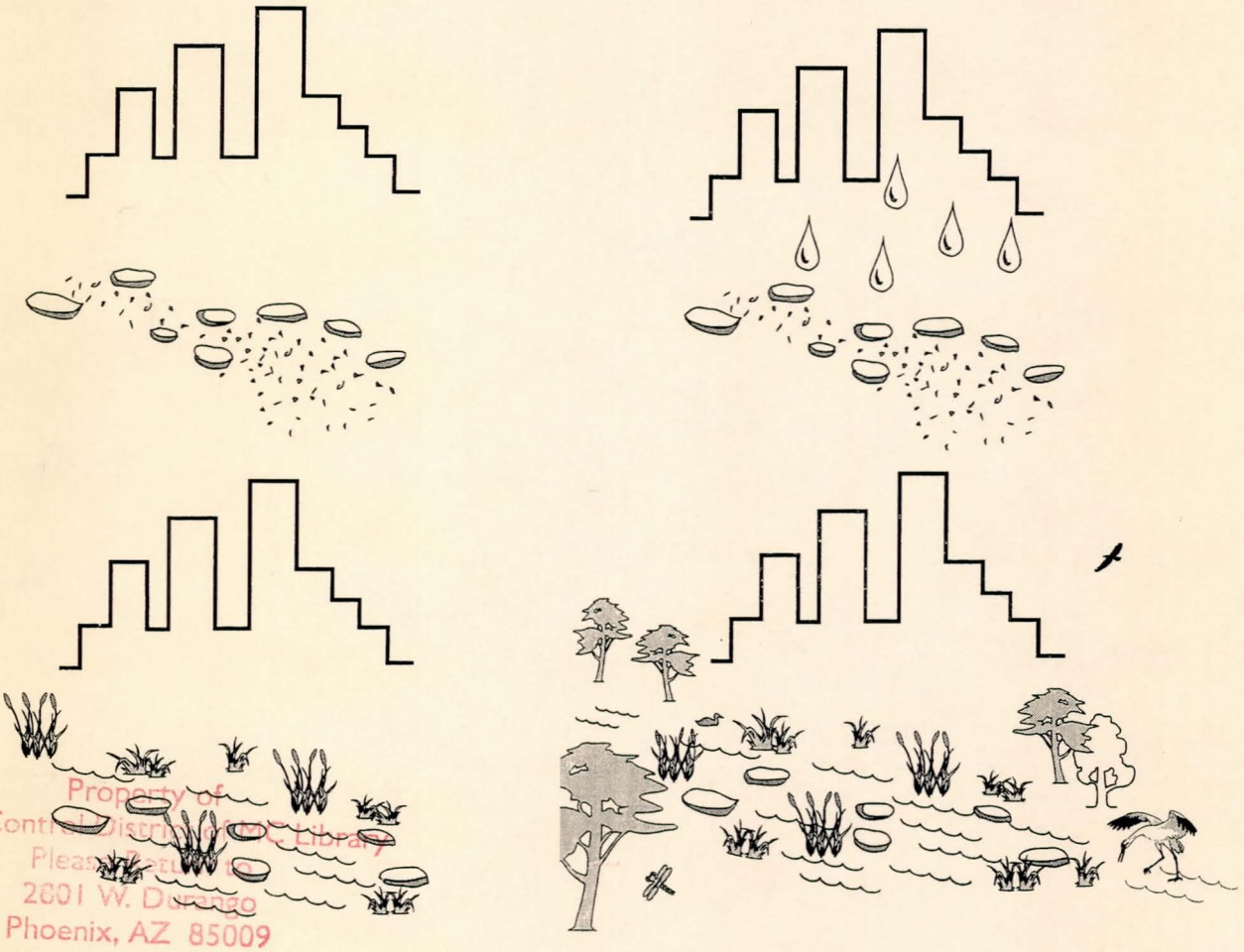
RIO SALADO, SALT RIVER, AZ

RECONNAISANCE REPORT



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US ARMY CORPS
OF ENGINEERS
Los Angeles District
South Pacific Division

March 1995

ABSTRACT

As directed by Congress, the Corps of Engineers conducted the Rio Salado, Salt River, Arizona Reconnaissance Study. The study area is located along the Salt River through Tempe and Phoenix, Arizona. In cooperation with Federal, state, local agencies, and through public workshops, a wide array of water resource problems and opportunities were identified. A reconnaissance level investigation of these problems and opportunities has led to the formulation and evaluation of two alternatives; both of which are economically justified and in the Federal interest. While the alternatives provide similar investments in riparian habitat restoration in conjunction with improved water quality, they differ in degree of recreation development as affected by Corps policies. Results of this study indicate that a Federal interest has been identified for environmental restoration involving riparian habitat restoration, water quality improvement, and recreation that is incidental or complimentary to a Corps primary project purpose. Currently, there is no economically justified Federal interest in flood control within the Rio Salado study area.

During the plan formulation process, the study team identified effective, integrated solutions to environmental resource problems. As identified in this reconnaissance study, the synergy among riparian habitat restoration measures, water treatment techniques, and recreation activities along the Salt River could be more fully explored during the feasibility study. A more detailed study of the overlapping water resource opportunities could lead to a more complete understanding of the net environmental gains of an integrated resources approach to water resources development.

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I AUTHORITY, PURPOSE AND SCOPE

1.1 Introduction

The Rio Salado Reconnaissance Study involves the investigation of the water resource problems and opportunities along the Salt River in the Phoenix and Tempe metropolitan areas of Maricopa County, Arizona (Figure 1.1). This report is organized to 1) outline the study purpose and scope of the study effort, 2) describe the study area, 3) describe present and future, without-project conditions, 4) present the problems addressed, 5) describe the alternatives considered, 6) present the results of the analysis of these alternatives, and 7) identify the alternative(s) which will likely have a Federal interest.

1.2 Authority

This study has been conducted under the authority of Public Law 761, Seventy-fifth Congress, June 28, 1938, referred to as "Gila River and Tributaries." Funds have been appropriated under the Senate Energy and Water Development Appropriations Bill, 1994, wherein Congress directed the "Corps of Engineers to conduct a reconnaissance study to investigate flooding and water quality problems in the Rio Salado area of the Salt River in Tempe and Phoenix. The study should consider water quality, recreation, and restoration of riparian habitat benefits as well as benefits traditionally displayed."

1.3 Purpose and Scope

This reconnaissance study provides an interim response to the study authority cited above. The study focuses on flood, water-quality, riparian habitat and recreation opportunities along the Salt River in the Phoenix and Tempe metropolitan areas.

The reconnaissance study and report shall accomplish the following four essential tasks:

1. The definition of problems and opportunities, and identification of potential solutions.

2. A determination whether the planning should proceed further, into a feasibility phase, based on a preliminary appraisal of consistency with U.S. Army Corps of Engineers policies, cost, benefits, and environmental impacts of the identified potential solutions.

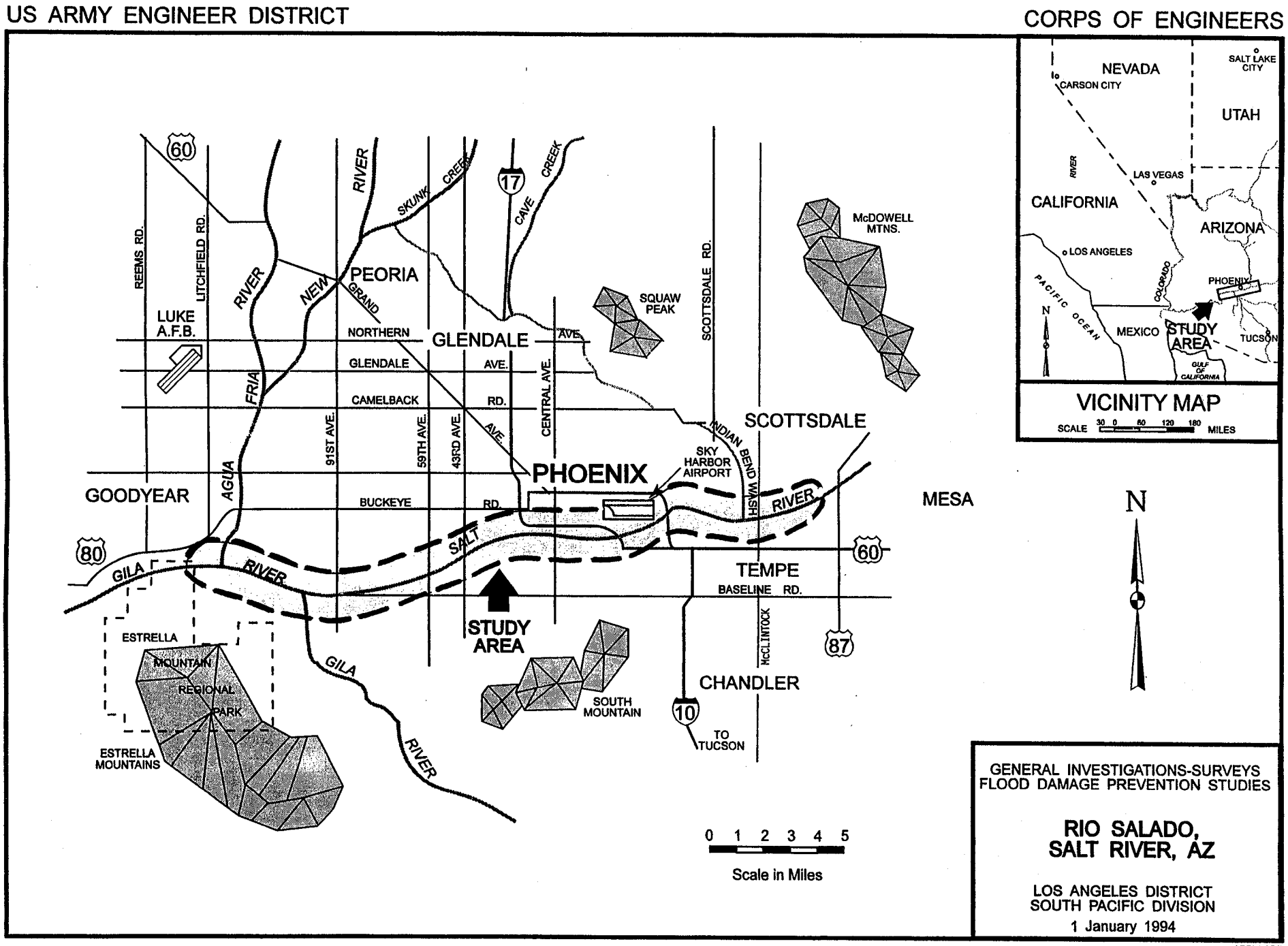


Figure 1.1. Location Map

3. An estimate of the time and costs for the feasibility phase.

4. An assessment of the level of interest and support of non-Federal interests in the identified potential solutions.

II STUDY AREA DESCRIPTION

2.1 Study Area

The study area (Figure 1.1) consists of approximately twenty-eight miles of the Salt River from the eastern municipal boundary of Tempe at McClintock Road, through Phoenix, to the confluence of Gila and Agua Fria Rivers in Maricopa County, Arizona.

The Salt River originates in the White Mountains of eastern Arizona and drains westward through the Phoenix metropolitan area to its confluence with the Gila River approximately 15 miles west of downtown Phoenix. Salt River flows have sustained agriculture in the Salt River Valley since at least 300 AD when the Hohokam Indians farmed the area. European settlers arrived and began farming in the Phoenix and surrounding areas in 1800's. Since then a series of dams have been constructed on the Salt and tributary Verde River and the metropolitan area has grown to approximately 2.2 million people. The damming of the river has provided a reliable water supply to the cities and local agriculture, but at a cost of virtually eliminating all but flood-related flows on the river through the study area.

Riparian vegetation through the study area has been significantly reduced in comparison to pre-dam conditions. Prior to construction of the dams and upstream removal of the water, sustained base flows would have created dense stands of native riparian vegetation along the river bottom. Now there is no base flow, and riparian vegetation along much of the study reach is confined to the upper terraces that have been created during flood events. The native vegetation has been significantly replaced by the exotic salt cedar (Tamarix chinensis). Salt cedar is an invasive phreatophyte with little aesthetic or habitat value.

The river's periphery of the fourteen mile reach from the Mesa/Tempe boundary to 40th Avenue in Phoenix is now highly urbanized. The next eight miles consist of agricultural and residential areas, interspersed with occasional industrial development. The remaining six miles is largely undeveloped.

Landfills and sand and gravel mining are currently the dominant use along the river within the urban areas. There are currently at least 23 landfills and 25 sand and gravel mines along the river between McClintock Avenue in Tempe and the Gila River. Several of the landfills are now classified by the U.S. Environmental Protection Agency as superfund sites. The river study reach is crossed by 16 bridges and 3 dip crossings. Residential density along the river is relatively light and generally disadvantaged.

2.2 Climate

The Rio Salado study area climate is characteristic of the Sonoran desert: hot and dry. The average annual daily maximum temperature is 85° F. On average, 91 days per year are above 100° F. Average annual daily minimum temperature is 57° F. On average, 9 days per year are below freezing. The potential evapotranspiration is slightly less than precipitation only in January. During the rest of the year, the soil moisture budget is deficient.

Average annual precipitation less than 8 inches. Precipitation is about equally divided between the summer and winter seasons. Summer storms are typically local, high-intensity thunderstorms and generally occur from July to September. Storms on record have produced over 5 inches of rainfall in a 24 hour period. Winter storms are typically wide-spread cyclonic storms with long-duration, low-intensity rain.

2.3 Topography, Drainage and Surface Water Flows

The Rio Salado study area is a flat alluvial valley with elevations ranging from 910 feet to 1,170 feet. The rugged South Mountains rise to an elevation of 2,500 feet approximately five miles south of the channel. Papago and Tempe Buttes at Tempe constrict the river and are the only hills immediately adjacent to the channel within the study reach.

The Salt River is the largest tributary of the Gila River and drains an area of approximately 13,700 mi^2 within the northern and eastern portions of the State of Arizona (Figure 2.1). The topography of the drainage area is extremely irregular and rugged, with elevations commonly to more than 7000 feet, and, at San Francisco Mountain in the Verde River basin, to more than

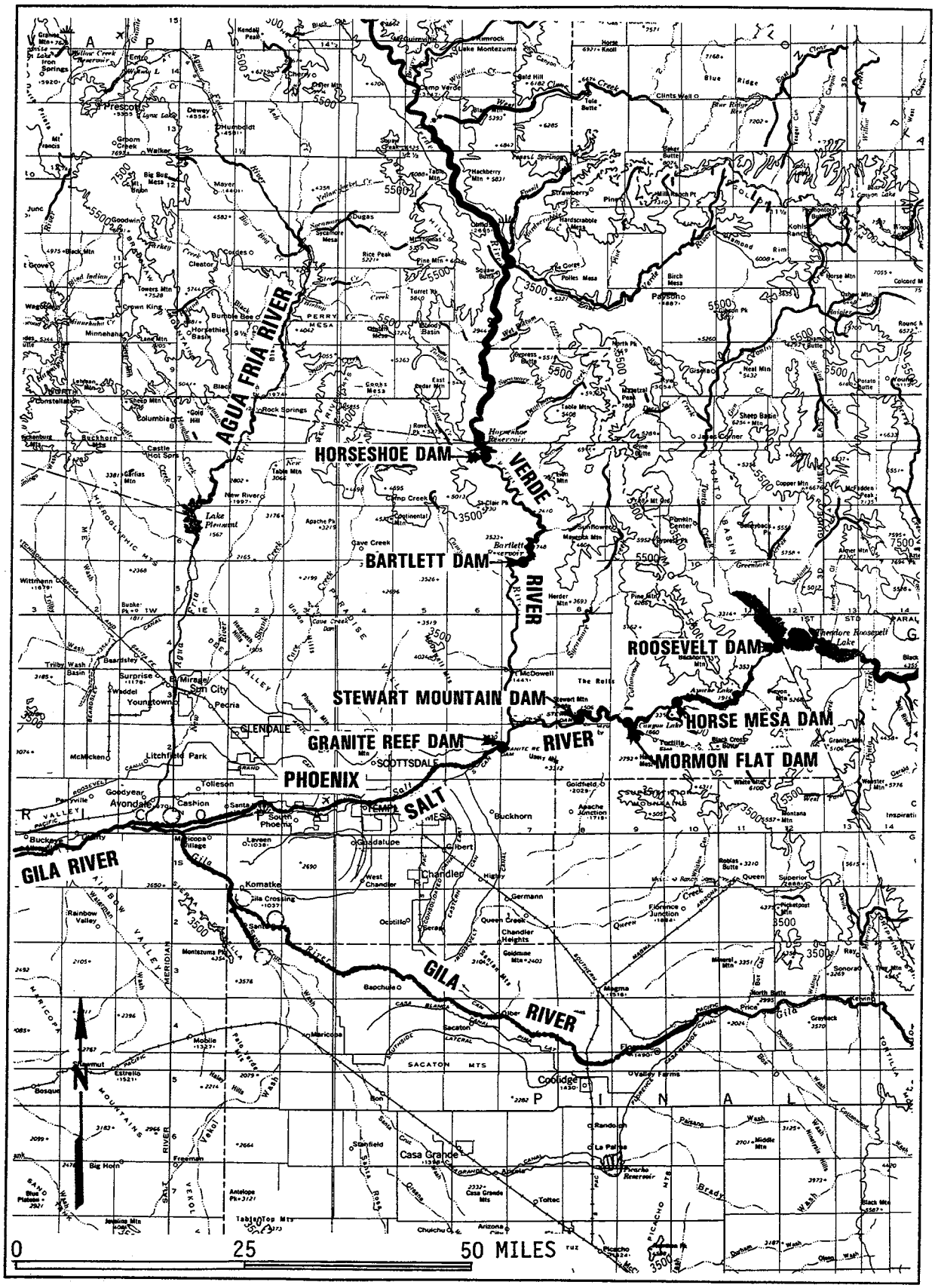


Figure 2.1. Regional Drainage Map

12,000 feet. The Verde River is the main tributary of the Salt River and includes 6,620 mi^2 of the Salt River drainage.

Several dams are operated on the Salt and Verde Rivers by the Salt River Project (SRP) to provide water supply, hydroelectric energy, and flood control (upon completion of Roosevelt Dam modifications) to the populace of the Salt River Valley, in Maricopa County. These dams are shown on Figure 2.1 and their approximate storage capacities at normal water surface are listed in Table 2.1.

Table 2.1. Salt River Project Dams - Salt and Verde Rivers.

SRP Dam	Location	Capacity at Normal Water Surface (ac-ft)
Roosevelt	Salt River	2,100,000*
Horse Mesa	Salt River	245,000
Mormon Flat	Salt River	58,000
Stewart Mountain	Salt River	70,000
Horseshoe	Verde River	131,000
Bartlett	Verde River	178,000

* Includes 565,000 ac-ft of flood control storage and 270,000 ac-ft of new conservation storage which will be available once the modifications to Roosevelt, currently in progress, are completed.

The climate of the Salt River Basin is generally semiarid, depending upon elevation. At lower elevations, it is hot and arid, while at higher elevations it may be cool and humid. Average annual precipitation in the basin ranges from less than 8 inches in the Phoenix vicinity to more than 30 inches in the highest mountains, and it is about equally divided between the summer and winter seasons.

Peak Discharge Frequency Analysis

Discharge frequency values for the Salt River in the vicinity of the Rio Salado study area were adopted from the Cliff Dam Alternatives study completed in 1988. The adopted discharges include a modified Roosevelt Dam. The dam is currently being raised, and upon completion, will have a 565,000 ac-ft flood control pool and will gain 270,000 ac-ft of conservation storage. A complete technical analysis of the impacts of this enlarged structure on the Salt River has not yet been completed. Currently, a water control plan for regulation of the flood control pool is being developed in the Section 7 for Modified Roosevelt Dam by the Los Angeles District, in cooperation with the U.S. Bureau of Reclamation. The discharge frequency values are presented in Table 2.2.

Volume of Salt River Flows

Granite Reef Dam is the downstream-most SRP dam on the Salt River and is located about 10 miles downstream from Stewart Mountain Dam and about 14 miles upstream of Tempe. Most of the water reaching Granite Reef Dam is diverted into the SRP canal system for agricultural, municipal, and industrial water use. Spills over Granite Reef Dam are caused by flood releases. In March of 1994, SRP completed a period of record analysis for the Roosevelt Dam Water Control Study. Under 1995 storage conditions (including new conservation storage at Roosevelt) and demand, the monthly operation of the SRP reservoir system was simulated, and the monthly total spill release at Granite Reef was estimated. The average annual spill was 247,000 ac-ft, but during 71 of the 105 years (68%) modelled, there were no spills over Granite Reef. The simulation also showed 16 periods (1 year or greater) of no spills ranging from 1-12 years. The average duration of no spill period was about 4.4 years. The results of the simulation are shown in Figure 2.2.

Table 2.2. Salt River Peak Discharge Rates, In cfs.

LOCATION	FLOOD RETURN PERIOD, IN YEARS						
	5	10	20	50	100	200	500
Confluence with Verde River	45,000	85,000	115,000	145,000	175,000	210,000	275,000
Mill Avenue Bridge	44,000	84,000	110,000	135,000	160,000	190,000	250,000
Above Confluence with Gila River	40,000	75,000	100,000	125,000	150,000	185,000	240,000

These discharges are adopted from the Cliff Dam Alternatives study completed in 1988 and assume the presence of a modified Roosevelt Dam.

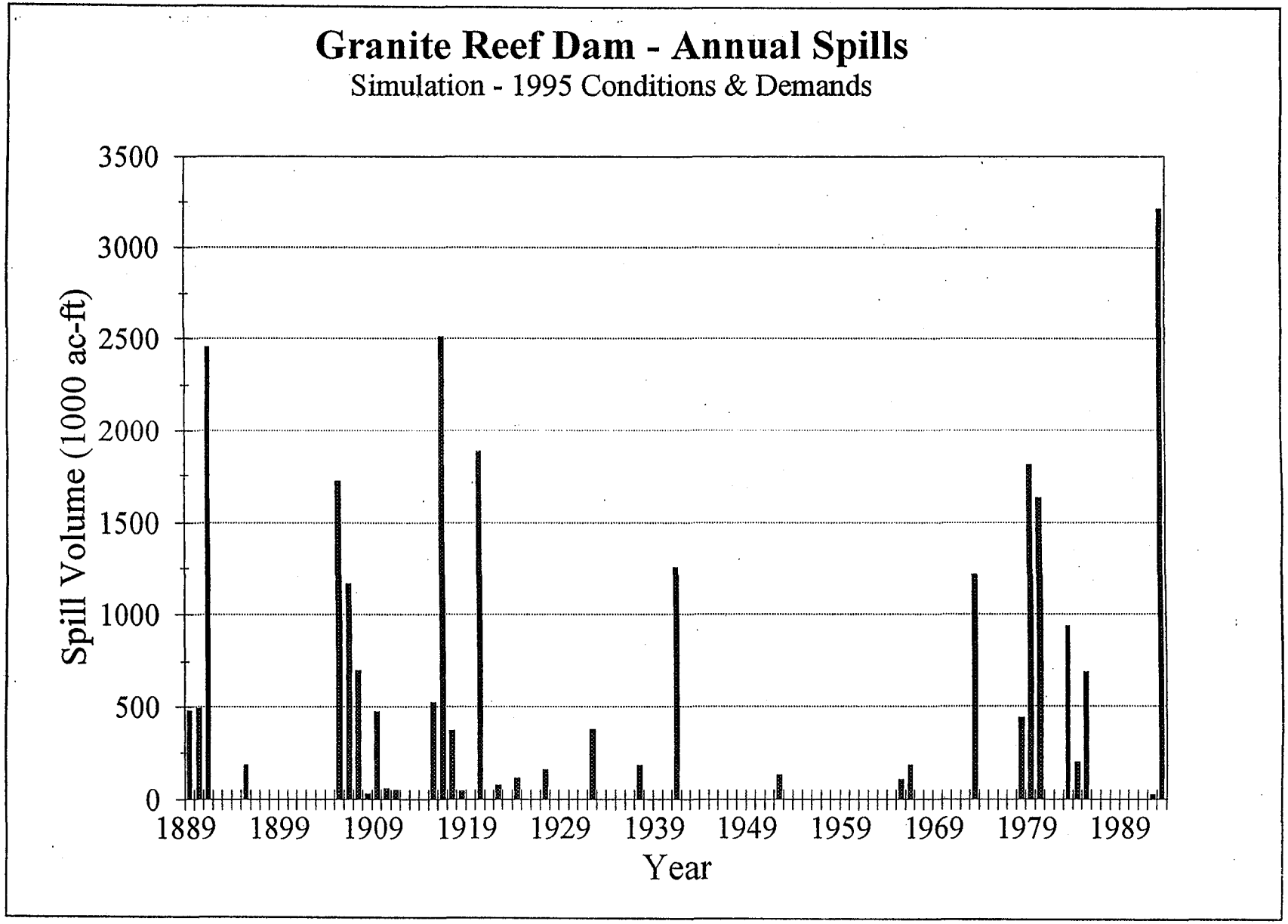


Figure 2.2. **Granite Reef Dam - Annual Spills into the Salt River**

2.4 Groundwater

The Rio Salado study area is located in the Phoenix Active Management Area (AMA) and is comprised of portions of two distinct but interconnected alluvial groundwater basins. These basins, West Salt River Valley (WSRV) and East Salt River Valley (ESRV), are shown on Figure 2.3.

There are three hydrogeologic units: the lower alluvial unit (LAU), the Middle Alluvial Unit (MAU), and the Upper Alluvial Unit (UAU). There is also a Red Unit which forms the base of the aquifer beneath part of the area north of the Salt River. The LAU overlies the Red Unit and consists mainly of conglomerate and gravel. The LAU is tapped by many city wells, and it is estimated that approximately 25 percent of the pumpage originates from this unit (ADWR, 1993). The MAU overlies the LAU and consists mainly of clay, silt, mudstone and some sand and gravel. The unit ranges in thickness from 100 feet to over 1600 feet in the deeper parts of the basin. The MAU is now the primary source of groundwater in the ADWR estimates that 50 percent of the total pumpage in the valley is from the MAU.

The UAU overlies the MAU and consists primarily of gravel, sand and silt. The amount of coarse-grained deposits is highest near the Salt and Gila Rivers. The thickness of the UAU is relatively uniform and ranges from 200 to 300 feet thick in ESRV and between 300 and 400 feet thick in the WSRV. In the past, the UAU was the primary source of groundwater in the valley, but because of dewatering and large areas of poor quality water, only about 25 percent of groundwater pumped in the valley is from the UAU. Important sources of recharge to groundwater in the valley are infiltration of Salt River flows, mountain recharge along the McDowell and Superstition Mountains, percolation of excess irrigation water, and canal seepage. Figure 2.4 shows a hydrogeologic profile along the Salt River from Granite Reef Dam to the confluence of the Salt and Gila Rivers. Figure 2.5 shows the depth to groundwater in the study area during the winter of 1983.

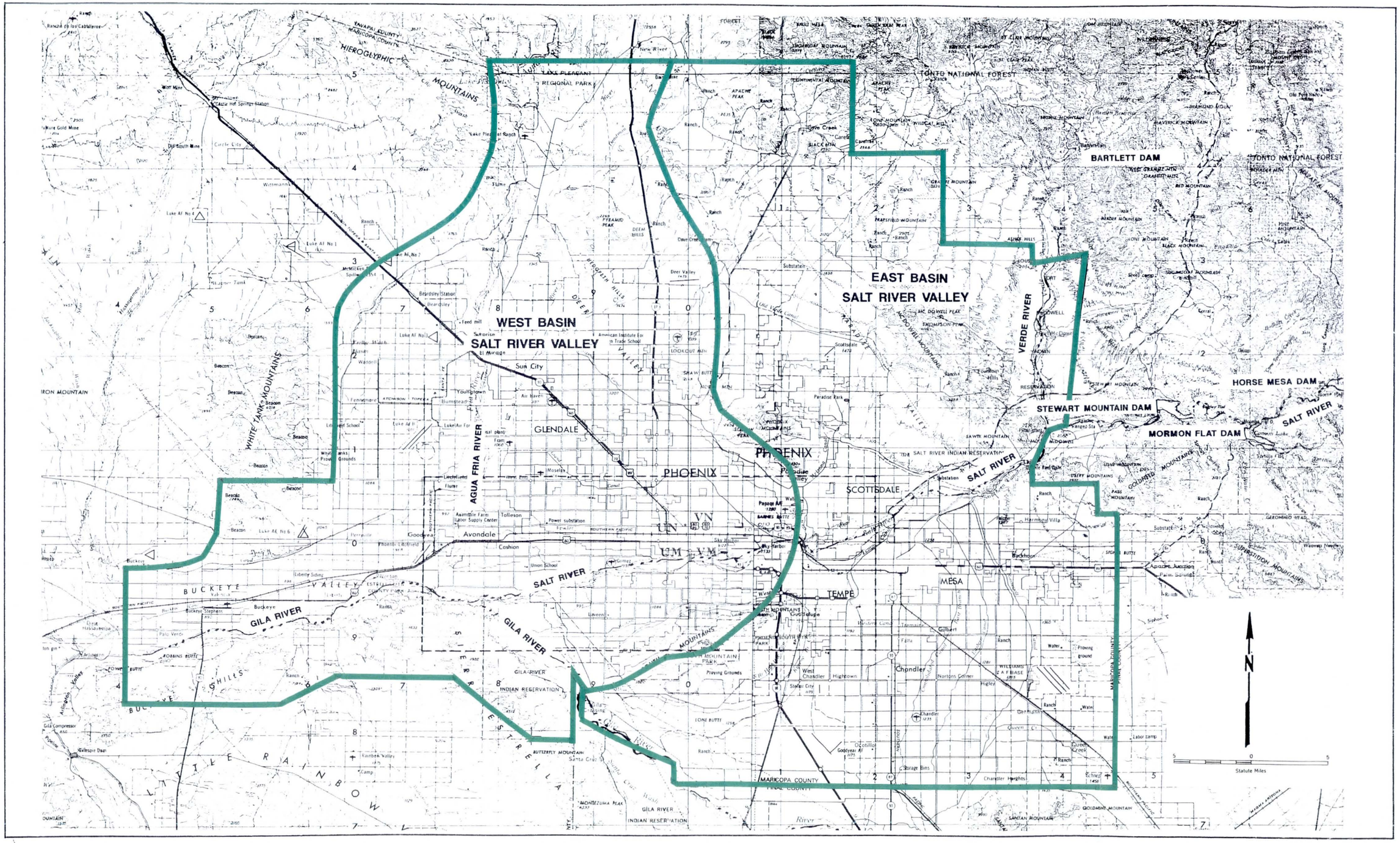
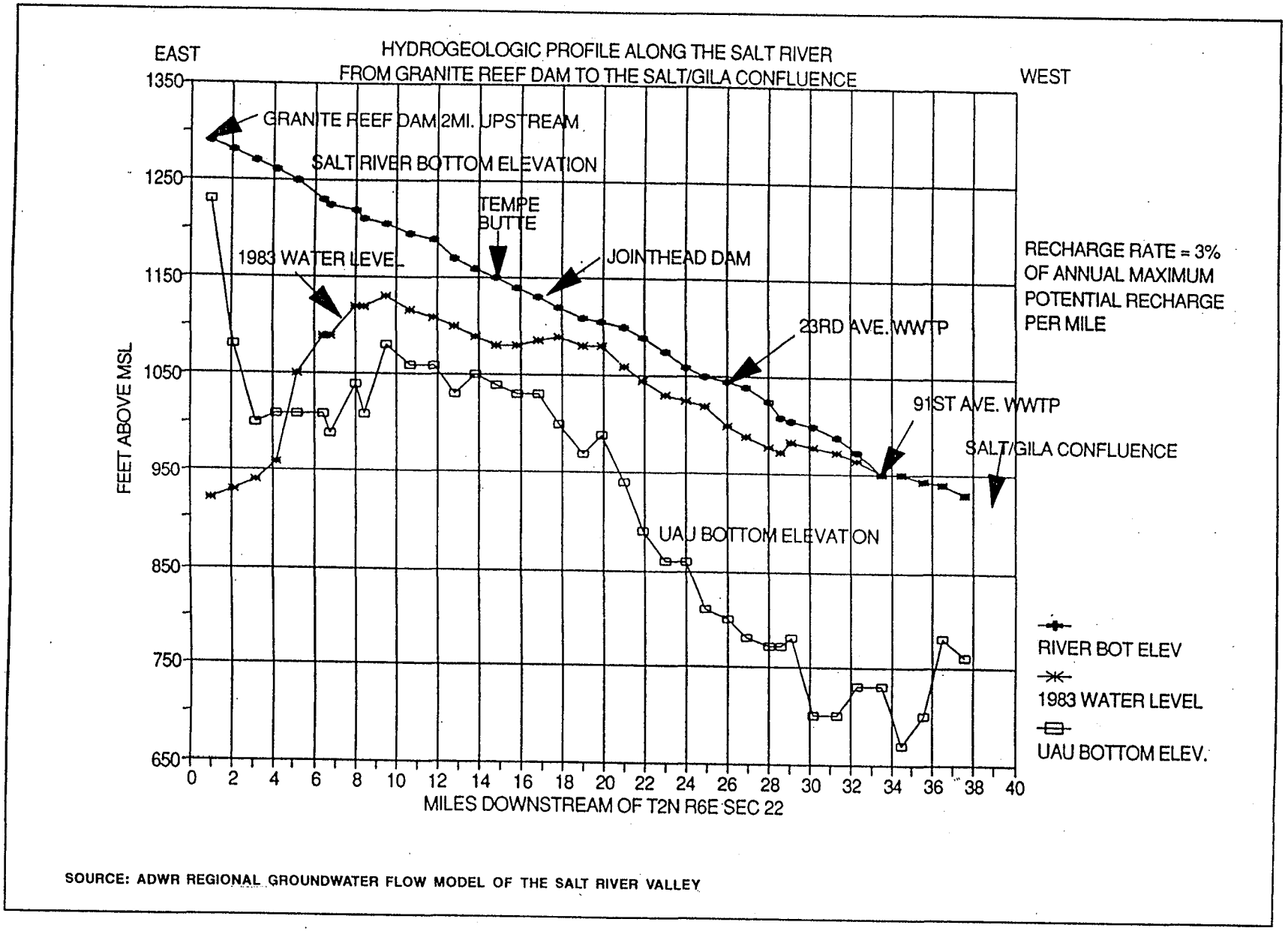
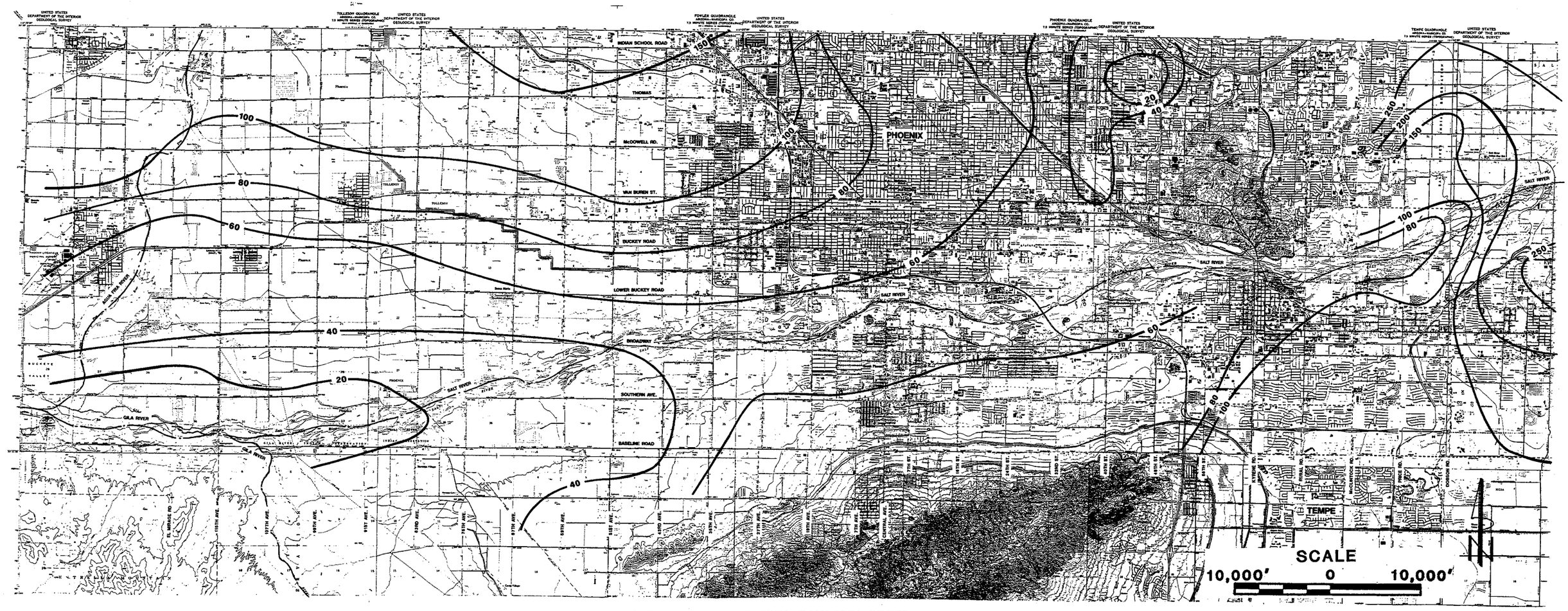


Figure 2.3. Alluvial Groundwater Basins



SOURCE: ADWR REGIONAL GROUNDWATER FLOW MODEL OF THE SALT RIVER VALLEY

Figure 2.4. Hydrogeologic Profile.



DEPTH TO WATER IN PHOENIX URBAN AREA, WINTER 1983 - 1993

Figure 2.5. Depth to Groundwater.

2.5 Riparian Habitat

Riparian habitats, defined as relating to, living on, or located on the banks of a natural watercourse, 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, 64 wildlife species presently listed as endangered and an additional 47 species being considered for listing are dependent on riparian habitats. The U.S. Council on Environmental Quality has 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.

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. Vegetation may also improve water quality in agricultural watersheds. Riparian vegetation is also important as a means of erosion control by reducing flow velocity and its erosive energy.

Historically, cottonwoods and willows and various species of mesquite covered hundreds of miles along the Salt River and is considered representative of the natural "climax" species for this area. The elimination of natural base flows due to Federal dams has reduced most natural Salt River flows to summer or fall rainfall-related flood events which favor the invasive, lower habitat value, salt cedar vegetation. Salt cedar had become well-established in the riparian corridor by the 1920's. In general, the presence of post-dam riparian vegetation diminished over time as vegetation removal programs (as early as the 1950's) and groundwater pumping (which lowered the water tables) intensified. At present, four major habitat types exist within the Rio Salado study area. These habitat types are salt cedar (tamarisk) mesquite habitat, cottonwood/willow riparian forest, and fresh-water marsh.

2.6 Population

The population of Maricopa County has grown by approximately 82 percent since the 1970's; from 1,297,000 in 1970 to 2,132,975 in 1990. The population is projected to continue to grow to 2,801,000 by the year 2000, representing a 31 percent increase. As shown in Table 2.3, population growth is expected to continue well into the future. The Phoenix metropolitan area

Table 2.3. Maricopa County Population - Actual and Projected.		
YEAR	POPULATION	% INCREASE
1970	1,297,000	--
1990	2,132,975	+82
2000	2,801,000	+31
2010	3,490,000	+25

has gone from a rank of 33rd in 1970 to 20th in 1988 and is projected to be the 13th largest metropolitan area in the United States by the year 2000. As the population grows in Maricopa County, so also will the demands for water supply, water quality, environmental quality, water-related recreation and flood protection.

III PREVIOUS STUDIES

City of Tempe Rio Salado Town Lake Feasibility Study Technical Memorandum 8.

CH2M Hill, April 1992. This documents examines the feasibility of the principal water features comprising the Rio Salado project. The report focuses on the engineering feasibility of the main body of water (called the Town Lake). The study includes information regarding the hydrogeology of the lake site and lake feasibility. The study discusses how much water is required to create and sustain a lake in the Salt River channel. The preferred Town Lake alternative has a water surface of approximately 165 acres. The construction cost ranges from $18,600,000 to $23,600,000.

The Economic Impact of the Proposed Rio Salado Development.

Deloitte & Touche, April 1994. This report analyzes the economic impact of this real estate development. The economic analysis was based on: 1) a one-time economic impact of constructing Rio Salado and 2) one-going operations of the businesses within Rio Salado. A gross expenditure approach was utilized in performing this study. This approach quantifies the direct spending that occurs within the City of Tempe, Maricopa County and the State of Arizona from Rio Salado operations. The construction of the Rio Salado development will have a one-time impact on the City of Tempe, Maricopa County and the State of Arizona that will occur over the construction period. Total construction costs are estimated to be $952,800,000.

Economic Impacts of Rio Salado and the Central Arizona Water Control Study's Plan Six Alternative.

Economic Planning Division, Valley National Bank of Arizona Rio Salado Development District, June 1983. The study quantifies, on an annual basis, new public dollar revenues derived from increased property and sales tax revenues and income generated by the Rio Salado project from the sale an/or lease of publicly owned land in the project area. The study also consolidates the overall economic benefits from the Bureau of Reclamation's Central Arizona Water Control Study Plan Six Alternative with those of Rio Salado. Conclusions from this study indicated that over a fifty year period, Plan Six-Rio Salado Projects, in combination, will provide $7.6 billion in public revenues and $2.4 billion in private benefits to the metropolitan region and the State of Arizona.

Rio Salado Draft Evaluation Report Part V - Water.

Water Resources Associates, Inc. November 17, 1982. The study evaluates the potential options and constraints associated with the water availability and Flood Management Plans of the Rio Salado project. Sources for domestic water include obtaining CAP allotment, obtaining water rights from surface and groundwater and from lands within the district. Sources for aesthetic and recreational water will can be from poor quality groundwater. Flood management plans were based on an existing condition scenario and also of an upstream flood control design condition.

Potential Reuse Options for Wastewater Effluent and Residual Solids.

U.S. Army Corps of Engineers Los Angeles District Phoenix Urban Study, June 1977. This report presents various practical reuse options and suggest considerations as to their individual feasibility for application in the Phoenix urban area. Each reuse option is individually discussed as it relates to quantity and quality and their resultant changes. Discussions of Arizona water rights, effluent ownership, and present and future reuse agreements.

Final Environmental Assessment East Papago Freeway (State Route 217).

Arizona Department of Transportation Environmental Planning Services, August 1987. The Final Assessment considers the likely impacts and effects of the alterative selected for design, right-of-way acquisition, and construction. This study is part of the East Papago and Hohokam Freeways Location Study.

Rio Salado Reconnaissance Study Appendix A: Environmental Evaluation.

August, 1994. This Environmental Assessment Evaluation presents a brief synthesis of present conditions, active and passive location of landfill sites, potential mitigation of upper aquifer contamination, preservation and/or reconstruction of ecological habitats and potential opportunities for water resources recreation based on demand and economic feasibility. The study area includes 28 miles of Rio Salado from Tempe through Phoenix to the confluence of Gila and Agua Fria Rivers.

Salt River Bank Stabilization Reconnaissance Report- Final.

U.S. Army Corps of Engineers Los Angeles District South Pacific Division, February, 1994. The study is located entirely within the Salt River Pima-Maricopa Indian reservation, east of Scottsdale, and within Maricopa County. Flood events in 1992 and 1993 caused erosion of landfill material into the Salt River. Several flood protection measures and alternatives were considered. Salt River Pima-Maricopa Indian Community initiated construction of bank stabilization of two of the landfill sites under study. The study concludes with a finding that Federal interest is not warranted at this time.

The Awareness, Knowledge, and Opinions of Metropolitan Phoenix Residents Regarding the Rio Salado Project.

Arizona State University, September 1982. This study determines the awareness, knowledge, and opinions of the residents of metropolitan Phoenix, regarding the Rio Salado Project. The study applied selected perspective and strategies from the fields of marketing and policy analysis to a large-scale project in the public sector.

Salt-Gila River Land Use and Structures Inventory Granite Reef Dam to Gillespie Dam.

The Flood Control District of Maricopa County, March 1, 1994. This report provides an inventory of various structure, utilities, and land use conditions along the Salt and Gila Rivers from Granite Reef Dam to Gillespie Dam. It has been prepared to provide input and support to the U.S. Army Corps of Engineers in its development of an Operations Manual for flood control space behind new Roosevelt Dam.

Tempe Rio Salado: An Urban Oasis.

The Waterfront Center, July 1994. The report provides an overview of plans before critical decisions are made to give an expert "second opinion" on the directions made on the project.

Rio Salado Channel Improvement Mill Avenue to Hayden Road.

Simons, Li & Associates, Inc. March 1989. The study is part of a comprehensive plan undertaken by the City of Tempe's Rio Salado Task Force. This report addresses issues related to channel design, determines appropriate hydraulic design criteria, and presents several alternative design concepts. The engineering analysis includes the evaluation of alternative river sections, alignments and profiles. In addition, the study identifies potential impacts due to the proposed changes.

Intensity Density: A Look at Phoenix Over the Next 25 Years.

City of Phoenix Planning Department, 1991. The study develops a geographic picture of what Phoenix will be like in 25 years given the current growth patterns, and reflecting the policies found in the General Plan. The study provides a general vision of what Phoenix's urban form will be like in 2015.

Final Draft Public Art Master Plan Rio Salado Tempe, Arizona.

Helene Fried Associates, Reid & Associates Architects & Planners, Inc., Tad Savinar, 1993. This document is a comprehensive Public Arts Master Plan for the Rio Salado Overlay District to include assessment analysis and recommendations regarding three primary areas of interest: public art, cultural facility development, cultural animation including festivals, exhibitions and special events.

Plan of Action & Cost Estimates for Investigation and Remediation of Waste Sites Within the Master Plan Area for the Rio Salado Development District.

Dames & Moore, September 17, 1987. The study investigates a plan of action for the investigation and remediation of waste sites within the Rio Salado Master Plan area and to provide an order-of-magnitude cost estimate for the implementation of the plan. Sixty-three landfills or dump sites were identified. The projected cost for investigation and remediation of waste sites range from $49,500,000 to $90,800,000.

South Phoenix Village Redevelopment Area Plan.

City of Phoenix, December 20, 1989. This plan acts as a guide for the rehabilitation and redevelopment activities in the area. The South Phoenix Village Redevelopment Area is one of eleven redevelopment areas located in South Mountain and Central City Villages.

Rio Salado Draft Evaluation Report.

Carr, Lynch Associates, November 15, 1982. This study is a first phase analysis of the reclamation of the Rio Salado. The study includes discussion on: 1) the physical structure of the project and its surrounding, 2) the social structure, 3) the economic situation, and 4) water supply and flood-control.

Tempe Rio Salado Wildlife Habitat Master Plan.

Howard Needles Tammen and Bergendoff, October 22, 1990. This master plan document is a site specific proposal to mitigate for habitat losses due to project construction. An Environmental Assessment of the proposed channelization of the Salt River prepared by the City of Tempe indicates that wildlife habitat will be lost due to propose channelization of the Salt River. This report documents the habitat restoration measures that are proposed by the City of Tempe to compensate for project habitat losses.

Red Mountain Freeway Landscape Concept Report.

HNTB Corporation, May, 1993. The purpose of this report is to present the landscape character desired by the City of Tempe for the Red Mountain Freeway (Segment 5) adjacent to the Rio Salado Park. The landscape concept is based on the following: 1) the unique setting adjacent to the Salt River and Rio Salado Park, 2) future and present land uses surrounding the freeway, 3) profile of the mainline and 4) the construction budget.

City of Tempe Rio Salado Plan.

City of Tempe, May 20, 1982. This document is a guidance for the City Council and its Boards and Commissions in making decisions concerning development in the Rio Salado Planning Area. The plan includes a description of the scope and concept of development and use for all lands within the Tempe Rio Salado area, a statement of goals and policies for the improvement, development and use of lands, relationships of various land uses, and description of methods and programs.

Summary Report Phoenix Urban Study Final Report.

U.S. Army Corps of Engineers Los Angeles District, December 1981. The study investigated water and related land resources issues in the Phoenix metropolitan area. Issues discussed include: water quality, flood-control, water conservation, Fish and Wildlife enhancement. None of the projects proposed by local agencies with the exception of flood-control along the Salt and Gila Rivers were found to warrant Federal interest.

Rio Salado Phase 3.

U.S. Army Corps of Engineers, May 1978. The study evaluates problems and alternative possibilities relating to flood control, waste water, flood water conservation, fish and wildlife recreation. The study extends along the Salt River from the Gila River confluence to the Granite Reef Dam focusing especially on the 16-mile reach between 27th Avenue in Phoenix and Country Club Drive in Mesa.

Rio Salado Reconnaissance Study Appendix A: Habitat Analysis in Appendix A:Environmental Evaluation.

September 1994. This study documents a field reconnaissance conducted to determine the present habitat values of the vegetation within the Rio Salado study area. Habitat types affected by the project include wetland, cottonwood/willow riparian forest, mesquite habitat and tamarisk. A total of 29 site were assessed during the field study.

Gila River and Tributaries Salt-Gila, Arizona Reconnaissance Report.

U.S. Army Corps of Engineers, December 1989. This study focuses on the flooding problems, and associated solutions, downstream from the confluence of the Verde and Salt River to Gillespie Dam. It was determined that no analyzed solution was economically justified, therefore the study should not proceed to the feasibility phase, but be terminated at the reconnaissance phase.

Central Maricopa County Drainage Area Arizona Reconnaissance Study.

U.S. Army Corps of Engineers Los Angeles District, June 1992. This study describes and analyzes flooding problems and water resource opportunities within the Phoenix metropolitan area to develop a wide range of alternatives that would reduce the severity, or totally eliminate these problems. Twenty three flooding problems were identified within Central Maricopa County. Two areas determine to have federal interest are White Tanks/Agua Fria drainage and Tres Rios were evaluated in the reconnaissance study. It was recommended that the study not proceed to the feasibility phase.

City of Tempe Rio Salado Design Study.

City of Tempe Planning Department. This design study examines the present condition in depth and makes recommendations for land use and transportation. Recommendations are related to the regional Rio Salado Plan, to Tempe's Neighborhood Development Program and to Arizona State University's planning program.

Rio Salado Phase 2 Planning Study.

Maricopa Association of Governments, July 1974. This document is a continuation of the study design presented in Phase I. An overall concept plan for the Rio Salado project area and specific plans for two demonstration projects are presented in this document. Specific details of water use and implementation recommendations are also presented.

Tempe Rio Salado Project Phase II.

City of Tempe Planning Division Community Development, January 27, 1978. Phase II is a Preliminary Design Study that present three alternatives: 1) limited water facilities with a semi-desert environment, 2) maximum water facilities with a verdant water oriented environment and 3) a quasi-water oriented environment that envisions less water.

Tempe Rio Salado.

City of Tempe Community Development Department. This document discusses in general the Tempe Rio Salado Project Area which consists of restoring a five mile stretch of the river into a linear green belt. This brief document provides a project overview and discusses the primary goals of the project, flood-control features, economic and social benefits to the Tempe citizens and the valley.

Geomorphic Assessment of the Lower Salt, Central Arizona - Draft.

Prepared by ASU for U.S. Army Corps of Engineers, August 1994. This report supports a reconnaissance-level geomorphologic evaluation of the Lower Salt River and a portion of the Gila River. The study discusses environmental history, hydrologic system, geomorphic system and engineering features of the Salt River.

Rio Salado Engineering Report

CH2M Hill, August 1992. This engineering report represents the findings of a one-year study of engineering feasibility of creating a Town Lake as part of the Rio Salado project. This report is intended to provide City decision makers with information regarding Town Lake and alternatives for lake water supply. Alternative methods of lake construction, alternative projects for protecting the lake from runoff, and alternative approaches for supplying the lake were presented in the report.

Special Study of Flood Damage Reduction Measures on the Salt and Gila Rivers.

U.S. Army Corps of Engineers Los Angeles District, December 1981. This document was prepared as a result of severe flooding along the Salt and Gila River. The flood damage reduction measures presented include discussion on floodproofing, relocation, floodplain regulations, preparedness planning, channel excavation and evaluation of hydraulic structures.

Environmental Assessment for that Portion of the Tempe Rio Salado Project.

City of Tempe Community Development Department, March 7, 1990. This environmental assessment is a follow-up to flood protection required by the location of the East Papago Freeway. The study area represents the second half of a channelization program that encompasses the Salt River floodplain from the Southern Pacific Railroad Bridge east to McClintock Drive.

Tempe Rio Salado Park Plan.

Arizona State University College of Architecture & Environmental Design, September 21, 1988. The report documents the process and the intent of the final product to help guide future development initiatives. This document was prepared as a companion document to the City of Tempe Rio Salado Master Plan. The plan combines development, organized sporting events, environmental concerns, economic interests and others to achieve a balanced development program.

Rio Salado Economic Development Area, Economic Development Opportunities: An Analysis of Long-Term Potential.

City of Phoenix Community and Economic Development Department, September 13, 1994. The study determines the economic future of the area given present conditions. The study also identifies the types and levels of economic development activities necessary to initiate and sustain continued economic development within the study area.

Potential Water Sources for Rio Salado a Preliminary Memorandum.

Rio Salado Development District, May 1982. This memorandum provides a basis for the determination of a source of water for the Rio Salado project. It identifies potential sources, gives general background on these sources, and provides a preliminary analysis of each.

A Vision for the Salt River Corridor.

City of Phoenix Planning Department, July, 1994. This report summarizes resulting problems and issues that are part of the setting of the present river. The report includes resources and activities that will be the basis of the area's restoration.

Phoenix Water Reclamation and Reuse Study Tres Rios Demonstration Wetlands Conceptual Design.

Bureau of Reclamation City of Phoenix in cooperation with Arizona Game and Fish, ADQ, Maricopa County Parks and Recreation, Flood Control District and EPA, October 1993. The study evaluates methods for reclaiming water from sewage effluent from the metropolitan area of Phoenix and develops plans for using the reclaimed water directly or through exchange mechanisms. This report presents a conceptual design for a constructed wetland demonstration project designed to improve the quality of treated effluent from the Phoenix area.

Phase I Environmental Assessment Rio Salado Development Area Site Located North of the Salt River and South of Hammond Lane Between 10th and 16th Streets, Phoenix, Arizona.

Prepared by SCS Engineers for the City of Phoenix, June 21, 1993. This site assessment is part of a larger environmental investigation of the proposed Rio Salado Development Area. Findings confirmed that the site contains landfilled areas, commercial/industrial, businesses and residences. It was recommended that field investigation be performed on a portion of the alignment to evaluate the potential presence of contaminants associated with the 14th Street Landfill.

Phase I Environmental Assessment Parcel Located North of Pioneer Street and South of the Salt River Between Central Avenue and 7th Street.

SCS Engineers prepared for the City of Phoenix, June 17, 1993. This document is an environmental assessment of a 65-acre property and is a part of a larger environmental investigation of the proposed Rio Salado Development Area. A park is proposed for one half of the site and a proposed roadway alignment for the other half.

Site Screening Report Rio Salado Development Area Bounded by Central Avenue, 16th Street, Watkins Street, and Illini Street.

SCS Engineering prepared for the City of Phoenix, July 30, 1993. This site screening study was performed as part of a project that included two specific sites within the Rio Salado Development Area (RSDA). The purpose of the study is to obtain information regarding known environmental concerns that may impact development within the RSDA.

Rio Salado Master Plan- Final Draft.

Carr, Lynch Associates, January 1985. This master plan document is a guideline for the development of the Rio Salado. It serves as a policy guide for an extending sequence of actions. The Master Plan involves a major reclamation of nearly 10,000 acres of land, including transformation of the present riverbed into a regional park, development of its banks, cultural and educational uses.

Central Arizona Project, Modified Roosevelt Dam.

In cooperation with the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, under the authority of Section 7, Flood Control Act of 1944, is in the process of developing a Water Control Plan, Manual, and Field Working Agreement for operating the flood control space at Modified Roosevelt Dam. As a result of this effort, new hydrology for the lower Salt and Gila Rivers will be developed and could affect floodplain delineations through the region. A draft of the Water Control Plan and Manual is scheduled for public release in December, 1995.

IV PUBLIC INVOLVEMENT

4.1 General

Several public involvement techniques utilized in the Rio Salado Reconnaissance Study and are discussed below.

4.2 Public Workshops

On June 2, and June 7, 1994 public workshops were held in Tempe and Phoenix, respectively. Public notification of the workshops was made through press releases and direct mailings to Federal, state, local agencies, civic organizations and individuals who have participated in previous local public water resources planning efforts. Representatives for the Cities of Tempe and Phoenix (the local sponsors) played an active role during the course of the workshops.

The purposes of the workshop were 1) announce the initiation of the reconnaissance study effort, 2) outline the goals and objectives of the study, 3) obtain input from participants relative to the problems and opportunities to be addressed in this reconnaissance study, 4) discuss the planning milestones schedule, 5) address questions raised by participants.

4.3 Rio Salado Task Force

A task force was organized to provide technical and local perspectives throughout the study; from the initial scoping effort though plan formulation and evaluation. The Task Force consisted of Federal, State, and local agencies. The Task Force met at major milestones during the planning process.

4.4 Technical Teams

Technical teams were organized to address specific technical areas involving the four major outputs of this reconnaissance study, i.e., flood control, riparian habitat restoration, recreation, and water quality. Technical team members consisted of a sub-set of the Task Force and met on an as-needed basis.

4.5 Agency Coordination

Throughout the reconnaissance study, coordination with Federal, state and local agencies and municipalities was an on-going process. Representatives from the agencies listed below served as an integral component of the planning process.

U.S. Bureau of Reclamation

U.S. Fish and Wildlife Service

Arizona Department of Environmental Quality

Arizona Department of Water Resources

Arizona Game and Fish Department

Flood Control District of Maricopa County

City of Phoenix

City of Tempe

4.6 Civic Organization Participation

During the course of the reconnaissance study, meetings with civic groups and organizations helped scope the problems, opportunities, and constraints to be addressed in the study effort. The following organizations were represented in the study:

Arizona Riparian Council

Arizona Rock Products Association

Maricopa Association of Governments

Salt River Project

Toxic Waste Investigative Group

V PLAN FORMULATION: PROBLEMS AND OPPORTUNITIES

5.0 Summary of Present and Future-Without-Project Conditions

As directed by Congress, the Rio Salado Reconnaissance Study investigated four water resources outputs including flood control, riparian habitat restoration, recreation and water quality. The without-project conditions relative to each of these outputs are summarized as follows:

Flood Control

1. Discharge-frequency estimates for the Salt River assume the presence of a modified Roosevelt Dam. The 100-year discharge is estimated at 160,000 cfs at the Tempe Bridge.

2. Approximately 530 structures are potentially subject to 100-year flooding of the Salt River. The total value of these structures is approximately $26,000,000 for the 100-year flood and $32,000,000 for the 200-year flood. Average annual flood-related damages are estimated by very preliminary methods at $145,000.

3. The 51st Avenue, 35th Avenue, 7th Avenue and 24th Street bridges have been identified as potentially subject to damage resulting from channel degradation caused by inflow to sand and gravel mines. The total replacement cost for the impacted bridges is estimated at $21,000,000. Average annual headcut-related damages, including bridge replacement and traffic detours, is estimated by very preliminary analysis at $530,000.

4. The 91st Avenue Wastewater Treatment Plant is subject to erosion damage on discharges exceeding a 20-year flood. Average annual damages are estimated at $354,000 to $654,000.

Riparian Habitat Restoration

1. Federal Dams constructed in the early 1900's in the upper Salt and Verde Rivers, upstream of Rio Salado, have, over the last eight decades, limited flows in the lower Salt River to spills associated with flood flows. As a result, virtually all historical downstream riparian habitat has been severely limited. Open water bodies supporting waterfowl and migratory species, have been eliminated.

2. Indian Bend Wash, a Corps flood-control project within the Rio Salado study area, has eliminated high value riparian communities, which represented one of the few sizeable remnants of the mesquite bosque community in central Arizona, and the last in the Phoenix Metropolitan area. Additionally, a significant portion of riparian acres removed by the project were not incorporated in the basis for mitigation.

3. Salt River riparian communities in the Rio Salado area are currently supported by wastewater effluent, agricultural tailwater, sporadic flood releases from upstream, and local storm-drain runoff. Local municipalities propose elimination of effluent discharges into the Salt River for economic reasons (avoid costly 1996 NPDES plant upgrades) and conservation reasons (groundwater recharge as a future water source). The impacts to riparian habitat will be detrimental.

4. Agricultural land use will give way to rapid urbanization of the Rio Salado area. As agricultural lands diminish, so also will the availability of agricultural tailwaters that are discharged into the Salt River. Agricultural tailwaters, currently supporting numerous riparian communities toward the western portion of Rio Salado would be significantly affected.

5. It is conceivable that NPDES permits for storm water runoff could force municipalities to collect storm water runoff for treatment at wastewater treatment plants or at separate, individual treatment facilities to be constructed. This expensive solution for NPDES compliance would, at the same time, curtail the availability of water for habitat currently supported by storm water runoff. This would have an additional impact on riparian habitat.

Recreation

1. The Phoenix metropolitan area of 2 million people has a very high unmet demand for water resource-based recreation which has been estimated at almost 12,000,000 user days per year.

2. Opportunities for water-related recreation activities within the Rio Salado area will be economically justified.

Water Quality

1. Over 55 major storm drains drain an area of 267 mi^2 which discharges into the Salt River. Estimated annual runoff from Phoenix and Tempe is 18,000 ac-ft and 11,000 ac-ft respectively. The quality of urban storm runoff from the Phoenix metropolitan area is highly variable and frequently exceeds water quality standards for bacteria, pesticides, petroleum products, metals, and nutrients.

2. There are a number of groundwater quality problems in the Salt River Valley. Much of the shallow groundwater in the vicinity of the western part of the project has elevated levels of TDS, chloride, and nitrate and areas of high and low levels of volatile halocarbons are present in many areas. Most of the inorganic problems (TDS, chloride, nitrate) can be traced to natural factors and long term irrigation practices. Nitrate levels are high throughout the area west of Central Avenue and significantly increase in the area northeast

of Tolleson. The City of Tolleson water supply may be threatened by contaminated groundwater plumes.

3. Trace organics such as volatile halocarbons are also a problem in wide areas near Phoenix. Volatile halocarbons are located in shallow groundwater beneath a number of landfills along the Salt River, near some industrial facilities, superfund sites, and beneath a large area between the Sky Harbor Airport and downtown Phoenix. The pesticide DBCP has been detected at concentrations exceeding the drinking water maximum contaminant level (MCL) of 0.02 parts per billion (ppb). DBCP is now a suspected carcinogen and was banned for agricultural purposes in 1979.

4. The Corps Indian Bend Wash flood control project flows through a Federal Superfund site and discharges its flows into the Salt River at Rio Salado. Several water quality concerns associated with Indian Bend Wash discharges have been expressed by local municipalities.

5.1 Flooding and Drainage

5.1.1 Without-Project (Present) Conditions

River Geomorphology

Within the study area, the Salt River flows through a major valley with a relatively flat floor of deep alluvium. Soils in the vicinity of the channel are of the hyperthermic torrifluvents association, a group of soils that are well-drained to excessively well-drained on nearly level or gently sloping surfaces. They are often sandy to gravelly, but may include lenses of finer particles. These soils are often redistributed by water flows associated with nearby active channels.

The Lower Salt River is associated with three pediment-inselberg complexes in the surrounding terrain: Spook, Papago and Bush Pediments. A pediment is usually an erosional ramp-like feature. It is a common feature found in most of the semiarid regions of the world. Pediments form at the base of mountains or extend outward from the base of an inselberg. The term inselberg refers to an isolated hill of solid rock.

Pediments can be characterized by two relatively easily identifiable qualities: (1) well-defined "break in slope" (a severe gradient change) between the pediment surface and the inselberg hill

slope of the same rock type and (2) a bedrock surface, in some cases covered with a layer alluvium not more in thickness than 1/100 of the width of the pediment.

Geomorphologists are still uncertain as to how pediments form. One theory suggests that pediments are relic features formed when the climate was different and have not been altered since then. Another theory suggests that pediments are caused by deep weathering of rock during moist periods followed by striping of the weathered material by erosion. Regardless of their formation processes, the slopes along the Lower Salt River appear to supply the river directly with small amounts of sediment compared to the direct fluvial inputs.

From Granite Reef Dam to the City of Tempe, the surrounding geology north and south of the river changes from bedrock outcroppings to valley fill and alluvium. Valley fill has been accumulating since the onset of the basin and range formation, so that in many portion of this reach of the river the fill is greater than 1000 feet deep. The underlying bedrock surface is below sea level in many areas. The valley fills tend to be more coarse near the mountain fronts, and more fine in the interior of the valley. Near the Salt River, the valley fills have been eroded as the river formed terraces during its evolution.

Most of the interior valley floor is covered by coarse to fine grained alluvium. This material has been continuously deposited by the shifting channels of streams draining the mountains. Sand and gravel, moderately well sorted and stratified, compose the bulk of the deposits left by the Salt River. These deposits are composed of well-rounded clasts and are locally interbedded with silts and clays. The fine sediments are derived from overbank flows.

From Tempe to the Agua Fria confluence with the Gila River, the channel is dominated by valley fills and alluvium. The water table is closer to the surface in the western portion of the study area because of shallow depths to bedrock and because of numerous relatively impermeable clay layers within the alluvium.

The geomorphologic history of the river is characterized by natural scour and fill events, floods, and channel shifts. However, urban development within the study reach has altered the channel from meandering to a straight channel with high banks in several reaches. The channel has shifted within the flood plain several times from the 1880's to present, meandering on the north side of the flood plain during some periods and on the south side during others. Channel shifts have distributed alluvial material across the entire width of the floodplain. The alluvium deposited by the river consists of cobbles, sands, silts and clays from numerous tributary streams within the watershed.

The river is dominated by scour and fill events which degrade the river in some areas and aggrade it in others. The scour and fill transportation of sediment has produced numerous thick deposits within the fluvial system: cobble lag surfaces, sand sheets (macro-forms), channel side bars, mid-channel bars, point bars and overbank deposits. Many of these deposits have recently been disturbed by intensive mining for sand and gravel. Mining of sediments alters later transportation events, by reducing the amount of material that can be transported by removal and compaction, loosening other sediments and sand pits serve as depositional traps for fine sediments.

Flood flows are probably the most important events in the transportation of sediment along the Salt River. Sediment transported in a scour and fill setting by flood flows tends to move in waves or pulses, rather than at a constant rate through time. In essence there are slugs of sediment moving downstream periodically during flow events. Prior to damming of the river, smaller flow events moved sediment (fine sands, silts and clays) by incising downward into the larger slugs of sediment found in the channel. However, incision and movement of sediment by these smaller events do not compare to the order of material move during a flood event.

In summation, the geomorphic history of the proposed study reach is a story of change. There have been continual changes in the vegetation found in the riparian corridor, both by natural and anthropogenic causes. The river has shifted its course on numerous occasions, creating new

depositional environments, new sediment sources and new mediums for plant establishment. At present the environment should be considered degradational, with the river continuing to incise downward. The sediment that is moved in this section of the river is carried downstream, with a large portion of it stored behind downstream dams.

Flooding

Figure 5.1 (A, B, C, D and E) illustrates the 200-year and 100-year floodplain limits extending from McClintock bridge to the Agua Fria River confluence. These floodplain limits are based upon the present (pre-modification of Roosevelt Dam) discharge estimates of 215,000 cfs for the 100-year flood and 260,000 cfs for the 200-year flood. Furthermore, the mapping is based upon 1992 topography which has since been modified in places. Major modifications have occurred in the Tempe area where soil-cement banks now contain the entire 100-year discharge. Floodplain mapping based upon recent topography and the post-dam-modification discharges was not available at the time of this study. The floodplain illustrated in Figure 5.1, and the related information provided below, are presented as the best information available at the time of this study and provide a reasonably accurate depiction of the floodplain conditions throughout the study area.

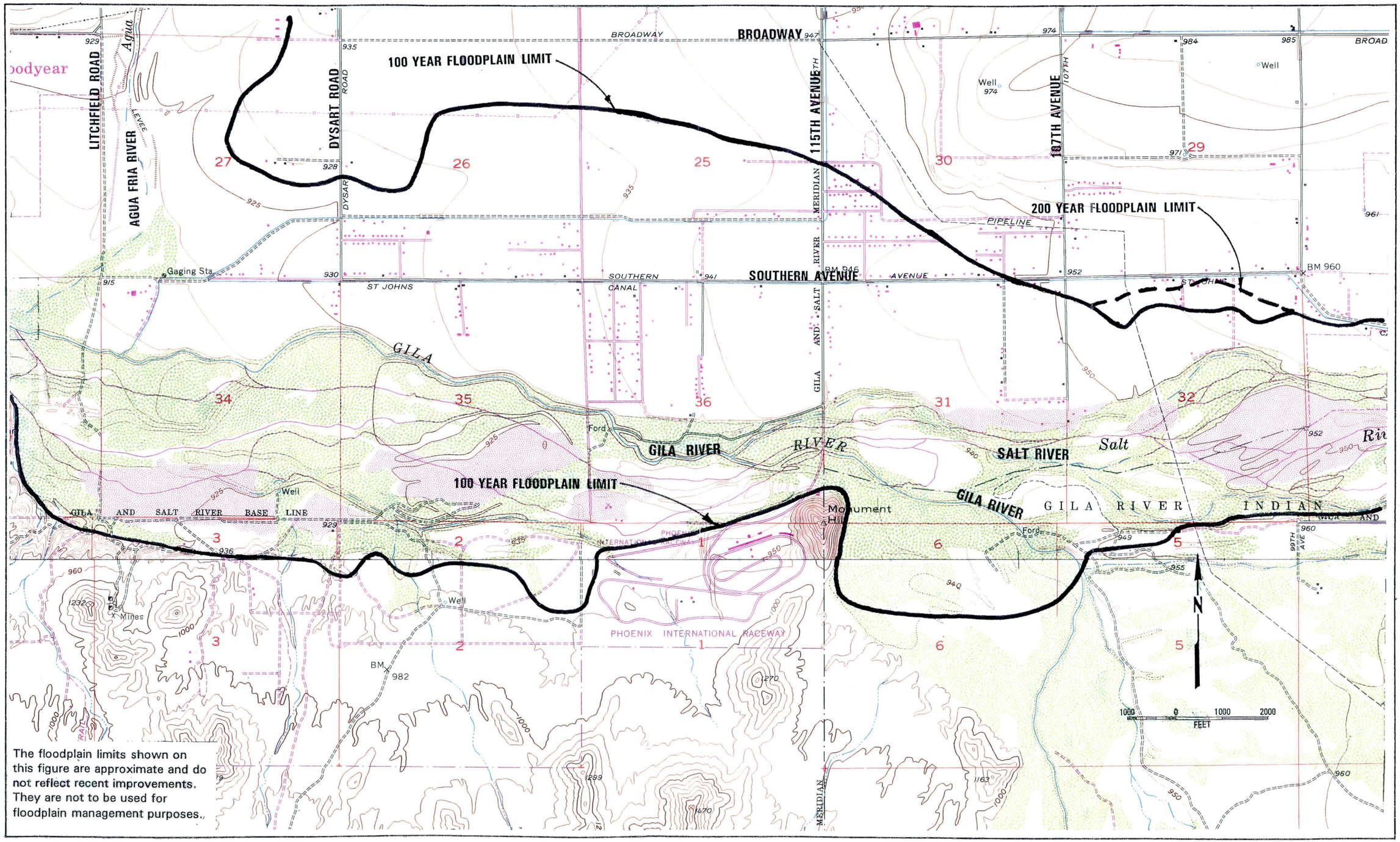
The floodplain ranges in width from approximately 500 feet at the 7th Street bridge to 10,000 feet at the Agua Fria River confluence. The floodplain mapping is adapted from preliminary mapping prepared by Michael Baker Jr Engineering (1993) for revisions to the Federal Insurance Rate Maps. Because these maps are preliminary, they are subject to change. The Rio Salado study area is divided into seven reaches for purposes of describing flood-related without-project conditions. Table 5.1 provides a summary of a preliminary inventory of structures, identified from aerial photographs, within the floodplain for each reach. The seven reaches are described below:

Reach 1: McClintock Road Bridge to the Hohokam Expressway bridge

Reach 2: Hohokam Expressway bridge to 16th Street bridge

Reach 3: 16th Street bridge to 35th Avenue bridge

Reach 4: 35th Avenue bridge to 51st Avenue bridge



The floodplain limits shown on this figure are approximate and do not reflect recent improvements. They are not to be used for floodplain management purposes.

Figure 5.1A. Salt River Floodplain Limits

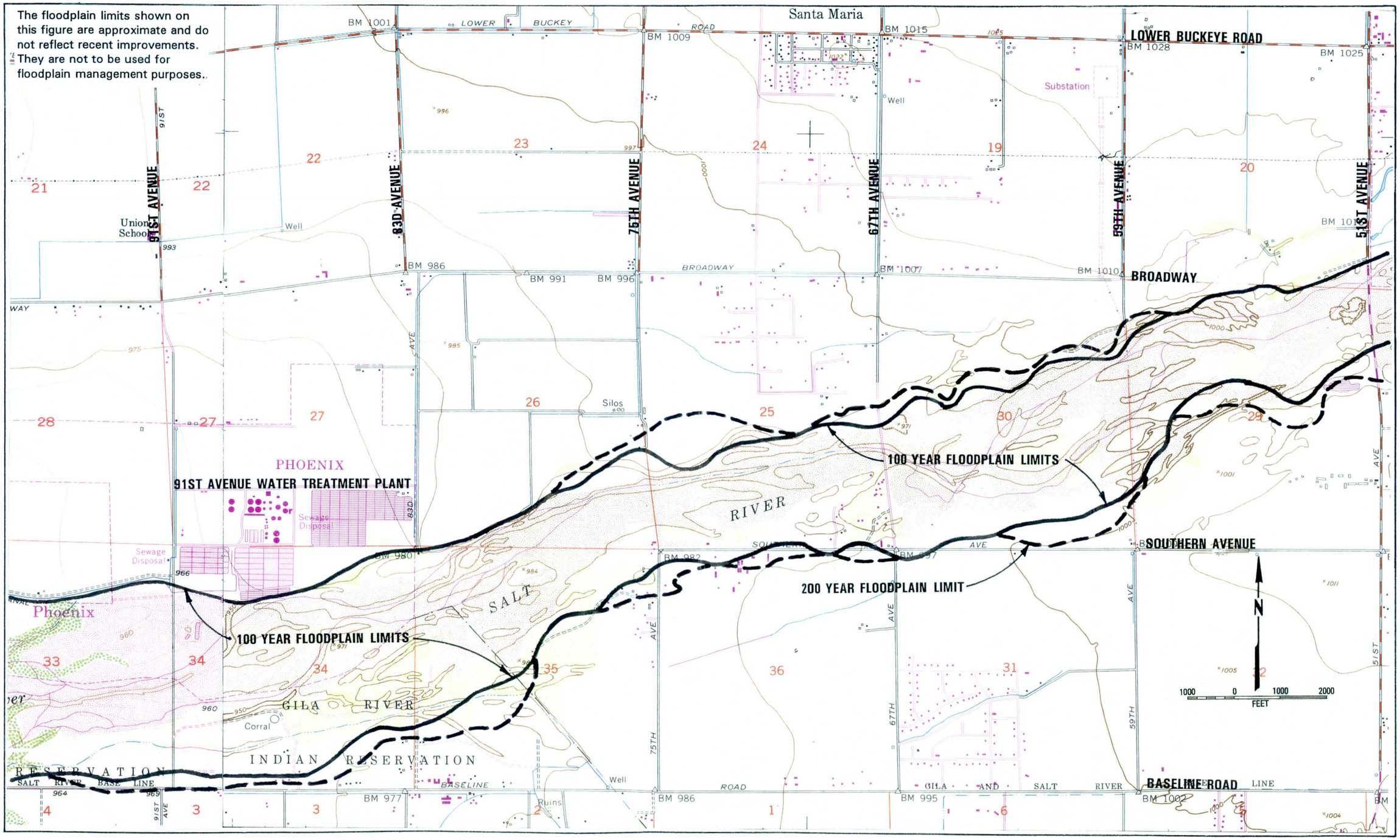


Figure 5.1B. Salt River Floodplain Limits

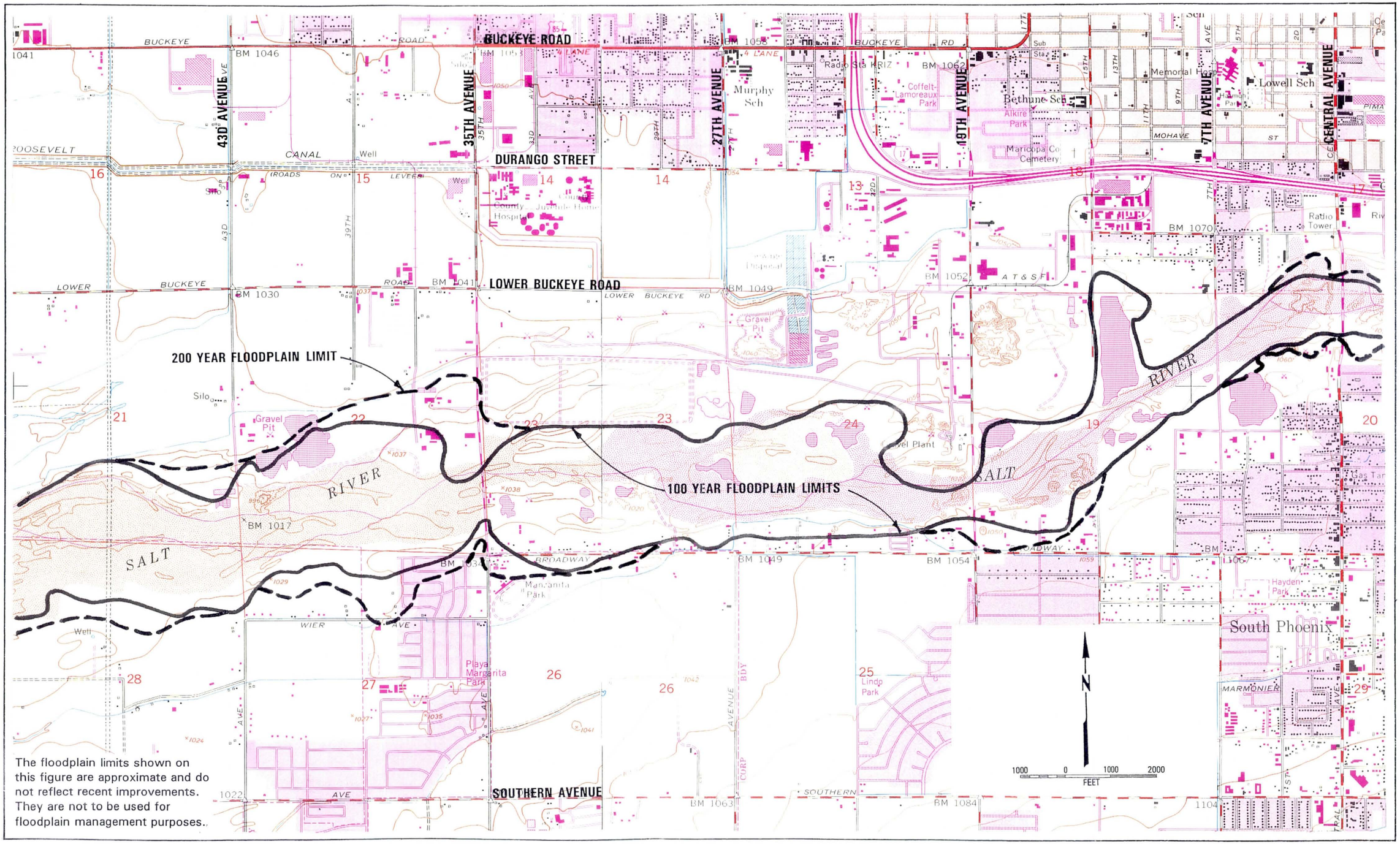
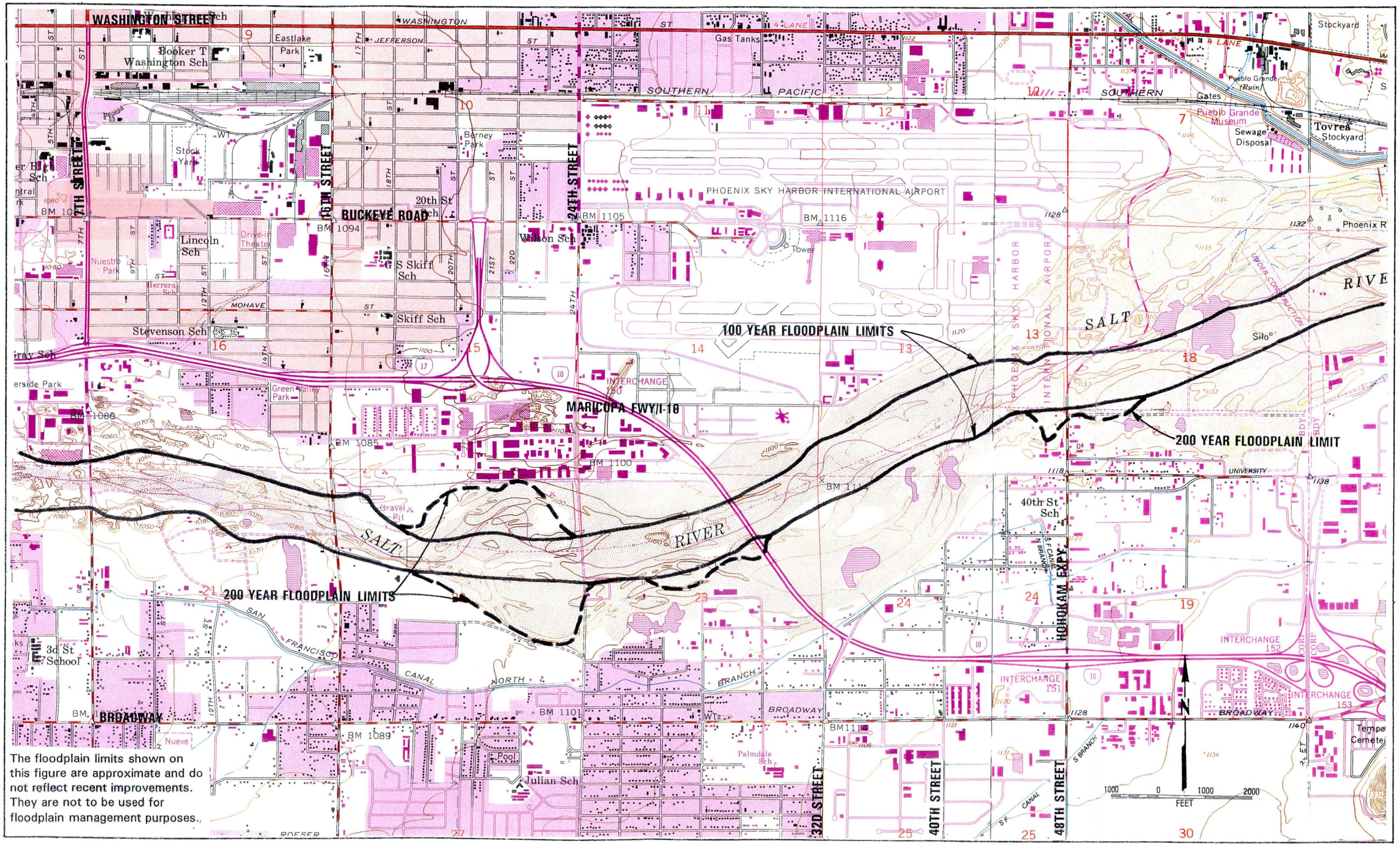
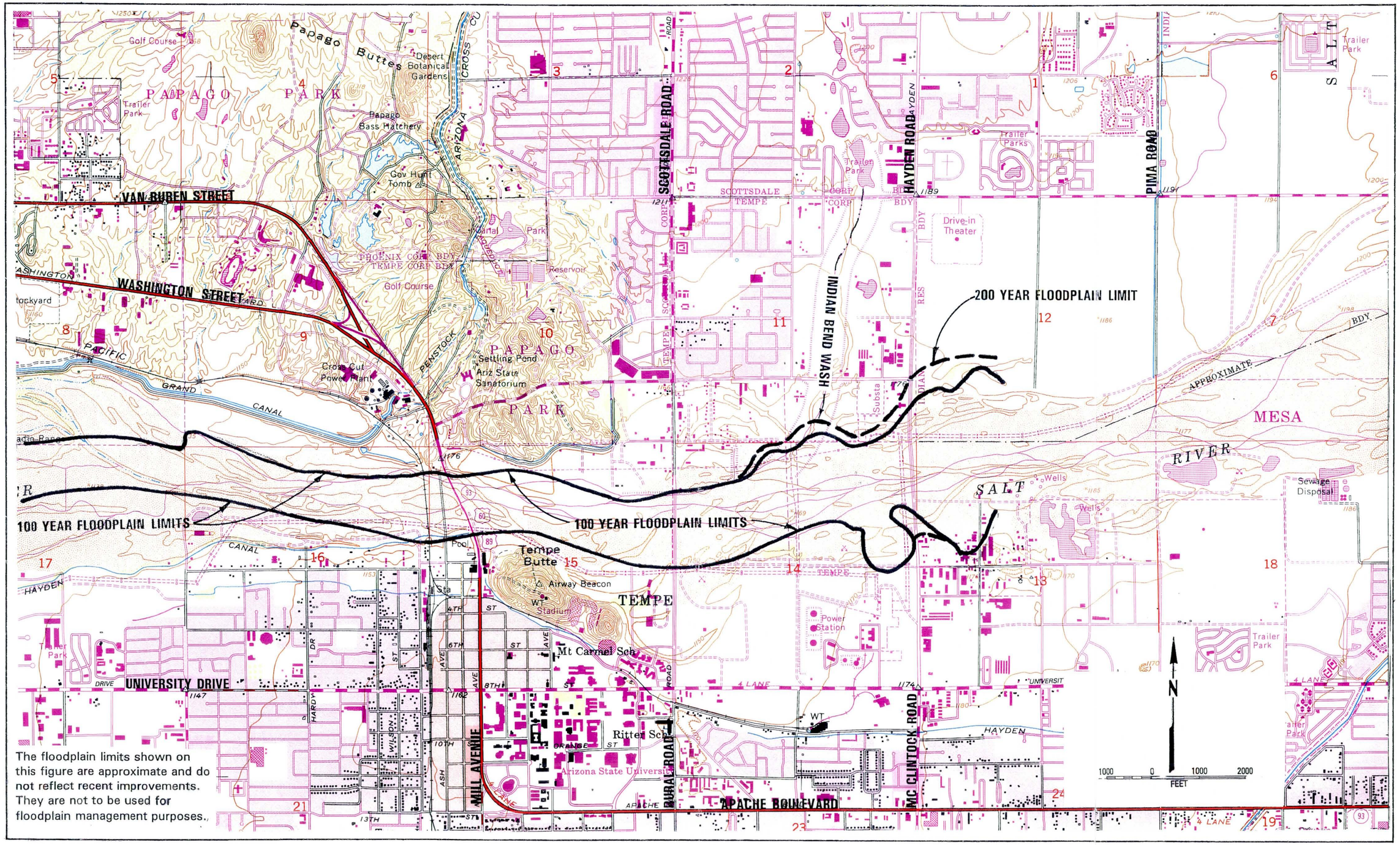


Figure 5.1C. Salt River Floodplain Limits.



The floodplain limits shown on this figure are approximate and do not reflect recent improvements. They are not to be used for floodplain management purposes.

Figure 5.1D. Salt River Floodplain Limits.



The floodplain limits shown on this figure are approximate and do not reflect recent improvements. They are not to be used for floodplain management purposes.

Figure 5.1E. Salt River Floodplain Limits

Table 5.1. Rio Salado Floodplain Structure Inventory.

Reach	Structure	100-Year Floodplain		200-Year Floodplain	
		No. of Structures	Cost	No. of Structures	Cost
McClintock to Hohokam Freeway	Houses Mobile Homes Comm./Ind.	0 0 2	$0 $0 $200,000	0 0 6	$0 $0 $600,000
Subtotal		2	$200,000	6	$600,000
Hohokam Freeway to 16th Street	Houses Mobile Homes Comm/Ind.	2 0 9	$100,000 $0 $900,000	2 0 9	$100,000 $0 $900,000
Subtotal		11	$1,000,000	11	$1,000,000
16th Street to 35th Avenue	Houses Mobile Homes Comm/Ind.	8 15 5	$400,000 $225,000 $500,000	8 15 5	$400,000 $225,000 $500,000
Subtotal		28	$1,125,000	28	$1,125,000
35th Street to 51st Avenue	Houses Mobile Homes Comm/Ind.	3 5 5	$150,000 $75,000 $500,000	55 10 20	$2,750,000 $150,000 $2,000,000
Subtotal		13	$725,000	85	$4,900,000
51st Street to 75th Avenue	Houses Mobile Homes Comm/Ind.	13 10 5	$650,000 $150,000 $500,000	15 10 5	$750,000 $150,000 $500,000
Subtotal		28	$1,300,000	30	$1,400,000
75th Avenue to Gila River Conf.	Houses Mobile Homes Comm/Ind.	15 16 2	$ 750,000 $ 240,000 $ 200,000	30 20 10	$1,500,000 $300,000 $1,000,000
Subtotal		33	$1,190,000	60	$2,800,000
Gila River Conf. to Agua Fria Conf.[1]	Houses Mobile Homes Comm/Ind.	290 65 45	$14,500,000 $975,000 $4,500,000	290 65 45	$14,500,000 $975,000 $4,500,000
Subtotal		400	$19,975,000	400	$19,975,000
Total		515	$25,515,000	620	$31,800,000

[1] 200-Year floodplain limits not available.

Reach 5: 51st Avenue bridge to 75th Avenue alignment

Reach 6: 75th Avenue alignment to the Gila River confluence

Reach 7: Gila River confluence to the Agua Fria River confluence

Reach 1 extends approximately 4 miles from the McClintock Road bridge to the Hohokam Expressway bridge (SR143). The 100-year floodplain varies in width from 1,000 feet to 2,400 feet from Rural Road to the Hohokam Expressway. There is soil-cement bank protection along the north and south banks of the river. These levees contain the 200-year discharge throughout most of the reach. There are two structures with a total value of approximately $200,000, located within the 100-year floodplain limits.

Reach 2 extends approximately 3 miles from the Hohokam Expressway to the 16th Street bridge. The 100-year floodplain in Reach 2 ranges in width from 700 to 1,800. There are 11 structures with a total value of approximately $1,000,000 within the 100-year floodplain. Sand and gravel mining pits exist along the north and south banks of the river downstream of the 24th Street bridge. The mining pits are within the 200-year floodplain but outside the 100-year floodplain. The Sky Harbor Airport is located along the north bank of the Salt River within this reach. Maricopa Freeway (I-10) and the proposed Sky Harbor Access Road cross the river within this reach.

Reach 3 extends approximately five miles from the 16th Street bridge to 35th Avenue bridge. The 100-year floodplain varies in width from 800 feet to 3,500 feet. Several sand and gravel mining activities exist along this reach, with very large pits near the 27th Avenue bridge and the 7th Avenue bridge. There are two landfills, at 19th and 27th Avenues within this reach. Approximately 28 structures with a total value of approximately $1,125,000 are within the 100-year floodplain in this reach. A wastewater treatment plant is located along the north bank at 23rd Avenue. The treatment plant is protected by a berm and is outside the 100- and 200-year floodplain.

Reach 4 extends for two miles from the 35th Avenue bridge to the 51st Avenue bridge. The 100-year floodplain within this reach varies from 1,300 feet to 3,500 feet wide. A large sand and

gravel mining operation exist approximately 1,500 feet downstream of the 35th Avenue bridge. Approximately 13 structures with a total value of approximately $725,000 are within the 100-year floodplain in this reach. The estimated value of structures within the 200-year floodplain is $4,900,000.

Reach 5 extends for 3 miles from the 51st Avenue bridge to the 75th Avenue alignment. The channel meanders and remains natural throughout most of this reach. The 100-year floodplain varies in width from 1,500 feet to 3,000 feet. A sand and gravel mining operation exists downstream of the 51st Avenue bridge. Approximately 28 structures with a value of approximately $1,300,000 are within the 100-year floodplain.

Reach 6 extends approximately 5 miles from the 75th Avenue alignment to the Gila River confluence. The 100-year floodplain widens from 3,000 feet to 7,000 feet at the Gila River confluence. Approximately one square mile of agricultural land is within the 100-year floodplain. Approximately 33 structures with a total value of approximately $1,190,000 are within the 100-year floodplain. The 91st Wastewater Treatment Plant is located along the north bank within this reach. The treatment plant is located outside of the 100-year floodplain, but it is possible that a 100-year flood could back up the plant's outflow channel and flood portions of the interior of the plant.

Reach 7 extends three miles from the Gila River confluence to the Agua Fria River confluence. The 100-year floodplain width ranges from 7,000 feet to approximately 10,000 feet. The Salt River remains natural with heavy vegetation within this reach. Several square miles of agricultural land is within the 100-year floodplain. Approximately 400 structures with an estimated value of $19,975,000 are within the 100-year floodplain in this reach.

Reach 7 includes the Holly Acres subdivision. The Flood Control District of Maricopa County in 1984 completed a 1.25-mile-long bank stabilization and levee project designed to protect the Holly Acres subdivision from flows up to 115,000 cfs (a 10-year discharge) plus three feet of freeboard. The 100-year discharge will overtop this levee in places and there is a flow break-out

of approximately 15,000 cfs on a 100-year discharge upstream of 116th Avenue that could affect this area. Construction of a proposed bridge at 116th Avenue will likely not improve the breakout condition.

The Flood Control District of Maricopa County has a project to clear a 1,000 foot wide corridor free of phreatophytes (primarily salt cedar) from 91st Avenue, through the study area, and continuing downstream to Gillespie Dam for a total distance of approximately 36 miles. This project, currently set aside pending the recommendations of the Flood Control District/Arizona State University Salt/Gila Policy Management Study, was designed to allow floodwater to flow unimpeded through a watercourse previously occupied by dense salt cedar stands. Although a wider clearing (2000 feet, for example) was desirable from a flood control standpoint, the environmental impacts prohibited this alternative from being fully developed and analyzed. The final 1,000 foot wide alignment avoided stands of cottonwoods and willows and included the natural low flow channel in many locations.

There are 25 roads crossing the Salt River along the study reach. Sixteen of these crossings are bridge structures. Figure 5.1 shows the locations of these crossings. Table 5.2 lists the crossings, flow capacities, average daily trips and approximate structure replacement costs.

Table 5.2. Summary of Road Crossings along the Salt River.

Crossing Name	Type of Crossing	Owner/ Maintenance[1]	Capacity (cfs)	Average Daily Trips (ADT) (vehicles/ day)	Structure Replacement Cost[2]
McClintock Road	bridge	COT	250000	51,635	$6,300,000
Rural Road	bridge	COT	250000	36,571	$6,600,000
Mill Avenue Bridges (2)	bridge	COT	250000	22,141	$11,600,000
Southern Pacific RR	bridge	SPRR	250000	Not Available	Not Available
Priest Drive	bridge	COT	289000	21,496	$5,500,000
Hohokam Expwy	bridge	ADOT	289000	Not Available	$8,600,000
Maricopa Fwy (I-10)	bridge	ADOT	215000	Not Available	$11,700,000
24th Street	bridge	COP	180000	19,780	$4,200,000
16th Street	bridge	COP	180000	22,880	$6,200,000
7th Street	bridge	COP	200000	20,500	$3,000,000
Central Avenue	bridge	COP	180000	25,000	$3,500,000
7th Avenue	bridge	COP	200000	19,100	$4,000,000
19th Avenue	bridge	COP	180000	16,900	$4,300,000
35th Avenue	bridge	COP	105000	15,000	$2,600,000
51st Avenue	bridge	MCDOT	200000	8,555	$6,000,000
67th Avenue	Paved Dip	MCDOT	<5000	2,425	$150,000
91st Avenue	Paved Dip	MCDOT	<5000	859	$250,000
115th Avenue	Paved Dip	MCDOT	<5000	3,257	$2,50,000
El Mirage Road	Paved Dip	MCDOT	<5000	306	$250,000
Total					$87,250,000

[1] COT City of Tempe
COP City of Phoenix
ADOT Arizona Department of Transportation
SPRR Southern Pacific Railroad

[2] Estimate based on $60/sf of bridge deck and $20/sy for dip crossings

Transportation

Bridge Scour

A preliminary scour analysis was performed for bridges crossing the Salt River along the study reach. Three bridges were identified to have potential scour problems during a 100-year flood. The 24th Street bridge, Central Avenue bridge, 35th Avenue Bridge and the 51st Avenue bridge were found to potentially have scouring depths lower than the present bridge supports. These bridges might be expected to fail during a 100-year flood. The total value of these three structures is approximately $13,700,000.

Headcutting from Sand and Gravel Mines

The many sand and gravel operations along the river are potentially subject to Salt River inflows during major flood events. As inflows occur, severe and rapid channel degradation can occur upstream and downstream of the pits. Nearby bridges can be significantly affected by this degradation, causing the bridges to fail. For example, during the 1993 floods, the degradation of the Alma School Road Bridges was so severe that the Maricopa County Department of Transportation has installed emergency stream grade-control protection to prevent failure of the bridges.

The proper evaluation of potential channel degradation from inflow to pits is complex. However, as a general rule for the Salt River, bridges should be located at least 200 feet upstream of the point where a line sloping upwards upstream at 1%, beginning at the vertical midpoint of the upstream edge of a pit, intersects the present stream bed as illustrated in Figure 5.2. Using this general guideline, five bridges within Rio Salado have been identified as potentially in danger of damage resulting from inflow to nearby pits. These bridges are at 51st Avenue, 35th Avenue, 19th Avenue, 7th Avenue and 24th Street. The total replacement cost for the impacted bridges is estimated at $21,100,000.

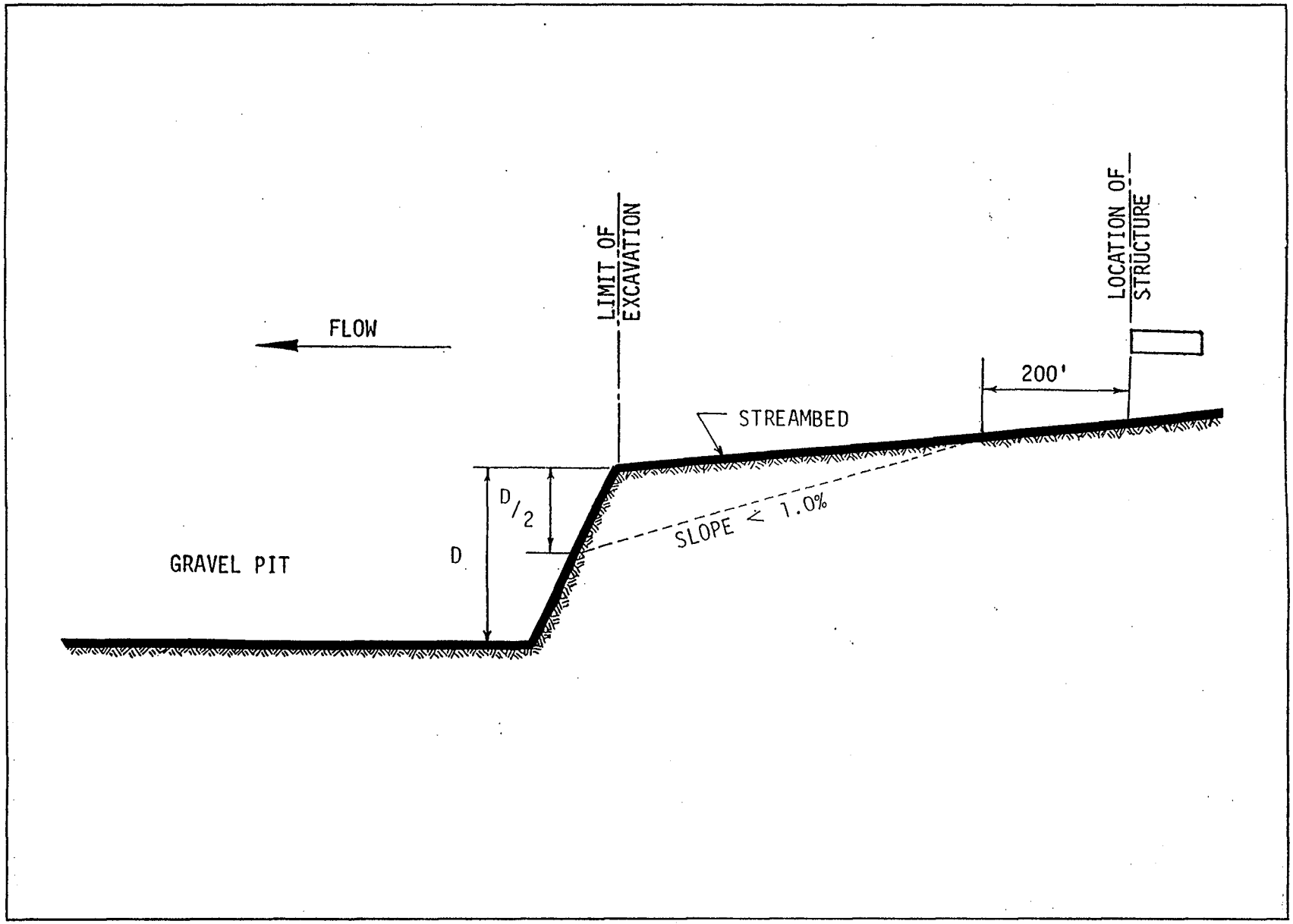


Figure 5.2. **Typical Channel Degradation and Bridge Setback Upstream of a Gravel Pit: Salt River**

91st Avenue Wastewater Treatment Plant

The 91st Avenue Wastewater Treatment Plant (WWTP), operated by the City of Phoenix Water Services Department, treats approximately 240 million gallons of effluent per day from the Phoenix area. The plant is located on the north bank of the Salt River at 91st Avenue near the confluence with the Salt and Gila Rivers.

The WWTP has no protection from erosion from the Salt River. Because of its close proximity to the river, the WWTP is in imminent danger of severe erosion damage. It is estimated that approximately 600 feet to 2,200 feet of bank migration, causing $17,725,000 to $32,725,000 in damages (including maximum possible fines) could occur on a 100-year event.

5.1.2 Future Without Project Conditions

Flooding

While the 1.25 mile levee project provides some protection to the Holly Acres subdivision, other less densely populated subdivisions and industrial/commercial lands will continue to be susceptible to flood damages under future-without-project conditions. Approximately 530 structures will potentially be subject to 100-year flooding of the Salt River (635 structures for 200-year flood) depending upon the elevation of the structures. The total value of these structures is approximately $26,000,000 for the 100-year flood and $32,000,000 for the 200-year flood. Average annual flood-related damages are estimated by very preliminary methods at $145,000.

As urban sprawl and commercial/industrial development continues west from the Phoenix metropolitan area, the threat of flood damages through the study area can be expected to increase in the future. In view of Arizona Department of Transportation plans to complete the outer-loop (South Mountain Freeway), future development is expected to occur along the freeway and to the west. In addition, the recreation complex that is being developed at Estrella Mountain Regional Park, will continue to attract off-site commercial and residential development in the area.

A second area concerning flood control pertains to releases of water stored in upstream dams built on the Salt River by the Bureau of Reclamation and operated by Salt River Project. While storage releases during periods of potential flooding are necessary from a dam safety standpoint,

these releases could result in a variety of downstream impacts on the Salt River. During periods of serious flood potential, large volumes of water are released from upstream dams and may cause flood damage in the Phoenix metropolitan area. At the same time, lower volume releases, which may not result in economic losses to public or private property, have an impact on riparian habitat and in particular that of the Yuma clapper Rail, a Federally listed Threatened and Endangered Species (T&E). Cattail/bulrush marsh communities provide habitat for the Yuma clapper Rail. As flows reach 10,000 - 15,000 cfs, nesting and cover habitat of the Yuma clapper Rail is overtopped with high water. The duration and extent to which habitat is unavailable to the species could have a serious impact on its recovery in the study area. Given the scouring effects of higher flows, the cattail/bulrush marsh communities, if unprotected, can be virtually destroyed as upstream dam releases approach 30,000 - 50,000 cfs.

Transportation

Bridge Scour

Under future-without-project conditions, the 24th Street bridge, 35th Avenue Bridge, Central Avenue bridge and the 51st Avenue bridge will continue to be subject to potential scour-related failure during a 100-year flood. The total replacement cost of these bridges is approximately $13,700,000.

Headcutting from Sand and Gravel Mines

There will continue to be a potential for damage to bridges resulting from channel degradation caused by inflow to sand and gravel mines under without-project conditions. The 51st Avenue, 35th Avenue, 7th Avenue and 24th Street bridges have been identified as potentially subject to this type of damage. The total replacement cost for the impacted bridges is estimated at $21,100,000. Average annual headcut-related damages, including bridge replacement and traffic detours, is estimated by very preliminary analysis at $530,000.

Low-flow Dip Crossings

There are four low-flow dip crossings along the study reach. These dip crossings are not designed to withstand a 100-year flood. These dip crossings will continue to be impassable during high river flows under without-project conditions. The total replacement cost for the dip crossings is estimated at $750,000.

Traffic Delay

During and after high flows of the Salt River, bridge and dip crossings may be impassable under future-without-project conditions. Assuming an average 60-day closure period, based on the experience of Gilbert Road during the 1993 flood, potential traffic delays are estimated by preliminary analysis at $722,800 per closure. Table 5.3 lists detour routes and operating plus travel time cost for each required detour. The bridges all have capacity to pass the 100-year discharge. Potential closures would be due to scour and erosion-related damages.

Table 5.3. Summary of Detour and Delay Cost for River Crossings.

Crossing Name	Average Daily Trips (ADT) (vehicles/day)	Detour Miles	Delay Cost (Based on 60 day closure)
McClintock Road	51,635	5.0	$3,170,390
Rural Road	36,571	2.5	$1,122,730
Mill Road	22,141	3.0	$ 815,670
Southern Pacific RR	Not Available	Not Available	Not Available
Priest Drive	29,085	2.5	$ 892,910
Hohokam Expwy	Not Available	3.5	Not Available
Sky Harbor Access	Not Available	Not Available	Not Available
Maricopa Fwy (I-10)	Not Available	3.2	Not Available
24th Street	Not Available	2.5	Not Available
16th Street	Not Available	3.4	Not Available
7th Street	Not Available	1.5	Not Available
Central Avenue	Not Available	1.5	Not Available
7th Avenue	Not Available	1.5	Not Available
19th Avenue	Not Available	3.5	Not Available
35th Avenue	Not Available	6.0	Not Available
51st Avenue	8,555	6.0	$ 630,330
67th Avenue	2,425	5.4	$ 160,807
91st Avenue	859	8.0	$ 84,390
115th Avenue	3,257	11.0	$ 440,000
El Mirage Road	306	10.0	$ 37,580

91st Avenue Wastewater Treatment Plant

The 91st Avenue Wastewater Treatment Plant will continue to be subject to erosion damage on discharges exceeding a 20-year flood under future-without-project conditions. Average annual damages are estimated at $354,000 to $654,000.

5.1.3 Opportunities

Flood-related damages are low in comparison to the potential cost of flood protection. The total value of structures within the floodplain averages approximately $981,000 to $1,223,000 per mile for the 100-year and 200-year floodplains, respectively. Flood protection costs, using soil cement, are estimated at approximately $2,500,000 per mile. Consequently, with the exception of the 91st Avenue Wastewater Treatment Plant, no opportunity for a Federally-funded flood-control project has been identified.

5.2 Riparian habitat

5.2.1 Environmental History - Pre-Dam-Construction

Historically, gallery forests of cottonwoods and willows covered hundreds of miles along the lower reaches of rivers like the Salt in the desert southwest. In modern times these forests are one of the most endangered in the U.S. Optimal conditions for cottonwood - willow forests are found in depositional environments where fine grained alluvial substrates are located on flood plains. 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.

Prior to dam construction in the early 1900's, the Salt River riparian vegetation appeared to be dominated by the cottonwood, willow and the various species of mesquite. This suite of vegetation is considered to be representative of the natural 'climax' species that would be found in an undisturbed riparian corridor along the Salt River. Cottonwoods occurred along the outer bank of the river, at the extreme edge of the natural riparian vegetation. The willow and mesquite bosques were located inward of the cottonwood, adjacent to the low flow channel and closer to where there was a more continuous flow of water. Some channel areas were barren,

while others had vegetation in strips along the low flow channels and abandoned high flow channels.

The Lower Salt River was originally a perennial stream fed by snowmelt from the mountains to the east and the highlands to the northeast. Its clear, streaming waters contrasted greatly with the muddy, sluggish Gila River to the south and west. Flows in the river had a distinct seasonal pattern, with highest flows occurring in December and January and lowest flows in October.

The bottom lands of the Salt River supported a variety of vegetation, including trees, shrubs, marsh plants, and some grasses. Large cottonwood, willow, and alder tress grew along the margins of the river, and mesquite, greasewood, palo verde, and sagebrush covered the low terraces. Dense mesquite and other shrubs made crossing the bottom land impossible in places, while in other locations the vegetation was more scattered. There were several species of fish in the waters, similar to those found in the Gila River.

Large, dense mesquite forests or bosques are found along abandoned lakes, lake edges and river flood plains in southern Arizona. Mesquite bosques were once the most abundant riparian type in the Southwest. Most modern mesquite bosques are large (typically one mile long and 600 feet wide), but these are small compared to pre-development bosques which spanned widths of 5 to 10 miles and extended for hundreds of miles. Mesquite bosques usually are found on the drier habitat types within the riparian continuum. The locations for this setting are flood plains or low terraces several yards above the streambed, and up to 45 feet above the water table.

The U.S. Bureau of Reclamation constructed a series of dams in the Salt and Verde River watersheds starting with Roosevelt Dam in the early 1900's. Perennial flows on the Salt River ceased, causing detrimental environmental impacts to natural wildlife habitat and riparian communities along the Salt River. The elimination of natural base flows due to dams and diversions has reduced most natural Salt River flows to summer or fall rainfall-related flood events which favor the invasive salt cedar vegetation. Unlike cottonwoods and willows, salt cedar has the ability to establish itself after floods that occur during any part of the growing season.

Salt cedar forests have low habitat value because of low plant species diversity, low canopy height, and low vertical and horizontal complexity.

The Salt cedar had become well established in the riparian corridor by the 1920's. The earliest account of this exotic species was around 1900, but it did not really begin to establish itself until the late 1910's and early 1920's. The coverage of salt cedar was heaviest in the 1940's. Photographs from the Mill Avenue Bridge from that period show the channel almost entirely covered with this species. In the 1950's there was a reduction of vegetation in general along the river. This was in response to vegetation removal programs and fluctuations in the groundwater levels. The trend of decreasing coverage of riparian vegetation continued until the mid 1960's. In the late 1960's the exotic species began to dominate the channel once again, increasing in density and areal extent. This continued until the early 1980's when vegetation clearing programs were enacted again. Table 5.4 provides a summary of historical phreatophyte cover of the study area.

Table 5.4. Historical Phreatophyte Cover of Individual Reaches, in Acres.

Year	Country Club to Mill Ave.	Mill Ave. to 7th St.	7th St. to 59th Ave.	59th Ave. to Mon. Hill	Total
1937	2,374	2,460	4,198	2,495	11,527
1957	1,315	1,783	1,993	2,259	7,350
1961	996	1,216	1,960	2,414	6,586
1971	1,536	841	246	911	3,534
1973	396	363	456	749	1,964
1979	315	560	575	1,016	2,466

5.2.2 Without-Project (Present) Conditions

Federal Dams

In contrast to the benefits of Federal Dams on the Salt River system which provide water conservation and hydropower, both of which led to the economic development of the Phoenix metropolitan area, the environmental impacts were significant.

As a high-value component of the Sonoran Desert ecosystem, riparian vegetation along the Salt River not only provided habitat to a major portion of wildlife in Arizona, but also established corridors for species migration and diversity along the Salt River channel. Few minor remnants of the once richly-diverse mesquite bosque communities of the Salt River currently exist. At present, the vegetation is restricted to certain reaches where there is groundwater near the surface or where effluent flows in the channel. A good example of this is the confluence of the Salt and Gila Rivers, where there is a relatively dense cover of vegetation. The Salt and Gila River confluence area has a high water table and continuous flow of effluent throughout most of the year. This area is dominated by salt cedar, but locally there are some sites where native species are present.

Today, threats to cottonwood and willow forests are primarily from human activities such as groundwater pumping, damming, surface flow diversion and regulation, and inter-basin groundwater and or surface water flow transfers. Salt cedar encroachment is another significant threat. Artificial inputs of water occasionally support riparian communities similar to natural assemblages, particularly in areas with waste water effluent such as at the 23rd and 91st Avenue wastewater treatment plants within the Rio Salado study area. 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.

In conjunction with the Bureau of Reclamation, the Corps of Engineers, under Section 7 of the Flood Control Act of 1944, is developing a Water Control Plan for operating the flood-control space at Modified Roosevelt Dam. Riparian habitat impacts as a result of flood-control releases from Modified Roosevelt Dam have not yet been determined. However, releases from upstream

Federal Dams could impact riparian habitat, in particular that of the Yuma clapper Rail. As cattail/bulrush marsh communities are inundated by high waters, feeding and nesting habitat of the clapper Rail becomes unavailable, causing stress on this endangered species. It appears that this habitat may be completely washed out when upstream dam releases approach 30,000 - 50,000 cfs. Salt River Project administrators report the frequency of releases of this magnitude have occurred 26 times since 1916 with an average duration of 2 to 4 days per release. Protection of this habitat from storage releases from Federally constructed dams, to provide for the flood control component at these facilities, would assist the U.S. Fish and Wildlife Service in their efforts to provide for a recovered population of the Yuma clapper Rail.

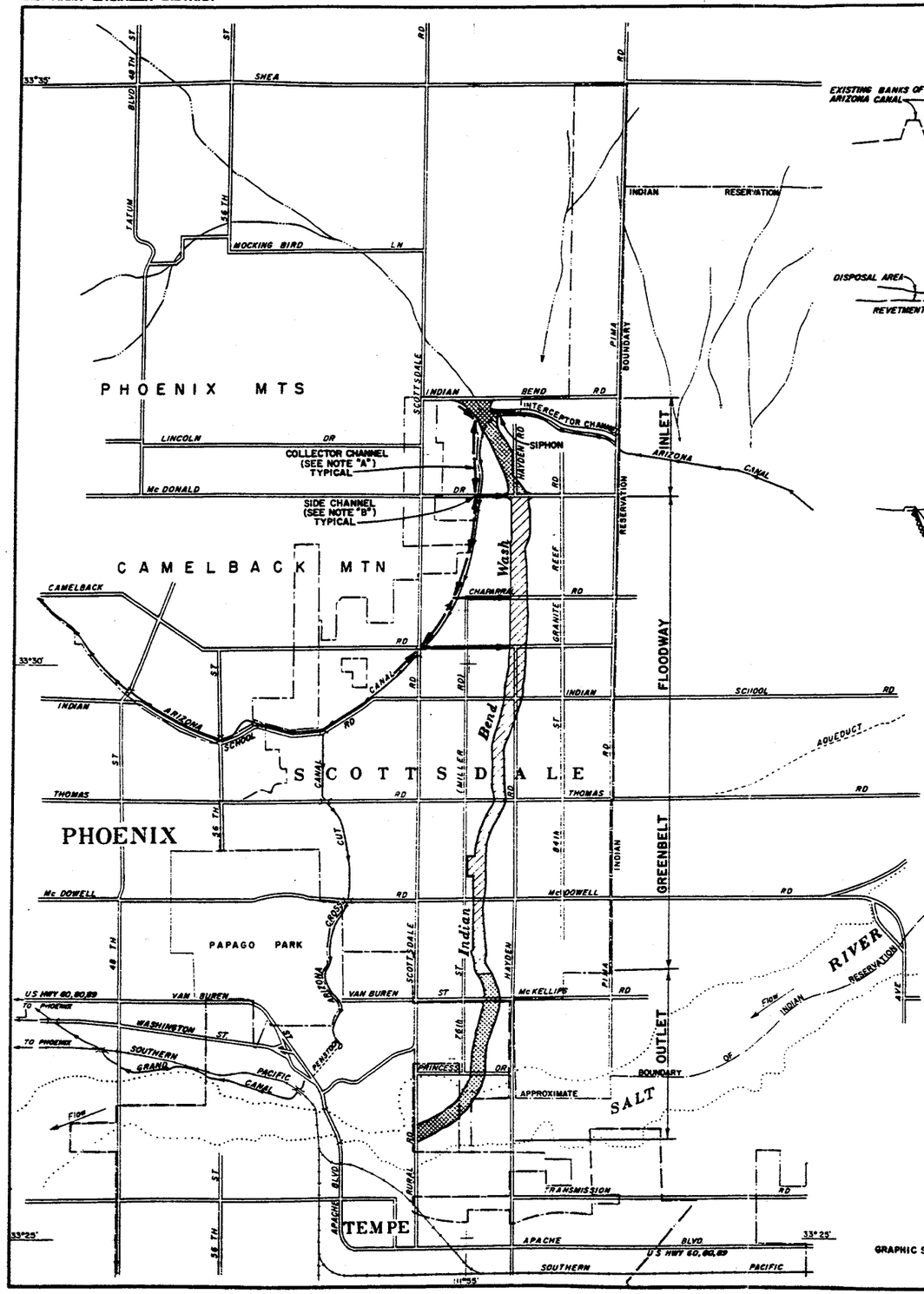
Indian Bend Wash

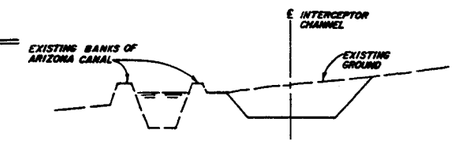
Indian Bend Wash is a Corps flood control project authorized for construction under the Flood Control Act of 1965 (PL89-298). The project combines structural and non-structural flood control measures to provide 100 year flood protection along Indian Bend Wash, southward to the Salt River (see Figure 5.3).

Prior to project development, Indian Bend Wash supported a diverse wildlife population. Appendix G contains a list of the predominating flora and wildlife species that previously occupied the area. The list of species was taken from the Indian Bend Wash FEIS, 1973.

Only three areas were identified as having value as wildlife habitat within the project limits. These areas included the inlet and outlet (Rio Salado Area) ends of the floodway and the collector channel area.

The Indian Bend Wash inlet included a high quality, undisturbed, historical mesquite bosque community was located in the area of Indian Bend Wash from Indian Bend Road to the Arizona Canal. This 28 acre mesquite bosque community provided habitat of excellent value for such species as morning and white-winged dove, Gambel's quail, songbirds, ground squirrels and rabbits. This mesquite bosque was a remnant of a habitat type which has practically disappeared from central Arizona. It is here where the inlet to Indian Bend Wash was located. The





TYPICAL SECTION AT INTERCEPTOR CHANNEL
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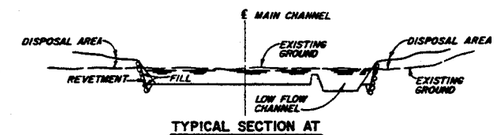

TYPICAL SECTION AT MAIN CHANNEL-INLET
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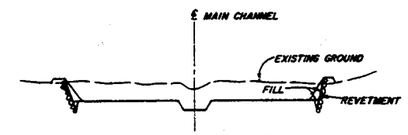

TYPICAL SECTION AT MAIN CHANNEL-OUTLET
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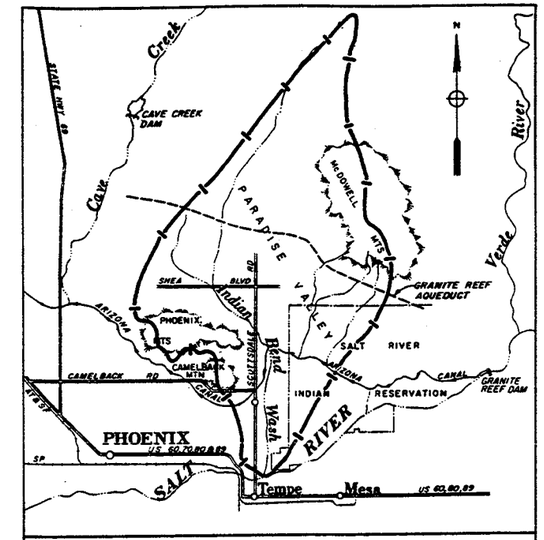


BASIN MAP

SCALE 5 0 5 10 MILES

BOUNDARY OF INDIAN BEND WASH DRAINAGE AREA

NOTE:

FLOOD CONTROL FEATURES INDICATED BY ARROWS(→) ARE AS FOLLOWS:

A. COLLECTION CHANNELS ADJACENT TO THE WEST SIDE OF THE ARIZONA CANAL

1) SOUTH OF INDIAN BEND ROAD TO SOUTH OF MC DONALD DRIVE: UNLINED OPEN TRAPEZOIDAL CHANNELS
2) SOUTH OF LINCOLN DRIVE TO SOUTH OF MC DONALD DRIVE: UNLINED OPEN TRAPEZOIDAL CHANNELS AND REINFORCED CONCRETE PIPES VARYING FROM 6 FEET TO 10 FEET IN DIAMETER
3) SOUTH OF MC DONALD DRIVE TO SOUTH OF CHAPARRAL ROAD: UNLINED OPEN TRAPEZOIDAL CHANNELS
4) SOUTH OF CHAPARRAL ROAD TO SOUTH OF CAMELBACK ROAD: UNLINED OPEN TRAPEZOIDAL CHANNELS AND REINFORCED CONCRETE PIPES VARYING FROM 6 FEET TO 10 FEET IN DIAMETER

B. SIDE CHANNELS FROM WEST OF THE ARIZONA CANAL TO INDIAN BEND WASH

1) MC DONALD DRIVE: THREE 78-INCH REINFORCED CONCRETE PIPES
2) CHAPARRAL ROAD: TWO 78-INCH REINFORCED CONCRETE PIPES
3) CAMELBACK ROAD: 12.5 FOOT WIDE BY 9 FOOT DEEP BOX CONDUIT.

GRAPHIC SCALE 1 0 1 MILES

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

GILA RIVER BASIN, ARIZONA

INDIAN BEND WASH

RECOMMENDED PLAN OF IMPROVEMENT

Figure 5.3. Indian Bend Wash Plan of Improvements

entrenchment of the inlet necessitated the removal of the last sizeable area of native wildlife habitat in the urbanized reach of Indian Bend Wash.

The collector channel along the Arizona Canal west of Indian Bend Wash was already urbanized, however, a mesquite habitat corridor existed for 1-1/4 miles along the west bank of the canal and ranged from 20 to 350 feet in width. This area was estimated to consist of 25 acres.

The outlet is located in the area from McKellips Road downstream to the confluence of Indian Bend Wash and the Salt River (Rio Salado). As stated in the FEIS this area provided habitat for a variety of birds and small wildlife species that were capable of living in an area surrounded by urban development.

Threatened and Endangered Species that occupied the area was the prairie falcon, which may have been an occasional migratory visitor to the area.

The habitat areas that occupied what is now the greenbelt floodway of Indian Bend Wash from the Arizona Canal to the Salt River has not been accounted for in terms of habitat acres impacted by the project. Figure 5.4 represents a map of the extent of natural vegetation presented in the FEIS. The shaded areas on the map represent the amount of natural habitat considered to be impacted by this project and do not include the floodway area. A possible reason for this omission is that the upstream high quality riparian communities were considered to be "superior to any found farther south along Indian Bend Wash." Descriptions of these habitats, however, indicate the role these communities played in supporting wildlife. The following was taken from the FEIS:

> "The entire reach along Indian Bend Wash from the Arizona Canal to the Salt River contains little unmodified natural habitat..... Cultivated agriculture and subsequent urbanization and development have so modified this area the majority of the reach has limited wildlife habitat. Where natural communities do exist, they are diverse and relatively dense riparian communities that support wildlife. The reach from Princess Road

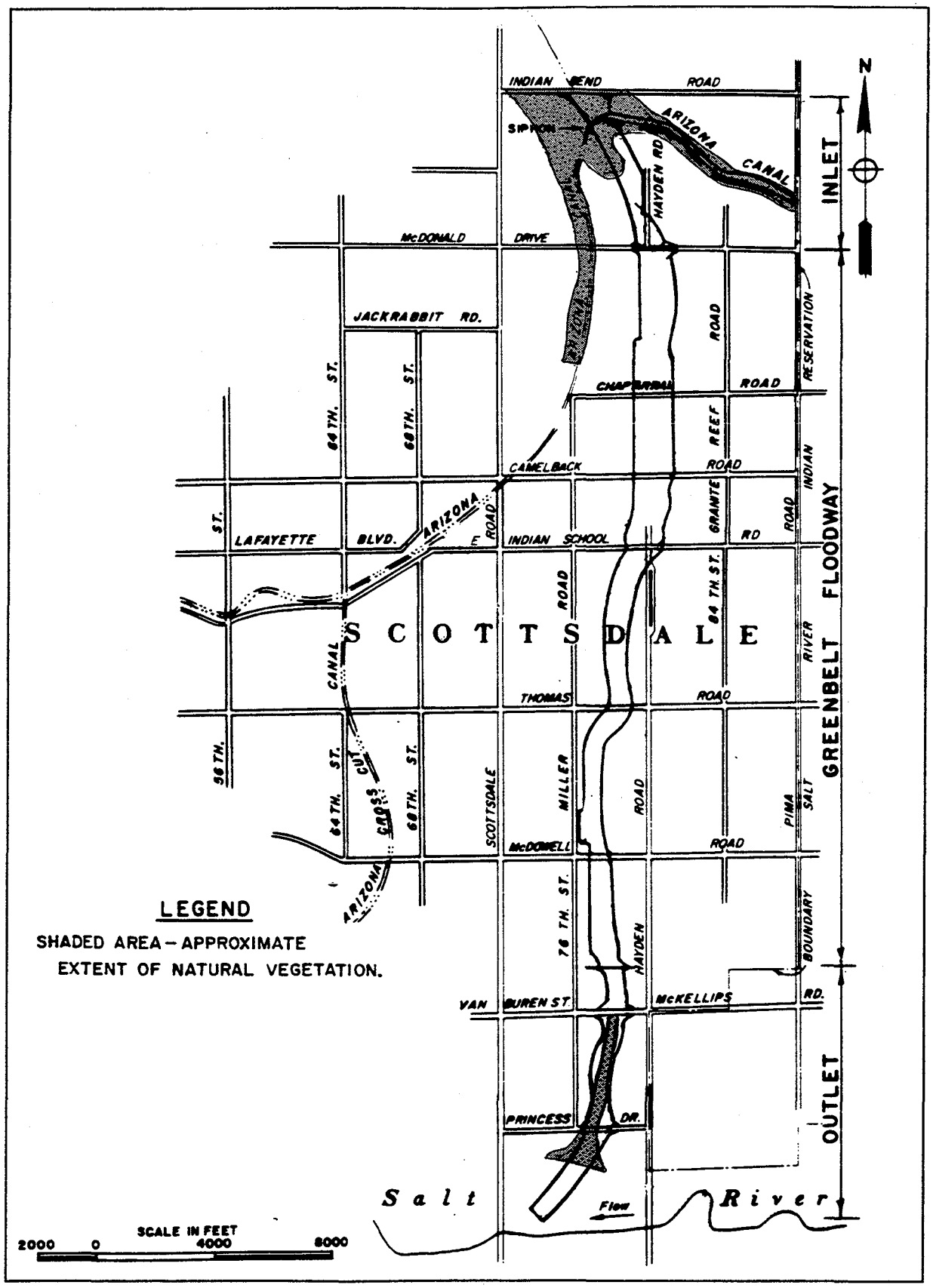


Figure 5.4. Natural Vegetation on Indian Bend Wash

to the Salt River is described as typical of an outwash plain. The dominant vegetation includes salt cedar, salt bush, creosote bush, some sage, and many annuals. The annual vegetation provided an energy base for a diverse fauna community."

This area now consists of a greenbelt floodway which totally removed the natural habitat. The FEIS specifically states that "replacement of natural desert flora with an urban greenbelt" is among the effects of constructing the greenbelt floodway. The floodway acres were, however, not accounted for in disclosing these environmental impacts. The FEIS states that in total only 41 acres of wildlife habitat was lost which includes 28 acres at the inlet, 11 acres at collector channels, a 5 to 10 feet wide strip 1,500 feet along the west bank of the Indian Bend Pump Lateral, and 2 acres at the outlet. No mention of the acres of "natural desert flora" is reported. To make matters more complicated, the 41 acres of wildlife habitat that were reported lost, were mitigated with 40 acres of wildlife habitat purchased near the Town of Buckeye on the Gila River approximately 50 miles away.

The environmental measures taken to mitigate the loss of wildlife habitat appear to have been incomplete on the basis of locality, equity, and loss of high value riparian habitat. With respect to locality, these wildlife communities represented the last sizeable area of native wildlife communities and the last sizeable area of native wildlife habitat in the urbanized reach of Indian Bend Wash. Mitigation measures at or near their original sites would have been beneficial for a variety of reasons. First, removing the habitat and replacing it with habitat some 50 miles from the site has an immediate impact on wildlife populations in this largely urbanized area. Second, there is no habitat continuity for surviving wildlife in the area or migratory species. Finally, maintaining the last vestige of natural habitat in the Scottsdale and Tempe urban areas is important ecologically from both an environmental and human community standpoint. Environmental restoration of this wildlife habitat at or near Indian Bend Wash at Rio Salado, Salt River is appropriate.

The issue of equity involves an incomplete accounting of acres actually impacted by the project. Not only was the number of acres impacted incomplete, but the importance of these acres may have been understated.

While habitat in the floodway may have been of lower quality when compared to the high quality mesquite bosque communities upstream, this area more than likely served as an important enclave for wildlife cover and security within the urban setting. Furthermore, the area served as an important potential migratory corridor within the five mile stretch of the floodway connecting the high value habitats at the upper end of the Wash with the communities in the Salt River. Environmental restoration measures should be considered in the vicinity of Indian Bend Wash at Tempe Rio Salado.

Present Habitat

The four major habitat types described below exist within the Rio Salado study area. Figure 5.5 (A and B) shows the location of all sites within the study area of identified habitat types.

