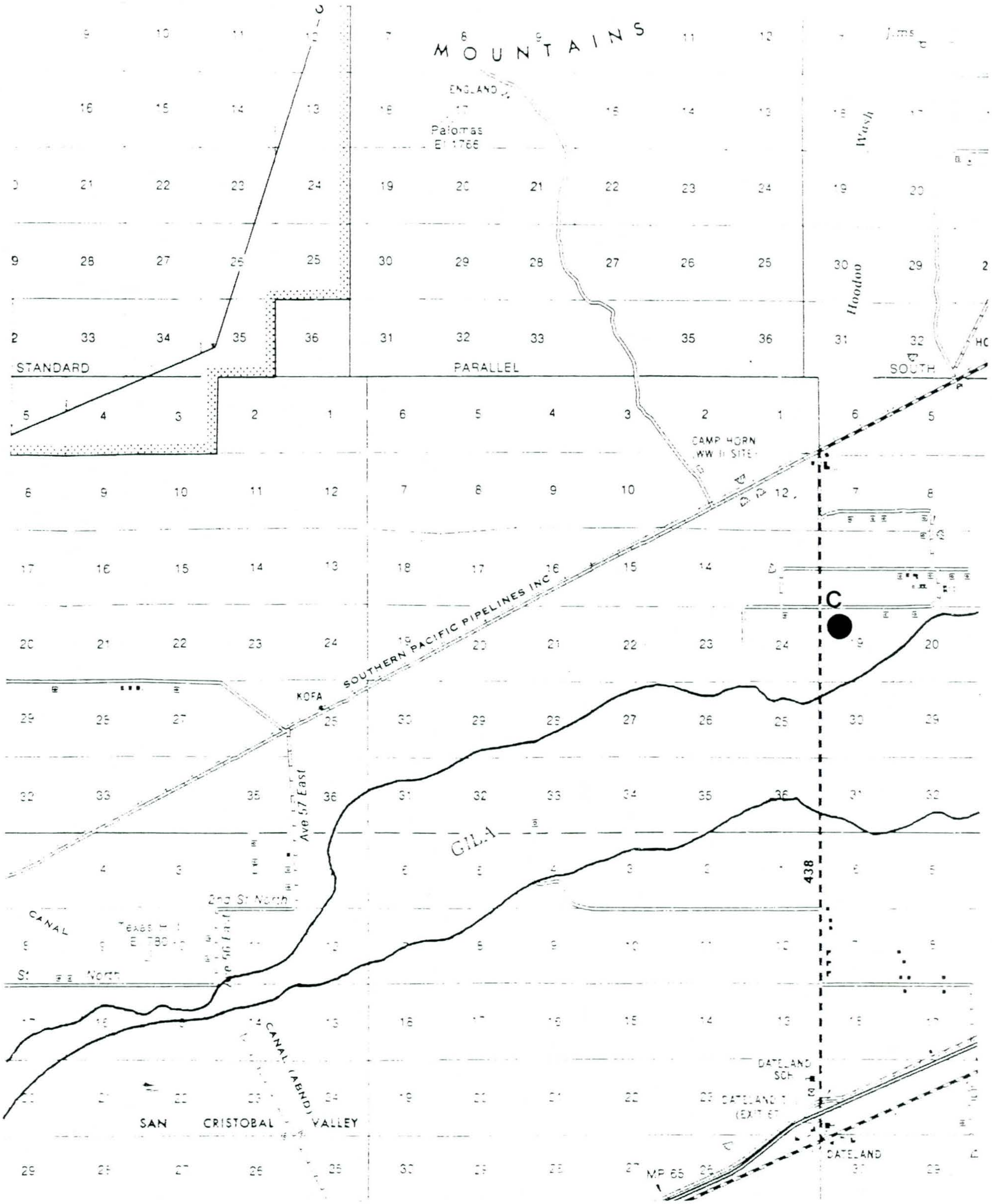
Appendix 11.1.4 Painted Rock vicinity (ADOT county map series).



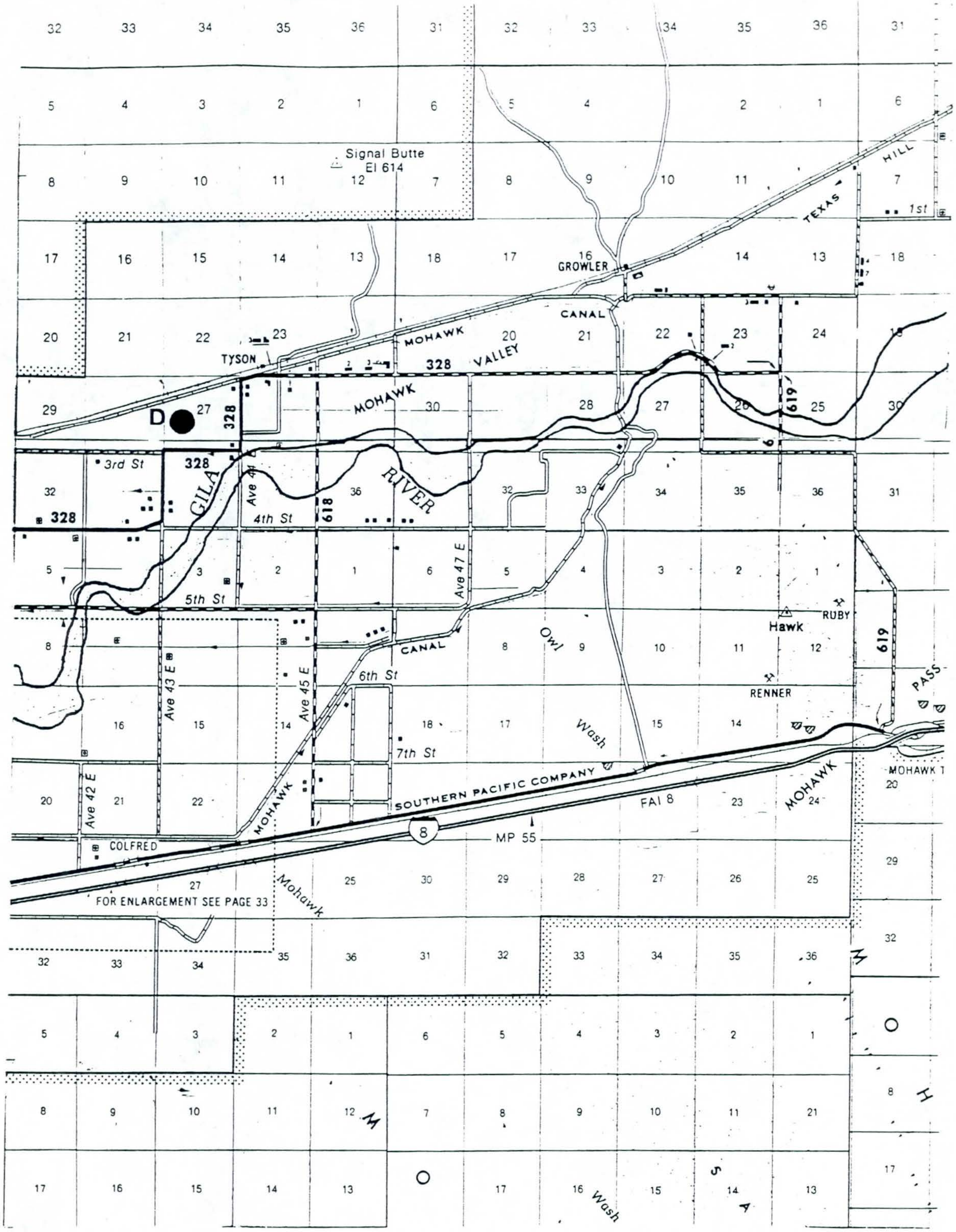
Appendix 11.1.5 Oatman vicinity (ADOT county map series).



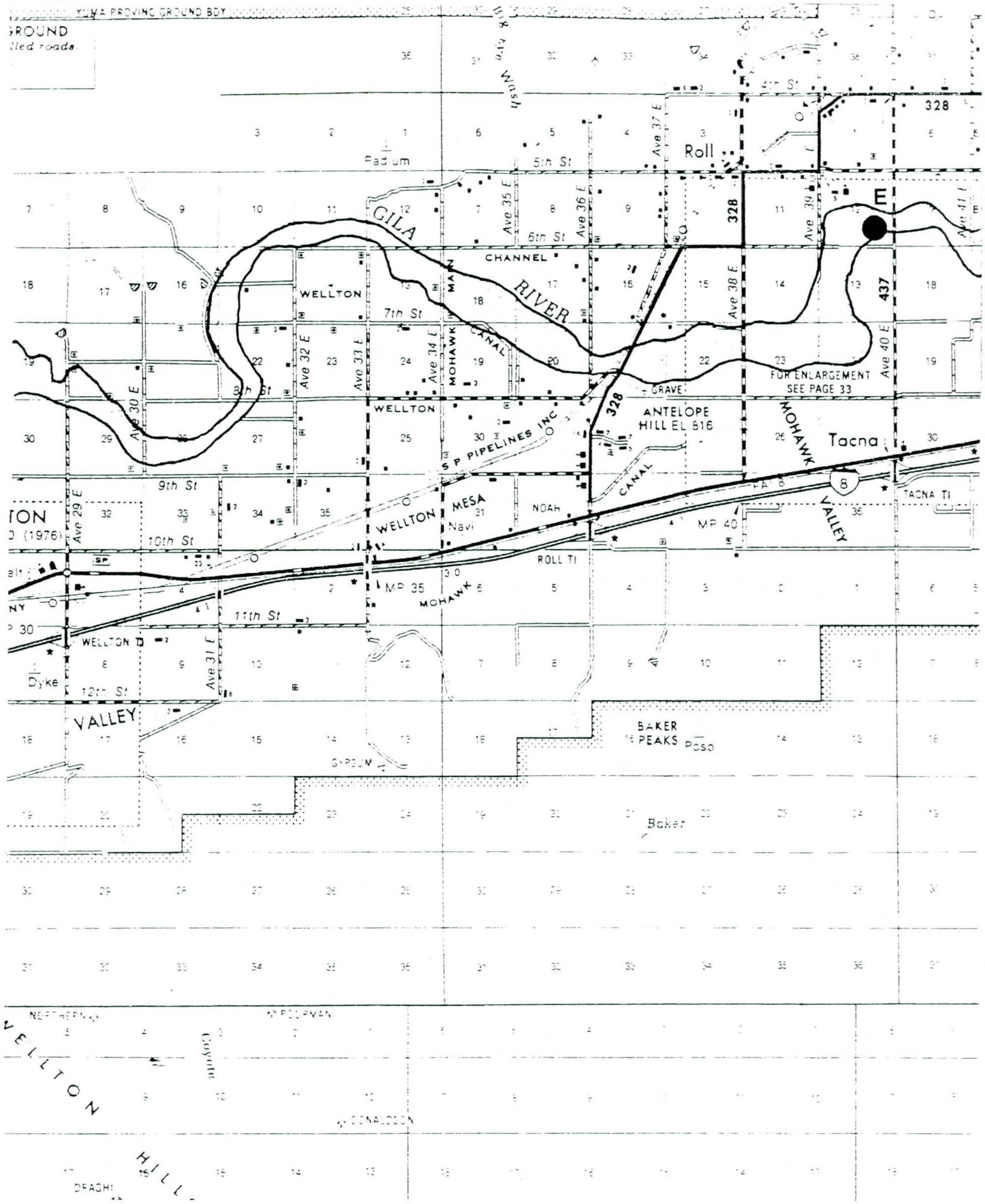
Appendix 11.1.6 Agua Caliente vicinity (ADOT county map series).



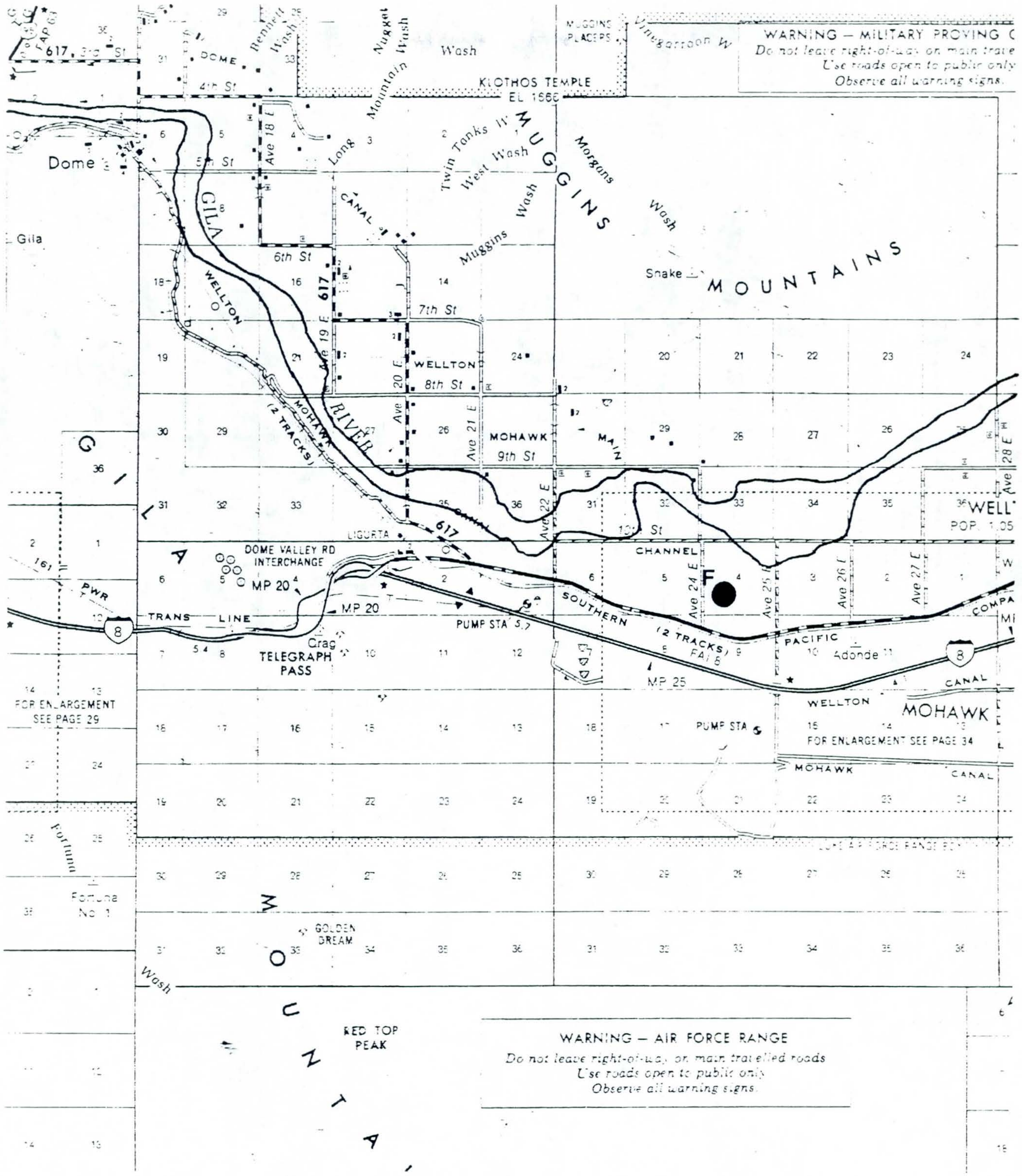
Appendix 11.1.7 Dateland vicinity (ADOT county map series).



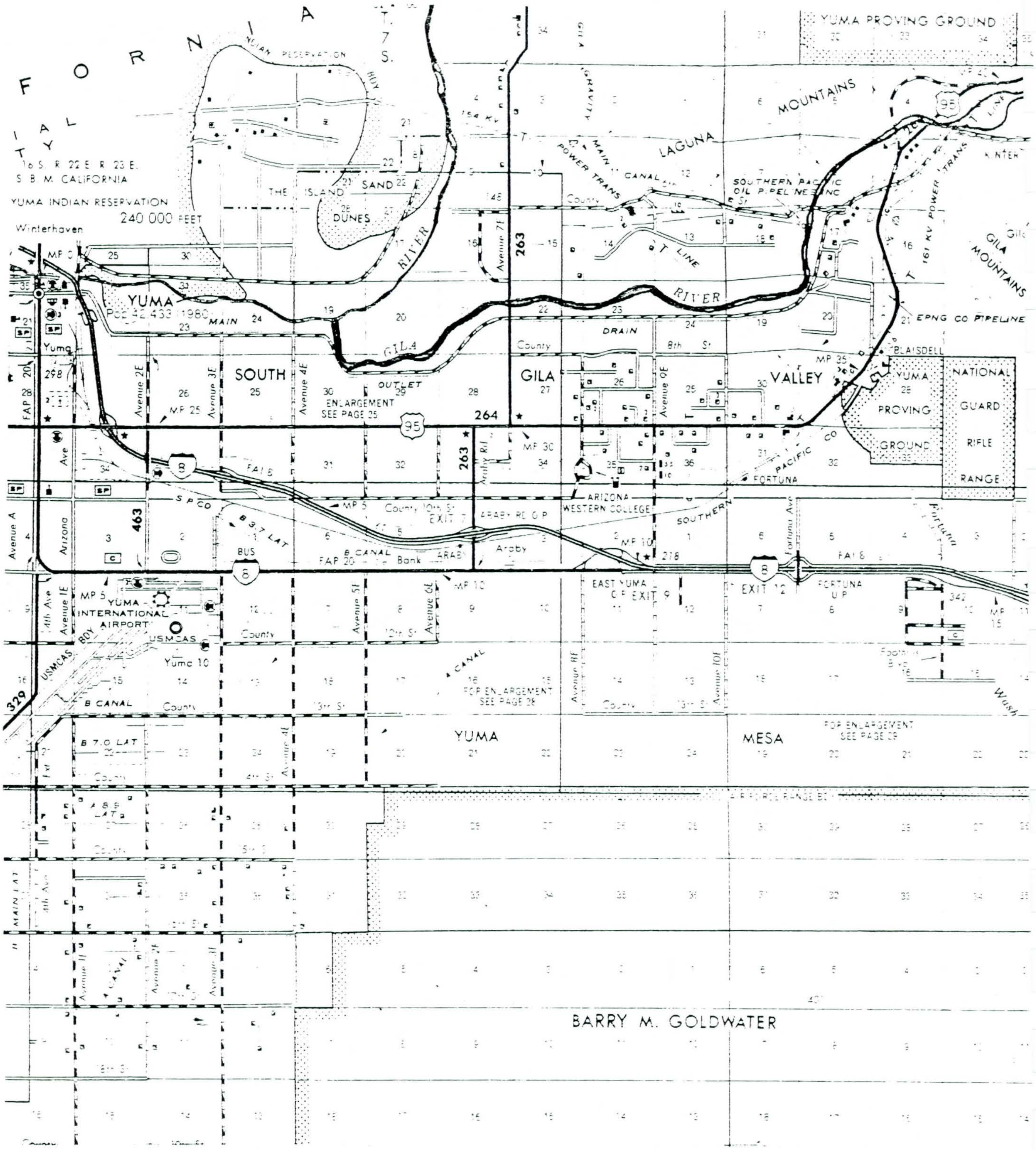
Appendix 11.1.8 Growler vicinity (ADOT county map series).



Appendix 11.1.9 Antelope Hill vicinity (ADOT county map series).



Appendix 11.1.10 Ligurta vicinity (ADOT county map series).



Appendix 11.1.11 Yuma vicinity (ADOT county map series).

APPENDIX 11.2 MAJOR REFERENCES FOR RIPARIAN ECOLOGY

Anderson, B.W. and R.D. Ohmart. 1985. Riparian vegetation as a mitigating process in streamand river restoration. Pages 41-79 in Gore, J.A. (ed.). The restoration of rivers and streams: theories and experience. Butterworth Publishers, Boston, Massachusetts.

Armour, C.L., D.F. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries. 16:7-11.

Asmussen, L.E., A.W. White,Jr., E.W. Hanson, and J.M. Sheridan. 1977. Reduction of 2,4-d load in surface runoff down a grassed waterway. Journal of Environmental Quality. 6:159-162.

Baird, K. 1989. High quality restoration of riparian ecosystems. Restoration and Management Notes. 7:60-64.

Brady, W., D. Patton, and J. Paxson, 1985. The development of Southwest riparian gallery forests. U.S. For. Serv. Gen Tech. Rep. RM-120:34-43.

Briggs, M.K. 1993. Developing plans for improving the condition of degraded riparian ecosystems: A guidebook for resource managers. The Rincon Institute, Tucson, Arizona.

Brown, D.E.,1982, Biotic communites of the American Southwest - U.S. and Mexico, Desert Plants, 4:1-342.

Carothers, S.W., G.s. Mills, and R.R. Johnson. 1990. The creation and restoration of riparian habitat in southwestern arid and semiarid regions. Pages 351-363 in Kusler, J.A. and M.E. Kentula (eds.). wetland creation and restoration: the status of the science. Island Press, Washington, D.C.

Carothers, S.W., R.R. Johnson, and S.W. Aitchison. 1974. Population structure and social organization of southwest riparian birds. American Zoologists. 14:97-108.

Chaimson, J.F. 1984. Riparian vegetation planting for flood control. pages 120-123 in Warner, R.E. and K.M. Hendrix, (eds.). Califronia Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley. Pp. 1035.

Chien, N. 1985. Changes in river regime after the construction of upstream reservoirs. Earth Surface Processes. 10:143-159.

Corbett, E.S. and J.A. Lynch. 1985. Management of streamside zones on municipal watersheds. Pages 187-190 in Johnson, R.R., C.D. Ziebell, D.R. Patton, R.F. Folliott, and R.H. Hamre, tech coords. Riparian Ecosystems and their management: Reconciling conflicting uses. Proceedings of 1st North American Riparian Conference U.S. Department of Agriculture and Forest Service General Technical Report RM-120. Pp. 523.

Davis, G.A. 1977. Management alternatives for the riparian habitat in the Southwest. pages 59-67 in Johnson, R.R. and D.A. Jones, tech. coords. Importance, preservation, and management of riparian habitats: A Symposium. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. RM-43. Pp. 217.

Emory, W.H. 1848. Notes of a military reconnaissance from Fort Leavenworth in Missouri to San Diego in California. 30th Congress, 1st Session. Senate document 167. Pp 614.

Everitt, B.L. 1980. Ecology of salt cedar - a plea for research. Environmental Geology. 3:77-84.

Everitt, B.L., 1968, Use of the cottonwood in an investigation of the recent history of a floodplain, American Journal of Science, 266:417-439.

Fenner, P., W.W. Brady, and D.R. Patton, 1985, Effects of regulated water flows on regeneration of Fremont cottonwood, Journal of Range Management, 38:135-138.

Frost, K.R. and K.C. Hamilton. 1960. Report on the Wellton Mohawk salt cedar clearing studies. Arizona Agriculture Experiment Station. Report 193. Pp 54.

Gary, H.L. 1965. Some site relations in three floodplain communities in central Arizona. Journal of the Arizona Academy of Science. 3:209-212.

Gavin, T.A. 1973. An ecological survey of a mesquite bosque. M.S. Thesis. Univ. of Arizona Tucson.

Groeneveld, D.P. and T.E. Griepentrog. 1985. Interdependence of groundwater, riparian vegetation, and streambank stability: A case study. pages 44-48 in Johnson, R.R., C.D. Ziebell, D.R. Patton, R.F. Folliott, and R.H. Hamre, tech coords. Riparian Ecosystems and their management: Reconciling conflicting uses. Proceedings of 1st North American Riparian Conference U.S. Department of Agriculture and Forest Service General Technical Report RM-120. Pp. 523.

Haase,E.F.,1972, Survey of floodplain vegetation along the lower Gila River in southwestern Arizona, Journal of the Arizona Academy of Science, 7:75-81.

Hanson, J.S., G.P. Malanson, and M.P. Armstrong. 1990. Landscape fragmentation and dispersal in a model of riparian forest dynamics. Ecological modelling. 49:277-296.

Harris, D.R. 1966. Recent plant invasions in the arid and semiarid Southwest of the U.S. Annals of the Association of American Geographers. 56(3):408-422.

Horton, J.S., F.C. Mounts, and J.M. Kraft, 1960, Seed germination and seedling establishment of phreatophyte species, U.S. Forest Service Rocky Mt. Forest and Range Experiments Station Paper, 48:1-17.

Jarrell,W.M. and R.A. Virginia, 1990, Soil cation accumulation in a mesquite woodland, Journal of Arid Environments, 18:51-58.

Johnson, R.R. 1978. The lower Colorado River: A western system. Pages 41-45 in Johnson, R.R. and J.F. McCormick, tech. coords. Strategies for protection and management of floodplain wetlands and other riparian ecosystems: Proc. of the Symposium. U.S. Dep. Agric. For. serv. Gen. Tech. Per. WO-12. Washington, D.C. Pp. 410.

Karr, J.R. and I.J. Schlosser. 1977. Impact of nearstream vegetation and stream morphology on water quality and stream biota. Env. Res. Lab. EPA-600/37-77-097,. U.S. EPA, Athens, GA. Pp. 91.

Kaufman, J.B. and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications... a review. Journal of Range Management. 37:430-438.

Knight, A.W. and R.L. Bottorff. 1984. The importance of riparian vegetation to stream ecosystems. pages 160-167 in Warner, R.E. and K.M. Hendrix, (eds.). Califronia Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley. Pp. 1035.

Lacey, J.R., P.R. Ogden, and K.E. Foster, 1975, Southern Arizona riparian habitat: Spatial distribution and analysis, Univ. of Arizona Office of Arid lands Bull., 8:1-148.

Li, R.M. and W.H. Shen. 1973. Effects of tall vegetation and flow sediment. Journal Hydraul. Div., ASCE. Vol 9(HY5) Proc. Paper 9748.

Lowe, C.H., (ed.). 1964. The vertebrates of Arizona. Univ. of Arizona Press, Tuscon. Pp. 270.

Mahoney, D.L. and D.C. Erman. 1984. The role of streamside buffer strips in the ecology of aquatic biota. pages 168-176 in Warner, R.E. and K.M. Hendrix, (eds.). Califronia Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley. Pp. 1035.

Martin, K.E. 1984. Recreation planning as a tool to restore and protect riparian systems. pages 748-757 in Warner, R.E. and K.M. Hendrix, (eds.). Califronia Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley. Pp. 1035.

Minckley, W.L. and J.N. Rinne, 1985, Large woody debris in hot desert streams: An historical review, Desert Plants, 7:142-153.

Minckley, W.L. and T.O. Clark, 1981, Vegetation of the Gila River resource area, eastern Arizona, Desert Plants, 3:124-140.

Minckley, W.L. and T.O. Clark, 1984, Formation and destruction of a Gila River mesquite bosque community, Desert Plants, 6:23-30.

National Research Council. 1992. Restoration of aquatic ecosystems: Science, Technology, and Public Policy. National Academy Press, Washington, D.C.

Ohmart, R.D. and B.W. Anderson, 1986, Riparian habitat, Pp. 169-200, in Cooperrider, A.Y., R.J. Boyd, and H.R. Stuart (eds.), Inventory and monitoring of wildlife habiata, U.S. Bureau of Land Management Serive Center, Denver, CO.

Ohmart, R.D., and B.W. Anderson. 1974. Vegetation management: Annual report. U.S. Dep. Inter., Bureau of Reclamation. Boulder city, Nevada.

Petts, G.E. 1985. Time scales for ecological concern in regulated rivers. Pp. 257-266. In: J.F. Craig, J.B. Kemper (eds.). Regulated Streams: Advances in Ecology. Plenum Press, New York.

Rea, A.M. 1983. Once a river: Bird life and habitat changes along the middle Gila. University of Arizona Press, Tucson, Arizona.

Reichenbacher, F.W. 1984. Ecology and evolution of southwestern riparian plant communities.Desrt plants. 6:15-22.

Reynolds, S.J.,1988, Geologic map of Arizona, Arizona Geological Survey Map 26.

Robinson, T.W. 1965. Introduction, spread and areal extent of salt cedar (tamarisk) in the Western States. U.S. Geological Survey Professional Paper. 498. Pp. 237.

Rosenberg, K.V., R.D. Ohmart, W.C. Hunter, and B.W. Anderson. 1991. Birds of the lower Colorado River Valley. University of Arizona Press, Tucson.

Rosgen, D.L. 1985. A stream classification system. U.S. For. Serv. Gen. Tech. Rep. RM-120:91-95.

Ross, C.P. 1922. The lower Gila region, Arizona - A geographic, geologic, and hydrologic reconnaissance with a guide to desert watering places. U.S. Geological Survey Water Supply Paper. 498. Pp. 237.

Stromberg, J.C., 1993a, Fremont cottonwood-goodding willow riparian forests: A review of their ecology, threats, and recovery potential, Journal of the Arizona - Nevada Academy of Science, 26:97-110.

Stromberg, J.C., 1993b, Riparian mesquite forests: A review of their ecology, threats, and recovery potential, Journal of the Arizona - Nevada Academy of Science, 27:111-124.

Stromberg, J.C., D.T. Patten, and B.D. Richter, 1991, Flood flows and dynamics of Sonoran riparian forests, Rivers, 2:221-235.

Stromberg, J.C., J.A. Tress, S.D. Wilkins and S.D. Clark, 1992, Response of velvet mesquite to groundwater decline, Journal of Arid Environments, 23:45-58.

Sullivan, M.E. 1991. Heavy metal concentration in riparian vegetation exposed to wastewater effluent. M.S. Thesis. Arizona State University. Tempe.

Szaro, R.C. 1989. Riparian scrubland and community types of Arizona and New Mexico. Desert Plants 9(3-4):1-138.

Tellman, B. 1992. Arizona's effluent dominated riparian areas: Issues and opportunities. University of Arizona Water Resources Research Center Issue Paper 12: 1-45.

U.S. Army Corps of Engineers. 1962. Reservoir Regulation Manual for Painted Rock Reservoir. L.A.D.M. 1130-2-43. Los Angeles.

U.S. Army Corps of Engineers. 1970. Infiltration of Painted Rock Reservoir releasing for Gila River improvement (Texas Hill to Gila Siphon). Draft of design memorandum no.2. Los Angeles.

U.S. Army Corps of Engineers. 1974. Report on Gila river and tributaries, downstream from Painted Rock Reservoir, Arizona. Los Angeles.

U.S. Army Corps of Engineers. 1977. Painted Rock Dam Operation Study Information Brochure. Los Angeles.

U.S. Army Corps of Engineers. 1986. Painted Rock Dam and Reservoir, Arizona: Information paper. Los Angeles.

U.S. Army Corps of Engineers. 1993. Painted Rock Dam (Smart Book).

U.S. Council on Environmental Quality. 1978. Environmental quality. The 9th report of the Council on Environmental Quality. U.S. Govt. Printing Office, Washington, D.C. (stock number 041-011-00040-8). Pp. 599.

Warren, D.K. and R.M. Turner. 1975. Salt cedar seed production, seedling establishment, and response to innudation. Journal of the Arizona Academy of Science. 10:135-144.

Williams, G.P., and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers. U.S. Geological Survey Professional Paper 1286:1-64.

Young, R.A., T. Huntrods, and W. Anderson. 1980. Effectiveness of vegetated bufferstrips in controlling pollution from feedlot runoff. Journal of Environmental Quality. 9:483-487.

APPENDIX 11.3 SOURCES OF HISTORICAL GROUND PHOTOGRAPHY

Arizona Agricultural Dept. (Envir. Service Div.)1601 N.7thSt......................407-2900
*No photos.
Arizona Game and Fish Dept.
Arizona Heritage Center--Tucson.. 628-5774
*Quite a few photos on file starting in the 1880's.
*Contact--Susan Peter
Arizona Historical Foundation--ASU, Tempe..966-8331
Arizona Historical Society--1300 N College Ave, Tempe............................929-0292
•Presently no librarian. Photos are not accessible.
*Contact--Zona Lorig
Arizona Historical Society--Yuma (Tues-Sat 10-4)...................................782-1841
*2 or 3 photos from 1910 of the Gila but no specific site names on them.
ASU Dept. of Archives and Manuscripts (LUHRS room)...........................965-4932
*Large photo collection starting in the 1880's.
Bureau of Land Mangement--3737 N 7th St., Phoenix...............................650-0518
*No photos on the Gila.
Bureau of Reclamation (Public Affairs)--23636 N. 7th St., Phoenix...............870-2896
*Have recent oblique aerial photos of Gillespie Dam.
*Contact--Joe Madrigal in Dept of Visual Communications
Bureau of Reclamation--Yuma...................................... 343-8100
*Send all of their material to the Washington Archives
Dept of Ag.--Soil Conservation Service (Irrigation and Power) Wellton............785-3351
*Aerial photographs from 1958-1993.
*Contact--Shirley Romine or Susan Dodd
Dept Library Archives + Public Rec. (Archives Div.)--1700 W. Washington......542-4159
*No photos, only planning maps of projects along the Gila.
*Contact--Carolyn
Dept Library Archives + Public Rec. (Research Lib.)--1700 W. Washington......542-3701
*Limited number of historical photos.
*Contact--Carol
Dept of Transportation--2901 W. Durango St...506-8795
*Have photos from 1957 to the present.
Geological Survey (Water Resources)--1545 W. University Dr.....................379-3086
*Nothing on hand, get their aerial photos from Souix Falls 1:125000 Scale.
Gila Bend Museum--Gila Bend.. ...683-2002
*Early photos of the Gila River, in the general vicinity of Gila Bend.
*Contact--John Laird
Gila River Arts and Crafts Center and Heritage Park--Sacaton, Az.................963-3981
*No photos of the Gila or the Salt.
Heard Museum--22 E. Monte Vista Rd., Phoenix....................................252-8840
*Contact--Richard Pearce-Moses
Sharlot Hall Museum--Prescott, Arizona..445-3 122
*A limited number of photos from Gila.

Soil Conservation Service--3003 N. Central Ave, Phoenix............................280-8801
    *No photos.
SRP Silva House Museum--7th St and Adams, Phoenix..............................236-5451
    *No photos of the Gila, but do have photos of the Salt.
State Land Az. Navigable Stream Adjudication..542-267 7
    *Have a list of historical photos.
    *Contact--Clyde Anderson
State Land Natural Resources (Hydrology)--1616 W. Adams St.....................542-3500
    *No photos.
U.S. Army Corps of Engineers--3636 N. Central Ave................................640-2003
    *1993 Flood aerial photographs. 1994, 1:400 aerial of WMIDD.
    *Contact--William Burton
USGS--845 N. Park Ave, Tucson.. .882-4795
    *Do not have any historical photos of the Gila
    *Contact--Tom McGarvin (Geologist of the Library)
Water Resources Adjudication--15 S. 15th Ave, Phoenix.............................542-1520
    *Could never get in contact with anyone here.
    *Contact--Sigfried Eichberg

APPENDIX 11.4 DESCRIPTIONS OF HISTORICAL GROUND PHOTOGRAPHS

1. Dept Library Archives + Public Rec. (Research Lib.)

*Photos for the last 20 years on the Gila River.
*Photo on the Gila River Below Great Bend. No date.
*Two drawings of the Gila River:
1. 1917 Crossing of the Gila at Florence.
2. Confluence of the Gila and the Colorado River, Yuma. No date.

2. LUHRS Room, 4th floor Hayden Library, Arizona State University.

A. **Gila River flood control in Graham County**
*Photos of the Gila River above the San Carlos 1900-1910.
*Many photos of the confluence of the Gila and its tributaries in this region (i.e. Blue River, San Francisco River, Indian Creek, Eagle Creek and Black Ca on).
*Many geomorphic pictures of bank erosion, flooding, sediment transport, drift materials, bank deposits, sediment deposits, arroyos, etc.
*Rip. vegetation, including many shots of tree species that are associated with this reach of the stream.

B. **Along the Gila River at high water, Yuma 1880.** Call#--CP SPC 199:2
*A stereopair for the old stereo viewers
*Flood stage of the river near Yuma.
*Good view of larger rip vegetation (trees) and other vegetation away from the river.

C. **3 men viewing Gila River during flood 1916.** Call#--CP CTH 1010-1011
*Uncompleted bridge, site unknown.
*Flood water and some rip. vegetation.

D. **Arizona Eastern Railroad File 1925-1928.** Call#--CP AE 1-289
*Photos taken along the Gila River during the construction of the railroad. AE denotes the photo numbers associated with the file labeling system. The symbol ' ' means that I thought it was a very good quality photo and that it was useful in terms of its portrayal of the geomorphology and riparian vegetation.
AE 1-6 (1927) 4X5 photos. Bridge after a flood, channel, rip. vegetation and sediment deposits.
AE 21-23 (1927) 4X5 photos. Bridge after a flood, channel, rip. vegetation and sediment deposits.
AE 53-54 (1925) 4X5 photos. Water flow, with sediment deposits and rip vegetation.
AE 56-57 (1925) 4X5 photos. Water heavily laden with sediments. Trees and reeds line the shoreline.

AE 63 (1925) 4X5 photo. Trees and reeds line the shoreline. Fine sediments deposited by the last flood are present.
AE 68 (1925) 4X5 photo. This photo shows possible depth to ground water from a pit that was dug to remove equipment after a flood event.
AE 80, 86-7 (1928) 4X5 photos. Bedforms, rip. vegetation and numerous small cut and fill terraces.
AE 129-135, 157 (1928) 8X10 photos. Construction of the Coolidge Dam. River is flowing in the background of many of these photos. The photos also provide a glimpse at the bar sediments, rip. vegetation and gravel mining that is taking place along the Gila during this time.
AE 140, 289 (1928) 8X10 photos. Gila River Bridge taken by H.P. Kelker. Shows sediments and the vegetation in this area.
AE 145 (1928) 8X10 photo. Gila River Crossing. A good view of the riparian vegetation as it grades away into the more xeric vegetation.
AE 176 (1928) 8X10 photo. Gila River with the bridge in the background. Offers unobstructed view of the sediment deposits and the rip. vegetation.
AE 181-2 (1926) 8X10 photos. Gila River Bridge. View of the vegetation along the shoreline.
AE 210 (1928) 8X10 photo. Coolidge Junction. Unobstructed view of the sediments, vegetation (riparian and xeric) and surrounding geomorphology.
AE 237 (1926) 8X10 photo. View from Antelope Hill looking up the river. By far the best shot of the collection. The photo shows all facets of the geomorphology and the riparian vegetation that are associated with the Gila River at this reach. This is a shot that could and should be rephotographed.
AE 247 (1926) 8X10 photo. Agua Fria River Bridge. Good view of the rip. vegetation.
AE 274-278 (1928) 8X10 photos. Gila River Bridge. Sediment and rip. vegetation.

E. **Construction of the Coolidge Dam** Call#--CP CTH 51
* (1927) 8X10 Photo. Initiation of the dam site, there is still free flowing water.
*Bar with vegetation downstream of the site.

F. **Water Development of the Gila River: Construction of Coolidge Dam.** M.A. Thesis 1987 ASU.
*Six 8X10 photos of the construction of the dam, similar to photos in the D and E of this reference list.

G. Carl T. Hayden Collection Call#--CP CTH 202, 503-523
*Very good quality 5X7 photos taken from Granite Reef Dam to the Salt/Gila junction in 1941.
*Show the vegetation of the time all along the river. Most of the vegetation that was depicted was slated to be cleared.
*Photos of the construction of the Granite Reef Dam, with good views of the flowing water

and the sediment deposited both in the channel and in bank deposits.
***CP CTH 503** is a photo of the 1905 flood looking towards Tempe Butte.
***CP CTH 202** "Abutments of diversion dam site looking downstream(1919). Postcard that is poor quality, but has an excellent view of vegetation in the area and also exposed bank sediments. Hard to make out because the postcard is very faded.
*A lot of Salt Cedar in the photos.
*None of the photos have specific site names, but could easily be rephotographed.

H. **Flood Damage Report Dec. 1965-Jan. 1966.** Call#--CE EPH QF-56
*8X10 photos. Good shots of the Salt from Granite Reef down to the confluence of the Gila River. Also, good shots from Gillespie Dam to the confluence of the Salt River.
*Most of the photos are from the Az. Game and Fish Dept., may be able to get original photos from them.

I. **Kelvin Bridge over the Gila River (1930).** Call#--CP SPC 117:19
*3X5 photo with fair clarity.
*Shows channel sediments and some vegetation in section, mostly trees and brush.

J. **Gila River bottom 25 miles S.W. of Phoenix (1931)** Call#--CP SPC 208:22
*Mostly shows the vegetation in this area (trees, brush and herbaceous material).

3. Arizona Historical Museum (Research Library), Tucson, Arizona

A. **South Pacific Railroad Series (1906).** Photo# 28753
*8X10 photo
*Flood waters from the Gila River burst through the bank of the Colorado River.
*Shows the floodwaters and vegetation near the confluence of the Gila and Colorado Rivers.

B. **'Places-Pictures: Gila River (1880's).** Photo# 3771
*8X10 photo. Probably the Gila River near its mouth according to a long time Yuma resident.
*Best vegetation photo that I have seen to date. Several different types of tree and shrub species are readily discernable.
*There are also beach bar deposits and older river terraces present in the picture.

C. **Places-Pictures: Gila River (1905).** Photo# 45701-705
*2X4 photo. Gila River Bridge after the flood.
*Good pictures of channel sedimentary deposits and some rip. vegetation.

D. **Photo Collection: John B. Richardson Box #2 (1920).** Photo# 77217
*2X4 photo. Gillespie Dam at the very onset of construction (setting up to build).

*Large quantities of sediment stored in the channel, the channel itself is braided.
*Vegetation is more grass and shrubs for this reach of the stream.

E. **Photo Collection: John B. Richardson Box #2 (1920).** Photo# 77214-216
*8X10 photos. All the photos are taken at or near the vicinity of the dam very close to the on set of dam construction.
*Excellent views of the vegetation and sediment deposits found in this section.
*Braided channel with thick bar deposits.
*Vegetation is very shrubby and with some saguaro cacti near the bank of the river.

4. Dept of Agriculture, Soil Consevation Service (Irrigation and Power), Wellton, Arizona

A. Aerial photos of the Gila River (1958-1993).

5. U.S. Army Corps of Engineers, Phoenix

A. "Environmental Study for the Gila River Below PRD". U of Az. Office of Arid Lands (1970).
*1930 &1970 photo of the Gila River at the Dome Gaging Station.
*Drastic Vegetation change between the 40 year period.
*Channel sediments, and regional geomorphology in each of the photos.

B. Aerial photos
*1:400 aerial photos of the reach of the Gila River that is found in the Wellton-Mowhawk Irrigation and Drainage District (1994).
*3/6/93 aerial photos of the flood from PRD to Yuma (EROS color photos)

6. Gila Bend Museum, Gila Bend, Arizona

A. Photo from south banke looking north near Gila Bend (1905).
*5X10 photo of flood flow in this section of the river.
*Not a high quality picture, but does show some vegetation and bank sediments

B. Gila River north of Gila Bend (1896).
*4X7 photo showing water flowing in the river, some vegetation and a small section of sediments.
C. Fortified Hill (a.k.a. 'Pointed Rock' and 'Jump Off') (1905).
*Flood flow
D. Okla Noonan (1910).
*5X7 photo picture of a woman named Okla Noonan with the river in the background.
*5-6 miles downstream from Gila Bend, shows some of the trees along the river.

E. Gillespie Dam Construction (1919).
*8X10 photo of flowing water, vegetation and sediment in the area at the onset of dam construction.
*The sediment in most areas has been very disturbed from dam construction.
F. There are a whole series of other pictures of Gillespie Dam from the 1920's.
*Most of the photos are 8X10's and show high water flows overtopping the dam.

7. Sharlot Hall Museum, Prescott, Arizona

A. Expedition on the Gila River (no date). Call# Misc. 237P
*A stereopair of men on the banks of the river.
*Trees in the background, flowing water with sandbars in the channels.
*No specific site name.
B. Gila River Bridge (no date). Call# BR-112P
*Large flow in the river, with large sandbars present.

APPENDIX 11.5 DESCRIPTIONS OF THE LOWER GILA RIVER IN THE HISTORICAL LITERATURE

11.5.1 Primary Sources

1700

"I ascended a hill to the westward, where we thought we should be able to see the Sea of California; but looking and sighting toward the south, the west, and the southwest, both with a long range telescope and without, we saw more than thirty leagues of level country, without any sea, and the junction of the Rio Colorado with this Rio Grande (or Rio de Hila, or Rio de los Apostoles), and their many groves and plains." (249)

". . . all were asking that I should cross over there, they sought and found me a ford where this Rio Grande [Gila River] divides into three branches; and, crossing it, after eight leagues of very good road I arrived at the first Yumas of the very large volumed Rio Colorado . . .." (251)

Kino, Eusebio Francisco. 1919. Kino's Historical Memoir of Pimeria Alta. Vol. 1. Edited by Herbert Eugene Bolton. Cleveland: Arthur H. Clark.

1746

"Passing on down [the Gila River] another five or six leagues and keeping it always in view with its willows and cottonwoods, we come to its confluence with the Rio de la Asuncion [Salt River], which in its turn is formed by the Salado and the Verde. A very pleasant country surrounds this fork of the rivers. Here the eye is regaled with creeks, marshes, fields of reed grass and an abundant growth of alders and cottonwood." (24)

Sedelmayr, Jacobo. 1955. Jacobo Sedelmayr, Missionary, Frontiersman, Explorer in Arizona and Sonora: Four Original Manuscript Narratives 1744-1751. Translated by Peter Masten Dunne. Tucson, AZ: Arizona Pioneers' Historical Society.

1775-1776

"On the banks of the Gila are cottonwoods, willows, and mesquites. Along this river there is little pasturage, but . . . everywhere there is an abundance of bushes and common reedgrass. No other fish is found in the river than the one they call matalote ['scrawny old nag'] . . .." (13)

Garces, Francisco. 1965. A Record of Travels in Arizona and California 1775-1776. Translated by John Galvin. San Francisco: John Howell Books.

1826-1827

"We thence returned down the Helay [Gila], which is here [the confluence with the Salt River] about 200 yards wide, with heavily timbered bottoms. We trapped its whole course, from where we met it, to its junction with Red river [Colorado River]." (61)

"We now took an ample abundance of beavers to supply us with meat . . .. Our horses also fared well, for we cut plenty of cotton-wood trees the bark of which serves them for food nearly as well as corn." (102)

Pattie, James Ohio. 1988. Personal Narrative of James O. Pattie. Edited by Richard Batman. Missoula, MT: Mountain Press.

1846-1847

At Gila Bend: "The river here is considerably larger than where we last saw it, as the Salt River comes in just below the Pimas -- it is also a little brackish. . . . we must depend on seeds and willows immediately on the River banks for food for our mules --in spots-- though they are few and far between a little patch of grass may be found, ten feet wide. This is immediately on the banks of the River and the Animal most frequently will have to stand in the water to pick the grass. . . . The River here is some 60 or 80 yards wide -- on an average 3 feet deep and rapid. We have seen more water fowel in the last two days, than we have yet met with on the River --ducks, brant geese & swan. The cotton wood shows the effect of frost very little . . .." (35)

Griffin, John S. 1943. A Doctor Comes to California: The Diary of John S. Griffin 1846-1847. San Francisco: California Historical Society.

1846-1848

" . . . I passed through a very uneven willow-grown bottom of the river and found [the mules] taking their ease at the water-edge, with some yellow, broken, years-old grass near, which had been their attraction . . .. The river is here brackish; this is caused by the Saline River, a larger stream than the Gila above, which flows into it below the Maricopa village." (167)

"Cottonwood-bark and branches, and mezquit, were added yesterday to the forage list. . . . Whenever there is a bed where the river sometimes flows, we find more or less grass; there is little doubt that only want of rain prevents its growth elsewhere; but the bottoms frequently show salty efflorescences; also much of it seems of mere clay, which I think will not produce vegetation. . . . The river is rapid, and in places three or four feet deep; and here it is one hundred and fifty yards wide." (168-69).

". . . three or four inches of water to be found on several rapids. . . . The mules were ordered to be sent across the river to browse in the young willows, flag-grass, etc., and it turned out they had to swim." (169-70)

The mouth of the Gila: "A vast bottom; the country about the two rivers is a picture of desolation; nothing like vegetation beyond the alluvium of the two rivers; bleak mountains, wild looking peaks, stony hills and plains, fill the view. We are encamped in the midst of wild hemp. The mules are in mezquit thickets, with a little bunch grass, a half a mile off." (170)

Cooke, Philip St. George. 1964. The Conquest of New Mexico and California in 1846 - 1848. Chicago: Rio Grande Press.

1847

"The absence of grass on a river bottom, with our limited information, is difficult to be accounted for, but I think it must be owing to a want of rain. The river does not habitually overflow; it did not last year; and, but for it old reputation for barrenness, it might be supposed that some late great flood had made a deposit so deep as to destroy the grass. . . . There is much large mesquite wood; the leaves are now falling and are said to be tolerably good food for mules. . . . The river bottom seems to expand today to many miles. For ten or fifteen miles there seems a very flat country at least. The vicinity of the river is ever marked by cottonwoods." (184)

"Wherever there is a bed where water sometimes runs, we find more or less grass; this favors the belief that want of rain prevents growth. But the bottoms are covered frequently with efflorscences of salt; this, on the Rio Grande, is said to make the land unproductive. Also, much of it seems of pure clay . . .. There is very little grass indeed, but it is a bottom of green weeds and willows and young cottonwoods." (186)

"The Gila is a rapid stream of clear water, in places three or four feet deep, and here about one hundred and fifty yards wide. The water is decidedly salty; in fact, Salt river is said to be the larger." (187)

"The river, where I have wanted it as a barrier to the mules, has always been but a few inches deep; here, where I must cross it, it is swimming." (197)

Cooke, Philip St. George. 1938. "Cooke's Journal of the March of the Mormon Battalion, 1846-1847," in Exploring Southwestern Trails 1846-1854, Southwestern Historical Series, vol. 7, ed. Ralph P. Bieber. Glendale, CA: Arthur H. Clark Company.