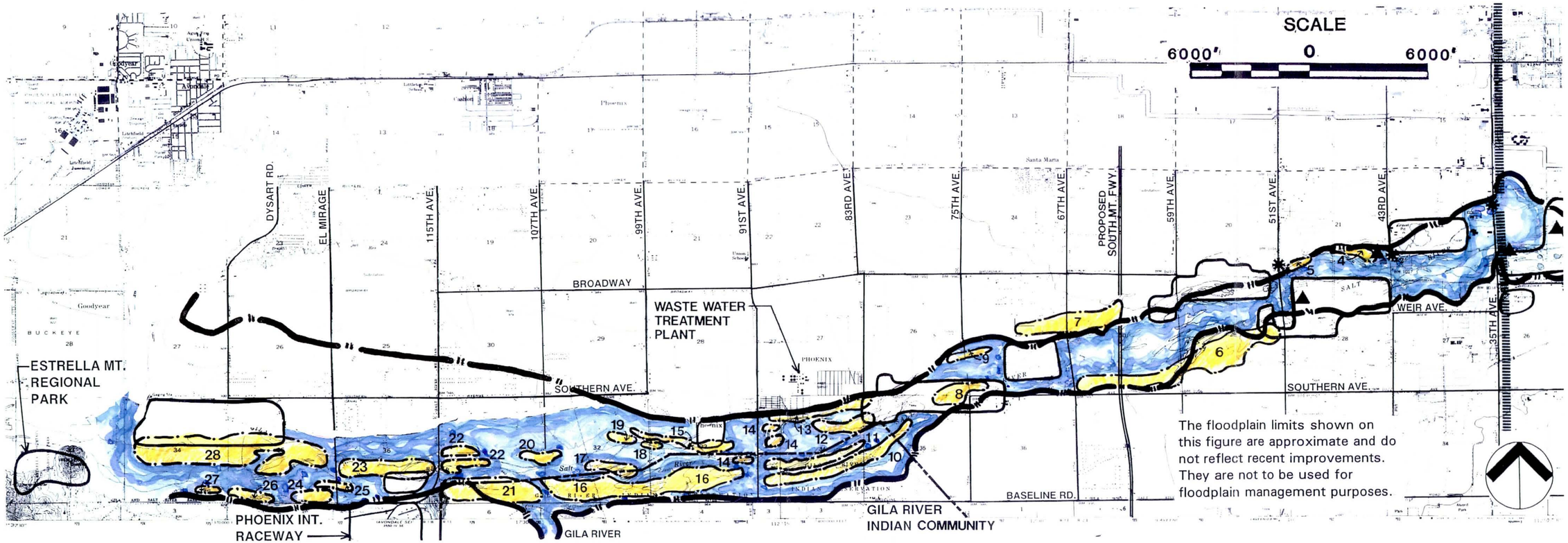
Wetland. This habitat type consists primarily of cattails, bulrushes, and occasionally water cress. This community is located at the lowest elevations of the river along the watercourse or in areas of shallow ponded water or heavily saturated soils.

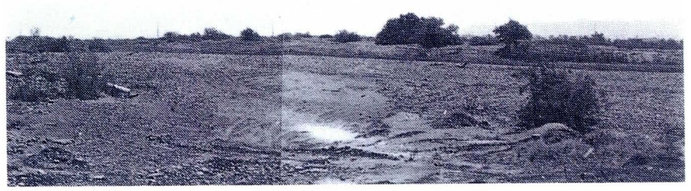
Cottonwood/willow riparian forest. This habitat is dominated by a combination of cottonwood and willow trees. This plant community is found along the active streambed of the river or on the first terrace above the river.

Mesquite habitat type. This habitat type is dominated by honey mesquite and is normally found on the upper terraces of the floodplain above the active river channel. The presence of mesquite within the project area is minimal and not evaluated in detail in this report. Tamarisk dominates the areas where mesquite would be located.

Tamarisk. Tamarisk is located on all floodplain elevations throughout the study area. Dense monotypic stands of tamarisk are found primarily on the upper terraces of the river. Tamarisk is also interspersed with stands of native vegetation at all elevations of the floodplain.

Evaluation of present riparian habitat conditions was based upon the following criteria used to estimate habitat quality of the Rio Salado Study Area:

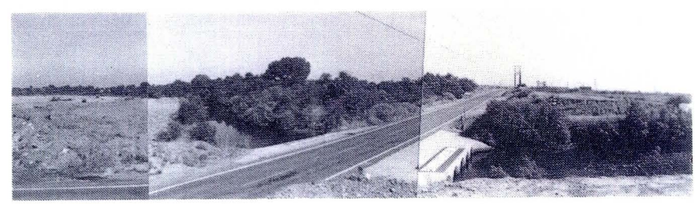




VIEW FROM 67TH AVE. NORTH BANK LOOKING SOUTH EAST

VIEW FROM 75TH AVE. NORTH BANK LOOKING SOUTH EAST

VIEW FROM 75TH AVE. NORTH BANK LOOKING SOUTH WEST



91ST AVE. VIEW NORTHWARD TOWARDS TREATMENT PLANT

LEGEND

- LANDFILL
- STORM DRAIN
- RIPARIAN SITE (#1-#28B)
- MATCHLINE
- 200 YR. FLOOD PLAIN
- CITY/ RESERVATION BORDER
- SAND/ GRAVEL OPERATION

EXISTING CONDITIONS

RIO SALADO
RECONNAISSANCE STUDY

NŪVIS
LANDSCAPE ARCHITECTURE AND PLANNING
JOB NO. 94-217.01
CALIFORNIA 1226
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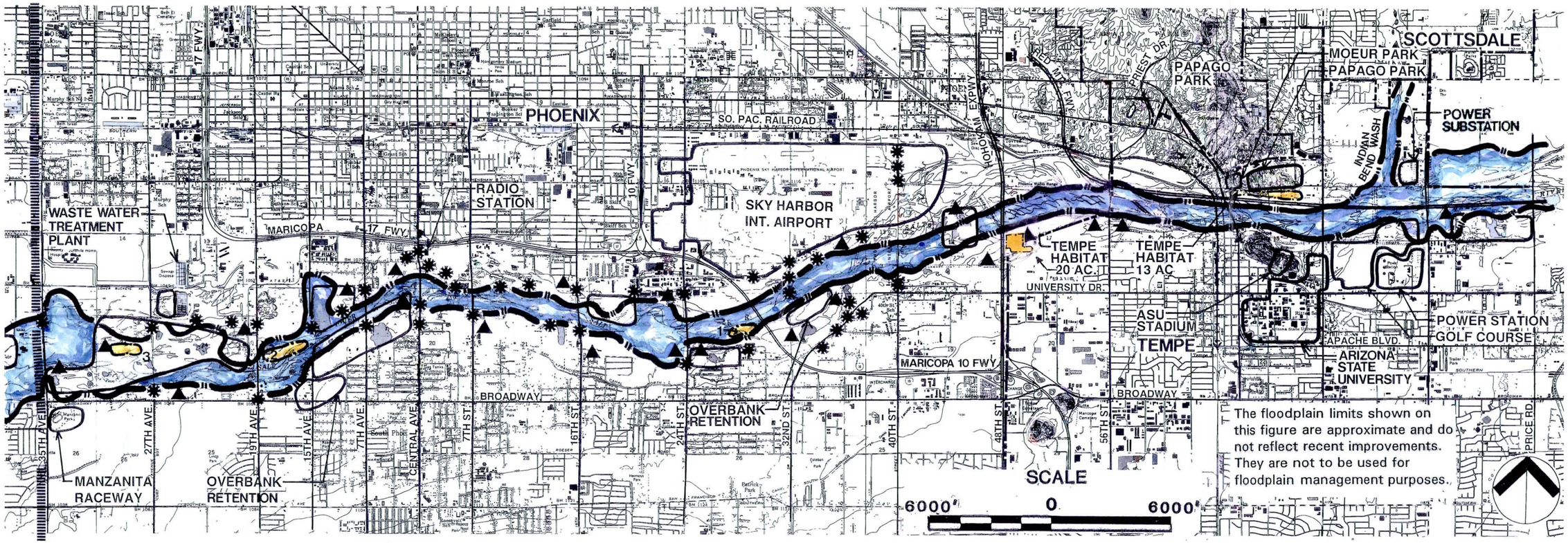
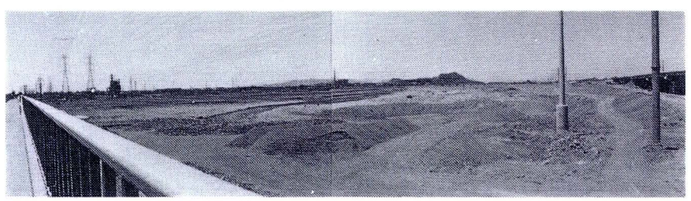
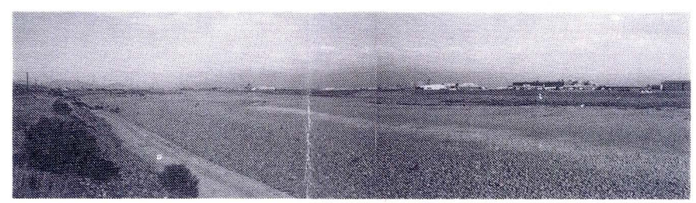
Figure 5.5A. Rio Salado Present Conditions.

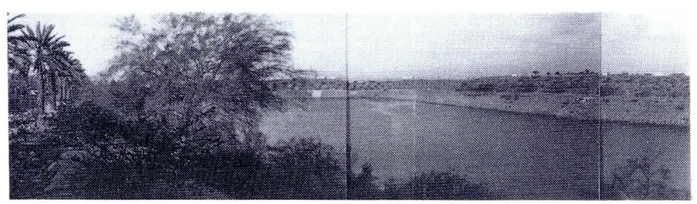




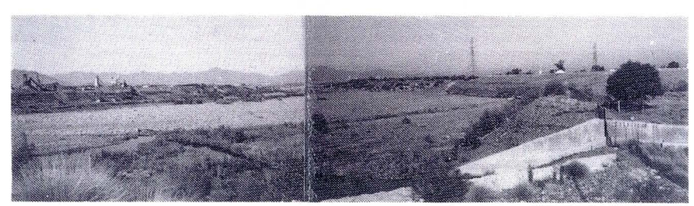
VIEW WEST FROM McCLINTOCK



VIEW FROM SOUTH BANK TOWARDS SKY HARBOR AIRPORT



VIEW OF OVERBANK RETENTION BASIN



VIEW OF CENTRAL AVE. DRAINAGE CHANNEL

LEGEND

- LANDFILL
- STORM DRAIN
- RIPARIAN SITE (#1-#28B)
- MATCHLINE
- 200 YR. FLOOD PLAIN
- CITY/ RESERVATION BORDER
- SAND/ GRAVEL OPERATION

EXISTING CONDITIONS

RIO SALADO
RECONNAISSANCE STUDY

NUVIS
LANDSCAPE ARCHITECTURE AND PLANNING
JOB NO. 94-217.01
CALIFORNIA 1226
9 / 26 / 94

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Figure 5.5B. Rio Salado Present Conditions.

Threatened and endangered species: Assessed value based on habitat suitability for the Yuma clapper rail, a federally listed endangered species. Areas with ponded water and stands of cattails were assessed a higher value.

Continual Water Source: Sites with visible water were assessed a value of 0.5, sites without water were assessed a value of 0.0. The team assumed that if water was present at the site then it was a reliable source present throughout the year, or most of the year. This assumption was made because the survey was conducted on the first two days in September, which is towards the end of the hot summer season, although monsoon rains do sometimes occur in September.

Bird/wildlife species present: Assessed value based on the wildlife species and sign observed during the survey.

Species composition: Assessed value based on the plant species present at the site with higher value given to areas of native plants, lower value given to areas dominated by invasive non-native plant species, primarily tamarisk.

Species density: Assessed value based on the percentage of vegetative ground cover present across all height classes. Cover was broken down into a percent scale and graded accordingly, below.

Height class (% of plants < 15' and % plants > 15'): For this category a scaled value was not assessed. Rather, the percentage of vegetation by foliage volume above and below 15 feet was determined. This percentage was later scaled along with the species composition and species density vales to determine a single habitat value for these criteria (see discussion below).

Disturbance within/adjacent to habitat: Areas with high levels of disturbance were assessed a low value while relatively undisturbed areas were assessed a high value. Disturbance included proximity of the site to urban or industrial areas, freeway and bridge over-crossings, sand and gravel operations, off-road vehicle use and illegal dumping. Undisturbed areas were those that appeared to have little human influence within or adjacent to the site.

The above criteria were developed by a riparian habitat team made up of personnel from the U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Arizona Game and Fish Department, Arizona Department of Environmental Quality, and the Flood Control District of Maricopa County. These criteria were applied to each of 28 sites visited by the riparian habitat team whereby an estimate of habitat value was determined and expressed in the form of habitat units. Habitat units serve as a combined measure of habitat quantity and quality of a given site and are used for comparative purposes. Estimates of habitat units are arrived at by multiplying the

habitat quality rating (on a scale of 0.0 to 1.0, with 1.0 being the highest value) by the number of acres of the site. Table 5.5 provides a summary of the present value of each site in terms of habitat units.

Tamarisk is the dominant habitat type, with over 900 acres located along the river under Without-Project (Present) Conditions. Approximately 780 acres of cottonwood/willow dominated habitat also exist in the study area. Freshwater-wetland-dominated habitat is limited, with approximately 18 acres in the study area, although this habitat type also exists in areas of cottonwood/willow-dominated habitat if adequate water is present.

Although tamarisk is the dominant plant community in terms of area, it has a much lower habitat value than cottonwood, willow, mesquite and other native species, although mature tamarisk stands provide some habitat value, most notably for doves. The habitat units associated with the cottonwood/willow habitat type exceed those of the tamarisk communities (305.8 habitat units for Tamarisk, 421.4 habitat units for Cottonwood/Willow). A reduction in tamarisk area would provide an opportunity for native species to increase.

The Tres Rios area downstream of 91st Avenue provides wetland and riparian habitat for numerous species of fish and wildlife, including waterfowl and Federal and State listed T&E Species. Both wetland and riparian habitats are disappearing at an alarming rate in Arizona and the Southwest. These habitats are used by a high percentage of Federal and state T&E species. For example, three pairs of Yuma clapper Rails (Rallus longirostris yumanensis), a Federally listed endangered species, were found nesting in the Tres Rios study area in 1991.

According to the USFWS, if the proper habitat was provided and managed for the Yuma clapper Rail, a significant increase in population would be expected in this area. The razorback sucker (Xyrauchen texanus), also an endangered species, was reintroduced in 1982 and could possibly still inhabit the area.

Table 5.5. Habitat Units for Without-Project (Present) Conditions by Habitat Type.			
Wetlands Dominant			
Site #	Area (In Acres)	Quality (0-1)	Habitat Units
5	6.61	0.46	3
25	11.2	0.74	8.3
Total	17.8		11.3
Tamarisk Dominant			
Site #	Area (In Acres)	Quality (0-1)	Habitat Units
2	54.5	0.18	9.8
8	12.6	0.32	4
10	147.4	0.2	29.5
11	53.8	0.24	12.9
12	34.4	0.24	8.3
16	180.5	0.29	52.3
18	12.2	0.43	5.3
21	117.4	0.34	39.9
24	20.8	0.22	4.6
28	348.1	0.4	139.2
Total	981.7		305.8

Table 5.5 (Cont). Habitat Units for Without-Project (Present) Conditions by Habitat Type.			
Cottonwood Willow Dominant			
Site #	Area (In Acres)	Quality (0-1)	Habitat Units
1	4.6	0.36	1.6
3	14.2	0.22	3.1
4	13.2	0.64	8.5
6	189.8	0.44	83.5
7	56.7	0.44	24.9
9	41.3	0.52	21.5
13	43.6	0.48	20.9
14	27.4	0.52	14.2
15	44.3	0.56	24.8
17	62.2	0.7	43.5
19	26.5	0.56	8.3
20	25.1	0.64	16.1
22	51.6	0.56	28.9
23	111.1	0.68	75.5
26	50.3	0.66	33.2
27	17.9	0.72	12.9
Total	779.8		421.4

The area downstream of 91st Avenue has undergone change in the last 10 to 15 years. A 1,000 foot wide channel clearing passes through the study area. While vegetation patterns have been modified by the clearing, habitat impacts have been mitigated. The Arizona Department of Game and Fish owns or manages several hundred acres in the area as this area is considered important for fish and wildlife resources, including T&E species.

The manner in which the issues of water quality and possible elimination of wastewater discharge into the Salt River are resolved could have a serious impact on riparian habitat including that of the Yuma clapper Rail. While phreatophytes are expected to continue to occupy the channel due to the high groundwater table in the study area, the cattail/bulrush communities which support habitat for the Yuma clapper Rail are more dependent upon surface flows. While other, less regular flows occur in the channel, such as upstream dam releases and agricultural tail water runoff, it appears that effluent from 91st Avenue plant plays a major role in supporting riparian habitat, especially the cattail/bulrush marsh communities which are directly supported by the continuous surface flows.

Riparian Habitat

There are currently 1,780 acres of riparian habitat in and along the Salt River through the study reach. Present water sources for these areas are sewage treatment plants and storm drain runoff, both of which may diminish or disappear in the near future. By using storage, skimming, and wetlands treatment for storm drain water, and/or wetlands treatment for sewage treatment plant water, many if not all of these areas could be preserved. The potential water demand to maintain habitat in all 1,780 acres ranges from a 4,300 acre-feet per year (3.84 MGD) to support Honey Mesquite habitat to almost 11,000 acre-feet per year (9.82 MGD) to support Bermuda and Rye Grass habitat.

The average annual total storm drain volume from the City of Phoenix is approximately 18,000 acre-feet per year. City of Tempe storm drains deliver approximately 11,000 acre-feet per year. However, stormwater flows are seasonal, unpredictable and flashy and cannot be relied upon as

a constant, reliable water source. A prudent habitat plan would account for years with less flow or provide supplemental water from pumping.

Sport Fisheries

Fishing currently occurs primarily at and downstream of the 91st Avenue Wastewater Treatment Plant. Upstream of this point there is not sufficient water to support fish, although the Arizona Game and Fish Department is actively pursuing a sport fisheries program.

Arizona's urban fishing program was first evaluated in the late 1970's (Edwards and Okamoto, 1980), and became a regular program of the Arizona Game and Fish Department in 1983. The program is a cooperative venture between the Department and municipalities, with urban fishing license sales and city grants ($560/acre of water) financing the management of the lakes. The lakes are stocked 26 times per year (Watt, 1986) with rainbow trout (November through March) and channel catfish (April through October). The lakes are managed on at put-and-take basis, with the expectation that virtually all of the stocked fish will be harvested (76% harvest rainbow trout; 87% harvest channel catfish (Watt and Parsons, 1990). The goal of the program has been to provide a local recreational fishery to urban residents and a site where urban youth can be introduced to sport fishing (Watt and Persons, 1990). These are currently 12 lakes in the Tucson and Phoenix metropolitan areas in the program (a 13th will be added in February 1995), ranging in size from 3 acres to 25 acres in size (Watt and Persons, 1990; AGFD Fisheries Branch, pers. com. 1994).

Licensing to fish in an urban lake is specific to the program. Urban anglers purchase a special license, and a general fishing license is not required. Youth under 14 and Pioneer license holders do not require an urban fishing license. Income form the city grants is managed in a Urban Trust Fund, and those monies may only be expended for the Urban Fishing Program.

License sales have climbed steadily since 1983, and appear to be related to the number of acres of urban fishing opportunity available (Watt, 1985; Watt and Persons, 1990). Urban lakes have demonstrated the highest angler use measured in Arizona, ranging from 3 angler hours per acre

per day to 96 angler hours per acre per day (Watt, 1986). Watt and Persons (1990) reported an average of 2 anglers observed per acre at urban lakes based upon instantaneous angler counts. Based upon all surveys (including incomplete trips) they estimated a total of more than 700,000 angler hours per year (or about 7,000 angler hours of recreation per acre per year) on the urban lakes. Using average duration of completed trips (4.6 hours), they estimated total use at just over 1 million angler hours.

The majority of the fishes currently managed in Arizona for sport purposes are nonnative (the exception being native Apache trout and roundtail chub). Prior to modification of Arizona's rivers and native fish community, a variety of native fishes were likely common to the Salt river valley in what is now the metropolitan area (Minckley, 1973). Desert and Sonora suckers (Catostomus Clarki and Catostomus insignis) were likely common, and currently are still rather common in the Salt and Verde rivers above Granite Reef Diversion Dam. Roundtail Chub (Gila robusta) and long fin dace (Agosia chrysogaster) were also likely be common, Roundtail chub is species (Category 2). Razorback sucker (Xyrauchen texanus), Colorado squawfish (Ptychocheilus lucius), spike dace (Meda fulgida), woundfin (Plagopterus argentissimus), loach minnow (Rhinichthys cobitis) and Gila topminnow (Pociliposis occidentalis), all listed as Federal Threatened or Endangered Species, also like made up part of the historic fish fauna of the lower Salt river. This fish fauna has been radically modified due to modification of stream hydrology (habitat modification) and introduction of nonnative fishes (predation and competition).

5.2.3 Future Without Project Conditions

Riparian habitat is dependent upon development disturbances and the availability of water. Present and future trends expected to affect riparian vegetation are as follows:

1. The City of Phoenix is proceeding with an aquifer recharge plan which will eliminate secondary discharges of wastewater effluent into the Salt River. This program particularly affects discharges from the 91st Avenue wastewater treatment plant. Riparian habitat and wildlife are expected to be significantly reduced as a result of this program.

2. Development within the Salt River floodplain can occur up to the regulatory floodway limits. Riparian vegetation outside of the floodway will be lost. The City

of Phoenix is currently planning annexations and expanded development in the Laveen area at the southwestern portion of the City.

3. Agricultural uses along the project area are being reduced by development. This reduction will be most pronounced in the southwestern portion of the City (lower Rio Salado study area). As agricultural uses decline, so will the availability of irrigation-related runoff into the river.

4. Storm water flows currently enter the river from the adjacent urban areas and from upstream. Most river flows are diverted out of the river for water supply upstream, but large flows originating on the Salt and Verde Rivers are allowed to flow through. Current modifications to Roosevelt Dam will probably result in reduced flood flows on the river, but the exact impact is unknown at this time. Local stormwater inflows are expected to continue, but could be reduced due to detention and recent Federal clean water requirements. It is assumed for purposes of this study that storm-water inflows will remain relatively constant over the next ten years, but it is possible that they could be reduced, if not eliminated, to comply with future NPDES requirements.

5. The Flood Control District of Maricopa County in the past maintained a 1,000-foot-wide clearing for flood-control purposes within the study area. Vegetation within this clearing was periodically removed to permit the unobstructed flow of flood waters. This maintenance has been discontinued pending recommendations from a management policy study currently underway.

Table 5.6 illustrates the estimated habitat areas and units associated with future-without-project conditions estimated based on assumptions #1 to #5 above. Table 5.7 provides a summary of present and future-without-project conditions for each of the three major habitat types. Figures 5.6 and 5.7 illustrate the present and future-without-project habitat conditions in graphical form.

A significant loss of habitat area and value is expected over the next ten years. Removal of treated wastewater flow and reduction of agricultural runoff will reduce the extent and quality of the vegetation currently relying on these sources. If flood control maintenance of the 1,000-foot clearing continues, it would have an impact on existing vegetation. A reduction in habitat quality, with a concomitant reduction in associated habitat units, is expected for future without project conditions. In all, a 55% reduction in total habitat units is expected. Wetlands, with a very high habitat value per unit area, will be the most affected in terms of relative loss in value, with an 80% loss.

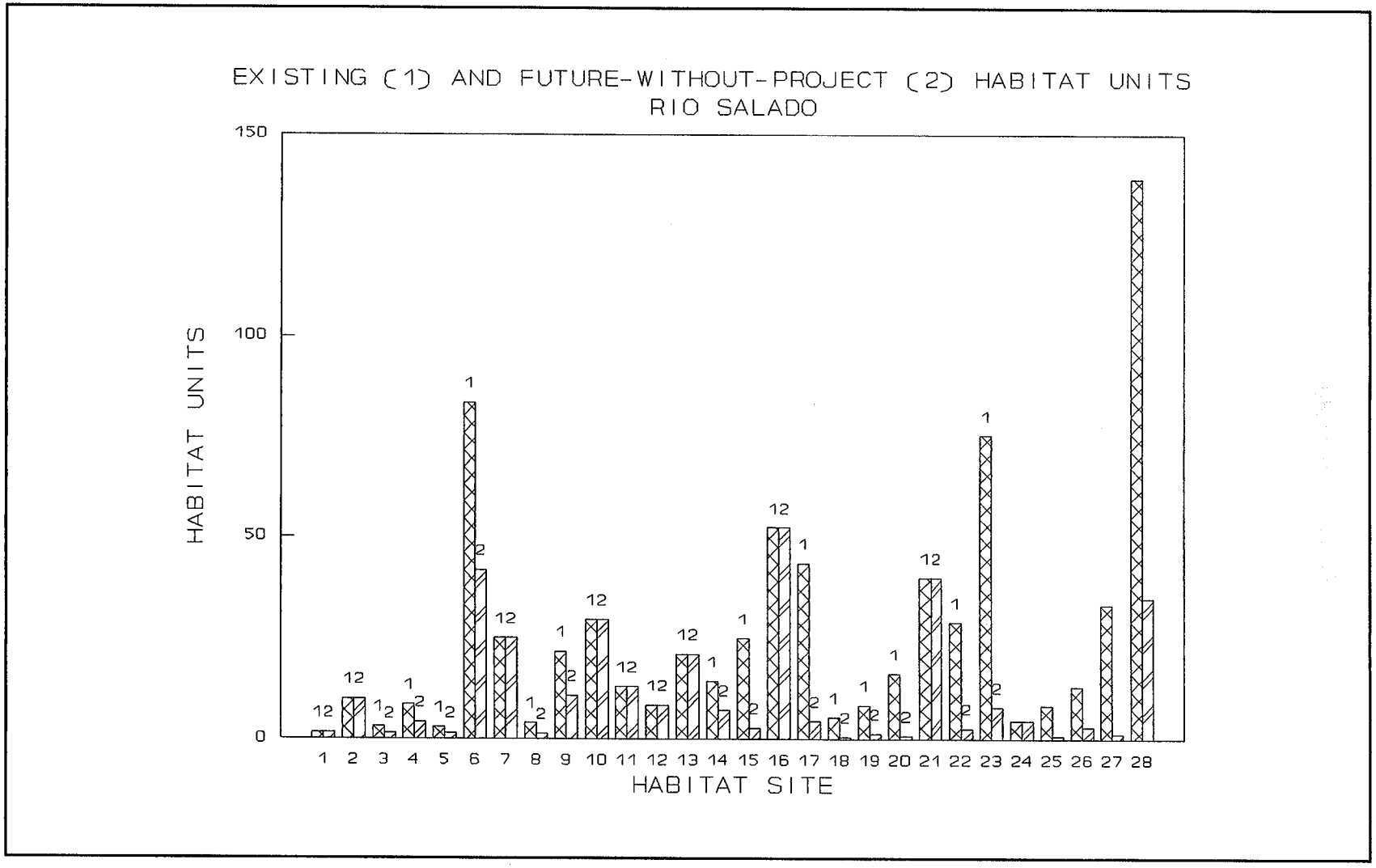


Figure 5.6. Present and Future, Without-Project Habitat Units According to Identified Habitat Site.

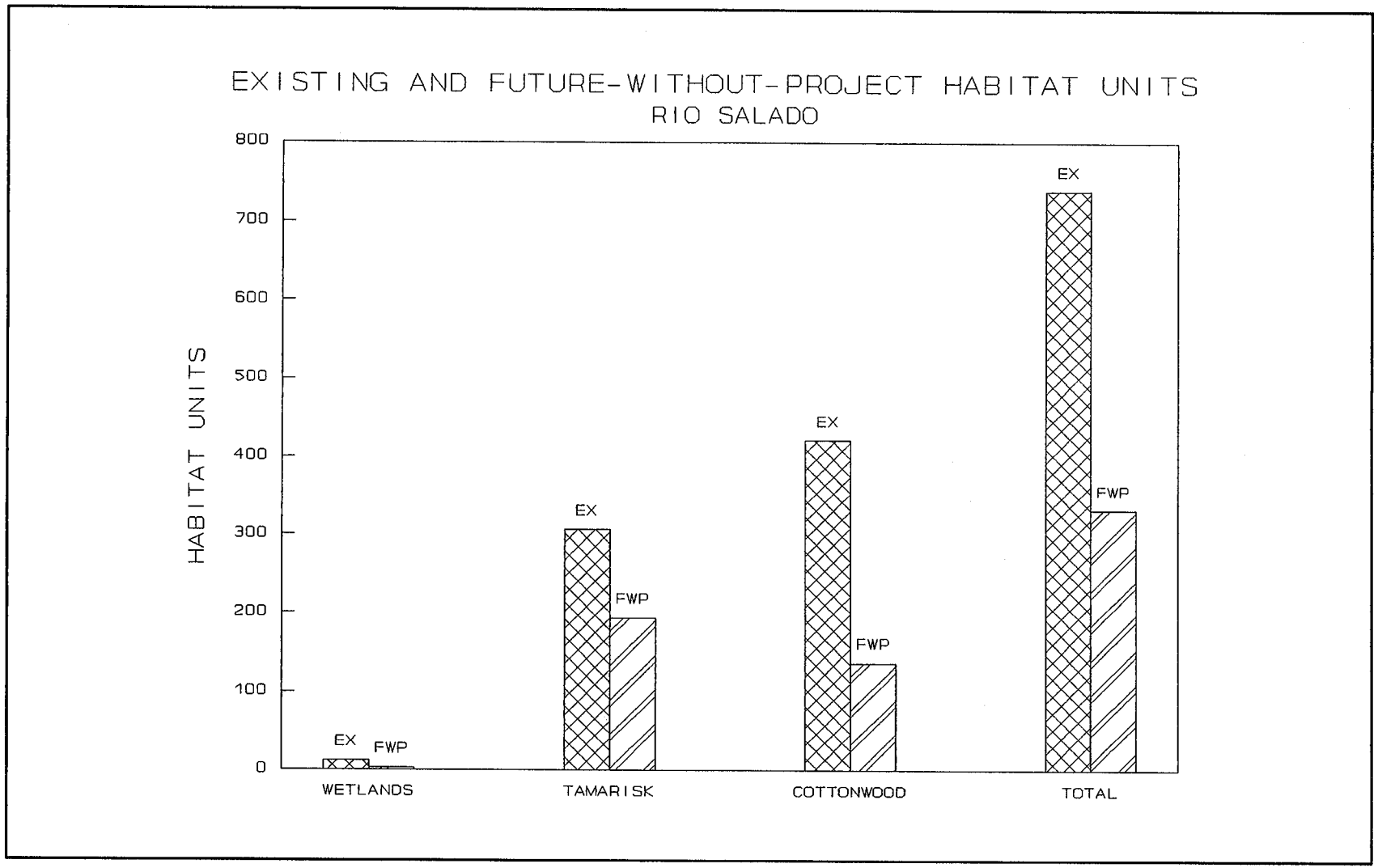


Figure 5.7. **Present and Future, Without-Project Habitat Units According Habitat Type.**

Table 5.6. Habitat Units for Future Without Project Conditions.				
Wetlands Dominant				
Site #	Area (Acres)	Quality (0-1)	Habitat Units	Water Source/Impact
5	6.6	0.23	1.5	Agricultural
25	11.2	0.07	0.8	Wastewater/Flood control maint.
Total	17.8		2.3	
Tamarisk Dominant				
Site #	Area (Acres)	Quality (0-1)	Habitat Units	Water Source/Impact
2	54.5	0.18	9.8	Water unknown/no disturbance expected
8	12.6	0.10	1.3	Water unknown/currently water stressed
10	147.4	0.20	29.5	Currently no water/no change
11	53.8	0.24	12.9	Currently no water/no change
12	34.4	0.24	8.3	Currently no water/no change
16	180.5	0.29	52.3	Currently no water/no change
18	12.2	0.04	0.5	Wastewater/Flood control maint.
21	117.4	0.34	39.9	Groundwater-Gila River/No disturbance expected
24	20.8	0.22	4.6	Upper Terrace/No disturbance expected
28	348.1	0.10	34.8	Wastewater
Total	981.7		193.3	

Table 5.6 (Cont). Habitat Units for Future Without Project Conditions.				
Cottonwood Willow Dominant				
Site #	Area (Acres)	Quality (0-1)	Habitat Units	Water Source
1	4.6	0.36	1.7	Stormwater
3	14.2	0.10	1.4	Wastewater
4	13.2	0.32	4.2	Agricultural
6	189.8	0.22	41.8	Water source unknown/Currently drought stressed
7	56.7	0.44	24.9	Water source unknown
9	41.3	0.26	10.7	Agricultural
13	43.6	0.48	20.9	Currently no water/no change
14	27.4	0.26	7.1	Agricultural
15	44.3	0.06	2.7	Wastewater/Flood control maint.
17	62.2	0.07	4.4	Wastewater/Flood control maint.
19	26.5	0.05	1.3	Wastewater/Flood control maint.
20	25.1	0.03	0.8	Wastewater/Flood control maint.
22	51.6	0.05	2.6	Wastewater/Flood control maint./future bridge crossing
23	111.1	0.07	7.8	Wastewater/Flood control maint./future bridge crossing
26	50.3	0.06	3.0	Wastewater/Flood control maint.
27	17.9	0.07	1.3	Wastewater/Flood control maint.
Total	779.8		136.6	

Table 5.7. Comparison of Riparian Habitat Conditions for Present and Future-Without-Project Conditions.						
Habitat Type	Present Area (In Acres)	Future-Without-Project Area (In Acres)	Percent Difference in Area	Present Habitat Units	Future-Without-Project Habitat Units	Percent Difference in Habitat Units
Wetlands	17.8	17.8	0%	11.3	2.3	-80%
Tamarisk	981.7	981.7	0%	305.8	193.3	-37%
Cottonwood	779.8	779.8	0%	421.4	136.6	-68%
Total	1,779.3	1,779.3	0%	738.5	332.2	-55%

In the future without project conditions the cottonwood/willow habitat is more severely affected then the tamarisk plant community. This is due to an anticipated reduction in the availability of water. Some of the tamarisk is located on flood terraces above the river channel, and away from present surface water. These plants are supported by groundwater. Because of this, these plant communities will be less affected by the reduction in wastewater, agricultural water, and the expected flood control maintenance.

In contrast to tamarisk, portions of the cottonwood/willow community are located on lower flood terraces and in the river along present surface water. These species are more affected by a reduction in water than tamarisk. In general, sites located downstream of the 91st Avenue wastewater treatment plant represent much of the highest quality cottonwood/willow habitat along the river. Tamarisk is present in these sites as well. These areas would be severely impacted by the removal of wastewater flows. Comparing Without-Project (Present) Conditions to future without project conditions shows a loss of 284.8 habitat units for the cottonwood/willow habitat type.

In the absence of a continuous water source in the river channel, riparian habitat within the sonoran desert ecosystem is expected to be severely impacted, including that of the Yuma clapper Rail, a Federally-listed threatened and endangered species. The USFWS has taken the position that a loss of these flows would result in the loss of most of the wetland and riparian habitats and the fish and wildlife populations they support.

The concern for wildlife habitat in the study area is further compounded by a water quality issue involving the City of Phoenix, the U.S. Environmental Protection Agency (EPA), the Arizona Department of Environmental Quality (ADEQ), the Arizona Game and Fish Department, and environmental interests. A water source supporting riparian habitat in the study area is secondary effluent from the 91st Avenue waste water treatment plant. The plant is operated by the City of Phoenix in conjunction with the Sub-Regional Operating Group (SROG) cities. Current plans may involve the elimination of this water source.

Current capacity of the 91st Avenue Wastewater Treatment Plant is 153 Million Gallons per Day (MGD). Contractual agreements for this effluent require the City to provide a maximum of approximately 123 MGD to the Palo Verde Nuclear Generating Power Plant (actual use rates range between 0 MGD on a frequent basis to a peak of 90 MGD which is very rare). A second contract exists with the Buckeye Irrigation Company which uses approximately 31.5 MGD. These flows are deliverable through an existing pipeline. At present, only Palo Verde Nuclear Plant flows use the pipeline. The Buckeye Irrigation Company currently takes its water from the natural channel through a diversion structure on the Gila River.

Proposed Surface Water Quality Standards (SWQS) and National Pollutant Discharge Elimination System standards administered by ADEQ and EPA, respectively, have prompted the City of Phoenix to conduct an analysis of the costs of upgrading the facility to meet these new discharge requirements. Current estimates include plant upgrades amounting to $350,000,000. The SROG cities evaluated the costs of moving forward with a plan for total reuse of the effluent through an aquifer recharge program rather than bearing the high costs of upgrading the present facility. The estimated cost of a groundwater recharge project is $150,000,000. While this project would

provide a future water supply, discharges into the Salt River would be eliminated. A discontinuation of waste water discharge will impact riparian habitat, including that of the Yuma clapper Rail. The manner in which the water quality issue is resolved will have a direct bearing on wildlife issues downstream of 91st Avenue.

The Bureau of Reclamation is conducting a Water Reclamation and Reuse Study in cooperation with the City of Phoenix. The objective of the study is to evaluate methods for reclaiming water from sewage effluent from the greater metropolitan area of Phoenix. A demonstration project consisting of 31 acres located at two sites adjacent to the 91st Avenue Wastewater Treatment Plant is being planned to test the capability of constructed wastewater treatment wetlands to treat the present effluent to levels that will satisfy expected 1997 NPDES permit requirements. In addition to obtaining a greater understanding of the capabilities of constructed wetlands, riparian habitat and water quality benefits are also expected to be provided by this project.

5.2.4 Opportunities

The primary constraint for the existence of cottonwood/willow, wetland habitat and wetlands along the river is the availability of water. It is essential to secure a water source in order to promote these habitat types within the study area. Once a water source has been identified species manipulation in the form of native species planting, and/or ruderal species removal can be accomplished. Endangered species restoration for the Yuma clapper rail could be done through the creation of freshwater ponds and marsh areas. Other restoration opportunities include the construction of wetlands for wastewater polishing.

Constructed wetlands offer a variety of habitat restoration and water quality opportunities for treating/polishing effluent from wastewater treatment plants, stormwater runoff, agricultural tailwater discharges, and contaminated groundwater.

The Indian Bend Wash through the City of Tempe contains a low-flow channel through a golf course between McKellips Road and Curry Road. This low-flow channel is approximately 14

acres in size and, if supplied with a reliable water source, provides an opportunity for establishment of wetlands.

Between Curry Road and the confluence with the Salt River, the Indian Bend Wash is virtually unimproved except as a flood-control structure. The low-flow channel continues for approximately 1,300 feet downstream of Curry Road, where it abruptly spreads to cover the entire channel width of 700 feet. Adjacent to, and approximately 5 feet above, the low flow channel, on both sides, is a wide, flat terrace of bare earth. Figure 5.8 shows the topography of the Indian Bend Wash Between Curry Road and the Salt River confluence. Figure 5.9 is a photograph showing this portion of the channel during a small runoff event. The water in the photograph marks the location of the low-flow channel.

The portion of the Indian Bend Wash between Curry Road and the Salt River provides an excellent opportunity for the establishment of wetlands in the low-flow channel and mesquite bosque on the in-channel terrace. There are currently two healthy mesquite trees on the terrace, indicating that the area is suitable habitat.

The City of Tempe has a well, referred to as Well #6, west of the Indian Bend Wash and South of McKellips Road. This well is contaminated with Trichloroethylene (TCE) to the point where the water cannot be used for drinking water, but it can be used for recreation-related river or lake water. The well has capacity for approximately 3 million gallons per day, and is not currently being used by the City other than for quarterly testing of water quality and groundwater levels. There is an opportunity to use this well to supply water to wetlands and riparian habitat in the Indian Bend Wash and Salt River.

An opportunity has been identified for a constructed wetlands in the area of the 91st Avenue Wastewater Treatment Plant and extending downstream through the confluence of the Salt, Gila and Agua Fria Rivers to the site of the Buckeye Irrigation District diversion (approximately seven miles). A constructed wetlands at this location, referred to as Tres Rios, would provide the following water resource opportunities: flood control, habitat diversity, Threatened and

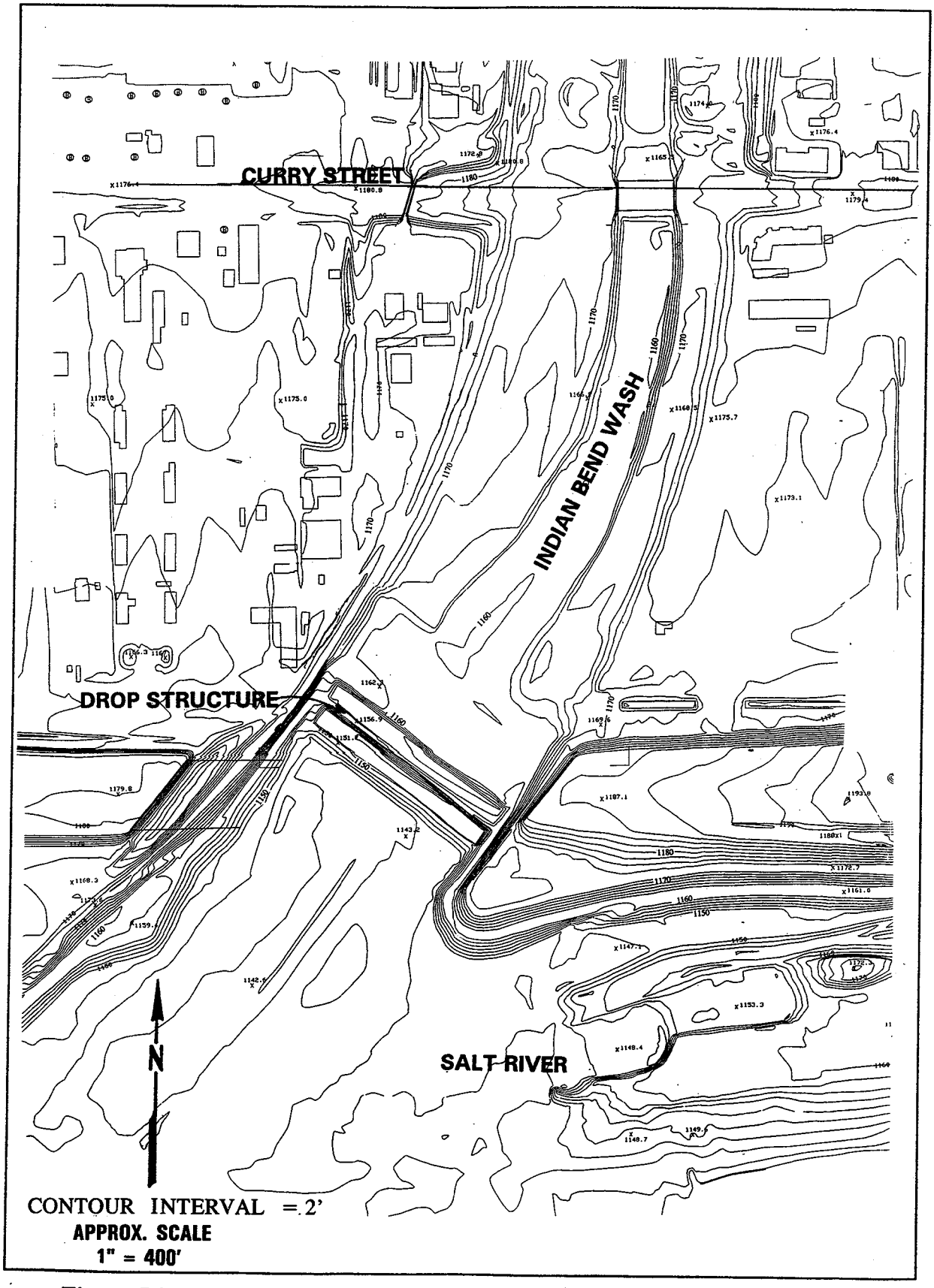
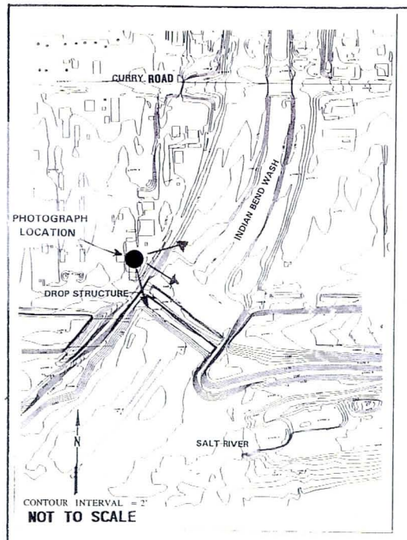


Figure 5.8. **Topography of Indian Bend Wash Between Curry Road and Salt River Confluence.**



Matches With Left Side Below

Matches With Right Side Above

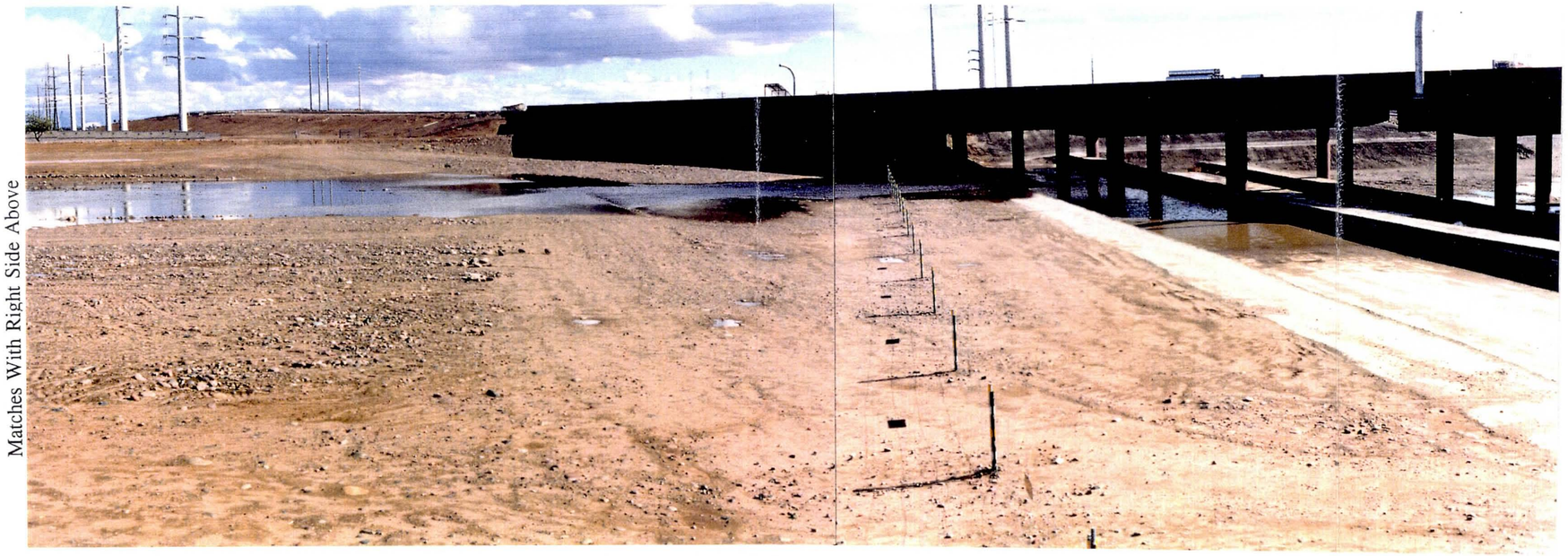


Figure 5.9. **Photograph of Indian Bend Wash Between Curry Road and Salt River Confluence.**

Endangered Species habitat (Yuma clapper Rail), water quality and recreation. While this opportunity exists, the Bureau of Reclamation in conjunction with the City of Phoenix is conducting the Phoenix Water Reclamation and Reuse Study and an alternative that is being investigated is a constructed wetlands at Tres Rios. The decision to proceed will be based on the conclusions of the 31-acre demonstration project described above. At this point in time the Corps of Engineers will not proceed with an investigation of a constructed wetlands at Tres Rios.

Development of a constructed wetlands at the 23rd Avenue Wastewater Treatment Plant is also an opportunity for habitat restoration and sustenance of present habitat downstream of the Plant that is currently supported by effluent discharged from the plant. A multi-purpose wetlands would polish effluent while restoring/maintaining habitat.

Stormwater inflows, stored in present sand and gravel pits provide another water-supply opportunity for habitat. The gravel pits also provide an excellent opportunity for construction of wetland habitats which could be used as water purification and storage areas. Discharges from the wetlands could be used to supply water-related recreation (lakes) or to feed cottonwood/willow habitats in or adjacent to the channel. This opportunity has particular significance in the area between 24th Street and 19th Avenue where the City of Phoenix has been planning a Lago de Vida concept Lake similar to the Town Lake currently being pursued by the City of Tempe. There are five major off-channel gravel pits in this area which have been identified as potential wetland habitats supplied by pumped groundwater and stormwater runoff.

Agricultural tailwaters contribute greatly towards sustaining riparian habitat. These discharges could be treated through constructed wetlands and discharged into the Salt River at a higher quality. Numerous locations have been identified along the Salt River, west of 59th Avenue.

An additional opportunity for habitat restoration is to create a self maintaining more "natural" habitat (habitat that would not require a human-manipulated water source to survive). Plants would be maintained for an establishment period only until they are self sustaining. This can be accomplished by using plant species appropriate for the elevation along the river (river channel,

first or second flood terrace above the river), and by using plants suitable for the water availability, either ground or surface water.

Riparian habitat restoration also provides the opportunity for the establishment of open water habitat for waterfowl and fish. A variety of fish species lived in the Salt River prior to the establishment of dams and agriculture upstream. Although it may not be possible to re-create pre-historic conditions, fish and waterfowl habitat can be created in lakes in or adjacent to the river channel.

Native fishes of the Southwest are a rare resource. Creating open water habitats for native fishes could provide a number of opportunities. Rearing and refuge areas could be developed as part of a Rio Salado project. Open water areas and reservoirs (abandoned gravel pits outside of the flood channel) could be utilized for restoration, experimentation, or environmental interpretation for native fishes.

There are many constraints to using the area as a restoration or refugium site, not the least of which is the federal status of many of the native fishes. If listed fishes were stocked as part of a Rio Salado project, they would be afforded the full protection of the Endangered Species Act. The only exception to this would be the opportunity to list re-introductions in the vicinity as "Experimental, Non-essential" under Section 10 of the Act. This requires a rule-making action on the part of the US Fish and Wildlife Service, and one that seems unlikely at this juncture.

It would not be possible to ensure the security of reintroduced stocks of native fishes. Native and nonnative fish interactions are an important constraint on the recovery of native fishes. The sites that would provide some opportunity for reintroduction in the Rio Salado Study area are highly modified and subject to continued human modification. Clearly, it is not possible to restore the historic hydrology (annual floods and perennial flow) of the lower Salt River through a Rio Salado project. Also, the removal of the influence of nonnative fishes from the river corridor is not likely. There could, however, be opportunities to work with fishes that are not yet listed

or to work in sites that are isolated from frequent influences by floods (gravel pits that may be serving as reservoirs for Rio Salado/Lago de Vida lakes).

5.3 Water Quality

5.3.1 Without-Project (Present) Conditions

Urban Storm Runoff

The Phoenix metropolitan area has a hot arid climate with an average annual rainfall of about 7.6 inches. Most of the precipitation occurs in two distinct seasons, summer (July through September) and winter (December through March), and is about equally divided between them. Figure 5.10 shows the monthly distribution of rainfall. Monthly, seasonal, and annual precipitation amounts vary considerably from year to year. During any season there may be long periods of no rainfall or local runoff.

The major sources of urban storm water in the Rio Salado study area are from the many storm drains which have outfalls to the Salt River. There are more than 50 storm drains with outfalls to the Salt River in Phoenix. These drains collect runoff from over 100 mi^2. In Tempe, six major urban watersheds with outfalls to the river were identified. Indian Bend Wash, Price Road drain, Farmer Avenue drain, Scottsdale Road drain, Dobson Road drain, and Pima Freeway drain, represent the major urban watersheds with a combined drainage area of about 267 mi^2. All of the outfalls within the study area are shown on Figure 5.5, 5.11 and 5.12.

The single largest tributary watershed is Indian Bend Wash with a drainage area of about 120 mi^2 below the Granite Reef Aqueduct. The wash was improved for flood control as part of a Corps project and is now a greenbelt with a system of parks, golf courses, and lakes. The 100-year and 10-year discharges for Indian Bend Wash are 30,000 cfs and 8,000 cfs, respectively.

Very little information is available regarding the quantity of urban storm runoff in the Phoenix area. For purposes of this study, a rough estimate of the quantity of urban storm runoff in terms of annual runoff and runoff resulting from the 10-yr, 24-hr storm was made using rainfall,

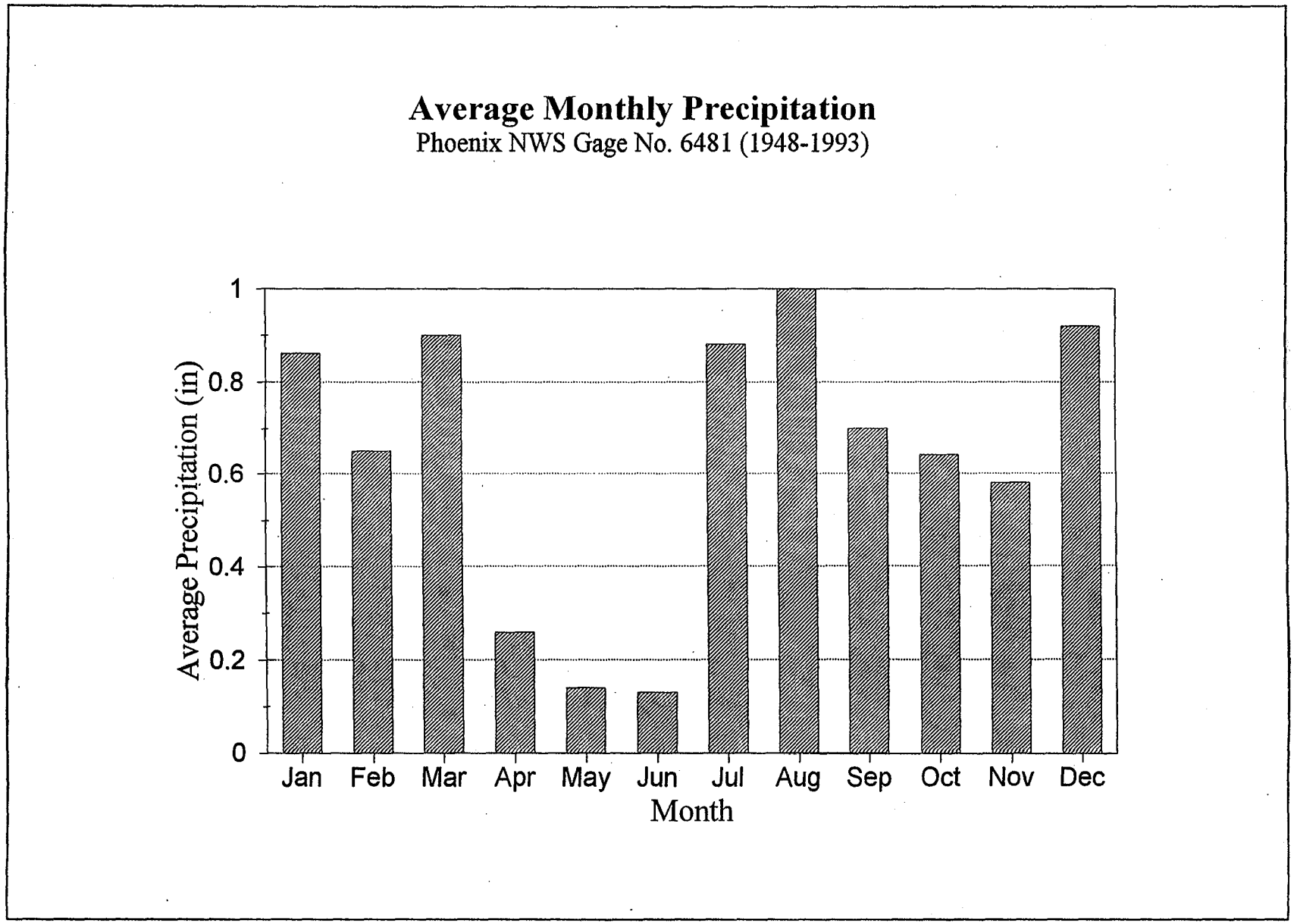


Figure 5.10. **Average Monthly Precipitation for Phoenix Area**

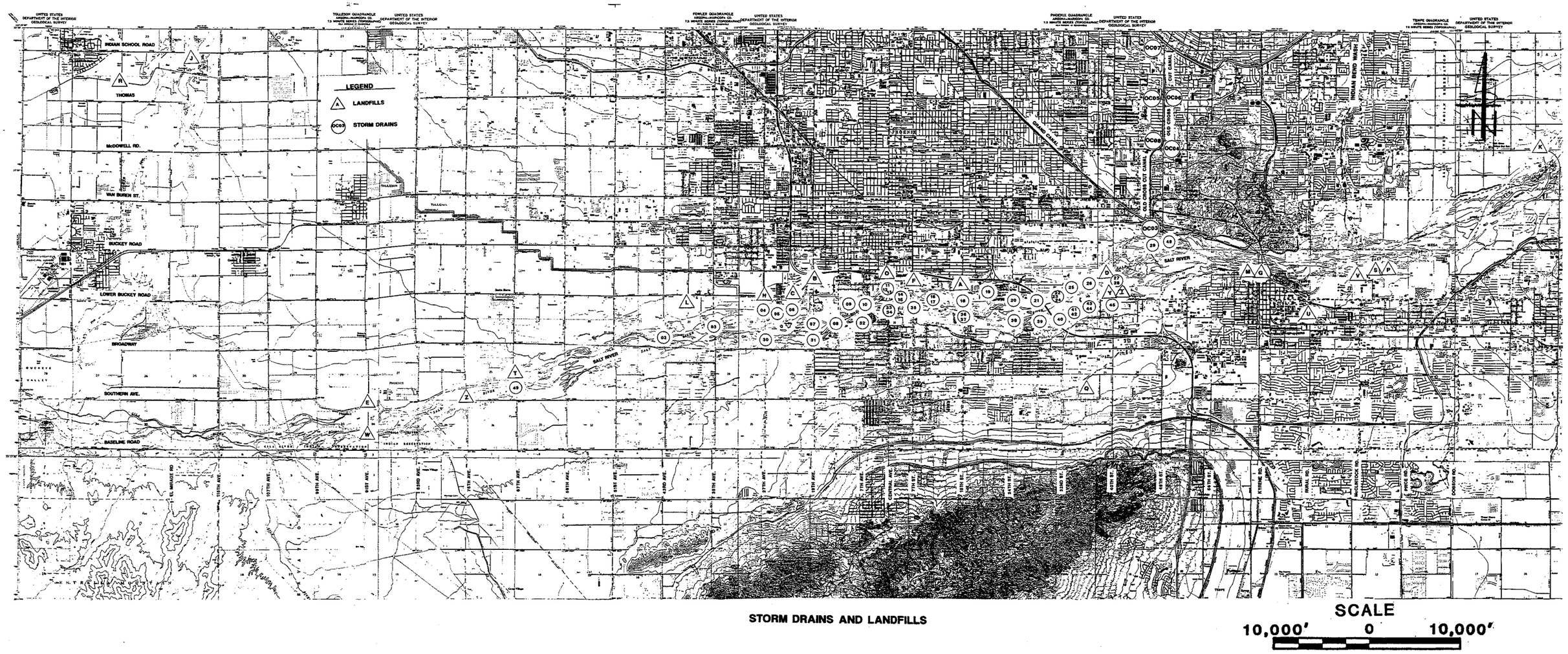


Figure 5.11. **Storm Drains and Landfills along Rio Salado Study Area**

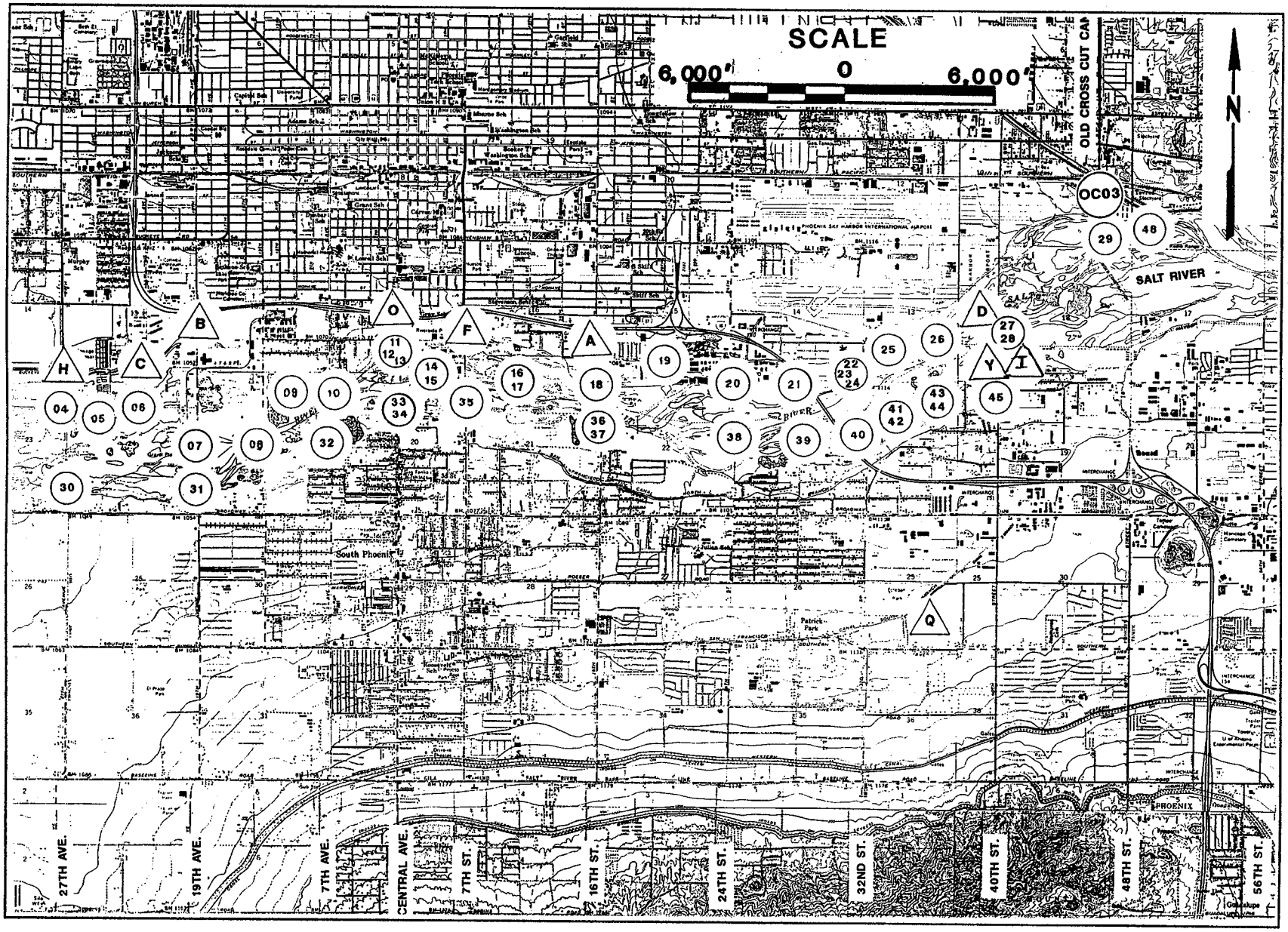


Figure 5.12. **Storm Drains and Landfills along Rio Salado at Central Phoenix.**

drainage area, land use and other runoff characteristics obtained from the Cities of Phoenix and Tempe. The runoff estimates are presented in Tables 5.8 and 5.9.

Two of the Tempe urban watersheds, Indian Bend Wash and the Price Road Tunnel, have storage capacity which may significantly reduce runoff. Indian Bend Wash has a series of lakes, with a total surface area of about 200 acres and about 1,500 ac-ft of storage. The Price Road tunnel is a 15,700-foot siphon with a storage capacity of about 118 ac-ft. For this analysis, these storage volumes are considered to be unavailable during storm runoff.

Discharges of Treated Wastewater

The 23rd Avenue Wastewater Treatment Plant treats 30 MGD with advanced secondary treatment and dechlorination. By 1994, it will have the capacity to treat 57 MGD this way. Sand filtration facilities are also being constructed at the plant.

Currently about 50% of the discharge from the 23rd Avenue Wastewater Treatment Plant is being diverted by a local farmer. The remaining water goes to the Salt River. This farmer uses what is needed, and then discharges the rest into the Salt River at 43rd Ave. Roosevelt Irrigation District (RID) is also working with the City to purchase (exchange) water from this treatment facility. When this occurs, the entire outflow will probably be used for irrigation during periods of high crop water demand. During October through February, however, most of the water has been discharged into the Salt River. Thus, the 57 MGD has been discharged into the Salt River during approximately 5 months out of 12. During the remaining months, the discharge may not occur.

Current capacity of the 91st Avenue Wastewater Treatment Plant is 153 Million Gallons Per Day (MGD). Contractual agreements for this effluent require operators to provide a maximum of approximately 123 MGD to the Palo Verde Nuclear Generating Power Plant (actual use rates range between 0 MGD, on a frequent basis, to a peak of 90 MGD which is very rare). A second contract is with the Buckeye Irrigation Company which uses approximately 31.5 MGD. These flows are deliverable through an existing pipeline. At present, only Palo Verde Nuclear Plant

Table 5.8 (Page 1 of 3). Hydrologic Characteristics and Runoff Estimates City of Phoenix Storm Drains.

Drain ID	Drainage Area (mi^2)	Land Use			Runoff Coefficient	Average Annual Runoff (ac-ft)	10-yr 24-hr Storm Runoff (ac-ft)
		Urban (%)	Agriculture (%)	Open Space (%)			
SR01	3.32	50	30	20	0.49	589	209
SR02	3.38	84	5	11	0.64	775	275
SR03	2.90	81	8	11	0.45	473	168
SR04	4.47	77	14	9	0.49	788	279
SR05	2.82	82	6	12	0.67	681	242
SR06	7.45	94	1	5	0.45	1208	428
SR07	0.92	94	3	3	0.64	214	76
SR08	5.69	85	3	12	0.41	844	299
SR09	9.23	98	1	1	0.62	2048	726
SR10	1.46	94	0	6	0.44	230	81
SR11	0.08	100	0	0	0.84	25	9
SR12	0.28	100	0	0	0.47	48	17
SR13	13.89	95	0	5	0.33	1644	583
SR14	0.12	100	0	0	0.74	32	11
SR15	1.93	94	0	6	0.43	301	107
SR16	0.08	100	0	0	0.85	25	9
SR17	1.14	90	0	10	0.58	239	85
SR18	4.20	99	0	1	0.57	858	304
SR19	3.85	85	0	15	0.48	662	235
SR20	5.40	90	0	10	0.44	853	302
SR21	0.98	95	0	5	0.90	318	113
SR22	0.74	100	0	0	0.90	240	85

Table 5.8 (Page 2 of 3). Hydrologic Characteristics and Runoff Estimates City of Phoenix Storm Drains.							
Drain ID	Drainage Area (mi^2)	Land Use			Runoff Coefficient	Average Annual Runoff (ac-ft)	10-yr 24-hr Storm Runoff (ac-ft)
		Urban (%)	Agriculture (%)	Open Space (%)			
SR23	0.14	80	0	20	0.80	41	14
SR24	4.24	86	0	14	0.36	548	194
SR25	0.20	0	85	15	0.84	61	21
SR26	0.02	77	0	23	0.78	6	2
SR27	3.04	87	0	13	0.35	389	138
SR28	0.17	100	0	0	0.90	54	19
SR29	0.50	32	0	68	0.33	60	21
SR30	2.38	18	82	0	0.24	209	74
SR31	2.86	47	32	21	0.22	228	81
SR32	1.42	76	11	13	0.38	195	69
SR33	1.32	85	0	15	0.43	206	73
SR34	0.04	74	0	26	0.47	7	2
SR35	2.34	65	5	30	0.29	247	88
SR36	1.90	67	5	28	0.25	170	60
SR37	0.60	85	0	15	0.44	95	34
SR38	1.80	56	49	5	0.22	141	50
SR39	4.34	68	23	9	0.39	607	215
SR40	0.50	85	0	15	0.64	115	41
SR41	0.06	95	0	5	0.67	14	5
SR42	0.22	90	0	10	0.65	51	18

Table 5.8 (Page 3 of 3). Hydrologic Characteristics and Runoff Estimates City of Phoenix Storm Drains.

Drain ID	Drainage Area (mi^2)	Land Use			Runoff Coefficient	Average Annual Runoff (ac-ft)	10-yr 24-hr Storm Runoff (ac-ft)
		Urban (%)	Agriculture (%)	Open Space (%)			
SR43	0.02	100	0	0	0.70	5	2
SR44	0.13	100	0	0	0.70	3	1
SR45	1.24	90	0	10	0.50	226	80
SR46	*	*	*	*	*	*	*
SR47	*	*	*	*	*	*	*
SR48	*	*	*	*	*	786	--*
SR49	7.40	*	*	*	0.29	27	279
OC01	0.13	*	*	*	0.60	18	10
OC02	0.21	*	*	*	0.24	85	6
OC03	0.39	*	*	*	0.60	95	30
OC04	0.75	*	*	*	0.35	35	34
OC05	0.25	*	*	*	0.39	34	13
OC06	0.32	*	*	*	0.30	52	12
OC07	0.43	*	*	*	*	*	18
OC08		*	*	*	*	*	*
TOTALS	111.13					17,600	6200

* Data Unavailable

Data Sources: Land Use, Drainage Area, and Runoff Coefficients from City of Phoenix. 10-yr 24-hr Rainfall of 2.4 inches from NOAA Atlas II

Table 5.9. Hydrologic Characteristics and Runoff Estimates: City of Tempe Drainage Basins.

Basin	Drainage Area (mi^2)	Land Use			Runoff Coefficient	Average Annual Runoff (ac-ft)	10-yr 24-hr Storm Runoff (ac-ft)
		Urban (%)	Agriculture (%)	Open Space (%)			
DO-1	21.3	89	5	6	0.03	222	79
PI-1	7.6	3	97	0	0.02	58	21
PI-2	10.0	5	95	0	0.00	13	5
Sub-total	17.6				0.01	71	105
PR-1	1.6	100	0	0	0.33	211	75
PR-2	34.0	91	9	0	0.06	828	294
PR-3	4.0	100	0	0	0.03	53	19
PR-4	40.2	27	54	19	0.05	799	283
PR-5	18.4	60	14	26	0.03	246	87
Sub-total	98.2				0.05	2136	758
FA-1	8.0	88	0	12	0.22	719	255
SC-1	2.1	62	0	38	0.24	201	71
Sub-total	10.1				0.22	919	326
IB-1	120.0	67	9	24	0.15	7471	2649
TOTAL	267.0					10,819	3839

Source: The hydrologic characteristics and annual runoff estimates are from reference (City of Tempe, Rio Salado Water Resources Master Plan, Draft Technical Memorandum 5, Storm Water Management, June 1991, by CH2M HILL)

The 10-yr 24-hr rainfall of 2.4 inches was determined from NOAA Atlas II

flows utilize the pipeline. The Buckeye Irrigation Company currently takes its water from the natural channel through a diversion structure on the Gila River.

Water Quality Criteria

The Environmental Protection Agency (EPA) and the State of Arizona have established water quality criteria which vary depending on designated water use. Uses fall into one of the categories listed in Table 5.10.

Arizona has established designated uses for navigable waters within the Rio Salado study area including the Salt River and Indian Bend Wash. Designated uses for these streams include partial body contact, fish consumption, aquatic and wildlife categories, and agricultural categories (Table 5.11). Criteria for selected parameters are summarized in Table 5.12.

Quality of Salt River Flows

Flow originating from the Salt River watershed upstream of the Phoenix metropolitan area is generally of good quality. Salt River flows contain sodium chloride (TDS) above and below Roosevelt Dam due to salt springs upstream of Roosevelt lake. Verde River water has a lower TDS content than Salt River water and tends to lower the overall TDS content in flows downstream of their confluence.

Flows in the Salt River commonly exceed standards for fecal coliform bacteria. Table 5.13 presents selected results from recent water quality sampling on the Salt River in the Phoenix area. These samples were taken prior to and during the high flows of January and February 1993. High levels of fecal coliform and fecal streptococci where detected in the first sample taken in August 1992.

Storm Water Quality

Storm runoff from the Phoenix metropolitan area can contribute to both surface and groundwater degradation the study area. Much of the metropolitan area is drained by storm sewers which discharge directly into the Salt River. Estimates of the runoff from these areas are presented in

Table 5.10. Designated Uses for Water Quality Standards.	
Designated Use	Description
A&Wc	Aquatic and Wildlife (cold water fishery)
A&We	Aquatic and Wildlife (ephemeral)
A&Wedw	Aquatic and Wildlife (effluent-dominated water)
A&Ww	Aquatic and Wildlife (warm water fishery)
AgL	Agricultural Livestock Watering
AgI	Agricultural Irrigation
DWS	Domestic Water Source
FBC	Full Body Contact
PBC	Partial Body Contact
FC	Fish Consumption
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant

Table 5.11. Designated Uses of Waterways within the Rio Salado Study Area.	
Reach	Designated Uses
Salt River (2 km below Granite Reef Dam to the I-10 bridge)	Aquatic and Wildlife (ephemeral) Partial Body Contact
Salt River (I-10 bridge to the 23rd Avenue WWTP)	Aquatic and Wildlife (warm water fishery) Partial Body Contact
Salt River (23rd Avenue WWTP to the Gila River Confluence)	Aquatic and Wildlife (effluent dominated water) Partial Body Contact Fish Consumption Agricultural Irrigation Agricultural Livestock Watering
Indian Bend Wash	Aquatic and Wildlife (warm water fishery) Partial Body Contact Fish Consumption
Indian Bend Wash Lakes	Aquatic and Wildlife (warm water fishery) Partial Body Contact Fish Consumption
Source: Arizona Administrative Code, ADEQ, Title 18, Ch.11, Appendix A	

Table 5.12. Numeric Water Quality Criteria (ADEQ) - Selected Parameters.

Parameter	DWS	FC	PBC	A&Ww (acute)	A&Ww (chronic)	A&Wedw (acute)	A&Wedw (chronic)	A&Wwe (acute)	A&Wwe (chronic)	AgI	AgL
TSS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TDS(1)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chloride(2)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fluoride (ppb)	4000	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrate (ppb)	10,000	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F. Coliform (cfu/100ml)			4000/1000	4000	1000	800	200				
Arsenic (ppb)	50 T	3.1 T	2800 T	360 D	190 D	360 D	190 D	440 D	230 D	2000 T	200 T
Cadmium (ppb)	5 T	83 T	70 T	(3)	(3)	(3)	(3)	(3)	(3)	50 T	50 T
Copper (ppb)	1000 D	NS	5200 D	(3)	(3)	(3)	(3)	(3)	(3)	5000 T	500 T
Lead (ppb)	50 T	NS	NS	(3)	(3)	(3)	(3)	(3)	(3)	(3)	100 T
Mercury (ppb)	2.1 T	0.6 T	42 T	2.4 D	0.01 D	2.6 D	0.2 D	5 D	2.7 D	NS	10 T
Silver (ppb)	NS	NS	NS	(3)	NS	(3)	NS	(3)	NS	NS	NS
Zinc (ppb)	5000 T	NS	28,000	(3)	(3)	(3)	(3)	(3)	(3)	10,000 T	25,000 T
TCE (ppb)	5	78	NS	20000	1300	20000	1300	20000	1300	NS	NS
PCE (ppb)	5	11	4000	6500	680	6500	680	15000	1600	NS	NS
TCA (ppb)	200	160000	13000	2600	1600	2600	1600	2600	1600	NS	NS
Benzene	5	120	470	2700	180	11000	700	NS	NS	NS	NS
DBCP	0.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chloroform	100	590	1400	14,000	900	14,000	900	NS	NS	NS	NS

(1) Water with concentrations above 250 mg/l has a salty taste.

(2) Water with TDS content of less than 500 mg/l is most desirable for domestic use.

(3) Criteria based on hardness, see Arizona Administrative Code (ADEQ), Title 18, Ch.11, Appendix A for equations.

T = Total Recoverable
D = Dissolved
NS = No Standard

Table 5.13. Salt River Water Quality Data.

Parameter	Date of Sample						Avg.
	24 Aug 92	9 Sep 92	31 Dec 92	4 Jan 93	12 Jan 93	11 Feb 93	
Discharge (cfs)	16,500	1140	10	8600	47,800	25,500	
Temperature (Celsius)		25.5	13	13	12	11	
D. Oxygen (mg/l)	5.6	5.9		10.2	8.1	8.7	7.7
COD (mg./l)	33	12	25	17	39	13	23
BOD_5 (mg/l)	10	30		7	<5.0	<5.0	11
Fecal Coliform (3cfu/100ml)	3000	450			290	100	768
Fecal Streptococci (cfu/100ml)	3400	48		540	1300	230	1103
Alkalinity (mg/l)	147	114		123	105		122
Sulfate (mg/l)		41	72	38	26	20	39
Chloride (mg/l)		140	150	92	83	21	97
Nitrate Nitrogen (mg/l)	0.13				<0.5	<0.5	
Phosphorous (mg/l)	0.08	0.03		0.09	0.43	0.2	.17
Cadmium (ug/l)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chromium (ug/l)	25	1	8	8	15	6	11
Copper (ug/l)	300	2	3	6	25	13	58
Lead (ug/l)	27	<1	<1	3	22	7	10
Mercury (ug/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel (ug/l)	49	2	2	4	21	10	15
Zinc (ug/l)	120	<10	<10	<10	50	<10	

Tables 5.8 and 5.9. In other areas, urban storm runoff is collected into percolation basins or discharged into dry wells. Concentrations of bacteria, metals, turbidity, petroleum products, pesticides and nutrients, and pesticides in urban storm runoff commonly exceed water quality standards. Because rainfall in central Arizona is intermittent and highly variable, the quality of urban storm runoff in the area is also highly variable.

Table 5.14 provides a summary of urban storm runoff sampling and analysis data developed by the USGS for Maricopa County. Three of the basins sampled by the USGS are tributary to the Salt River within the Rio Salado study area at 48th Street, 23rd Avenue, and South Mountain Park, and represent light industry, heavy industry, and undeveloped areas. The fourth basin studied is tributary to the Agua Fria River and is primarily residential. Selective mean concentrations for all four basins were: fecal coliform, 4,800 colonies per 100 milliliters; fecal streptococci, 9,100 colonies per 100 milliliters; dissolved solids, 81 mg/l and suspended solids, 607 mg/l. The largest concentrations of constituents were from 23rd Avenue which represents a heavy industrial area. The insecticides DDT and DDE were also measured from the 23rd Avenue basin. These are probably residual insecticides from the 1950's and 1960's when large areas of the Phoenix metropolitan area were still used for agriculture.

CH2M Hill estimated the average annual pollutant concentrations for runoff from areas draining through the City of Tempe. These estimates are presented in Table 5.15 and show high levels of fecal coliform.

Treated Wastewater

Table 5.16 summarizes three months of water quality monitoring reports for discharge from the 23rd Avenue and 91st Avenue Wastewater Treatment Plants.

The 91st Avenue Plant currently has three modules. One has a 30 MGD capacity to treat with biodenitrification, and the other two do not. The source water has a total nitrogen content of 25 mg/l, part as nitrate-nitrogen and part as ammonia-nitrogen. The City intends to increase the plant capacity by 30 MGD, and add biodenitrification within three years. Because most of the

Table 5.14. Summary Statistic for USGS Investigation of Storm Water Quality - Maricopa County.					
Property or Constituent	Maximum	Minimum	Mean	Median	Number of Samples
Conductance	266	52	128	99	15
S. Solids (mg/l)	3390	<1	607	229	16
Dissolved Solids (mg/l)	158	35	81	76	14
Fecal Coliform (col/100ml)	11,000	970	4800	4600	15
Fecal Streptococci (col/ml)	26,000	1000	9100	8500	15
COD (mg/l)	21,000	<10	1900	140	15
BOD (5-day;mg/l)	3600	<5	310	30	14
Ammonia, total (mg/l)	.89	.07	.39	.38	15
Nitrite + Nitrate (mg/l)	4.7	.42	1.3	.77	15
Nitrogen, Ammonia + organic (mg/l)	3	.60	1.74	1.70	15
Phosphorus,total (mg/l)	1.70	.11	.53	.43	15
Arsenic, total (ug/l)	21	2	7.7	5.0	17
Cadmium, total (ug/l)	6	<1	1.5	1.0	17
Chromium, total (ug/l)	120	<1	24	10	17
Copper, total (ug/l)	320	7	110	52	10
Lead, total (ug/l)	620	8	140	51	17
Nickel, total (mg/l)	120	4	37	17	17
Zinc, total (ug/l)	980	30	300	170	17

discharge is to the Salt River, the strict standards require the discharge to support fish life. Items of specific concern are nitrate levels, and urban pesticides such as Diazanon.

The City of Phoenix has five drinking water treatment plants. One of these plants is located near Fountain Hills, another is located at 7th Street & Indian Hills. The other plants are not in the scope of this study. The CAP Water is higher in sulfates (SO_4) and calcium carbonate ($CaCO_3$). The total water supply to the City of Phoenix is approximately 250 MGD during the winter.

Table 5.15. Average Annual Estimated Pollutant Concentrations, Tempe Urban Watersheds.			
Parameter	Indian Bend Wash	Price Road Tunnel	PI-1 FA-1 SC-1 DO-1
TSS	5.56	42	278
TDS	534	534	534
BOD	30	41	47
TP	0.11	0.20	0.35
OP	0.08	0.14	0.24
NH4	1.02	1.41	1.60
Nitrate-Nitrogen	0.68	1.06	1.58
Organic N	2.22	3.05	3.46
TN	4.25	5.85	6.65
Fecal Coliform	818	818	8178
Total Copper	<0.05	<0.05	0.06
Total Lead	<0.02	<0.02	0.05
Total Zinc	0.14	0.20	0.26

Source: City of Tempe, Rio Salado Water Resources Master Plan, Draft Technical Memorandum 5, CH2M Hill, June 1991

Table 5.16. City of Phoenix Discharge Monitoring Report Summary for May - July 1994 (mg/l).				
Parameter		Permit Requirement	91st Ave. WWTP	23rd Ave. WWTP
Flow in conduit through treatment plant (MGD)	91st Ave 23rd Ave	153.75 37.2	101.5	32.91
Chlorine, Total Residual	91st Ave 23rd Ave	Rept[2] .05 Rept .011	[3]	[3]
PH		6.5-9.0	7.2-7.4	7.0-7.3
Total Suspended Solids 7 day avg.		4.5	9.0	7.0
Settleable Solids		1	<.1	<.1
BOD Carbonaceous - 5-day 20C		Rept	10	5
Coliform, Fecal General		800	93	57
Cyanide[1]		200	[3]	[3]
Mercury		.2	[3]	[3]
Arsenic[1]		98.7	4	3
Selenium[1]		50	[3]	[3]
Thallium[1]		40	[3]	[3]
Beryllium[1]		5.3	[3]	[3]
Boron[1]		1000	423	380
Nickel[1]		Rept	[3]	[3]
Silver[1]		142	[3]	[3]
Zinc[1]		73.3	[3]	.13
Cadmium[1]		29.5	<.7	1.03
Lead[1]		148	[3]	3.7
Chromium[1]		223	[3]	[3]

Table 5.16. City of Phoenix Discharge Monitoring Report Summary for May - July 1994 (mg/l).			
Parameter	Permit Requirement	91st Ave. Treatment Plant	23rd Ave. Treatment Plant
Copper[1]	142	6	6
2-Methyl-4, 6-Dinitrophenol	765	[3]	[3]
2-Chlorophenol	2000	[3]	[3]
2-Nitrophenol	Rept	[3]	[3]
2,4-Dichlorophenol	365	[3]	[3]
2,4-Dimethylphenol	2120	[3]	[3]
2,4-Dinitrophenol	365	[3]	[3]
2,4,6-Trichlorophenol	3.6	[3]	[3]
4-Chloro-3-Methylphenol	30	[3]	[3]
4-Nitrophenol	Rept	[3]	[3]
Phenol, Single Compound	2560	<4	.6
Pentachlorophenol	13.0	[3]	[3]

Source: City of Phoenix NPDES Discharge Monitoring Reports, May-July 1994
1 Total Recoverable
2 No standard. Report required to Arizona Department of Water Resources.
3 Not Available

Groundwater

Inorganic Chemical Constituents

There are a number of groundwater quality problems in the Salt River Valley. Most of the inorganic problems can be traced to natural factors and long-term irrigation practices. High salinity, chloride and nitrate concentrations are commonly found in shallow groundwater beneath irrigated or formerly irrigated land. Irrigation practices can also be associated with high nitrate levels in some areas, but there is also evidence that high nitrate levels occur naturally in parts of the valley. An example of this is the large area of high nitrate in the western part of the valley.

This area extends from northwest Phoenix through Glendale and Tolleson, to the west of Buckeye. High nitrate levels were observed in this area when many Salt River Project wells were first drilled in the 1930's. Therefore, it appears that high nitrate levels predated the widespread use of chemical fertilizers. Figures 5.13, 5.14 and 5.15 show the content of Total Dissolved Solids (TDS in terms of electrical conductivity), chloride, and nitrate in the groundwater near Rio Salado. All three constituents are high in the study area, chloride and TDS are especially high at the western end of the study area north of the confluence of the Salt and Verde River. Nitrate levels are greater than 25 mg/l throughout the area west of Central Avenue. A pocket of 90 mg/l concentrations (as nitrate) is located northeast of Tolleson. Table 5.17 summarizes the public health effects of excess levels of chloride, TDS, and nitrates. Table 5.18 summarizes the effect on agriculture.

Trace Organics

Over the past 15 years, a number of instances of shallow groundwater degradation by trace organic constituents have been detected in the Rio Salado study area. The most significant instances involve the pesticide DBCP or volatile halocarbons. DBCP has been detected at concentrations exceeding the drinking water MCL at several well sites in the study area. DBCP is a pesticide that was used extensively on citrus groves and some other crops in the Salt River Valley. DBCP is now a suspected carcinogen and was banned for agricultural purposes in 1979. Figure 5.16 shows the SRP well locations in or near the study area which have tested positive for DBCP.

Numerous incidents of volatile halocarbon contamination have been detected in the Rio Salado study area. Volatile halocarbons are located in shallow groundwater beneath landfills along the Salt River, near some industrial facilities, and beneath a large area between the Sky Harbor Airport and Downtown Phoenix. In many cases of volatile halocarbon contamination, the problems are limited to plumes in specific areas and can be associated with specific sources

Table 5.17. Public Health Significance of Chloride, TDS, and Nitrate.	
Parameter	Public Health Significance
Chloride	Chloride in low concentrations is not harmful to humans. However, water with concentrations above 250 mg/l has a salty taste, which is considered objectionable by most people.
TDS	Water with TDS content of less than 500 mg/l is most desirable for domestic use. Standards generally recommend a limit of 1000 mg/l for potable water.
Nitrate	In 1940 it was found that drinking water with high nitrate content often caused methemoglobinemia in infants. This is a condition that reduces the bloods ability to carry oxygen. The EPA has established a MCL for nitrate-nitrogen in drinking water of 10 mg/l (45 mg/l as nitrate).
Primary Source: Chemistry for Environmental Engineering, Sawyer and McCarty, 1978	

Table 5.18. Significance of Chloride, TDS, and Nitrate in Irrigation Water.				
Parameters	No Problems (mg/l)	Increasing Problems (mg/l)	Severe Problems (mg/l)	Problems
TDS	<500	500-2000	>2000	Salinity effects on crop yield
Chloride	<142	142-355	>355	If water is absorbed by roots only.
Chloride	<106	>106		If water is also absorbed by leaves.
Nitrogen	<5	5-30	>30	Excess nitrogen may delay harvest time and adversely affect yield or quality of sugar beets, grapes, citrus, avocados, apricots, etc.
Source: SRP 1993 Water Quality Report				

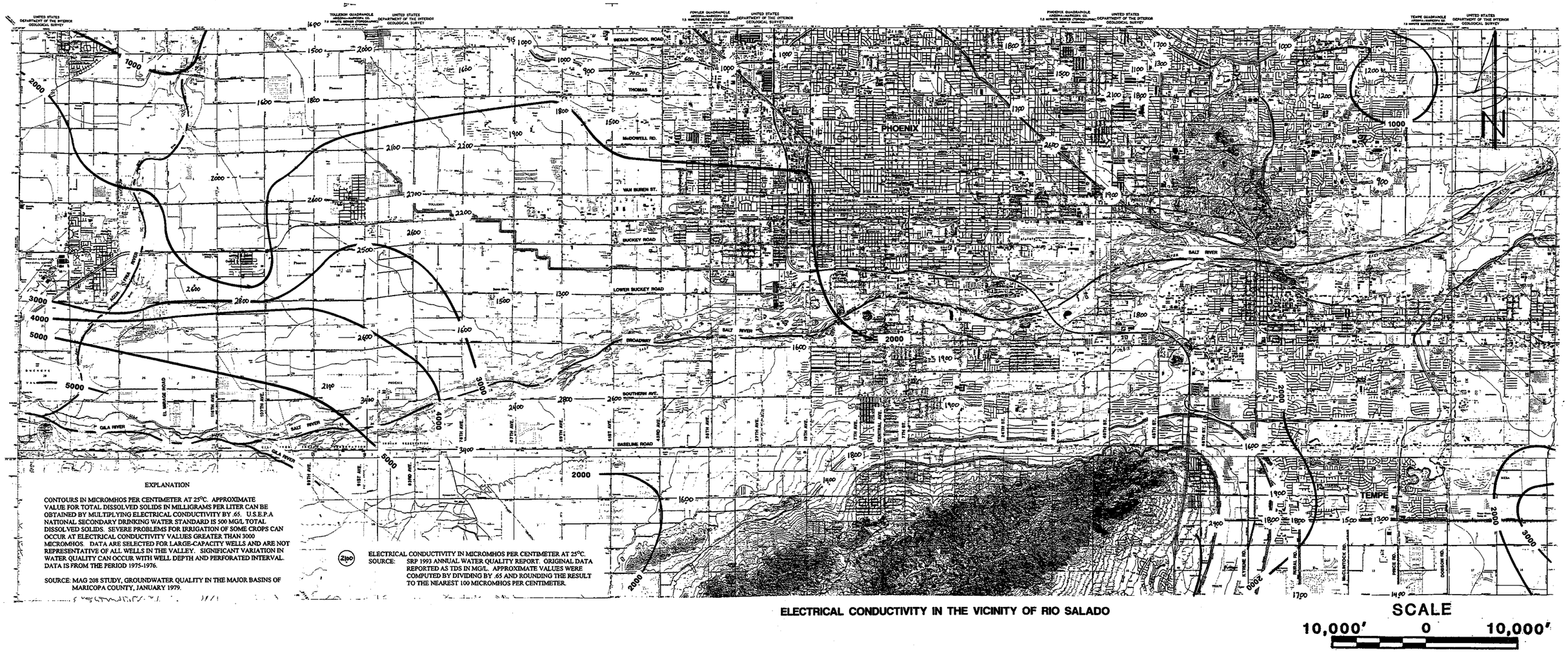


Figure 5.13. **Total Dissolved Solids in Rio Salado Area Groundwater in Terms of Electrical Conductivity**

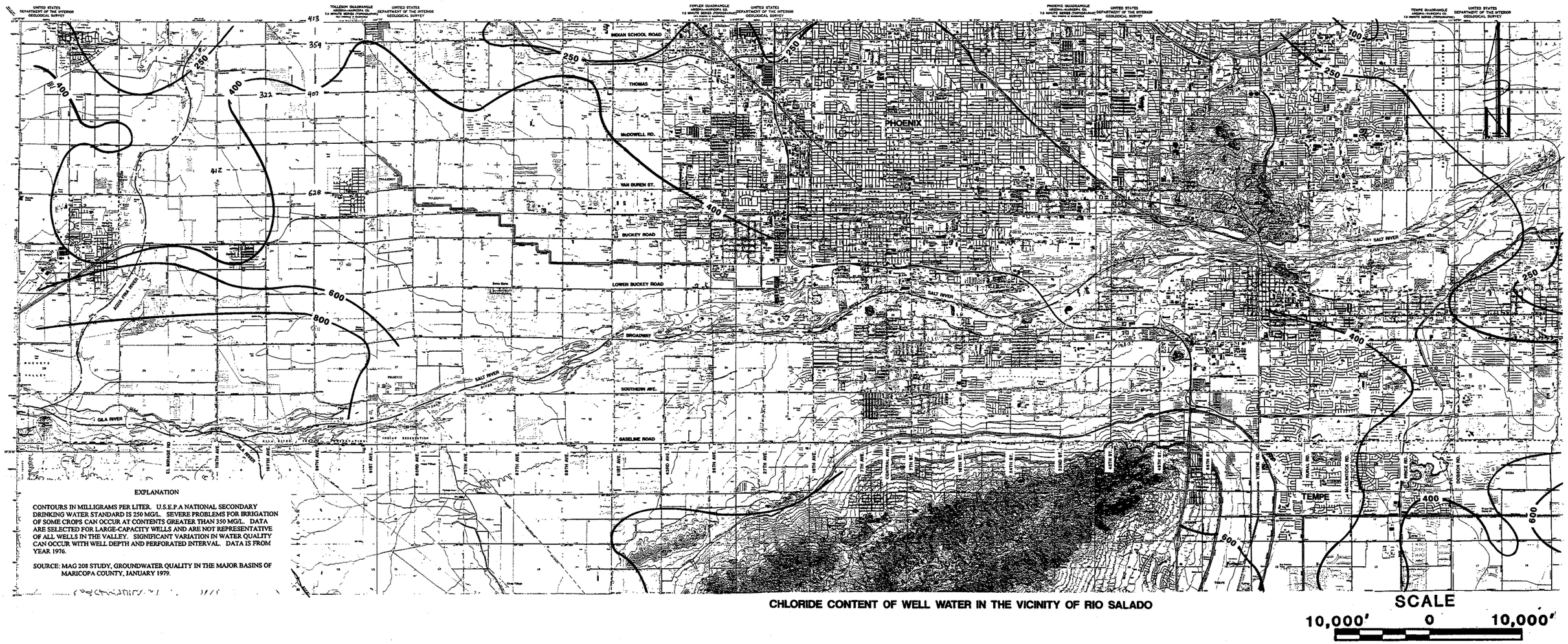
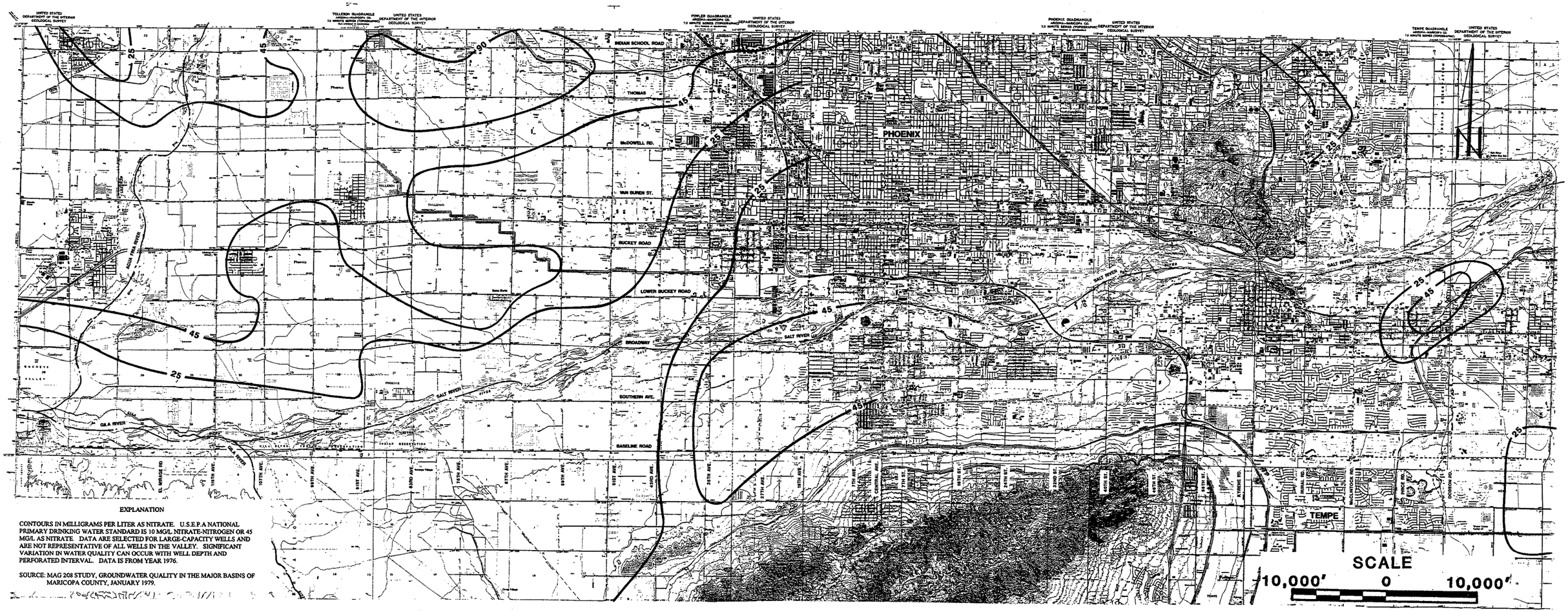


Figure 5.14. Chloride Content of Well Water in the Vicinity of Rio Salado



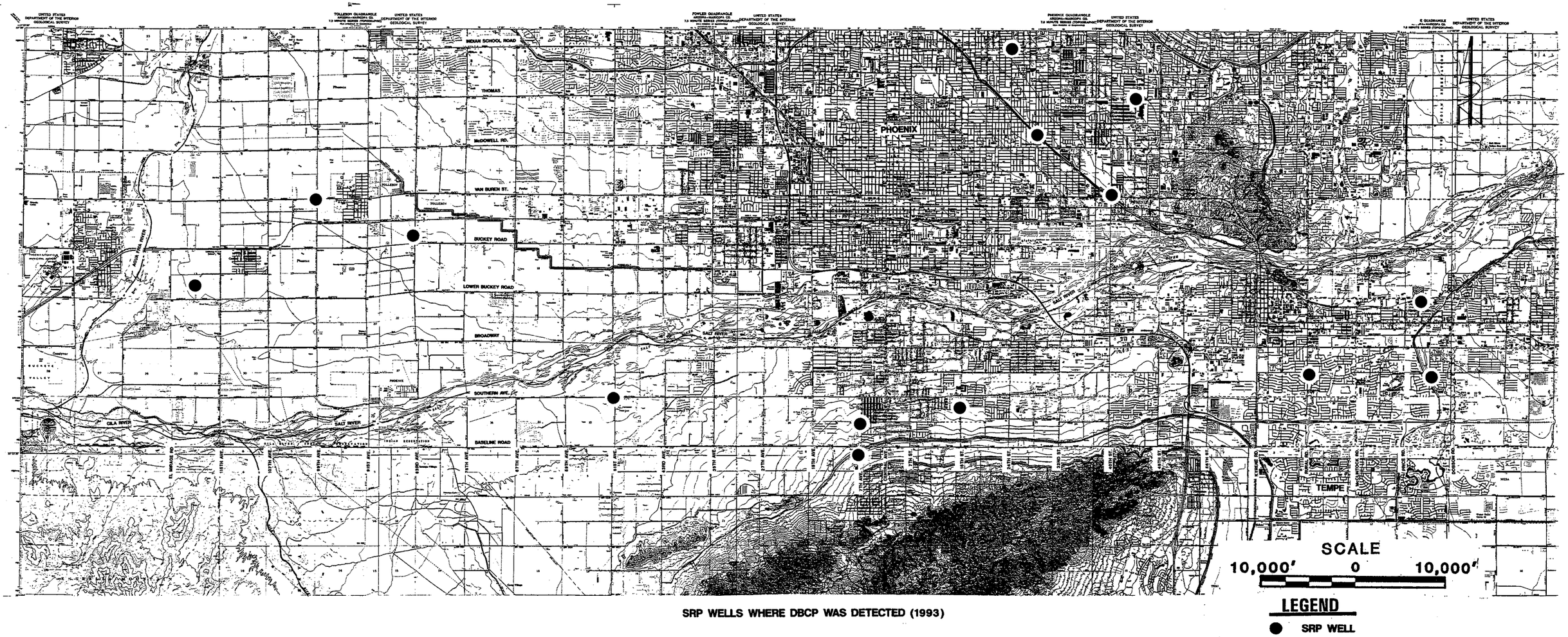
EXPLANATION

CONTOURS IN MILLIGRAMS PER LITER AS NITRATE. U.S.E.P.A NATIONAL PRIMARY DRINKING WATER STANDARD IS 10 MG/L NITRATE-NITROGEN OR 45 MG/L AS NITRATE. DATA ARE SELECTED FOR LARGE-CAPACITY WELLS AND ARE NOT REPRESENTATIVE OF ALL WELLS IN THE VALLEY. SIGNIFICANT VARIATION IN WATER QUALITY CAN OCCUR WITH WELL DEPTH AND PERFORATED INTERVAL. DATA IS FROM YEAR 1976.

SOURCE: MAG 208 STUDY, GROUNDWATER QUALITY IN THE MAJOR BASINS OF MARICOPA COUNTY, JANUARY 1979.

NITRATE CONTENT OF WELL WATER IN VICINITY OF RIO SALADO

Figure 5.15. Nitrate Content of Well Water in the Vicinity of Rio Salado



SRP WELLS WHERE DBCP WAS DETECTED (1993)

Figure 5.16. SRP Wells Where DBCP Was Detected

(examples: 19th Avenue, 27th Avenue, and Estes Landfills, and Motorola 52nd Street). These plumes are usually well defined and involve relatively small amounts of groundwater. However, a large area of low level volatile halocarbon contamination involving larger amounts of water has also been delineated. This area stretches from the Motorola 52nd Street Superfund site southwest to Sky Harbor Airport, west through downtown Phoenix and through the West Van Buren area, almost to Tolleson. There are many possible sources of this low level contamination. Attempts are being made through state and federal remediation programs such as the Water Quality Assurance Revolving Fund (WQARF) and the EPA's Superfund program to define the extent of contamination and to implement remediation. Because of the size of the affected area, it is difficult to partition the problem areas into specific sites with identified parties. Figure 5.17 shows the location of WQARF and Federal Superfund sites and the extent of volatile halocarbon contamination in the study area. Table 5.19 summarizes the identified problems at each site. Open and closed landfills along the Salt River are shown on Figures 5.5, 5.11 and 5.12 and are listed in Tables 5.20 and 5.21.

Because of poor inorganic chemical quality of the shallow groundwater in the Rio Salado study area, use of shallow groundwater for public supply is limited. New public water supply wells which tap potable groundwater in the Lower and Middle Alluvial Units have been developed for several decades. Much of the shallow groundwater is of suitable quality for industrial or agricultural purposes only. The deeper water is generally unaffected by irrigation and industrial practices and has lower salinity and nitrate concentrations. An important issue in the Salt River Valley is protection of the higher quality water in the deeper aquifers from the poorer quality water in the upper aquifer.

Other possible sources of groundwater quality degradation in the study area are leaking underground storage tanks, dry wells which extend close to or into the upper part of shallow aquifers, settling basins, and past well construction practices.

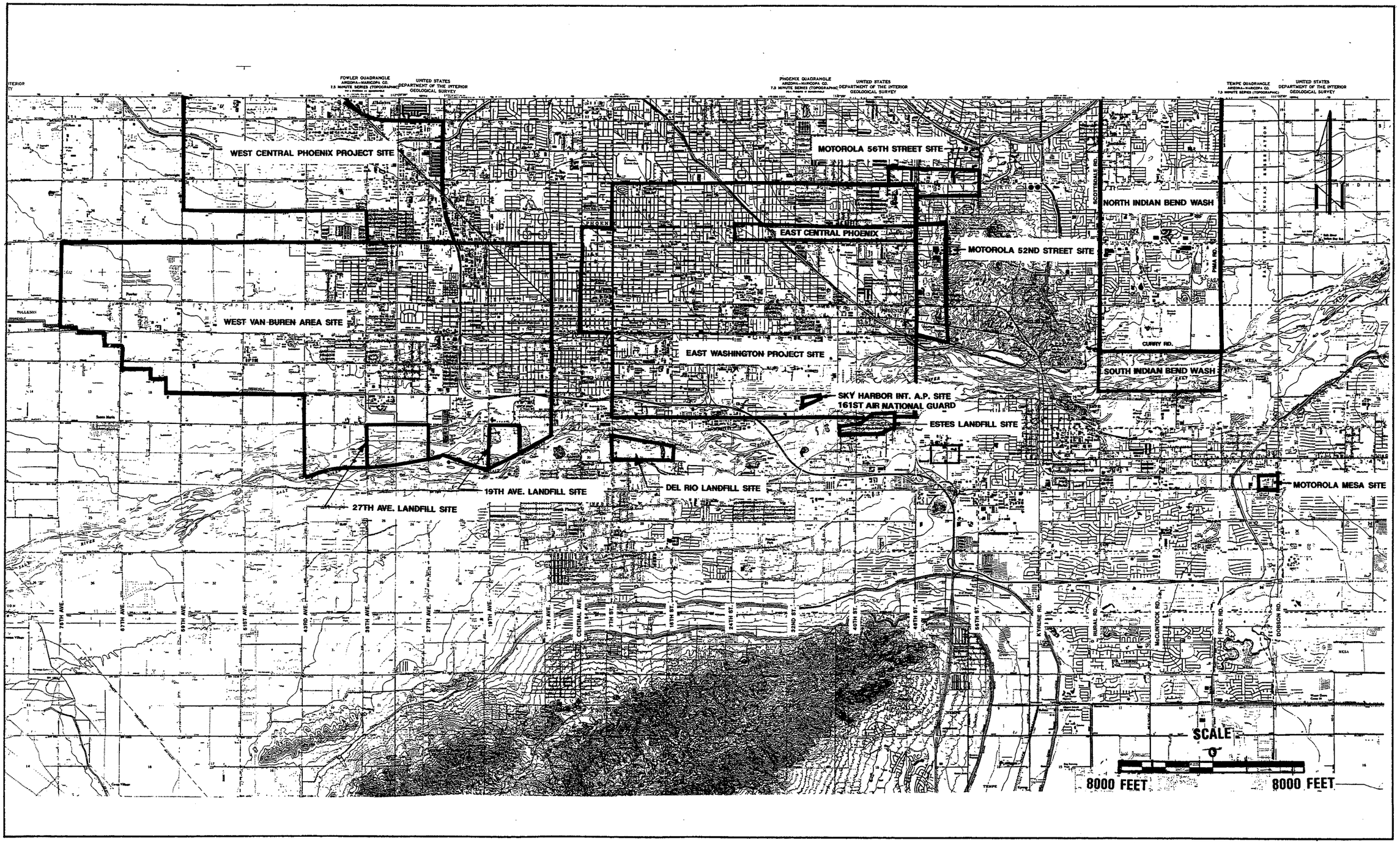


Figure 5.17. WQARF and Superfund Sites in Rio Salado Area

Table 5.19. WQARF and Federal Superfund Sites Located In or Near the Study Area.

Site	Location	Primary Contaminants	Source	Comments
19th Avenue Landfill	In Phoenix along the Salt River between 15th & 19th Avenues.	vinyl chloride, TCE, PCE 1,1-dichloroethene	Municipal and Industrial Wastes	VOC contaminants at levels exceeding MCLs on and off site. A federal superfund site. Groundwater to be monitored but no cleanup necessary. The site will be capped and provided with bank protection.
Motorola 52nd Street	Eastern part of Phoenix about 1 mile north of the Salt River	TCE, PCE, TCA	Land Disposal at Industrial Plant Dry wells formerly used	A federal Superfund site. Groundwater cleanup underway
North Indian Bend Wash	Cities of Scottsdale and Tempe	TCE, PCE, chloroform, TCA, DCE	Land disposal practices at industrial facilities	VOCs have been found in upper, middle and lower alluvial unit. Well conduits a contributing factor. A federal superfund site.
South Indian Bend Wash	City of Tempe	VOCs, Organic Compounds, Metals	Not presently determined.	Federal Superfund site.
161st Air National Guard	51 acres at Sky Harbor Airport	benzene, ethylbenze, PCE, TCE, DCE, DCA	Aircraft maintenance activities, refueling operations	Under Department of Defense Installation Restoration Program. Being cleaned up as part of new runway installation at Sky Harbor.
East Central Phoenix	Between 48th and 24th Streets and Camelback and Thomas Roads in Phoenix	TCE PCE 1,1,1-trichloroethene	Industrial facilities and other sources possible.	PCE levels exceeding MCL detected downstream facilities. State WQARF site.
East Washington	Between 48th Street and 7th Ave. and Thomas and Lower Buckeye	TCE, PCE, 1,1,1-trichloroethene 1,1-dichloroethylene, vinyl chloride	Industrial Facilities. Exact source has not yet been determined.0.2	Large area of VOC contamination. Difficult to identify sources. State WQARF site.
Estes Landfill	South of Salt River between 40th and 45th Streets in Phoenix.	vinyl chloride 1,2-dichloroethene TCE	Estes Landfill	On going remedial investigation.
Northwest Tempe	Between 14th Street and 10th Place & between Edward Drive and Park Lane in Tempe.	1,1,1-trichloroethene 1,1-dichloroethylene	Industrial facilities	A plume of VOCs has been identified and is being investigated.

Table 5.19 (Cont). WQARF and Federal Superfund Sites.				
Site	Location	Primary Contaminants	Source	Comments
Sky Harbor	Between 24th and 44th Streets and north of the Salt River.	TCE,PCE,1,1,1-trichloroethene	Industrial Facilities. Possible airport operations.	Subunit of the East Washington WQARF area.
West Central Phoenix	Phoenix	TCE,PCE,DCE	Industrial Facilities	Three distinct plumes. State WQARF site.
West Van Buren	25 square miles in northwest Phoenix	TCE,DCE,PCE, petroleum products	Industrial Facilities	Little remediation. Proposed measures to attempt to prevent contamination from reaching City of Tolleson wells.
27th Avenue Landfill	Between 35th and 27th Avenues	VOCs,benzene, Methylene Chloride	Landfill	City of Phoenix has submitted a closure permit under the ADEQ Aquifer Protection Permit Program.
Del Rio Landfill	Between 7th and 16th Streets, north of the Salt River in Phoenix.	VOCs	Apparent upgradient source	Well defined plume
Motorola 56th Street	Northwest corner of 56th Street and Earll Drive in Phoenix	TCE,DCE	Disposal of Solvents	Prior to 1962 all discharges of solvents were to dry wells or sewage leach fields.

Table 5.20. Active Landfills in the Vicinity of Rio Salado Study Area.

Facility Name	Types of Wastes	Operator Name	Approximate Location
27th Avenue	Rubbish Municipal Solid Waste Liquid Waste	City of Phoenix	SW Corner of 27th Avenue and Lower Buckeye Road
40th Street	Rubbish	Bradley Investment Company	North Side of Magnolia East of 40th Street
Litchfield/Avondale	Rubbish	Calmat of Arizona	South of Indian School Road, West Side of Agua Fria River
Tri-City	Rubbish Municipal Solid Waste	Salt River-Pima Tribe	1 Mile North of McDowell, off Beeline Hwy (AZ 87)
Weinberger Construction Debris	Rubbish	Glenn Weinberger	.5 Miles South of Lower Buckeye Road on 39th Avenue

Table 5.21. Closed Solid Waste Landfills in the Vicinity of Rio Salado Study Area.

Facility Name	Types of Wastes	Operator Name	Approximate Location
16th Street	Rubbish Municipal Solid Waste Other?	City of Phoenix	1 Mile South of I-10 on 16th Street
19th Avenue	Rubbish Septage Municipal Solid Waste Liquid Waste	City of Phoenix	1 Mile South of I-10 on the East Side of 19th Avenue
22nd Avenue	Rubbish Municipal Solid Waste Other?	City of Phoenix	22nd Avenue and Lower Buckeye Road
Estes	Rubbish Municipal Solid Waste Other?	City of Phoenix	East Side of 40th Street, South of the Salt River
91st Avenue	Rubbish Municipal Solid Waste	City of Phoenix	West Side of 91st Avenue, Opposite 91st Avenue Waste Water Treatment Plant
Ameron	Rubbish	Ameron Pipe Division	West of 12th Street, South of Watkins in Phoenix
ASU No. 1	Rubbish Municipal Solid Waste	Arizona State University	Along West Side of Scottsdale Road, South of Salt River
ASU No. 2	Rubbish Municipal Solid Waste	Arizona State University	Along East Side of Scottsdale Road, South of Salt River
Avondale	Rubbish Municipal Solid Waste Other?	Maricopa County	North Side of the Intersection of US 80 and the Agua Fria

Table 5.21 (Cont). Closed Solid Waste Landfills in the Vicinity of Rio Salado Study Area (cont.)

Facility Name	Types of Wastes	Operator Name	Approximate Location
Central Avenue	Rubbish	Union Rock and Materials	.25 Miles South of I-10 on Central Avenue
First Street	Rubbish	Kachina Ready-Mix	NE Corner of First Street and Clark Drive, Tempe
Juice of Life	Rubbish Municipal Solid Waste	Mike Neils	5837 S. 36th Street, Phoenix
Old Town Dump	Rubbish Municipal Solid Waste	Goodyear Tire & Rubber	Dysart Road to Rid Canal
Perry Lane Methane			NE Corner of 1st Street and Perry Lane
Reed Construction	Rubbish Municipal Solid Waste	Reed Construction Company	West Side of 67th Avenue on Salt River
RRCA (old Tempe)	Rubbish Municipal Solid Waste Other?	Raymond Edwards	1.3 Miles North of Apache Blvd. on Hayden Road
Tempe #1		City of Tempe	South Side of Salt River on Hayden Drive
Tolleson	Rubbish Municipal Solid Waste	City of Tolleson	91st Avenue and the Salt River
Tri-City (old)		Salt River-Pima Tribe	North Bank of Salt River West of Country Club Road
Wayne Oxygen	Liquid Waste	Wayne Oxygen Company	2615 S. 40th Street, Phoenix
William Roer	Rubbish Municipal Solid Waste	William Roer	75th Avenue North of Southern Avenue, on South Side of Salt River

5.3.2 Future Without Project Conditions

It is expected that much of the Salt River Valley will be urbanized within the next several decades. This will cause a significant reduction in the amount of pumped shallow groundwater for irrigation. Because this water is of poor quality and not directly suitable for public supply, there will be very few users of this groundwater once widespread irrigation has stopped in the valley. At the same time it is expected that the shallow groundwater will be recharged for decades from deep percolation of water currently stored in the vadose zone. This recharge water is generally of poor quality in terms of salinity, chloride, and nitrate content, and will further degrade the quality of shallow groundwater.

Without future pumping and with continued recharged from irrigation water stored in the vadose zone, the following problems may occur:

1) Shallow poor quality groundwater will eventually migrate downward and contaminate the good quality groundwater in deeper strata. Water levels in wells tapping deep units are usually lower than those in shallow wells, resulting in a substantial downward gradient. Thousands of potential well conduits exist in the valley. As water levels declined in the 1970's, deeper composite wells were drilled in search of higher yields. These wells are commonly perforated over hundreds of feet and if not properly destroyed, create flow paths for poor quality shallow water to deeper high quality water.

2) Shallow water levels are becoming a problem in parts of the Phoenix metropolitan area. In some areas, depth to groundwater is now less than 50 feet. Rising water levels can cause significant nuisance problems for construction of new buildings or maintenance of existing structures with underground areas. Another problem is the existence of thousands of dry wells in the metropolitan area, which are used for the disposal of storm runoff. Some of these wells may have the effect of discharging urban storm runoff to shallow groundwater, if water levels rise sufficiently.

As the City of Phoenix moves forward with its aquifer recharge plan, secondary effluent flows into the Salt River would be discontinued. From a technical standpoint, water quality standards pertaining to the 91st Avenue effluent have been satisfied as the zero discharge scenario becomes reality.

5.3.3 Opportunities

Water Demand and Projected Cost

The present and projected population for the city of Phoenix, the city of Tempe, and the city of Tolleson is shown in Table 5.22. In addition, the present and projected demand as well as the present and projected cost of water in these water service areas is displayed.

For the total Phoenix Active Management Area (AMA), 1990 water demand totaled 2,336,000 acre feet.

The following is the demand breakdown by use:

Agriculture:	1,544,000 acre feet
Municipal:	669,000 acre feet
Industrial:	123,000 acre feet

Tolleson and other surrounding communities greatly rely on groundwater for their supply. Groundwater contamination from landfills and excess nitrates, sulfates, pesticides, and metals significantly increase groundwater pumping costs and the cost of water to the City of Tolleson.

Phoenix and Tempe have the same present and future cost of water because they are comprised of water providers with common characteristics. Both Phoenix and Tempe rely on SRP (Salt River Project) and CAP (Central Arizona Project) water for the majority of their supply.

Water Quality Improvement Methods

Table 5.23 lists "best available technology" practices for treating eight pollutants which present a problem in the study area.

Air Stripping

Air Stripping is considered a full-scale/innovative treatment process. It removes dissolved gas contaminants through volatilization by greatly increasing the surface area of water exposed to air. Targeted groups are halogenated and non-halogenated volatile organic compounds. It may be used, but is less effective against halogenated and non-halogenated semivolatile organic compounds and fuels. Typical specific constituents treated are carbon dioxide, and hydrogen sulfide, for the purpose of taste and odor removal.

Table 5.22. Population and Water Demand Projections (1994 Price Levels).

Year		1990	1995	2000	2005	2010	2015	2020	2025
Phoenix	Population	1000580	1086643	1173033	1266829	1376360	1506642	1627085	1736729
	Wtr Demand (Acre Feet)	271232	290441	309723	330658	355105	384183	411066	435538
Tempe	Population	142684	158522	165638	170162	173758	176829	180303	184255
	Wtr Demand (Acre Feet)	43633	49221	51732	53328	54597	55680	56906	58301
	$ Per AF	140	139	142	144	144	145	146	147
Tolleson	Population	4445	4522	5706	11347	15443	16820	17448	17896
	Wtr Demand (Acre Feet)	1544	1567	1926	3638	4881	5299	5489	5625
	$ Per AF	155	163	201	221	221	247	251	254

Source: Arizona Department of Water Resources (1993 Report)

Table 5.23. Pollutant Versus Best Available Technology Treatment.	
Pollutant	Treatment
Volatile Pesticides	Air Stripping
Industrial Solvents	Air Stripping
Nonvolatile Pesticides	Granular Activated Carbon, Reverse Osmosis
Nitrate	Electrodialysis, Reverse Osmosis, Biodenitrification, Anion Exchange, Distillation, Chemical Reduction
DBCP	Air Stripping, Granular Activated Carbon
Chloride (ref. BW Poln. Control 1985)	Ion Exchange, Electrodialysis, Reverse Osmosis (evap. ponds, holding basins, deep well injection)
TDS	Reverse Osmosis, Electrodialysis, Ion Exchange, Distillation
Mercury	Bioremediation

Types of air stripping processes are packed tower aeration (PTA), diffused aeration, tray aeration, and spray aeration. The most effective of these at treating VOCs is the Packed Tower. Water is passed down and air pushed up through a cylindrical shell packed with high-surface-area material. This method is reported to be sufficient to remove volatile pesticides such as DDT and DBCP. However when gas-off treatment is required for emission control, PTA is usually more expensive than Granular Activated Carbon.

Reverse Osmosis

Reverse Osmosis uses pressure to force water through tube like vessels that contain rolled-up sheets of semipermeable membranes. Water can pass through the membrane sheets, but salt and any other undesirable constituents are left behind. The wastewater left behind is more concentrated but still of large volume and must be disposed of.

This process is good for treating brackish water and meeting future drinking water standards. However, it merely concentrates the constituents in the water. Reverse Osmosis can generate drinking water from unusable water. It does not treat pollutants.

Distillation

Distillation is the mechanical process of removing dissolved and suspended solids by vaporizing water with heat. A pressure tank is traversed by steam coils, and a moisture separator. The removed vapor is then condensed into product water at the outlet. The remaining brine is a slurry which must be disposed. Distillation is more expensive than Reverse Osmosis or Electrodialysis and is not a treatment for pesticides or industrial solvents.

Evaporation Ponds, Holding Basins, Deep Well Injection

Evaporation ponds are designed to allow for evaporation of water leaving a concentrated brine similar to distillation. Unlike distillation, this process does not recover the vaporized water.

Holding basins provide separation through settling and floating. They do not treat dissolved constituents, but are useful, inexpensive part of a treatment system.

Deep well injection of wastewater is being proposed in the Phoenix area for water exchange purposes. Although this process may treat against Chloride, meeting the required standard of 10 mg/l for Nitrates would require further treatment of the wastewater. This treatment would concurrently treat against chlorides and result in water of sufficient quality for uses other than injection.

Biodenitrification, Bioremediation, Chemical Reduction

Biodenitrification is the ultimate removal mechanism for nitrates. This occurs through anaerobic metabolism in bottom sediments with release of gaseous nitrogen to the atmosphere. This process occurs in a well designed wetlands treatment process.

Bioremediation detoxifies organics through the use of microorganisms. Microorganisms degrade compounds in the dissolved phase, and bacteria converts mercury.

Chemical Reduction chemically converts hazardous contaminants to non-hazardous contaminants or less toxic compounds that are more stable, less mobile, and/or inert. It targets inorganics with effective treatment of non-halogenated volatile and semivolatile organic compounds, fuel hydrocarbons, and pesticides. The reducing/oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, and chlorine, and chlorine dioxide. A combination of these agents, or combination with (UV) oxidation, makes the process more effective. This process is not cost effective for high concentrations due to increased amounts of oxidizing agents required. Efficiency is decreased by oil and grease, therefore this would not be a good initial treatment for storm drain water.

These three treatment processes address an entire pollution problem rather than the smaller spectrum of a water cleaning problem. Unfortunately, they are NOT considered the best available technology for pesticides including DBCP, industrial solvents, or total dissolved solids (TDS).

Ion Exchange, Anion Exchange

Ion Exchange is most extensively used for water softening. It is typically comprised of a bed packed with ion exchange resin beads which are pre-saturated with an exchangeable ion. Water is passed through the media until the effluent shows contamination. The reactivation of the media requires a regenerant solution and rinsing water in preparation for another treatment cycle.

Ion Exchange is currently considered the best treatment for nitrate removal. The process traps nitrate ions and releases chloride ions. Only recently has a nitrate selective resin been developed. Approximately two percent of treated water becomes wastewater as a result of back flushing the resin with salt water. Although nonhazardous, disposal of this water in the Phoenix area may be difficult in large quantities because it may overtax the wastewater treatment facilities, and it is not suitable for recharge.

In 1990, Boyle Engineering proposed construction of a 10.4 MGD Ion Exchange Plant for the City of Phoenix. Treatment cost was determined at that time to be 30 percent less than the Central Arizona Project (CAP) water. The plant was not constructed, and plans to do so are unknown by City officials.

Granular Activated Carbon (GAC)

The full scale/conventional technology of Granular Activated Carbon is a method that captures dissolved organic contaminants by passing water through a series of canisters containing activated carbon which adsorbs the organic contaminants. Periodic replacement or regeneration of saturated carbon is required. Effectiveness may be limited to metals, carbon pore size, and operating temperature. Target groups are halogenated and non-halogenated semivolatile organic compounds with potentially useful but less effective treatment of halogenated volatile organic compounds, fuel hydrocarbons, pesticides, and inorganics. DBCP has been specifically and successfully removed from Fresno California well water using a GAC system designed by Boyle Engineering.

Granular Activated Carbon systems are commercially available, but are rated worse for overall cost. Although GAC successfully removes organics from water, there still remains the problems of either; a) disposing of the carbon resin, or b) regeneration through burning the constituent from the walls of the carbon pores, which then may be dispersed into the air.

Electrodialysis

Electrodialysis removes dissolved solids from water under an electric potential gradient. Cation and anion-permeable membranes are used alternately in a cell with alternatively charged

electrodes on each side. When an electromotive force is imposed, all positive ions move toward the anode and all negative ions move toward the cathode. Electrodialysis reversal (EDR reverses the charge intermittently in order to defer clogging the membranes thus extending the time between regenerating and virtual life of the membranes.

EDR is currently being used in Tolleson, west of Phoenix, to remove nitrates from their groundwater. The treated water is blended with untreated water and distributed to the municipal water supply. Their regenerating brine is sent to the 91st Avenue Treatment Plant.

Wetlands Treatment Capabilities

Wetlands can be an effective way of treating stormwater and domestic and municipal sewage, as well as removing nitrates (one of the major groundwater quality concerns in this area). The particular benefit of wetlands treatment is that, unlike typical mechanical treatments, it removes some pollutants by transforming them into other, non-hazardous constituents. Nitrogen is removed by conversion into nitrate. The nitrates are removed by anaerobic metabolism in the bottom sediments with release of gaseous nitrogen to the atmosphere. Biochemical oxygen demand is metabolized by microbes, and Coliform bacteria die off.

Table 5.24 describes the potential removal rates of various constituents from four water sources. The removal rates are in percent removed with regard to their concentration into and out of the controlled area.

Rio Salado wetlands could be created from any combination of groundwater, waste water, or storm water. As discussed in the Water Quality Improvements Section, each source has its own pretreatment requirements, as well as water quantity available. A previous Corps Study presented the alternative of using the 91st Avenue Wastewater Treatment Plant water to create a wetlands and enhance the riparian habitat downstream of the plant.

Another location of interest would be near Central Avenue where the City of Phoenix has plans for an urban lake (Lago de Vida). At this location there are several large storm drains. By

Table 5.24. First-Pass Removal Efficiency in Wetlands (Values in Percent of Removal).								
Source	TSS	BOD/COD	TN	TP	TIN & NO_3	Col. Bac	Heavy Metals	Toxic Organics
Domestic Municipal Waste	55[1] 72 94	80 90 95	25 70 93	12 40 57	--* 80 --	80 95 99	0 50 99	-- -- --
Storm-water	43 63 95	40 -- 80	36 -- 70	43 53 85	-- -- --	-- -- --	5 50-70 95	69 95 100
Indust. Waste	42 -- 100	29 -- 100	69 -- 98	30 -- 73	-- -- --	-- -- --	6 70-85 97	-- -- --
Agricult. Runoff	54 -- 82	75 -- 97	-- -- --	66 -- 81	82 -- 96	-- 62 --	-- -- --	-- -- --

TSS = Total suspended solids
BOD = biochemical oxygen demand and/or
COD = chemical oxygen demand
TN = total nitrogen
TP = total phosphorus
TIN = total inorganic nitrogen and/or
NO_3 = nitrate nitrogen
col. bac. = coliform bacteria

[1] Values listed are percent removed (top = minimum, middle = typical and bottom = maximum) with regard to initial concentration into and out of the controlled area. .

detaining this storm water in nearby gravel pits, a more constant flow could be attained for the wetlands. The pits would require lining in order to adequately store storm runoff. The quality of the storm water would improve through settling while being stored in the pits before being released into the wetland. Skimming would remove the oils and floating material before discharging into the wetlands for further treatment. When the storm drains do not provide enough water for the wetlands, pumping contaminated water from the shallow aquifer would sustain the wetlands, and make it possible to create a wetlands to treat the poor quality shallow aquifer water for nitrates. This water would be the most likely to meet the criteria for sustaining Lago de Vida.

Water Quality Improvement Sources

Wastewater Treatment Plants.

The two sewage treatment plants (23rd Ave. and 91st Ave.) which discharge water into the Salt River were discussed in Section 3.3. They have capacity to treat 30 and 150 MGD respectively, to a level exceeding secondary treatment. Because proposed NPDES requirements are so stringent and costly to attain, the City of Phoenix anticipates selling this water to farmers, and/or power plants, or injecting it after additional treatment. A visible option to utilizing this water is to create a wetlands near a sewer outfall. The water is rich in nitrogen and already treated for many other water quality concerns (refer to Table 5.16 for water quality of discharge). This water could be used as a steady supply to a wetlands where nitrates would be reduced to the MCL of 10 mg/l as nitrogen, or it could be used intermittently as available.

Storm Drain Water.

Storm drains offer a large intermittent source of varied quality water. The Federal government may, in the near future, require treatment using best management practices before discharge into the Waters of the United States is permitted. Otherwise, storm drain water quality will not improve. Best management practices for treating this water could include skimming off the oils, settling the suspended solids, and allowing a wetlands type of treatment to remove the remaining toxins and nitrates.

The City of Tempe has an aggressive on-site storage policy which retains the poor quality first flush water. Although the smaller events do not reach the Salt River, the water quality of the discharge is of better quality than that of Phoenix.

Without treatment, urban storm runoff is not suitable for injection and may not meet future requirements for percolation. It contains varying degrees of fecal coliform and streptococci, is usually high in suspended solids and oils, and in some cases contains DDT and its degradation product DDE.

There are many expensive physical treatments for the pollutants found in this storm water. However, for small quantities the best management practices are the most natural. By retaining the discharge in a pond, for example an abandoned gravel pit, suspended solids would settle to the bottom. Oils and pesticides could be skimmed off the top. For additional treatment, this water could then be directed into a wetlands area where its water quality would be further improved. With proper planning and design, it is possible to construct a system whose outlet water would be suitable for recharge into the ground for ground water quality improvement, or directed to support other riparian areas.

Such a project would require a pilot study to determine the efficiency of the wetlands, and thus the outlet water quality and its use after discharge. The wetlands would require a supplemental water supply during years with little or no rain.

Groundwater

The use of the water stored in the upper aquifer of the study area is decreasing for two primary reasons: (1) because urbanization of the valley is increasing, the amount of pumping for irrigation is declining and (2) the poor quality shallow groundwater in most areas cannot be directly used for public supply without costly treatment. This shallow groundwater has areas of elevated TDS, chlorides, nitrates, volatile halocarbons, DBCP and other contaminants. In most areas, it is only usable for irrigation and industrial uses.

As pumping of this water decreases, and pumping of deeper groundwater increases, the potential for degradation of deeper better quality water increases. The potential for rising groundwater levels also increases, which can cause further degradation of the shallow groundwater contaminants in the Vadose Zone. A strong argument can be made for the benefits of managing this poor quality water. However, there are some institutional obstacles including legal issues, availability of poor quality water permit from ADWR, and municipal conservation requirements. If these obstacles can be overcome, a large reservoir of water becomes available. Preliminary estimates indicate that at least tens of thousands of ac-ft could be available on a annual basis. This water could be used to maintain, enhance, or create riparian habitat or could be used as

source water for recreational lakes and/or wetlands. The creation of wetlands would have the dual benefits of creating habitat and improving the quality of the water.

The Indian Bend Wash is a Corps of Engineers project which flows through two Federal Superfund sites. Superfund-site-related pollutants (See Table 5.19) from Indian Bend Wash are currently discharged into the Salt River and will enter the proposed Tempe Town Lake and any other downstream recreational facility which allows direct inflows from the Salt River. Riparian habitat and endangered species could be affected, as well as any casual users of Salt River water. An opportunity has been identified to utilize the water-quality components of the Rio Salado project to improve the quality of water originating in the Indian Bend Wash to prevent future damages that could occur in association with the use or contact with this water.

5.4 Recreation

5.4.1 Without-Project (Present) Conditions

Recreation is hereby defined as the pursuit of amicably and environmentally appropriate leisure time activities for physical, mental, social, and spiritual fulfillment and/or rejuvenation. Present, identified recreation within and adjacent to the Salt River channel includes those activities that are sponsored by local municipalities, private developers, and Arizona State University. Particular types of acceptable activities include golf, organized sports, walking, jogging, equestrian riders, off-road bicyclists, bird watching/counting, fishing, photography, picnicking, and bathing.

Six general recreation categories were identified for purposes of evaluation along the Rio Salado study area:

- Watercraft-Related (revenue potential)
- Water-Based Patronage (revenue potential)
- Non-Structured Passive Linear (non-revenue potential)
- Defined Open Space (revenue and non-revenue potential)

- Interpretive/Environmental Education, Non-Structured (non-revenue potential)
- Interpretive/Environmental Education, Structured (revenue potential)

Other types of recreation currently occurring in the Rio Salado study area are considered undesirable for purposes of this study and include illegal shooting, unauthorized off-road vehicle use, and other illegal or socially inappropriate behavior.

Current recreation service and demand levels were determined from present facilities sustained by local municipalities, Maricopa County, State and Tonto National Forest facilities within a fifty-mile radius of the Rio Salado study area as summarized in Table 5.25. Without-Project (Present) Conditions are graphically presented on Figure 5.5.

Table 5.25. Present and Future, Without-Project Recreation Service and Demand Levels for Rio Salado Study Area.

Recreation Category	Current Level[1]	Desirable Level	Unmet Demand
Watercraft-Related	-0-	4,000,000	4,000,000
Water-Based Patronage	2,000	4,000,000	3,998,000
Passive Linear (Non-Structured)	7,000	2,000,000	1,993,000
Defined Open Space	5,000	1,500,000	1,495,000
Interpretive/Environmental Education (Structured and Non-Structured)	1,000	500,000	499,000
Total	15,000	12,000,000	11,985,000

[1]All Units are in Annual User-Days

Watercraft-related recreation in the area is currently zero due to the absence of a sufficient and reliable water body in the area. There is a small amount of water-based patronage of stores in

the area due primarily to fishing downstream of 91st Avenue. Passive, non-structured linear recreation and defined open space constitute the majority of present uses. These activities include hunting, fishing, bird-watching, jogging, hiking and horse-back riding. The majority of these activities, particularly the legal hunting, fishing and bird-watching take place downstream of 91st Avenue where the riparian habitat has been least disturbed and there is a reliable source of water from the 91st Avenue wastewater treatment plant. Jogging, hiking, horseback riding and the passive use of open space occur throughout the study area and are the primary recreational activities upstream of 91st Avenue. Other, undesirable, recreational activities such as those described above occur throughout the study area and are not evaluated for purposes of this study.

The analysis summarized in Table 5.25 demonstrates that there currently exists a significant unmet demand for all identified Rio Salado recreation categories. The present river and adjacent open space currently satisfies less than 0.35% of the present recreational demand for all categories.

5.4.2 Future Without Project Conditions

Recreation along the study area is currently highly dependent upon the present availability of surface water and riparian habitat, both of which are dependent upon the supply and availability of surface and ground water. In the absence of a Corps of Engineers project, recreational use and demand will remain the same under future, without-project conditions as under present conditions. These recreation service levels and unmet demand are listed in Table 5.25, and indicate that there will continue to be an unmet demand of 11,985,000 user days of recreation along the study area.

Sport fisheries along the Salt River will remain limited and in the area downstream of 91st Avenue.

5.4.3 Opportunities

Many outdoor recreation activities can be observed along a river corridor. According to *Lifestyle Market Analysts*, a survey of households in 212 metropolitan areas revealed the following overall participation rates:

40.4% walk for health,

32.8% pursue physical exercise

14.9% bicycle,

13.75% boat or sail, and

12.4% run or jog.

Trends associated with uses of channel corridors provides evidence where spending associated with activities has been quantified. These recreation pursuits include:

wildlife-related recreation,

river boating,

trail-related recreation, and

traditional park (open space) endeavors.

SCORP has identified the following index of preference averages for overall demand for outdoor activities:

Attending/Visiting Historical Place		3.56
Attending/Visiting Open Space Activities		3.33
Attending/Visiting Archaeology Sites		3.29
Camping		3.07
Participating in On-foot Activities		2.79
Non-motorized Riding		2.65
Water-oriented		2.59
swimming, pools	water skiing/jetskiing	
swimming, lakes	motor boating	
rafting/kayaking	sailing/windsurfing	
canoeing	tubing	
Fish/Hunting		2.50
Winter Activities		2.45
Nature Study/Birdwatching		2.42
Sports Activities		2.39
Off-highway Driving		2.06

Recreation resources are inadequate and demand is rising. Based on an assessment workshop for SCORP, recreation needs for a metropolitan area were ranked in importance as follows: picnicking, tennis, baseball/ softball, bicycling, handball/squash/racquetball, water skiing, rafting/tubing, open water swimming, non-powered boating, pool swimming, volleyball/basketball/badminton, hiking/backpacking, horseback trails, trailbiking.

Arizonans believe in the importance of protecting the state's outdoor recreation resources. According to SCORP, ninety-four percent (94%) have said that parks and recreation areas are important to their everyday lifestyles. There is strong support for protecting natural and cultural resources and for environmental education. Arizonans care deeply about the state's air, water, and riparian areas. Seventy-five percent (75%) favor preserving rivers and stream-side habitats, even if it means limiting some uses of privately owned lands.

SCORP also indicates that personal watercraft use is rapidly increasing, most boating occurs on weekends and holidays, and water resource managers emphasized the importance of developing safety and basic support facilities. Among wildlife associated activities, anglers ranked second with 480,000 participants in 1991 resulting in 5,922,000 visitor user days and $156,874,000 in expenditures.

Ranking of overall demand for outdoor activities (applicable to water resource) in the recent SCORP included: visiting outstanding scenic areas, visiting historical place, visiting botanical garden, picnicking, walking, visiting archaeological site, attending outdoor performance, fishing in natural setting, day trail hiking, open water swimming, attending outdoor sports event, bicycling, playground, motor boating, horseback riding, tubing, softball/baseball, rafting and kayaking, canoeing, mountain biking, nature study/bird watching, water-skiing/jet skiing, fishing in urban setting, sailing/windsurfing, and jogging/running, golfing.

Ranking of the latent or unmet need for outdoor recreation activities (applicable to water resource) in the recent SCORP included: fishing in natural setting, picnicking, visiting historic place, visiting outstanding scenic areas, walking, visiting botanical garden, trail hiking, visiting

archaeological site, horseback riding, golfing, bicycling, playground, attending outdoor performance, motor boating, open water swimming, water-skiing/jet skiing, softball/ baseball, mountain biking, nature study/birdwatching, jogging/running, tubing, rafting or kayaking, fishing in urban setting, canoeing, sailing/windsurfing.

According to SCORP, favorite activities (applicable to water resource) ranked by the youth population included: basketball, public swimming, hanging out, baseball, horseback riding, football/soccer, motorcycle riding, roller skating, and fishing in a natural setting. Interestingly, the latent demand activities (applicable to water resource) ranked included: horseback riding, water-skiing/jet skiing, and public swimming.

Multi-purpose recreation trail systems are gaining in popularity. River channels, in particular, become a significant recreation, education, social, and travel route resource to be preserved, enhanced, maintained, and protected. The environmental benefit is the contribution to a healthful, non-motorized transportation option. Well developed trails provide a visually satisfying experience and generally accommodate a wide variety of trail users.

Rio Salado is ideally located to address several of the identified recreation needs from both the State and County assessments with particular attention on

- lakes for fishing, swimming, and non-powered boating;
- local wilderness and camping areas;
- scenic drives and walking trails;
- horseback riding trails;
- public golf courses;
- court games;
- rollerskating (go-carting and skateboarding); and
- open space for field games.

In the 1988 Parks and Recreation Long Range Plan for the City of Phoenix, one goal: *Unique open spaces should be preserved and protected,* includes the following medium priority open space objectives:

- acquire and develop a demonstration section of the Rio Salado Project and
- acquire and develop the Agua Fria River flood plain in cooperation with Glendale and Avondale.

Recreation needs for Maricopa County, as identified in 1981, include:

- additional public parks which provide large undeveloped open areas and small pockets of development for structured recreation activities and support facilities;
- centrally located recreation areas with indoor and outdoor recreation facilities for all ages;
- an open-air or domed multiple-use sports complex for track and field, football, soccer, and other organized sports; fields for organized or unorganized sports;
- additional public land for future recreation development and open space requirements; and
- complex of lighted game courts to accommodate a variety of hard surface games; turf or sand areas like volleyball.

The Phoenix Empowerment Zone has the potential to become a center of economic opportunity, environmental beauty, recreational amenities, arts, and entertainment. The areas of economic opportunity identified include a linear urban river park to replace the present expansive, channelized dry river bed. The present recontoured channel provides a natural link to the area's future economy and quality of life through a truly visionary project. Envisioning the Rio Salado as the site of a world-renowned desert river recreational amenity would:

- provide appealing open and green space,
- enhance the hospitality and tourism-oriented nucleus,
- create a large recreational amenity,
- provide opportunities for growth development,
- allow for much-needed flood control,
- generate tax revenues from a variety of sources, and
- dynamically enhance the quality of life for residents.

For this stage of reconnaissance study, the following recreation opportunities were identified:

- *Environmental Sensitive Areas*: pristine native areas set aside with no development nor direct exposure from public use activities minimizing adverse impacts to identified scientific, ecological, cultural, or aesthetic features.

- *Present Habitat Sites*: present habitat areas allocated for mitigation or restoration with limited or no development and exposure for public use activities.

- *Riparian Habitat Restoration*: areas directly related to refurbishment or reconstruction for contaminate treatment options with limited development and exposure for public use activities.

- *Low Intensity Recreation*: open space with minimum development for passive-type recreation opportunities.

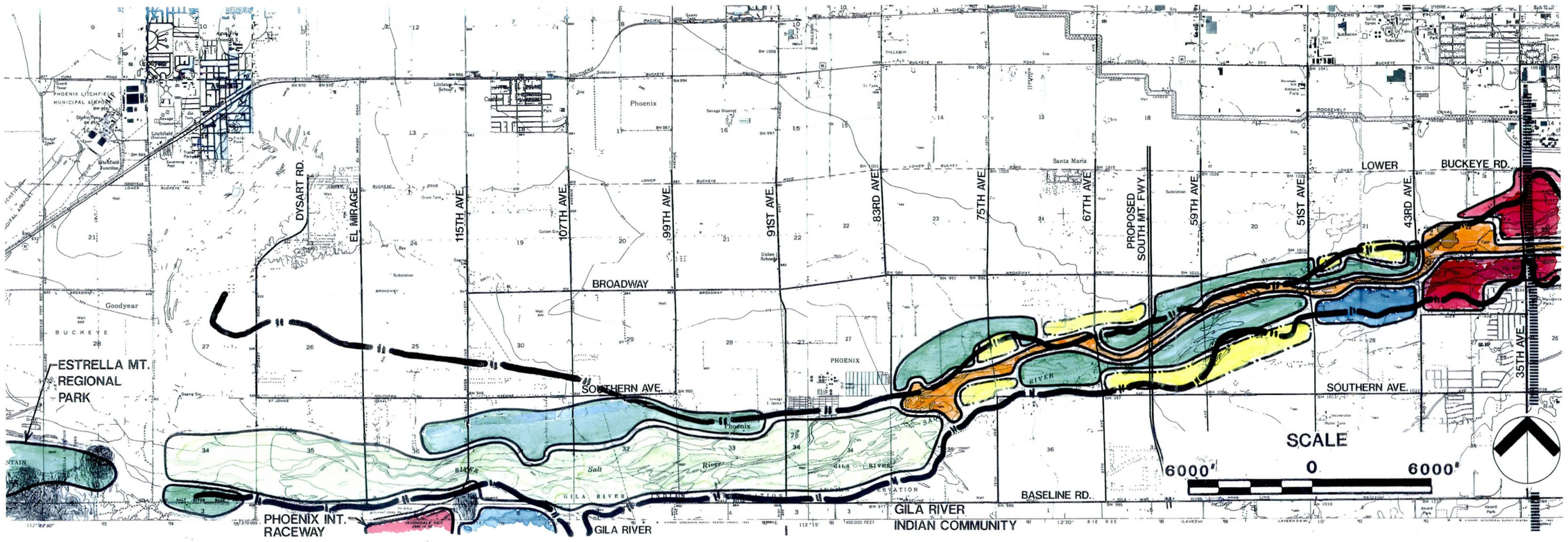
- *Medium Intensity Recreation*: open space developed for semi-active type recreation opportunities.

- *High Intensity Recreation*: developed areas with structural and/or architectural support facilities for active type recreation opportunities.

- *Operations*: land set aside for maintenance, flood control, or other operational facilities.

At this stage of evaluation, potential considerations have been designated by a land use designation system described above and graphically presented on Figure 5.18 (A and B).

Much of the historic (pre-1880) aquatic fauna has been eliminated from the Rio Salado Reconnaissance area. While the likelihood of fully restoring these fishes in this ares (through reintroduction) are limited, there may be some opportunities. The constraints include the significant nonnative fish fauna that would be contributed intentionally (stocking for recreation) or unintentionally (potential fish movement from upstream locations or illegal stockings) and availability of water. It would be possible to look to reintroductions of listed or not-yet-listed native fishes in the project area as refugia, holding ponds, or experiment sites. Not likely constraint that the Corps and the municipalities would need to take under advisement is that reintroductions of listed species would be fully protected by the Endangered Species act, unless

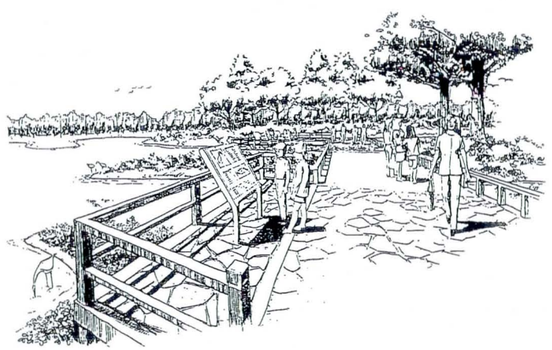


The floodplain limits shown on this figure are approximate and do not reflect recent improvements. They are not to be used for floodplain management purposes.

RIO SALADO RECREATION OPPORTUNITIES

LEGEND

- HIGH INTENSITY RECREATION
- MEDIUM INTENSITY RECREATION
- LOW INTENSITY RECREATION
- ENVIRONMENTAL SENSITIVE AREAS
- EXISTING HABITATS
- RIPARIAN HABITAT RESTORATION



ENVIRONMENTAL SENSITIVE AREA

LOW TO MEDIUM INTENSITY RECREATION

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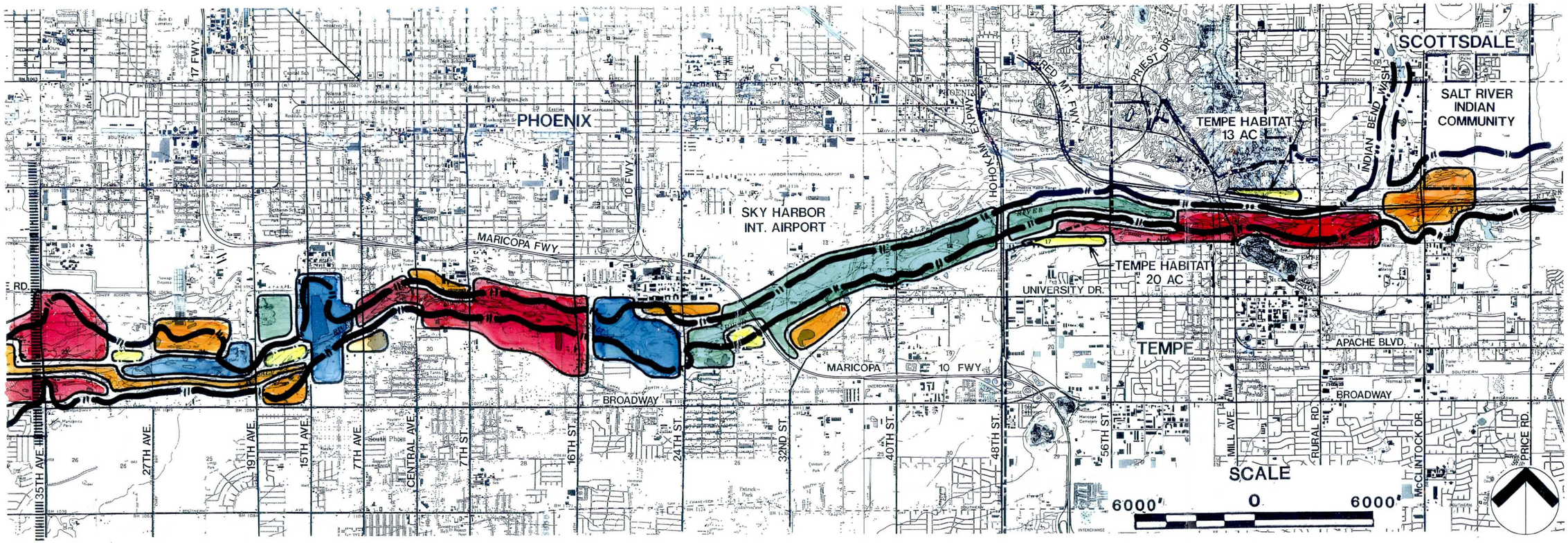
LANDSCAPE ARCHITECTURE AND PLANNING
JOB NO. 94-217.01
CALIFORNIA 1226
9 / 26 / 94

RIO SALADO
RECONNAISSANCE STUDY

ARMY CORPS OF ENGINEERS • LOS ANGELES DISTRICT

Figure 5.18A. Rio Salado Recreation Opportunities

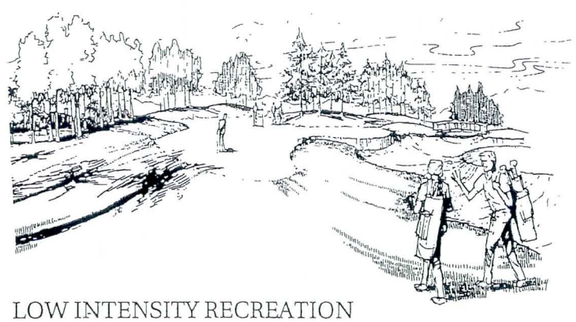


The floodplain limits shown on this figure are approximate and do not reflect recent improvements. They are not to be used for floodplain management purposes.

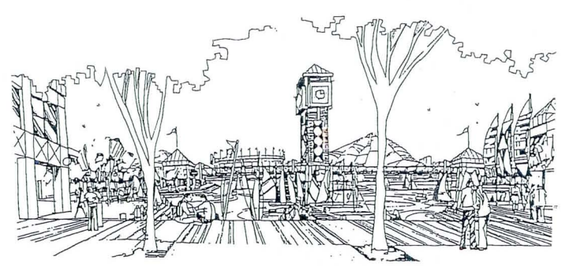
RIO SALADO RECREATION OPPORTUNITIES

LEGEND

- HIGH INTENSITY RECREATION
- MEDIUM INTENSITY RECREATION
- LOW INTENSITY RECREATION
- ENVIRONMENTAL SENSITIVE AREAS
- EXISTING HABITATS
- RIPARIAN HABITAT RESTORATION



LOW INTENSITY RECREATION



HIGH INTENSITY RECREATION
FROM TEMPE RIO SALADO DEVELOPMENT PLAN

LAND USE DESIGNATION PLAN

RIO SALADO
RECONNAISSANCE STUDY

NŪVIS
LANDSCAPE ARCHITECTURE AND PLANNING
JOB NO. 94-217.01
CALIFORNIA 1226
9 / 26 / 94

ARMY CORPS OF ENGINEERS • LOS ANGELES DISTRICT

Figure 5.18B. Rio Salado Recreation Opportunities

they were identified as non-essential, experimental pollution under a rule making process by the Fish and Wildlife Service.

Opportunities associated with the Rio Salado include construction of open water sites that exceed 9 feet in depth and 3 surface acres in extent as potential fisheries. These sites could be managed as Urban Fishing Lakes, with special intensive management and stocking, or as self supporting city lakes. Experience has suggested that attempting to manage these kinds of waters without intensive attention rarely meets public angling expectations. With approximately 120 acres of urban waters made available at Lago de Vida, considerable economic benefit can be expected to local economies and considerable angling recreation opportunity can be generated. Watt and Persons (1990) reported 226,552 visits to urban lakes in 1987-88 (approximately 2,490 angler visits/acre - computed at 91 acres in the program at the time).

A 120-acre urban lake could generate up to 300,000 annual angler visits, creating significant benefits for the local community. Watt (1986) reported that urban lakes draw recreationists from the nearby neighborhood in high density urban areas. On average, urban anglers traveled from 7 to 11 miles one-way to their urban lake. About 71% of all of the urban anglers contacted by Watt (1986) reported that they traveled 10 miles (one-way) or less to their urban lake. A small percentage of urban anglers traveled more than 20 miles (one-way) for the opportunity to fish an urban lake.

Daily expenditures by anglers were estimated by the US Fish and Wildlife Service (1993) at approximately $67 per day in 1990 dollars. (Caution should be used in grossly applying this estimate. It was derived from census interviews of anglers in general, who often travel distance to fish and includes food, lodging, bait, fuel, and equipment expenditures that may not be applicable to urban angling.) A more conservative estimate of $10 expenditure per angler per day would mean raw expenditures of $3,000,000 per year on a 120-acre lake.

Other, non-urban, angling opportunities could be generated by restoration in the western half of the Rio Salado study area. The area currently gets angling pressure directed at naturally reproducing warmwater fish populations that occur in reliable pools in the Salt River channel.

Constraints include accumulated organics (largely pesticides) in the river sediments have required a human health advisory for consumption of those fish. A human health risk assessment has been completed from 59th avenue downstream and anglers are advised not to consume fish from the Salt River in that area. A similar assessment will be necessary for areas above 59th avenue.

Riparian restoration in the western, more rural portions of the Rio Salado Reconnaissance Study area would create additional nesting habitat for white-winged and mourning dove. There is considerable hunting pressure for these species along the Salt and Gila rivers in western Maricopa County. Daily hunter expenditures are estimated at approximately $101 per hunter day (US Fish and Wildlife Service 1990).

Non-consumptive wildlife recreation (nature photography, birdwatching, etc.) is an important component of any view of riparian restoration benefits in Arizona. Riparian restoration along Arizona's rivers provides a significant boon to migratory birds (neotropical migrants), and in-turn provides opportunities for non-consumptive recreation. There is significant tourism and visitation to Arizona for bird watching, in particular. The US Fish and Wildlife Service (1993) reports an estimated 435,000 Arizonans participate in non-consumptive wildlife recreation away from their primary residences. Total participation (Arizona residents and nonresidents) in non-consumptive wildlife recreation away from a primary residence was estimated at 820,000, making expenditures of $187,000,000 for trips and expenditures. While it may be difficult to quantify the exact increase in participation in such activities should riparian restoration activities be undertaken in the Rio Salado Study area, those values should not be ignored.

For the purposes of this study, a wide array of recreation opportunities are presented. Corps involvement in the development of recreation projects, however, will be consistent with Corps policy wherein Federal participation is limited to: (1) recreation projects that are "incidental" or complementary to a Corps primary project purpose, and (2) where the cost of the recreation development is no more than ten percent of the total project cost (ER 1105-2-100, 4.3.c and Policy Guidance Letter #36).

VI PLAN FORMULATION AND EVALUATION

6.1 Planning Objectives and Constraints

6.1.1 Objectives

The Federal objective in water resources planning, as stated in the Principles and Guidelines (P&G) is to contribute to National Economic Development (NED) in order to alleviate problems and/or realize opportunities related to water and related land resources, consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders and other Federal planning requirements. The Corps Civil Works budget guidance assigns high priority to the restoration of ecosystems and associated ecological resources. Consistent with the analytical framework established by the P&G, alternatives presented in this reconnaissance report address environmental restoration measures that result in monetary and non-monetary benefits. As stated in Engineering Circular, EC 1105-2-206, 7 March 1994, these measures do not need to exhibit net NED benefits, and should be viewed as exceptions that are compatible with the P&G selection criteria, and offered for consideration and budget support.

The general objective of the Reconnaissance Study is to determine whether or not the planning effort should proceed to the more detailed feasibility phase. This objective is accomplished by determining whether there is at least one alternative that satisfies the Federal Government criteria for participation, and identifying a local sponsor(s) willing to serve as a cost-share partner.

Specific planning objectives of the Rio Salado reconnaissance study have been identified as follows:

- Protect and, as appropriate, improve present Threatened and Endangered Species Habitat.
- Restore riparian habitat in the area of Indian Bend Wash at Tempe.
- Increase waterfowl habitat restoration.
- Increase riparian habitat in areas associated with discharge from wastewater treatment plants.
- Secure water supplies which currently sustain present riparian habitat.

- Identify and secure additional water sources wherein riparian habitat can be restored and sustained.

- Reduce flood related damages and costs where economically justified.

- Improve aquifer water quality.

- Improve surface water quality within the study area.

- Provide water-related recreation opportunities in Tempe and Phoenix.

6.1.2 Constraints

The following planning constraints have been identified for consideration in developing alternatives:

- **Biological Resources.** Riparian vegetation is subject to many disturbances and variability in water supply. Any mapping of vegetation therefore is limited by the fact that it simply represents a "point in time" condition.

  Based on recent studies by Arizona Department of Transportation for State Route 153, there are no known identified endangered or threatened wildlife species in the Tempe region of the Rio Salado. U. S. Fish and Wildlife Service, also, have not identified endangered species or their critical habitat within the Tempe area. However, three endangered species, the Yuma clapper rail, the peregrin falcon and American bald eagle, have the potential for living in the study area. The Southwestern willow flycatcher may also inhabit the area.

- **Cultural Resources.** The entire project area (area of potential effects [APE]) as proposed has not been studied to determine the presence or absence of cultural resources. A records and literature search has been initiated at the regional archeological clearing house (State Historic Preservation Office, Phoenix) to inventory all previous studies involving the project area of potential effects (APE). The State Historic Preservation Office and the Office of Cultural Resource Management, Department of Anthropology, Arizona State University, have developed inventories of recorded archaeological sites and previously conducted archaeological surveys. Undeveloped areas along the Rio Salado contain numerous archeological sites, and in many cases have been ranked as high sensitivity districts. There are several developed areas along the Rio Salado which have been ranked moderately sensitive, since they contain extensive evidence of past Hohokam habitation sites and irrigation systems. Although in many cases no surface evidence remains, sub-surface materials are a real possibility. The potential for the presence of additional

archaeological sites within the APE is high. The potential for the presence of historic sites within the APE is also high.

Preliminary results of the record search indicate that the proposed project may have an effect on at lease one property listed in the National Register of Historic Places. The proposed project has the potential of affecting additional National Register listed or eligible sites. Based on the results of the records search, additional archaeological surveys will more than likely be required since our preliminary investigations indicate that only a portion of the project APE has been surveyed. All potential National Register eligible properties within the project APE have yet to be identified. Until these studies are completed, the overall effect on National Register listed or eligible properties is unknown.

- **Hazardous, Toxic and Radioactive Waste.** The soils within the river are potentially subject to contamination from several non-point sources: toxic materials in discharge from storm water collector systems carrying metals, grease, and oils or minimal toxicity from overland flows transmitting sediment and fertilizers. However, as of 1989, municipal testing at storm water discharge points has not indicated contaminants in sufficient quantities to discount use of soils from the river channel for certain types of projects. There are no known sources of persistent pesticides and only two minor petroleum spills have been recorded within the western end of the Tempe reach.

  Two sewage treatment plants (point-source pollution) are located within this section of the Salt River - at 23rd and 91st Avenues.

  Twenty four (24) official landfill sites occur along Salt River's edge - five (5) are active. These landfills present numerous constraints for development. Leachate was produced at the two (2) Estes sites (near 40th Street) from 1978 to 1981. This was caused when the water table rose as a result of recharging from the 1978 flood. The water mixed with the landfill matter to produce leachate which migrated through the aquifer and contaminated local ground water and wells. Testing revealed excess of common cations and anions. The most dangerous substance was a potential carcinogen, vinyl chloride. The ground water is unsuitable for domestic use without prior treatment. Other landfill sites have not been tested but are presumed to be contaminated.

  The Arizona Department of Health is concerned with the build-up of methane. These gases are created within the landfill matter as a by-product of the decomposition process of solid waste. Unfortunately, methane gas is known to migrate and can become trapped under structures. City of Phoenix has/will be installing gas monitoring and migration control systems at several locations.

- **Land Use**. The present uses of the bed and banks are varied. Extensive active and inactive sand and gravel mines are located in the area. Other uses include landfills, sewage treatment plants, silt extraction operations, "free" dumping grounds, agriculture, limited residential development and recreation facilities. The floodplain is also used for illegal dumping of solid wastes and for other unauthorized activities such as off-road vehicle use, hunting, and shooting.

- **Noise**. Due to intense urbanization along certain reaches of this 28-mile stretch of the Salt River, noises today are generated from commercial and military aircraft, trains, cars, buses, trucks, motorcycles, construction, and urbanized air conditioning units. In most cases, these types and levels of noises are considered acceptable as indigenous noise associated with urban life.

  Given particular NEF (noise exposure forecast) and Ldn (24-hour sound levels weighted for night-time annoyance) levels, several areas within the project area are currently severely impacted. This means that several residential areas are already experiencing unduly high noise levels and some types of recreation activities would be somewhat incompatible.

  In the western section of the river, high levels of noise are generated seasonal when the Phoenix International Raceway is operating.

- **Water Quality.** Any activity within the Salt River, including Rio Salado, must comply with Federal Clean Water Act (404 and 401) guidelines and NPDES water quality standards. Aquifer protection and poor-quality groundwater permits will be required. Sand and gravel mines, landfills and urban stormwater runoff could have an impact on water quality.

- **Water Rights/Land Ownership.** The water rights and land within the Rio Salado study area are currently under a variety of public and private ownerships.

- **Floodplain Regulations.** Maricopa County and the Cities of Phoenix and Tempe all have comprehensive floodplain management ordinances that regulate activities in the floodplain. It is Federal policy to comply with such regulations where possible.

- **Sand and Gravel Operations.** There are sand and gravel operations with vested rights to operate within the Rio Salado study area. These operations provide a much-needed product to the growing community, as well as a substantial employment base to the South Phoenix area.

- **Public Sentiment.** Public sentiment regarding Rio Salado has varied considerably in the past. Given the results of the 1988 bond election, in which a Rio Salado bond was defeated, initial public sentiment may not be favorable.

- **Jurisdictional Fragmentation.** The study area is under the jurisdiction and interest of Federal, state, county, and local agencies, and three cities (Tempe, Phoenix and Avondale). In addition, two Indian Communities (i.e., the Salt River-Pima-Maricopa, and the Gila River) are located in the upstream and downstream ends of the study area. Coordination among various agencies' policies, permits, and plans will be challenging.

- **23rd Avenue Wastewater Treatment Plant.** Impacts to the 23rd Avenue Wastewater Treatment Plant must be avoided.

6.2 Planning Alternatives

In response to Congressional direction, Rio Salado alternatives were formulated in consideration of restoration of riparian habitat, water quality and recreation as well as benefits traditionally displayed (i.e., flood control). To this end, a variety of multi-purpose features have been incorporated into the alternatives, producing a mix of resource outputs.

A low level of flood damages can occur in the study area. As a result, no Federal interest was identified for flood control. However, flood control features have been included in the analysis of alternatives because they provide flood protection in support of other resource objectives and achieve incidental flood control benefits. A streambank erosion protection problem was identified at the 91st Avenue Wastewater Treatment Plant. However, because it is not considered to be a flooding problem, it is recommended that the bank erosion analysis be conducted under the authority of Section 14 of the Flood Control Act of 1946.

Two alternatives have been formulated in response to the array of water resource problems in the Rio Salado study area. Alternative A represents an environmental restoration alternative wherein riparian habitat restoration, water quality and recreation benefits are provided. Alternative B is similar to Alternative A in every way except that the recreation component is expanded substantially to include the development of recreation lakes in the Salt River channel at Tempe and Phoenix. Each alternative is discussed in greater detail in the sections that follow. Technical details are provided in Appendix F.

and mesquite bosque habitat in Indian Bend Wash within the City of Tempe. The concept and function of the wetland are described below.

Inflatable Dam. The Salt River impoundment structure will consist of a 6-foot, inflatable rubber dam at the location shown in Figure 6.2. Figure 6.3 shows a typical cross section of the dam. The dam will impound all flows in the Salt River to a maximum ponding depth of six feet. Existing soil cement banks will confine the lateral extent of ponding.

An inflatable rubber dam is selected because it is the most efficient method of impounding flood flows in a flood-control channel without increasing the flood risk. The inflatable dam will obstruct flows in the Salt River. Flows causing a ponding depth in excess of six feet (total ponding volume = 450 acre feet in addition to the permanent pond) will pass over the structure and continue downstream. Flood-related impacts will be avoided by deflating the dam for river discharges in excess of the 10-year flood. The dam has the advantage that it can be inflated at the tail end of large floods in order to capture the receding flows for use in the wetland. Furthermore, a rubber dam will permit sediment transport past the structure during large flows.

Salt River Wetland. The Salt River portion of the Tempe Wetland (Figure 6.2) will consist of a 20-acre pond immediately upstream of the inflatable dam, 4 acres of hydrophytic vegetation at the upstream edge of the pond, 15 acres of cottonwood/willow riparian vegetation along a low-flow channel and a 90-acre, naturally-occurring revegetation area between the pond and a grade-control structure downstream of the McClintock Road bridge. The pond will be approximately 5 feet deep.

Indian Bend Wash Wetland and Mesquite Bosque. The Indian Bend Wash currently includes a low-flow channel approximately 150 feet wide from McKellips Road to the confluence with the Salt River. The low-flow channel widens to cover the entire bottom width of the flood control channel near the confluence. This area, supplied with water at McKellips Road, can be converted into a wetland of approximately 18 acres in size. Figures 6.4, 6.5, 6.6, and 6.7 show the concept plan view and cross section of the wetlands.

The Indian Bend Wash between Curry Street and the Salt River currently consists of bare ground. There is a low-flow channel situated approximately 5 feet below a terrace between the outer levees. The terrace would be vegetated with mesquite trees to create a mesquite bosque habitat of approximately 4 acres.

Introduction of the mesquite bosque will affect the hydraulics of the Indian Bend Wash. Preliminary analysis indicates that the water surface elevation could be increased by approximately one foot without mitigation. Mitigation in the form of widening the low-flow channel or increasing the levee height will be required to compensate for any increase in water surface elevation. The design as presented herein is conceptual and will be studied in more detail in the feasibility study.

- **Jurisdictional Fragmentation.** The study area is under the jurisdiction and interest of Federal, state, county, and local agencies, and three cities (Tempe, Phoenix and Avondale). In addition, two Indian Communities (i.e., the Salt River-Pima-Maricopa, and the Gila River) are located in the upstream and downstream ends of the study area. Coordination among various agencies' policies, permits, and plans will be challenging.

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6.2.1 Alternative A: Environmental Restoration

Alternative A achieves environmental restoration opportunities in Indian Bend Wash and the Salt River channel at Tempe and Phoenix. Habitat restoration is accomplished through the use of constructed wetlands, re-establishing high-wildlife value mesquite bosque communities, and restoring riparian vegetation along streambanks. Approximately 300 acres of habitat would be restored rsulting in a substantial increase in habitat units. In conjunction with the accomplishment of riparian habitat restoration objectives, incidental recreation opportunities wouls also be provided to offset the enormous unmet demand for recreation.

The restoration of riaparian habitat involves features that are someshat uniqui as the project would take advantage of existing enviromnental problems in the study area and converts these problems into opportunities for greater environmental gain.

Wetlands and riparian habitat in Alternative A will be constructed within the channels of the Salt River and Indian Bend Wash. Methods for preserving the integrity of these habitats during flood flows will be explored in the feasibility study. The geomorphic and sediment transport features of the project, and potential related impacts and mitigation measures, will also be investigated in detail in the feasibility study.

Alternative A includes two components: Tempe Cienega and Phoenix Lago de Vida (Figure 6.1). Each are described below in detail:

TEMPE CIENEGA

Description

Tempe Cienega restores habitat lost as a result of the construction of Indian Bend Wash and upstream Federal Dams. Tempe Cienega restores scarce wetland, riparian and mesquite bosque vegetation and consists of 1) an inflatable dam to serve as a water impoundment structure in the Salt River approximately 350 feet upstream of the Indian Bend Wash 2) a constructed wetland in the Rio Salado channel upstream of the impoundment structure, and 3) a constructed wetland

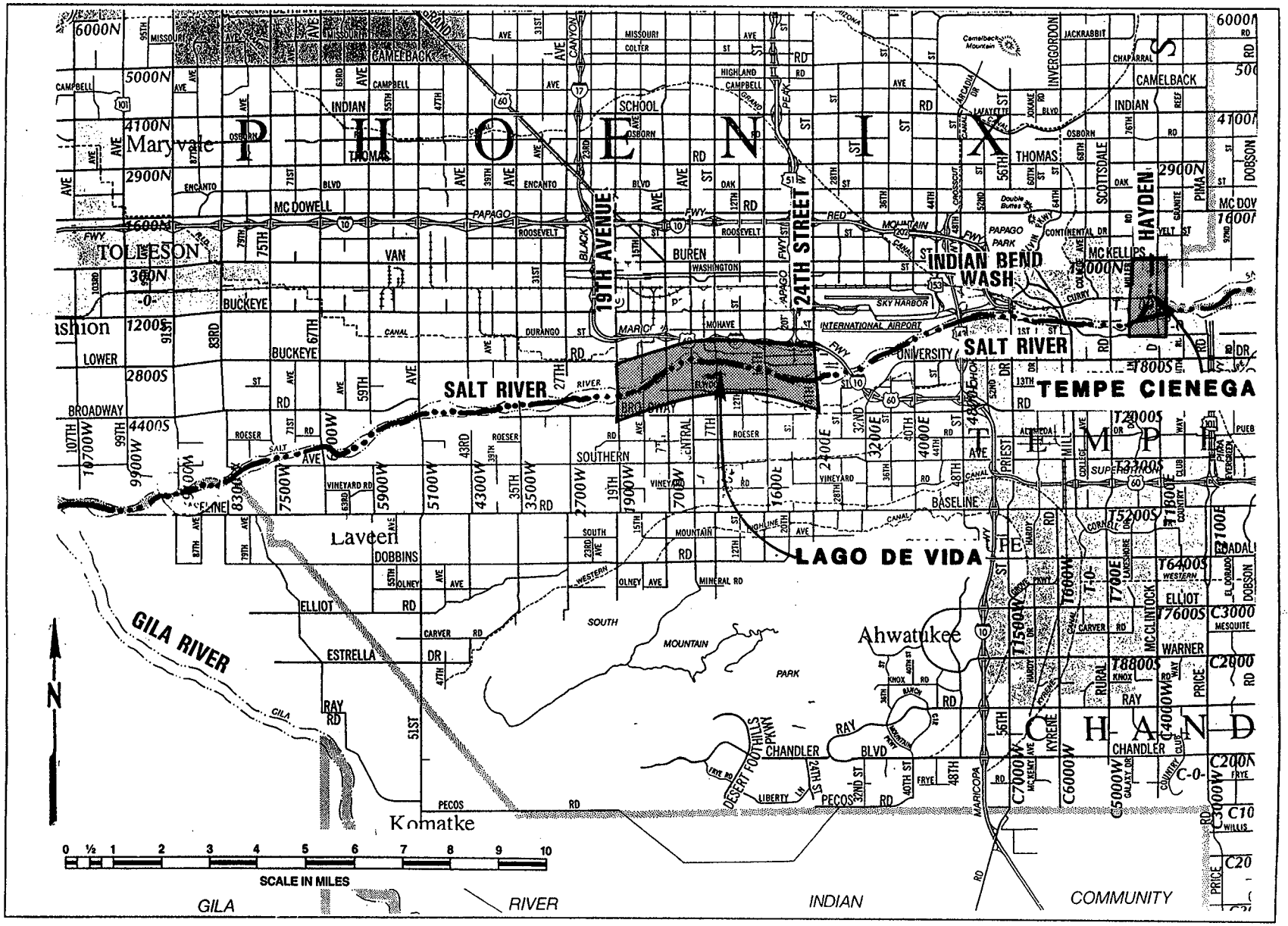

Figure 6.1. Alternative A.

and mesquite bosque habitat in Indian Bend Wash within the City of Tempe. The concept and function of the wetland are described below.

Inflatable Dam. The Salt River impoundment structure will consist of a 6-foot, inflatable rubber dam at the location shown in Figure 6.2. Figure 6.3 shows a typical cross section of the dam. The dam will impound all flows in the Salt River to a maximum ponding depth of six feet. Existing soil cement banks will confine the lateral extent of ponding.

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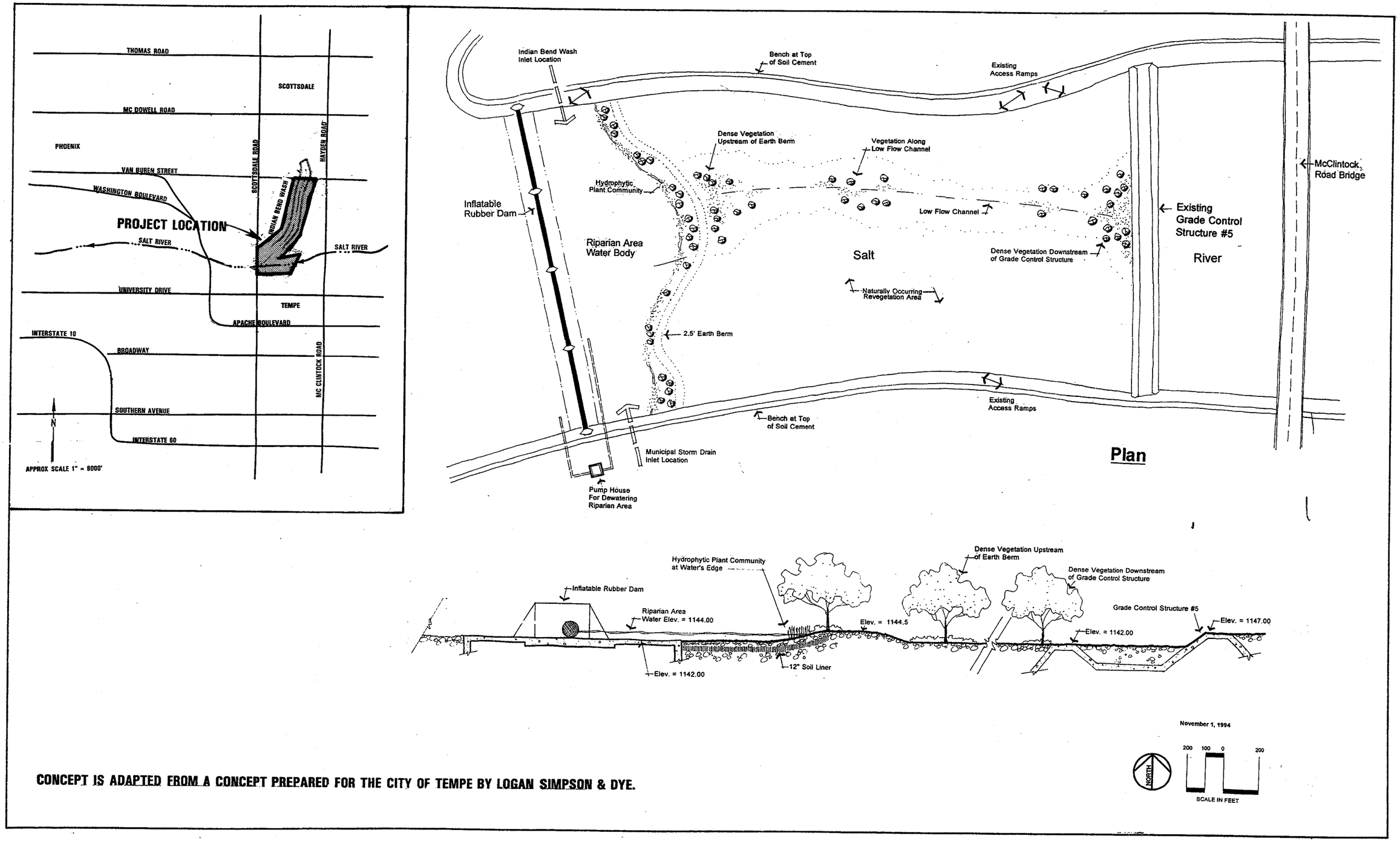


CONCEPT IS ADAPTED FROM A CONCEPT PREPARED FOR THE CITY OF TEMPE BY LOGAN SIMPSON & DYE.

Figure 6.2. Tempe Cienega.

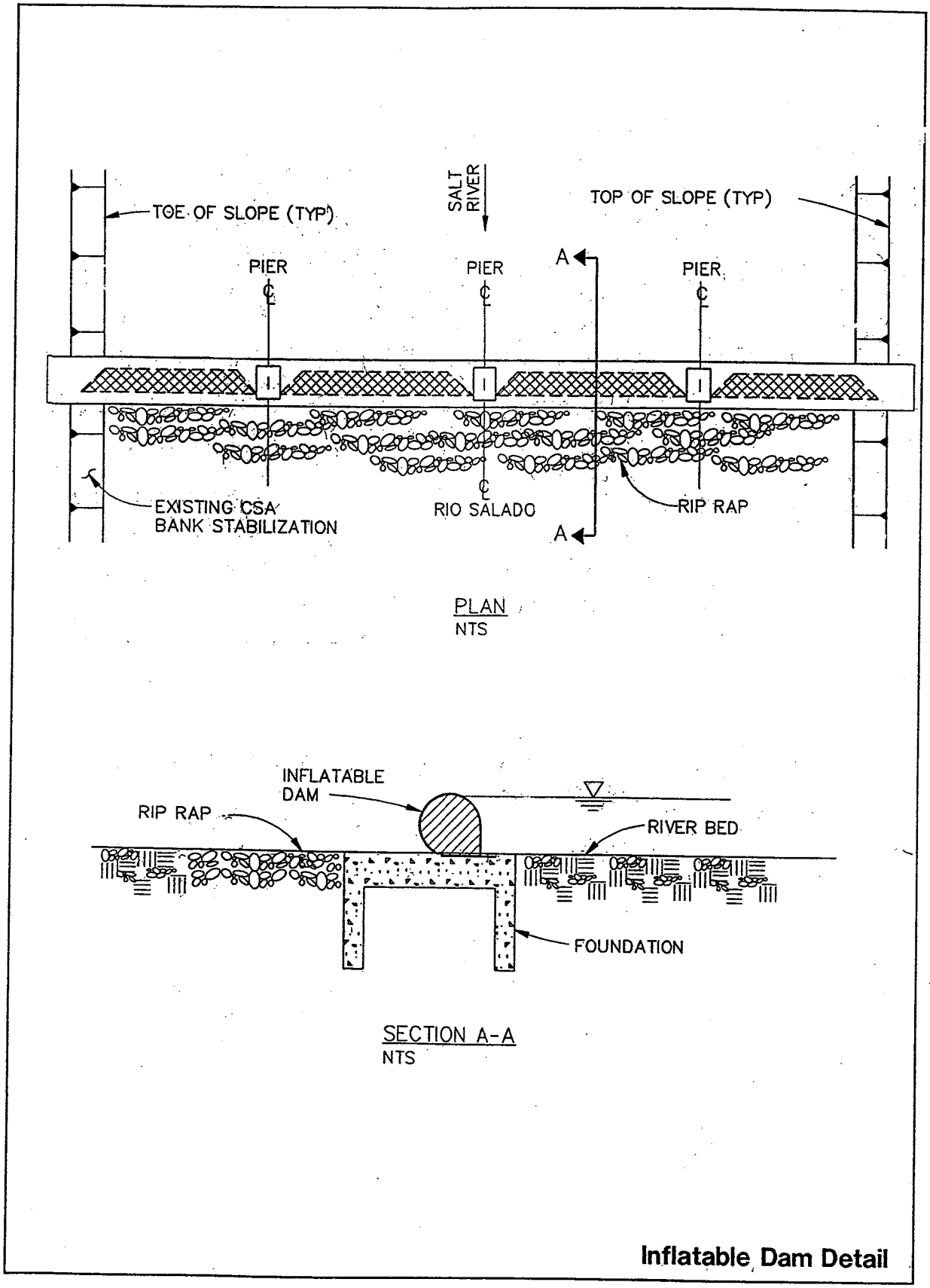


Figure 6.3. Inflatable Dam Detail

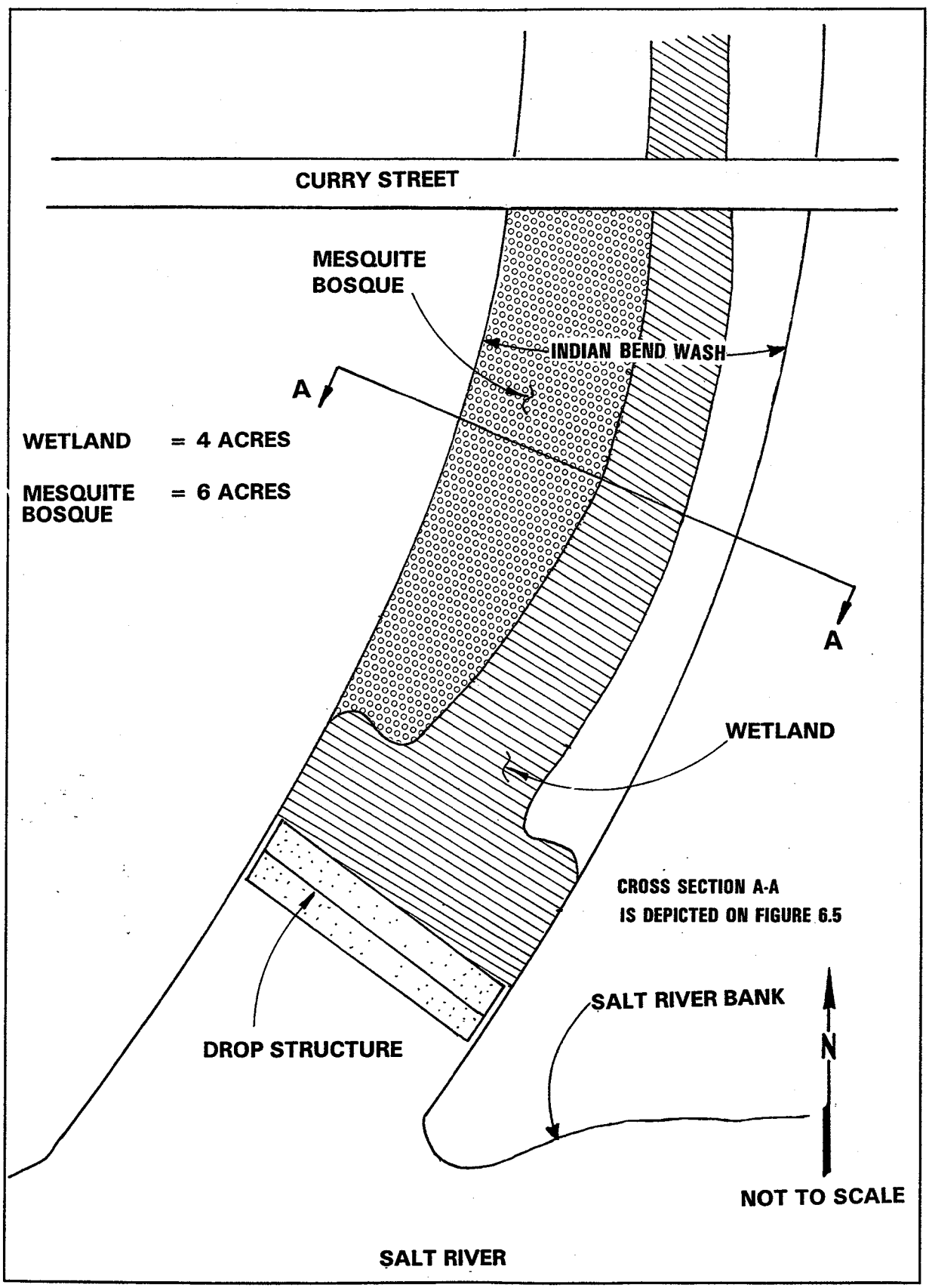


Figure 6.4. **Indian Bend Wash Component of Tempe Cienega: Curry Road to Salt River.**

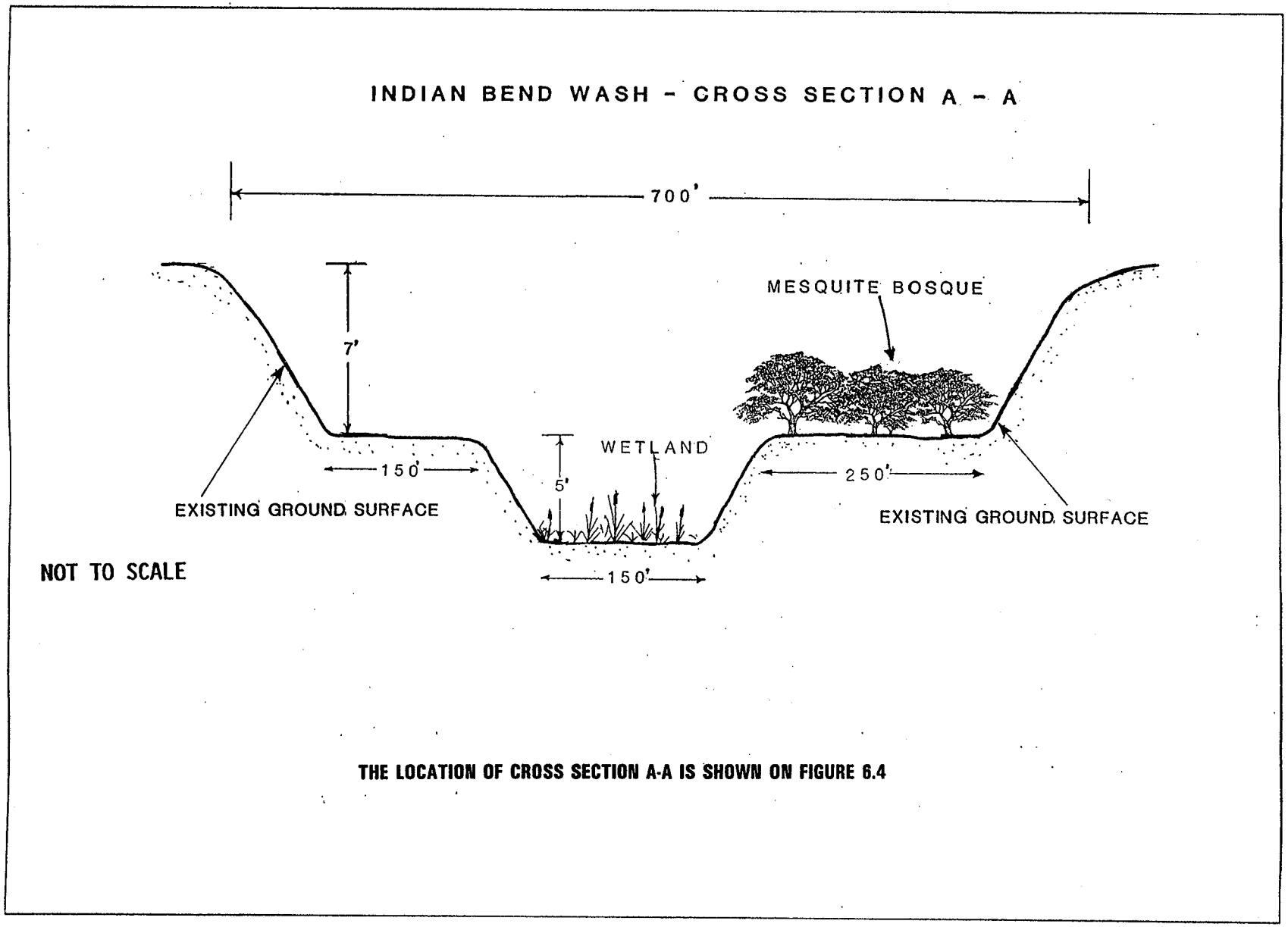


Figure 6.5. **Typical Cross Section for Indian Bend Wash Component of Tempe Cienega: Curry Road to Salt River.**

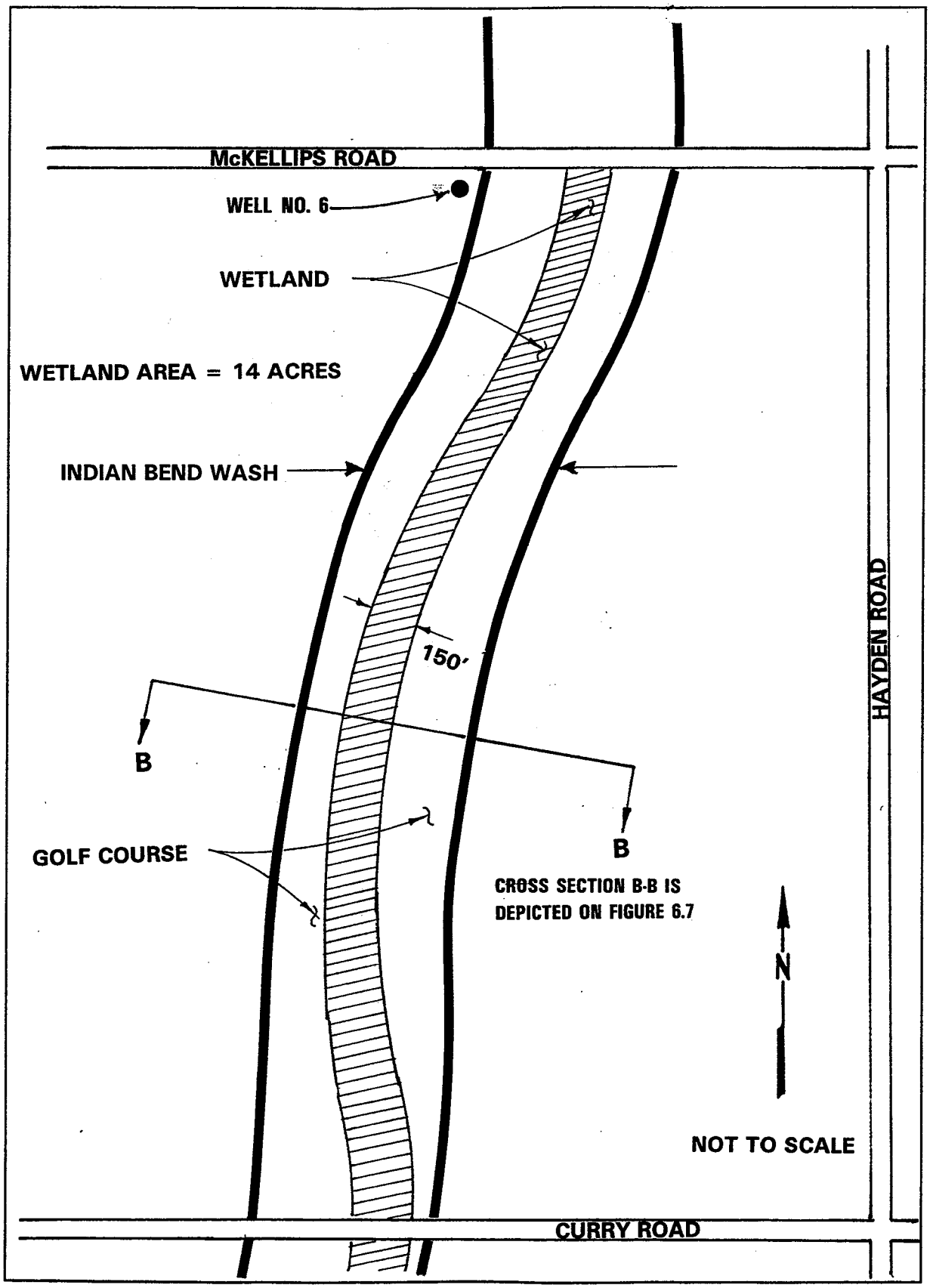


Figure 6.6. **Indian Bend Wash Component of Tempe Cienega: McKellips Road to Curry Road.**

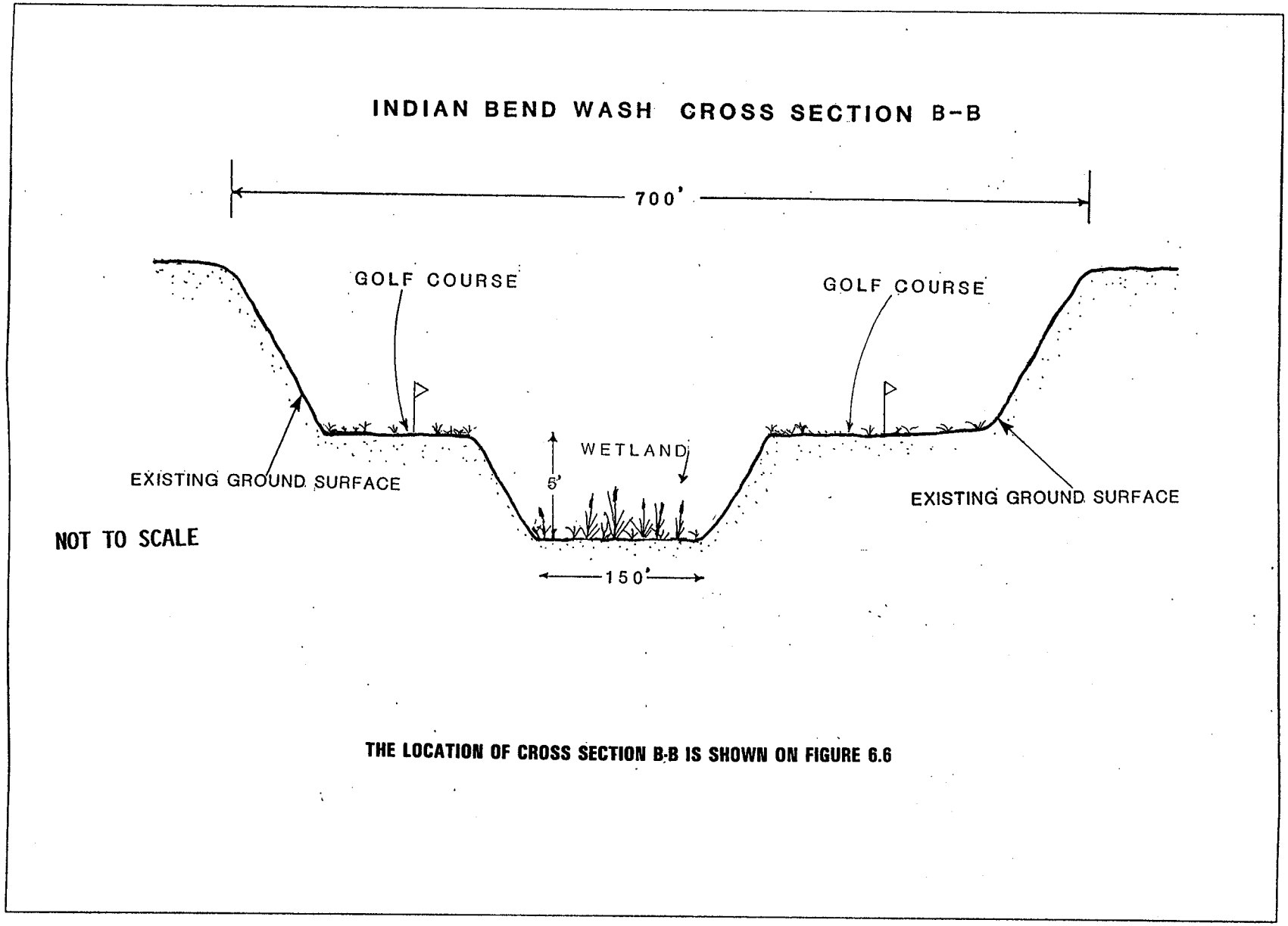


Figure 6.7. **Typical Cross Section for Indian Bend Wash Component of Tempe Cienega: McKellips Road to Curry Road.**

Benefits

Habitat

Table 6.1 provides a summary of habitat benefits from Tempe Cienega. An overall increase of 23 habitat units is expected, with the majority of the increase being in wetlands. Under present conditions there are no habitat units at the restoration sites.

Tempe Cienega will replace existing bare earth with a mesquite forest habitat that is in severe decline elsewhere in the Southwest. The mesquite forest, with adjacent wetland and cottonwood/willow vegetation will provide shelter and a food source for a wide variety of native birds, mammals and reptiles including those adapted the xeric conditions of the desert as well as those adapted to wet environments. Animal populations and species diversity will be significantly increased. Migratory bird species often rely on these types of habitats, which are significantly declining, as temporary resting and foraging places during migration.

Water Quality

Tempe Cienega will provide water quality benefits in the form of TCE clean-up of water from Well #6. Exposure of Well #6 water to the air along Tempe Cienega will release the contaminants and improve water quality. The purified water can be infiltrated back into the ground if desired. The amount of purified water will be the difference between the maintenance needs of Tempe Cienega, including evaporation, and the pumping rate. If a pumping rate of 3 million gallons per day is used, the net treated water would range from 0.85 to 2.15 million gallons per day.

Table 6.1. Habitat Units for Future With-Project Conditions: Tempe Cienega in Alternative A.

Mesquite Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source
Indian Bend Wash	4	0.60	2.4	Groundwater
Wetlands Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source
Salt River	4.0	0.56	2.2	Groundwater and Salt River Flows
Indian Bend Wash	18.0	0.58	10.4	Groundwater
Subtotal	22.0	--	12.6	Groundwater and Salt River Flows
Cottonwood Willow Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source/Impact
Salt River at Tempe	15.0	0.5	7.5	Groundwater and Salt River Flows
Total	41	--	22.5	Groundwater and Salt River Flows

Cost

A preliminary cost estimate is provided in Table 6.2.

Table 6.2. Preliminary Cost Estimate for Tempe Cienega in Alternative A.			
Cost Item	Quantity	Unit Cost	Cost
Land Purchase	LS	LS	$70,000
Inflatable Dam at Salt River.	1	LS	$2,700,000
Excavation	160,000 cubic yards	$2/cubic yard	$320,000
Water Supply Wells and Pumps	LS	LS	$500,000
Piping	1 mile	$55/foot	$290,400
Wetland, Riparian Vegetation and Mesquite Bosque Establishment[1]	41 Acres	$11,000/acre	$451,000
Seepage Control	LS	LS	$875,000
Total			$5,206,400
Engineering, Contingencies and Administration (55%)			$2,863,500
Total Cost			$8,069,900

[1] United States Bureau of Reclamation, 1992. Vegetation Management Study, Lower Colorado River, Phase I.

The annualized cost, assuming an interest rate of 8% and a project life of 50 years, is $657,800. The annualized cost per habitat unit is $28,600.

PHOENIX LAGO DE VIDA

Description

Phoenix Lago de Vida also restores habitat in the Salt River as well as provides incidental recreation and water quality benefits. From the City of Phoenix' standpoint, Lago de Vida is intended to bring "life" back into the Salt River in the form of riparian habitat, wildlife, recreation, improved water quality and urban re-development. The project is located in the Salt River channel from 24th Street to 19th Avenue.

The restoration of riparian habitat involves features that convert existing environmental problems into opportunities for greater environmental gain. As identified earlier, surface water from storm drains and ground water is of poor quality. Additionally, the existence of abandoned sand and gravel pits which line the Salt River channel through the City of Phoenix cause aesthetic challenges for the community as it strives to accomplish urban redevelopment goals. Thbese two problems, however, become integral components of environmental restoration.

The abandoned pits are incorporated into the scheme for riparian habitat restoration as they become storage basins by capturing storm drain runoff. Because a continuous water source in the lower Salt River is the limiting factor for riparian habitat restoration, the runoff that is stored in these pits can be metered out into the wetlands providing a water source while treating and improving the quality of urban runoff entering the Salt River channel. Hydrologic estimates indicate that the drainage area could produce sufficient amounts of runoff to sustain the wetlands. However, during dry periods groundwater pumping from areas of poor quality will serve as a supplemental water source while treating contaminated groundwater using various conventional methods (e.g., air stripping) and discharging the outfall into the wetlands for additional treatment including nitrate removal.

The riparian restoration concept is shown in Figures 6.8 and 6.9 and described below:

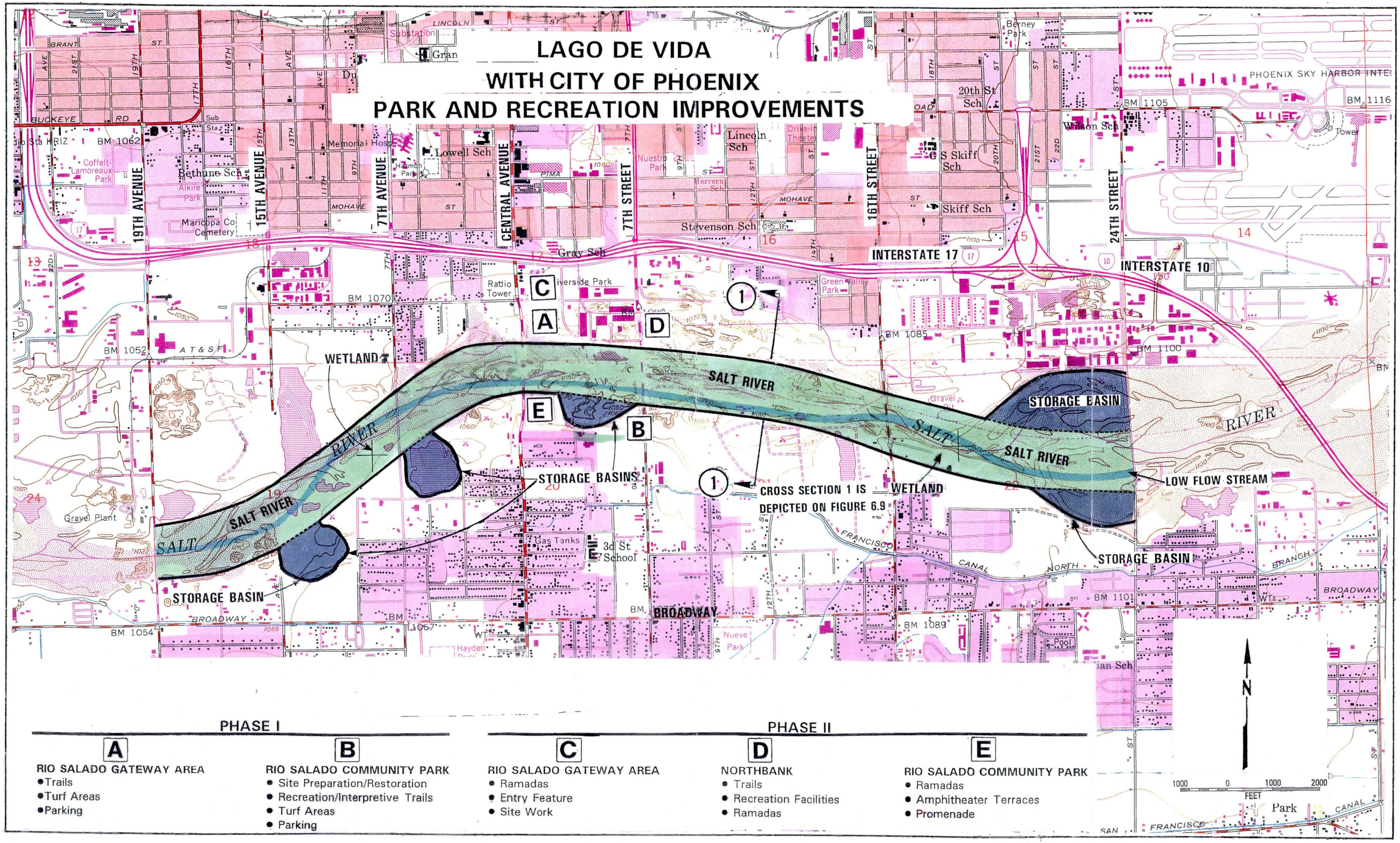


Figure 6.8. **Alternative A Lago de Vida Plan View.**

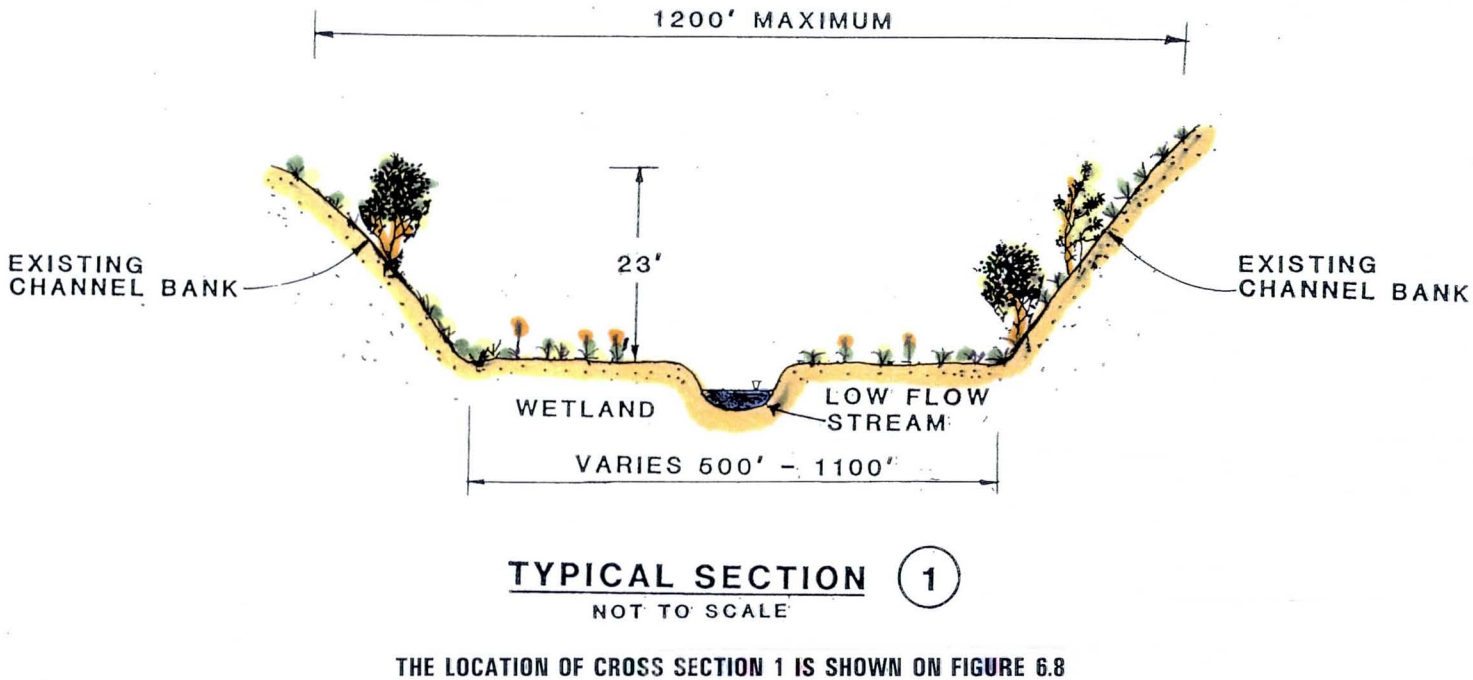


Figure 6.9. Typical Cross Section for Alternative A Lago de Vida.

Wetlands. A 240-acre wetland will be constructed within the stream channel between 24th Street to 15th Avenue. A perennial, low-flow stream will meander through, and supply water to the wetlands. The remainder of the low-flow channeland channel banks will be vegetated with native riparian vegetation.

Gravel Pits/Storage Basins. Gravel pits along Lago de Vida Riparian Restoration will be converted to storage basins for collecting storm drain runoff and the Salt River. These basins will then serve as water sources for the Lago de Vida wetland.

Incidental Recreation Facilities. In addition to riparian restoration, a recreation component is included within Lago de Vida as developed by the City of Phoenix.

The Lago de Vida riparian restoration project will be approximately 1,200 feet wide to conform to the width of the present 100-year floodplain. The City of Phoenix is planning recreational and urban development alongside Lago de Vida Riparian Restoration in a separate project.

Benefits

Habitat

Table 6.3 provides a summary of habitat benefits to be derived from the riparian restoration at Lago de Vida. A total of 160 habitat units is provided at Lago de Vida with the majority of the increase being in wetland habitat.

Table 6.3. Habitat Units for Future With Project Conditions: Alternative A at Lago de Vida.

Habitat Type	Area (Acres)	Quality (0-1)	Habitat Units
Wetlands	240.00	0.64	154
Cottonwood-Willow (On channel banks)	12.0	0.5	6.0
Total	252	--	160

Lago de Vida will be a significant improvement in habitat over the without-project condition. The 240-acre increase in wetland vegetation will provide substantial block of scarce habitat

suitable for wetland-dependent wildlife. Overall, species diversity throughout the study area will be enhanced in comparison to the present condition in which there is virtually no riparian habitat.

Recreation

Figure 6.8 identifies and locates various recreation features that are incidental to the primary project purpose of riparian habitat restoration. As developed by the City of Phoenix these recreation facilities would complement the environmental objectives of the Lago de Vida project.

Table 6.4 lists the projected number of annual recreation user days for Lago de Vida according to the general recreation categories identified in Section 5.4.1.

Table 6.4. Projected Number of Annual Recreational User Days for Lago de Vida, Alternative A.

Recreation Category	Future, Without-Project Level	Service Level Increment with Lago de Vida	Total With-Project Service Level
Watercraft-Related	0	0	0
Water-Based	2,000	0	2,000
Passive Linear	7,000	800,000	807,000
Defined Open Space	5,000	550,000	555,000
Interpretive/EnvEd	1,000	50,000	51,000
Total	15,000	1,400,000	1,415,000

To convert the annual user days of unmet demand to an annual dollar amount the recreation experience can be evaluated according to the following criteria:

Recreation Experience

Availability of Opportunity

Carrying Capacity

Accessibility

Environmental Factors

Based on the above criteria, the project was assigned a UDV multiplier of $3.72. Using this factor, the recreation benefit provided by Lago de Vida is 1,400,000 x $3.72 = $5,208,000 per year.

Water Quality

Lago de Vida will serve to remove volatile hydrocarbons as well as nitrate contaminants. Volatile hydrocarbons will be removed in the same manner (airstripping) as for Tempe Cienega. Details on water quality improvements are provided in Appendix D.

Cost

A preliminary cost estimate for Lago de Vida Riparian Restoration for Alternative A is provided in Table 6.5. Table 6.6 presents a cost estimate for the recreation component of Lago de Vida in Alternative A.

Table 6.5. Preliminary Cost Estimate for Lago de Vida Riparian Restoration, Alternative A.

Cost Item	Quantity	Unit Cost	Cost
Land Purchase	LS	LS	$300,000
Water Supply Wells and Pumps	LS	LS	$2,000,000
Stormwater Collection	LS	LS	$2,500,000
Piping	7 miles	$55/foot	$2,033,000
Water Recovery System	LS	LS	$2,000,000
Seepage Control	LS	LS	$3,500,000
Wetland Establishment	240 Acres	$11,000/acre	$2,640,000
Recreation	See Table 6.6	See Table 6.6	$2,494,000
Total			$17,467,000
Engineering, Contingencies and Administration (55%)			$9,606,900
Total Cost			$27,073,900

Table 6.6. Cost Estimate for Recreation Component of Lago de Vida.[1]	
Cost Item	Cost in Dollars
Land Purchase	$300,000
Trails	$154,000
Turf	$190,000
Restrooms	$120,000
Parking	$89,000
Sitework	$1,156,000
Ramadas	$257,000
Entry Feature	$50,000
Playground	$145,000
Amphitheater Terraces	$15,000
Promenade	$18,000
Total	$2,494,000[2]

1 Cost Estimate Provided by the City of Phoenix.
2 Total cost, including 55% contingencies, engineering and administration, = $3,865,700. Average Annual Cost = $315,100.

The annualized cost, assuming an interest rate of 8% and a project life of 50 years, is $2,206,900. The annualized cost of habitat-related improvements only (wetland establishmlent, land, water supply wells and pumps, stormwater collection, piping, water recovery system and seepage control) is $1,891,800. The annualized cost per habitat unit at Lago de Vida is $11,800.

BENEFIT/COST SUMMARY

Annualized costs of Alternative A are summarized in Table 6.7.

Table 6.7. Summary of Annualized Costs for Alternative A.	
Cost Item	Annualized Cost
Tempe Cienega	$657,800
Lago de Vida Habitat Component	$1,891,800
Lago de Vida Recreation Component	$315,100
Total	$2,864,700

As an environmental restoration alternative, Alternative A will provide habitat and water quality benefits. Habitat benefits are summarized in Table 6.8.

Table 6.8. Comparison of Riparian Habitat Conditions for Future-With-Project and Future-Without-Project Conditions - Alternative A.

Habitat Type	Future-Without-Project Area (In Acres)	Future-With-Project Area (In Acres)	Percent Difference in Area	Future-Without-Project Habitat Units	Future-With-Project Habitat Units	Increase in Habitat Units	Percent Difference in Habitat Units
Mesquite	0	4	>+100%	0	2.4	2.4	>+100%
Wetlands	17.8	279.8	+1,471.9%	2.3	169.5	167.2	+7,270%
Cottonwood	779.8	806.8	+3.5%	136.6	150.1	13.5	+10%
Total	797.6	1,090.6	+36.7%	138.9	322.0	183.1	+132%

Additional benefits include the following:

1. The project will be a major contribution towards Federal goals of protecting T&E Species habitat.

2. The project will contribute towards the National interim goal of no net loss of wetlands, and long term goal of increasing the quantity and quality of wetlands (WRDA 90).

3. Continuous surface flows will remain in the river channel and support riparian habitats.

4. Species diversity among flora and fauna will be enhanced

5. Significant water-based recreation opportunities are provided.

As a planning objective, securing water supplies which currently sustain riparian habitat provided a focus for protecting present habitat. A constructed wetlands at Tempe Cienega and Phoenix Lago de Vida would restore riparian habitat where currently none exists. The reach of the Salt River from Phoenix Lago de Vida (19th Avenue) to 91st Avenue, however, includes riparian habitat sites of varying quality; some of which are currently sustained by agricultural tailwater discharges and storm drain runoff. Opportunities for securing water sources in the future in order to sustain these specific sites are recommended for further investigation during the feasibility study.

A summary of the benefit/cost analysis for Alternative A is presented in Table 6.9.

Table 6.9. Summary of Benefit/Cost Analysis for Alternative A.

HABITAT RESTORATION					
SITE	ACRES	BENEFITS	HABITAT UNIT COST	ANNUAL COST	TOTAL FIRST COST
TEMPE CIENEGA	4 Mesquite 22 Wetlands 15 Riparian	23 Habitat Units Water Quality Improvement	$28,600	$657,800	$8,069,900
PHOENIX LAGO DE VIDA	240 Wetlands 12 Riparian	160 Habitat Units Water Quality Improvement	$11,800	$1,891,800	$23,208,200
TOTAL	293	183 Habitat Units Water Quality Improvement	$13,900	$2,549,600	$31,278,100

RECREATION COMPONENT			
SITE	ANNUAL BENEFITS	ANNUAL COST	TOTAL FIRST COST
PHOENIX LAGO DE VIDA	$5,208,000	$315,100	$3,865,700
TOTAL MONETARY BENEFITS/COSTS	$5,208,000	$2,864,700	$35,143,800

Annual financial benefits of at least $5,208,000 are derived from the recreation benefit at Lago de Vida (undetermined water-quality benefits are achieved at Tempe Cienega and Lago de Vida). Based solely recreation-related benefits and costs, the expected benefit/cost ratio is 16.5. An overall increase of 132% in desirable (wetlands, mesquite and cottonwood-willow) habitat units is expected, with the majority of the increase being in wetland habitat. The total habitat increase to be derived from the alternative is 183 habitat units. The annualized cost per habitat unit, not considering recreation costs, is $2,549,600/183 = $13,900.

6.2.2 Alternative B: Comprehensive Water Resources Development

Alternative B (Figure 6.10) represents a comprehensive water resources development strategy wherein riparian habitat restoration and recreation share foremost as primary project purposes. The two alternatives are similar in terms of habitat restoration, including the unique features of converting environmental problems into opportunities for environmental gains. The significant differences between the two alternatives are the development of recreation lakes in Tempe and Phoenix. A lake development in Tempe, called Town Lake, involves construction of a 200-acre lake immediately downstream of Tempe Cienega (the whole of which is called Tempe Rio Salado). In Phoenix, Lago de Vida would be developed differently from that in Alternative A. In this alternative Lago de Vida would include a 120-acre lake adjacent to a 120-acre wetland.

Wetlands and riparian habitat will be constructed within the channel of the Salt River. Methods for preserving the integrity of these habitats during flood flows will be explored in the feasibility study. The geomorphic and sediment transport features of the project, and potential related impacts and mitigation measures, will also be investigated in detail in the feasibility study.

TEMPE RIO SALADO

The Tempe Rio Salado project consists of two components: Tempe Cienega and Tempe Town Lake. These two major components take advantage of a proposed impoundment structure which will be common to both. The impoundment structure is used to collect water and provide habitat at Tempe Cienega while at the same time containing water for an urban recreation lake downstream. Detailed descriptions of each component follow.

TEMPE CIENEGA

The Tempe Cienega description, benefits and costs are the same as described for Alternative A and are reproduced below for convenience.

Description

Tempe Cienega restores habitat lost as a result of the construction of Indian Bend Wash and upstream Federal Dams. Tempe Cienega restores scarce wetland, riparian and mesquite bosque

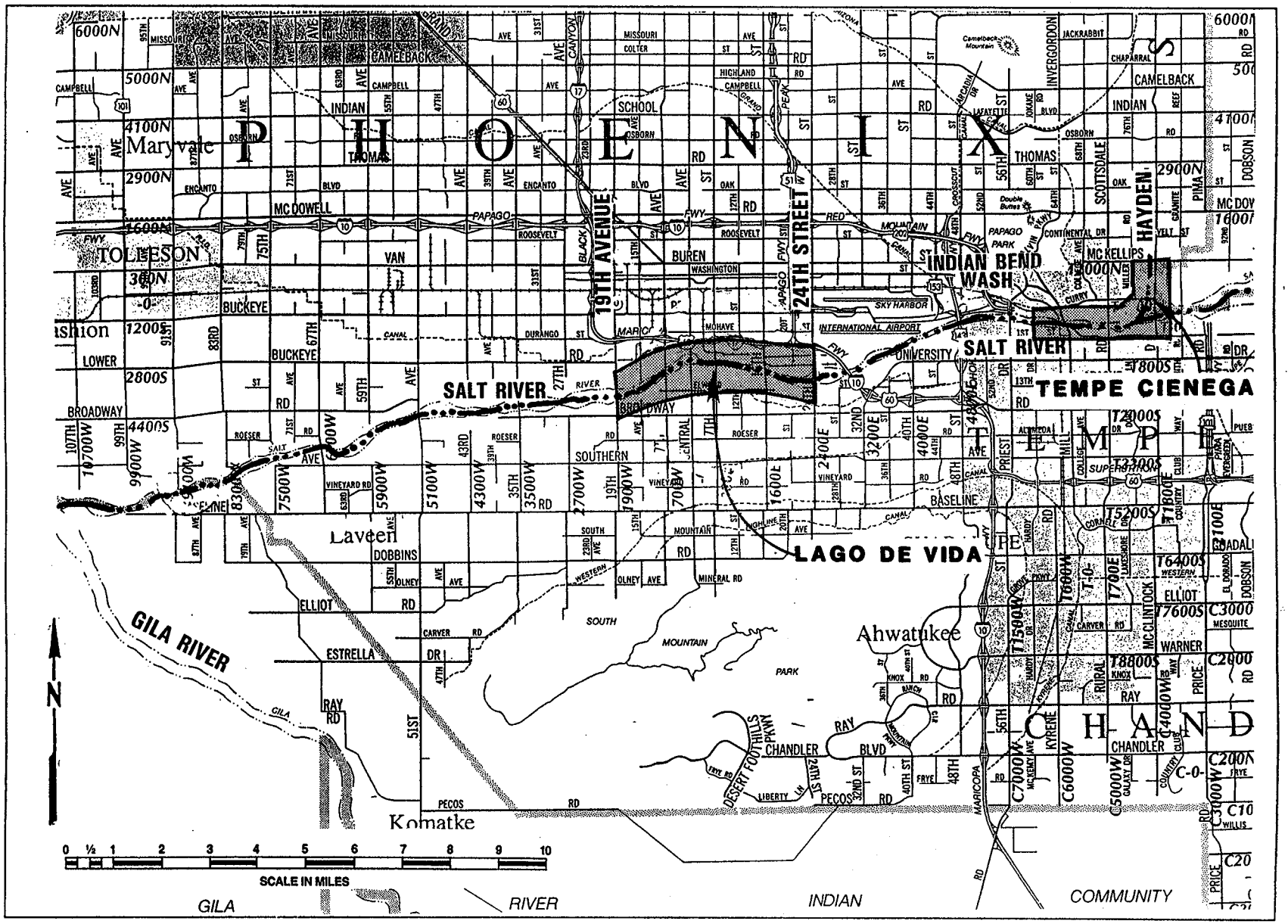


Figure 6.10. Alternative B.

vegetation and consists of 1) an inflatable dam to serve as a water impoundment structure in the Salt River approximately 350 feet upstream of the Indian Bend Wash 2) a constructed wetland in the Rio Salado channel upstream of the impoundment structure, and 3) a constructed wetland and mesquite bosque habitat in Indian Bend Wash within the City of Tempe. The concept and function of the wetland are described below:

Inflatable Dam. The Salt River impoundment structure will consist of a 6-foot, inflatable rubber dam at the location shown in Figure 6.2. Figure 6.3 shows a typical cross section of the dam. The dam will impound all flows in the Salt River to a maximum ponding depth of six feet. Existing soil cement banks will confine the lateral extent of ponding.

An inflatable rubber dam is selected because it is the most efficient method of impounding flood flows in a flood-control channel without increasing the flood risk. The dam will be inflated during low flows and when there is no flow, and deflated to allow large floods to pass unimpeded. The dam has the advantage that it can be inflated at the tail end of large floods in order to capture the receding flows for use in the wetland. Furthermore, a rubber dam will permit sediment transport past the structure during large flows.

Salt River Wetland. The Salt River portion of the Tempe Wetland (Figure 6.2) will consist of a 20-acre pond immediately upstream of the inflatable dam, 4 acres of hydrophytic vegetation at the upstream edge of the pond, 15 acres of cottonwood/willow riparian vegetation along a low-flow channel and a 90-acre, naturally-occurring revegetation area between the pond and a grade-control structure downstream of the McClintock Road bridge. The pond will be approximately 5 feet deep.

Indian Bend Wash Wetland and Mesquite Bosque. The Indian Bend Wash currently includes a low-flow channel approximately 150 feet wide from McKellips Road to the confluence with the Salt River. The low-flow channel widens to cover the entire bottom width of the flood control channel near the confluence. This area, supplied with water at McKellips Road, can be converted into a wetland of approximately 18 acres in size. Figures 6.4, 6.5, 6.6, and 6.7 show the concept plan view and cross section of the wetlands.

The Indian Bend Wash between Curry Street and the Salt River currently consists of bare ground. There is a low-flow channel situated approximately 5 feet below a terrace between the outer levees. The terrace would be vegetated with mesquite trees to create a mesquite bosque habitat of approximately 4 acres.

Introduction of the mesquite bosque will affect the hydraulics of the Indian Bend Wash. Preliminary analysis indicates that the water surface elevation could be increased by approximately one foot without mitigation. Mitigation in the form of widening the low-flow channel or increasing the levee height will be required to compensate for any increase

in water surface elevation. The design as presented herein is conceptual and will be studied in more detail in the feasibility study.

Benefits

Habitat

Table 6.10 provides a summary of habitat benefits from Tempe Cienega. An overall increase of 23 habitat units is expected, with the majority of the increase being in wetlands. Under present conditions there are no habitat units at the restoration sites.

The Tempe Cienega will replace existing bare earth with a mesquite forest habitat that is in severe decline elsewhere in the Southwest. The mesquite forest, with adjacent wetland and cottonwood/willow vegetation will provide shelter and a food source for a wide variety of native birds, mammals and reptiles including those adapted the xeric conditions of the desert as well as those adapted to wet environments. Animal populations and species diversity will be significantly increased. Migratory bird species often rely on these types of habitats, which are significantly declining, as temporary resting and foraging places during migration.

Water Quality.

Tempe Cienega will provide water quality benefits in the form of TCE clean-up of water from Well #6. Exposure of Well #6 water to the air along Tempe Cienega will release the contaminants and improve water quality. The purified water can be infiltrated back into the ground if desired. The amount of purified water will be the difference between the maintenance needs of Tempe Cienega, including evaporation, and the pumping rate. If a pumping rate of 3 million gallons per day is used, the net treated water would range from 0.85 to 1.94 to 2.15 million gallons per day.

Table 6.10. Habitat Units for Future With Project Conditions: Tempe Cienega in Alternative B.				
Mesquite Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source
Indian Bend Wash	4	0.60	2.4	Groundwater
Wetlands Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source
Salt River	4.0	0.56	2.2	Groundwater and Salt River Flows
Indian Bend Wash	18.0	0.58	10.4	Groundwater
Subtotal	22.0	--	12.6	Groundwater and Salt River Flows
Cottonwood Willow Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source/Impact
Salt River at Tempe	15.0	0.5	7.5	Groundwater and Salt River Flows
Total	41	--	22.5	Groundwater and Salt River Flows

Cost

A preliminary cost estimate is provided in Table 6.11.

Table 6.11. Preliminary Cost Estimate for Tempe Cienega in Alternative B.

Cost Item	Quantity	Unit Cost	Cost
Land Purchase	LS	LS	$70,000
Inflatable Dam at Salt River.	1	LS	$2,700,000
Excavation	160,000 cubic yards	$2/cubic yard	$320,000
Water Supply Wells and Pumps	LS	LS	$500,000
Piping	1 mile	$55/foot	$290,400
Wetland, Riparian Vegetation and Mesquite Bosque Establishment[1]	41 Acres	$11,000/acre	$451,000
Seepage Control	LS	LS	$875,000
Total			$5,206,400
Engineering, Contingencies and Administration (55%)			$2,863,500
Total Cost			$8,069,900

[1] United States Bureau of Reclamation, 1992. Vegetation Management Study, Lower Colorado River, Phase I.

The annualized cost, assuming an interest rate of 8% and a project life of 50 years, is $657,800. The annualized cost per habitat unit is $28,600.

TEMPE TOWN LAKE

Description

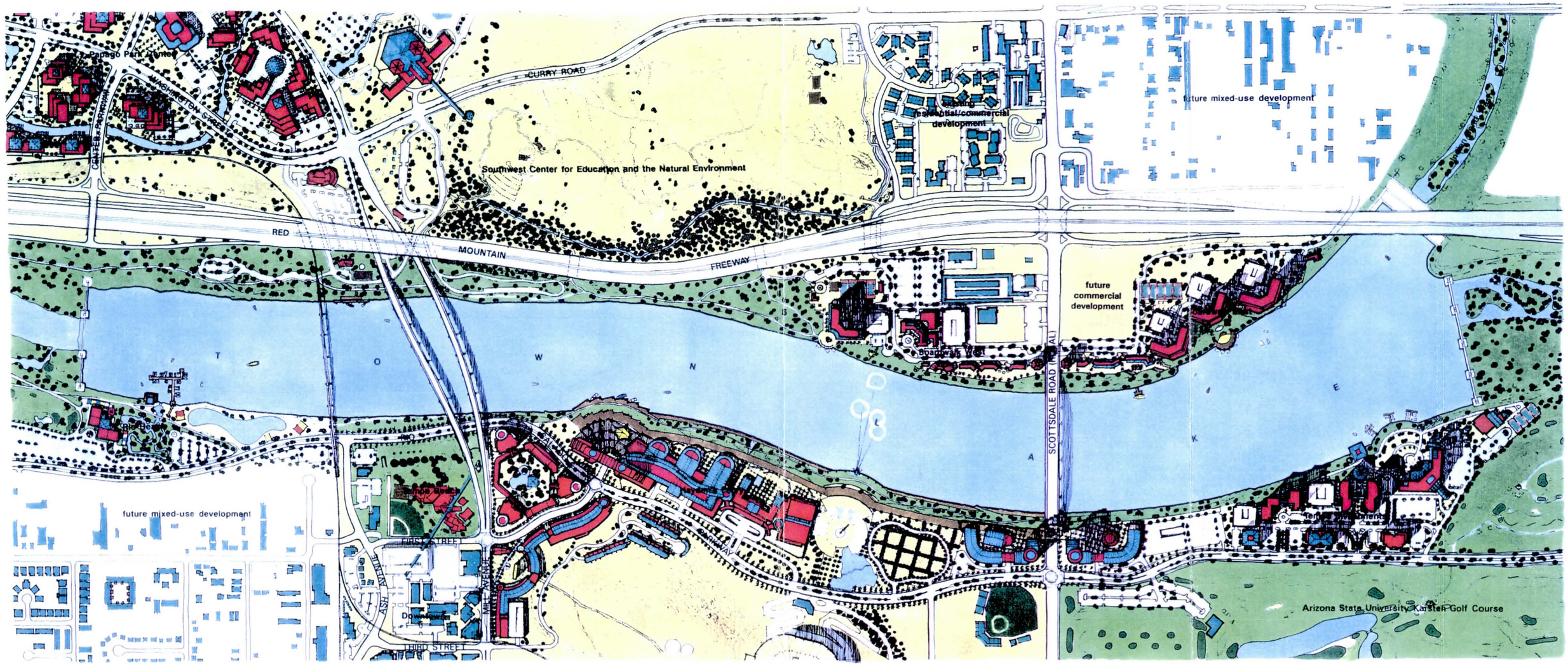
Tempe Town Lake (Figure 6.11) is a 200-acre recreation lake which will extend from about 1,500 feet west of Mill Avenue, east to the Indian Bend Wash. The lake would be contained by inflatable rubber dams and the present soil cement banks. Due to the relatively gentle slope of the channel, two rubber dams (at each end of the lake) are needed to maintain lake levels. The upstream rubber dam is included as a component of the Tempe Cienega portion of the riparian habitat restoration component of the project. Construction of the downstream dam is to be provided by recreation funds to complete Town Lake. The lake will be used primarily as a boating lake of sufficient water quality to be permitted for partial body contact. Swimming in Rio Salado will not be allowed due to safety considerations and the high cost of consistently maintaining a highly-transparent water quality.

Fishing sailing, paddle-boating, canoeing, hiking, bicycling, horseback riding, golf, soccer and softball are a few of the planned recreation activities. Along the channel banks will be trails for bicycling, hiking and equestrian use as well as playing fields and golf courses.

Major design features of Tempe Town Lake are described below:

Impoundment Structures. In conjunction with the impoundment structure at Tempe Cienega, a 16-foot-high, air-inflatable rubber dam is located approximately two miles downstream to contain water for Tempe Town Lake. An inflatable dam is selected as the downstream dam as it meets several criteria including hydraulic, sediment transport, flood control, aesthetics, operational flexibility and safety. The downstream dam is similar to the upstream dam, but is 10 feet higher. The upstream dam at Tempe Cienega contains water for Tempe Town Lake on the downstream side of the dam. During those periods when the Salt River flows, the upstream dam would have water on the upstream side for habitat restoration and on the downstream side to maintain Town Lake.

The inflatable dam configuration is shown schematically in Figures 6.2 and 6.3. Each dam segment will be independently operable to allow flexibility for low flow and sediment passage, and to be able to exercise each segment for maintenance checks. One of the manufacturers of inflatable dams claims that the 16-foot dam could be overtopped by about 6 feet without inducing instability.



tempe rio salado

Conceptual Development Plan

TOWN LAKE VICINITY

NORTH

PLAN AREA

CITY OF TEMPE ARIZONA

Community Development Department

Figure 6.11. Tempe Town Lake Plan View.

The downstream dam would be constructed in four sections near the soil cement grade control structure between Priest Drive and Mill Avenue. The inflatable dam at Tempe Cienega will also be constructed in four sections, connected by concrete floodwalls at the confluence of Indian Bend Wash and the Salt River. The dams will be constructed across the main channel of the Salt River. The lake will be situated within the main channel, contained by soil cement bank protection at the sides and by the dams at the upper and lower ends. All flows on the Salt River, including those from Indian Bend Wash, will pass through the lake.

Water Demands. The base water demands for Rio Salado are lake evaporation and seepage (infiltration through the bottom and sides of the lake). Additional water demands include irrigation water for landscaping the Rio Salado project developments and creation of artificial wetlands.

The annual average evaporation demand for the selected lake is estimated at 1.1 million gallons per day (mgd, 2.2 mgd with "safety factor." 1.1 mgd is approximately 6 feet per year on a 200-acre lake). The monthly rates should vary from 0.4 mgd in December to 1.7 mgd in June.

Seepage Losses. Based on the studies including drilling and monitoring of groundwater levels, without seepage control the Rio Salado itself may be expected to lose approximately 0.2 feet/day, on the average, during steady state conditions. With available seepage control technologies, seepage may be reduced to approximately 0.01 feet/day. Three seepage control methods were investigated which include slurry trench cutoff walls, liners, and well recovery systems.

Without seepage control, annual seepage may range in the order-of-magnitude of 16,000 ac-ft (14.1 mgd) for a lake surface area of 200 acres. With effective seepage controls, annual net seepage losses for a 200-acre lake may range in the order-of magnitude of under 0.2 (theoretically zero with pumped recovery methods) to 400 ac.ft. (0.4 mgd) based on liner construction techniques. Actual seepage will vary with clogging and natural variability within the geologic and man-placed materials.

Landscape Irrigation. The demand for landscape irrigation water depends on the size of the area to be irrigated, vegetation type, and method of irrigation. Final landscaping plans have not yet been developed, so no exact estimates have been made. However, landscape irrigation is an important water demand, and therefore merits consideration.

Preliminary estimates of areas that will be irrigated by the City of Tempe were prepared by City planning staff. Based on the City's estimate of future landscaped areas, the irrigation demand range from 0.04 mgd in December to 0.33 in June.

An additional landscape-related demand to be considered is the proposed wetlands area downstream of the lake on about 3.5 acres of planting areas, a rough approximation of the

average monthly demand ranges from 0.02 mgd in December and January to 0.14 mgd in June and July.

Water Sources. The potential sources of water for Tempe Rio Salado are reclaimed waste water, the Salt River, Salt River Project water, storm water, and groundwater. Reclaimed water is the most probable source of water, either through direct reuse or indirectly through water exchanges. Direct reuse of reclaimed water occurs in supply alternatives that physically pipe the reclaimed water from the City's water reclamation facilities to Rio Salado. Indirect reuse of reclaimed water occurs in supply alternatives that use aquifer storage and recovery (ASR) technology to transform the water in legal and technical terms from reclaimed water into groundwater. Indirect reuse is also considered in alternatives that are based on trading reclaimed water for other physical sources of water. Considering options for direct and indirect reuse of reclaimed water, the potential sources of supply include the Salt River, Salt River Project, Central Arizona Project, urban storm water, reclaimed water, and groundwater.

All water supply options included in this study are based on filling the lake and maintaining wetlands by capturing receding Salt River flows. In other words, following any Salt River flow event that requires the lowering of the inflatable dams, the dams would be inflated to capture pools of water behind both the upstream and downstream dams at the conclusion of the river flow event. Other sources of water considered herein are intended to serve as makeup water for lake evaporation and seepage losses, supply to other water features such as wetlands, and irrigation demands.

Stormwater Management. Stormwater represents a potential resource. Stormwater is a source of additional water to the lake, but pollutant loads carried in runoff discharges may result in adverse lake water quality impacts.

As expected for a desert environment, the average storm volume, intensity, and annual number of storms in Phoenix are low compared to other parts of the nation. The average storm produces 0.42 inches of rain over 8.1 hours. In addition, the time between storm events is long, averaging 579 hours, or just over 24 days. Rainfall occurs 1.4 percent of all hours in Phoenix, based on the average storm duration and time between storms.

The major sources of urban storm water that affect the Tempe Rio Salado site include:

- Indian Bend Wash
- Price Road Drain
- Tempe/Scottsdale
- Mesa
- Salt River Pima-Maricopa Indian Community

The two largest watersheds are Indian Bend Wash and the Price Road Drain. Indian Bend Wash drains a major portion of Scottsdale north of the Rio Salado site, while the Price Road Drain conveys storm water from much of Mesa, and Chandler, south of the Salt

River. In addition, 14 storm drain outfalls have been located that discharge into the Salt River in the reach\proposed for Rio Salado.

Flood Control. The Salt River is the primary conveyance facility for flood water from the Salt River and Verde River watersheds through the Phoenix valley. The design flood for the river in the Rio Salado project area is the 100-year event. Recently-completed and ongoing channelization projects in the area are intended to ensure that the design flood is safely conveyed through the valley. The Arizona Department of Water Resources (ADWR) and the Flood Control District of Maricopa County (FCDMC) will require that the Rio Salado project not jeopardize the capacity of the river to contain flood water, even in the event of a dam failure.

The Salt River is a complex and dynamic system. Physical changes to one reach of the system invariably affect the rest of the system. The ability of the river to transport sediment is one of the characteristics that must be carefully considered when modifications to the river are proposed. The final project must minimize sediment transport-related impacts to the Salt River system. Specific design criteria for flood control include:

- The capacity of the channel and bridge structures to pass the design event must not be compromised.
- The water surface elevation during a-100-year flood event must not be increased by more than 1 foot.
- The flood wave that would result from a spontaneous failure of the dam must be contained in the channel.
- The single-event general scour downstream of the lake must not significantly increase.
- The equilibrium slopes of the channel must be maintained.

Benefits

Tempe Town Lake is estimated to attract three to five million visitors per year with an annual recreation benefit of $18,600,000. Table 6.12 lists the projected number of annual user days for Tempe Town Lake.

To convert the annual user days of unmet demand to an annual dollar amount the recreation experience were evaluated according to recreation experience, availability of opportunity, carrying capacity, accessibility and environmental factors.

Table 6.12. Projected Number of Annual Recreational User Days for Tempe Town Lake, Alternative B.			
Recreation Category	Future, Without-Project Level	Service Level Increment	Total With-Project Service Level
Watercraft-Related	-0-	1,800,000	1,800,000
Water-Based	2,000	1,800,000	1,802,000
Passive Linear	7,000	800,000	807,000
Defined Open Space	5,000	550,000	555,000
Interpretive/EnvEd	1,000	50,000	51,000
Total	15,000	5,000,000	5,015,000

Based on the above criteria, the project was assigned a Unit Day Value (UDV) multiplier of $3.72. Using this factor, the recreation benefit provided by the Tempe Rio Salado is 5,000,000 x $3.72 = $18,600,000 per year.

The lake could be stocked with rainbow trout and channel catfish for sport fishing, which could generate up to 300,000 angler visits per year. Assuming $10 expenditure per angler day, raw expenditures by fisherman at Tempe Rio Salado could reach $3,000,000 per year.

Total benefits, including recreation and fisheries, will be approximately $21,600,000 per year.

Cost

A preliminary cost estimate for Tempe Town Lake is provided in Table 6.13. The preliminary benefit/cost ratio, using recreation-related benefits and costs only, is $21,600,000/$3,687,400 = 5.9.

Table 6.13. Preliminary Cost Estimate for Tempe Town Lake.	
Cost Item	Preliminary Cost Estimate
Land Purchase	$330,000
Construction Cost	$20,900,000[1]
IDC (7 Months at 8%)	$2,943,600
Urban Fisheries	$5,011,700[2]
Subtotal Cost	$29,185,300
Engineering, Contingencies and Administration (55%)	$16,051,900
Total Cost	$45,237,200
Annual Cost	$3,687,400

1 Bank protection has already been constructed and is not included in this cost. This cost includes the cost of the downstream inflatable dam only.

2 Based upon information provided by the Arizona Game and Fish Department (Appendix C)

PHOENIX LAGO DE VIDA

Description

In Alternative B, the Lago De Vida project would consist of a habitat restoration, water quality, and recreation complex involving a 120-acre wetlands, riparian vegetation along the streambank, and a 120-acre recreation lake located within the Salt River channel near central Phoenix. The lake would be designed to support fishing and urban recreation activities. Habitat along the river would transition from streamside vegetation to an open body of water adjacent to a wetlands. Several abandoned gravel pits along the river channel would be converted into storage basins collecting urban storm drain runoff and treating it through a constructed wetlands. The location of a sizeable body of water and riparian habitat in the central city would assist the City to realize the greenbelt concept long envisioned for the Salt River Corridor. The following describe the various features (Figures 6.12 and 6.13) proposed at Lago de Vida:

Lakes. A series of three lakes will extend for a distance of two miles along the north side of the Salt River between 16th Street and 7th Avenue. The lakes will be approximately 500 feet wide and 10 feet deep with occasional islands for use by sports fishermen and waterfowl. Total lake area will be 120 acres.

The purpose of three lakes rather than one is to avoid the need for a large drop (approximately 16 feet) from the river bed to the lake surface at the upstream end of the two-mile reach. The drop would be required because the river bed slopes upward in the upstream direction at a slope of approximately 0.0016 feet per foot, but the lake water surface is horizontal. By using three lakes, the 16-foot drop can be spread into three drops of approximately 5 or 6 feet each. The drops will be protected against drop scour during large floods by soil cement toe-down or aprons.

Levee and Low-Flow Flood-Control Channel. The lakes will be separated from the main channel flow by a soil-cement levee. This levee will rise approximately 10 feet above the channel bed to prevent frequent low flows and sediment from entering the lakes.

Wetlands. A 120-acre wetland will be constructed within the stream channel between 24th Street to 15th Avenue. A perennial, low-flow stream will meander through, and supply water to, the wetlands. The remainder of the low-flow channel and channel banks will be vegetated with native riparian vegetation.

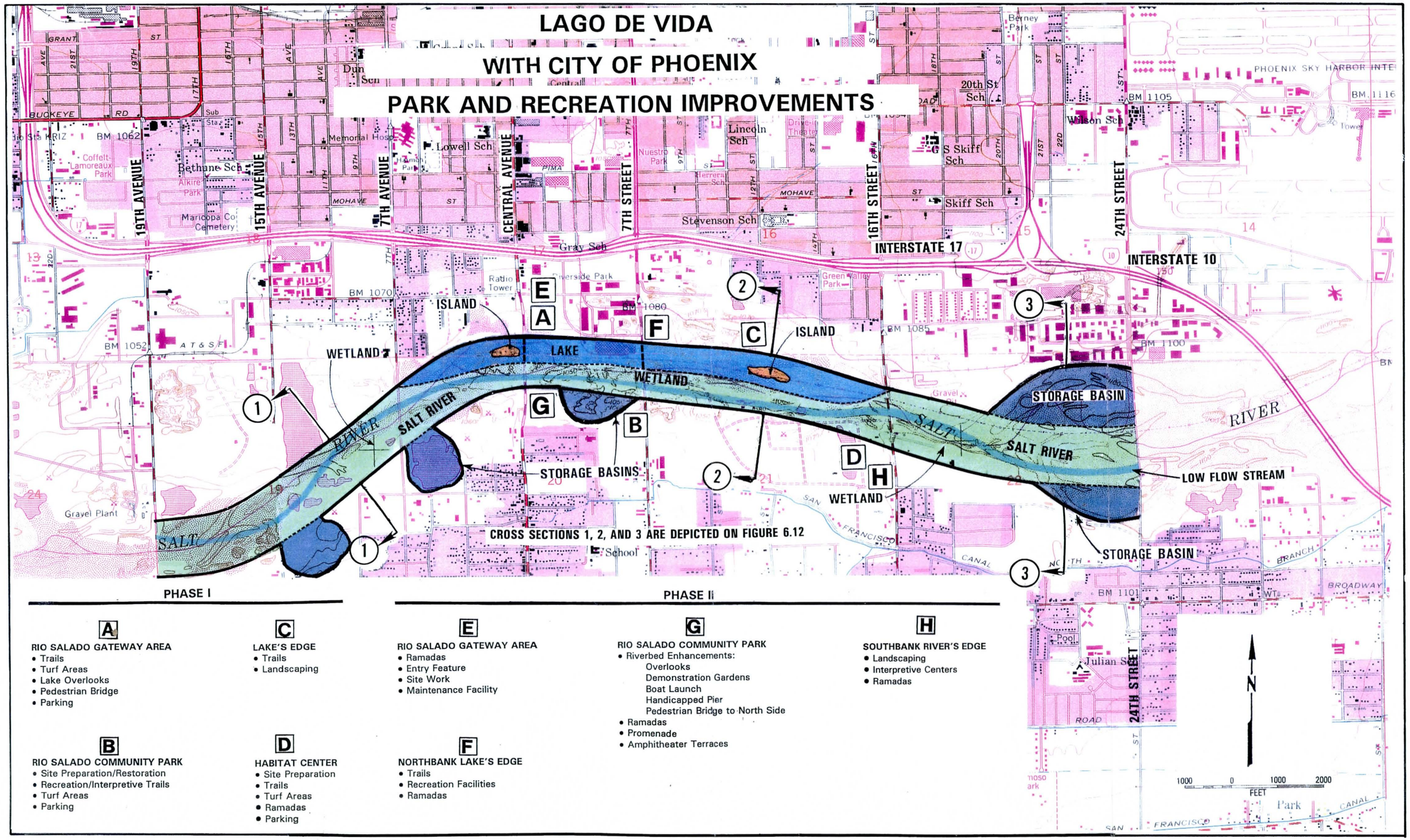
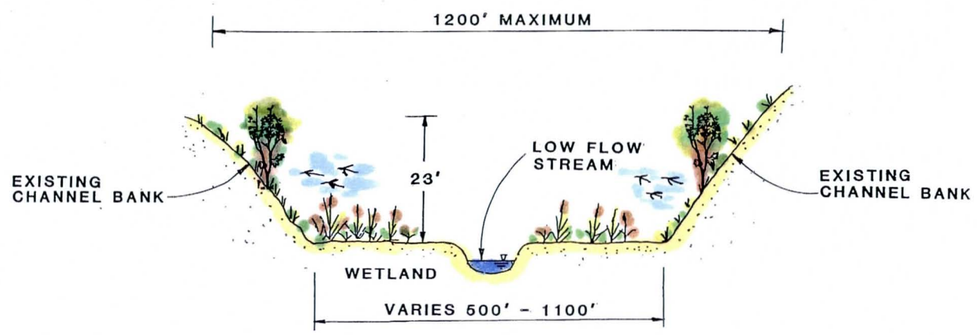
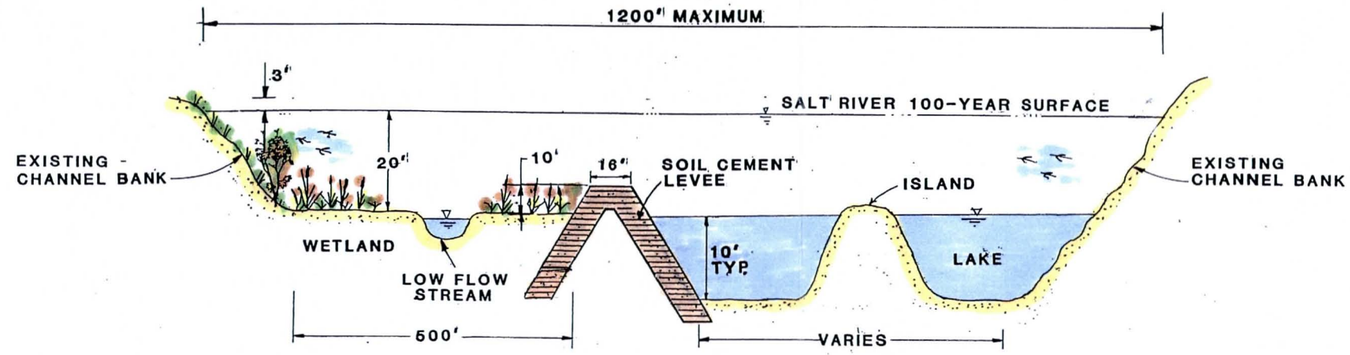


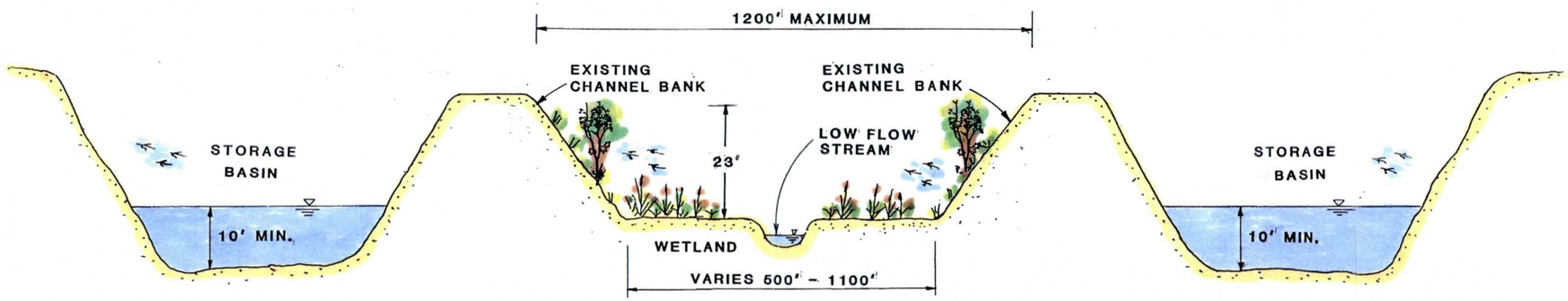
Figure 6.12. Alternative B Lago de Vida Plan View.



TYPICAL SECTION (1)
NOT TO SCALE



TYPICAL SECTION (2)
NOT TO SCALE



TYPICAL SECTION (3)
NOT TO SCALE

THE LOCATION OF CROSS SECTIONS 1, 2, AND 3 IS SHOWN ON FIGURE 6.12

Figure 6.13. Typical Cross Sections for Alternative B at Lago de Vida.

Gravel Pits/Storage Basins. Gravel pits along Lago de Vida Riparian Restoration will be converted to storage basins for runoff water from local storm drains and the Salt River.

Recreation Facilities. In addition to riparian restoration, a recreation component is included within Lago de Vida as developed by the City of Phoenix.

The Lago de Vida project will be approximately 1,200 feet wide to conform to the width of the present 100-year floodplain. The City of Phoenix is planning recreational and urban development alongside Lago de Vida Riparian Restoration in a separate project.

Flood Control

The low-flow flood-control channel will be 500 feet wide and have capacity for approximately a 5-year flood (45,000 cfs). Higher flows will overflow the levee and enter the lake, above which there will be sufficient conveyance to carry the 100-year discharge within the limits of the present floodplain. Table 6.14 provides a summary of present and preliminary, proposed hydraulic conditions.

The levee configurations shown in Figures 6.12 and 6.13 are conceptual only and not intended for use as final design. The levee heights, toe-downs and alignments will be the subject of a detailed hydraulic and scour analysis during the feasibility study.

Table 6.14. Present and Proposed Flood Hydraulic Conditions for Lago de Vida Riparian Restoration.

PRESENT CONDITIONS[1]			
DISCHARGE (cfs)	RETURN PERIOD[2] (Years)	FLOW DEPTH (Feet)	FLOW VELOCITY (fps)
40,000	5	11.5	6.5
215,000	100	25.8	11.5
PROPOSED (FUTURE-WITH-PROJECT) CONDITIONS[3]			
40,000	5	9.2	8.5
215,000	100	25.3	16.5
215,000[4]	100	16.7	12.7

1 Average conditions from HEC-2 based on 1992 topography.
2 Based on Present Conditions, Prior to Modification of Roosevelt Dam.
3 Channel bottom width (low-flow channel) = 500 feet; channel slope = 0.0016; Mannings roughness = 0.03; channel side slopes = 1:1.
4 Assumes channel bottom width = 1,000 feet. This is considered representative of conditions that would exist during a large flood.

Benefits

Habitat

Table 6.15 provides a summary of habitat benefits to be derived from the riparian restoration at Lago de Vida for Alternative B. This alternative provides an overall increase of 83 habitat units, with the majority of the increase being in wetland habitat.

Table 6.15. Habitat Units for Future With Project Conditions: Alternative B at Lago de Vida.

Habitat Type	Area (Acres)	Quality (0-1)	Habitat Units
Wetlands	120.00	0.64	77
Cottonwood-Willow (On channel banks)	12.0	0.5	6.0
Total	132	--	83

Lago de Vida will be a significant improvement in habitat over the without-project condition. The 120-acre increase in wetland vegetation will provide substantial block of scarce habitat suitable for wetland-dependent wildlife. The lake will provide an opportunity to restore native fish to the area. The lake, wetland and cottonwood/willow vegetation represent a significant improvement for a wide variety of water-related wildlife including ducks, shorebirds, and raptors. A significant number of passerine (perching) birds rely heavily on this type of oasis habitat for normal existence and particularly during migration. The presence of this habitat for migratory birds will help increase bird survival in other areas far removed from Lago de Vida. Native mammals will be drawn to the improvements as well. Overall, species diversity throughout the study area will be enhanced in comparison to the present condition in which there is virtually no vegetative habitat.

Recreation

Figure 6.12 identifies and locates various recreation features as developed by the City of Phoenix that would complement the environmental objectives of the Alternative B Lago de Vida project. Table 6.16 lists the projected number of annual recreation user days for Lago de Vida according to the general recreation categories identified in Section 5.4.1.

Table 6.16. Projected Number of Annual Recreational User Days for Lago de Vida in Alternative B.

Recreation Category	Future, Without-Project Level	Service Level Increment with Lago de Vida	Total With-Project Service Level
Watercraft-Related	-0-	1,800,000	1,800,000
Water-Based	2,000	1,800,000	1,802,000
Passive Linear	7,000	800,000	807,000
Defined Open Space	5,000	550,000	555,000
Interpretive/EnvEd	1,000	50,000	51,000
Total	15,000	5,000,000	5,015,000

The recreation benefit provided by the Alternative B Lago de Vida is 5,000,000 x $3.72 = $18,600,000 per year.

The 120-acre lake at Lago de Vida could be stocked with rainbow trout and channel catfish for sport fishing. It may also be possible, depending upon habitat conditions, competition and lake usage, to re-introduce some native fishes which may include the Desert and Sonora suckers, Roundtail Chub, long fin dace, Razorback sucker, Colorado squawfish, spike dace, woundfin, loach minnow and Gila topminnow. All of these native species are listed as Federal Threatened or Endangered Species.

Sport fishing in the lake is expected to generate up to 300,000 angler visits per year. Assuming a conservative estimate of $10 expenditure per angler day, raw expenditures by fisherman at Lago de Vida could reach $3,000,000 per year. Total recreation-related benefits, including fisheries, are $21,600,000 per year.

Water Quality

Lago de Vida will serve to remove volatile hydrocarbons as well as nitrate contaminants. Volatile hydrocarbons will be removed in the same manner (airstripping) as for Tempe Cienega. A 120-acre wetland could treat as much as 7,200 acre-feet of year for nitrates. This is equal to the average amount of urban storm runoff entering from drains 11-20 and 33-39.

Erosion Control

The riparian vegetation proposed for the channel banks at Lago de Vida will increase the stability of the channel banks and help reduce lateral erosion of the Salt River.

Cost

A preliminary cost estimate for Lago de Vida Riparian Restoration in Alternative B is provided in Table 6.17. Table 6.18 provides a cost estimate for the Recreation Component of Lago de Vida in Alternative B.

The annualized cost, assuming an interest rate of 8% and a project life of 50 years, is $4,344,200. The annualized cost of habitat-related improvements only (wetland establishment, land, water supply wells and pumps, stormwater collection, piping, water recovery system and seepage control) is $1,706,000. The annualized cost per habitat unit at Lago de Vida is $20,600.

The annualized cost of the recreation component of Lago de Vida including fisheries costs, is $2,619,200. Based on recreation-related benefits and costs only, the benefit/cost ratio for Lago de Vida is $21,600,000/$2,619,200 = 8.3.

Table 6.17. Preliminary Cost Estimate for Lago de Vida Riparian Restoration, Alternative B.			
Cost Item	Quantity	Unit Cost	Cost
Land Purchase	LS	LS	$300,000
Soil Cement Bank Protection, 8 Feet Thick	155,000 cubic yards	$22/cubic yard	$3,410,000
Excavation	3,500,000 cubic yards	$2/cubic yard	$7,000,000
Water Supply Wells and Pumps	LS	LS	$2,000,000
Stormwater Collection	LS	LS	$2,500,000
Piping	7 miles	$55/foot	$2,033,000
Water Recovery System	LS	LS	$2,000,000
Wetland Establishment	120 Acres	$11,000/acre	$1,320,000
Seepage Control	LS	LS	$3,500,000
Urban Fisheries	120 acres	$245,100/year	$3,006,900
Recreation (Not including fisheries)	See Table 6.18	See Table 6.18	$7,314,000
Total			$34,383,900
Engineering and Contingencies (55%)			$18,911,100
Total Cost			$53,295,000

Table 6.18. Cost Estimate for Recreation Component of Lago de Vida in Alternative B.[1]	
Cost Item	Cost in Dollars
Land Purchase	$600,000
Trails	$276,000
Turf	$738,000
Lake Enhancement (Overlooks, Trailhead Parking, Pedestrian Bridge, Demonstration Gardens, Handicap Pier, Launch)	$1,249,000
Landscaping	$541,000
Restrooms	$210,000
Parking	$179,000
Demolition/Abatement	$198,000
Sitework	$2,229,000
Ramadas	$466,000
Entry Feature	$50,000
Maintenance Facility	$168,000
Playground	$145,000
Amphitheater Terraces	$15,000
Promenade	$18,000
Interpretive Centers	$88,000
Total	$7,314,000[2]

1 Cost Estimate Provided by the City of Phoenix. Estimates include Phases I and II. Estimates do not include fisheries costs.

2 Total cost, including 55% engineering, contingencies and administration, = $11,336,700. Average Annual Cost = $924,100.

BENEFIT/COST SUMMARY

Annualized costs of Alternative B are summarized in Table 6.19.

Table 6.19. Summary of Annualized Costs for Alternative B.

Cost Item	Annualized Cost
Tempe Cienega	$657,800
Tempe Town Lake	$3,687,400
Lago de Vida Habitat Component	$1,706,000
Lago de Vida Recreation Component	$1,304,000
Total	$7,355,200

As an environmental restoration alternative, Alternative B will provide habitat and water quality benefits (Tables 6.20 and 6.21). An overall increase of 76% in desirable (wetlands, mesquite and cottonwood-willow) habitat units is expected, with the majority of the increase being in wetland habitat. The total habitat increase to be derived from the alternative is 106 habitat units. The annualized cost per habitat unit, not considering recreation costs, is $2,363,800/106 = $22,300.

Table 6.20. Comparison of Riparian Habitat Conditions for Future-With-Project and Future-Without-Project Conditions - Alternative B.

Habitat Type	Future-Without-Project Area (In Acres)	Future-With-Project Area (In Acres)	Percent Difference in Area	Future-Without-Project Habitat Units	Future-With-Project Habitat Units	Increase in Habitat Units	Percent Difference in Habitat Units
Mesquite	0	4	>+100%	0	2.4	2.4	>+100%
Wetlands	17.8	159.8	+797.8%	2.3	92.5	90.2	+3,922%
Cottonwood	779.8	806.8	+3.5%	136.6	150.1	13.5	+10%
Total	797.6	970.6	+21.7	138.9	245.0	106.1	+76%

Additional benefits include the following:

1. The project will be a major contribution towards Federal goals of protecting T&E Species habitat.

2. The project will contribute towards the National interim goal of no net loss of wetlands, and long term goal of increasing the quantity and quality of wetlands (WRDA 90).

3. Continuous surface flows will remain in the river channel and support riparian habitats.

4. Species diversity among flora and fauna will be enhanced

5. Significant water-based recreation opportunities are provided.

Annual financial benefits of at least $43,200,000 are derived from 1) a fisheries benefit at Lago de Vida = $3,000,000, 2) a recreation benefit at Lago de Vida = $18,600,000 (Undetermined water-quality benefits are achieved at Tempe Cienega and Lago de Vida), and 3) a fisheries benefit at Tempe Town Lake = $3,000,000, and 4) a recreation benefit at Tempe Town Lake = $18,600,000. An examination of recreation-related costs versus recreation-related benefits indicates a benefit/cost ratio of 6.9.

Table 6.21. Summary of Benefit/Cost Analysis for Alternative B.

HABITAT RESTORATION					
SITE	ACRES	BENEFITS	HABITAT UNIT COST	ANNUAL COST	TOTAL FIRST COST
TEMPE CIENEGA	4 Mesquite 22 Wetlands 15 Riparian	23 Habitat Units Water Quality Improvement	$28,600	$657,800	$8,069,900
PHOENIX LAGO DE VIDA	120 Wetlands 12 Riparian	83 Habitat Units Water Quality Improvement	$20,600	$1,706,000	$20,929,700
TOTAL	173	106 Habitat Units Water Quality Improvement	$22,300	$2,363,800	$28,999,600

RECREATION COMPONENT			
SITE	ANNUAL BENEFITS	ANNUAL COST	TOTAL FIRST COST
PHOENIX LAGO DE VIDA	$21,600,000	$2,619,200	$32,132,900
TEMPE TOWN LAKE	$21,600,000	$3,687,400	$45,237,200
RECREATION SUBTOTAL MONETARY BENEFITS/COSTS	$43,200,000	$6,306,600	$77,370,100
TOTAL MONETARY BENEFITS/COSTS	$43,200,000	$8,670,400	$106,369,700

VII CONCLUSIONS

The Rio Salado, Salt River, Arizona Reconnaissance Study addressed several water resource problems including riparian habitat restoration, flood control, recreation, and water quality. Results of this study indicate there currently is no economically justified Federal interest in flood control within the Rio Salado study area. This is due in large part to recent channel improvements of the Salt River by Maricopa County through much of the urban area and on-going modifications to Roosevelt Dam which will provide additional flood storage capacity on the Salt River. While flood damages do occur along the Salt River, the benefits are substantially lower than the costs of protection.

A Federal interest has been identified for environmental restoration involving riparian habitat restoration, water quality improvement, and incidental recreation (i.e., recreation projects that are complimentary to a Corps primary project purpose). The Salt River and Indian Bend Wash are two water courses whose environmental settings have been substantially altered by Federal projects. With the advent of Federal dams constructed on the upper Salt River, the riparian ecosystem of the once perennial Salt River has been reduced to that of a dry riverbed, devoid of the highly valued mesquite bosques that once occupied the floodplain and provided richly diverse riparian habitat within the Sonoran desert ecosystem. Currently, the lower Salt River is characterized as an effluent-dominated watercourse, where existing riparian habitat occurs only at those locations where wastewater effluent and seasonal agricultural tailwaters are discharged into the river. Significant environmental impacts have also taken place at Indian Bend Wash where the last remnant of a large mesquite bosque community in the region has been displaced by a Corps of Engineers flood control project along the wash at its confluence with the Salt River. The problems of environmental quality are further compounded by water quality contamination stemming from high technology-industrial wastes, landfill leachate, agricultural practices, and storm drain runoff draining the Phoenix metropolitan area.

As a component of environmental quality, outdoor recreation, as currently available along the Salt River through Tempe and Phoenix, is significantly deficient in meeting the recreation demand of over 2 million people in the greater Phoenix area. In accordance with Corps policy, Federal

participation is limited to recreation projects that are "incidental" to Corps primary project purposes, which in this case is fish and wildlife habitat restoration, and where the costs of such a recreation project amounts to no more than 10 percent of total project cost.

A reconnaissance level investigation of the environmental problems and water resource opportunities has led to the formulation and evaluation of two alternatives. Alternative A provides for environmental restoration including riparian habitat restoration, water quality improvement, and incidental recreation. This alternative includes two components, i.e., Tempe Cienega and Phoenix Lago de Vida. Over 300 acres of wetlands, mesquite, willow, and cottonwood habitats would be restored. The net effect is a 132 percent increase in habitat units. Because water is the limiting factor for riparian habitat restoration in this arid environment, opportunities for providing a continuous water source were uniquely combined with measures to solve water quality problems. The result is a net gain in environmental quality. Surface water quality in the Salt River would be improved by collecting storm drain runoff in abandoned sand and gravel pits rather than continuing to discharge these flows into the river. These pits would then serve as water supply basins for the wetlands which simultaneously provide treatment of the runoff. Water supplies to the wetlands would be supplemented by contaminated groundwater which, when brought to the surface, would be treated using conventional methods such as airstripping. The wetlands themselves provides further treatment of the water as nitrates, a major water quality problem in the area, are removed. Alternative A also provides incidental recreation to help satisfy a portion of the unmet recreation demand. Consistent with Corps policy, the extent of recreation development has been limited to that which costs no more than ten percent of total project cost. An estimated 1,400,000 annual recreational user days are provided. Total first costs for this alternative have been estimated at $35,143,800. Based solely upon recreation-related benefits and costs, a benefit/cost ratio of 16.5 has been determined.