1848-1849

"Must say something of the Rio Gila, and the magnificent mountains of gold and silver that skirt its fertile valley! It is beyond doubt that there are portions of its valley unsurpassed by any in the world for its fertility, but at the same time it is also equal to any in its barrenness of all vegetable productions. Corn is raised in considerable quantity immediately along its banks, but not in abundance. Now and then is found a small favored spot covered with what we call 'salt grass' the remainder is nothing but cottonwood (thinly scattered along the margin) coarse chapparral bushes and weeds, and the water willow. . . . There are fish in the Gila, game upon its valley, and ducks and geese upon its waters."

"The Gila runs like a wild torrent and over its extensive sand bottom, which is overflowed annually, are a great number of lakes, ponds, lagoons &c and is eminently suited for fish, ducks, geese &c and nothing else. . . . A species of game on the Gila, by far the most abundant, has been neglected: the Partridge or properly speaking, the Quail." (72)

"Talking of fish, I will not contradict the authorities who have made all believe that the Colorado and Gila are almost run away with by the fish, but remark that there may be an abundance of them, but they are too smart for white folks to catch!" (82)

Couts, Cave Johnson. 1961. Hepah, California! The Journal of Cave Johnson Couts from Monterey, Nuevo Leon, Mexico to Los Angeles, California during the Years 1848-1849. Edited by Henry F. Dobyns. Tucson, AZ: Arizona Pioneers' Historical Society.

1849

Middle Gila: "The Gila at this point is narrow, not more than one hundred yards, and flows at the rate of six miles an hour." (217)

Lower Gila: "We found excellent grass along the river bottom -- a species of coco grass and timothy. Whole acres of Mexican sunflowers covered the entire bottom. Quail and a species of dove were in the greatest abundance. The river at this point branches and flows with much less rapidity than above, over broad, sandy bed -- perfect quicksand." (221)

"The last freshet had left a laguna, which prevented us from approaching the river with our animals. The water in the laguna was not at all palatable." (223)

Durivage, John E. 1937. "Letters and Journals of John E. Durivage," in Southern Trails to California in 1849, Southwestern Historical Series, vol. 5, ed. Ralph P. Bieber. Glendale, CA: Arthur H. Clark Company.

1849

". . . while breakfasting in the Gila bottom, a herd of deer --the largest I ever saw, being as big as common burros-- came into view forty yards away." (84)

"The north side of the Gila at this time was the U. S., its south bank Mexico. Frequently as we meandered its bottom, we waded its broad, shallow stream just to be again in the land of the free and the home of the brave." (84)

"A half-day's journey above its mouth, the Gila leaves the base of a steep range of bare mountains coming in from the southwest with a ridge swerving sharp as a case knife. Here, for the second time since leaving the Pima Village, we found the river waist-deep -- deep enough for bathing, in which we all indulged.

As fast as hook could be thrown in, long slender trout were caught . . . ." (84-5)

"The bottoms were fertile but showed flood-drift several feet high on trees and brush." (85)

Harris, Benjamin Butler. 1960. The Gila Trail: The Texas Argonauts and the California Gold Rush. Edited by Richard H. Dillon. Norman: University of Oklahoma Press.

June 1849

"[We] again came to the valley of the Gila, which bore the appearance of former cultivation . . .. Its water was most grateful to us . . .. The Doctor occasionally shoots birds from which we have some fine stews. . . . The valley is wide, and shows evident marks of cultivation." (75)

"Passing down the river at a mile distant, --its course being indicated by a line of cottonwoods, and running under a mountain on the opposite side, while on this side a plain extends two or three miles to some mountains-- . . .. [We] set out for the river. The sun reflected the sand, produced a burning heat. We found it more than a mile to water. The river was at this place a quarter of a mile wide. The volume of water at times must be immense, as there is brush and other substances lodged in the mesquites from ten to twenty feet high, through the adjoining plain, over which we have been traveling." (76)

". . . we came near the river again . . .. I found the bank 40 or 50 feet high and very steep, composed of large black blocks, which rest on carbonate of lime, which easily washes away, and precipitates the huge masses into the bed of the stream below. . . . we descended into the bed of the river by a very steep path. The stream, as its present stage, does not occupy more than one-fourth of the bottom; the remainder consists of a deep bed of sand, baked so hard and cracked so deep, that it was difficult to ascertain the depth of the fissures. Going on, we crossed a deep ravine . . .. Shortly after we descended the table-land into the river bottom. The banks here are low, and the land fertile, covered with alluvial soil from the overflowing of the river, with scattered heaps of drift-wood and a heavy crop of weeds, but no grass." (77)

"... moving down the river, we passed the end of the bluff, composed of large blocks of granite, which projected nearly to the river, on which were chiseled some inscriptions in Spanish, in large characters, also some hieroglyphics. A mile below ... the bank was high and perpendicular ...." (78)

"... our course to-day, for ten miles, lay through the rich river bottoms, which are occasionally overflowed, leaving a rich deposit of mud. ... a narrow growth of cottonwoods line the river; flowers of various kinds and brilliant colors are abundant.... In the river are ducks, geese and swan." (78-9)

"On approach to the river, the ground is covered with a saline efflorescence." (79)

"Passing among sand and gravel hills along the bends of the river ...." (81)

At the confluence of the Colorado and the Gila: "The waters of the Gila are clear and sea green." (83)

Clarke, Asa Bement. 1988. Travels in Mexico and California: Comprising a Journal of a Tour from Brazos Santiago, through Central Mexico, by Way of Monterey, Chihuahua, the Country of the Apaches, and the River Gila, to the Mining Districts of California. Edited by Anne M. Perry. College Station: Texas A&M University Press.

August 1849

"The river overflows nearly every acre of the bottom lands, and the soil and rocks all indicate volcanic action. ... The soil on the river bottoms here is a yellow loam, and in the road from one to five inches deep in fine dust, clouds of which envelop us at every step whilst journeying on the bottoms. The river is wider and better timbered and begins to look like a river." (156)

"At all our river camps we have done without a spear of grass. At these camps we find indisputable evidence of the presence of the beaver, deer, and wolves ...." (158)

"Nothing is seen along this day's journey but deep sands and dust, high weeds, a little mesquite, some rattama [rattan palm?] and the cottonwoods, and if our conjectures are right, we will soon exchange this accursed and God-forsaken region for, we hope, a more favored part of creation." (159)

Evans, George W. B. 1945. Mexican Gold Trail: The Journal of a Forty-Niner. Edited by Glenn S. Dumke. San Marino, CA: Huntington Library.

December 1849

Just upstream of Painted Rock: "We . . . ascended a steep hill covered with loose round stone, and, from the look of the adjacent mountains, looked much like the work of an eruption. From this hill, looking east, may be seen a vast plain, and the course of the beautiful Gila easily traced by a handsome growth of cottonwood & willow. Before we ascended the hill we passed a little forest, accacia . . .. The road descending followed for some distance the bed of a dry branch and part of it was quite rough." (218)

Just downstream of Painted Rock: ". . . we came in sight of the river, quite unexpectedly. It here spreads over a large extent of ground forming several channels." (219)

"Our camp is close to the river at a point of rocks consisting of large boulders on which many a Californian had graved his name . . .. There are large quantities of ducks, geese, brant & crane. Also quail are abundant through the river bottom. We cut down cottonwoods & willows for our oxen & horses." (220)

After significant rains: "The main road having been overflowed, we went considerable distance out of our way. . . . One place, where the road runs on the bottom, we drove through 2 ft. of water for about 50 yds. . . . After we reached the hill road we travelled without difficulty, excepting that the floating sand made it heavy pulling. We soon reached a mountain near which the river runs, and to get around whose point we descended to the bottom again & found it nearly overflowed." (225-6)

"We were in the bottom all day and touched near the river at several points. We have seen some deer tracks but not a single hoof since we have been on the river. Ducks, geese, brant, & crane are tolerable plenty, but keep close to the other shore generally, & therefor out of reach. The poor quail is our only victim, but even he is extremely shy. Mr. Adams saw a bear last Saturday, on a cottonwood tree a short distance from camp, & panther & wildcat track may be found occasionally you will see one running as if he would never stop. They are mostly of the black-tailed specie. The raven, hawk, & owl are also inhabitants of this country." (227)

"Part of the road, where it runs near the river, had been washed away since the last waggon passed over it, & I could hear it tumbling down as I rode along. . . . Most of the ground we have passed over today was of most barren nature, its only growth the larrea, with now and then an acacia, & at long intervals a mezquite. We camped without a spear of grass for our hungry animals & nothing but some cottonwoods & willow for them to appear their hunger." (227-8)

Eccleston, Robert. 1950. Overland to California on the Southwestern Trail 1849. Edited by George P. Hammond and Edward H. Howes. Berkeley and Los Angeles: University of California Press.

1849-1850

"The river bottom here forms a great flat, which was, I think, once irrigated; at all events, it is cut up by a great many lagoons, nearly all muddy , but the water is not so salt in those that do not run, as to be undrinkable; in some places the water is so impregnated that as the water evaporates, a cake of pure salt is deposited . . .. The country is nearly flat, and on the light sandy soil there is found grass, in some places very sparse and thin, and in others pretty good." (157)

About 100 miles below the Pima villages: "The sandy desolation of the river bottom is beyond belief . . .. A few cotton-woods and scrub-willow, with dried weeds, and some sunflower plants, make thickets here and there, and this is all that is to be seen in the way of vegetation . . .. The river here is a very rapid stream at this season, about a hundred and fifty yards wide, and from eighteen to twenty inches deep, with very deep holes in places. The bottom is shifting quicksand, delightfully varied with drift logs, put exactly where they can best trip up the mules. . . . We look and long for Gila trout, and wild-foul, but in vain." (159-160)

Audubon, John Woodhouse. 1984. Audubon's Western Journal 1849-1850, Being the MS. Record of a Trip from New York to Texas, and an Overland Journey through Mexico and Arizona to the Gold-Fields of California. Tucson, AZ: University of Arizona Press.

1850-1853

"As far as I could judge, from a bird's-eye view taken from Fort Yuma, I should think the bottom-land of the Gila was from three to four miles wide near the junction [with the Colorado River]. The portion towards the river is thickly covered with cotton-wood, and with willows on the margin, while that further back has nothing but mezquit. . . . The Gila was not over fifty yards wide at its mouth; but its width varies much in different seasons, being influenced by the rise of the Colorado, as well as the state of its own waters. The Colorado was now so high as to cause the Gila to flow back full fifteen miles. The Gila was still low, and, except near the junction, but a diminutive stream. It is doubtful whether it can ever be navigated, except at its floods, and there are by no means regular." (159-60)

"The Gila here widens considerably, and is proportionably shallow and filled with sand-bars. . . . the river as before making a large bend to the north. We could trace its course from the bright green line of cotton-woods and willows, as it wound away through the desert. . . . the valley seemed to expand to the width of nearly three miles, above one half of which was thickly wooded with with cotton-wood, mezquit, and willow. . . . Near by was a lagoon, which had the appearance of having been recently filled with water. . . . So thick was the wood [along the river], that it was found impracticable to force our wagons through. This was the most beautiful spot we had encamped in since leaving the little valley of San Isabel, in California." (198)

"It now became necessary to cross the Gila, as the plateau rose abruptly from the margin of the river, not leaving passage wide enough for a mule. Our route had hitherto been wholly on the south side since leaving the Colorado. . . . The river where we crossed was about three feet deep in the channel. After getting over, we had to traverse another half mile of deep sand, and then recross, to get on the southern bank once more." (204)

Near Painted Rock? : "The bottom-land, or valley, which is visible from the summit of this bluff for twenty miles, is altogether sand, with a few clumps of willows on the margin of the river. Not an acre of arable land is visible. The bluff, which is but the termination of the plateau or desert, rises about one hundred and twenty feet above the bed of the stream. The river from here is quite open on the north and west, so that the mountains on the Colorado which we saw at Fort Yuma were distinctly visible." (205-6) (illustration on 205)

Five or six miles downstream of Gila Bend? : ". . . after a march of eight miles across a bend, we again struck the river near a point where out surveying parties had had a station, and had remained several days. There we found an abundance of mezquit and willows, but no appearance of grass. Near us was a sluice, which a year before was the main branch of the river, the stream having since found another channel." (207-8)

Bartlett, John Russell. 1854. Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua, Connected with the United States Boundary Commission, during the Years 1850, '51, '52, and '53. Vol. 2. New York: D. Appleton & Company.

1856

At the confluence with the Colorado River: "The Gila is clearer [than the Colorado], and its temperature warmer, but somewhat brackish in its taste, owing to the large quantity of earthy salts held in solution. . . . The Gila becomes so low that a sand-bar forms at its mouth during the summer, and at no time does it supply much water." (102)

110 miles above Yuma: "The valley of this part of the Gila is the same in appearances as that of the Colorado; the soils seems to be more sandy, and contains more alkaline matter; a white efflorescence covers nearly the whole surface. Little grass grows excepting the spots subject to overflow. The same freshet which molested us so much at the initial point here proved a benefit, as we were only able to find grazing where the river had risen over

its banks." (117)

"The Gila, near its mouth, is one hundred and fifty feet wide. The depth of the channel . . . is very varible." (128)

Emory, William H. 1987. Report on the United States and Mexican Boundary Survey Made under the Direction of the Secretary of the Interior. Vol. 1. Austin, TX: Texas State Historical Assocation.

1857-1858

" . . . little that is favorable either to stock raising or agriculture can be said for the part of this stretch over which we passed. An occasional bottom of limited fertility and extent, that could be irrigated is found; but 'no range' that offers any inducements to the stock raiser. . . . [The north side of the river] was decidedly more broken, otherwise presented a similar appearance to the [south side]. The entire distance was marked by cottonwood or mezquit trees on the river banks, and willows in the bottoms." (230-31)

Reid, John C. 1935. Reid's Tramp, or a Journal of the Incidents of Ten Months Travel Through Texas, New Mexico, Arizona, Sonora, and California. Austin, TX: Steck Company.

January 1864

"Little was there now to indicate the grandeur of this wild stream of the desert during seasons of flood. A glaring sand-bottom fringed with cotton-wood and arrowweed, through which in shallow veins the water coursed, leaving here and there patches of sand as a resting-place for numerous aquatic fowl, whose wild cries disturbed the solitude, formed the chief characteristics of the Gila in January, 1864. A few miles beyond Arizona City we struck off to the right, and for the next ten or fifteen miles travelled on the upper stratum of the Gila bottom, which we found well wooded with mesquit." (75)

"Quail were very abundant as we drew near our first camping-place on the Gila. . . . We camped at Gila City, a very pretty place, encircled in the rear by volcanic hills and mountains, and pleasantly overlooking the bend of the river, with its sand-flats, arrow-weeds, and cotton-woods in front." (76)

"We soon found ourselves involved in a labyrinth of thickets and arroyas bordering on the river, through which we struggled for three hours before we could get to the water. When we finally made our way down to the sand-bottom, the opposite side of the river presented a perpendicular wall of rocks which forbade any attempt at an exit." (83)

". . . at length we descended from the mesa, and reached the stretch of sand-bottom opposite Oatman's Flat. In crossing the river, which appeared to be only a few inches deep, our animals sank in a bed of quicksand . . .." (83)

Browne, J. Ross. 1951. A Tour through Arizona, 1864, or, Adventures in the Apache Country. Tucson, AZ: Arizona Silhouettes.

1909-10

"Any one who has seen the marvellous changes brought about in the arid regions of the Gila River through irrigation will easily understand the unusual opportunity presented here for agriculture on a large scale." (162)

Lumholtz, Carl. 1971. New Trails in Mexico: An Account of One Year's Exploration in North-Western Sonora, Mexico, and South-Western Arizona, 1909-1910. Glorieta, NM: Rio Grande Press, Inc.

11.5.2 Secondary Sources

Bolton, Herbert Eugene, ed. 1946. Spanish Exploration in the Southwest 1542 - 1706. New York: Barnes & Noble.

Bolton, Herbert Eugene. 1964. Coronado: Knight of Pueblos and Plains. Albuquerque: University of New Mexico Press.

Calvin, Ross. 1946. River of the Sun: Stories of the Storied Gila. Albuquerque: University of New Mexico Press.

Corle, Edwin. 1951. The Gila: River of the Southwest. Lincoln: University of Nebraska Press.

Davis, Goode P., Jr. 1986. Man and Wildlife in Arizona: The American Exploration Period 1824-1865. Edited by Neil B. Carmony and David E. Brown. [Phoenix, AZ]: Arizona Game & Fish Department.

Rea, Amadeo M. 1983. Once a River: Bird Life and Habitat Changes on the Middle Gila. Tucson, AZ: University of Arizona Press.

U. S. Pacific Railroad Exploration and Surveys. 1853-86. Explorations for a Railroad Route from the Mississippi River to the Pacific Ocean -- General Report. Washington, D.C.

APPENDIX 11.6 HYDROLOGIC AND WATER QUALITY DATA SOURCES

Arizona Department of Environmental Quality. 1990. Recommended Aquatic and Wildlife Protection Criteria for the Priority Pollutants. Phoenix, AZ: Arizona Department of Environmental Quality.

Arizona Department of Environmental Quality. 1993. Arizona Water Quality Assessment 1992. Phoenix, AZ: Arizona Department of Environmental Quality.

Babcock, H .M. 1977. Annual Summary of Ground-Water Conditions in Arizona, Spring 1976 to Spring 1977. U. S. Geological Survey Water-Resources Investigations Open-File Report 77-106. Tucson, AZ: U. S. Geological Survey.

Bookman-Edmonston Engineering, Inc. 1992. Yuma County Water Resource Management Assessment. Yuma, AZ: City of Yuma, Arizona.

Bryan, Kirk. 1925. The Papago Country, Arizona: A Geographic, Geologic, and Hydrologic Reconnaissance with a Guide to Desert Watering Places. U. S. Geological Survey Water-Supply Paper 499. Washington, D. C.: U. S. Government Printing Office.

Bureau of Water Quality Control, Division of Environmental Health Services, Arizona Department of Health Services. 1976. Water Quality in Arizona: A Report Prepared for U. S. Environmental Protection Agency. [Phoenix, AZ]: Arizona Department of Health Services.

Denis, E. E. 1975. Maps Showing Ground-Water Conditions in the Waterman Wash Area, Maricopa and Pinal Counties, Arizona -- 1975. Arizona Water Commission Hydrologic Map Series Map h-1. Phoenix, AZ: U. S. Geological Survey.

Dutt, G. R., and McCreary, T. W. 1970. The Quality of Arizona's Domestic, Agricultural, and Industrial Waters. University of Arizona Agricultural Experiment Station report 256. Tucson, AZ: University of Arizona.

Halpenny, L. C., and others. 1952. Groundwater in the Gila River basin and adjacent areas, Arizona -- a summary. U. S. Geological Survey Open-File Report. Tucson, AZ: U. S. Geological Survey.

Ligner, J. J., White, Natalie D., Kister, L. R., and Moss, M. E. 1969. Water Resources. Arizona Bureau of Mines Bulletin 180: 471-570.

Mock, Peter A., Burnett, Earl E., and Hammett, B. A. 1988. Digital Computer Model Study of Yuma Area Groundwater Problems Associated with Increased River Flows in the

Lower Colorado River from January 1983 to June 1984. Arizona Department of Water Resources Open-File Report no. 6. Phoenix, AZ: Arizona Department of Water Resources.

Resource Management International, Inc. 1994. Wellton-Mohawk Gila River Flood Channel Restoration Project Administrative Draft Environmental Assessment [draft]. Prepared for the U. S. Army Corps of Engineers.

Sebenik, P. G. 1981. Maps Showing Ground-Water Conditions in the Gila Bend Basin Area, Maricopa County, Arizona -- 1979. Arizona Department of Water Resources Hydrologic Map Series Report no. 3. Phoenix, AZ: Arizona Department of Water Resources.

Stulik, R. S., and Moosburner, Otto. 1969. Hydrologic Conditions in the Gila Bend Basin, Maricopa County, Arizona. Arizona State Land Department Water-Resources Report no. 39. Phoenix, AZ: Arizona State Lands Department.

U. S. Army Corps of Engineers. 1970. Infiltration of Painted Rock Reservoir Releases for Gila River Improvement (Texas Hill to Gila Siphon). Draft of Design Memorandum no. 2. Los Angeles: U. S. Army Corps of Engineers.

U. S. Army Corps of Engineers. 1975. Report on Release-Salinity Study for Painted Rock Dam. Los Angeles: U. S. Army Corps of Engineers.

U. S. Geological Survey. [various years]. Water Resources Data - Arizona. U. S. Geological Survey Water-Data Reports. Washington, D. C.: U. S. Government Printing Office.

University of Arizona, School of Earth Sciences, Office of Arid Land Studies. 1970. Environmental Study for the Gila River below Painted Rock Dam. A report prepared for the U. S. Army Corps of Engineers. October.

Water Assessment Section and Groundwater Hydrology Section, Office of Water Quality, Arizona Department of Environmental Quality. 1990. State of Arizona Water Quality Assessment Report for 1990 (Water Years 1988-89) Clean Water Act Section 305(b) Report. Phoenix, AZ: Arizona Department of Environmental Quality.

Water Quality and Waste Programs, Arizona Department of Environmental Quality. 1992. 1991 Annual Report. Phoenix, AZ: Arizona Department of Environmental Quality.

Weist, W. G., Jr. 1965. Geohydrology of the Dateland-Hyder Area, Maricopa and Yuma Counties, Arizona. Arizona State Land Department Water-Resources Report no. 23.

Phoenix, AZ: Arizona State Lands Department.

Western Technologies, Inc. 1983. Painted Rock Dam Water Quality Study Final Report. Phoenix, AZ: U. S. Army Corps of Engineers.

Wilkins, D. W. 1978. Maps Showing Ground-Water Conditions in the Yuma Area, Yuma County, Arizona -- 1975. U. S. Geological Survey Water-Resources Investigations Open-File Report 78-62. Tucson, AZ: U. S. Geological Survey.

APPENDIX 11.7 HYDROLOGIC AND WATER QUALITY DATA

11.7.1 Discharge Data of the Lower Gila River

11.7.1.1 Maximum Annual Discharge of the Lower Gila River

Year	Near Dome Discharge (cfs)	Below Painted Rock Dam Discharge (cfs)	Below Gillespie Dam Discharge (cfs)	Year	Near Dome Discharge (cfs)	Below Painted Rock Dam Discharge (cfs)	Below Gillespie Dam Discharge (cfs)
1906	95000			1958	217		474
1922			32700	1959	590		430
1923			13100	1960	675	216	580
1924			70000	1961	113	83	82
1925			12500	1962	43	0	0
1926			25200	1963	2310	36	50
1927			60000	1964	1.7	84	140
1928			7270	1965	115	70	124
1929			15900	1966	615	2480	48800
1930	2340		11100	1967	60	147	1260
1931	10200		16500	1968	87	280	4840
1932	16800		32400	1969	51	120	165
1933	338		820	1970	61	454	4360
1934	82		1810	1971	547	364	1000
1935	651		6280	1972	51	0	0
1936	0		2390	1973	1380	2830	17000
1937	8110		24500	1974	137	851	57
1938	7920		35800	1975	33	214	77
1939	632		2720	1976	120	220	1200
1940	0		1540	1977	1050	5	100
1941	13500		29900	1978	127	585	80700
1942	0		530	1979	3060	3290	90400
1943	0		1640	1980	4010	5020	124000
1944	0		380	1981	3960	5020	366
1945	0		1050	1982	461	144	3620
1946	0		2530	1983	3230	4550	34400
1947	119		1880	1984	3290	4000	77000
1948	0		158	1985	3490	4240	27300
1949	0		665	1986	134	321	600
1950	0		655	1987	186	47	1220
1951	1080		10900	1988	52	72	980
1952	91		372	1989	902	35	915
1953	32		78	1990	823	4.1	1160
1954	33		1490	1991	1900	291	1800
1955	581		3140	1992	1810	3020	13000
1956	44		0	1993	27700		
1957	32		65				

11.7.1.2 Mean Monthly Discharge, Gila River below Gillespie Dam (cfs)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1938	0	0	0	7.3	0	3049	2.1	0	0	0	4.5	0
1939	0	0	37	1.7	0	0	0	0	0	0	204	366
1940	0	0	0	0	0	1.7	0	0	0	0	102	0
1941	0	39	58	701	1663	5601	5107	3852	40	10	93	15
1942	6.3	4.3	131	86	36	27	0.13	0	0	0	0	0
1943	3.1	8.5	0	23	9.5	30	0	0	0	0	117	42
1944	0	0	29	23	98	56	3.8	0	0	0	16	0
1945	0	0	13	0	0	4.6	0	0	0	0	103	0
1946	20	0	11	23	0	0	0	0	0	7.8	1.2	431
1947	11	9.4	35	18	1.5	0.13	0	0	0	0	113	18
1948	0	0	0	0	4.1	0	0	0	0	0	11	0
1949	0	0	0	0	0	0	0	0	0	6	83	85
1950	21	0	0	0	0	0	0	0	0	11	35	0
1951	0	0	0	10	0.75	0	0	0	0	50	1340	321
1952	2.1	8.1	0	44	0.14	0	0	0	0	0	1.6	0
1953	0	3.3	0	0	0	0	0	0	0	0	0.81	0
1954	0	0	0	0	0	5.5	0	0	0	29	255	4
1955	0	0	0	0	0	0	0	0	0	237	1404	18
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	5.6	0	0	0	0	0	0	0.27	0
1958	0	46	0	0	3.2	6.1	0	0	0	0.32	20	48
1959	0	0	0	0	3.9	1.9	0	0	0	0	98	0
1960	24	24	86	72	0	0	0	0	0	0	1.3	0
1961	0	0	0	0	0	0	0	0	0	2.6	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	2.2	0	0	0	0.36	0	0	0	0	0	17	1.3
1964	0	0	0	0	0	0	0	0	0	0	27	22
1965	0	0	0	0	4.6	0	1.1	0	0	0	0	8.1
1966	0	0	405	6233	242	6	0	0	0	0	0	171
1967	0	0	0	0	0	0	0	0	0	0	0	69
1968	0	0	967	129	247	256	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	9.1	7.3
1970	0	0	0	0	0.89	35	11	0	0	0	0	361
1971	11	26	33	27	17	20	19	19	16	10	200	13
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	255	0	6.7	210	103	3428	8467	3044	58	19	0	0
1974	10	15	20	30	40	50	40	31	11	8.9	13	16
1975	21	49	54	60	56	49	42	33	20	7.5	2.7	3.9
1976	6.7	11	22	30	47	39	37	31	6.3	6.4	14	103
1977	65	61	56	61	69	55	26	38	16	5.2	2.6	9.9
1978	151	143	147	237	346	9699	128	13	11	7.1	8.1	11
1979	34	31	11763	14552	3706	7686	7081	209	11	5.3	31	5.2
1980	106	74	95	167	36433	2179	1016	352	20	22	49	20
1981	67	110	34	21	37	60	1.2	0	0.09	4.9	0.09	8.9
1982	157	104	26	0.79	22	266	3.1	0.46	0.28	0.09	0.07	40
1983	108	104	1103	669	7392	6931	4701	594	3	2.2	31	125
1984	10143	250	829	169	114	29	8.6	6.2	21	417	650	302
1985	154	260	3475	4081	2711	6441	1111	338	1	0.86	0.2	0.3
1986	260	320	433	418	147	61	0.33	4.2	1.6	24	4.2	66
1987	209	169	111	93	93	267	36	2.9	0.25	0.48	14	128
1988	174	127	322	197	37	32	16	8.8	0	0	17	69
1989	305	57	29	189	38	16	16	20	2.8	0.23	1.9	67
1990	258	231	97	241	157	19	0.54	0.36	0.23	52		
1991	171	136	182	175	92.5	237	355	15.2	1.21	0	1.39	52
1992	136	173	241	767	2952	4417	1450	275	46.2	26.9	788	355

11.7.1.3 Mean Monthly Discharge, Gila River below Painted Rock Dam (cfs)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1960	0	0	2.6	58	1.2	0.35	0.03	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0.92	3.2
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	1.2	0
1964	0	0	0	0	0	0.25	0.16	0.02	0	0	6.2	7.5
1965	5.9	0.78	0.95	1.7	2.2	1.8	1.3	0.04	0	0	0	0
1966	0	0	1.7	1442	1628	1237	22	9.4	3.2	0.48	0	9
1967	2.3	1	1.8	2	2	2.7	1.9	0.27	0	0	0.02	13
1968	0	0	4.5	11	102	62	2.2	1.8	1.7	8.6	32	19
1969	43	4.5	3.3	3.4	2.7	2.6	1.5	0.62	0.08	0	0.01	0
1970	0	0	0	0	0	0	0	0	0	0	0	50
1971	0.56	0.2	0.45	0.6	0.77	0.8	0.19	0	0	0.01	42	6.6
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	15	4.6	0	24	0.27	375	1977	2453	1077	284	269	34.3
1974	243	93	217	209	242	148	134	164	224	222	245	225
1975	22	1.8	1.4	1	0.5	2.4	2.2	4.5	4.5	5.2	0.5	1.8
1976	2.6	2.4	2	2.2	2.2	2.2	2.7	4.1	2.8	0.51	44	8.2
1977	3.3	2.4	1.8	2	0.86	0.41	0.1	0	0	0	0	0
1978	0	0	0	0	0	382	307	263	301	136	316	112
1979	281	227	722	1978	2864	2848	2956	2961	2872	2935	2958	2927
1980	2793	2777	2887	2163	1703	3725	4184	4165	2562	3286	4504	4602
1981	3996	1183	94	90	68	62	47	38	18	5.7	6.6	5.1
1982	6.1	2.5	4.1	6.6	7.7	22	54	8.3	5.5	4.5	11	24
1983	0.64	0.52	0.82	146	132	2159	3266	3761	2997	737	1048	993
1984	1214	3513	3733	2237	1317	226	71	21	36	35	54	129
1985	10	44	226	2583	3588	3671	3623	1718	21	23	16	3.7
1986	2.5	5.6	19	296	181	116	32	24	9.5	16	20	15
1987	11	2.3	12	17	27	26	19	19	15	14	10	0.17
1988	0	0	7.8	13	13	10	7.2	5.4	0	0	0	0
1989	0	0	0.2	7.5	14	12	7.4	0.24	0	0	0	0
1990	0	0	0	0	0.22	1.46	2.19	0	0	0	0	0
1991	0	0	14.3	57	10.8	65.1	130	12.3	0.9	0.042	0	0
1992	0	0	0	31	447	2140	2641	1218	266	11.1	74.7	268

11.7.1.4 Mean Monthly Discharge, Gila River near Dome (cfs)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1905	ND	ND	ND	3077	12253	16593	12910	4874	725	71	0	50
1906	179	4557	6100	2221	3024	9368	7099	1987	77	0	408	72
1907	0	0	5405	ND	ND	ND	ND	ND	ND	ND	ND	ND
1929	ND	ND	ND	ND	ND	ND	ND	0	0	0	0.06	50
1930	31	0	0	0	0	30	0	0	0	0	191	0
1931	0	0	0	0	1405	34	0	0	0	0	236	136
1932	0.06	23	107	23	2929	1337	101	3.3	0.57	0	0	0
1933	19	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	2.7	0
1935	0	0.03	0	0	60	29	0	0	0	0	0	13
1936	0	0	0	0	0	0	0	0	0	0	0	0
1937	0	0	0	0	1281	1233	113	0	0	0	0	0
1938	0	0	0	0	0	0	0	0	0	0	0	0
1939	0	0	0	0	0	0	0	0	0	0	0	0
1940	0	0	0	0	0	0	0	0	0	0	0	0
1941	0	0	0	11	0	3124	3043	3435	74	1.4	1.2	0
1942	0	0	0	0	0	0	0	0	0	0	0	0
1943	0	0	0	0	0	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	4.2	0.53	0.47	0.59	0.47	0.29	3.3	12	0	0	0	0
1953	0	0	2.3	0.69	0	0	0	0	0	0	6.8	2
1954	0.1	4.7	1.5	0	0.01	3.4	2.7	0	0.04	0.69	0.07	1.2
1955	4.1	3.6	8	0.93	2.4	1.8	0.07	0.22	0	0.42	116	70
1956	7.3	0.23	0.28	0.72	3.2	0.09	0	0	0	0.07	0.01	0.01
1957	0	1	0.06	0	0	1.3	0	0	0	0	1.6	0.8
1958	0.02	0	0	0	3.9	0.35	1	0.05	0	8.6	0.44	0
1959	0.23	0	0	0.08	0.41	0.14	0.42	1.8	0.19	2.6	43	3.3
1960	1.4	0.78	0.12	5.2	9.7	19	17	19	8.1	5.3	7.1	77
1961	20	29	77	103	44	6.9	5	5.1	4.1	3.9	6.1	4.8
1962	4.7	4.7	4	6.2	5.8	5.5	4.5	5.7	3.4	3.5	5.1	4.2
1963	3.9	3.7	3.1	2.4	1.6	4.3	4.1	1.4	4.8	8.2	1.9	90
1964	0.82	0.5	0.39	0.27	0.57	0.42	0.28	0.15	0	0	0.01	0
1965	0	0	0	0	0.1	0.11	4.4	0.05	0.01	0	0	0
1966	0	0.13	0.59	1.5	53	527	39	1.9	5.6	6.2	4.6	4.6
1967	5	3.7	1.7	0.65	0.81	0.93	0.81	0.08	0	0	0	4.7
1968	0.03	0.21	0.64	0.41	0.72	1.1	1.1	0.4	0.86	4.6	1.5	0.35
1969	0.7	0.58	0.83	1.2	0.92	0.71	0.39	0.57	2.9	5.6	2.1	2
1970	0.82	1.4	1.1	2.1	1.9	2.4	4.2	4.7	3.5	3.1	9.7	3.8
1971	2.8	1.9	3.7	2.4	2.2	3.1	6.8	1.7	0.5	0.12	4.8	36
1972	2.9	1.2	0.91	1.2	0.87	0.97	2.5	2.3	1.8	1.5	5.5	9.1
1973	27	1.2	1.2	1.3	1.8	1	2.7	793	791	79	45	0.84
1974	4.8	3.4	3	1.7	1.4	0.66	4.2	0.21	0.16	1.8	2.2	9.1
1975	0.48	0.31	0.51	0.51	1.2	2.2	7.2	3.8	1.6	0.73	0.41	0.39
1976	0.35	0.31	0.72	1.8	1.3	1	0.57	0.66	0.29	0.17	0.05	12
1977	1.3	0.92	0.62	0.81	0.88	0.75	0.45	0.52	0.59	0.19	2.4	43
1978	0.82	0.38	0.35	4.1	1.1	6.6	0.4	0.17	0.02	0	0	0
1979	0.19	0.14	0.11	240	1553	2130	2144	2275	2107	2154	2345	2280
1980	2162	2254	2257	2212	1194	3179	3604	3619	2688	1602	3075	3511
1981	3691	1777	299	151	102	74	45	21	28	16	8.6	2.9
1982	14	6.2	9.3	7.4	5.9	11	6.5	1.3	2.5	3.3	30	3.7
1983	2.5	1.8	3.5	2.5	1.6	296	2219	2422	2610	490	663	765
1984	590	2317	2977	2267	1345	414	158	63	26	48	39	11
1985	13	17	19	1071	2856	3383	3282	2071	186	68	54	45
1986	51	48	45	34	57	64	33	7.4	3.7	4.6	5.4	7.1
1987	17	14	15	13	11	12	13	2.8	12	16	34	5.3
1988	8	5	4.3	9.2	14	18	11	7.2	1.6	1.1	2.5	5.9
1989	2.3	3.7	2.3	1.6	1.4	12	6.6	17	10	67	46	5.7
1990	5.4	11	3.6	2.2	1.6	2.2	1.5	1.4	1.1	5	27	39.3
1991	4.62	9.93	3.76	4.03	2.58	3.59	3.72	3.35	2.72	2.91	1.11	4.67
1992	2.62	3.23	4.24	4.46	5.76	272	1602	910	228	10.3	2.84	2.09
1993	5.16	5.54	5.36	2949	10730	22550	15790	9198	4976	2689	2050	2207

11.7.2 Mean Monthly Discharge of the Lower Gila River

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Gila River near Dome												
Pre-1938	532.10	2095.20	2862.40	2022.30	624.03	72.96	6.45	76.16	29.18	22.91	458.00	1161.20
1938-1959	0.64	0.47	142.34	138.66	156.78	3.37	0.63	7.69	3.51	0.73	0.46	0.57
1960-1992	186.55	220.63	316.83	401.06	371.60	264.72	139.76	194.91	211.83	201.26	197.65	174.05
Gila River below Painted Rock Dam												
1960-1992	344.91	374.47	524.27	590.67	510.67	315.67	234.06	292.70	286.56	262.18	238.35	241.14
Gila River below Gillespie Dam												
1938-1959	42.85	82.73	399.22	232.41	175.09	1.82	15.96	181.93	61.27	2.89	5.39	14.27
1960-1992	1253.43	2395.84	1838.17	1068.12	218.92	10.74	27.07	81.85	88.47	557.73	107.61	892.90
1938-1992	541.30	1034.99	928.38	539.63	161.58	5.22	17.71	108.98	62.65	234.39	47.16	379.10

11.7.3 Total Dissolved Solids in the Lower Gila River

Month/Year	Total Dissolved Solids (mg/l)	Mean Daily Discharge (cfs)	Month/Year	Total Dissolved Solids (mg/l)	Mean Daily Discharge (cfs)	Month/Year	Total Dissolved Solids (mg/l)	Mean Daily Discharge (cfs)
Nov-83	630	2317	Nov-86		14	Nov-89	1120	11
Dec-83		2977	Dec-86		15	Dec-89	5750	3.6
Jan-84		2267	Jan-87		13	Jan-90	4840	2.2
Feb-84	850	1345	Feb-87		11	Feb-90	2740	1.6
Mar-84		414	Mar-87		12	Mar-90	4870	2.2
Apr-84		158	Apr-87		13	Apr-90	5170	1.5
May-84	1800	63	May-87		2.8	May-90	820	1.4
Jun-84	2200	26	Jun-87		12	Jun-90	824	1.1
Jul-84		48	Jul-87		16	Jul-90	859	5
Aug-84		39	Aug-87	626	34	Aug-90	323	27
Sep-84	2700	11	Sep-87		5.3	Sep-90	132	39.3
Oct-84		13	Oct-87	2310	8	Oct-90	4780	4.62
Nov-84	2100	17	Nov-87	3470	5	Nov-90	856	9.93
Dec-84		19	Dec-87	1820	4.3	Dec-90	2210	3.76
Jan-85		1071	Jan-88	1200	9.2	Jan-91	1990	4.03
Feb-85	690	2856	Feb-88		14	Feb-91	940	2.58
Mar-85		3383	Mar-88	2220	18	Mar-91	3410	3.59
Apr-85		3282	Apr-88	3290	11	Apr-91	3330	3.72
May-85	900	7.4	May-88	1930	7.2	May-91	1590	3.35
Jun-85	1100	3.7	Jun-88	2640	1.6	Jun-91	930	2.72
Jul-85		4.6	Jul-88	2730	1.1	Jul-91	872	2.91
Aug-85	1200	54	Aug-88		2.5	Aug-91	747	1.11
Sep-85		45	Sep-88	2420	5.9	Sep-91	524	4.67
Oct-85		51	Oct-88	11600	2.3	Oct-91	1910	2.62
Nov-85	1400	48	Nov-88	3900	3.7	Nov-91	5270	3.23
Dec-85		45	Dec-88	3200	2.3	Dec-91	2600	4.24
Jan-86	1400	34	Jan-89	4400	1.6	Jan-92	953	4.46
Feb-86		57	Feb-89	5340	1.4	Feb-92	3290	5.76
Mar-86	1500	64	Mar-89	2540	12	Mar-92	871	272
Apr-86		33	Apr-89	2160	6.6	Apr-92	680	1602
May-86	2400	7.4	May-89	1490	17	May-92	873	910
Jun-86	1400	3.7	Jun-89	1520	10	Jun-92	1420	228
Jul-86		4.6	Jul-89	2120	67	Jul-92	2020	10.3
Aug-86	1500	5.4	Aug-89	3130	46	Aug-92	1200	2.84
Sep-86		7.1	Sep-89	2550	5.7	Sep-92	821	2.09
Oct-86		17	Oct-89	5440	5.4			

11.7.4 General Depth to Groundwater in the Lower Gila River Region

Location	Year	Depth to Groundwater	Source
Gillespie Dam to Gila Bend			
Cotton Center	1946	77 feet	Halpenny and others 1952
	1968	100 feet	Stulik and Moosburner 1969
	1979	60 to 80 feet	Sebenik 1981
Gila Bend area	1968	60 feet	Stulik and Moosburner 1969
	1979	30 to 60 feet	Sebenik 1981
Painted Rock Dam to Texas Hill			
Near Painted Rock Mountains	1953	8 feet	U. S. Army Corps of Engineers 1970
Dendora Valley	1960s	< 25 to 200 feet	Ligner *et al.* 1969
Two miles downstream of Painted Rock Dam	1974	20 feet	U. S. Army Corps of Engineers 1975
Halfway between Painted Rock Mountains and	1964	27 feet	U. S. Army Corps of Engineers 1970
Texas Hill	1960s	< 25 to 300 feet	Ligner *et al.* 1969
Palomas-Sentinel Plain	1964-5	20 to 30 feet	Weist 1965
Dateland-Hyder area	1962	17 feet	U. S. Army Corps of Engineers 1970
Texas Hill	1974	< 7 feet	U. S. Army Corps of Engineers 1975
Texas Hill to Dome			
Wellton-Mohawk Drainage and Irrigation District	1960s	< 15 to 75 feet	Ligner *et al.* 1969
	1991	< 10 feet	Bookman-Edmonston Engineering, Inc. 1992
Yuma	1960s	10 to 15 feet	Ligner *et al.* 1969
	1982	10 to 14 feet	Mock *et al.* 1988
	1988	8 to 12 feet	Bookman-Edmonston Engineering, Inc. 1992

11.7.5 Depth to Groundwater for Five Wells Near the Lower Gila River

Well # keyed to lettered locations on maps in Appendix 11.1:

Well A, near Cotton Center, map 11.1.3
Well B, near Painted Rock Dam, map 11.1.4
Well C, near Dateland, map 11.1.7
Well D, near Tyson, map 11.1.8
Well E, near Tacna, map 11.1.9

Well #	U. S. G. S. Well #	Period of Record	Depth to Groundwater - Extremes of Record Highest (ft)	Year	Lowest (ft)	Year
A	C-04-04 09BBA1	1953-present	70.9	1953	153.47	1965
B	C-04-07 34CDC	1953-present	6.79	1984	54.5	1977
C	C-06-12 19BBA	1945-present	22.8	1984	44.86	1950
D	C-07-16 27CCC	1956-present	3.87	1960	18.88	1956
E	C-08-17 12DDD	1974-present	7.63	1980	14.81	1978
F	C-09-19 04CDD	1946-present	8.7	1980	23.6	1946

Well #	1983	1984	1985	Depth to Groundwater for Exact Well 1986	1987	1988	1989	1990	1991	1992
A	NA	NA	NA	NA	NA	79.70	94.3	91.9	96.9	100.0
B	NA	NA	NA	NA	NA	27.64	29.5	33.0	29.9	29.8
C	29.9	22.8	24.4	22.92	23.5	24.9	25.3	27.6	28.07	31.9
D	NA	NA	NA	NA	NA	6.7	5.6	5.9	5.17	4.7
E	NA	NA	NA	NA	11.2	10.3	10.1	11.1	11.6	10.1
F	NA	NA	NA	NA	14.3	12.6	14.2	14.4	11.6	15.2

APPENDIX F

ECONOMICS

US Army Corps
of Engineers
Los Angeles District

RECONNAISSANCE REPORT

GILA RIVER, GILLESPIE DAM TO YUMA
MARICOPA AND YUMA COUNTIES, AZ

ECONOMIC APPENDIX

U.S. Army Corps of Engineers
Los Angeles District
300 North Los Angeles Street
Los Angeles, California 90053

January, 1995

APPENDIX

ECONOMIC EVALUATION
GILLESPIE TO YUMA, AZ

Table of Contents

APPENDIX

ECONOMIC EVALUATION
GILLESPIE TO YUMA, AZ

List of Tables

1.0 Purpose

The purpose of this economic appendix is to determine the without project flood damage for the study area, assess the potential for water conservation behind Painted Rock Dam, and present the economic methodologyused in these calculations.

2.0 Study Authority

The Gillespie Dam to Yuma Reconnaissance study is an interim study conducted under the authorization of Public Law 761, Seventy-fifth Congress, the Flood Control Act of 1938.

3.0 Study Area Location

The study area extends 164 miles along the Gila River from Gillespie Dam west to the City of Yuma. The study area encompasses portions of both Yuma and Maricopa counties. Gillespie Dam lies 60 air miles southwest of Phoenix in south central Arizona, while the City of Yuma lies on the Colorado River at the confluence with the Gila River in southwestern Arizona, 10 miles north of the border between the United States and Mexico.

Interstate Highway 8 runs the entire distance from Gila Bend to Yuma south of the river. There are nine bridges across the Gila River that connect the communities downstream of the dam, only six of which were designed to sustain flows of 10,000 ft^3/s.

The Gila River basin is the largest drainage area tributary to the Lower Colorado River, with a total drainage area of 58,200 mi^2, approximately 50,900 mi^2 of which lies above Painted Rock Dam.

4.0 1993 Flood Event

Large flood flows have caused extensive damages in the study area. The January 4th flood event at Painted Rock Dam had an estimated inflow on the 8th of January of 186,000 ft_3/s, the second largest annual flow event since the completion of the dam in 1960. This corresponds to an estimated exceedence interval of a 100-year event. The maximum 60 and 90 day inflow volumes exceeded record flows and represent recurrence intervals of greater than the 500-year and 1,000-year storm event, respectively.

Painted Rock Dam, approximately 40 miles downstream of Gillespie Dam, was constructed by the Crops of Engineers in 1959 as a flood control structure. Despite the protection afforded by Painted Rock Dam, several major storms in the winter and spring of 1993 resulted in overflowing of the spillway, significant damages to agriculture, transportation facilities, homes, and infrastructure. More detailed description of damages is provided in Section 5.0, by reach.

5.0 Study Area by Reach

Reach 1 extends from the Gillespie Dam along the Gila River to the eastern edge of Painted Rock Dam. This area consists mainly of farmland and was greatly affected by the 100 feet breach in Gillespie Dam. Consequently, farmers have suffered crop loss and induced electrical, emergency, and water pumping costs, in addition to losing portions of their land from river rechannelization. Palomar Ranches is the owner of Gillespie Dam and has hitherto not committed to repairing the breach.

Reach 2 consists of the area surrounding Painted Rock Dam. Painted Rock Dam, located 38 miles downstream of Gillespie Dam, was built in 1959 and is operated and maintained by the Corps of Engineers. The dam is earthen filled with a crest length of 4,780 feet and a gross capacity of 2,476,339 million acre feet at the spillway crest (elevation 661).

The 3rd Reach encompasses the area along the Gila River between Painted Rock Dam and Texas Hill. The county line between Maricopa and Yuma lies nearly halfway through this reach. Much of the land is non-irrigated desert. Thus, no appreciable damages occurred or were evaluated.

Reach 4 extends from Texas Hill to the City of Dome, the boundaries of the Wellton-Mohawk Irrigation and Drainage District (WMIDD). According to the "Draft 1993 Arizona Flood Damage Study", the WMIDD has 105 miles of levees along 60 miles of river. The levees are typically uncompacted fill and were intended to provide protection up to 10,000 cfs. Approximately, 65 miles of the levees were damaged to varying degrees. WMIDD stated that, generally speaking, channel scouring had occurred throughout the 60 miles of river. Thus, reconstruction of the 10,000 cfs levees will actually result in an approximate 15,000 cfs level of protection. This estimate is based on water surface elevation primarily and may not take in to account structural/velocity considerations.

In addition, WMIDD suffered damage to their irrigation and canal system. They operate and maintain approximately 280 miles of irrigation canals and laterals, which supply water to 640 acre parcels. Seven miles of minor laterals were destroyed during the 1993 floods. Furthermore, water supply disruptions occurred.

Reach 5 includes the area between the City of Dome and the City of Yuma, along the southwest portion of the Gila River. This reach contains two water districts that experienced minimal damages to agriculture and their infrastructure. The Bureau of Reclamation operates and maintains a levee system from Dome to the confluence with the Colorado River that sustained considerable damages but is being repaired to withstand 50,000 cfs in future storm events.

6.0 Methodology

The methodology employed in this appendix is in accordance with the current ER 1105-2-100, Policy and Planning, Planning Guidance and the National Economic Development Manual Agricultural Flood Damage. Average annual values are based on a Federal discount rate of 7 3/4 percent and a 100-year period of analysis. Backup data is on file at the Los Angeles District.

7.0 Exceedence Frequencies

The amount of land inundated at varying discharge levels was based on the 1993 storm event and plotted in 5,000 cfs increments between 15,000 cfs and 40,000 cfs. The exceedence frequencies used to calculate the expected annual damages are based on the simulated Painted Rock outflow discharge-frequency curve developed by the Hydrology and Hydraulics Branch. Table 1 provides the discharge-frequency relationship, along with the total land inundated at these frequencies.

Table 1
Discharge-Frequency Relationship

Discharge (cfs)	Frequency	Total Land Inundated	% of 25,000 cfs Land Inundated
15,000	100	30,399	78%
20,000	105	37,338	96%
25,000	111	38,754	100%
30,000	127	44,302	114%
35,000	143	45,210	117%
40,000	167	47,374	122%

8.0 Agricultural Inundation

Inundation damages in the study area are primarily agricultural and are based on the damage estimates resulting from the 1993 flood event. The amount of agricultural land damaged in 1993 is based on the acreage reported to the Arizona Stabilization and Conservation Service for federal aid.

8.1 Agricultural Intensification

In both Maricopa and Yuma Counties, the availability of suitable land for the production of "other" crops does not appear constrained by basic crops production. Thus, as per the ER 1105-2-100 guidance, agricultural intensification benefits will not be evaluated.

8.2 Agricultural Damage Methodology

Crop budgets were obtained through the "1990 Arizona Field Crop Budgets--Yuma County" extension bulletin issued by the Cooperative Extension at the University of Arizona, College of Agriculture. The costs estimated in the crop budgets are based on a five-year average. The 1993 crop budgets were not used, because the storm event affected yields; thereby, reflecting abnormal costs. While the crop mixture in these counties is dependent on market prices, the percentage of different crop types planted each month has remained relatively consistent over the past five years.

Agricultural damages for Maricopa County are based on Yuma County's crop budgets due to the similarity in costs and the limited amount of agricultural damage in Maricopa County. Crop yields and season average prices are based on the "1992 Arizona Agricultural Statistics" provided by the Yuma County Extension Services. The ratio of crop acreage damaged in 1993 to the total land inundated in 1993 is applied to the total land inundated at each discharge level to determine the acres of cropland inundated in each event. Crop acreage and the corresponding discharge-frequency relationships are presented in Table 2.

Table 2
CROP ACREAGE INUNDATED BY EVENT AND AT EACH FLOW LEVEL

Frequency	FT^2/S	TOTAL ACREAGE
100-year	15,000 cfs	11,382
105-year	20,000 cfs	13,111
111-year	25,000 cfs	13,590
127-year	30,000 cfs	15,788
143-year	35,000 cfs	16,082
167-year	40,000 cfs	16,902

8.3 Crop Yields and Prices

The following paragraphs provide the yields and prices for each crop type. Prices for federally subsidized croplands are based on the Department of Agriculture's normalized prices (ER 1105-2-100, 6-22 b.). Non-basic crop prices are based on a statewide 3-year average of the crop's market price. Yields were based on a 3-year average of the crop yields by county provided in the "1992 Arizona Agricultural Statistics" handbook.

8.3.1 Alfalfa

The NED normalized prices are applicable for alfalfa and is set at $88.51/ton. At an average yield of 8.97 tons per acre, the per acre dollar value is $793.64. The crop budget for alfalfa is based on a 3-year cycle and the variable operating expenses once the stand establishment is complete.

8.3.2 Barley

The NED normalized prices are applicable for barley and is set at $2.87/bushel ($.06/lb.). At an average yield of 4773.3 lbs. per acre, the per acre dollar value is $285.41.

8.3.3 Durum Wheat

NED normalized prices are applicable for durum wheat and is set at $3.85/bushel. At an average yield of 101.33 bushels per acre, the per acre gross income is $390.13.

8.3.4 Pima Cotton (Long Staple)

The Pima cotton acreage versus the Upland cotton acreage is based on the 1992 and 1993 Principle Crops table in the "1992 Agricultural Statistics" handbook. This table presents the total acreage harvested by county and by crop type. Pima cotton constitutes approximately 10% of the total cotton production in Maricopa and Yuma Counties.

Pima cotton is not subject to normalized prices. According the "1992 Agricultural Statistics" handbook, the three year (1990-1992) seasonal average price for Pima cotton is $.942 per pound (ER 1105-2-100, Sec. III, 6-22.b). With an average production yield of $900 lbs/acre, the gross dollar value per acre is $848.

Table 3 **Pima Cotton** **Seasonal Average Price**	
Year	$ Price per lbs.
1990	1.04
1991	.976
1992	.81
Average:	.942

8.3.5 Upland Cotton (Short Staple)

The percentage of Upland Cotton acreage harvested in Maricopa and Yuma counties is based upon the total acreage counts by crop type and county, as per the "1992 Agricultural Statistics" handbook. Upland cotton constitutes approximately 90% of the total cotton grown in these counties.

Upland Cotton is subject to NED normalized prices, which equals $.634/pound. At an average yield of 1,116 lbs. per acre, the per acre gross income is $703.

8.3.6 Watermelon

Watermelon is classified as an "other" crop and is not subject to NED normalized prices. The three year seasonal average price for watermelon, based on the "1992 Agricultural Statistics" handbook is $6.22 per cwt. At an average yield of 364 cwt. per acre, the per acre gross income is $2,264. As mentioned above, land intensification benefits are not under consideration in this study. Table 4 lists the three-year seasonal average price for watermelon.

Table 4 **Watermelon** **Seasonal Average Price**	
Year	**$ Price/Cwt.**
1990	**$6.95**
1991	**$6.84**
1992	**$4.87**
Average	**$6.22**

8.3.7 Western Head Lettuce

Western Head Lettuce is not classified as a "basic" crop and is not, therefore, subject to NED normalized prices. The seasonal average price for Head lettuce is based on a 5-year average, due to large fluctuations in the market price between 1988 and 1992. The 5-year average price for western headlettuce, based on the "1992 Agricultural Statistics" handbook is $6.70 per carton and listed in Table 5. At an average yield of 573.2 cwt. per acre, the per acre gross income is $3,840. As mentioned above, land intensification benefits are not under consideration in this study.

Table 5
Western Head Lettuce
Seasonal Average Price

Year	$ Price/Ctn.
1988	$12.70
1989	$7.60
1990	$3.67
1991	$4.62
1992	$4.90
Average	$6.70

8.4 Farm Budget Analysis

The determination of agricultural crop flood damage is based on the relationship between when the flood occurs and the stage of the crop. Throughout the year, the flood loss potential of a particular crop varies, based on the capital outlay to produce the crop and the development of the crop itself.

Potential crop damages fall into two categories: (1) Direct Production Investments (DPI) and (2) Net Income Losses (NI). As a reduction in the yield of "other" crops resulting from a significant storm event raises the market price of that particular produce item in the short term, net income losses to regional farmers represent a transfer and are, therefore, not evaluated for non-basic crops. As potential losses vary throughout the year, the time-of-year flood probabilities were based on the long-term average of total precipitation for the counties as stated in the "1992 Arizona Agricultural Statistics" handbook.

8.4.1 Alfalfa

Table A-1 of Appendix A is a listing of alfalfa's production cost function detailing the assignment of operating costs. Table 6 is a monthly accumulation of NED inundation reduction categories of DPI and NI with their associated time-of-flood damage probabilities.

Table 6
ALFALFA: FLOOD DAMAGE ANALYSIS

MONTH	MONTHLY		CUMMU.DPI	POTENTIAL		WEIGHTS (%)	WEIGHTED LOSS	
	DPI	HARVEST		DPI LOSS	NI LOSS		DPI	NI
FEB	31.17		31.17	31.17	517.82	6.94	2.16	35.94
MAR	0.00		31.17	31.17	517.82	6.62	2.06	34.28
APR	0.00		31.17	31.17	517.82	4.42	1.38	22.89
MAY	0.00		31.17	31.17	517.82	1.26	0.39	6.52
JUN	0.00		31.17	31.17	517.82	0.63	0.20	3.26
JUL	0.00		31.17	31.17	517.82	8.20	2.56	42.46
AUG	11.90		43.07	43.07	517.82	20.19	8.70	104.55
SEP	34.07		77.14	77.14	517.82	9.78	7.54	50.64
OCT	13.93		91.08	91.08	517.82	9.15	8.33	47.38
NOV	0.00		91.08	91.08	517.82	7.57	6.89	39.20
DEC	0.00		91.08	91.08	517.82	14.20	12.93	73.53
JAN	24.65	149.75	115.72		0.00	11.04	0.00	0.00
TOTAL	121.72	149.75					53.15	460.66

8.4.2 Barley

Table A-2 of Appendix A is a listing of barley's production cost function detailing the assignment of operating costs. Table 7 is a monthly accumulation of NED inundation reduction categories of DPI and NI with their associated time-of-flood damage probabilities.

Table 7
BARLEY: FLOOD DAMAGE ANALYSIS

MONTH	MONTHLY		CUMMU.DPI	POTENTIAL		WEIGHTS (%)	WEIGHTED LOSS	
	DPI	HARVEST		DPI LOSS	NI LOSS		DPI	NI
DEC	62.79		62.79	62.79	165.42	14.20	8.92	23.49
JAN	8.58		71.37	71.37	165.42	11.04	7.88	18.26
FEB	9.39		80.76	80.76	165.42	6.94	5.60	11.48
MAR	7.20		87.96	87.96	165.42	6.62	5.82	10.95
APR	0.00		87.96	87.96	165.42	4.42	3.89	7.31
MAY	0.00		87.96	87.96	165.42	1.26	1.11	2.08
JUN	11.87	20.16	99.83	0.00	0.00	0.63	0.00	0.00
TOTAL	99.83	20.16					33.22	73.58

8.4.3 Durham Wheat

Table A-3 of Appendix A is a listing of Durham wheat's production cost function detailing the assignment of operating costs. Table 8 is a monthly accumulation of NED inundation reduction categories of DPI and NI with their associated time-of-flood damage probabilities.

Table 8

DURHAM WHEAT: FLOOD DAMAGE ANALYSIS

MONTH	MONTHLY		CUMMU.DPI	POTENTIAL		WEIGHTS (%)	WEIGHTED LOSS	
	DPI	HARVEST		DPI LOSS	NI LOSS		DPI	NI
DEC	62.50		62.50	62.50	266.62	14.20	8.88	37.86
JAN	0.00		62.50	62.50	266.62	11.04	6.90	29.44
FEB	22.18		84.70	84.70	266.62	6.94	5.88	18.50
MAR	5.80		90.48	90.48	266.62	6.62	5.99	17.65
APR	0.00		90.48	90.48	266.62	4.42	4.00	11.78
MAY	0.00		90.48	90.48	266.62	1.26	1.14	3.36
JUN	11.87	21.16	102.35	0.00	0.00	0.63	0.00	0.00
TOTAL	102.35	20.16					32.79	118.59

8.4.4 Pima Cotton (Long Staple)

Table A-4 of Appendix A is a listing of Pima cotton's production cost function detailing the assignment of operating costs. Table 9 is a monthly accumulation of NED inundation reduction of DPI with the associated time-of-flood damage probabilities. Net income loss is not evaluated for Pima cotton, because it is a non-basic crop.

Table 9

PIMA COTTON: FLOOD DAMAGE ANALYSIS

MONTH	MONTHLY		CUMMU.DPI	POTENTIAL		WEIGHTS (%)	WEIGHTED LOSS	
	DPI	HARVEST		DPI LOSS	NI LOSS		DPI	NI
DEC	17.97	17.97		17.97	571.53	14.20	2.55	81.16
JAN	26.01	43.98		43.98	571.53	11.04	4.86	63.10
FEB	3.61	47.59		47.59	571.53	6.94	3.30	39.66
MAR	14.65	62.24		62.24	571.53	6.62	4.12	37.83
APR	10.29	72.53		72.53	571.53	4.42	3.20	25.26
MAY	39.77	112.30		112.30	571.53	1.26	1.41	7.20
JUN	12.72	125.02		125.02	571.53	0.63	0.79	3.60
JUL	31.02	156.04		156.04	571.53	8.20	12.80	46.86
AUG	80.43	236.47		236.47	571.53	20.19	47.74	76.53
SEP	9.49	245.96	70.56	0.00	0.00	9.78	0.00	0.00
OCT	27.35	273.31		0.00	0.00	9.15	0.00	0.00
NOV	20.79	294.10		0.00	0.00	7.57	0.00	0.00
DEC	0.00	294.10		0.00	0.00	14.20	0.00	0.00
TOTAL	305.10	1,981.61	2,190.52	964.94	3,418.73		80.78	278.60

8.4.5 Upland Cotton (Short Staple)

Table A-5 of Appendix A is a listing of Upland cotton's production cost function detailing the assignment of operating costs. Table 10 is a monthly accumulation of NED inundation reduction categories of DPI and NI with their associated time-of-flood damage probabilities.

Table 10

UPLAND COTTON: FLOOD DAMAGE ANALYSIS

MONTH	MONTHLY		CUMMU.DPI	POTENTIAL		WEIGHTS (%)	WEIGHTED LOSS	
	DPI	HARVEST		DPI LOSS	NI LOSS		DPI	NI
DEC	15.91		15.91	15.91	376.77	11.04	1.76	41.60
JAN	26.01		41.92	41.92	376.77	6.94	2.91	26.15
FEB	3.61		45.53	45.53	376.77	6.62	3.02	24.96
MAR	16.74		62.27	62.27	376.77	4.42	2.75	16.64
APR	10.29		72.56	72.56	376.77	1.26	0.92	4.75
MAY	28.92		101.48	101.48	376.77	0.63	0.64	2.38
JUN	42.36		143.84	143.84	376.77	8.20	11.80	30.90
JUL	82.34		226.18	226.18	376.77	20.19	45.66	76.07
AUG	29.07		255.25	255.25	376.77	9.78	24.96	36.85
SEP	40.75	93.01	296.00	0.00	13.89	9.15	0.00	1.27
OCT	0.00		296.00	0.00	13.89	7.57	0.00	1.05
NOV	20.79	4.90	316.79	0.00	0.00	14.20	0.00	0.00
DEC	0.00		316.79	0.00	0.00	11.04	0.00	0.00
TOTAL	316.79	97.91	2,190.52	964.94	3,418.73		94.41	262.62

8.4.6 Watermelon

Table A-6 of Appendix A is a listing of Watermelon's production cost function detailing the assignment of operating costs. Table 11 is a monthly accumulation of NED inundation reduction of DPI with the associated time-of-flood damage probabilities. Net income loss is not evaluated for Watermelon, because it is a non-basic crop.

Table 11
WATERMELON: FLOOD DAMAGE ANALYSIS

MONTH	MONTHLY		CUMMU.DPI	POTENTIAL DPI LOSS	WEIGHTS (%)	WEIGHTED DPI LOSS
	DPI	HARVEST				
DEC	27.86		27.86	27.86	14.20	3.96
JAN	240.95		268.81	268.81	11.04	29.68
FEB	127.25		396.06	396.06	6.94	27.49
MAR	245.39		641.45	641.45	6.62	42.46
APR	92.38		733.83	733.83	4.42	32.44
MAY	0.00	1124.07	733.83	0.00	1.26	0.00
JUN	0.00		733.83	0.00	0.63	0.00
TOTAL	733.83	1124.07				136.03

8.4.7 Western Head Lettuce

Table A-7 of Appendix A is a listing of Western Head lettuce's production cost function detailing the assignment of operating costs. Table 12 is a monthly accumulation of NED inundation reduction of DPI with the associated time-of-flood damage probabilities. Net income loss is not evaluated for Head lettuce, because it is a non-basic crop.

Table 12

WESTERN LETTUCE: FLOOD DAMAGE ANALYSIS

MONTH	MONTHLY		CUMMU.DPI	POTENTIAL	WEIGHTS	WEIGHTED LOSS
	DPI	HARVEST		DPI LOSS	(%)	DPI
JUL	106.66		106.66	106.66	8.20	8.75
AUG	141.24		247.90	247.90	20.19	50.05
SEP	320.18		568.08	568.08	9.78	55.56
OCT	220.37		788.45	788.45	9.15	72.14
NOV	244.67		1033.12	1,033.12	7.57	78.21
DEC	1.02		1034.14	1,034.14	14.20	146.85
JAN	15.37		1049.51	1,049.51	11.04	115.87
FEB	0.00		1049.51	1,049.51	6.94	72.84
MAR	0.00		1,049.51	1,049.51	6.62	69.48
APR	0.00	1942.57	1,049.51	0.00	4.42	0.00
TOTAL	1,049.51					669.74

8.5 1993 Direct Production Investment and Net Income Losses

The monthly and total without project direct production investment and net income losses for the 1993 storm event by month and by crop type is presented in Table 13 as an example of time-of-flood damage probabilities. Table 13 also provides the percent of total acreage and the monthly breakdown of expected crop acreage by crop type. This crop mixture is based on discussions with agricultural experts at the Arizona Stabilization and Conservation Association and the Yuma County Extension Services. For each month, the total acreage is multiplied by the percentage of crop type in each month. The monthly acreage is applied to the total direct production expenses and net income losses to yield total damages by month. The monthly damages are summed horizontally and multiplied by the weighted percentages that a storm event might occur in any given month. Total 1993 direct production investment and net income losses equalled $5,456,928. Total damages by storm event are provided in Table 14.

TABLE 13: AGRICULTURAL DAMAGES AND CROP MIXTURE BY MONTH												
Month		Acres Fallow	Wheat	Alfalfa	Upland Cotton	Pima Cotton	Barley	Head Lettuce	Watermelon	Totals	Storm Probabilities	Weighted Damages
January	NI & DPI Loss	$0.00	$1,118,192	$2,068,784	$43,529	$7,110	$88,495	$1,354,978	$21,919	$4,703,006	11.04%	$519,212
	% of Total Land	11.21%	25.00%	50.00%	.85%	.09%	2.75%	9.50%	.60%	100.00%		
	Acres	1,523	3,398	6,795	116	12	374	1,291	82	13,590		
February	NI & DPI Loss	$0.00	$1,193,549	$2,984,327	$258,259	$96,760	$100.368	$2,816,601	$13,580	$7,463,443	6.94%	$517,963
	% of Total Land	5.85%	25.00%	40.00%	5.00%	1.15%	3.00%	19.75	0.25%	100.00%		
	Acres	795	3,398	5,436	680	156	408	2,684	34	13,590		
March	NI & DPI Loss	$0.00	$1,213,254	$2,984,327	$536,993	$99,049	$103,304	$2,112,450	$16,495	$7,065,873	6.62%	$467,761
	% of Total Land	5.85%	25.00%	40.00%	10.00%	1.15%	3.00%	14.81%	0.19%	100.00%		
	Acres	795	3,398	5,436	1,359	156	408	2,013	26	13,590		
April	NI & DPI Loss	$0.00	$1,213,254	$1,492,164	$1,099,157	$363,242	$103,304	$0.00	$12,580	$4,283,702	4.42%	$189,340
	% of Total Land	7.72%	25.00%	40.00%	20.00%	4.15%	3.00%	0.00%	0.13%	100.00%		
	Acres	1,049	3,398	5,436	2,718	564	408	0	17	13,590		
May	NI & DPI Loss	$0.00	$1,213,254	$1,193,731	$1,462,378	$385,672	$103,304	$0.00	$6,290	$4,364,629	1.26%	$54,994
	% of Total Land	2.68%	25.00%	40.00%	25.00%	4.15%	3.00%	0.00%	0.17%	100.00%		
	Acres	364	3,398	5,436	3,398	564	408	0	23	13,590		
June	NI & DPI Loss	$0.00	$606,627	$1,193,731	$1,591,905	$392,846	$51,652	$0.00	3,145	$3,836,761	.63%	$24,191
	% of Total Land	7.68%	20.00%	40.00%	25.00%	4.15%	3.00%	0.00%	0.17%	100.00%		
	Acres	1,044	2,718	5,436	3,398	564	408	0	23	13,590		
July	NI & DPI Loss	$0.00	$0.00	$1,193,731	$1,843,681	$410,341	$0.00	$72,476	$0.00	$3,520,229	8.2%	$288,659
	% of Total Land	25.85%	0.00%	40.00%	25.00%	4.15%	0.00%	5.00%	0.00%	100.00%		
	Acres	3,513	0	5,436	3,398	564	0	680	0	13,590		
August	NI & DPI Loss	$0.00	$0.00	$2,286,762	$1,932,570	$455,702	$0.00	$168,449	$0.00	$5,935,878	20.19%	$977,899
	% of Total Land	35.85%	0.00%	30.00%	25.00%	4.15%	0.00$	5.00%	0.00%	100.00%		
	Acres	4,872	0	4,077	3,398	564	0	680	0	13,590		

TABLE 13: AGRICULTURAL DAMAGES AND CROP MIXTURE BY MONTH

Month		Acres Fallow	Wheat	Alfalfa	Upland Cotton	Pima Cotton	Barley	Head Lettuce	Watermelon	Totals	Storm Probabilities	Weighted Damages
September	NI & DPI Loss	$0.00	$0.00	$2,425,666	$996,285	$227,851	$0.00	$2,316,076	$0.00	$5,935,878	9.78%	$580,529
	% of Total Land	10.85%	0.00%	30.00%	25.00%	4.15%	0.00%	30.00%	0.00%	100.00%		
	Acres	1,475	0	4,077	3,398	564	0	4,077	0	13,590		
October	NI & DPI Loss	$0.00	$0.00	$2,991,655	$33,978	$0.00	$0.00	$3,750,284	$0.00	$6,775,917	9.15%	$619,996
	% of Total Land	8.00%	0.00%	37.00%	20.00%	0.00%	0.00%	35.00%	0.00%	100.00%		
	Acres	1,087	0	5,028	2,718	0	0	4,757	0	13,590		
November	NI & DPI Loss	$0.00	$0.00	$3,309,945	$16,989	$0.00	$0.00	$4,492,859	$0.00	$7,819,793	7.57%	$591,958
	% of Total Land	11.00%	0.00%	40.00%	17.00%	0.00%	0.00%	32.00%	0.00%	100.00%		
	Acres	1,495	0	5,436	2,310	0	0	4,439	0	13,590		
December	NI & DPI Loss	$0.00	$313,094	$3,475,443	$0.00	$0.00	$93,042	$4,497,294	$0.00	$8,378,873	14.20%	$1,189,800
	% of Total Land	16.00%	7.00%	42.00%	0.00%	0.00%	3.00%	32.00%	0.00%	100.00%		
	Acres	2,174	951	5,708	0	0	408	4,349	0	13,590		
Total Unweighted Damages		$0.00	$6,871,225	$27,600,266	$9,785,724	$2,438,574	$643,467	$21,581,467	$74,009	$68,994,733		$6,022,303

9.0 Without Project Damage Methodology - Other Categories

9.1 Detour Costs

Due to significant upgrades in the level of protection to transportation infrastructure, detour costs were not evaluated. Further analysis of the protection to bridge crossings and roadways will be conducted in the feasibility study. The amount of detour costs damages at each discharge level are based on the ratio of total land inundated in the 1993 storm event (based on 25,000 cfs) to the total land inundated at the other discharge levels (please refer to Table 1). This ratio was applied to each of the damage categories to determine damages at each discharge level.

9.2 Emergency Damages

Emergency damage costs are based on the clean-up, debris removal, and emergency service costs experienced during the 1993 storm event. Costs were collected from each water district, from individual farmer surveys, and from FEMA damage survey reports for each of the county agencies and water districts. Emergency damages at each discharge level were determined as per the methodology described in Section 7.4 and are listed by storm event in Table 14, while the expected annual damages are listed in Table 15.

9.3 Farm Infrastructure

Farm infrastructure damages include the costs to repair wells, ditches, pumps, and canals to their pre-flood condition. These costs were derived from the individual farmer surveys residing in Maricopa County. Farm infrastructure damages at each discharge level were determined as per the methodology described in Section 7.4 and are listed by storm event in Table 14, while the expected annual damages are listed in Table 15.

9.4 Fence Damage

Fence damages were based on the individual farmer surveys reporting the 1993 storm damages. Fence damages at each discharge level were determined as per the methodology described in Section 7.4 and are listed by storm event in Table 14, while the expected annual damages are listed in Table 15.

9.5 Land Restoration

Land restoration costs include the costs to relaser level the damaged cotton acreage following a flood event. The category land restoration also includes the costs to repair damages to the private farmers' irrigation systems in Yuma County. Irrigation damages for private farmers in Maricopa County were available through the individual farm surveys. Thus, the costs to repair the irrigation systems in Maricopa County are not included under the land restoration category, but rather under the farm infrastructure category, outlined in section 7.8.

Both the laser level costs and the irrigation repair costs are based upon figures computed for the Lower Santa Cruz Reconnaissance study, which were based on agricultural damage reports compiled by the Arizona Stabilization and Conservation Service. Laser level costs were based on the required light, medium, and heavy laser leveling costs following a historic flood event. Laser level costs, updated from 1989, are equal to $400 per acre, while the irrigation repair costs are equal to $523 per acre.

Land Restoration costs at each discharge level were determined as per the methodology described in Section 7.4 and are listed by storm event in Table 14, while the expected annual damages are listed in Table 15.

9.6 Public Infrastructure Damages

These damages are based on the costs to repair the public infrastructure for each of the water districts that incurred damage from the 1993 floods to pre-flood conditions. Included in these costs are repairs to irrigation canals, ditches, and levees operated and maintained by the Wellton-Mohawk Irrigation District, the Yuma Irrigation District, and the North Gila Irrigation District. A further description of historic damages experienced by WMIDD is provided in Section 6.0. Damages were gathered through FEMA disaster survey reports and documentation provided by the water districts and confirmed through discussions with water district personnel. Public infrastructure damages at each discharge level were determined as per the methodology described in Section 7.4 and are listed by storm event in Table 14, while the expected annual damages are listed in Table 15.

9.7 Roadway Damages

Roadway damages are based on the roadway repair costs reported to FEMA and to the Federal Highway Administration in order to repair the roads to pre-flood conditions. Roadways that are undergoing significant improvement were omitted from the 1993 damage figures. Such improvements prevent similar damages in less frequent storm events than that of 1993. Roadway damages at each discharge level were determined as per the methodology described in Section 7.4 and are listed by storm event in Table 14, while the expected annual damages are listed in Table 15.

9.8 Structure and Content Damages

Structure damages in Yuma County are based on the sum of the value of the structure prior to the 1993 floods minus the value following the 1993 storm event. The depreciation in structure values due to the flood were collected and provided by the Tax Assessor's Office. Twenty-Seven structures were damaged, one of which is a restaurant, while the other twenty-six are single-family residences. The average loss in structure value for all of the structures is $10,076.88, totalling $272,075.

Maricopa County structure damages consisted of three single-family residences located on farmland. The floods knocked through the house walls, necessitating that the structures be demolished and rebuilt. Replacement costs are estimated at $202,400.

Content damages are based on 55% of the total structure damage reported from the 1993 storm event. Content and structure damages at each discharge level were determined as per the methodology described in Section 7.4 and are listed by storm event are listed in Table 14, while the expected annual damages are listed in Table 15.

9.9 Utility Damages

Utility damages include damage to the public utilities in Reaches 3 and 4 experienced by Wellton-Mohawk Irrigation and Drainage District and the City of Yuma. The damage figures were obtained through FEMA's damage survey reports.

Utility damages at each discharge level were determined as per the methodology described in Section 7.4 and are listed by storm event in Table 14, while the expected annual damages are listed in Table 15.

9.10 Water Costs

Due to the breach in Gillespie Dam, farmers located south of the dam were forced to increase groundwater pumping to replace the loss in surface water diverted at Gillespie Dam in order to irrigate their fields. According to the legal counsel for the Gila Bend-Dendora Valley Water User Association, a significant portion of the water for irrigation in the local electrical district was supplied by gravity diversions at Gillespie Dam. When the dam was breached in early January, the dam no longer served as a diversion structure for delivery of water into the Gila Bend and Enterprise Canals, resulting in increased water costs of $117,000.

The increased water costs experienced at each discharge level were determined per the methodology described in Section 7.4 and are listed by storm event in Table 14, while the expected annual damages are listed in Table 15.

10.0 Without Project Damages

The without project damages by storm frequency and discharge level are listed in Table 14, while the expected annual damages by reach are listed in Table 15. The non-damaging event in Reach 1 is the 91-year event and in Reaches 4 and 5 is the 59-year event. There is a large increase in damages between the non-damaging events and the next largest event due to the fact that once the flood waters surpass the protective measures in place, damages are significant.

TABLE 14
DAMAGES BY STORM EVENT AND DISCHARGE
OCTOBER, 1993 PRICE LEVELS ($1000)

		59-YEAR	100-YEAR	105-YEAR	111-YEAR	127-YEAR	143-YEAR	167-
REACH	DAMAGES	10,000 CFS	15,000 CFS	20,000	25,000	30,000 CFS	35,000	40,000
REACH 1								
	CROP	0	713.0	817.0	846.7	985.0	1003.2	1054.6
	FARM INFRASTRUCTURE	0	599.8	687.2	712.2	828.6	843.9	887.1
	FENCES	0	15.0	17.2	17.8	20.7	21.1	22.14
	LAND RESTORATION	0	433.1	484.7	502.4	584.5	595.3	625.7
	STRUCTURE	0	170.4	195.3	202.4	235.5	239.8	252.1
	WATER	0	98.5	112.9	117.0	136.1	138.6	145.7
REACH 4								
	CROP	0	5007	5736.5	5945.8	6917.0	7044.7	405.5
	EMERGENCY	0	10394.6	11909.1	12343.6	14359.7	14624.8	15374
	LAND RESTORATION	0	5742	5751.3	6818.6	7932.3	8078.7	8492.6
	PUBLIC INFRASTRUCTURE	0	17706.6	20286.5	21026.6	24460.9	24912.6	26188.8
	ROADWAYS	0	13097.8	15006.1	15553.6	18094.0	18428.1	19372
	STRUCTURE	0	217.3	249	258.0	300.2	305.7	321.4
	UTILITIES	0	394.8	452.3	468.8	545.4	555.5	584
REACH 5								
	CROP	0	64.4	73.8	76.5	89.0	90.6	95.3
	EMERGENCY	0	196.4	224.9	233.2	271.2	276.3	290.4
	LAND RESTORATION	0	73.9	84.6	87.7	102.0	103.9	109.2
	PUBLIC INFRASTRUCTURE	0	114.2	130.8	135.6	157.8	160.7	168.9
	STRUCTURE	0	11.82	13.5	14.0	16.3	16.6	17.5
	UTILITIES	0	63.9	73.2	75.9	88.2	89.9	94.5
	TOTAL	0	69,225.72	81,442.95	89,576.20	105,289.18	111,684.20	113,646.8

TABLE 15 GILLESPIE TO YUMA Without Project Expected Annual Damage All Reaches ($1000s)				
	Reach 1	Reach 4	Reach 5	Total
Structure	2.48	3.59	.20	6.26
Content	1.24	1.97	.11	3.32
Crop	10.37	82.68	1.06	94.11
Land Restoration	6.15	94.48	1.22	101.85
Emergency	.00	171.64	3.24	174.88
Farm Infrastructure	8.72	0	0	8.72
Utilities	0	6.52	1.06	7.57
Water	1.43	0	0	1.43
Fences	.22	0	0	.22
Roads	0	216.28	0	216.28
Irrigation	0	292.38	1.89	294.27
All Damage Categories	30.60	869.54	8.77	908.91

11.0 Water Conservation

Two water conservation alternatives at Painted Rock Dam have been considered in the study. The dam currently is operated exclusively to provide flood protection for agricultural lands along the lower Gila River, along the Lower Colorado near Yuma, Arizona, and in the Imperial Valley in California. Alternatives being evaluated are, 1) seasonal storage to elevation 598 feet and 2) seasonal storage to elevation 634 with release rates matching Mexico's historical demand schedule.

11.1 Relationship to the Colorado River System

The Gila River flows into the Colorado River near Yuma, Arizona. Water supply on the Colorado River is over allocated. Currently the Colorado River is used to allocate the lower basin states 7.5 million acre-feet and Mexico 1.5 million acre-feet annually. Gila River flows could contribute to this allocation for the Lower Basin States and conserve water in the main stem of the Colorado River for future use.

Both Mexico and the Lower Basin States receive there water through the Colorado from storage at Hoover Dam. California and Arizona farmers establish contracts with the Bureau of Reclamation within the total allowed allocation for their state. The contractor then possess the right to place orders for Colorado River System Water. Mexico by treaty has been given a similar right to place orders for water. Water supply storage on the Colorado River system is primarily at Hoover Dam. Agricultural contractors place orders at Hoover Dam and three days later water is diverted from the River through a system of canals located primarily downstream of Imperial Dam. If rain occurs during the three day period the contractor has the right to cancel the order. The water would then be lost to Mexico but not counted against the treaty requirements. Only water specifically ordered by Mexico through the system is counted against the treaty.

Water storage at Painted Rock is attractive due to the shortened delivery time of the water to Mexico and the agricultural interests. This would lead to less waste in delivery and more water available in the system. These water savings would increase the number of surpluses in the Colorado River system. Surplus water on the system is currently marketed to municipal and industrial (M&I) users like the Metropolitan Water District (MWD) and Southern Nevada Water Authority.

11.2 Value of Water

Like any other Corps water supply/conservation project, the value of the water conserved behind Painted Rock is equal to the least cost alternative for supplying that water in the "service area". The service area is the area where the conserved water has a beneficial effect. In the case of some alternatives this may not be the area where the Painted Rock conserved water is used. For example, if the Wellton-Mohawk Irrigation District diverts water from the Gila River it could be assumed they would correspondingly reduce their demand for Colorado River system water (over 400,000 AF annually). Additional water would then be available in the system which could be used for M&I purposes if surpluses exist. If Wellton-Mohawk for whatever reason did not reduce its use of Colorado River system water or if system surpluses did not exist the water would be valued as agricultural water.

The value of the water must then be assumed to equal a range of values between agricultural water and full M&I usage. Agricultural water is valued as the resource cost of supplying the water to its end-use. This would include any pumping and transportation costs and any infrastructure required. This cost is assumed to equal $50 per AF. M&I water is similarly valued. The M&I rate used for this study is the typical surplus water rate for MWD, $200 per AF. This rate again represents the resource cost of supply of the water to MWD's service area including power purchased from the Bureau of Reclamation to pump system water through the Colorado River Aqueduct to Southern California.

No attempt has been made to determine the specific split of usage of Painted Rock water. This determination could only be made after an exhaustive study of the Colorado River system including future demands of all users, likelihood of surpluses, and legalities of water usage and transfers. Preliminary discussions between users, particularly at the state level, indicated substantial difference in interpretation of existing and proposed regulation regarding water sources such as Painted Rock. Therefore, a specific breakdown of water conserved behind Painted Rock was considered inappropriate for this level of study. Benefit-cost calculations assume a mid-range value of water conserved (50-50 split between agricultural and M&I values), or $125 per acre foot.

11.3 Alternative Evaluation

Alternative 1, Seasonal Storage, stores up to 371,000 acre-feet (elevation 598) of water with a fixed release rate of 500 cfs during water conservation operations. The yield from this water represents water delivered from the seasonal allocation of water supply space beginning 1 March and continuing through 1 December. The yield from this operation equals 27,500 AF. It is presumed that this water will be used to satisfy treaty requirements to Mexico during the seasonal period. This would require the water flowing through the Wellton-Mohawk area which may increase groundwater pumping costs. Assuming a mid-range water value of $125 per acre foot, total annual benefits equal $3,437,500. Quantifiable costs include real estate costs of $1,860,000 for the acquisition of lands in the seasonal storage pool or on an annual basis, $144,200. Total annual costs of $168,700 include an additional annual $24,500 in operation and maintenance for the water conservation operations. The resultant benefit-cost ratio is 20.4. The net benefits and benefit-cost ratio for this alternative are shown in Table 16.

Alternative 2, Seasonal Matching, stores up to 1,265,000 acre-feet of water after 1 March. This water is released at a rate matching historical average monthly deliveries to Mexico. Average annual yield for this alternative is 47,900 acre-feet. Assuming a mid-range water value of $125 per acre foot, annual benefits equal $5,987,500. Identifiable costs include real estate acquisitions of $5,600,000 or $434,200 annually. Total annual costs of $458,700 include an additional $24,500 in operation and maintenance for water conservation operations. The resultant benefit-cost ratio is 13.1. Net benefits and the benefit-cost ratio for this alternative are shown in Table 16.

TABLE 16
WATER CONSERVATION ALTERNATIVE BENEFIT/COST RATIO

ALTERNATIVE	B/C RATIO	NET BENEFITS
1 - SEASONAL	20.4	3,268,800
2 - MATCHING	13.1	5,528,800

APPENDIX A

PRODUCTION COST FUNCTIONS
GILLESPIE TO YUMA, AZ

Table A-1 ALFALFA: FARM BUDGET ANALYSIS

MONTH	OPERATION	OPERATING COSTS				NUMBER OF TIMES	VARIABLE COST	DIRECT PRODUCT INVESTMENT
		MACH	LABOR	SERV	MATLS			
JAN	IRRIGATE		1.45			17	24.65	24.65
FEB	RERUN BORDERS	0.64	0.62			1	1.26	1.26
JAN	SWATHING	4.44	1.35			9	52.11	0.00
JAN	RAKING	0.92	0.48			9	12.60	0.00
JAN	BALING	2.96	0.89		2.35	9	55.80	0.00
JAN	ROADSIDING	2.77	0.48			9	29.25	0.00
FEB	APPLY HERB.			8.25	9.77	1	18.02	18.02
FEB	APPLY HERB.			3.50	8.39	1	11.89	11.89
AUG	APPLY INSECT.			3.50	8.40	1	11.90	11.90
SEP	APPLY FERT.			6.25	27.82	1	34.07	34.07
OCT	RENOVATE	1.64	1.36			.3	0.90	0.90
OCT	PLANT	3.83	2.28		37.34	.3	13.03	13.03
	PICKUP USE 40 MI/AC	8.05				1	8.05	8.05
	OPER. INT. @ 12.5%			2.29		1	2.29	2.29
	SUBTOTAL	25.25	8.91	23.79	94.07		275.82	126.06

Table A-2 BARLEY: FARM BUDGET ANALYSIS

MONTH	OPERATION	OPERATING COSTS				NUMBER OF TIMES	VARIABLE COST	DIRECT PRODUCT INVESTMENT
		MACH	LABOR	SERV	MATLS			
DEC	DISK	3.76	2.07			1.0	5.83	5.83
DEC	APPLY FERT/INJ	6.40	3.11		13.48	1.0	22.99	22.99
DEC	LASER LEVEL	3.33	2.07			1.0	5.40	5.40
DEC	PLANT	2.61	1.55		19.60	1.0	23.76	23.76
DEC	MAKE BORDERS	0.79	0.78			1.0	1.57	1.57
DEC	IRRIGATE		3.24			.3	3.24	3.24
JAN	APPLY HERB			8.25	.33	4.0	8.58	8.58
FEB	IRR/RUN FERTIL		1.45		5.27	1.0	6.72	6.72
FEB	APPLY HERB			8.25	.65	1.0	2.67	2.67
MAR	IRRIGATE		1.80			1.0	7.20	7.20
JUN	COMBINE HAR-VEST	7.92	2.24			1.0	10.16	0.00
JUN	HAUL, CUSTOM			10.00		1.0	10.00	0.00
JUN	KNOCK BORDERS	0.64	0.62			1.0	1.26	0.00
JUN	DISK RESIDUE	3.76	2.07			1.0	5.83	5.83
	PICKUP USE	6.04				1.0	6.04	6.04
	PROD CREDIT			4.29		1.0	4.29	0.00
	SUBTOTAL	35.25	21.00	30.79	39.33		125.54	99.83

Table A-3 DURHAM WHEAT: FARM BUDGET ANALYSIS

MONTH	OPERATION	OPERATING COSTS				NUMBER OF TIMES	VARIABLE COST	DIRECT PRODUCT INVESTMENT
		MACH	LABOR	SERV	MATLS			
DEC	DISK	3.76	2.07			1.0	5.83	5.83
DEC	APPLY FERT/INJ	6.40	3.11		14.94	1.0	24.45	24.45
DEC	LASER LEVEL	3.33	2.07			1.0	5.40	5.40
DEC	PLANT	2.61	1.55		17.85	1.0	22.01	22.01
DEC	MAKE BORDERS	0.79	0.78			1.0	1.57	1.57
DEC	IRRIGATE		3.24			1.0	3.24	3.24
FEB	APPLY HERB			8.25	.33	0.5	4.29	4.29
FEB	IRR/RUN FERTIL		1.45		5.27	2.0	13.44	13.44
FEB	APPLY HERB			8.25	.65	0.5	4.45	4.45
MAR	IRRIGATE		1.45			4.0	5.80	5.80
JUN	COMBINE HARVST	7.92	2.24			1.0	10.16	0.00
JUN	HAUL, CUSTOM			11.00		1.0	11.00	0.00
JUN	KNOCK BORDERS	0.64	0.62			1.0	1.26	0.00
JUN	DISK RESIDUE	3.76	2.07			1.0	5.83	5.83
	PICKUP USE	6.04				1.0	6.04	6.04
	OPER INT @ 12.5%			4.58		1.0	4.58	0.00
	SUBTOTAL	35.25	20.65	32.08	39.04		129.35	102.35

Table A-4 **PIMA COTTON: FARM BUDGET ANALYSIS**

MONTH	OPERATION	OPERATING COSTS				NUMBER OF TIMES	VARIABLE COST	DIRECT PRODUCT INVESTMENT
		MACH	LABOR	SERV	MATLS			
DEC	PLOW	9.03	3.11			1	12.14	12.14
DEC	DISK	3.76	2.07			1	5.83	5.83
JAN	LASERP LEVEL	3.33	2.07			1	5.40	5.40
JAN	APPLY HERB			8.25	5.77	1	14.02	14.02
JAN	DISK	1.20	1.04			1	2.24	2.24
JAN	LIST	2.80	1.55			1	4.35	4.35
FEB	PREIRRIG.		3.61			1	3.61	3.61
MAR	MULCH	1.50	1.24			1	2.74	2.74
MAR	PLANT	3.09	1.55		6.23	1	10.87	10.87
MAR	REMOVE CAP		1.04			1	1.04	1.04
APR	CULTIVATE	1.88	1.55			3	10.29	10.29
MAY	IRRIGATE		2.17			5	10.85	10.85
MAY	IRR/RUN FERT		2.17		7.47	3	28.92	28.92
JUL	APPLY HERB			8.25	9.42	1	17.67	17.67
JUN	HAND WEED		12.72			1	12.72	12.72
JUL	APPLY INSECT			3.50	0.95	3	13.35	13.35
AUG	APPLY INSECT			3.50	8.26	5	58.80	58.80
AUG	APPLY INSECT			3.50	3.71	3	21.63	21.63
SEP	APPLY INSECT			3.50	5.99	1	9.49	9.49
OCT	APPLY DEFOL			4.00	15.28	1	19.28	19.28
OCT	APPLY DEFOL			4.00	4.07	1	8.07	8.07
OCT	PREPARE ENDS	.46	.26			1	0.71	0.00
NOV	FIRST PICK	24.56	5.61			1	30.17	0.00
NOV	MAKE MODULE	6.16	2.59		.63	1	9.38	0.00
NOV	ROOD COTTON			25.00		1	25.00	0.00
SEP	HAUL-CUSTOM			5.29		1	5.29	0.00
SEP	GINNING			105.88		1	105.88	0.00
DEC	CLASSING			2.21		1	2.21	0.00
NOV	CUT STALKS	1.83	1.04			1	2.87	2.87
NOV	DISK RESIDUE	3.76	2.07			1	5.83	5.83
	PICKUP USE 60 MI/AC	12.09				1	12.09	12.09
	OPER. INT. @ 12.5%			13.83		1	13.83	0.00
	SUBTOTAL	75.45	47.46	190.71	67.78		486.58	294.10

Table A-5 **UPLAND COTTON: FARM BUDGET ANALYSIS**

MONTH	OPERATION	OPERATING COSTS				NUMBER OF	VARIABLE	DIRECT
		MACH	LABOR	SERV	MATLS	TIMES	COST	PRODUCT INVESTMENT
DEC	DISK	6.97	3.11			1	10.08	10.08
DEC	PLOW	3.76	2.07			1	5.83	5.83
JAN	LASERPLANE	3.33	2.07			1	5.40	5.40
JAN	APPLY HERB			8.25	5.77	1	14.02	14.02
JAN	DISK	1.20	1.04			1	2.24	2.24
JAN	LIST	2.80	1.55			1	4.35	4.35
FEB	PREIRRIG.		3.61			1	3.61	3.61
MAR	MULCH	1.50	1.24			1	2.74	2.74
MAR	PLANT	2.69	1.55		7.18	1	11.42	11.42
MAR	REMOVE CAP	1.54	1.04			1	2.58	2.58
APR	CULTIVATE	1.88	1.55			3	10.29	10.29
MAY	IRR/RUN FERT		2.17		7.47	3	28.92	28.92
JUN	IRRIGATION		2.17			2	4.34	4.34
JUN	HAND WEED		20.35			1	20.35	20.35
JUN	APPLY HERB			8.25	9.42	1	17.67	17.67
JUL	HAND WEED		6.36			.5	3.18	3.18
JUL	APPLY INSECT			3.50	6.68	2	20.36	20.36
JUL	APPLY INSECT			3.50	8.26	5	58.80	58.80
AUG	APPLY INSECT			3.50	3.71	3	21.63	21.63
AUG	IRR/RUN FERT		2.17		5.27	1	7.44	7.44
SEP	APPLY INSECT			3.75	5.99	1	9.74	9.74
SEP	APPLY DEFOL			4.00	16.44	1	20.44	20.44
SEP	APPLY DEFOL				6.57	1	10.57	10.57
SEP	PREPARE ENDS	.46	.25			1	0.71	0.00
SEP	FIRST PICK	24.56	5.61			1	30.17	0.00
SEP	MAKE MODULE	6.16	2.59		.63	1	9.38	0.00
NOV	ROOD COTTON			50.00		1	7.65	0.00
SEP	HAUL-CUSTOM			7.65		1	107.06	0.00
SEP	GINNING			107.06		1	107.06	0.00
DEC	CLASSING			4.55		1	4.55	0.00
NOV	CUT STALKS	1.83	1.04			1	2.87	2.87
NOV	DISK RESIDUE	3.76	2.07			1	5.83	5.83
	PICKUP USE 60 MI/AC	12.09				1	12.09	12.09
	OPER. INT. @ 12.5%			12.42		1	0.00	0.00
	SUBTOTAL	74.53	63.61	220.43	83.39		578.37	316.79

Table A-6 WATERMELON: FARM BUDGET ANALYSIS

MONTH	OPERATION	OPERATING COSTS				NUMBER OF TIMES	VARIABLE COST	DIRECT PRODUCTION INVESTMENT
		MACH	LABOR	SERV	MATLS			
DEC	RIP	4.68	2.64			1.3	9.52	9.52
DEC	DISK	2.43	1.33			2	7.52	7.52
DEC	LASER LEVEL	3.43	1.98			2	10.82	10.82
JAN	SOIL FERTILITY			3.00		1	3.00	3.00
JAN	APPLY FERTIL.	1.99	1.98		41.72	1	45.69	45.69
JAN	LIST	2.48	1.33			1	3.81	3.81
JAN	SHAPE BEDS	16.66	10.58			2	54.48	54.48
JAN	PLANT	6.05	4.53		62.13	1	72.71	72.71
JAN	MAKE DITCHES	0.97	1.40			7	9.59	9.59
JAN	DUST CONTROL	0.13	0.15			150	42.00	42.00
JAN	IRRIGATE		4.98			1	4.98	4.98
JAN	KNOCK DITCHES	0.47	0.20			7	4.69	4.69
FEB	CULTIVATE	4.38	3.97			6	50.10	50.10
FEB	THINNING	1.73	75.42			1	77.15	77.15
MAR	APPLY FERTIL.	4.67	2.89		20.34	2	55.80	55.80
MAR	APPLY INSECT.	2.06	1.98		13.63	6	106.02	106.02
MAR	APPLY HERB.	1.99	1.98		6.50	1	10.47	10.47
MAR	INCORPORATE HERB.	5.32	4.53			1	9.85	9.85
MAR	HAND WEEDING	2.08	52.37			1	54.45	54.45
MAR	IRRIGATE		2.20			4	8.80	8.80
APR	TURN VINES		28.28			1	56.56	56.56
APR	IRRIG/RUN FERT.		3.31		14.60	1	35.82	35.82
MAY	CUT MELONS		52.92			4	211.68	0.00
MAY	LOAD PRODUCE	53.91	97.04		34.65	4	742.40	0.00
MAY	HAUL, CUSTOM			170.00		1	170.00	0.00
JUN	RESIDUE DISPOSAL	2.43	1.33			1	3.76	0.00
	PICKUP USE 50 MI/AC	11.26				1	11.26	0.00
	OPER. INT @ 8.5%			23.35		1	23.35	0.00
		129.12	358.32	196.35	193.57		1,890.28	733.83

Table A-7 WESTERN LETTUCE: FARM BUDGET ANALYSIS

MONTH	OPERATION	OPERATING COSTS MACH	LABOR	SERV	MATLS	NUMBER OF TIMES	VARIABLE COST	DIRECT PRODUCTION INVESTMENT
JUL	RIP	7.21	3.97			1.3	14.53	14.53
JUL	DISK	2.78	1.33			2	8.22	8.22
JUL	LASER LEVEL	8.1	3.97			2	24.14	24.14
JUL	MAKE BORDERS	0.15	.2			1	0.35	0.35
JUL	PREIRR		4.41			2	8.82	8.82
JUL	SOIL FERTILITY			3		1	3.00	3.00
JUL	DUST CONTROL	0.13	.15			170	47.60	47.60
AUG	APPLY FERT	.6	.66		60.72	1	61.98	61.98
AUG	APPLY HERB	3.15	1.33		74.78	1	79.26	79.26
SEP	LIST	1.85	1.59			1	3.44	3.44
SEP	PLANT	7.92	3.97		121.8	1	133.69	133.69
SEP	SET SPRINKLERS	.71	6.02			1	6.73	6.73
SEP	IRRIG/2ND SYSTEM	102.63	5.96			1	108.59	108.59
SEP	REMOVE SPRINKLERS	0.71	6.02			1	6.73	6.73
SEP	MAKE DITCHES	0.47	0.2			1	0.67	0.67
SEP	IRRIGATE/RUN FERT		3.96		8.02	1	11.98	11.98
SEP	FIELD SCOUTING			6		3	18.00	18.00
SEP	APPLY INSECT			4.32	6.41	1	10.73	10.73
SEP	APPLY INSECT			4.32	5.49	2	19.62	19.62
OCT	APPLY INSECT	0.17	.13		24.96	2	50.52	50.52
OCT	IRR/RUN FERT		1.32		16.05	4	69.48	69.48
OCT	THINNING	1.73	37.71			1	39.44	39.44
OCT	CULTIVATE	3.22	1.98		16.05	1	21.25	21.25
OCT	APPLY FUNGICIDE	0.17	0.13		39.38	1	39.68	39.68
OCT	APPLY INSECT	0.17	0.13		35.96	3	108.78	108.78
NOV	BIRD CONTROL			15		1	15.00	15.00
NOV	MAKE DITCHES	0.24	.1			2	0.68	0.68
NOV	IRR/RUN FERT		1.32		20.06	1	21.38	21.38
NOV	HAND WEEDING	0.17	18.86			1	19.03	19.03
NOV	APPLY INSECT	0.17	.13		39.6	2	79.80	79.80
DEC	KNOCK BORDERS	0.15	.2			1	0.35	0.35
DEC	KNOCK DITCHES	0.47	.2			1	0.67	0.67
DEC	HARVEST, LOAD			1416	526.57	1	1942.57	0.00
JAN	DISK RESIDUE	2.78	1.33			1	4.11	4.11
	PICKUP USE 50 MI/AC	11.26				1	11.26	11.26
	OPERATING INT @ 8.5%			15.36		1	15.36	15.36
	SUBTOTAL	145.85	107.28	1448.64	995.85		3007.44	1049.51

APPENDIX G

ENVIRONMENTAL RESTORATION

THE STATE OF ARIZONA

GAME & FISH DEPARTMENT

2221 West Greenway Road, Phoenix, Arizona 85023-4399 (602) 942-3000

December 16, 1994

Mr. Joe Dixon
U.S. Army Corps of Engineers
3636 N. Central Avenue, Suite 740
Phoenix, Arizona 85012-1936

Re: Gila River Reconnaissance Study - Environmental Restoration Technical Appendix

Dear Mr. Dixon:

The Department has reviewed the technical appendix, "Habitat Analysis of the Lower Gila River, Arizona", for the Gila Reconnaissance Study. The analysis and plan are technically sound and we believe that implementation of habitat improvement measures analyzed could result in significant restoration of important habitat types historically found along the river corridor.