Alternative B represents a comprehensive water resources development alternative wherein environmental restoration and water-based recreation opportunities are combined. The recreation component is designed to offset the enormous unmet demand for water-based recreation. Recreation costs in this alternative are not limited to a percentage of total project cost. The

environmental features presented in Alternative A, including riparian habitat restoration and improved water quality, are incorporated into the development of urban lake recreation areas in the Cities of Tempe and Phoenix. Both lakes would be constructed within the Salt River channel, adjacent to the Tempe Cienega and Phoenix Lago de Vida riparian habitat restoration sites. An estimated 5,000,000 annual recreational user days are provided. In contrast to Alternative A, riparian habitat restoration benefits of Alternative B are slightly lower as half of the wetlands acres (120 acres) at Phoenix Lago de Vida would be replaced by an urban recreation lake. A total of 180 acres of riparian habitat would be restored in this alternative, affecting an increase of 76 percent in habitat units. As presented in Alternative A, the opportunities for combining a continuous water source with measures to improve water quality are similarly included in Alternative B. Total first costs for this alternative have been estimated at $106,369,700. Based solely upon recreation-related benefits and costs, a benefit/cost ratio of 6.9 has been determined.

In summary, two reconnaissance level alternatives have been identified as having a Federal interest. While both alternatives provide environmental restoration benefits, Alternative A provides only incidental recreation consistent with Corps policy. In contrast, Alternative B establishes water-based recreation as a primary project purpose equal to that of riparian habitat restoration. Federal participation in the construction of projects in both alternatives is possible if, according to Corps policy, the local sponsors decide to fully fund that portion of recreation costs which exceed the ten percent rule. Federal participation would then proceed as appropriate.

VIII RECOMMENDATIONS

As a result of the reconnaissance level investigations into environmental restoration with incidental recreation 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 a cost-shared environmental restoration feasibility study be initiated for the Salt River at Rio Salado, Tempe and Phoenix, Arizona.

I recommend that no Federal action be taken at this time towards a cost shared feasibility study for flood control along the Salt River in the area of Rio Salado, Tempe and Phoenix, Arizona.

Although addressed in this reconnaissance study, the synergy among riparian habitat restoration measures, water treatment techniques, and recreation activities along the Salt River would be more fully explored during the feasibility study. A more detailed study of the overlapping water resource opportunities could lead to a more complete understanding of the net environmental gains of an integrated resources approach to water resources development.

for Michal R. Robinson
Colonel, Corps of Engineers
District Engineer

APPENDICES

APPENDIX A

ENVIRONMENTAL EVALUATION

Appendix A

Environmental Evaluation

Rio Salado, Salt River, Arizona Reconnaissance Study

Phoenix/Tempe, Arizona

February 1995

Appendix A
Environmental Evaluation
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1.0 BACKGROUND

1.1 Authority

This study has been conducted under the authority of Public Law 761, Seventy-fifth Congress, June 28, 1938, which reads, in part, as follows:

> SEC. 6. 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 water-flow retardation and soil-erosion prevention on the watersheds of such localities:
>
> Gila River and tributaries, Arizona and New Mexico.

1.2 Purpose

The purpose of this Environmental Evaluation is to provide supplemental habitat analysis and recreation opportunity information for the Rio Salado Reconnaissance Study being conducted by the U. S. Army Corps of Engineers, Los Angeles District, South Pacific Division.

1.3 Study Area Description

The study area consists of approximately twenty-eight (28) miles of the Salt River from the eastern municipal boundary of Tempe at McClintock Road, through Phoenix, to the confluence of Gila and Agua Fria Rivers in Maricopa County, Arizona.

1.4 Scope of Environmental Evaluation

This Environmental Evaluation presents a brief synthesis of:

- existing conditions information based on an informal literature search, discussions with recreational and environmental resource specialists, and cursory field investigation;
- active and passive location of landfill sites;

- potential mitigation of upper aquifer contamination;
- plausible preservation and/or reconstruction of ecological habitats; and
- examining the realm of potential opportunities for water resource recreation based on demand and economic feasibility.

2.0 EXISTING ENVIRONMENT WITHOUT PROJECT BY RESOURCE

2.1 Physical Setting

Dam construction throughout the Salt River's upper watershed in the early 1900's changed the original character of the river and by the 1940's the river ceased to flow. This stretch of river in the urbanized areas of Tempe and Phoenix is essentially an expansive dry river bed dominated by large expanses of cobble and rubble.

Recent channelization projects by the Arizona Department of Transportation (ADOT) and the new Priest Drive bridge constructed by Maricopa County have physically altered the natural character of the western portion of the river.

Based on the "Geomorphic "Naturalness" Classification for River Channels" by Dr. William L. Graf, the portions of the river through Tempe are classified "7" - Completely Artificial. In Phoenix between 24th and 15th the classification changes to "6" - Essentially Artificial. As the river moves away from Phoenix and into the Gila Indian Reservation, the classifications move to "5" - Mostly Modified and "4" - Substantially Modified. At the confluence of the Gila River it becomes "3" - Partly Modified.

> #7 Completely Artificial: 100% engineered and/or built channel with altered processes and sediment
>
> #6 Essentially Artificial: 90% - 100% altered channel patterns and cross-sectional shapes or sediment characteristics as a result of human activities; largely artificial channel due to engineered bed and/or banks including dredging but with a few natural forms or processes remaining
>
> #5 Mostly Modified: 50% - 90% altered channel patterns and cross-sectional shapes or sediment characteristics as a result of human activities; major modifications to channel forms and processes with most of the channel area disturbed by mining, development of structures

#4 Substantially Modified: 10% - 50% altered channel patterns and cross-sectional shapes or sediment characteristics as a result of human activities

#3 Partly Modified: 10% altered channel patterns and cross-sectional shapes or sediment characteristics as a result of human activities; obvious modifications by flow regulation of altered sediment supply resulting in channel metamorphosis, scattered structures

2.2 Air Quality

The Phoenix area has been classified as Non-Attainment Area for PM_{10} by the Environmental Protection Agency which has determined that airborne dust is the dominant particulate pollutant in the Phoenix air.

Air quality is normally considered to relate only to items such as airborne particulates and exhaust emissions as a result of vehicular traffic. Odors, however can influence personal perceptions of the air quality, and the odors from the sludge beds of the sewage treatment plants located at 27th and 91st Avenues can be considered very offensive.

2.3 Water Quality

Water, from upstream dams, is the common thread between the presence and sustainability of riparian habitats and recreation pursuits. In the Southwest, the quantity and quality of water in time and space vary markedly. Channels can change from dry, intermittent conditions to those of violent floods in minutes.

Further discussion of water quality is found in the main body of the Reconnaissance Study and in Appendix D of this report.

2.4 Biological Resources

Team members from ACOE, Maricopa County Flood Control District, U. S. Fish and Wildlife Service, Arizona Department of Environmental Quality, and Arizona Game & Fish field analyzed and mapped existing riparian habitats downstream of 48th Avenue as part of this Environmental Evaluation. Site visits also served to identify areas for potential growth based on areas of standing water.

2.4.1 Vegetation

Vegetation within the floodplain is subject to many disturbances, primarily flood events. Any mapping of vegetation therefore is limited by the fact that it simply represents a "point in time" condition. The four major habitat types within the study area include: fresh water marsh, cottonwood/willow riparian forest, mesquite habitat, and tamarisk. Desert scrub is also present.

Fresh water marsh. This habitat type consists primarily of cattails, bulrushes, and occasionally water cress. This community is located at the lowest elevations of the river along the watercourse or in areas of shallow ponded water or heavily saturated soils. This vegetation association is rare due to the lack of continuous standing water in this desert environment.

Cottonwood/willow riparian forest. This habitat is dominated by a combination of cottonwood and willow trees. This plant community is found along the active streambed of the river or on the first terrace above the river. These riparian trees are utilizing groundwater, storm water runoff, and seasonal low-flow releases for sustenance. U. S. Fish and Wildlife Service and the Arizona Game and Fish Department have identified twenty-three (23) acres of cottonwood/honey mesquite habitat and 113 acres of desert scrub in stratified clusters along the edge of the channel from McClintock Road to the Southern Pacific railroad bridge. Significant segments of riparian habitat are located downstream of the 91st Street Wastewater Treatment Plant. This habitat is sustained by effluent released from the plant.

As recently as April 1994, 800 volunteers replanted 2000 trees and shrubs as part of Project Habitat in a twenty (20) acre managed wetland/riparian area near 52nd Street. ADOT has

replaced thirteen (13) acres of habitat in the channel effected by construction of the Hohokam Expressway.

Mesquite habitat type. This habitat type is dominated by honey mesquite and is normally found on the upper terraces of the floodplain above the active river channel. The presence of mesquite within the project area is minimal; tamarisk dominates the higher terraces where mesquite would be located.

Tamarisk. Tamarisk is located on all floodplain elevations throughout the study area. Dense monotypic stands of tamarisk are found primarily on the upper terraces of the river. Tamarisk is also interspersed with stands of native vegetation at all elevations of the floodplain.

Desert Scrub. Desert scrub plants, xerophytic in character, occur in irregular, random locations within the river bed where storm water collects. Sampling of flora include: desert broom, creosote bush, desert salt bush, quail bush, arrowweed, brome grass, brittle bush, burrobrush, and thistle. Salt cedar, an exotic plant with little habitat value, occurs as the dominant plant in the river bottom in the Tempe section.

2.4.2 Wildlife

Existing habitat within the river channel is part of a continuous wildlife corridor providing shade; protection from predators; and foraging, nesting, and/or breeding habitat for migratory birds.

There are no known fish species that inhabit the area. During flow periods, a wide variety of aquatic organisms exist in the channel. Since flows are often brief and drought conditions usually exist, relatively few organisms are capable of surviving long periods of dry channel. Based on studies of other ephemeral streams, some of the organisms might include flatworms, nematodes, isopods, crayfish, eliminthid beetles, and small crustaceans in addition to blue-green and green algae.

A partial list of wildlife include roadrunners, heron, doves, hawks, quail, sparrows, hummingbirds, mockingbirds, starlings, finches, killdeers, rabbits, snakes, toads, lizards, and turtles. Migratory birds that may frequent the river include ducks, kestrels, thrashers, and swallows.

2.4.3 Threatened and Endangered Species

The U.S. Fish and Wildlife Service provided a list of federally endangered, threatened, proposed and candidate species which may occur in the study area (Section 10).

Based on recent studies by ADOT for State Route 153, there are no known identified endangered or threatened wildlife species in the Tempe region of the Rio Salado. U. S. Fish and Wildlife Service, also, have not identified endangered species or their critical habitat within the Tempe/Phoenix area.

According to the Arizona Game & Fish Department, "two federally listed species are the Yuma clapper rail (Rallus longirostris yumanensis), (federally listed endangered, state threatened) and the bald eagle (Haliaeetus leucocephalus),(federal and state listed endangered). Clapper rail is likely at the edge of its distribution, but is known from both above and below the project area."

In relation to the project area, the principle population of the Yuma clapper rail is found in the Arlington Valley, on the Arlington Wildlife Management Area just above Gillespie Dam. This is located some distance downstream of the project area. Yuma clapper rail could be located within the project area in areas of cattail marsh over approximately one acre in size.

The bald eagle is seen most often along oceans or near rivers and lakes. These birds feed primarily on fish and nest in tall trees or on cliffs. Due to the lack of significant standing water and thus fish along the Salt River, the eagle would be an uncommon visitor within the project area.

2.5 Aesthetics

Visual impact and view potential were considered in this portion of the evaluation. In several areas, views from the channel include, dwelling units, light industrial buildings, gravel mining operations, and scattered wetland riparian habitat.

The Papago Buttes to the north and Tempe Butte to the south are visible landmarks in the eastern portion of the project area.

Sporadic or seasonal emergence of various ephemeral aquatic ecosystems and the multiple sand and gravel mining operations provide an insignificant but mentionable aesthetic value within a dry river wash.

2.6 Cultural Resources

The entire project area (area of potential effects, [APE]) as proposed has not been studied to determine the presence or absence of cultural resources. A records and literature search has been initiated at the regional archaeological clearing house (State Historic Preservation Office, Phoenix) to inventory all previous studies involving the project area of potential effects (APE). The State Historic Preservation Office and the Office of Cultural Resource Management, Department of Anthropology, Arizona State University, have developed inventories of recorded archaeological sites and previously conducted archaeological surveys. Undeveloped areas along the Rio Salado contain numerous archaeological sites, and in many cases have been ranked as high sensitivity districts. There are several developed areas along the Rio Salado which have been ranked moderately sensitive, since they contain extensive evidence of past Hohokam habitation sites and irrigation systems. Although in many cases no surface evidence remains, sub-surface materials are a real possibility. The potential for the presence of additional archaeological sites within the APE is high. The potential for the presence of historic sites within the APE is also high.

2.7 Hazardous, Toxic and Radioactive Waste

Soils within the river bed are very gravelly sands to the very fine sandy loam of alluvial deposits. The soils within the river are potentially subject to contamination from several sources: (1) toxic materials in discharge from storm water collector systems carrying metals, (2)grease, and (3) oils of minimal toxicity from overland flows transmitting sediment and fertilizers. However, as of 1989, municipal testing at storm water discharge points has not indicated contaminants in sufficient quantities to discount use of soils from the river channel for certain types of projects. There are no known sources of persistent pesticides and only two minor petroleum spills have been recorded within the western end of the Tempe reach.

Two (2) sewage treatment plants are found within this section of the Salt River - at 27th and 91st Avenues.

Twenty four (24) official landfill sites occur along Salt River's edge - five (5) are active. These landfills present numerous constraints for development. Leachate was produced at the two (2) Estes sites (near 40th Street) from 1978 to 1981. This was caused when the water table rose as a result of recharging from the 1978 flood. The water mixed with the landfill matter to produce leachate which migrated through the aquifer and contaminated local ground water and wells. Testing revealed excess of common cations and anions. The most dangerous substance was a potential carcinogen, vinyl chloride. The ground water is unsuitable for domestic use without prior treatment. Other landfill sites have not been tested but are presumed to be contaminated.

Department of Health is concerned with the build-up of explosive gases - primarily methane. These gases are created within the landfill matter as a by-product of the decomposition process of solid waste. Unfortunately, methane gas has been known to migrate and can become trapped under structures. City of Phoenix has/will be installing gas monitoring and migration control systems.

No radioactive waste disposal sites are located within the project area.

2.8 Land Use

Within the 200 year floodplain, the river's periphery of the fourteen (14) mile reach from the Mesa/Tempe boundary to 40th Avenue in Phoenix is now highly urbanized. The next eight (8) miles consists of agricultural and residential areas, interspersed with occasional light industrial development. The remaining six (6) miles is largely undeveloped.

The uses of the bed and banks are varied. Sand and gravel mines are found in extensive operation. Other uses include active and passive landfills, sewage treatment plants, silt extraction operations, "free" dumping grounds, and various recreation amenities and facilities.

2.9 Noise

Due to intense urbanization along certain aspects of this 28-mile stretch of the Salt River, noises today are generated from commercial and military aircraft, trains, cars, buses, trucks, motorcycles, construction, and urbanized air conditioning units. In most cases, these types and levels of noises are considered acceptable as indigenous noise associated with urban life.

Given particular NEF (noise exposure forecast) and Ldn (24-hour sound levels weighted for night-time annoyance) levels, several areas within the project area are currently severely impacted. This means that several areas are already experiencing unduly high noise levels and some types of recreation activities would be somewhat incompatible.

Noise levels are highest in the central portion of the Phoenix stretch of the Salt River between 44th and 24th Streets due to the proximity of Sky Harbor Airport which is located on the north bank of the river.

In the western section of the river, high localized levels of noise are generated seasonally when the International Raceway is operating.

2.10 Recreation

Recreation is hereby defined as the pursuit of amicably and environmentally appropriate leisure time activities for physical, mental, social, and spiritual fulfillment and/or rejuvenation. For this phase of this study, recreation opportunities were based on probable activities, broken down into the following six (6) overall categories:

WATERCRAFT RELATED (revenue potential opportunities)

WATER-BASED SUPPORT ENDEAVOR (revenue potential)

NON-SUPPORT PASSIVE LINEAR (non-revenue potential)

DEFINED OPEN SPACE (revenue and non-revenue potential)

INTERPRETIVE/ENVIRONMENTAL EDUCATION, NON-STRUCTURED (non-revenue potential)

INTERPRETIVE/ENVIRONMENTAL EDUCATION, STRUCTURED (revenue potential)

The individual recreation opportunities that are included in each of the overall categories are listed in Table 2.10.1

Existing recreation within and adjacent to the Salt River channel, identified and evaluated during the study, included those desirable recreation activities that are sponsored by local municipalities, private developers, and Arizona State University.

Tempe Beach Park, just west of Mill Avenue and south of Rio Salado Parkway, constitutes a unique interface between the urban downtown core and the channel. Moeur Park is located immediately east at the intersection of Mill Avenue and Curry Road. The river edge east of Mill Avenue on the north bank is dominated by Tempe's 480 acre Papago Park.

The 9-hole Rio Salado Golf Course is located in the Indian Bend Wash just south of McKellips Road and includes a low-flow channel capable of conveying approximately 30,000 cubic feet per second of water.

Arizona State University, in Tempe, has several existing and planned recreation opportunities. Current facilities include football and baseball stadiums, tennis courts, track facility, and the 18-hole Karsten golf course.

Table 2.10.1

Proposed Recreation Classifications

WATERCRAFT RELATED (revenue potential opportunities)

bumper boats	motor boats	sailing
canoeing	paddle boats	tubing
hobby boats	parasailing	water skiing
jet ski	rafting	windsurfing
kayak		

WATER-BASED SUPPORT ENDEAVOR (revenue potential opportunities)

amphitheater	miniature golf
commercial eating areas	recreation-oriented retail
conference center	recreation vehicle camping
family entertainment center	swimming, open/beach oriented
fishing, casting	swimming, pool
fishing, natural	water park
fishing, urban	water slides
golf practice range	

NON-SUPPORT PASSIVE LINEAR (non-revenue potential)

bicycle	hiking	sitting areas
equestrian	roller blading	strolling
fitness trail		

DEFINED OPEN SPACE (revenue and non-revenue potential)

backpacking	hunting	softball
basketball	photography	volleyball
botanical garden	picnic, group	youth day camp
camping	picnic, individual	youth sports

golf course	sculpture gardens	tennis courts
hobby planes	soccer, outdoor	hockey, roller

INTERPRETIVE/ENVIRONMENTAL EDUCATION, NON-STRUCTURED
(non-revenue potential)
archaeology
bird watching/counting
historical sites

INTERPRETIVE/ENVIRONMENTAL EDUCATION, STRUCTURED
(revenue potential)

aquarium	environmental education center
scenic/viewshed areas	zoo

Phoenix, to date, has insignificant organized or planned recreation activities or pursuits located within or adjacent to the Salt River.

Other unorganized activities include, but are not limited to, jogging, equestrian use, off-road bicycling, bird watching/counting, fishing, hiking, photography, picnicking, and bathing. Types of undesirable activities would include shooting, off-road vehicle use, and illegal or socially, inappropriate behavioral endeavors.

2.11 Transportation

This urbanized area, not unlike others, has a heavy reliance on the automobile.

The vehicular traffic/transportation pattern, in the north-south directions are handled by a number of dry, all-weather bridge crossings on several major arterial streets and several low flow channel crossings. The Red Mountain Freeway, one of the primary corridors for the Phoenix metropolitan area, will provide a ten (10) lane transportation facility along the north bank running east and

west. It connects Interstate 10 with the Outer Loop, Red Mountain, Pima, and Superstition freeways to the west.

The Rio Salado Parkway parallels the south bank above the 100-year flood level. Since it follows the contours near Mill Avenue, a portion of it is closed during major floods.

Phoenix Sky Harbor Airport which handles both commercial and Air National Guard aircraft is located on the north bank of the Salt River between 24th and 44th Streets.

3.0 ALTERNATIVE PLANS CONSIDERED

3.1 Alternative Plan A - Environmental Restoration

The environmental restoration alternative includes several environmental restoration features along the Salt River including a constructed wetlands and mesquite bosque at Tempe Cienega, located in the Salt River and Indian Bend Wash, a constructed wetlands, waterfowl/fisheries lake, upland riparian vegetation along the streambank, and water quality improvement at a constructed 240 acre wetland between 19th Avenue and 24th Street in Phoenix.

Tempe Cienega restores scarce wetland, riparian and mesquite bosque vegetation, and consists of three main components.

The first component, an inflatable dam to impound water in the Salt River approximately 350 feet upstream of Indian Bend Wash. The inflatable rubber dam will impound all Salt River flows to a maximum ponding depth of six feet, during non flood conditions. During flood flow periods the dam will be deflated, and water will flow downstream uninterrupted by the impoundment structure.

The second component will consist of a 5 foot deep, 20-acre pond immediately upstream of the inflatable dam, 4 acres of hydrophytic vegetation at the upstream edge of the pond, and 15 acres of predominately cottonwood/willow riparian vegetation along the low flow channel. In addition, a 90-acre area will be allowed to naturally revegetate between the pond and a grade control, structure downstream of the McClintock Bridge.

The third component consist of converting an 18-acre area in the low flow channel of Indian Bend Wash near the confluence with the Salt River into a wetland and creating a 4-acre mesquite bosque habitat on the terrace between Curry Street and the Salt River.

The Lago De Vida riparian restoration project covers an area approximately 1,200 feet wide and stretches from 24th Street to 19th Avenue. The project consists of a 240-acre wetland which will be constructed along the low flow channel.

The low flow stream will meander down the low flow channel, and will be lined by hydrophytic vegetation to serve as a wetland. The remainder of the low flow channel and the channel banks will be vegetated with native riparian vegetation.

10 percent incidental recreation at Lago de Vida

3.2 Alternative Plan B - Comprehensive Water Resources Development. (Multi-purpose environmental restoration and recreation)

Alternative Plan B is identical to Alternative Plan A, except that a 120-acre lake and a 120-acre wetland will be developed in the Lago de Vida area instead of the 240-acre wetland. The comprehensive alternative includes the development of Tempe Town Lake and Lago De Vida.

Tempe Town Lake project consists of a 200-acre recreational lake, in the Salt River channel, which will stretch from Indian Bend Wash to just downstream of Mill Avenue. The lake will have inflatable rubber dams at each end of the lake, and will be used primarily as a boating lake. Full body contact will not be allowed in the lake due to safety and water quality concerns. Fishing, sailing, paddle-boating, canoeing, hiking, bicycling, horseback riding, golf, soccer, and softball are a few of the planned recreational activities. A complete description of the Tempe Town Lake is given in the main body of the Reconnaissance Report.

The recreational components of the Lago De Vida project consists of the environmental enhancement as stated above with the exceptions that there will be no in-channel wetlands, and the lake will be used exclusively for recreational purposes. The three proposed lakes will stretch the two miles between 16th Street and 7th Avenue will be approximately 500 feet wide with a depth of 10 feet, and will contain small islands for use by sports fishermen and waterfowl. The stocking of fish will not be primarily the native fishes stated above, but will also include rainbow trout and channel catfish for sportfishing. The total surface area of the lakes will be 120 acres.

3.3 Alternative Plan C - No Action Plan

If no action or project is undertaken in this study area, the riparian and wetland habitats, already impacted by lack of water throughout most of the year with sporadic uncontrolled floodflows resulting from winter storms, will continue to degrade rapidly. The continued use of the river channel for unauthorized purposes with no planned development will continue to destroy any habitat that currently exists in the channel. Urban runoff will continue, but will not be sufficient to maintain the riparian areas except immediately adjacent to the outfalls, with an associated decline in any recreation, aesthetic, educational, and historical-cultural values.

The Cities of Tempe and Phoenix will continue to develop their portions of the river, and will coordinate with the Salt Gila River Watercourse Master Plan currently being developed by Maricopa Association of Governments. Funding for these projects will have to be strictly local, and will depend more heavily upon the local fiscal situation.

4.0 ENVIRONMENTAL EFFECTS OF PLANNING ALTERNATIVES

4.1 Environmental Restoration

4.1.1 Physical Setting

The Papago and Tempe Buttes would continue to standout as visible landmarks. However, there is the potential that they would be enhanced with the landscape and riparian habitat improvements proposed. The physical setting along the river channel would take on a new configuration due to the increase in the wetlands. This would be similar to the physical setting described for Alternative Plan A, but without the urban lake.

4.1.2 Air Quality

The air quality may be balanced between the amount of development proposed and the amount of riparian habitat/ vegetation proposed.

Due to the type of air pollutants identified, Phoenix Zoning Administration has placed emphasis on enforcing regulations regarding developing the desert character of the Rio Salado.

4.1.3 Water Quality

New water bodies will have to be isolated from the contaminated groundwater and wells from landfill sites. Water pumped from the vicinity of the landfills, which is desirable by Maricopa County, will need to be carefully monitored and heavily diluted with unpolluted water.

Appropriate bank stabilization and armoring efforts at existing landfill sites would create a barrier preventing leachate from entering the floodflows and infiltrating the aquifer. In other areas, channel edge stabilization and bank protection by revegetation would reduce sediment transport and minimize erosion reducing turbidity levels.

Contouring of the floodplain would create opportunities to direct and control flows to better facilitate groundwater recharge.

Although not potable for human consumption, secondary treated water from the 27th Avenue sewage treatment plant could be reused for irrigation and habitat restoration areas.

Water quality impacts will be as stated for the previous alternative, except that the 120 acre open water lake will not be constructed, but will be replaced by an additional 120 acres of wetlands.

4.1.4 Biological Resources

4.1.4.1 Vegetation

With the environmental restoration plan, freshwater marsh, mesquite bosque and cottonwood/willow riparian habitat would be constructed along the Salt River. The proposal entails creation of approximately 1138 acres of freshwater marsh, 120 acres of wetlands, 17 acres of cottonwood/willow woodland, and 6 acres of mesquite bosque. A discussion of the value of this habitat can be found in Section 9.0, the Habitat Analysis portion of this Appendix. Habitat would be constructed primarily to benefit wildlife and improve water quality in the river.

Specific aspects to meeting state and federal regulations for restoring riparian habitat include: analysis of existing soils, site location, implementation schedule, soil preparation, species composition and density, planting methods, water availability, watering methods, plant survival goals, guarantee period, control of undesirable plant species, pre- and post-project photo-documentation, and annual and final reports.

The ecological benefits of trees and shrubs adjacent to an aquatic zone of riparian areas include:

- providing shade which modifies the intensity of the sun, heat and glare and prevents water temperatures from rising to lethal levels for fishes,
- root systems which aid in the reduction of bank erosion and silt production,
- production of large woody organic debris piles which provide cover for fishes and habitat for invertebrates,
- and decomposition of leaves provides nutrients and food for both terrestrial and aquatic macro-invertebrates and, in turn, fishes.

4.1.4.2 Wildlife

Constructed wetland areas would provide a significant benefit to wildlife currently located within the study area and promote use of the area by additional adjacent wildlife populations. Riparian habitats are rare and declining within the southwestern United States; maintaining and expanding riparian areas would constitute a significant benefit to populations of invertebrates, amphibians, reptiles, birds and mammals. Expanded habitat along the river would aid the river's function as a linear movement corridor critical for local population dispersion as well as migratory species such as neotropical birds, waterfowl, and certain bats (USFWS, September 1994).

Constructed wetland areas would provide a significant benefit to wildlife currently located within the study area and promote use of the area by additional adjacent wildlife populations. This alternative would not enhance the return of fish to the Phoenix area, as no urban lake will be constructed.

4.1.4.3 Threatened and Endangered Species

The creation or re-creation of wildlife and aquatic habitats could increase the probability of reintroduction of endangered or threatened species within the restored habitat sanctuaries and refuges. Constructed wetland areas could serve as establishment sites for nesting and migrating neotropical birds like the southwestern willow flycatcher (federally proposed endangered) and the lowland leopard frog.

With the construction of freshwater marsh habitat and wetland areas significant habitat opportunities for the Yuma clapper rail would exist. This bird could potentially expand into restored areas. Benefits to this endangered bird species from increases in habitat areas would occur.

Arizona Game and Fish feel that it would be unlikely that a eagle habitat could be created, though they forage and nest in areas within thirty (30) miles of the City of Phoenix.

4.1.5 Aesthetics

Visual impact on the surrounding community and transportation corridors that cross the river channel and view potential from the river would greatly improve with proposed riparian habitat and wetlands. The created greenbelt would become an inviting feature for several walks of life and leisure time pursuits.

4.1.6 Cultural Resources

Preliminary results of the record search indicate that the proposed project may have an effect on at least one property listed in the National Register of Historic Places. The proposed project has the potential of affecting additional National Register listed or eligible sites. Based on the results of the records search, additional archaeological surveys will more than likely be required since our preliminary investigations indicate that only a portion of the project APE has been surveyed. All potential National Register eligible properties within the project APE have yet to be identified. Until these studies are completed, the overall effect on National Register listed or eligible properties is unknown.

4.1.7 Hazardous, Toxic and Radioactive Waste

City of Phoenix's understanding of the ACOE proposed future project conditions include construction projects to restore identified hazardous locations, to treat and reuse contaminated non-point surface runoff, polluted groundwater, and waste water effluent based on:

- treatment of methods of contaminated ground and surface waters landfill bank protection,
- in-channel landfill and dump site identification and removal, and
- mitigation of existing landfills.

4.1.8 Land Use

For this stage of reconnaissance study, proposed land uses were classified in relationship to the following land use designation categories:

- Environmental Sensitive Areas: pristine native areas set aside with no development nor direct exposure from public use activities minimizing adverse impacts to identified scientific, ecological, cultural, or aesthetic features.
- Existing Habitat Sites (Existing Habitat Conservation): existing habitat areas allocated for mitigation or enhancement with limited or no development and exposure for public use activities.
- Riparian Habitat Restoration: areas directly related to refurbishment or reconstruction for contaminate treatment options with limited development and exposure for public use activities.

4.1.9 Noise

Due to the nature of ecological habitat restoration for fish and wildlife and providing the type of water resource based recreation opportunities as proposed, any proposed ACOE project conditions that would be considered on or within the channel would not impact current noise decibel ranges.

4.1.10 Recreation

Rivers, trails, and greenway corridors are traditionally recognized for their environmental protection, recreation values, and aesthetic appearance. These corridors also have the potential to create jobs, enhance property values, expand local businesses, attract new or relocating businesses, increase local tax revenues, decrease local government expenditures, and promote a local community.

River corridors provide a variety of amenities that people value - attractive views, open space preservation, and convenient recreation opportunities. This can be reflected in increased real estate property values and marketability for property located near the Rio Salado. Leisure and recreation expenditures can account for a substantial part of people's discretionary spending.

Based on this alternative, the following matrix has been generated to show the projected number of annual recreation user days for Lago de Vida according to the general recreation categories identified in Section 2.10:

Recreation Category	Future Without Project Level	Service Level with Lago de Vida	Total With-Project Service Level
Watercraft Related	-0-	-0-	-0-
Water-Based	2,000	-0-	2,000
Passive Linear	7,000	800,000	807,000
Defined Open Space	5,000	550,000	555,000
Interpretive/EnvEd	1,000	50,000	51,000
TOTAL	15,000	1,400,000	1,415,000

The natural human attraction to riparian areas in an arid climate places additional demand on these resources. Many forms of recreation activity, such as picnicking, camping, hiking, vehicular recreation, photography, and nature study, are highly dependent on or enhanced by the presence of riparian and wetland areas.

4.1.11 Transportation

Projected and current upgrading of the municipal road systems may maintain the numerous major arterial and collector needs.

4.2 Comprehensive Water Resources Development

4.2.1 Physical Setting

The river channel itself would take on several new configurations. The Tempe Town Lake and Phoenix's Lago De Vida projects include year-round lakes with continually moving low flow channels that enter and exit the lakes through restored riparian habitat environments. With the potential of year-round water sources below these two major projects, there is potential that the current barren, cobble become riparian habitat all year.

The physical setting along the river channel would take on a new configuration due to the increase in the wetlands. This would be similar to the physical setting described for Alternative Plan A, but without the urban lake.

4.2.2 Air Quality

The air quality may be balanced between the amount of development proposed and the amount of riparian habitat/ vegetation proposed.

Due to the type of air pollutants identified, Phoenix Zoning Administration has placed emphasis on enforcing regulations regarding developing the desert character of the Rio Salado.

The air quality may be balanced between the amount of development proposed and the amount of riparian habitat/ vegetation proposed.

The air quality impacts would be as stated in Section 4.1.2.

4.2.3 Water Quality

The Cities of Tempe's and Phoenix's understanding of the ACOE proposed future project conditions include creating a channel configuration that would allow projected flood releases and support habitat restoration, recreation, and integrate with adjacent urban development based on:

- construction of a low flow channel that would allow passage of a defined level of nuisance water and high frequency storm waters in a configuration to maximize opportunities for habitat restoration and development;
- creation of terraced areas above the low flow channel which would support habitat areas;
- definition of levels of flood flows in the low flow channel and on each terraced "zone";
- design of flow velocities on various terraces that can sustain the zone improvements and activities to the greatest extent during flood events;
- creation of flood control facilities west of 35th Avenue that will maintain existing natural channel configuration; and
- location of areas that can be integrated with water quality improvement projects such as constructed wetlands and groundwater and surface water retention areas.

Water quality impacts will be as stated for the previous alternative, except that the 120 acre open water lake will not be constructed, but will be replaced by an additional 120 acres of wetlands.

4.2.4 Biological Resources

4.2.4.1 Vegetation

Creation of recreation lakes along the Salt River may adversely impact vegetation within the channel depending upon the location of the lakes. Riparian and freshwater wetland habitat are found within the channel as described in the existing conditions. Inundation of these areas with a recreation lake would impact any vegetation found in the channel. Vegetative resources are most significant downstream of the proposed lakes; the river channel in the lakes areas are fairly devoid of vegetative resources.

With the Environmental Restoration Plan B, No Urban Lake, the impacts to vegetation would be as stated for the previous alternative, except that an additional 120-acres of wetlands will be created.

4.2.4.2 Wildlife

Permanent aquatic features could provide the opportunity for introducing the kinds of fish suitable to support recreational fishing or native species re-introduced on behalf of conservation. To support urban fisheries, lakes would need to be a minimum of three surface acres with a maximum depth that equals or exceeds ten feet.

Constructed wetland areas would provide a significant benefit to wildlife currently located within the study area and promote use of the area by additional adjacent wildlife populations. This alternative would not enhance the return of fish to the Phoenix area, as no urban lake will be constructed.

4.2.4.3 Threatened and Endangered Species

Recreation lakes are not expected to adversely or positively affect federally listed species. The lakes would support primarily recreational fishing species rather than sensitive native species.

The creation or re-creation of wildlife habitats could increase the probability of reintroduction of endangered or threatened species within the restored habitat sanctuaries and refuges.

4.2.5 Aesthetics

Visual impact on the surrounding community and transportation corridors that cross the river channel and view potential from the river would greatly improve with the development of the proposed Tempe Town Lake.

Visual impact on the surrounding community and transportation corridors that cross the river channel and view potential from the river would greatly improve with the development of the proposed Lago de Vida project by Phoenix.

Visual impact on the surrounding community and transportation corridors that cross the river channel and view potential from the river would greatly improve with proposed riparian habitat and increased wetlands. The created greenbelt would become an inviting feature for several walks of life and leisure time pursuits as was stated for the previous alternative.

4.2.6 Cultural Resources

The impacts to cultural resources as a result of this alternative plan are as stated for the environmental restoration alternative plan.

The impacts associated with this alternative are as stated below. Preliminary results of the record search indicate that the proposed project may have an effect on at least one property listed in the National Register of Historic Places. The proposed project has the potential of affecting additional National Register listed or eligible sites. Based on the results of the records search, additional archaeological surveys will more than likely be required since our preliminary investigations indicate that only a portion of the project APE has been surveyed. All potential National Register eligible properties within the project APE have yet to be identified. Until these studies are completed, the overall effect on National Register listed or eligible properties is unknown.

4.2.7 Hazardous, Toxic and Radioactive Waste

The treatment of HTRW will be as stated for the environmental restoration alternative plan.

The impacts to HTRW sites is as addressed in the previous alternative.

4.2.8 Land Use

For this stage of reconnaissance study, proposed land uses were classified in relationship to the following land use designation categories:

- Low Intensity Recreation: open space with minimum development for passive-type recreation opportunities.
- Medium Intensity Recreation: open space developed for semi-active type recreation opportunities.
- High Intensity Recreation: developed areas with structural and/or architectural support facilities for active type recreation opportunities.
- Operations: land set aside for maintenance, flood control, or other operational facilities.

The existing vacant land between the northside of the channel and the industrial/commercial developments on the west and east sides of Rural Road have been designated as mixed use commercial in the Tempe 2000 General Plan.

The Phoenix Empowerment Zone has the potential to become a center of economic opportunity, environmental beauty, recreational amenities, arts, and entertainment. The areas of economic opportunity identified include a linear urban river park to replace the existing expansive, channelized dry river bed. The existing recontoured channel provides a natural link to the area's future economy and quality of life through a truly visionary project. Envisioning the Rio Salado as the site of a world-renowned desert river recreational amenity would:

- provide appealing open and green space,

- enhance the hospitality and tourism-oriented nucleus,
- create a large recreational amenity,
- provide opportunities for growth development,
- allow for much-needed flood control,
- generate tax revenues from a variety of sources, and
- dynamically enhance the quality of life for residents.

Features of the Salt River Pima-Maricopa Indian Community General Development Plan includes encouraging commercial and recreation development at the eastern boundary with the Rio Salado District and the western tip of the Indian community at Hayden Road. The policy currently indicates that sand and gravel mining as well as other industrial uses will continue to be the predominant landscape feature near the river. These economic activities are a vital resource to the overall health of this community.

Although precise plans for the Gila River Indian Community have not been identified, it appears that little change is expected in current land uses.

Land Uses are as addressed in the previous alternative.

4.2.9 Noise

Due to the nature of recreation activities and methods for providing the type of water resource based recreation opportunities as proposed, there will be a temporary impact to current noise decibel ranges during the construction phase of the project. Once construction is completed, there will be no noticeable increase in noise levels over current levels.

Due to the nature of ecological habitat restoration for wildlife and providing the water as proposed, any proposed ACOE project conditions that would be considered on or within the channel would not impact current noise decibel ranges.

4.2.10 Recreation

The Arizona Statewide Comprehensive Outdoor Recreation Plan (SCORP) has summarized demand for recreation activities based on percentages of survey responses for those visiting particularly categorized areas and those preferring to visit those types of areas:

Recreation Areas	% Visited	% Preferred
Community Parks/Rec Areas	81.1	15.5
State, county, national parks	74.4	32.1
Backcountry areas	49.8	16.4
Water-based recreation areas	64.8	18.8
Historical & cultural sites	56.4	6.9
Commercial outdoor recreation	39.1	7.4

Many outdoor recreation activities can be observed along a river corridor. According to "Lifestyle Market Analysts", a survey of households in 212 metropolitan areas revealed the following overall participation rates:

40.4% walk for health,
32.8% pursue physical exercise
14.9% bicycle,
13.75% boat or sail, and
12.4% run or jog.

Trends associated with uses of channel corridors provides evidence where spending associated with activities has been quantified. These recreation pursuits include:

wildlife-related recreation,
river boating,
trail-related recreation, and
traditional park (open space) endeavors.

SCORP has identified the following index of preference averages for overall demand for outdoor activities:

Attending/Visiting Historical Place	3.56
Attending/Visiting Open Space Activities	3.33
Attending/Visiting Archaeology Sites	3.29
Camping	3.07
Participating in On-foot Activities	2.79
Non-motorized Riding	2.65
Water-oriented	2.59
swimming, pools / water skiing/jetskiing	
swimming, lakes / motor boating	
rafting/kayaking / sailing/windsurfing	
canoeing / tubing	
Fish/Hunting	2.50
Winter Activities	2.45
Nature Study/Birdwatching	2.42
Sports Activities	2.39
Off-highway Driving	2.06

Although recreation resources appear to be adequate, demand is rising. Based on an assessment workshop for SCORP, recreation needs for a metropolitan area were ranked in importance as follows: picnicking, tennis, baseball/ softball, bicycling, handball/squash/racquetball, water skiing, rafting/tubing, open water swimming, non-powered boating, pool swimming, volleyball/basketball/badminton, hiking/backpacking, horseback trails, trailbiking.

Arizonans believe in the importance of protecting the state's outdoor recreation resources. According to SCORP, ninety-four percent (94%) have said that parks and recreation areas are important to their everyday lifestyles. There is strong support for protecting natural and cultural

resources and for environmental education. Arizonans care deeply about the state's air, water, and riparian areas. Seventy-five percent (75%) favor preserving rivers and stream-side habitats, even if it means limiting some uses of privately owned lands.

SCORP also indicates that personal watercraft use is rapidly increasing, most boating occurs on weekends and holidays, and water resource managers emphasized the importance of developing safety and basic support facilities. Among wildlife associated activities, anglers ranked second with 480,000 participants in 1991 resulting in 5,922,000 visitor user days and $156,874,000 in expenditures.

Ranking of overall demand for outdoor activities (applicable to water resource) in the recent SCORP included: visiting outstanding scenic areas, visiting historical place, visiting botanical garden, picnicking, walking, visiting archaeological site, attending outdoor performance, fishing in natural setting, day trail hiking, open water swimming, attending outdoor sports event, bicycling, playground, motor boating, horseback riding, tubing, softball/baseball, rafting and kayaking, canoeing, mountain biking, nature study/bird watching, water-skiing/jet skiing, fishing in urban setting, sailing/windsurfing, and jogging/running, golfing.

Ranking of the latent or unmet need for outdoor recreation activities (applicable to water resource) in the recent SCORP included: fishing in natural setting, picnicking, visiting historic place, visiting outstanding scenic areas, walking, visiting botanical garden, trail hiking, visiting archaeological site, horseback riding, golfing, bicycling, playground, attending outdoor performance, motor boating, open water swimming, water-skiing/jet skiing, softball/ baseball, mountain biking, nature study/birdwatching, jogging/running, tubing, rafting or kayaking, fishing in urban setting, canoeing, sailing/windsurfing.

According to SCORP, favorite activities (applicable to water resource) ranked by the youth population included: basketball, public swimming, hanging out, baseball, horseback riding, football/soccer, motorcycle riding, roller skating, and fishing in a natural setting. Interestingly,

the latent demand activities (applicable to water resource) ranked included: horseback riding, water-skiing/jet skiing, and public swimming.

Multi-purpose recreation trail systems are gaining in popularity. River channels, in particular, become a significant recreation, education, social, and travel route resource to be preserved, enhanced, maintained, and protected. The environmental benefit is the contribution to a healthful, non-motorized transportation option. Well developed trails provide a visually satisfying experience and generally accommodate a wide variety of trail users.

The Rio Salado District is ideally located to address several of the identified recreation needs from both the State and County assessments with particular attention on:

- lakes for fishing, swimming, and non-powered boating;
- local wilderness and camping areas;
- scenic drives and walking trails;
- horseback riding trails;
- public golf courses;
- court games;
- roller skating (go-karting and skateboarding); and
- open space for field games.

Recreation needs for Maricopa County, as identified in 1981, include:

- additional public parks which provide large undeveloped open areas and small pockets of development for structured recreation activities and support facilities;
- centrally located recreation areas with indoor and outdoor recreation facilities for all ages;
- an open-air or domed multiple-use sports complex for track and field, football, soccer, and other organized sports; fields for organized or unorganized sports;
- additional public land for future recreation development and open space requirements; and

- complex of lighted game courts to accommodate a variety of hard surface games; turf or sand areas like volleyball.

Tempe Beach Park projected development will increase public usage with cultural, performing, and visual arts. Other forms of active and passive recreation are being planned and implemented by the City of Tempe's Rio Salado Development Plan for the channel itself. Examples include: active water resource recreation such as sailing, paddle boats, cable-powered skiing, swimming, hiking, bicycling, jogging, horse-back riding, fishing, and picnicking. Future development of Papago Park will accommodate the Arizona Historical Society and Water/Energy Conservation Center and the Hohokam Indian Archaeological/Cultural Center.

Tempe's Rio Salado Development Plan, is a moderate water development encompassing 200 acres and covering approximately four and one-half miles on the south bank. It is estimated that the development plan will attract three to five million visitors per year with an annual recreation benefit of $11,000,000.

The 15-year eventual build-out includes multi-use lakes, ponds, and interconnecting streams for sailing, paddle boating, and canoeing; multi-field sports complex; ice arena; amusement park; beach and boardwalk; 18-hole lighted golf course; miniature golf; family entertainment center and "midway"; hotel; restaurants; retail area; 10,000 capacity amphitheater; residential units; health club; and conference center.

If Tempe Lake was the only project developed, the following matrix of projected number of annual user days has been generated:

Recreation Category	Future Without Project Level	Service Level with Tempe Rio Salado	Total With-Project Service Level
Watercraft Related	-0-	1,800,000	1,800,000
Water-Based	2,000	1,800,000	1,802,000
Passive Linear	7,000	800,000	807,000
Defined Open Space	5,000	550,000	555,000
Interpretive/EnvEd	1,000	50,000	51,000
TOTAL	15,000	5,000,000	5,015,000

City of Phoenix is looking to the private sector to provide more than 700 acres of recreational development including a 10-field softball complex, ice arena, 162-acre water/two mile water attraction site, and 18-hole golf course.

In the 1988 Parks and Recreation Long Range Plan for the City of Phoenix their goal: Unique open spaces should be preserved and protected, includes the following medium priority open space objectives:

- acquire and develop a demonstration section of the Rio Salado Project and
- acquire and develop the Aqua Fria Wash flood plain in cooperation with Glendale and Avondale.

City of Phoenix's understanding of the ACOE proposed project conditions include constructing open space and recreation facilities along the river corridor to relate to urban recreation needs, redevelopment programs and to integrate with the restored habitat locations based on:

- providing a permanent water source in the river to support adjacent recreation and open space areas;
- defining site and functional criteria for each facility usage projections;
- supporting requirements for the physical setting to integrate with flood control and habitat improvements;

- and evaluating the validity of Lago de Vida ... in relationship to water source, infiltration lining, low flow bypass, configuration to coordinate with abutting urban redevelopment, and flood protection.

The following projected, ultimate usage levels based on annual person visit estimates reflect the City of Phoenix Parks and Recreation Department's expectations resulting from an ACOE development project along Rio Salado. These estimates do not include private or commercial enterprises that could supplement the Corps' project, particularly as foreseen in the Central Corridor - additional golf courses in conjunction with associated residential developments.

-	sports complex	400,000
-	golf course (in rounds)	155,000
-	Esperanza, Central Corridor Park	1,000,000
-	Promesa Park/Urban Marketplace	100,000
-	Union Rock Urban Lake	2,000,000
-	Ecology Center (27th Ave Landfill)	300,000
-	Laveen Recreation Area	500,000
-	Cedars Shores Recreation Area	45,000

If Lago de Vida was the only project developed, the following matrix of projected number of annual user days has been generated:

Recreation Category	Future Without Project Level	Service Level with Lago de Vida	Total With-Project Service Level
Watercraft Related	-0-	1,800,000	1,800,000
Water-Based	2,000	1,800,000	1,802,000
Passive Linear	7,000	800,000	807,000
Defined Open Space	5,000	550,000	555,000
Interpretive/EnvEd	1,000	50,000	51,000
TOTAL	15,000	5,000,000	5,015,000

Recreational opportunities associated with this alternative will be similar to those described for the previous alternative, except that there will be no urban lake.

The natural human attraction to riparian areas in an arid climate places additional demand on these resources. Many forms of recreation activity, such as picnicking, camping, hiking, vehicular recreation, photography, and nature study, are highly dependent on or enhanced by the presence of riparian and wetland areas.

A comprehensive project would meet, if not exceed the unmet annual user day demand presented in the above scenarios.

4.2.11 Transportation

Projected and current upgrading of the municipal road systems may maintain the numerous major arterial and collector needs.

City of Tempe began construction of a parkway system which runs along the river bottom connecting into the freeway system.

City of Mesa is considering continuation of a similar system. Maricopa County has recently improved river crossings at 91st Avenue and 115th Avenue.

The Salt River Pima-Maricopa Indian Community is planning extension of Curry Road from Hayden Road across Pima Road.

Projected and current upgrading of the municipal road systems may maintain the numerous major arterial and collector needs.

4.3 No Action Plan

4.3.1 Physical Setting

With forward-thinking planning, the current significant physical attributes will be preserved in perpetuity. The physical aspects of the channel will be dependent on the availability and quality of water resources.

4.3.2 Air Quality

With the projected increase in population, urban growth, air and vehicular transportation, and possible decline in vegetation, the air quality of the Phoenix area could suffer a significant negative affect.

4.3.3 Water Quality

Further discussion of water quality is found in the main body of the Reconnaissance Study and Appendix D of this report.

4.3.4 Biological Resources

4.3.4.1 Vegetation

Riparian habitat is highly dependent upon the availability of surface water and development-related disturbances. A significant loss of habitat area and value is expected over the next ten years due to the removal of water sources currently supporting riparian resources. Future without project conditions assume the removal of wastewater effluent from the river and the reduction of agricultural runoff. In the future without project conditions the cottonwood/willow habitat is more severely affected than the tamarisk plant community.

Future riparian habitat conditions in absence of any improvement or enhancement measures would continue their dependence on the seasonal/periodic wet-dry cycles. Due to recent growth policy changes in the City of Phoenix, there would be no guarantee of preserving current outer bank areas and with the loss of effluent discharge from the sewage treatment plant(s) and agricultural tailwater the riparian habitat would probably diminish and disappear.

4.3.4.2 Wildlife

The USFWS has taken the position that the loss of continuous water flows within the channel would result in the loss of most of the wetland and riparian habitats and the fish and wildlife populations they support. Most significantly would be the expected reduction in value of the habitat supported by the 91st Avenue wastewater treatment plant.

4.3.4.3 Threatened and Endangered Species

In the absence of a continuous water source in the river channel, existing riparian and freshwater marsh habitat within the Sonoran desert ecosystem is expected to be severely impacted. The Yuma clapper rail, if present in the project area, would be adversely affected by the reduction in freshwater marsh habitat.

4.3.5 Aesthetics

In the future without project conditions, the effects to the aesthetics of the area would be negligible, or would experience an increase in the negative aesthetic value of the channel in relationship to the projected urban growth.

4.3.6 Cultural Resources

In the absence of the project, there will be continued bank erosion along the river, and development by both the Cities of Tempe and Phoenix. This will potentially have adverse effects on National Register eligible properties since they are often located in proximity to watercourses.

4.3.7 Hazardous, Toxic and Radioactive Waste

As the City of Phoenix moves forward with its aquifer recharge plan and elimination and closing of landfill sites, hazardous and toxic waste concerns should be minimized.

4.3.8 Land Use

It is expected that the Salt River Valley will become largely urbanized within the next several decades. Urban sprawl and commercial/industrial development is projected to continue west from

the Phoenix metropolitan area. Prime sites may be adjacent to the 100 year and 200 year flood plains, increasing the congested "edge" with buildings and assorted development opportunities.

4.3.9 Noise

With the projected increase in population and development, there will be an increase in decibel levels, and not necessarily from acceptable sound sources.

4.3.10 Recreation

City of Phoenix Parks and Recreation Department's 1994 assessment of current recreation usage data reflected 7,280 annual person visits to the channel area. The following population ratio standards were adopted by the City of Phoenix in their recreation plan:

Recreation Category	Current Level	Desired Level	Ideal Level
park	2.71/1000	6.25/1,000	10.5/1000
hiking	1/10,000	1/8000	1/4000
equestrian	1/10,000	1/8000	1/4000
bicycle	1/9500	1/2000	1/1200
his/interp	-0-	1/5000	1/2500

The above numbers were utilized, in addition to the NRPA standards, to generate the following matrix for the defined recreation categories based on a fifty mile radius recreation demand/market area with the current relative population of 2,500,000. Current recreation service levels in acres (A) and miles (M) were determined from existing facilities sustained by the municipalities, Maricopa County, state and Tonto National Forest facilities within the fifty mile radius:

Recreation Category	Service Level	Desired Level	Unmet Demand
Watercraft Related	12,500A	15,000A	3,500A
Water-Based	12,500A	15,000A	3,500A
Passive Linear	760M	830M	70M
Defined Open Space	13,000A	26,250A	13,250A
Interpretive/EnvEd	166,100A	1,000A	(165,100A)

Taking into account the entire twenty-eight miles and the probable types of recreation opportunities in addition to the known projected number of annual user days from Tempe and Phoenix, the following matrix has been generated:

Recreation Category	Current Level	Desirable Level	Unmet Demand
Watercraft Related	-0-	4,000,000	4,000,000
Water-Based	2,000	4,000,000	3,998,000
Passive Linear	7,000	2,000,000	1,993,000
Defined Open Space	5,000	1,500,000	1,495,000
Interpretive/EnvEd	1,000	500,000	499,000

On the rest of the river, lack of access would not change, therefore natural gravitational activities, conceivably limited to those of the undesirable and unregulated nature, would occur intuitively and uncontrollably. Taking into account the entire twenty-eight miles and the probable types of recreation opportunities, the following matrix has been generated:

Recreation Category	Current Level	Desirable Level	Unmet Demand
Watercraft Related	-0-	4,000,000	4,000,000
Water-Based	2,000	4,000,000	3,998,000
Passive Linear	7,000	2,000,000	1,993,000
Defined Open Space	5,000	1,500,000	1,495,000
Interpretive/EnvEd	1,000	500,000	499,000

4.3.11 Transportation

Arizona Department of Transportation has plans to complete the Outer-Loop (South Mountain Freeway) approximately 1.5 miles east of the study. This will encourage localized growth patterns and increase in vehicular circulation patterns.

Sky Harbor Airport had planned to increase its number of runways, but this proposal has been rejected. However, as Phoenix is a hub for airline travel, there is a potential for increased flight operations to occur in the future.

5.0 FEASIBILITY REPORT NEEDS

This section addresses the steps to be taken beyond reconnaissance and into feasibility and conceptual design. Within the framework of a comprehensive development plan based on environmental and economic considerations, the Rio Salado could become a regional attraction sought for its beauty and recreational attributes. In addition, it can be an enhancement of great value to local interests in the development of housing, commercial, and recreational assets.

A records and literature search and an archeological survey of the entire proposed project is required. Mitigation measures for any cultural resource listed or eligible for listing in the National Register that will be affected by the proposed action will be negotiated with the State Historic Preservation Officer and the Advisory Council on Historic Preservation resulting in a Memorandum of Agreement.

Opportunities abound for the satisfaction of leisure and recreation needs. The evident potential of water for these purposes should be explored and exploited. Development of cost shared public recreational facilities should maximize resources but be consistent with maintaining an appropriate economic feasibility.

Building equitable and beneficial partnerships with effected municipalities, Maricopa County, Arizona State University, Arizona Department of Transportation, Gila Indian Community, Salt River Pima-Maricopa Indian Community, Bureau of Land Management, and various private property owners and commercial developers will be significant to the success of the feasibility stages proposed to follow this evaluation.

Other means for effectively addressing the recreation and habitat restoration needs may include building partnerships with Arizona Association for Learning in and About the Environment (AALE), Arizona Association of Counties, Governors' Biodiversity Council, Rails-to-Trails Conservancy, Arizona Department of Education (ADE), Arizona Department of Environmental Quality (ADEQ), Arizona Department of Water Resources (ADWR), Arizona Game and Fish Department (AGFD), Arizona Office of Tourism (AOT), Arizona Outdoor Recreation

Coordinating Commission (AORCC), Arizona Parks and Recreation Association (APRA), Arizona Parks and Recreation Foundation (APRF), Arizona Recreation Tourism Council (ARTC), Arizona State Land Department (ASLD), Arizona State Parks Board (ASPD), Commission on the Arizona Environment (CAE), Environmental Education Advisory Council (EEAC), Governor's Riparian Task Force, Salt River Project, U. S. Department of Interior (DOI), U. S. Forest Service (USFS), ASU Department of Recreation Management and Tourism (DRMT), and ASU West Leisure Studies.

5.1 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.

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 Fish and Wildlife Coordination 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.

5.2 Rationale for Additional Environmental Impact and Benefit Analyses in the 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 without the proposed project than with the proposed project's riparian habitat improvements and mitigation measures. It appears that a properly designed project and management program to preserve and restore the riparian areas throughout the Rio Salado region would significantly increase these unique and valuable wetland and riparian resources. This analysis provides a compelling basis for further environmental considerations in the feasibility study phase.

If rehabilitation of the Rio Salado region is not undertaken soon, additional degradation will occur, and what is left of this valuable and unique type of environment, and endangered species habitat, will disappear entirely from the metropolitan Phoenix area. Wetlands protection is legislatively a mission of the Corps of Engineers, and, therefore, in the Federal interest.

5.3 Cost Estimate for Feasibility Study Environmental Impact Statement (EIS)

The following is a preliminary cost estimate for preparation of an Environmental Impact Statement in the feasibility study phase. An EIS is appropriate because of the many and varied factors related to the Rio Salado area, and the controversial nature of the project due to the historical perspective of the project in the Phoenix/Tempe area. The time required for the preparation of the document would be about 18 months, depending 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.

These preliminary costs are subject to change at the time that public scoping occurs for the Feasibility Study EIS.

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

Additional Archaeological Contracts

Cultural Resources Field Surveys	$15-20/acre
Archaeological Testing	$60-100,000/site

6.0 COORDINATION

During the preparation of this Appendix A for the Rio Salado Reconnaissance Study, NUVIS contacted the following individuals and agencies to glean information:

Individual	Agency/Affiliation	Specialty
Peter Atonna	City of Phoenix	Planner
Carey Casey	ACOE/Los Angeles	GIS
Duane Dawson	City of Tempe	Recreation
Manny Dominguez	City of Tolleson	Public Works
Jody Fisher	ACOE/Los Angeles	Water Quality
Cliff Ford	ACOE/Los Angeles	Civil Engineer
Dr. Wm. L. Graf	ASU Dept of Geography	Community Dev
Scott B. Grubb	Ariz Dept Parks	Recreation
Howard Hargis	City of Tempe	Engineer
Jan Hatmaker	City of Phoenix	Noise/Air
John Karakawa	ACOE/Los Angeles	Design
James Coffman	City of Phoenix	Recreation
Ed Louie	ACOE/Los Angeles	Recreation
Michelle Mackey	ACOE/Los Angeles	Rec. Impacts
Dennis Marfise	ACOE/Los Angeles	Hydrology
Ronald MacDonald	ACOE/Los Angeles	Ecology
Ron McKinstry	U. S. Fish & Wildlife	Fish & Wildlife
Steve Nielsen	City of Tempe	Community Dev
Greg Peacock	ACOE/Los Angeles	Hydrology
Dick Perreault	Maricopa County	Flood Control
Kris Randall	Ariz Dept Env Quality	Rip/Wetlands
Lawrence M. Riley	Ariz Dept Game & Fish	Env. Compliance
Robert Sejkora	Ariz Dept Parks	Water Resources
Scott Solliday	Tempe Hist Museum	History

Bruce Swanson	City of Phoenix	Recreation
Paul Walker	City of Goodyear	Recreation
Ted Yee	ACOE/Los Angeles	Hydrology

Results of the archival studies and archaeological surveys, along with the Corps' determinations of eligibility, will be sent to the Arizona State Historic Preservation Officer for review and comment. If it is determined that the project will have an adverse effect on National Register listed or eligible properties, the Advisory Council on Historic Preservation will be afforded the opportunity to comment on the project in accordance with Section 106 of the National Historic Preservation Act.

7.0 PREPARERS

The following individuals were instrumental in the preparation of this Appendix A for Rio Salado Reconnaissance Study:

Individual	Affiliation	Role
Robert R. Cardoza	NUVIS	Administrator
Ron Conner	ACOE/Los Angeles	Economist
Matt DeHeras	NUVIS	Graphics
Jennifer Eckert	ACOE/Los Angeles	Biology
Paul LeBrun	ACOE/Phoenix	Study Manager
Rod McClean	ACOE/Los Angeles	Archaeology
Tomas Munoz	NUVIS	Project Manager
Laura Skiff	NUVIS	Graphics
Daniel Sulzer	ACOE/Los Angeles	Economist
Leslee A. Temple	NUVIS	Project Principal
Alex Watt	ACOE/Los Angeles	Env. Protection

8.0 REFERENCES

Apache Powder Superfund Site, U. S. Environmental Protection Agency, July 1994.

Arizona Riparian Inventory and Mapping Project, Arizona Game and Fish Department, December 1993.

Arizona Statewide Comprehensive Outdoor Recreation Plan (SCORP), Arizona State Parks Board.

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

City of Phoenix Rio Salado Enhancement Project, Cella Barr Associates, September 29, 1993.

Economic Impacts of Protecting Rivers, Trails and Greenway Corridors, USDOI National Park Service, Rivers, Trails and Conservation Assistance Program, 1982.

Empowerment Zone Strategic Plan, BRW Inc and Arizona State University, June 1994.

Environmental Assessment, City of Tempe, Community Development Department, March 1990.

Development Plan, City of Tempe, Community Development Department, January 1994.

Landiscor Aerial Photos 1994.

Long Range Plan Update Board Report, Tempe Community Services Department, 1989.

Notes on Geomorphic "Naturalness" Classification for River Channels, Dr. William L. Graf, ASU Department of Geography.

Parks and Recreation Long Range Plan, City of Phoenix, June 1988.

Phoenix Water Reclamation and Reuse Study Tres Rios Demonstration Wetlands Conceptual Design, Bureau of Reclamation, October 1983

Predevelopment Hydrology of the Salt River Indian Reservation, East Salt River Valley, Arizona, U. S. Geological Survey Water Resources Investigations Report 91-4132, November 1991.

Public Arts Master Plan, The Rio Salado Overlay District, Tempe Municipal Arts Commission, 1994.

Rio Salado Environmental Education Workshop, City of Tempe, October 1991.

Riparian Management: Common Threads and Shared Interests, U. S. Forest Service, Rocky Mountain Forest and Range Experiment Station, February, 1993.

Riparian Protection Program Legislative Report, Arizona Department of Water Resources, February 1994.

Rio Salado Engineering Report, CH2MHill, August 1992.

Rio Salado Master Plan, Carr, Lynch Associates, October 1983 and January 1985.

Rio Salado Project Volume I, Daniel, Mann, Johnson, & Mendenhall, April 1979.

Rio Salado Town Lake Feasibility Study, CH2MHill, April 1992.

Statewide Comprehensive Outdoor Recreation Plan (SCORP), Arizona State Parks Board, 1994.

Superfund Information Packet, Arizona Department of Environmental Quality, December 1993. December 1993.

The Development of an Arizona Riparian Habitat Evaluation Model with Wildlife Values, Revegetation and Wildlife Management Center and Center for Environmental Studies Arizona State University, 1993.

The Economic Impact of the Proposed Rio Salado Development, City of Tempe Community Development Department, April 1994.

The Gila, River of the Southwest, Edwin Corle.

The Swilling Legacy, Earl Zarbin, August 1978.

Water...in the Valley Today, Salt River Project.

Wildlife Habitat Masterplan, HNTB, October 22, 1990.

9.0 HABITAT ANALYSIS

I. Introduction

A field reconnaissance study was to conducted to determine the existing habitat values of the vegetation within the Rio Salado study area. A modified habitat evaluation procedure analysis was conducted; a group of environmental professionals was assembled to qualitatively assess the value of the habitat along the river. This value, multiplied by the acreage of each habitat area, was converted to Habitat Units. These habitat units represent the existing habitat value of the vegetation in the study area. This existing value is projected into the future under both with project and without project conditions to determine the habitat units associated with these future conditions.

II. Affected Environment.

Fresh water marsh. This habitat type consists primarily of cattails, bulrushes, and occasionally water cress. This community is located at the lowest elevations of the river along the watercourse or in areas of shallow ponded water or heavily saturated soils.

Cottonwood/willow riparian forest. This habitat is dominated by a combination of cottonwood and willow trees. This plant community is found along the active streambed of the river or on the first terrace above the river.

Mesquite habitat type. This habitat type is dominated by honey mesquite and is normally found on the upper terraces of the floodplain above the active river channel. The presence of mesquite within the project area is minimal; tamarisk dominates the areas where mesquite would be located.

Tamarisk. Tamarisk is located on all floodplain elevations throughout the study area. Dense monotypic stands of tamarisk are found primarily on the upper terraces of the river. Tamarisk is also interspersed with stands of native vegetation at all elevations of the floodplain.

III. Methodology.

A. General.

A field team was assembled to qualitatively assess the habitat value of the existing habitat within the Rio Salado study area. The team consisted of individuals from various resource agencies within Arizona and the Los Angeles District, Corps of Engineers.

Field team members included:

Ron McKinstry, U.S. Fish and Wildlife Service
Larry Riley, Arizona Department of Fish and Game
Kris Randall, Arizona Department of Environmental Quality

Anne Blech, Flood Control District of Maricopa County
Jennifer Eckert, Alex Watt, and Paul LeBrun, Corps of Engineers

Prior to conducting the field investigation, areas of existing habitat were identified and mapped on a 1994 Landiscorp aerial photo (scale: 1 inch to 1200 feet) of the study area. In addition, the qualitative parameters, or rating criteria, upon which to assess the habitat were determined by group consensus.

The field investigation was conducted September 1 and 2, 1994. During the field investigation, the team walked each of the sites identified on the aerial photo and graded the site for each of the rating criteria. The grading was on a scale ranging from zero to one (0 - 1.0), with 1.0 being the highest value. Sites were added and deleted during the field reconnaissance as the aerial photo was ground-truthed. In total, 29 sites were mapped and assessed during the field study.

The rating criteria used include the following:

Threatened and endangered species: Assessed value based on habitat suitability for the Yuma clapper rail, a federally listed endangered species. Areas with ponded water and stands of cattails were assessed a higher value for this category.

Continual Water Source: Sites with visible water were assessed a value of 0.5, sites without water were assessed a value of 0.0. The team assumed that if water was present at the site than it was a reliable source present throughout the year, or most of the year. This assumption was made because the survey was conducted on 1 and 2 September, which is towards the end of the hot summer, although monsoon rains do occur in September.

Bird/wildlife species present: Assessed value based on the wildlife species and sign observed during the survey.

Species composition: Assessed value based on the plant species present at the site with higher value given to areas of native plants, lower value given to areas dominated by invasive non-native plant species, primarily tamarisk.

Species density: Assessed value based on the percentage of vegetative ground cover present across all height classes. Cover was broken down into a percent scale and graded accordingly, below.

Percent Plant Cover	Assessed Value
0 - 20%	0.0 - 0.2
20 - 40%	0.2 - 0.4
40 - 60%	0.4 - 0.6
60 - 80%	0.6 - 0.8
80 - 100%	0.8 - 1.0

Height class (% of plants < 15' and % plants > 15'): For this category a scaled value was not assessed. Rather, the percentage of vegetation by foliage volume above and below 15 feet was determined. This percentage was later scaled along with the species composition and species density vales to determine a single habitat value for these criteria (see discussion below).

Undisturbance within/adjacent to habitat: Areas with high levels of disturbance were assessed a low value while relatively undisturbed areas were assessed a high value. Disturbance included proximity of the site to urban or industrial areas, freeway and bridge overcrossings, sand and gravel operations, off-road vehicle use and illegal dumping. Undisturbed areas were those that appeared to have little human influence within or adjacent to the site.

In sum, a total of 29 sites along the Salt River were identified on the map and assessed. The results of the site assessments with the values for each of the rating criteria are shown in Table 1. Field notes on each of the sites are found in Appendix F of this report (To Be Added). These data were then used to determine the habitat units associated with each site.

B. Habitat Units Determination.

To determine the habitat value of each site (in habitat units), one must multiply the assessed value of the site by the acreage of the site. The above rating criteria were averaged and multiplied by the acreage of each site to determine the number of habitat units associated with each site.

To determine the overall assessed value of the site, the rating criteria were averaged. However, prior to determining the average rating criteria, species composition, species density and height class were combined into one overall number, representing value of the habitat to wildlife. This combined rating criteria was added to the remaining criteria (threatened and endangered species, continual water source, bird/wildlife species present, and level of undisturbance) and divided by five to form the average value associated with each of the sites.

Table 1. Rating Criteria Field Values.

Site	1	2	3	4	5	6a	7	8	9	9a	10	11	12	13	14	15
T&E Species	0.1	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0.2
Water	0.5	0.5	0	0	0.5	0.5	0.5	0	0.5	0.5	0	0	0	0	0.5	0.5
UnDisturb	0.1	0.1	0	0.1	0.5	0.3	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.8	0.6	0.6
Sp. present	0.2	0.1	0	0.1	0.8	0.7	0.3	0.7	0.3	0.6	0.2	0.3	0.3	0.7	0.6	0.6
Sp. Composition	0.6	0.4	0	0.3	0.9	0.4	0.4	0.7	0.4	0.5	0.2	0.5	0.4	0.6	0.7	0.8
Sp. Density	0.8	0.3	0	0.1	0.8	0.8	0.2	0.5	0.3	0.4	0.8	0.8	0.7	0.8	0.7	0.7
Height Class																
% Plants < 15'	90	100	0	100	50	100	30	50	100	40	60	20	100	50	80	50
% Plants > 15'	10	0	0	0	50	0	70	50	0	60	40	80	0	50	20	50
Site	16	16a	17	18	19	20	21	22	23a	23b	24	24a	25			
T&E Species	0	0.7	0.2	0.2	0.3	0	0.2	0.8	0	0.9	0.3	0.6	0.2			
Water	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0.5	0.5	0.5	0.5			
UnDisturb	0.8	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.7			
Sp. present	0.4	0.8	0.6	0.6	0.8	0.4	0.6	0.6	0.3	0.8	0.8	0.8	0.4			
Sp. Composition	0.2	0.7	0.7	0.7	0.7	0.2	0.5	0.7	0.2	0.8	0.7	0.7	0.4			
Sp. Density	0.9	0.4	0.7	0.7	0.6	0.9	0.6	0.8	0.7	0.3	0.7	0.6	0.7			
Height Class																
% Plants < 15'	70	60	60	60	70	90	60	50	80	100	60	80	90			
% Plants > 15'	30	40	40	40	30	10	40	50	20	0	40	20	10			

Species composition, species density and height class were combined into one number based on a habitat evaluation model formulated under contract for the AZ Dept of Game and Fish (Anderson and Ohmart, 1993). The "Arizona Riparian Habitat Evaluation Model with Wildlife Values" was developed to predictwildlife values for the various riparian habitat types in Arizona. To predict the wildlife values associated with riparian communities, the model used the criteria of tree species composition and density data, and the foliage profile/vertical configuration of the vegetation. These criteria correspond to the study team field ranking criteria of species composition, species density, and height class, respectively.

The study team field ranking for these criteria were input into the Anderson-Ohmart Arizona Riparian Habitat Evaluation Model to formulate one number which represents the wildlife value associated with each of the sites. This value, referred to as the Anderson-Ohmart value, or A-O value, was averaged along with the remaining rating criteria to derive an overall value for each of the sites. Table 2 shows the inputs into the Habitat Evaluation Model for each of the sites and the final A-O value derived from the model. Table 3 shows the five values associated with each of the rating criteria, and the total and average value of these ranking criteria. The average value multiplied by the number of acres for each site gives the habitat units associated with each site, also on Table 3. These values show the existing habitat value or the existing conditions of the vegetation within the project area. Table 3a displays the habitat units for existing conditions by habitat type.

Future Without Project Conditions. Table 4 illustrates the estimated habitat units associated with future without project conditions. The future without project habitat units were estimated based on several assumptions. These assumptions include the elimination of wastewater effluent from the river; the reduction of agricultural runoff; and the maintenance of storm water in the river. The future assumptions also include the flood control maintenance of the river starting from 91st Avenue and continuing downstream off the project area.

Table 2. Habitat Evaluation Model Worksheet.

SITE	1	2	3	4	5	6a	7	8	9	9a	10	11	12	13	14	15
1st Dom	CW	TAM		CW	WIL	WETLAND	WIL	WIL	TAM	WIL	TAM	TAM	TAM	CW-WIL	WIL	CW
2nd Dom	WIL	WIL		WIL	CW		CW		CW-WIL			WIL-CW		TAM	TAM	WIL-MESQ
Series	1	3		1	1		1	1	3	1	3	3	3	1	1	1
Density	0.8	0.3		0.1	0.8	0.8	0.2	0.5	0.3	0.4	0.8	0.8	0.7	0.8	0.7	0.7
Height Class																
Pct<15'	90	100		100	50	100	30	50	100	40	60	20	100	50	80	50
Pct>15	10	0		0	50	0	70	50	0	60	40	80	0	50	20	50
Veg Class	VI	VI		VI	IV	VI	VI	IV	VI	VI	VI	II	VI	IV	VI	IV
Veg Value	2.6	-1.9	??	2.6	2.8		2.6	2.8	-1.9	2.6	-1.9	-1.3	-1.9	2.8	2.6	2.8
A-O Value	0.89	0.21	??	0.89	0.92	0.80	0.89	0.92	0.21	0.89	0.21	0.30	0.21	0.92	0.89	0.92
SP. Present	0.2	0.1		0.1	0.8	0.7	0.3	0.7	0.3	0.6	0.2	0.3	0.3	0.7	0.6	0.6
SITE	16	16a	17	18	19	20	21	22	23a	23b	24	24a	25			
1st Dom	TAM	CW	TAM	WIL	WIL	TAM	WIL-CW	WIL	TAM	OPEN WAT	WIL	WIL	TAM			
2nd Dom		WIL		CW	CW		TAM	CW-TAM	CW	CATTAIL	TAM	CW	CW-WIL			
Series	3	1	3	1	1	3	1	1	3		1	1	3			
Density	0.9	0.4	0.7	0.7	0.6	0.9	0.6	0.8	0.7	0.3	0.7	0.6	0.7			
Height Class																
Pct<15'	70	60	60	60	70	90	60	50	80	100	60	80	90			
Pct>15'	30	40	40	40	30	10	40	50	20	0	40	20	10			
Veg Class	IV	IV	IV	IV	IV	VI	IV	IV	VI	VI	IV	VI	VI			
Veg Value	-1.7	2.8	-1.7	2.8	2.8	-1.9	2.8	2.8	-1.9	??	2.8	2.6	-1.9			
A-O Value	0.24	0.92	0.24	0.92	0.92	0.21	0.92	0.92	0.21	0.90	0.92	0.89	0.21			
Sp. Present	0.4	0.8	0.6	0.6	0.8	0.4	0.6	0.6	0.3	0.8	0.8	0.8	0.4			

Table 3 Project Site Habitat Values.

SITE	1	2	3	4	5	6a	7	8	9	9a	10	11	12	13	14	15
T&E	0.1	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0.2
Water	0.5	0.5	0	0	0.5	0.5	0.5	0	0.5	0.5	0	0	0	0	0.5	0.5
UnDisturb	0.1	0.1		0.1	0.5	0.3	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.8	0.6	0.6
A-O Value	0.9	0.2	é	0.9	0.9	0.8	0.9	0.9	0.2	0.9	0.2	0.3	0.2	0.9	0.9	0.9
Sp. Present	0.2	0.1	É	0.1	0.8	0.7	0.3	0.7	0.3	0.6	0.2	0.3	0.3	0.7	0.6	0.6
TOTAL	1.79	0.91	0.00	1.09	3.22	2.30	2.19	2.22	1.61	2.59	1.01	1.20	1.21	2.42	2.59	2.82
Avg. Value	0.36	0.18	0.00	0.22	0.64	0.46	0.44	0.44	0.32	0.52	0.20	0.24	0.24	0.48	0.52	0.56
Acreage	4.6	54.5	19.5	14.2	13.2	6.61	189.8	56.7	12.6	41.3	147	53.8	34.4	43.6	27.4	44.3
Habitat Units	1.6	9.8	0	3.1	8.5	3	83.5	24.9	4	21.5	29.5	12.9	8.3	20.9	14.2	24.8
SITE	16	16a	17	18	19	20	21	22	23a	23b	24	24a	25			
T&E	0	0.7	0.2	0.2	0.3	0	0.2	0.8	0	0.9	0.3	0.6	0.2			
Water	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0.5	0.5	0.5	0.5			
UnDisturb	0.8	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.7			
A-O Value	0.2	0.9	0.2	0.9	0.9	0.2	0.9	0.9	0.2	0.9	0.9	0.9	0.2			
Sp. Present	0.4	0.8	0.6	0.6	0.8	0.4	0.6	0.6	0.3	0.8	0.8	0.8	0.4			
TOTAL	1.44	3.52	2.14	2.82	3.22	1.71	2.82	3.42	1.11	3.70	3.32	3.59	2.01			
Avg. Value	0.29	0.70	0.43	0.56	0.64	0.34	0.56	0.68	0.22	0.74	0.66	0.72	0.40			
Acreage	181	62.2	12.2	26.5	25.1	117.36	51.57	111.1	20.8	11.2	50.3	17.9	348			
Habitat Units	52.3	43.5	5.3	8.3	16.1	39.9	28.9	75.5	4.6	8.3	33.2	12.9	139			

Table 3a. Habitat Units for Existing Conditions by Habitat Type			
Wetlands Dominant			
Site #	Acreage	Quality	H. U. 's
6a	6.61	0.46	3.00
23b	11.20	0.74	8.30
Total	17.80		11.30
Tamarisk Dominant			
Site #	Acreage	Quality	H. U. 's
9	12.60	0.32	4.00
10	147.40	0.20	29.50
11	53.80	0.24	12.90
12	34.40	0.24	8.30
16	180.50	0.29	52.30
17	12.20	0.43	5.30
20	117.40	0.34	39.90
23a	20.80	0.22	4.60
25	348.10	0.40	139.20
Total	927.20		296.00
Cottonwood Willow Dominant			
Site #	Acreage	Quality	H. U. 's
1	4.60	0.36	1.60
4	14.20	0.22	3.10
5	13.20	0.64	8.50
7	189.80	0.44	83.50
8	56.70	0.44	24.90
9a	41.30	0.52	21.50
13	43.60	0.48	20.90
14	27.40	0.52	14.20
15	44.30	0.56	24.80
16a	62.20	0.70	43.50
18	26.50	0.56	8.30
19	25.10	0.64	16.10
21	51.60	0.56	28.90
22	111.10	0.68	75.50
24	50.30	0.66	33.20
24a	17.90	0.72	12.90
Total	779.80		421.40

Table 4. Habitat Units for Future Without Project Conditions.

Wetlands Dominant				
Site #		Area	Q	Habitat Units Units Units Water Source/Impact
6a	3.3	0.23	7.6	Aggie
23b	1.1	0.07	0.08	Wastewater/Flood control maint.
Total	4.4		7.7	
Tamarisk Dominant				
Site #	Area	Quality	Habitat Units	
9	3.8	0.1	0.38	Water unknown/currently water stressed
10	147.4	0.2	29.5	Currently no water/no change
11	53.8	0.24	12.9	Currently no water/no change
12	34.4	0.24	8.3	Currently no water/no change
16	180.5	0.29	52.3	Currently no water/no change
17	1.2	0.04	0.05	Wastewater/Flood control maint.
20	117.4	0.34	39.9	Groundwater-Gila River/No disturbance expected
23a	20.8	0.22	4.6	Upper Terrace/No disturbance expected
25	104	0.1	12.5	Wastewater?
Total	663.3		160.4	
Cottonwood Willow Dominant				
Site #		Acreage	Quality	H. U. 's Water Source/Impact
1	4.6	0.36	1.6	Stormwater
4	4.3	0.1	0.43	Wastewater
5	6.6	0.32	2.1	Aggie
7	94.9	0.22	20.9	Water source unknown/Currently drought stressed stressed
8	56.7	0.44	24.9	Water source unknown
9a	20.7	0.26	5.4	Aggie?
13	43.6	0.48	20.9	Currently no water/no change
14	13.7	0.26	3.6	Aggie
15	4.4	0.06	0.27	Wastewater/Flood control maint.
16a	6.2	0.07	0.43	Wastewater/Flood control maint.
18	2.6	0.05	0.13	Wastewater/Flood control maint.
19	11.7	0.03	0.35	Wastewater/Flood control maint.
21	5.1	0.05	0.25	Wastewater/Flood control maint./future bridge crossing
22	11.1	0.07	0.77	Wastewater/Flood control maint./future bridge crossing
24	5	0.06	0.3	Wastewater/Flood control maint.
24a	1.8	0.07	0.13	Wastewater/Flood control maint.

Essential to the existence of healthy plant communities along the Salt River is the presence and availability of water. Removal of wastewater and reduction of agricultural runoff would reduce the extent and quality of the vegetation currently relying on these sources. Flood control maintenance of the river is expected to adversely affect existing vegetation through clearing operations. A reduction in habitat quality along the river with a concomitant reduction in associated habitat units would be expected in the future without project conditions.

C. Observations.

Existing Conditions. Several observations about existing conditions can be made from the data in Table 3a. First, tamarisk is the dominant habitat type, with over 900 acres located along the river. Approximately 780 acres of cottonwood/willow dominated habitat also exist in the study area. Freshwater wetland dominated habitat is limited in extent, with approximately 18 acres found in the study area, although this habitat type is also found in areas of cottonwood/willow habitat if adequate water is present.

Although tamarisk is the dominant plant community in terms of acreage, the habitat units associated with the cottonwood/willow habitat type exceed those of the tamarisk communities (296 H.U's for Tamarisk, 421 H.U.'s for CW/Will). Cottonwood/willow habitat is far more valuable to wildlife than tamarisk, though mature tamarisk stands to provide some habitat value, most notably for doves.

Future Without Project Conditions. Based on the future without project assumptions, it is expected that the value and overall acreage of habitat along the river will be reduced.

In the future without project conditions the cottonwood/willow habitat is more severely affected then the tamarisk plant community. This is due to an anticipated reduction in the availability of water. Some of the tamarisk is located on flood terraces above the river channel, and away from existing surface water; these plants are supported by groundwater. Because of this, these plant communities will be less affected by the reduction in wastewater, agricultural

water, and the expected flood control maintenance. The habitat units associated with the tamarisk community are expected to be reduced from 296 H.U.'s to 184 H.U.'s or a 38% reduction in value.

In contrast to tamarisk, portions of the cottonwood/willow community are located on lower flood terraces and in the river along existing surface water. These species are more affected by a reduction in water than tamarisk. In general, sites located downstream of the 91st Avenue wastewater treatment plant represent much of the highest quality cottonwood/willow habitat along the river. These areas would be severely impacted by the removal of wastewater flows and the program of flood control maintenance. Comparing existing conditions to future without project conditions shows a reduction from 421 total H.U.'s to 137 H.U.'s for the cottonwood/willow habitat type or a 68% reduction in value.

IV. Project Alternatives.

The primary constraint for the existence of cottonwood/willow and freshwater marsh habitat along the river is the availability of water. It is essential to secure a water source in order to promote these habitat types within the study area. Once a water source has been identified species manipulation in the form of native species planting, and/or ruderal species removal can be accomplished. Endangered species enhancement for the Yuma clapper rail could be done through the creation of freshwater ponds and marsh areas.

The emphasis for habitat restoration is to create a self maintaining more "natural" habitat (habitat that would not require a human-manipulated water source to survive). Plants would be maintained for an establishment period only until they are self sustaining. This can be accomplished by using plant species appropriate for the elevation along the river (river channel, first or second flood terrace above the river) and for the water availability, either ground or surface water.

A. Alternative A: Environmental Restoration. This alternative seeks to maximize the native wetland habitats along the Salt River through construction of new habitat. The construction of

wetland habitat, primarily cattail marsh, is proposed at several locations along the Salt River and Indian Bend Wash. A detailed description is provided in the text of the main report.

Indian Bend Wash.

Approximately 18 acres of freshwater marsh would be constructed within the Indian Bend Wash from just downstream of McKellips Road to the confluence of the Salt River. Six acres of mesquite bosque are proposed for the area from Curry Street to the Salt River confluence. The freshwater marsh would be located in the bottom of the Indian Bend Wash channel with the mesquite bosque located on a terrace above the active channel bottom. Fourteen of the eighteen acres of marsh would be adjacent to an existing golf course with the remaining four acres adjacent to the mesquite. These wetland areas would be supported by pumped groundwater.

Tempe Wetlands.

The Tempe Wetlands would consist of approximately 4 acres of freshwater marsh and 15 acres of cottonwood willow woodland constructed in the Salt River. The cottonwood willow restoration would be done along the sides of the Salt River to avoid the center of the active channel and thus minimize conflicts with flood control needs. An impoundment structure would be required across the Salt River to form a backwater area thus supplying the necessary water to support the wetlands.

Phoenix Wetlands (Lago de Vida).

The Phoenix Wetlands would consist of approximately 240 acres of freshwater marsh and 12 acres of cottonwood willow woodland. The freshwater marsh would be located slightly off the active channel and would be supported by pumped groundwater. The cottonwood willow woodland would avoid the active channel and thus conflicts with flood control needs and would also be supported by pumped groundwater.

B. Alternative B: Comprehensive Water Resources Development. Alternative B represents a comprehensive water resources development strategy wherein riparian habitat restoration and recreation share foremost as primary project purposes. The two alternatives are similar in terms

of habitat restoration, including the unique features of converting environmental problems into opportunities for environmental gains at Tempe (Indian Bend Wash and Salt River) and Lago de Vida in Phoenix. The major difference between the two, from a habitat restoration perspective, is a reduced habitat restoration area at Lago de Vida for Alternative B. Alternative B at Lago de Vida has 120 acres of wetland restoration rather than 240. Otherwise, the two alternatives are the same in terms of habitat restoration.

C. Future With Project Conditions. Under future with project conditions the site conditions listed in Table 4 would remain unchanged. New habitat would be created at Lago de Vida and Tempe Cienega (see the text of the main report for alternative details) where currently there is none. Table 5 illustrates the estimated habitat units associated with future with project conditions for Alternatives A and B.

The future with project conditions result in a net gain of habitat and associated habitat units within the study area. With the construction of the project alternative as described below approximately 142 to 262 acres of freshwater marsh would be constructed along with 27 acres of cottonwood willow woodland and 4 acres of mesquite. The habitat units associated with these proposed areas are added to the future habitat units associated with the existing habitat currently found along the river.

In assessing project impacts, a comparison is made between the future with and future without project conditions. This comparison can be found in Table 6, below. An overall increase in both the acreage and the habitat units associated with each of the habitat types occurs in the future with project conditions. Most significantly, the freshwater marsh habitat would increase by approximately 142 to 262 acres and 90 to 168 habitat units (for Alternatives B and A respectively). There is also an increase associated with the cottonwood/willow, tamarisk and mesquite habitat types. At this time, there is little mesquite within the project area, occasional plants are present but no exclusive stands exists. This project proposes to restore approximately 4 acres of this habitat type.

Table 5.A. Habitat Units for Future With-Project Conditions: Tempe Cienega in Alternatives A and B.

Mesquite Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source
Indian Bend Wash	4	0.60	2.4	Groundwater
Wetlands Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source
Salt River	4.0	0.56	2.2	Groundwater and Salt River Flows
Indian Bend Wash	18.0	0.58	10.4	Groundwater
Subtotal	22.0	--	12.6	Groundwater and Salt River Flows
Cottonwood Willow Dominant				
Site	Area (Acres)	Quality (0-1)	Habitat Units	Water Source/Impact
Salt River at Tempe	15.0	0.5	7.5	Groundwater and Salt River Flows
Total	41	--	22.5	Groundwater and Salt River Flows

Table 5.B. Habitat Units for Future With Project Conditions: Alternative A at Lago de Vida.			
Habitat Type	Area (Acres)	Quality (0-1)	Habitat Units
Wetlands	240.00	0.64	154
Cottonwood-Willow (On channel banks)	12.0	0.5	6.0
Total	252	--	160

Table 5.C. Habitat Units for Future With Project Conditions: Alternative B at Lago de Vida.			
Habitat Type	Area (Acres)	Quality (0-1)	Habitat Units
Wetlands	120.00	0.64	77
Cottonwood-Willow (On channel banks)	12.0	0.5	6.0
Total	132	--	83

Table 6.A.	Comparison of Riparian Habitat Conditions for Future-With-Project and Future-Without-Project Conditions - Alternative A.						
Habitat Type	Future-Without-Project Area (In Acres)	Future-With-Project Area (In Acres)	Percent Difference in Area	Future-Without-Project Habitat Units	Future-With-Project Habitat Units	Increase in Habitat Units	Percent Difference in Habitat Units
Mesquite	0	4	>+100%	0	2.4	2.4	>+100%
Wetlands	17.8	279.8	+1,471.9%	2.3	169.5	167.2	+7,270%
Cottonwood	779.8	806.8	+3.5%	136.6	150.1	13.5	+10%
Total	797.6	1,090.6	+36.7%	138.9	322.0	183.1	+132%

Table 6.B.	Comparison of Riparian Habitat Conditions for Future-With-Project and Future-Without-Project Conditions - Alternative B.						
Habitat Type	Future-Without-Project Area (In Acres)	Future-With-Project Area (In Acres)	Percent Difference in Area	Future-Without-Project Habitat Units	Future-With-Project Habitat Units	Increase in Habitat Units	Percent Difference in Habitat Units
Mesquite	0	4	>+100%	0	2.4	2.4	>+100%
Wetlands	17.8	159.8	+797.8%	2.3	92.5	90.2	+3,922%
Cottonwood	779.8	806.8	+3.5%	136.6	150.1	13.5	+10%
Total	797.6	970.6	+21.7	138.9	245.0	106.1	+76%

V. References

Anderson, B., R. Ohmart. 1993. The Development of an Arizona Riparian Habitat Evaluation Model with Wildlife Values. Prepared for Arizona Game and Fish Department, Contract No. G30025-B.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ARIZONA ECOLOGICAL SERVICES STATE OFFICE
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September 19, 1994

In Reply Refer To:
AESO/SE
2-21-94-I-525

Mr. Robert S. Joe
U.S. Army Corps of Engineers
P.O. Box 2711
Los Angeles, California 90053-2325

Dear Mr. Joe:

This letter is in response to your August 12, 1994, request for information on listed or proposed threatened or endangered species and candidate species that may occur in the area of the 100-year floodplain of the Salt River from the eastern boundary of Tempe to the confluence of the Agua Fria River, for the proposed study area of the Salt River, Rio Salado, Arizona Reconnaissance Study.

Our data indicate the following listed and candidate species may occur in the proposed project area:

Endangered
Lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*)
American peregrine falcon (*Falco peregrinus anatum*)
Bald eagle (*Haliaeetus leucocephalus*)
Yuma clapper rail (*Rallus longirostris yumanensis*)

Proposed Endangered
Southwestern willow flycatcher (*Empidonax traillii extimus*)

Candidate Category 1
Cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*)

Candidate Category 2
California leaf-nosed bat (*Macrotus californicus*)
Spotted bat (*Euderma maculatum*)
Greater western mastiff-bat (*Eumops perotis californicus*)
Yavapai Arizona pocket mouse (*Perognathus amplus amplus*)
Loggerhead shrike (*Lanius ludovicianus*)

(Northern) Buff-breasted flycatcher (*Empidonax fulvifrons pygmaeus*)
Roundtail chub (*Gila robusta*)
Longfin dace (*Agosia chrysogaster*)
Desert sucker (*Catostomus [Pantosteus] clarki*)
Sonora sucker (*Catostomus insignis*)
Maricopa tiger beetle (*Cicindela oregona maricopa*)

Endangered and threatened species are protected by Federal law and must be considered prior to project development. Candidate species are those which the Fish and Wildlife Service (Service) is considering adding to the threatened or endangered species list. Category 1 candidates are those for which the Service has enough information to support a proposal to list. Category 2 species are those for which the Service presently has insufficient information to support a proposal to list. Although candidate species have no legal protection under the Endangered Species Act, they should be considered in the planning process in the event they become listed or proposed for listing prior to project completion.

If any proposed action may affect riparian areas, the following concerns should be noted. The Service is concerned about the protection of riparian habitats because they are rare and declining in the southwestern United States. Because many plant and animal species only occur or are more abundant in riparian areas, protecting and conserving riparian areas is critical to preserving genetic, species, population, and community diversity throughout Arizona. Maintaining hydrologic and other environmental conditions that support healthy riparian ecosystems is essential to the maintenance of healthy populations of plants, invertebrates, fish, amphibians, reptiles, birds, and mammals. Riparian areas also provide linear corridors critical to migratory species such as neotropical birds, waterfowl, and certain bats. The Service recommends that effects to riparian areas be avoided or mitigated.

The State of Arizona protects some species not protected by Federal law. We suggest you contact the Arizona Game and Fish Department and the Arizona Department of Agriculture for state-listed or sensitive species in the project area.

We appreciate your efforts to identify and avoid impacts to listed and sensitive species in your project area. In future communications on this project, please refer to consultation number 2-21-94-I-525. If we may be of further assistance, please contact Brenda Andrews or Tom Gatz.

Sincerely,

Sam F. Spiller
State Supervisor

cc: Director, Arizona Game and Fish Department, Phoenix, Arizona

APPENDIX B

PLANNING AID LETTER: U.S. FISH AND WILDLIFE SERVICE

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

March 7, 1995

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 on the Rio Salado Reconnaissance Study (Study) addresses the problems and opportunities for fish and wildlife resources in the study area. It is being provided pursuant to the Fish and Wildlife Coordination Act (FWCA)(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 (Service) report under Section 2(B) of the FWCA.

PURPOSE OF THE STUDY

The purpose of the Study being conducted by the Corps of Engineers (Corps), under authority of Senate Appropriations Bill H.R. 2445, is to fully describe and analyze problems and opportunities related to flooding, erosion, water quality, riparian habitat and recreation within the study area and to develop a wide range of alternatives that would reduce the severity, or totally eliminate these problems and take advantage of the opportunities.

The entire study reach provides opportunities for the restoration and enhancement of habitat for numerous fish and wildlife species including the endangered Yuma clapper rail and Southwestern willow flycatcher. Riparian and wetland areas could be restored and/or enhanced by the creation of open water areas, selective clearing of exotic saltcedar, and planting of cottonwood, willow and other important wildlife vegetation species.

One of the goals of the Study is to analyze opportunities for the preservation and enhancement of the existing ecosystem.

DESCRIPTION OF STUDY AREA

The reconnaissance study area is located along the Salt River in Maricopa County, Arizona. The area consists of approximately twenty-eight miles of the Salt Rivers 100-year floodplain and is bounded on the upstream end by the eastern municipal boundary of Tempe at McClintock Road and on the downstream end by the confluence of the Agua Fria River.

The present surface flow of the Salt River within the study area is attributed to releases from upstream impoundments, effluent from water treatment facilities, agricultural return flows, and local storms. This surface flow supports riparian habitat and water obligate species. The river from its eastern boundary to 23rd Avenue in Phoenix is essentially an ephemeral waterway that is dry most of the year with the exception of periodic flows. From 23rd Avenue west it has perennial flows maintained by effluent from the water treatment plants, agricultural return flows and local storm flows.

ALTERNATIVES

In response to Congressional direction, Rio Salado alternatives were formulated in consideration of flood control, water quality, recreation, and restoration of riparian habitat.

As a result of relatively low level of flood damage in the study area, no Federal interest was identified for flood control. However, flood control features have been included in the analysis of alternatives because they provide flood protection in support of other resource objectives and achieve incidental flood control benefits.

Alternative A: Environmental Restoration

Under this alternative, opportunities to protect, enhance, or create 300 acres of important wetland and riparian habitat which supports or could support the endangered Yuma clapper rail and Southwestern willow flycatcher along with other species of migratory and resident wildlife would be investigated. Also, opportunities to improve groundwater quality of the shallow aquifer and methods of improving surface water quality within the study area would be analyzed.

This alterative would include several environmental restoration features along the Salt River including:

- A constructed wetland and mesquite bosque at Tempe (Tempe Cienega).
- A constructed wetland, waterfowl/fisheries lakes, riparian vegetation, and water quality improvement at Phoenix Lago de Vida.

Alternative B: Recreation

This alternative would analyze the present recreation activities in the study area within Tempe and Phoenix. Based on future demand, a plan for providing water based recreation would be prepared.

The plan will include approximately 180 acres of open water at the Tempe Town Lake and Phoenix Lago de Vida. The lakes will be used primarily for boating, with water quality permitting partial body contact. No swimming would be allowed.

Fishing, sailing, paddle-boating, canoeing, hiking, bicycling, horseback riding, golf, soccer and softball are a few of the planned recreation activities.

EXISTING BIOLOGICAL RESOURCES

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 along with 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 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 Salt 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, 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.

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. Five Federally listed 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 western end of 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 Salt 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), cactus ferruginous pygmy-owl (Glaucidium brasilianum), black-necked stilt (Himantopus mexicanus), black-crowned night heron (Nycticorax), and white-faced ibis (Plegadis chihi).

Riparian and wetland ecosystems are important resources nationwide. They provide functions such as food, cover, 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. According to most estimates, over 90% of the native riparian areas along Arizona's major desert watercourses have been lost, altered or degraded as a result of man's activities. Riparian areas are now Arizona's most threatened natural communities. Nationally 64 wildlife species presently listed as endangered and an additional 47 species being considered for listing are dependent on riparian habitats. Arizona Game and Fish Department estimates that 75% or more of all Arizona's native wildlife species depend on healthy riparian systems during some portion of their life cycle. In addition, riparian areas are critical to the survival of approximately 60% of the fish and wildlife

species currently in jeopardy of extirpation from the state of Arizona. All of Arizona's 27 remaining native freshwater fish species depend entirely on streams, riparian areas and wetlands for their survival. Also, as many as 50% of bird species in Arizona are found primarily in riparian vegetation and may be dependent on those habitats. Portions of the river that contain perennial flows provide important aquatic habitat and support a diversity of wildlife, including Federally listed endangered species. 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.

PRELIMINARY ANALYSIS OF PROPOSED PROJECT

It is assumed farming practices would decrease from present level with no change in irrigation methods. It is also assumed that no additional flood control features would be implemented or constructed. However, we expect that vegetative clearing would continue below 91st Avenue by the Flood Control District of Maricopa County. We also expect that periodic releases from upstream reservoirs would continue to inundate vegetation causing losses of valuable species such as honey mesquite, cottonwood, and willow. However, these releases would 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 would return to pre-flood levels. A loss of marsh habitat due to the scouring effects of the 1993 floods would affect species dependant on and associated with those habitats. However, it is expected that new wetlands would develop over time in those areas where high soil moisture is maintained. Local storm flows would continue to provide water to the riparian and wetland habitats.

The City of Phoenix is presently investigating alternate methods of disposing effluent wastewater from the treatment plants at 23rd and 91st Avenues. One of the options is to suspend releases into the Salt River. This would adversely impact the wetland and riparian habitats maintained by effluent flows. The cottonwood and willow would be more severely affected than saltcedar by the reduction in effluent flows.

The construction of Tempe Town Lake and Phoenix Lago de Vida would provide open water habitat that would benefit fish and wildlife resources in the study area. This would promote the conservation of the Yuma clapper rail by the creation of conditions suitable for growth of marsh vegetation. Also, waterfowl, shorebirds, and wading birds would benefit. The construction of approximately 180 acres of open water at the two lakes would provide opportunities for the creation of a substantial urban fishery. Most urban lakes are managed on a put-and-take basis. Rainbow trout are stocked during the cooler months (November through March) and channel catfish are stocked during the warmer months (April through October). The lakes must exceed 9 feet in depth and have acceptable water quality to provide these benefits.

Creating open water areas in abandoned gravel pits outside the flood channel could also provide habitat for native fish. Prior to modification of flows in the Salt River, a variety of native fish were likely common in what is now the metropolitan area. Desert and Sonora suckers, roundtail chub, and longfin dace were likely common. Also, the Federally listed razorback sucker, Colorado squawfish, spikedace, woundfin, loach minnow and Gila topminnow were probably found in the lower Salt River. The potential exists for the reintroduction of native fish into the project area in refugia, holding ponds, or other experimental sites.

The construction of wetlands at the Tempe Cienega would provide habitat for the endangered Yuma clapper rail, waterfowl, shorebirds, and wading birds. It would also increase riparian habitat adjacent to the wetlands. This would provide nesting and forging habitat for white-winged and mourning doves, migrating neotropical birds, and resident birds.
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. By providing a reliable water supply, this habitat type could be established, benefitting migratory neotropical birds along with many other species of resident birds, mammals, reptiles and amphibians. Data from riparian habitats and 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.

The construction of 180 acres of urban lakes and the restoration of riparian habitat would result in significant recreational benefits by providing an increase in angling, hunting, nature photography, birdwatching,and other water based activities.

The ability of these study alternatives to provide fish and wildlife benefits depends on having water of acceptable quality for the creation of wetlands and riparian habitat.

PRELIMINARY RECOMMENDATIONS

1. All of the alternatives resulting in the preservation, enhancement or creation of wetland and riparian habitat should be implemented.

The Service 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
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.

APPENDIX C
FISHERIES ANALYSIS

IMPORTANCE OF DESERT RIPARIAN HABITATS

"Riparian habitats in the arid Southwest provide forage, water, and cover for a substantial number of game and non game species, as well as providing essential components for aquatic life. Importance of riparian habitats is further evidenced by considering that a majority of special category wildlife species are obligate riparian inhabitants" (AGFC 1991). As the Arizona Game and Fish formalized its recognition of the importance of riparian areas as keystones in Arizona's ecosystems, it provided specific direction to the areas and open waters. "It is the policy of the Arizona Game and Fish Commission that the Department shall recognize riparian habitats as areas of critical environmental importance to wildlife and fisheries. The Department shall actively encourage management practices that will result in maintenance of current riparian habitat, and restoration of past or deteriorated riparian habitat in accordance with the Department Wildlife Habitat Compensation procedures. Further, the Department shall actively encourage the maintenance, restoration, and protection of instream flows, which are often essential to maintaining riparian habitat" (AGFC 1991).

Although riparian areas cover a very small percentage of the land in the arid southwest (less then 2%), they are among the most biologically productive of all lands (Rinne 1993). Wetland and riparian areas are very productive ecosystems that provide important habitat for many wildlife species in Arizona (Brown et al. 1979; Ohmart and Anderson 1982; Anderson and Ohmart 1984; Valencia et al. 1993) and that provide crucial life support functions for a diversity of species (Jones 1986). Ohmart and Anderson reported that 60 percent of vertebrate species in the arid Southwest are obligate users of riparian areas, and that another 10 to 20 percent were facultative riparian users. Rinne (1993) reported that current riparian areas have become reduced by more than 80% compared to historic conditions.

Since pre-historic times, the Salt River has provided the necessities for habitation by people and wildlife. Those necessities clearly focused on water. During the last century, we have found the means to capture the what is necessary for human habitation and have inexorably modified the Salt River to meet our needs. The Salt River channel, as it passes through the cities of Mesa, Tempe, Phoenix, and Buckeye is a remnant of the river that originally nurtured the area. It's

waters have been captured for productive human use and its banks have been fortified against the inevitable floods that can still threaten its banks. In capturing the River, we have lost some of the values that perhaps first drew people to it. The once lush vegetation nurtured by the river and its periodic floods has largely been eliminated, and with it the wildlife that depended upon the water and vegetation for sustenance and refuge.

The proposed Rio Salado/Lago de Vida projects present the opportunity to restore some of the values that originally made the banks of the Salt River a habitable place. By essentially recreating a river within the River a critical portion of the riparian habitat once present could be restored. This is by no means a simple undertaking in that many of the benefits accrued to the public with the construction of major dams on the salt river and the institution of flood management are to be maintained. The challenge of securing a water source is considerable. Further, the risks to artificially created streambeds and wetland/riparian zones from future flooding are real if the facilities and restored habitats are not designed to take advantage of the hydrologic actions of flood flows rather than to stand in the face of them.

URBAN FISHING AND FISH HABITAT OPPORTUNITIES AND RIO SALADO RECONNAISSANCE

Background- Urban Fishing

Arizona's urban fishing program was first evaluated in the late 1970s (Edwards and Okamoto, 1980), and became a regular program of the Arizona Game and Fish Department in 1983. The program is a cooperative venture between the Department and municipalities, with urban fishing license sales and city grants ($560/acre of water) financing the management of the lakes. The lakes are stocked 26 times per year (Watt, 1986) with rainbow trout (November through March) and channel catfish (April through October). The lakes are managed on a put-and-take basis, with the expectation that virtually all of the stocked fish will be harvested (76% harvest rainbow trout; 87% harvest channel catfish 0 Watt and Parsons, 1990). The goal of the program has been to provide a local recreational fishery to urban residents and a site where urban youth can be introduced to sport fishing (Watt and Persons, 1990). These are currently 12 lakes in the Tucson and Phoenix metropolitan areas in the program (a 13th will be added in February 1995), ranging

in size from 3 acres to 25 acres in size (Watt and Persons, 1990; AGFD Fisheries Branch, pers. com. 1994).

Licensing to fish and urban lake is specific to the program. Urban anglers purchase a special license, and a general fishing license is not required. Youth under 14 and Pioneer license holders do not require an urban fishing license. Income form the city grants is managed in a Urban Trust Fund, and those monies may only be expanded for the Urban Fishing Program.

License sales have climbed steadily since 1983, and appear to be related to the number of acres of urban fishing opportunity available (Watt, 1985; Watt and Persons, 1990). Urban lakes have demonstrated the highest angler use measured in Arizona, ranging from 3 angler hours per acre per day to 96 angler hours per acre per day (Watt, 1986). Watt and Persons (1990) reported an average of 2 anglers observed per acre at urban lakes based upon instantaneous angler counts. Based upon all surveys (including incomplete trips) they estimated a total of more than 700,000 angler hours per year (or about 7,000 angler hours of recreation per acre per year) on the urban lakes. Using average duration of completed trips (4.6 hours), they estimated total use at just over 1 million angler hours.

Criteria for urban lakes are rather simple. Lakes are expected to exceed 3 surface acres; have a maximum depth that equals or exceeds 10 feet; have acceptable water quality; and have public use facilities including restrooms, access, and parking. The use of effluent in urban lakes have been problematic in the past. The relatively higher nutrient loads and fertility of effluent of the results in algal blooms or macrophyte growth that may increase pH to unacceptable levels. When pH climbs above 9 to 9.5, fish mortality may be imminent. Lake temperatures may also constrain the timing or duration of rainbow trout stockings. If wastewater is to be used in an urban fishing environment, nutrient levels must be controlled. Polishing wetlands that remove nutrient loads may be very useful in raising water quality to acceptable levels.

Note: The criteria for entry into an urban management program is pretty simple. The lakes are (or can be) managed as put-and-take fisheries. Thus little is expected of those waters in terms

of supporting fishes over an extended period. Many urban lakes are also managed for a resident population of warmwater fishes; a more sensitive set of requirements apply here.

MINIMUM WATER QUALITY STANDARDS ARE:

pH cannot exceed 9.0 and temperature cannot exceed 70 F for stocking of rainbow trout.

pH cannot exceed 9.5 for stocking of channel catfish.

These are the primary management species for urban fishing. As productivity of waters increases (N&P), then the potential for algal blooms or macrophyte production that may increase pH above tolerable levels for fishes could limit the utility of a body of water as an urban fishery. N/P ratios are particularly important in determining the productive capacity of these waters. Eutrophic systems will be more susceptible to summerkills due to high pH and low DO. Some attention should also be paid to Nitrite levels. There are issues with some fishes with regard to Nitrite toxicity (channel catfish).

The R3 reports metals issues. Metal toxicity is to some extent mediated by water hardness. Attention should be paid to anticipated hardness, to evaluate potential toxicity of metals and possible implications.

Accumulation of metals and organics in sediments may need to be addressed. Periodic flushing by flood flows may address this question adequately.

Background - Native Fishes

The majority of the fishes currently managed in Arizona for sport purposes are nonnative (the exception being native Apache trout and roundtail chub). Prior to modification of Arizona's rivers and native fish community, a variety of native fishes were likely common to the Salt river valley in what is now the metropolitan area (Minckley, 1973). Desert and Sonora suckers (Catostomus Clarki and Catostomus insignis) were likely common, and currently are still rather common in the Salt and Verde rivers above Granite Reef Diversion Dam. Roundtail Chub (Gila robusta) and long fin dace (Agosia chrysogaster were also likely be common, Roundtail chub is species (Category 2). Razorback sucker (Xyrauchen texanus), Colorado squawfish (Ptychocheilus

lucius), spike dace (Meda fulgida), woundfin (Plagopterus argentissimus), loach minnow (Rhinichthys cobitis) and Gila topminnow (Pociliposis occidentalis), all listed as Federal Threatened or Endangered Species, also like made up part of the historic fish fauna of the lower Salt river. This fish fauna has been radically modified due to modification of stream hydrology (habitat modification) and introduction of nonnative fishes (predation and competition).

Much of the historic (pre-1880) fauna has been eliminated from the Rio Salado Recon area. While the likelihood of fully restoring these fishes in this ares (through reintroduction) are limited, there may be some opportunities. The constraints include the significant nonnative fish fauna that would be contributed intentionally (stocking for recreation) or unintentionally (potential fish movement from upstream locations or illegal stockings) and availability of water. It would be possible to look to reintroductions of listed or not-yet-listed native fishes in the project area as refugia, holding ponds, or experiment sites. Not likely constraint that the Corps and the municipalities would need to take under advisement is that reintroductions of listed species would be fully protected by the Endangered Species act, unless they were identified as non-essential, experimental pollution under a rule making process by the Fish and Wildlife Service.

Opportunities-Urban Fishing

Opportunities associated with the Rio Salado include construction of open water sites that exceed 9 feet in depth and 3 surface acres in extent as potential fisheries. These sites could be managed as Urban Fishing Lakes, with special intensive management and stocking, or as self supporting city lakes. Experience has suggested that attempting to manage these kinds of waters without intensive attention rarely meets public angling expectations. With an approximate 300 acres of available Urban Waters made available (Rio Salado and Lago de Vida), considerable economic benefit can be expected to local economies and considerable angling recreation opportunity can be generated. Watt and Persons (1990) reported 226,552 visits to urban lakes in 1987-88 (approximately 2,490 angler visits/acre - computed at 91 acres in the program at the time).

There are significant recreational benefits that can be accrued to the local community. 300 acres of urban lakes could generate up to 747,000 angler visits. Urban angling recreation serves the

local community. Watt (1986) reported that urban lakes draw recreationists from the nearby neighborhood in high density urban areas. On average, urban anglers traveled from 7 to 11 miles one-way to their urban lake. About 71% of all of the urban anglers contacted by Watt (1986) reported that they traveled 10 miles (one-way) or less to their urban lake. A small percentage of urban anglers traveled more than 20 miles (one-way) for the opportunity to fish an urban lake.

Daily expenditures by anglers were estimated by the US Fish and Wildlife Service (1993) at approximately $67 per day in 1990 dollars. (Caution should be used in grossly applying this estimate. It was derived from census interviews of anglers in general, who often travel distance to fish and includes food, lodging, bait, fuel, and equipment expenditures that may not be applicable to urban angling.) That could generate a raw expenditure in the local economy of $50 million. The Arizona Game and Fish Department estimated the daily expenditures of Urban and Fish Department estimated the daily expenditures of Urban Anglers at approximately $28 million could be contributed to the local economy. Even with a more conservative estimate of $10 expenditure per angler day, raw expenditures could reach $7.5 million. The value of those expenditures in the local economy are significantly greater than the raw expenditures themselves.

Other, non-urban, angling opportunities could be generated by restoration activities in the western half of the Rio Salado Recon Study area. The area currently gets angling pressure directed at naturally reproducing warmwater fish populations that occur in reliable pools in the Salt River channel. There are issues to contend with, however, in that accumulated organics (largely pesticides) in the river sediments have required a human health advisory for consumption of those fish. A human health risk assessment has been completed from 59th avenue downstream and anglers are advised not to consume fish from the sea. A similar assessment will be necessary for areas above 59th avenue.

Opportunities - Hunting Recreation

Riparian restoration in the western, more rural portions of the Rio Salado Recon Study area would create additional nesting habitat for white-winged and mourning dove. There is considerable hunting pressure for these species along the Salt and Gila rivers in western Maricopa

County. Daily hunter expenditures are estimated at approximately $101 per hunter day (US Fish and Wildlife Service 1990).

Opportunities - Nonconsumptive Wildlife Associated Recreation

Nonconsumptive wildlife recreation (nature photography, birdwatching, etc.) is an important component of any view of riparian restoration benefits in Arizona. Riparian restoration along Arizona's rivers provides a significant boon to migratory birds (neotropical migrants), and in-turn provides Opportunities for nonconsumptive recreation. There is significant tourism and visitation to Arizona for bird watching, in particular. The US Fish and Wildlife Service (1993) reports an estimated 435,000 Arizonans participate in nonconsumptive wildlife recreation away from their primary residences. total participation (Arizona residents and nonresidents) in nonconsumptive wildlife recreation away from a primary residence was estimated at 820,000, making expenditures of $187 million for trips and expenditures. While it may be difficult to quantify the exact increase in participation in such activities should riparian restoration activities by undertaken in the Rio Salado Study area, those values should not be ignored.

Opportunities - Native Fishes

Native fishes of the Southwest are a rare resource. Creating openwater habitats for native fishes could provide a number of opportunities. Rearing and refuge areas could be developed as part of a Rio Salado project. Open water areas and reservoirs (abandoned gravel pits outside of the flood channel) could be utilized for restoration, experimentation, or environmental interpretation for native fishes.

There are many constraints to using the area as a restoration or refugium site, not the least of which is the federal status of many of the native fishes. If listed fishes were stocked as part of a Rio Salado project, they would be afforded the full protection of the Endangered Species Act. the only exception to this would be the opportunity to list reintroductions in the vicinity as "Experimental, Non-essential" under Section 10 of the Act. This requires a rule-making action on the part of the US Fish and Wildlife Service, and one that seems unlikely at this juncture.

We would be unable to assure the security of reintroduced stocks of native fishes. Native and nonnative fish interactions are in an important constraint on the recovery of native fishes. The sites that would provide some opportunity for reintroduction in the Rio Salado Study area are highly modified and subject to continued human modification. Clearly, we will not be able to restore the historic hydrology (annual floods and perennial flow) of the lower Salt River through a Rio Salado project. Nor are we likely to be able to remove the influence of nonnative fishes from the river corridor. There could, however, be opportunities to work with fishes that are not yet listed or to work in sites that are isolated from frequent influences by floods (gravel pits that may be serving as reservoirs for Rio Salado/Lago de Vida lakes).

REFERENCES

Anderson, B.W., and R.D. Ohmart. 1984. Vegetation management study for the enhancement of wildlife along the lower Colorado River. Final Report to US Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

Arizona Game and Fish Commission (AGFC). 1991. Riparian Habitat- Commission Policy AZ.13. Arizona Game and Fish Department Operating Manual.

Brown, D.E., C.H. Lowe, 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. Journal of the Arizona-Nevada Academy of Science. 15:1-16.

Edwards, G., and G. Okamoto. 1980. Fishing in the City. Research Branch, Arizona Game and Fish Department, Phoenix, Arizona. 119 pp.

Jones, K.B. 1986. Deserts. Pages 123-145 in A.Y Cooperrider, R.J. Boyd, and H.R. Stuart [eds.]. Inventory and monitoring of wildlife habitat. USDI Bureau of Land Management Service Center, Denver, Colorado.

Minckley, W.L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix, Arizona 293 pp.

Ohmart, R.D., and B.W. Anderson. 1982. North American desert riparian ecosystems. Pages 433-479 in G.L. Bender [ed.]. Reference handbook on the deserts of North America. Greenwood press, Westport, Connecticut.

Rinne, J.N. 1993. A wildlife viewpoint southwestern riparian-stream areas: habitats for fishes. Pages 46-51 in B. Tellman, H.J. Cortner, M.G. Wallace, L.F. DeBano, R.H. Hamre [technical coordinators] Riparian management: common threads and shared interests. A

western regional conference on river management strategies. Technical Report No. RM-226, US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 419 pp.

US Fish and Wildlife Service. 1993. U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. 1991 National survey of fishing, hunting, and wildlife-associated recreation - Arizona. U.S. Government Printing Office, Washington, D.C. 41 pp.

Valencia, R.A., F.A. Wennerlund, R.A. Winstead, S. Woods, L. Riley, E. Swanson, and S. Olson. 1993. Arizona riparian inventory and Mapping project. Arizona Game and Fish Department, Phoenix, Arizona. 134 pp.

Watt, B. 1986. Survey of 1985 urban anglers. Fisheries Branch, Arizona Game and Fish Department, Phoenix, Arizona. 28 pp.

Watt, B., and W.R. Persons. 1990. Arizona urban fishing program roving creel survey November 1987 to October 1988. Fisheries Branch, Arizona Game and Fish Department, Phoenix, Arizona. 64 pp.

THE STATE OF ARIZONA

GAME & FISH DEPARTMENT

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MEMO

TO: Paul LeBrun
US Army Corps of Engineers

FROM: Larry Riley, Environmental Compliance
Habitat Branch

SUBJECT: Costs related to Stocking Urban Fishing Waters

DATE: February 15, 1995

You inquired about stocking costs. There are two ways to address this question, 1) stocking to meet an intensive use fishery [like a designated Urban Lake, or 2) stocking to provide a self-sustaining population.

The answer to the second question is pretty straight forward. Costs can be minimal. Initial stockings of fingerling (~3 in.) warmwater fish species can be made to initiate a fish community in a newly created lake. These stockings can be accomplished at a minimal cost. The fisheries manager takes advantage of the new habitat to allow for growth and [if habitat is acceptable] natural reproduction. Our experience suggests that many small impoundments that are heavily utilized [like lakes in urban parks] may not be able to support an acceptable number of quality sized fish to meet the public's desires. This is usually associated with heavy fishing pressure and intensive removal of fishes.

In answer to this issue, the Department has developed intensive use stocking programs for selected waters. The Urban Fishing program is the ultimate extension of strategy. Meeting the intensive use expectations of anglers requires stocking "catchable" sized fish. In our Urban Fishing program, adult anglers (over the age of 13) that desire to fish at a designated Urban Lake purchase a special license. Revenues from those license sales are used to finance the program, along with a contribution from the participating municipality (based on a per water surface acre assessment). The commercially purchased "catchable" fish are priced and stocked by the pound:

SPECIES	No./pound	Cost/pound	Stocking Rate
Rainbow Trout	3	$1.89	34 lbs/acre
Channel Catfish	2	$.73 - $1.23	100 lbs/acre

Rainbow trout are stocked November - March (requiring the cooler water temperatures of winter months in the desert), and channel catfish are stocked April - October. Stockings are made bi-weekly. Routine stockings are necessary because of the intensive removal of the stocked fish by anglers. Stockings may be supplemented at times with "incentive fish" - a few individuals that exceed the normal size of stocked fish - as a marketing incentive.

LR:lr

FISHERIES COSTS

The following per-year fisheries costs are based upon information provided in the February 15, 1995 memo from the Arizona Game and Fish Department, and an assumed stocking frequency of once every two weeks:

Town Lake

Rainbow Trout: (2x/Month x 5 Months) x $1.89 x 34 lbs/acre = $128,520
Catfish: (2x/Month x 7 Months) x $1.00 x 100 lbs/acre = $280,000

Lago de Vida

Rainbow Trout: (2x/Month x 5 Months) x $1.89 x 34 lbs/acre = $77,112
Catfish: (2x/Month x 7 Months) x $1.00 x 100 lbs/acre = $168,000

APPENDIX D

WATER QUALITY ANALYSIS

WATER QUALITY

EXISTING CONDITIONS AND OPPORTUNITIES

RIO SALADO RECONNAISSANCE STUDY

USACOE
LOS ANGELES DISTRICT

SEPTEMBER 1994

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WATER QUALITY- EXISTING CONDITIONS AND OPPORTUNITIES
RIO SALADO RECONNAISSANCE STUDY

I. INTRODUCTION

The purpose of this report is to describe, based on existing data, surface and groundwater quality in the Rio Salado project study area and to identify opportunities for water quality improvement. The Rio Salado study area is defined to be the area in the vicinity of the Salt River from the confluence with the Agua Fria River, upstream through the City of Phoenix to the eastern boundary of the City of Tempe. The study area is shown on Figure 1.1 of the main report.

The report begins with a discussion of some of the state and federal water quality standards, follows with discussion of the quality and quantity of surface and groundwater in the study area and ends with a discussion of water quality opportunities.

In summary, this investigation found that there are significant surface and groundwater quality problems in the study area. The quality of urban storm runoff from the Phoenix metropolitan area is highly variable and frequently exceeds water quality standards for bacteria, pesticides, petroleum products, metals, and nutrients. The quality of this urban runoff is summarized in Tables 9 and 10. Much of the shallow groundwater in the vicinity of the western part of the project has elevated levels of TDS, chloride, and nitrate and areas of high and low levels of volatile halocarbons are present in many areas. These areas were located and are shown on

Figures 5.13 - 5.15 of the main report. The water quality problems in the study area also present opportunities for remmediation through constructed wetlands and for preservation, enhancement, and creation of riparian habitat.

II. WATER QUALITY CRITERIA

The Environmental Protection Agency (EPA) and the State of Arizona have established water quality criteria which vary for parameters depending on the designated use of the water. Uses fall into one of the following categories:

Designated Uses	
A&Wc	Aquatic and Wildlife (cold water fishery)
A&We	Aquatic and Wildlife (ephemeral)
A&Wedw	Aquatic and Wildlife (effluent dominated) water)
A&Ww	Aquatic and Wildlife (warm water fishery)
AgL	Agricultural Livestock Watering
AgI	Agricultural Irrigation
DWS	Domestic Water Source
FBC	Full Body Contact
PBC	Partial Body Contact
FC	Fish Consumption
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant

Arizona has established designated uses for navigable waters within the Rio Salado study area including the Salt River and Indian Bend Wash. Designated uses for these streams include

partial body contact, fish consumption, aquatic and wildlife categories, and agricultural categories. These uses by stream reach are shown below in Table 1. Criteria for selected parameters are summarized in Table 2. For some parameters the water quality criteria are determined from characteristics of the water source. For example, the ammonia criteria is a function of designated use, water temperature, and pH. For several metals, the criteria for aquatic and wildlife uses is based on designated use and water hardness (measured as $CaCO_3$) and must be computed with an equation with water hardness as an input variable. The equations needed to calculate the criteria for these metals and criteria for other parameters not shown in Table 2 are contained in Arizona Administrative Code (ADEQ), Title 18, Ch. 11, Appendix A.

Table 1
Designated Uses of Waterways within the Rio Salado Study Area

Reach	Designated Uses
Salt River (2 km below Granite Reef Dam to the I-10 bridge)	Aquatic and Wildlife (ephemeral) Partial Body Contact
Salt River (I-10 bridge to the 23rd Avenue WWTP)	Aquatic and Wildlife (warm water fishery) Partial Body Contact
Salt River (23rd Avenue WWTP to the Gila River Confluence)	Aquatic and Wildlife (effluent dominated water) Partial Body Contact Fish Consumption Agricultural Irrigation Agricultural Livestock Watering
Indian Bend Wash	Aquatic and Wildlife (warm water fishery) Partial Body Contact Fish Consumption
Indian Bend Wash Lakes	Aquatic and Wildlife (warm water fishery) Partial Body Contact Fish Consumption

Source: Arizona Administrative Code, ADEQ, Title 18, Ch.11, Appendix A.

Table 2

Numeric Water Quality Criteria (ADEQ) - Selected Parameters

Parameter	DWS	FC	PBC	A&Ww (acute)	A&Ww (chronic)	A&Wed w (acute)	A&Wedw (chronic)	A&Wwe (acute)	A&Wwe (chronic)	AgI	AgL
TSS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TDS[1]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chloride[2]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fluoride (ppb)	4000	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrate (ppb)	10,000	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F. Coliform (cfu/100ml)			4000/1000	4000	1000	800	200				
Arsenic (ppb)	50 T	3.1 T	2800 T	360 D	190 D	360 D	190 D	440 D	230 D	2000 T	200 T
Cadmium (ppb)	5 T	83 T	70 T	(3)	(3)	(3)	(3)	(3)	(3)	50 T	50 T
Copper (ppb)	1000 D	NS	5200 D	(3)	(3)	(3)	(3)	(3)	(3)	5000 T	500 T
Lead (ppb)	50 T	NS	NS	(3)	(3)	(3)	(3)	(3)	(3)	(3)	100 T
Mercury (ppb)	2.1 T	0.6 T	42 T	2.4 d	0.01 D	2.6 D	0.2 D	5 D	2.7 D	NS	10 T
Silver (ppb)	NS	NS	NS	(3)	NS	(3)	NS	(3)	NS	NS	NS
Zinc (ppb)	5000 T	NS	28,000	(3)	(3)	(3)	(3)	(3)	(3)	10,000 T	25,000 T

Table 2 (cont.)

Numeric Water Quality Criteria (ADEQ) - Selected Parameters

Parameter	DWS	FC	PBC	A&Ww (acute)	A&Ww (chronic)	A&Wedw (acute)	A&Wedw (chronic)	A&Wwe (acute)	A&Wwe (chronic)	AgI	AgL
TCE (ppb)	5	78	NS	20000	1300	20000	1300	20000	1300	NS	NS
PCE (ppb)	5	11	4000	6500	680	6500	680	15000	1600	NS	NS
TCA (ppb)	200	160000	13000	2600	1600	2600	1600	2600	1600	NS	NS
Benzene	5	120	470	2700	180	11000	700	NS	NS	NS	NS
DBCP	0.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chloroform	100	590	1400	14,000	900	14,000	900	NS	NS	NS	NS

(1) Water with concentrations above 250 mg/l has a salty taste.

(2) Water with TDS content of less than 500 mg/l is most desirable for domestic use.

(3) Criteria based on hardness, see Arizona Administrative Code (ADEQ), Title 18, Ch.11, Appendix A for equations.

T = Total Recoverable
D = Dissolved
NS = No Standard

III. SURFACE WATER

This section describes the quantity and quality of surface water in the Rio Salado Study area. Sources of surface water include runoff from the Salt River and Indian Bend Wash watersheds, urban storm runoff from the Cities of Tempe and Phoenix, and sewage effluent from municipal waste water treatment plants.

3.1 Salt River

The Salt River is the largest tributary of the Gila River and drains an area of approximately 13,700 mi^2 within the northern and eastern portions of the State of Arizona. The topography of the drainage area is extremely irregular and rugged, with elevations commonly exceeding 7000 feet, and, at San Francisco Mountain in the Verde River basin, exceeding 12,000 feet. The Verde River is the main tributary of the Salt River and includes 6,620 mi^2 of the Salt River drainage.

Several dams are operated on the Salt and Verde Rivers by the Salt River Project (SRP) to provide water supply, hydroelectric energy, and flood control (upon completion of Roosevelt Dam modifications) to the populace of the Salt River Valley, in Maricopa County. These dams are shown on Figure 2.1 of the main report and their approximate storage capacities at normal water surfaces are listed in Table 3.

Table 3

Salt River Project Dams - Salt and Verde Rivers

SRP Dam	Location	Capacity at Normal Water Surface (ac-ft)
Roosevelt	Salt River	2,100,000*
Horse Mesa	Salt River	245,000
Mormon Flat	Salt River	58,000
Stewart Mountain	Salt River	70,000
Horseshoe	Verde River	131,000
Bartlett	Verde River	178,000

* Includes 565,000 ac-ft of flood control storage and 270,000 ac-ft of new conservation storage which will be available once the modifications to Roosevelt, currently in progress, are completed.

The climate of the Salt River Basin is generally semiarid, depending upon its elevation. At lower elevations it is hot and arid, while at higher elevations it may be cool and humid. Average annual precipitation in the basin ranges from less than 8 inches in the Phoenix vicinity to more than 30 inches in the highest mountains, and it is about equally divided between the summer and winter seasons.

3.1.1 Peak Discharge Frequency Analysis. Discharge frequency values for the Salt River in the vicinity of the Rio Salado study area were adopted from the Cliff Dam Alternatives

study completed in 1988. The adopted discharges include a modified Roosevelt Dam. The dam is currently being raised, and upon completion, will have a 565,000 ac-ft flood control pool and will gain 270,000 ac-ft of conservation storage. A complete technical analysis of the impacts of this enlarged structure on the Salt River has not yet been completed. Currently, a water control plan for regulation of the flood control pool is being developed in the Section 7 for Modified Roosevelt Dam by the Los Angeles District , in cooperation with the U.S. Bureau of Reclamation. The discharge frequency values are presented in Table 4.

Table 4

Salt River Peak Discharge Frequency Values

	FREQUENCY, in years						
Location	5	10	20	50	100	200	500
Confluence with Verde	45,000	85,000	115,000	145,000	175,000	210,000	275,000
Mill Ave Bridge	44,000	84,000	110,000	135,000	160,000	190,000	250,000
Above Confluence with Gila River	40,000	75,000	110,000	125,000	150,000	185,000	240,000

3.1.2 Volume of Salt River Flows. Granite Reef Dam is the last SRP dam on the Salt River and is located about 10 miles downstream from Stewart Mountain Dam and about 14 miles upstream of Tempe. Most of the water reaching Granite Reef Dam is diverted into the SRP canal system for agricultural, municipal, and industrial water use. Spills over Granite Reef are either caused by flooding or releases from upstream reservoirs. In March of 1994, SRP completed a period of record analysis for the Roosevelt Dam Water Control Study. Under 1995 storage conditions (including new conservation storage at Roosevelt) and demand, the monthly operation of the SRP reservoir system was simulated and the monthly total spill release at Granite Reef was estimated. The average annual spill was 247,000 ac-ft, but during 71 of the 105 years (68%) modelled, there were no spills over Granite Reef Dam. The simulation also showed 16 periods (1 year or greater) of no spills ranging from 1-12 years. The average duration of no spill period was about 4.4 years. The results of the simulation are shown in Figure 2.2 of the main report.

3.1.3 Quality of Salt River Flows. Flow originating from the Salt River watershed upstream of the Phoenix metropolitan area is generally of good quality. Salt River flows maintain a sodium chloride character both above and below Roosevelt Dam. This is due to salt springs upstream of Roosevelt Lake which contribute water high in mineral content. Verde River water has a lower TDS content than Salt River water and tends to lower the overall TDS content in flows downstream of their confluence. SRP reported TDS concentrations in the Salt and Verde Rivers above Granite Reef Dam as averaging 550 mg/l and 280 mg/l respectively in 1989 (Graf 1994) and ranged from 990 to 1,460 mg/l in the Salt River above Roosevelt Lake in 1993 (SRP,1993). Flows in the Salt River commonly violate quality standards for fecal coliform

bacteria, as would be expected. Table 5 presents selected results from recent water quality sampling on the Salt River in the Phoenix area. These samples were taken prior to and during the high flows of January and February 1993. High levels of fecal coliform and fecal streptococci were detected in the first sample taken in August 1992.

Table 5
Salt River Water Quality Data

Parameter	Date and Location of Sample						
	24th St. Bridge		Priest Ave. Bridge				
	24Aug 92	9 Sep 92	31 Dec 92	4 Jan 93	12 Jan 93	11 Feb 93	Average
Discharge (cfs)	16,500	1140	10	8600	47,800	25,500	
Temperature Celsius)		25.5	13	13	12	11	
D. Oxygen (mg/l)	5.6	5.9		10.2	8.1	8.7	7.7
COD (mg./l)	33	12	25	17	39	13	23
BOD_5 (mg/l)	10	30		7	<5.0	<5.0	11
Fecal Coliform (cfu/100ml)	3000	450			290	100	768
Fecal Streptococci (cfu/100ml)	3400	48		540	1300	230	1103
Alkalinity (mg/l)	147	114		123	105		122
Sulfate (mg/l)		41	72	38	26	20	39
Chloride (mg/l)		140	150	92	83	21	97
Nitrate Nitrogen (mg/l)	0.13				<0.5	<0.5	
Phosphorous (mg/l)	0.08	0.03		0.09	0.43	0.2	.17
Cadmium (ug/l)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chromium (ug/l)	25	1	8	8	15	6	11
Copper (ug/l)	300	2	3	6	25	13	58
Lead (ug/l)	27	<1	<1	3	22	7	10
Mercury (ug/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel (ug/l)	49	2	2	4	21	10	15
Zinc (ug/l)	120	<10	<10	<10	50	<10	

Source: Maricopa County Flood Control District
All Samples Collected by the USGS

3.2 Urban Storm Runoff

3.2.1 Climate. The Phoenix metropolitan area has a hot arid climate with an average annual rainfall of about 7.6 inches. Most of the precipitation occurs in two distinct seasons, summer (July through September) and winter (December through March), and is about equally divided between them. The monthly distribution of rainfall is described as follows:

MONTH	AVERAGE PRECIPITATION(INCHES)
January	0.79
February	0.63
March	0.85
April	0.23
May	0.19
June	0.17
July	0.77
August	1.07
September	0.74
October	0.69
November	0.56
December	0.91

Monthly, seasonal, and annual precipitation amounts vary considerably from year to year. During any season there may be long periods of no rainfall and therefore long periods of no local runoff.

3.2.2 Watersheds and Outfall Locations. The major sources of urban storm water in the Rio Salado study area are from the many storm drains which have outfalls to the Salt River. In Phoenix, there are more than 50 storm drains with outfalls to the Salt River. These drains collect runoff from over 100 mi^2. In Tempe, five major urban watersheds with outfalls to the river were identified (Ref. 6 - Technical Memorandum #5). The major urban watersheds with a combine drainage area of about 267 mi^2: Indian Bend Wash, Price Road Drain, Farmer Avenue drain, Scottsdale Road drain, Dobson Road drain, and Pima Freeway drain which drains an area within the Salt River Pima-Maricopa Indian Community. All of the outfalls in the study area are shown on Figures 5.11 and 5.12 of the main report.

The single largest watershed is Indian Bend Wash with a drainage area of about 120 mi^2 below the Granite Reef Aqueduct. The wash was improved for flood control as part of a Corps project and is now a greenbelt with a system of parks, golf courses, and lakes. The discharge frequency values for the wash are presented in Table 6.

Table 6

Discharge Frequency Values
Indian Bend Wash at the Salt River

Frequency, years	Peak Discharge
10	8000
25	14,000
50	21,000
100	30,000

3.2.3 Runoff Estimates. Very little information is available regarding the quantity of urban storm runoff in the Phoenix area and therefore the rainfall/runoff relationship is also not well defined. In order to estimate the quantity of urban runoff, basin characteristic such as drainage area and land use were obtained from the Cities of Phoenix and Tempe. The following simple relationship was used to generate rough estimates of annual runoff and runoff resulting from the 10-yr 24-hr storm:

Volume = XCiA

where:

X = Conversion Factor

C = Effective runoff coefficient

i = Total Precipitation (inches)

A = Drainage Area (mi^2)

Effective runoff coefficients were obtained from both cities and are based on land use and local Storm Water retention practices. A 10-yr 24-hr rainfall of 2.4 inches was determined from NOAA Atlas II and an annual rainfall amount of 6.77 inches was adopted from the results of an analysis by CH2M Hill. While the average annual rainfall in the Phoenix area is about 7.6 inches, it was determined that only about 6.77 inches falls during storm events greater than 0.1 inches. Storm events of less than 0.1 inches are less likely to produce runoff and therefore 6.77 inches could be an estimate of the effective annual rainfall for the study area. The hydrologic characteristics for the urban areas and resulting runoff estimates are presented in Tables 7 and 8.

Two of the urban watersheds, Indian Bend Wash and the Price Road Tunnel, have storage capacity which may significantly reduce runoff. Indian Bend Wash has a series of 200 lakes, with a total surface area of about 200 acres and about 1,500 ac-ft of storage (CH2M Hill, 1991). The Price Road tunnel is a 15,700 foot siphon with a storage capacity of about 118 ac-ft. For this analysis, these storage volumes were considered to be unavailable during storm runoff.

Table 7
Hydrologic Characteristics and Runoff Estimates
City of Phoenix Storm Drains

		Land Use					
Drain ID	Drainage Area (mi^2)	Urban (%)	Agriculture (%)	Open Space (%)	Runoff Coefficient	Average Annual Runoff (ac-ft)	10-yr 24-hr Storm Runoff (ac-ft)
SR01	3.32	50	30	20	0.49	589	209
SR02	3.38	84	5	11	0.64	775	275
SR03	2.90	81	8	11	0.45	473	168
SR04	4.47	77	14	9	0.49	788	279
SR05	2.82	82	6	12	0.67	681	242
SR06	7.45	94	1	5	0.45	1208	428
SR07	0.92	94	3	3	0.64	214	76
SR08	5.69	85	3	12	0.41	844	299
SR09	9.23	98	1	1	0.62	2048	726
SR10	1.46	94	0	6	0.44	230	81
SR11	0.08	100	0	0	0.84	25	9
SR12	0.28	100	0	0	0.47	48	17
SR13	13.89	95	0	5	0.33	1644	583
SR14	0.12	100	0	0	0.74	32	11
SR15	1.93	94	0	6	0.43	301	107
SR16	0.08	100	0	0	0.85	25	9
SR17	1.14	90	0	10	0.58	239	85
SR18	4.20	99	0	1	0.57	858	304
SR19	3.85	85	0	15	0.48	662	235
SR20	5.40	90	0	10	0.44	853	302
SR21	0.98	95	0	5	0.90	318	113
SR22	0.74	100	0	0	0.90	240	85

Table 7 (cont.)
Hydrologic Characteristics and Runoff Estimates
City of Phoenix Storm Drains

		Land Use					
Drain ID	Drainage Area (mi^2)	Urban (%)	Agriculture (%)	Open Space (%)	Runoff Coefficient	Average Annual Runoff (ac-ft)	10-yr24-hr Storm Runoff (ac-ft)
SR23	0.14	80	0	20	0.80	41	14
SR24	4.24	86	0	14	0.36	548	194
SR25	0.20	0	85	15	0.84	61	21
SR26	0.02	77	0	23	0.78	6	2
SR27	3.04	87	0	13	0.35	389	138
SR28	0.17	100	0	0	0.90	54	19
SR29	0.50	32	0	68	0.33	60	21
SR30	2.38	18	82	0	0.24	209	74
SR31	2.86	47	32	21	0.22	228	81
SR32	1.42	76	11	13	0.38	195	69
SR33	1.32	85	0	15	0.43	206	73
SR34	0.04	74	0	26	0.47	7	2
SR35	2.34	65	5	30	0.29	247	88
SR36	1.90	67	5	28	0.25	170	60
SR37	0.60	85	0	15	0.44	95	34
SR38	1.80	56	49	5	0.22	141	50
SR39	4.34	68	23	9	0.39	607	215
SR40	0.50	85	0	15	0.64	115	41
SR41	0.06	95	0	5	0.67	14	5
SR42	0.22	90	0	10	0.65	51	18

Table 7 (cont)
Hydrologic Characteristics and Runoff Estimates
City of Phoenix Storm Drains

		Land Use					
Drain ID	Drainage Area (mi^2)	Urban (%)	Agriculture (%)	Open Space (%)	Runoff Coefficient	Average Annual Runoff (ac-ft)	10-yr 24-hr Storm Runoff (ac-ft)
SR43	0.02	100	0	0	0.70	5	2
SR44	0.13	100	0	0	0.70	3	1
SR45	1.24	90	0	10	0.50	226	80
SR46	*	*	*	*	*	*	*
SR47	*	*	*	*	*	*	*
SR48	*	*	*	*	*	786	*
SR49	7.40	*	*	*	0.29	27	279
OC01	0.13	*	*	*	0.60	18	10
OC02	0.21	*	*	*	0.24	85	6
OC03	0.39	*	*	*	0.60	95	30
OC04	0.75	*	*	*	0.35	35	34
OC05	0.25	*	*	*	0.39	34	13
OC06	0.32	*	*	*	0.30	52	12
OC07	0.43	*	*	*	*	*	18
OC08		*	*	*	*	*	*
TOTALS	111.13					17,600	6200

* Data Unavailable

Data Sources: Land Use, Drainage Area, and Runoff Coefficients from City of Phoenix
10-yr 24-hr Rainfall of 2.4 inches from NOAA Atlas II

Table 8
Hydrologic Characteristics and Runoff Estimates
City of Tempe Drainage Basins

		Land Use					
Basin	Drainage Area (mi^2)	Urban (%)	Agriculture (%)	Open Space (%)	Runoff Coefficient	Average Annual Runoff (ac-ft)	10-yr 24-hr Storm Runoff (ac-ft)
DO-1	21.3	89	5	6	0.03	222	79
PI-1	7.6	3	97	0	0.02	58	21
PI-2	10.0	5	95	0	0.00	13	5
Sub-total	17.6				0.01	71	105
PR-1	1.6	100	0	0	0.33	211	75
PR-2	34.0	91	9	0	0.06	828	294
PR-3	4.0	100	0	0	0.03	53	19
PR-4	40.2	27	54	19	0.05	799	283
PR-5	18.4	60	14	26	0.03	246	87
Sub-total	98.2				0.05	2136	758
FA-1	8.0	88	0	12	0.22	719	255
SC-1	2.1	62	0	38	0.24	201	71
Sub-total	10.1				0.22	919	326
IB-1	120.0	67	9	24	0.15	7471	2649
TOTAL	267.0					10,819	3839

Source: The hydrologic characteristics and annual runoff estimates are from reference __ (City of Tempe, Rio Salado Water Resources Master Plan, Draft Technical Memorandum 5, Storm Water Management, June 1991, by CH2M HILL)

The 10-yr 24-hr rainfall of 2.4 inches was determined from NOAA Atlas II.

3.2.4 Storm Water Quality. Storm runoff from the Phoenix metropolitan area can contribute to both surface and groundwater degradation in the study area. Much of the metropolitan area is drained by storm sewers which discharge directly into the Salt River. Estimates of the runoff from these areas is presented in Tables 7 and 8. In other areas, urban runoff is collected into percolation basins or discharged into dry wells. Concentrations of bacteria, metals, turbidity, petroleum products, pesticides and nutrients, and pesticides in urban storm runoff commonly exceeded exceed water quality standards. Because of the intermittent and high variability of rainfall and runoff in central Arizona, quality of urban runoff in the study area is also highly variable but is generally of poor quality.

The USGS (Lopes, 1992) investigated the properties of urban storm runoff in Maricopa County. Storm runoff samples were collected from four drainage basins with residential, light-industrial, heavy-industrial, and undeveloped land uses. Three of the basins are tributary to the Salt River and have outfalls which are on or contribute to an outfall within the Rio Salado study area. These three basins are located at 48th Street, 27th Avenue, and an channel at South Mountain Park, and represent light industry, heavy industry, and undeveloped areas. The fourth basin is a tributary to the Agua Fria River and is primarily residential. Selective mean concentrations for all four basins were: fecal coliform, 4,800 colonies per 100 milliliters; fecal streptococci, 9,100 colonies per 100 milliliters; dissolved solids, 81 mg/l and suspended solids, 607 mg/l. The largest concentrations of constituents were from 27th Avenue which represents a heavy industrial area. The insecticides DDT and DDE were also measured from the 27th Avenue basin. These are probably residual insecticides from the 1950's and 1960's

when large areas of the Phoenix metropolitan area were still used for agriculture. Complete summary statistics for the USGS study are presented in Table 9.

Table 9

Summary Statistic for USGS Investigation of Storm Water Quality - Maricopa County

Property or Constituent	Maximum	Minimum	Mean	Median	Number of Samples
Conductance	266	52	128	99	15
S. Solids (mg/l)	3390	<1	607	229	16
Dissolved Solids (mg/l)	158	35	81	76	14
Fecal Coliform (col/100ml)	11,000	970	4800	4600	15
Fecal Streptococci (col/ml)	26,000	1000	9100	8500	15
COD (mg/l)	21,000	<10	1900	140	15
BOD (5-day;mg/l)	3600	<5	310	30	14
Amonia, total (mg/l)	.89	.07	.39	.38	15
Nitrite + nitrate (mg/l)	4.7	.42	1.3	.77	15
Nitrogen, amonia + organic (mg/l)	3	.60	1.74	1.70	15
Phosphorus,total (mg/l)	1.70	.11	.53	.43	15
Arsenic, total (ug/l)	21	2	7.7	5.0	17
Cadmium, total (ug/l)	6	<1	1.5	1.0	17
Chromium, total (ug/l)	120	<1	24	10	17
Copper, total (ug/l)	320	7	110	52	10
Lead, total (ug/l)	620	8	140	51	17
Nickel, total (mg/l)	120	4	37	17	17
Zinc, total (ug/l)	980	30	300	170	17

Source: Selected Physical, Chemical, and Microbial Characteristics of Storm Water, Maricopa County, Arizona, T.J. Lopes, 1992

CH2M Hill (Reference 6) estimated the average annual pollutant concentrations for runoff from areas draining through the City of Tempe. These estimates are presented in Table 10 and show high levels of fecal coliform.

Table 10

Average Annual Estimated Pollutant Concentrations
Tempe Urban Watersheds

Parameter	Indian Bend Wash	Price Road Tunnel	PI-1 FA-1 SC-1 DO-1
TSS	5.56	42	278
TDS	534	534	534
BOD	30	41	47
TP	0.11	0.20	0.35
OP	0.08	0.14	0.24
NH4	1.02	1.41	1.60
Nitrate-Nitrogen	0.68	1.06	1.58
Organic N	2.22	3.05	3.46
TN	4.25	5.85	6.65
Fecal Coliform	818	818	8178
Total Copper	<0.05	<0.05	0.06
Total Lead	<0.02	<0.02	0.05
Total Zinc	0.14	0.20	0.26

Source: City of Tempe, Rio Salado Water Resources Master Plan, Draft Technical Memorandum 5, CH2M Hill, June 1991

3.3 Reclaimed Water

3.3.1 23rd Avenue Waste Water Treatment Plant. The 23rd Avenue Plant treats 30 MGD with advanced secondary treatment and dechlorination. By 1994 it will have the capacity to treat 57 MGD this way. Sand filtration is also being constructed. Table 11 summarizes three months of monitoring reports for the treatment plant's discharge.

Currently about 50% of the discharge is being diverted by a local farmer and the remaining water is going to the Salt River. This farmer uses what is needed, and then discharges the rest into the Salt River at 43rd Ave. Roosevelt Irrigation District (RID) is also working with the City to purchase (exchange) water from this treatment facility. When this occurs, the entire outflow will probably be used for irrigation during periods of high crop water demand. During October through February, however, most of the water will be discharged to the Salt River. Thus the 57 MGD will be discharged to the Salt River during approximately 5 months out of 12. During the remaining months, the discharge may not occur.

3.3.2 91st Avenue Waste Water Treatment Plant. The 91st Avenue Plant has three modules. One has a 30 MGD capacity to treat with biodenitrification, and the other two do not. The source water has a total nitrogen content of 25 mg/l, part as nitrate-nitrogen and part as ammonia-nitrogen. The City intends to increase the plant capacity by 30 MGD, and add biodenitrification within three years. Because most of the discharge is to the Salt River, the strict

standards require the discharge to support fish life. Items of specific concern are nitrate levels, and urban pesticides such as Diazanon. Table 11 summarizes three months of monitoring reports for the treatment plant's discharge.

Discharge of the treated water is to the Palo Verde Nuclear Generating Plant (currently 20-40 MGD with a right to take more), and the Salt River. The Buckeye Irrigation District diverts most of the Salt River flow at 47th Ave (about four miles downstream from the treatment plant) into the Buckeye Canal for irrigation use. Two discharge alternatives are being considered by the City: (1) recharge and storage and recovery near the Agua Fria River (AFR),and (2) irrigation of farmland or the local Gila Indian Reservation in exchange for CAP water. The Corps' creation of a wetlands as a preliminary treatment to the City's Aquifer Storage Recovery alternative may be a beneficial use of some of the effluent.

Average long term water supply for the City of Phoenix is 5% from local ground water, 20% from Central Arizona Canal (CAP) at Union Hills, and 75% Salt River Project (SRP) and Verde Plant (10 MGD) the Val Vista Road near the Verde and Salt River confluence. There are five drinking water treatment plants, one near Fountain Hills, one at 7th Street & Indian Hills. The others are not in the scope of this study. The Colorado River Water is higher in sulfates (SO_4) and calcium carbonate ($CaCO_3$). The total water supply to the City of Phoenix is approximately 250 MGD during the winter.

TABLE 11

CITY OF PHOENIX EFFLUENT DISCHARGE MONITORING REPORT SUMMARY FOR MAY - JULY 1994 (mg/l)

Parameter		Permit Requirement	91st Ave. Treatment Plant	23rd Ave. Treatment Plant
Flow in conduit through treatment plant (MGD)	91st Ave 23rd Ave	153.75 37.2	101.5	 32.91
Chlorine, Total Residual	91st Ave 23rd Ave	Rept[2] .05 Rept .011	***	 ***
PH		6.5-9.0	7.2-7.4	7.0-7.3
Total Suspended Solids 7 day avg.		4.5	9.0	7.0
Settleable Solids		1	<.1	<.1
BOD Carbonaceous - 5-day 20C		Rept	10	5
Coliform, Fecal General		800	93	57
Cyanide, Total Recoverable		200	***	***
Mercury		.2	***	***
Arsenic[1]		98.7	4	3
Selenium[1]		50	***	***
Thallium[1]		40	***	***
Beryllium[1]		5.3	***	***
Boron[1]		1000	423	380
Nickel[1]		Rept	***	***
Silver[1]		142	***	***
Zinc[1]		73.3	***	.13

Parameter	Permit Requirement	91st Ave. Treatment Plant	23rd Ave. Treatment Plant
Cadmium[1]	29.5	<.7	1.03
Lead[1]	148	***	3.7
Chromium[1]	223	***	***
Copper[1]	142	6	6
2-Methyl-4, 6-Dinitrophenol	765	***	***
2-Chlorophenol	2000	***	***
2-Nitrophenol	Rept	***	***
2,4-Dichlorophenol	365	***	***
2,4-Dimethylphenol	2120	***	***
2,4-Dinitrophenol	365	***	***
2,4,6-Trichlorophenol	3.6	***	***
4-Chloro-3-Methylphenol	30	***	***
4-Nitrophenol	Rept	***	***
Phenol, Single Compound	2560	<4	.6
Pentachlorophenol	13.0	***	***

Source: City of Phoenix NPDES Discharge Monitoring Reports, May-July 1994
[1] Total Recoverable
[2] No standard. Report required to Arizona Department of Water Resources.
*** Not Available

IV. GROUNDWATER CONDITIONS

4.1 Hydrogeologic Setting.

The Rio Salado study area is located in the Phoenix Active Management Area (AMA) and is comprised of portions of two distinct but interconnected alluvial groundwater basins. These basins, West Salt River Valley (WSRV) and East Salt River Valley (ESRV), are shown on Figure 2.3 of the main report. The subsurface geologic conditions in the Salt River Valley (SRV) are described by the USBR (1976), the USGS (Laney and Hahn, 1986; Brown and Pool, 1989), and by ADWR (Corkhill, 1993). All three investigations divide the basin-fill sediments into three hydrogeologic units. However, the units have sometimes been defined differently. This report uses the most recent division of hydrogeologic units, as described by ADWR.

There are three hydrogeologic units: the lower alluvial unit (LAU), the Middle Alluvial Unit (MAU), and the Upper Alluvial Unit (UAU). There is also a Red Unit which forms the base of the aquifer beneath parts of the area. The LAU overlies the Red Unit and consists mainly of conglomerate and gravel. The LAU is tapped by many city wells and it is estimated that approximately 25 percent of the pumpage in the SRV originates from this unit (ADWR, 1993). The MAU overlies the LAU and consists mainly of clay, silt, mudstone and some sand and gravel. The unit ranges in thickness from 100 feet to over 1600 feet in the deeper parts of the basin. The MAU is now the primary source of groundwater in the valley. ADWR estimates that

about one half of the total pumpage in the valley is from the MAU. The UAU overlies the MAU and consist primarily of gravel, sand and silt. The amount of coarse-grained deposits in this unit is highest near the Salt and Gila Rivers. The thickness of the UAU is relatively uniform and ranges from 200 to 300 feet thick in ESRV and between 300 and 400 feet thick in the WSRV. In the past, the UAU was the primary source of groundwater in the valley, but because of lower water levels and large areas of poor quality water, only about one fourth of groundwater pumped in the valley is from the UAU. Important sources of recharge to groundwater in the valley are infiltration of Salt River flows, mountain recharge along the McDowell and Superstition Mountains, percolation of excess irrigation water, and canal seepage. Figure 2.4 of the main report shows a subsurface hydrologeologic section along the Salt River from Granite Reef Dam to the confluence of the Salt and Gila Rivers. Figure 2.5 of the main report shows the depth to groundwater in the study area during the winter of 1983.

4.2 Hydrologic System

4.2.1 Predevelopment Hydrologic System. The predevelopment hydrologic system of the Salt River Valley (SRV) is described by the Arizona Department of Water Resources (ADWR). Prior to the arrival of non-Indian settlers in the 1860's and 1870's, the hydrologic system in the SRV was in a state of equilibrium. Flows into and out of the SRV were in approximate balance and water levels generally remained constant. The main components of the predevelopment groundwater budget were underflow, stream channel infiltration, mountain

front recharge, and evapotranspiration. An approximate predevelopment groundwater budget is presented in Table 12 and the components are described below.

Table 12.

Estimated Predevelopment Groundwater Budget for SRV

Source of Inflow to SRV	Volume (ac-ft/yr)
Stream Channel Recharge	100,000
Groundwater Inflow	30,000
Mountain Front Recharge	10,000
Total Inflow	140,000
Groundwater Discharge to Stream Channel	60,000
Evapotranspiration	80,000
Total Outflow	140,000

Groundwater Flow

In general, groundwater moved east to west through the SRV. Most of the Salt River Valley groundwater moved in a direction towards the lower topographic areas. Substantial groundwater

flow underflow moved northwestward along the Gila River and passed through the gap between the South Mountains and the Sierra Estrella.

Stream Recharge

Prior to development of the valley and construction of upstream reservoirs, the Salt and Gila Rivers were perennial throughout the SRV. The rivers were significant sources of groundwater recharge in some areas and recipients of groundwater discharge in other areas. The reaches of the river can be classified as losing or gaining. The rivers 'lose' water where the groundwater table elevation is lower than the water level in the river channel. Similarly, the river 'gains' when groundwater is discharged into the river, where the water table is higher than the water level in the channel. ADWR estimated the total recharge from the Agua Fria River, Cave Creek, New River, Skunk Creek, and Queen Creek to be about 20,000 acre-feet per year.

Mountain Front Discharge.

Mountain-front recharge is water that infiltrates into the alluvial material along the interface between mountains and the alluvial groundwater basin. The amount of mountain-front recharge depends on average precipitation. The ADWR estimated that mountain-front recharge in the SRV is only significant along the McDowell and Superstition Mountains.

Evapotranspiration

Under predevelopment conditions, ADWR identified evapotranspiration as the major source of discharge from the groundwater system in the SRV. Evapotranspiration is the process of evaporation from water surfaces and moist soil and transpiration from vegetation. During the predevelopment period, there was approximately 48,000 acres of phreatophytes along the Salt and Gila Rivers. ADWR used an evapotranspiration rate of 1.6 acre-feet per acre per year to estimate a loss of 76,000 acre-feet per year.

4.2.2 Modern Hydrologic System. Irrigation was originally developed by diversion of streamflow into canals. By the turn of the century, much of the valley was waterlogged, due to recharge from canal seepage and deep percolation, combined with a lack of groundwater pumping. Beginning in the 1920's and 1930's, substantial groundwater pumpage began for irrigation and to control shallow groundwater levels. Following World War II, extensive pumpage began, primarily for irrigation. This resulted in extensive groundwater overdraft. With the advent of the State Groundwater Management Act, the extent of overdraft has been curtailed through management procedures such as decreased irrigation pumpage, water conservation practices, and intentional recharge projects. By the late 1980's, water levels within the Salt River Project had essentially stabilized. Continuing overdraft was present, however, in some off-project areas.

4.2.3 Future Hydrologic System. Because of several factors, water levels are projected to be stable or rise in parts of the Salt River Valley in the future. First, as irrigated lands are urbanized, the normal tendency is for less groundwater to be pumped. Increasing water conservation practices, reuse of sewage effluent in the valley itself, as opposed to exportation to downstream areas, and increased recharge and underground storage are examples of these factors. Because most of the shallow groundwater beneath formerly irrigated areas is of unsuitable quality

for public supply, less and less groundwater is being pumped from shallow strata. When all factors are considered, there appears to be more than an adequate supply available within the Salt River Project. In off-project areas, some overdraft will apparently continue where imported water supplies are not adequate for development, and significant groundwater pumpage is necessary. There is a need to have a groundwater management goal that involves stabilizing water levels within a certain range, includes addressing shallow groundwater problems areas and areas of rising water levels. This should be done in conjunction with developing a plan to pump poor quality shallow groundwater for some use, in areas where irrigation is no longer practiced.

4.3 Groundwater Quality

4.3.1 Inorganic Chemical Constituents. There are a number of groundwater quality problems in the Salt River Valley. The regional groundwater problems associated with inorganic chemical constituents were described in the MAG 208 Water Quality Management Program (Schmidt, 1979). Most of the inorganic problems can be traced to natural factors and long-term irrigation practices. High salinity, chloride and nitrate concentrations are commonly found in shallow groundwater beneath irrigated or formerly irrigated land. Irrigation practices can also be associated with high nitrate levels in some areas, but there is also evidence that high nitrate levels occur naturally in parts of the valley. An example is the large area of high nitrate in the western part of the valley. This area extends from northwest Phoenix through Glendale and Tolleson, to the west of Buckeye. High nitrate levels were observed in this area when many Salt River Project wells were first drilled in the 1930's. Therefore, it appears that high nitrate levels predated the widespread use of chemical fertilizers. Figures 5.13 - 5.15 of the main report show the content of Total Dissolved Solids (TDS) in terms of electrical conductivity, chloride, and nitrate in the groundwater near the Rio Salado

study area. All three constituents are high in the study area, chloride and TDS are especially high at the western end of the study area north of the confluence of the Salt and Verde River. Nitrate levels (as nitrate) are greater than 25 mg/l throughout the area west of Central Avenue. A pocket of 90 mg/l concentrations (as nitrate) is located northeast of Tolleson. Table 13 summarizes the public health effects of excess levels of chloride, TDS, and nitrates and Table 14 summarizes the effect on agriculture.

Table 13

Public Health Significance of Chlorides, TDS, and Nitrates.

Parameter	Public Health Significance
Chloride	Chloride in low concentrations is not harmful to humans. However, water with concentrations above 250 mg/l has a salty taste, which is considered objectionable by most people.
TDS	Water with TDS content of less than 500 mg/l is most desirable for domestic use. Standards generally recommend a limit of 1000 mg/l for potable water.
Nitrate	In 1940 it was found that drinking water with high nitrate content often caused methemoglobinemia in infants. This is a condition that reduces the bloods ability to carry oxygen. The EPA has established a MCL for nitrate-nitrogen in drinking water of 10 mg/l (equivalent to about 45 mg/l as nitrate).
Primary Source: Chemistry for Environmental Engineering, Sawyer and McCarty, 1978	

Table 14

Significance of Chloride, TDS, and Nitrate in Irrigation Water.

Parameters	No Problems (mg/l)	Increasing Problems (mg/l)	Severe Problems (mg/l)	Problems
TDS	<500	500-2000	>2000	Salinity effects on crop yield
Chloride	<142	142-355	>355	If water is absorbed by roots only.
Chloride	<106	>106		If water is also absorbed by leaves.
Nitrogen	<5	5-30	>30	Excess nitrogen may delay harvest time and adversely affect yield or quality of sugar beets, grapes, citrus, avocados, apricots, etc.
Source: SRP 1993 Water Quality Report				

4.3.2 Trace Organics. Over the past 15 years, a number of instances of shallow groundwater degradation by trace organic constituents have been detected in the Rio Salado study area. The most significant instances involve the pesticide DBCP or volatile halocarbons. Beneath or downgradient of present or former citrus and deciduous orchards near Mesa, and South Mountain, DBCP has been detected at concentrations exceeding the drinking water maximum contaminant level (MCL of 0.02 ppb). DBCP is a pesticide that was used extensively on citrus groves and some other crops in the Salt River Valley. DBCP is now a suspected carcinogen and was banned for agricultural purposes in 1979. Figure 5.16 of the main report shows the SRP well locations in or near the study area which have tested positive for DBCP.

Numerous incidents of volatile halocarbon contamination have been detected in the Rio Salado study area. Volatile halocarbons are located in shallow groundwater beneath a number of landfills along the Salt River, near some industrial facilities, and beneath a large area between the Sky Harbor Airport and downtown Phoenix. In many cases of volatile halocarbon contamination, the problems are limited to plumes in specific areas and can be associated with specific sources (examples: 19th Avenue, 27th Avenue, Estes landfills and Motorola 52nd Street). These plumes are usually well defined and involve relatively small amounts of groundwater. However, a large area of low level volatile halocarbon contamination involving larger amounts of water has also been delineated. This area stretches from the Motorola 52nd Street Superfund site southwest to Sky Harbor Airport, west through downtown Phoenix and through the West Van Buren area, almost to Tolleson. There many possible sources of this low level contamination. Attempts are being made through state and federal remediation programs such as the Water Quality Assurance Revolving Fund (WQARF) and the EPA's Superfund program to define the extent of contamination and to implement remediation. Because of the size of the affected area, it is difficult to partition the problem areas into specific sites with identified parties. Figure 5.17 of the main report shows the

location of WQARF and Federal Superfund sites and areas and the extent of volatile halocarbon contamination in and near the study area. Table 15 summarizes the identified problems at each site. Open and closed landfills along the Salt River are shown on Figures 5.11 and 5.12 of the main report and are listed in Tables 16 and 17.

Table 15: WQARF and Federal Superfund Sites in or Near the Study Area

Site	Location	Primary Contaminants	Source	Comments
19th Avenue Landfill	In Phoenix along the Salt River between 15th & 19th Avenues.	vinyl chloride TCE PCE 1,1-dichloroethene	Municipal and Industrial Wastes	VOC contaminants at levels exceeding MCLs on and off site. A federal superfund site. Groundwater to be monitored but no cleanup necessary. The site will be capped and provided with bank protection.
Motorola 52nd Street	Eastern part of Phoenix about 1 mile north of the Salt River	TCE PCE TCA	Land Disposal at Industrial Plant Dry wells formerly used	A federal Superfund site. Groundwater cleanup underway.
North Indian Bend Wash	Cities of Scottsdale and Tempe	TCE PCE chloroform TCA DCE	Land disposal practices at industrial facilities	VOCs have been found in upper, middle and lower alluvial unit. Well conduits a contributing factor A federal superfund site.
South Indian Bend Wash	City of Tempe	VOCs Organic Compounds Metals	Not precisely determined yet, probably industrial sites and former landfills	Federal Superfund site.
161st Air National Guard	51 acres at Sky Harbor Airport	benzene ethylbenzene PCE TCE DCE DCA	Aircraft maintenance activities, refueling operations	Under Department of Defense Installation Restoration Program Being cleaned up as part of new runway installation at Sky Harbor.
East Central Phoenix	Between 48th and 24th Streets and Camelback and Thomas Roads in Phoenix	TCE PCE 1,1,1-trichloroethene	Industrial facilities and other sources possible	PCE levels exceeding MCL detected downstream facilities. State WQARF site.
East Washington	Between 48th Street and 7th Ave. and Thomas and Lower Buckeye	TCE PCE 1,1,1-trichloroethene 1,1-dichloroethylene vinyl chloride	Industrial Facilities Exact source has not yet been determined.	Large area of VOC contamination. Difficult to identify sources. State WQARF site.
Estes Landfill	South of Salt River between 40th and 45th Streets in Phoenix.	vinyl chloride 1,2-dichloroethene TCE	Estes Landfill	On going remedial investigation.
Northwest Tempe	Between 14th Street and 10th Place & between Edward Drive and Park Lane in Tempe.	1,1,1-trichloroethene 1,1-dichloroethylene	Industrial facilities	A plume of VOCs has been identified and is being investigated.

Table 15: WQARF and Federal Superfund Sites

Site	Location	Primary Contaminants	Source	Comments
Sky Harbor	Between 24th and 44th Streets and north of the Salt River.	TCE PCE 1,1,1-trichloroethene	Industrial Facilities Airport operations possibly	Subunit of the East Washington WQARF area.
West Central Phoenix	Phoenix	TCE PCE DCE	Industrial Facilities	Three distinct plumes. State WQARF site.
West Van Buren	25 square miles in northwest Phoenix	TCE DCE PCE petroleum products	Industrial Facilities	Little remediation. Proposed measures to attempt to prevent contamination from reaching City of Tolleson wells.
27th Avenue Landfill	Between 35th and 27th Avenues	VOCs benzene Methylene Chloride	Landfill	City of Phoenix has submitted a closure permit under the ADEQ Aquifer Protection Permit Program.
Del Rio Landfill	Between 7th and 16th Streets, south of the Salt River in Phoenix.	VOCs	Apparent upgradient source	Well defined plume
Motorola 56th Street	Northwest corner of 56th Street and Earll Drive in Phoenix	TCE TDCE	Disposal of Solvents	Prior to 1962 all discharges of solvents were to dry wells or sewage leach fields.

Table 16

Active Landfills
Vicinity of Rio Salado Study Area

Map ID	Facility Name	Types of Wastes	Operator Name	Approximate Location
H	27th Avenue	Rubbish Municipal Solid Waste Liquid Waste	City of Phoenix	SW Corner of 27th Avenue and Lower Buckeye Road
I	40th Street	Rubbish	Bradley Investment Company	North Side of Magnolia East of 40th Street
J	Litchfield/Avondale	Rubbish	Calmat of Arizona	South of Indian School Road, West Side of Agua Fria River
K	Tri-City	Rubbish Municipal Solid Waste	Salt River-Pima Tribe	1 Mile North of McDowell, off Beeline Hwy (AZ 87)
L	Weinberger Construction Debris	Rubbish	Glenn Weinberger	.5 Miles South of Lower Buckeye Road on 39th Avenue

Source: Directory of Arizona, Municipal Solid Waste Landfills, Rubbish Landfills & Private Solid Waste Landfills, March 1993, ADEQ.

Table 17
Closed Solid Waste Landfills
Vicinity of Rio Salado Study Area

Map ID	Facility Name	Types of Wastes	Operator Name	Approximate Location
A	16th Street	Rubbish Municipal Solid Waste Other?	City of Phoenix	1 Mile South of I-10 on 16th Street
B	19th Avenue	Rubbish Septage Municipal Solid Waste Liquid Waste	City of Phoenix	1 Mile South of I-10 on the East Side of 19th Avenue
C	22nd Avenue	Rubbish Municipal Solid Waste Other?	City of Phoenix	22nd Avenue and Lower Buckeye Road
D	Estes	Rubbish Municipal Solid Waste Other?	City of Phoenix	East Side of 40th Street, South of the Salt River
E	91st Avenue	Rubbish Municipal Soild Waste	City of Phoenix	West Side of 91st Avenue, Opposite 91st Avenue Waste Water Treatment Plant
F	Ameron	Rubbish	Ameron Pipe Division	West of 12th Street, South of Watkins in Phoenix
G	ASU No. 1	Rubbish Municipal Solid Waste	Arizona State University	Along West Side of Scottsdale Road, South of Salt River
M	ASU No. 2	Rubbish Municipal Solid Waste	Arizona State University	Along East Side of Scottsdale Road, South of Salt River
N	Avondale	Rubbish Municipal Solid Waste Other?	Maricopa County	North Side of the Intersection of MC 85 (Formerly US 80) and the Agua Fria River

Table 17 (cont.)
Closed Solid Waste Landfills
Vicinity of Rio Salado Study Area

Map ID	Facility Name	Types of Wastes	Operator Name	Approximate Location
O	Central Avenue	Rubbish	Union Rock and Materials	.25 Miles South of I-10 on Central Avenue
P	First Street	Rubbish	Kachina Ready-Mix	NE Corner of First Street and Clark Drive, Tempe
Q	Juice of Life	Rubbish Municipal Solid Waste	Mike Neils	5837 S. 36th Street, Phoenix
R	Old Town Dump	Rubbish Municipal Solid Waste	Goodyear Tire& Rubber	Dysart Road to Rid Canal
S	Perry Lane Methane			NE Corner of 1st Street and Perry Lane
T	Reed Construction	Rubbish Municipal Solid Waste	Reed Construction Company	West Side of 67th Avenue on Salt River
U	RRCA (old Tempe)	Rubbish Municipal Solid Waste Other?	Raymond Edwards	1.3 Miles North of Apache Blvd. on Hayden Road
V	Tempe #1		City of Tempe	South Side of Salt River on Hayden Drive
W	Tolleson	Rubbish Municipal Solid Waste	City of Tolleson	91st Avenue and the Salt River
X	Tri-City (old)		Salt River-Pima Tribe	North Bank of Salt River West of Country Club Road
Y	Wayne Oxygen	Liquid Waste	Wayne Oxygen Company	2615 S. 40th Street, Phoenix
Z	William Roer	Rubbish Municipal Solid Waste	William Roer	75th Avenue North of Southern Avenue, on South Side of Salt River

Source: Directory of Arizona, Closed Solid Waste Landfills (CSWLF), March 1993, ADEQ.

Because of poor inorganic chemical quality of the shallow groundwater (nitrate, chloride, and TDS) use of shallow groundwater in the Rio Salado study area for public supply is very limited. New public water supply wells which tap potable groundwater in the Lower and Middle Alluvial Units have been developed for several decades. Much of the shallow groundwater is of suitable quality now only suitable for industrial or agricultural purposes. The deeper water is generally unaffected by irrigation and industrial practices and has lower salinity and nitrate concentrations. An important issue in the Salt River Valley is protection of the higher quality water in the deeper aquifers from the poorer quality water in the upper aquifer.

Other possible sources groundwater quality degradation in the study area are leaking underground storage tanks, dry wells which extend close to or into the upper part of shallow aquifers, settling basins, and past well construction practices.

4.3.3 Future Conditions

It is expected that much of the Salt River Valley will be urbanized within the next several decades. This will cause a significant reduction in the amount of pumped shallow groundwater for irrigation. Because this water is of poor quality and is not directly suitable for public supply, there will be very few users of this groundwater once widespread irrigation has stopped in the valley. At the same time it is expected that the shallow groundwater will be recharged for decades from deep percolation of water currently in the vadose zone (Schmidt, 1989). This recharge water is generally of poor quality in terms of salinity, chloride, and nitrate content, and will further degrade the quality of shallow groundwater.

Without future pumping and with continued recharged from irrigation water stored in the vadose zone, the following problems may occur:

1) Shallow poor quality groundwater will eventually migrate downward and contaminate the good quality groundwater in deeper strata. Water levels in wells tapping deep units are usually lower than those in shallow wells, resulting in a substantial downward gradient. Thousands of potential well conduits exist in the valley. In search of higher yields as water levels declined in the 1970's, deeper composite wells were drilled. These wells are commonly perforated over hundreds of feet and if not properly destroyed, create flow paths for poor quality shallow water to deeper high quality water.

2) Shallow water levels are becoming a problem in parts of the Phoenix metropolitan area. In some areas, depth to groundwater is now less than 50 feet. Rising water levels can cause significant nuisance problems for construction of new buildings or maintenance of existing structures with underground areas. Another problem is the existence of thousands of dry wells in the metropolitan area, which are used for the disposal of storm runoff. Some of these wells may have the effect of discharging urban runoff directly to shallow groundwater, if water levels rise sufficiently.

4.4 Groundwater Quantity

In order to determine the amount of poor quality groundwater available (considering only hydrogeological factors, as opposed to legal and other factors), one can take into account the thickness of saturated deposits in the Upper Alluvial Unit and multiply this by the specific yield of these deposits. As a result of extensive groundwater modeling studies, the ADWR has

prepared computer printouts indicating the approximate thickness of saturation of each major geologic unit, the storage coefficients, and the amount of recharge in each model cell. From this information, one can determine the amount of groundwater in storage in the Upper Alluvial Unit and the recharge to this unit.

Presently recharge is primarily from streamflow in the Salt River, canal seepage, deep percolation of excess applied irrigation water, and storm runoff. Near the Salt River in much of the study area, streamflow recharge is predominant except during periods of no river flow. At these times, recharge from other sources is important, as evidenced by changes in groundwater quality that have been observed at many monitoring sites along the river since the late 1970's.

V. WATER QUALITY ENHANCEMENT OPPORTUNITIES

5.1 Water Quality Improvements.

5.1.1 Wastewater Treatment Plants. The two sewage treatment plants (23rd Ave. and 91st Ave.) which discharge water into the Salt River were discussed in Section 3.3. They have capacity to treat 30 and 150 MGD respectively, to a level exceeding secondary treatment. Because proposed NPDES requirements are so stringent and costly to attain, the City of Phoenix anticipates selling this water to farmers, and/or power plants, or injecting it after additional treatment. A visible option to utilizing this water is to create a wetlands near a sewer outfall. The water is rich in nitrogen and already treated for many other water quality concerns (refer to Table 11 for water quality of discharge). This water could be used as a steady supply to a wetlands where nitrates would be reduced to the maximum contaminant level (MCL) of 10 mg/l as nitrogen, or it could be used intermittently, when farmers use all of the effluent for irrigation.

5.1.2 Storm Drain Water. As discussed in Section 3.2 titled Urban Storm Water, many storm drains currently discharge into the Salt River offering a large intermittent source of varied quality water. In the near future, the quality of this water may require treatment before discharge into a Federally regulated water course is permitted. From discussions with various local agencies, if this does not happen, storm drain water quality is not likely to improve. One of the best management practices for treating this water would be skimming off the oils, settling the

suspended solids, and then allowing a wetlands type of treatment to remove the remaining toxins and nitrates.

The City of Tempe has an aggressive on-site storage policy which retains the poor quality first flush water. Although the smaller events do not reach the Salt River, the water quality of the discharge is of better quality than that of Phoenix. Approximately 10,800 ac-ft per year of Tempe Storm Drain water discharging into the Salt River has been estimated according to a Tempe Report.

The City of Phoenix storm drains collect water from over a 100 square mile area and have a total mean annual discharge of about 18,000 ac-ft. Refer to Tables 7 and 8 for water quantities of specific storm drains. Water quality of the discharge is varied with poor quality water during the first flush period of a storm, and improving as the event continues. Refer to Tables 9 and 10 for water quality information and compliance.

Without treatment, this urban runoff water is not suitable for injection and may not meet future requirements for percolation. It contains varying degrees of fecal coliform and streptococci, is usually high in suspended solids and oils, and in some cases contains DDT, and its degradation product DDE, (especially at 27th Avenue, ref. 2).

There are many expensive physical treatments for the pollutants found in this storm water. However, for small quantities the best management practices are the most natural. By retaining the discharge in a pond, for example an abandoned gravel pit, suspended solids would settle to the bottom. Oils and pesticides could be skimmed off the top. For additional treatment, this water could then be directed into a wetlands area where its water quality would be further improved. With proper planning and design, it is possible to construct a system whose outlet

water would be good enough quality to be recharged into the ground for ground water quality improvement, or directed to support other riparian areas.

Such a project would require a pilot study to determine the efficiency of the wetlands, and thus the outlet water quality and its use after discharge. The wetlands would require a supplemental water supply during years with little or no rain. It would also have to be strategically located in or along the river bed in such a way as to avoid being washed out in a frequent flood.

5.1.3 Groundwater. As discussed in Section 4.2, use of the water stored in the upper aquifer of the study area is decreasing for two primary reasons: (1) because urbanization of the valley is increasing, the amount of pumping for irrigation is declining and (2) the poor quality shallow groundwater in most areas cannot be directly used for public supply without costly treatment. This shallow groundwater has areas of elevated TDS, chlorides, nitrates, and volatile halocarbons, DBCP, and other contaminants. In most areas it is only usable for irrigation or industrial uses.

As pumping of this water decreases and pumping of deeper groundwater increases, the potential for degradation of deeper better quality water increases. The potential for rising groundwater levels also increases, which can cause further degradation of the shallow groundwater contaminants in the Vadose zone. A strong argument can be made for the benefits of managing this poor quality water. However, there are some institutional obstacles including: legal issues, availability of poor quality water permit from ADWR, and municipal water

conservation requirements. If these obstacles can be overcome, a large reservoir of water becomes available. Preliminary estimates indicate that at least tens of thousands of ac-ft could be available on an annual basis. This water could be used to maintain, enhance, or create riparian habitat or could be used as source water for recreational lakes and/or wetlands. The creation of wetlands would have the dual benefits of creating habitat and improving the quality of the water.

A more detailed investigation of the water balance in the study area should be undertaken to verify the conclusions of this report. In addition, the feasibility of overcoming the institutional concerns regarding legal issues, regulatory concerns, and conservation requirements must be determined.

5.2 Design Considerations.

5.2.1 Riparian Habitat. There is currently 1800 acres of habitat in and along the Salt River through the study reach. Each area is specifically described in the Environmental Evaluation, Appendix A of this report. Existing water sources for these areas are sewage treatment plants and storm drain runoff, both of which may disappear to some degree in the near future. By using storage, skimming, and wetlands treatment for storm drain water, and/or wetlands treatment for sewage treatment plant water, many if not all of these areas could be preserved. Table 18 presents the potential water demand from these areas depending on what type of area they were to support. The locations have been described in the Environmental

Appendix, Appendix A, as well as shown on a plate. The range of water requirement to maintain a habitat in all 1800 acres is about 4300 acre-feet per year (3.8 MGD) to almost 11,000 acre-feet per year (9.6 MGD). By using this table along with storm drain and gravel pit information, a design to support this habitat with storm drain and sewage water could be formulated. The average annual total storm drain volume exceeds 20,000 acre-feet per year (ac-ft/yr), however a prudent design would account for years with less flow, or provide supplemental water from pumping. The treatment requirement of the storm drain water would depend on each individual storm drain used. Most drains would require settling and skimming in the gravel pit as well as some wetlands treatment in order to improve the water quality to EPA's standards for riparian habitat. The sewage treatment plants would discharge to a wetlands from which higher quality water could be used for further riparian purposes.

5.2.2 Wetlands Treatment Capabilities. Wetlands can be an effective way of treating stormwater and domestic and municipal sewage, as well as removing nitrates (one of the major groundwater quality concerns in this area). The particular benefit of wetlands treatment is that it removes some pollutants by transformation into other non-hazardous constituents. The Ion Exchange and Activated Carbon leave either a resin containing the offending constituent, or requires burning off the constituent which is an air quality problem. Air stripping mearly transfers the constituent from the water into the air, but does NOT render it nontoxic. In a wetlands, however, biochemical oxygen demand and coliform bacteria go through microbial metabolism and die off respectively. Similarly, nitrogen is removed by transferring the various forms of nitrogen into nitrate. The nitrates are removed by anaerobic metabolism in the bottom

sediments with release of gaseous nitrogen to the atmosphere. From reported data of existing wetlands, (ref. 3) Table 19 describes the potential removal rates of various constituents from four water sources. The removal rates are in percent removed with regard to their concentration into and out of the controlled area. These percent removals (removal efficiencies - RE) are reported as minimum, typical, and maximum values. Typical does not represent mean because not enough data was collected to compute statistical values. However it does indicate a trend.

Table 18 Consumptive Use of Plants Potential Rio Salado Riparian Project Sites					
Riparian Location	Area (acres)	Honey Mesquite (ac-ft/yr)	Fresh Water Marsh (ac-ft/yr)	Tall & Short Willow (ac-ft/yr)	Bermuda & Rye Grasses (ac-ft/yr)
1	4.63	11	19	21	28
2	54.55	131	218	251	327
3	19.50	47	78	90	117
4a	3.31	8	13	15	20
4b	10.91	26	44	50	65
5	13.22	32	53	61	79
6a	6.61	16	26	30	40
7	189.75	455	759	873	1139
8	56.70	136	227	261	340
9	12.56	30	50	58	75
9a	41.32	99	165	190	248
10	147.44	354	590	678	885
11	53.88	129	216	248	323
12	34.38	83	138	158	206
13	43.64	105	175	201	262
14a	14.55	35	58	67	87
14b	4.30	10	17	20	26
14c	8.60	21	34	40	52
15	44.30	106	177	204	266
16	180.50	433	722	830	1083
16A	13.55	33	54	62	81
16B	48.60	117	194	224	292
17	12.23	29	49	56	73
18	26.45	63	106	122	159
19	25.12	60	100	116	151
20a	90.25	217	361	415	541
20b	27.11	65	108	125	163
21a	37.36	90	149	172	224
21b	14.21	34	57	65	85
22	111.07	267	444	511	666
23a	20.83	50	83	96	125
23b	11.24	27	45	52	67
24	50.25	121	201	231	301
24a	17.85	43	71	82	107
25a	96.20	231	385	443	577
25b	251.90	605	1008	1159	1511
Total	1798.85	4317	7195	8275	10793

Table 19
Removal Efficiency In Wetlands
(Values in Percent of removal)

Source	TSS	BOD/COD	TN	TP	TIN & NO_3	Col. Bac.	Metals	Toxic Organics
Domestic Municipal Waste	55 72 94	80 90 95	25 70 93	12 40 57	--* 80 --	80 95 99	0 50 99	-- -- --
Storm-water	43 63 95	40 -- 80	36 -- 70	43 53 85	-- -- --	-- -- --	5 50-70 95	69 95 100
Indust. waste	42 -- 100	29 -- 100	69 -- 98	30 -- 73	-- -- --	-- -- --	6 70-85 97	-- -- --
Agricult. runoff	54 -- 82	75 -- 97	-- -- --	66 -- 81	82 -- 96	-- 62 --	-- -- --	-- -- --

TSS - Total suspended solids
BOD - biochemical oxygen demand and/or
COD - chemical oxygen demand
TN - total nitrogen
TP - total phosphorus
TIN - total inorganic nitrogen and/or
NO_3 - nitrate nitrogen
col. bac. - coliform bacteria
heavy metals
toxic organic substances

ref. 3

5.2.3 Wetlands - Water Sources. In this study area wetlands could be created from any combination of groundwater, waste water, or storm water. As discussed in the Water Quality Improvements Section, each source has its own pretreatment requirements, as well as water quantity available. A previous Corps Study presented the alternative of using 91st Avenue Wastewater Treatment Plant water to create a wetlands and enhance the riparian habitat downstream of the plant.

Another location of interest would be near Central Avenue where the City of Phoenix would like to see a "Town Lake". At this location there are several large storm drains. By detaining this storm water in nearby gravel pits, a more constant flow could be attained for the wetlands. These pits would require lining, but would contribute to the enhancement of its water quality through settling. Skimming would remove the oils and floating material before discharging into the wetlands for further treatment. When the storm drains do not provide

enough water for the wetlands, pumping water from the shallow aquifer would sustain the wetlands.

It would also be possible to create a wetlands to treat the poor quality shallow aquifer water for nitrates. This water would be the most likely to meet the criteria for sustaining a "Town Lake".

5.2.4 Wetlands - Design Requirements. There are many criteria in creating a wetlands with high removal rates of the above constituents. A pilot site would be required to fully determine the efficiency of the site. The following, however is a general description of the initial assumptions and requirements for such a site.

Assumptions:

1. Removing Nitrates is the design criteria. In the City of Phoenix near Central Ave. and the Salt River, nitrate levels in the groundwater contain 45 mg/l as nitrate, but just upstream of the confluence it is much less, 25 mg/l. The nitrate MCL for recharging into the groundwater is 10 mg/l as nitrogen (45 mg/l as nitrate) with a stipulation that no degrading of existing water quality be permitted. Therefore a wetlands design reducing nitrates from 45 to 25 mg/l will be considered.

2. A removal efficiency K of .1 day^{-1} , and a depth of water of 1 foot will be assumed for the following designs. The removal rate could be .2, but without a pilot study such determination is not feasible.

3. The following equations were used to determine each design requirement.

- c = final concentration of nitrates after wetlands treatment (25 mg/l)
- c_i = initial concentration of nitrates = 45 mg/l
- K = .1 day^{-1}
- Retention time = T (days) = $(-\ln(1- (c_i - c) / c_i)) / K$
- Surface area = SA = ((T in days x Q in cfs) / H)(86,400 / 43,560) acres

- Average Velocity = V = 24,000 (K) / 86,400 ft / s

- Width of wetlands = W = (Q in cfs / V in ft/s) feet (depth = 1 foot)

- Length of wetlands = L = (SA in acres x 43,560 / Width in feet) feet

Table 20

Sizing of Wetlands For Various Inflows
For Initial Nitrate Concentration of 45 mg/l

$K = .1\ day^{-1}$

c_i = 45 mg/l around Central Ave. c = 25 mg/l final conc.

Retention Time = 6 days Length = 14,000 feet (total)

Average Velocity = V = 0.03 ft/s Depth = 1 foot

Q (MGD)	1	5	10	30	60	90
SA (acres)	18	92	184	550	1100	1700
W (ft)	56	280	560	1700	3350	5000 +

Although these wetlands were designed to treat nitrates, they may be used for size approximations for Storm Water sources of water in the area. When a specific site and water source is chosen, then each constituent can be analyzed to determine its potential reduction through wetlands treatment. It should be noted that the Tres Rios wetlands sizing can not be compared to the above computations as their water treatment purposes are different.

5.2.5 Lake. This Section discusses some of the design criteria for creating a lake along the Salt River near Central Avenue. Computations were done on a 100 acre lake for initial sizing purposes. Two options were considered, 1. without lining the lake, and 2. with lining the lake to prevent losses through seepage. Water sources would be from ground water unless sufficient area is available for wetlands treatment of storm water, and the lake is small enough to be significantly effected by storm water quantities.

Design Parameters

Surface Area = 100 acres

Depth = 20 feet

Volume = 2,000 acre-feet (ac-ft)

Water Demand For Maintaining the Lake

Parameter	Without Liner	With Liner
Surface Area	100 acres	100 acres
Evaporation 6 ft/yr[1]	600 ac-ft/yr	600 ac-ft/yr
Seepage Area[2]	100 acres	100 acres
Seepage loss .2 ft/day/ft[1] to 1 ft/day .01 ft/day/ft[1]	7519 to 37,600 ac-ft/yr	380 ac-ft/yr
Total Lake losses	8200 ac-ft/yr	980 ac-ft/yr
= Total Lake Demand	7.25 MGD	0.87 MGD

[1] Reference Rio Salado Technical Memorandum No. 7 by CH2MHILL 1992.

[2] For a 1000 x 4360 foot lake assuming that the side along the lake is impermeable to prevent erosion during floods, the seepage area of three sides and the bottom is 103 acres.

Water Supply for Maintaining the Lake

By capturing discharge from the seventeen storm drains from Central Avenue upstream to the I-10, a 43 sq. mi. area of runoff is captured. The sum of drains 11-20 and 33-39 (see plate on storm drains) produce an average annual runoff of more than 7200 ac-ft (6.4 MGD). To treat this amount of water a 120 acre wetlands would be necessary (see table 18). Referring to the previous table, it is apparent that even if the average annual rainfall occurred, these storm drains could not keep up with lake losses. Rather than reducing the lake size, by lining the lake, losses are reduced to an average of 980 ac-ft/yr (.87 MGD). This is approximately 13 % of the average annual storm drain discharge, and 45 % of the 10-yr 24-hr storm drain volume. There may be sufficient water quantity to sustain a 100 acre lined lake, however sufficient space must be available to store this storm water and treat it through wetlands. To treat .87 MGD through wetlands would require 16 acres of wetlands, and an undetermined amount of gravel pit area. (A range of 20 - 2181 ac-ft would be required depending on the effect of not capturing the entire 10-yr 24-hr runoff, and untreated disposal of excess retained volume.) Maintenance of the lake is possible provided that; 1. Treatment of storm water is successful through a pilot program, 2. there is sufficient land to achieve specific goals of water treatment, and 3. ADEQ allows treatment of the water to take place within a portion of the river bed, but preferably above the 25-yr flow.

To maintain the lined lake with ground water, only one 1 MGD pump would be required. This is however insufficient to fill the lake, or maintain an unlined lake.

Filling the Lake

In order to fill the 2,000 ac-ft lake in 6 months, pumped water would be required at a rate of 4.5 MGD. This would also make up for 0.87 MGD evaporation and seepage losses during filling. Filling the lake with five 1 MGD pumps would be sufficient for the 100 acre lake.

Water Quality Concerns

1. A lake near Central Avenue along the Salt River will be surrounded by hazardous waste landfills, and at least one WQARF site. Lining the lake would reduce complications of seepage between the lake and such sites.
2. The lake must be built off line from the river in order to reduce sediment accumulation during floods.
3. The initial depth of lake, 20 feet, requires further study to consider the possibility of stratification in the lake.
4. Inflow water quality will determine the potential use of the lake for recreation purposes.

VI. BEST AVAILABLE TECHNOLOGY TREATMENT PROCESSES.

6.1 General. This section discusses twelve "best available technology" practices for treating eight constituents which present a problem is the study area. The wetlands treatment process is discussed in the Section on Opportunities because it is not a synthetic treatment, is relatively new, and not yet well established in its potential to remove pollutants. Table 21 presents the potential treatments for water containing specific pollutants found in the study area.

Table 21

Pollutant Versus Treatment

Pollutant	Treatment
Volatile Pesticides	AS
Industrial Solvents	AS
Nonvolatile Pesticides	GAC, RO
Nitrate	ED, RO, Biodenitrification, Anion Exchange, Distillation, Chemical Reduction
DBCP	AS, GAC
Chloride (ref. BW Poln. Control 1985)	IE, ED, RO (evap. ponds, holding basins, deep well injection)
TDS	RO, ED, IE, Distillation
Mercury	Bioremediation

AS - Air Stripping
GAC - Granular Activated Carbon
RO - Reverse Osmosis
ED - Electrodialysis
IE - Ion Exchange

6.2 Air Stripping. Air Stripping is considered a full-scale/innovative treatment process. It removes dissolved gas contaminants through volatilization by greatly increasing the surface area of water exposed to air. Targeted groups are halogenated and non-halogenated volatile organic compounds. It may be used, but is less effective against halogenated and non-halogenated semivolatile organic compounds and fuels. Typical specific constituents treated are carbon dioxide, and hydrogen sulfide, for the purpose of taste and odor removal.

Types of air stripping processes are packed tower aeration (PTA), diffused aeration, tray aeration, and spray aeration. The most effective of these at treating VOCs is the Packed Tower. Water is passed down and air pushed up through a cylindrical shell packed with high-surface-area material. This method is reported to be sufficient to remove volatile pesticides such as DDT and DBCP. However when gas-off treatment is required for emission control, PTA is usually more expensive than Granular Activated Carbon.

6.3 Reverse Osmosis. Reverse Osmosis uses pressure to force water through tube like vessels that contain rolled-up sheets of semipermeable membranes. Water can pass through the membrane sheets, but salt and any other undesirable constituents are left behind. The wastewater left behind is more concentrated but still of large volume and must be disposed of.

This process is good for treating brackish water and meeting future drinking water standards. However it merely concentrates the constituents in the water. Reverse Osmosis can generate drinking water from unusable water. It does not treat pollutants.

6.4 Distillation. Distillation is the mechanical process of removing dissolved and suspended solids by vaporizing water with heat. A pressure tank is traversed by steam coils, and a moisture separator. The removed vapor is then condensed into product water at the outlet. The remaining brine is a slurry which must be disposed of.

Distillation is more expensive than Reverse Osmosis or Electrodialysis and is not a treatment for pesticides or industrial solvents.

6.5 Evaporation Ponds, Holding Basins, Deep Well Injection. Evaporation ponds are designed to allow for evaporation of water leaving a concentrated brine similar to distillation. Unlike distillation, this process does not recover the vaporized water.

Holding basins provide separation through settling and floating. They do not treat dissolved constituents, but are useful, inexpensive part of a treatment system.

Deep well injection of wastewater is being proposed in the Phoenix area for water exchange purposes. Although this process may treat against Chloride, meeting the required standard of 10 mg/l for Nitrates would require further treatment of the wastewater. This treatment would concurrently treat against chlorides and result in water of sufficient quality for uses other than injection.

6.6 Biodenitrification, Bioremediation, Chemical Reduction. Biodenitrification is the ultimate removal mechanism for nitrates. This occurs through anaerobic metabolism in bottom sediments with release of gaseous nitrogen to the atmosphere. This process occurs in a well designed wetlands treatment process.

Bioremediation detoxifies organics through the use of microorganisms. Microorganisms degrade compounds in the dissolved phase, and bacteria converts mercury.

Chemical Reduction chemically converts hazardous contaminants to non-hazardous contaminants or less toxic compounds that are more stable, less mobile, and/or inert. It targets inorganics with effective treatment of non-halogenated volatile and semivolatile organic compounds, fuel hydrocarbons, and pesticides. The reducing/oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, and chlorine, and chlorine dioxide. A combination of these agents, or combination with (UV) oxidation, makes the process more effective. This process is not cost effective for high concentrations due to increased amounts of oxidizing agents required. Efficiency is decreased by oil and grease, therefore this would not be a good initial treatment for storm drain water.

These three treatment processes address an entire pollution problem rather than the smaller spectrum of a water cleaning problem. Unfortunately, they are NOT considered the best available technology for pesticides including DBCP, industrial solvents, or total dissolved solids (TDS).

6.7 **Ion Exchange, Anion Exchange**. Ion Exchange is most extensively used for water softening. It is typically comprised of a bed packed with ion exchange resin beads which are presaturated with an exchangeable ion. Water is passed through the media until the effluent shows contamination. The reactivation of the media requires a regenerant solution and rinsing water in preparation for another treatment cycle.

Ion Exchange is currently considered the best treatment for nitrate removal. The process traps nitrate ions and releases chloride ions. Only recently has a nitrate selective resin been developed. Approximately two percent of treated water becomes wastewater as a result of back flushing the resin with salt water. Although nonhazardous, disposal of this water in the Phoenix area may be difficult in large quantities because it may overtax the wastewater treatment facilities, and it is not suitable for recharge.

The Glenwood Project in Southern California had the following results from an Ion Exchange system which was designed to remove nitrates from a ground water supply.

- Began Operation in July 1989
- Capacity = 1600 gpm (2.3 MGD)
- Cost = $127 per acre-foot (1990 dollars at 4.5 percent APR and 20 year life expectancy)
- Initial and final water quality measurements are as follows:

Constituent	Raw	Treated
Nitrate	99 mg/l	23 mg/l
Sulfate	88 mg/l	0 mg/l
Chloride	61 mg/l	187 mg/l
Bicarbonate	181 mg/l	145 mg/l

In 1990, Boyle Engineering proposed construction of a 10.4 MGD Ion Exchange Plant for the City of Phoenix. Treatment cost was determined at that time to be 30 percent less than the Central Arizona Project (CAP) water. The plant was not constructed, and plans to do so are unknown by City officials.

6.8 **Granular Activated Carbon (GAC)**. The full scale/conventional technology of Granular Activated Carbon is a method that captures dissolved organic contaminants by passing water through a series of canisters containing activated carbon which adsorbs the organic contaminants. Periodic replacement or regeneration of saturated carbon is required. Effectiveness may be limited to metals, carbon pore size, and operating temperature. Target groups are halogenated and non-halogenated semivolatile organic compounds with potentially useful but less effective treatment of halogenated volatile organic compounds, fuel hydrocarbons, pesticides, and inorganics. DBCP has been specifically and successfully removed from Fresno California well water using a GAC system designed by Boyle Engineering.

Granular Activated Carbon systems are commercially available, but are rated worse for overall cost. Although GAC successfully removes organics from water, there still remains the problems of either; a) disposing of the carbon resin, or b) regeneration through burning the constituent from the walls of the carbon pores, which then may be dispersed into the air.

6.9 **Electrodialysis**. Electrodialysis removes dissolved solids from water under an electric potential gradient. Cation and anion-permeable membranes are used alternately in a cell with alternatively charged electrodes on each side. When an electromotive force is imposed, all

positive ions move toward the anode and all negative ions move toward the cathode. Electrodialysis reversal (EDR reverses the charge intermittently in order to defer clogging the membranes thus extending the time between regenerating and virtual life of the membranes.

EDR is currently being used in Tolleson, west of Phoenix, to remove nitrates from their groundwater. The treated water is blended with untreated water and distributed to the municipal water supply. Their regenerating brine is sent to the 91st Avenue Treatment Plant.

6.10 Summary. In summary, there are many physical treatment processes for the problem constituents in this area. However, in order to treat a combination of pollutants, it is apparent that a combination of treatment processes would be required. This results in costly treatment processes. The wetlands, however, is reported to treat, not just separate, almost everything except Total Dissolved Solids (TDS). Wetlands treatment may be the "Best Management Practice" for treating the water sources of concern in this study.

References

1. Remediation Technologies Screening Matrix, United States Environmental Protection Agency and Air Force, July 1993

2. Journal of Environmental Quality, vol 20, Oct-Dec 1991, Number 4, "Drinking Water from Agriculturally Contaminated Groundwater." by Goodrich, Lykes, and Clark.

3. A Regional Groundwater Flow Model of the Salt River Valley - Phase I, Phoenix Active Management Area, Hydrogeologic Framework and Basic Data Report, Corkhill, Corell, Hill, and Carr. ADWR, April, 1993.

4. A Regional Groundwater Flow Model of the Salt River Valley - Phase II, Phoenix Active Management Area, Numerical Model, Calibration, and Recommendations, Corkhill and Corell, ADWR, March 1994.

5. Draft Arizona Water Resources Assessment, Volumes I and II, ADWR, August 1993

6. Rio Salado Water Resources Master Plan, Draft Technical Memorandums 1-7, CH2M Hill, July 1992 Reprint

7. Rio Salado Town Lake Feasibility Study, CH2M Hill, April 1992

8. Rio Salado Engineering Report,CH2M Hill, August 1992

9. Groundwater Quality in the Major Basins of Maricopa County, Phoenix Urban Study, USACOE, Schmidt , Dec 1978

10. Indian Bend Wash, General Design Memorandum Phase II, USACOE, May 1975

11. Central Maricopa County Drainage Area, Reconnaissance Study, USACOE, June 1992

12. Salt River Project, Annual Water Quality Report, 1993

14. Draft Nonpoint Source Assessment Report, ADEQ, 1988

15. Directory of Arizona Closed Solid Waste Landfills, ADEQ, March 1993

16. Directory of Arizona Municipal Solid Waste Landfills, ADEQ, March 1993

17. NPDES, Discharge Monitoring Reports, 23rd and 91st Avenue WWTP, City of Phoenix, May-June 1994

18. Selected Physical, Chemical, and Microbial Characteristics of Storm Water, Maricopa County, Arizona, USGE, Lopes, Phillips, and Fossum, Sep 1992

19. Developing Integrated Management Strategies for Groundwater Production, Recharge, and Protection in the Salt River Valley, Schmidt, Sep 1989

APPENDIX E
GEOMORPHIC ANALYSIS

GEOMORPHIC ASSESSMENT OF THE LOWER SALT RIVER, CENTRAL ARIZONA

by

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EXECUTIVE SUMMARY

This report supports a reconnaissance-level geomorphologic evaluation of the Lower Salt River and a portion of the Gila River in the Phoenix metropolitan area of central Arizona. In addition to providing concepts and reviews, the report is a source document for photographic and numerical data. Because it was prepared in a short period of time, the report is at a reconnaissance level.

The environmental history of the river in this study area is one of dessication through irrigation diversions and groundwater pumpting, damaging flood flows accompanied by destructive channel instability and downcutting, and loss of riparian vegetation. Between the late 1800s and the present, the hydrologic regime of the river has been changed from one characterized by perennial flow punctuated by high early spring discharges and occasional large floods to its present condition of no natural flows and only sporatic floods created by dam releases and/or spills. Pumping has lower the groundwater table up to several hundred feet in the portions of the study area, but in the vicinity of the confluence of the Salt and Gila Rivers it remains within a few feet of the surface because of shallow bedrock and continuous irrigation return flows in the Gila system.

The geomorphology and riparian ecosystem of the river have changed in response to the adjustments in hydrology. Under natural conditions the channel was a sand-bed braided configuration, but hydrologic changes have converted it to a compound channel, with a slightly meandering low flow channel nested inside a wider braided one. Erosion by flood flows have stripped the sand strata from the channel floor and uncovered the underlying boulder and cobble layer. The eyewitness accounts and historical photographes reveal that before extensive development of the region, much of the channel was without vegetation, with bands of cottonwood and willow along the edges. The lowest terrace, which in many cases may have acted as a flood plain, was often covered by mesquite bosques. During the early 20th century, tamarisk (salt cedar), an exotic plant native to the Mediterranean area, spread throughout the previously barren areas and created dense forests and thickets across throughout the channel system. Cottonwoods and mesquite were cut for human use, and the Lower Salt River became part of the 85 percent of the natrual riparian environments lost in Arizona within the last century. In some reaches, particularly the Tempe Rio Salado area and in Phoenix, channelization has imposed a designed configuration. Under present conditions, the channel of the stream in the study area ranges from completely artificial in the urbanized area to essentially natural in the Salt and Gila confluence area.

It is not possible to restore the present system to its predevelopment condition because of limitations associated with hydrology as well as urban and agricultural development. The present condition of the river as derelict land should not continue, however, and the river may be viewed as a restoration opportunity wherein a compromise position between the two extremes is possible. Without restoration and associated flood control projects, those reaches of the Lower Salt River that are engineered will be endangered by flows in the channel because of the mobility of bed materials and erosion

associated channel instability. Injections of sediment from Indian Bend Wash, a constructed channel that is a Corps of Engineers project, will cause significant problems in the main stream. The prospects of an improvement in the riparian ecosystem through increased coverage of natural vegetation and reduced coverage of exotic tamarisk are minimal without investment in environmental restoration projects.

Such projects include the management management of dam releases to permit trickle flows during spring months, management of stormwater and agricultural runoff in constructed ecosystems with artificial perched water tables, and the maintenance of artificial riparian ecosystems with pumped and treated groundwater. Temporary storage reservoirs retained by inflatable dams in northeast Mesa might be effective in increasing the availability of water in low flow months, but linings of the reservoirs to reduce lateral transmissivity would be required.

Additional potential projects included in a restored Lower Salt River are the development of Granite Reef Dam into a museum and visitor center as a cooperative effort among local water agencies, the conversion of the Jointhead Dam area east of Sky Harbor into an environmental and historical museum and working riparian restoration area for public visitation. The establishment of a Salt and Gila River Data Center to reduce duplicative study efforts and provide public access to documents should be administered by the Corps of Engineers as the primary integrative river management agency for the river in the metropolitan area.

Constraints on restoration projects include problems with flood control (water and sediment), water quality, and private property rights. Social issues also present problems, including the displacement of homeless people now living in the river bed area, crime that might be aided by the development of restored areas, and neighborhood destruction.

Disclaimer: This report expresses the opinions of its authors, and does not necessarily represent opinions or policies of the U.S. Army Corps of Engineers or Arizona State University.

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1 INTRODUCTION

1.1 The Lower Salt River

The Salt River drains 14,500 square miles of mountainous, desert terrain in central and eastern Arizona. The stream rises in the White Mountains of eastern Arizona and flows generally westward to its junction with the Verde River, a northern tributary draining the edge of the Colorado Plateau near Flagstaff. From this junction near Mesa, the Salt River flows westward across the broad Salt River Valley to its confluence with the Gila River. The Gila continues westward to its great bend in the Arlington and Gila Bend area, and thence west to Yuma where it empties into the Colorado River. The Phoenix metropolitan area is situated near the center of the Salt River Valley, and includes the lowest reaches of the Salt River as well as a portion of the Gila River below its confluence with the Salt. During the twentieth century, the Phoenix area has changed from an agricultural region to an urban region, resulting in significant changes in the physical characteristics of the rivers. Agricultural and urban activities have given rise to an intricate network of structures associated with the river for irrigation, drainage, erosion protection, and flood control. Numerous upstream dams on the Salt and Gila rivers have radically altered the hydrologic regime of the streams, causing further changes in the channels. After damaging floods in 1978, 1980, and the early 1990s, environmental managers have sought a clearer understanding of river forms and processes that are now partly natural, but significantly modified. This understanding is a prerequisite for choosing among alternative management strategies for the rivers as managers seek to balance competing interests of flood control, habitat enhancement and wildlife protection, recreation, water quality, and a range of aesthetic considerations.

The purpose of the present report is to assess the past and present geomorphic conditions of the Lower Salt River and a portion of the Gila River in the Phoenix metropolitan area (Figure 1; see Appendices 8.1 for general locations and 8.2 for specific locations). This report is related to a recent, similar geomorphological assessment for the Lower Gila River, a reach of the Gila extending from the vicinity of Gillespie Dam in the Arlington area to Yuma (Graf *et al.*, 1994). Some broadly defined descriptive and bibliographic information is the same in the two reports, but they are generally separate, address different areas, and explore different specific issues.

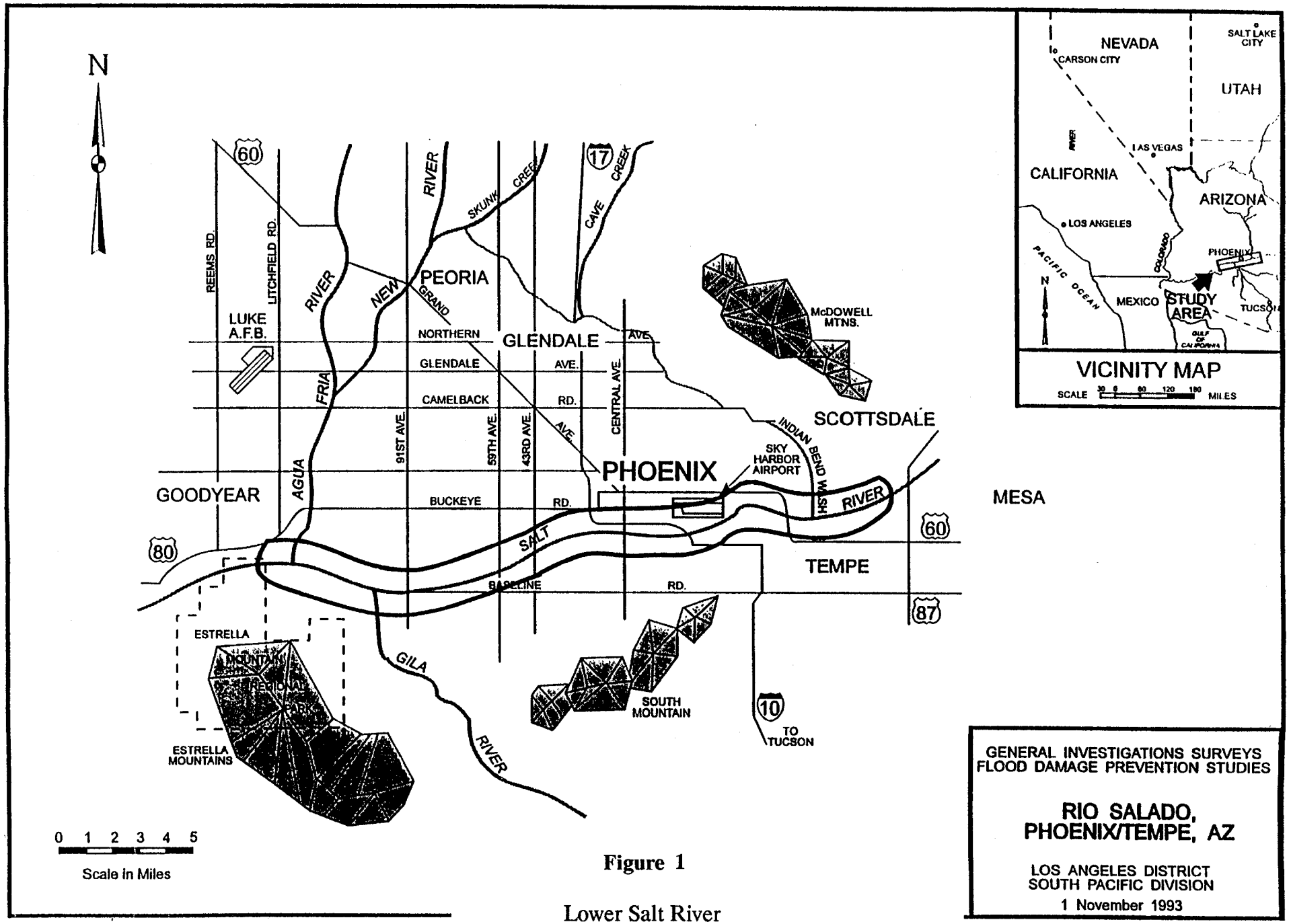
1.2 The Institutional Setting

Several governmental agencies have administrative interests in the Lower Salt and Lower Gila rivers. Upstream dams were built by or are operated by the Bureau of Reclamation, Bureau of Indian Affairs, and the Salt River Project, while the Corps of Engineers built and operates a major flood control structure downstream from the study area (Table 1). In Maricopa County, which encompasses the entire study area for this report, municipalities have direct interests in management of the rivers, and the Maricopa County Flood Control District is the primary entity for flood protection.

The U.S. Army Corps of Engineers has a long history of river engineering

US ARMY ENGINEER DISTRICT

CORPS OF ENGINEERS



GENERAL INVESTIGATIONS SURVEYS
FLOOD DAMAGE PREVENTION STUDIES

RIO SALADO, PHOENIX/TEMPE, AZ

LOS ANGELES DISTRICT
SOUTH PACIFIC DIVISION
1 November 1993

Figure 1

Lower Salt River

ARPL1.CDR

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).

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 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 Salt River. Though the Corps has not built local channel facilities along the Lower Salt River, 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 Corps of Engineers has several proposed projects related to the Lower Salt River. Although it is not known which, if any, of the projects may eventually be completed, they represent an indication of the interest of the Corps in the study area (Table 2).

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).

The Salt River Project grew out of an association of irrigators in the Salt River Valley. Irrigation has been conducted in the Salt River Valley since at least 300 AD when the Hohokam people grew corn, beans, and squash with water from canals connected to the rivers. Modern irrigation began in 1867 with the opening of canals to provide water near the present site of Phoenix. Jack Swilling, an ex-Confederate cavalry soldier re-excavated some ancient canals, delivered water to crops, and ignited interest in water development for agricuture in the area (Salt River Project, 1983). Swilling simply cleaned sediment from the preexisting canals once used

Table 2. U.S. Army Corps of Engineers, Proposed Projects on the Lower Salt River.

(Source: U.S. Army Corps of Engineers Memo, P. Atonna to P. LeBrun, June 1, 1994)

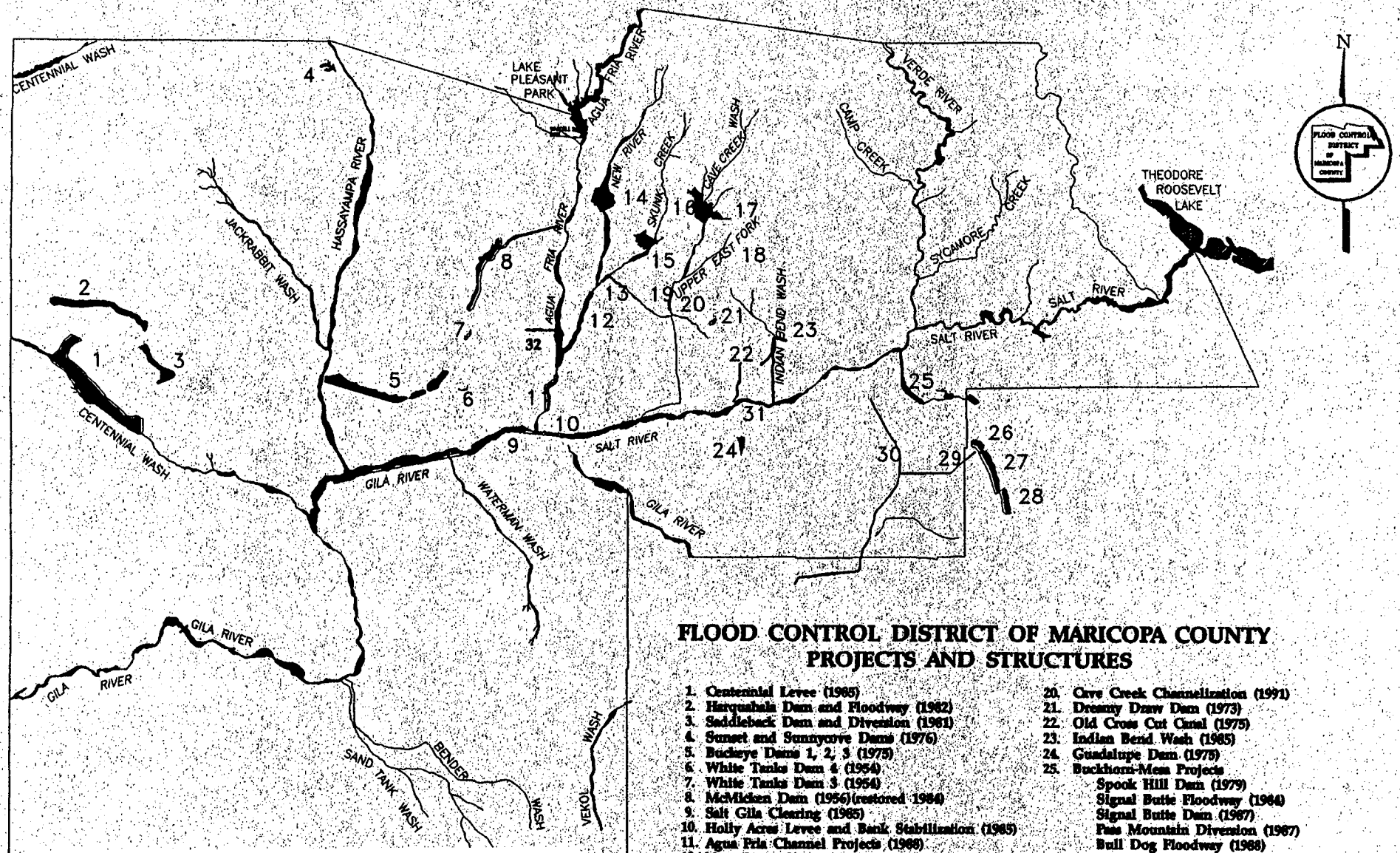
Location	Activity
Tempe to 35th Avenue	Reconfigure floodway to provide low flow channel, terraces to serve as substrate for revegetation and public recreation facilities
Granite Reef Dam to Agua Fria River	Revegetation for riparian zones
Granite Reef Dam to Agua Fria River	Reintroduction of native wildlife to restored and created habitat areas
Granite Reef Dam to Agua Fria River	Install bank protection for landfill sites
16th Street to 7th Avenue	Construct a permanent lake adjacent to the downtown area for recreation
Granite Reef Dam to Agua Fria River	Develop master plan for water releases from upstream dams
Granite Reef Dam to Agua Fria River	Develop master plan for reclamation of present sand and gravel mining sites and planning for future sites
Granite Reef Dam to Agua Fria River	Construct wetland treatment facilities at all major stormwater outfalls
35th Avenue to Agua Fria River	Develop a master plan and construct channel and bank configurations to serve multiple uses
Granite Reef Dam to Agua Fria River	Develop water supplies for free flowing stream to sustain habitat areas
24th Street to 67th Avenue	Develop a series of park and recreation sites: a. Sports Park, south bank, 16th-24th Streets b. Rio Salado Golf Course, Park, landfill site, south bank, 7th-16th Streets c. Esperanza Park, north bank, 7th Street-Central Avenue d. Promesa Park, south bank, 7th Street-Central Avenue e. Union Rock Urban Lake, south bank, east of 7th Avenue f. Ecology Study Center, north bank, 23rd Avenue Wastewater Plant outfall-35th Avenue g. Laveen Recreation Area, south bank, 35th-51st Avenues h. Cedars Shores Recreation Area, north side, 51st-67th Avenues

by the Hohokam. Through the following two decades, canal development in the Salt River Valley spread widely, but control of the flow of the Salt River was problematic: it was too low in the summer, and winter or spring floods constantly damaged irrigation works. In 1889, the Committee on Irrigation and Arid Lands of the U.S. Senate visited the area as part of its investigation of the possibility of federal support for irrigation developments that were too expensive for local interests to fund. After considerable debate at the federal level, President Theodore Roosevelt signed the National Reclamation Act (also known as the Newlands Act) into law on June 17, 1902. The act provided for the formation of the U.S. Reclamation Service (later renamed the Bureau of Reclamation) and the expenditure of federal funds to support construction of dams and delivery systems for irrigation districts. The Salt River Project (SRP) was created in 1903 as an entity to negotiate with the federal government for large-scale construction projects for the storage and delivery of irrigation water (Smith, K. L., 1986).

Until the mid-twentieth century, SRP was primarily a water-storage and delivery agency for agricultural users, but after World War II, the Phoenix urban area grew rapidly, and the mission for SRP changed. In 1903, the local community included fewer than 20,000 persons, by 1967 it had grown to 800,000, and in 1994 the population approached 2 million. To accommodate the shift from agricultural to urban emphasis, SRP adjusted to deal with urban water delivery issues, and it became a major component of the regional electrical power grid (Smith, C. L., 1972). SRP operates the six major dams upstream from the metropolitan area on the Salt River, and therefore must be taken into account in any plans for managing river flows and floods through the urban area. SRP also owns land parcels in and near the river channel.

The Flood Control District of Maricopa County (FCDMC) is also a primary agency involved with the management of the Lower Salt River and the portion of the Gila River included in the present study. Although Maricopa County had undertaken some flood control efforts on a relatively small scale before the early 1980s, widespread, coordinated projects became much more common after the Arizona State Legislature mandated the formation county flood control districts (Arizona Revised Statutes, Section 48-3601). The flood control district builds various flood control structures, often in cooperation with other agencies such as the Arizona Department of Transportation and the U.S. Soil Conservation Service. In addition, the FCDMC manages flood-plain development by delineating flood plains and administering regulations for flood-plain users. The FCDMC coordinates the participation of the county in the National Flood Insurance Program (NFIP, administered by the U.S. Department of Housing and Urban Development), as established by Congressional action in 1968 and revised in 1973. The availability of federally insured loans and other federal assistance related to flood plains is dependent on adherence to federal and state rules and regulations as administered by the Flood Control District. In exercising its responsibilities, the Flood Control District has completed 32 projects and structures within Maricopa County, including vegetation clearing projects, levees, bank stabilization, and channel improvements (Figure 2).

The municipalities of Mesa, Tempe, and Phoenix have direct interests in the Lower Salt River because the stream flows directly through their jurisdictions. Tempe and Phoenix have direct construction interests in the channel. Tempe has committed itself to an ambitious effort to convert five miles of the Salt River Channel and adjoining areas into a variety of land uses ranging from habitat reconstruction to intensive commercial and residential activities. In 1989, the city



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY PROJECTS AND STRUCTURES

1. Centennial Levee (1985)
2. Harquahala Dam and Floodway (1982)
3. Saddleback Dam and Diversion (1981)
4. Sunset and Sunnycove Dams (1976)
5. Buckeye Dams 1, 2, 3 (1975)
6. White Tanks Dam 4 (1954)
7. White Tanks Dam 3 (1954)
8. McMicken Dam (1956)(restored 1984)
9. Salt Gila Clearing (1985)
10. Holly Acres Levee and Bank Stabilization (1985)
11. Agua Fria Channel Projects (1968)
12. New River Channelization
13. Skunk Creek Channelization (1991)
14. New River Dam (1985)
15. Adobe Dam (1984)
16. Skunk Creek Channels and Levee (1985)
17. Cave Buttes Dam (1980)
18. East Fork Cave Creek
19. Arizona Canal Diversion Channel (1993)
20. Cave Creek Channelization (1991)
21. Dreamy Draw Dam (1973)
22. Old Cross Cut Canal (1975)
23. Indian Bend Wash (1985)
24. Guadalupe Dam (1975)
25. Buckhorn-Mesa Projects
    - Spook Hill Dam (1979)
    - Signal Butte Floodway (1984)
    - Signal Butte Dam (1987)
    - Pass Mountain Diversion (1987)
    - Bull Dog Floodway (1988)
    - Apache Junction Dam (1988)
26. Powerline Dam (1967)
27. Vineyard Dam (1968)
28. Rittenhouse Dam (1969)
29. Powerline Floodway (1968)
30. East Maricopa Floodway (1989)
31. Salt River Channel
32. Dysart Drain

Figure 2

Projects of the Flood Control District of Maricopa County

adopted the Tempe Rio Salado Master Plan to guide the development under the general direction of the City of Tempe Community Development Department (Figure 3). The Arizona Department of Transportation, in association with the Red Mountain Freeway on the north bank of the river, channelized the stream from the Hohokam Expressway (roughly the alignment of 48th Street) and Mill Avenue, and the Flood Control District of Maricopa County extended the project upstream to McClintock Drive, a short distance upstream from Indian Bend Wash (a Corps of Engineers Project). The channel design includes grade control structures to limit scour, channel migration, and degradation, and the general capacity of the channel is 250,000 cubic feet per second. The expected 100-year flood for the reach after the nearly-complete improvements to Roosevelt Dam is 160,000 cubic feet per second. The redesigned channel removes about 850 acres of land from the previously defined flood plain (City of Tempe, 1993).

1.3 Purpose and Scope of this Report

This report was commissioned under the provisions of Contract DACW09-94-M-0494, U.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 Salt 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 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 3).

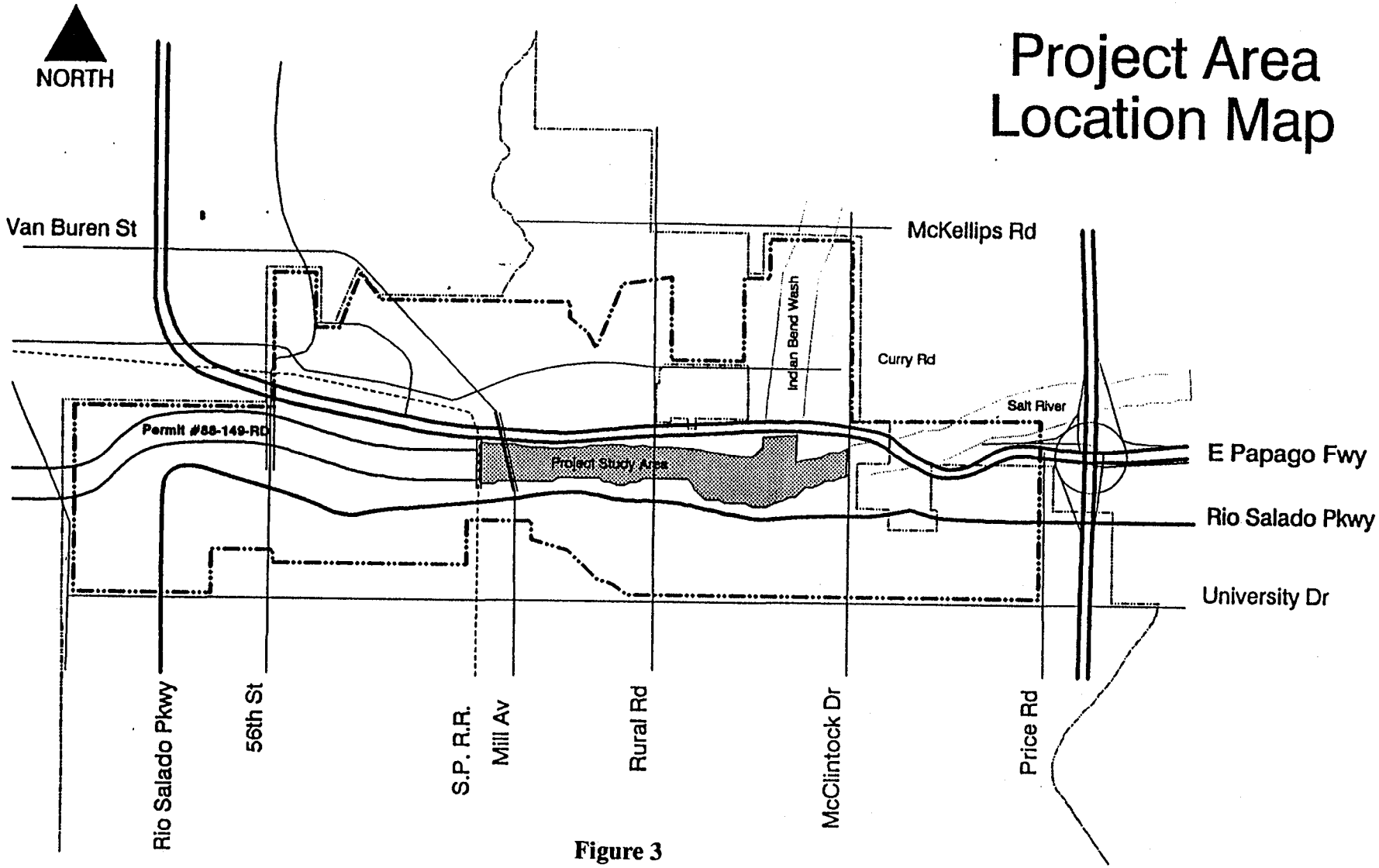


Figure 3

Tempe Rio Salado Project Area

Table 3. General Corps of Engineers project process.

(Source: Goldfarb, 1988, p. 80-82)

	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

1.4 Significance of the Lower Salt River

1.4.1 Urban Significance

The Lower Salt River provides water to the most largest and perhaps most important metropolitan area in the interior southwestern United States. The area is diverse, both culturally and economically, with the bulk of the economy relying on high tech manufacturing, government, non-tourist services, trade and construction. The river is part of the social, economic, historical, and natural landscapes of the region, and management of the river takes place within a complicated urban context.

The greater Phoenix area is an urban center consisting of 25 cities, covering 9,226 square miles of land in Maricopa County. It has a population of 2.2 million people, making it the 20th largest metropolitan area in the United States and the largest metropolitan area in the Rocky Mountain Region. The population in the greater Phoenix area accounts for 58% of the total population in the state of Arizona (SRP, 1993). From 1981 to 1991 in-migrations have exceeded out-migrations. In 1993 the bulk of the in-migrations came from California (79,214), Colorado (25,228), Illinois (23,781), Texas (23,491), New Mexico (12,006), Utah (11,708). Despite being a favorite area for retirees, the Valley's median age is 32, which is lower than the national figure (Meyer *et al*, 1993).

Employment growth has kept pace with the population growth, and as of May 1994 the unemployment rate for the greater Phoenix area was 4.6 percent compared to 6.0 percent at the national level and 5.9 percent at the state level (Az. Workforce, 1994). Total employment for the state of Arizona (May, 1994) is approximately 1.9 million of which 1.21 million are employed in metropolitan Phoenix. The Valley has sustained an annual growth rate over the past 43 years has been 6.3 percent. Much of the employment growth is in response to the population growth, but the location of Phoenix also plays a major role. Phoenix is centrally located between Texas, California and Mexico markets and can be reached in two hours by plane from most of these markets.

Sky Harbor International Airport plays a vital role in the Phoenix metropolitan area economy. It is the seventh busiest airport in the United States, and it is served by all the major airlines (SRP, 1993). Statistics for 1988 showed that the airport had an $11.7 billion dollar economic impact on the greater Phoenix area (College of Business, 1989). On a daily basis the airport's economic impact is roughly $32 million dollars. The direct employment of the airport (1988) was 21,497, and the total employment involved with the airport services was 199,219 (College of Business, 1989). On a given day in 1988, 461 airliners arrive and depart from Sky Harbor airport, carrying 43,629 passengers to and from the Valley. In 1988 over 15 million people used Sky Harbor. There were also 276 tons of air cargo a day moved in 1988 (100,740 tons a year). Products from the Phoenix metropolitan area are exported via Sky Harbor International Airport to Mexico, United Kingdom, Japan, Canada, Taiwan, Malaysia, Germany, France, Hong Kong and South Korea. In 1992 the total state exports brought in $6.2 billion (Meyer *et al.*, 1993).

The top 10 employers in Maricopa County during 1993 were the State of Arizona

(34,000), Motorola (20,000), Maricopa County (11,975), Samaritan Health System (11,873), Allied Signal Aerospace Co. (10,500), City of Phoenix (10,227), Honeywell (8,250), America West Airlines (7,743), Arizona State University (7,500), American Express Travel Related Services Co. (7,000) and Arizona Public Service Co. (7,000) (Meyer and others, 1993). Other large employing fields are construction (57,400), trades (252,000), finance, insurance, real estate (75,700), and services (297,600) (Meyer and others, 1993). Fifty percent of Phoenix's manufacturing jobs are within the high tech fields of electronic components, aerospace, computers, scientific instrumentation and telecommunications (SRP, 1993). This can be compared to the national level, where only 16% of manufacturing jobs are in the high tech industries. The 10 largest manufacturing firms in metropolitan Phoenix are: Motorola Inc., Allied Signal Aerospace Co., Honeywell Inc., Intel Corp., AT&T Network Cable Systems, McDonnell Douglas Helicopter Co., Cyprus Copper Co., Phoenix Newspapers Inc., Phelps Dodge Corp., and Karsten Manufacturing Corp. (Meyer *et al.*, 1993).

The Phoenix area is also the focal point for the health care industry, including the 350,000 square foot Mayo Clinic in Scottsdale. Other major health care institutes include the Good Samaritan Medical Center, Phoenix Children's Hospital, Barrow Neurological Institute, the Maricopa Burn Center and Arizona Heart Institute. Education in the greater Phoenix area also plays a significant role in terms of the economy and the labor force. Arizona State University has an enrollment of 44,000 students and offers 88 different bachelor's programs, 97 programs for master's degrees and 52 doctoral degree programs. ASU had to construct a new campus (ASU West) in the fall of 1988 to serve to the needs of the growing population and the technology firms. A third campus may be opened in the future in the Southeast Valley (SRP, 1993). There is also a strong community college district (Maricopa Community College District), which is the second largest in the nation, with nine colleges, two college-centers, a skill center and 89,735 students enrolled (1992). The community college district has developed several customized training programs that support the local businesses and industries.

Phoenix also has several cultural and tourist attractions, which further supplement the quality of life as well as the economy. More than 20 museums can be found in the Valley, including the renown Heard Museum of Anthropology and Primitive Arts. Phoenix Symphony Hall is home to the Phoenix Symphony Orchestra, Ballet Arizona and many other visiting musical performers. There is also the Scottsdale Center for the Arts, the Herberger Theater, the Sun Dome, Phoenix Art Museum, Taliesen West, Gammage Auditorium, Desert Sky Pavilion, the Red River Opry and America West Arena. The Phoenix Zoo, the largest privately supported zoo in the nation, is another large attraction and the Desert Botanical Garden contains one of the largest collections of desert plants in the world. The metro Phoenix area is home to 8 of the top 25 Arizona tourist attractions (Meyer *et al.*, 1993).

Urban Phoenix offers participating and spectator sports. Greater Phoenix has more than 120 golf courses and 1000 tennis courts. The mountains that ring the valley also provide excellent hiking, walking, horse riding and mountain biking trails. Spectator sports also abound, Phoenix Suns, Arizona Cardinals, Phoenix Roadrunners, Phoenix Firebirds, and Phoenix Cobras. In the spring the Cactus League plays a major role in the local sports scene, from March to April

million in revenue (Meyer *et al.*, 1993). There are numerous PAC-10 collegiate athletic activities available at Arizona State University. The area also hosts the New Year's Day Fiesta Bowl football game. In the next two years Phoenix will host the NBA All-Star Game (Feb. 1995) and the NFL Super Bowl (Jan. 1996).

1.4.2 Agricultural Significance

In addition to the urban context, the Lower Salt River is also part of the agricultural matrix of the region. Management of the river directly affects agricultural activities because the river supplies irrigation water and is located near much of the agricultural land. Protection and enhancement of agricultural lands are part of any overall management plan for the river.

Cultivation of crops in the Valley began around 300 B.C., with the rise of the Hohokam Indians. The Hohokams were an agriculturally based society relying heavily upon the water flowing in the Salt River. They developed a series of brush dams and a network canals in and around what is today Phoenix to supply water. Some of these canals are still present today. In the 1860' and 1870's settlers from the Church of Jesus Christ of Latter Day Saints (the Mormons) in Salt Lake City came to the region to acquire additional agricultural land. They settled for the most part in the Lehi and Mesa townships in 1877 and 1878 respectively. In many cases the Mormons cleaned and reused the canals built by the Hohokam civilization.

As population increased in the late 1800s and early 1900s and farmers had to battle with floods, droughts and other water problems, and there was an urgent need to deliver a more constant flow of water for irrigation (Figure 4). The Salt River Water Users Association was developed in order to acquire the needed funding for the construction of storage (Roosevelt) and diversion (Granite Reef) dams. The federal government also bought the existing canals to integrate them into one organization for the purpose of developing a consistent flow of water to the surrounding communities. The Salt River Project (SRP) later evolved out of this integrated system, because there was a need to negotiate with the Bureau of Reclamation. At present SRP is the operating body of a much more extensive systems of canals and dams that supply water to metropolitan Phoenix.

The main crops presently grown in the SRP district are compiled in Table 4. The SRP farming district accounts for 9 percent of the total acres covered by these crops in the state of Arizona. On the national scale (1990), the SRP farming district accounts for approximately 0.003 percent of the total acreage covered by these crops and 0.002 percent of the national value of these crops. The major cash crops for this area are alfalfa and other hay, cotton, nursery-flowers and onions. The four most extensive crops in terms of acreage are alfalfa and other hay, cotton, sorghum and wheat. The value of the agricultural crops in the SRP district has generally declined from 1990 to 1993, even though more land was planted in 1993 than 1990 (SRP Crop Reports 1990-1993). From 1990 to 1993 the gross yield per acre dropped from $788.95 to $642.54. The decline may be the result of numerous causes, including urban encroachment onto farmlands, farming of marginal lands, cost of irrigation, ground water quality, market values and market needs. It would appear that the overall agricultural significance of SRP district is at the local level, rather than the state or national level.

Figure 4. Flood damage from the 1905 event in Tempe: a rail bridge east of the present Mill Avenue Bridge. View is from the north bank, looking south, with the flank of Tempe Butte on the left. Wreckage from the bridge remained in the channel at the location shown here until it was removed in 1987 during channelization for the Tempe Rio Salado Project (U.S. Reclamation Service Photograph 555, U.S. Geological Survey Photography and Field Records Library, Denver)

Table 4. Crops in Maricopa County, Arizona.

(Sources: SRP Corp. Report, 1993; Agricultural Statistics, 1991; Arizona Statistical Abst., 1993)

CROP	Acres (1993)	Value (1993)	Acres (1990)	Value (1990)	Tot. Az. Acres (1991)	Tot. U.S. Acres (1990)	Tot. U.S. Value (1990)
Barley	1153	$299,780	1192	$350,448	20000	8201000	$905,923,000
Sorghum	2499	$589,389	1045	$236,588		10535000	$1,201,581,000
Wheat	2474	$755,807	1818	$621,756	68000	77286000	$7,298,833,000
Alfalafa & Other Hay	45932	$19,560,813	44278	$21,791,368	200000	26750000	$11,138,492,000
Cotton (upland)	21980	$14,092,917	23026	$18,518,430	359000	12196800	$4,923,943,000
Cotton Seed		$2,758,490		$2,467,466			$739,238,000
Cotton (Am. Egypt)	121	$73,756	2409	$2,043,579	103000	231700	$182,650,000
Cotton Seed		$10,196		$175,375			
Lettuce	24	$60,900	256	$748,851	#	231300	$846,973,000
Onions	259	$2,445,343	91	$410,865	#	138340	$488,786,000
Potatoes	85	$206,869	0	$0	6000	1388200	$2,409,052,000
Cantaloupes	287	$957,002	258	$768,453	#		
Grapefruit	589	$591,491	662	$3,859,460	6200	133400	$380,764,000
Lemons-Limes	107	$253,349	17	$79,662	15400**	68300	$322,393,000
Oranges-Tangerines	1032	$901,731	1165	$2,714,963	13600	632900	$1,749,743,000
Pecans	26	$67,860	12	$20,741			$247,590,000
Nursery-Flowers	318	$5,776,680	310	$5,577,830			$502,551,000
Totals	76886	$49,402,373	76539	$60,385,735	875200	247556940	$33,338,512,000

These items were all considered under one category of vegetables (84,000 acres) and the 84,000 acres are included in the 1991 total.
** This number includes only the total acres of lemons.

1.4.3 Environmental Significance

The Salt 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, though in some reaches wastewater effluent provides a small flow of water in the bed of the stream. The biological environment depends upon the landscape or the river for a substrat and upon its water for survival.

The riparian vegetation along the channels of the Lower Salt River 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 complex. The riparian vegetation is greatly effected by the high water flows. In many cases the riparian vegetation is located on the terraces that have been created during flood events. At present most of the communities 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 salt cedar-willow-arrow weed complexes have filled the niche created by human disturbances. In most reaches of the river the salt cedar-willow-arrow weed complexes make-up approximately 95-100% of the riparian vegetation. The most prominent species in the salt cedar-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 as endangered species.

The fish and wildlife species have been cataloged in Table 5. 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 Salt River. It does however, give the scope of the species that inhabit the different ecosystems. The riparian vegetation and artificial effluent dominated wetland areas support most of these wildlife species. In some cases the migratory birds also use agricultural fields for food and cover, especially fields where grasses are grown. At this time, there are no endangered species known to inhabit the study area. There are possibly two Federally listed candidate species: Mexican garter snake (*Thamnophis eques*), and lowland leopard frog (*Rana yavapaiensis*). Candidate species are those species that may warrant either a listing of endangered or threatened status at the state or federal level. Other endangered and candidate species may periodically inhabit this area, but most of these species are located outside of the present study area.

Table 5. Common Plant and Animal Species Along the Lower Salt River.

(Source: Bureau of Reclamation, 1993)

Common Names	Scientific Names	Common Names	Scientific Names
Birds		**Birds**	
lesser nigthawk	Chordeiles acutinpennis	northern rough-winged swallow	Stelgidopteryx serripennis
black pheobe	Sayornis nigricans	common raven	Corvus corax
mourning dove	Zenaida macroura	cactus wren	Campylorhynchus brunneicapillus
white-winged dove	Zenaida asiatica	northern mockingbird	Mimus polyglottos
Gambel's quail	Callipepla pambelii	black-tailed gnatcather	Poilioptila melanura
black-crowned night heron	Nycticorax nycticorax	ruby-crowned kinglet	Regulus calendula
green-backed heron	Butorides striatus	phainopepla	Phainopepla nitens
great blue heron	Ardea herodias	European starling	Sturnus vulgaris
Gadwall	Anas strepera	Bell's vireo	Vireo bellii
mallard	Anas platyrhynchos	yellow-rumped warbler	Dendroica coronata
green-winged teal	Anas crecca	common yellowthroat	Geothlypis trichas
cattle egret	Bubulcus ibis	**Mammals**	
great Egret	Casmerodius albus	coyote	Canis latrans
American wigeon	Anas americana	gray fox	Urocyon cinereoargenteus
cinnamon teal	Anas cyanoptera	raccoon	Procyon lotor
ring-necked duck	Anthya collaris	striped skunk	Mephitis mephitis
lesser scaup	Anthya affinis	cactus mouse	Peromyscus eremicus
common merganser	Mergus merganser	deer mouse	Peromyscus maniculatus
turkey vulture	Cathartes aura	southern grasshopper mouse	Onychomys torridus
Cooper's hawk	Accipiter cooperii	white-throated woodrat	Neotoma albigula
Harris' hawk	Parabuteo unicinctus	desert cottontail	Sylviagus audubonii
red-tailed hawk	Buteo jamaicensis	black-tailed jackrabbit	Lepus californicus
osprey	Pandion haliaetus	western pipistrelle	Pipistrellus hesperus
American kestrel	Falco sparverius	big brown bat	Eptesicus fuscus
killdeer	Charadrius vociferus	**Reptiles**	
greater yellowlegs	Tringa melanolueca	Sonora mud turtle	Kinosternon sonoriense
spotted sandpiper	Actitis macularia	spiny softshell	Trionyx spiniferus
black pheobe	Sayornis nigricans	banded gecko	Coleonyx variegatus
blue grosbeak	Guiraca caerulea	lesser earless lizard	Holbrookia maculata
summer tanager	Piranga rubra	greater earless lizard	Holbrookia texana
Gila woodpecker	Melanerpes uropygialis	long-tailed brush lizard	Urosaurus graciosus
verdin	Auriparus flaviceps	tree lizard	Urosaurus ornatus
Bewick's wren	Thryomanes bewickii	side-blotched lizard	Uta stansburiana
loggerhead shrike	Lanius ludovicianus	regal horned lizard	Phrynosoma solare
least sandpiper	Calidris minutilla	western whiptail	Cnemidophorus tigris
greater roadrunner	Geococcyx californianus	coachwhip	Masticophis flagellum
great horned owl	Bubo virginianus	Sonora gopher snake	Pituophis melonaleucus
barn owl	Tyto alba	checkered garter snake	Thamnophis marcianus
western screech owl	Otus kennicottii	black-necked garter snake	Thamnophis cyrtopsis
Anna's hummingbird	Calypte anna	common kingsnake	Lampropeltis getulus
black-chinned hummingbird	Archilochus alexandri	western diamondback rattlesnake	Crotalus atrox
northern flicker	Colaptes auratus	**Amphibians**	
ladder-backed woodpecker	Picoides scalaris	Sonoran desert toad	Bufo alvarius
Vermilion flycatcher	Pyrocephalus rubinus	Great Plains toad	Bufo cognatus
red-winged blackbird	Agelaius phoeniceus	western spadefoot toad	Scaphiopus hammondi
brown-headed cowbird	Molothrus ater	lowland leopard frog	Rana yavapaiensis
hooded oriole	Icterus cucullatus	bullfrog	rana catesbiana
northern oriole	Icterus galbula	**Fish**	
northern cardinal	Cardinalis cardinalis	threadfin shad	Dorosoma petenense
Pyrrhuloxia	Cardinalis sinuatus	carp	Cyprinus carpio
black-headed grosbeak	Pheucticus melanocephalus	red shiner	Notopis lutrensis
house finch	Carpodacus mexicanus	channel catfish	Ictalurus punctatus
Abert's towhee	Pipilo aberti	largemouth bass	Micropterus salimoides
white-crowned sparrow	Zonotrichia leucophrys	green sunfish	Chaenobryttus cyanellus
Lincoln's sparrow	Melospiza lincolnii	blue tilapia	Tilapia aurea
song sparrow	Melospiza melodia	yellow bullhead	Ameiurus natalis
western kingbird	Tyrannus verticalis		

2 Without Project Conditions

2.1 The Study Area

2.1.1 Climate, Soils, and Geomorphology

The study area for this report consists of the channel and near-channel areas of the Salt River from Granite Reef Dam to the Gila River, and the Gila River to its confluence with the Agua Fria River--a total distance of about 41 miles (shown generally on Figure 1; see Appendix 8.2 for greater locational detail). In this area, the river flows through a major structural valley with a relatively flat floor of deep alluvium, with its elevation above sea level falling from about 1300 feet to about 910 feet at the confluence of the Gila and Agua Fria rivers. The reach is in one of the warmest and driest climates in the American Southwest, typified by the climatological records for the airport at Phoenix. The average annual daily maximum temperature is 85 degrees F (on average, 91 days per year are above 100 degrees F), average annual daily minimum temperature is 57 degrees F (on average, 9 days per year are below freezing), and average annual precipitation is 7.5 inches (with the summer monthly maximum resulting from August convective storms) (Sellers, Hill, and Sanderson-Rae (1986). The potential evapotranspiration is slightly greater than precipitation in only in January, and during the rest of the year, the soil moisture budget is deficient (Hendricks, 1985, p. 41-2).

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 on nearly level or gently sloping surfaces (Hendricks, 1985, p. 74-5). 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. The entire study area has been mapped in great detail for soils by the U.S. Soil Conservation Service which has published maps made on aerial photography at a scale of 1:20,000 (1 inch representing 1,667 feet) (U.S. Department of Agriculture, 1974; 1977). These maps provide a view of soil conditions in and near the channel in the early 1970s. Since that time, conditions within the channel have changed in many areas, though the flood-plain and terrace soils remain generally unchanged. The importance of the soil surveys is that they describe soil physical and chemical conditions, water and soil relationships, and recommended plant covers.

The Lower Salt River is associated with three pediment-inselberg complexes in the surrounding terrain: Spook, Papago and Bush Pediments. The pediment-inselberg complex has been likened to a conveyor belt, along which particles are entrained and eroded. Processes on these features are directly connected to the Salt River, and an understanding of the sediment regime of the system depends in part on understanding the surrounding slopes. A pediment is usually an erosional ramp-like feature. It is a common feature found in most of the semiarid regions of the world. Pediments form at the base of mountains or extend outward from the base of an inselberg. The term inselberg refers to an isolated hill of solid rock, a good example of this would be Papago Buttes. Pediments can be characterized by two relatively easily identifiable qualities: (1) well-defined "break in slope" (a severe gradient change) between the pediment surface and the inselberg hillslope of the same rock type and (2) a bedrock surface, in some cases covered with a layer alluvium not more in thickness than 1/100 of the width of the pediment.

Geomorphologists are still uncertain as to how pediments form. Many different theories attempt to explain pediments and this has given rise to what has been called the pediment problem. The pediment problem arises from two basic questions: (1) What process(es) form a pediment? and (2) What causes the sharp break in slope between the mountain front and the pediment?

Of the more recent research two particular theories are of interest because they are the most widely accepted, but they contradict each other. One theory, presented by T.M. Oberlander in 1972 and 1974, suggests that pediments are relic features, that is, they formed when the climate in this area was different and have not been altered since then. About 16,000 years ago, the climate in this area was much wetter, and it is possible pediments were formed by a process of parallel linear slope retreat. Another theory for the formation of pediments also suggests that they formed under a different climate and are no longer forming under the present-day, drier conditions (Twidale, 1976, 19780). In this explanation, deep weathering of rock during moist periods is followed by striping of the weathered material by erosion. Abrahams *et al.* (1984) argued that pediments are continuing to form under the present-day, drier conditions, with pediments reflecting a mutual adjustment between gradient and particle size. Irrespective of their formation processes, the slopes along the Lower Salt River appear to supply the river directly with small amounts of sediment compared to the direct fluvial inputs.

2.1.2 Geology

The study area is located in the Basin and Range geomorphic province (Fenneman, 1916). This province covers a large section of the southwestern United States and northern Mexico (Thornbury, 1965). It is characterized by internal drainage, which is prevalent in the northern section and is found locally in the southern section. Although there are numerous geologic structures in the province, the most common type is block faulting. Block faulting produces a topography of sharp contrasts, where isolated, almost parallel mountain ranges rise in stark contrast above low lying desert plains. In many cases, the basin areas are filled with thousands of feet of sediment and debris, weathered in and transported from the adjacent mountains. However, some of the basin areas are pediments, erosional surfaces cut into the edges of nearby uplands.

The geology (mapped in Figure 5) of the eastern portion of the study area has been examined in detail by Drosendahl (1989), with ages of rocks determined by Stuckless and Sheridan (1971) and Stuckless and Naesar (1972). Granite Reef Dam is bounded on the south by the Usery Mountains and to the north by the McDowell Mountains. The Usery Mountains are composed of Precambrian Camelback Granite (1.4 million years old), which tends to be coarse grained and in porpheritic. The granite is locally sheared and fractured. Veins, dikes, and mafic inclusions are common features associated with the fractured rock. At the edges of the Camelback Granite, slope angles tend to be low, less than 10 degrees. The low angle slopes are erosional surfaces associated with pediment and inselberg complexes, and they are usually covered with a thin veneer (about 2 feet) of weathered granite grus.

To the north, the southern end of the McDowell Mountains consist mainly of Tertiary Geronimo Head Tuff (16 to 24 million years old). The tuff was derived from the Superstition Caldera complex in the Superstition Mountains, and is formed from partially welded to nonwelded rhyolitic ash flows and epiclastic breccias. Locally the tuffs are cut by basalt dikes and sills, which

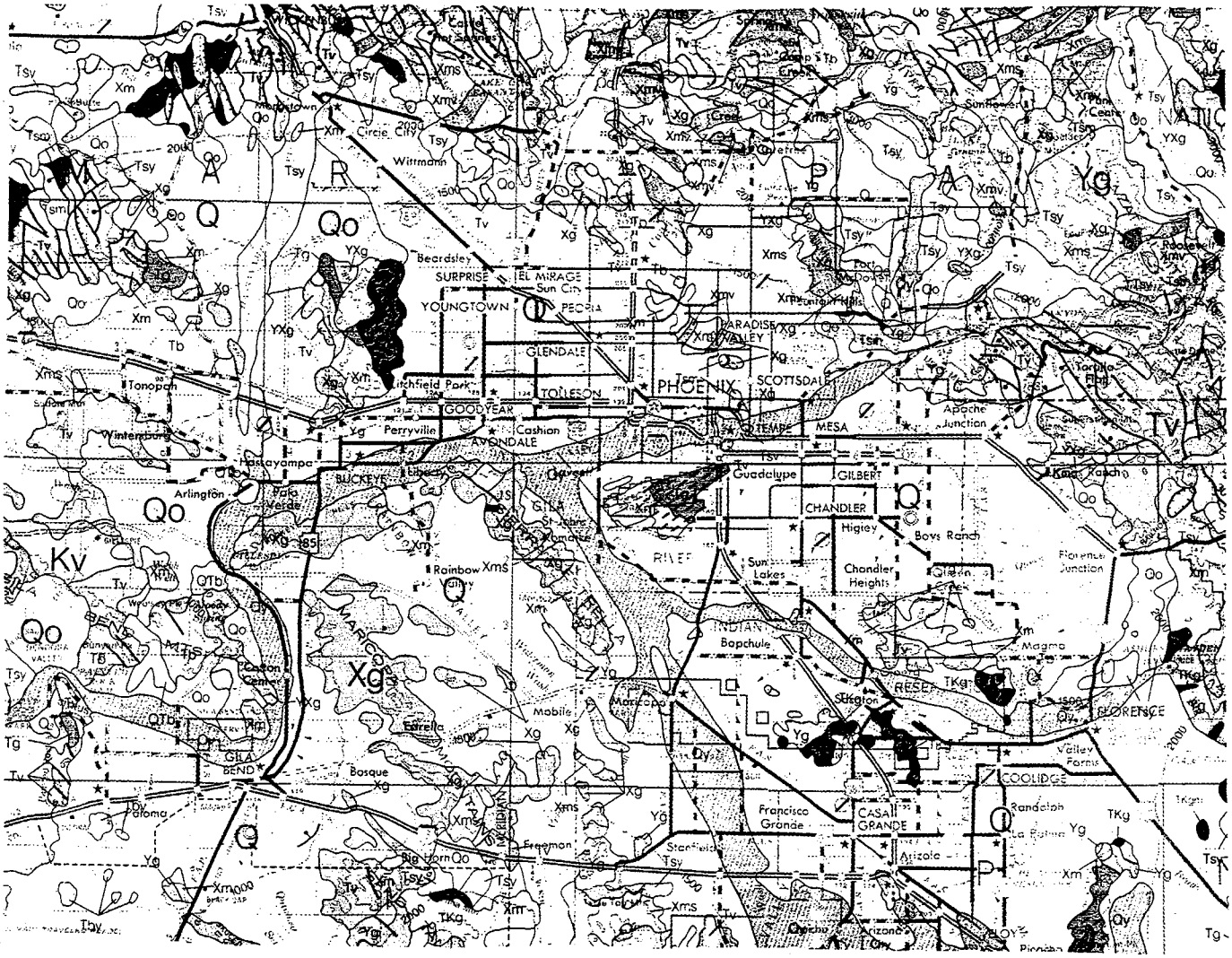


Figure 5. Portion of the Geologic Map of Arizona (Reynolds, 1988) showing the Lower Salt River and part of the Gila River in the study area. The legend for the mapping units are on the following two pages.

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).
	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).
	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 sub-volcanic 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.
TKgr	Granitic rocks (early Tertiary to Late Cretaceous; 45 to 75 Ma)—Commonly muscovite-garnet-bearing peraluminous granite and associated pegmatite.
	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.

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 P[P.
P[P	Sedimentary rocks (Permian and Pennsylvanian)—Hermit Shale, Supai Group, Naco Group, De Chelly Sandstone, Cutler Group, Pakoon Limestone, Callville Limestone, and Queantoweap Sandstone.
M€	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.
	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	Thrust or reverse fault
Fault	Middle Tertiary mylonitic fabric; lined pattern is approximately parallel to lineation.
Low-angle normal fault	Mesozoic to early Tertiary metamorphic fabric in Proterozoic to Mesozoic sedimentary rocks
Detachment fault	

have formed along pre-existing faults. The basalts have ages ranging from 17.7 to 18.7 million years. The Gernoimo Head Tuff overlies the Camelshead Formation, which consists of poorly to moderately sorted and stratified sandstones and conglomerates.

From Granite Reef Dam to the city of Tempe, the surrounding geology north and south of the river changes from bedrock outcroppings to valley fill and alluvium. Valley fill has been accumulating since the onset of the basin and range formation, so that in many portion of this reach of the river the fill is greater than 1000 feet deep. The underlying bedrock surface is below sea level in many areas. The valley fills tend to be more coarse near the mountain fronts, and more fine in the interior of the valley. Near the Salt River, the valley fills have been eroded as the river formed terraces during its evolution.

In the interior of the valley, most of the valley floor is covered by coarse to fine grained alluvium. This material has been continuously deposited by the shifting channels of streams draining the mountains. Sand and gravel, moderately well sorted and stratified, compose the bulk of the deposits left by the Salt River. These deposits are composed of well-rounded clasts and are locally interbedded with silts and clays. The fine sediments are derived from overbank flows.

Near Tempe, the river is constricted by Papago Buttes to the north and Tempe Butte to the south. Papago Buttes are Tertiary breccia of the Camelshead Formation (Péwé *et al.*, 1986). The sedimentary breccia was deposited during alluvial fan formation during the Tertiary. The fanglomerate has subsequently consolidated to form breccia. There are also outcrops of the Camelback Granite and Precambrian metarhyolite directly adjacent to Papago Buttes. On the south bank of the river, Tempe Butte consists of late Tertiary rhyodacite, underlain by interbedded strata of the Tempe Beds, layers of arkosic sandstones, siltstones, and tuffs.

From Tempe to the Agua Fria confluence with the Gila River, the geology associated with the channel is dominated by valley fills and alluvium. The water table is closer to the surface in the western portion of the study area because of shallow depths to bedrock and because of numerous relatively impermeable clay layers within the alluvium. South of this reach is South Mountain, a metamorphic core complex composed mostly of Precambrian granite gneiss (Wilson *et al.*, 1957; Reynolds, 1985). At the western edge of the study area are the Sierra Estrella Mountains. Like the South Mountains, they are mostly Precambrian granite and gneiss. Both ranges include local outcrops of Precambrian schists and Cretaceous granites.

2.1.3 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 ecosystems as riparian associations of any kind (excluding marshes) which is in or adjacent to drainage ways and or their flood plains and which is further characterized by species and or life forms different from that of the immediatelysurrounding non-riparian climax. This also includes plant communities located along drainage ways 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 obligated 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, 1993a and b). These forests commonly occur with other riparian assemblages because fluvial processes such as flood-plain 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). Assemblages include Sonoran interior marshlands dominated by *Typha spp.* (cattail), *Scirpus spp.* (bulrush), or other emergents; Sonoran riparian scrubland dominated by *Baccharis 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 channel 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 . The life spans of these trees are from 100 to 150 years (Stromberg

et al. 1991).

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. 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 forest life spans (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 or low terraces 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 (400-2000/acre) 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 this species. Others can include: *Acacia gregii* Gray (catclaw acacia), *Celtis reticulata* Torr. (netleaf hackberry), *Cercidium floridum* Benth. (blue palo verde), *Chilopsis linearis* (Cav.) Sweet (desert willow), *Fraxinus 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 basques go through cycles of formation and destruction on time scales 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 basques. 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 basques 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 basques 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). In this area immediately downstream from the study area of the present report, most of the changes occurred with the arrival of Anglo-American settlers. Riparian forests of mesquite, cottonwoods, and willow were replaced with salt 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 passing 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 may have been construction of dams and the resulting new channel 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 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.

Within the study area, some reaches of the Lower Salt River between Granite Reef Dam and the confluence with the Gila River were at one time nearly completely covered with tamarisk, but they are now almost completely without the plant. Dense forests once existed along the river in northeast Tempe, especially between Rural Road and McClintock Drive as revealed by historical photography. As groundwater pumping accelerated during the 1950s and 1960s, the water table was lowered along the river in this reach, and the depth to groundwater became too great to support dense growth of phreatophytes (Table 6). Although there are records of tamarisk roots extending to a depth of 55 feet, the critical depth to groundwater appears to be between 15 and 30 feet. When water is deeper than this general threshold zone, phreatophytes do not survive in this area, while water at shallower depths supports dense growth (Graf, 1980; 1982). Wastewater effluent supports a narrow strip of phreatophytes downstream from the 91st Avenue Wastewater Treatment Plant, and relatively dense growth across much of the channel thrives on high groundwater fed by the Gila River in the vicinity of its confluence with the Salt.

2.2 Environmental History

2.2.1 Photographic Environmental History

Analysis of the environmental history of the Salt River from Granite Reef Dam to the confluence of the Agua Fria River is facilitated by the use of historical ground photographs, aerial photographs and written accounts. The following pages will discuss the environmental history through observations from historical ground photographs and aerial photographs, focusing on reconstructing the history of the riparian vegetation as well as the geomorphology of the area (see Appendix 8.4 for sources of historical photography and descriptions of representative photos). Later pages explore the written accounts.

Prior to 1890 (pre-development), the riparian vegetation appeared to be dominated by the cottonwood, willow and the various species of mesquite. This type of vegetation was common in all of the pictures from this time period. This suite of vegetation is considered to be representative of the natural 'climax' species that would be found in undisturbed riparian corridor along the Salt River. Cottonwoods occurred along the outer bank of the river, at the extreme edge of the natural riparian vegetation. The willow and mesquite basques were located inward of the cottonwood, adjacent to the low flow channel and closer to where there was a more continuous flow of water. Some channel areas were barren, while others had vegetation in strips along the low flow channels and abandoned high flow channels (Figures 6 and 7).

In the 1920s tamarisk had become well established in the riparian corridor. The earliest account of this exotic species was around 1900, but it did not really begin to establish itself until the late 1910's and early 1920's. The coverage of tamarisk was

Table 6. Historical Phreatophyte Cover of Individual Reaches.

(Source: Unpublished data, W. L. Graf)

Year	Country Club to Mill Ave.	Mill Ave. to 7th St.	7th St. to 59th Ave.	59th Ave. to Mon. Hill	Total
1937	2,374	2,460	4,198	2,495	11,527
1957	1,315	1,783	1,993	2,259	7,350
1961	996	1,216	1,960	2,414	6,586
1971	1,536	841	246	911	3,534
1973	396	363	456	749	1,964
1979	315	560	575	1,016	2,466

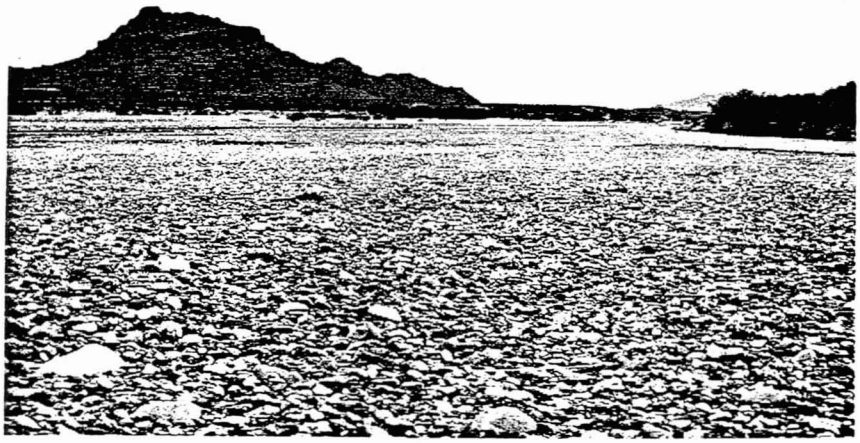


Figure 6. The McDowell Crossing area of the Salt River in northeast Mesa, with McDowell Peak or Red Mountain in the background. Above: view in 1905 (photo from the Library of Congress). Below: view in 1981 (Graf photo 41-20). Note change in bed material from sand to cobbles as a result of downcutting.