We are also interested in aspects of the water conservation portion of the Reconnaissance Study which investigate modifications to the operation of Painted Rock Dam. Based on our experience working with the Corps toward revision of the operation of Alamo Dam, we believe that there is the potential for significant improvement in habitat conditions along the river below Painted Rock Dam through the re-establishment of natural processes, related to the shape of the hydrograph, which stimulate natural revegetation in pattern, if not in scale.

As mentioned in our letter of October 31, the Department is very interested in participating in riparian restoration aspects of any future studies but we are uncertain that we could bear the cost-share burden entirely. The October 31 letter also discusses constraints related to our Heritage Fund.

We appreciate the opportunity to work with your office on this effort and other efforts which benefit the wildlife resources of Arizona.

Sincerely,

Bruce D. Taubert
Assistant Director

BDT:ww

cc: Sam Spiller, US Fish and Wildlife Service, Phoenix

ARIZONA RIPARIAN COUNCIL

Center for Environmental Studies Box 873211
Arizona State University Tempe AZ 85287-3211

December 20, 1994

Mr. Sam Arrowood
U.S. Army Corps of Engineers
Los Angeles District
Arizona Area Office, Planning Section C
Phoenix AZ 85012-1936

Re: Habitat Analysis of the Lower Gila River, Arizona

Dear Mr. Arrowood:

Thank you for letting the Arizona Riparian Council be a part of your technical review team for the Lower Gila River Reconnaissance study. I appreciate the opportunity to comment on the study, Habitat Analysis of the Lower Gila River, Arizona prepared by the Harris Environmental Group. Current conditions, future conditions without any management plans, and future conditions with proposed habitat restoration projects of vegetation along the lower Gila River were reviewed in the study.

The study area which extends from Painted Rocks Dam, west to the confluence with the Colorado River has responded positively to the stream flows of 1993. Reestablishment of riparian vegetation in some areas along the channel are positive signs that portions of the Gila River can be rehabilitated. In the study, alternatives are outlined in the study which present potential rehabilitation opportunities for increasing and maintaining riparian vegetation. The alternatives recognize and incorporate the hydrologic conditions that exist in Arizona.

The Arizona Riparian Council supports the technical merits of this study and recommends the Corps continue efforts to develop environmental opportunities to restore riparian vegetation and improve wildlife habitat for this portion of the Gila River.

Sincerely,

Kris Randall

Kris Randall
President

President, Kris Randall (602) 207-4510•Vice President, Ruth Valencia (602) 789-3510
Secretary, Cindy D. Zisner (602) 965-2490•Treasurer, Diane Laush (602) 870-6763

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

Fife Symington, Governor   Edward Z. Fox, Director

Nonpoint Source Unit, 5th Floor
1-800-234-5677 (Arizona Only)
FAX (602) 207-4467
(602) 207-4510

December 20, 1994

Mr. Sam Arrowood
U. Army Corps of Engineers
Los Angeles District
Arizona Area Office, Planning Section C
Phoenix AZ 85012-1936

Re: Habitat Analysis of the Lower Gila River, Arizona

Dear Mr. Arrowood:

Kris Randall of my staff has reviewed the Habitat Analysis of the Lower Gila River, Arizona prepared by the Harris Environmental Group. The study evaluates current conditions, future conditions without any management plans, and future conditions with proposed habitat restoration projects of vegetation along the lower Gila River. The study area extended from Painted Rocks Dam, west to the confluence with the Colorado River.

The rehabilitation alternatives outlined in the study present potential opportunities for increasing and maintaining riparian vegetation which are appropriate for the conditions in Arizona. ADEQ supports the technical merits of this study and recommends the Corps continue efforts to develop environmental opportunities to restore riparian vegetation for this portion of the Gila River.

Sincerely,

Brian Munson
Director, Water Division

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ARIZONA ECOLOGICAL SERVICES STATE OFFICE
2321 W. Royal Palm Road, Suite 103
Phoenix, Arizona 85021-4951

Telephone: (602) 640-2720 FAX: (602) 640-2730

December 22, 1994

In Reply Refer To:
AESO/ES

Mr. Sam Arrowood
Project Manager
Planning Section C
U.S. Army Corps of Engineers
3636 N. Central Avenue, Suite 740
Phoenix, Arizona 85012-1936

Dear Mr. Arrowood:

We have reviewed the Draft Habitat Analysis of the Gila River, Arizona (Analysis), dated November 28, 1994, and have the following comments.

The analysis was drafted for the Gila River, Gillespie Dam to Yuma Reconnaissance Study (Study) being conducted by the Corps of Engineers. The analysis will be used as an appendix to the Environmental Restoration alternative to the study.

The methodology used to determine the habitat values of the vegetation along the lower Gila River, from Painted Rock Dam west to the river's confluence with the Colorado River is technically sound. The use of these values in environmental restoration along the Gila River will result in the increase in important wetland and riparian habitat types along the river.

If we can be of further assistance or you have any questions, please contact Ron McKinstry or Don Metz.

Sincerely,

Sam F. Spiller

Sam F. Spiller
State Supervisor

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM (AES)
Director, Arizona Game and Fish Department, Phoenix, AZ

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
YUMA DISTRICT OFFICE
YUMA RESOURCE AREA
3150 WINSOR AVENUE
YUMA, ARIZONA 85365

TAKE PRIDE IN AMERICA

IN REPLY REFER TO:

6760 (055)

December 20, 1994

Sam Arrowood
U.S. Army Corps of Engineers
Los Angeles District
3636 North Central Avenue, Suite 740
Phoenix, Arizona 85012-1936

Dear Mr. Arrowood:

The Yuma Resource Area supports the U.S. Army Corps of Engineer's proposed environmental restoration project for the Lower Gila River. The Bureau of Land Management has recognized the importance of protecting and improving valuable riparian resources and has implemented its Riparian-Wetland Initiative for the 1990's strategic plan as part of the Bureau's Fish and Wildlife 2000 Program. The environmental restoration on public lands within the proposed project will help meet objectives outlined in this strategic plan. Yuma Resource Area staff wildlife biologists look forward to coordinating with your agency on these projects in the future.

If you have any questions, please contact Wildlife Biologist David Smith at the above address or call 602-726-6300.

Sincerely,

Patricia A. Boykin

acting

Joy Gilbert
Area Manager

United States Department of the Interior
BUREAU OF LAND MANAGEMENT
Phoenix District Office
2015 West Deer Valley Road
Phoenix, AZ 85027

In reply refer to:
1700(026)

January 3, 1995

W. Michael Ternak, PE
Study Manager
U. S. Army Corps of Engineers
Los Angeles District
3636 North Central Avenue
Suite 740
Phoenix, AZ 85012-1936

Dear Sir:

I would like to thank both you and Sam Arrowood for involving us (BLM) in the Gila River Environmental Restoration Reconaissance Study. I hope our participation has strengthened your proposals. The concepts, techniques, and ideas brought forward are innovative and applicable, and we support your recommendation to proceed with the Feasibility portion of the process. We are glad that you have found a sponsor agency and will continue to provide input into the process. We have a chance to do some worthwhile riparian work. Thank you for the opportunity.

Sincerely

Hector B. Abrego

John R. Christensen
for Area Manager
Lower Gila Resource Area

Habitat Analysis of the Lower Gila River, Arizona

Conducted for the
U.S. Army Corps of Engineers
Los Angeles District

by

Dr. Lisa K. Harris, Dr. Margaret Livingston,
Mark Briggs, and David Harnish
Harris Environmental Group
1749 E. 10th Street
Tucson, Arizona 85719

December 1994

A. INTRODUCTION

A reconnaissance study was conducted to determine the habitat values of the vegetation along the lower Gila River, from Painted Rock Dam, west to the river's confluence with the Colorado River. A modified habitat evaluation procedure was conducted. The vegetation communities along the river were assessed in terms of the value they offer as wildlife habitat, and habitat units were calculated based on the assessed value of the vegetation community and its size in acres.

The Painted Rocks Dam was constructed in 1959. Since then, the riparian community has been altered, and the value of the area in terms of wildlife habitat has declined. This study evaluates, in terms of habitat units, the vegetation communities present before the dam was built (called modern historic conditions), current conditions, future conditions without any management plans, and future conditions with the proposed habitat restoration project.

B. VEGETATION COMMUNITIES

Currently, there are 4 vegetation communities found along the lower Gila River, from Painted Rock Dam to its confluence with the Colorado River. According to Brown, Lowe, and Pase (1979) these can be described as:

Cottonwood-Willow Series (223.21): This vegetation Series occurs along the lower channels of the Gila river with intermittent stream flow (particularly during winter and spring months). This Series is typical of major stream beds where alluvial sands, clays, and gravels on flood plains occur. The predominant species in these Series are: *Populus fremontii*, and willows (*Salix* spp.) such as *S. gooddingii* and *S. exigua*.

Saltcedar Disclimax Series (234.72): This vegetation Series occurs in areas along the Gila River that are relatively saline sites and have more stabilized flow due to damming. Stabilized flow has aided in effective dissemination of saltcedar (*Tamarisk chinensis*) and evergreen athel (*Tamarix aphylla*) in areas that were most likely previously cottonwood-willow communities. Dense thickets of these plants and other salt-shrub species such as arrowweed (*Pluchea sericea*) are typical for this Series.

Leguminous Short Tree Species (224.52): This Series is listed under Sonoran Riparian and Oasis Forests (224.5), and the Sonoran Desert Scrub (154.1) Biomes. For the study area, this Series is within the Sonoran Desert Scrub Biome. This Series is found along larger drainage-ways of the Gila River and relatively drier areas along the major channels where cottonwood-willow and saltcedar disclimax Series do not prevail. Some of the predominant species in this Series for this region are: western honey mesquite (*Prosopis glandulosa* var. *torreyana*), blue paloverde (*Cercidium floridum*), smoketree (*Dalea spinosa*), and canyon ragweed (*Ambrosia ambrosioides*).

Cattail Series (Wetlands/Marsh) (224.71): This Series is classified under the Sonoran Interior Marshland Biome. In this relatively rare Series, plants are frequently dependent on waste water discharges, agricultural drains, and silt-laden reservoirs due to the lack of available natural springs or groundwater tables. The prevalent species is cattail (*Typha domingensis*) followed by bulrushes (*Scirpus* spp.). These species may intermingle with adjacent scrubland species such as saltcedar, arrowweed, quailbush (*Atriplex lentiformis*), and mesquite.

Historically, the Gila River was dominated by cottonwood, willow, and different species of mesquite. In addition, there were more emergent plant species along the edge of the low flow channel of the river (Graf et al. 1994). Historical photos indicate that there was a constant flow of water within the river throughout the year. Early accounts by missionaries in the 18th century described "groves of cottonwoods, alder, willow, and mesquite along the river" and "the lack of grass suitable for pasturage" (Graf et al. 1994:32). In addition, other visitors to the valley wrote that "thickets of mesquite covered the lower terrace, making travel to the water difficult" (Graf et al. 1994:34). The oxbow lakes formed from overflow channels "provided water and shade for birds, mammals, including duck, geese, swan, quail, dove, crane, raven, hawk, owl, beaver, deer, wolf, panther, wildcat, and possibly bear" (Graf et al. 1994:34).

C. HABITAT ANALYSIS METHODOLOGY

Habitat values for the vegetation communities along the lower Gila River, from the Painted Rocks Dam west to the river's confluence with the Colorado River, were analyzed using a modified Habitat Evaluation Procedure (HEP), as well as professional knowledge. The methodology is commonly used by state and federal agencies such as the Arizona Game & Fish Department and U.S. fish & Wildlife Service. The methodology was also most recently used by the U. S. Army Corps of Engineers for the Rio Salado Habitat Analysis report (September, 1994) and Ohmart and Anderson (1993).

To assess the current conditions of the vegetation communities present, 17 representative sites along the lower Gila were visited and 6 variables were measured at each site. Sites were selected based on the nature of their vegetation communities, and were representative of the communities present. Five representative sites within the Dendora Valley, 2 sites within the Agua Caliente area, 3 sites within the BLM-owned area, and 7 sites in the Wellton-Mohawk Valley area were included in the analysis. On-site field work was conducted on 13 November, 19 November, and 20 November, 1994. Because of the reconnaissance nature of this project, and the short time allowed to complete the analysis, there may be smaller vegetation communities within the Gila River riparian area that were not analyzed.

The assessment of the current conditions of the present vegetation communities is based on a one-time (November) evaluation of each site. At other times of the year, water may be present in specific portions of the year. For example, in the Dendora Valley, water is present during the winter months of the year. At the time of the evaluation, there was little water in that reach of the river.

Thematic map layers of the lower Gila riparian area were created by digitizing boundaries from the USGS topographic maps (1965, 1973, 1982, 1986) into AUTOCAD, Release 12. The acreage of each site or polygon was generated from the AUTOCAD program. Vegetation communities were designated by on-site field work on November 13, 1994, November 19 - 20, 1994, from aerial photographs from 1953, 1958, 1969, 1978, 1986-87, and 1993, and from a video and still photographs taken on an aerial fly-over on November 9, 1994. The designated vegetation communities were digitized with AUTOCAD to complete the thematic map layers of the riparian area.

The 6 categorical variables were defined as (see Exhibit 1 for a complete description of the values of each variable):

Vegetation Series: A description of the type of dominate vegetation present, based on the Brown, Lowe, and Pase (1979) hierarchical plant classification system. Each site was described according to its Brown, Lowe, and Pase (1979) series. The series were then combined into a second classification system based on 8 vegetation series (Ohmart and Anderson, 1993).

Vegetation Structure: The vegetation communities found within the site were described based on the structural diversity outlined in Ohmart and Anderson (1993). The value of the variable ranges from 1 - 6, where 1 is the most vertically structured plant community and 6 represents the community with the least vertical structure.

Threatened and Endangered Species Habitat: Sites were assessed for habitat suitable for threatened and endangered species, specifically the Yuma Clapper Rail (*Rallus longirostris yumanensis*), a federally listed endangered species, and the Southwestern Willow Flycatcher (*Empidonax traillii expimus*), a federally proposed endangered species. The preferred habitat is ponded water with late seral cattails (*Typhus* spp.) for the Yuma Clapper Rail, and cottonwood-willow trees with water and cattails for the Southwestern Willow Flycatcher (Eddleman, 1989). Habitat that can support the Southwestern Willow Flycatcher can also support other Neotropical migrant bird species. The value of the variables ranged from 0 - 1.0, with 1.0 representing ponded water with late seral cattails and cottonwoods, 0.5 as ponded water with no cattails or cottonwood trees, and 0.0 as not suitable habitat.

Continual Water Source: Sites were assessed for visible water. Visible water was given the highest value of 1.0, visible but minimal water (large puddles, no associated aquatic plants) was rated as 0.5, and no standing water was given a 0.0 value.

Bird/Wildlife Species Present: The presence and/or sign of wildlife and bird species was assessed for each site. The types of possible wildlife and bird species found to inhabit the lower Gila River was based on reports conducted by the University of Arizona (1970) and

Graf et al. (1994). In addition to actual observation of wildlife species, the value for bird/wildlife species was also based on the vegetation community and structural diversity present. The sites with a high structural diversity and presence of native vegetation and/or marsh conditions were given the highest values. The range of values was between 0 and 1.0, with 1.0 representing the potential for all possible species to be present.

Undisturbed/disturbed habitat: Sites were assessed for the degree of disturbance that occurred within the site, as well as adjacent to it. Areas with high levels of disturbance were assessed a low value while relatively undisturbed areas were assessed a high value. Disturbances included recent grading, proximity to agricultural land, and illegal dumping. Undisturbed areas were those that appeared to have little human influence. Values ranged from 0 - 1.0, with 1 being assigned to areas that were relatively free of disturbance.

In addition to measuring these 6 variables, each site was examined for evidence of deposition or degradation based on position of root flares of in-channel vegetation, evidence of recent flow events based on debris accumulation on in-channel features (such as bridges), width of active channel, width of vegetation communities, description of geomorphic landscape such as main channel, secondary terraces, elevation of secondary terraces above channel bed, evidence of alluvial deposition on secondary terraces, and presence of shallow saturated soils.

The historical pre-dam conditions were assessed by measuring the vegetation communities present in 1953 aerial photographs of the Dendora Valley and Aqua Caliente areas, 1958 aerial photographs of the Wellton-Mohawk Valley and BLM-owned areas, and a description of the pre-development ecological conditions (Graf et al. 1994). Based on the conditions outlined in Graf et al. (1994) and observations taken from the aerial photographs of the study area, the values of the 6 variables were estimated and the area for each of the historic streamside vegetation communities was determined. Habitat units for each of the vegetation communities were calculated.

For future conditions, with and without restoration projects, we estimated the values of the 6 variables and calculated the habitat units. Our assessments were based on the estimated conditions that are likely to occur in the future for each of the current vegetation type.

The *Vegetation Series* and *Vegetation Structure* variables were used to determine the wildlife values computed by Anderson and Ohmart (1993). The elevation (ft) of the lower Gila River ranges from 135 feet at its confluence with the Colorado River and 532 feet in Dendora Valley, just below Painted Rock Dam. According to the latitudinal and longitudinal blocks described in Anderson and Ohmart (1993), the lower Gila River is located in block 5. Based on this information we were able to use Anderson and Ohmart's (1993) look-up Table 4 to compute the wildlife values. These values were referred to as A-O values.

The A-O values were re-scaled to a 0.0 - 1.0 scale by adding 3.3 to the value and dividing by 6.6. The re-scaled A-O values were then consistent with the scale of our other variables.

For each site the value of the variables *Threatened and Endangered Species Habitat, Continual Water Source, Bird/Wildlife Species Present, Undisturbed/Disturbed Habitat*, and the *Re-scaled A-O Value* were added for a total and then averaged.

The acreage of each site was determined from our computerized maps of the area. A *Habitat Unit* value was then determined by multiplying the *Acreage* by the *Average Value* of the habitat.

D. RESULTS

Modern Historic Vegetation Communities

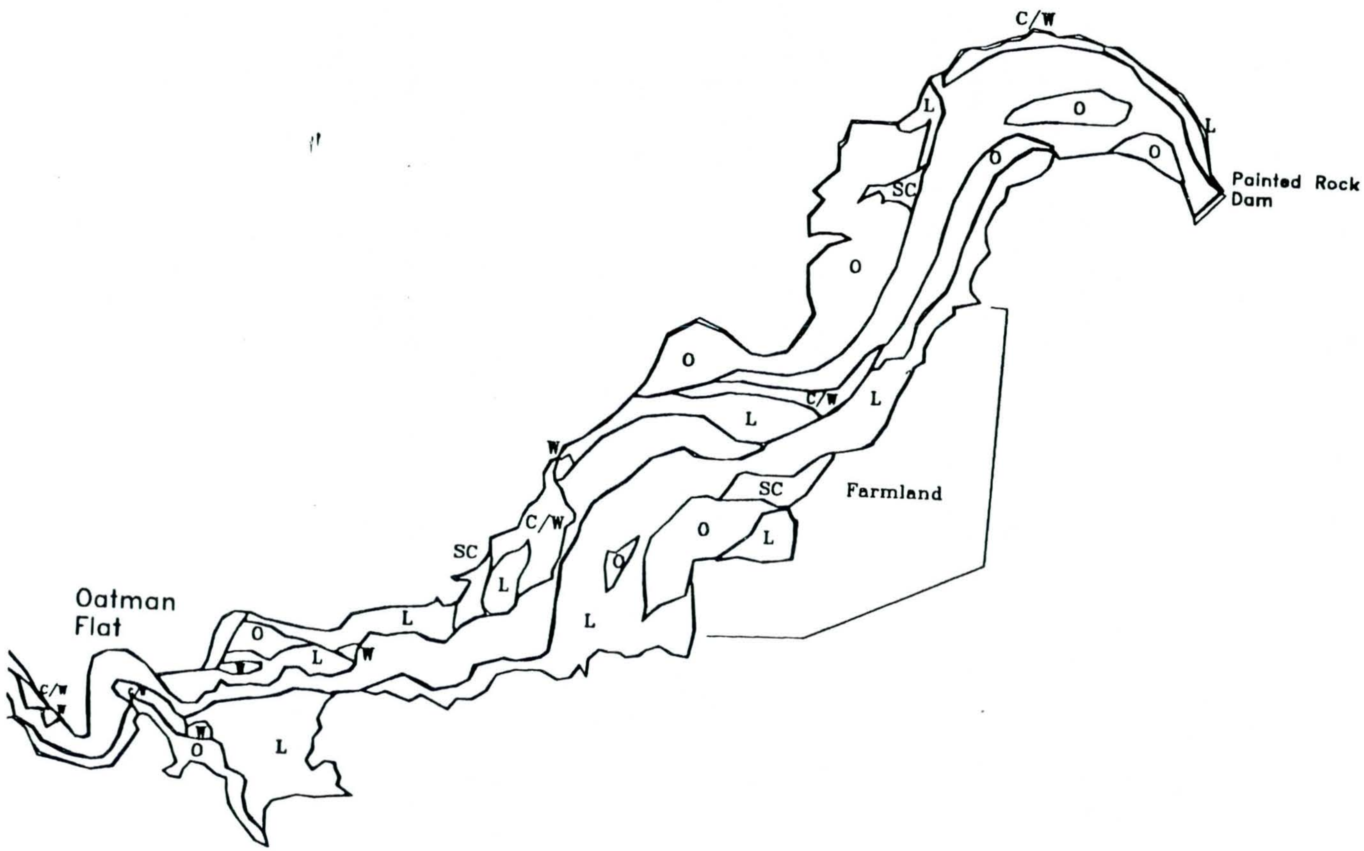
Modern historic vegetation communities were primarily leguminous short tree species, cottonwood/willow, and marsh/wetland communities. There were several areas near agricultural lands that were dominated by saltcedar (Figures 1 - 4). Because of the scale of the maps, the marsh/wetland communities were hard to distinguish and the number of marsh/wetland sites may be under-represented. Habitat units for these four communities are shown in Tables 1 and 2.

In the upper portion of the Lower Gila River (BLM property, Aqua Caliente, and Dendora Valley), the predominant vegetation community contained leguminous short tree species, such as mesquite. The Wellton-Mohawk area was also dominated by leguminous short tree species (Figure 4). However, the mesquite trees were more dense in this area and formed mesquite bosques. In addition, there was more vegetation growing in the channel in the Wellton-Mohawk Valley than in the upper portion of the river, suggesting the presence of more marsh/wetland communities in the lower section of the river.

Current Vegetation Communities

The current vegetation communities within the three upper designated areas (Dendora Valley, Agua Caliente, and the BLM property) of the river, were primarily saltcedar, with remnant stands of mesquite (Figures 5 - 8). There were a few young cottonwood/willow communities within the BLM property. Cottonwood/willow, wetland/marsh, leguminous short trees, and saltcedar communities were found within the Wellton-Mohawk Valley area (Figure 8). Saltcedar plants were found in all of the sites.

Figure 1: Dendora Valley Area Modern Historic Vegetation Communities (1953)
Location: Oatman Flat to Painted Rock Dam



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

0 1 Mile N ↑

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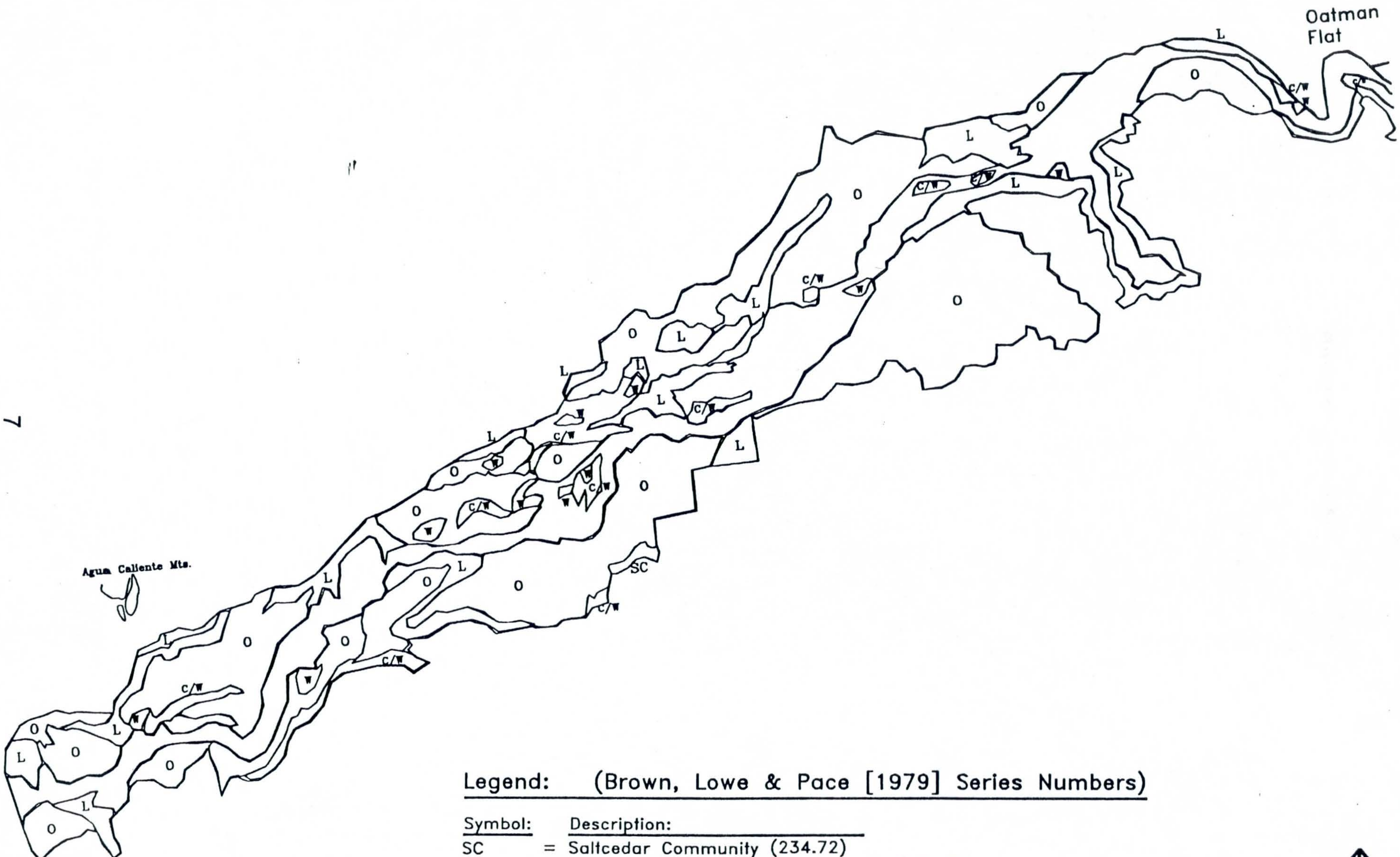
Figure 2: Agua Caliente Area Modern Historic Vegetation Communities (1953)
Location: Agua Caliente Mts to Oatman Flat



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

0 1 Mile N ↑

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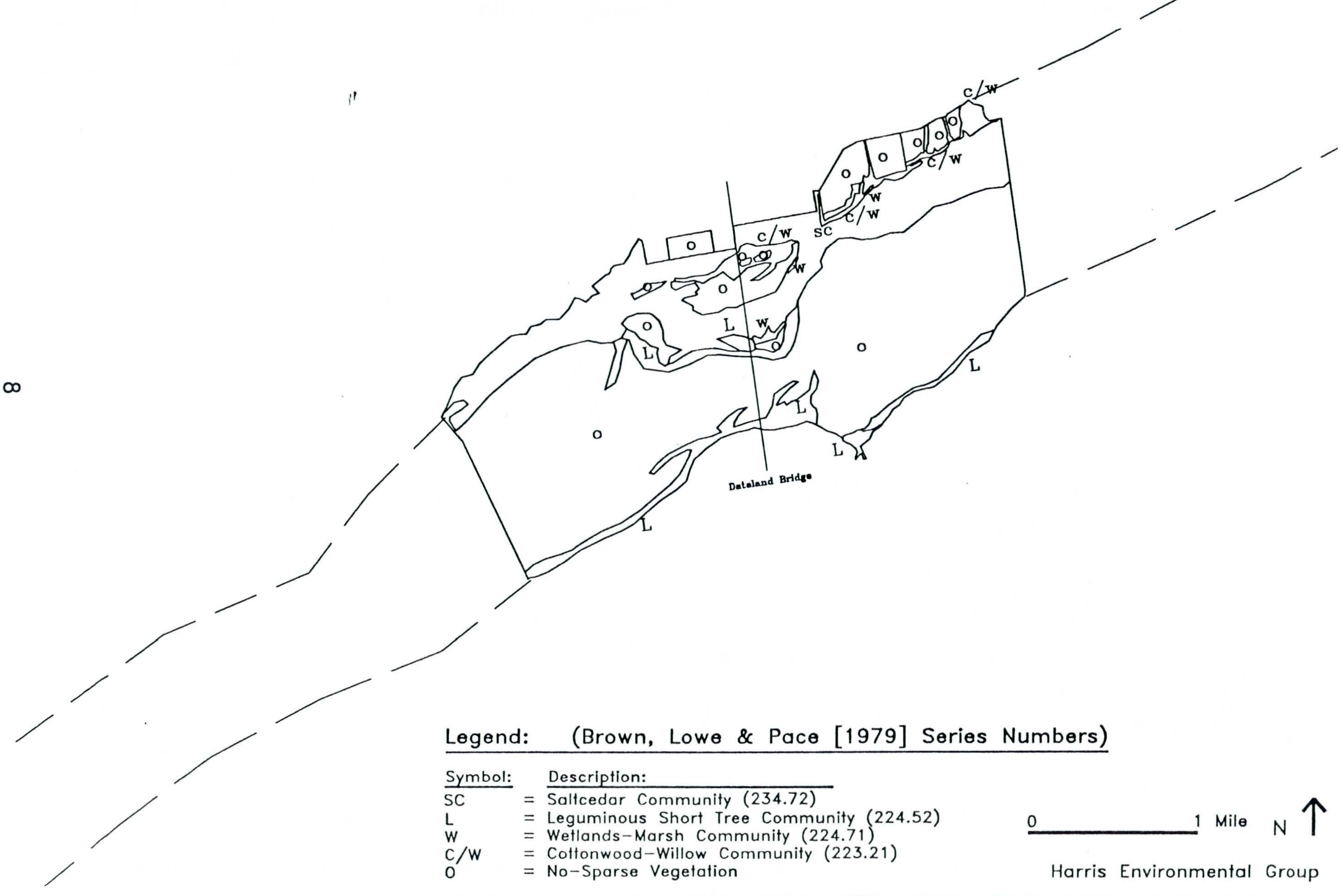
Figure 3: BLM-Owned Property Modern Historic Vegetation Communities (1958)
Location: (1.7) Miles West of Dateland Bridge to (1.5) Miles East
(Available Aerial Photographs for Dateland Bridge Only)



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

0 1 Mile N

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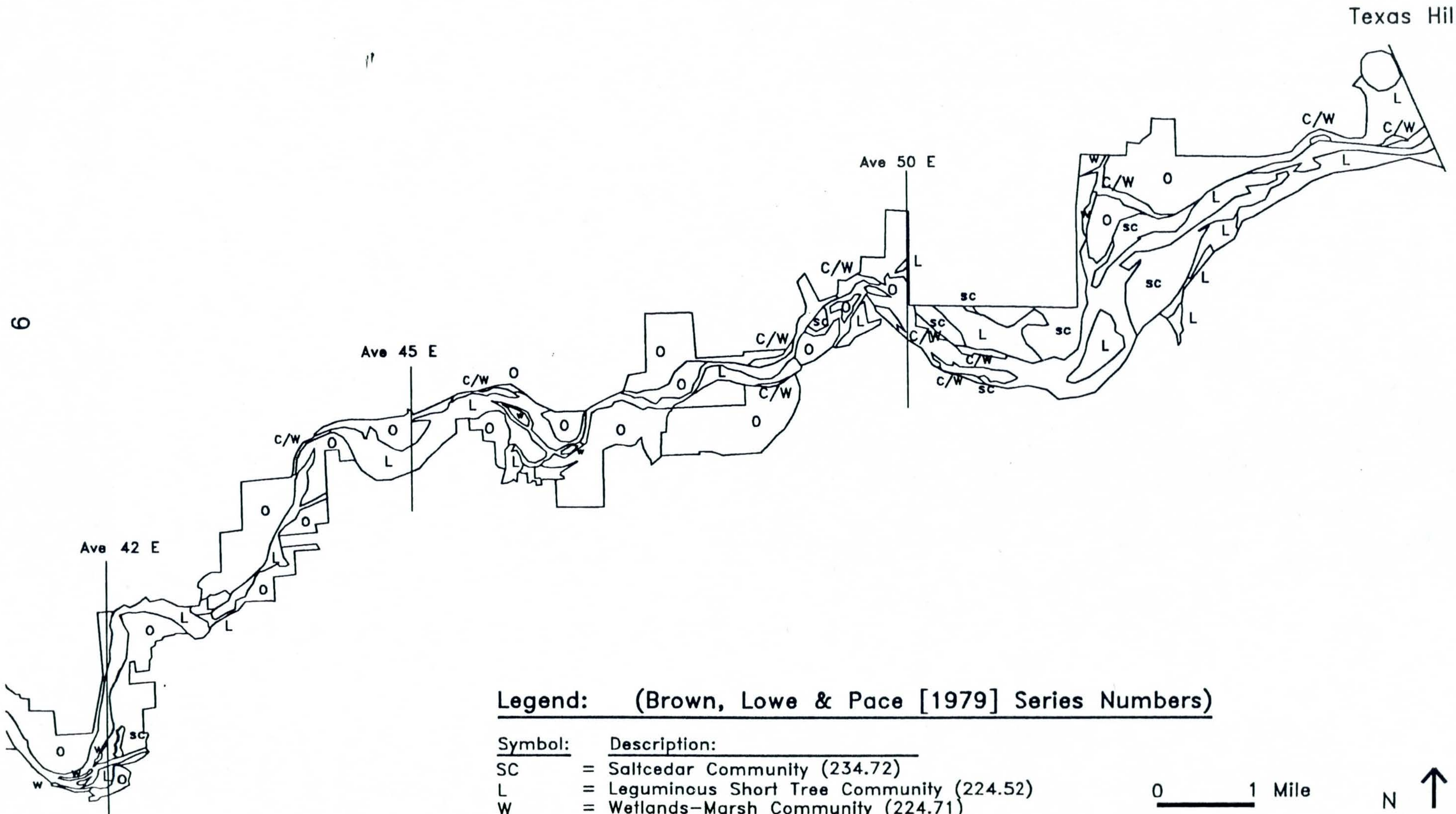
Figure 4: Wellton-Mowhawk Modern Historic Vegetation Communities (1958)
Location: Ave 42 E to Texas Hill



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

0 ___ 1 Mile N ↑

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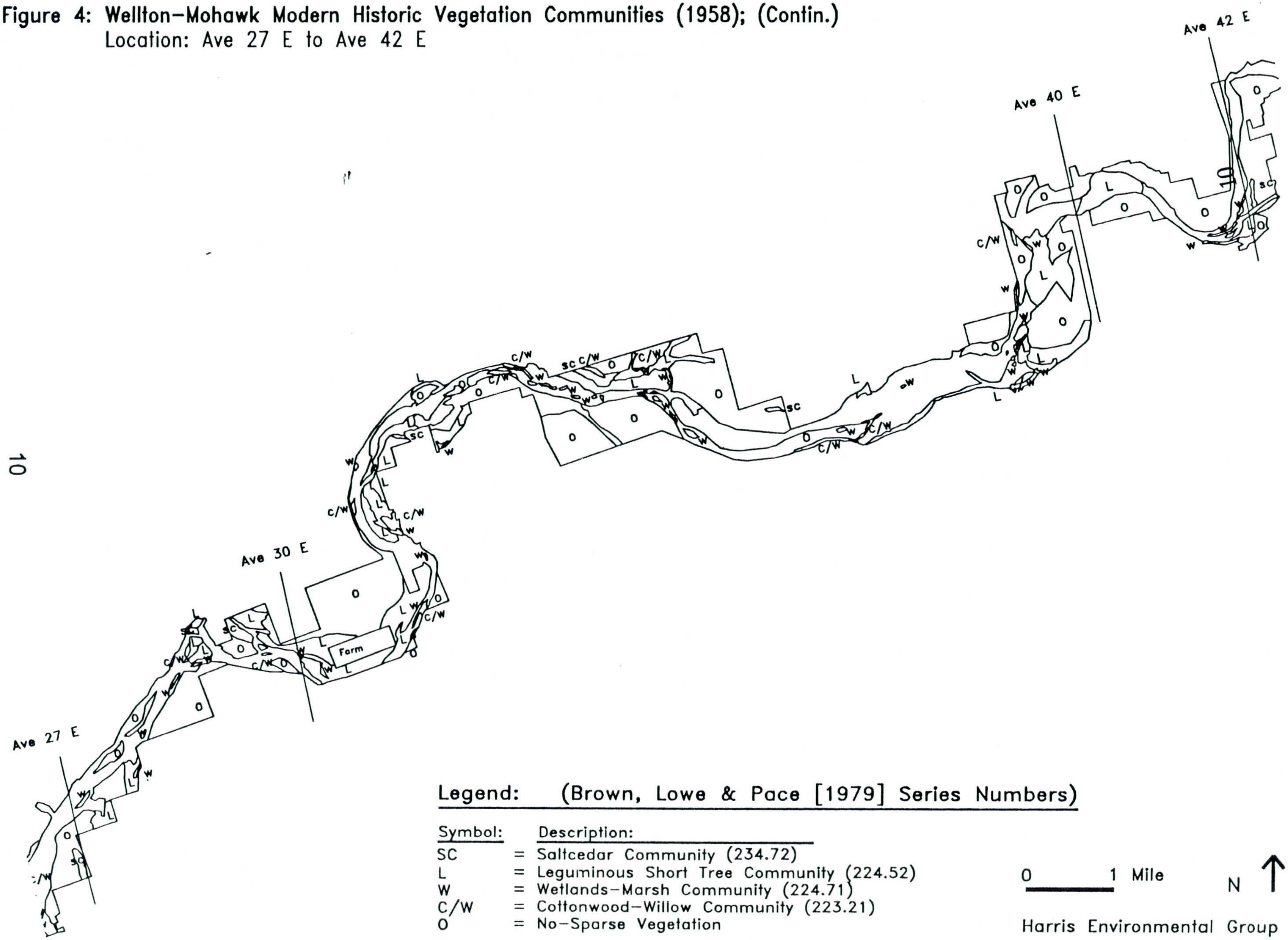
Figure 4: Wellton-Mohawk Modern Historic Vegetation Communities (1958); (Contin.)
Location: Ave 27 E to Ave 42 E

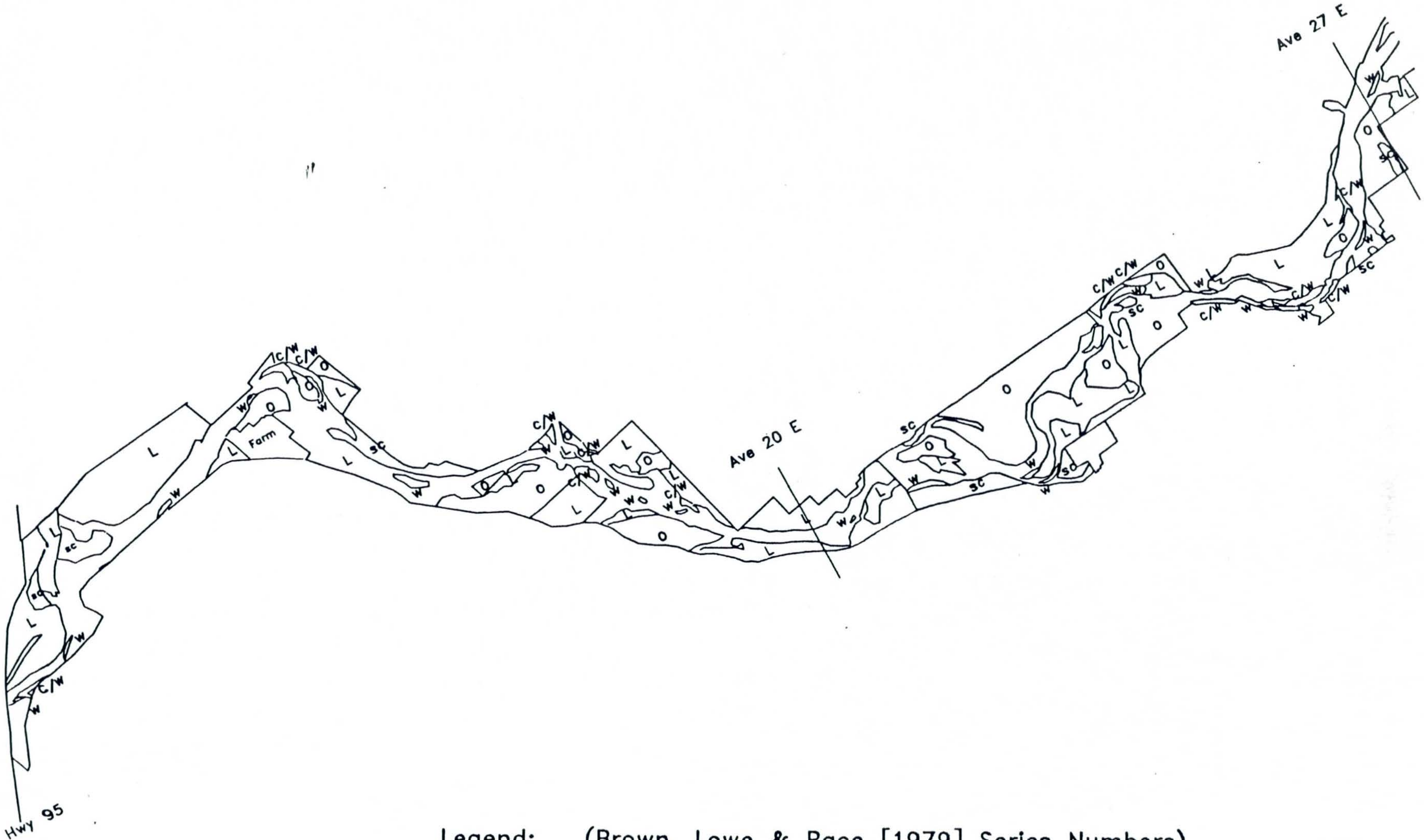


Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

0 1 Mile N

Figure 4: Wellton-Mowhawk Modern Historic Vegetation Communities (1958); (Contin.)
Location: Hwy 95 to Ave 27 E



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

0 ____ 1 Mile   N ↑

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Table 1: Modern Historic Habitat Assessment

Vegetative Communities	Veg. Series	Veg. Structure	T & E	Water	Wildlife	Dist.	A-O
Cottonwood-Willow	1	2	1.0	0.5	1.0	1.0	3.2
Leguminous Short Tree	2	4	0.0	0.0	0.7	1.0	1.6
Wetland-Marsh	1	2	1.0	1.0	1.0	1.0	3.2
Saltcedar	3	5	0.0	0.0	0.2	0.5	-1.8
Open Space (Sparse Veg.)	2	6	0.0	0.0	0.2	1.0	1.4

Dendora Valley/Agua caliente Area: based on 1953 aerial photographs.
Wellton-Mohawk Valley/BLM Property: based on 1958 aerial photographs

Table 2: Modern Historic Habitat Units (Unadjusted)

Dendora Valley/Agua Caliente Area (Based on 1953 aerial photographs)

Vegetative Community	T & E Species	Water	Wildlife Present	Dist.	Rescaled A-O	Total	Avg. Value	Prelim. Acres	Habitat Units
Cottonwood-Willow	1.0	0.5	1.0	1.0	0.98	4.48	0.90	1302.2	1171.9
Leguminous Short Tree	0.0	0.0	0.7	1.0	0.74	2.44	0.49	5730.4	2807.9
Wetland -Marsh	1.0	1.0	1.0	1.0	0.98	4.98	1.00	291.8	291.8
Saltcedar	0.0	0.0	0.2	0.5	0.23	0.93	0.19	153.5	29.2
Open Space (Sparse Veg)	0.0	0.0	0.2	1.0	0.71	1.91	0.38	15754.0	5986.5

Wellton-Mohawk Area (Based on 1958 aerial photographs)

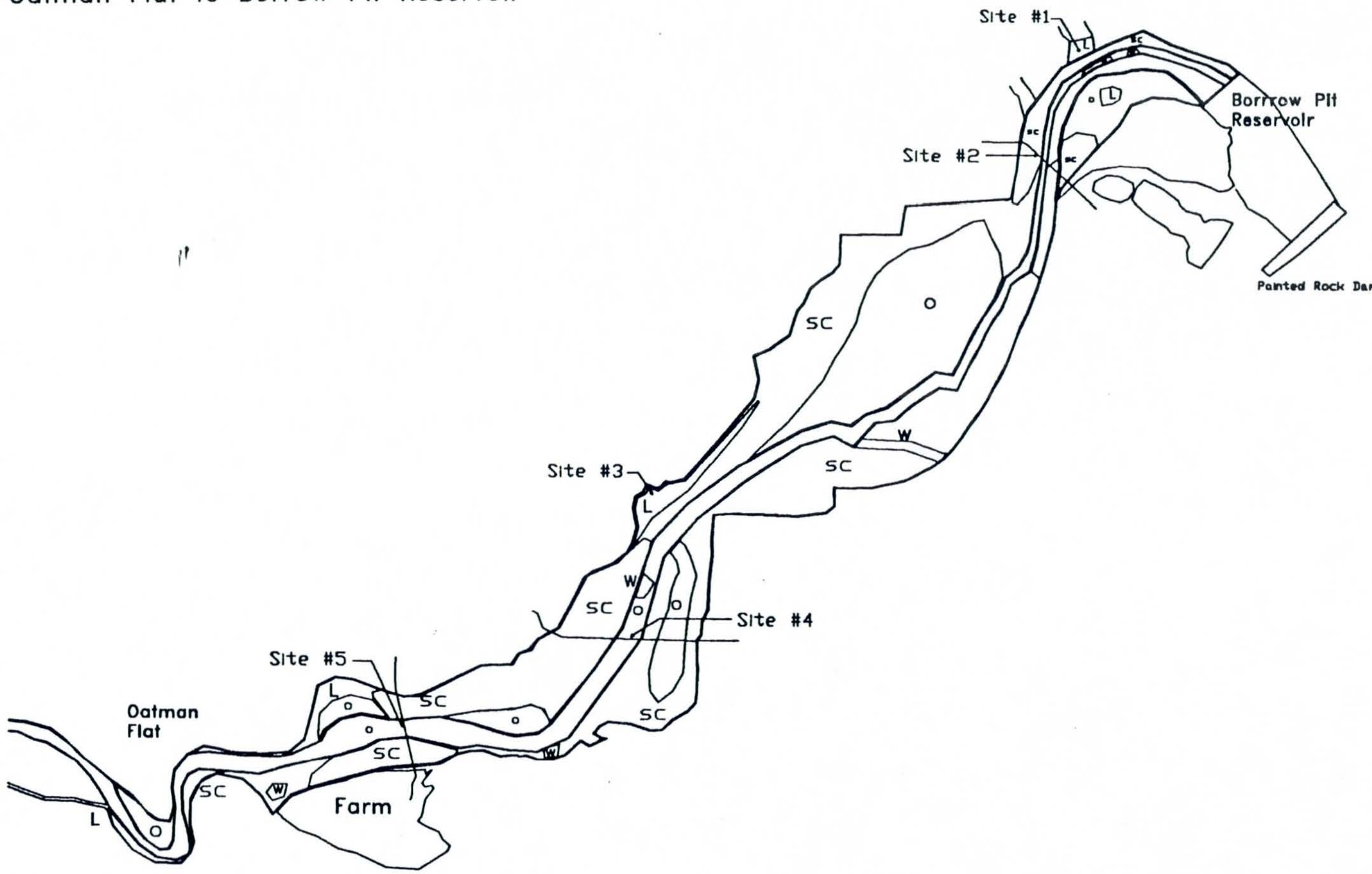
Vegetative Communiy	T & E Species	Water	Wildlife Present	Dist.	Rescaled A-O	Total	Avg. Value	Prelim. Acres	Habitat Units
Cottonwood-Willow	1.0	0.5	1.0	1.0	0.98	4.48	0.90	499.2	404.3
Leguminous ShortTree	0.0	0.0	0.7	1.0	0.74	2.44	0.49	7078.4	3468.4
Wetland -Marsh	1.0	1.0	1.0	1.0	0.98	4.98	1.00	236.8	236.8
Saltcedar	0.0	0.0	0.2	0.5	0.23	0.93	0.19	2182.4	414.7
Open Space (Sparse Veg.)	0.0	0.0	0.2	1.0	0.71	1.91	0.38	9529.6	3621.2