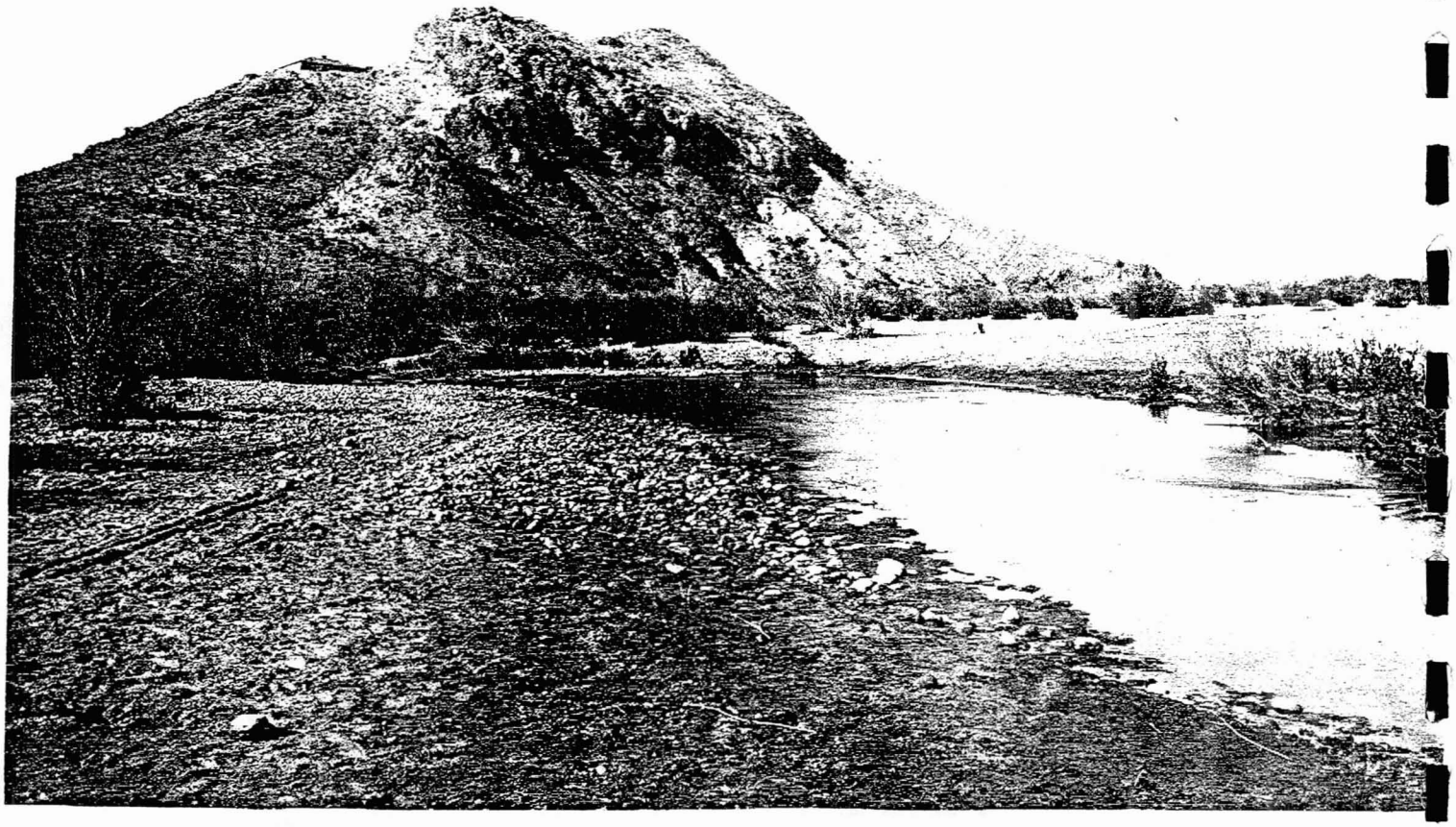


Figure 7. The south branch of the Salt River Channel in Tempe in 1902, looking west toward Tempe Butte, without tamarisk. The area shown in the left foreground of the photo is now the north end of Sun Devil Stadium, and the entire area of the foreground is now a parking lot.

heaviest in period of the 1940's. Pictures from the Mill Avenue Bridge showed the channel almost entirely covered with this species. In the 1950's there was a reduction of vegetation in general along the river. This was in response to vegetation removal programs and fluctuations in the groundwater levels. Photographs of the vegetation removal programs show removal of not only the exotic species, but also the removal of the native species. The trend of decreasing coverage of riparian vegetation continued until the mid 1960's. In the late 1960's the exotic species began to dominate the channel once again, increasing in density and areal extent. This continued until the early 1980's when vegetation clearing programs were enacted again. At present the vegetation is restricted to certain reaches where there is groundwater near the surface or where effluent flows in the channel. A good example of this is the confluence of the Salt and Gila Rivers, where there is a relatively dense cover of vegetation. The Salt and Gila River area has a high water table and continuous flow of effluent throughout most of the year. This area is dominated by tamarisk, but locally there are some sites where native species are present.

The historical photography shows that the geomorphologic history of the river is very complex. It is characterized by scour and fill events, floods and channel shifts. The ground photographs and aerial photographs document the impact on riparian systems caused by the meandering nature of the river system. However, more recently urban development in the region has altered the channel from meandering, to a straight channel with high banks in several reaches. Comparative photos show the channel has shifted within the flood plain several times from the 1880s to present, meandering on the north side of the flood plain during some periods and on the south side during others. Channel shifts have distributed alluvial material across the entire width of the floodplain. The alluvium deposited by the river consists of cobbles, sands, silts and clays from numerous tributary streams within the watershed. From well log data, it is evident that this depositional history has been continuous over a long period of time.

Photos from the 1880s to the 1970s provide evidence that the river is dominated by scour and fill events, which degrade the river in some areas and aggrade it in others. The scour and fill transportation of sediment has produced numerous thick deposits within the fluvial system: cobble lag surfaces, sand sheets (macro-forms), channel side bars, mid-channel bars, point bars and overbank deposits (Figure 8). Many of these deposits have recently been disturbed by intensive mining for sand and gravel. Mining of sediments alters later transportation events, by reducing the amount of material that can be transported by removal and compaction, loosening other sediments and sand pits serve as depositional traps for fine sediments.

Sediment transported in a scour and fill setting tends to move in waves or pulses, rather than at a constant rate through time. In essence there are slugs of sediment moving downstream periodically during flow events. The historical photography confirms that flood flows are probably the most important events in the transportation of sediment. Flood flows have the highest potential to move material. During a flood event the bulk of the sediment is moved as bedload, but there is also movement of sediment as washload, in solution and suspension. Prior to damming of the river, smaller flow events moved

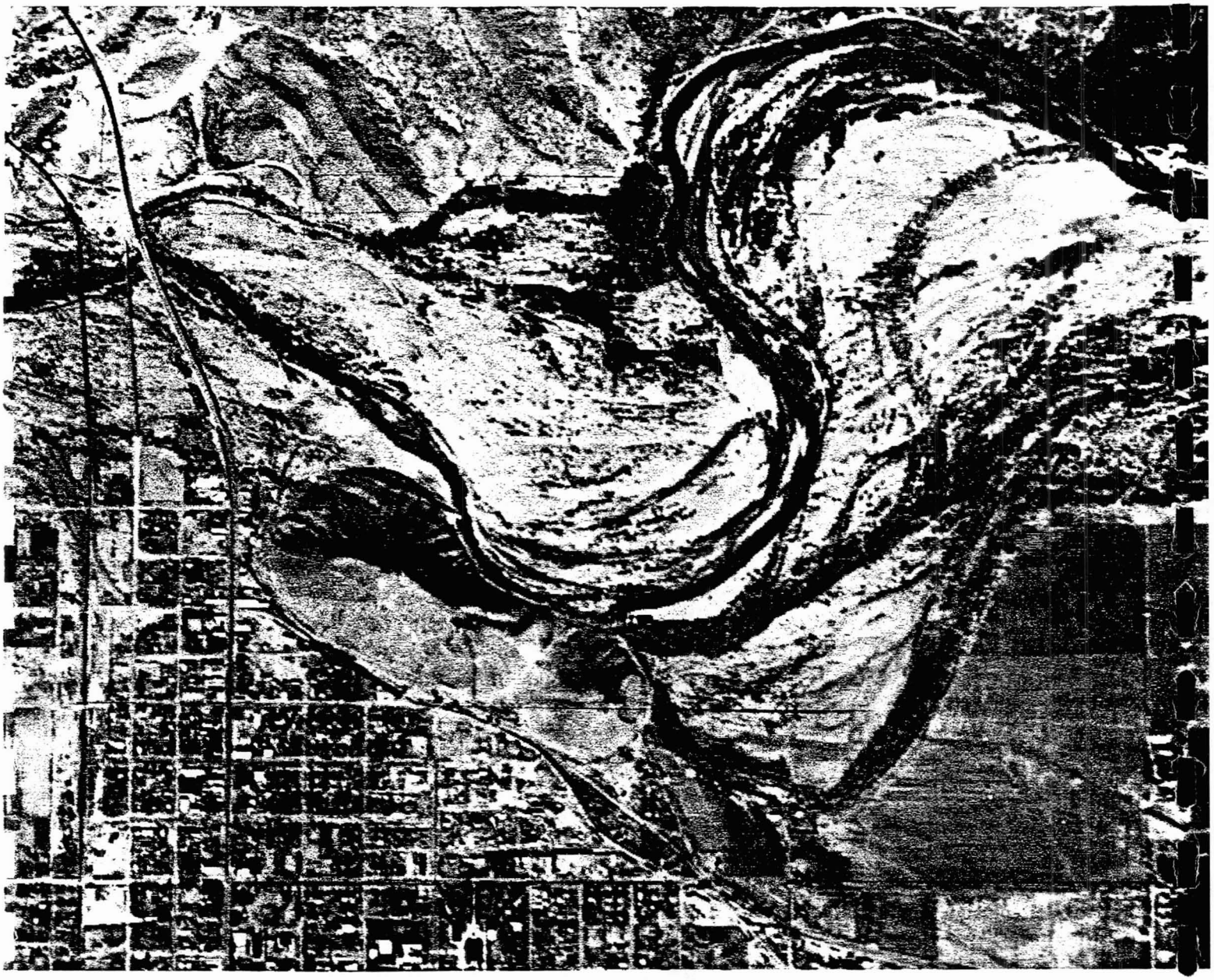


Figure 8. Aerial view of the Salt River in Tempe, including the Mill Avenue Crossing, taken in 1937 with north toward the top. Note the south channel branch near Tempe Butte, similar to the configuration shown in the 1902 photo in Figure 7. The meander in the upper right corner of the view is now completely urbanized. (Photo obtained by K. Randall from the U.S. National Archives, Washington, D.C., Record Group 114).

sediment (fine sands, silts and clays) by incising downward into the larger slugs of sediment found in the channel. However, incision and movement of sediment by these smaller events do not compare to the order of material move during a flood event.

In summation, the environmental history of the proposed study reach is a story of change. There have been continual changes in the vegetation found in the riparian corridor, both by natural and anthropogenic causes. The river has shifted its course on numerous occasions, creating new depositional environments, new sediment sources and new mediums for plant establishment. At present the environment should be considered degradational, with the river continuing to incise downward. The sediment that is moved in this section of the river is carried downstream, with a large portion of it stored behind downstream dams.

2.2.2 Pre-Development--Prior to About 1890

Written accounts of the Lower Salt River before extensive development by Anglo-Americans provide a view of the general hydrologic conditions and vegetation types that naturally existed along the river. These descriptions of the river prior to 1890 come from a few brief mentions (and one longer account) of the area in the letters and journals of missionaries, trappers, and government agents. Major trails through Arizona followed by early settlers, trappers, and miners on their way to California did not pass through this area, making accounts from this early period scarce. See Appendices 8.5 and 8.6 for sources and quotes from accounts.

Prior to development, the Lower Salt River was a perennial stream fed by snowmelt from the mountains to the east and the highlands to the northeast. Its clear, streaming waters contrasted greatly with the muddy, sluggish Gila River to the south and west. John Russell Bartlett (1854, 243-4), who provides the most extensive accounts of the Salt River during this period, notes that "the quantity of water passing down the Salinas is more than double that of the Gila, which only becomes a respectable river after it receives the waters of the former." Flows in the river had a distinct seasonal pattern, with highest flows occurring in December and January and lowest flows in October (Halpenny and Greene, 1975). The high flows, estimated at several hundred thousand cubic feet per second by Halpenny and Greene (1975), covered the flood plain and low terraces with large amounts of sediment. Bartlett (1854, 240-1) states: "The margin of the river on both sides, for a width of three hundred feet, consists of sand and gravel, brought down by freshets when the stream overflows its banks; and from the appearance of the drift-wood lodged in trees and bushes, it must at times be much swollen, and run with great rapidity."

The written accounts provide little information on the geomorphology of the river. The main channel ranged in width from 80 to 120 feet near present-day downtown Phoenix to about 750 feet a few miles below Granite Reef Dam (Figure 9). Halpenny and Greene (1975), drawing from various historical sources and personal experience, suggest that while the high flows in the winter determined the width, depth, and capacity of the river bed, the steady snowmelt flows in the spring established the dimensions of the main channel (or channels).

The bottom lands of the Salt River supported a variety of vegetation, including trees, shrubs, marsh plants, and some grasses. Large cottonwood, willow, and alder tress grew along the margins of the river, and mesquite, greasewood, paloverde, and sagebrush covered the low

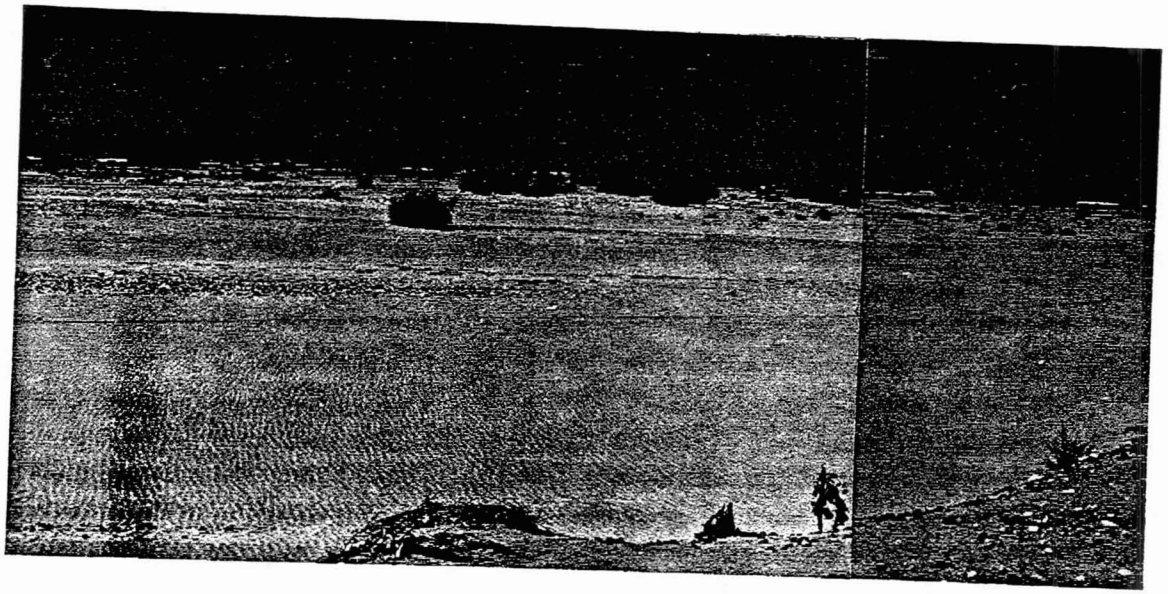


Figure 9. Views of the Salt River looking southwest near the site of Sky Harbor Airport. Above: the earliest readily available photograph of the river, taken about 1892 and included in the Arizona Governor's Report to Congress in 1896 (Photo #10191, Arizona Historical Society, Tucson, Hazard-Dyson Collection). Below: the same view in September 1980 (W. L. Graf Photo 39-1,2).

terraces. Dense mesquite and other shrubs made crossing the bottom land impossible in places, while in other locations the vegetation was more scattered. Bartlett (1854) noted several species of fish in the waters, similar to those he found in the Gila River.

Almost all accounts mention the agricultural potential of the soils in the valley. Several writers note that the land appeared to have been cultivated and that canals once supplied water to fields from the river. Surveyor William Pierce (1867, Book 1328, 29-31) called the area "some of the best agricultural land I have seen in the Territory" (Figure 10). The surveyed plat maps by Pierce and other early surveyors for the entire study area are in Appendix 8.7. Agriculture returned to the Salt River Valley in the 1860s, as settlers excavated canals to carry water from the river to fields.

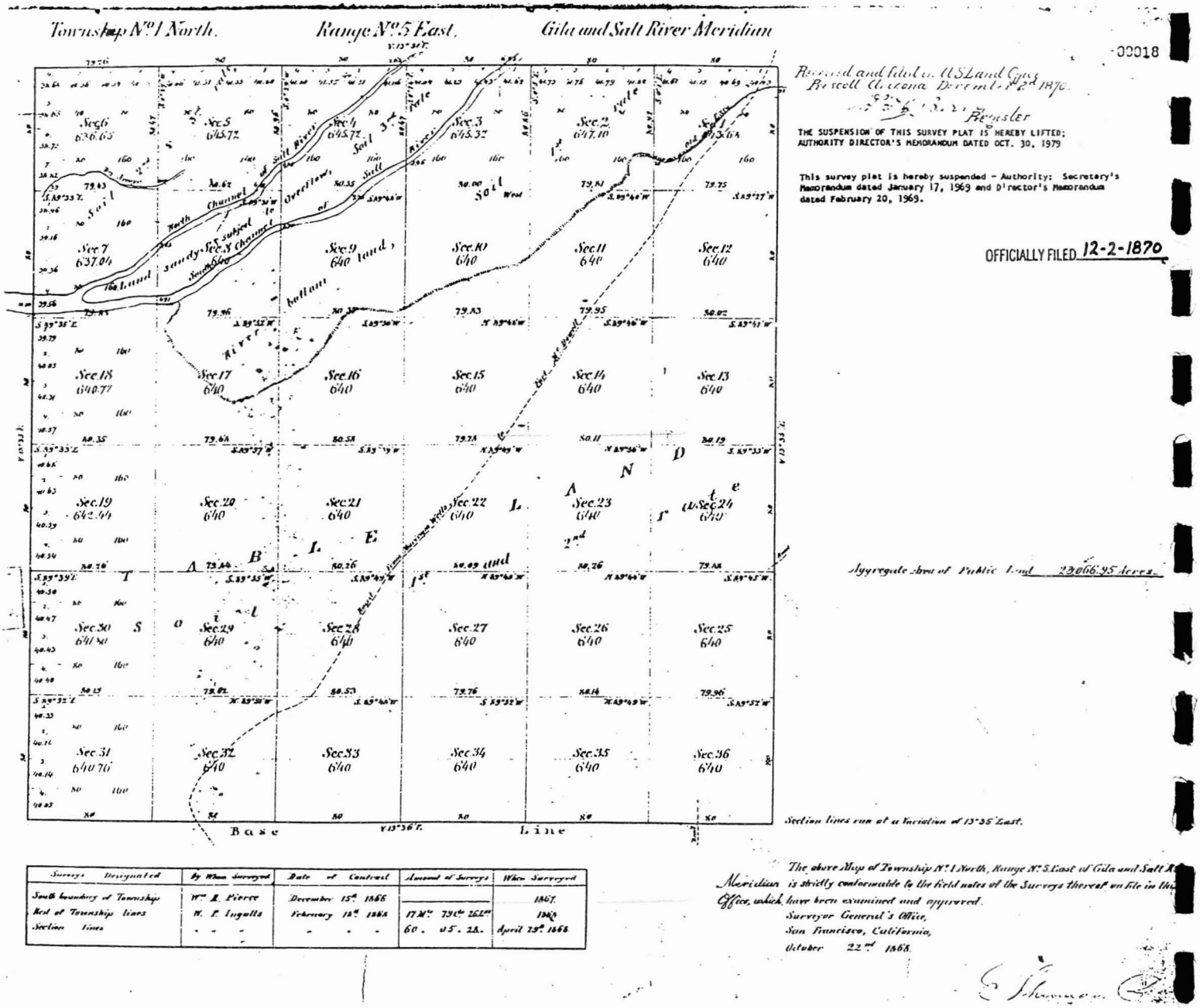
2.2.3 Post-Development, Pre-Dam--1890-1938

Most written accounts from the late 1800s and early 1900s provide a glimpse of the perception of the Salt River rather than the river itself. Pamphlets published by various city and county agencies and businesses during this period attempted to entice farmers and businesses to settle in the Salt River Valley. Despite its importance to agriculture and to individual farmers (as reflected in personal journals), the Salt River essentially ceased to exist in the eyes of the pamphlet writers as anything other than the unlimited source of water for irrigation. When these advertisements mention the river itself, the language of reclamation dominates the description:

> "The river's flow has been measured and the water supply, for twenty years past, is absolutely known. Engineering observation and research have demonstrated the fact that at the head of a gorge, seventy miles east of Phoenix, there lies a dam site such as is rarely offered by Nature to man, and above it a reservoir site, wherein can be stored the greatest flood that ever tore down the river channel, possible to devastate and then idly to escape useless to the sea. There is nothing experimental about the irrigation situation of the Salt River Valley (McClintock, 1908, 9). This transformation of the desert has been accomplished by the scientific conservation and control of the waters of one tiny, but ever-flowing stream, the Salt River (Smith, 1927)."

Irrigation canals offered aesthetic or recreational values, and observers often commented on their clear waters and shady, cottonwood-lined banks, while at the same time ignoring the river. A few personal accounts of the river from this period also emphasize the importance of the water of the river to agriculture, and hence life, in the valley. These statements highlight the natural variabilities in the flow of the river and the growing competition for the limited resource of water. In a personal narrative, Leonard R. Dykes (no date, 21) recalled that the family's irrigation system was "very, very uncertain" and that the flow of the Salt River "varied from dangerous floods during the rainy season [winter] to a trickle during the hot, dry summers. High flows frequently disrupted daily life by flooding fields, damaging irrigation systems, and prohibiting crossing the river. Thomas W. Jones (1952, 18-9), recalling the 1891 flood in Lehi, wrote: "by the end of January the once clear, gently flowing river swept by in great waves of turbulent muddy water laden with all kinds of debris."

The wide natural fluctuations in flow conditions, which impacted water availability,



Surveys Designated	By Whom Surveyed	Date of Contract	Amount of Surveys	When Surveyed
South boundary of Township	Wm. R. Pierce	December 15th 1866		1867.
Rest of Township lines	W. F. Ingalls	February 18th 1868	17 M. 79 ch. 26 lk.	1868
Section lines	" " "	" " "	60. 05. 28.	April 25th 1868.

Figure 10. First surveyed map of the Salt River in northwest Mesa, made in 1870 from field surveys in 1866 and 1868. Note the divided channel and the note southeast of the channel indicating "river bottom land, soil 1st rate," apparently an area of high flow and not an isolated terrace.

became a matter of several legal disputes. The opinion of Judge Kibbey, rendered in 1892, estimated the seasonal range in the flow of the Salt River to be "from thousands of cubic feet per second to about, at a minimum, three hundred cubic feet per second" (Clark, 1936, 3). A declining water table also impacted water disputes and flow in the river. Lee (1905) reported that the water table lowered between six and 20 feet in the east valley in four years and attributed this decline to prevailing drought conditions and increased ground water pumping. This decline may explain Lee's observation that while the Salt River is perennial at Tempe, "the river bed to both the east and west of Tempe is dry" (Lee, 1905, p. 122). All other accounts depict the river as containing flow even during the driest months; thus, Lee's observation documents the increasing impact of human activity on the hydrology of the Salt River. See Appendix 8.8 for the 1937 aerial photography covering the entire study area.

2.2.4 Post-Dam--1938-1978

Post-dam accounts of the Lower Salt River depict further changes to both the hydrology and geomorphology of the river channel (Figure 11). Closure of Bartlett Dam on the Verde River in 1938 effectively stopped natural flows on the Lower Salt River. By 1957, dam releases, or flood flows, and effluent were the only sources for flow in the Salt River; damming upstream and pumping of ground water along the river had effectively ended perennial flow (Halpenny and Greene, 1975). The river, in the words of Milton MacKaye (1947, 89), "isn't a river at all, but a low-lying rugged basin, as empty of moisture as your living room."

Significant encroachment upon the flood plain by human activity in particular areas altered the appearance of the channel. Clearly, the prevalent perception that dams and other works had tamed the Salt River encouraged use of the river for a variety of activities that the threat of floods would have precluded. Areas near Tempe and central Phoenix in particular experienced radical changes by 1958: "Sand and gravel companies have operated in the river bottom; subdivisions have encroached upon the old original flood channels; a large sanitary fill has been built; and other types of work by man have tended to constrict or obliterate the original channel" (Flood Protection Improvement Committee, 1958).

As the City of Phoenix and the surrounding communities exploded in size, aggregate mining consumed an increasingly large portion of the river channel and flood plain. The excavation of large gravel pits obliterated sections of the channel (Briggs and Werho, 1966). Under the perception of the tamed river, mining operations erected expensive machinery in the bed of the river as well as levees and dams of boulders to protect their investments. These objects contributed to a potential problem greater than the gravel pits themselves. In 1959, obstructions occupied 39 percent of the river bed between 40th Street and 19th Avenue in Phoenix: "by 1959 the river bed contained a hodge-podge of obstructions of various types, all of which tended to impede or change the direction of flow of flood runoff" (Halpenny and Greene, 1975, p. 4-7). The reports by the Flood Protection Improvement Committee (1958) and Halpenny and Greene (1975) document a growing concern for the fate of these in-channel activities.

2.2.5 Metropolitan Era--Post 1978

The year 1978 marked a significant change for the Lower Salt River. After May 1941,

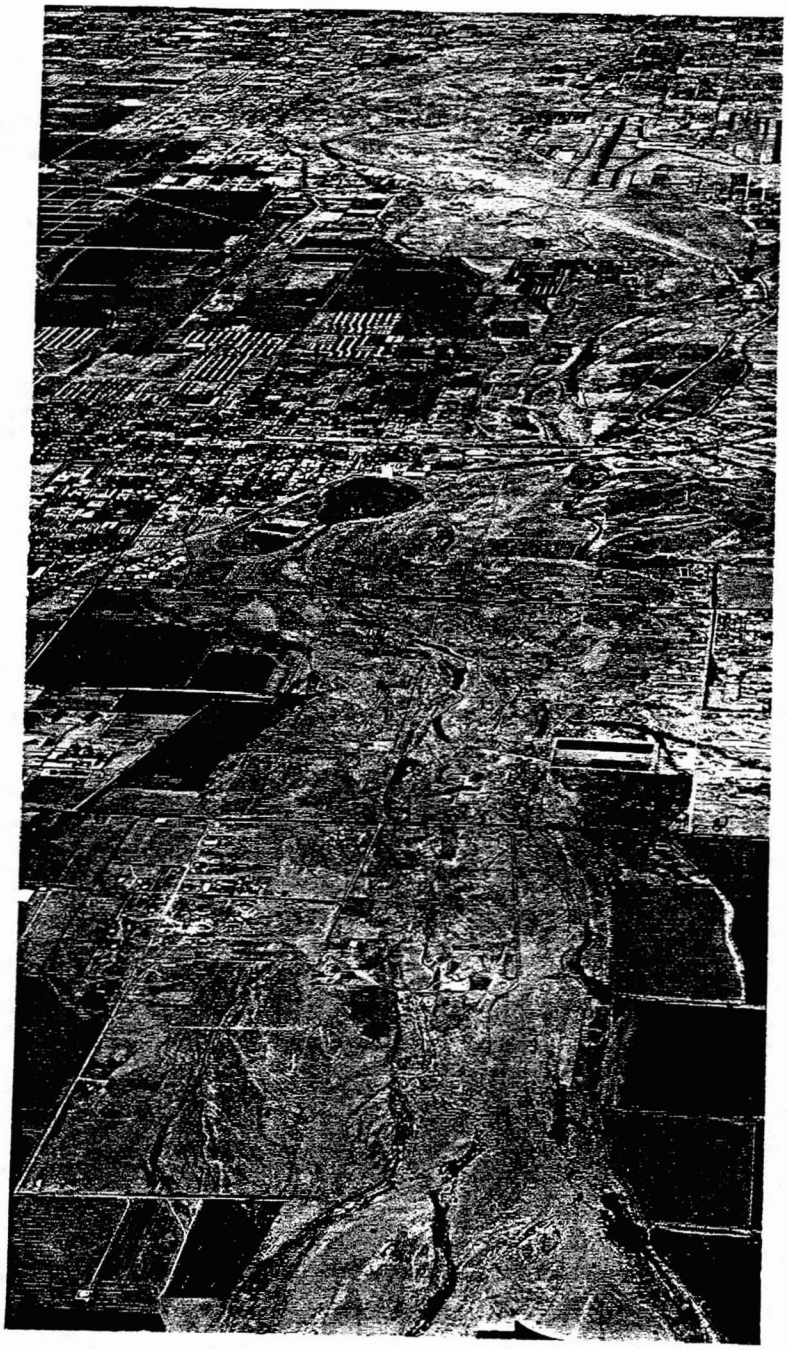


Figure 11. Aerial photograph of the Salt River looking west in northwest Mesa and Tempe, showing channel conditions on October 2, 1962. Note the lack of vegetation due to groundwater pumping, construction and agriculture encroaching on the high flow channel in the foreground, and the straightened channel near the airport in the background (Maddock Associates Aerial Survey, Inc. Photo 31).

there had been only a few relatively minor releases of water into the channel (particularly 1965-6 and 1973), and except for vegetation adjustments, channel conditions had been relatively unchanging. The geomorphology of the channel had been static for more than a third of a century. Landowners and resource managers had become accustomed to a river that was effectively inactive, and the channel had come to be viewed as a stable portion of the landscape, available for use with few restrictions. The year 1978 was when those conditions and perceptions changed.

Two large floods, one beginning in March and peaking at 95,800 cubic feet per second and the other beginning in December and peaking at 110,000 cubic feet per second, initiated considerable geomorphologic adjustments in the channel. Those adjustments continued in 1980 when a February flood peaked at 137,725 cubic feet per second, and during a variety of much smaller flows between 1980 and 1994 changes continued at a reduced rate and magnitude. The period between 1978 and the present has therefore been radically different from the 1941-1978 period, and the resulting geomorphic changes have altered the channel to the degree that it is unlikely that pre-1978 conditions will ever exist again.

During the post-1978 period, there were some vegetation changes, and a variety of geomorphic modifications including changes in channel width, depth, gradient, and pattern, as well as in bed materials that affected the entire river in the study area. Construction projects also modified the geomorphic environment of the channel. The vegetation changes were significant reductions in riparian communities through erosion, loss of substrate, and lowering of water tables, so that during the 1941-1978 period, there was a steady decline of the area covered by riparian vegetation (recall Table 6). A riparian forest on the north bank of the river immediately downstream from Granite Reef Dam was almost totally destroyed by erosion (Figure 12), and small pockets of phreatophytes throughout the system were removed. In the vicinity of the confluence of the Salt and Gila Rivers, the phreatophyte forest (mostly of tamarisk) that extended across the channel area was cleared by flows to create linear swaths through the dense growth. In small patches throughout the system, the floods of 1978 and 1980 left accumulations of sand in the form of midchannel bars, channel sidebars, and streamlined tail deposits behind obstructions that subsequently became seed beds for new growth. By 1990, these new areas were covered with vegetation, including tamarisk and some cottonwood and willow. This new growth was dense only in those areas with water tables within about 15 feet of the surface as in the Salt and Gila confluence area, but in other reaches the growth survived on sporadic runoff.

Channel widening during the high flows of 1978 and 1980 floods was prominent in the reach of the river from 43rd Avenue to 67th Avenue (on the west side of the urban area), especially where agricultural activities had encroached on the historically active channel area. Some fields had been extended into the high-flow zone of the compound channel, and these fields were partially destroyed. Some channel widening also occurred in the reach immediately east of Gilbert Road (in northeast Mesa). In the reach between McClintock Drive and the Alma School Road Crossing in Tempe and Mesa, the channel was more narrow than it had been previously because sand and gravel mines concentrated the flow in mid-channel areas through pits several tens of feet deep. This concentrated flow therefore did not spread laterally as it had done previously under more natural conditions. Structures and resistant banks in the Phoenix area, between the Interstate 10 bridge crossing and about 19th Avenue confined the flow to a path that

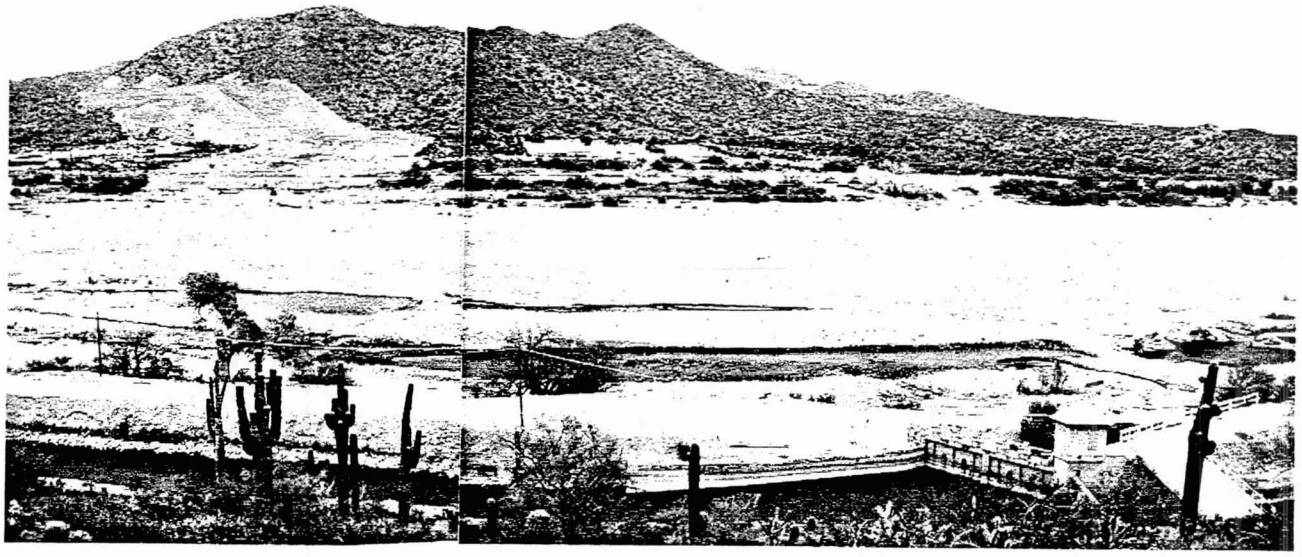


Figure 12. Salt River channel 0.4 miles below Granite Reef Dam, from the north bank, looking southwest, showing the loss of riparian habitat along the north bank of the channel. Above, view in September, 1949 (copy of Corps of Engineers photograph, W. L. Graf Photo 33-21, center of a panaramic view). Below, same view in January, 1981 (W. L. Graf Photo 41-13).

Table 7. Historical Channel Widths of the Lower Salt River.

(Source: Unpublished data, W. L. Graf)

Year	Flow	Country C.	McClint.	Rural	Mill	48th St.	40th St.	24th St.	16th St.	7th St.	Central	19th Ave.	35th Ave.	51st Ave.	91st Ave.
1868	Low	250	370	510	1450	920	1060	1320	920	530	570	480	400	530	400
1900	Low														350
1903	Low	690	420	420	320	480	210	420	320	320	320	130	260	180	590
1914	Low							210	160	210	160	110	110	160	440
1915	Low	320	320	160	110										
1961	Low					610	610					480	880	550	760
1965	Flood	1620	1580	1500	970										
1971	Low	240						500		460				150	340
1973	Low	310	310	310	790	350	180	260	240	290	220	110	370	700	170
1978	Flood			880	1230		2020	650	590	360	830	530	920	980	1410
1979	Low	490	520	310	420	350	170	240	170	140	420	420	490	210	280
1980	Flood	1510	1320	1510	1130	750	1700	790	660	920	920	660	660	1490	2640
1980	Low	420													
Maximum Possible		1890	1580	1510	1230	5280	3960	3170	660	920	1450	660	1810	1980	3960
Minimum Observed		270	310	160	110	350	170	210	160	140	160	110	110	150	170
Mean, Low Flow		389	388	342	618	542	446	492	362	325	338	288	411	350	458
St. Dev. Low Flow		149	77	118	471	212	348	385	285	135	146	173	221	200	201

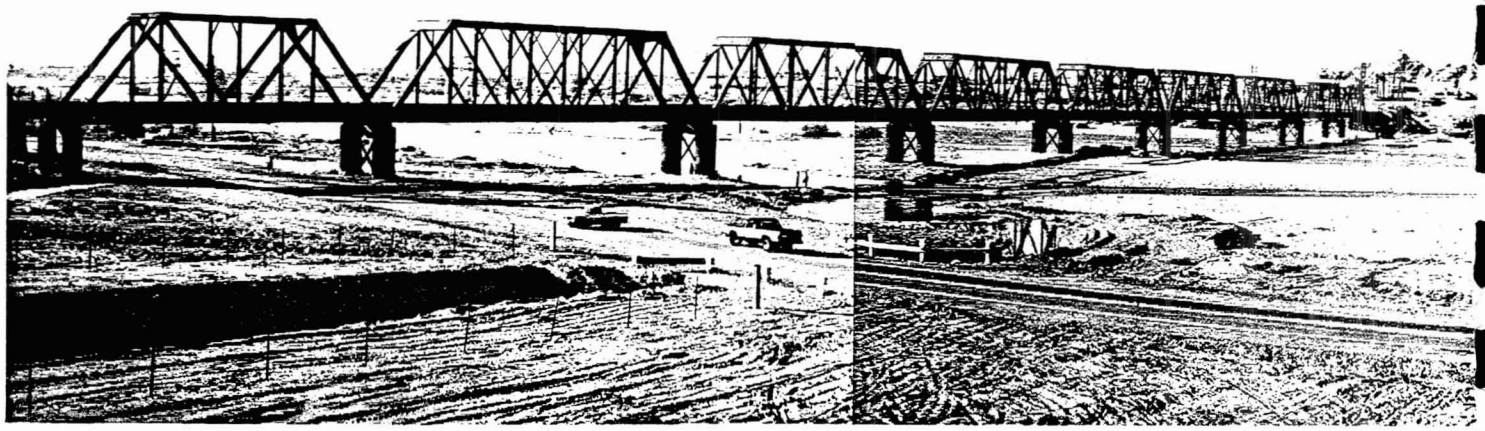
was more narrow than it would have been under completely natural circumstances. Overall, considering the known history of channel changes in the river, there is no natural tendency to widen or narrow the channel except where human interference plays a role (Table 7).

Channel depth increased dramatically during the post-1978 period in the Mesa and Tempe area, and decreased in the reaches in the vicinity of the Salt and Gila confluence. These changes were linked to each other because sediment evacuated from the upstream reaches was deposited in the downstream areas. Repeat surveys of channel cross sections in the Tempe area near Arizona State University showed that between 1969 when measurements were made by Ruff (1972) and 1981 when measurements were made by Graf (1983), the channel floor was lowered through erosion about 15 feet (Figure 13). Observations through repeat photography show that this lowering occurred at the Southern Pacific Rail Road Bridge in Tempe, where progressively greater amounts of the support piers were exposed during the post-1978 period. Repeat photography and direct observations by one of the authors (Graf) showed that the deepening of the channel also included areas upstream from Tempe, at least upstream beyond the McDowell Crossing, located about 1.5 miles east of the Gilbert Road Crossing, and in lesser amounts all the way to Granite Reef Dam, where historical photography showed downcutting extending to the apron of the dam (Miller, 1988, p. 73).

The sediment produced from this downcutting was substantial: the volume was probably about 645,480,000 cubic feet (15 feet deep, 500 feet wide, 16.3 miles long) or about 30.66 million tons (assuming sediment density of 95 pounds per cubic foot, an commonly used value). Flows in the channel moved these materials downstream and deposited some of them in the vicinity of the Salt and Gila confluence and in the reach between the confluence and the Agua Fria River. Deposition occurred in this reach because the gradient of the system is less there than farther upstream on the Salt River. Channel aggradation on the order of about 3 to 6 feet was common through the entire portion of the Gila between the Salt River and at least the area near Buckeye. Miller Road, immediately south of Buckeye, was buried to a depth of about 6 feet throughout much of its traverse across the channel, with most of the deposition in the high flow zone, outside the thalweg channel (Chin, 1988).

The floods during the post-1978 period appeared to change the pattern of the river channel and did change its location in some cases. Because the 1941-1978 period was one of low flows, the came to be viewed as a single thread channel, occasionally dividing into multiple threads. With the advent of high discharges, however, the channel took on a more braided appearance. In fact, this braided condition had existed often before 1941, so its reappearance was not really a change, but rather a return to previous configurations. Because landuses had encroached upon this high flow, braided channel in some areas, it appeared that the river was changing drastically, but in fact it was merely behaving in a predictable fashion. Significant changes did occur, however, in the location of the thalweg, or low flow channel as a result of erosion and sedimentation during the flood events (Figure 14 and Appendix 8.13). In the reach between Country Club Drive and McClintock Drive (Hayden Road) in Tempe and Mesa, the low flow channel shifted southward half a mile. Upstream from the Interstate Bridge Crossing it developed a temporary northward meander in 1978, but the feature later disappeared. West of 91st Avenue, the low flow channel shift northward, and the Gila River between the Salt and Agua Fria rivers shifted southward half a mile. Although these changes appeared to be large, they did

Figure 13. This page and the following two pages show the Southern Pacific Railroad Bridge immediately downstream from the Mill Avenue Crossing in Tempe. The views are from the south abutment (left bank) of the Ash Avenue Bridge, looking northwest. The sequence of photos shows the loss of riparian vegetation and the entrenchment of the channel--as erosion lowers the channel floor through the sequence, progressively greater amounts of the piers of the bridges are revealed. The X-shaped cross supports between the piers provide useful markers. The entrenchment was so great between 1949 and 1980 that the 1980 flood water surface elevation was only slightly higher than the surface of the 1949 bed. Above, June, 1949 (Corps of Engineers Photograph, W. L. Graf (copy photograph) Photo 32-30. Below, January 1980 (W. L. Graf Photo 33-7).



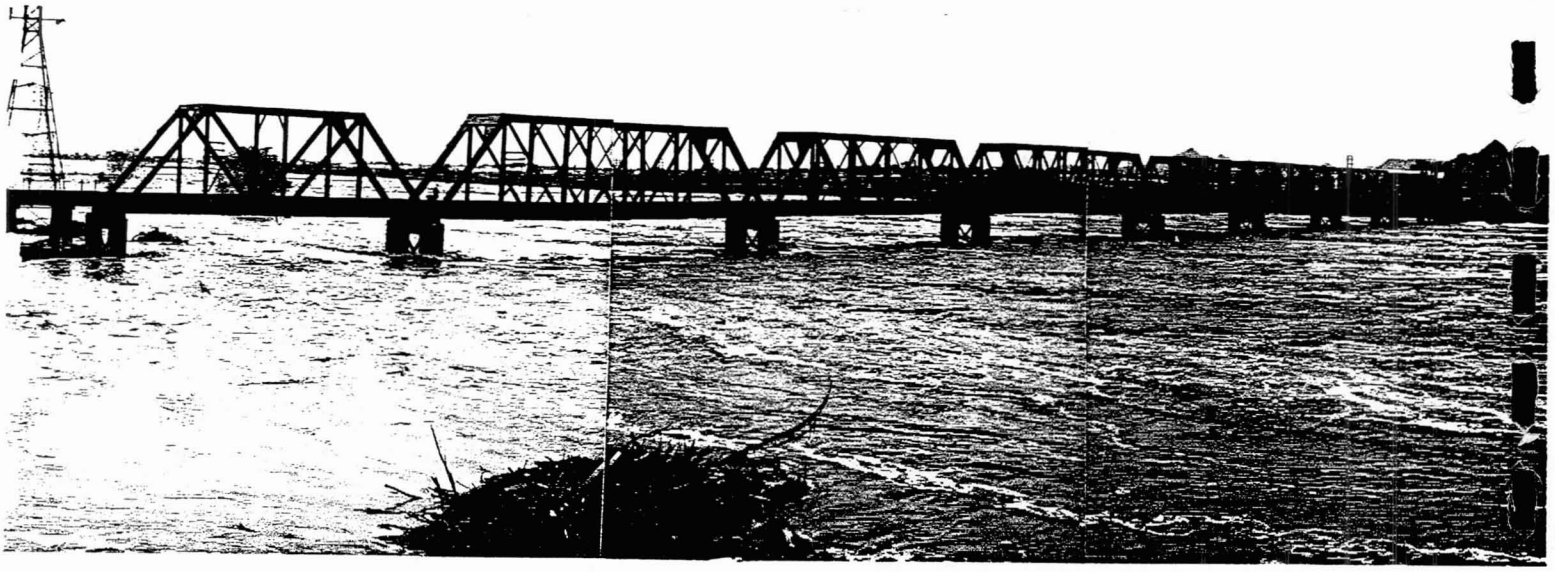


Figure 13 (continued). Above, February, 1980, with about 5,000 cubic feet per second discharge in the channel (W. L. Graf Photo 33-10). Below, February, 1980, with about 120,000 cubic feet per second in the channel (W. L. Graf Photo 35-3).

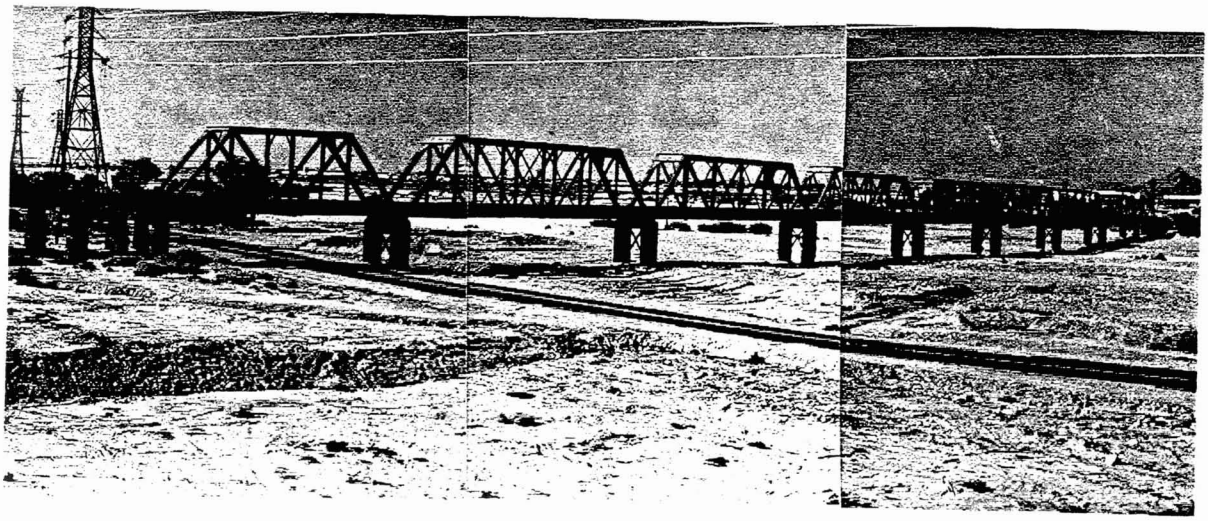


Figure 13 (continued). View in October, 1980 (W. L. Graf Photo 39-20).

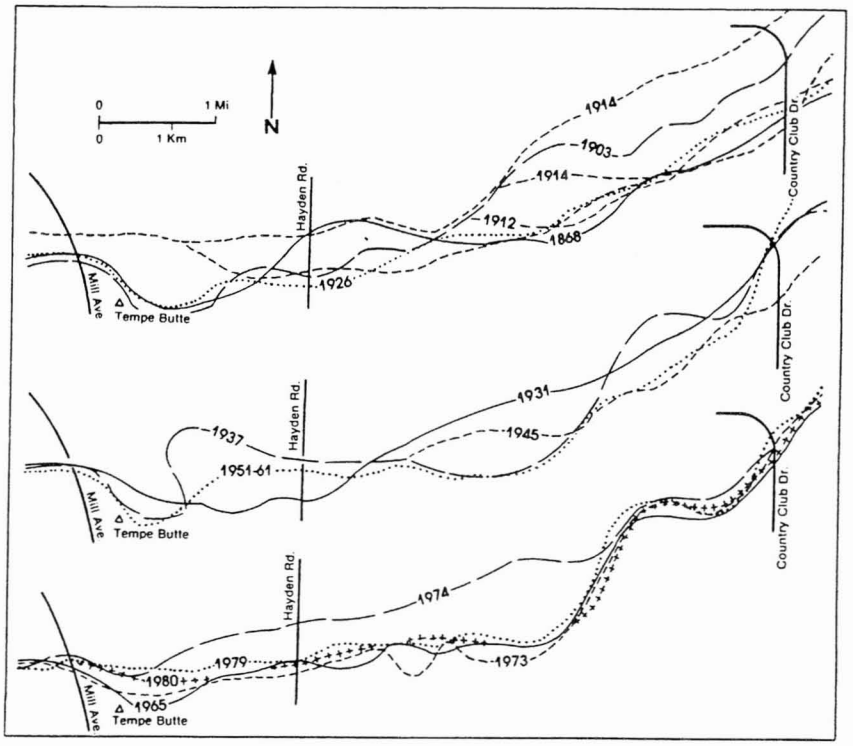


Figure 14. Example of historic channel locations for the thalweg of the Salt River between Country Club Crossing and Mill Avenue Crossing, 1868 - 1980 (from Graf, 1983).

not result in movement of the channel outside areas it had occupied during the previous century.

Despite notable location changes from time to time, the thalweg or low flow channel of the Lower Salt River has had a consistent sinuosity over the past century. Sinuosity is defined by the along-channel distance divided by the straight-line distance between the beginning and ending points of a segment. Thus, a sinuosity of 1.00 would denote a perfectly straight channel and a sinuosity of 2.00 would be a highly sinuous channel wherein the along-channel distance is twice as long as the straight-line distance between its beginning and ending points. Most natural channels vary between 1.00 and 4.00 (Gordon et al., 1992, p. 313), though channels with sinuosity greater than 2.00 are unusual. The sinuosity of the Lower Salt has had a mean sinuosity of 1.08 over the past 125 years, and despite numerous changes in channel location, deviations from the mean have been surprisingly small (Table 8). The channel may radically adjust its position, but overall it generally preserves the mean sinuosity--a meander eliminated in one location is almost always replaced by a meander in a different but nearby position.

The general gradient of the Lower Salt River between Granite Reef Dam and the Gila confluence is about 0.0021, although there are numerous local variations. The gradient has decreased to a minor degree because of erosion in the upper reaches and deposition in the lower reaches. The gradient of the Gila River between the confluence with the Salt and the Agua Fria River is about 0.0012, so that it is logical to expect deposition of materials from the Salt River in the channel of the Gila as a result of reduced gradient and associated reduced transport capacity for flows.

The channel degradation in Mesa and Tempe resulted in substantial changes in bed sediments in the Salt River in that area (Figure 15). As the channel cut downward, it exposed a series of well-defined strata. During the pre-1978 era, numerous historical photographs show that the channel was sandy, except at a few locations where cobble bars were common such as McDowell Crossing (about 2 miles east of Gilbert Road). Downcutting during the 1978 floods removed this sandy layer and began exposing a cobble layer. The 1980 flood further excavated the channel bed, in some places cutting completely through the cobble layer and extending into a mixed sand and cobble zone beneath. Later, smaller flows continued the excavation, in some places down to still another cobble layer. In deposition areas west of Phoenix, deposits also brought about changes in bed sediments. In areas that were once sandy, cobbles from the Salt River built bars, and sandy deposition outside the low flow channel created streamlined depositional forms.

Part of the explanation of the downcutting of the channel in Tempe and Mesa is that upstream dams are storing sediments once carried by flood flows, so the relatively clear water entering the study area are capable of entraining sediments that are not replaced by materials from upstream. The 1978-1980 flows may also have been so large that degradation would have occurred in any case.

2.3 Hydrologic System

2.3.1 Surface Water Hydrology

The operations of seven dams have significantly impacted the natural hydrologic

Table 8. Historical Sinuosity of the Channel of the Lower Salt River.

(Source: Graf, 1982)

Year	Country Club to Mill Ave.	Mill Ave. to 7th Street	7th Street to 59th Ave.	59th Ave. to Mon. Hill	Mean
1868	1.01	1.11	1.06	1.04	1.05
1907	1.06	1.08	1.05	1.05	1.06
1914	1.07	1.07	1.08	1.01	1.06
1926	1.06	1.12	1.14	1.03	1.09
1931	1.1	1.07	1.06	1.03	1.06
1937	1.29	1.05	1.06	1.02	1.13
1951	1.01	1.09	1.05	1.12	1.07
1961	1.01	1.12	1.06	1.16	1.08
1971	1.09	1.05	1.08	1.16	1.07
1973	1.17	1.06	1.07	1.08	1.1
1978	1.16	1.06	1.04	1.11	1.08
1979	1.14	1.11	1.01	1.12	1.1
1980	1.12	1.02	1.01	1.07	1.05
Mean	1.1	1.08	1.06	1.08	1.08
St. Dev.	0.08	0.03	0.03	0.05	0.02

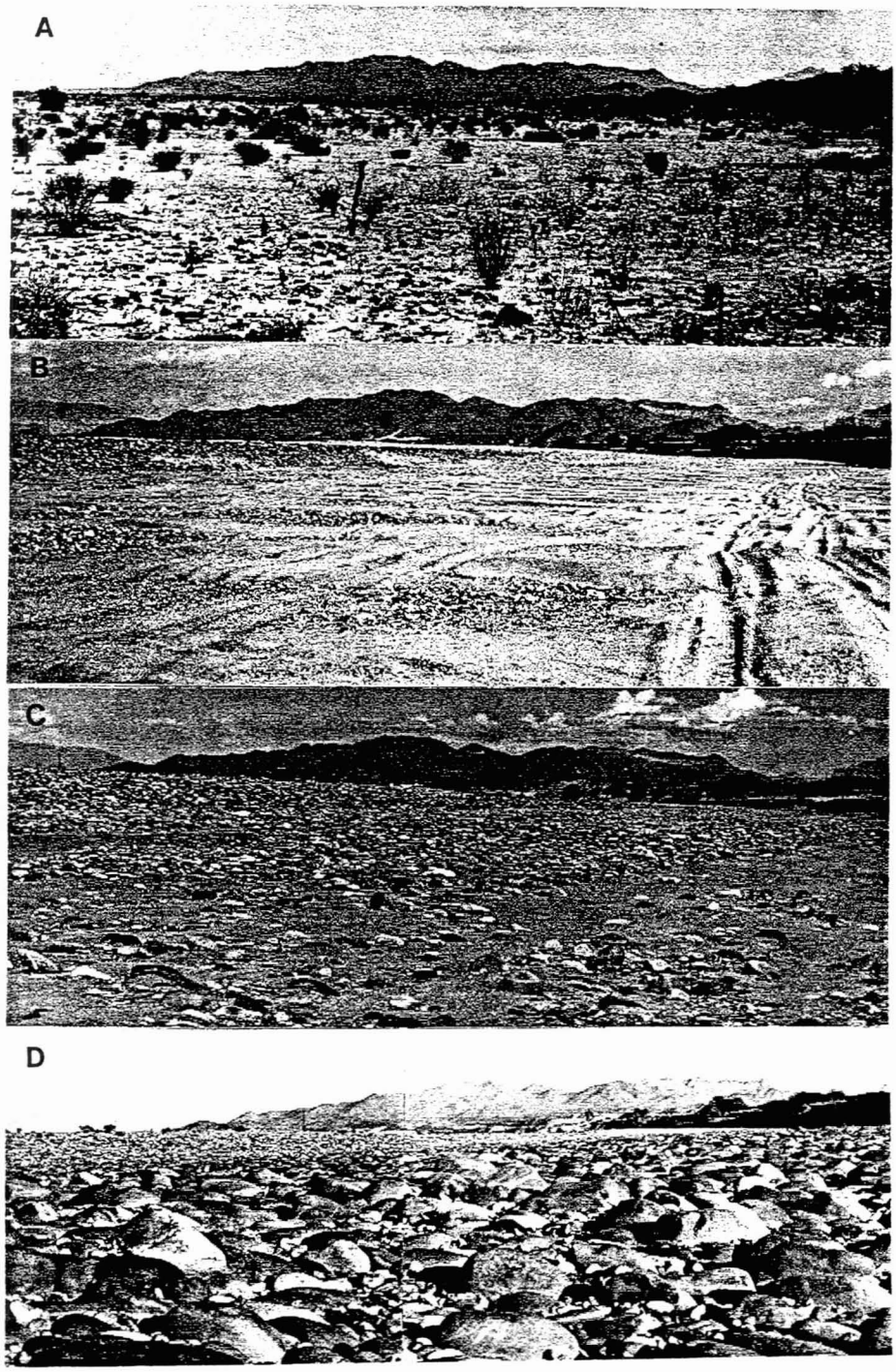


Figure 15. Series of historical photographs showing the progressive changes in bed material in the Salt River about 1.5 miles upstream from the Gilbert Road Crossing in northeast Mesa, as the channel excavated downward through a series of different strata. Note the progressive coarsening of the bed materials as the sand fraction has winnowed away. View is looking east, upstream. A, September, 1949 (Corps of Engineers, W. L. Graf (copy photograph) Photo . B, January, 1980, after major floods in 1979 (W. L. Graf Photo). C, December, 1980, after a major flood in early 1980 (W. L. Graf Photo). D, November, 1980, after a series of moderate floods.

regime of the Lower Salt River, altering both the magnitude and timing of flows. Since the closure of Bartlett Dam on the Verde River in 1938, the Lower Salt River has contained water only as a result of controlled or uncontrolled releases from Granite Reef Dam.

Appendix 8.10 contains discharge data including annual peak flows, flood peaks and durations, and mean monthly records. Salt River Project, the entity that manages the reservoirs upstream of the study area, releases water only for flood-control purposes, either to lower reservoir levels prior to winter rains or when the reservoirs are unexpectedly full. Most importantly, the system of dams upstream has eliminated perennial flow and the steady high winter flows. Climatically drier years, such as the period between 1942 and 1964 result in no releases, leaving the Salt River dry except for storm water runoff, groundwater emergence, and effluent. Since 1965, releases, about two per year, have lasted an average of 22.5 days with a peak mean daily flow of 13,960 cfs. Prior to 1938, an average of 413,000 acre-feet of water flowed through the channel annually. Since 1965, the channel has carried an average of only 293,000 acre-feet per year, with less than 10,000 acre-feet in almost three-fifths of the years.

Releases from the Granite Reef Dam mimic the natural seasonal variation in flows on the Salt River, probably because reservoir water levels respond to the same climatic controlling factors as pre-Bartlett Dam surface flows. Little data exist to document the seasonal fluctuations in flows on the Salt River. Appendix 8.10.2 contains monthly mean discharge data for the Salt River at McDowell for 1904-1910, but as this record covers only seven years, it does not give the best picture of seasonal flow variations. Records of mean monthly discharge on the Verde River below Bartlett Dam for the water years 1904-1938 serve as a surrogate for such records on the Salt River (Figure 16). The headwaters of the two rivers lie in similar topographic positions, and the rivers are otherwise hydrologicly similar. Under more natural conditions, flows peaked in late winter (February and March), supplied by storms and snowmelt. Flows were lowest in June, averaging only six percent of the mean high flows in February. Data for the years 1965-1993 show that flow occurs most frequently during the months of March and April and least frequently in July and August, much like the natural pattern. The systems of dams upstream of the study reach effectively delay the flows by one month. This delay becomes insignificant, however, in light of the extended periods of no flow in a river that is perennial under natural conditions.

The magnitudes of peak annual discharges on the Salt River are comparable with peak flows prior to the closure of Bartlett Dam, but high flows occur less frequently after 1938 (Figure 17). The mean peak annual discharge was 32,000 cfs before 1938 and 16,500 cfs from 1938 to present. This apparent reduction in flood magnitude results from frequent low-flow years. Only one-quarter of the years since 1938 experienced a peak discharge greater than 10,000 cfs, whereas prior to 1938 two-thirds of the years experienced flows higher than 10,000 cfs. Upstream dams have exacerbated high-flow conditions when they do occur. Prior to damming, only one year on record experienced a peak annual discharge greater than 100,000 cfs, while three such flows have occurred in the past 16 years.

Lack of gauging stations on the main river and on tributaries hinders detailed understanding of the surface hydrology of the Lower Salt River, forcing reliance on hydrologic data from releases from Granite Reef Dam. Water balance calculations show that the Salt River loses water to infiltration as it travels through the study area. During the floods of 1965-1966, 29

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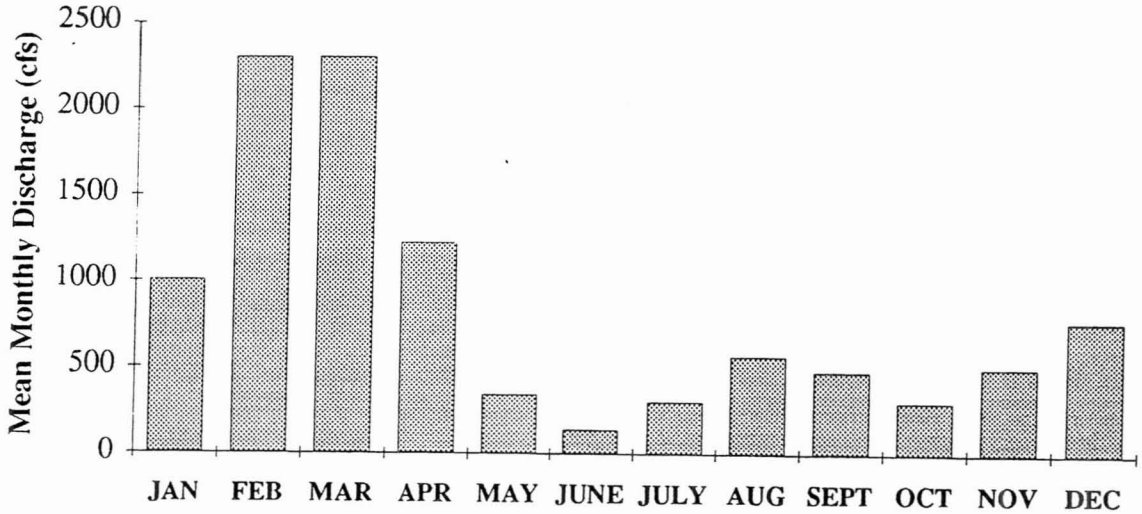


Figure 16. Mean monthly discharge for the Verde River below Bartlett Dam, 1904-1938, showing the seasonal pattern for the Verde River prior to the closing of Bartlett Dam, a reasonable surrogate for flows in the Salt River in the study area (data from the U.S. Geological Survey).

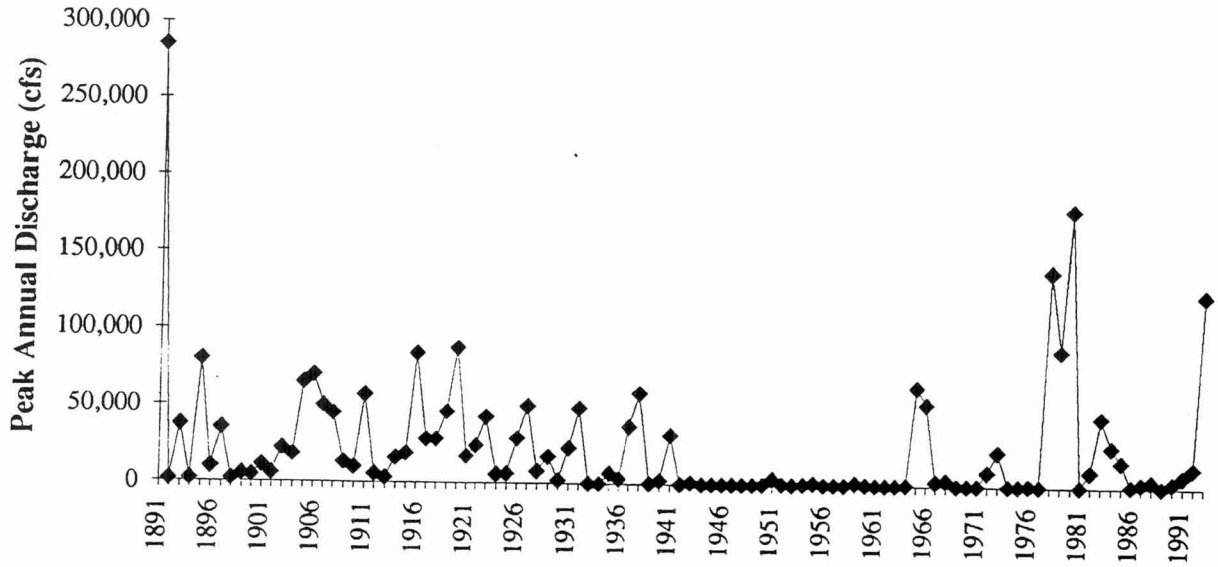


Figure 17. Annual peak flow of the Salt River for major releases from Granite Reef Dam, 1891-1993 (data from the Salt River Project).

percent of the 611,800 acre-feet of water released from Granite Reef Dam percolated into the bed of the channel between Granite Reef Dam and Gillespie Dam (Aldridge, 1970). Surface flows totaling 660,000 acre-feet were depleted by 17 percent during the February-March 1978 flows (Aldridge and Eychaner, 1984). Corkhill et al. (1993) performed a similar analysis for the years 1978-1988, showing that an average of 12 percent of the flow from Granite Reef Dam enters the ground water system through the bed of the channel (Table 9). The amount of infiltration is loosely related to the volume and rate of water release rather than the duration of the release.

2.3.2 Ground Water Hydrology

This section provides an overview of the hydrogeology, depth to ground water, and direction of ground water flow in the Salt River Valley with an emphasis on conditions near the river itself. Appendix 8.12 and the works cited here present more extensive discussions of ground water hydrology. The elevation of the water table and the direction of subsurface flows have changed drastically since the early 1900s due to pumping of water for agricultural, industrial, and other uses. For the purposes of this discussion, the study area has been broken down into six reaches of the Salt River that have similar hydrologic characteristics: reach one, Granite Reef Dam to McKellips Road; reach two, McKellips Road to Mill Avenue; reach three, Mill Avenue to Interstate 10, including all of Sky Harbor Airport; reach four, Interstate 10 to the 23rd Avenue Waste Water Treatment Plant; reach five, the 23rd Avenue Waste Water Treatment Plant to the 91st Avenue Waste Water Treatment Plant; and reach six, the 91st Avenue Waste Water Treatment Plant to the confluence with the Agua Fria River.

Three hydrologic units underlie the Salt River Valley. The U. S. Bureau of Reclamation, U. S. Geological Survey, and the Arizona Department of Water Resources have independently identified these units, but their descriptions and nomenclature differ slightly. This report uses the units described by Arizona Department of Water Resources in Corkhill et al. (1993). The three hydrogeologic units are: (1) the Lower Alluvial Unit (LAU), (2) the Middle Alluvial Unit (MAU), and (3) the Upper Alluvial Unit (UAU). The Salt River flows over the UAU and was once the most important source of ground water recharge for this unit (Wolcott, 1952). Composed predominantly of gravel and sand, the UAU ranges from 100 feet to 400 feet in thickness under the Salt River. The unit is thinnest near mountain fronts and bedrock outcrops, such as Tempe Butte and lower Papago Park. Primarily accessed for surface use over the MAU and LAU, water within the UAU is legally referred to as subflow to differentiate it from ground water in the MAU and LAU (K. Randall, 1994, personal communication). This discussion will use the term ground water to refer to water in the UAU. Historically, surface flows from streams and washes provided most water to recharge the UAU. Presently the minor recharge sources --such as seepage from canals and irrigated land, underflow along major streams, and rainfall-- have become more important (Wolcott, 1952).

Ground water naturally flows toward the Salt River and along the river westward, generally following the topography of the land surface. Near Tempe and Buckeye, bedrock constrictions force water to the surface (Wolcott, 1952). Excessive pumping has led to

Table 9. Groundwater Recharge from Historical Surface Flows.

(Source: Corkhill *et al.*, 1993)

Calender Year	Salt River Inflow at Granite Reef	Gila River Inflow at Laveen	Santa Cruz River Inflow at Laveen	Agua Fria River Inflow at Avondale	Gila River Inflow Estimated Baseflow	Gila River Outflow Gillespie Dam	Estimated Potential Maximum Recharge	Recharge as Percentage of Granite Reef Discharge
1978	13,893,000	44,000	21,100	81,600	30,200	1,333,100	233,100	16.8%
1979	1,997,100	102,600	30,400	40,300	81,700	2,030,500	221,600	11.1%
1980	2,061,400	25,900	700	168,500	61,600	2,339,600	-21,500	-1.0%
1981	100	0	100	0	900	1,000	100	100.0%
1982	178,300	300	2,600	ND	16,800	97,900	100,100	56.1%
1983	1,744,400	178,700	135,900	ND	104,600	1,928,500	235,100	13.5%
1984	271,200	16,800	5,500	ND	31,900	236,400	89,000	32.8%
1985	773,400	191,400	7,900	ND	84,300	956,200	100,800	13.0%
1986	8,400	0	0	ND	8,100	9,000	7,500	89.3%
1987	29,800	0	700	ND	25,000	41,800	13,700	46.0%
1988	20,400	0	700	ND	14,600	15,400	20,300	99.5%
1978-1988 Totals	8,473,800	559,700	205,600	290,365	459,700	8,989,400	999,800	11.8%

ND = No data, Agua Fria gage discontinued in 1982

1980 data contains probable extreme gaging inaccuracies

drawdown of the water table in some well fields. These human-created lows deflect the flow of ground water, reversing the flow in some cases. Drawdown in the Deer Valley and Queen Creek areas in the 1940s and 1950s caused flow to move away from the Salt River rather than toward it (Wolcott, 1952). The Deer Valley low has persisted into the 1980s and a new low has developed west of Luke Air Force Base in the west valley (Brown and Pool, 1989). Naturally, the movement of water toward the river channel and flow within the channel created a mound of ground water under the channel, accessed by a variety of riparian plants. Deflecting flow away from the river contributes to the water table decline near the river by destroying the ground water mound.

Depth to ground water has fluctuated greatly since development of the Salt River Valley began in the late 1890s. Initially, diversion of water from the river for irrigation led to a rise in the water table. Canal seepage locally raised the water table as much as 20 feet above the natural water table (Thomsen and Miller, 1991). As development preceded, ground water became an important water source for agriculture. Over 75 percent of the pumped ground water in the Salt River Valley is used for agriculture (Wilson,1991). Drought conditions and pumping between 1895 and 1905 caused a decline the well levels of 8 - 20 feet in the Mesa/Tempe area (Lee, 1905). The water table declined steadily from the 1930s into the 1960s due to increased pumping. The magnitude of these declines varied spatially, from a few feet in some places to a few hundred feet in others (Wolcott, 1952; Bureau of Reclamation, 1976). Reaches one and two (Granite Reef Dam to Mill Avenue) have experienced the greatest increases in depth to ground water (Table 10). Reaches three and six, where shallow bedrock forces water to the surface, depth to ground water is only 10 to 30 feet greater than in the early 1900s. Reach six historically has the shallowest ground water, as indicated by data in Table 10 and by phreatophyte vegetation. This area also receives substantial underflow from the Gila River. Corkhill *et al.* (1993) estimate that underflow from the Gila provided approximately 32,000 acre-feet per year prior to development, but contributes only 2,000 acre-feet per year presently.

During the 1980s, pumping of ground water has declined in the Salt River Valley (Wilson, 1991). Data for seven wells along the Salt River for the years 1987-1992 indicate that while ground water levels do not exhibit a distinct upward or downward trend, the levels fluctuate considerably (Table 11). Depth to ground water decreases downstream, from an average of approximately 260 feet near Granite Reef Dam to less than 10 feet near Buckeye. Water levels upstream (i.e., in reaches one and two) fluctuate the most from year to year, on average seven to 19 feet, and exhibit the greatest range in levels for the years 1987-1992. Wells further downstream show less change and a small range in levels. These areas receive some ground water recharge from waste water treatment plants, irrigation seepage, and underflow from the Gila River.

2.3.3 Water Quality

Contaminants of surface water and ground water include naturally occurring and artificial (human-made) substances introduced into a system by a variety of means. Technically, to be considered contaminants, these substances must be present in concentrations greater than some established level which varies by substance. Federal (primarily the Environmental Protection Agency (EPA)) and State agencies establish these standards, but do not necessarily explain the

Table 10. General Depths to Groundwater near the Lower Salt River.

Year	Granite Reef Dam to McKellips Rd.	McKellips Rd. to Mill Ave.	Mill Ave. to Interstate 10	Interstate 10 to 23rd Ave.	23rd Ave. to 91st Ave.	91st Ave. to Agua Fria	Source
c. 1900	0 - 40 feet	0 - 10 feet	0 - 40 feet	ND	ND	ND	Thomsen and Miller, 1991
1913	10 - 50 feet	0 - 10 feet	0 - 10 feet	0 - 10 feet	0 - 10 feet	0 - 10 feet	McDonald et al., 1947
1945	50 - 150 feet	0 - 50 feet	0 - 10 feet	10 - 50 feet	10 - 50 feet	0 - 10 feet	McDonald et al., 1947
1952	100 - 140+ feet	20 - 80 feet	40 - 60 feet	40 - 60 feet	20 - 40 feet	<20 - 40 feet	Wolcott, 1952
1964	ND	ND	ND	80 - 100 feet	60 - 80 feet	40 - 60 feet	Bureau of Reclamation, 1976
1972	ND	ND	ND	60 - 80 feet	40 - 60 feet	<20 - 40 feet	Bureau of Reclamation, 1976
c. 1986	190- 250 feet	90 - 140 feet	10 - 60 feet	ND	ND	ND	Thomsen and Miller, 1991

Table 11. Depths to Groundwater at Specific Wells.

(U.S. Geological Survey Data)

Well #	U. S. G. S. Well #	Location	Period of Record	Depth to Groundwater - Extremes of Record Highest (ft)	Year	Lowest (ft)	Year
A	A-02-06 32ACD	Val Vista Dr. & Lehi Rd.	1959-present	282	1985	402.7	1979
B	A-01-05 06BDD	Pima Rd. & McDowell Rd.	1957-present	77.1	1983	165.4	1979
C	A-01-04 18DAD	University Dr. & SR 143	1951-present	18.93	1983	61.8	1976
D	A-01-02 26AAA	Broadway Dr. & 27th Ave.	1948-present	27.7	1979	74.42	1959
E	A-01-02 19BAA	Lower Buckeye Rd. & 67th Ave.	1957-present	43.4	1984	113.12	1962
F	A-01-01 19DCD1	Broadway Dr. & 107th Ave.	1952-present	24.8	1985	59.7	1964
G	B-01-02 36 BBC	Southern Ave. & Cotton Lane	1951-present	6.0	1983	70.53	1965

Table 11. Depths to Groundwater at Specific Wells (continued).

(U.S. Geological Survey Data)

	Depth to Groundwater for Exact Well					
Well #	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
A	289.20	282.60	286.20	ND	313	314.2
B	138.30	136.80	135.90	148.1	165.4	100.4
C	36.10	36.20	37.70	48.8	49.9	50.9
D	41.00	42.90	ND	ND	48.4	49.9
E	52.40	51.00	52.20	60.0	61.9	59.5
F	26.50	27.10	26.40	28.8	31.4	29.4
G	11.40	11.08	11.90	10.6	10.9	18.1

ND = no data available

Table 11. Depths to Groundwater at Specific Wells (continued).

(U.S. Geological Survey Data)

Well #	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	1298	1250-1260	297.04	31.6	7.64
B	1201	1180-1190	137.48	65.0	19.38
C	1130	1120-1130	43.27	14.8	2.96
D	1042	1020-1030	45.55	8.9	1.78
E	1025	980-990	56.17	10.9	2.94
F	965	935-945	28.27	5.0	1.66
G	891	880-890	12.33	7.5	1.99

basis for the hazard levels. Standards also vary by water use, for example, drinking water, irrigation, or recreation. Appendix 8.11 provides some of the standards for various contaminants by water use. Contaminants in the surface and ground waters of Arizona fall into seven categories: volatile organic compounds (VOCs), pesticides, metals, nutrients, ions, micro-organisms, and radiological substances (Table 12). Similar quality issues exist for all water sources in the Lower Salt River, namely contamination by volatile organic compounds (VOCs) and various metals, ions, nutrients, and herbicides. As previously discussed, surface water naturally provides the main source of recharge for ground water. Shallow ground water in other reaches of the river often emerges in the channel, creating surface flows. Effluent from water treatment plants and other industries contributes to both surface and subsurface flows. Thus, contaminants do not remain in one part of the system, but endanger all water sources.

This section gives a broad overview of water quality in the Lower Salt River hydrologic system and discusses each of the major contaminant types, including occurrences and sources. Table 13 presents violations of water quality regulations in 1989-1991 for water sources in or near the Lower Salt River, as published in the Arizona Department of Water Quality (ADEQ) 1992 Annual report. These violations are listed by reach of the Salt River, using the same subdivisions employed in the discussion of ground water: reach 1, Granite Reef Dam to McKellips Road; reach 2, McKellips Road to Mill Avenue; reach 3, Mill Avenue to Interstate 10; reach 4, Interstate 10 to 23rd Avenue Wastewater Treatment Plant; reach 5, 23rd Avenue Wastewater Treatment Plant to 91st Avenue Wastewater Treatment Plant; and reach 6, 91st Avenue Wastewater Treatment Plant to the confluence with the Agua Fria River. ADEQ provides the most spatially extensive and reliable water quality information. Additionally, Table 14 shows the 1989 range in water quality parameters for Salt River Project (SRP) wells near the Salt River by reach, using the six previously defined reaches. Notably, Salt River Project did not test some of the wells for metals or VOCs, the most prevalent contaminants in the region.

The most prevalent water contaminants in the Lower Salt River area are volatile organic compounds (VOCs), organic solvents widely used by both small and large industries and airports, and often found in landfills (Table 12). VOCs are the primary contaminants associated with Federal Superfund sites and State of Arizona Water Quality Revolving Assurance Fund sites and are most frequently the result of improper disposal of industrial solvents, degreasers, and other compounds (Arizona Department of Water Quality, 1990). Major disposal practices which have led to ground water contamination include injection of waste into dry wells, disposal in surface impoundments which leak, dumping into dry washes, unregulated landfilling, and leaking underground storage tanks. Water quality violations cited by ADEQ show the presence of VOCs in ground water in areas near every reach of the Lower Salt River, especially common in the Central Phoenix area (Table 13). VOCs appeared in ground water in two of the four areas near the Salt River where SRP tested for these substances, between Granite Reef Dam and McKellips Road and between Mill Avenue and Interstate 10 (Table 14). Comparison of the two sources suggests that in reach 3, VOCs in ground water relate directly to Sky Harbor Airport and the Estes/Bradley Landfill, both located on the Salt River. In a Water Quality Revolving Assurance Fund (WQARF) study commissioned by ADEQ, VOCs in the ground water in the east central Phoenix area came from several sources and their occurrence in the ground water was spatially discontinuous. Major VOC sources, such as the Motorola 52nd Street Superfund Site, did not release plumes of contaminants, but rather created localized contamination around multiple source

Table 12. Types of Water Contaminants in the Lower Salt River.

(Source: 1988 and 1989 Annual Reports, Arizona Department of Environmental Quality)

Contaminant Category	Principal Contaminants	Typical Sources	Potential Health Impacts
Volatile Organic Compounds (VOCs)	*Organic Solvents* Trichloroethene (TCE) Tetrachloroethylene (PCE) 1,1,1 Trichloroethane (TCA) Chloroform 1,1 Dichloroethylene (DCE) 1,1 Dichloroethane (DCA) Benzene	Landfills Underground Storage Tanks Airports High Technology Industry	Carcinogen
Pesticides	Dibromochloropropane (DBCP) Ethylene dibromide (EDB)	Agriculture (soil fumigants) Urban Runoff	Toxics Carcinogen
Metals	Arsenic Barium Boron Chromium Copper Iron Lead Mangenese Selenium Zinc	Landfills Mines Metal Finishing Natural Origin Landfills	Toxics Carcinogen
Nutrients	Nitrate	Agriculture (fertilizers) Wastewater Treatment Septic Tanks Industrial Manufacturing	Methemoglobinemia (blue-baby disease)
Ions	Total Dissolved Solids (TDS) Sulfate Chloride Fluoride	Mines Agriculture Natural Origin	Taste, Hardness Laxative Effect Toxics
Micro-organisms	Fecal Coliform	Septic Tanks Wastewater Treatment	Infectious Disease
Radiological		Mines Natural Origin	Carcinogen

Table 13. Water Quality Violations in the Phoenix Area.

(Source: Arizona Department of Environmental Quality, 1992)

Reach	Water Source	Location	Comments
Entire study area	Surface water	Salt River *Granite Reef Dam to Gila River*	Non-support due to mercury low pH, TDS 1050-1450 Several toxics exceeding standards
1	Groundwater	Mesa (Northeast Mesa)	VOCs in groundwater: TCE; PCE; and 1,1-DCE
1,2	Groundwater	Mesa (South Mesa area)	VOCs in groundwater: TCE; PCE; and 1,1,1-DCE
2	Groundwater	Mesa (Mesa Motorola)	VOCs in groundwater: TCE; PCE; and 1,1,1-DCE
2	Groundwater	Scottsdale	VOCs TEC, PCE, DCE, TCA, and DCA in groundwater due to electronics and metal plating industries
2	Surface water	McKellips Park Lake, Indian Bend Wash, Scottsdale	Contaminated by TCE from Superfund Site Algae blooms, fish kill in 1987 Sources: urban runoff and land disposal
3	Groundwater	Phoenix (Motorola 56th Street)	VOCs: TCE; PCE; 1,1-DCE; Chloroform; and freon 113 in groundwater
3	Groundwater	Phoenix (Motorola 52nd Street)	VOCs: Twenty-seven compounds including TCE; PCE; TCA; 1,1-DCE; TRANS1,2-DCE; and freon 113 in groundwater due to electronics and semi-conductor industry
3	Groundwater	Phoenix (East Washington area)	VOCs TCE; PCE; 1,1-DCE; 1,1,2-TCA; chloroform; freon 11; 1,1-DCA; TRANS1,2-DCE; and vinyl chloride in groundwater
3	Groundwater	Phoenix (east central Phoenix)	VOCs TCE; 1,1,1-TCA; and PCE in groundwater due to improper disposal of dry-cleaning chemicals
3	Groundwater	Phoenix (Estes/Bradley Landfill)	VOCs TCE; 1,1-DCE, TRANS1,2-DCE; vinyl chloride in groundwater due to landfill
3	Groundwater	Phoenix (Sky Harbor Airport)	VOCs: TCE; PCE; 1,1-DCE; TRANS1,2-DCE; 1,1,1-TCA; 1,1-DCA; benzene; and toluene in groundwater
4	Groundwater	Phoenix 19th Avenue	Contamination by metals
4	Groundwater	Phoenix (19th Avenue)	VOCs: 1,1-DCE in groundwater

Table 13. Water Quality Violations in the Phoenix Area (continued).

Reach	Water Source	Location	Comments
4	Groundwater	Phoenix (West central Phoenix)	VOCs: TCE; PCE; and 1,1-DCE in groundwater
4	Groundwater	Phoenix (Honeywell Deer Valley)	VOCs: TCE in groundwater
4	Effluent *Salt River*	Ameron Inc., Phoenix	Non-support due to soluable solids, pH
5	Effluent *Salt River*	Anderson Clayton & Co., Phoenix	Non-support due to soluable solids, pH
5	Effluent *Salt River*	23rd Avenue Wastewater Treatment Plant, Phoenix	Partial support due to soluable solids and pH
5,6	Groundwater	Phoenix (West Van Buren)	VOCs in groundwater: TCE; PCE; 1,1-DCE; and 1,1,1-TCA
5,6	Surface water	Salt River below 59th Avenue Gila River *Salt River to Painted Rock Dam*	Fish advisory, chemicals of concern: chlordane, DDT, dieldrin, toxaphene, methymercury
6	Surface water	Gila River *Salt River to Agua Fria River*	Non-support due to mercury TDS 1400-2280 Occassional dissolved oxygen and pH violations
6	Effluent *Salt River*	91st Avenue Wastewater Treatment Plant, Phoenix	Threat due to TDS
6	Effluent *Salt River*	Tolleson Wastewater Treatment Plant	Non-support due to metals (chromium, copper, mercury, arsenic), flow, chlorine, pH, biological oxygen demand, and phenols
6	Effluent *Agua Fria River*	Loral Corporation, Litchfield	Non-support due to toluene, metals, methal-chloride, pH
Outside study area	Groundwater	Luke Air Force Base	VOCs in groundwater Trace levels of PCE and TCE in groundwater
Outside study area	Effluent *Agua Fria River*	Luke Air Force Base	Exceeded NPDES permit requirements for: boron, phenol, ammonia, mercury, biological oxygen demand, soluable solids, sulfide, fecal coliform
Outside study area	Groundwater	Buckeye	Nitrate contamination, most likely due to agriculture Contamination by metals
Outside study area area	Groundwater	Liberty (Gila River)	Contamination by major cations and anions TDS 3,000 - 5,000 mg/l

Table 14. Water Quality in Wells near the Lower Salt River.

(Source: Salt River Project, 1990)

Substance	Granite Reef Dam to McKellips Rd.	McKellips Rd. to Mill Ave.	Mill Ave. to Interstate 10	Interstate 10 to 23rd Ave. WWTP	23rd Ave. WWTP to 91st Ave. WWTP	91st Ave. WWTP to Agua Fria
Ions and Nutrients (mg/l)						
Total Dissolved Solids	***398-765****	***584-798****	***1154-1463****	***1161-1440****	***873-1083****	***1520****
Boron	0.1-0.19	0.18-0.4	***0.39-1.89****	***0.64-1.24****	***0.55-0.71****	***0.94****
Sodium	110-169	138-188	285-481	318-347	200-288	416
Potassium	2.3-4.7	4.1-5.3	4.2-6.4	4.8-8.2	4.4-5.0	4.9
Calcium	22-58	49-67	29-82	66-81	48-68	82
Magnesium	8.6-22	18-32	12.0-37	24-39	22-27	36
Carbonate	ND	ND	ND	ND	ND	ND
Bicarbonate	***207-323****	***195-378****	***470-488****	***342-549*****	***336-421****	***451****
Nitrate as NO3	***7.4-57****	***8.2-48****	***42-55****	***50-55****	26-39	***56****
Chloride	***94-255****	***168-282****	***320-325****	***365-485*****	***247-310****	***471*****
Fluoride	0.28-0.61	0.19-0.40	0.38-4.36	0.45-0.67	0.34-0.73	0.68
Sulfate	40-120	44-83	125-345	160	104-145	233
Phosphate	ND	ND	ND	ND	ND	ND
Metals (µg/l)						
Arsenic	6.0-13	4.0-6	<15	ND	NT	11
Barium	18-63	38-66	40-107	31	NT	31
Cadmium	ND	ND	ND	ND	NT	ND
Chromium	18-27	14-17	<19	15	NT	ND
Lead	2.0-6	<2	<14	ND	NT	ND
Mercury	ND	ND	ND	ND	NT	ND
Selenium	<2	ND	2.0-3	ND	NT	ND
Silver	<1	ND	ND	1	NT	1
Other Contanimants (µg/l)						
Volatile Compounds (VOCs)	1,1 DCA 1.9 METHCHL 0.7 PCE 0.6 1,1,1 TCA 0.6 TCE 3.3	NT	***1,1 DCE 24**** CHLORO 0.8	ND	ND	NT
Herbicides	NT/ND	ND	ND	***DBCP 0.35****	NT	NT
Chlorinated herbicides	NT/ND	ND	ND	ND	NT	NT
Pesticides	NT/ND	ND	ND	ND	NT	NT
Number of wells included	6	6	2	2	3	1

ND = Not Detected
NT = Not Tested
* = Increasing problems, exceedence of EPA or Arizona Action maximum levels
** = Severe problems

areas (Earth Technology Corporation (Western), 1990). While VOCs are a major water quality concern throughout the study area, the variety of sources and their spotty distribution makes them extremely difficult to isolate and remove from the hydrologic system.

Metals as contaminants do not occur to the same spatial extent as VOCs. Possible sources of metal contamination include landfills, mines, metal finishing, and natural origins (ADEN, 1988, 1989). The surface waters of both the Salt and Gila Rivers in the study area exceed the maximum allowable limit for mercury. ADEN (1993) states that mercury contamination is commonly associated with mining operations and effluent-dominated waters, such as the Salt River below 91st Avenue, and that water quality violations frequently appear to be linked with the remobilization of contaminated sediments during higher than normal flows. Effluent from three sources near or on reach 6 of the Salt River contained unacceptable concentrations of mercury and/or other metals in 1989-1991 (ADEN, 1992). While metals appeared in some of the SRP ground water wells, their concentrations did not exceed the maximum allowable limits. The exact sources and extent of contamination of surface waters by mercury and other metals remains unclear, though sediments play an important role in understanding the distribution.

Several ions and nutrients also exceed maximum allowable levels in ground water, surface water, and effluent in the study reach. Nitrates, added to the hydrologic system as fertilizer or from feed lots, ranged from 2 - 172 mg/l in Salt River Project wells throughout the valley in 1989 (SRP, 1990). Near the Salt River, wells in five out of six reaches exceeded the Environmental Protection Agency standard of 45 mg/l for Nitrate. Historically, nitrate levels have increased due to leaching of irrigated soils and sewage seepage (Brown and Pool, 1989). Wells in all reaches of the river exceeded recommended concentrations of bicarbonate and chloride, 90 mg/l and 250 mg/l respectively. Boron presents another potential danger to plants, occurring in problematic levels in wells in the lower four reaches of the river. While boron naturally occurs in the Salt River waters, waste water treatment plants also contribute to high levels of boron. Boric acid is heavily used in some areas to control cockroaches in municipal sewer systems (ADEN, 1993), and boron may also leach into the ground water from irrigated fields which receive waste water or sludge.

Total dissolved solids (TDS) likely warrant the least concern among all contaminants. Historically, TDS concentrations in surface and ground waters exceed the recommended standards for irrigation waters (500 mg/l), ranging between 500 to 5,000 mg/l (Table 15). The long history of irrigation in the valley has produced little long-term change in the chemical quality of the ground water since 1900 (Thomsen and Miller, 1991). TDS in both the ground water and surface water of the Salt River increased during the first half of this century, peaking around 1950 at 3,500 - 4,000 mg/l (Halpenny and Greene, 1975). More recent data show that TDS has declined since then, probably due to ground water recharge (Brown and Pool, 1989). SRP wells data suggest that TDS pose the greatest danger to plants in the lower four reaches of the river (Table 15). In 1989, SRP wells ranged in TDS concentration from 230 -3,670 mg/l, with a median of 910 mg/l (SRP, 1990). Surface waters of the Salt and Verde Rivers generally contain lower TDS concentrations, averaging 552 mg/l and 282 mg/l respectively in 1989 above Granite Reef Dam (SRP, 1990). These concentrations are significantly lower than historic measurements: Halpenny and Greene (1975) report TDS levels in the Salt River at low flow as 1,850 mg/l in 1900, 2,490 mg/l in 1912, 2,900 mg/l in 1930 and 3,500 mg/l in 1943. TDS

Table 15. Total Dissolved Solids in Salt River Water.

(Source: Salt River Project, 1990)

Year	Granite Reef Dam to McKellips Rd.	McKellips Rd. to Mill Ave.	Mill Ave. to Interstate 10	Interstate 10 to 23rd Ave. WWTP	23rd Ave. WWTP to 91st Ave. WWTP	91st Ave. WWTP to Agua Fria	Source
1945	500 - 1,000 mg/l	500 - 1,500 mg/l	1,000 - 1,500 mg/l	1,000 - 1,500 mg/l	1,500 - 3,000 mg/l	2,000 - 4,000+ mg/l	McDonald et al., 1947
1980	< 1,000 mg/l	1,000 - 3,000 mg/l	1,000 - 3,000 mg/l	1,000 - 3,000 mg/l	1,000 - 5,000 mg/l	3,000 - 5,000 mg/l	Daniel, 1981
1985	ND	ND	ND	479 - 919 mg/l	560 - 3600 mg/l	1700 - 2100 mg/l	Brown and Pool, 1989

concentrations on average vary with the amount of flow. For example, during the 1978-80 floods, the Salt and Verde Rivers ranged between 100 and 900 mg/l TDS for lower flows and between 200 and 500 mg/l TDS for higher flows (Brown and Pool, 1989). While TDS in surface and ground waters may cause problems for salt-sensitive crops and other plants, the present concentrations do not significantly differ from more natural conditions along the Salt River.

2.4 Geomorphic System

2.4.1 Channel Types and Forms

The channel of the Lower Salt River and the Gila River between the Salt and Agua Fria rivers 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 than one low flow channel, usually one that is clearly the thalweg plus additional channels that are occupied only at moderate or high flows. This condition was recognized by early surveyors who mapped multiple channels in some cases (Figure 18), and high flow channels in others (Figure 19). 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 study area channels. First, braided channels typically carry large amounts of sediment compared to the capacity of the stream, and the Lower Salt River appears to be "overloaded" with sediment in its lowest reaches. Second, such streams also have gradients that are relatively steep or they generate high amounts of stream power. The Lower Salt River 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 along parts of the Lower Salt River, especially in the north Mesa area. Finally, braiding usually results from highly variable discharges such as those found in glacial or dryland rivers such as the Salt. For these reasons, braiding of at least parts of the Lower Salt 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 Salt River is the compound form (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. They are the sites of standing water for a period, and eventually they fill with sediment during moderate floods. Upstream dams prevent moderate flows, but occasional catastrophic floods (perhaps accompanied by spills from the dam) make the broad, braided part of the channel

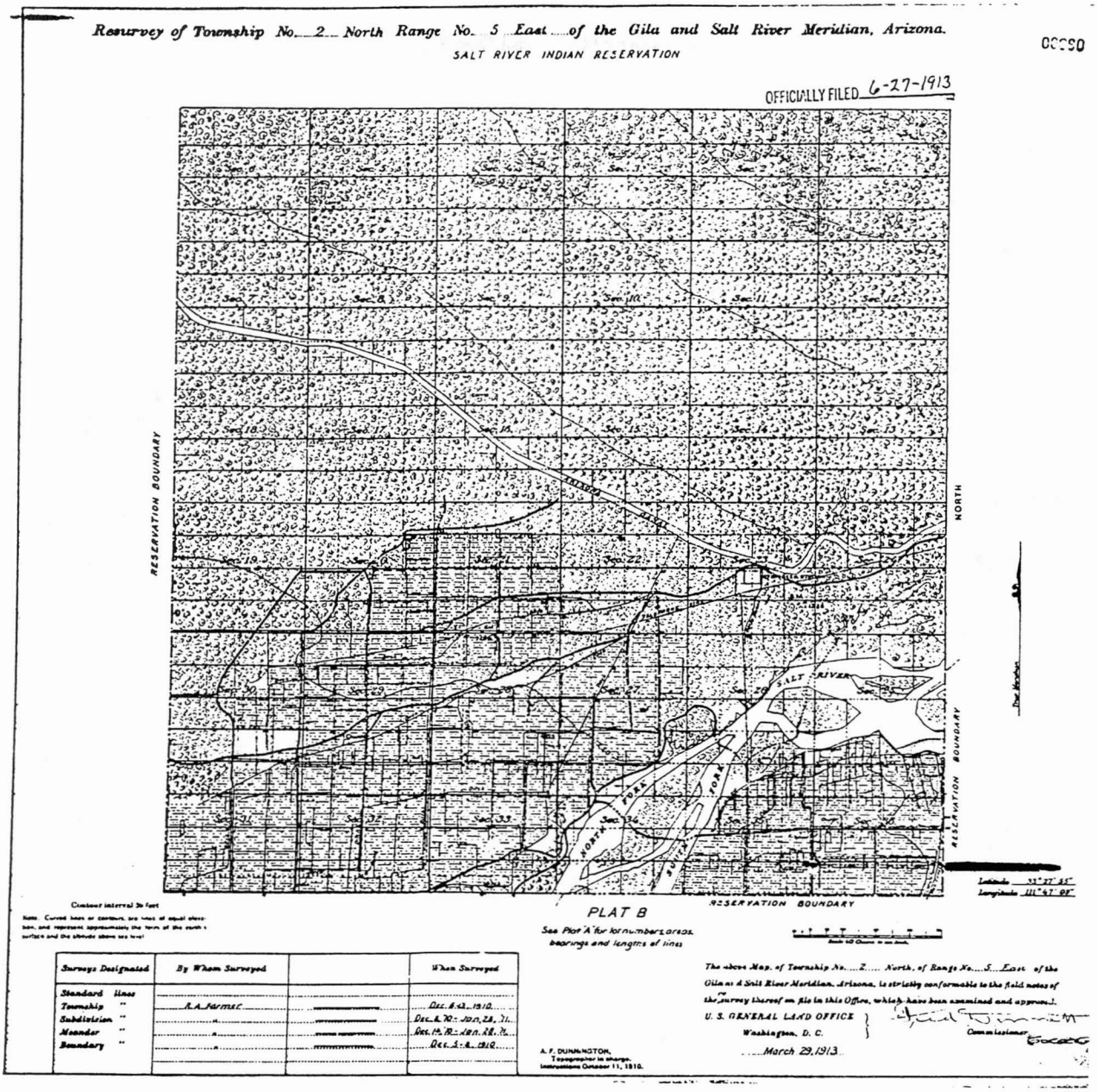


Figure 18. General Land Office Survey plat map made in 1910 of a township in north Mesa that includes a portion of the Salt River, mapped by the surveyor as having multiple channels.

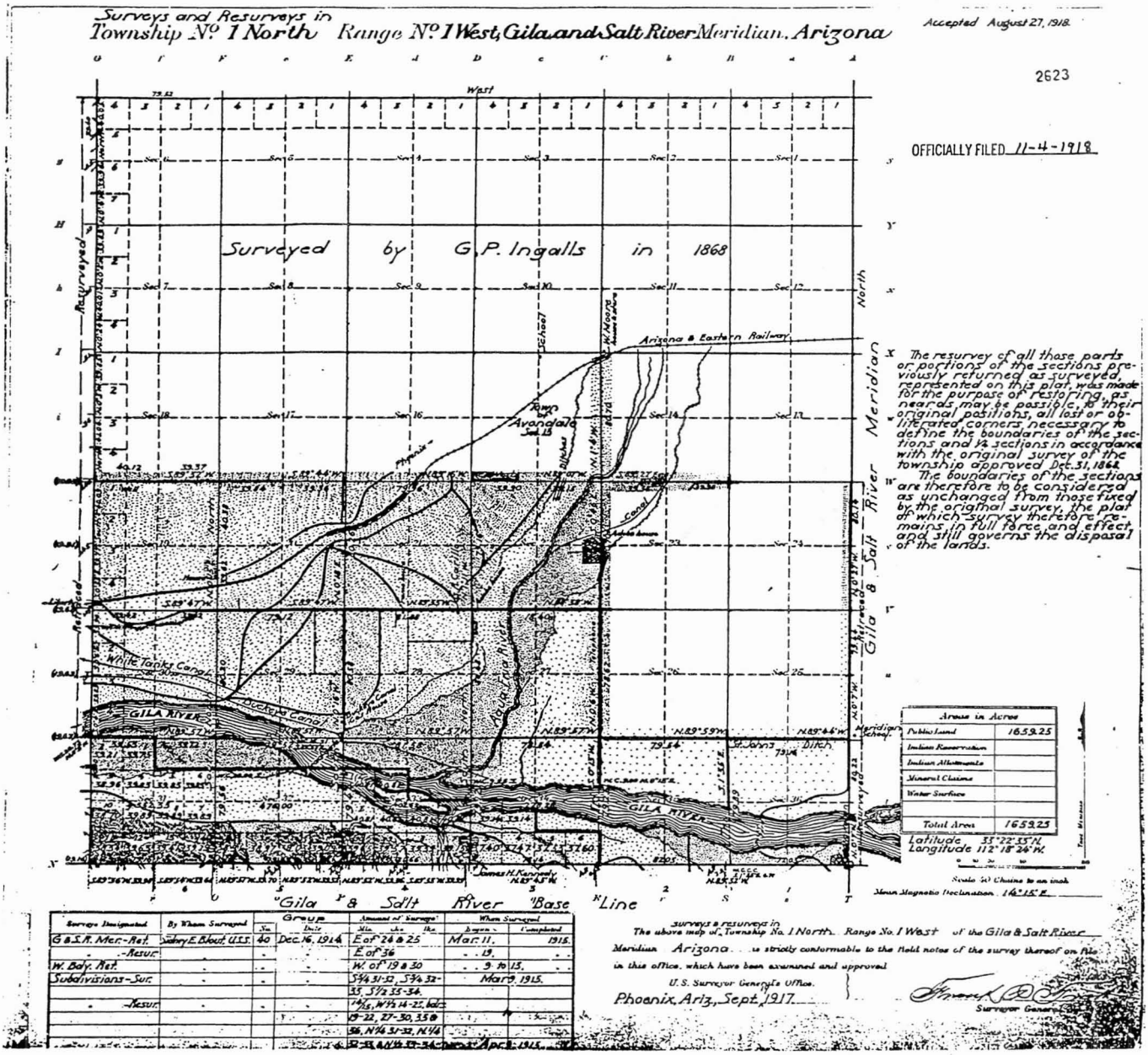


Figure 19. General Land Office Survey plat map made in 1915 of a township that includes the confluence of the Agua Fria and Gila rivers. The surveyor shows the wider, high flow channel of Gila River.

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 Salt River has compound channels in several segments.

The channel between Granite Reef Dam on the Salt River and the Agua Fria confluence on the Gila River has 8 naturally defined geomorphic divisions. Within each division, channel width, depth, pattern, and gradient are relatively similar, and are different from adjacent divisions. Refer to Appendix 8.2 for topographic maps that include mile marks.

1. Miles 0 to 4.3, Granite Reef Dam to Val Vista Road. Channel constricted by bedrock associated with Mount McDowell (also known as Red Mountain) and Schlects Butte, and by impinging terrace edges; channel is relatively straight and only half as wide as the next division downstream; one low flow channel.

2. Miles 4.3 to 13.2, Val Vista Road to Pima Road. Very wide channel, not restricted, especially on the north bank, some erosion into the south bank where the channel is eroding a low-level terrace; braided channel with multiple threads; considerable locational instability for low flow channel; portion of the channel from Country Club Drive to Pima Road is extensively mined for sand and gravel.

3. Miles 13.2 to 16.4, Pima Road to Mill Avenue. A more narrow channel division than the one immediately upstream, partly constricted by Tempe Butte and the Papago Hills; a compound channel division, with a single low flow channel (occasionally in the past, two such channels) that have had radical meanders, probably as a result of reduced gradient immediately upstream from the Mill Avenue narrows. Major changes to the channel as a result of channelization by the Arizona Department of Transportation and the Flood Control District of Maricopa County in association with the Tempe Rio Salado Project have erased most of this natural channel configuration.

4. Miles 16.4 to 21.5, Mill Avenue to 24th Street. A wide, unstable portion of the channel in its original, natural condition, with several threads formed by low and moderate flows set within a wider braided configuration. Four channels once existed at the 48th Street Crossing, but engineer projects associated with the Tempe Rio Salado Project, Phoenix Sky Harbor Airport, and the Interstate 10 Bridge have produced a new, artificial channel configuration.

5. Miles 21.5 to 26.8, 24th Street to 27th Avenue. A more narrow channel than the division immediately upstream, generally with a single-thread low flow channel with low sinuosity and substantial stability. The division is strongly affected by sand and gravel mining operations, urban engineering, and bank stabilization.

6. Miles 26.8 to 31.7, 27th Avenue to 75th Avenue. A wide, unstable division with a single thread low flow channel, different from the division above because of its width, and different from the division below because of its single thread. This division has been moderately affected by sand and gravel mining.

7. Miles 31.7 to 37.5, 75th Avenue to the Gila River Confluence. A wide, unstable division

with multiple low flow channels and numerous mid-channel islands and bars that in some cases approach half a mile in length and a quarter of a mile in width (Figure 20).

8. Miles 37.5 to 41.0, Gila River Confluence to the Agua Fia River Confluence. A wide, multiple thread portion of the Gila River, different from the upstream divisions because of its reduced gradient, dense vegetation, and substantial deposition (Figure 21).

At what discharge do bed materials begin to move, resulting in channel changes, erosion, and sedimentation? The exact threshold discharge for any particular cross section can be calculated using standard engineering and geomorphic functions related to the Equation of Continuity, Manning Equation, shear stress or tractive force, and critical values based on the characteristics of the sediment. For the Salt River in the vicinity of Tempe, calculations estimated that the bed materials were likely to move when discharge exceeded about 25,000 cubic feet per second (Graf, 1983). Observations during several discharges above and below this value confirm that 25,000 cubic feet per second is useful threshold value for this particular reach of the river, but other reaches, with different hydraulic conditions and sediments, are likely to have different thresholds of instability. The Tempe Rio Salado Project has altered the conditions in the Tempe reach, so its threshold of instability may now be different. Sensitivity analysis of the mathematical relationships shows that the threshold is not likely to deviate by more than about 30 percent from the stated figure, however, so that as a rule of thumb, discharges in the range of about 15,000 to 40,000 cubic feet per second are likely to result in sediment transport and channel instability throughout most of the study area.

The boundaries of the high flow channel, the braided portion of the river occupied by water only during major floods, have remained fairly stable over the last 125 years. Erosion damage has occurred to properties developed within this zone because of erosion and sedimentation that is expectable in braided streams, and to a lesser degree along its edges as minor expansions have occurred. The truly mobile portion of the channel system is the low flow channel, usually a single thread, occasionally a multiple thread. The exact location of the thalweg, or lowest flow channel, change with almost every flood of even moderate proportions. Therefore, its position on a long-term basis is a question of probability. Investigation of the position of the thalweg channel over the period 1868-1980 shows that in some reaches, the thalweg channel is located in the same position more than half the time, but in other reaches, it location might be anywhere within the high-flow boundaries (Graf, 1981; 1983).

In order to construct maps depicting the locational probability, it is necessary to begin with maps showing the locations of the thalweg channel at various times, as shown in Figure 14 and Appendix 8.15 A grid of squares superimposed on the thalweg channel maps provides a sampling scheme, and the number of years each square was occupied by the thalweg channel can be tallied. This tally, divided by the total number of years of record, provides a number

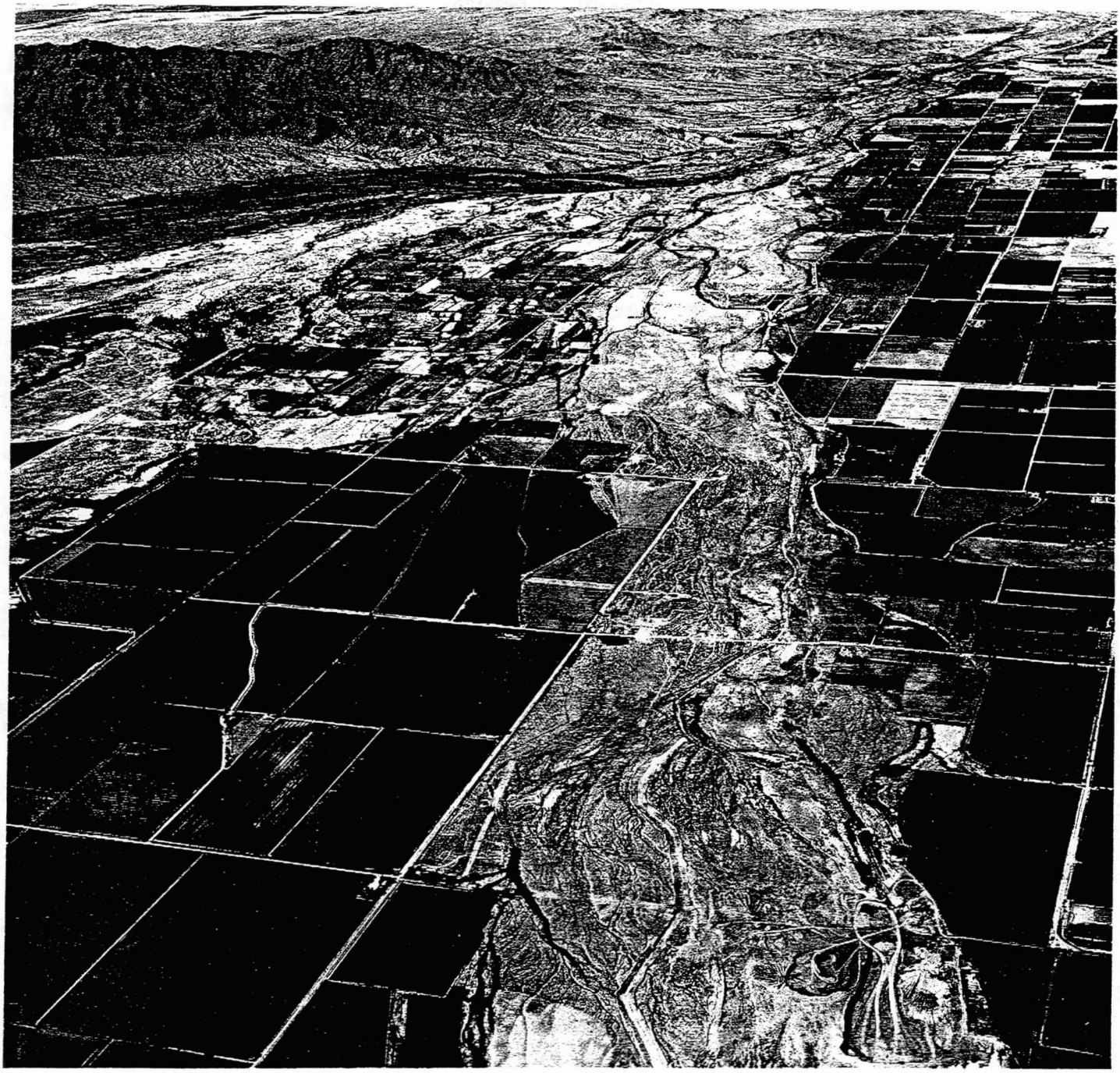


Figure 20. Oblique aerial photograph made on October 2, 1962, looking west along the Salt River from near 75th Street alignment to the vicinity of the Salt and Gila confluence area (Maddock Associates Aerial Survey, Inc. Photo 42).

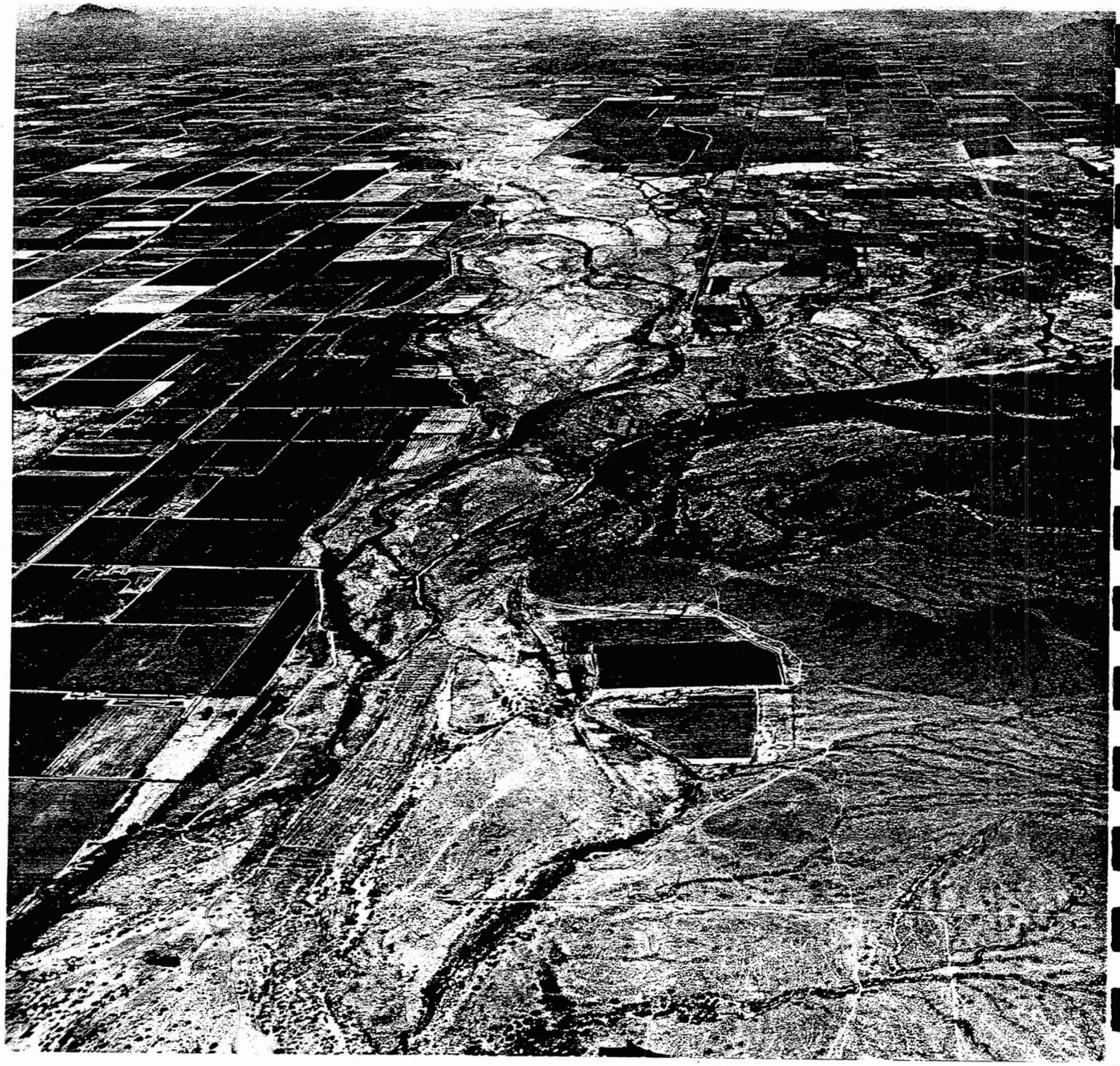


Figure 21. Oblique aerial photograph made on October 2, 1962, looking east along the Gila and Salt rivers from near 115th Street alignment. The large dark field in the right foreground is the present site of the Phoenix International Raceway (Maddock Associates Aerial Survey, Inc. Photo 19).

representing the percent of years in the record when a channel was located in each square--that is, the probability of finding a channel in each square throughout the past record. The values in each square can be mapped, and contoured to provide a more easily interpreted representation of a locational probability map.

Figure 22 shows an example locational probability map for the thalweg channel near the Interstate 10 Bridge. Appendix 8.16 provides similar maps for the study area (except for the reaches upstream from Country Club Crossing due to incomplete data). In the vicinity of Hayden Road, the channel has been in one location only 25 percent of the time, and at other individual points along the cross section, it has been present for less than 25 percent of the time, a fairly unstable situation. In a reach downstream from the Mill Avenue Crossing, the channel occupied one area for 58 percent of the time, a reasonably stable situation for dryland, braided or compound river. The Interstate 10 Bridge Crossing is in a precarious position, because the channel has been located in a variety of positions across the high flow zone, with no real preferred location. When the original Interstate Bridge was built, the piers were sunk into the alluvium to depth reflecting the surface configuration, with deeper piers under the low flow channel. True to story told in the locational probability maps, the 1980 flood produced a locational change for the thalweg channel, and it undermined a shallow pier set on a pad about 24 feet below the surface. The shift in location for the low flow channel was entirely expectable given the nature of the record of the channel in that reach.

Whether the past is a reliable predictor of the future for channel locations is questionable for those portions of the channel that are heavily engineered. The Tempe Rio Salado Project has created an entirely artificial arrangement that may or may not obey the established probability maps. Elsewhere, except for radical changes brought about by sand and gravel mining, the maps may be more reliable as estimates for future probable locations for the thalweg channel. Constructed channels, constructed wetlands, and bank stabilization efforts are most likely to be successful if channels are arranged into their most probable configuration based on their natural behavior. Hesperger (1994) has suggested using the probability maps as a basis for environmental restoration on the Gila River in the vicinity of Buckeye.

2.4.2 Terraces

The channel of the Lower Salt 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 Salt there are usually two or three terraces above channel level (Figure 23). They are high above the channel in mountain areas, but as the streams issue on the alluvial surfaces of the Salt River Valley, they converge vertically toward modern river level. Although they are obvious landscape features in agricultural areas because landuse outlines their extent, their topographic 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. Work by Péwé and his associates has defined and named three

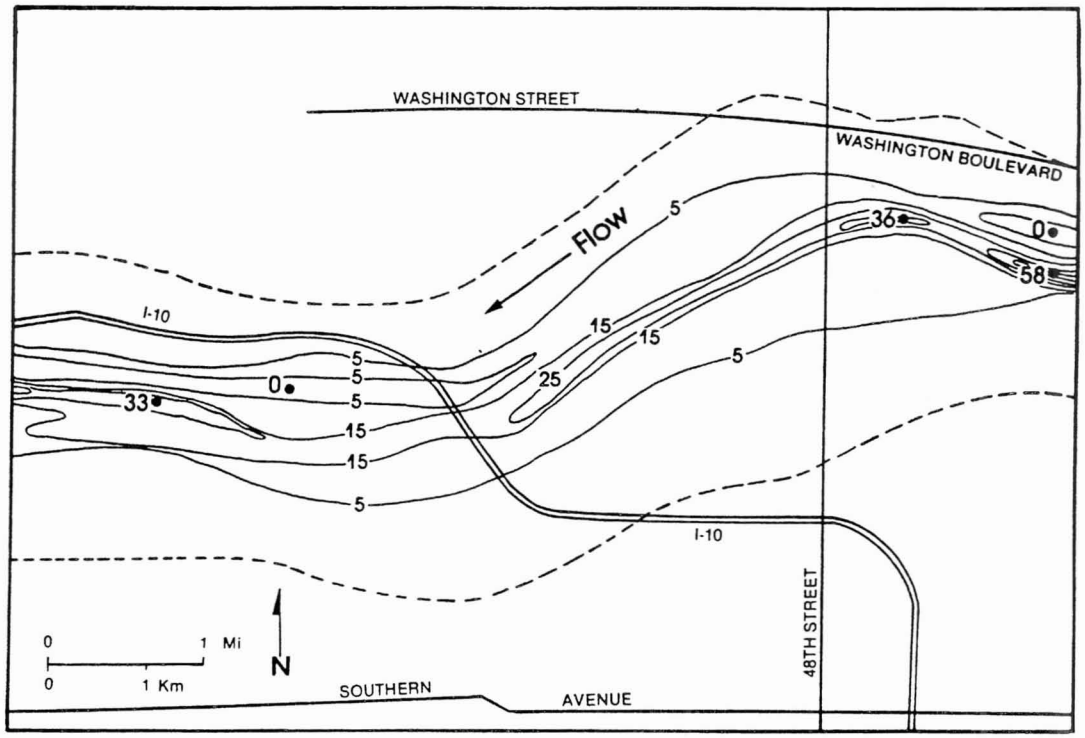


Figure 22. Locational probability map for the Salt River in the vicinity of the Interstate 10 Bridge. The thalweg is often in a single particular location at the right (east) margin, but in the vicinity of the bridge, the probability of its occupying one particular alignment is relatively low and the location is unstable.

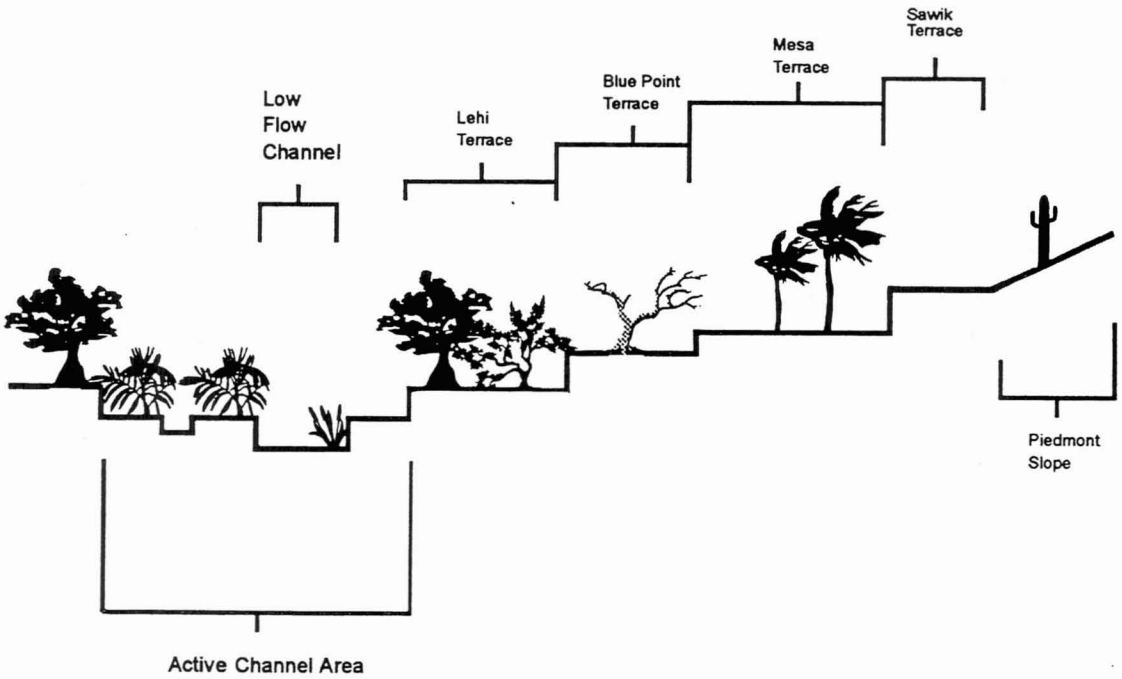


Figure 23. Schematic diagram, not to scale, of a partial cross section of the Lower Salt River showing an active channel area with a low flow and high flow component. A series of terraces rise to the right of the channel, to a desert slope. Each part of the sequence has distinctive vegetation.

commonly found terraces that flank the Agua Fria River (Péwé, 1976), Verde River (Pope and Péwé, 1973), Salt River (Péwé, 1978), Queen Creek (Péwé, 1978), and Gila River (Péwé, 1978). The terraces, from lowest to highest, have the names Lehi, Blue Point, Mesa, and Sawik, derived from locations where they are well defined.

The lowest terrace, the Lehi Terrace, is subject to flooding in extreme events, and usually has some fine-grained soils that reflect minor deposition during floods. It is named after the settlement of Lehi (near northeast Mesa) which is built on the terrace. 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 "river bottom land," separate from terraces (Figure 10). The Blue Point Terrace is discontinuous in the study area, and occurs as relatively small wedges between the Lehi Terrace below and the Mesa Terrace above. An example of the Blue Point Terrace lies along the south bank of the Salt River in northeast Mesa at the Val Vista Road alignment. The Mesa Terrace, upon which the cities of Mesa and Tempe are constructed, is extensive, while the older and higher Sawik Terrace occurs in remnants well away from the river. All the terraces contain sediments dominated by cobbles with a matrix of gravel and sand that is moderately well sorted. The sediments in the terraces are highly similar to the sediments on the floor of the modern channel (Kokalis, 1971), so it is likely that they were moved in an energy regime similar to the modern one. The terraces are therefore not likely to be the product of hydroclimatic change, but their genesis remains to be investigated.

The ages of the terraces are related to their elevation above the modern channel, ranging from the youngest close to the channel and the oldest lying at the greatest elevation. The oldest of the four terraces is the Sawick Terrace which varies in elevation from 120 to 180 above the present river channel. The age of the Sawik Terrace is about 2 million years old. The next oldest terrace is the Mesa Terrace, which varies from 80 to 160 feet above the present day channel. The age o f the Mesa Terrace is not known, but it is older than the Blue Point Terrace and younger than the Sawik Terrace. The Blue Point Terrace is next terrace below the Mesa Terrace. It's elevation varies from 20 to 40 feet above the present channel. Like the Mesa Terrace the age of this terrace is not known. The youngest paired terrace is the Lehi Terrace, which began its formation during the late Pleistocene. The Lehi Terrace is in the Salt River floodplain and is only 5 to 10 feet above the present channel in the study area (Drosendahl, 1989), and it continues to receive deposition during flood events.

Thus, in moving from the channel center outward the following sequence of landforms is common along the Lower Salt River (Figure 23): low flow channel (often meandering, sometimes multiple threads), high flow channel (often braided), first terrace (occasionally flooded), second terrace (usually not flooded in the present hydrologic regime), third terrace (not flooded in the present hydrologic regime), 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.

2.4.3 Sediment Transport and Deposits

The Lower Salt River is a conduit for the movement of sediment as well as water, and the

sediments in the system determine in part the behavior of the system. Sediments form the substrate for riparian ecosystems, and transport contaminants adsorbed onto sedimentary surfaces. An understanding of the geomorphic systems therefore relies partly on knowledge about the sediments of the system, but this is probably the most poorly known aspect of the river. There are no sediment measuring stations on the Salt River, and conclusions about sediment dynamics rest on empirical evidence and estimates made from use of mathematical models.

The amount of sediment transported in various discharge events has not been accurately measured. Simulations using engineering models (reviewed by Simons and Sentürk, 1992) can provide general estimates, though such estimates should be viewed with caution and large error envelops should be employed with using the estimates for planning and management. The models cannot provide highly accurate results because the Salt River does not meet assumptions built into the models as a result of unstable beds and banks, poor discharge data, impacts on the processes by built structures and mining pits in the channel, and sediments that are highly variable from place to place as well as vertically through the bed material. Imperfect as they are, model predictions with their error envelops are the preferred approach to estimation because direct measurement of the sediment transport process is not feasible.

The main channel of the Lower Salt River is rich in cobbles and boulders. The river has a gradient that is steeper than that of the Gila River, so that the Salt appears capable of transporting these large sedimentary particles readily during flood events. The cobbles and boulders are deposited in sheets and long, narrow bars aligned along the length of the channel in zones of deposition, particularly in reaches near northeast Mesa and near the confluence with the Gila River. The bed and banks also contain considerable quantities of sand which is transported in moderate flows. The sand is deposited in midchannel and channel sidebars throughout the system, but especially in the Salt and Gila confluence area. In some cases, these channel sand accumulations may be large, up to a third of a mile in length. They are ephemeral, however, and subject to remobilization quickly in subsequent flow events. Indian Bend Wash is a sand supplier for the river, and floods which issue from the wash into the dry Salt River bed often leave sand deposits in the main channel as a result of reduced gradients. In the late 1980s, a large sand accumulation developed upstream from the Rural Road Crossing as a result of several discharges from Indian Bend Wash.

2.4.4 Sediment Quality

Within the study area the issue of sediment transport and storage are important factors in a discussion on the issue of sediment quality. Sediment in the Salt River is brought by numerous tributary washes and streams as well as from bank erosion. The sediment ranges from cobbles to clay-size particles, all of which are transported during flow events. On a geologic time-scale, the river has been a meandering system, with numerous cut and fill sequences and many channel shifts. Sedimentation has taken place over the entire flood plain in response to the channel shifts. Observations from historical ground photographs and aerial photographs have shown several depositional features: cobble lag surfaces, sand sheets (macro-forms), channel side bars, mid-channel bars, pointbars and overbank deposits. The bulk of the sediment transport has historically taken place during flood events, when the river has it's greatest capacity and competence. The largest quantity of material is moved as bedload, but finer material is also

carried in suspension. As will be discussed later in this section, fines are critical to any assessment of sediment quality. Movement of sediment does not have a fixed rate, instead it tends to move in pulses or waves. Within the stretch from Granite Reef Dam to confluence of the Agua Fria the sedimentation history can be characterized as a scour and fill system. However, over the last century, this section of the river has been dominated more by degradational processes. The best evidence to support this idea is the downstream storage of large amounts of sediment behind dams and as channel macro-forms.

The issue of sediment quality is one of adsorption of contaminants to the surface of the sediment. Warren and Zimmerman (1994), are the most recent to analyze the importance of that surface coatings (i.e. Fe and Mn oxides and organic particulate matter) as sorbents of contaminants in a natural fluvial system. In a dryland river setting iron, manganese, and calcium carbonate surface coatings are more important to the adsorption of contaminants to the surface of sediments than organic matter. In the study area, the lack of organic material is in direct response to the ephemeral nature of the stream. Under a more consistent water flow regime, organic material would be present and act as a chelating agent, sequestering contaminants to the surface of the sediment. Along with the surface coatings, the surface area of the sediment plays an vital role in the adsorption of contaminants. Finer particles have a larger surface area to volume ratio (higher specific area) and are more likely to adsorb contaminants on their surfaces than coarser sediments (Forstner and Wittmann, 1979, Forstner, 1980, Levinson, 1980, Salomons and Forstner, 1984, Ratha and Sahu, 1993, Mogollon and Bifano, 1994). Any assessment of sediment quality should address how and where the fine sediments are transported and deposited.

A list of known contaminants in the reach of the river from Granite Reef Dam to the confluence of the Agua Fria can be found in Table 12, section 2.3.3. The degree of contamination varied, and the major contaminates cited were: DDT, DDE, chlordane, dieldrin, toxaphene, methymercury, chlorine, methal-chloride, soluble solids, total dissolved solids, phenols, metals and pesticides (ADEQ, 1993). The sources of contaminants can be derived from a number of point source and non point source sites. Some point sources of contaminants can be naturally occurring. In most cases natural point sources are bedrock. Bedrock can create high levels of a contaminants, but these high levels should be considered the natural levels for this particular region. The weathering and subsequent erosion of the weathered material is what releases the contaminants into the system. In the case of bedrock, heavy metals and heavy minerals are the most important contaminants released during these processes. A 1994 paper by Baker and others shows the Verde Formation (a soft, white alluvial deposit located along the Verde River) is responsible for arsenic levels from 25 g/L to 200 g/L just above Granite Reef Dam. In 1992 the Maximum Contaminant Level for arsenic was 50 g/L. Other major anthropogenic point sources of contaminants from Granite Reef Dam to the Agua Fria River are: (1) Avondale POTW, (2) 23rd Ave POTW, (3) 91st Ave POTW, (4) Tolleson POTW, (5) USAF Luke Air Force Base, and (6) Loral Corp. For more details the reader is directed to the ADEQ Surface Water Quality Division's database and the National Pollutant Discharge Elimination Program also at ADEQ.

Non-point source pollutants are from storm water runoff, dewatering operations, sand and gravel operations, wildcat dumping, agriculture and landfills. The stormwater runoff in the Phoenix metropolitan area releases volatile organic compounds, trace metals and pesticides. Wildcat dumping is ubiquitous along the banks and in the bed of the river. The major

contaminants released from wildcat dumping are volatile organic compounds. Agriculture within the watershed contributes large quantities of pollutants into the fluvial sediments. The major pollutants identified from the agricultural non point sources were: DDT, DDE, DDD chlordane, dieldrin, and toxaphene (ADEQ, 1993). The landfills provide many of the heavy metals that are present within the system.

Although a complete system wide assessment of the sediment quality is not possible at this time, concentrations from previous studies below the present study area can provide some insights into the issue of sediment quality. Two studies from the Middle Gila River in the vicinity of Gillespie Dam north to the Hassayampa River and south to the Barrow Pit Lake (Painted Rock Dam) will be relied upon for discussion of sediment quality (Earth Technology Corp., 1993 and Draft, 1994). The metals and pesticides discovered in this reach of the stream are compiled in Table 16.

With regard to the heavy metals antimony was the only one higher than the Arizona Ingestion Health-Based Guidance levels. However, upstream of this area ADEQ has concerns about level of mercury, released by several point sources (ADEQ, 1993). In almost all cases the concentrations of heavy metals in this reach of the stream were above average concentrations found in other southwestern Arizona sediments. A second untitled draft study of organochlorine pesticides in the same area found that only DDT, DDE, DDD and toxaphene were detectable in the sediment and soil samples. These pesticides were detected at relatively low concentrations. DDE was found to be more predominant of the three species of DDT ranging from 0.01-0.79 ppm (Draft, 1994).

In summary, there are several types of contaminants found throughout the study area. Based upon other researchers reports it would seem that the sediment quality is worse than in other parts of southwestern Arizona, but is still not at a level where it could be considered harmful by the Arizona Ingestion Health-Based Guidance levels. A more detailed study of the entire reach is needed to fully understand the transport and depositional history of contaminants within this reach of the Salt River.

Table 16. Metal Contaminant Concentrations (mg/kg) in the Middle Gila River Sediments.

(Source: Earth Technology Corp., 1993)

Heavy Metal	Painted Rock Dam (1981-1989)	Painted Rock Dam (1992)	Gillespie Dam (1980-1989)	Lower/Middle Gila River (1992)	Average Concentrations in SW. AZ. Soils	Az. IHBGLS*
Antimony	36	not detected	137	not detected	1	60
Arsenic	25.8	27	5.5	not detected	12.7	1000
Beryllium	1.7	not detected	1.3	not detected	2.5	0.14
Cadmium	0.5	1.3	0.4	0.9	0.4	100
Chromium	44.5	25.2	61	22	85.2	2000
Copper	83.1	122	65.9	65.2	34.4	26000
Lead	40.5	49	31	33	30	400
Mercury	0.34	not detected	0.2	0.3	0.12	40
Nickel	43.3	39.9	34	44	40.5	2000
Selenium	0.4	not detected	3	not detected	0.3	900
Silver	not analyzed	not detected	73.1	not detected	0.5	1000
Thallium	35.2	not detected	not detected	not detected	0.7	10
Zinc	115	110	103	82	72.8	100000

* Ingestion Health-Based Guidance Levels for Soil
Source: Earth Technology Corp. 1993

2.5 Engineered Features of the Lower Salt River

2.5.1 Granite Reef Dam

The modern version of Granite Reef Dam originated after drought struck the Salt River Valley from 1898 to 1904. Valley farmers called for further investigation of a storage dam site on the upper Salt River. During this time the National Irrigation Act (1902) had been passed to help finance reclamation activities. The federal government through this act, was willing to financially support the construction of an upstream reservoir on the Salt River. However, funding for the project could not commence until the farmers had organized themselves into some type of water district, because federal law prohibited the National Reclamation Association from dealing with individuals. After convincing many of the skeptical farmers in the region, the Salt River Valley Water Users Association was established in 1903 and construction on Roosevelt Dam was initiated (Smith, 1972). At the same time the federal government also realized that the water distribution system in the Salt River Valley needed to be improved. The improvements included buying all of the canals in the Salt River Valley in 1905 as well as the construction of Granite Reef Dam. Construction of Granite Reef Dam began in 1906 and was completed in 1908.

Granite Reef Dam is located 22 miles east of Phoenix. It is a concrete gravity structure anchored to Precambrian granite that runs the width of the channel at this point. The concrete for the dam was mostly made with natural gravel and sand from the local area, into which boulders and other broken rocks were added. The dam consists of a weir with 166 flashboards and 128 feet of embankment wings. The structural height of the dam is 29 feet, with a weir crest elevation of 1310 feet. Granite Reef Dam was constructed for and still operates as a diversion structure. It is the principle take-out point for all of the Salt River irrigation water used in metropolitan Phoenix. The present diversion capacity was unavailable, but the dam diverts water from the Salt River via two main sluiceways and headworks (Figure 24). The south abutment has a sluiceway with two 15'X 9' slide gates and headworks that consist of nine 7'X 5' slide gates. The north abutment has a sluiceway made-up of four 15'X 9' slide gates and a headwork that consists of eighteen 7' X 5' slides gates, five of which do not work. The headworks are the intake structures at each end of the dam through which water is drawn into the canals. The intakes at the north end of the dam have the capacity to take in 2,000 cfs and the south end has the capacity to intake 1,500 cfs. The north abutment diverts water into the Arizona Canal and the south abutment diverts water into the Southern Canal. These two main canals then carry water throughout the Valley to other canals on both sides of the river.

There have not been any significant changes to Granite Reef Dam since it was been built. The sluice gates and the diversion gate were changed in 1958 under the Rehabilitation and Betterment program. The most recent report for the structure is from the Water Resources Department at the Salt River Project. The 1986 Safety of Dams investigation reported that the are no notable changes in the conditions of dam from the 1958 investigation. The general condition of the dam concrete was fair to poor, with extensive cracking and minor spalling. The condition of the apron was generally good, but minor repairs are needed on the sluice gates,

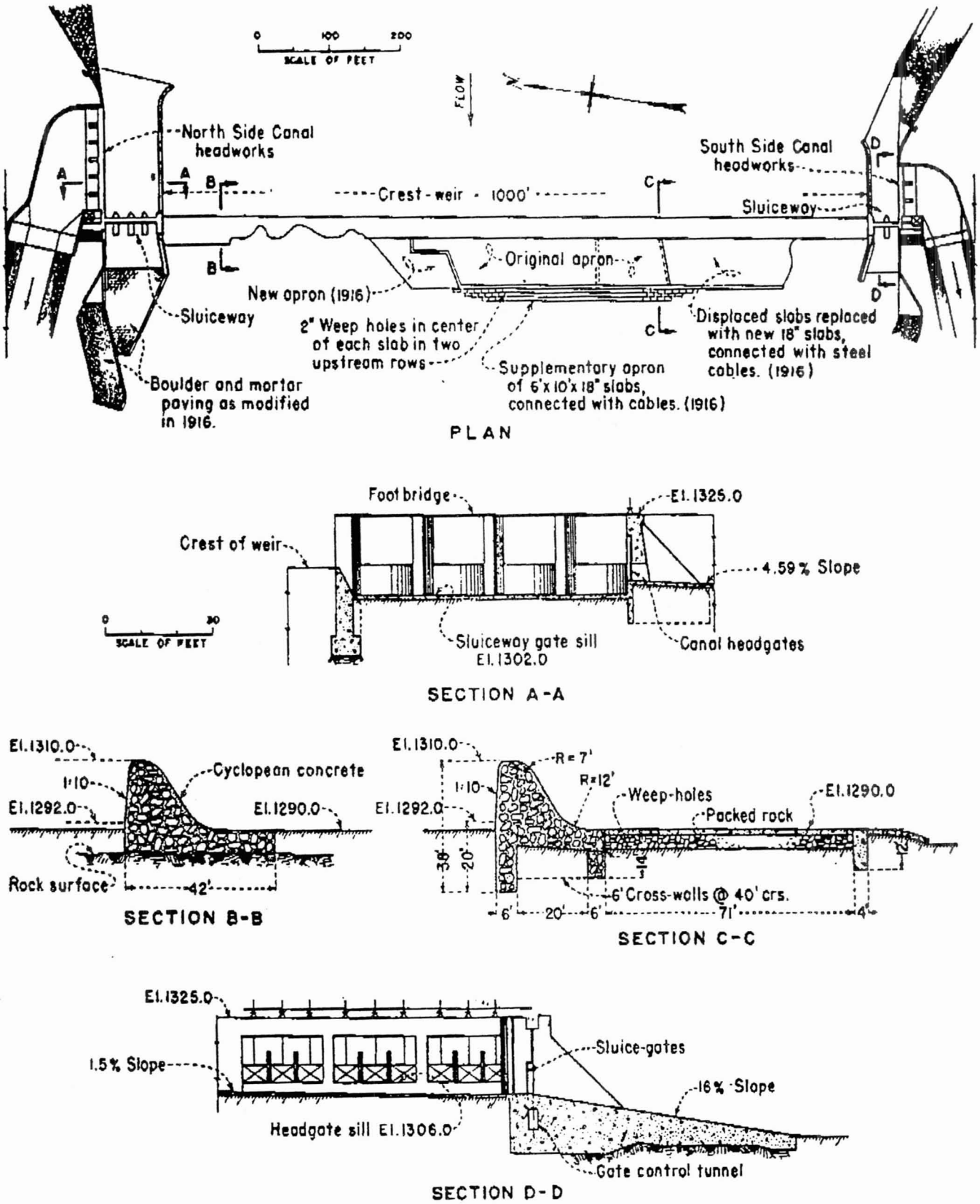


Figure 24. Sketch plans for Granite Reef Dam (provided by Salt River Project).

and the diversion gates are corroded.

2.5.2 Indian Bend Wash

Indian Bend Wash project, a flood control project designed by the U. S. Army Corps of Engineers, impacts both the geomorphology and water and sediment quality of the Salt River. The project, intended to protect the cities of Scottsdale and Tempe from floodwaters, incorporates a greenbelt which allows for recreational use the floodplain. Indian Bend Wash Park contains parks, golf courses, playgrounds, lakes, and walking and bike paths. Originally presented in 1961, the plan for the project was authorized by Congress in the Flood Control Act of 1965. The floodway conducts waters from the McDowell and Phoenix Mountains and the Arizona Canal to the Salt River. It also receives surface runoff from several major streets and will receive run off from the Pima Freeway after it is completed in Scottsdale. Lee (1988) provides a detailed description of the dimensions of the floodway and the recreational facilities it contains.

Indian Bend Wash impacts the geomorphology of the Salt River by contributing water and sediment to the main channel. Gage records of annual peak discharges from the wash for 1961 to 1984 varied from 0 to 4380 cfs, with a mean of 555 cfs (Figure 25). Notably, the highest flows do not occur in the same years as floods in the Salt River, suggesting that flows in Indian Bend Wash result from localized precipitation events in the Scottsdale area. Although no measurements of sediment discharge have been made, the amount of sediment entering the Salt River from Indian Bend Wash can alter bed morphology near the confluence. For example, construction of the floodway made large amounts fine sediment available for transport in the wash. Flows moved this sediment down into the Salt River, depositing the material near the Scottsdale Road bridge as the flow spread out and was unable to transport the sediment further. No flows occurred on the Salt River which were large enough to transport this material through the system. A large bar formed just downstream of the bridge and this bed feature continued to grow with each flood event (Clark, 1991). This bar was removed after the 1992-93 floods because it presented a large obstruction in the channel. Protection and energy-dissipation structures along the mouth of the wash will likely increase sedimentation near the confluence.

Indian Bend Wash also presents a potential water and sediment quality hazard to the Salt River. The floodway lies in the Indian Bend Wash Superfund Site, where volatile organic compounds (VOCs), cyanide, acids, and heavy metals from several industries have contaminated the soil (ADEQ, 1993). Arizona Department of Environmental Quality (1993) reports that surface water in one of the lakes in the floodway, McKellips Park Lake, experienced algae blooms and fish kills in 1987 and contains tetrachloroethylene (TCE) from the Superfund Site. Urban runoff and disposal of substances in landfills are specifically cited as the sources of the contaminants in the lake. During higher flow events, this contaminated water, lake sediments, and soil moves down Indian Bend Wash and into the Salt River system. The extent of surface water contamination in Indian Bend Wash and the rate at which these materials are moved to the Salt River is unknown. Contaminated sediment could accumulate near the confluence of Indian Bend

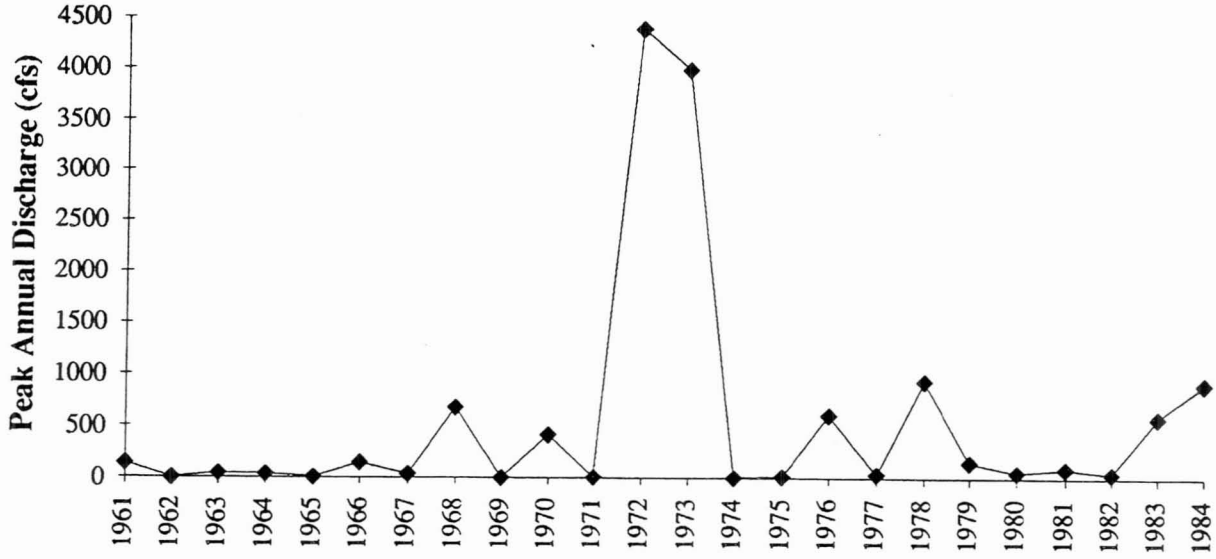


Figure 25. Peak annual discharge for Indian Bend Wash at Scottsdale, 1961-1984 (data from the U.S. Geological Survey).

Wash and the Salt River, much as the large sand bar formed near the Scottsdale Road bridge during the 1980s.

2.5.3 The Rio Salado Project

The Rio Salado Project was conceived by a student in the College of Architecture at Arizona State University in 1966. The project design was for a linear park and greenbelt along a flowing Salt River. The original concept also linked the metropolitan Phoenix area with the Gulf of California in order to increase international commerce. A series of locks, similar to the Panama Canal, were to be constructed to allow ships to transport goods to and from the Valley. The link to the Gulf of California never came to fruition, but the linear greenbelt was met with a great deal of public and private support. Official backing of the project began in 1969, when the Valley Forward Association and the Maricopa Association of Governments accepted the original concept of a linear greenbelt (RSDP, 1994).

The Rio Salado Design Study (1977) was generated for a five mile stretch of river in Tempe. The study provided three alternatives along which the Rio Salado Project could be developed: a desert-oriented landscape with limited water features; a water intensive development; or a moderate water-use plan. In the same year the Department of Health, Education and Welfare provided for a further in-depth study on the same five miles of the river in Tempe. As public and private interest continued to increase, the Tempe Rio Salado Advisory Commission (1979) was established to get broad citizen input, explore all avenues to improve the project and to advise the City Council. The Arizona House and Senate then created the valley-wide Rio Salado Development District in 1980. The Rio Salado Development District was formed to devise a plan that would extend the greenbelt over the entire length of the metropolitan area. In 1986, the State legislature approved a referendum for financing a Valley-wide Rio Salado Project, which was voted down on November 3, 1987. The negative vote canceled a Valley-wide greenbelt, but the Tempe City council decided that it would continue with the project on the section of the river passing through Tempe (RSDP, 1994).

The Rio Salado Project covers the stretch of the river from 48th Street to Price Road (Figure 3). The project is comprised of lands owned by the State of Arizona, Maricopa County Flood Control District, Bureau of Land Management, Arizona State University, City of Tempe, and a single private property owner. Project funding is through the Maricopa County Flood Control District, the Arizona Department of Transportation and locally generated revenues. Construction of the project will progress from west to east in conjunction with the construction of the East Papago Freeway. The Tempe Rio Salado project was created with the idea of development of land along the Salt River, recreation facilities and flood control through channelization of the river (City of Tempe, 1990).

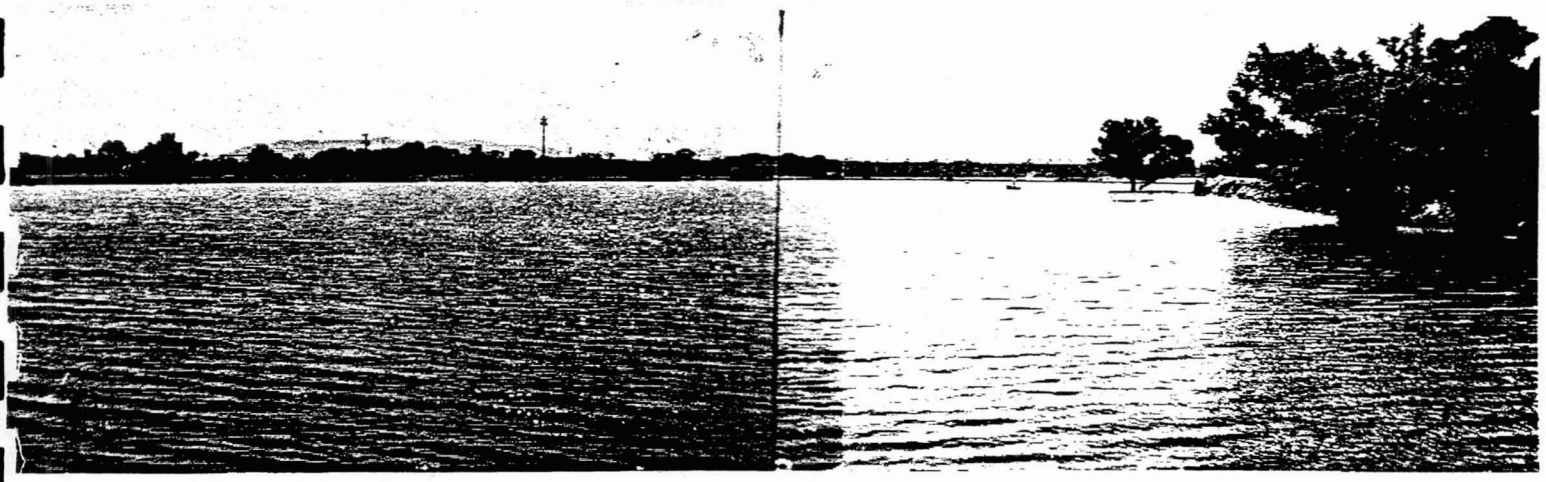
The channel is designed to support the "worst case" scenario, the 100 year flood (215,000 cfs). Channelization of the river will occur through the construction of a 900-1000 foot wide stabilized bank floodway channel. The channel is aligned, such that the south channel bank will be offset 100 feet to the north at Rural Road, while keeping the channel bend radius at a minimum. A compound channel with both north and south terraces was found to best accommodate the idea of flood abatement and future human constructed environs (CRS Sirrine, Inc, 1989). The

southside terrace will be 150 feet wide on the westside of the project and will taper eastward to the Mill Avenue Bridge to an 80 foot terrace. The 80 foot terrace will continue to a point east of Rural Road, where a trapezoidal channel cross-section will continue for the remainder of the reach. The north bank terrace begins at a width of 100 feet in the west and narrows to 24 feet when it reaches the tri-city sewer line. The 24 foot terrace continues throughout the remainder of the reach. Bank stabilization will occur at two levels: soil cement will be used to the height of the ten year flood event and above that, a combination of wire-tied rock mattresses and rip-rap will be applied. A system of earth covering over the two areas will permit the introduction of vegetation (City of Tempe, 1990).

A low flow channel will also be installed throughout the human-made floodway. The low flow channel ranges from 300-500 feet wide and five feet deep. It is large enough to accommodate standard SRP releases of up to 5000 cfs from the upstream dams without damaging the established human-made environments in the floodway. A series of grade control structures will be established upstream and downstream of the channel limits as well as the confluence of Indian Bend Wash, to prevent channel profile erosion. The grade control structures are designed to limit scouring, lateral migration of the stream channel and degradation of the stream bed up to a 250,000 cfs flood event. The design also plans for some natural aggradation to occur within the system, which would provide a substrate for riparian vegetation to become established (City of Tempe, 1990).

The city of Tempe has developed a water plan for over 300 surface acres of lakes and streams within the human-made floodway. Artificial conservation lakes have existed in the reach in the past, sometimes associated with Tempe Beach Park (Figure 26). The plan calls for the use of effluent water, treated to full body contact standards, for recreational, park irrigation, freeway landscaping and for sale to private users. The reclaimed water will be produced at two Tempe water reclamation facilities, capable of producing millions of gallons of water a day. The effluent will be pumped to the head of the lake system at McClintock Drive and allowed to flow free downstream at roughly 1 to 2 cfs. Once downstream the water will be allowed to recharge the aquifer or there is also the chance that it may be pumped back to the head of the system. Another alternative in the water plan is to use water from the Central Arizona Project, which would be delivered through the Salt River Project canal system. A large portion of the water will be used for an artificial lake between Hardy Drive and Indian Bend Wash. The lake will cover 165 surface acres and water for the lake will be held back by an inflatable dams at each end of the lake. The dams will be constructed of rubber material and built in four spans of 200 feet each.

The Rio Salado Plan also calls for the construction of two native riparian habitats, that have already been established. The first site is located between 52nd Street and the Hohokam Expressway. It consists of the following species: desert hackberry (*Celtis pellida*), native



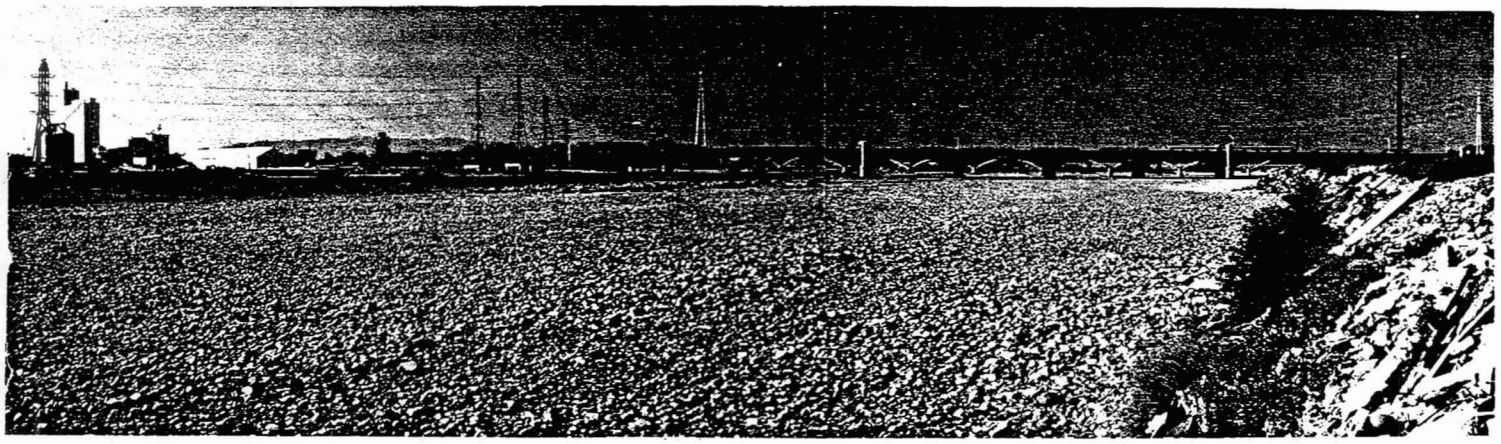


Figure 26. Above: conservation lake at Tempe immediately above the Mill Avenue Crossing (the Mill Avenue Bridge and the Southern Pacific Railroad Bridge are barely visible beyond the fishing boat) as seen from the north bank looking west in September, 1949 (Corps of Engineers Photo, W. L. Graf (copy photograph) Photo 43-9). Below, the same view in October, 1980, showing a very different situation.

Arizona ash (*Fraxinus velutina*), Fremont cottonwood (*Populus fremontii*), velvet mesquite (*Prosopis velutinia*), Gooding willow (*Salix goodingii*), Mexican elder (*Sambucus mexicana*). At the center of this site are two small pond areas. The major site is located north of the East Papago Freeway between College and Mill Avenues. The species that were established include desert hackberry, catclaw acacia (*Acacia greggii*), Fremont cottonwood, velvet mesquite, Gooding willow, and Mexican elder. Both sites were established in consultation with members of the Center for Environmental Studies at Arizona State University. There was an attempt at both sites to remove the exotic plant species and continued removal is planned.

A series of other development activities are planned over the next several years. These combined with developments already completed will be located on or adjacent to the human-made floodway. Without going into great detail, a brief list of proposed developments is presented: (1) a recreation site west of Priest Dr., (2) ice arena site, (3) water reclamation facility, (4) Rio Beach, (5) East Papago Freeway, (6) Papago Park Center, (7) Tempe Beach Park, (8)Southwest Center for Education and Natural Environment, (9) Hayden's Ferry, (10) The Boardwalk East, (11) The Boardwalk West, and (12) Private Development Site on Rural and Rio Salado Parkway. For an in depth explanation of each of these developments, the reader is directed to the City of Tempe Community Development Department.

2.5.4 Sky Harbor Airport

Sky Harbor International Airport, the major airport for Phoenix and the surrounding communities, is located between 44th and 24th Streets along the Salt River in Phoenix. The City of Phoenix obtained the property and the original airport in 1935, and by 1946 it was one of the busiest airports in the United States (City of Phoenix, 1986). Terminal 1 opened in 1952. When Terminal 2 opened in 1962, the City hoped to close Terminal 1, but could not because use of the airport continually exceeded the expectations of planners. After the opening of Terminal 3 in 1979, officials again planned but were unable to close Terminal 1. Terminal 4 was added in 1992.

Activities at Sky Harbor began to directly impact the geomorphology of the Salt River in the early 1960s when the channel was realigned to accommodate the expansion of the airport's south runway. The runway extended into the channel at the east end of the airport. When high flows in 1965-66 damaged the runway, it was quickly rebuilt with protection (City of Tempe, 1993). Restoration of the south runway after significant damage by the 1978-80 floods further impacted the Salt River channel. The river was rechannelized and diked near the airport for a cost of nearly $14 million (City of Phoenix, 1986). Recently, the Federal Aviation Administration has proposed the addition of the third runway at Sky Harbor, south of the present south runway. This third runway further encroaches on the channel of the Salt River; when it is in place with its accompanying embankments and bank protection, it will constrict and reorient the channel. The City of Tempe (1993), strongly opposed to the position of the third runway, points out that "as a result of repeated encroachments upon the Salt River channel, and notwithstanding a system of levees and bank protection, Sky Harbor has not withstood a major flood without suffering extensive disruption."

Sky Harbor Airport also contributes contaminants to the sediment and water of the Salt River. Volatile organic compounds and petroleum products accumulate on the runways and other

surfaces and are washed into the river during storm events. A drain to the east of the airport conducts runoff and waste water to the Salt River channel. The quantity and quality of this water is unknown, but this drain did at one time support dense riparian vegetation (K. Randall, 1994, personal communication). This vegetation has been removed, possibly because of the hazard to air traffic posed by birds attracted to the area.

2.5.5 Bridges

Bridges over the Salt River represent loci of intense conflict between floods and the every-day lives of the inhabitants of the Salt River Valley. Eighteen bridges, 17 of which support automobiles, cross the Salt River in the study area (Table 17). The responsibility for the structures falls on five entities: the State of Arizona, Maricopa County, the City of Tempe, the City of Phoenix, and the Southern Pacific Railroad. These structures range from 505 feet to 1602 feet in length.

While all but two of the present bridges that have been completed are less than 15 years old, bridge building has a long history in the Salt River Valley. Many early bridges located near old Hayden's Ferry and new Mill Avenue were destroyed in floods in the late 1800s and early 1900s. The first Southern Pacific Railroad bridge experienced a common cycle: originally built in 1887, destroyed by floods in 1891, rebuilt and destroyed by a flood again in 1905, rebuilt and damaged by a flood in 1912, and then repaired (Nagel, 1988). The Ash Avenue Bridge, built in 1911 and dismantled in 1992?, was the first non-railroad bridge to survive any number of years. The oldest bridge on the Lower Salt River is the southbound Mill Avenue bridge, completed in 1931.

Bridges experienced build-destroy-rebuild cycles into the late 1970s and early 1980s as three major flood events hit the Salt River Valley. Floods in February 1978 and again in December 1978 closed ten of the 13 bridges crossing the Salt River (U. S. Army Corps of Engineers, 1979a, 1979b). During both events, only the Mill Avenue and Central Avenue bridges remained open, although neither structure escaped damage. Floods during February 1980 again closed 19 crossings (including bridges and dip crossings), excluding the Mill Avenue and Central Avenue structures (U. S. Army Corps of Engineers, 1980). Of the ten damaged bridges, only three reopened within a month of the flood event. The U. S. Army Corps of Engineers (1981) estimates that during a period of 17 days a minimum of $8.4 million was lost due to transportation difficulties without the bridges.

Bridges impact the geomorphology of the river channel in three ways. First, they constrict the flow of water because they limit the width of the channel. This constriction reduces channel capacity, especially immediately upstream from the bridge, causing water to pile up behind the

Table 17. Bridges Across the Salt River in the Study Area.

(Data from Arizona Department of Transportation and City of Tempe)

Route	Year Completed	Structure Length (ft)	Max. Span Length (ft)	Custodian	AZDOT Structure #
FAS 229 Gilbert Road	1990	1302	65	Maricopa County	7780
State Route 87, mile 177.22 (Country Club Drive)	1982	1348	135	State of Arizona	1812
Alma School Road					
north channel	1980	936	59	Maricopa County	8853
south channel	1980	410	59	Maricopa County	8853
State Route Loop 202					
eastbound	1994	5287	140	State of Arizona	2268
westbound	1994	5165	140	State of Arizona	2269
Hayden Road (McClintock Drive)	1984	1184	115	City of Tempe	9694
Scottsdale Road (Rural Road)	1981	1333	121	City of Tempe	9693
Mill Avenue					9954
northbound	1994	1510	150	City of Tempe	
southbound	1931	1577	150	City of Tempe	9954
Southern Pacific Railroad	1912				
Priest Drive	1992?			City of Tempe	ND
State Route 143, mile 1.37 (Hohokam Expressway)	1990	1161	129	State of Arizona	2182
Interstate 10, mile 150.72	1986	1083	134	State of Arizona	2003
24th Street	1980	864	72	City of Phoenix	9701
16th Street	1982	1110	120	City of Phoenix	9784
7th Street	1983	678	135	City of Phoenix	9742
Central Avenue	1975	900	98	City of Phoenix	9324
7th Avenue	1987	753	125	City of Phoenix	9898
19th Avenue	1982	1007	125	City of Phoenix	9741
35th Avenue	1983	505	125	City of Phoenix	9743
51st Avenue	1981	1602	100	Maricopa County	9692

structure. The increase in depth of flow upstream of the bridge may lead to overbank flows, exacerbating flooding of areas near the river channel and inducing sedimentation. Also, the increase in depth of flow causes flow to accelerate through the bridge area, leading to local degradation of the channel bed. This scour can undermine the bridge supports, leading to failure of the structure. The constriction of the channel may also lead to deposition downstream of the bridge where the channel suddenly widens to its preferred width. The sudden decrease in depth of flow decreases the amount of energy available for sediment transport, leading to sedimentation.

Second, bank protection, such as riprap or soil cement, frequently accompanies bridges. This protection may increase turbulence in the flow, dissipating the amount of energy available for sediment transport and causing deposition of bars near the protected features. Deposition may also occur downstream of the bridge supports: flow diverges around the pilings, creating an area of flow separation, or dead water, on the lee side of the support.

Third, the bridges serve as anchor points for the location of the main channel of the river, much as the Salt River is constrained by the bedrock of Tempe Butte and Papago Park. When planners decide to construct a bridge and its accompanying protection, they essentially fix the position of the channel at a certain point along the river. If the channel's position at that point has been relatively stable over a few decades, this fixing of its position may not have a large impact on the river. However, if the position of the channel is fixed at a point where, historically, the channel frequently shifts in order to adjust to variations in water and sediment discharge, this fixing limits the river's ability to adjust to those variations. Adjustments may then occur in a different location where historically change has been minimal. Thus, bridges may reduce shifting of the channel locally, but may induce change in the position of the channel upstream or downstream of the bridge.

In addition to bridges, roads cross the Salt River at dip crossings, locations where the paved road dips down the bank of the river and crossed on the channel floor. Presently, there are five main dip crossings on the Salt River: Staley Avenue, McKellips Avenue, 67th Avenue, 91st Avenue, and 115th Avenue. Historically, dip crossings occurred in numerous places, an economical and quick alternative to bridges. While less common and less important than bridges, dip crossings do locally impact the geomorphology of the channel. The road material renders a portion of the bed of the channel immobile during flow events, increasing scour locally both upstream and downstream of the crossing. Eventually, this degradation can undermine the crossing, allowing pieces of the road material to be transported a short distance downstream. Generally, however, the impact of crossings on the geomorphology of the river is less significant than that of bridges.

2.5.6 Channelization

Channelization of approximately seven miles of the Salt River between McClintock Drive (Hayden Road) and 24th Street has radically altered the geomorphology of the river, creating an artificial landscape. In the early 1960s, the river was straightened and embankments constructed to protect the first south runway at Sky Harbor Airport (see section 2.5.4). The county Flood Control District extended these modifications through the Tempe area as protection for the Papago Freeway in the 1980s. The freeway, encroaching on the natural floodplain of the river,

follows the north bank of the channelization for four miles. Earth-filled embankments protected with soil cement create a trapezoidal channel designed to contain the 100-year flow (250,000 cfs). Originally, the channel contained an inset, low-flow channel which meandered across the bottom of the floodway over loose cobbles. High flows in 1992-1993 removed these artificial low terraces or channel side-bars, redistributing the material across the floodway and moving some downstream.

Channelization has altered the width, pattern, and bedforms of the channel, as well as removing any natural vegetation. All of these changes have created a more hydraulically efficient channel, decreasing the possibility of flooding in the area while increasing the potential for erosion within the channel and for downstream flooding (Keller, 1976). The artificial channel is wide enough to accommodate high flows, such as the 1992-1993 floods. The river now follows a path determined by human activity rather than natural processes. Once a meandering stream, with a particularly large bend upstream of Tempe Butte, the river is straight from McClintock Drive to 48th Street where the channel abruptly curves to the south to avoid Sky Harbor Airport. The addition of the third runway at Sky Harbor Airport will exacerbate this sudden change in direction. Evaluating the geomorphic processes operating in this reach becomes extremely difficult given that the channelized river contains few natural elements.

Other embankments and protection structures employed by landfills and aggregate mines in the Phoenix, Tempe, and Mesa areas impose constraints similar to channelization on the river. The upper and lower portions of the study reach do not contain significant levees, with the exception of bridge crossings and the Holly Acres Bank Stabilization Project. Constructed in 1983-1984, the Holly Acres Levee is an earthen dike extending for approximately one mile on the north side of the Gila River near 115th Avenue (Flood Control District of Maricopa County, 1994). It was designed to protect the community of Holly Acres from flows up to 125,000 cfs. Extended by sand bags, the levee was not overtopped by flows up to 137,300 cfs during the 1992-1993 floods.

2.5.7 Sand and Gravel Mining

Sand and gravel mining operations, commonly located in dry river beds in Maricopa County, impact both the geomorphology and water and sediment quality of the Salt River. Because these operations are poorly regulated, only incomplete information on past locations of mines is available. The Arizona Department of Mines and Mineral Resources (1993) has mapped 82 aggregate pits in Maricopa County since 1917, 28 of which were located on the Salt River flood plain (Table 18). Seventeen privately owned operations and the Arizona Department of Transportation actively mine aggregate in the Phoenix metropolitan area (Phillips et al., 1993). Operations in the floodplain must obtain a permit from the Maricopa County Flood Control District, and several other agencies including the Corps of Engineers, but details of the mining

Table 18. Active Sand and Gravel Mines Along the Lower Salt River

(Data from Arizona Department of Mines and Mineral Resources, 1994 Commodities Listing; listing incomplete)

Pit Name	Location (Township and Range)
Grand State Sand and Gravel	T.2N, R.6E, Sec. 21, S2
Sand and gravel pit	T.2N, R.6E, Sec. 30, S2
Johnson Stewart Pit #1	T.1N, R.5E, Sec. 4
Mesa Pit and Plant	T.2N, R.5E, Sec. 34, S2
Mesa Pit and Plant	T.2N, R.5E, Sec. 33
Mesa Sand and Rock Pit #1	T.1N, R.5E, Sec. 3, NW
Screening plant and shop	T.1N, R.5E, Sec. 5, NE
Mesa Sand and Gravel Pit	T.1N, R.5E, Sec. 8
Arizona Sand and Rock Plant #3	T.1N, R.5E, Sec. 20, NE
Nesbitt Plant and Pit	T.1N, R.4E, Sec. 13, N2
Hayden Road Pit	T.1N, R.4E, Sec. 11, NE
United Metro Plant #6	T.1N, R.3E, Sec. 13, S2
Valley Redi-Mix Plant	T.1N, R.3E, Sec. 13, E2
Gravel pits 1	T.1N, R.3E, Sec. 22, NW
Arizona Sand and Rock Main Plant	T.1N, R.3E, Sec. 16, C
Union Rock and Materials	T.1N, R.3E, Sec. 20
United Metro Pit	T.1N, R.2E, Sec. 23, E2
Reeves Pit #1	T.1N, R.2E, Sec. 23, S2
Gravel pit 9	T.1N, R.2E, Sec. 29, NE
Union Rock	T.1N, R.2E, Sec. 20, W2
Gravel pit 10	T.1N, R.2E, Sec. 30, SW
Sand and Gravel Operation	T.1N, R.1E, Sec. 25, W2
Sun Materials	T.1N, R.1E, Sec. 26, SW
Gravel pit 5	T.1N, R.1E, Sec. 32, SW
Gravel pit 4	T.1N, R.1E, Sec. 30, NE

sites are not regulated. Along the Salt River, mining has concentrated in two areas: near Mesa, particularly in the vicinity of McClintock and McKellips Roads, and in Phoenix, between 24th Street and 83rd Avenue. Simons, Li & Associates (1989) provides detailed discussion of impact of gravel mining on river hydraulics and summaries of legal conflicts over flood damages and gravel mining in Arizona. Three aspects of sand and gravel mining impact the Salt River: removal of materials, creation of pits, and erection of protective structures.

Sand and gravel mining essentially remove sediment stored in the channel, on the floodplain, and in terraces along the river, disrupting the sediment budget of the river. In rivers where upstream materials do not move downstream to replace sediment, the mining creates a deficit in the budget. Without sufficient sediment to move, the river may scour the bed of the river or become highly unstable, changing position and eroding its banks (Chang, 1988). Such local changes can impact areas both upstream and downstream, particularly if the river lowers its bed. Aggregate mining also reduces the amount of fine material available for transport: extensive mining can lead to the formation of an amour layer, a layer of coarser materials (cobbles) in the channel (Rundquist, 1980).

Removal of sand and gravel creates pits which impact both the geomorphology and the water and sediment quality of the river. Unprotected pits can deflect flow and thus alter the pattern of the channel. Studies on the gravel mining in arctic and subarctic rivers show that mining increases the number of flow channels in both braided and meandering streams (Rundquist, 1980). Pits also serve as fine sediment traps: some gravel pits along the Salt River have been repeated excavated, filled with new sediments by floods, and then reexcavated. However, refilling of some pits is becoming less common because there is less sand on the channel floor than prior to the 1978-1980 floods. Figure 27 shows a multi-year sequence of events at one sand and gravel mine in the channel of the Salt River in north Mesa.

While pit refilling adds to the notion that sand and gravel are renewable resources, it poses a potential hazard to water and sediment quality. Contaminants, particularly heavy metals, are often transported on or with fine sediments. When fine materials accumulate in gravel pits, contaminants may accumulate there also. These concentrations may then leach into the high ground water along the channel during flow events. Abandoned or finished pits may be used as landfills. Carreiro (1975) discusses uses of reclaimed pits in southern California, including uses as recreation and wildlife sites. Left alone, the pits tend to accumulate standing water and become a public safety hazard.

Recently in the study area, the protective structures erected by sand and gravel operations have had the greatest impact on the Salt River. After significant damages to equipment by floods in the 1960s and 1970s, operations have built extensive embankments to protect both their machinery and pits. These embankments often extend into the main channel of the river, deflecting flow and potentially causing problems with overbank flows and scour in other locations. Maps of the 100-year floodplain highlight the impact of these structures: the irregular shape of the 100-year flow area, with angular edges, of the channel in areas of mining follows the

Figure 27. The photos on this the following three pages show the same sand and gravel mine from essentially the same viewpoint over a period of several years and through several floods. The view is from the south bank of the Salt River looking north about two miles east of the Gilbert Road Crossing. Above, the active mine in January, 1980 (W. L. Graf Photo 30-18). Below, February, 1980, with discharge about 30,000 cfs (W. L. Graf Photo 33-17)

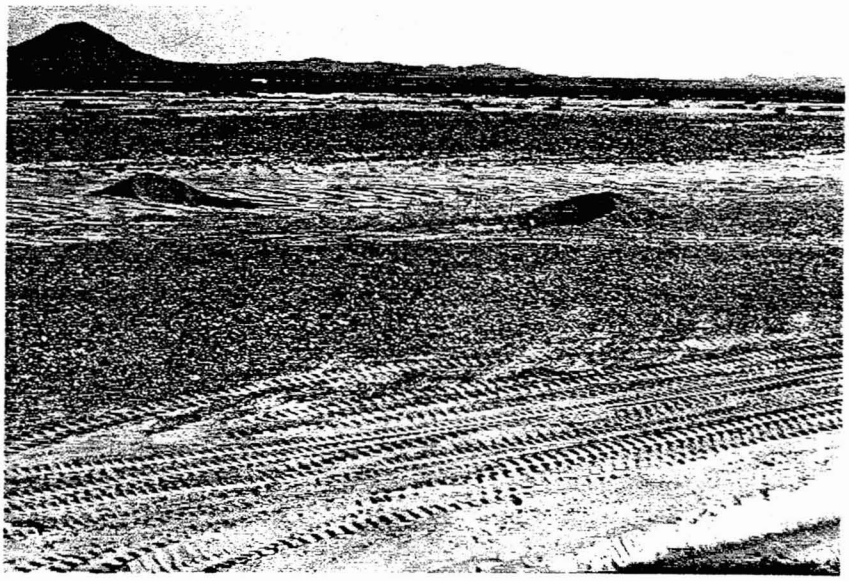


Figure 27 (continued). Above: February, 1980, with discharge of 120,000 cfs (W. L. Graf Photo 34-20). Below: the completely refilled mine in April, 1980, with two shallow prospects excavated (W. L. Graf Photo 38-6).

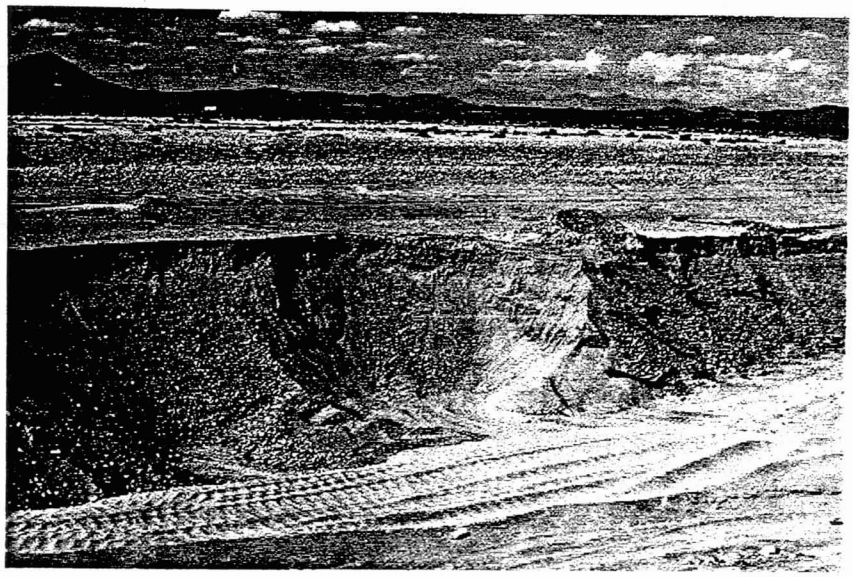


Figure 27 (continued). Above: the mine redeveloped in October, 1980, with the two prospects still in evidence as markers for comparison with the previous photograph (W. L. Graf Photo 40-2). Below: the mine inundated by a flow in October, 1983, shown with the discharge at about 40,000 cfs (W. L. Graf Photo 42-0).

Figure 27 (continued). The same sand and gravel mine as in previous views, shown in December, 1983, after the flood waters had dissipated. Note that the pit had not refilled with sediment, with only the construction of a sand delta at the upstream entry point in the right portion of the view. Some sandy beaches developed on the sides of the pit (W. L. Graf Photo 45-0.

lines of these embankments.

2.5.8 23rd Avenue Wastewater Treatment Plant

The 23rd Avenue Wastewater Treatment Plant (WWTP) is currently going through a series of upgrades and modifications, which will allow the plant to meet state water standards. It is not beneficial to discuss the present operating conditions of the plant, because they will change when the upgrades and the modifications are completed. In place of the operating conditions, a brief overview of changes to the plant is provided. All material for this overview was supplied by the Phoenix Water and Wastewater Department, Planning and Engineering Division. The upgrades and modifications have been divided into two contracts. Work on contract No. 1 has been completed. Contract No. 1 involved upgrading and expanding the odor control facilities, non-hazardous waste disposal facilities, screening and grit handling building and installation of chlorination and dechlorination equipment. There were also additional treatment facilities constructed: primary influent parshall flume, new engine driven blower for No. 3 in Blower building No. 1, modifications to Blower No. 2, new primary sedimentation basin, new digester and modification to the existing digester building.

The second contract is currently underway, with a proposed finishing date of January 1995. Modifications to take place under Contract No. 2 are: changes to two existing aeration basins, construction of two new aeration basins, four secondary clarifiers, a return activated sludge pumping station, chlorination and dechlorination, chlorine and sulfur dioxide storage buildings, modifications to existing chlorination and dechlorination buildings, digester modifications, tertiary treatment facilities, modification of existing return activated sludge pumping station and clarifier, new blower building and storm drain facilities. Completion of these two contracts will significantly reduce contaminants presently found in the effluent. The City of Phoenix maintains a complete set of monitoring data of the present conditions.

Upon completion of the construction planned in contract No. 2, the 23rd Avenue The plant will have the potential to handle an annual flow of 57 mgd. The present service area can not provide this level of water, so additional water will be pumped via the Salt River Outfall Pump Station. The Salt River Outfall Pump Station is currently under construction and is expected to be completed by January 1995. The most recent effluent flows (July 1993 to June 1994) have been plotted in Figure 28. The highest daily maximum effluent flow during this time period was 36.9 mgd in June of 1994.

The future distributions of effluent from the 23rd Avenue Plant is based upon the completion of all of the modifications in January of 1995. There are presently two stakeholders involved in the consumption of the effluent from the 23rd Avenue plant. The first is the Roosevelt Irrigation District (RID)/SRP. The City of Phoenix has entered an agreement with the RID to provide between 30 and 57 mgd via canals, while in return, an equal amount of groundwater would be pumped from wells located on the RID lands and diverted

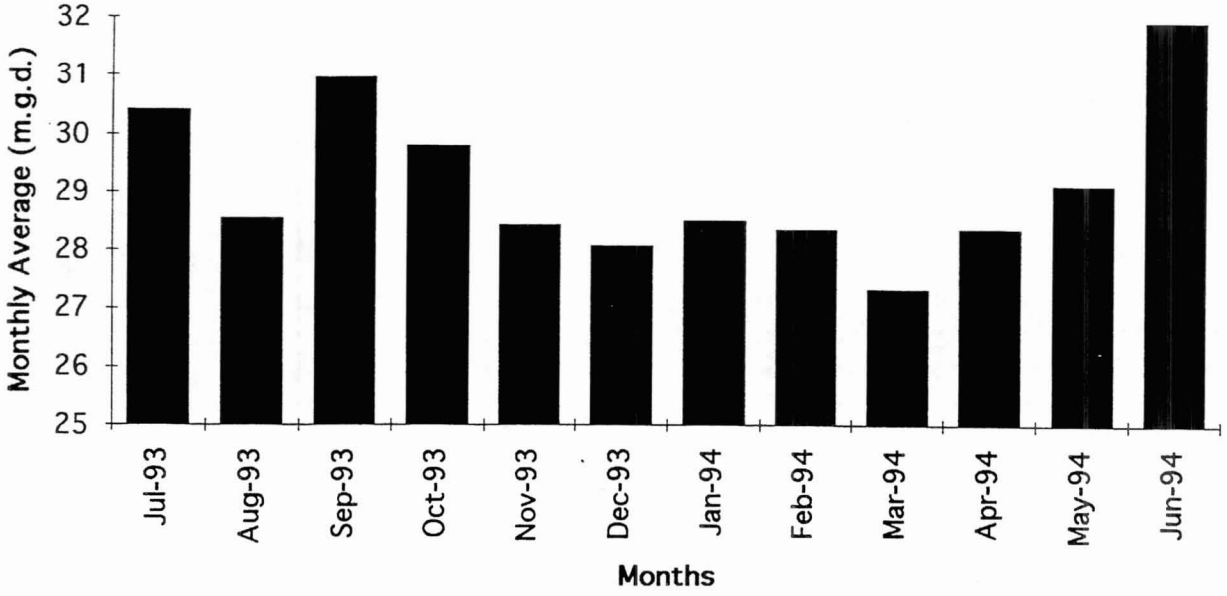


Figure 28. Monthly effluent flows from the 23rd Avenue Wastewater Treatment Plant (data provided by the City of Phoenix).

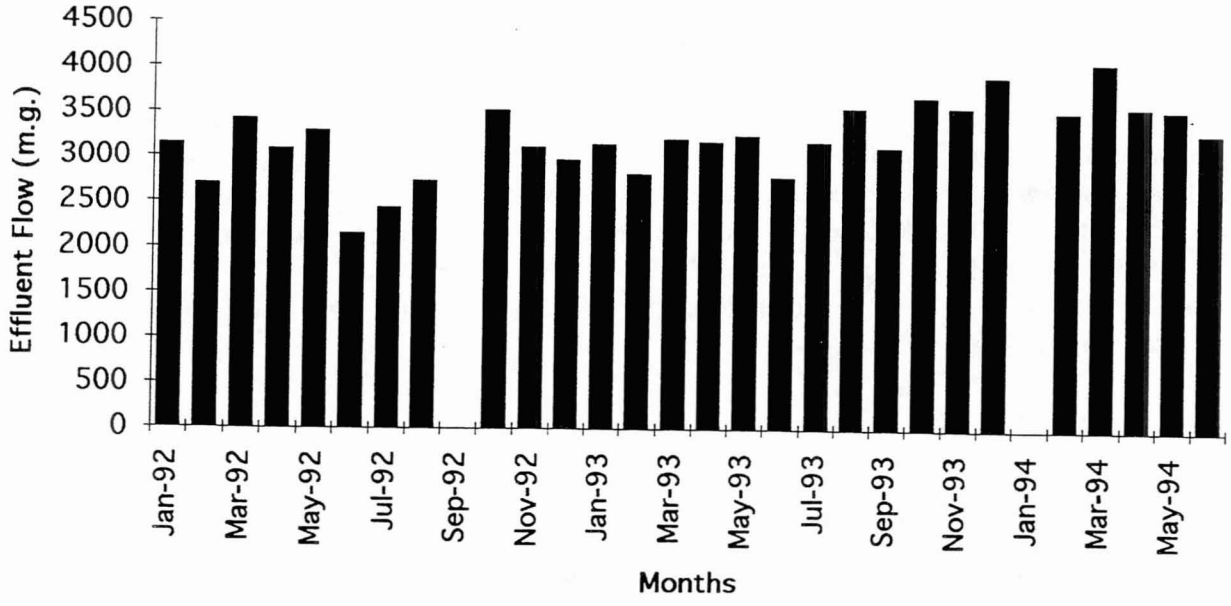


Figure 29. Monthly effluent flows from the 91st Avenue Wastewater Treatment Plant (data provided by the City of Phoenix).

into the SRP distribution system. The groundwater would be used by SRP customers for irrigation. SRP would then deliver to Phoenix's water treatment facilities, SRP surface waters at 0.91 acre-feet per acre-foot delivered by the city to RID. It is anticipated that RID will use 57 mgd during the summer months (March through October) and 25-30 mgd for the rest of the year. The second stakeholder is Peterson Farms, which has no written agreement with the City of Phoenix. Historically, Peterson Farms has diverted effluent directly from the effluent channel. It is expected that this use will continue and that Peterson Farms will utilize 1-10 mgd throughout the year.

2.5.9 91st Avenue Wastewater Treatment Plant

Like the 23rd Avenue plant, the 91st Avenue Wastewater Treatment Plant is currently going through a series of upgrades and modifications. It is not beneficial to discuss the present operating conditions of the plant, because they will change when the upgrades and the modifications have been completed. In place of the operating conditions, a brief overview of changes to the plant is provided. All material for this overview was supplied by the Phoenix Water and Wastewater Department, Planning and Engineering Division. A new design for the 91st Avenue plant is currently underway to convert the existing high rate activated sludge process to a nitrification and denitrification process. The change is an attempt to comply with a future Aquifer Protection Permit and ensure continued compliance with the National Pollutant Discharge Elimination System Permit. The design is planned to be completed by December 1994 and construction is planned to begin in April 1995. Construction is anticipated to be completed by April 1997.

The design will consist of upgrading the plants 1,2 and 3 primary sedimentation basins, addition of new chemical handling facilities, modification of the flow splitting structures, sludge pumping and piping, upgrading the aeration facilities, replacing plant 3 IMLR pumps and Nocardia Sprays, modifying the plant air header, adding a new digester, upgrading and expanding the electrical and instrumentation systems for the new process, upgrading the chlorination facilities, reuse water system and dewatering wells, and providing a plant-wide security system. Simultaneously, a second design is underway to provide sludge dewatering and thickening facilities. This design will develop an entirely new sludge processing facility. Construction of this facility is anticipated to begin in April 1995 and be completed in October 1996.

The calculated monthly flows for the 91st Avenue plant over the last two years are displayed in Figure 29. The flows are calculated daily rather than measured. The calculation is done by measuring the influent and then subtracting the usage and the measured amount sent to Palo Verde Nuclear Generating Station. It is done to monitor the effluent released for consumption by the Buckeye Irrigation District. In 1994 the peak discharge from the plant reached 156.13 mgd. The effluent has also been monitored for contaminants. The city of Phoenix maintains the most recent monitoring for the period from July 1, 1993 to June 30, 1994. During this time period several contaminants were high enough to eclipse the detection limits used in the analysis. The following are a list of the contaminants that appear above the detection limits: ammonia (as N), arsenic, boron, cadmium, copper, cyanide, and selenium. When the design for 1997 is complete, it is expected that the water quality should become better.

Present agreements for use of effluent from the 91st Avenue plant are with the Buckeye Irrigation Company (BIC) and the Arizona Nuclear Power Project (ANPP). BIC negotiated a contract in 1971 with the City of Phoenix to acquire effluent until the year 2011. The contract calls for the BIC to receive 26.7 mgd on average (30, 000 acre-feet a year). The irrigation demand of the Buckeye District is highly variable with the season. All of the allotted water is continuously diverted from the river into the BIC canal (9 miles south of the 91st Avenue plant), whether the water is needed or not. The excess tailwater is returned to the Hassayampa River downstream of the Buckeye District. A new contract is currently being negotiated between BIC and the Multi-Cities Subregional Operating Group (SROG) [Glendale, Mesa, Phoenix, Scottsdale, Tempe, and Youngtown] to acquire 40,000 acre-feet per year through the year 2030. The ANPP negotiated a contract in 1973 with the SROG for 125 mgd (140,000 acre-feet per year). The water is diverted prior to chlorine contact and conveyed via a pipeline to the Palo Verde Nuclear Generating Station for cooling the reactors.

The future distribution of reclaimed waters from the 91st Avenue Plant is still not decided. At present there are four proposed alternatives: (1) No Project Alternative; (2) Tres Rios Demonstration Wetlands; (3) Recharge/Storage/Recovery (Reclaimed Water Study) and (4) Gila River Indian Community. Under the no Project Alternative the discharge of effluent would remain as it has been historically. However, with more stringent water quality standards expected in the future, additional plant upgrades and costs will become necessary. The Tres Rios Demonstration Wetlands will be discussed in more detail in the next section. With the Tres Rios alternative, water would be further cleaned by allowing the water to pass through a series of wetland environments and then into the Salt River. The Reclaimed Water Study is an alternative where all the reclaimed water from the treatment plant is conveyed to a recharge, storage and recovery facility located at the confluence of the Agua Fria and the New Rivers. Under this alternative the BIC and ANPP agreement would be fulfilled by conveying the reclaimed water to BIC via the ANPP pipeline. Direct Discharge to the Salt River would be eliminated. The final alternative is to provide an additional 50-100 mgd of reclaimed water to the Gila River Indian Community for irrigation of agricultural and non-agricultural land, groundwater recharge, storage and recovery. In this alternative the direct discharge to the Salt River would be eliminated.

2.5.10 The Tres Rios Project

The Tres Rios project is situated on a seven mile reach of the Salt River between 91st Avenue and the Buckeye Diversion site. It is located at the confluence of the Salt, Gila and Agua Fria Rivers. The U.S. Army Corps of Engineers was initially in charge of assessing the viability of the Tres Rios site. In its original plan, Tres Rios was designed to manage runoff and waste water that was generated in this area. During the project assessment, the U.S. Army Corps of Engineers lost funding support, and the project was inherited by the U.S. Bureau of Reclamation. In conjunction with the city of Phoenix, the Bureau of Reclamation slightly altered the end product of the project, with an emphasis on water reclamation and reuse. At present Tres Rios is an attempt to plant riparian vegetation and establish areas of open water within the channel, for the sole purpose of cleaning the effluent discharged from the 91st Avenue waste water treatment plant.

At the heart of the Tres Rios project is the issue of water quality and its downstream

effects. The 91st Avenue waste water treatment plant releases effluent into the bed of the Salt River. Except for minor contributions from the Gila River, this is the only source of flowing water in this section of the river. For all practical purposes the waste water effluent released from the 91st Avenue plant is the river along this reach. At present the 91st Avenue plant releases denitrified water from the plant into the effluent channels and leaching ponds and this water is then carried into the Salt River.

At the broadest level the Bureau of Reclamation is attempting to take effluent water and clean it so that it meets navigable water standards. In order to do this, they have proposed to create a constructed wetlands along the north bank of the Salt River extending up to the edge of the 1000 foot cleared floodway. The vegetation would be protected from flood discharges by artificially constructed dikes. The effluent from the 91st Avenue plant would provide a moisture source for the vegetation along the north bank. By providing the reestablished plant communities with effluent water, the Bureau of Reclamation is confident that the vegetation would remove some of the impurities in the water. In an attempt to further removed unwanted chemicals the Bureau of Reclamation will also construct a series of wetland areas (ponded areas) in the 1000 foot cleared floodway. The wetlands will provide areas of standing water where the effluent can be aerated and certain chemicals will be removed.

In an attempt to determine the cost of this project, the U.S. Bureau of Reclamation is currently assessing the Tres Rios project, such that: (a) all of the effluent will be allowed to flow into the river channel, or (b) the effluent will be completely diverted so that no water will be released to the channel. The Bureau of Reclamation hopes that by examining these two extremes an idea of the overall cost of the project will emerge. Bureau of Reclamation has established two sites at which they are trying to determine what if anything can be done with the effluent. The first site is just to the west of the plant on the west side of 91st Avenue and has been labeled the Cobble Site by the Bureau. The second site lies just to the east of the plant and is refereed to as the Hayfield Site. The sites were established to analyze what type of purification can be attained by establishing vegetation and providing areas of standing water.

2.5.11 Landfills

Landfills, commonly located in dry river beds in Maricopa County, impact both the geomorphology and water and sediment quality of the Salt River. Maricopa County Flood Control District reported 24 active landfills and dump sites in or near flood plains in Maricopa County in 1989, eight of which were located along the Salt River. Such extensive use of rivers as solid waste disposal sites reflects the public perception of dry channels as essentially dead rivers, offering no aesthetic, recreational, or other benefits to the surrounding communities. Landfills contain industrial waste products, household garbage, tires, and vegetative waste (Flood Control District of Maricopa County, 1994). Various county, city, and private interests operate the sites, making identification of active and inactive landfills difficult. A set of land use maps recently compiled by the Flood Control District of Maricopa County provides the best single source of locational information for all active and notable inactive landfills, but these maps do not include all inactive landfills along the Salt River. These landuse maps provided the landfill data reported in

Table 19.

Landfills and particularly their protective structures impact the geomorphology of the channel because they form artificial landforms on the floodplain. Waste disposal builds up low terraces along the main channel of the river constrain the width of the main channel, as do natural terraces. Landfills encroaching onto the floodplain constrict the channel, posing potential flooding and erosion problems for the opposite side of the channel. Landfills also erode like natural terraces, contributing their contents as sediment in the river. The exact impact of the landfills on the river depends on the location of the landfill relative to the pattern of geomorphic processes in the river. For example, a landfill located on the outside of a meander activated during floods will likely experience erosion because scour naturally occurs there. Embankments commonly protect landfills from flows in the channel. However, the composition, size, and arrangement of the embankments affects their effectiveness in preventing erosion or inundation of the landfill. During the 1992-93 floods, portions of the Tri-City Landfill on the Salt River eroded because the high flows quickly undermined the silt-fill levees.

More critically, landfills contribute significant amounts of various contaminants to ground and surface waters and sediment. Elevated ground water during flood events leads to leaching of contaminants from the landfill into both the groundwater and soil (Maricopa Association of Governments, 1980b). Flows may inundate disposal pits, picking up contaminants before returning to the river channel or percolating into the groundwater system. Erosion of the landfill entrains debris in the flood waters which carries the contaminants downstream both in the water and as sediment.

Events at the 19th Street landfill, a Superfund Site, illustrate the hazards that landfills pose to water and sediment quality. Some portions of the landfill fall within the 100-year floodplain. In 1979, flooding raised the water table, filled several disposal pits, breached levees surrounding the area, and washed debris into the river (ADEQ, 1993). Refuse in the landfill contained volatile organic compounds (VOCs) and pesticides, which contaminated soils in the area. Groundwater at the site contained VOCs, pesticides, heavy metals and beta radiation. State of Arizona Health Services determined the site was a environmental and health hazard and closed it in 1980. The closed Estes/Bradley (40th Street) landfills pose a similar threat to water and sediment quality along the river. This site is currently under a Water Quality Assurance Revolving Fund (WQARF) study.

Table 19. Active and Inactive Landfills Along the Lower Salt River.

(Data from the Flood Control District of Maricopa County)

Pit Name or Street Location	Township and Range Location
Tri-Cities Landfill, Salt River Indian Reservation	T.2N, R.5E, Secs.26, 27, & 34
First Street and Price Road, Tempe	T.1N, R.5E, Sec. 13, N2
Estes/Bradley/40th Street Landfills (WQARF site)	T.1N, R.4E, Sec. 18
Interstate 10 to 16th Street, Phoenix	T.1N, R.3E, Secs. 22, 23
Del-Rio Landfill (16th Street)	T.1N, R.3E, Sec. 21, N2
19th Avenue Landfill (Superfund Site)	T.1N, R.3E, Sec. 19, W2
27th Avenue Landfill (City of Phoenix)	T.1N, R.2E, Sec. 23
Abandoned Salt River Project Landfill	T.1N, R.2E, Sec. 30, NW
Possible Abandoned Landfill	T.1N, R.1W, Sec. 36, S2

2.6 Naturalness of the Lower Salt River

2.6.1 Scale for Naturalness

The engineered structures reviewed in the previous sections, along with altered flows of water and sediment discussed earlier, have changed the general condition of the Lower Salt River. 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.

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 (Table 20 outlines the scale and provides illustrative examples).

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.

Table 20. 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.

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.

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 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 21), the flow of the Lower Salt River below Granite Reef Dam would be defined as completely artificial.

2.6.2 Application of the Scale to the Lower Salt River

Application of the naturalness scale for geomorphology to the Lower Salt River from Granite Reef Dam to the Agua Fria confluence shows that there is considerable geographic variation within the system with reference to its naturalness. The most natural geomorphologic conditions exist at the downstream end of the system, west of the 91st Avenue Wastewater Treatment Plant. The channel through Tempe and east Phoenix is completely artificial because of the Tempe Rio Salado Project and channelization associated with Phoenix Sky Harbor Airport. Other scattered reaches that are completely artificial have been modified by sand and gravel mining. West of 27th Avenue, the channel is partly artificial and partly natural, while in the Phoenix area, only a few natural charactertistics remain after extensive bank stabilization, engineering modifications, and structures. Appendix 8.2 contains complete map coverage of the study area with segments and their naturalness scale values plotted on U.S. Geological Survey

Table 21. 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

Table 22. Geomorphic Naturalness Classification Applied to the Lower Salt River.

Mile Marks		Landmark Within Segment	Naturalness Class
From	To		
0.0	1.2	Granite Reef Dam	3. Partly Modified
1.2	2.2	Higley Road Alignment	2. Essentially Natural
2.2	3.0	Near Sunshine Acres	4. Substantially Modified
3.0	4.1	West of Greenfield Road Alignment	2. Essentially Natural
4.1	4.9	West of Val Vista Road Alignment	4. Substantially Modified
4.9	7.2	Gilbert Road Crossing	3. Partly Modified
7.2	8.8	North of Lehi	5. Mostly Modified
8.8	9.6	Center Road Alignment	6. Essentially Artificial
9.6	11.7	McKelleps Road Crossing	5. Mostly Modified
11.7	12.7	Dobson Road Alignment	6. Essentially Artificial
12.7	22.3	Tempe and East Phoenix	7. Completely Artificial
22.3	26.6	Phoenix	6. Essentially Artificial
26.6	27.4	27th Avenue Alignment	7. Completely Artificial
27.4	28.7	35th Avenue Crossing	6. Essentially Artificial
28.7	29.9	51st Avenue Crossing	5. Mostly Modified
29.9	30.9	59th Avenue Alignment	6. Essentially Artificial
30.9	32.8	67th Avenue Crossing	4. Substantially Modified
32.8	33.7	East of 83rd Avenue Alignment	6. Essentially Artificial
33.7	35.2	91st Avenue	5. Mostly Modified
35.2	36.7	99th Avenue Alignment	4. Substantially Modified
36.7	37.9	Salt and Gila Confluence	3. Partly Modified
37.9	41.5	Dysart Road Crossing	2. Essentially Natural

topographic base maps.

2.7 Values in the Without Project Condition

In the without project condition, most of the benefits of the Lower Salt River channel are indirect--that is, the benefits accrue to many people who do not come into direct contact with the river but who none-the-less obtain some benefit from its existence. These indirect benefits include wastewater disposal, materials, transportation, groundwater recharge, and water quality considerations.

Many people derive benefit from the river channel indirectly, because the channel serves as a wastewater disposal area, a source for building material, and a transportation route. All users of the urban wastewater treatment system benefit from the presence and use of the channel as a conduit for effluent from the 91st Avenue Wastewater Treatment Plant. Without the channel, injection wells or pipelines would have to be maintained to handle effluent. Any use of the channel area by the City of Phoenix to conduct wastewater should have some dollar value attached to it in economic analysis of the system. The channel also serves as the dumping area for stormwater runoff, a benefit that accrues to several municipalities along the river length. Evaluation of this benefit is obvious if alternatives are considered. For example, on-site retention pools for stormwater would occupy valuable urban lands and pose temporary hazards that are avoided by using the channel.

The channel is also the source of almost all the sand and gravel used in construction in Maricopa County. Mining for these materials poses challenges for environmental restoration because of the geomorphologic disruption it causes, but mining may also provide opportunities for the development of lakes, recreation areas, and constructed ecosystems. The benefits from mining therefore must include the market value of the materials removed, as well as the use values that occur after mining.

The channel of the Salt River from east Phoenix through west Mesa is also an air transportation route. As part of a multi-city noise abatement agreement, aircraft leaving Phoenix Sky Harbor Airport to the east are required by local operating rules to follow the river at least to the Price Road Alignment before turning. If the river were in a different location or arrangement, property values east of the airport would be substantially reduced because there would be no exit route for aircraft that could avoid residential areas. The empty spaces on the other side of the airport show the likely effects on land use of such an arrangement. The river channel therefore benefits land users and air travelers in a real, though difficult to evaluate, fashion.

The river channel is a major groundwater recharge mechanism. One-third or more of the water flowing into the Salt River Valley during flood events seeps into the groundwater system, and during many flood events the water levels in wells near the river respond by rising several tens of feet. The channel is an efficient recharge mechanism because of its porous sediments, and any engineering or restoration efforts that reduce this role would also reduce the recharge benefits.

The channel also performs a filtering effect on water that passes over or through it. Many

metals and organic contaminants adsorb onto the sedimentary particles, and in most cases the concentrations of contaminants is one to several orders of magnitude greater in the sediments than it is in the water. The sediments become contaminated by this process, but they are less mobile than the water, and are perhaps less valuable than the water. This benefit might be evaluated by calculating the worth of the water if the contaminants were to remain in the water, resulting in degraded quality.

3 FUTURE WITHOUT PROJECT CONDITIONS

3.1 General Nature of the Future Without Project Conditions

The near future is likely to be an extension of the recent past for the partly natural hydrologic and geomorphic processes operating in the Lower Salt River System. Occasional releases of water over Granite Reef Dam from the upper watershed of the Salt and Verde systems is likely, because the present climatological circulation system that produces the discharges seems well established. The Office of Climatology at Arizona State University and the Arizona State Climatologist agree that a return to the 1941-1978 conditions seems unlikely in the near future. Predictability of the discharge events may improve if a clearer understanding of the El Niño connections emerges from ongoing research.

The channel of the Lower Salt River between Granite Reef Dam and McClintock Drive is continuing to degrade and erode deeper into its bed sediments. A headcut of several feet is now (mid-1994) eroding upstream in the vicinity of the Alma School Road and Country Club Drive, indicating that the channel is not in equilibrium. Recent discharges have caused some downcutting in the north and northeast Mesa portions of the channel, where the bed is now 20 feet below its pre-1941 position. Channel locational instability, especially in reaches west of 19th Avenue, will continue, with the low flow channel changing its position with each moderate or large flow event. Some bank erosion should be expected as when the low flow alignment impinges on the edge of the high flow zone or on terrace edges. Channel instability downstream from 91st Avenue to the Agua Fria River will be likely to be greater than in other parts of the Lower Salt River.

With regard to human activities, the future without project conditions will not be an unchanged extension of the conditions prevailing in 1994. Public statements by civil and private authorities provide an informal glimpse of what is likely to happen with river management over the next decade. Sand and gravel mining will continue to be a feature of the geomorphology of the river, but there will probably not be an expansion of mining between Granite Reef Dam and Gilbert Road because rich alternative sources of material are available on lands of the Salt River Pima Tribe, north of the river. These alternative sources will be used instead of the more heavily regulated channel sites. After about ten years, the Maricopa Association of Governments (MAG) group anticipates more rapid urban growth in the west valley, so that an increase in number and intensity of sand and gravel mining operations downstream from 27th Avenue is likely. In all cases, transportation costs are a major consideration in locating mines, so that mining expansion will occur near economic development and freeway construction

The Tempe Rio Salado Project will transform about 5 miles of the Salt River from about McClintock Crossing to the Hohokam Expressway (48th Street alignment) into a completely engineered and landscaped river with a 250,000 cubic feet per second flood channel. Construction associated with Phoenix Sky Harbor Airport will be likely to produce a constricted, hardened channel with an alignment unlike the natural arrangement. Bank stabilization and channelization will be likely to occur in the reach of the river through Phoenix where there will be no project on the scale of the Tempe Rio Salado Project, but where more limited developments including parks and constructed riparian ecosystems are likely.

Downstream from the 91st Avenue Wastewater Treatment Plant, the installation of constructed wetlands for partial removal of contaminants from wastewater is likely, with attending changes in vegetation and contamination of sediments. While the city of Phoenix envisions increasing vegetation cover in the area, the Flood Control District of Maricopa County contemplates reducing vegetation cover. The Flood Control District has a decade-old program of clearing a floodway through the phreatophytes downstream from 91st Avenue, and the agency would prefer to maintain a clear path for flood waters. However, the cost of maintenance under the present slash and burn process is becoming unacceptable, and the Flood Control District is actively exploring alternatives to maintain the clearing. Irrigation tail waters into the Gila River above its confluence with the Salt are likely to continue to promote high water tables and dense growth of phreatophytes in and near the channel of the rivers in the vicinity of their confluence and downstream to the Agua Fria River confluence.

Water quality in the Lower Salt River will continue to be an issue in environmental management. Stormwater runoff with associated pollutants will be likely to increase as the freeway system expands, especially along the Red Mountain Freeway alignment on the north bank of the river in the Tempe area. Construction improvements in and near the channel outlined above will also increase stormwater flows and their input of contaminants. Indian Bend Wash will continue to inject its water and (of equally importance) sediment into the main channel system.

3.2 Future of Riparian Habitats

The future of riparian habitats along the Lower Salt River may be considered on a reach-by-reach basis downstream from Granite Reef Dam. The reach immediately below the dam and for a downstream distance of about a mile is likely to continue to lose its riparian vegetation because it will continue to lose the necessary substrate to support such vegetation. Channel sidebars of sand will become increasingly unlikely because the Salt River Project dredges the basin behind the dam. When moderate or high flows occur, sediments from upstream are trapped in this basin, but water from the flows continues over the dam to erode deposits downstream. This process has been well established since 1978, and it will continue under without-project conditions. An additional problem is anticipated construction in the area. The Bureau of Reclamation has publicly stated that it intends to replace the siphon tubes for the Central Arizona Project Canal which pass under the Salt River channel immediately downstream from Granite Reef Dam (Figure 30). These activities will insure at least temporary instability for the habitats of the reach, but they also offer the possibility of some constructed riparian ecosystems along a short section of the reach.

Habitat along the Lower Salt River through north Mesa to McClintock Drive is not likely to improve under the without project conditions. The survival of riparian vegetation and phreatophytes depends on high water tables that once existed in the area. The dramatic drawdowns of watertables in the area will not be reversed under any scenario for the next decade, and the watertables are so far below the surface that recharge by flood flows will not raise them to within 15 feet of the surface where they might sustain dense cover of phreatophytes. Scattered patches of willow, cottonwood, and tamarisk may survive on sporadic surface flows, but if the flows are in the 20,000-25,000 cubic feet per second range, physical destruction of the communities is possible. Some riparian vegetation was lost during the 1993 flow which was in

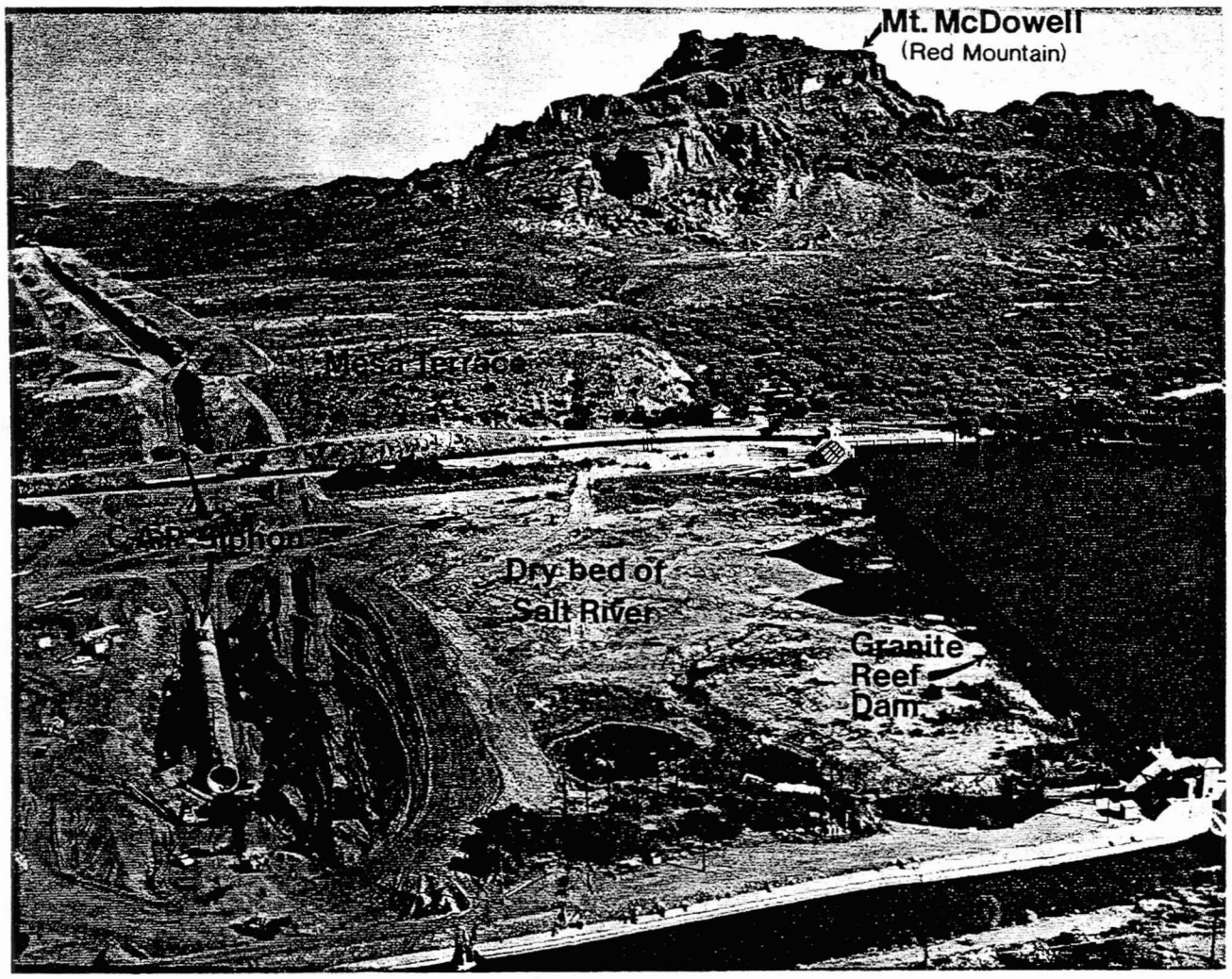


Figure 30. Granite Reef Dam, looking north across the channel from Schlect's Butte on the south bank, showing the construction of the Central Arizona Project siphon in September, 1971 (photo by N. Leatham, Arizona Republic, and published in Péwé, 1978).

this general range. Loss of substrate in the reach below Granite Reef Dam implies that without specific restoration, the reduction in riparian vegetation between the mid-1960s and the mid-1980s is unlikely to reverse itself (Figure 31).

On the terraces in the north Mesa reach of the river, some limited wetlands and riparian vegetation is likely to survive, nourished by stormwater runoff and irrigation tail waters. Wastewater flows are likely to be larger on the north bank, which drains considerable areas into the Salt River channel. Drains on the south bank serve smaller areas because the Mesa Terrace drains generally southward, away from the Salt River and into the Gila River. Municipal drains in both Mesa and Tempe generally flow to the Gila system, following a prehistoric system of drainage established by an ancestral Salt River that did not follow the present course of the river.

Small wetland areas are likely to continue to exist in association with sand and gravel mining operations in the vicinity of the processing plants where materials are washed with water. Wastewater from these washing operations are discharged on site, and in some cases support wetland conditions. An artificial wetland of this type, complete with cattails, occurs on the south bank of the river at a sand and gravel operation 1.2 miles east of the Gilbert Road Crossing. Larger wetland areas may exist in abandoned mining pits, especially the deepest ones that may intercept perched water tables.

The Tempe Rio Salado Project will create built environments along the river in Tempe, including some wetlands and riparian vegetation in artificial conditions. Along the river through Phoenix, phreatophyte vegetation will continue to grow on sandy deposits in the river bed, surviving on local stormwater runoff. The relatively barren channel west of 19th Avenue is not likely to change its condition because it is similar in circumstance to the river in north Mesa.

Habitat in the vicinity of the 91st Avenue Wastewater Treatment Plant may undergo some changes. If the City of Phoenix establishes constructed wetlands for water treatment purposes, some increase in riparian vegetation can be anticipated. However, if the city eventually conducts its wastewater to the Buckeye Heading by pipe instead of the present practice of discharging it into the channel, some loss of riparian vegetation will occur. The north bank zone of the high flow channel between 91st Avenue and the Agua Fria will lose most of its riparian vegetation, and the habitat will deteriorate from a wildlife perspective.

3.3 Future of Flooding Impacts

The impact of flooding on the Lower Salt River under the without project conditions will be geographically variable, with the greatest impacts likely to occur in the lowest reaches of the system. In the reach between Granite Reef Dam and McClintock Drive, channel erosion will continue, but because the stream is entrenching itself, lateral instability will not be pronounced except in the those reaches affected by sand and gravel mining pits or by associated levees or channel works. Damage in this reach is likely to be limited to the mining operations or to bridges that experience excessive scour similar to the 1980 case of the Interstate 10 Bridge. Bridge approaches, particularly at the Gilbert Road Crossing where they are roads built on the high flow channel and Lehi Terrace surfaces, are likely to be inundated and eroded, but repair costs for these damages will be minor, and construction of larger structures to avoid approach problems is

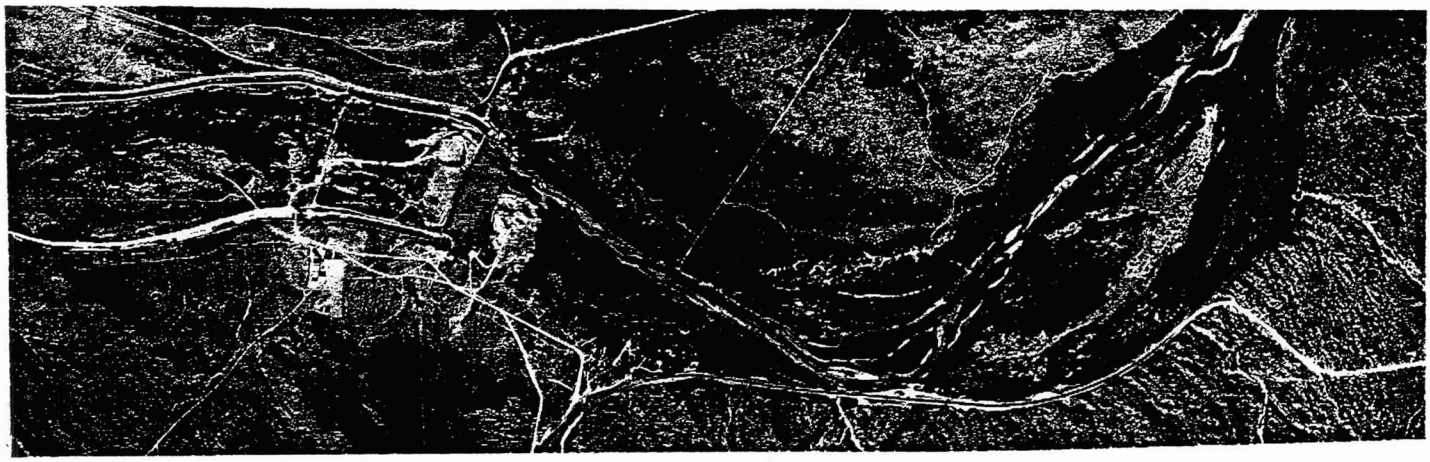


Figure 31. Aerial photographs showing the decline in vegetation below Granite Reef Dam through loss of substrate to erosion (and to a lesser, temporary degree above the dam). Above: conditions in February, 1965 (Arizona Department of Transportation Photo 287, 11-5). Below: conditions in November, 1985 (Arizona Department of Transportation Photo 2348, 6-17).

not warranted.

Sand and gravel mine pits in the north Mesa reach of the river are not likely to refill with sediment during flood events of moderate magnitude. During the 1980 flood, some pits filled with sediment completely and became extensions of the bed of the channel. The sediment that filled the pits apparently came from the channel floor upstream which still contained considerable sand at that time. After the 1980 flood, however, this sand supply was reduced. During several recent moderate flows, none of the pits filled with sediment. During the 1993 flow, one of the authors (Graf) conducted river-level investigations of the flow and sediment processes when the discharge was 10,000-15,000 cubic feet per second by floating the river from the Country Club Drive Crossing to the Rural Road Crossing using an inflatable kayak. In this discharge range, drop structures such as the one downstream from the McClintock Road Crossing were drowned and safe to traverse.

Direct observation during this investigation showed that sand and gravel pits were turbulent reaches, with hydraulic jumps and rapids common at the upstream edges which were slowly eroding headward. The water flow in the interior of the pits consisted of numerous cells of upwelling flows and recirculation eddies, sometimes with flow in the upstream direction. Turbulent conditions also existed at the downstream exits from the pits, but they were much less intense than on the upstream edges. After the flows ceased, inspection of the dry channel showed that none of the pits had filled with sediment, but each had developed deltas, sometimes on several sides of the pit, with collapse structures on the sides and deep water fine deposits in the center.

Flood damage to the Tempe Rio Salado Project during construction phases should be expected. The much filmed collapse of the second Mill Avenue Bridge during the 1993 flow may be repeated in less spectacular form during the construction of other features of the project. While the design of the channel is such that its capacity is 250,000 cubic feet per second, damage is highly likely at discharges even as low as 25,000-40,000 cubic feet per second. These lower discharges are likely to develop low flow channel characteristics with a meandering thalweg within the design channel. In those places where flow lines impinge on the built edges of the channel, significant erosion is inevitable. Unconsolidated bed sediments will be mobilized to a depth equal to twice the depth of water flow (as indicated in past events), and undercutting of the soil cement sides of the design channel will result. Sediment inputs from Indian Bend Wash will continue to complicate the processes in the Rio Salado Project area.

Channel instability should also be expected in the vicinity of Phoenix Sky Harbor Airport unless extensive hard engineering approaches are employed. The thalweg channel is highly likely to erode design channel margins, because the design channel does not follow historically established configurations. Locational probability analysis of the past 125 years shows that the channel is inherently unstable in the reach in any case. Channelization efforts during the 1960s had almost no effect on the location of the channel during later flood events, and although the present design channel is of larger capacity, it is unlikely to solve the problem of thalweg instability during large flows.

In the Phoenix area, flood damages will probably be similar in the near future to those in

the recent past. High channel banks, some hardening of banks by bridge abutments and riprap, and vertical channel stabilization by drop structures will lend stability to this reach. Sand and gravel mines provide deep pits in some parts of the reach which can serve as flood storage, further reducing the potential for flood damage to other property.

Between 19th Avenue and 91st Avenue, however, considerable channel instability should be expected within the next decade under the without project assumption. Historically the channel has been locationally unstable in this reach, and sand and gravel mining operations are likely to promote that instability because the high flow channel is wide and the mining pits will be likely to redirect the thalweg channel into configurations that have not previously existed. Because there are no large sediment sources upstream from the reach, the mining pits are not likely to fill with sediment, and during flows they will not become uninterrupted extensions of the bed. Because of sand and gravel mining and natural channel instability, parts of the 91st Avenue Wastewater Treatment Plant are at some risk, and ponds and other structures associated with the plant may experience damage in the next decade.

Between 91st Avenue and the Agua Fria River, considerable instability is likely under the without project conditions. Inundation of the high flow zone and the lowest portions of the Lehi Terrace are inevitable and are to be expected under naturally occurring conditions. The location of the low flow or thalweg channel will remain unstable, even with vegetation clearing for a floodway. If the Flood Control District of Maricopa County constructs a pilot channel in the area, and if that channel is relatively straight, it will be unstable in moderate to high flows. The greatest hazard to stability in the Salt and Gila confluence area is the possibility of simultaneous large floods in the two watersheds. Such a combined flood, possibly the product of a large winter storm system dropping large amounts of precipitation on warm snow at higher elevations of the watersheds, would produce catastrophic erosion of the Lehi Terrace and properties in the Holly Acres area, as well as resulting in extensive inundation damage.

4 WITH-PROJECT CONDITIONS AND ASSOCIATED BENEFITS

4.1 Opportunities for Riparian Habitat Restoration

4.1.1 Dam Operations

The key to habitat restoration in the Lower Salt River is the availability of water, free from limiting contaminants and in quantities larger than are presently available in the river channel and on nearby surfaces. It is unlikely that the managers of the Salt River Project storage reservoirs in the upper watershed will provide water for habitat restoration, because the Project is obligated to conserve as much flow as possible and to distribute it to its service area. However, since 1978 there have been numerous releases of water over Granite Reef Dam that do not have such restrictions. These releases represent valuable water that could support habitat restoration. If releases appear to be inevitable, they should be conducted with as discharges of duration as long as possible. While downstream channel users may prefer no releases at all, long duration discharges result in lower stages, so that benefits accrue not only to riparian habitats needing long-term contact with discharges but also to other land users. Erosion potential is also reduced by low stage flows.

The possibility of a reregulation structure should also be considered for installation below Granite Reef Dam in the reach from the present dam to at least the Gilbert Road Crossing. These structures could not be large storage reservoirs which would inundate properties near the river, but there might be a series of small inflatable dams arranged to create a stair-step series of storage lakes along the channel. Low level releases from this series of holding basins to provide water for habitats downstream. Because the channel is entrenched between terraces, there is considerable storage volume available--considerable with respect to needs of scattered restoration projects downstream if not with respect to larger Salt River Project Reservoirs. Inflatable structures are desirable so that periodically they might be removed to insure the throughflow of sediment that otherwise might restrict reservoir capacity. As sand and gravel mines cease production in the north Mesa area, they also might serve as holding basins for slow releases to downstream habitats. Both the channel holding basins and the mines should be lined with clay or plastic to prevent losses through peculation.

4.1.2 Channel Configurations

Channelization projects, constructed wetlands, and restored ecosystems should seek to replicate the natural channel as closely as possible in terms of width, depth, gradient, pattern, and terrace arrangement. Of these characteristics, the most important are pattern and terrace arrangement. Constructed channel environments should replicate the compound channel geomorphology, with a defined low flow or thalweg channel slightly meandering within a broader, braided high flow channel system. The location of the thalweg channel should be such that it flows through the zones of high locational probability established by the historical record. Some deviation in thalweg location away from these high probability areas during moderate to high discharges should be anticipated, but the high probability alignments represent potentially the most stable arrangements. Constructed wetlands and artificial or restored ecosystems should be located away from the high probability locations for the thalweg, in those parts of the high flow

channel least likely to experience erosion by the migrating low flow channel.

Restored ecosystems should seek to duplicate the natural vertical sequence of landforms and vegetation associations. In depressions in the high flow, braided channel, marsh vegetation is likely to succeed, but to occasionally be eliminated by major floods. Cottonwood and willow should be encouraged along the edges of low flow channels and the edges of the high flow channel where it meets the lowest, or Lehi, terrace. If the terrace does not exist, it might be constructed. The lowest terrace should include some fine grained materials as it did under natural conditions, and it should be expected to receive over-bank flows during high flow events. The lowest terrace should be the site for restored mesquite bosques because this is the geomorphic position they occupied under natural circumstances.

The high watertables that existed under natural circumstances may not be possible under modern conditions, but perched watertable can be constructed by providing a clay or plastic liner at depth below the surface. When water is applied to the surface, in will then percolate a short distance vertically, to be held in place close to the surface by the liner. Such liners may be required under all reconstructed wetlands and restored ecosystems irrespective of their geomorphic position.

4.1.3 Sediment Dynamics

Movement of sediment through the Lower Salt River system should be encouraged. The creation of ephemeral sand bars in mid-channel or channel side locations would duplicate the dynamic characteristics of the natural system, and would provide new seedbeds for phreatophyte vegetation. Such vegetation is likely to be mostly tamarisk unless active management encourages the growth of cottonwood and willow. Tamarisk did not exist in the natural system, so that active management and phreatophyte control will be required to approach natural conditions. A careful balance with other management objectives will be required, because at some point the encouragement of channel vegetation will conflict with flood control objectives.

Contaminated sediment that accumulates in constructed wetlands for water treatment should not be ignored. It will become mobile during moderate to large flood events, and it will be distributed in the downstream direction, with concentrations of contaminated sediment occurring in bars, beaches, and behind dams downstream. The sediments will enter new chemical environments that may have different pH conditions from the point of origin. The effect of these sediments on habitats is uncertain, but it should be investigated before redistribution occurs so that adequate plans may be developed.

4.1.4 Wastewater Effluent

The use of effluent for development and maintenance of riparian habitat in the present study area involves the 23rd and 91st Avenue plants. The 23rd Avenue plant is expected to produce 57 mgd of effluent by January 1995. All of this effluent is promised to the Roosevelt Irrigation District/Salt River Power and the Petersons Farms. It is highly unlikely that this would be an alternative source of water to develop and maintain a hydrophytic riparian environment. All of the effluent from the 23rd Avenue plant is taken

up by the previously named stakeholders.

The 91st Avenue plant is a similar circumstance, with most of its water promised to the Buckeye Irrigation District and the Palo Verde Nuclear Generating Facilities. The removal of water for vegetation restoration would probably not be a viable use. The only potential for the effluent in this reach of the river would be the excess water from the Buckeye Irrigation District, which is just pumped to the Hassayampa River during off season growing period. This is something that would have to worked out with the Buckeye Irrigation District and it would probably not be cost efficient. The four alternatives that were discussed in section 2.5.9 could also make effluent water even a more less likely alternative. At present it is uncertain which of these alternatives will be emplaced at the 91st plant, but future use of effluent would have to address these alternatives.

4.1.5 Agricultural Runoff

There is a potential to use agricultural tailwater for the development and maintenance of riparian environments. Specific sites where agricultural tailwater entered the river channel could not be identified using the aerial photography. Do to time constraints, it was not possible to go out and identify all of the agricultural drains in the study area. It is thought that the agricultural runoff is minute in comparison to the amount of agricultural water that infiltrates into the substrate. Many of the agricultural fields are constructed, so that a minimal amount of water runs off the surface of the field. Much of the excess agricultural water percolates downward through the soil and into the water table. This being the case, it would be more cost efficient to pump and treat the groundwater than to attempt to capture the agricultural runoff. Alternatively, if the groundwater is near the surface, it may be accessible by digging to the level of the water table, allowing the groundwater to come to the surface. This would provide an area to establish hydrophytic plant species.

Several agricultural sites were identified from the aerial photographs. For future investigation into this option the following areas should be analyzed: fields north of Thomas between Higley Road. and Greenfield Road.; the Salt River Indian Reservation west of Hayden Road. all along the north bank of the Salt River; on the north bank of the Salt River south of lower Buckeye Rd. between 43rd Avenue and 83rd Avenue; along the north bank of the river from 91st Avenue to the confluence of the Agua Fria River; and on the south bank of the Salt River from 43rd Avenue to the Avenue. These are the most probable sites for agricultural runoff and agricultural drainage to the water table.

4.1.6. Stormwater Drainage

Stormwater drainage represents a largely untapped source of surface water for use in environmental restoration. Some large drainage systems with outfalls to the river already exist. For example, the Alma School Drain empties into the river in north Mesa, and the 48th Street drain supplies runoff near the Interstate 10 Bridge. These systems can be improved to insure that all have energy dissipation structures and temporary retention structures at their outlets. Reconstructed ecosystems could be developed within these retention areas, especially if they are

underlain with clay or plastic layers to prevent rapid percolation loss of the water--the developement of an artificial perched water table. The water quality of stormdrain products may be a problem in some cases, and should be fully investigated. Minor treatment of the runoff may be possible, and in any case, the benefits of riparian systems at outfall sites may contribute to improvement of water quality through trapping of contaminants, especially metals from industrial sites.

Recent stormwater monitoring in the Phoenix metropolitan area shows that the city has lower levels of contaminants than those generally found in other American cities assessed by the U.S. Environmental Protection Agency's National Urban Runoff Program. Lead and zinc are especially low, except for discharges from obvious industrial sources (Lohse *et al.*, 1994). The data show why average values should not be used for environmental restoration planning, because although the overall means are low, there is considerable geographic variation, and some sites may be undesirable for restoration because of locally high concentrations.

4.2 Additional Suggested Improvements

4.2.1 Granite Reef Dam Visitor Center

Granite Reef Dam is presently a waste public relations opportunity. The urbanization of the east valley and increased traffic by recreationists using the Salt River upstream from the dam has created within the last ten years considerable opportunity for public visitation to the structure. In order to protect the structure and surroundings from vandalism, fences and gates have been erected. Rather than restricting access to the structure, it should be developed into a public museum and information center, possibly serving as a visitor center and control point for entry into the recreation area upstream. A visitor center could educate the public the valley canal system and how it operates, the Central Arizona Project with its syphon, penstocks, and pumping station nearby, the history and culture of the Salt River Indian Reservation and its peoples, and environmental restoration work. The center could be a useful cooperative venture involving the Corps of Engineers, Bureau of Reclamation, Salt River Project, and native Americans.

4.2.2 Joint Head Dam Restored Area

The Joint Head Dam area is now a plot of land completely isolated from the constructed river channel east of Phoenix Sky Harbor Airport. Approach roads to the airport pass by the area and define its western, southern, and eastern edges. The Grand Canal defines the northern edge. The result is a site for environmental restoration and possibly a natural-historical park area. The concrete sill of the dam remains, as well as the ruins of the control gate structures that once diverted water into the Grand Canal, but that now serve only as emergency outlet drains for the canal. The site once supported extensive riparian vegetation (Figure 32), and it is a trap for water even in its present undeveloped state, some xeric vegetation flourishing there. If urban runoff from the high ground to the north and from the nearby road network were directed to the area, even more vegetation would be possible. A historical park focusing on the local canal network, would complement the Pueblo Grande park downstream, and it would be accessible from the

Figure 32. Historical views of the Joint Head Dam area as seen from the north abutment of the dam, looking south across the channel. See also following page. Above: 1941, when the grown of phreatophytes was probably at its maximum (Photo 508, Carl Haden Collection, Arizona Room, Arizona State University Hayden Library). Below: September, 1949, showing some loss of vegetation--the box in the left foreground contains stream gage equipment (Corps of Engineers Photo, W. L. Graf (copy photograph) Photo 34-6).

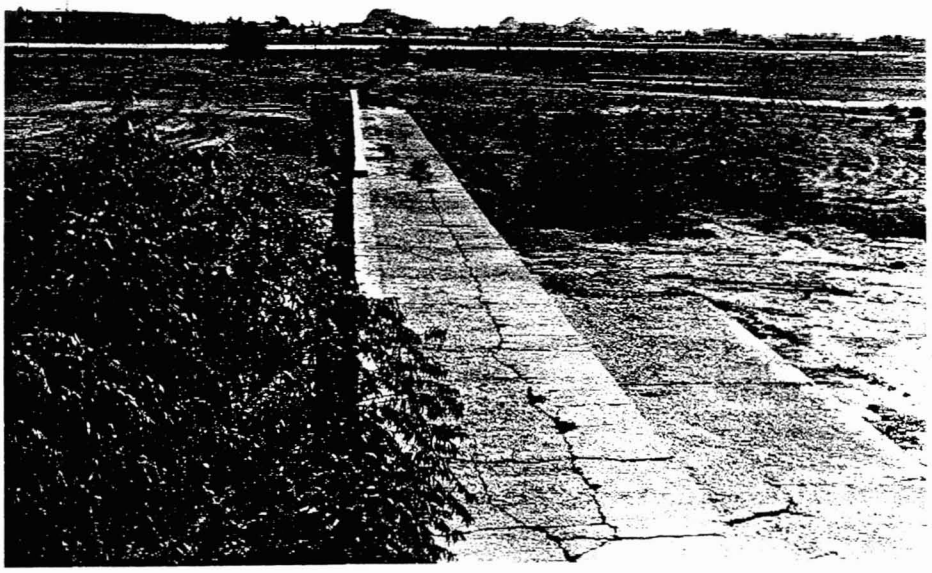


Figure 32 (continued). Above: December, 1980, with the sill of the dam buried by sediment (W. L. Graf Photo 40-29). Below: January, 1993, with the sill exposed by erosion (W. L. Graf Photo 116-3).

remnants of 48th Street on the north bank.

4.2.3 Salt-Gila River Data Center

During the conduct of investigations for this report, it became obvious that huge amounts of data have been collected by a variety of agencies interested in the Lower Salt River. These data are found in hundreds of published and unpublished reports, agency memos and files, on paper, tape, and disk. Maps, both historical and modern, are numerous but scattered in a score of locations. Aerial and ground photography are held by many agencies, but are often poorly indexed. Often, agencies and their contractors are completely unaware of the holdings of each other, and sometimes data collection efforts are unknowingly duplicated. Given the economic, cultural, and natural importance of the river to the Phoenix metropolitan area, it is critical that these data be assembled in one central location or clearing house. Such a clearing house or central depository would result in better informed decisions by managers, improved public and agency access to documents and information, and elimination of costly duplicative efforts.

For lack of a better term, such a Salt-Gila River Data Center would automatically receive a copy of any studies or data generated by agencies or their contractors working on any aspect of the Salt and Gila rivers in Maricopa County. The center would accept surplus documents and data from any agencies, as well as trying to obtain additional documents and information as time permits. The center would probably not require much investment in terms of personnel, since several agencies already maintain libraries and collections, particularly the Salt River Project and the Flood Control District of Maricopa County. Space for the institute would probably be the major investment cost. Because the center collections would be wide ranging and unrestricted, and because their regulatory responsibilities extend across the entire river system, the most appropriate agency to administer a central clearing house would either be the Corps of Engineers or the Flood Control District.

4.3 Constraints

4.3.1 Potential for Flooding and Possible Controls

Despite significant structural efforts, flow in the channels of the Lower Salt River will continue to occur on an occasional basis. The local media and general population often refer to any flow in the channels as a flood, testimony to the cultural perception of the river that has no water most of the time. A public education effort such as that being undertaken by the City of Tempe for its Rio Salado Project would be helpful for many agencies managing the river. Damages from water flowing in the channel are now minimized by the numerous bridged crossings that preserve the flow of cross-river traffic, and those using the channel directly, particularly sand and gravel miners, can adequately prepare for low to moderate flows.

If flooding is considered to mean those discharges that cause sediment motion and channel adjustments, flood damages in the with project condition will include the destruction of some constructed wetlands, restored ecosystems, and channel works. This destruction is inevitable because floods as large as 150,000 cubic feet per second are possible even with the rebuilt Roosevelt Dam. Even larger flows are possible downstream from the Salt and Gila confluence in

the event of simultaneous flooding in both watersheds. Flows of this magnitude must be taken into account in any planning for environmental restoration, and additional upstream flood control might be contemplated, including the rebuilding of dams other than Roosevelt to increase flood storage. While such efforts in the past may not have been cost effective, the protection of increasingly valuable property in the metropolitan area, increased population, and installation of economic developments and environmental restoration projects in and along the river may justify reevaluation.

Evaluation of flood control works on Indian Bend Wash may also be justified by the increased investments downstream, especially in the Tempe and airport areas. Control of water discharges with their temporary storage for later, slow release would greatly enhance environmental restoration downstream. Control of sediment discharges is of at least equal importance, especially given that the new Clean Water Act will probably designate sediment as a pollutant.

4.3.2 Water Quality

Any environmental restoration effort will require water free of high levels of contaminants. Potential sources of water, including effluent, irrigation drain water, stormwater runoff, and pumped groundwater all potentially pose contaminant problems. A significant constraint therefore on restoration is that these waters may have to be treated before they are used for environmental restoration. For consistent sources of water, particularly pumped groundwater, moderate scale treatment plants may be required, but such an arrangement has the advantage of collecting the water in a centralized location for processing and then distribution. Control of such as system might be technically sophisticated, but it would be easily managed. For intermittent sources such as stormwater runoff, smaller package plants such as those used in remote locations on public lands and for small municipalities might accomplish the task inexpensively. In any case, processing potentially would be needed to control heavy metal ions, organic chlorines associated with herbicides and pesticides, hydrocarbons associated with tank leakage,

4.3.3 Social Costs

Flood control and environmental restoration projects in the Lower Salt River will also encounter social costs that should be mitigated before the projects begin. These costs include considerations for aircraft noise, neighborhood separation, crime, nuisances, and the homeless. Any restored areas east of Phoenix Sky Harbor Airport will have low overflights of numerous aircraft on a daily basis. Although federal regulations are forcing the modernization of airline fleets with quieter aircraft, noise levels along the river between Price Road and the Hohokam Expressway Crossing are an obvious consideration for potential users. Noise levels are especially high between Mill Avenue and the Hohokam Expressway, a possible constraint in the development of areas to be used by persons outside buildings. The use of the airspace may also constrain choices for restored habitats, because bird flights would pose a serious hazard for flight safety.

The Lower Salt Rive has traditionally be a dividing line between neighborhoods north of the river and those south of the channel. City of Phoenix officials would like to see better north-

south connections in the city across this river dividing line, but some environmental restoration or flood control projects might increase the divisions rather than reducing them. Numerous crossing points for foot traffic might alleviate part of this problem, and design of park areas, automatically assumed to be oriented along the length of the river should include design elements that make connections across the river as well.

Criminal activities sometimes are advantaged by areas remote from buildings and lights, and shielded by dense vegetation. These characteristics also typify restored environments and constructed wetlands. In rural settings, these areas are probably not significant places for crime, but next to an urban area such as downtown Phoenix, they may offer safe haven for criminals or their activities. Because the City of Phoenix anticipates the possibility of constructing park-like environments along part of the river, planners might consider including in park development plans the location of a district police station part of the park space. Such stations are needed in any case, and location of one at the river might deter some criminal activities. The City of Tempe has located one of its substations in an urban park near the Tempe Canal, and has had considerable success with the arrangement.

Flood control projects, restored environments, and especially constructed wetlands may be viewed by neighboring residents as nuisances. The introduction of standing water near residences may be perceived as a safety hazard for children, and as a breeding area for insects or odors. This latter problem has already appeared in management of the river downstream from the 91st Avenue Wastewater Treatment Plant. Over 300 residents of the Holly Acres area sued the City of Phoenix (*Brogdon vs. Phoenix*), charging the operation of the plant stimulated the production of undesirable insects and odors. The suit was settled out of court with payments to the plaintiffs. Planners should consider such potential actions before installing restoration projects, many of which duplicate in part the same situation.

To most residents of the Phoenix metropolitan area, the present alignment of the channel is a blank portion of the map of population. In fact, the river channel is the location of a significant number of homeless people who roam the city by day and who sleep under bridges, in structures along the channel, and in riparian woodlands at night. Some individuals have constructed makeshift houses of discarded lumber under some bridges. During the winter, as many as 100 nomads, some with vehicles, others without, colonize portions of the channel downstream from 91st Avenue. Flood control projects and environmental restoration are likely to displace these individuals, and provision should be made for them prior to initiating projects. After environmental restoration projects are finished, unplanned for but almost certain users will include the homeless.

4.4 With Project Benefit Categories

This report focuses on the geomorphology of the Lower Salt River rather than economic considerations, but geomorphology can inform on economic values, especially those associated with environmental restoration. The economic benefits accruing from environmental restoration of the Lower Salt River are connected to the following groups: people who live near the channel, people who directly use the channel area but do not live close to it, and people who are non-users. Additional sources of benefits include wildlife and water quality.

For those persons living near the channel, environmental restoration is certain to increase property values. Though no published studies exist of this phenomenon, direct observation of the impact of the Indian Bend Wash project on nearby property values in Scottsdale may provide some insight. Before the project, the wash was an unstable, sandy floored channel that threatened nearby property by inundation and erosion. Historical aerial photography shows that in 1961 the wash was a sandy ribbon with trees and shrubs, and little in the way of urbanization in its vicinity. By 1973 the Indian Bend Wash Project had begun, and the undesirability of the wash as a location was obvious, because most areas around it had been converted to residential housing or commercial uses. A quarter-mile wide strip on either side of the wash was not used, however. By 1980, numerous investments in residential and commercial uses had been made to take advantage of the aesthetically pleasing environment offered by the wash and the project.

It might be argued that the high value investment near Indian Bend Wash would have occurred without the project because of intensive economic pressure in the growing metropolitan area, but this is not the case as demonstrated by the fate of the land along the Salt River where the wash joins the main stream (south of Curry Road, west of the wash, east of Rural Road). The Salt River had not been restored or modified until the Tempe Rio Salado Project began making an impact in the late 1980s. Property values have traditionally been low in the area despite development pressure, and land uses typically have been small industrial concerns, storage yards, materials processing plants, and other low value, low risk uses. This comparative experience indicates that property values near restored or engineered river landscapes are likely to increase, with associated property tax revenue increases for the jurisdictions involved.

In addition to those living or working near the river, there is another group of users who would experience direct benefits from a with-project condition, but who do not live adjacent to the channel. These users are often recreationists. Depending on the type of environmental restoration, such users might be hikers, walkers, bicyclists, bird watchers, swimmers, or anglers. In many cases, especially for those afoot, they do not require intensive hard engineering projects. The potential user-days for environmental restoration of portions of the Lower Salt River might be estimated by comparison with use data for similar environments: Indian Bend Wash, South Mountain Park, and Papago Park for the urban area and Estrella Regional Park for those areas away from the city center. The attachment of a dollar value to the user-day is a standard economic exercise that can be substantiated with user surveys (see, for example, Harpman *et al.*, 1993).

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 Salt River.

Any environmental restoration effort along the Lower Salt River is likely to have associated wildlife benefits. The remains as a corridor for wildlife movement even in its present status, so that the development of riparian habitats would enhance an existing situation. The measurement of these benefits has many of the components outlined above for river channels. Wildlife is directly related to recreation because some users come to an area for the expressed purpose of viewing wildlife. Some non-users derive benefit from the preservation and propagation of wild species even if those users do not directly interact with the wildlife. Standard techniques used in water resource development projects could be applied to evaluation of environmental restoration benefits along the Lower Salt River. Anderson and Ohmart (1993) have proposed a specific model that might be applied to restored riparian areas--the model would lend some consistency to the evaluation of potential wildlife benefits and is objective rather than subjective.

Environmental restoration would also generate substantial benefits related to water quality. Almost all restoration efforts and efforts directed to constructed ecosystems require water with improved quality. Treatment of pumped groundwater, effluent, or stormwater runoff for use in constructed environments would improve water quality for all subsequent uses. Evaluation of the improvement using standard economic models could improve reasonable assessment of the outcomes of environmental restoration, and indirect, non-use values a would be high because of the premium placed on water quality in present American society.

5 INFORMATION SOURCES

5.1 Hydrology

Despite the importance of the water of the Salt River and its tributaries to various agencies and groups in the Lower Salt River Valley, data for surface hydrology is scarce, scattered among different sources, inconsistent, and sometimes of poor quality. The U. S. Geological Survey published daily discharge data (unless otherwise indicated) for the specified water years for these locations (in downstream order):

*Verde River below Bartlett Dam (09510000) 1904-1992
*Salt River at McDowell (09502500) 1904-1910
Diversions from Salt River at Granite Reef Dam, AZ (09512000) 1913-1992 (monthly)
Salt River at Alma School Road Near Mesa, AZ (09512060) 1991-1992
*Indian Bend Wash at Scottsdale (09512100) 1961-1984
Salt River at Jointhead Dam at Phoenix, AZ (09512170) 1979-1980
Salt River at 24th Street, at Phoenix, AZ (09512190) 1983, 1985-1986, 1989-1992
Salt River Tributary in South Mountain Park, at Phoenix, AZ (09512200) 1961-1992
Gila River at U. S. Highway 85, Near Buckeye, AZ (09514300) 1979-1980, 1989-1992

This study discusses the marked records (*) in section 2.3.1 Surface Hydrology (Indian Bend Wash is discussed in section 2.5.2) and appendix 8.X contains these data. Additionally, a handful of U. S. Geological Survey Water-Supply Papers, listed in Appendix 8.12, provide summaries and analyses of some of the existing data.

Salt River Project provides estimates of releases from Granite Reef Dam based on gage heights and data on releases from upstream dams. This record includes peak mean daily flow during each release, dates of releases, total number of releases, and total number of days of the releases for significant water releases from 1911 to present. Also, it contains a list of annual peak discharges and annual total volume of water released for the years 1891 to present. Section 2.3.1 discusses and appendix 8.x contains these data.

Information on groundwater is available from a variety of sources. This report draws from various reports by the U. S. Geological Survey, U. S. Bureau of Reclamation, Arizona Department of Water Resources, Arizona Department of Environmental Quality, Arizona State Land Department, and others. These sources are listed in appendix 8.X and are available from the individual agencies or from the Government Documents Collection, Hayden Library, Arizona State University. Data on depth to groundwater in wells in the study area are available in U. S. Geological Survey Water Resource Data Reports for Arizona and from the Arizona Department of Water Resources.

Water quality information can be obtained from many of the same sources as listed for groundwater information. This report draws largely from reports by the Arizona Department of Environmental Quality, which provide information on locations where water quality parameters are violated. Both the U. S. Geological Survey and Salt River Project provide annual listing of water quality for wells in the study area. However, these data are of limited use because most

wells are only tested for general water chemistry (*e.g.*, salinity, pH, ions) and not for the contaminants (*e.g.*, VOCs, pesticides) that are of the greatest concern in the study area. Additionally, the Arizona Department of Water Resources has general water chemistry data for wells in the study area, but again they do not test for contaminants. The Arizona Department of Environmental Quality Annual Water Quality Reports appear to be the most efficient sources for water quality data for groundwater, surface water, and effluent. These sources are listed in Appendix 8.12 and are available from the individual agencies or from the Government Documents Collection, Hayden Library, Arizona State University.

5.2 Geology

The primary source of riparian ecology information is the Center for Environmental 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.

5.3 Riparian Ecology

The primary source of riparian ecology information is the Center for Environmental 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.

5.4 Historical Accounts

Historical accounts of the Lower Salt River prior to extensive development, summarized in section 2.2.1, were taken from a few published diaries and letters and original surveyor's notes from the first Cadastral surveys of the area. The published personal accounts are available from Hayden Library at Arizona State University in Tempe, Arizona. The survey notes, as well as the maps, are available from the Bureau of Land Management Public Information Room in Phoenix, Arizona.

Post-development historical accounts, summarized in sections 2.2.2 and 2.2.3, were obtained largely from pamphlets produced by the City of Phoenix, Maricopa County, or local businesses which describe the attractions of the Salt River Valley. The tone of these informational fliers clearly indicates bias as the authors' attempted to cast life in the Valley in the best light in order to entice settlers, businesses, and of course, money. With this rose-colored filter in mind, these accounts provide a valuable commentary on the perception of the river during this period. The accounts discussed and provided represent only a few of the pamphlets available in the Arizona Collection / Luhrs Reading Room and Arizona Historical Foundation Collection in Hayden Library at Arizona State University, Tempe, Arizona.

Appendices 8.5 and 8.6 provide the historical accounts, their sources, and secondary sources which provide additional background information on the history of Anglo-American settlement in the Salt River Valley. While early historical accounts of the Salt River are few, the list of secondary sources represents only a sample of the writings on the history of irrigation, the Salt River Project, and cities in the Valley.

5.5 Historical Ground Photographs

Historical ground photography is a relatively untapped source of valuable information about past conditions in and near the channel. Photographs show geomorphic, sedimentologic, and botanical conditions with surprising clarity, and with some field experience it is often possible to easily identify the location of individual photographs. In some cases, determine of the exact location is more difficult, requiring triangulation of various landmarks in the photograph matched with similar measurements in the field. Comparative photographs made by revisiting and rephotographing sites is becoming an increasingly common method of documenting environmental change, and because of the rich supply of historical photography along the Lower Salt River, it should be exploited for study of this system.

In addition to the readily accessible sources for historical photography in the local area (listed in Appendix 8.4.1), several possible sources remain to be explored. The Huntington Library at Stanford University, U.S. Geological Survey Photography and Field Records Library in Denver, Bureau of Reclamation Files, Corps of Engineers Files both locally and at offices of upper levels in Los Angeles and San Francisco, Western History Collection of the Denver Public Library, and the Library of Congress are likely targets for a more extended search.

5.6 Aerial Photography

A partial listing of aerial photography sources can be found in Table 23. The most efficient approach to evaluation of study area by aerial photographs is the Noble Science Library Map Room on the campus Arizona State University. The Landis aerial photographs and the Landiscor aerial photos provide partial (1969-1978) and full (1979-1994) coverage of the study area. Additionally, there is the Rupp aerial photography, which has better scale to work with than the Landis photos. The Map Room only has 1986-1990 Rupp photography. Other local collections of aerial photographs is the Maricopa County Flood Control District and the Army Corps of Engineers, both with extensive collections.

The local photos can be further supplemented by EROS Data Center of the U.S. Geological Survey in Sioux Falls, South Dakota and by the Fairchild Collection at Department of Geology, Whittier College in Whittier, California. The EROS Data Center operates through mail queries and maintains a collection of all the photography taken by the Survey. It also contains older photos taken by the U.S. Air Force, U.S. Army, and newer photos taken from orbital altitudes. The oldest readily available aerial photography of the study area is probably that held by the National Archives in Washington, D.C. The photos were taken in 1937. Appendix 8.7 shows portions of the index sheets made with this photography.

Table 23. Sources of Aerial Photography for the Lower Salt River.

Location	Title	Years	Scale	Coverage
Noble Science Library (ASU)	Landis Aerial Photo's and Landiscor Aerial Photos	1969-1994	1":2000'	There is partial coverage from 1969-1978. Full coverage from 1979-1994.
Noble Science Library (ASU)	Arizona 7.5 minute Series Orthophotoquad	1971	1:24,000	Full coverage
Noble Science Library (ASU)	Rupp aerial photographs	1986-1990	1":400' & 1":600'	Full coverage
Noble Science Library (ASU)	Fairchild Aeromaps	1972	1":2000'	Full coverage
Natinal Archives, Washington D.C.	U.S. Dept. of Ag., Soil Conservation Service	1937		Full coverage
USGS Survey Offices, Phoenix	Army Corps of Engineers photographs	1951		Full coverage
EROS, Sioux Falls, S.D.	USGS photographs	1961		Full coverage
EROS, Sioux Falls, S.D.	USGS photographs	1965		Full coverage
EROS, Sioux Falls, S.D.	USGS photographs	1971		Full coverage
EROS, Sioux Falls, S.D.	USGS photographs	1973		Full coverage
Az. Dept. Of Transportation	Maricopa County photographs	1978		Full coverage
Maricopa County Flood Control District	Maricopa County photographs	1979		Full coverage
Maricopa County Flood Control District	Maricopa County photographs	1980		Full coverage
Maricopa County Flood Control District	Maricopa County photographs	1980		Full coverage

6 CONCLUSIONS

6.1 A Landscape Approach to Decision-Making

A review of the data and ideas expressed in this report from a geomorphological perspective suggests that decision-makers trying to plan, finance, build, maintain, and administer the Lower Salt River must have some clear understanding of the dynamics of the system. It is not characterized by stability, an attribute prized by administrators, but rather by a propensity for change. Understanding this geomorphological change, and working with it rather than against it is the key to success in the long run. The river landscape is not simply an assemblage of sediment, water, vegetation, and structures. It is in fact three landscapes superimposed on one another. First is a landscape of resistance, formed mostly by the materials, landform shapes, vegetation, and structures. This resistance can be measured or estimated (by Manning's roughness coefficient, for example), and it has a particular geographic distribution. The landscape of resistance is greater in riparian woodlands than on bare channel surfaces, for instance, and the resistance varies considerably along the channel. It is greatest in the Salt and Gila confluence area because of low gradients and more dense vegetation; it is least in the designed channel in Tempe. This landscape of resistance can be used by decision-makers to predict unstable channel locations as well as sediment transport and deposition locations. Decisions about management of the river can be made with the expressed idea of manipulating this resistance landscape to achieve desired ends.

Second is the landscape of energy, or in its proper terms from applied physics, power. Flowing water converts its potential and kinetic energy into power which it exerts on the wetted perimeter, the channel walls and floors. Stream power is sensitive to depth of flow and to even modest changes in gradient. Channel works drastically alter stream power, as in the Tempe and airport reach where the new design channel has a steeper gradient than the natural channel that once existed there, bringing about an increase in stream power (and thus, erosive capability). Managers can choose to make efforts to mitigate this effect, by causing flows to spread laterally and thus become less deep, bringing about an associated reduction in power. Stream power also varies geographically throughout the study area, and understanding that distribution can make the entire system easier to understand and control.

Third is the landscape of geomorphological work, the movement of mass from one place to another. In a river system, this work is in the form of sediment transport, and it is readily predictable by comparing the landscape of resistance to the landscape of power. As with the other measures, the landscape of geomorphic work has considerable variation from place to place. Where the power exceeds resistance, much work is accomplished, sometimes including the unhappy circumstance of destruction of valuable structures or ecosystems. Where the power is less than the resistance, stability occurs and no work is performed. Managers of the river desiring to promote stability must work with both the power and resistance to achieve the desired end. Any planned project for the river should be accompanied by some analysis of the implications of the project on the distributions of resistance, power, and work.

6.2 A General System View

Any reader with the perseverance to read this entire document must, by these final pages, realize that the Lower Salt River is a complex general system. Each segment of the channel is connected upstream and downstream to the rest of the system, and laterally to environments on the banks and terraces. Any projects that are contemplated for the river are likely to focus on very limited segments of the channel, but the effects of the projects will extend throughout the system. The major ingredient missing from much of the previous planning and construction along the Lower Salt River has been this general system perspective. If Tempe constructs a Rio Salado Project, it will affect upstream areas by increasing gradient and perhaps stimulating erosion. If Phoenix streamlines the channel, water and sediment will cascade downstream to affect the Salt and Gila confluence area. The construction of wetlands for effluent treatment near 91st Avenue will impact areas downstream when contaminated sediments are mobilized. The restoration of riparian environments anywhere in the system with be likely to draw water from one place and use it in another. Any structural actions will certainly have social consequences. The river has been managed one segment at a time, with decisions taken on limited parts of the channel by separate agencies. The Corps of Engineers, because of its regulatory responsibilities and its combined flood control and restoration mission, is uniquely positioned to insure that future management of the river takes into account the true complexity of the system. The river is becoming so divided into segments, that the chance to deal with it as a functional whole is slipping away. By working in interagency, cooperative groups, decision-makers have a last opportunity at the end of the twentieth century to deal with the river as a whole, integrated entity.

7 REFERENCES

Abrahams, A. D., A. J. Parsons, R. U. Cooke, and R. W. Reeves. 1984. Stone movement on hillslopes in the Mojave Desert, California: A 16 year record. *Earth Surface Processes and Landforms* 9: 365-370.

Aldridge, B. N. 1970. *Floods of November 1965 to January 1966 in the Gila River Basin, Arizona and New Mexico, and Adjacent Basins in Arizona.* U. S. Geological Survey Water-Supply Paper 1850-C. Washington, D. C.: U. S. Government Printing Office.

Aldridge, B. N., and Eychaner, J. H. 1984. *Floods of October 1977 in Southern Arizona and March 1978 in Central Arizona.* U. S. Geological Survey Water-Supply Paper 2223. Washington, D. C.: U. S. Government Printing Office.

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.

Anderson, B. W., and Ohmart, R. D. 1993. *The Development of an Arizona Riparian Habitat Evaluation Model with Wildlife Values.* Phoenix: Arizona Game and Fish Department, Contract Report G30025-B.

Arizona Department of Mines and Mineral Resources. 1993. Commodity Listing for Maricopa County. Phoenix: Arizona Department of Mines and Mineral Resources.

Arizona State Department of Health Services. 1977. Water Quality Management Basin Plan, Salt River Basin, Arizona, Final Report. Phoenix: Arizona State Department of Health Services.

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: Arizona Department of Environmental Quality, Office of Water Quality, Water Assessment Section and Groundwater Hydrology Section.

Arizona Department of Environmental Quality. 1989. State of Arizona 1988 Annual Report Arizona Groundwater Quality Sampling Results. Vol. 1. Phoenix: Arizona Department of Environmental Quality.

Arizona Department of Environmental Quality. 1993. Arizona Department of Environmental Quality Arizona Water Quality Assessment 1992. Phoenix: Arizona Department of Environmental Quality.

Arizona Department of Environmental Quality. 1988. State of Arizona 1987 Annual Report Arizona Groundwater Quality Sampling Results and Enforcement Actions. Phoenix: 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.

Baker, L. A., T. Qureshi, and L. Farnsworth. 1994. Sources and fate of arsenic in the Verde and Salt Rivers, Arizona. In press

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.

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.

Briggs, P. C., and Werho, L. L. 1966. *Infiltration and Recharge from the Flow of April 1965 in the Salt River Near Phoenix, Arizona.* Arizona State Land Department Water-Resources Report Number 29. Phoenix: Arizona State Land Department.

Brown, James G., and Pool, D. R. 1989. *Hydrogeology of the Western Part of the Salt River Valley Area, Maricopa County, Arizona.* U. S. Geological Survey Water-Resources Investigations Report 88-4202. Tucson: U. S. Geological Survey.

Brown D.E. 1985. *Arizona Wetlands and Waterfowl.* Tucson.: University of Arizona Press.

Brown, D.E. 1982. Biotic communites of the American Southwest - U.S. and Mexico, *Desert Plants*, 4:1-342.

Bureau of Reclamation, Lower Colorado Region, United States Department of the Interior. 1976. *Central Arizona Project: Geology and Ground-Water Resources Report Maricopa and Pinal Counties, Arizona.* 2 vols. Washington, D. C.: Government Printing Office.

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.

Carreiro, Ken. 1975. Reclamation of Sand and Gravel Pits. *California Geology,* December, 267-273.

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.

Chang, Howard H. 1988. *Fluvial Processes in River Engineering.* New York: John Wiley & Sons.

Chin, A. 1988. Buckeye Crossing. In *The Salt and Gila Rivers in Central Arizona: A Geographic Field Trip Guide*, ed. by W. L. Graf. Tempe: Arizona State University, Department

of Geography, p. 145-160.

City of Phoenix. 1986. *Sky Harbor International Airport*. Phoenix: City of Phoenix.

City of Phoenix. 1994. *Arizona's Workforce*. Phoenix: Arizona Deptartment of Economic Security.

City of Tempe. 1990. Environmental Assessment for that Portion of the Tempe Rio Salado Project from the Southern Pacific Railroad Bridge to McClintock Drive In. Tempe: Community Development Department.

City of Tempe, 1993. Comments on the Draft Environmental Impact Statement for the Proposed Expansion of Phoenix Sky Harbor Airport. 2 vols. Tempe: City of Tempe.

City of Tempe. 1994. Rio Salado Development Plan. Tempe: City of Tempe Community Development Department.

Clark, Vernon Leonidas. 1936. *History of the Salt River Valley Water Users' Association.* Phoenix: Salt River Project Archives.

Clark, Sandra. 1991. Field Examination, Sand Deposits in a Gravel Bed River: the Salt River, Central Arizona. Unpublished manuscript. Tempe: Department of Geography.

College of Business. 1989. *Economic Impact of the Phoenix Airport System Update:1988. Tempe, Arizona*: Economic Outlook Center Arizona State University.

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.

Corkhill, Edwin F., Corell, Steve, Hill, Bradley M., and Carr, David A. 1993. *A Regional Groundwater Flow Model of the Salt River Valley -- Phase I: Phoenix Active Management Area Hydrogeologic Framework and Basic Data Report*. Arizona Department of Water Resources, Hydrology Division Modeling Report No. 6. Phoenix: Arizona Department of Water Resources.

CRS Sirrine, I. 1989. Rio Salado Channel Improvements. Phoenix:

Daniel, D. L. 1981. Maps Showing Total Dissolved Solids Content of Groundwater in Arizona. State of Arizona Department of Water Resources Hydrologic Map Series Report Number 2. Phoenix: State of Arizona Department of Water Resources.

Draft. 1994. Chemical Quality Report, Arizona Department of Environmental Quality, Clean Lakes Program. Untitled.

Drosendahl, J. K. 1989. Environmental Geology of the Rio Salado Development District-Eastern Part, Maricopa County, Arizona. Ph.D. diss., Arizona State University.

Dykes, Leonard R. Leonard Dykes Papers, MS CM MSM-249. Department of Archives and Manuscripts, Hayden Library, Arizona State University, Tempe.

Earth Technology Corporation. 1994. Lower Middle Gila River Study and Painted Rocks Lake Phase 1 Diagnostic/Feasibility Study Maricopa County, Arizona. Tempe:

Earth Technology Corportaion (Western). 1990. *Water Quality Assurance Revolving Fund Phase I Report East Central Phoenix Area Task Assignment E-2 Phoenix, Arizona*. Phoenix: Arizona Department of Environmental Quality.

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.

Environmental Planning Services, Highways Division, Arizona Department of Transportation. [1990?]. *Pima Freeway (Loop 101) Environmental Assessment, Salt River Pima-Maricopa Indian Community, Maricopa County, Arizona*. Phoenix: Arizona Department of Transportation.

Evans, Kenneth E, 1988. Interstate-10 Bridge Crossing. In *The Salt and Gila Rivers in Central Arizona: A Geographic Field Guide*, ed. by W. L. Graf. Department of Geography Publication 3. Tempe: Arizona State University, pp. 121-30.

Feldman, D. L. 1991. *Water Resources Management: In Search of An Environmental Ethic*. Baltimore: Johns Hopkins University Press.

Fenneman, N. M. 1916. Physiographic divisions of the United States. *Association of American Geographers Annals* 6: 19-98.

Flood Protection Improvement Committee. 1958. Report of Flood Protection Improvement Committee. Phoenix: City of Phoenix.

Flood Control District of Maricopa County. 1994. *Salt-Gila River Land Use and Structures Inventory, Granite Reef Dam to Gillespie Dam*. Phoenix: Flood Control District of Maricopa County.

Flood Control District of Maricopa County. 1993. *Flood Control District of Maricopa County, 1993 Annual Report*. Phoenix: Flood Control District of Maricopa County.

Forstner, U., and G. T. W. Wittmann. 1979. *Metal Pollution in Aquatic Environments*. New York: Springer-Verlag.

Forstner, U. 1980. Trace element analysis of polluted sediments, part 1, assessment of sources and intensities. *Envrionmental Technical Letters* 1: 494-505.

Gordon, N. D., McMahon, T. A., and Finlayson, B. L. 1992. *Stream Hydrology: An Introduction for Ecologists*. New York: John Wiley & Sons.

Graf, W. L., Beyer, P. J., Rice, J. L., and Wasklewicz, T. A. 1994. *Geomorphic Assessment of the Lower Gila River, West Central Arizona*. U.S. Army Corps of Engineers, Arizona Area Office, Contract Report DACW09-94-M-0494.

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. 1980. Riparian Management: a flood control perspective. *Journal of Soil and Water Conservation* 35:158-161.

Graf, W. L. 1981. Channel instability in a braided sand-bed river. *Water Resources Research* 17:1087-1094.

Graf, W. L. 1983. Flood-related channel change in an arid-region river. *Earth Surface Processes and Landforms* 8:125-139.

Graf, W. L. 1982. Tamarisk and river channel management. *Environmental Management* 6:283-296.

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.

Gregory, K. J., and Park, C. C. 1974. Adjustment of river channel capacity downstream from a reservoir. *Water Resources Research* 10:870-873.

Halpenny, L. C., and Greene, D. K. 1975. *Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona*. Tucson: Water Development Corporation.

Harpman, D. A., Sparling, E. W., and Waddle, T. J. 1993. A Methodology for Quantifying and Valuing the Impacts of Flow Changes on a Fishery. *Water Resources Research* 29:575-582.

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.

Hendricks, D. 1985. *Arizona Soils*. Tucson: University of Arizona, College of Agriculture.

Hesperger, A. M. 1994. The Use of Landscape Ecology to Create Planning Options for River

Corridor Management. Unpublished Master of Environmental Planning Thesis, Arizona State University.

Jones, Thomas W. 1952. Lehi During the Term of Bishop Thomas Evan Jones. In W. Earl Merrill, J. Emerson Miller, and Stella R. Miller, eds., *75th Anniversary Diamond Jubilee History of Lehi 1877-1952*. Mesa: Lehi Ward Church of Jesus Christ of Latter-Day Saints.

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.

Keith, S. B. 1969. Sand and Gravel. *Arizona Bureau of Mines Bulletin* 180: 424-441.

Keller, Edward A. 1976. Channelization: Environmental, Geomorphic, and Engineering Aspects. In *Geomorphology and Engineering*, edited by D. R. Coates. Stroudsburg, PA: Dowden, Hutchinson & Ross, Inc.

Kokalis, P. G. 1971. Terraces of the Lower Salt River Valley, Arizona. Unpublished Department of Geology MA Thesis, Arizona State University.

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.

Lee, Steven E. 1988. Indian Bend Wash. In *The Salt and Gila Rivers in Central Arizona: A Geographic Field Guide*, ed. by W. L. Graf. Department of Geography Publication 3. Tempe: Arizona State University, pp. 93-104.

Lee, Willis Thomas. 1905. *Underground Waters of Salt River Valley, Arizona*. U. S. Geological Survey Water-Supply and Irrigation Paper No. 126. Washington, D. C.: Government Printing Office.

Levinson, A. A. 1980. *Introduction to Exploration Geochemistry*. Wimette: Applied Publication.

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.

Lowe, C.H., (ed.). 1964. *The Vertebrates of Arizona*. Tucson: University of Arizona Press.

MacKaye, Milton. 1947. Phoenix. *The Saturday Evening Post*, 18 October, 37, 88-90, 93-95.

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 Management. Warner, R.E. and K.M. Hendrix, eds. Berkeley: University of California Press. Pp. 168-176.

Maricopa Association of Governments. 1980. *208 Water Quality Management Program.*

Maricopa Association of Governments Regional Solid Waste Needs Assessment August, 1980. Phoenix: Maricopa Association of Governments.