Table 2:
(Continued)

BLM Area (Based on 1958 aerial photographs)

Vegetative Community	T & E Species	Water	Wildlife Present	Dist.	Rescaled A-O	Total	Avg. Value	Prelim. Acres	Habitat Units
Cottonwood-Willow	1.0	0.5	1.0	1.0	0.98	4.48	0.90	69.9	62.9
Leguminous Short Tree	0.0	0.0	0.7	1.0	0.74	2.44	0.49	180.0	88.2
Wetland-Marsh	1.0	1.0	1.0	1.0	0.98	4.98	1.00	4.0	4.0
Saltcedar	0.0	0.0	0.2	0.5	0.23	0.93	0.19	7.9	1.5
Open Space (Sparse Veg.)	0.0	0.0	0.2	1.0	0.71	1.91	0.38	1991.7	756.8

Figure 5: Dendora Valley Area Current Vegetation Communities
Location: Oatman Flat to Borrow Pit Reservoir



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands–Marsh Community (224.71)
C/W	=	Cottonwood–Willow Community (223.21)
O	=	No–Sparse Vegetation

0 1 Mile

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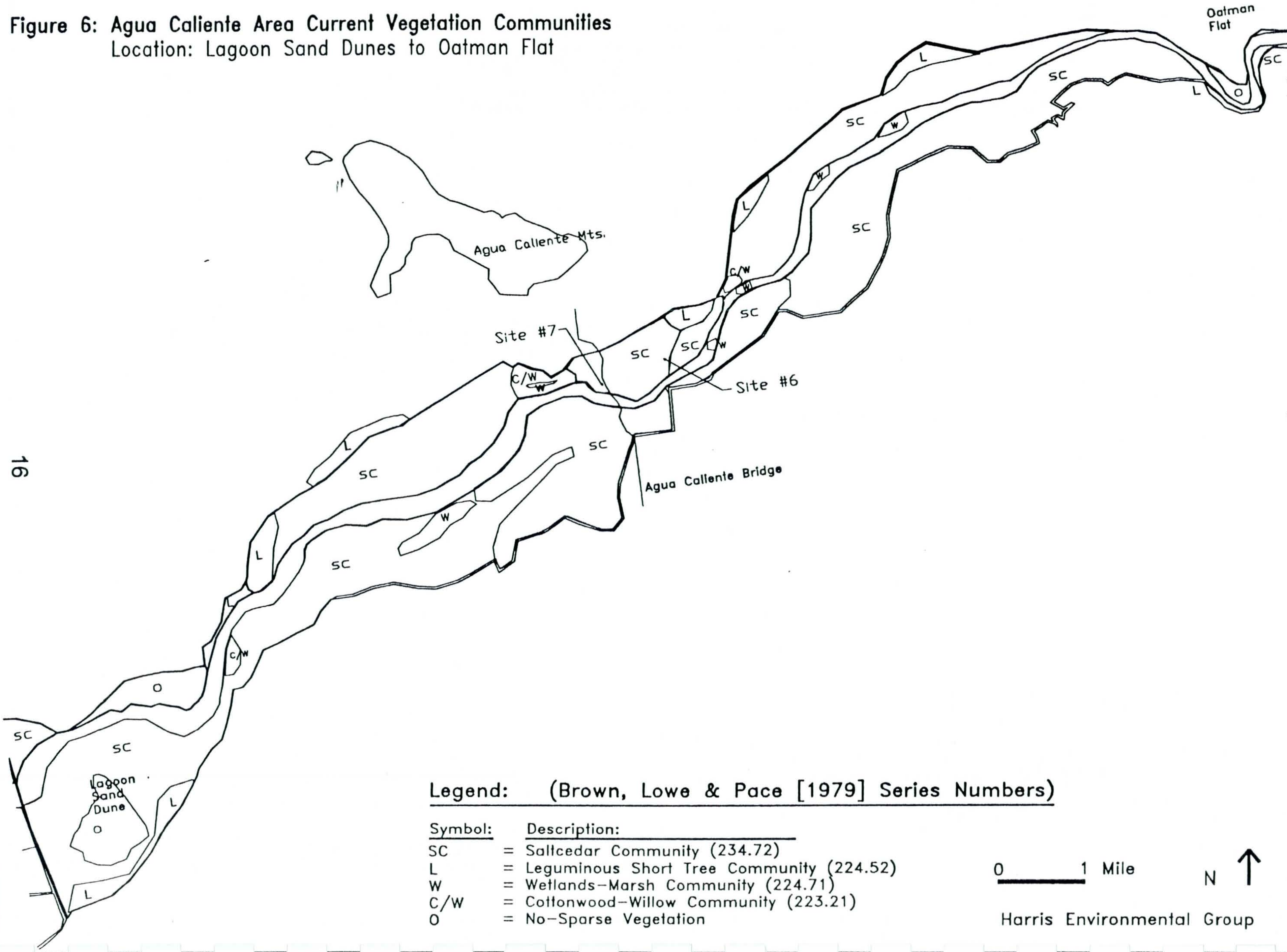
Figure 6: Agua Caliente Area Current Vegetation Communities
Location: Lagoon Sand Dunes to Oatman Flat



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

0 1 Mile

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Figure 7: BLM-Owned Property Current Vegetation Communities
Location: Ave 56 E (Texas Hill) to Lagoon Sand Dune

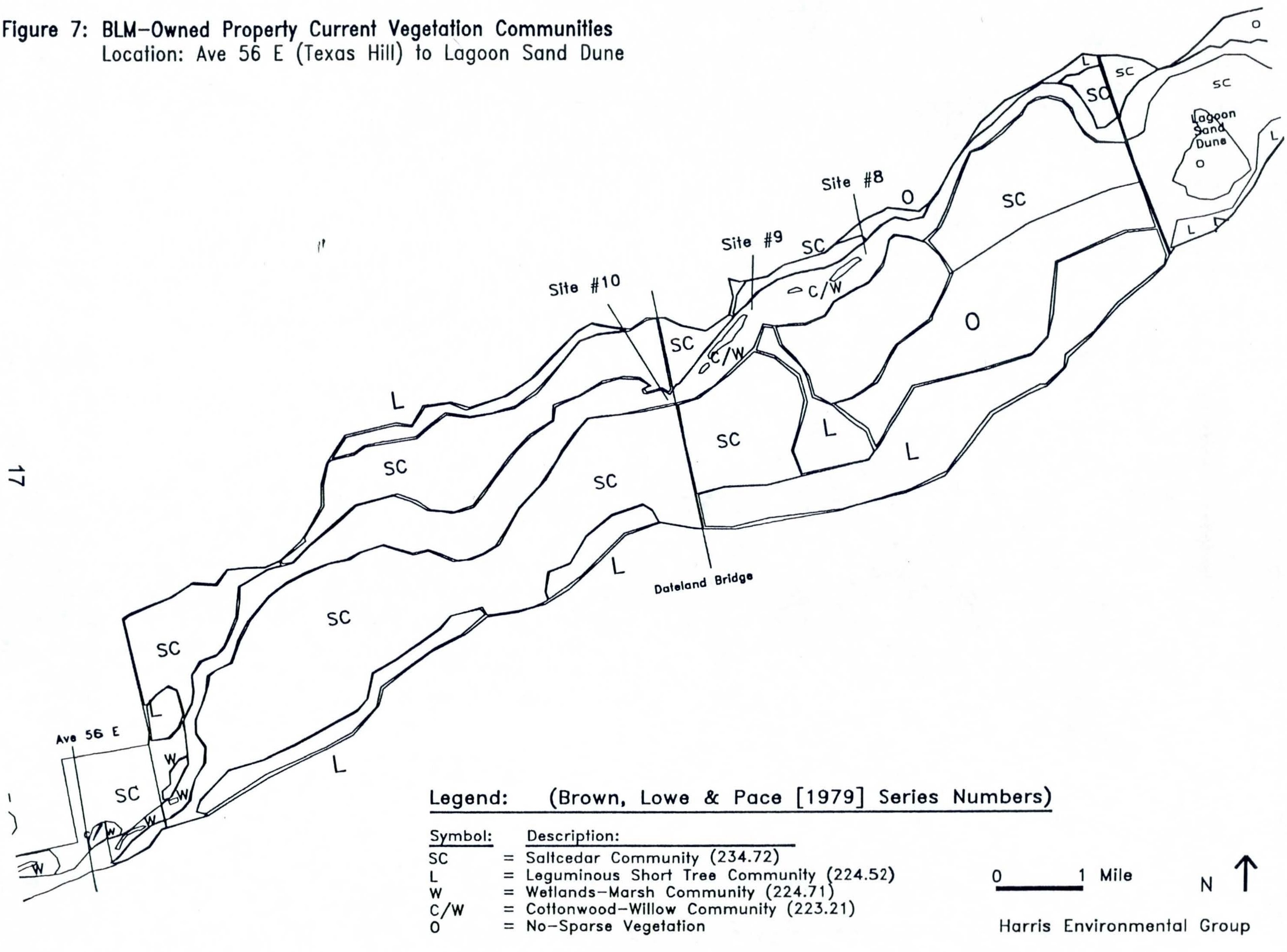
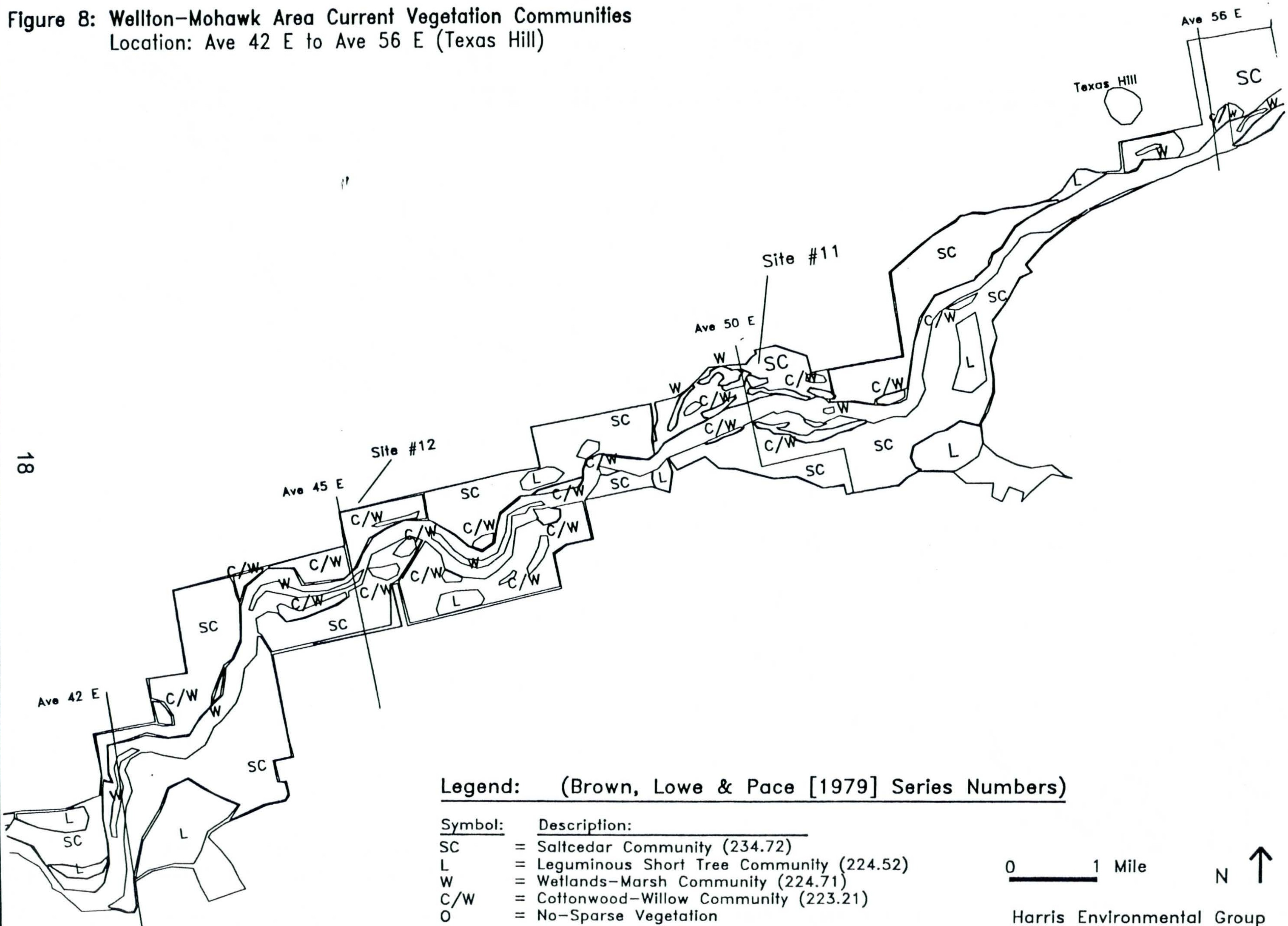


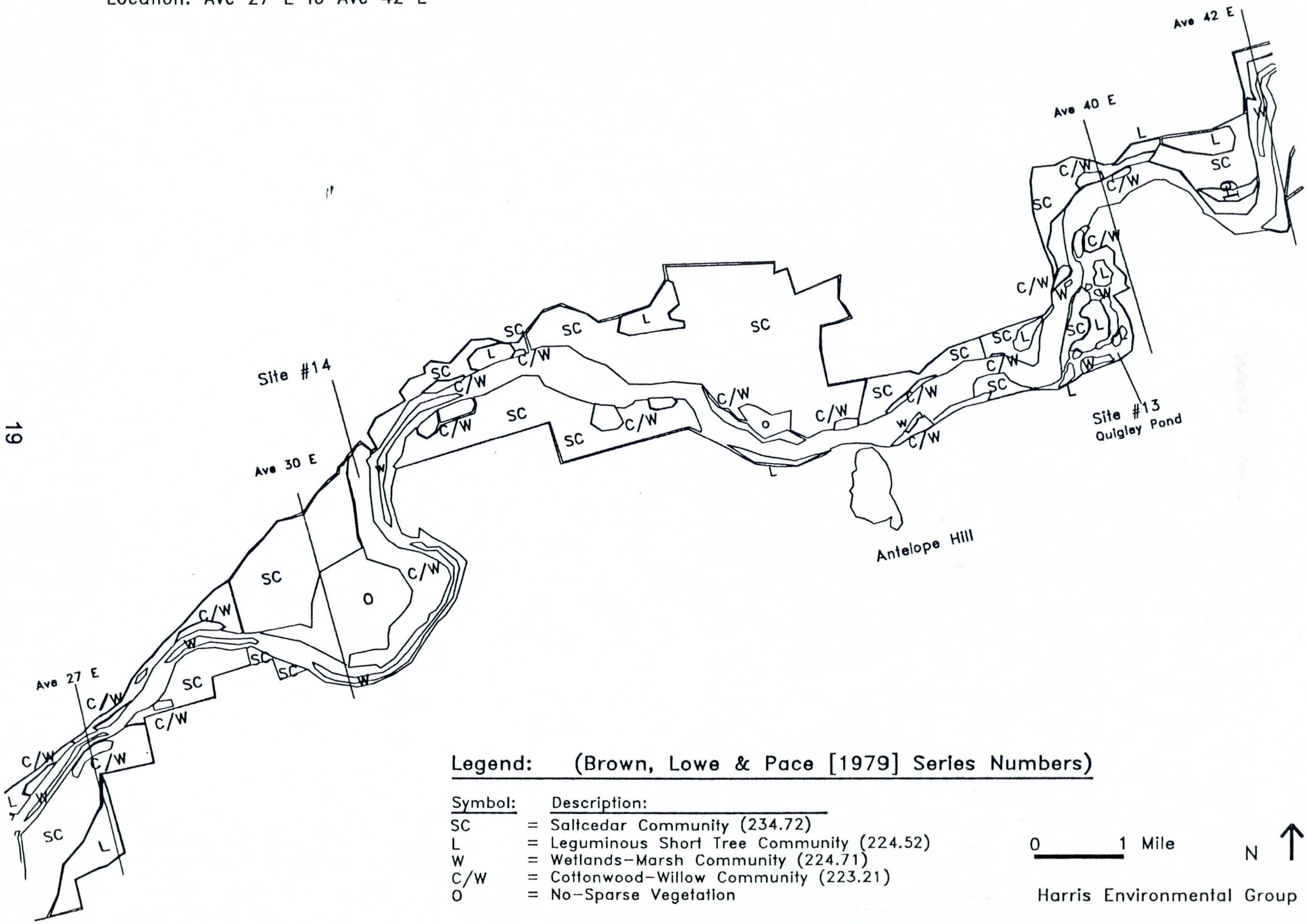
Figure 8: Wellton-Mohawk Area Current Vegetation Communities
Location: Ave 42 E to Ave 56 E (Texas Hill)



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

Figure 8: Wellton-Mohawk Area Current Vegetation Communities; (Continued)
Location: Ave 27 E to Ave 42 E



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

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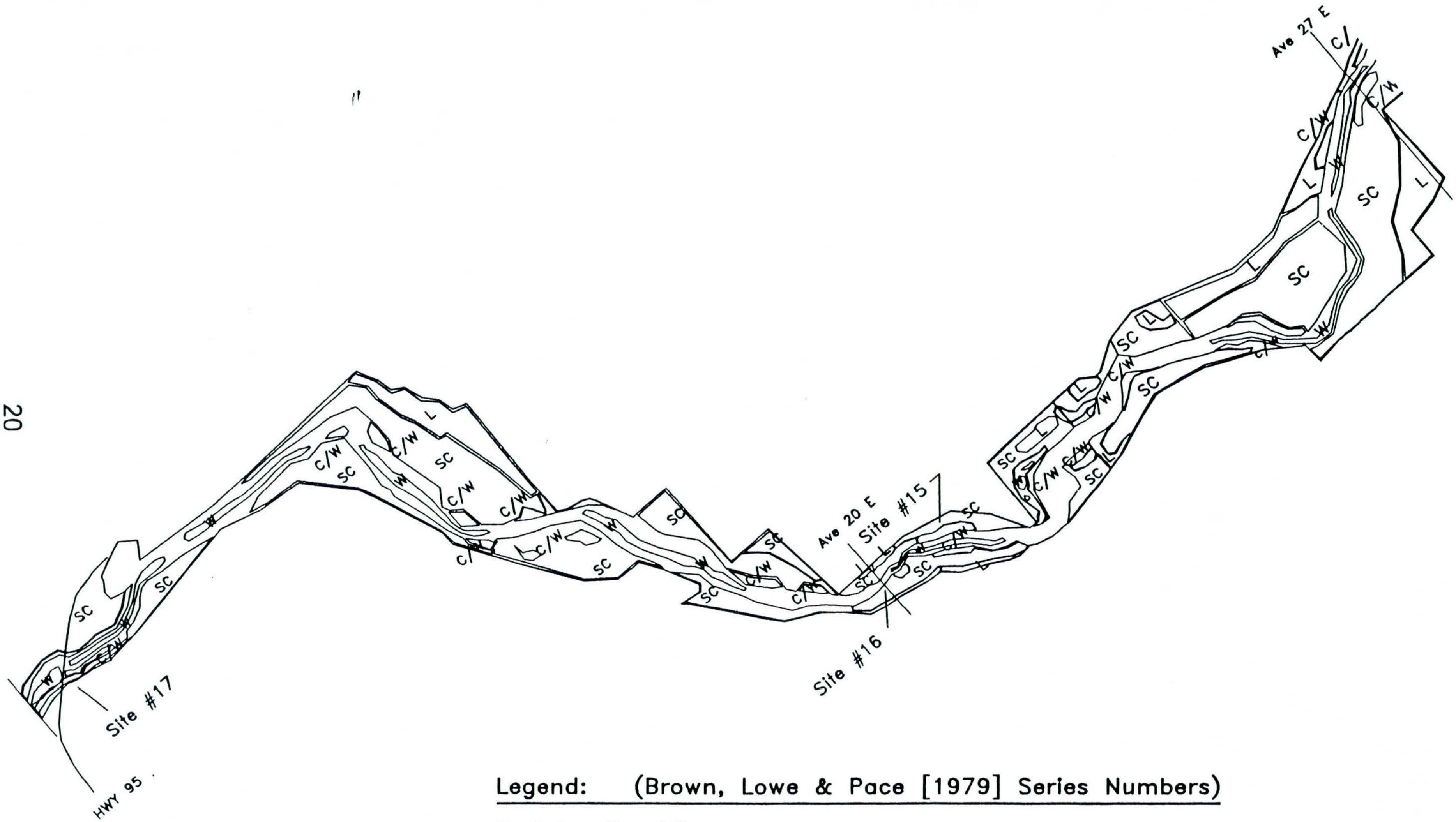
Figure 8: Wellton-Mohawk Area Current Vegetation Communities; (Continued)
Location: Hwy 95 to Ave 27 E



Legend: (Brown, Lowe & Pace [1979] Series Numbers)

Symbol:		Description:
SC	=	Saltcedar Community (234.72)
L	=	Leguminous Short Tree Community (224.52)
W	=	Wetlands-Marsh Community (224.71)
C/W	=	Cottonwood-Willow Community (223.21)
O	=	No-Sparse Vegetation

0 1 Mile

N ↑

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There was no running water in the river channel in Dendora Valley (Figure 5), Aqua Caliente (Figure 6), and the BLM property (Figure 7). However, because of agricultural practices in the Wellton-Mohawk Valley area, running water was found in the entire portion of that section of the river. The majority of the cottonwood/willow communities were young and originated from the 1993 flood. Only two sites (14, 16) had a few mature willow and/or cottonwood trees.

Current habitat characteristics of the 17 sites are shown in the work sheet in Table 3. The variables used to determine the habitat values for each of the sites is shown in Table 4. Descriptions of each site, produced from field notes, are located in Exhibit 2.

The communities most beneficial to wildlife species are those with native plants; cottonwood/willow, mesquite, and marsh/wetlands. The saltcedar community is the least beneficial in terms of supporting wildlife species. The high water table in the Wellton-Mohawk Valley area supported vegetation communities that rated higher in Habitat Units than those areas without a water source, such as in the upper portion of the river. The site that had the highest habitat value was Quigley Pond (Site 13), a wetland/marsh area with leguminous short trees managed by the Arizona Game and Fish Department. The areas with the lowest wildlife values were found in the Dendora Valley and Agua Caliente region of the river.

Future Vegetation Community Conditions

If no habitat restoration projects are initiated, over time some of the cottonwood/willow and leguminous short tree communities will convert to saltcedar communities. One exception would be Quigley Pond (Site 13) that is actively managed by the Arizona Game and Fish Department. While there are many stands of cottonwood/willow tree communities along portions of the river. These trees are young (from the 1993 flood) and in all probability less than 50% will survive in the long-run unless active management techniques are implemented. Based on these assumptions, the habitat units for the future without project conditions are presented in Table 5.

Table 3: Current Situation Habitat Assessment

Site No.		Veg. Series	Veg. Structure	T & E Species	Water	Wildlife Present	Dist.	A-O Value
1		2	5	0.0	0.0	0.7	1.0	1.4
2		3	4	0.0	0.5	0.5	1.0	-1.6
3		2	3	0.0	0.5	0.7	1.0	1.6
4		3	6	0.0	0.0	0.2	0.0	-1.8
5		3	4	0.0	0.0	0.5	0.5	-1.6
6		3	4	0.0	0.0	0.2	0.5	-1.6
7		3	4	0.0	0.0	0.2	0.5	-1.6
8		3	5	0.0	0.0	0.5	0.5	-1.8
9		1	3	0.0	0.0	0.5	1.0	2.9
10		3	5	0.0	0.0	0.5	1.0	-1.8
11		1	3	0.5	1.0	0.7	1.0	2.9
12		3	4	0.0	0.0	0.5	1.0	-1.6
13		2	1	1.0	1.0	0.7	1.0	2.9
14		3	4	1.0	1.0	0.7	1.0	-1.6
15		1	2	1.0	1.0	0.7	1.0	3.2
16		3	3	1.0	1.0	0.7	1.0	-1.6
17		3	44	1.0	1.0	1.0	0.7	-1.6

Table 4: Current Situation Habitat Units

Site No.	T & E Species	Water	Wildlife Present	Dist.	Rescaled A-O	Total	Ave. Value	Acres	Habitat Units
1	0.0	0.0	0.7	1.0	0.7	2.4	0.48	2.6	1.2
2	0.0	0.5	0.5	1.0	0.3	2.3	0.46	408.3	187.8
3	0.0	0.5	0.7	1.0	0.7	2.9	0.58	82.2	47.7
4	0.0	0.0	0.2	0.0	0.2	0.4	0.08	1024.0	81.9
5	0.0	0.0	0.5	0.5	0.3	1.3	0.26	756.5	196.7
6	0.0	0.0	0.2	0.5	0.3	1.0	0.20	1932.3	386.5
7	0.0	0.0	0.2	0.5	0.3	1.0	0.20	479.6	95.9
8	0.0	0.0	0.5	1.0	0.23	1.73	0.35	934.5	327.1
9	0.0	0.0	0.5	1.0	0.94	2.44	0.49	31.9	15.6
10	0.0	0.0	0.5	0.5	0.23	1.23	0.25	1402.1	350.5
11	0.5	1.0	0.7	1.0	0.94	4.14	0.83	177.9	147.7
12	0.0	0.0	0.5	1.0	0.26	1.76	0.35	949.2	332.2
13	1.0	1.0	1.0	1.0	0.79	4.79	0.96	192.1	184.4
14	1.0	1.0	0.7	1.0	0.94	4.64	0.93	794.3	738.7
15	1.0	1.0	0.7	1.0	1.00	4.70	0.94	32.4	30.5
16	1.0	1.0	0.7	1.0	0.26	3.96	0.79	231.2	182.6
17	1.0	1.0	0.7	0.5	0.26	3.46	0.69	222.5	153.5

Table 5: Habitat Units for Future Without Project Conditions

Cottonwood	Willow	Dominant			
Site No.	Area (Acres)	Quality (0-1)	Habitat Units	Water Source	Impact
9	31.9	.79	25.2	Agriculture	Change to saltcedar
11	177.9	.79	140.5	Agriculture	Change to saltcedar
15	32.4	.79	25.2	Agriculture	Change to saltcedar
Total	342.2		191.3		
Wetland	**Marsh**	**Dominant**			
Site No.	Area (Acres)	Quality (0-1)	Habitat Units	Water Source	Impact
13	192.1	.96	184.4	Agriculture	No change (Quigley Pond)
14	794.3	.79	627.5	Agriculture	Change to saltcedar
Total	986.4		811.9		
Leguminous	**Short Tree**	**Dominant**			
Site No.	Area (Acres)	Quality (0-1)	Habitat Units	Water Source	Impact
1	2.6	.26	0 .7	Flood Control	Change to saltcedar
3	82.2	.26	21.4	Ground Water	Change to saltcedar
Total	84.8		22.1		
Saltcedar	**Dominant**				
Site No.	Area (Acres)	Quality (0-1)	Habitat Units	Water Source	Impact
2	408.3	.46	187.8	No Water	No change
4	1024.0	.08	81.9	No Water	No change
5	756.5	.26	196.7	No Water	No change
6	1932.3	.20	386.5	No Water	No change
7	479.6	.20	95.9	No Water	No change
8	934.5	.35	327.1	Agricultural	No change
10	1402.1	.25	350.5	No Water	No change
12	949.2	.35	332.2	Agricultural	No change
16	231.2	.79	182.6	Agricultural	No change
17	222.5	.69	153.5	Agricultural	No change
Total	8340.2		2294.7		

E. RESTORATION STRATEGIES

In this section several restoration strategies are presented for re-establishing native plant communities along the Lower Gila River. To be successful in restoration efforts, these strategies will most likely be used in conjunction with one another, depending on the site-specific conditions.

A Rare Opportunity

By taking into consideration the entire lower reach of the Gila River, the Corps of Engineers has a rare opportunity to develop restoration strategies that are based on a broad evaluation of river conditions. Evaluating degraded riparian areas from a perspective that includes surrounding uplands, reaches upstream and downstream from the degraded riparian area, and tributaries was a commonality among many successful riparian restoration projects in Arizona (Briggs 1992). Taking into consideration only isolated components of a watershed (e.g., evaluating only a specific riparian site) will be ecologically incomplete, often failing to provide the information needed to fully understand why the riparian ecosystem has become degraded.

Additionally, the 1993 flood events fostered the emergence of riparian habitat. However, this immature habitat, created by such a rare event, will likely not survive and eventually again be overrun with exotic saltcedar. By incorporating measures to encourage the continued survival of the flood-created emergent riparian habitat, significant increases over and above active revegetation can be achieved.

Considering the entire lower reach of the Gila River has several advantages over an approach that considers only a narrow part of a stream system:

- The Corps of Engineers will be able to choose sites where the potential for restoration success is high. Sites that have been severely impacted can be avoided, for example, in favor of sites that will respond more rapidly to restoration. Such an approach is cost-effective, producing greater results for money spent;

- The Corps of Engineers will be able to tailor restoration methodologies to address specific site conditions. Riparian revegetation, for example, may be more effective in the Dendora Valley area than the Wellton-Mohawk reach, while selective clearing of saltcedar without revegetation may be more effective in the Wellton-Mohawk reach than the Dendora Valley reach;

- The Corps of Engineers will be able to design restoration strategies that work with stream processes rather than against them. For example, reaches characterized by enhanced instability due to significant sediment deposition can be avoided in favor of areas that are in dynamic equilibrium.

Restroation Objectives

Although one emphasis of restoration is to improve streamside habitat for listed and proposed endangered species, such as the Yuma Clapper Rail and the Southwestern Willow Flycatcher, the restoration strategies presented in this report were also developed with the general idea of improving streamside habitat along the lower Gila River for other wildlife species, including waterfowl, small mammals, and amphibians. For several of the restoration strategies, incidental benefits are improved aesthetics for recreational purposes, and increased groundwater recharge in selected areas.

With the exception of strategy #1 - Preserving Existing Native Vegetation, each of the proposed restoration strategies was not designed as a blanket approach for the entire lower reach of the Gila River. Instead, each strategy should be considered as being appropriate for only certain reaches of the Lower Gila River. The Corps of Engineers should consider combining strategies and modifying them to better suit specific site characteristics.

Format

Strategies are presented in three parts. A brief introduction describes the strategy, recommendations follow as to where the strategy would be most effectively used, and the final part describes some potential issues that will need to be addressed if the strategy is selected, and its limitations and advantages.

Strategies:

1. Preserving Existing Native Vegetation

Description
Native streamside vegetation communities along the Lower Gila River need to be identified, their overall health determined, and potential problems regarding their long-term survival addressed.

Recommendations
Of the restoration strategies presented in this report, this strategy is the only one that should be applied to the entire lower reach of the Gila River. Preserving already existing native vegetation communities is one of the single most important restoration strategies that the Corps of Engineers can undertake to ensure the continued existence of the Gila River's native riparian ecosystem.

Preserving already existing native vegetation is easier and less expensive than trying to establish native vegetation communities in areas where they no longer exists. It is important to note that this strategy should not be applied solely toward the preservation of habitat for the Yuma Clapper Rail or Southwestern Willow Flycatcher (i.e., open water with bulrushes, cattails, and reeds, adjacent to cottonwood and willow trees), but other vegetation associations such the mesquite bosque, and the more xeric plant associations that are found along some of Gila River's tributaries (e.g.,creosote, mesquite, blue paloverde, and quailbush found along the July Fourth Wash, just downstream from the Painted Rock Dam) should be preserved as well.

Other Issues

Two of the most formidable threats to existing native vegetation communities along the Lower Gila River are probably declining water availability and competition from non-native vegetation. Of the study sites along the Lower Gila River, the Wellton-Mohawk site has the greatest abundance of native riparian species. Numerous willow and cottonwood trees have established following the large flood events of January and February 1993. Therefore, one priority should be to protect these native species from desiccation during the dry summer months by providing supplemental water (strategies for providing native plants with supplemental water are discussed in Strategy #2). In addition to providing supplemental water, selective saltcedar removal will have to be performed to prevent these pockets of native plants from being overrun (see Strategy #3).

2. Revegetating With Native Riparian Species

Description

Riparian revegetation involves planting trees, shrubs, forbs, and/or grasses to replace species that may have been lost or planting native species adaptive to the current conditions. Revegetation uses all types of propagules, including cuttings, poles, seedlings, and seeds. When used effectively, revegetation can produce dramatic results, helping to replace lost riparian vegetation and stabilize deteriorating conditions, thereby initiating recovery of the riparian ecosystem. Although revegetation plays a role in some of the other restoration strategies, it is presented separately so that some of the general issues associated with its use can be discussed.

Recommendations

Revegetation should be used in the Dendora Valley and Agua Caliente areas where native riparian plants are either uncommon or completely absent. The lack of native seed sources, the proliferation of saltcedar along this reach of the Gila river, and the artificial alteration of river flow by Painted Rock Dam greatly reduces the possibility for natural regeneration of native riparian plants. Artificial revegetation is therefore one of the few options remaining for re-establishing native riparian plants along this reach of the Gila River. Revegetation should not be extensively used in areas where significant numbers of native riparian species remain (e.g., Wellton-Mohawk reach). In such areas, other strategies should be implemented that will preserve existing native species and promote natural regeneration (see Strategy #1).

Other Issues

Riparian revegetation produces only marginal results because it often does not address the causes of degradation. The factors responsible for the initial degradation of the riparian areas often hamper or prevent establishment of artificially planted vegetation as well.

Riparian revegetation is most effective when sites are characterized by two attributes. First, site conditions should be such that the potential for natural regeneration is minimal. This does not imply that natural regeneration is a negative result. On the contrary, natural regeneration is the revegetationist's ally, and fostering natural regeneration should be the aim of most riparian recovery projects. However, revegetation efforts may be squandered in areas that experience strong natural regeneration. In such situations, it may be wise to postpone revegetation or consider alternate sites (Briggs 1994).

Second, revegetation needs to be used in areas where plantings are likely to survive. Along the Lower Gila River, whether or not planted vegetation survives may be determined most by water availability, channel stability, soil salinity, and competition from non-native species.

Water Availability
One of the main constraints to past riparian revegetation projects is the lack of sufficient water. Many riparian vegetation communities are composed of phreatophytes that can establish and survive only in areas where they can develop root systems to saturated soils (Campbell and Green 1968; Fenner et al. 1984; Reichenbacher 1984). The riparian water table is the primary source of water for most phreatophyte trees (Busch et al. 1992), and when the water table drops below the root zone, it becomes very difficult for these species to survive (Fenner et al. 1984; McBride and Strahan 1984).

The following strategies may be used either alone or in concert to overcome low water availability:

> i - Establish vegetation only in areas where shallow saturated soils are found within 3 meters of the soil surface. In the study area, groundwater is deepest between Painted Rock Dam and Texas Hill and near Yuma (Graf et al. 1994). Therefore, in these areas revegetation with phreatophytes should be avoided unless supplementary water is used;
>
> ii - In areas where groundwater frequently drops 3 or more meters below the soil surface, use species that are better adapted in obtaining water from greater depths (e.g. mesquite);
>
> iii - Pump water from conveyance channels to irrigate seedlings until their root systems are better established. Graf et al. (1994) noted, however, that this water is generally of low quality;
>
> iv - Excavate down to saturated soils (see restoration Strategy #8).

Channel Stability
The dynamic nature of alluvial stream channels makes streamside revegetation risky. However, some channels are inherently unstable, greatly reducing the chances that planted vegetation will actually establish. Such channels may no longer be experiencing equal rates of deposition and erosion and have fallen out of dynamic equilibrium. The breach of Gillespie Dam has

contributed significantly greater amounts of fine materials to the Lower Gila River, potentially affecting channel stability throughout this area (Graf et al. 1994). The washload, or finer particles, are suspended in the water, whereas the bedload, or heavier materials, are deposited in the reservoir. In general, much of the Lower Gila River is experiencing significant sediment deposition, a characteristic of a river system where available sediment far exceeds the capacity to transport it. The manner that sediment is moving along the Lower Gila River needs to be studied in more detail. Significant aggradation will not only affect revegetation efforts, but other restoration strategies as well (e.g., excavation strategies, placement of in stream structures).

Soil Salinity
Increasing salinization is becoming a major environmental problem in many arid and semi-arid parts of the world. Whereas soils in humid regions are leached through the soil profile by continuous precipitation, soils in arid regions accumulate salts through the processes of evaporation and upward capillary movement of moisture from the water table (Chapman 1975).

The level of total dissolved solids (TDS) in the Wellton-Mohawk has presented a problem to agriculture in the past (Graf et al. 1994) and could present problems when planting with native riparian species that are typically intolerant to even moderate levels of salinity. From his revegetation work along the Colorado River, Anderson (1989) cautioned against planting Fremont cottonwoods and Goodding willows in areas where soil electroconductivity levels are greater than 2.0 dS m^{-1} (1.3 ppt). He noted that 4-year-old trees planted in areas of high salinity (greater than 2.0 dS m^{-1}, or 1.3 ppt) had 67% less foliage volume than trees planted at the same time in less saline soils. Therefore, in areas where salinity is a problem, soil testing is warranted so that riparian species can be planted only in areas characterized by salinity levels of 1.3 ppt or less.

Competition From Non-Native Vegetation
Saltcedar is by far the most prominent streamside plant in the Dendora Valley, Agua Caliente, and BLM study areas. If native plants are to be re-established in these areas, saltcedar will have to be controlled (see Strategy #3).

Match Plant Species To Geomorphic Landform
Species need to be planted on landforms to which they are adapted. Species such as bulrushes and cattails can be planted in low-lying areas where prolonged inundation is likely, however planting these same species on upper terraces would not be effective, nor can these species survive in a thalweg where frequent flow events can easily remove them. On upper terraces where depth to saturated soils frequently exceeds 5 meters, revegetating with species such as mesquite, blue paloverde, quailbush, and catclaw acacia (*Acacia greggii*) would be more effective than trying to plant native phreatophytes such as willow and cottonwood trees which are better adapted to the more dynamic environment of lower terraces.

3. Removing Saltcedar

Description

Saltcedar is an aggressive colonizer that has established in dense thickets along many parts of the Gila River. In many situations, saltcedar will out compete native vegetation for moisture, nutrients, sunlight, and space. Given the abundance of saltcedar along much of the Lower Gila River, implementing removal strategies will be an important component of many of the restoration strategies presented in this report.

Recommendations

Saltcedar is most abundant along the Dendora Valley and Agua Caliente reaches. Any restoration effort proposed for this area will have to develop some plan to control and remove saltcedar.

Successfully controlling saltcedar can be the key to revegetating areas choked by this aggressive non-native species (Barrows 1993). Results of several revegetation projects demonstrate that clearing saltcedar prior to planting provides planted seedlings with a head start, allowing artificially-planted riparian vegetation to successfully establish despite prolific saltcedar regeneration (Briggs 1992).

Some of the best results of removing saltcedar have been with herbicides. For example, Arsenel, a broad-spectrum herbicide is specifically labeled for use on saltcedar. It can be applied as either preemergence or postemergence to the weed. However, postemergence application has achieved the best success. Arsenel does not significantly leach into the ground water, and should not effect wildlife, recreation, or irrigation. It quickly degrades and does not persist in the soil for prolonged periods of time.

Other Issues

Salt excreted from the leaves of saltcedar can alter the immediate soil environment. In some cases, soil salinity increases to such an extent that it can impede the establishment of native plant species (Anderson, pers. comm., 1993). Such a scenario may apply to abandoned terraces along the Gila River which have been dominated for years by saltcedar.

4. Flooding Dedicated Agriculture Fields

Description

Dedicated agriculture fields can be flooded during specific times of the year to provide temporary habitat for waterfowl. In addition, this strategy can improve habitat conditions for the Yuma Clapper Rail, Southwestern Willow Flycatcher, and other species that depend on riparian vegetation. This strategy can be accomplished by constructing berms to reduce runoff and pumping water directly onto the field (Hill 1989). This strategy is being used to provid habitat for geese, swans, ducks, and shore birds in many of the U.S. Fish and Wildlife Service's refuges.

Recommendations

This strategy is presented as a stop-gap measure that can be implemented while other, longer-lasting, restoration strategies are developed. This strategy may be applicable to the Wellton-Mohawk area where farmland is being taken out of production as a result of damage from the 1993 floods.

Other Issues

There are several issues associated with this strategy that may greatly limit its use. Some of these issues are: cost of water, water quality (i.e., how does flooding affect the concentrations of salinity, herbicides, heavy metals, etc.), the effects of flooding on the spread of saltcedar and other weeds, and the rate of water loss.

5. Rehabilitating Dedicated Farmland

Description

This strategy involves revegetating dedicated agricultural land along the Gila River with native desert plants. Large amount of agricultural farmland along the Lower Gila River may become available for restoration as farmland is no longer put into production in the near future. Once part of the active Gila River flood plain, many farmland areas are currently only affected by river flow when statistically rare precipitation events occur (e.g., the rainfall of January and February 1993). This "removal" from the active Gila River flood plain is caused by the combined effects of channelization, river impoundment, and levee construction.

Recommendations

Particularly given the large area that out-of-production farmland may comprise in the near future, it is important that potential restoration project partners, such as the Arizona Game and Fish Department, work with area farmers and the Wellton-Mohawk Irrigation Drainage District and begin to develop restoration strategies for these areas. Important lessons can be taken from abandoned farmland restoration efforts along the Santa Cruz River (Jackson 1991). Involvement of local sponsors will be crucial for the successful implementation of this strategy.

6. Altering Channel Form

Description

Altering the cross sectional form of the channel to mimic a more natural situation can be used to promote the conservation and enhancement of wildlife habitat (Nature Conservancy Council 1983). One example of this is to shape and position stream banks to encourage the establishment of native vegetation. Narrow channels that cut through significantly elevated flood plains offer little potential for the establishment of native riparian species. Such a situation offers only two landforms for vegetation establishment: the narrow channel where plants are vulnerable to flood damage, and the abandoned flood plain, where water availability may be a problem (Fig. 9).

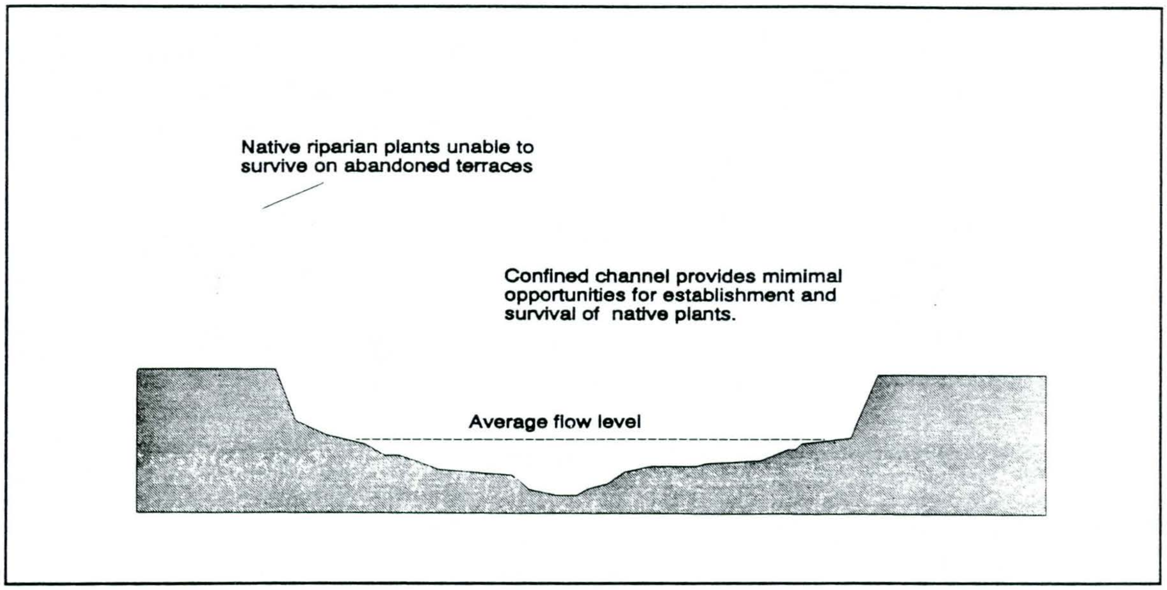

Figure 9. Flood-bank engineering that is not conducive to the establishment of native riparian species.

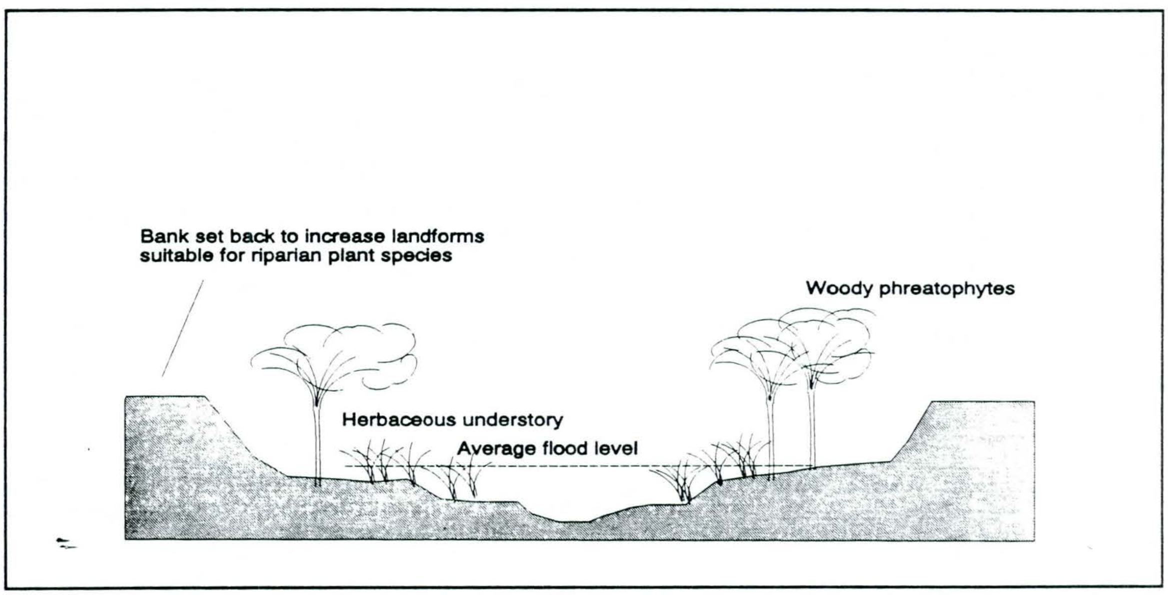

Figure 10. Multi-stage channel design. Channel has been widened to form a multi-step design, where lower steps are inundated at least several times each year.

Altering the cross sectional shape of the channel so that elevation change from the main channel to abandoned terraces occurs much more gradually will provide a greater diversity of sites for vegetation establishment (Fig. 10). Low elevation terraces may provide sufficient water availability for native riparian species (e.g., cottonwoods) and yet be high enough in elevation to afford some protection from flooding. Higher terraces may be better suited to species like mesquite that can survive in drier conditions. However, mesquite is adapted to finer particle size in terms of soil characteristics.

Recommendations
This strategy is most appropriate for channel reaches characterized by a relatively narrow main channel surrounded by significantly elevated flood plains. Several study sites in the Agua Caliente and Dendora Valley region fit this description. To be effective, this strategy should be combined with releases from Painted Rock Dam (Strategy #10) that inundate specified landforms and are timed to coincide with seed dissemination of native riparian species. In addition, selective clearing of saltcedar and using revegetation to establish native riparian species may be necessary.

Other Issues
Artificially manipulating the form of the main channel is jeopardized by large flow events that can undo careful planning and manipulations. The Lower Gila is characterized in some reaches by loss of capacity leading to significant rates of aggradation (Graf et al. 1994). Such extensive deposition threatens the practicality of this strategy by increasing channel instability. The manner that sediment is moving through the Lower Gila River needs to be carefully studied and dynamically stable areas identified before this strategy is implemented. As mentioned above,the effectiveness of this strategy to establish native vegetation is also influenced by depth to groundwater, competition from saltcedar, soil salinity, and other issues.

7. Enhancing Existing Oxbows

Description
Reestablishing meanders, or preventing the erosion of currently existing meanders, can increase the amount and diversity of riparian plant communities. Preserving and constructing meanders to emulate the morphology of natural stream channels has been used for years in West Germany (Brookes and Gregory 1988).

As compared to a straight channel, meanders reduce the slope of the river thereby reducing flow velocity and sediment-carrying capacity. The channel shifts across its floodplain by eroding the outside bends and depositing sediment on the inside. The depositional areas often have characteristics suitable for the establishment of riparian vegetation (naturally or artificially). In addition, pools also form in the region of high velocity and turbulence.

Recommendations
For this strategy, efforts should focus on preserving meanders in the Wellton-Mohawk area that were formed when the river broke out of its channel during the winter flooding in 1993. In

addition, the Corps of Engineers and local sponsors can take advantage of the proposed modification of existing channels at specific sites. These oxbow areas with their associated open water are considered critically important to many wildlife species, including the endangered Yuma Clapper Rail and the proposed endangered Southwestern Willow Flycatcher. To be most effective, this strategy should be combined with selective clearing of saltcedar and revegetation with native riparian species. Preserving already existing meanders is preferable to creating meanders. Creating meanders in areas where they do not currently exist will be expensive and is not likely to produce successful results.

Utilize Oxbows Created by WMIDD Proposed Levee Repairs

The Wellton Mohawk Irrigation and Drainage District (WMIDD) is proposing rebuilding and modifying existing flood-damaged levees at specific sites along a 60 mile reach of the river, between Texas Hill and Dome. Some levees on either side of the main channel may be reinstalled across meanders, and the Corps of Engineers and local sponsors can take advantage of the WMIDD's proposed projects by utilizing oxbows at these sites. (Fig. 11).

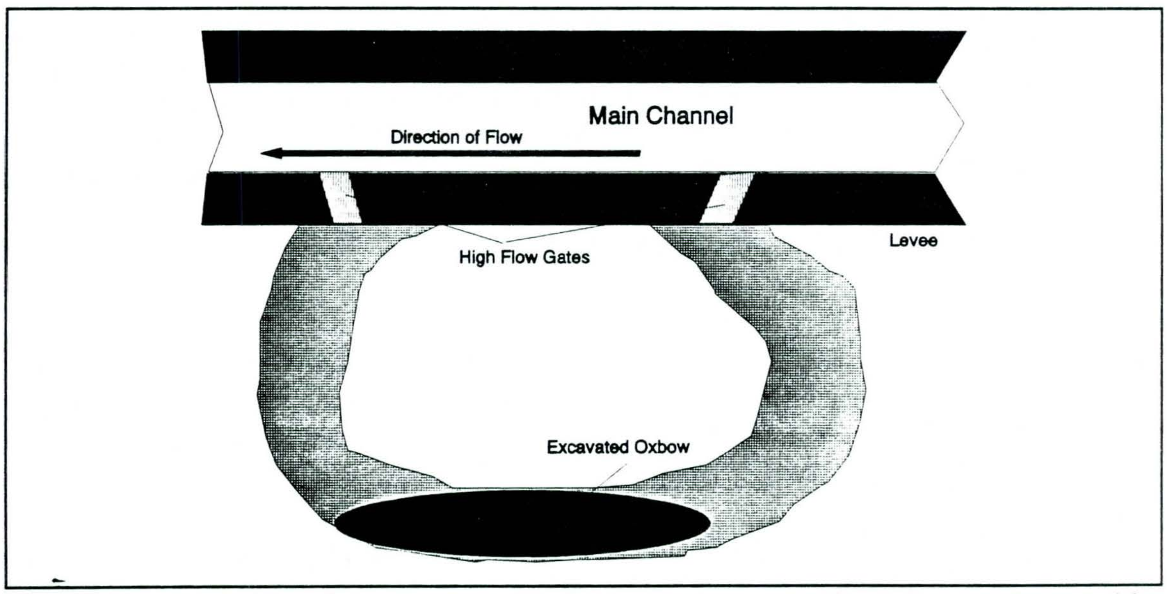

Figure 11. Plan view of the first strategy for preserving meanders. Levees damaged by flooding are repaired across channel meanders. Gates installed in the levees ensure that some water replenishment occurs during high flow events. Oxbows are excavated to roughly a meter below the saturated zone of the soil profile, providing open water habitat.

Flow gates installed in the levees will supply replenishing flows to the oxbows during periods of high flow. Oxbows can be excavated to groundwater to ensure that a certain amount of open water exists throughout the year. Cattails, bulrushes, reeds (*Phragmites* spp.) can be planted along the sides of the oxbow lake. Willows, cottonwoods, and other woody riparian plant species can be planted around the periphery of the excavated lake. In addition, selective clearing of saltcedar will have to occur to ensure that the newly created wetland will not be overrun by this pervasive species.

Other Issues
This strategy is vulnerable to damage from large flood events that overtop the proposed levees. As with Strategy #6, sediment movement along the Lower Gila River should be better understood. In addition, fluctuation of groundwater levels need to be ascertained with a greater degree of accuracy so that the depth of excavation is done in such a manner that open water area persists through the year.

8. Creating Open Water Sites Through Excavation

Description
Excavating dry surfaces to groundwater will provide open water sites that are currently a rarity along the Lower Gila River flood plain. When revegetated with water-loving plants such as reeds, cattails, and bulrushes, such areas will provide habitat for the Yuma Clapper Rail and other bird species. In addition, native threatened and endangered fish species, and other aquatic organisms, could be re-introduced at specific sites. Creating lagoons by excavation was used at Backtoft Sands, Great Britain to provide habitat for wader and waterfowl species (Hill 1989).

Recommendations
It is important that this restoration strategy be used only in areas where saturated soils occur within a few meters of the soil surface. According to Graf et al. (1994), groundwater is at or within a meter of the soil surface along the Lower Gila River reach from Texas Hill and Dome. Graf et al. (1994) also identified an area just downstream from Dendora Valley where groundwater is forced to the surface. This area may also be ideal for establishing open water sites through excavation.

In addition, this strategy should be used only in areas that afford at least some protection from flooding (e.g., upper terraces, behind levees). Due to the large amounts of sediment that are transported by the Gila River, an excavated area exposed to flooding could be filled in by one flood event.

Other Issues
This strategy does not address some of the other issues involved in re-establishing native vegetation communities along the lower Gila River, including competition from saltcedar and lack of native seed sources. This strategy would therefore be most effective if combined with several of the other strategies presented in this report, including preserving meanders,

revegetating with native species, and selective removal of saltcedar. In addition, groundwater fluctuation (seasonal and diurnal) needs to be considered so that the optimum excavation depth can be accurately ascertained.

9. Allow The River To Seek Its Own Path

Description
This strategy encourages a hands-off approach that allows the river to return on its own to a more natural condition.

Recommendations
This strategy can be combined with altering dam releases to mimic natural flow patterns and increasing the width of the active Gila River flood plain by removing or distancing levees from the Gila River channel. This strategy may be most appropriate for reaches bordered by non-productive farmland, between Dendora Valley and Texas Hill (Agua Caliente and BLM-owned property). Levees protecting the farmland can either be removed or set back to allow the channel greater freedom. The principal aim is to return the Gila River to a more natural hydrologic state. This strategy need not apply to the entire Gila River flood plain. A meander belt that allows for the migration of individual bends over a ten to twenty year period can be established over the period of time required for planning and management.

There are several advantages that this strategy has over many of the other strategies mentioned in this report, including:

i - this strategy gives the river freedom to move across its flood plain and is therefore the definitive approach for working with stream processes rather than against them;

ii - by its very nature, a hands-off approach does not include expensive manipulations and may therefore be less expensive than other strategies;

iii - relying on natural channel healing processes also eliminates the potential that expensive strategy restoration strategies will be destroyed by large flow events.

Other Potential Issues
One disadvantage of this strategy is that it may take a long period of time before the river re-establishes itself in a state of dynamic equilibrium (i.e., it may be some time before results are achieved). In addition, this strategy does not directly address some of the other issues contributing to the decline of native riparian ecosystems (e.g., competition from saltcedar, lack of native seed sources).

10. Alter Dam Releases

Description
Altering dam releases to emulate natural flow patterns can help to spark natural regeneration of native riparian plant species.

Recommendations
A large spring flood of several thousand cubic feet per second should be released from the Painted Rock Dam to coincide with seed dissemination of native riparian species such as cottonwoods and willows (late March to early April). The alternative, late season releases (summer) enhances the conditions for saltcedar growth.

Other Issues
Altering dam releases probably will not solve the saltcedar problem, nor will it result in natural regeneration of native riparian species in areas where seed sources for these species are lacking. In addition, altering dam releases is a very complicated situation as the dam does not fill every year.

F. CONCLUSION

Applying the habitat restoration strategies throughout the Lower Gila riparian area would cause the naturally occurring vegetation communities to recover. Sensitive habitat communities that are classified as a Resource Category I, such as the cottonwood-willow and leguminous short tree communities would benefit from revegetation attempts. Any increase in the size and/or health of the Resource Category I communities would benefit many wildlife species, including threatened and endangered species such as the Yuma Clapper Rail and the Southwestern Willow Flycatcher.

Given a high level of management over a period of several years, the cottonwood/willow community would increase in size and the area that is currently dominated by saltcedar trees would convert to leguminous short tree species (Table 6). Based upon these assumptions, a comparison of riparian habitat conditions for long term future-with-project and future-without-project conditions in representative areas is shown in Table 7. There would be an increase of over 100% in all vegetation communities, with an over 400% gain in the wetland-marsh community.

Upon a review of this report, representative members of the Corps of Engineers, Arizona Game and Fish Department, Bureau of Land Management, and U.S. Fish and Wildlife Service, discussed which restoration strategies applied to each reach of the Lower Gila River. Based upon that discussion, the following restoration strategies should be further investigated during the feasibility analysis of this project.

Table 6: Habitat Units for Future <u>with</u> Project Conditions

Cottonwood	Willow	Dominant			
Site No.	Area (Acres)	Quality (0-1)	Habitat Units	Water Source	Impact
9	31.9	.94	30.0	Agricultural	Mature Cottonwoods/Willows
11	177.9	.94	167.2	Agricultural	Mature Cottonwoods/Willows
15	32.4	.94	30.5	Agricultural	Mature Cottonwoods/Willows
Total	342.2		227.7		
Wetlands	**Marsh**	**Dominant**			
Site No.	Area (Acres)	Quality (0-1)	Habitat Units	Water Source	Impact
13	192.1	.96	184.4	Agricultural	No Change (Quigley Pond)
14	794.3	.94	746.6	Agricultural	Mature Cottonwoods/Willows
Total	986.4		931.0		
Leguminous	**Short Tree**	**Dominant**			
Site No.	Area (Acres)	Quality (0-1)	Habitat Units	Water Source	Impact
1	2.6	.48	0.2	Flood Control	Eliminate Saltcedar
3	82.2	.48	39.5	Groundwater	Eliminate Saltcedar
Total	84.4		39.6		
Saltcedar	**Dominant**				
Site No.	Area (Acres)	Quality (0-1)	Habitat Units	Water Source	Impact
2	408.3	.48	196.0	No Water	Change to Leguminous Trees
4	1024.0	.48	491.5	No Water	Change to Leguminous Trees
5	756.5	.48	363.1	No Water	Change to Leguminous Trees
6	1932.3	.48	927.5	No Water	Change to Leguminous Trees
7	479.6	.48	230.2	No Water	Change to Leguminous Trees
8	934.5	.48	448.6	Agricultural	Change to Leguminous Trees
10	1402.1	.79	1107.7	No Water	Change to Leguminous Trees
12	949.2	.79	750.0	Agricultural	Change to Leguminous Trees
16	231.2	.79	182.6	Agricultural	Change to Leguminous Trees
17	222.5	.79	175.8	Agricultural	Change to Leguminous Trees
Total	8340.2		4873.0		

Table 7: Comparison of Riparian Habitat Conditions for Future-with-Project and Future-without-Project Conditions
(Representative areas only, for comparison purposes)

Habitat Type	Future Without-Project Area (Acres)	Future With-Project Area (Acres)	Percent Difference in Area	Future Without-Project Habitat Units	Future With-Project Habitat Units	Percent Difference in Habitat Units
Cottonwood-Willow	0	342.2	>+100	0	227.7	>+100
Wetland-Marsh	192.1	986.4	+413.5	184.4	931.0	+405
Leguminous Short Tree Species	0	4957.4	>+100	0	4912.6	>+100
Saltcedar	9561.5	0	>+100	3135.6	0	>+100

A. Dendora Valley Restoration Strategies (Following numbering sequence set out in above text)

1. Preserving Existing Native Vegetation
2. Revegetating With Native Riparian Species
3. Removing Saltcedar
6. Altering Channel Form
   a. Deepen side swales in channel
   b. Create temporary off-channel berms to back water up to create marsh/wetland conditions when water is present
8. Creating Open Water Sites Through Excavation
9. Allow the River to Seek Its Own Path
10. Alter Dam Releases

B. Agua Caliente Restoration Strategies (Following numbering sequence set out in above text)

1. Preserving Existing Native Vegetation
2. Revegetating With Native Riparian Species
3. Removing Saltcedar
6. Altering Channel Form
   a. Off-stream storage for ground water storage facilities
   b. Open water
9. Allow the River to Seek Its Own Path
10. Alter Dam Releases

C. BLM-Owned Property Restoration Strategies (Following numbering sequence set out in above text)

1. Preserving Existing Native Vegetation
2. Revegetating With Native Riparian Species
3. Removing Saltcedar
9. Allow the River to Seek Its Own Path
10. Alter Dam Releases

D. *Mohawk-Wellton Valley Restoration Strategies* (Following numbering sequence set out in above text)

1. Preserving Existing Native Vegetation
2. Revegetating With Native Riparian Species
3. Removing Saltcedar
4. Flooding Dedicated Agriculture Fields (flooding fields taken out of production by WMIDD)
5. Rehabilitating Dedicated Farmland
   a. Provide native riparian vegetation
   b. Provide native grains
7. Enhance Existing Oxbows
8. Create Open Water Sites Through Excavation

If these restoration strategies were adopted in the 4 sections of the Lower Gila River, many acres of both existing and new native vegetation communities would be preserved and protected. In order to create areas that contain native riparian plant communities, many acres of saltcedar would be eradicated. Table 8 shows the number of acres and their associated habitat units for each of the existing native vegetation communities in each of the 4 sections of the Lower Gila River, if they were preserved. Table 9 shows the number of acres and habitat units associated with establishing new native vegetation communities in each of the 4 sections of the river if the restoration strategies were implemented. Finally, Table 10 shows how many acres of saltcedar, and the associated habitat units, would be removed if these native riparian communities were established.

Table 8: Habitat Unit Values From Preserving Existing Vegetation Communities (Strategy #1)

Location	Ave. Value*	Acres	Habitat Units
Dendora Valley			
Leguminous Short Tree	.48	239.7	115.1
Cottonwood-Willow	.94	0.0	0.0
Marsh-Wetland	.95	85.0	80.8
Agua Caliente			
Leguminous Short Tree	.48	930.6	446.7
Cottonwood-Willow	.94	190.2	178.8
Marsh-Wetland	.95	158.0	150.1
BLM-Owned			
Leguminous Short Tree	.48	1726.5	828.7
Cottonwood-Willow	.94	99.2	93.3
Marsh-Wetland	.95	49.8	47.3
Wellton-Mowhawk			
Leguminous Short Tree	.48	2743.2	1316.7
Cottonwood-Willow	.94	2080.7	1955.9
Marsh-Wetland	.95	1094.9	1040.2

* Calculated by averaging the Average Value for conditions for each vegetation community, based on values in Table 6.

Table 9: Proposed Increase in Acres and Habitat Units by Location and Vegetation Community from Restoration Strategy #2

Location	Ave. Value*	Acres	Habitat Units
Dendora Valley			
Leguminous Short Tree	.48	500	240.0
Cottonwood-Willow	.94	50	47.0
Marsh-Willow	.95	200	190.0
Agua Caliente			
Leguminous Short Tree	.48	300	144.0
Cottonwood-Willow	.94	40	37.6
Marsh-Wetland	.95	100	95.0
BLM-Owned Property			
Leguminous Short Tree	.48	300	144.0
Cottonwood-Willow	.94	40	37.6
Marsh-Willow	.95	75	71.2
Wellton-Mohawk			
Leguminous Short Tree	.48	100	48.0
Cotttonwood-Willow	.94	100	94.0
Marsh-Wetland	.95	400	380.0

* Calculated by averaging the *Average Value* for future conditions for each vegetation community, based on values in Table 6.

Table 10: Proposed Decrease in Acres and Habitat Units of Saltcedar by Location from Restoration Strategy #2

Location	Value*	Area (Acres)	Habitat Units
Dendora Valley	.2	750	150
Agua Caliente	.2	340	68
BLM-Owned Property	.2	340	68
Wellton-Mohawk	.2	200	40

* Saltcedar Values for modern historic conditions in Table 2.

LITERATURE CITED

Anderson, B.W. 1989. Research as an integral part of revegetation projects, p.413-419. In: D.L. Abell (technical coordinator) Proceedings of the California Riparian Systems Conference: protection, management, and restoration for the 1990's; September 22-24, Davis, California. General Technical Report PSW-110. U.S. Department of Agriculture, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Anderson, B. W., and R. D. Ohmart. 1993. The development of an Arizona riparian habitat model with wildlife values. Arizona Game and Fish Department, Phoenix, Az. Contract No. G30025-B. 34pgs.

Anderson, B.W., R.D. Ohmart, and J. Disano. 1978. Revegetating the riparian floodplain for wildlife, p.318-331. In: Strategies for Protection and Management of Floodplain wetlands and Other Riparian Ecosystems. U.S. Department of Agriculture, Forest Service. Calloway Gardens, Georgia.

Barrows, C.W. 1993. Tamarisk Control II. A success story. Restoration and Management Notes 11:35-38.

Briggs, M. 1992. An evaluation of riparian revegetation efforts in Arizona. Master's thesis, School of Renewable Natural Resources, University of Arizona, Tucson, AZ.

Briggs, M. 1994. Repairing degraded riparian ecosystems -- a guidebook for ecosystem managers. In cooperation with: World Wildlife Fund, Arizona Game & Fish Department, U.S. Bureau of Reclamation, U.S. Bureau of Land Management, U.S. Fish & Wildlife Service. Rincon Institute, Tucson, Arizona.

Brookes, A. and K. Gregory. 1988. Channelization, river engineering and geomorphology, pp. 145-167. In: J.M. Hooke (ed.) Geomorphology in Environmental Planning. John Wiley & Sons Ltd.

Brown, D. E., Lowe, C. H., and C. P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. J. Arizona - Nevada Academy of Science 14, (Suppl.1):1-16.

Busch, S.E., N.L. Ingraham, and S.S. Smith. 1992. Water uptake in woody riparian phreat ophytes of the southwestern U.S.: a stable isotope study. Ecological Applications 2:450-459.

Campbell, C.J., and W. Green. 1986. Perpetual succession of stream-channel vegetation in a semiarid region. Journal of the Arizona Academy of Science 5:86-97.

Chapman, V.J. 1975. The salinity problem in general, its importance, and distribution with special reference to natural halophytes, p. 7-24. In: A. Poljakoff-Mayber and J. Gale (eds.) Plants in saline environments. Springer-Verlag, New York.Eddleman, W. R. 1989. Biology of the Yuma Clapper Rail in the Southwestern

Eddleman, W. R. 1989. Biology of the Yuma Clapper Rail in the Southwestern U.S. and Northwestern Mexico, Final Report. Submitted to the U.S. Bureau of Reclamation, Yuma Projects Office, and the U.S. Fish and Wildlife Service Region 2. Intra-Agency Agreement No. 4-AA-30-02060. Wyoming Cooperative Research Unit, Univ. of Wyoming. 127pgs.

Fenner, P., W.W. Brady, and D.R. Patton. 1984. Observations on seeds and seedlings of Fremont Cottonwood. Desert Plants 6:55-58.

Graf, W. L., P. J. Beyer, J. L. Rice, and T. A. Wasklewisz. 1994. Geomorphic assessment of the lower Gila River, west central Arizona. Conducted for the U.S. Army Corps of Engineers, Los Angeles District. Contract DACW09-94-M-0494. 142pgs.

Hill, D.A. Manipulating water habitats to optimize wader and wildfowl populations, pp.377. In: G.P. Buckley (ed.) Biological Habitat Reconstruction. Belhaven Press, New York.

Howard, S.W., A.E. Dirar, J.O. Evan, and F.D. Provenza. 1983. The use of herbicides and/or fire to control saltcedar (tamarix). Proceedings of the Western Society of Weed Science 36:65-72.

Jackson, L.L., J.R. McAuliffe, and B.R. Roundy. 1991. Desert restoration. Restoration and Management Notes 9:70-79.

McBride, J.R., and J. Strahan. 1984. Establishment and survival of woody riparian species on gravel bars of an intermittent stream. The American Midland Naturalist 112:235-245.

Nature Conservancy Council. 1983. Nature conservation and river engineering (NCC, UK).

Neill, W.M. 1990. Control of tamarisk by cut-stump herbicide treatments. Tamarisk control in southwestern United States. Cooperative National Park Resources Studies Unit, Special Report No. 9:91-98.

Reichenbacher, F.W. 1984. Ecology and evaluation of southwestern riparian plant communities. Desert Plants 6:15-22.

Sudbrock, A. 1993. Tamarisk control I. Fighting back - an overview of the invasion, and a low-impact way of fighting it. Restoration and Management Notes 11:31-34.

University of Arizona, Office of Arid Lands Studies. 1970. Environmental study for the Gila River below Painted Rock Dam. Conducted for the Department of the Army, Los Angeles District Corps of Engineers, Contract No. DACW09-70-C-0079. 92pgs.

Exhibit 1: Habitat Analysis Variables and Definitions of Variable Values.

1. *Vegetation Series* based on Omhart and Anderson (1993). Brown, Lowe, and Pace (1979) plant hierarchy listed in parentheses.

    1= Willow/Sycamore Ash/Ash Oak Communities: *Populus-Salix* association with one or more of the following (222.214):
    Chrysothamus nauseosus
    Sporobolus airoides
    Sarcobatus vermiculatus
    Atriplex spp.
    Suaeda spp.
    Including *Populus wislizeni* (223.213) and *Populus angustifolia* (222.321)

    Populus fremontii-Salix association (223.211)
    Populus fremontii association (223.212)
    Populus fremontii, Brickellia longifolis-Acacia greggii (223.2121)

    Platanus wrightii-Fraxinus velutina-Populus fremontii, Platanus wrightii-Fraxinus velutina-Pinus engelmannii-Quercus arizonica (223.2211 and 223.2211)

    Platanus wrightii association (223.222)
    Fraxinus velutina association (223.223)

    Populus spp. and *Salxi* spp. with *Washingtonia filifera* (224.512)

    Populus fremontii-Salxi gooddingii, Populus fremontii, Salix gooddingii, Populus fremontii-Prosposis velutina (224.523, 224.531,, 224.532, and 224.534)

    2= *Prosopis glandulosa var. torreyana* (154.173)
    Atriplex spp., *Propopsi glandulosa* (154.177)

    Alnus oblongifolia association (223.224)
    Juglans major association (223.225)

    Prosopis velutina association (224.521 including 224.5211, 224.5212)

    Cercidium floridum association (224.523 including 224.5231), *Prosopis glandulosa, Ambrosia ambrosioides*

    Prosopis velutina mixed deciduous tree association (*Populus, Sambucus, Celtis, Fraxinus*) (224.523)

Exhibit 1 Cont.

Prosopis velutina, Populus fremontii association (224.524)
Prosopis velutina, Ambrosia ambrosioides, Ambrosia cordifolia, Celtis pallida (224.7124)
Sporobolus-Prosopis (352.23)

3= Tamarisk: *Tamarix* sp.-*Sporobolus airoides* (222.2163)

Tamarix disclimax series and mixed shrub association, *Tamarix-Salsola* association (234.721 and 234.722)

Mixed shrub (seepwillow, burrobush, and tamarisk) (342.43

4= Mesquite/Salt Cedar: *Prosopis glandulosa*/Saltcedar association often mixed with *Tessaria, Atriplex* spp.

5= *Prosopis pubescens-P. glandulosa* var *torreyana-Tessaria sericeas, Prosopis pubescens-Tamarix* spp. (234.711)

6= *Atriplex lentiformis-A. canescens* mixes

7= Shrub communities: *Atriplex* spp. (154.177), *Suaeda torreyna* (154.171), *Baccharis salificolia-B. sarothroides* communities, *Lycium* spp. (352.42)

8= Arrowweed and Arrowweed-like communities: *Allenroffea, Baccharis* spp. (154.173)

2. *Vegetation Structure*, based on structural diversity, 1 being the more structured, 6 being the least structured (based on figure 1, page 29, in Omhart and Anderson, 1993)

Exhibit 1 Continued

3. *Threatened or Endangered Species Habitat (T/E)*: Yuma Clapper Rail and Southwestern Willow Flycatcher habitat
   - 0.0 = None (No suitable Habitat)
   - 0.5 = Ponded water but no cattails
   - 1.0 = Ponded water and late seral cattails

4. *Water*: Continual water source

   - 0.0 = None
   - 0.5 = Visible water but minimal amounts
   - 1.0 = Visible water

5. *Wildlife*: Bird and wildlife species present and/or sign present during survey. Based on (1970) and Graff et al. (1994).

   - 0.0 = 0 - 19% of the potential species may be present
   - 0.2 = 20 - 49% of the potential species may be present
   - 0.5 = 50% of the potential species may be present
   - 0.7 = 51 - 90% of the potential species may be present
   - 1.0 = 91 - 100% of the potential species may be presnet

6. *Undisturbed/disturbed habitat*: Disturbance includes proximity of the site to urban or industrial areas, recent grading, proximity to agricultural land, and illegal dumping. Undisturbed areas were those that appeared to have little human influence.

   - 0.0 = A lot of disturbance
   - 0.5 = slight disturbance
   - 1.0 = no or minimal disturbance

Exhibit 2: Site Descriptions From On-Site Field Work Along The Lower Gila River.

Site 1: This site was classified as Leguminous Short Tree Series. Predominant species were: blue paloverde (*Cercidium floridum*), honey mesquite (*Prosopis glandulosa* var. *torreyana*), smoketree (*Dalea spinosa*), canyon ragweed (*Ambrosia ambrosioides*), and burroweed (*Hymenoclea salsola*). Terraces above this Series included species such as creosote (*Larrea tridentata*), all-scale (*Atriplex polycarpa*), white bursage (*Ambrosia dumosa*), and catclaw acacia (*Acacia greggii*).

Transition between main channel and surrounding terraces was abrupt with terraces averaging 8 meters in elevation higher than channel bed. Erosion of channel banks was dramatic in some areas, showing significant gullying. Width of channel at confluence with the Gila River was roughly 60 meters. In-channel depositional rates (aside from deposition as a result of channel bank erosion) appeared to be minimal. Saltcedar was the dominate plant species at the confluence of Fourth of July Wash and the Gila River and appeared to be spreading up the Fourth of July Wash channel. Saltcedar became the dominate in-channel species about 120 meters from the confluence.

Site 2: This site was classified as Saltcedar Disclimax Series. Predominant species were: Saltcedar and evergreen athel (*Tamarisk* spp.), quailbrush (*Atriplex lentiformis*), and arrowweed (*Pluchea sericea*).

Transition between main channel and surrounding terraces was abrupt with terrace surfaces about 8 meters in elevation higher than the channel bed. Saturated soils were found immediately below the soil surface, however this could be the result of recent rains and therefore may only be a transitory characteristic of this site. Some erosion of channel banks and toe deposition was evident. Elevation changes along the terraces were gradual. Aggradational rates along this reach appeared to be minimal. Terrace vegetation communities on the right (looking downstream) of the main channel were roughly 520 meters wide, those on the left side of the channel were roughly 700 meters wide. Terraces were characterized by significant alluvial deposition in some areas, possibly due to major flooding during the winter of 1993.

Site 3: This site was classified as Leguminous Short Tree Series, but was intermingling Saltcedar Disclimax Series. Along with species listed for Site 2, graythorn (*Zizyphus obtusifolia*) and wolfberry (*Lycium andersonii*) were present.

Main channel was 250 meters wide and was divided roughly in-half by a sand bar that was 50 meters wide. As with site #2, the transition between main channel and surrounding terraces was abrupt, but elevation differences between the two landforms were less, with terrace surfaces 2.5 meters higher in elevation than the channel bed. Terrace vegetation communities on the left side of the channel were 1.5 kilometers wide,

Exhibit 2 Continued

those on the right side of the channel were roughly .5 kilometers wide. Channel bank erosion and extensive toe deposition may be an indication of channel widening. Deposition of in-channel vegetation root flares may be an indication that this reach was experiencing significant aggradational rates. Depth to saturated soils appeared to be significant (i.e., greater than that which is conducive to the natural establishment of native phreatophytic vegetation).

Site 4: This site was classified as Saltcedar Disclimax Series. Along with species listed in 2, Russian thistle (*Salsola kali*) and seepweed (*Suaeda torreyana*) were prevalent.

Channel morphologic characteristics were much like site #2. Given the presence of a healthy mesquite bosque, depth to saturated soils along this reach may be less than at site #3.

Site 5: This site was classified similar to Site 4. A few cattails *(Typha domingensis*) were also found.

The main channel was over 1000 meters wide. Transition from channel bed to upper terraces was gradual on the right side of channel and abrupt on the left side. Isolated stands of cattails and the presence of saturated soils just beneath the channel bed may be an indication that plant water availability at this site was high. Root flares of in-channel vegetation were covered by 5 to 10 cm of alluvium, possible indicating significant aggradational rates along this reach. Terrace vegetation communities along both sides of this reach were not extensive due to significant agricultural activities.

Site 6: This site was classified similar to Site 4.

Transition between main channel and surrounding terraces was abrupt with terrace surfaces averaging 8 meters in elevation higher than the channel bed. Main channel was 450 meters wide. In-channel depth to saturated soils was minimal. Pools of standing water were present, possibly due to agricultural runoff. Terrace vegetation communities along the left side of channel were non-existent due to agricultural activities. Terrace vegetation communities on the right side of main channel were over .5 kilometer wide.

Exhibit 2 Continued

Site 7: This site was classified similar to Site 4.

Transition between main channel and surrounding terraces was abrupt with terraces averaging 8 meters in elevation higher than the channel bed. Main channel was over 425 meters wide. Channel morphologic characteristics were much like site #3, with the main channel divided roughly in-half by a depositional bar. As with site #6, depth to saturated soils along the main channel appeared to be minimal. Terrace vegetation communities along the left side of channel were influenced by agriculture. Terrace vegetation communities on the right side of main channel were over .5 kilometer wide.

Site 8: This site was classified similar to Site 2. Along with speices listed in 2 there were several stands of cattails and some young willow stands (<25 feet tall). There was no water present.

The main channel was 35 meters wide and was surrounded on both sides by active terraces that were 1 meter higher in elevation. Surrounding landforms step-up gradually to abandoned terraces which were roughly 3 meters higher in elevation than the main channel bed. Main channel and active terraces showed significant aggradational rates. Saturated soils in the main channel and active terraces were found to be 5 to 10 cm below the soil surface. Upper terrace vegetation communities on both side of the channel were over .75 kilometers wide.

Site 9: This site was classified as Cottonwood-Willow Series. Many medium height willows (10-30 ft) were present. Cattails were present in patchy areas within the river channel. Some arroweed was also growing in the understory. There was no water visiable.

The channel was braided, featuring three thalwegs. Distance across the braided channel, between upper terraces, was almost 1.5 kilometers. Vegetation growing on in-channel depositional features indicated the presence of saturated soils at shallow depths. Aggradation characteristics were much like site #8.

Site 10: This site was classified similar to Site 8.

Channel morphology, aggradation characteristics, and water availability were similar to site 8.

Exhibit 2 Continued

Site 11: This site was classified as Cottonwood-Willow Series. Medium height cottonwoods (about 30 feet) and willows were on the 2nd terrace of the river bed. Some standing water was present.

The main channel was 80 meters wide and was surrounded on both sides by active terraces that were 1.5 meters in elevation higher than the channel bed. Abandoned terraces were over 3 meters in elevation higher than the elevation of the main channel bed. Distance between abandoned terraces (active terrace-main channel-active terrace) was over 500 meters. The presence of native phreatophytes (*Salix* sp.) and standing water indicated a higher water availability than that found along the Gila River reach that extends from the Painted Rock Dam through the BLM study areas.

Site 12: Site site was classified as a Saltcedar Disclimax Series. Predominant species were: Saltcedar and evergreen athel (*Tamarisk* spp.) and arrowweed (*Pluchea sericea*). Young willows ans some mature cottonwood trees were located in the upper terrace of the river channel. There was no running water.

Channel morphology and aggradation characteristics were similar to site 11.

Site 13: Quigley Pond, north of Tacna, Arizona. This site was classified as a Leguminous Short Tree Series. There were a series of ponded ares with late stage seral cattails and other plants found in a marsh/wetlands community. Waterfowl was present. Some saltcedar was present at the edge of the site.

Oxbow contained numerous open water sites.

Site 14: This site was classified similar to site 10. There were several (>5) mature cottonwood trees present.

Main channel was 440 meters wide and contained two thalwegs that contained above surface water. Upper terraces were almost 3 meters higher in elevation than the main channel and the transition between main channel and upper terraces was abrupt. Significant in-channel aggradation was evident.

Exhibit 2 Continued

Site 15: This site was classified similar to site 10. The river channel contained free-running water, with cattails and bulrushes present along the banks. Small, sparse, saltcedar and arrowweed, were found on the 1st terrace, between the marsh/wetland community and the cottonwood-willow community. Migrating waterfowl were present.

Channel morphology, aggradation, and water availability characteristics were similar to site 14.

Site 16: This site was classified as Saltcedar Disclimax Series. Saltcedar was the dominent community on the upper terrace, with willow and small cottonwood (*Populus* spp.) intermingled with the Saltcedar. The river channel contained clear running water, and along its banks was a marsh/wetlands community with cattails and bulrushes. Ponded water with fish were present.

The main channel was 10 meters wide and was surrounded on both sides by active terraces whoses surfaces were 1 meter higher in elevation than the channel bed. Landforms on both sides of the channel gradually stepped up to abandoned terraces which were roughly 3 meters higher in elevation than the main channel bed. Distance between abandoned terraces (active terrace-main channel-active terrace) was over 60 meters. The presence of native phreatophytes (*Salix* sp.) and standing water indicated high plant water availability.

Site 17: This site was classified as Saltcedar Disclimax Series. Saltcedar and evergreen athel (*Tamarisk* spp.) were the dominent species. Running clear water, with scattered small ponded areas, was present in the river channel. Along the banks of the water were cattails, bulrushes, and sparse young willow.

Channel morphology and water availability characteristics were similar to site 16.

COST ESTIMATE ADDENDUM

to the

HABITAT ANALYSIS REPORT

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21 December 1994

From: Arizona Real Estate Project Office

To: Arizona Planning Section

Subject: Gila River Downstream from Painted Rock Dam

For purposes of cost effectiveness a nominal value of $250 per acre was considered reasonable for estimating potential the real estate acquisition costs for lands in the lower Gila River floodplain. The $250 per acre includes the fee simple land value, manhours to complete title search, the negotiations and acquisitions. Procurement of these lands has been proposed to create environmental restoration projects downstream from Painted Rock Dam in Maricopa and Yuma Counties. As of this date definitive sites and their sizes have not yet been identified. However, it is known that the sites will be within the historical Gila River floodplain. It is recognized that these vast undeveloped desert lands in the floodplain have extremely limited utility and a nominal value of $250.00 per acre is felt appropriate.

Brian Kirchner

Brian Kirchner
Appraiser
COE Arizona Real Estate Office

SUMMARY OF MODERN HISTORIC, EXISTING AND FUTURE CONDITIONS

Table 1 provides a summary of modern historic, existing, future-without-project and future-with-project habitat areas and values over the entire study area. The table shows clearly that saltcedar has been increasing dramatically and at the expense of the native cottonwood-willow, leguminous short tree (mesquite) and wetland/marsh vegetation. Exceptions occur in the Wellton-Mowhawk area where cottonwood-willow and wetland/marsh vegetation have increased, and in the BLM lands where leguminous short tree and wetland/marsh vegetation have increased in area and habitat units. These exceptions are due to: 1) active restoration and preservation of cottonwood-willow and wetland/marsh vegetation in the Wellton-Mowhawk area by the Arizona Game and Fish Department, 2) favorable groundwater conditions in many areas downstream of Texas Hill due to the importation of Colorado River Water for Irrigation, and 3) unusual conditions favorable to the establishment of cottonwood-willow and wetland/marsh vegetation created by the 1993 flood. In general, favorable communities, defined as those that are native to the area, have declined by more than 40,000 acres while saltcedar has increased by approximately the same amount. Because saltcedar is less desirable as habitat for wildlife, the total number of habitat units has declined by nearly 7,000. This is roughly equivalent to the permanent loss of 7,000 acres of wetland/marsh.

The flood of 1993 was the first that overtopped the Painted Rock Dam spillway and passed downstream unregulated by the Corps of Engineers. The peak flood discharge was approximately 25,800 cfs, which, prior to the construction of the dam, would have been a five-year flood. In effect, flood conditions were created which were similar to the conditions that existed prior to the construction of the dam. These conditions included sustained overbank flow and flow in secondary channels, bank erosion, transport and deposition of sediment in the channel overbanks and thorough saturation of all floodplain sediments. As a result, cottonwood-willow and wetland/marsh vegetation began to rebound in the form of young communities. The fact that these communities returned so quickly after the flood demonstrates that with the right conditions habitat can be restored on the lower Gila River. However, because these communities are young, and a repeat of the 1993 flood conditions is unlikely, it is probable that most will not survive without a restoration project. It is assumed that in the absence of a Corps project, only 30% of these communities will survive in the future-without-project condition. The remaining 70 percent will be overtaken by salt cedar, as has been demonstrated to be the current trend.

The proposed preservation and restoration projects identified in the main report will result in a net increase of more than 7,000 acres of cottonwood-willow, leguminous short tree and wetland/marsh vegetation, and a corresponding decrease in saltcedar. The net increase in habitat units will be approximately 3,570. The majority of the increase is in the Wellton-Mowhawk area due to the large existing community that will be preserved in that reach.

Table 1. Summary of Modern Historic, Existing, Future-Without-Project and Future-With-Project Habitat Areas and Values for Lower Gila River Study Area.

Area	Vegetative Community	Modern Historic Conditions		Existing Conditions		Future Without Project (FWOP) Conditions		Future With Project (FWP) Conditions		Difference (FWP-FWOP)	
		Acres	HU[1]	Acres	HU	Acres	HU	Acres	HU	Acres	HU
DENDORA VALLEY AND AGUA CALIENTE	Cottonwood Willow	1302	1172	190[2]	179[2]	57	54	280	263	223	209
	Leguminous Short Tree	5730	2808	1170	562	936	449	1970	946	1034	497
	Wetland-Marsh	292	292	243[2]	231[2]	73	69	543	516	470	447
	Open Space	15754	5987	5139	2055	4625	1850	4839	1936	214	86
	Saltcedar	153	30	12156	3343	13207	2641	11266	2253	-1941	-388
	All Communities	23231	10289	18898	6370	18898	5063	18898	5914	0	851
WELLTON-MOWHAWK[3]	Cottonwood Willow	845	683	2080	1956	624	587	2180	2049	1556	1463
	Leguminous Short Tree	11959	5860	2743	1317	2194	1053	2843	1365	649	311
	Wetland-Marsh	400	400	1095	1040	329	312	1495	1420	1167	1108
	Open Space	16102	6118	7698	3079	6928	2771	7298	2919	370	148
	Saltcedar	3687	700	21450	5899	24991	4998	21250	4250	-3741	-748
	All Communities	32993	13761	35066	13291	35066	9721	35066	12003	0	2282
BLM LANDS[3]	Cottonwood Willow	599	539	99[2]	93[2]	30	28	139	131	109	102
	Leguminous Short Tree	1539	753	1727	829	1382	663	2027	973	645	310
	Wetland-Marsh	34	34	50	48	15	14	125	119	110	105
	Open Space	17035	6474	5387	2155	4848	1939	5312	2125	464	185
	Saltcedar	68	17	12112	3331	13100	2620	11772	2354	-1328	-266
	All Communities	19275	7817	19375	6456	19375	5264	19375	5702	0	436
ALL LANDS	Desirable Communities	71591	31120	27621	13544	22041	9790	29051	14761	7010	4971
	Saltcedar (Undesirable)	3908	747	45718	12572	51298	10260	44288	8858	-7010	-1402
	All Communities	75499	31867	73339	26116	73339	20050	73339	23618	0	3569

1 Habitat Units based on the assessed value of the vegetation community and its size, in acres

2 This existing is young vegetation that has appeared since and because of the unique conditions created by the 1993 flood. Because these habitats are young and created by the conditions following a very rare flood, they are not expected to survive without assistance, and are not considered representative of the true existing condition in these areas.

3 Modern historic areas and habitat units for the BLM Lands and Wellton/Mowhawk are extrapolated from aerial photographs covering only portions of, but considered representative of, the entire study area in these areas.

ASSUMPTIONS

- 70% of 1993 flood-created cottonwood-willow and wetland-marsh habitat will die off and be replaced by salt cedar in future-without-project conditions.
- Mesquite (leguminous short tree) will gradually decline 20% and be replaced by salt cedar in future-without-project conditions.
- Open space will gradually decline 10% and be taken over by proliferating salt cedar in the future-without-project condition.
- Existing conditions include previous restoration projects by locals.
- Average habitat value/acre of salt cedar = 0.28 based on weighted average from Table 5 of main report.

COST ESTIMATES

Table 2 summarizes preliminary per-acre costs for revegetation and preservation of existing communities. The source of each cost estimate item is provided as a footnote in the table. The general procedure for cottonwood-willow restoration, as described by the Fish and Wildlife Service for successful restoration projects in New Mexico, is a follows:

1. Uproot and remove saltcedar with a root plow, followed by a root rake. It is very important to remove the root crown bud. Root plowing and raking also prepares the soil so normally grading and supplemental preparation is not necessary.

2. Obtain cottonwood or willow poles from existing healthy sites.

3. Using a machine-powered augur, drill holes to a depth sufficient to supply water to the transplanted tree, insert the poles and fill the hole. A planting density of approximately 100 trees per acre has been sufficient. There is no watering and no follow-up maintenance.

It is assumed for purposes of Lower Gila River cost estimating that some saltcedar removal and limited, temporary, supplemental irrigation will be necessary after the initial planting. These costs have been estimated at 10% of the planting costs. Costs for preservation of existing communities are considered to be equal to the maintenance costs of restored communities. Marsh and mesquite restoration costs are assumed to be equal to those of the cottonwood and willow.

Costs for restoration in the BLM lands, Agua Caliente and Dendora Valley are estimated to be higher than those for the Wellton-Mowhawk area due to more limited access, more difficulty in obtaining water, supplemental irrigation and the probable need for additional site grading for water control purposes. Restoration in these areas is estimated at $9,600 per acre. Restoration in the Wellton-Mowhawk area is approximately $1,000 per acre.

Table 2. Per-Acre Costs for Revegetation along the Lower Gila River, All Sites.

COST ITEM	COST PER ACRE
COSTS FOR RESTORATION IN BLM LANDS, AGUA CALIENTE AND DENDORA VALLEY[1]	
Salt Cedar Removal[2]	$500
Earthwork (Grading)[3]	$6,000
Plant Establishment[4]	$2,000
Monitoring and Maintenance[5]	$850
Land Purchase	$250
Total[6]	$9,600
COSTS FOR RESTORATION IN WELLTON-MOWHAWK AREA	
Removal of Salt Cedar and Site Preparation[7]	$310
Plant Establishment[8]	$370
Monitoring and Maintenance[5]	$70
Land purchase	$250
Total	$1,000

1 Costs for the BLM lands, Agua Caliente and Dendora Valley are higher than those for the Wellton-Mowhawk area for the reason that these are generally on more rugged terrain requiring more site preparation (earthwork), water-control structures and a more intensive planting regime, possibly with some local, temporary, supplemental watering.

2 Based upon Maricopa County Costs for 1,000-foot Clearing on Salt River, and upon U.S. Fish and Wildlife Service costs for saltcedar clearing in New Mexico.

3 Assumed two acre-feet of earth moved at a cost of $2.00/cubic yard.

4 From: United States Bureau of Reclamation, 1992. Vegetation Management Study, Lower Colorado River, Phase I.

5 From: United States Bureau of Reclamation, 1992. Vegetation Management Study, Lower Colorado River, Phase I. Assumed to be 10% of initial revegetation cost, not including real estate costs. Maintenance costs for existing vegetation are assumed equal to this amount plus real estate costs.

6 Number in parenthesis is rounded for cost estimating purposes.

7 From U.S. Fish and Wildlife Service in New Mexico. Includes site preparation.

8 From U.S. Fish and Wildlife Service in New Mexico. Includes cutting poles, drilling holes and planting. No maintenance costs required.

Table 3 provides an estimate of specific habitat restoration costs and incremental gains in habitat units. The project total initial cost is estimated at $26,748,839. The gain in ripaian habitat units is 4,971 at the expense of 1,402 low quality saltcedar habitat units, for a net gain in habitat units of 3,568. The average aggregate intial cost is $7,497 per habitat unit. Unit costs are lowest in the Wellton-Mowhawk area due to lower unit costs for restoration and the presence of a larger community of existing habitat that will be preserved. Unit costs as low as $610 per habitat unit in this area are considered extremely cost effective and supportive of Federal participation in a restoration project along the Lower Gila River.

Table 3. Cost Estimate for Habitat Restoration and Preservation along the Lower Gila River.

Plant Community	Area Preserved	Preservation Cost	Net Gain in Habitat Units	Cost/Habitat Unit	Area Restored	Restoration Cost	Net Gain in Habitat Units	Cost/Habitat Unit	Total Cost	Total Net Gain in Habitat Units	Total Cost/Habitat Unit
Dendora Valley and Agua Caliente											
Leguminous Short Tree	1,170	$1,287,000	66	$19,643	800	$7,680,000	224	$34,286	$8,967,000	290	$30,972
Cottonwood-Willow	190	$209,000	98	$2,124	90	$864,000	67	$12,973	$1,073,000	165	$6,502
Wetland-Marsh	243	$267,300	128	$2,096	300	$2,880,000	225	$12,800	$3,147,300	353	$8,929
Open Space	4,839	NA[3]	43	NA	NA	NA	NA	NA	NA	43	NA
Subtotal	6,442	$1,763,300	334	$5,276	1,190	$11,424,000	516	$22,157	$13,187,300	850	$15,517
Contingencies		$264,495[1]	NA	NA	NA	$2,970,240[2]	NA	NA	$3,234,735	NA	NA
Total		$2,027,795	334	$6,067		$14,394,240	516	$27,917	$16,422,035	850	$19,324
BLM-Owned Property											
Leguminous Short Tree	1,727	$1,899,700	97	$19,666	300	$2,880,000	84	$34,286	$4,779,700	181	$26,466
Cottonwood-Willow	99	$108,900	51	$2,133	40	$384,000	30	$12,973	$492,900	81	$6,111
Wetland-Marsh	50	$55,000	26	$2,095	75	$720,000	56	$12,800	$775,000	83	$9,394
Open Space	5,312	NA	93	NA	NA	NA	NA	NA	NA	93	NA
Subtotal	7,188	$2,063,600	267	$7,737	415	$3,984,000	170	$23,456	$6,047,600	437	$13,853
Contingencies		$309,540[1]	NA	NA	NA	$1,035,840[2]	NA	NA	$1,345,380	NA	NA
Total		$2,373,140	267	$8,888		$5,019,840	170	$29,528	$7,392,980	437	$16,935
Wellton-Mowhawk											
Leguminous Short Tree	2,743	$877,760	154	$5,710	100	$100,000	28	$3,571	$977,760	182	$5,381
Cottonwood-Willow	2,080	$665,600	1077	$618	100	$100,000	74	$1,351	$765,600	1151	$665
Wetland-Marsh	1,095	$350,400	575	$610	400	$400,000	300	$1,333	$750,400	875	$858
Open Space	7,298	NA	74	NA	NA	NA	NA	NA	NA	74	NA
Subtotal	13,216	$1,893,760	1880	$1,008	600	$600,000	402	$1,493	$2,493,760	2282	$1,093
Contingencies		$284,064[1]	NA	NA	NA	$156,000[2]	NA	NA	$440,064	NA	NA
Total		$2,177,824	1880	$1,159		$756,000	402	$1,881	$2,933,824	2282	$1,286
Project Total	26,846	$6,578,759	2481	$2,652	2,205	$20,170,080	1088	$18,545	$26,748,839	3568	$7,497

1 Assumed 20% of total cost.
2 Assumed 31% = 20% contingencies, 5% engineering and design and 6% supervision and administration.
3 Not Applicable. Note: Preservation of some open space is expected to occur as an indirect result of project-related activities. There is no cost associated with this item.

APPENDIX H

ENVIRONMENTAL EVALUATION

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ARIZONA ECOLOGICAL SERVICES STATE OFFICE
2321 W. Royal Palm Road, Suite 103
Phoenix, Arizona 85021-4951

Telephone: (602) 640-2720 FAX: (602) 640-2730

October 28, 1994

In Reply Refer To:
AESO/SE

Colonel Michal R. Robinson
District Engineer
Army Corps of Engineers
P.O. Box 2711
Los Angeles, California

Dear Colonel Robinson:

This planning aid letter addresses effects of the proposed Gila River, Gillespie Dam to Yuma Reconnaissance Study (Study) on fish and wildlife resources. It is being provided pursuant to the Fish and Wildlife Coordination Act (Act)(48 stat. 401, as amended; 16 U.S.C. 661 et seq.) and has been developed in coordination with the Arizona Game and Fish Department (AGFD). It does not constitute the Fish and Wildlife Service (FWS) report under Section 2(B) of the Act.

DESCRIPTION OF PROJECT

The purpose of the Study being conducted by the Corps of Engineers (Corps), under authority of Section 116(b) of the Water Resources Development Act of 1993, is to analyze water conservation and the possibility of the protection and enhancement of the environmentally sensitive riparian and wetland areas along the Gila River.

The water conservation alternative would investigate the potential for conserving floodwaters behind Painted Rock Dam for releases and use by other entities. Preliminary analysis indicates that on an average annual basis, about 21,600 to 28,400 acre-feet of water would be available.

The entire study reach from Gillespie Dam to Yuma has great value for activities under the environmental restoration alternative. Opportunities for the restoration and enhancement of habitat for the endangered Yuma clapper rail and proposed Southwestern willow flycatcher would be examined. Riparian and wetland areas could be restored and enhanced by the deepening of off channel swales and oxbow meanders, selective clearing of exotic saltcedar with the planting of cottonwood and willow and other important wildlife vegetation species. Also, the acquisition of recently abandoned farmlands for the creation of riparian habitat will be analyzed.

DESCRIPTION OF PROJECT AREA

The reconnaissance study is located along the Gila River in Maricopa and Yuma Counties, Arizona. The study area is defined as the Gila River 100-year floodplain and is bounded on the upstream end by Gillespie Dam and the downstream end by the Colorado River.

The study area is divided into five reaches for the purposes of analysis.

Reach 1 extends from Gillespie Dam 14 miles downstream to the upstream extent of Painted Rock Reservoir and is comprised of limited agricultural areas on both sides of the river.

Reach 2 consists of the maximum extent of Painted Rock Reservoir up to the 661-foot elevation of the spillway.

Reach 3 covers the 59-mile stretch of river from Painted Rock Dam to Texas Hill and is primarily open desert with very limited farmlands along the river.

Reach 4 extends for 56 miles from Texas Hill to Dome, and traverses the Wellton-Mohawk Irrigation and Drainage District. The District maintains a flood control project including vegetative clearing 250 feet wide with levees to protect the agricultural lands adjacent to the river. This reach is the most important from an agricultural aspect and was responsible for most of the crops grown in Yuma County in 1992.

Reach 5 covers the remaining 11 miles of the river and extends from Dome to Yuma.

Much of the present surface flow of the Gila River within the study area is attributed to releases from upstream impoundments, agricultural return flows, and local storms. This surface flow supports riparian habitat and water obligate species. The river is essentially an ephemeral waterway that is dry most of the year with the exception of periodic flows.

ALTERNATIVES

Water Conservation

Under this alternative the conservation of floodwaters behind Painted Rock Dam for release by other entities would be investigated. Those entities that have expressed an interest include.

1. The Bureau of Reclamation - The Bureau indicated the water could be used to meet obligations to Mexico.

2. Wellton-Mohawk Irrigation and Drainage District - The water would be used for irrigation.

3. Others - A number of potential users may be interested in the conserved water including metropolitan water districts.

It is estimated that on an average annual basis, about 21,600 to 28,400 acre-feet of water could be available for these uses.

Environmental Restoration

Under this alternative opportunities to protect, enhance or create important wetland and riparian habitat which supports or could support the endangered Yuma clapper rail and proposed Southwestern willow flycatcher along with other species of migratory and resident species of wildlife will be investigated.

EXISTING ENVIRONMENT

The study area is below the confluence of three major rivers: the Gila, Salt, and Agua Fria. The headwaters of the Gila River drain off the eastern slopes of the Mogollon Mountains and the western slopes of the Black Range in New Mexico. The Salt River originates in the White and Blue Mountains in eastern Arizona with the main tributaries being the Black and White Rivers. It is a major tributary of the Gila River. The Agua Fria River begins south of Prescott and drains the eastern slope of the Bradshaw Mountains and the western slope of the Mingus Range and the Black Hills.

The study area is characterized by three distinct habitat types: desert upland, riparian forest, and marsh.

The upland community is the predominant habitat on the higher bench areas within the flood plain. This community is characterized primarily by shrubs, and annual and perennial herbs and grasses. Shrubs include creosote, catclaw, bursage, desert broom, saltbush, brittle bush, and saltcedar. Wildlife species that can be found in the uplands include javelina, mule deer, coyote, badger, various rodents, a variety of reptiles, and avian species such as the red-tailed hawk, cactus wren, Gambel's quail, and curve-billed thrasher.

Reaches of the Gila River that receive perennial flows support a narrow riparian community dominated by willow, cottonwood, and introduced saltcedar. Although saltcedar is an invader and has formed dense groves covering extensive areas, it does provide some wildlife habitat, especially for nesting doves. Riparian forests supports a large variety of wildlife species such as bats, skunks, raccoons, amphibians and reptiles, and a host of birds including hooded orioles, Abert's towhees, yellow and yellow-rumped warblers, red-winged blackbirds, Cooper's hawks, and various flycatchers. Many of the bird species are neotropical migrants and depend extensively on riparian communities for feeding and nesting needs.

Marsh areas exist where surface water and suitable soils are present. Vegetation includes cattails, bulrush, sedges, rushes and other emergent vegetation. A variety of amphibian and fish species and a host of avifauna such as rails, egrets, herons, shorebirds, and waterfowl are dependant upon this habitat type.

SPECIAL STATUS SPECIES

The project area provides wetland and riparian habitat for numerous species of fish and wildlife, including Federal and State listed threatened and endangered species. Four Federally listed and one proposed species have been known to occur in the study area. These are the Yuma clapper rail (Rallus longirostris yumanensis), bald eagle (Haliaeetus leucocephalus), peregrine falcon (Falco peregrinus anatum), brown pelican (Pelecanus occidentalis), and Southwestern willow flycatcher (Empidonax traillii extimus).

The Yuma clapper rail is presently found in the study area and is stable in its numbers. Primary habitat for the Yuma clapper rail consists of mature cattail/bulrush stands situated in shallow water near high ground. They use marsh habitat for foraging, nesting, roosting, and loafing. Preservation of this habitat is essential for these rails to successfully breed and continue to exist in the area.

The bald eagle and peregrine falcon are migrants that are occasionally seen in the study area, there are no known nest sites in the study area. The brown pelican is often blown up river from the coast by storms but is not a resident of the study area.

The Southwestern willow flycatcher is considered a rare migrant into the lower Gila River. Existing vegetative conditions does not provide suitable habitat for this spices.

State sensitive species which may occur in the study area include lowland leopard frog (Rana yavapaiensis), belted kingfisher (Ceryle alcyon), great egret (Casmerodius albus), snowy egret (Egretta thula), osprey (Pandion haliaetus), American bittern (Botaurus lentiginosus), least bittern (Ixobrychus exilis), ferruginous pygmy owl (Glaucidium brasilianum), black-necked stilt (Himantopus mexicanus), black-crowned night heron (Nycticorax), and white-faced ibis (Plegadis chihi).

FUTURE WITHOUT PROJECT

The without project condition assumes farming practices would remain as they are today, with no change in irrigation methods or number of acres farmed. Also, that no additional flood control features would be implemented or constructed. However, we expect that vegetative clearing will continue through the Wellton-Mohawk Irrigation and Drainage District. We also expect that periodic releases from upstream reservoirs will continue to inundate vegetation causing losses of valuable species such as honey mesquite and cottonwood. However, these releases do create high soil moisture resulting in high seed germination of desirable species such as cottonwood and willow. Under these conditions it is expected the riparian habitats will return to pre-flood levels. A loss of marsh habitat due to the scouring affects of the 1993 floods will in turn affect those species dependant on and associated with those habitats. However, it is expected that new wetlands will develop in the newly created oxbows. Fish and wildlife resources in the study area are expected to remain at present levels.

FUTURE WITH PROJECT

The alternatives and opportunities associated with each are ranked and discussed according to our perspective from most to least favorable to the riparian and marsh habitats within to study area.

Water Conservation

This alternative would provide open water habitat to support waterfowl and could support a fishery, if the water is impounded for a period long enough for the fish species to become established.

Emergent vegetation which supports a number of species including the endangered Yuma clapper rail would be provided. Also, soil moisture along the periphery of the lake and along the Gila River would be conducive to the establishment of riparian habitat. Local storm flows will continue to provide water to the riparian habitat.

Environmental Restoration

1. Deepening of off channel swales or oxbows - The deepening of oxbows would provide more open water habitat that would constitute a increase in benefits to both fish and wildlife resources in the study area. This alternative would promote the conservation of the Yuma clapper rail by the creation of conditions suitable for growth of marsh vegetation. If these oxbows were deepened six to eight feet below normal ground-water elevation within the river channel, they would provide fish habitat during flood flows and when no water is being released from upstream reservoirs. Also, soil moisture conditions conducive to the reestablishment of riparian species such as cottonwood/willow would be created.

2. Selective clearing of saltcedar vegetation - Data from riparian habitats and from

revegetation experiments on the lower Colorado River indicated that if saltcedar habitats were cleared, they could be replaced with smaller numbers of honey mesquite, cottonwood and willow trees and still enhance the area for wildlife.

3. Planting of cottonwood/willow trees - Cottonwood/willow habitat is far more valuable to wildlife than most other species of riparian habitat. The primary constraint for the existence of cottonwood/willow is the availability of water. With the establishment of this habitat type, migratory neotropical birds along with many other species of resident birds, mammals, reptiles and amphibians would be benefited.

4. Acquisition of recently abandoned farmland - These lands contain stands of cottonwood/willow which have germinated since the 1993 flood flows. By placing these lands in public ownership this valuable existing habitat could be protected and expanded by assuring a water source and enhancing the area through control of saltcedar growth and planting of more cottonwood/willow. This action would benefit those wildlife species normally associated with riparian forest.

5. Planting of native grains - The planting and irrigating of native grains would benefit waterfowl, and other bird species in the study area.

6. Recharge of the groundwater through off stream storage - The storage of flood flows and/or normal river flows in off-stream basins upstream of the Agua Caliente crossing would provide benefits to migratory waterfowl and other species associated with open water. The Yuma clapper rail and other native species supported by emergent vegetation would also benefit from this alternative. By recharging the aquifer, soil moisture would increase and improve the riparian vegetation in the study area. This would benefit those bird and other species dependent on the habitat.

DISCUSSION

Riparian and wetland ecosystems are important resources nationwide. They provide functions such as wildlife habitat and travel corridors for terrestrial and aquatic species including endangered species, neotropical migratory birds, shorebirds, herons and egrets, and waterfowl. Water quality functions including filtering and removal of nutrients or toxins, groundwater recharge, modification of flood flows, sediment and streambank stabilization and recreational uses are also provided. However, riparian and wetland ecosystems have been significantly degraded or destroyed by human activity and are much reduced in extent and disappearing at an alarming rate. Riparian habitat should be afforded a high priority status in any land planning or management efforts because of their importance to fish and wildlife for biological diversity and recreational activities. For instance, 64 wildlife species presently listed as endangered and an additional 47 species being considered for listing are dependent on riparian habitats. It is estimated that approximately only 5% of the original riparian habitat remains along the Gila River. Portions of the river that contain perennial habitat remains along the Gila River. Portions of the river that contain perennial flows provide important aquatic habitat and supports a diversity of wildlife, including Federally listed endangered species.

Variations in flow rates, duration, and frequency of occurrence can have detrimental impacts on riparian and wetland habitats. The current operating schedule of upstream reservoirs in the study area are subject to periods of inundation and flood flows as well as periods without flows. Large releases have a scouring effect, leaving only vegetation that can withstand inundation and water erosional force. This oscillating flow regime also affects sediment load and channel configuration.

The goal of the Study is the analyze the opportunities of the preservation and enhancement of the existing ecosystem.

The FWS considers the riparian and wetland ecosystem located along the Gila River to be unique within this ecoregion. Aggressive wildlife and vegetation management techniques designed to reverse past damage and minimize future degradation are necessary, if these areas are expected to function as habitat for increasing numbers of wildlife and as corridors for wildlife migration.

PRELIMINARY RECOMMENDATION

1. That all of the alternatives resulting in the preservation, enhancement or creation of wetland and/or riparian habitat be implemented.

The FWS is available to assist you by providing more detailed information and recommendations as this study becomes more defined. We appreciate the opportunity to provide planning assistance in this study. If we can be of further assistance or you have any questions, please contact Ron McKinstry or Don Metz.

Sincerely,

Sam F Spiller

Sam F. Spiller
State Supervisor

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM. (AES)
Director, Arizona Game and Fish Department, Phoenix, AZ.
Chief, Planning Section, Corps of Engineers, Phoenix, AZ.

Draft

Environmental Evaluation

for

Gillespie to Yuma.

October 1994

Executive Summary

This environmental evaluation (EE) has been prepared in order to identify potential environmental effects associated with flood protection measures being investigated along the Gila River, Arizona, between Gillespie Dam and Yuma. This flood protection study has examined several alternatives that could be considered for the proposed project. This document has addressed the environmental resources as they exist today, with the Wellton-Mohawk Irrigation and Drainage District's 10,000 cubic foot per second (cfs) levee system in place, and the potential effects associated with and without additional flood protection. The resources addressed include biological resources, cultural resources, land use, recreation, water quality, air quality, noise, aesthetic resources, and hazardous and toxic waste.

The results of this reconnaissance-level analysis suggests the costs of mitigation to vary widely between the alternatives. The actual costs of the mitigation for each of the alternatives has not been determined as there are numerous factors which will only be apparent when the project is studied in greater detail during the feasibility phase where the extent of short- and long-term effects are qualified and quantified. Where feasible, alternatives should be formulated to avoid the disturbing areas which contain fully developed habitat. Where adverse effects are unavoidable, either in those areas of existing habitat, or in other areas along the Gila River, appropriate mitigation measures will need to be developed.

This evaluation is not a National Environmental Policy Act (NEPA) document. It is to be used in the planning process to assist in the identification of a viable solution to flooding problems along the Gila River between Gillespie Dam and Yuma. A NEPA document must be formally coordinated with Federal, State and local agencies, interested environmental groups, and affected landowners.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Figure

Table

1.0 INTRODUCTION

1.1 Authority.

The Los Angeles District has been directed to perform feasibility level studies for flooding protection along the Gila River, Arizona, between Gillespie Dam and Yuma, as authorized by Section 116(b) of the Water Resources Development Act of 1993.

Funding for the Gillespie to Yuma Reconnaissance Study was appropriated by the Water and Energy Development Appropriations Bill of 1993.

1.2 Purpose of Study.

1.1 General. The proposed project is located along the Gila River in Maricopa and Yuma Counties, Arizona from Gillespie Dam to the confluence of the Colorado River and includes the area affected by releases from Painted Rock Dam.

The Corps of Engineers has pursued the potential of a feasibility study for the construction of a flood control system along the Gila River for the purposes of reduction of flooding, reduction of damages to the surrounding agricultural area and for the protection and enhancement of the environmentally sensitive riparian and wetland areas along the river.

The scope of this environmental evaluation consists of addressing the environmental issues within the project study area, as they exist today, and the potential effects of the project on them. These include biological, cultural, land use, recreation, agricultural, water quality, air quality, and noise. The study area is defined as the lower one hundred sixty four (164) miles of the Gila River from Gillespie Dam to its confluence with the Colorado River. This lower portion of the Gila River drains an area of 58,000 square miles, slightly over one-half of the State of Arizona.

The study area is considered an area of prime importance for agriculture at the National level, and is considered an environmentally sensitive area with a number of prehistoric and historic sites, and six Federally endangered species occurring along this reach of river. Flooding and sedimentation presently affects all of these sensitive areas/issues, and the proposed flood control project will lessen the impact on these areas and resources.

The reconnaissance-level alternatives that have been developed for the project are described in Chapter 3.

The purpose of the study is to complete a reconnaissance study and report to determine if there is a Federal interest in flood protection along the Gila River between Gillespie Dam and Yuma. The flood control measures would protect agricultural land and provide environmental enhancement as a mitigation benefit, and environmental protection as a project benefit, as well as protecting the local population from potential danger. This allows a unique opportunity for the Corps to identify future environmental benefits to a project from the mitigation actions of that project.

2.0 NEED FOR ACTION

2.1 General Description of Problems and Opportunities

Within recent history, there have been seven flooding events (1978, 1979, 1980, 1983, 1985, 1992, and 1993) which have resulted in flows in excess of 10,000 cfs in the Gila River system. In all but the 1993 floods Painted Rock Dam fulfilled its purpose and protected those areas downstream, and the Corps kept releases from Painted Rock Dam at less than 5,000 cfs. In the 1993 flood event, releases from Painted Rock Dam were kept to below 10,000 cfs until January 21, 1993, when they were slowly increased to 22,500 cfs, where they were held until the spillway was overtopped at the end of February. The outlet work releases were then cut back to try to maintain the combined outlet works and spillway releases at 22,500. The peak discharge occurred on February 28, 1993, at a level of 25,845 cfs, after which flows dropped to 5,000 cfs in late May.

Damages to the downstream area totalled approximately $50 million, with an additional $10 million being spent in direct flood fighting costs. The floods destroyed over 65 percent of the flood control facilities in the area, and disrupted traffic systems in the area cutting off the areas on the north side of the river from the emergency services which are located on the south side.

The Wellton-Mohawk Irrigation and Drainage District (WMIDD) had constructed a flood control channel designed to contain 10,000 cfs through approximately 65 miles of the district. This channel was severely damaged during the 1993 flood event, and WMIDD has been funded by the Federal Emergency Management Agency (FEMA) to re-establish the 10,000 cfs flood protection.

The reconstructed Wellton-Mohawk channel will replace the protection that was in place prior to the 1993 flood event, but will not give the area full protection from potential controlled releases of 22,500 cfs that could occur from Painted Rock Dam.

During large flood flows in excess of 10,000 cfs, water flows out of the Gila River channel, overtops levees, and floods adjacent farm lands and roads. Crops and croplands (many in agricultural preserves) are damaged or lost, and soils are carried in the overland flow to be deposited either on other fields or carried downstream. This is a major problem due to the farming practices in the area, where close to the river only the top 18 inches may be the agricultural prism of topsoil, and any removal of soil or deposition may change the irrigation patterns. The fields are laser-leveled to determine the irrigation requirements, and any change in elevation of the fields requires major changes in the gravity feed systems used for irrigation.

Riparian vegetation along the Gila River was destroyed and damaged during the 1993 flood event, stream banks were severely eroded, and an estimated 14.6 million cubic yards of sediment were carried downstream and deposited in the area of Morales Dam on the Colorado River.

Containment of the amount of sediment that is eroded from upstream agricultural land and transported downstream into the Colorado River during flood events provides an opportunity for the future restoration and subsequent protection of a highly valuable environmental habitat. Once a system of containment is inaugurated, natural restoration would be able to occur, and re-establish a highly valuable riparian/wetland environment.

Additionally, it allows the Corps of Engineers to utilize current law, legislation, and policy guidance to participate in identification of environmental benefits that could be gained from mitigation efforts during the construction of a project.

The reconnaissance-level alternatives that have been developed for this project are described below.

2.2 Scope of Environmental Evaluation.

The scope of this environmental evaluation consists of addressing the environmental issues within the study area, as they exist today, and the potential effects of the potential project or the future without the project on the wildlife resources of the area. Identification of resources include biological, cultural, land use, recreation, water quality, air quality, noise, and aesthetics. This reconnaissance level environmental evaluation is based on available data and input from the study manager, and more detailed investigation and analysis is expected to be undertaken during the feasibility phase.

2.3 Study Area Description.

The study area is defined as the Gila River flood plain in Maricopa and Yuma Counties, Arizona. The location is in Arizona, approximately 60 miles downstream of the City of Phoenix, to the confluence of the Colorado River at the City of Yuma. The study area is bounded on the upstream end by Gillespie Dam, and downstream by the Colorado River (See Figure 1).

The study area is divided into five reaches for purposes of analysis (See Figure 2). Reach 1 extends from Gillespie Dam 14 miles downstream to the upstream extent of Painted Rock Reservoir and is comprised of limited agricultural areas on both sides of the river. Reach 2 consists of the maximum extent of Painted Rock Reservoir up to the 661 foot elevation of the spillway. Reach 3 covers the 59 mile stretch of river from Painted Rock Dam to Texas Hill, and is primarily open desert with very limited farmlands along the river. Reach 4 extends for 56 miles from Texas Hill to Dome, and traverses the Wellton-Mohawk Irrigation and Drainage

Figure 1.

Figure 2.

District (WMIDD). This reach is the most important from an agricultural aspect and was responsible for most of the $454 million value for crops grown in Yuma County in 1992. Reach 5 covers the remaining 11 miles of the river and extends from Dome to Yuma.

The existing environment and the environmental impact sections will describe the river by reach, which will allow an evaluation of the most feasible alternatives on a reach by reach basis.

3.0 ALTERNATIVES CONSIDERED.

3.1 Alternatives Dropped From Consideration.

The project has reviewed several alternatives which have been examined to determine their feasibility, and which were dropped from consideration due to various concerns. These alternatives included complete channelization, construction of an upstream dam to reduce discharge, change in operations at Painted Rock Dam.

3.2 Alternative 1 - Environmental Restoration.

This alternative would restore and enhance riparian habitat along the entire stretch of river, and would shift the habitat values along the lower Gila towards the historic conditions. No additional flood control would result from this alternative.

Five major components of the environmental restoration alternative have been identified, however other areas along the reach of river will be evaluated during feasibility. The five components selected as being the best candidates for restoration, were determined through a series of meetings with the Resource Agencies. The areas selected are as follows:

Dendora Valley - This area is immediately downstream of Painted Rock Dam, and covers an area of ____ acres. There is extensive riparian habitat at both the upstream and the downstream ends of the valley. This would require the deepening of sloughs to create wetland and open water areas for emergent vegetation which would be suitable habitat for the Yuma clapper rail, as well as for migratory waterfowl. Additional work would include the removal of tamarisk and the planting of willows and cottonwoods along the river, and the planting of mesquite on the upper terraces. Joint development of the area with the Resource Agencies would allow the creation of wildlife viewing areas and interpretive trails along the borrow pit lake at the foot of the dam.

Agua Caliente Crossing - This area contains one of the last remnants of the relic mesquite bosques along the Gila River, and has been maintained by the past agricultural practices of growing citrus along the bluff tops, with the irrigation water percolating down and maintaining the groundwater at a level which the mesquite roots could access. The removal of the citrus has changed the ground water regime in the area, and the current practice of pumping the aquifer for irrigation of crops has lowered the ground water in the area. Restoration of habitat in this area would entail offstream storage and percolation to help raise the groundwater which would enhance the mesquite. The offstream storage and percolation areas would create wetlands and open water ponds with emergent vegetation which would be suitable habitat for the Yuma clapper rail and migratory waterfowl. Additional work in this area would include tamarisk removal and the planting of cottonwoods and willows along the river.

Oxbow/Slough Enhancement - This utilizes the 13 oxbows that were created within the Wellton-Mohawk district as a result of mitigation for the pre-93-flood levee system (6 oxbows - 456.7 acres), and those that have been set aside as part of the post flood levee system (9 oxbows - 1588.3 acres). The enhancement would require the removal of tamarisk, the deepening of several of the oxbows to reach groundwater, and the planting of emergent and riparian plants. This would create habitat suitable for the Yuma clapper rail and migratory waterfowl.

Recently Abandoned Farmlands - The 1993 flood along the Gila River broke out of the leveed river channel and inundated farmlands throughout along the river. Farmers in several areas along the lower Gila have determined that the damages to their farms are not economically repairable, and have taken their fields out of production. These fields are outside the WMIDD levees, and have remnant irrigation systems in place. Along the edges of these fields, high quality stands of willow and cottonwood have matured due to the past irrigation practices. Since the flood extensive stands of cottonwood/willow have developed in the abandoned fields, and these are currently in danger of dying off due to the lowering of the groundwater through bank return, and the cessation of irrigation on these fields. These lands could be obtained and with minimal work would become excellent habitat through development of the existing stands of willow/cottonwood. The area could also provide a food source for native species through the production of native grains in conjunction with the University of Arizona's Office of Arid Land Studies.

Prime Habitat Acquisition - Several areas of prime habitat occur throughout the lower Gila river basin, and have been identified by BLM and AGFD, as areas that need to be acquired and developed to protect and expand the existing valuable habitat. These areas would require minimal surface grading to fully develop their potential as habitat for clapper rail and dove.

This alternative would not be restricted to the five major components, but would be a corridor approach, with additional areas being added, and the overall alternative being further refined during the Feasibility stage

3.3 Alternative 2 - Future Without The Project (No Project Alternative)

This alternative would maintain the existing conditions with the area between Texas Hill and Dome having 10,000 cfs protection from the existing WMIDD levees. No additional flood protection would result from this alternative.

4.0 EXISTING ENVIRONMENT.

4.1 Physical Setting

The study area lies along the Gila River between Gillespie Dam and Yuma. The area between Gillespie Dam and the Painted Rock reservoir has irrigated farmland on both sides of the river. Painted Rock reservoir is a flood control basin covering in excess of 86,000 acres. Downstream from Painted Rock to Texas Hill, the area is predominately open desert, with small parcels of farmland. Between Texas Hill and Dome, the area makes up the Wellton-Mohawk Irrigation and Drainage District with the land on both sides of the river being irrigated.

Downstream of Dome, the river flows through a narrow pass to the north of the Gila Mountains, and through a small area of open desert before coming to the irrigated farmlands of the Yuma Plain.

4.1.1 Geology/Physiography

The study area lies within the Sonoran desert physiographic province, characterized by discontinuous, subdued mountain ranges. The ranges are generally rugged and rise abruptly to elevations of about 4,000 feet, from the relatively flat desert, where elevations slowly drop from 746 feet at Gillespie Dam to 130 feet at the confluence of the Gila and Colorado Rivers at Yuma.

4.1.2 Soils

The soils in the study area are mainly deep, silty, sandy soils which are gently sloping, and range from well drained to somewhat excessively drained. The area includes the Gila floodplain, low terraces, alluvial fans, and drainageways. The soils in the area downstream of Texas Hill are affected by saline groundwater as a result of leaching of irrigation water and a closed groundwater basin.

4.2 Climate

The climatic conditions of the project area are best described as a desert climate, typical of the arid southwestern United States. The area is dominated by continental air masses, receives 90 percent of the total possible sunshine, and is characterized by high daytime temperatures, relatively low humidity, and low average annual precipitation.

Climatic data for the project area can de obtained from records kept at Phoenix on the eastern end of the area, and at Yuma in the west. Temperature and rainfall averages for Phoenix and Yuma are listed below in Table 1.

Table 1. Temperature and Precipitation Averages

	PHOENIX		YUMA	
	Temp Max/Min	Precip. (in)	Temp Max/Min	Precip. (in)
January	65/38	0.7	68/43	0.4
February	69/41	0.6	73/46	0.4
March	74/45	0.8	78/50	0.3
April	84/52	0.3	86/57	0.1
May	93/60	0.1	93/64	0.0
June	101/68	0.1	101/71	0.0
July	105/77	0.8	106/81	0.2
August	102/76	1.2	104/81	0.6
September	98/70	0.7	100/74	0.4
October	88/57	0.5	90/62	0.3
November	75/45	0.5	76/50	0.2
December	66/38	0.8	68/44	0.5

Most precipitation occurs during the two distinct seasons, with the majority of the winter storms occurring in the upper reaches of the Salt and Gila Rivers. In the project area, most of the flood producing precipitation results from summer storms centered over the lower Basin area, or from short duration showers.

Annual relative humidity averages about 38 percent, which is higher than expected in a desert area due to the influx of marine air from the Gulf of California during the summer months.

Winds throughout the area average 7.8 miles per hour as recorded at Yuma, with the lowest recordings occurring in September, and the highest in July.

4.3 Water Resources

4.3.1 Surface Water

Surface water flows in the study area originate from two major sources. The Salt-Gila River flowing into Painted Rock Dam, with its associated controlled releases, and the uncontrolled drainage area downstream of Painted Rock.

Releases from Painted Rock Dam have historically been held to 5,000 cfs, however the flood of 1993 resulted in releases being increased to a maximum controlled release of 22,500 cfs, before the spillway was overtopped, and uncontrolled releases reached a record high of 25,845 cfs. The flows into Painted Rock during the 1993 flood reached a maximum of approximately 186,000 cfs, with a total of 3.6 million acre feet of water flowing into Painted Rock during a sixty day period.

Water quality in the Gila River is generally relatively poor with total dissolved salts (TDS) values averaging over 1870 parts per million (ppm) compared with values of 767 ppm average at Imperial Dam on the Colorado River during low flow periods (USBR Water Operations, December 1993). During flood events, TDS levels improve substantially with averages of about 513 ppm compared to the Colorado which averages 725 ppm.

4.3.2 Ground Water

Ground water in the study area tends to be relatively saline due to the irrigation practices, and the high evaporation rate. Ground water levels in the area are affected by limited amounts of groundwater recharge, ponding of water in Painted Rock Reservoir, the importation of 278,000 acre feet of Colorado River water each year for irrigation, and the geologic structures in the Gila Basin.

The aquifers in the region are both shallow and deep, with the shallow aquifer in Dendora Valley being at a level of about 10-15 feet, and the deep aquifer which is pumped for agricultural irrigation being at about 200 feet. The level of the aquifer at the Agua Caliente crossing is about 30 feet due to the drawdown due to pumping, whereas the groundwater levels in the Wellton-Mohawk Irrigation and Drainage District (WMIDD) at between four and eight feet due to the importation of the Colorado water for irrigation.

WMIDD pumps groundwater down to levels compatible with agricultural production, and this has been successful except during sustained surface flows in the Gila River such as the flows during 1993. The current TDS levels for the groundwater pumped by WMIDD averages approximately 3,400 ppm.

4.4 Air Quality

The entire study area is in attainment for all airborne constituents regulated by the U.S. Environmental Protection Agency (EPA), except for Reach 5, and the western two miles of Reach 4. These areas lie within the Yuma Metropolitan Air Pollution District (YMAPD).

The EPA has designated the YMAPD as non-attainment for PM10 (particulate matter 10 microns and smaller). The majority of the study area is either farmland or open desert, and is therefore subject to occasional dust related to the operation of agricultural machinery or high winds.

4.5 Biological Resources

4.5.1 Vegetation

The study area lies within the Sonoran desert region. The principal vegetation found along the river includes saltbush, creosote bush, mesquite, desert holly, and saltcedar. Within some reaches, the riparian vegetation consists of cottonwoods and willows, along with saltcedar and various species of mesquite. Wetland areas consist mainly of cattail, nut sedge, with some trees and grasses. Ocotillo and creosote bush and cacti, such as barrel, cholla, and saguaro, are found in the foothills and on lower mountain slopes. Agricultural fields are adjacent to the river in many reaches. Reach 1 includes some riparian vegetation and wetland in the upper portion with agricultural fields predominating in the lower portion of the reach. Reach 2 consists of Painted Rock Dam. Reach 3 has some agriculture and dense riparian forest in the upper portion immediately downstream from Painted Rock Dam. The remainder of the reach consists of open desert (creosote and saltbush) with riparian bands along the river and some agricultural fields at the Agua Caliente crossing. Reach 4 consists of the Wellton-Mohawk Irrigation District. Agricultural lands occupy most of the land adjacent to the river, with riparian and wetland along many of the terraces along the river. The upper portion of Reach 5 consists of a strip of riparian adjacent to the river, a small amount of agriculture, and open desert (creosote and saltbush) on the uplands. The remainder of the reach, as it opens into the Yuma plain, consists mainly of agricultural fields.

A listing of plant species found in the study area is found in Table 2.

4.5.2 Fish and Wildlife

Fish occur only in areas with year round water and consist almost entirely of introduced, non-native species, including tilapia, carp, red shiner, sailfin mollie, and goldfish. Wildlife within the study area occur mainly within the riparian and open desert areas. Areas under intensive agriculture supports little wildlife except some upland birds. Wildlife inhabiting the riparian corridor include mule deer, fox, coyote, rabbits, various species of rodents, snakes, lizards, and amphibians. Birds found in the area include several species of waterfowl and upland birds.

Table 2. Plant Species Adjacent to and Within the Project Area

Common Name	Scientific Name
catclaw acacia	*Acacia greggii*
sand verbena	*Abronia villosa*
fiddleneck	*Amsinckia intermedia*
four-wing saltbush	*Atriplex canescens*
quailbush	*Atriplex lentiformis*
saltbush	*Atriplex polycarpa*
seepwill baccharis	*Baccharis glutinosa*
mustard	*Brassica tournefortii*
red maids	*Calandrinia ciliata*
desert pincushion	*Chaenactis stenoides*
rabbitbush	*Chrysothamnus* sp.
Bermuda grass	*Cynodon dactylon*
nut sedge	*Cyperus eragostis*
cryptantha	*Cryptantha angustifolia*
white brittlebrush	*Encelia farinosa*
salt heliotrope	*Heliotropium curassavicum*
desert lily	*Hesperocallis undulata*
camphor-weed	*Heterotheca psamnophila*
creosote	*Larrea divericata*
red sprangletop	*Leptochloa filiformis*
yellow sweetclover	*Melilotus officinalis*
thread plant	*Nemacladus glanduliferus*
yellow paloverde	*Parkinsonia floridum*
blue paloverde	*Parkinsonia microphyllum*
mistletoe	*Phoradendron californicum*
common reed	*Phragmites australis*
knotweed	*Polygonum* sp.
rabbitsfoot grass	*Polypogon monspeliensis*
cottonwood	*Populus fremontii*

Common Name	Scientific Name
honey mesquite	Prosopsis glandulosa
screw bean mesquite	Prosopsis pubescens
willow	Salix gooddingii
London rocket	Sisymbrium irio
spiny sowthistle	Sonchus asper
globemallow	Sphaeralcea ambigua
tamarisk, salt cedar	Tamarix chinensis
arrowweed	Tessaria sericea
cattail	Typha latifolia

4.5.3 Threatened and Endangered Species

A listing of Federal and State listed Endangered and Threatened species, as well as those species proposed for listing which potentially occur within the study area is shown in Table 3.

Yuma Clapper Rail. - The Yuma Clapper Rail breeds in freshwater or brackish marshes and is endangered as the result of habitat loss, especially due to stream channelization and the elimination of its marsh habitat. Within the study area, the Yuma clapper rail occurs within marsh habitat on the lower Gila River, near the mouth in Reach 5, and in several marsh areas within Reach 4.

Osprey. - Ospreys are not known to nest in the study area and are considered rare/uncommon summer/late summer visitors. This species is considered to be threatened in the State due to natural rarity and loss of breeding habitat along major river systems.

Bald Eagle. - The bald eagle is known to nest along river corridors in Arizona, primarily on the Salt, Verde, and Bill Williams rivers. Threats to its continued existence include ingestion of lead-poisoned prey, loss of perches and aquatic habitat for foraging, loss of riparian habitat for nesting, disturbance at nests, timber harvest degradation of winter roosting habitat, and shooting. There are no known eagle nests or roosts in the study area and foraging use is extremely rare.

Yellow-Billed Cuckoo. - The yellow-billed cuckoo is found primarily in the central and southern parts of Arizona. It has been extirpated from most of the Lower Sonoran areas. This species breeds in heavy, mature riparian vegetation along wooded streams. It is threatened by the loss of riparian gallery forests through clearing, stream diversions, water management, agriculture, and urbanization. There is no habitat for this species in the study area.

Southwestern Willow Flycatcher. - The Southwestern willow flycatcher is a small, insectivorous bird found in riparian habitats, especially cottonwood-willow communities. It has suffered a dramatic recent decline, due to loss and fragmentation of riparian habitat, tamarisk invasion, brood parasitism, and depredation. The few acres of existing cottonwood-willow habitat remaining in the study area is not suitable in acreage or composition to provide habitat for nesting use by this species.

Table 3. Listing of Special Status Species

SPECIES	FEDERAL STATUS *	STATE STATUS *
Yuma clapper rail	E	E
Osprey		T
Bald eagle	E	E
Yellow-billed cuckoo	C2	T
Southwestern willow flycatcher	Proposed E	E
Sonoran pronghorn	E	E
Spotted bat	C2	SC
White-faced ibis	C2	
Western snowy plover	C2	SC
Long-billed curlew	C2	
Belted kingfisher		SC
Loggerhead shrike	C2	
Cowles fringe-toed lizard	C2	SC
Lowland leapord frog	C2	

* E - Endangered
T - Threatened
C2 - Candidate Category 2
SC - Arizona State candidate species

Sonoran Pronghorn. - The Sonoran pronghorn is limited to a small population in the extremely arid flatlands of southwestern Arizona and into Mexico. Population losses have resulted from unregulated or unlawful hunting, conversion of habitat to grazing lands, agriculture, and urbanization. There is no habitat for this species in the study area.

The remaining species in Table 3 are candidates for listing and other sensitive species. They have been identified by the U. S. Fish and Wildlife Service, the Arizona Game and Fish Department, and the Arizona Department of Agriculture as potentially present within the vicinity of the study area.

4.5.4 Wetlands

As noted in paragraph 4.5.1, wetlands occur within the riparian areas in Reaches 1, 3, 4, and 5. Characteristic plant and animal species are described in paragraphs 4.5.1 and 4.5.2, above. Wetlands have hydric regimes which, under normal circumstances, are sufficient to maintain soil saturation or inundation conditions. The wetlands within the study area include emergent marsh (cattail or sedge) growing within littoral areas along open water oxbows or within larger marsh stands. Some wetlands often include lower-lying riparian associations (salt cedar and arrowweed) growing adjacent to the emergent vegetation. Other wetlands are dominated exclusively by riparian species (salt cedar and willow).

4.6 Cultural Resources

While the project area has been regularly inhabited, both prehistorically and historically, Bureau of Reclamation surveys in 1983 and 1984 of portions of the project's area of potential effects (APE) uncovered no significant archaeological sites and very few historical sites within the project area. This is likely due to the project area being within the Gila River flood plain where flooding and intensive agriculture, most cultural and historical resources have been previously lost. There is an extensive group of petroglyphs on the northeast face of Antelope Hill, however, these petroglyphs would not be affected by the quarry on the northwest face. The Wellton-Mohawk project involves the reconstruction of levees and the construction of new levees outside the pre 1993 flood levee/channel zone. An archaeological survey of all the new levee areas will be completed prior to construction of the levees. The ruins of the Ocean-to-Ocean Highway Bridge, which once crossed the Gila River near Avenue 36E, are located within the project area. This structure is listed in the National Register of Historic Places.

4.7 Land Use

Land use in the study area can be classified by three uses, vacant space, flood control reservoir, and agriculture. Vacant space comprises of open desert, with no delineated fields, and areas set aside for wildlife habitat.

The Painted Rock reservoir covers approximately 86,000 acres, and is primarily open desert which is subjected to periodic flooding.

The primary land use throughout the study area is agriculture, with WMIDD encompassing approximately 125,000 acres of land of which approximately one half is currently under crop production. The major crops grown are cotton, hay, wheat, lettuce, alfalfa, grass seed, and other assorted seeds and vegetables.

4.8 Recreation

Recreation in the study area includes hunting, fishing, bird watching, swimming, boating, and off-road vehicle use. The area supports substantial numbers of quail, doves, cottontail rabbits, and waterfowl, which are hunted along the river, and adjacent to the agricultural lands. Deer and bighorn sheep are hunted on the adjacent mountain ridges.

Fishing, swimming, and boating occur along the Gila River during the periods of flowing water, with limited opportunities for these activities when water is not being released from Painted Rock Dam, and only a few pools remain along the river channel.

4.9 Noise

Noise is not considered a significant concern for people living in the study area. The major noise producing agents in the study area are the traffic on Interstate 8, trains, the military ranges, farm equipment, and local traffic including trucks.

4.10 Aesthetics

The visual quality and sensitivity of the study area depends upon numerous variables including the number of people who view the area and their perceptions of the view. The major sensitive visual receptors in the project area include the local population and the people transiting the area.

The scenic quality changes throughout the project area, with a mixture of open desert, agricultural fields, riparian vegetation along the river channel, creosote desert bajadas, and rugged mountains, and a checkerboard pattern of transportation routes.

4.11 Hazardous, Toxic and Radioactive Waste

There are several landfill sites within the study area. One is located near the town of Gila Bend, but is above the reservoir elevation. The other site is located three miles north of the Gila

River near Avenue 38, north of the town of Roll. This site is 30 feet above the river elevation, and was not affected by the 1993 flood event.

No radioactive waste sites are known to exist in the project area.

5.0 ENVIRONMENTAL IMPACTS.

5.1 Alternative Plan 1 - Environmental Restoration.

5.1.1 Geology/Physiography

No unique geologic features have been identified within the project area vicinity. The environmental restoration will not impact the physiography of the area. No impacts to geologic resources are expected to occur as a result of environmental restoration.

5.1.2 Soils

The soils along the Gila River have a low potential for wind- or water-caused erosion in areas that have vegetative cover. The enhancement and restoration of riparian areas along the river will help maintain this low erosion potential.

5.1.3 Water Resources

5.1.3.1 Surface Water

The enhancement/restoration of the riparian and wetland areas along the lower Gila will help improve the water quality through the water treating capacity of the wetlands. As a result of this alternative, wetlands will be developed and/or enhanced at several areas along the lower Gila including throughout Dendora Valley, in the area of the Agua Caliente Crossing, at the oxbows and sloughs throughout the Wellton Mohawk Irrigation and Drainage District, and at other sites determined during feasibility.

5.1.3.2 Ground Water

Ground water along the lower Gila will be affected by this alternative, in that groundwater levels in the shallow aquifer will be raised in Dendora Valley and at the Agua Caliente crossing area, through the use of Gila river water to irrigate the vegetation in the riparian areas. Areas in the Wellton Mohawk region will not be affected as the restoration/enhancement throughout the region will utilize groundwater for riparian growth, and will not import water which could raise the groundwater in this region.

5.1.4 Air Quality

The construction/planting phase of the alternative is anticipated to create short term impacts including increased dust and vehicle emissions. These activities would be temporary and would be spread over the entire Lower Gila. No long term effects are expected, and no State or Federal standards would be exceeded as a result of the activities.

5.1.5 Biological Resources

5.1.5.1 Vegetation

The enhancement/restoration of riparian habitat along the lower Gila will increase the amount of vegetation throughout the region, and will reduce the ratio of exotics to native species. There will be an increase in the numbers of willow, cottonwood, mesquite, and emergent species, along with a reduction in the numbers of salt-cedar. This will have a positive affect on the biological resources of the area, and will shift the habitat values towards a more natural state along the lower Gila.

5.1.5.2 Fish and Wildlife

The alternative will have a major affect on the wildlife of the area as it will increase the amount and quality of the habitat along the lower Gila especially in Dendora Valley and around the Agua Caliente crossing. There will be an increase in habitat values with the associated increase in wildlife. Dove habitat will be increased as will the area of open water available for migratory waterfowl.

5.1.5.3 Threatened and Endangered Species

The alternative will increase the amount and quality of the habitat for the Yuma clapper rail and the southwestern willow flycatcher, especially in the Dendora Valley area and at the oxbow sites. This will have a positive effect on both these species of concern.

5.1.5.4 Wetlands

The alternative will increase the areas of wetlands along the lower Gila, through the development of offstream wetlands in the area of the Agua Caliente crossing, and through the enhancement of the oxbows in the Wellton Mohawk area and in Dendora Valley. This will shift the total amount of wetlands along the lower Gila to a more historic condition, and will provide a tremendous benefit to wildlife.

5.1.6 Cultural Resources

Although there are numerous archeological sites found within the APE, none should be impacted by the alternative. The sites are located outside the areas where construction related to the environmental restoration/enhancement is to take place. If during the construction phase it is found that the project will have an effect on any sites located within the APE, the sites will be evaluated and a memorandum of agreement will be executed between the Corps, the State Historic Preservation Officer, and the Advisory Council on Historic Preservation.

Compliance with Section 106 of the National Historic Preservation Act for any proposed alternatives along the Gila River between Gillespie Dam and Yuma will have to occur. Coordination with the State Historic Preservation Officer and the Advisory Council on Historic Preservation would be required to comply with Section 106.

5.1.7 Land Use

This alternative will have minimal effect on the existing land use in the area, as enhancement will occur in areas presently used for wildlife habitat, and restoration will occur in areas that have been removed from agriculture and are currently fallow. The alternative will not have a significant effect on land use.

5.1.8 Recreation

This alternative will have a positive affect on recreation in that it will provide more opportunities for recreational activities such as bird watching and hunting.

5.1.9 Noise

The alternative will not have any long term effects on noise levels along the lower Gila. Noise levels will be increased during the planting phase, but will return to current levels immediately thereafter.

5.1.10 Aesthetics

The increase in riparian habitat along the lower Gila will enhance the aesthetics of the area, and will return the area to a more historic condition, with a more continuous riparian corridor through the area. This will not have a significant impact on the aesthetics of the area.

5.1.11 Hazardous, Toxic and Radioactive Waste

A more detailed records and literature search will be required during the feasibility to determine the potential for hazardous and toxic waste in the study areas. Testing of potential sites will be required. If found, removal will be necessary.

5.2 Alternative 2 - Future Without the Project, (No Project Alternative)

The No Project Alternative will not increase the amount of riparian habitat along the lower Gila, and will actually result in an increase in the amount of salt-cedar with a corresponding decrease in the habitat values.

6.0 FEASIBILITY REPORT COMPLIANCE

6.1 Applicable Federal Environmental Statues

If a feasibility study is recommended, a NEPA document will be required to address all project environmental resources and issues. The environmental document will be prepared in accordance with the requirements of Section 102 of this Act and with the Council of Environmental Quality Regulations for implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR Parts 1500-1508).

The U. S. Fish and Wildlife Service will be funded to prepare a Coordination Act Report (CAR), in accordance with the Fish and Wildlife Coordination Act. The CAR will provide input to the Corps on biological resources within the study area and will identify their concerns, as necessary.

Other environmental laws and regulations that will be complied with in the environmental documentation include, but are not limited to, the Clean Water Act, the Clean Air Act, the National Historic Preservation Act, the Wild and Scenic Rivers Act, the Endangered Species Act of 1973, the Migratory Bird Treaty Act, Executive Order 11990 for the Protection of Wetlands, and Executive Order 11988 for Floodplain Management.

6.2 Rationale to Continue into Feasibility Study Phase

Presentation of rationale for conducting more detailed environmental analyses in the feasibility phase is not a function or purpose of this environmental evaluation. Only the environmental aspects of the study area as they relate to potential project impacts are briefly addressed here. See the main text for the presentation of conclusions and recommendation.

The environmental evaluation indicates that there would be potentially greater adverse impacts to natural and economic resources without the proposed project than with the proposed project's improvements and mitigation measures. Habitat benefits would result from the creation of riparian habitat. It appears that a properly designed project and management program for environmental restoration would significantly reduce the economic and recreational loss. This analysis provides a basis for further environmental considerations in the feasibility study phase.

If environmental restoration along the Lower Gila River is not undertaken soon, this valuable and unique type of environment, and endangered species habitat, will be severely degraded due to the accelerated erosion and the continued sediment transport downstream into the Colorado River. Wetlands protection is legislatively a mission of the Corps of Engineers, and, therefore, in the Federal interest. In this instance, the environmental restoration provides the opportunity to identify and propose environmental measures by which Federal wetland protection objective can be achieved.

6.3 Cost Estimate for Feasibility Study Environmental Documentation.

The following is a preliminary cost estimate for preparation of an Environmental analysis in the feasibility study phase. The time required for the preparation of the environmental document would depend upon the complexity and the controversy associated with the project, and the time needed for proper interface between involved agencies, organizations, and other interested persons. This could be as long as 18 months if an Environmental Impact Statement is required.

The following preliminary cost estimate is for the preparation of an Environmental Impact Statement (EIS) for the subject study.

Estimated in-house costs in hired-labor

EIS Preparation, Coordination, and Review	$100,000
Ecological/Biological Support	65,000
Cultural Resources Support	35,000
Travel and Miscellaneous	12,000
SUBTOTAL	$212,000

Contracts required

U.S. Fish and Wildlife Service Funding	30,000
HTRW Studies	40,000
Ecological Studies/Biological Assessment	60,000
TOTAL	$342,000

6.4 Mitigation Costs

6.4.1 Water Conservation Alternative.

The exact mitigation that would be required as a result of water conservation has not been determined at this time. The mitigation will depend upon the specific direct and indirect impacts, and upon the specific area impacted.

Several possible mitigation methods should be considered including the eradication of Tamarisk in the project area, the planting of riparian habitat in the project area, the purchase of easements, the purchase of off-site land for restoration, and the restoration of wetlands to replace those impacted by the project.

7.0 COORDINATION

Future draft environmental documents would need to include coordination with Federal, State, and local agencies including, but not limited to the following:

Environmental Protection Agency
State of Arizona
Arizona Department of Water Resources
U. S. Fish and Wildlife Service
Arizona Game and Fish Department
Soil Conservation Service
State Historic Preservation Office
Arizona Department of Environmental Quality
Wellton-Mohawk Irrigation and Drainage District
Bureau of Reclamation
Maricopa County
Yuma County
International Boundary Water Commission
Bureau of Land Management
Department of the Interior
Salt River Project
San Lucy District
Arizona Department of Transportation

8.0 PREPARERS

Alex Watt	Environmental Coordinator
Roderick McLean	Archaeologist
Jennifer Eckert	Biologist
Ronald MacDonald	Senior Ecologist

Reviewers:

Stephen Dibble	Senior Archaeologist
Nedeania Kennedy	Chief, Environmental Support Section
Ruth Villalobos	Chief, Environmental Resources Branch

APPENDIX I

REAL ESTATE

RECONNAISSANCE LEVEL COST ESTIMATE

for

PAINTED ROCK RESERVOIR
WATER CONSERVATION PROJECT ALTERNATIVES

for

PLANNING SECTION C
PHOENIX ARIZONA PROJECT OFFICE

by

ARIZONA REAL ESTATE OFFICE
DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
PHOENIX ARIZONA PROJECT OFFICE

JANUARY 1995

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PAINTED ROCK RESERVOIR
WATER CONSERVATION PROJECT

1. AUTHORITY

This report is prepared in response to ENG service request #95-6035 RH from Planning Section C, Phoenix Project Office, dated 01 December 1994.

2. PURPOSE

Under consideration is the feasibility of two water conservation alternatives for water storage at either a contour elevation of 598 or 634 in Painted Rock Reservoir, Maricopa County, Arizona. This report provides a cost estimate for those lands held in private ownership which would be impacted by the creation of either storage basin. There is an existing flowage easement to the contour elevation of 661, and the proposed alternatives would further burden the real estate interests. The creation of a storage basin would change the function of the dam from strictly flood control to flood control and water storage for downstream water conservation.

3. CONTINGENCY

Included in this report was a 25% contingency factor and a 10% severance factor. The contingency and severance factors used in this report were based on (1) the level of the report, (2) time constraints, (3) unknown condemnation settlements, (4) undetected improvements, (5) minor project design changes, (6) unknown property splits, and (7) market data availability.

4. FUNCTION

The value estimates developed in this reconnaissance level report will be used to indicate the real estate costs for the water conservation project located within Painted Rock Reservoir. This report is for internal planning purposes to determine the costs associated with the proposed storage basin alternatives. It has not been completed for acquisition purposes and should not be used for funding purposes.

5. DATE OF VALUE

The date of value is 02 January 1995.

6. SPECIAL FEATURES

This cost estimate does not include any supplemental value for subsurface mineral deposits and/or rights. The physical inspection of the area and aerial maps covering some of the area did not indicate any ongoing mining operations on the subject lands. Market data did not appear to reflect any enhancement to values resulting from potential mineral rights. Mineral rights such as oil and gas, sand and gravel, could potentially affect the cost estimate.

7. RECOMMENDED ESTATE

The recommended estate to be acquired is the fee simple interest for either storage basin alternative.

8. ASSUMPTIONS AND LIMITING CONDITIONS

This report and the value estimates it contains are expressly subject to the following:

A. No responsibility is assumed for matters which are legal in nature.

B. The information and the data secured by the appraiser, oral and written, is considered to be from reliable sources; however, no guarantee is made as to its absolute accuracy.

C. If any of the valuation estimates developed in this report are used in another report or document, this report should be cited as the source by footnote.

D. Maps and other illustrations used herein are for illustration and are provided only to assist the reader in visualizing the property. They are believed to be reliable and indicative of the property appraised but are not represented as legal surveys, nor for legal reference.

E. Any adjustment, revision or change in the application of data or values as they appear in this report will invalidate same, unless approved by the Phoenix Real Estate Project Office.

F. This appraisal report is based on data available at the time of the valuation, and no conditions exist that were not discoverable through a normal, diligent investigation. If additional information is received at a later date, that information could affect the valuation estimate.

G. Possession of this report or a copy of this report does not carry with it the right to publication or reproduction without the written consent of the Phoenix Real Estate Project Office.

H. Acreage figures developed in this report where estimated solely by the appraiser as no support was provided from cadastral section due to limited time constraints. Planning provided topographic maps with delineated contour elevations of 598 and 634. Based on assessor maps, take areas were plotted and an approximate acquisition acreage figure was calculated. For this reconnaissance level report the acreage figures are felt to be satisfactory, but at feasibility the acreage figures could be subject to revision.

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The general area of Painted Rock Reservoir was inspected on 02 January 1995.

10. GENERAL PROJECT AND AREA DESCRIPTION

The subject area is located in south western Arizona in Maricopa County on the west side of the county near Gila Bend. Arizona is the sixth largest state in the USA in land area and twenty-fourth in total population. The 1990 census data indicates Arizona has an estimated population of 3,665,000. The population growth rate continues to be greater than the national rate with a growth rate of 2.5%. An increase in population typically creates demand for residential, commercial and industrial property and should positively affect the value of these properties.

Long term economic projections for Arizona and Maricopa County are positive and growth is expected to continue primarily in the Phoenix metropolitan area. There is an exodus from California with people migrating to Arizona for climate, lifestyle, and affordability. There are a wide array of activities including hunting, fishing, water sports, sight seeing and cultural events in the state of Arizona. Growth in the community of Gila Bend has been relatively slow and future growth is projected to remain fairly static.

The Phoenix metropolitan area appears to be recovering from the recession with marked improvement occurring in 1994. Stronger retail sales and an improved home sales market reflect an improving economy. Areas which remained largely undeveloped are now seeing new construction. Developers report that skilled labor is short and construction schedules are not able to keep up with current demand. Residential development is anticipated to rise although commercial development is expected to lag for sometime.

The subject area is situated in the extreme desert climate of Arizona. Winters are warm and pleasant with numerous "snowbirds" flocking to this area, but summers are hot and dry. Air conditioning for autos and homes is an absolute must in order to survive the harsh summer months. Rainfall is limited with average amounts being between four to seven inches.

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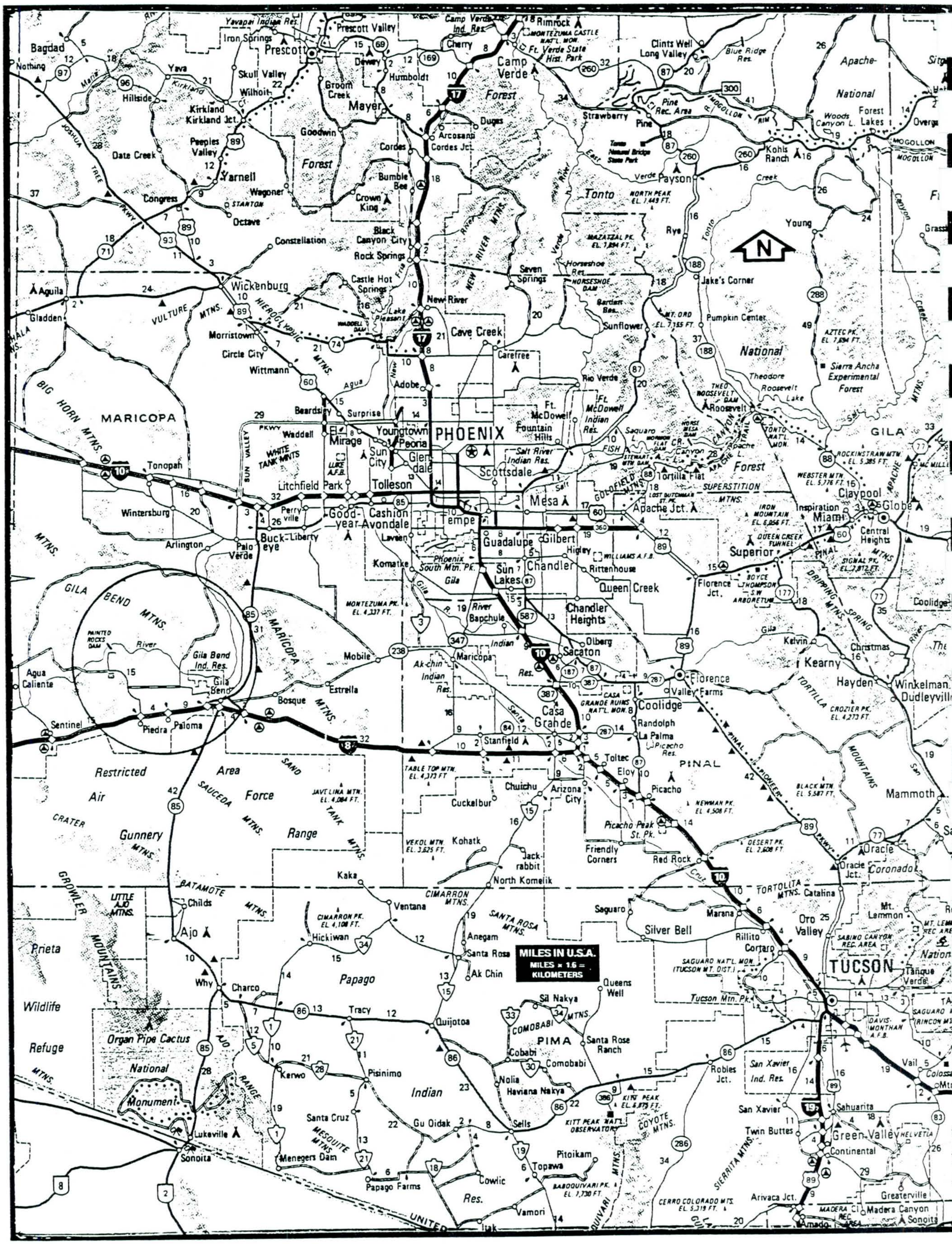

MILES IN U.S.A.
MILES × 1.6 = KILOMETERS
N
PHOENIX
TUCSON
Prescott
Prescott Valley
Camp Verde
Wickenburg
Mesa
Tempe
Scottsdale
Glendale
Peoria
Chandler
Gilbert
Guadalupe
Sun City
Youngtown
El Mirage
Surprise
Tolleson
Litchfield Park
Goodyear
Avondale
Cashion
Buckeye
Liberty
Casa Grande
Coolidge
Florence
Eloy
Picacho
Marana
Oro Valley
Globe
Miami
Superior
Payson
Sacaton
Maricopa
Gila Bend
Ajo
Why
Sells
Lukeville
Sonoita
Green Valley
Sahuarita
San Xavier
Kearny
Hayden
Winkelman
Mammoth
Oracle
Apache Jct.
Queen Creek
Arizona City
Stanfield
Tonopah
Aguila
Congress
Yarnell
Bagdad
Cordes Jct.
Black Canyon City
New River
Cave Creek
Carefree
Fountain Hills
Sun Lakes
MARICOPA
PINAL
PIMA
GILA
Tonto National Forest
Apache-Sitgreaves National Forest
Prescott National Forest
Papago Indian Res.
Organ Pipe Cactus National Monument
Cabeza Prieta Wildlife Refuge
Restricted Air Force Gunnery Range
SUPERSTITION MTNS.
SIERRITA MTNS.
SANTA ROSA MTNS.
GILA BEND MTNS.
BIG HORN MTNS.
VULTURE MTNS.
HIEROGLYPHIC MTNS.
WHITE TANK MTNS.
NEW RIVER MTNS.
GROWLER MOUNTAINS
MOGOLLON RIM
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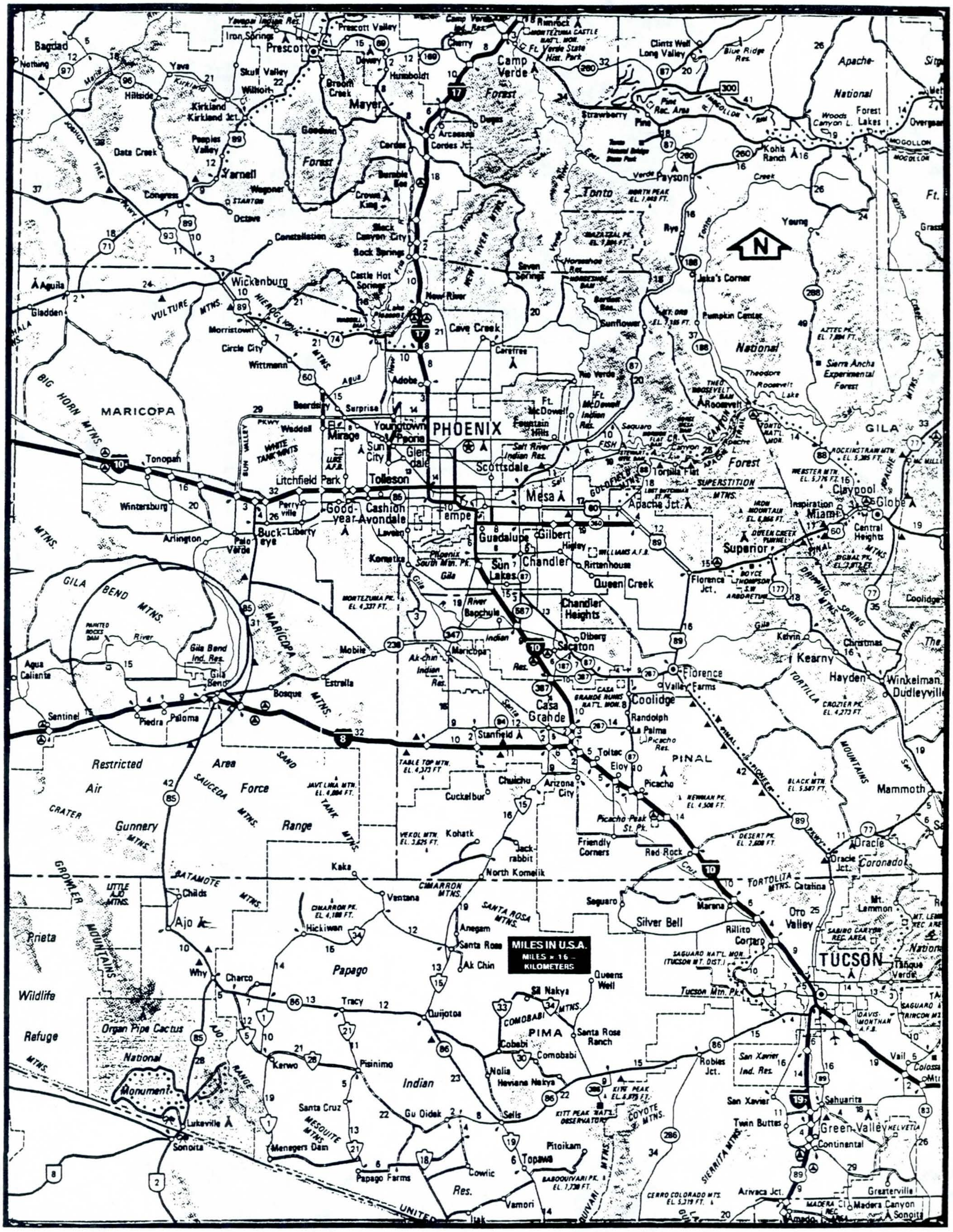

MILES IN U.S.A.
MILES × 1.6 = KILOMETERS
PHOENIX
TUCSON
MARICOPA
GILA
PINAL
PIMA
Prescott
Prescott Valley
Bagdad
Iron Springs
Skull Valley
Wilhoit
Kirkland
Kirkland Jct.
Hillside
Yava
Peoples Valley
Yarnell
Congress
Date Creek
Wagoner
Octave
Stanton
Wickenburg
Aguila
Gladden
Constellation
Morristown
Circle City
Wittmann
Mayer
Humboldt
Dewey
Cherry
Camp Verde
Cordes
Cordes Jct.
Arcosanti
Dugas
Crown King
Bumble Bee
Black Canyon City
Rock Springs
Castle Hot Springs
New River
Cave Creek
Carefree
Payson
Pine
Strawberry
Kohls Ranch
Rye
Jake's Corner
Punkin Center
Young
Sunflower
Rio Verde
Roosevelt
Tonto
National
Forest
Apache
Prescott
Claypool
Globe
Miami
Inspiration
Central Heights
Superior
Apache Jct.
Mesa
Tempe
Scottsdale
Gilbert
Chandler
Guadalupe
Higley
Queen Creek
Rittenhouse
Chandler Heights
Sun Lakes
Glendale
Peoria
Youngtown
Sun City
El Mirage
Surprise
Beardsley
Waddell
Litchfield Park
Tolleson
Goodyear
Avondale
Cashion
Perryville
Buckeye
Liberty
Palo Verde
Arlington
Wintersburg
Tonopah
Laveen
Komatke
Riverside
Bapchule
Maricopa
Sacaton
Olberg
Florence
Florence Jct.
Valley Farms
Coolidge
Casa Grande
Randolph
La Palma
Toltec
Eloy
Picacho
Picacho Peak St. Pk.
Red Rock
Marana
Silver Bell
Rillito
Cortaro
Oro Valley
Catalina
Oracle
Oracle Jct.
Mammoth
Kearny
Hayden
Winkelman
Dudleyville
Kelvin
Christmas
Stanfield
Mobile
Estrella
Bosque
Gila Bend
Paloma
Piedra
Sentinel
Agua Caliente
Ajo
Why
Childs
Lukeville
Sonoita
Organ Pipe Cactus National Monument
Cabeza Prieta Wildlife Refuge
Restricted Air Force Gunnery Range
Papago Indian Res.
Sells
Topawa
Pisinimo
Quijotoa
Santa Rosa
Ak Chin
Anegam
Hickiwan
Ventana
Kaka
Tracy
Charco
Kerwo
Santa Cruz
Gu Oidak
Cowlic
Vamori
Papago Farms
Menegers Dam
Pitoikam
Nolia
Cobabi
Comobabi
Queens Well
Santa Rosa Ranch
North Komelik
Jackrabbit
Kohatk
Chuichu
Cuckelbur
Arizona City
Friendly Corners
Saguaro
Robles Jct.
San Xavier
Twin Buttes
Sahuarita
Green Valley
Continental
Arivaca Jct.
Amado
Madera Canyon
Greaterville
Vail
Tanque Verde
Mt. Lemmon
Coronado
UNITED

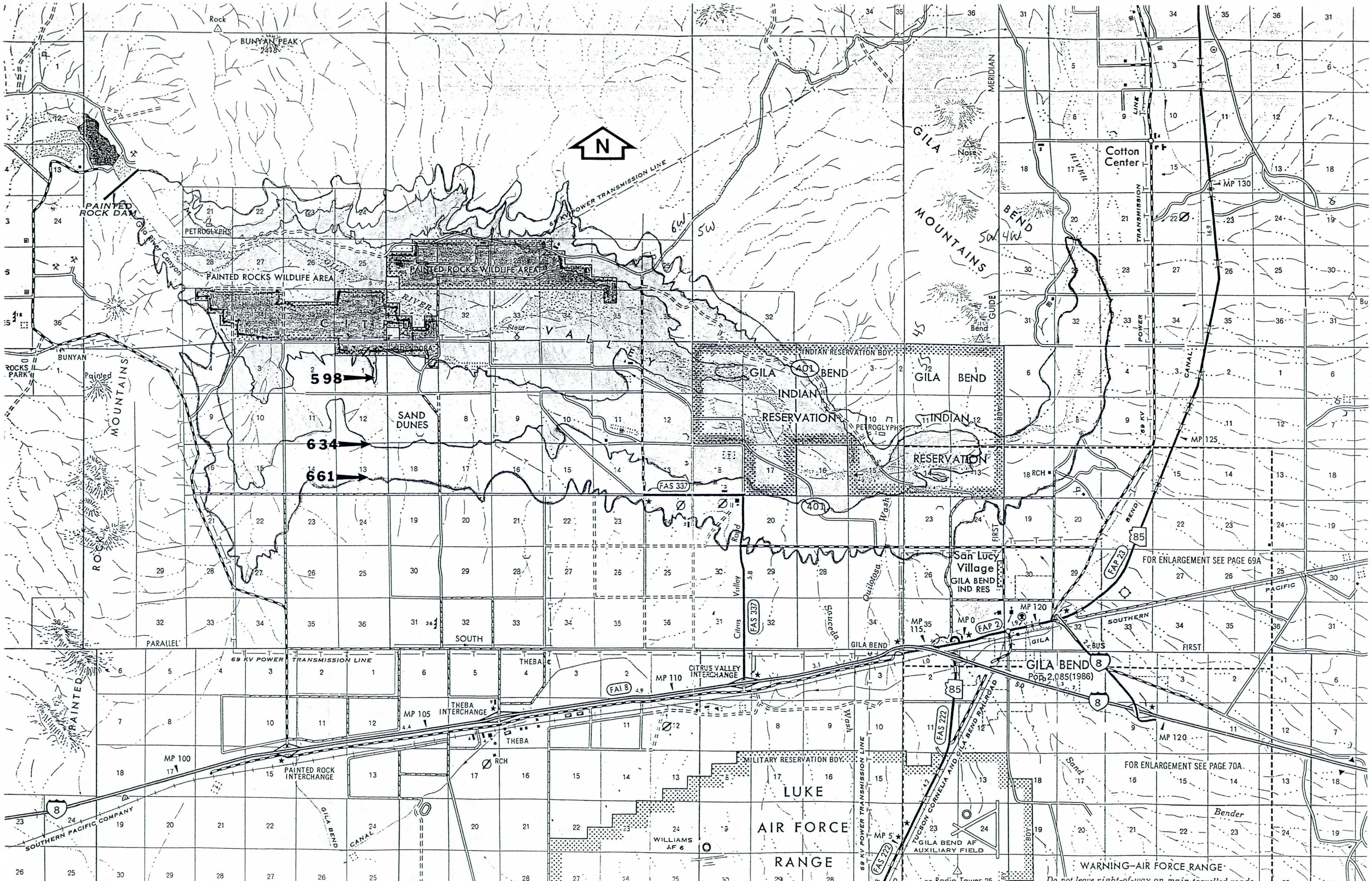
Gila Bend is an agricultural community established as an overland stage coach route in 1871 and was incorporated in 1962. It is located 116 miles east of Yuma, 124 miles west of Tucson and 79 miles southwest of Phoenix. Gila Bend has an estimated population of approximately 1,800 people and is situated at an elevation of 735 feet. This area for centuries was a thriving Indian village. The San Lucy Indian Village is north of the central portion of Gila Bend. Native Americans that resided in this area were active farmers along the Gila River. Jesuit Missionary Father Ensebio Francisco Kino established farming in 1699.

Agriculture is still the mainstay of the economy with over 90,000+ acres under cultivation and cotton is the main crop. Behind agriculture is the service industry. As stated, Gila Bend is located off of I-8 which is the main southern east west route from San Diego to Tucson and Phoenix. State Route 85 runs through town which is the north south route from Mexico to Phoenix. Gila Bend serves as a stopping point for fuel, food and occasional lodging.

Area scenic attractions include the picturesque mountains that surround the area. There area remnants of other earlier civilizations and Painted Rocks State Park's historic features petroglyphs. West of town is the site of the infamous 1851 Oatman Massacre, where all but three children of a westward-bound family were slaughtered by Apaches.

Painted Rock Reservoir was constructed by the U.S. Army Corps of Engineers in 1959 and is located north west of town. Painted Rock Reservoir has a maximum storage capacity of 2,491,700 acre-feet which is up to an existing flowage easement contour elevation height of 661 feet. Painted Rock Dam is an earth-fill structure some 4,780 feet long and 181 feet above the streambed. Painted Rock Reservoir was constructed for flood control and is dry most of the time.

The dam has been operated to minimize damage from flood waters in areas downstream from the dam. The dam is operated for flood control purposes only and accommodates other interests only if they are consistent with operation for flood control purposes. This study is considering alternatives for adding a water conservation purpose to the facility. This report addresses the real estate costs associated with the feasibility of two water conservation alternatives. These alternatives require water be stored on a more permanent basis for purposes of downstream water conservation. Water storage alternatives consider seasonal storage below elevations of 598 or 634, respectively. These elevation have been shown on the enclosed map. Clearly either alternative adversely impacts those lands held in private ownership and following in this report is a value estimate of those lands.



BUNYAN PEAK
2418
N
PAINTED ROCK DAM
PETROGLYPHS
PAINTED ROCKS WILDLIFE AREA
PAINTED ROCKS WILDLIFE AREA
GILA RIVER
GILA VALLEY
69 KV POWER TRANSMISSION LINE
GILA BEND MOUNTAINS
PAINTED ROCK MOUNTAINS
SAND DUNES
598
634
661
GILA BEND INDIAN RESERVATION
GILA BEND INDIAN RESERVATION
PETROGLYPHS
INDIAN RESERVATION BDY.
Cotton Center
San Lucy Village
GILA BEND IND RES
FOR ENLARGEMENT SEE PAGE 69A
GILA BEND
Pop. 2,085 (1986)
SOUTHERN PACIFIC
CITRUS VALLEY INTERCHANGE
THEBA INTERCHANGE
THEBA
PAINTED ROCK INTERCHANGE
SOUTHERN PACIFIC COMPANY
MILITARY RESERVATION BDY.
LUKE AIR FORCE RANGE
WILLIAMS AF 6
GILA BEND AF AUXILIARY FIELD
TUCSON CORNELIA AND GILA BEND RAILROAD
FOR ENLARGEMENT SEE PAGE 70A.
WARNING–AIR FORCE RANGE
Do not leave right-of-way on main travelled roads.

11. DEFINITIONS

MARKET VALUE: The most probable price which a property should bring in a competitive and open market under all conditions requisite to a fair sale, the buyer and seller, each acting prudently, knowledgeably and assuming the price is not affected by undue stimulus. Implicit in this definition is the consummation of a sale as of a specified date and the passing of title from seller to buyer under conditions whereby: (1) buyer and seller are typically motivated; (2) both parties are well informed or well advised, and each acting in what he considers his own best interest: (3) a reasonable time is allowed for exposure in the open market; (4) payment is made in terms of cash in U.S dollars or in terms of financial arrangements comparable thereto; and (5) the price represents the normal consideration for the property sold unaffected by special or creative financing or sales concessions granted by anyone associated with the sale.

HIGHEST AND BEST USE: The use, from reasonably probable and legal use of vacant land or an improved property, which is physically possible, appropriately supported, financially feasible, and results in the highest value. The four criteria that highest and best use must meet are legal permissibility, physical possibility, financial feasibility, and maximum profitability.[1]

It is important to note that highest and best use is not determined through subjective analysis by the property owner, the developer, or the appraiser. It is shaped by the competitive forces of the market in which it is located. The four criteria of legal permissibility, physical possibility, financial feasibility, and maximal productivity are always considered in that order, for it makes no difference that a property is maximally productive or even financially feasible for a given use if is legally prohibited or physically impossible to develop the property to that use.

Listed on the enclosed spread sheets are the various uses of land within the two proposed alternatives. The highest and best use of the properties has been determined to be desert, vacant, irrigated field crop/under rehab, abandoned irrigated field cropland and irrigated field crop land. A detailed highest and best use analysis of each parcel is considered beyond the scope of this reconnaissance level cost estimate. Changes in current uses are considered unlikely as the area is within the Painted Rock Reservoir flowage easement. The lands are situated in a remote

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[1] The Dictionary of Real Estate Appraisal, 3rd edition, Chicago:Appraisal Institute, 1993, page 171.)

area of southeast Maricopa County, Arizona which historically has experienced relatively static growth.

Also this area experienced a dramatic flood in early 1993. Some of the land is being reclaimed to its original irrigated farmland uses. Some of the lands still do not have adequate irrigation delivery systems. The concrete ditches are busted up and sections are missing and the wells need fixing as well. Power lines are in need of repair and clearing of hanging debris. Overall the amount of weeds and thick brush that has started to grow is a severe hinderance to reclaiming lands.

12. VALUATION

The project property values are based on comparable sales and additional sales information derived from various knowledgeable sources in the market place. All comparable sales data is contained in backup files maintained in the Arizona Real Estate project office. Listed below is a range of values for property types by use and on the following page are the estimated values.

DESERT LAND

$50 - $150

IRRIGATED FIELD CROPLAND

$900 - $1,500 in production

$250 - $800 for abandoned land with potential for rehab.

NATIVE / RIVER BOTTOM LANDS

$100 - $150

The estimate of values for the various lands was relied upon from the sales comparison approach. The income and cost approaches were not analyzed in this reconnaissance level cost estimate. The income approach may have some limited use in estimating value, but it is felt that more support would be relied upon from the market approach. The cost approach would not apply unless there were building improvements. There does not appear to be any building improvements located within the alternative areas.

ELEVATION 598					ESTIMATED		ESTD	
	LOCATION			OWNERSHIP	ACREAGE		VALUE	ESTIMATED
OWNERSHIP		Section	APN	ACREAGE	TAKE	USE	PER AC.	VALUE
BFT Co.	T4S R6W	35	401-75-012	118.8	118.8	Vacant	$150	$17,820
BFT Co.	T4S R6W	36	401-75-016	40	40	Vacant	$150	$6,000
Narramore, Dan	T5S R6W	1	403-15-001	157.6	78.8	IFC-/Rehab	$500	$39,400
Narramore, Dan	T5S R6W	1	403-15-002	140	140	IFC-/Rehab	$500	$70,000
Narramore, Dan	T5S R6W	1	403-15-003	20	20	IFC-/Rehab	$500	$10,000
Narramore, Dan	T5S R6W	2	403-15-004	157.6	78.8	IFC-/Rehab	$500	$39,400
Narramore, Dan	T5S R6W	2	403-15-005	160	160	IFC-/Rehab	$500	$80,000
Narramore, Dan	T5S R6W	2	403-15-006	160	160	IFC-/Rehab	$500	$80,000
Narramore, Dan	T5S R6W	2	403-15-007	157.6	157.6	IFC-/Rehab	$500	$78,800
Gila Bend Indian Res.	T5S R5W	5	N/A	640	60	Vacant	$150	$9,000
Gila Bend Indian Res.	T5S R5W	6	N/A	640	640	Vacant	$150	$96,000
Gila River Land Co.	T5S R6W	3	403-18-023	160	160	IFC-Rehab	$500	$80,000
Gila River Land Co.	T5S R6W	3	403-18-024	160	160	IFC-Rehab	$500	$80,000
Gila River Land Co.	T4S R6W	26	401-75-001	78.79	78.79	Vacant	$150	$11,819
Gila River Land Co.	T4S R6W	34	401-75-008	160	160	Vacant	$150	$24,000
Gila River Land Co.	T4S R6W	34	401-75-009	160	160	Vacant	$150	$24,000
Gila River Land Co.	T4S R6W	35	401-75-010	80	80	Vacant	$150	$12,000
Gila River Land Co.	T4S R6W	36	401-75-014	40	40	Vacant	$150	$6,000
Gila River Land Co.	T4S R6W	36	401-75-015	158.8	158.8	Vacant	$150	$23,820
Gila River Land Co.	T4S R6W	36	401-75-013	80	80	Vacant	$150	$12,000
Gila River Land Co.	T4S R6W	36	401-75-018	120	120	Vacant	$150	$18,000
Gila River Land Co.	T4S R6W	36	401-75-019	40	40	Vacant	$150	$6,000
Gila River Land Co.	T4S R6W	36	401-75-020	156	156	Vacant	$150	$23,400
Gila River Land Co.	T5S R6W	4	403-18-001	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	4	403-18-002	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	5	403-18-006	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	5	403-18-007	160	160	Vacant	$150	$24,000
Gila River Land Co.	T4S R6W	33	401-76-018	17	17	Vacant	$150	$2,550
Gila River Land Co.	T4S R6W	33	401-76-019	38.8	38.8	Vacant	$150	$5,820
Gila River Land Co.	T4S R6W	33	401-76-020	12	12	Vacant	$150	$1,800
Gila River Land Co.	T4S R6W	33	401-76-021	40	40	Vacant	$150	$6,000
Grasser, Jennie	T4S R6W	33	401-76-017	40	40	Vacant	$150	$6,000
Hackenberg, Walter	T4S R6W	32	401-76-016B	40	40	Vacant	$150	$6,000
Katahira, Hiroko	T4S R6W	32	401-76-016A	40	40	Vacant	$150	$6,000
Prudential	T5S R6W	10	403-18-027B	100	20	Desert	$150	$3,000
Prudential	T5S R6W	5	403-18-005	320	320	Desert	$150	$48,000
Prudential	T5S R6W	6	403-18-013	40	10	Desert	$150	$1,500
Prudential	T5S R7W	1	403-19-001	160	100	Desert	$150	$15,000
Prudential	T5S R7W	1	403-19-002	320	20	Desert	$150	$3,000
Prudential	T5S R7W	2	403-19-005	640	400	Desert	$150	$60,000
Prudential	T5S R7W	10	403-19-007	640	80	Desert	$150	$12,000
Prudential	T5S R7W	3	403-19-006	640	640	Desert	$150	$96,000
Prudential	T5S R7W	4	403-19-013	616	40	Desert	$150	$6,000
S & P Farms	T5S R6W	11	403-15-021	80	80	Ab-IFC	$250	$20,000
S & P Farms	T5S R6W	11	403-15-022	157.6	40	Ab-IFC	$250	$10,000
S & P Farms	T5S R6W	3	403-18-022	160	160	Ab-IFC	$250	$40,000
S & P Farms	T5S R6W	3	403-18-025	160	160	Ab-IFC	$250	$40,000
S & P Farms	T5S R6W	10	403-18-028	160	80	Ab-IFC	$250	$20,000
S & P Farms	T5S R6W	4	403-18-003	40	40	Vacant	$150	$6,000
S & P Farms	T5S R6W	4	403-18-004	40	40	Vacant	$150	$6,000
Sayegh, Musa	T4S R6W	33	401-76-023	44	44	Vacant	$150	$6,600
Shetayh, Ziad	T4S R6W	33	401-76-022	40	40	Vacant	$150	$6,000
				9,010.59	6,229.39			$1,376,728.50
				Total Ownership	Total Take Ac's			Total Estimated
				Acres				Value

	ELEVATION 598				
		OWNERSHIP	ESTIMATED	ESTIMATED	
	OWNERSHIP	ACREAGE	ACREAGE TAKE	VALUE of TAKE	
1	BFT Co.	158.80	158.80	$23,820	
2	Gila Bend Indian Reservation	1,280.00	700.00	$105,000	
3	Gila River Land Co.	2,141.39	2,141.39	$433,209	
4	Grasser, Jennie	40.00	40.00	$6,000	
5	Hackenberg, Walter	40.00	40.00	$6,000	
6	Katahira, Hiroko	40.00	40.00	$6,000	
7	Narramore, Dan	952.80	795.20	$397,600	
8	Prudential	3,476.00	1,630.00	$244,500	
9	S & P Farms	797.60	600.00	$142,000	
10	Sayegh, Musa	44.00	44.00	$6,600	
11	Shetayh, Ziad	40.00	40.00	$6,000	
			6,229.39	$1,376,729	
	LAND				
	Acreage Fee Acquisition	6,229.39	$1,376,728.50		
	IMPROVEMENTS				
	None		0.00		
	CONTINGENCIES	25%	344,182		
	SEVERANCE	10%	137,673		
	NO RELOCATIONS		0.00		
	TOTAL		**$1,858,583**	**rd**	**$1,860,000**

ELEVATION 634								
					ESTIMATED		ESTD	
	LOCATION			OWNERSHIP	ACREAGE		VALUE	ESTIMATED
OWNERSHIP		Section	APN	ACREAGE	TAKE	USE	PER AC.	VALUE
Bauer, Steven	T5S R6W	9	403-18-018	120	120	Vacant	$150	$18,000
BFT Co.	T4S R6W	35	401-75-012	118.8	118.8	Vacant	$150	$17,820
BFT Co.	T4S R6W	36	401-75-016	40	40	Vacant	$150	$6,000
Gila Bend Indian Res.	T5S R5W	12	N/A	640	110	Vacant	$150	$16,500
Gila Bend Indian Res.	T5S R5W	11	N/A	640	300	Vacant	$150	$45,000
Gila Bend Indian Res.	T5S R5W	13	N/A	640	160	Vacant	$150	$24,000
Gila Bend Indian Res.	T5S R5W	14	N/A	640	520	Vacant	$150	$78,000
Gila Bend Indian Res.	T5S R5W	15	N/A	640	550	Vacant	$150	$82,500
Gila Bend Indian Res.	T5S R5W	10	N/A	640	40	Vacant	$150	$6,000
Gila Bend Indian Res.	T5S R5W	9	N/A	640	545	Vacant	$150	$81,750
Gila Bend Indian Res.	T5S R5W	4	N/A	640	100	Vacant	$150	$15,000
Gila Bend Indian Res.	T5S R5W	5	N/A	640	460	Vacant	$150	$69,000
Gila Bend Indian Res.	T5S R5W	8	N/A	640	640	Vacant	$150	$96,000
Gila Bend Indian Res.	T5S R5W	17	N/A	640	640	Vacant	$150	$96,000
Gila Bend Indian Res.	T5S R5W	7	N/A	640	640	Vacant	$150	$96,000
Gila Bend Indian Res.	T5S R5W	6	N/A	640	640	Vacant	$150	$96,000
Gila River Land Co.	T5S R6W	13	403-15-032	40	40	IFC/Rehab	$500	$20,000
Gila River Land Co.	T5S R6W	13	403-15-033	160	160	IFC/Rehab	$500	$80,000
Gila River Land Co.	T5S R6W	3	403-18-023	160	160	IFC/Rehab	$500	$80,000
Gila River Land Co.	T5S R6W	3	403-18-024	160	160	IFC/Rehab	$500	$80,000
Gila River Land Co.	T4S R6W	26	401-75-001	78.79	78.79	Vacant	$150	$11,819
Gila River Land Co.	T4S R6W	34	401-75-008	160	160	Vacant	$150	$24,000
Gila River Land Co.	T4S R6W	34	401-75-009	160	160	Vacant	$150	$24,000
Gila River Land Co.	T4S R6W	35	401-75-010	80	80	Vacant	$150	$12,000
Gila River Land Co.	T4S R6W	36	401-75-014	40	40	Vacant	$150	$6,000
Gila River Land Co.	T4S R6W	36	401-75-015	158.8	158.8	Vacant	$150	$23,820
Gila River Land Co.	T4S R6W	36	401-75-013	80	80	Vacant	$150	$12,000
Gila River Land Co.	T4S R6W	36	401-75-018	120	120	Vacant	$150	$18,000
Gila River Land Co.	T4S R6W	36	401-75-019	40	40	Vacant	$150	$6,000
Gila River Land Co.	T4S R6W	36	401-75-020	156	156	Vacant	$150	$23,400
Gila River Land Co.	T5S R6W	4	403-18-001	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	4	403-18-002	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	5	403-18-006	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	5	403-18-007	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	5	403-18-006	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	5	403-18-007	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	4	403-18-001	160	160	Vacant	$150	$24,000
Gila River Land Co.	T5S R6W	4	403-18-002	160	160	Vacant	$150	$24,000
Gila River Land Co.	T4S R6W	33	401-76-018	17	17	Vacant	$150	$2,550
Gila River Land Co.	T4S R6W	33	401-76-019	38.8	38.8	Vacant	$150	$5,820
Gila River Land Co.	T4S R6W	33	401-76-020	12	12	Vacant	$150	$1,800
Gila River Land Co.	T4S R6W	33	401-76-021	40	40	Vacant	$150	$6,000
Grasser, Jennie	T4S R6W	33	401-76-017	40	40	Vacant	$150	$6,000
Hackenberg, Walter	T4S R6W	32	401-76-016B	40	40	Vacant	$150	$6,000
J & R Ltd.	T5S R5W	16	403-14-019	440	440	Vacant	$150	$66,000
J & R Ltd.	T5S R5W	16	403-14-001	40	40	Vacant	$150	$6,000
J & R Ltd.	T5S R5W	16	403-14-018	160	160	Vacant	$150	$24,000
Katahira, Hiroko	T4S R6W	32	401-76-016A	40	40	Vacant	$150	$6,000
Narramore, Dan	T5S R6W	12	403-15-024	80	80	IFC/Rehab	$500	$40,000
Narramore, Dan	T5S R6W	12	403-15-025	80	80	IFC/Rehab	$500	$40,000
Narramore, Dan	T5S R6W	12	403-15-023	160	160	IFC/Rehab	$500	$80,000
Narramore, Dan	T5S R6W	12	403-15-029	160	160	IFC/Rehab	$500	$80,000
Narramore, Dan	T5S R6W	12	403-15-028A	40	40	IFC/Rehab	$500	$20,000
Narramore, Dan	T5S R6W	12	403-15-028B	40	40	IFC/Rehab	$500	$20,000
Narramore, Dan	T5S R6W	12	403-15-026	40	40	IFC/Rehab	$500	$20,000
Narramore, Dan	T5S R6W	12	403-15-027	40	40	IFC/Rehab	$500	$20,000
Narramore, Dan	T5S R6W	1	403-15-001	157.6	157.6	IFC/Rehab	$500	$78,800
Narramore, Dan	T5S R6W	1	403-15-002	140	140	IFC/Rehab	$500	$70,000
Narramore, Dan	T5S R6W	1	403-15-003	20	20	IFC/Rehab	$500	$10,000
Narramore, Dan	T5S R6W	2	403-15-004	157.6	157.6	IFC/Rehab	$500	$78,800
Narramore, Dan	T5S R6W	2	403-15-005	160	160	IFC/Rehab	$500	$80,000
Narramore, Dan	T5S R6W	2	403-15-006	160	160	IFC/Rehab	$500	$80,000
Narramore, Dan	T5S R6W	2	403-15-007	157.6	157.6	IFC/Rehab	$500	$78,800

ELEVATION 634								
OWNERSHIP	LOCATION	Section	APN	OWNERSHIP ACREAGE	ESTIMATED ACREAGE TAKE	USE	ESTD VALUE PER AC.	ESTIMATED VALUE
Prudential	T5S R5W	20	403-15-50A	631	70	IFC	$1,200	$84,000
Prudential	T5S R6W	13	403-15-030	315	115	Desert	$150	$17,250
Prudential	T5S R6W	13	403-15-031	117.5	117.5	Desert	$150	$17,625
Prudential	T5S R6W	11	403-15-015	80	80	Desert	$150	$12,000
Prudential	T5S R6W	14	403-15-034	632.7	195	Desert	$150	$29,250
Prudential	T5S R6W	10	403-18-026	320	320	Desert	$150	$48,000
Prudential	T5S R6W	10	403-18-027A	60	60	Desert	$150	$9,000
Prudential	T5S R6W	10	403-18-027B	100	100	Desert	$150	$15,000
Prudential	T5S R6W	5	403-18-005	320	320	Desert	$150	$48,000
Prudential	T5S R6W	6	403-18-011	320	320	Desert	$150	$48,000
Prudential	T5S R6W	6	403-18-012	80	80	Desert	$150	$12,000
Prudential	T5S R6W	6	403-18-013	40	40	Desert	$150	$6,000
Prudential	T5S R6W	7	403-18-014	640	640	Desert	$150	$96,000
Prudential	T5S R6W	8	403-18-015	640	640	Desert	$150	$96,000
Prudential	T5S R6W	9	403-18-016	320	320	Desert	$150	$48,000
Prudential	T5S R6W	9	403-18-017	160	160	Desert	$150	$24,000
Prudential	T5S R6W	18	403-18-021	640	80	Desert	$150	$12,000
Prudential	T5S R6W	17	403-18-020	640	80	Desert	$150	$12,000
Prudential	T5S R6W	16	403-18-019	640	40	Desert	$150	$6,000
Prudential	T5S R6W	5	403-18-005	320	320	Desert	$100	$32,000
Prudential	T5S R7W	1	403-19-001	160	160	Desert	$100	$16,000
Prudential	T5S R7W	1	403-19-002	320	320	Desert	$100	$32,000
Prudential	T5S R7W	12	403-19-009	640	560	Desert	$150	$84,000
Prudential	T5S R7W	13	403-19-010	640	40	Desert	$150	$6,000
Prudential	T5S R7W	11	403-19-008	640	570	Desert	$150	$85,500
Prudential	T5S R7W	2	403-19-005	640	640	Desert	$100	$64,000
Prudential	T5S R7W	15	403-19-012	640	470	Desert	$150	$70,500
Prudential	T5S R7W	10	403-19-007	640	640	Desert	$150	$96,000
Prudential	T5S R7W	9	403-19-014	640	200	Desert	$150	$30,000
Prudential	T5S R7W	3	403-19-006	640	640	Desert	$150	$96,000
Prudential	T5S R7W	4	403-19-013	616	100	Desert	$150	$15,000
Prudential	T5S R7W	16	403-19-015	640	30	Desert	$100	$3,000
S & P Farms	T5S R5W	18	403-15-039	80	80	Aban/IFC	$250	$20,000
S & P Farms	T5S R5W	18	403-15-042	40	40	Vacant	$150	$6,000
S & P Farms	T5S R5W	18	403-15-038	40	15	Vacant	$150	$2,250
S & P Farms	T5S R5W	18	403-15-037	80	60	Vacant	$150	$9,000
S & P Farms	T5S R5W	18	403-15-041	40	40	Aban/IFC	$250	$10,000
S & P Farms	T5S R5W	18	403-15-045	40	40	Aban/IFC	$250	$10,000
S & P Farms	T5S R5W	18	403-15-047	80	80	Aban/IFC	$250	$20,000
S & P Farms	T5S R5W	18	403-15-044	40	40	Vacant	$150	$6,000
S & P Farms	T5S R5W	18	403-15-043	80	80	Vacant	$150	$12,000
S & P Farms	T5S R5W	18	403-15-036	40	40	Vacant	$150	$6,000
S & P Farms	T5S R6W	11	403-15-018	78.8	78.8	Vacant	$150	$11,820
S & P Farms	T5S R6W	11	403-15-016	80	80	Vacant	$150	$12,000
S & P Farms	T5S R6W	11	403-15-017	78.8	78.8	Vacant	$150	$11,820
S & P Farms	T5S R6W	11	403-15-019	40	40	Aban/IFC	$250	$10,000
S & P Farms	T5S R6W	11	403-15-020	40	40	Aban/IFC	$250	$10,000
S & P Farms	T5S R6W	11	403-15-021	80	80	Aban/IFC	$250	$20,000
S & P Farms	T5S R6W	11	403-15-022	157.6	157.6	Aban/IFC	$250	$39,400
S & P Farms	T5S R6W	3	403-18-022	160	160	Aban/IFC	$250	$40,000
S & P Farms	T5S R6W	3	403-18-025	160	160	Aban/IFC	$250	$40,000
S & P Farms	T5S R6W	10	403-18-028	160	160	Aban/IFC	$250	$40,000
S & P Farms	T5S R6W	4	403-18-003	40	40	Vacant	$150	$6,000
S & P Farms	T5S R6W	4	403-18-004	40	40	Vacant	$150	$6,000
Sayegh, Musa	T4S R6W	33	401-76-023	44	44	Vacant	$150	$6,600
Shetayh, Ziad	T4S R6W	33	401-76-022	40	40	Vacant	$150	$6,000
Tilley, Harold	T5S R5W	21	403-14-014A	635	200	Vacant	$150	$30,000
Tilley, Harold	T5S R5W	22	403-14-015B	626	90	IFC	$1,200	$108,000
				30,825	21,430			**$4,152,193.50**
				Total Ownership Acreage	Total estimated take acreage			Total estimated value

	ELEVATION 634				
		OWNERSHIP	ESTIMATED	ESTIMATED	
	OWNERSHIP	ACREAGE	ACREAGE TAKE	VALUE of TAKE	
1	Bauer, Steven	120.00	120.00	$18,000	
2	BFT Co.	158.80	158.80	$23,820	
3	Gila Bend Indian Reservation	8,320.00	5,345.00	$801,750	
4	Gila River Land Co.	2,981.39	2,981.39	$629,209	
5	Grasser, Jennie	40.00	40.00	$6,000	
6	Hackenberg, Walter	40.00	40.00	$6,000	
7	J & R Ltd.	640.00	640.00	$96,000	
8	Katahira, Hiroko	40.00	40.00	$6,000	
9	Narramore, Dan	1,592.80	1,592.80	$796,400	
10	Prudential	13,872.20	8,467.50	$1,270,125	
11	S & P Farms	1,675.20	1,630.20	$348,290	
12	Sayegh, Musa	44.00	44.00	$6,600	
13	Shetayh, Ziad	40.00	40.00	$6,000	
14	Tilley, Harold	1,261.00	290.00	$138,000	
		30,825.39	21,429.69	**$4,152,194**	
	LAND				
	Acreage Fee Acquisition	21,429.69	$4,152,194		
	IMPROVEMENTS				
	None		0.00		
	CONTINGENCIES	25%	1,038,049		
	SEVERANCE	10%	415,219		
	NO RELOCATIONS		0.00		
	TOTAL		**$5,605,462**		
				rd	**$5,600,000**

13. PUBLIC LAW 91-646 AND PL 100-17

Public Law 91-646 and Public Law 100-17 regarding relocation costs of persons or businesses have not been considered in this report. It does not appear that any persons or business are located in the alternative areas.

14. CONTAMINATION AND TOXIC CONCERNS

The general area has been inspected and there were not noted to be any hazardous or toxic concerns. It should be noted that the 598 elevation alternative covers over 9,000 acres and the 634 elevation alternative covers nearly 31,000 acres. A detailed acre by acre inspection was not conducted due to the level of this report, time constraints and lack of access into a majority of the project area.

The appraiser is not qualified to detect hazardous or toxic substances, nor qualified to determine the effect, if any, of unknown or known substances. The cost estimate is based on the project area being free of hazardous waste contamination, and should an assessment indicate an adverse condition exists the conclusions of this report may require some sort of revision.

15. SUMMARY

Alternative (1)

6,229.39 acres at elevation 598	$1,860,000

Alternative (2)

21,429.69 acres at elevation 634	$5,600,000

16. CERTIFICATION

I certify that, to the best of my knowledge and belief:

I personally inspected the area of the subject properties of the report, and have considered the pertinent facts affecting the value thereof.

The facts and data reported by the appraiser and used in this report are true and correct.

That all market data pertaining to the final value estimate has been accumulated from various sources and, where possible, personally examined and verified as to details, motivation and validity.

That the reported analyses, opinions, and conclusions are limited only by the assumptions and limiting conditions stated in this review report, and are my personal, unbiased professional analyses, opinions and conclusions.

I have no present or prospective interest in the property that is the subject of this report and I have no personal interest or bias with respect to the parties involved.

My compensation is not contingent on an action or event resulting from the analyses, opinions, or conclusions in, or the use of, this report.

No one provided significant professional assistance to the undersigned in the preparation of this report.

Date: 06 January 1995

Brian Kirchner

Brian Kirchner
Cal. Certified General Appraiser

STATEMENT OF PROFESSIONAL QUALIFICATIONS
for
BRIAN KIRCHNER

Professional Experience

Department of the Army, Los Angeles District, Phoenix Project Office, Corps of Engineers April 1994

Department of the Army, Sacramento District, Corps of Engineers September 1991 to April 1994

Independent real estate appraiser conducting assignments in Northern California May 1990 to August 1991

Agricultural real estate appraiser for Western Farm Credit Bank in Sacramento, Ca. July 1987 to May 1990

Loan Officer/Appraiser for Farm Credit Association of Woodland, Woodland California
May 1986 to July 1987 - Appraisal work performed 50% of the time.

Professional Licenses

State of California Real Estate Salesperson License expiration 11/97

State of California Certified General Appraiser, AG 018950, Issued 03/94

Education

California State University, Chico: Bachelor of Science Degree
May 1984

Monterey Peninsula Junior College: Associate of Arts Degree
May 1981

Successfully completed courses:

December 1986	Real Estate Principles, TRI-REALTORS
May 1987	A-10 Fundamentals of Appraisal*
January 1988	A-20 Principles of Rural Appraisal*
August 1998	Report Writing Seminar*
December 1988	A-30 Advanced Rural Appraisal*
March 1991	A-12 Code of Ethics and Uniform Standards of Professional Appraisal Practice*
August 1992	The Appraisal of Partial Acquisitions**
November 1993	Legal Aspects of Real Estate and Agency Relationships
December 1993	Environmental Contamination in Real Estate**
November 1994	Basic Income Capitalization***
December 1994	Advanced Income Capitalization***

*American Society of Farm Managers and Rural Appraisers
**International Right Of Way Association
***Appraisal Institute