McClintock, Jas H. 1908. *Phoenix, Arizona, in the Great Salt River Valley.* Phoenix: City of Phoenix and Maricopa County Board of Trade.

McDonald, H. R., Wolcott, H. N., and Hem, J. D. 1947. *Geology and Ground-Water Resources of the Salt River Valley Area, Maricopa and Pinal Counties, Arizona.* Tucson: U. S. Geological Survey.

Meyer, Hendricks, Victor, Osborn, and Maledon. 1993. *Market Facts: All About Business In Phoenix. Phoenix*: Business Journal Special Supplement.

Miller, T. A. 1988. Granite Reef Dam. In *The Salt and Gila Rivers in Central Arizona: A Geographic Field Trip Guide*, ed. by W. L. Graf. Tempe: Arizona State University, Department of Geography, p. 67-76.

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. 1984. Formation and destruction of a Gila River mesquite bosque community. *Desert Plants* 6:23-30.

Minckley, W.L. and Clark, T.O. 1981, Vegetation of the Gila River resource area, eastern Arizona. *Desert Plants* 3:124-140.

Mogollon, J. L., and C. Bifano. 1994. Topography, weather and human activity effects on the behavior of metallic elements in a tropical catchment. *Chemical Geology* 114: 69-82.

Nagel, Pamela M. 1988. Hayden's Ferry Crossing. In *The Salt and Gila Rivers in Central Arizona: A Geographic Field Guide*, ed. by W. L. Graf. Department of Geography Publication 3. Tempe: Arizona State University, pp. 105-12.

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.

Oberlander, T. M. 1974. Landscape inheritence in the pediment problem in the Mojave Desert of Southern California. *American Journal of Science* 274: 849-875.

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.

Ohmart, R.D., and Anderson, B. W. 1974. Vegetation management: Annual report. U.S. Dep. Inter., Bureau of Reclamation. Boulder city, Nevada.

Parsons, A. J., and A. D. Abrahams. 1987. Gradient-particle size relations on quartz monzonite debris slopes in the Mojave Desert. *Journal of Geology* 95: 423-452.

Petts, G. E. 1984. *Impounded Rivers: Perspectives for Ecological Management.* Chichester: John Wiley & Sons.

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.

Pewe, T. L., C. S. Wellendorf, and J. T. Bales. 1986. Environmental Geology of the Tempe Quadrangle, Maricopa County, Arizona. Geologic Investigation Series Folio of the Tempe Quadrangle, Arizona Maps GI-2-A-B-C.

P w, T. L. 1976. Terraces of the Lower Agua Fria River Valley, Maricopa County, Arizona (abstract). *Journal of the Arizona Academy of Science*, Proceedings Supplement 11:93.

P w, T. L. 1978. Terraces of the Lower Salt River Valley in Relation to the Late Cenozoic History of the Phoenix Basin, Arizona. In *Guidebook to the Geology of Central Arizona*, Burt, D. M., and P w, T. L., eds. Tucson: Arizona Bureau of Geology and Mineral Technology, Special Paper No. 2, 1-46.

Phillips, K. A., Niemuth, N. J., and Bain, D. R. 1993. *Active Mines in Arizona--1994.* Department of Mines and Mineral Resources Directory 42. Phoenix: Arizona Department of Mines and Mineral Resources.

Pierce, William H. 1867. Surveyor's notes for Cadastral Surveys of the Salt River Valley. General Land Office, U. S.

Pope, C. W., and P w, T. L. 1973. Geology of the Lower Verde River Valley, Maricopa County, Arizona (abstract). *Journal of the Arizona Academy of Science,* Proceedings Supplement 8:42.

Rahtha, D. S., and B. K. Sahu. 1993. Soure and distribution of metals in urban soil of Bombay, India, using multivariate statistical techniques. *Environmental Geology* 22: 276-285.

Reynolds, S. J. 1985. *Geology of the South Mountains, Central Arizona.* Tucson: Arizona Bureau of Geology and Mineral Technology, Geological Survey Branch.

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.

Ruff, P. 1972. Unpublished Surveys of the Salt River, Tempe, Arizona. Stored in the Hayden

Library of Arizona State University, Tempe.

Rundquist, L. A. 1980. Effects of Gravel Removal on River Hydrology and Hydraulics. In *Gravel Removal Studies in Arctic and Subarctic Floodplains in Alaska*, prepared by Woodward-Clyde Consultants. Fish and Wildlife Service/Office of Bioloigcal Services-80/08. Washington, D.C.: Government Printing Office.

Salomons, W., and U. Forstner. 1984. *Metals in the Hydrocycle*. New York: Springer-Verlag.

Salt River Project. [1990?]. *Annual Water Quality Report 1989*. Phoenix: Salt River Project.

Salt River Project. 1983. *Salt River Project Canals.* (Phoenix: Salt River Project).

Sellers, W. D., Hill, R. H., and Sanderson-Rae, M. 1986. *Arizona Climate: The First Hundred Years.* Tucson: University of Arizona.

Simons, Li & Associates, Inc. 1989. *Effects on In-Stream Mining on Channel Stability*, Report Number FHWA-AZ89-250. 3 vols. Phoenix: Arizona Department of Transportation.

Simons, D. B., and Sentürk, F. 1992. *Sediment Transport Technology: Water and Sediment Dynamics.* Littleton, Colo.: Water Resources Publications.

Smith, Gusse Thomas. 1927. *Phoenix and the Interesting Salt River Valley*. Phoenix: Maricopa County Immigration Commissioner and Phoenix Chamber of Commerce.

Smith, C. L. 1973. *The Salt River Project: A Case Study in Cultural Adaptation to an Urbanizing Community.* Tucson: University of Arizona Press.

Smith, K. L. 1986. *The Magnificent Experiment: Building the Salt River Reclamation Project, 1890-1917.* Tucson: University of Arizona Press.

SRP Business and Development. 1993. *Economic Assets of Greater Phoenix. Tempe, Arizona:* Salt River Project.

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.

Stuckless, J. S., and C. W. Naesar. 1972. *Rb-Sr and fission track age determinations in the Precambrian plutonic basement around the Superstition volcanic field, Arizona.* U.S. Geological Survey Professional Paper 800-B: B192-B194.

Stuckless, J. S., and M. F. Sheridan. 1971. Tertiary volcanic stratigraphy in the Goldfield and Superstition mountains, Arizona. *Geological Society of America Bulletin* 82: 3235-3240.

Tellman, B. 1992. Arizona's effluent dominated riparian areas: Issues and opportunities. University of Arizona Water Resources Research Center Issue Paper 12: 1-45.

Thomsen, B. W., and Miller, B. H. 1991. *Ground-Water Conditions in and Near the Salt River Indian Reservation, South-Central Arizona.* U. S. Geological Survey Water-Resources Investigations Report 89-4176. Tucson: U. S. Geological Survey.

Thornbury, W. D. 1965. *Regional Geomorphology of the United States.* New York: John Wiley and Sons, Inc.

Twidale, C. R. 1976. *Analysis of Landforms.* Sydney: John Wiley and Sons.

U. S. Army Corps of Engineers. 1979a. *Flood Damage Report, Phoenix Metropolitan Area, December 1978 Flood.* Los Angeles: U. S. Army Corps of Engineers.

U. S. Army Corps of Engineers. 1981. *Flood Damage Survey, Phoenix, Arizona, February 1980.* Los Angeles: U. S. Army Corps of Engineers.

U. S. Army Corps of Engineers. 1979b. *Flood Damage Report, 28 February - 6 March 1978 on the Storm and Floods in Maricopa County, Arizona.* Los Angeles: U. S. Army Corps of Engineers.

U.S. Department of Agriculture. 1974. *Soil Survey, Eastern Maricopa and Northern Pinal Counties Area, Arizona.* Washington, D.C.: Government Printing Office.

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. Department of Agriculture. 1977. *Soil Survey, Maricopa County, Central Part.* Washinton, D.C.: Government Printing Office.

Walsh, R. G., Gillman, R. A., and Loomis, J. B. 1982. *Wilderness Resource Economics: Recreation Use and Preservation Values.* Denver: American Wilderness Alliance.

Warren, L. A., and A. P. Zimmerman. 1994. The importnace of surface area in metal sorption by oxides and organic matter in a heterogeneous natural sediment. *Applied Geochemistry* 9: 245-254.

Williams, G.P., and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers. U.S. Geological Survey Professional Paper 1286:1-64.

Wilson, E.D., R. T. Moore, and H. W. Peirce. 1957. Geologic Map of Maricopa County, Arizona. Tucson, Arizona: Arizona Bureau of Mines University of Arizona.

Wilson, Richard P. 1991. *Summary of Ground-Water Conditions in Arizona 1985-86*. U. S. Geological Survey Water-Resources Investigations Report 90-4179. Washington, D. C.: Government Printing Office.

Wolcott, H. N. 1952. Salt River Valley Area, Maricopa and Pinal Counties. In *Groundwater in the Gila River Basin and Adjacent Areas, Arizona -- a Summary*, ed. by L. C. Halpenny. U. S. Geological Survey Open-File Report. Tucson: U. S. Geological Survey, pp. 137-45.

Wolman, M. G., and Leopold, L. B. 1957. *River Flood Plains: Some Observations on Their Formation*. U.S. Geological Survey Professional Paper 282-C. Washington, D.C.: Government Printing Office, 87-107.

8 APPENDICES

8.1 General Locational Maps

The following pages contain maps for the purpose of general location purposes. The maps are portions of sheets published by the Arizona Department of Transportation for Maricopa County. The legend for symbols used on the maps are given below.

PRIMITIVE TO UNIMPROVED
GRADED AND DRAINED
GRAVEL
PAVED: LOW TYPE
PAVED: HIGH TYPE

FREEWAY

FAP 13 — FEDERAL-AID PRIMARY
481 — FEDERAL-AID SECONDARY
5310 — FEDERAL-AID URBAN

17 66 — HIGHWAY ROUTE MARKER
89 37

HIGHWAY INTERCHANGE

7.2 — MILEAGE BETWEEN POINTS
MP 320 — MILEPOST

RAILROAD AND STATION

GRADE SEPARATIONS

HIGHWAY TUNNEL

HIGHWAY BRIDGE

AIRSTRIP
COMMERCIAL AIRPORT
MUNICIPAL AIRPORT
MILITARY AIRFIELD
HELIPORT
INTERMITTENT STREAM
NARROW STREAM (LIVE)
WIDE STREAM WITH DOCK OR BOAT LANDING
LAKE, RESERVOIR OR POND WITH DAM
SPRING
TAILINGS POND

DIKE OR LEVEE

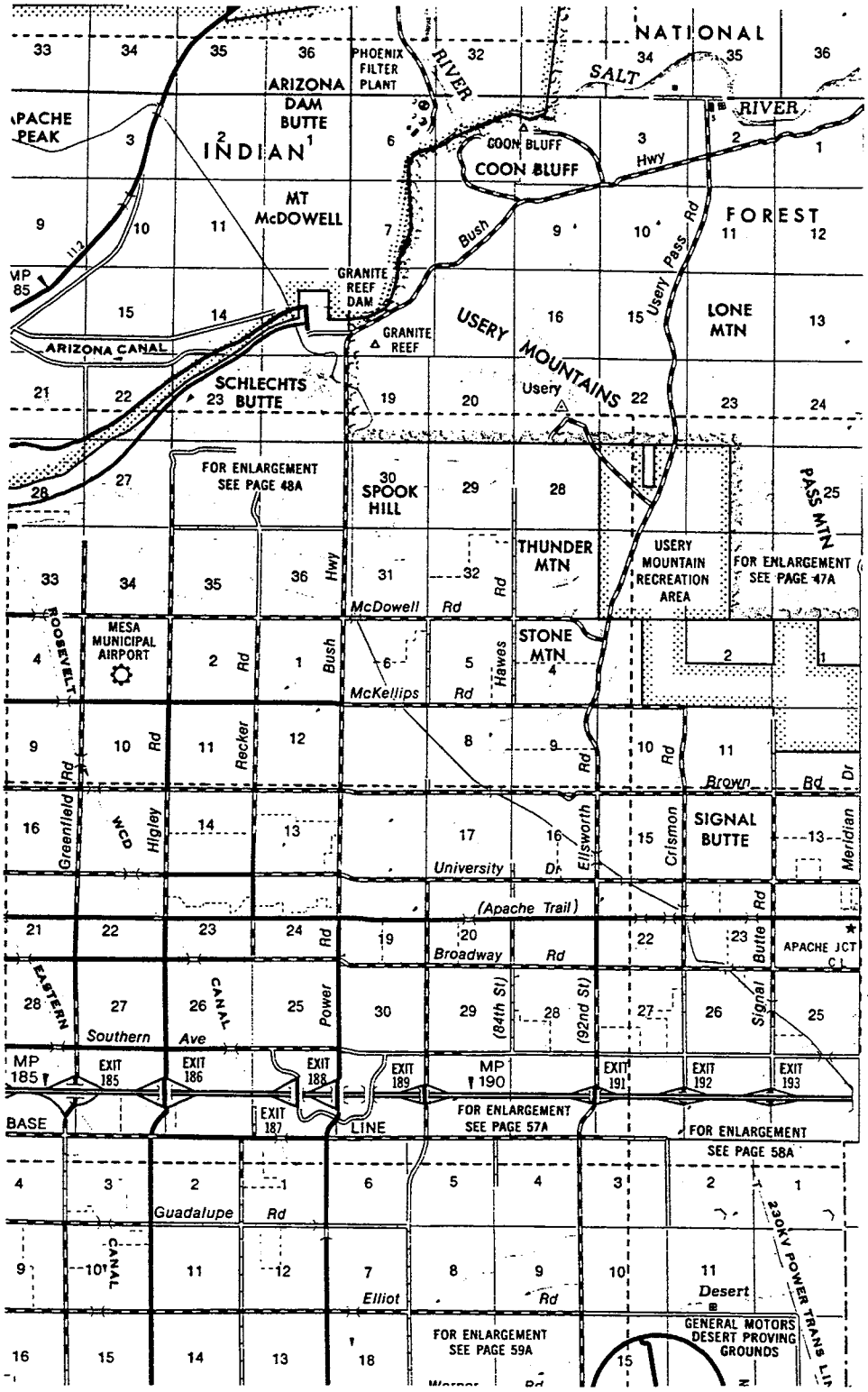
NATIONAL BOUNDARY
STATE BOUNDARY
COUNTY BOUNDARY
TOWNSHIP OR RANGE LINE
SECTION LINE
Sage — TRIANGULATION STATION (WITH NAME)
G — GAS LINE
T — TRANSMISSION LINE
UNDERGROUND COAXIAL CABLE
NATIONAL FOREST BOUNDARY
PARK OR RESERVATION BOUNDARY

RANCH OR FARM
11 — DWELLING OR DWELLINGS
TENANT HOUSES
17 — SEASONAL DWELLING OR DWELLINGS
TRAILER PARK
CEMETERY
HOSPITAL OR FIRST AID STATION
SCHOOL
CHURCH
PAROCHIAL SCHOOL
GOVERNMENT BUILDING
COURTHOUSE
LIBRARY
LAW ENFORCEMENT OFFICE
FIRE STATION
TOWN HALL OR COMMUNITY HALL
CORRECTIONAL INSTITUTION
POST OFFICE
BUSINESS OR TRADING POST
COMMUNICATION TOWER
WELL
WINDMILL
WATER RETARDING OR DIVERSION STRUCTURE
WATER TANK
FACTORY OR INDUSTRIAL PLANT
MINE OR PROSPECT
POWER PLANT
TRANSFORMER STATION
WAREHOUSE
STOCKYARD OR CORRAL
GRAVEL PIT
DUMP—GARBAGE, RUBBISH AND OTHER
JUNKYARD—AUTO, SCRAP METAL
SEWAGE DISPOSAL PLANT
S C — STATE OR COUNTY HIGHWAY MAINTENANCE YARD
PICNIC GROUND
CAMPSITE
BALL FIELD
ROADSIDE REST
SP — SMALL PARK
C — GOLF COURSE OR COUNTRY CLUB
A — AMUSEMENT PARK OR RODEO GROUNDS
OBSERVATION OR LOOKOUT TOWER
INDIAN RUIN
SMALL MONUMENT, RESERVATION, OR POINT OF INTEREST
COUNTY SEAT
OTHER CITIES AND POPULATED PLACES
INCORPORATED CITY
CONGESTED AREA, CULTURE NOT SHOWN

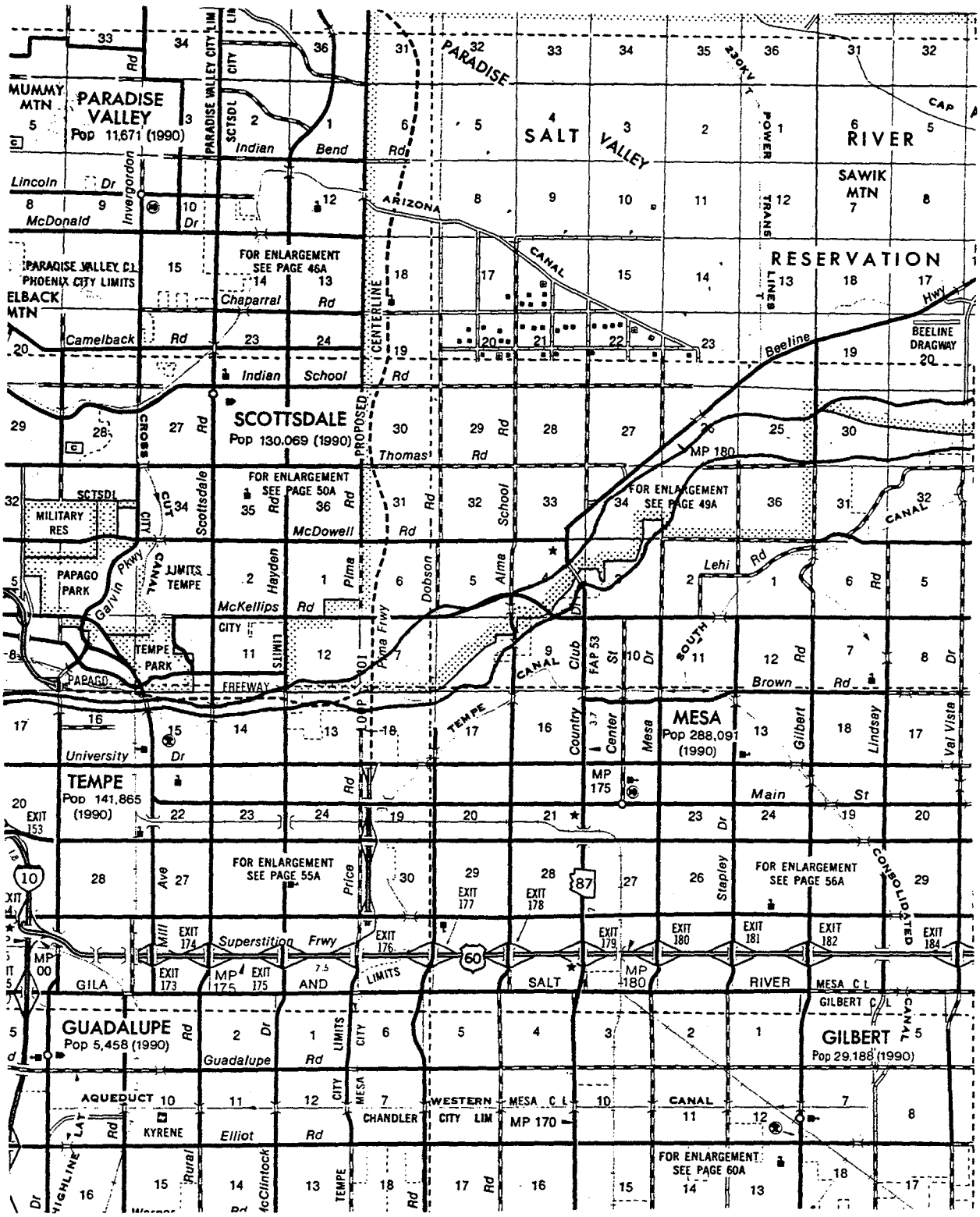
GENERAL HIGHWAY MAP
MARICOPA COUNTY, ARIZONA
ARIZONA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PHOTOGRAMMETRY AND MAPPING
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
1954

SCALE
1 0 1 2 3 4 5
STATUTE MILES

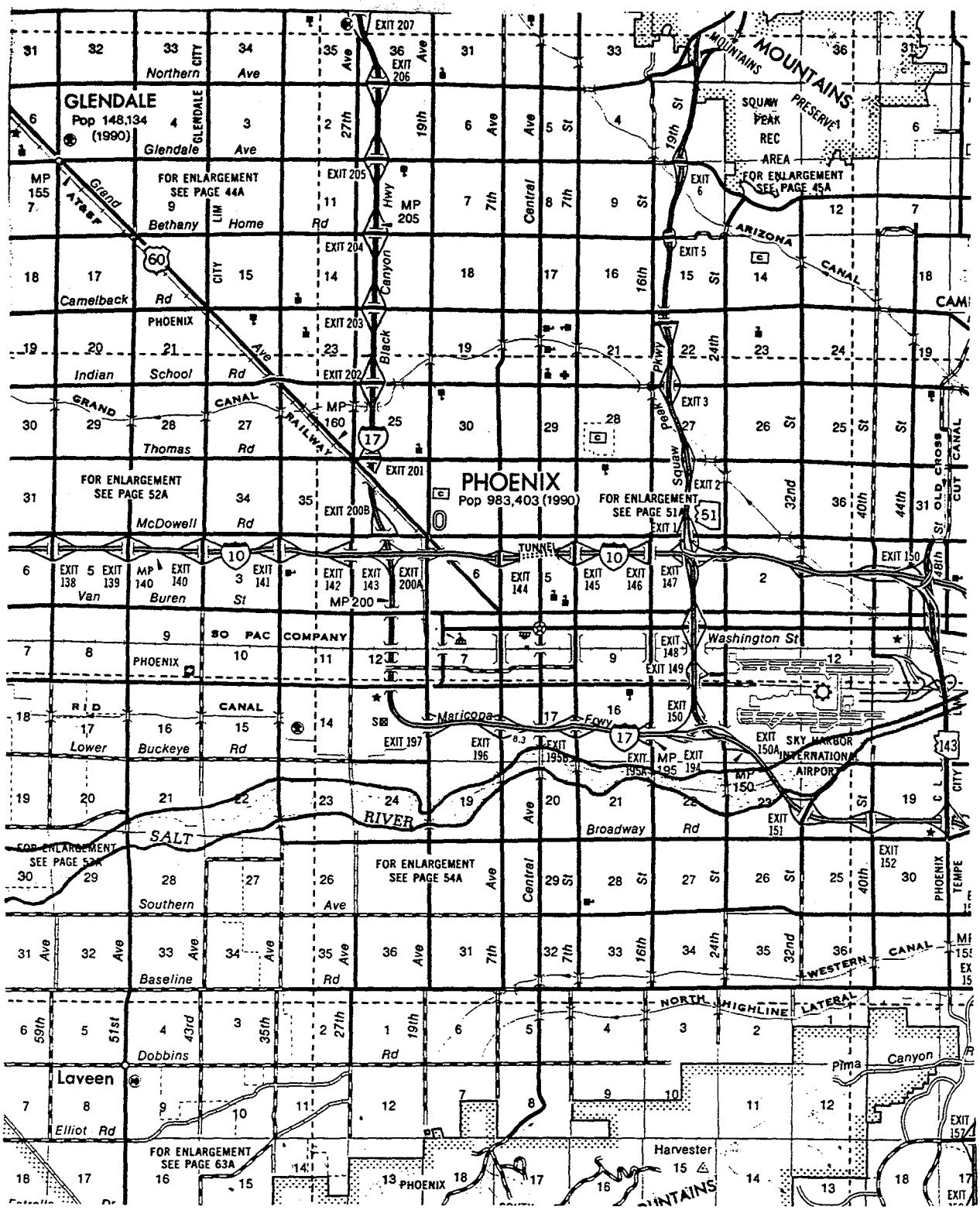
TRANSVERSE MERCATOR PROJECTION, ARIZONA CENTRAL ZONE
COMPILED BY PHOTOGRAMMETRIC METHODS
1927 NORTH AMERICAN DATUM
CONTROL BY U.S. COAST AND GEODETIC SURVEY, U.S. GEOLOGICAL SURVEY
U.S. FOREST SERVICE AND U.S. GENERAL LAND OFFICE
INVENTORY 1954



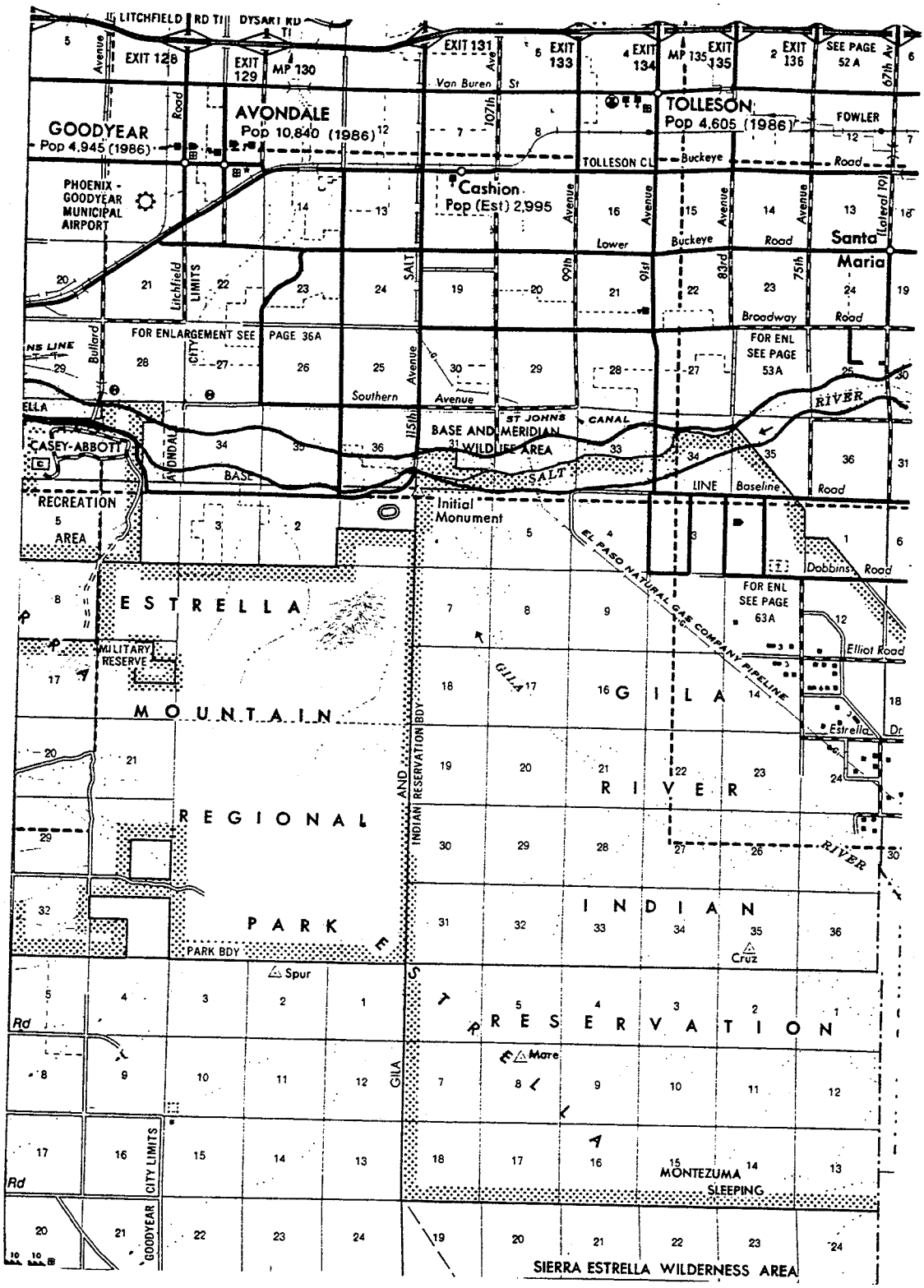
8.1.1 Northeast Mesa



8.1.2 North Mesa and Tempe


GLENDALE
Pop 148,134 (1990)
PHOENIX
Pop 983,403 (1990)
MOUNTAINS
SQUAW PEAK REC AREA
FOR ENLARGEMENT SEE PAGE 45A
FOR ENLARGEMENT SEE PAGE 44A
FOR ENLARGEMENT SEE PAGE 52A
FOR ENLARGEMENT SEE PAGE 51A
FOR ENLARGEMENT SEE PAGE 54A
FOR ENLARGEMENT SEE PAGE 63A
ARIZONA CANAL
GRAND CANAL
SALT RIVER
SKY HARBOR INTERNATIONAL AIRPORT
Washington St
Maricopa Fwy
Broadway Rd
Northern Ave
Glendale Ave
Bethany Home Rd
Camelback Rd
Indian School Rd
Thomas Rd
McDowell Rd
Van Buren St
Lower Buckeye Rd
Southern Ave
Baseline Rd
Dobbins Rd
Elliot Rd
Harvester
Pima Canyon
NORTH HIGHLINE LATERAL
WESTERN CANAL
TUNNEL
SO PAC COMPANY
Laveen

8.1.3 Phoenix



8.1.4 The Salt and Gila Confluence Area

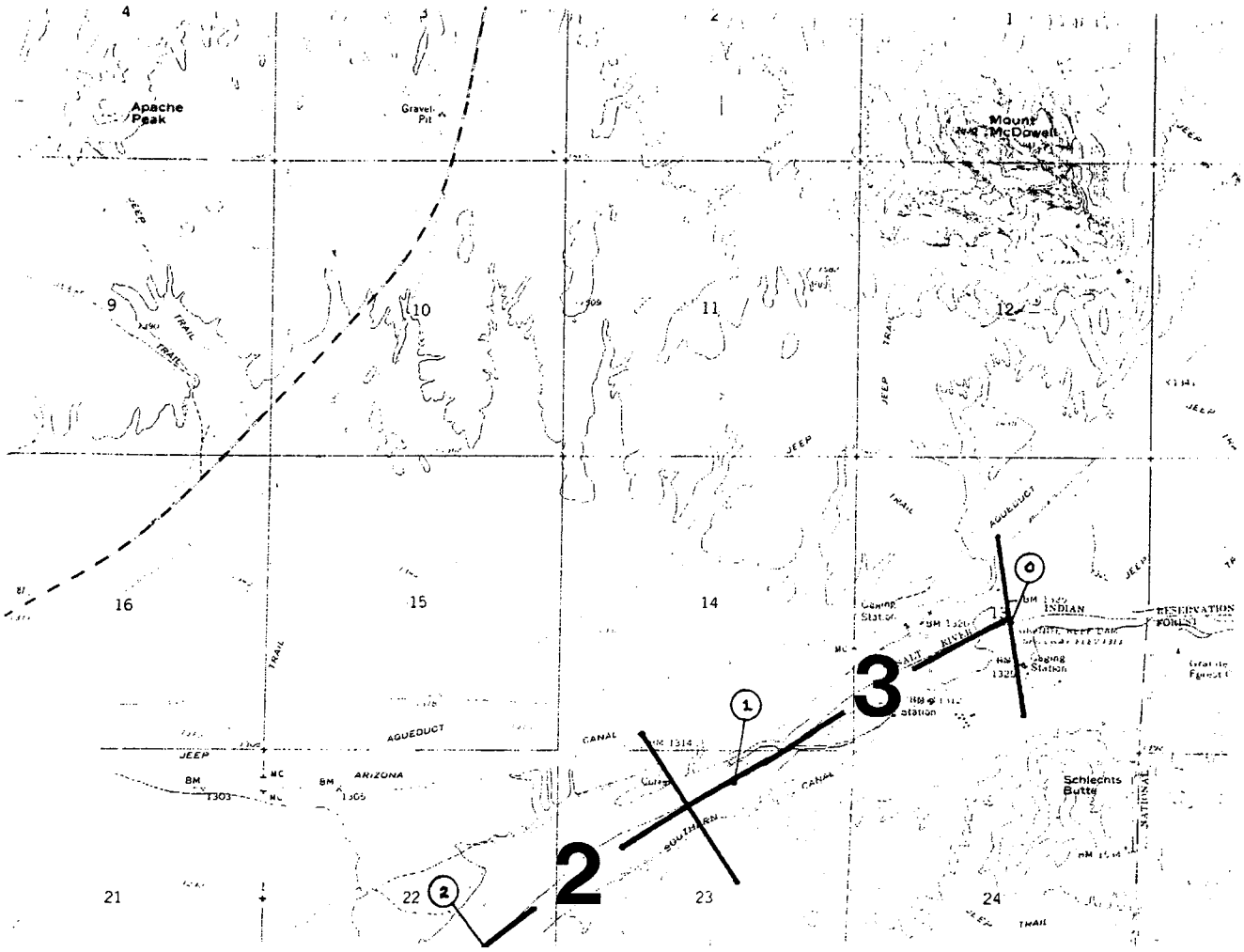
8.2 Naturalness Classification for the Lower Salt River

The following pages contain base maps with each section of the channel classified according to its naturalness. The classes are identified by numbers as follows:

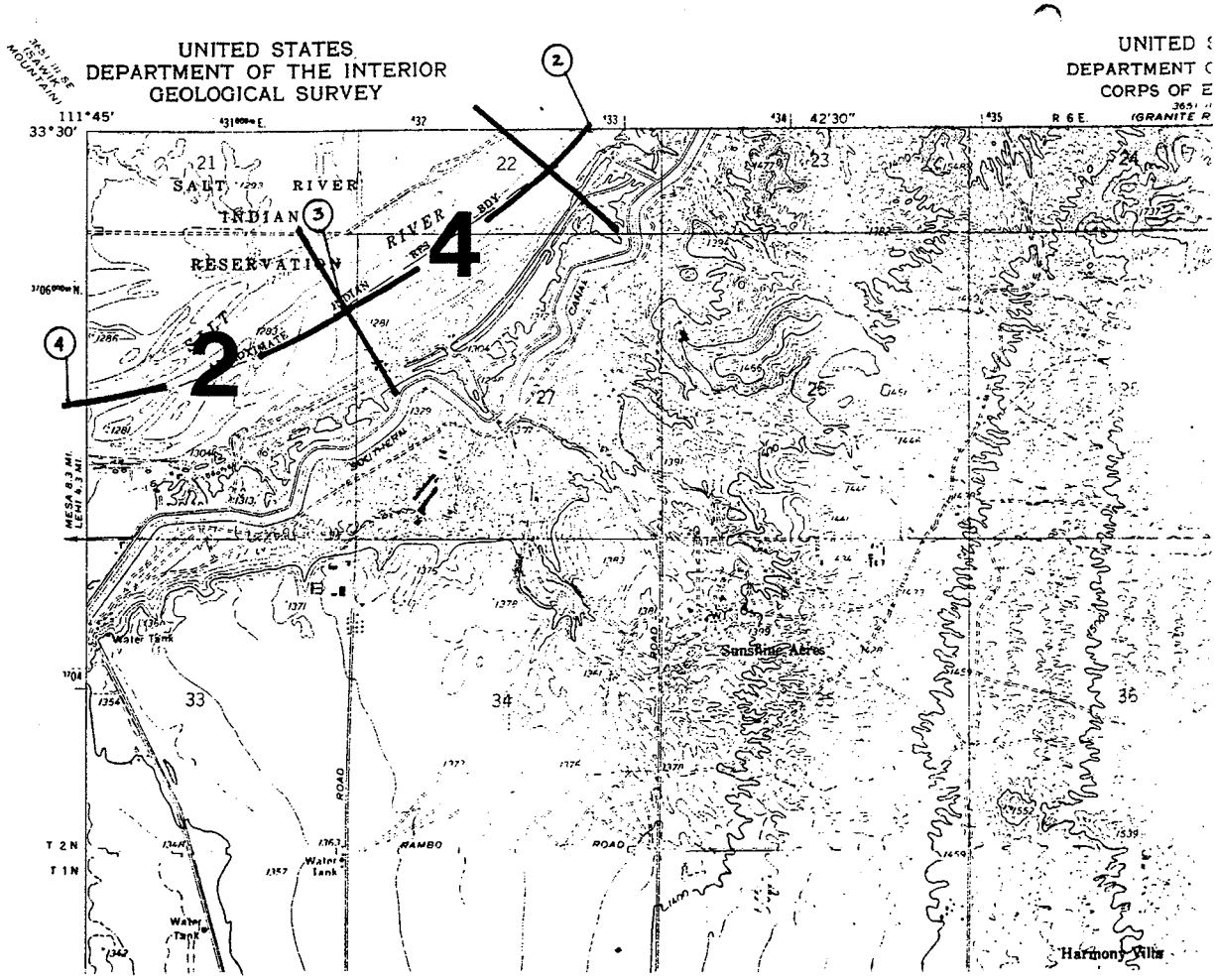
1. Completely Natural
2. Essentially Natural
3. Partly Modified
4. Substantially Modified
5. Mostly Modified
6. Essentially Artificial
7. Completely Artificial

The classifications were assigned by analysis of conditions on January 4, 1994, as represented in Landiscor Aerial Photography images. The base maps for this appendix are portions of U.S. Geological Survey 7.5' quadrangles, in some cases reassembled to show the river more clearly when it falls on map borders and corners.

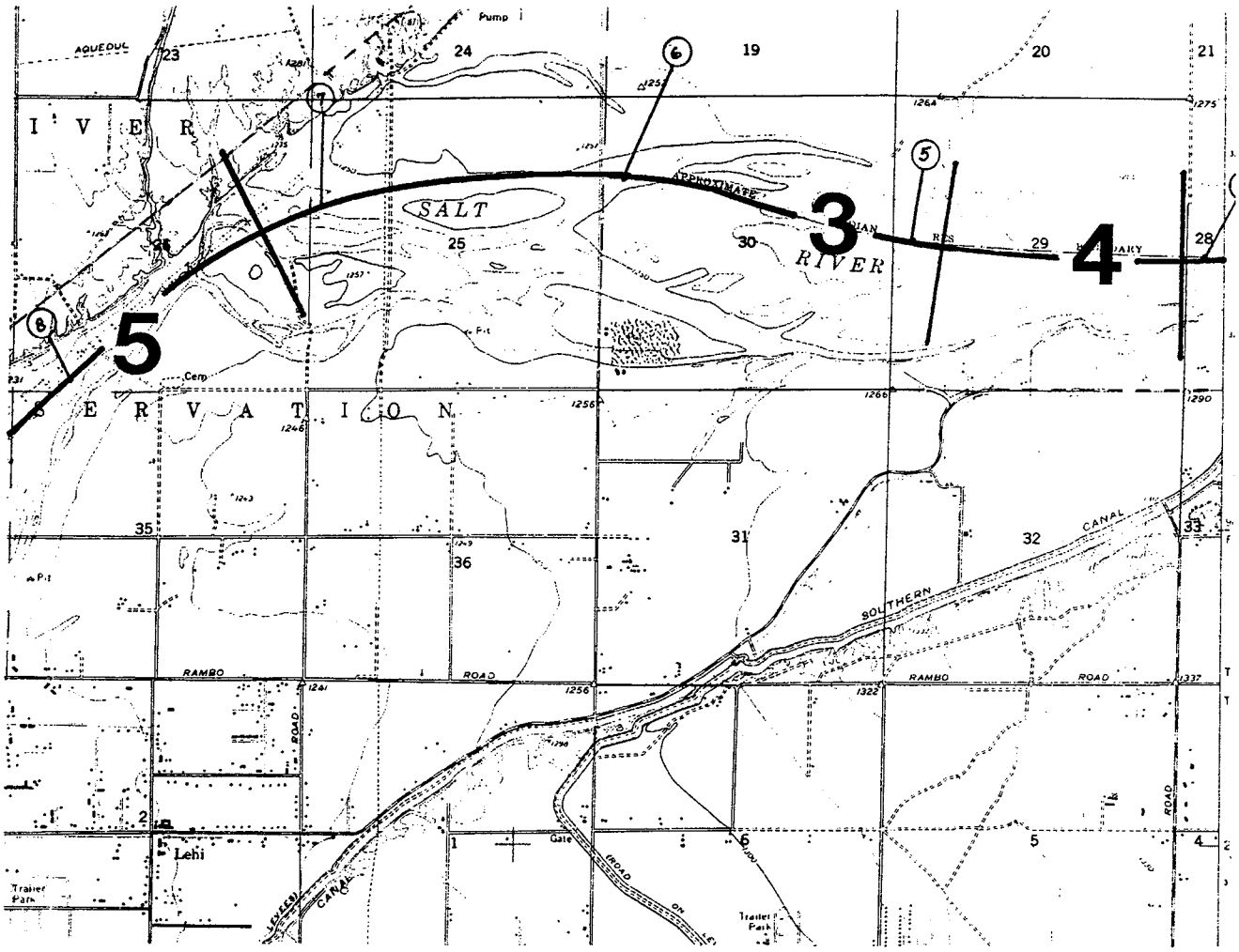
8.2.1 Near Granite Reef



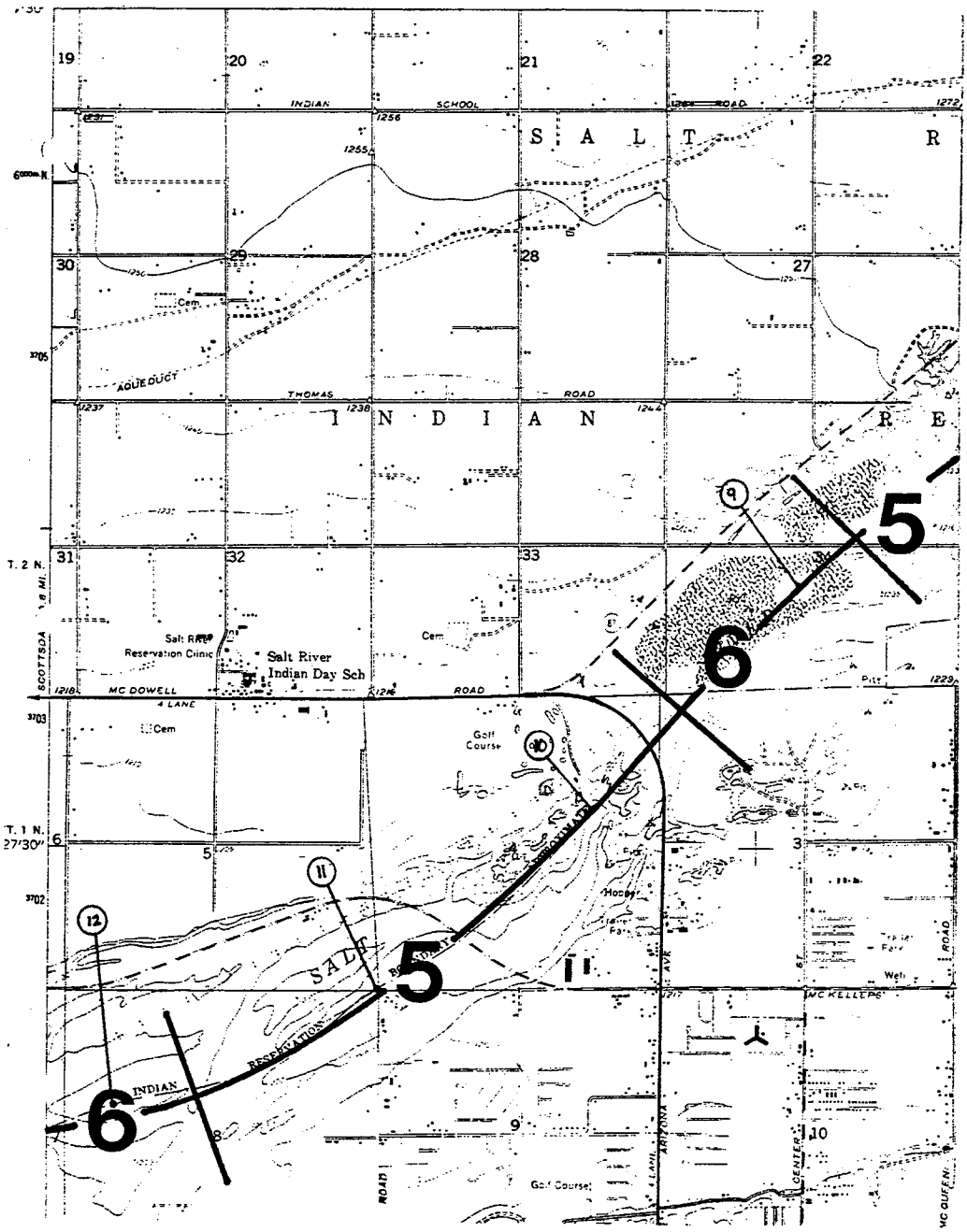
8.2.2 Vicinity of Higley Road Alignment



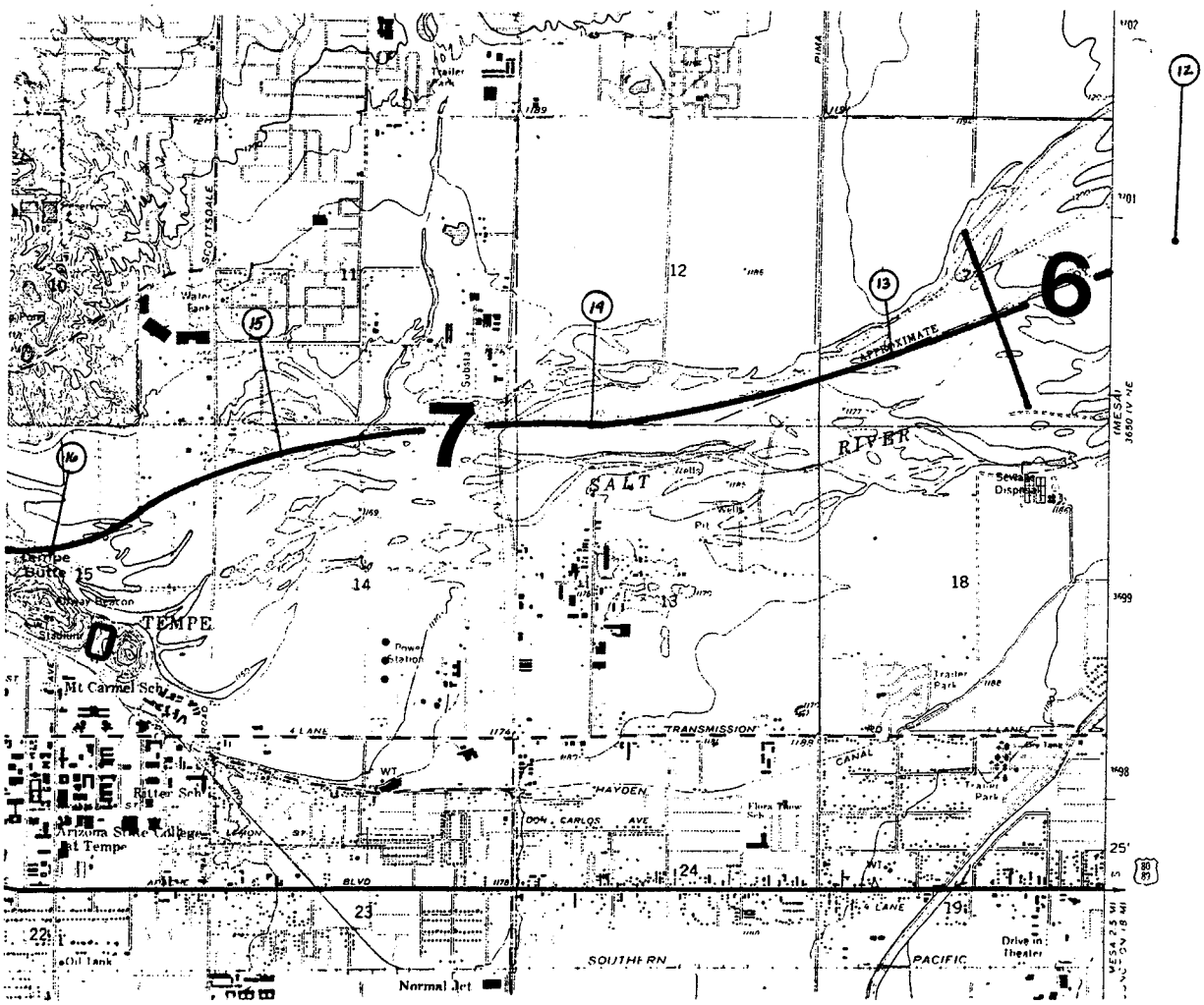
8.2.3 Vicinity of Lehi



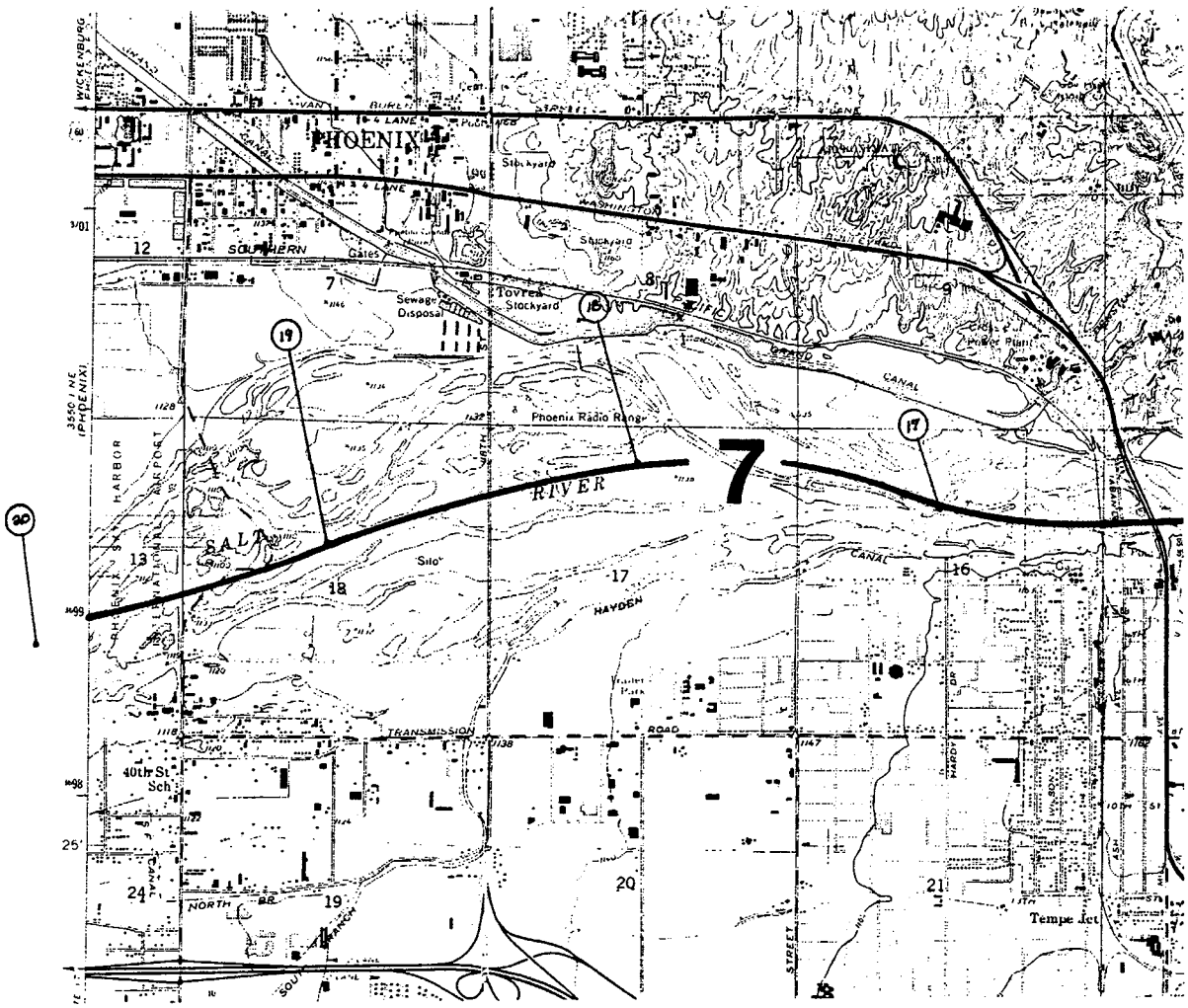
8.2.4 Vicinity of Country Club Drive Crossing



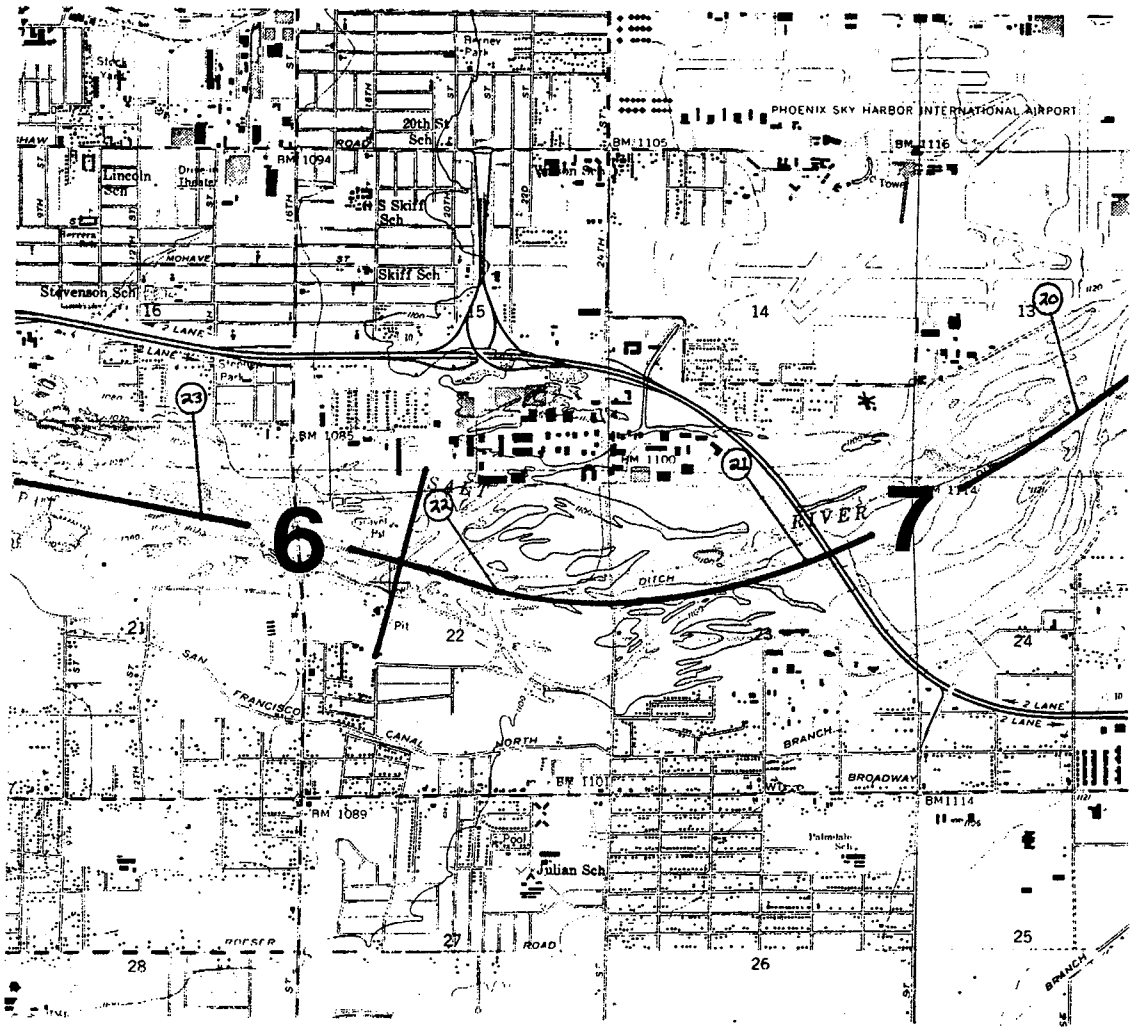
8.2.5 Vicinity of Rural Road Bridge



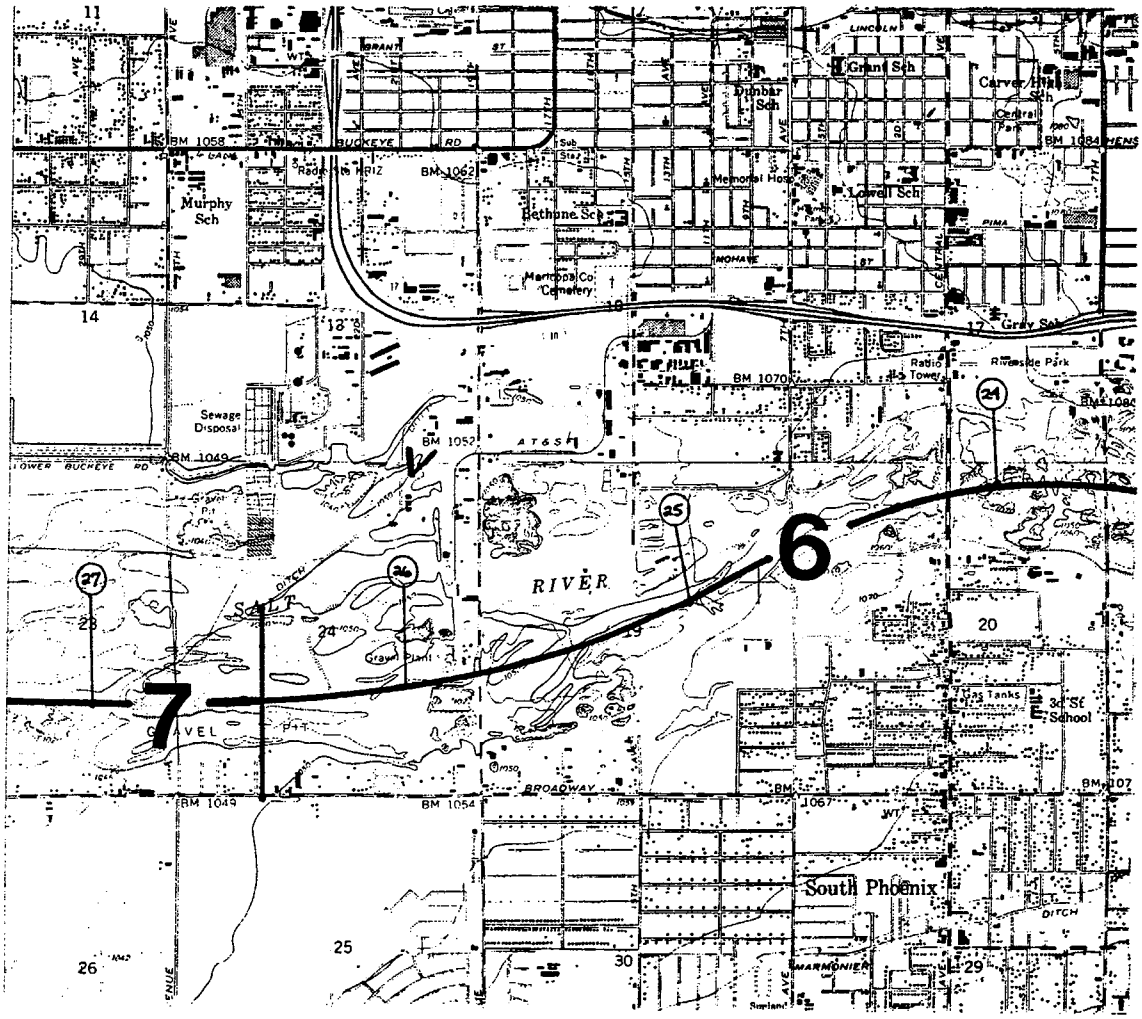
8.2.6 Vicinity of Hohokam Expressway Bridge



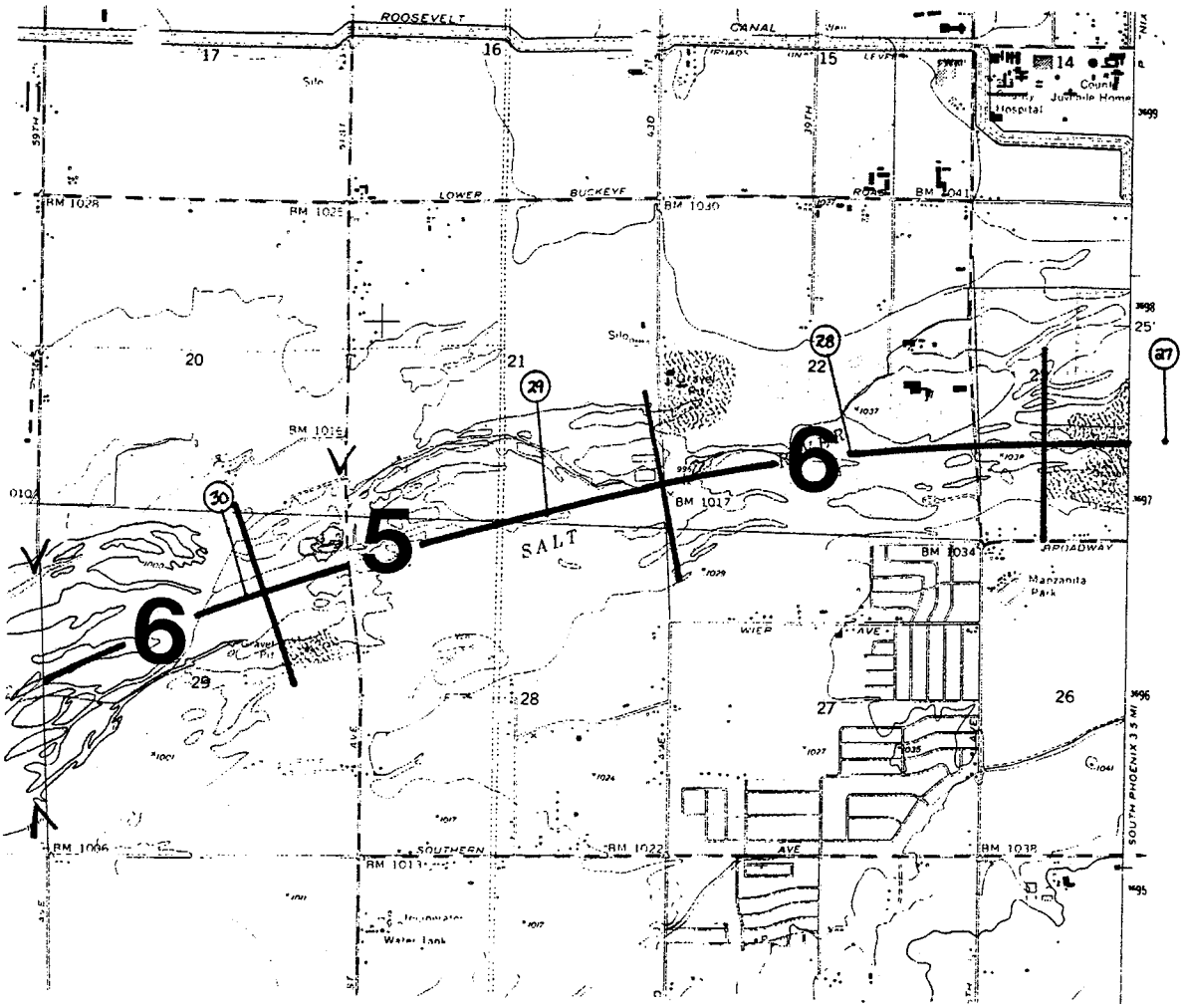
8.2.7 Vicinity of Interstate 10 Bridge



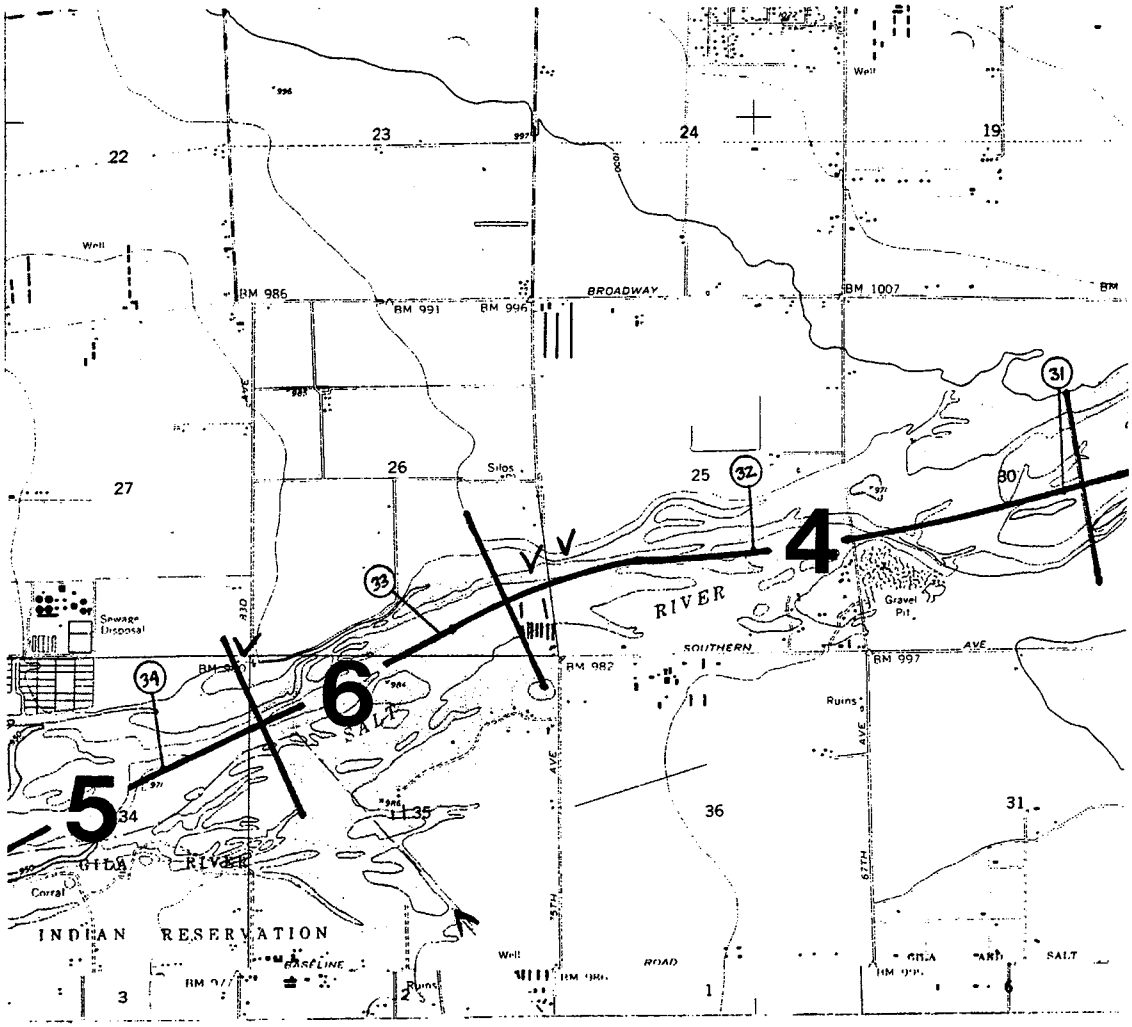
8.2.8 Vicinity of Central Avenue Bridge



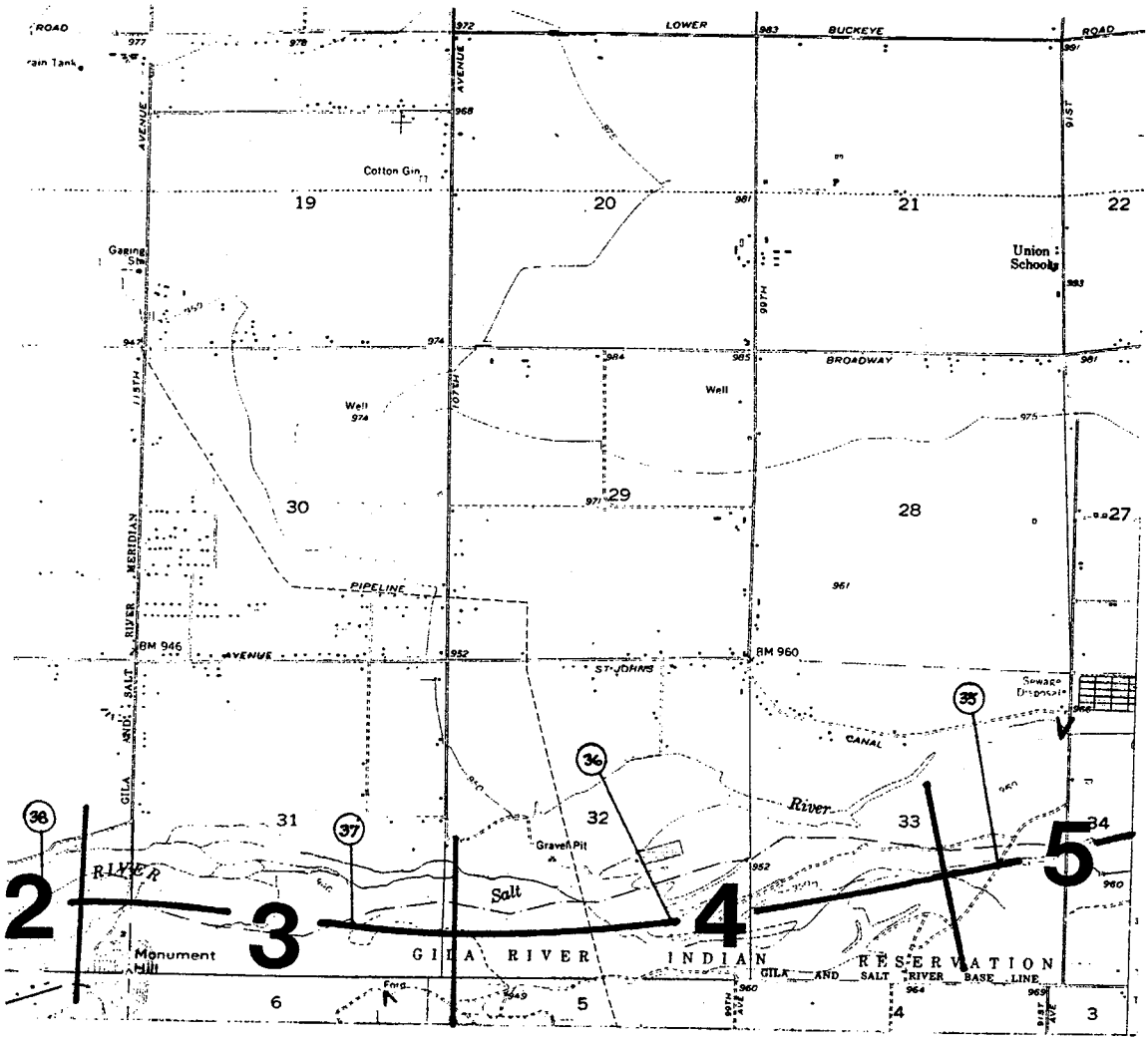
8.2.9 Vicinity of 43rd Avenue Alignment



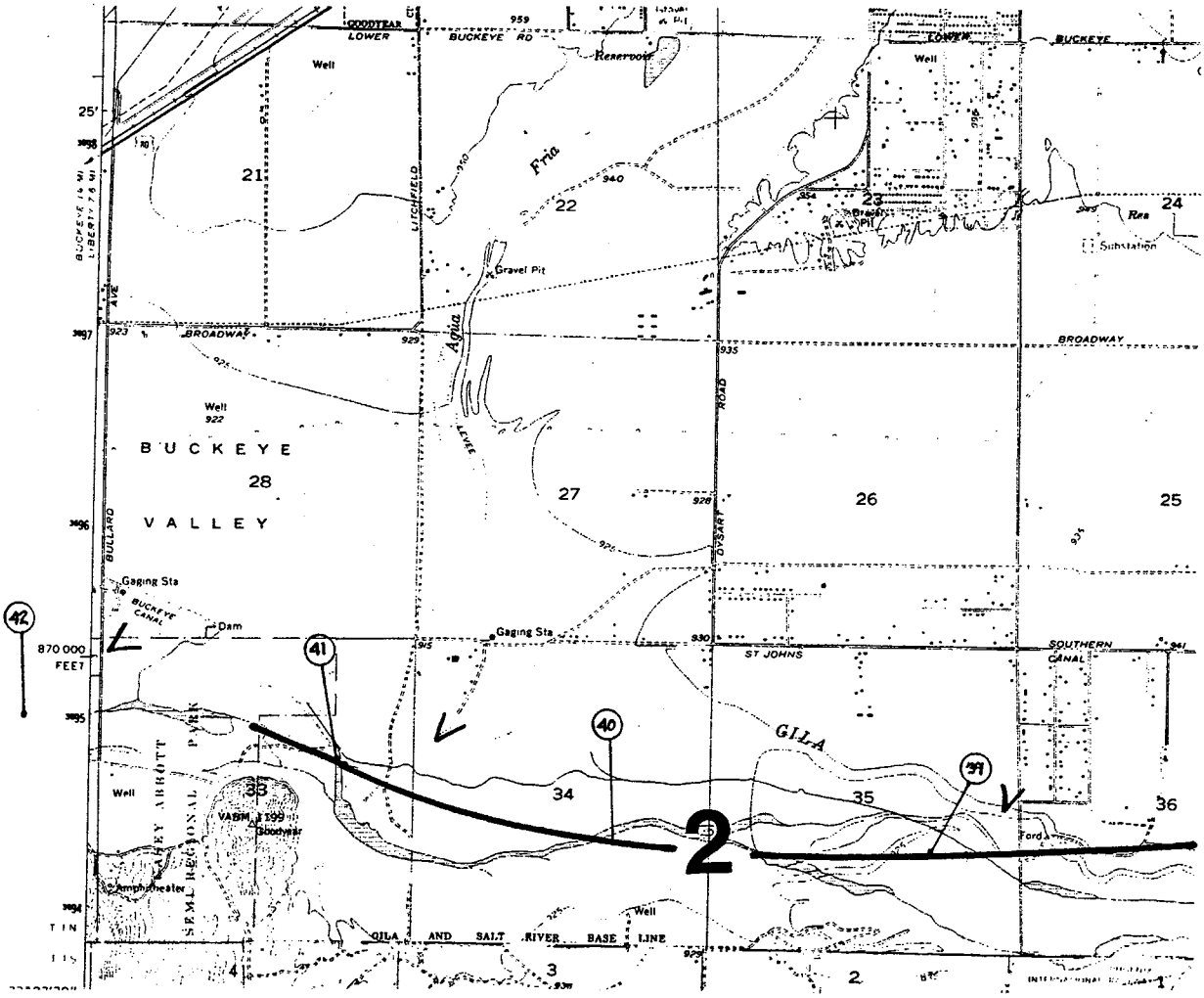
8.2.10 Vicinity of 75th Avenue Alignment



8.2.11 Vicinity of 99th Avenue Alignment



8.2.12 Vicinity of the Gila and Agua Fria Confluence



8.3 Additional Sources 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.

8.4 Historical Ground Phtography

8.4.1 Sources of Historical Ground Photography

Arizona Heritage Center--Tucson
*Contact--Susan Peter (628-5774)
Arizona Historical Foundation--ASU, Tempe (966-8331)
Arizona Historical Society--1300 N College Ave, Tempe
*Presently no librarian. Photos are not accessible.
*Contact--Zona Lorig (929-0292)
ASU Dept. of Archives and Manuscripts (LUHRS room)
*Large photo collection starting in the 1880's. (965-4932)
Bureau of Land Mangement--3737 N 7th St., Phoenix (650-0518)
*No photos
Bureau of Reclamation (Public Affairs)--23636 N. 7th St., Phoenix
*Contact--Joe Madrigal in Dept of Visual Communications (870-2896)
Bureau of Reclamation--Yuma (343-8100)
*Send all of their material to the Washington Archives
Dept Library Archives + Public Rec. (Archives Div.)--1700 W. Washington
*Contact--Carolyn (542-4159)
Dept Library Archives + Public Rec. (Research Lib.)--1700 W. Washington
*Contact--Carol (542-3701)
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.
Heard Museum--22 E. Monte Vista Rd., Phoenix
*Contact--Richard Pearce-Moses (252-8840)
Sharlot Hall Museum--Prescott, Arizona
*A limited number of photos (445-3122)
Soil Conservation Service--3003 N. Central Ave, Phoenix (280-8801)
*No photos.
SRP
*Contact--Shelley Dudley (236-6627)
State Land Az. Navigable Stream Adjudication
*Have a list of historical photos.
*Contact--Clyde Anderson (542-2677)
State Land Natural Resources (Hydrology)--1616 W. Adams St (542-3500)
*No photos.
Tempe Historical Museum
*Contact--Richard Bauer (350-5130)
USGS--845 N. Park Ave, Tucson
*Do not have any historical photos
*Contact--Tom McGarvin (882-4795)
Water Resources Adjudication--15 S. 15th Ave, Phoenix
*Contact--Sigfried Eichberg (542-1520)

8.4.2 Descriptions of Representative Photographs

**The code for the description indicates the significant features found in the photographs.
W=flowing water, F=flood, S=sediment, V=vegetation, M=meandering, C=channelized river.

Photo Location	Call #	Size	Date	Title	Description**
Tempe Historical Museum		11X17	1880	Hayden Mill	W,M,V
LUHRS Room (ASU)	cp spc 131:34	8X10	1885	West from Tempe Butte	W, M, S, V
LUHRS Room (ASU)	cp spc 131:35	8X10	1886	Salt River News	V, W, S
LUHRS Room (ASU)	cp spc 131:32	8X10	1880's	Tempe Butte looking west	W, M, S, V
Tempe Historical Museum	os 49	11X17	1887	West From Tempe Butte	W,M,S,V
LUHRS Room (ASU)	cp mcl 97563.T3	8X10	1888	Flood at railroad bridge	V, F, M
Tempe Historical Museum	os 128	11X17	1888	West from Tempe Butte	F,M,V
Tempe Historical Museum	os 129	11X17	1890	West from Tempe Butte	V,W,S,M
LUHRS Room (ASU)	cp cth 18	8X10	1895	Hayden's Ferry	W, M, V, S
Tempe Historical Museum	os 231	11X17	1900	Hayden Mill	V, M, W, S
Tempe Historical Museum	os 255	11X17	1900	Crossing the Salt River	V,W,S
LUHRS Room (ASU)	cp lfpc 1095	2X2	1900's	Salt River near Phoenix	F, S
LUHRS Room (ASU)	cp spc 134:25	8X10	1905	Bridge washout	V, F
LUHRS Room (ASU)	F819.P57.P58	3X5	1905	Hayden's Ferry	W, M, S, V
LUHRS Room (ASU)	F819.P57.P58	3X5	1905	Tempe Butte	F, V
Tempe Historical Museum	os 149	11X17	1907	Tempe Butte	F,V
Tempe Historical Museum	1f8-A 3&4	2X22	1907	Panorama of Granite Reef Dam	V, W,M
LUHRS Room (ASU)	cp spc 53:5	3X5	1908	Granite Reef Dam	W, V, S
LUHRS Room (ASU)	cp spc 53:14	8X10	1908	Granite Reef Dam	W, V, S
LUHRS Room (ASU)	cp spc 53:17	4X5	1908	Granite Reef Dam	W
LUHRS Room (ASU)	cp qrsrp 21	5X7	1909	Granite Reef Dam	W
LUHRS Room (ASU)	cp mcl 34967.A3	8X10	1910	Bridge over the Salt River	S, V, W
LUHRS Room (ASU)	cp spc 81:3	3X5	1910	Bridge in Tempe	W, S, V
LUHRS Room (ASU)	cp hu 234	3X5	1910	Tempe State Bridge	W, S, V
LUHRS Room (ASU)	cp spc 81:4	2X3	1911	Railroad Bridge Tempe	F, V
LUHRS Room (ASU)	cp cth 507	5X7	1911	Jointhead Dam	W, V, S
Tempe Historical Museum	os 233	11X17	1912	Hayden Mill	W,M,V
LUHRS Room (ASU)	cp spc 205:1	5X7	1913	Tempe State Bridge	V, W, S
LUHRS Room (ASU)	cp spc 205:2	5X7	1913	Tempe State Bridge	W, S, V, M
Tempe Historical Museum	os 2	11X17	1914	Tempe State Bridge	V,W,S
LUHRS Room (ASU)	cp mcl 103003.T3	8X10	1915	Car stalled near railroad bridge	V, W, S
LUHRS Room (ASU)	cp spc 217	5X7	1916	Tempe State Bridge	V, W, S
Tempe Historical Museum	os 150	11X17	1916	Santa Fe Railroad Bridge	F,V
LUHRS Room (ASU)	cp gm 62	2X3	1917	Granite Reef Dam	F
LUHRS Room (ASU)	cp spc 233:2	3X9	1920	S.P.R.R. Bridge Tempe	F, V
LUHRS Room (ASU)	cp spc 134:8	2X3	1920	Santa Fe R.R. Bridge Tempe	W, V
LUHRS Room (ASU)	cp hu 235	3X5	1920	Tempe State Bridge	W, S, V
LUHRS Room (ASU)	cp hu 236	3X5	1920	Tempe State Bridge	W, S, V
LUHRS Room (ASU)	cp hu 237	3X5	1920	Tempe State Bridge	W, S, V
LUHRS Room (ASU)	cp hu 238	3X5	1920	Tempe State Bridge	W, S, V
LUHRS Room (ASU)	cp hu 239	3X5	1920	Tempe State Bridge	W, S, V
LUHRS Room (ASU)	cp hu 240	3X5	1920	Tempe State Bridge	W, S, V
Tempe Historical Museum	os 91	11X17	1921	Aerial View of Tempe	W,S,M,V
SRP Archives		8X22	1926	West from Tempe Butte	W,V, M, S
SRP Archives		8X22	1926	West from Tempe Butte	F,V, M, S
LUHRS Room (ASU)	cp gm 60	2X3	1928	Granite Reef Dam	W, V
LUHRS Room (ASU)	cp cth 121	8X10	1929	Air Photo Looking North along Mill Ave.	S, W, V

SRP Archives		5X7	1930's	15 photos of sites west of Phoenix	S, V
LUHRS Room (ASU)	cp spc 117:45	3X5	1931	Tempe State Bridge	F, V
LUHRS Room (ASU)	cp msm 145	8X10	1931	Mill Ave. Bridge	F, M, V,
Tempe Historical Museum	os 136	11X17	1931	West from Tempe Butte	F,V
LUHRS Room (ASU)	cp gm 59	3X5	1932	Granite Reef Dam	F
LUHRS Room (ASU)	cp gm 61	2X3	1932	Granite Reef Dam	V
LUHRS Room (ASU)	cp msm 145	8X10	1933	Mill Ave. Bridge	V
Tempe Historical Museum	os 6	11X17	1933	Panorama west of Tempe Butte	V, S
Az. Hist. Foundation (ASU)	fp-kr 452	2X2	1940	South of Tempe	F,V
Az. Hist. Foundation (ASU)	fp-kr 453	2X2	1940	West From Tempe	F, M, V
Az. Hist. Foundation (ASU)	fp-kr 454	2X2	1940	Mill Ave. Bridge	F,M, V
LUHRS Room (ASU)		8X10	1941	Aerial Photo of Salt River	V
LUHRS Room (ASU)	cp cth 504	5X7	1941	Mill Ave	V
LUHRS Room (ASU)	cp cth 505	5X7	1941	Mill Ave	V
LUHRS Room (ASU)	cp cth 506	5X7	1941	Mill Ave	V
LUHRS Room (ASU)	cp cth 508	5X7	1941	Jointhead Dam	W, V, S
LUHRS Room (ASU)	cp cth 509	5X7	1941	Jointhead Dam	W, V, S
LUHRS Room (ASU)	cp cth 511	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 512	5X7	1941	Between Granite Reef Dam and Tempe	W, V, S
LUHRS Room (ASU)	cp cth 513	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 514	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 515	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 516	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 517	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 518	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 519	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 520	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 521	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 522	5X7	1941	Between Granite Reef Dam and Tempe	V, S
LUHRS Room (ASU)	cp cth 523	5X7	1941	Between Granite Reef Dam and Tempe	V, S
SRP Archives		3X5	1942	28 photos of vegetation clearing Tempe	V, S
LUHRS Room (ASU)	cp cth 218	5X7	1955	Salt River South of the Verde Confluence	W, V, S
LUHRS Room (ASU)	cp cth 219	5X7	1955	Salt River South of the Verde Confluence	W, V, S
LUHRS Room (ASU)	F819.P57.P58	3X4	1955	Aerial photo of Tempe Butte	M, V, S
SRP Archives		2X2	1969	East of Granite Reef Dam	W, V, S
LUHRS Room (ASU)	cp spc 131:26	4X5	1975	Fording the river at Mill	W, C, V
LUHRS Room (ASU)	F819.P57.P58	3X4	1977	Aerial photo of Tempe Butte	C, V, S
LUHRS Room (ASU)	cp msm 146.1	8X10	1989	Mill Ave. Bridge	C, V, S
LUHRS Room (ASU)	cp msm 146.4	8X10	1989	S.P.R.R. Bridge	C, V, S

LUHRS Room (ASU)	cp spc 131:34	8X10	1885	West from Tempe Butte	W, M, S, V
LUHRS Room (ASU)	cp spc 131:35	8X10	1886	Salt River News	V, W, S
LUHRS Room (ASU)	cp spc 131:32	8X10	late 1880's	Tempe Butte looking west	W, M, S, V
LUHRS Room (ASU)	cp mcl 97563.T3	8X10	1888	Flood at railroad bridge	V, F, M
LUHRS Room (ASU)	cp cth 18	8X10	1895	Hayden's Ferry	W, M, V, S
LUHRS Room (ASU)	cp lfpc 1095	2X2	`1900's	Salt River near Phoenix	F, S
LUHRS Room (ASU)	cp spc 134:25	8X10	1905	Bridge washout	V, F
LUHRS Room (ASU)	F819.P57.P58	3X5	1905	Hayden's Ferry	W, M, S, V
LUHRS Room (ASU)	F819.P57.P58	3X5	1905	Tempe Butte	F, V
LUHRS Room (ASU)	cp spc 53:5	3X5	1908	Granite Reef Dam	W, V, S
LUHRS Room (ASU)	cp spc 53:14	8X10	1908	Granite Reef Dam	W, V, S
LUHRS Room (ASU)	cp spc 53:17	4X5	1908	Granite Reef Dam	W
LUHRS Room (ASU)	cp qrsrp 21	5X7	1909	Granite Reef Dam	W
LUHRS Room (ASU)	cp mcl 34967.A3	8X10	1910	Bridge over the Salt River	S, V, W
LUHRS Room (ASU)	cp spc 81:3	3X5	1910	Bridge in Tempe	W, S, V
LUHRS Room (ASU)	cp hu 234	3X5	1910	Ash Ave Bridge	W, S, V
LUHRS Room (ASU)	cp spc 81:4	2X3	1911	Railroad Bridge Tempe	F, V
LUHRS Room (ASU)	cp cth 507	5X7	1911	Jointhead Dam	W, V, S
LUHRS Room (ASU)	cp spc 205:1	5X7	1913	Ash Bridge Tempe	V, W, S
LUHRS Room (ASU)	cp spc 205:2	5X7	1913	Ash Bridge Tempe	W, S, V, M
LUHRS Room (ASU)	cp mcl 103003.T3	8X10	1915	Car stalled near railroad bridge	V, W, S
LUHRS Room (ASU)	cp spc 217	5X7	1916	Ash Bridge Tempe	V, W, S
LUHRS Room (ASU)	cp gm 62	2X3	1917	Granite Reef Dam	F
LUHRS Room (ASU)	cp spc 233:2	3X9	1920	S.P.R.R. Bridge Tempe	F, V
LUHRS Room (ASU)	cp spc 134:8	2X3	1920	Santa Fe R.R. Bridge Tempe	W, V
LUHRS Room (ASU)	cp hu 235	3X5	1920	Ash Ave Bridge	W, S, V
LUHRS Room (ASU)	cp hu 236	3X5	1920	Ash Ave Bridge	W, S, V
LUHRS Room (ASU)	cp hu 237	3X5	1920	Ash Ave Bridge	W, S, V
LUHRS Room (ASU)	cp hu 238	3X5	1920	Ash Ave Bridge	W, S, V
LUHRS Room (ASU)	cp hu 239	3X5	1920	Ash Ave Bridge	W, S, V
LUHRS Room (ASU)	cp hu 240	3X5	1920	Ash Ave Bridge	W, S, V
SRP Archives		8X22	1926	West from Tempe Butte	W,V, M, S
SRP Archives		8X22	1926	West from Tempe Butte	F,V, M, S
LUHRS Room (ASU)	cp gm 60	2X3	1928	Granite Reef Dam	W, V
LUHRS Room (ASU)	cp cth 121	8X10	1929	Air Photo Looking North along Mill Ave.	S, W, V

8.5 Additional Sources for Historical Eyewitness Accounts

Coues, Elliot. 1878. Birds of the Colorado Valley: A Repository of Scientific and Popular Information Concerning North American Ornithology. U. S. Geological Survey of the Territories, Miscellaneous Publications No. 11. Washington, D. C.: Government Printing Office.

Davis, Arthur Powell. 1897. Irrigation Near Phoenix, Arizona. Washington, D. C.: Government Printing Office.

Masse, W. Bruce. 1976. The Hohokam Expressway Project: A Study of Prehistoric Irrigation in the Salt River Valley, Arizona. Tucson, AZ: Arizona State Museum, University of Arizona.

Masse, W. Bruce. 1981. Prehistoric Irrigation Systems in the Salt River Valley, Arizona. Science 214: 408-15.

Murphy, Merwin L. 1975. W. J. and the Valley: The Story of W. J. Murphy and His Part in Developing the Salt River Valley in Arizona. Department of Archives and Manuscripts, Hayden Library, Arizona State University, Tempe, AZ.

Peplow, Edward H., Jr. 1970. The Taming of the Salt: A Collection of Biographies of Pioneers Who Contributed Significantly to Water Development in the Salt River Valley. Phoenix, AZ: Community Relations Department of the Salt River Project.

Ruff, Paul F. 1971. A History of the Salt River Channel in the Vicinity of Tempe, Arizona, 1868-1969. Department of Archives and Manuscripts, Hayden Library, Arizona State University, Tempe, AZ.

Salt River Project. 1941. The Salt River Project of Arizona. Phoenix, AZ: Salt River Project.

Salt River Project. 1954. Salt River Project: First Project Organized under the Reclamation Act of 1902, Major Facts in Brief. Phoenix, AZ: Salt River Project.

Salt River Project. 1969. Major Facts in Brief about the Salt River Project. Phoenix, AZ: SRP.

Sargent, Charles S. 1978. The Story of Salt River Valley Urban Growth: Past - Present - Future. Scottsdale, AZ: SRVisions.

Smith, Courtland L. 1972. The Salt River Project: A Case Study in Cultural Adaptation to an Urbanizing Community. Tucson, AZ: University of Arizona Press.

Smith, Gusse Thomas. 1930s. The Salt River Valley and Phoenix. Phoenix, AZ: Maricopa County Immigration Commissioner and Phoenix Chamber of Commerce.

Zarbin, Earl. 1980. Salt River Canals: 1867 - 1875. Phoenix, AZ: Salt River Project.

Zarbin, Earl. 1984. The Swilling Legacy. Phoenix, AZ: Salt River Project.

8.6 Eyewitness Historical Accounts

8.6.1 Pre-Development (Prior to 1890)

[No specific date]

"Under virgin conditions the Salt River in the Phoenix area was an uncontrolled stream. The size of the stream ranged from a low flow of 1,000 cfs or so, which occurred generally in October, to a raging torrent carrying several hundred thousand cubic feet per second in December or January in some years. Every spring the flow gradually increased, in response to snowmelt, and the period of spring runoff lasted 2 to 2-1/2 months. Every summer a series of freshets occurred in response to summer rainstorms. The width, depth, and capacity of the river bed was determined by the occasional period of high runoff in the winter. . . . The width, depth, and capacity of the main channel within the river bed was determined primarily by the relatively steady flows that occurred every spring. Runoff caused by summer storms recarved the materials within the river bed. The low flow during October wandered downstream in the most convenient channel within the river bed." (4-3, 4-4)

"The annual cycle of runoff in this reach of the Gila River [Salt-Gila confluence to Gillespie Dam] before the advent of substantial settlement by man was virtually as described for the Salt River in a preceding section . . .. The stream was uncontrolled, and discharge ranged from low, steady flow in October to high steady flow in the spring snowmelt season, with occasional severe flooding in the period December-February. Vegetation was the same as along the Salt River, with cottonwood, mesquite, batamote, creosote bush, and other brush. There was no saltcedar." (5-1)

Halpenny, L. C., and Greene, D. K. 1975. Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona. Tucson, AZ: Water Development Corporation.

1744

". . . the full-streamed Rio de la Asuncion . . ." (20)

At the confluence of the Salt and Gila Rivers: "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

"[The Salt River] is much larger than the Gila; it rises a great deal in the summer as the snow-masses melt in the mountains in which it rises and through which it flows." (9)

"The Gila receives the larger part of its waters from the Asuncion [i.e., the Salt River], which rises greatly with the melting of the snows of the mountain ranges through which it passes." (12)

"I believe that on the Asuncion River [i.e., the Salt River] there will be found places suitable for crops, for use when there may not be direct access to the Gila ...." (95)

Garces, Francisco. 1965. A Record of Travels in Arizona and California 1775-1776. Translated by John Galvin. San Francisco: John Howell Books.

1826-1827

At the confluence of the Salt and Gila Rivers: "[The Salt River] affords as much water at this point as the Helay [Gila River]." (61)

Description of the Black River, probably the Salt River: "We found it abound with beavers. It is a most beautiful stream, bounded on each side with high and rich bottoms." (61)

Pattie, James Ohio. 1988. Personal Narrative of James O. Pattie. Edited by Richard Batman. Missoula, MT: Mountain Press.

1846-1847

At the confluence of the Salt and Gila Rivers: "A great deal of land is cultivated [by the Native Americans], but there is still a vast portion within the level of the Gila that is yet to be put under tillage." (86)

William H. Emory in:
U. S. Army Corps of Topographical Engineers. 1848. Notes of a Military Reconnaissance, from Leavenworth in Missouri, to San Diego, in California, Including Part of the Arkansas, Del Norte, and Gila Rivers. Thirtieth Congress -- First Session, Ex. Doc. No. 41. Washington, D. C.: Wendell and Van Benthuysen.

1850-1853

"... in about eight miles [we] struck the Salinas [Salt River], about twelve miles from its mouth, where we stopped to let the animals rest and feed. The bottom, which we crossed

diagonally, is from three to four miles wide. The river we found to be from eighty to one hundred and twenty feet wide, from two to three feet deep, and both rapid and clear. In these respects it is totally different from the Gila, which for the two hundred miles we has traversed its banks, was sluggish and muddy, a character which I think it assumes after passing the mountainous region and entering one with alluvial banks. The water is perfectly sweet, and neither brackish nor salt, as would be inferred from the name. We saw from the banks many fish in its clear waters, and caught several of the same species as those taken in the Gila. The margin of the river on both sides, for a width of three hundred feet, consists of sand and gravel, brought down by freshets when the stream overflows its banks; and from the appearance of the drift-wood lodged in trees and bushes, it must at times be much swollen, and run with great rapidity. The second terrace or bottom-land varies from one to four miles in width, and it exceedingly rich. As it is but little elevated above the river, it could be irrigated with ease. At present it is covered with shrubs and mezquit trees, while along the immediate margin of the stream large cotton-wood trees grow." (240-1)

"... finding a little patch of poor grass, we thought it best to stop for the night.... As we brought no tents, we prepared our beds on the sand." (241)

"We continued our course due east up the river, towards some singular piles of rock with fantastic tops, appearing like works of art.... We passed over the edge of a mountain, at the base of which the river ran, and then came to a wide and open plain, stretching some twenty-five or thirty miles eastwardly and southwardly. Entering this, we attempted to cross the bottom, which was so thickly overgrown with weeds and bushes that we could not penetrate it. We tried in vain to get through, but finding ourselves scattered, and fearing we should lose sight of each other, we retraced our steps along the margin of the hill, until we passed the jungle. The bottom now became more open, and five or six miles further brought we to the plateau. On our way we saw many traces of ancient irrigating canals, which were the first evidences that the country has been settled and cultivated." (242-3)

"As it was now growing very warm, we left the plateau and struck off for the Salinas, encamping beneath some tall cotton-woods ...." (243)

"Mr. Leroux, who had before come down the Salinas, pointed out to me a mountain some six or eight miles off, at the base of which the river San Francisco or Verde enters from the north. Since we struck the Salinas, its course had been mostly east and west; and as far as it could be traced by the cotton-woods and verdure which mark its course, its direction indicated the same. We supposed ourselves now to be from thirty-five to forty miles from its mouth. Looking east from where we were, the whole prospect was shut in by mountains rising one above the other. I was informed by Leroux, that such was the character of the country all the way to New Mexico; and that there were no more broad desert plains or luxuriant valleys like those of the Salinas and Gila rivers for the entire distance.... We found the river clear and rapid, as at the first camp, with many trout, whose silvery sides glittered in the translucent stream. The quantity of water passing down the Salinas is more than double that of the Gila, which only becomes a respectable river after it receives the

waters of the former. Yet there are seasons when the whole is evaporated, or absorbed by the sandy bed through which it passes, before reaching the Colorado." (243-4)

"The whole of this broad valley appeared to have been cultivated, though now overgrown with mezquit shrubbery." (245)

"There is no doubt that this valley, as well as that of the Verde and Gila Rivers, were once filled with a dense population . . .." (247)

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.

1867

Remarks on the area from Monument Hill to 36 miles upstream :

Tier 1 North, Range 6 East (north Mesa, just below Granite Reef Dam): "Vegetation: greasewood brush with good grass." (Book 1328, 28)

"This soil could be classified as first-rate composed of a sandy loam light, rich and easily worked, with the exception of three or four miles in [Township 1 North,] Range 3 East, the soil of which is 3rd rate, composed of granite debris. The surface is generally level sloping gradually toward the north. Vegetation --mesquit and greasewood brush and in some places grass-- in no place however abundant except on the last six miles. The Salt River is at this season of the year [January] at least a very large stream. Nor do I think it ever entirely dry. It has moreover a very heavy fall of I should think 12 to 15 ft. to the mile which renders it especially valuable for irrigation. I consider this valley --from 6 to 10 miles wide and extending from its mouth upward to the mountains about forty miles-- as some of the best agricultural land I have seen in the Territory and would recommend that it be subdivided at an early day. No timber but a few scattering mesquit trees." (Book 1328, 29-31)

Near 115th Avenue: "A little of the land along the Salt River . . . 1st rate but the fact that there is no water on or near the rest of the line (the Agua Fria being dry) renders it almost valueless for agricultural purposes."

Pierce, William H. 1867. Surveyor's notes for Cadastral Surveys of the Salt River Valley. General Land Office, U. S.

1868

Tier 2 North, Range 6 East (from Granite Reef Dam to approximately 6 miles downstream):

"The Bottom lands are good 1st and 2nd [rate] soils and is situated on both sides of the Salt River, a fine stream of pure water running in a westerly direction through the middle of the Township. It is fordable during six or seven months of the year in Sec. 29 at the crossing of the Fort McDowell & Maricopa Wells Road. Timber: Cottonwood and willows on both banks of Salt River, also some scattering mesquite, palo verde and greasewood upon the high land. . . . To left bank of Salt River about 7.50 chains wide [about 750 feet], high rocky banks -- rapid current . . .." (Book 1, 605)

At the confluence of the Salt and Gila Rivers (T. 1 N, R. 1 W): "[The Gila River] is a fine stream of water about 10.00 chains wide. The right bank and bed are sandy and has a rapid current generally. The quality of the land is about the general average -- good [two unreadable words]. There are some scattering cottonwoods on the banks of the Gila River. The Eastern part is covered with a vast growth of mesquite while over the remainder of the township there is a scattering growth of mesquite, sage brush and greasewood. The Agua Fria Creek enters the township in section 2 and runs southernly through it and empties into the Gila River. It is a wide but shallow water course [with] sandy banks and bed and dry except during times of great freshets." (Book 1, 423-424)

Ingalls, George P. 1868. Surveyor's notes for Cadastral Surveys of the Salt River Valley. San Francisco: U. S. Surveyor General's Office.

1868

" . . . [Ingalls] primarily was concerned with the soil┌s quality and the various types of vegetation, including cottonwood and willow trees along the river banks. Mesquite grew densely in some places, and scatterings of mesquite, willows, palo verdes, greasewood and sagebrush grew in other locations. The river bed varied from three-quarters of a mile to 1-1/2 miles wide. The irrigable land generally was six to 10 feet above the water, which was fished by settlers and Indians."

Zarbin, Earl. 1984?. The Swilling Legacy. [This is Zarbin┌s summary of: Ingalls, Wilfred F. 1868. Surveyor's notes for Cadastral Surveys of the Salt River Valley. General Land Office, U. S.]

8.6.2 Post-Development, Pre-Dam (1890-1938)

1890s

Near Mesa: "Our irrigation system prior to the Roosevelt Dam was very, very uncertain. There was no water available except the natural flow of the Salt River, and this varied from dangerous floods during the rainy season to a trickle during the hot, dry summers. Another hazard was that fact that the Dams built to divert water from the river to the irrigation canals were made of brush and rocks. A flood in the river would wash out all the dams. Of course everyone went to work to build new dams when the water subsided but in the mean time no water was available and damage to crops could not be prevented. During the summer of hot dry years water was severely rationed . . .." (21)

"It was necessary to ford the river at Tempe and during the rainy season when the river carried considerable water, a trip to Phoenix [from Mesa] by fording the river was impossible. History states that there was a ferry at Tempe known as the Hayden Ferry but we never investigated the possibility of going that way. Whenever the 'Salt' could not be forded we remained in Mesa." (30)

Dykes, Leonard R. Leonard Dykes Papers, MS CM MSM-249. Department of Archives and Manuscripts, Hayden Library, Arizona State University, Tempe, AZ.

1890

"We were much surprised on entering Salt River valley. . . . Now there opened before us a sight truly lovely. A fertile looking soil and miles of level plain. In the distance the green cottonwood trees . . .. Although Salt River valley is naturally fertile, owing to the dryness of the climate, there is no grass except a little coarse stuff called sacaton." (243)

Jones, Daniel W. 1890. Forty Years among the Indians: A True Yet Thrilling Narrative of the Author┌s Experiences among the Natives. Salt Lake City: Juvenile Instructor Office.

1891

"The fall of 1890 was very dry. In January of the following year the rain started. It rained and rained till everyone knew it could rain, even in this part of Arizona. The roads seemed like bottomless pits of mud. By the end of January the once clear, gently flowing river swept by in great waves of turbulent muddy water laden with all kinds of debris. The river started to creep over the nearest farm land." (18-19)

Jones, Thomas W. 1952. Lehi During the Term of Bishop Thomas Evan Jones. In W. Earl Merrill, J. Emerson Miller, and Stella R. Miller, eds., 75th Anniversary Diamond Jubilee History of Lehi 1877-1952. Mesa, AZ: Lehi Ward Church of Jesus Christ of Latter-Day

Saints.

1891

"The great flood of February 1891 widened the river bed. No substantial changes in width of the river bed occurred after that flood until the present [1975]."

Halpenny, L. C., and Greene, D. K. 1975. Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona. Tucson, AZ: Water Development Corporation.

1892

"While the river during the months in which hay and grain and the ordinary agricultural crops are being grown had in it a cast volume of water, this volume diminished with the advance of the season, from thousands of cubic feet per second to about, at a minimum, three hundred cubic feet per second, and as both the increase of population and the different products to which the land was cultivated increased, the demand for water in the summer months, when the supply is least, aggravated by an unnecessary and very considerable waste of water, exceeded the supply." (3)

From the opinion of Judge Kibbey, rendered in 1892, as quoted in:

Clark, Vernon Leonidas. 1936. History of the Salt River Valley Water Users' Association. Phoenix, AZ: Salt River Project Archives.

1893-1894

General descriptions of the Salt River Valley and Phoenix:

"Mountains of grandeur flank fertile valleys . . .." (3)

"a valley of wonderful fertility"
"a tract of farming land unequaled for fertility or extent"
"living water, which flows along every street" (4)

Maricopa Investment Company. 1894. Phoenix and the Salt River Valley, Arizona, 1893-4. Phoenix: Maricopa Investment Company.

1894

"Are there any poisonous reptiles? Yes, in the adjacent mountains, but irrigation drives them away from the cultivated lands and very few are now to be found in the valley." (6)

"Orange Judd, editor of The Prairie Farmer, after a visit to the Salt River Valley, said of its soil, editorially: "Most of these valleys soils are the accumulated washings from the surrounding hills, made up of the fine particles that have been, during countless centuries; disintegrated by frost, or the chemical action of the atmosphere. The water he (the farmer) uses is also charged with a new fertility, thus produced annually and gathered from the sides of the mountains scores and hundreds of miles away, so that every flowing of the land benefits it. . . . This is no theoretical idea. We have seen thousands of acres here growing crops that rival in luxuriance those found in the famed valley of the Nile, which derives its vivifying liquid, bearing fertilizing elements, from the far off lands in Upper Egypt and beyond. . . . This valley of the "Salt" derives its luxuriousness from the mountain regions of interior arid Arizona. The Special Committee of the U. S. Senate Report 928, part 1, May 5, 1890, page 60, say: "Within our border there cannot be found a soil so uniformly fertile and so capable of varied production, under irrigation, as that of the Gila, Salt and Santa Cruz Rivers in Southern and Central Arizona. Analysis of this soil shows its fertile qualities to be superior to that of the Nile earth." (6-7)

"The mild climate and luxuriant pastures [of alfalfa] are attracting attention to this valley as a favorable locality for the breeding of fine pedigreed stock." (10)

"Are there any fish? Yes; the streams and canals are full of them." (13)

"The name Salt River is misleading. In its course through the mountains, ere it debouches in this valley, it passes by some saline springs, and thus we have the name "Salt River.F So slight, however, is the admixture from these saline deposits that the water of the stream is not changed in any way, being clear, sweet and wholesome." (24)

"Birds are creatures of taste, who know the right thing when they see it, and this country swarms with song birds . . .." (26)

Phoenix Chamber of Commerce. 1894. The Salt River Valley, Arizona: Questions Answered and Current Comment that May Be Found Interesting to the Home Seeker and Investor. Phoenix: Phoenix Chamber of Commerce.

1905

"The [Salt River] valley thus filled with debris may or may not correspond with the present course of the river. Changes in the riverFs course over an aggrading area are the rule rather than the exception. Old channels, therefore, which do not correspond with the present river's course are to be expected in the valley fill, and incidentally these old channels are likely to give the most productive wells. The old debris-filled channels may be narrow like the present channel of Salt River near the upper end of the valley, or may be

miles in width according to circumstances." (118)

"The only supply of water that is quantitatively adequate to explain the phenomena is that from the river and from the flood waters entering the valley from the surrounding hills. . . . During the past few years the shallow wells throughout the valley have been lowered repeatedly. South of Tempe, where the water level is said to have been formerly with 2 feet of the surface, it is now 8 feet. At Mesa it has lowered 12 feet in four years; at the Phoenix Indian School it has lowered 20 feet in ten years. This is commonly attributed to the drought which has prevailed during the past few years. It may be partly due also to the increasing number of wells in use." (120-21)

"The river is considered the most important source of the underflow. There is a permanent water supply in it from the head of the valley to the Tempe canal, north of Mesa. Below the head-gates of the Tempe canal, a short space occurs in which the river is practically dry for the greater part of the year. Further downstream underground water returns to the river bed; that is, the river cuts beneath the water table and the underflow returns in part, making a surface flow of something like 35 second-feet. It is evident, therefore, that from the head of the valley to the Tempe canal the surface flow of the river is at a higher level than the general surface of the underground water on either side. . . . North of Mesa the river bed is at the same elevation as the water table, while at Tempe the river bed is below the water table. This explains the return of the underflow to the surface, making a perennial stream at Tempe, while the river bed both east and west of Tempe is dry. (121-22)

" . . . the common salt so abundant in Salt River is probably due to large salt springs. Several springs were found along the upper reaches of Salt River whose water is described as a weak brine." (147)

Lee, Willis Thomas. 1905. Underground Waters of Salt River Valley, Arizona. U. S. Geological Survey Water-Supply and Irrigation Paper No. 136. Washington, D. C.: Government Printing Office.

1908

"The fear of drought is not a perpetual nightmare, and the flood and hailstorm are never feared." (6)

"Only three-fifths of [the Salt River valley] now is cultivated, for the Salt is an erratic sort of stream. For weeks its flow may forbid passage at any ford, and yet within a month the traveler may cross dryshod. . . . The depth to water and the quality thereof is known on almost every square mile. The land has been surveyed, and every contour marked on maps. The river's flow has been measured and the water supply, for twenty years past, is absolutely known. Engineering observation and research have demonstrated the fact that

at the head of a gorge, seventy miles east of Phoenix, there lies a dam site such as is rarely offered by Nature to man, and above it a reservoir site, wherein can be stored the greatest flood that ever tore down the river channel, possible to devastate and then idly to escape useless to the sea. There is nothing experimental about the irrigation situation of the Salt River Valley." (9)

McClintock, Jas H. 1908. Phoenix, Arizona, in the Great Salt River Valley. Phoenix: City of Phoenix and Maricopa County Board of Trade.

1927

"This system [of dams on the Salt River] feeding two thousand miles of canals and ditches is a triumph of modern engineering skill which laughs at any story of drought the big trees may ever tell in the future of the great Salt River Valley."

"This transformation of the desert has been accomplished by the scientific conservation and control of the waters of one tiny, but ever-flowing stream, the Salt River."

Smith, Gusse Thomas. 1927. Phoenix and the Interesting Salt River Valley. Phoenix: Maricopa County Immigration Commissioner and Phoenix Chamber of Commerce.

8.6.3 Post-Dam (1938-1978)

1947

"The Salt River is, to a casual visitor, a gross exaggeration in terms. Except in rare flood times, it isn't a river at all, but a low-lying rugged basin, as empty of moisture as your living room. The mountain snow water which once coursed between its banks is now impounded by a series of dams forty to ninety miles away, and routed through an elaborate system of canals to the thirsty soil of the valley. . . . The good irrigated earth of the Salt River Valley is the solid foundation upon which the continuing prosperity of Phoenix has been based for many years." (89)

"The course of the canals is inevitably marked by lines of cottonwood trees." (89)

"There is, however, a more immediate problem: water. During the last decade the area has depended more and more on deep wells to augment irrigation by surface water, and now almost all the valley's agriculture owes its life to pumping. A sensible underground water code is desperately needed. Subterranean streams are not inexhaustible; the water table around Phoenix is steadily sinking. In Litchfield Park and Queen Creek it is lower by thirty feet than fifteen years ago, and in Deer Valley lower by thirty-five feet. The United States Geological Survey reports that Maricopa County is currently pumping eighteen times what experts consider to be a safe yield." (95)

MacKaye, Milton. 1947. Phoenix. The Saturday Evening Post, 18 October, 37, 88-90, 93-95.

1957

". . . perennial flow of the Salt River at the confluence with the Gila River ended in 1957, and thereafter the river system carried only flood flows and effluent."

Halpenny, L. C., and Greene, D. K. 1975. Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona. Tucson, AZ: Water Development Corporation.

1958

Phoenix Metropolitan area: "Originally, natural flood channels existed through to the Salt River. However, since the area has been built up all of the old flood channels have been substantially obliterated. Storm Drains constructed by the City of Phoenix partially alleviate drainage problems. At the present time a serious flood hazard exists from flood waters from Cave Creek, Sunnyslope, Dreamy Draw and the Salt River. In the past large property damage has resulted from floods." (Appendix II, 1)

Salt River Area: "From Granite Reef to Tempe the channel is reasonably well defined and hasn't been materially encroached upon. . . . However, an entirely different problem exists as one approaches Tempe. Works of man have been such as to almost completely obliterate the original channel in many areas -- particularly from Tempe southwest to approximately 35th Avenue. Sand and gravel companies have operated in the river bottom; subdivisions have encroached upon the old original flood channels; a large sanitary fill has been built; and other types of work by man have tended to constrict or to obliterate the original channel. From 35th Avenue to within a mile of the junction with the Gila River, the brush is presently not very heavy and the channel has not been seriously encroached upon. . . . It must be pointed out that the hazards to life and property are great in this area. . . . At present, there is no defined channel." (Appendix II, 1-2)

Flood Protection Improvement Committee. 1958. Report of Flood Protection Improvement Committee. Phoenix, AZ: City of Phoenix.

1966

"In the 19-mile reach from Granite Reef Dam to 48th Street, the channel is poorly defined and meanders across a wide flood plain that has an average gradient of 9 feet per mile. In the lower 10 of this reach, from Oak Street to 48th Street, a few gravel pits have been dug into the natural channel. The 4-mile reach from 48th to 16th Street has been modified by man and has an average width of about 350 feet from 48th to 40th Street and about 100 feet from 40th to 16th Street. In the lower 2-mile reach from 16th Street to 7th Avenue the channel has been obliterated by several large gravel pits. (1)

Briggs, P. C., and Werho, L. L. 1966. Infiltration and Recharge from the Flow of April 1965 in the Salt River near Phoenix, Arizona. Arizona State Land Department Water-Resources Report No. 29. Phoenix, AZ: U. S. Geological Survey.

1975

"The combination of storage of Salt River runoff behind dams for later use to irrigate land and generate electric power, and the diversion of stored water to irrigate valley lands, has reduced the once mighty and turbulent Salt River to a dry river bed most of the time in the Phoenix area. Much of the winter and summer runoff originating downstream from the dams can be collected into the canal system. . . . During the past 30 to 35 years a strong temptation has existed to assume that the Salt River is under full control and that little or no flow is likely to occur. Such an assumption is absolutely unwarranted by the facts relating to what will happen in the way of runoff when the meteorological situation develops that is conducive to maximum runoff." (4-4, 4-6)

"During the past 30 to 35 years the metropolitan area of Phoenix has expanded tremendously. Large quantities of sand and gravel were needed for construction, and the

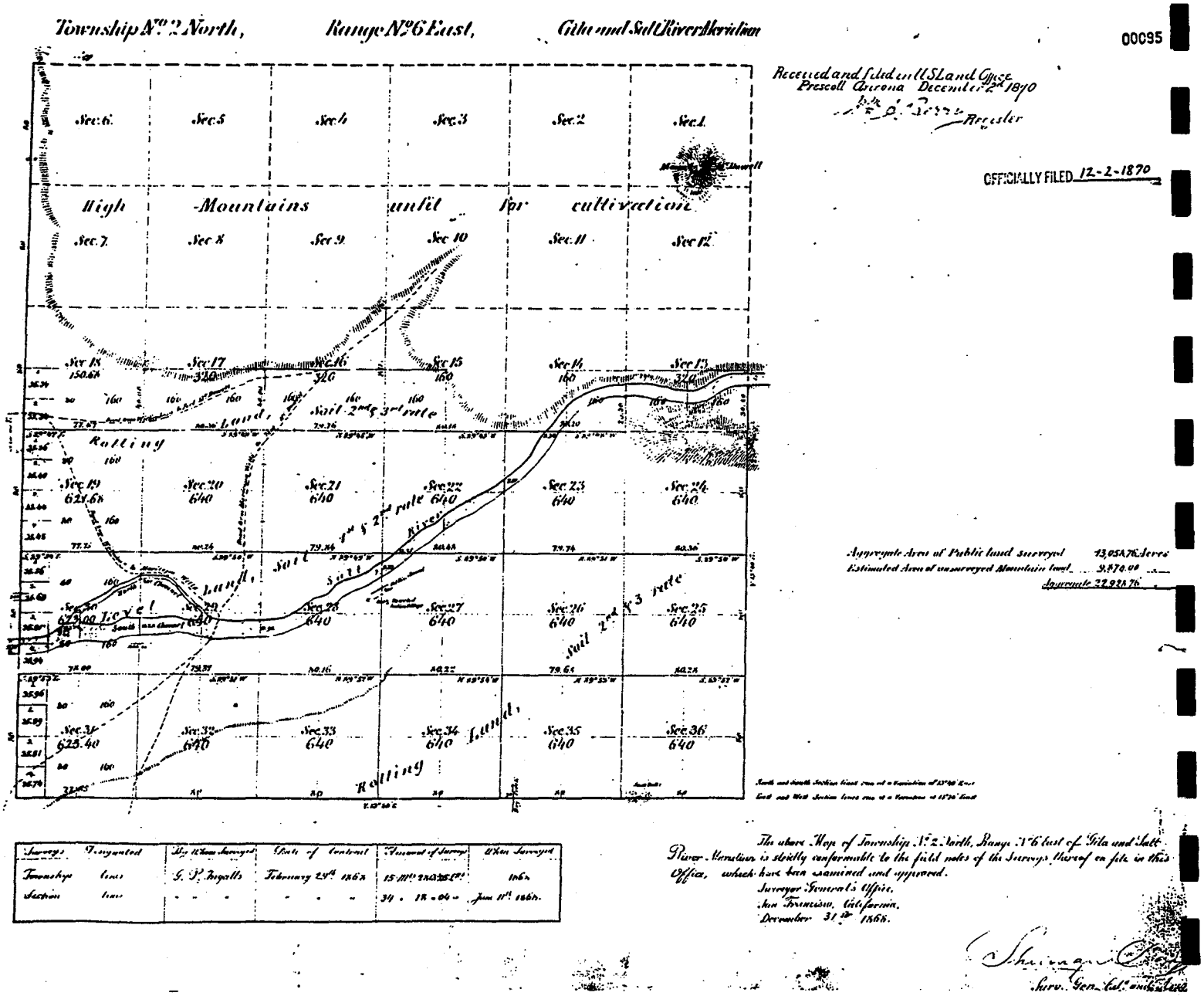
dry bed of the Salt River afforded a practically inexhaustible supply. The river stayed dry year after year, and no serious danger was apparent that would preclude excavation of large deep pits nor erection of expensive machinery within the river bed. By 1959 the river bed contained a hodge-podge of obstructions of various types, all of which tended to impede or change the direction of flow of flood runoff. Boulders are an unwanted byproduct when obtaining gravel and sand for construction. There were dams and dikes constructed with waste boulders. There were deep pits and the associated sorting and washing equipment, stockpiles and roads. In addition there were feed-lots, high-tension towers, radio towers, and junk yards. As of July 1, 1959, obstructions occupied 39 percent of the river-bed area in the reach from 40th Street downstream to 19th Avenue in Phoenix." (4-7)

Halpenny, L. C., and Greene, D. K. 1975. Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona. Tucson, AZ: Water Development Corporation.

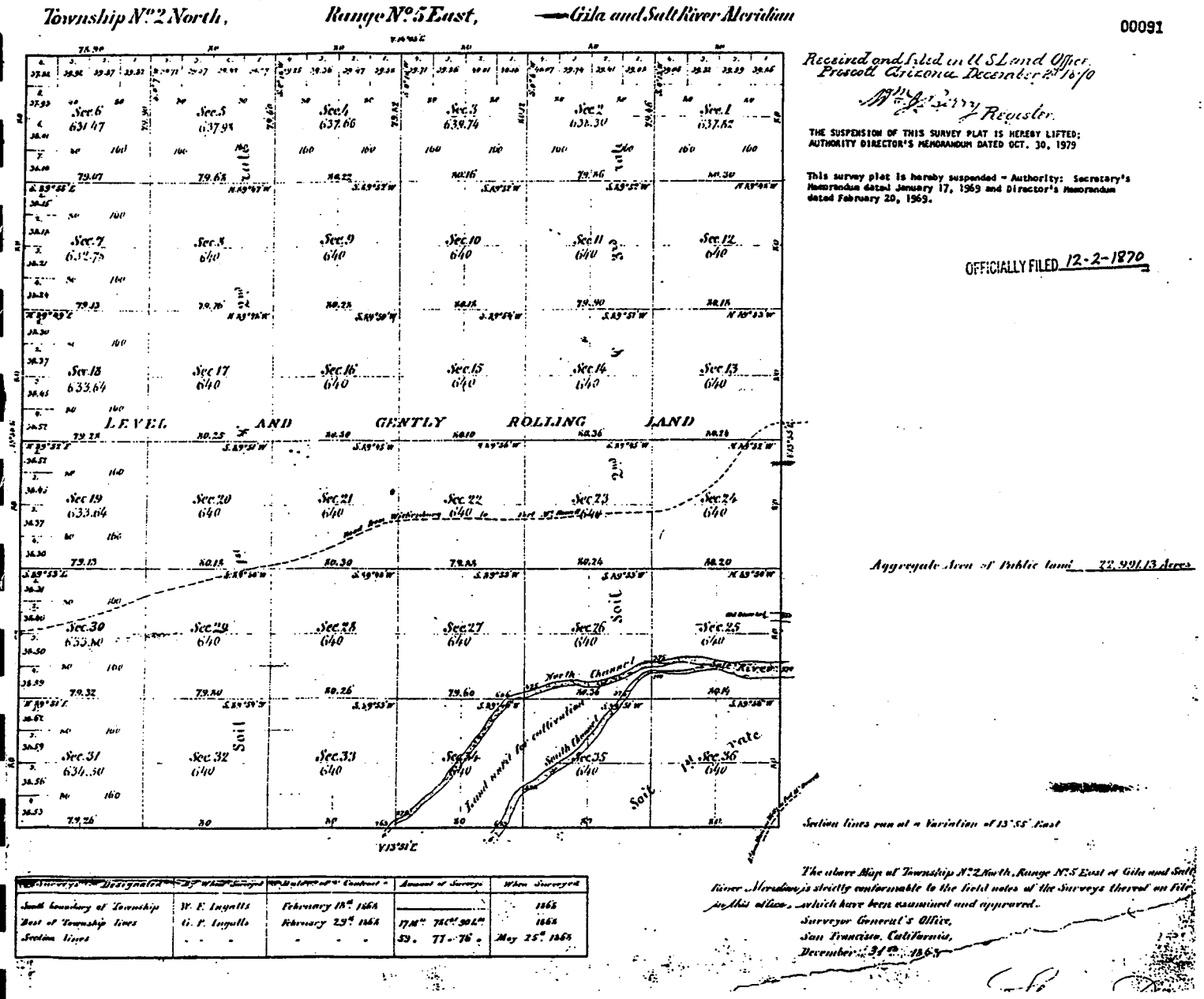
8.7 General Land Office Maps, 1868

The maps on the following pages represent the first cadastral surveys of the Lower Salt River. They were created by surveyors who laid out the township and range lines and who included major physical features such as buttes and the the river. The maps provide the earliest accurate, comprehensive view of the planimetric character of the river. Locations correlated to modern features are not always obvious, but the section numbers can provide a guide to using the maps in Appendix 8.2 to determine modern locations.

8.7.1 Granite Reef to Higley Road Alignment

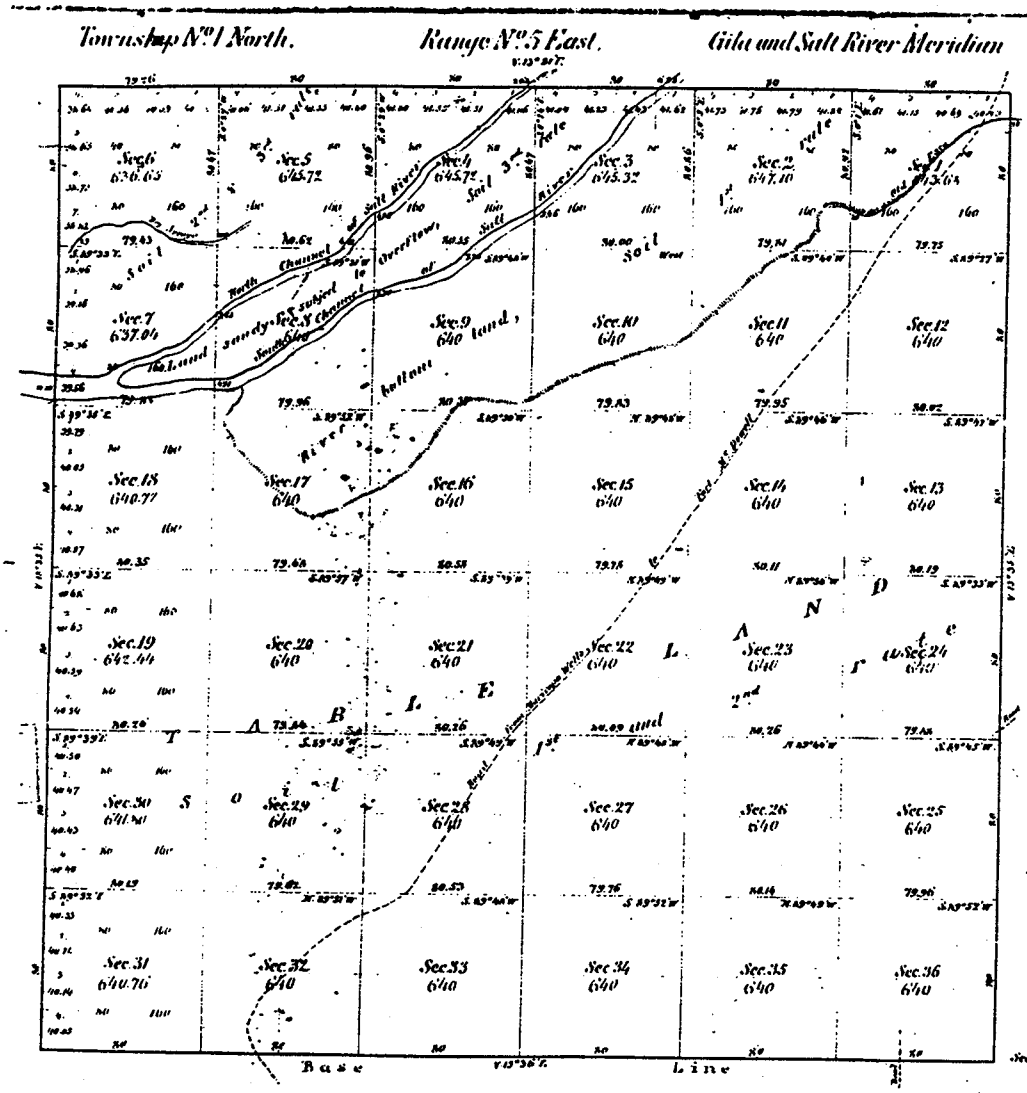


8.7.2 Higley Road Alignment to Center Street Alignment



Surveys Designated	By Whom Surveyed	Date of Contract	Amount of Surveys	When Surveyed
South boundary of Township	W. F. Ingalls	February 18th 1866		1866
East & Township lines	G. P. Ingalls	February 23rd 1866	17 M. 78 Ch. 50 Lk.	1866
Section lines	- - -	- - -	53. 77 - 76.	May 25th 1868

8.7.3 Center Street Alignment to Country Club Drive Crossing



00018

Revised and filed in U.S. Land Office
Roswell Arizona December 2nd 1870.
Frensler

THE SUSPENSION OF THIS SURVEY PLAT IS HEREBY LIFTED; AUTHORITY DIRECTOR'S MEMORANDUM DATED OCT. 30, 1979

This survey plat is hereby suspended - Authority: Secretary's Memorandum dated January 17, 1969 and Director's Memorandum dated February 20, 1969.

OFFICIALLY FILED 12-2-1870

Aggregate area of Public Land 23066.95 Acres.

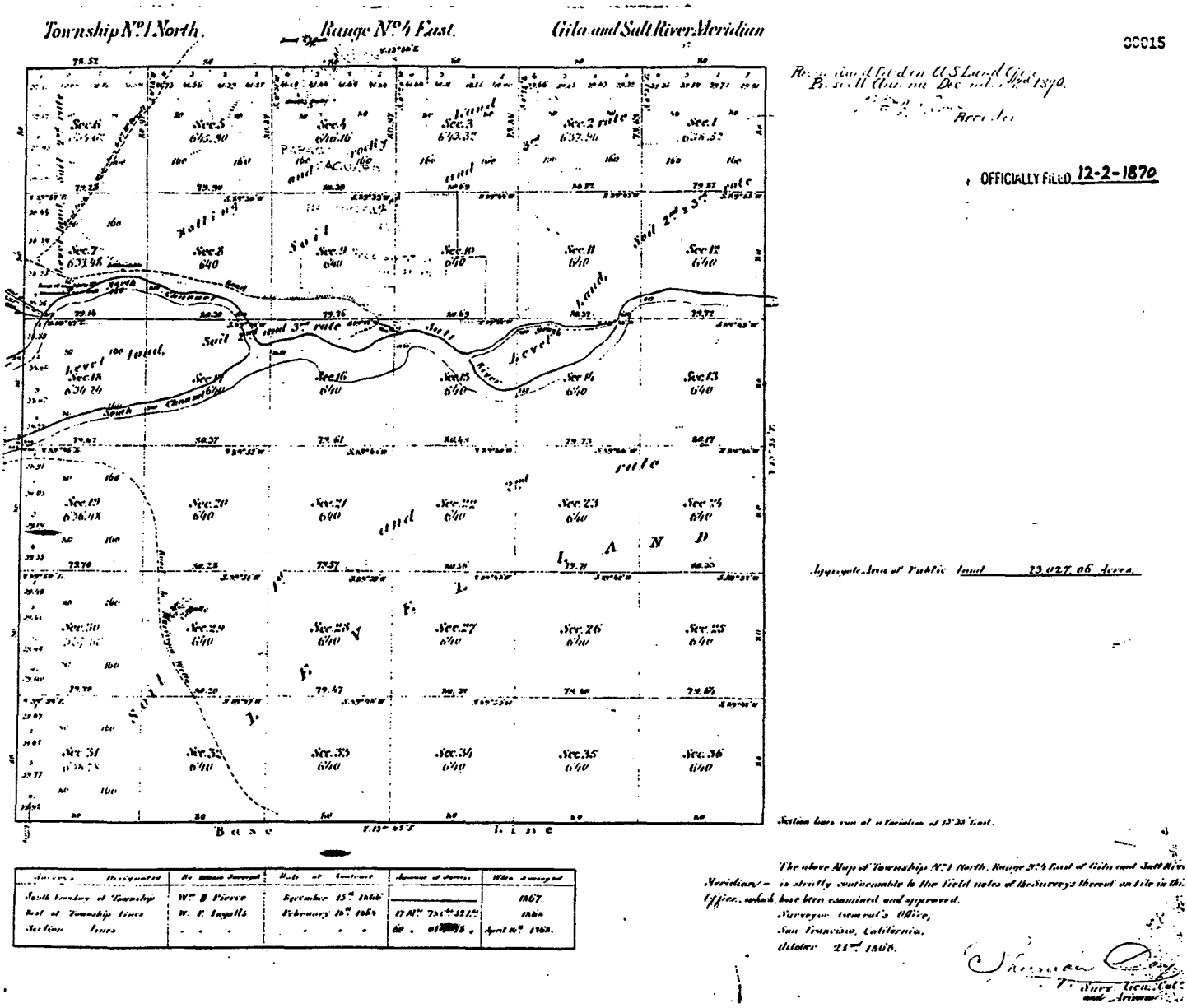
Section lines run at a variation of 13°35' East.

Surveys designated	By Whom Surveyed	Date of Contract	Amount of Surveys	When Surveyed
South boundary of Township	Wm. H. Pierce	December 15th 1866		1867.
Rest of Township lines	W. F. Ingalls	February 18th 1868	17 M.s 79 ch.s 26 Lk.s	1868
Section lines	- - -	- - -	60. 05. 28.	April 29th 1868

The above Map of Township No. 1 North, Range No. 5 East of Gila and Salt River Meridian is strictly conformable to the field notes of the Surveys thereof on file in this Office, which have been examined and approved.

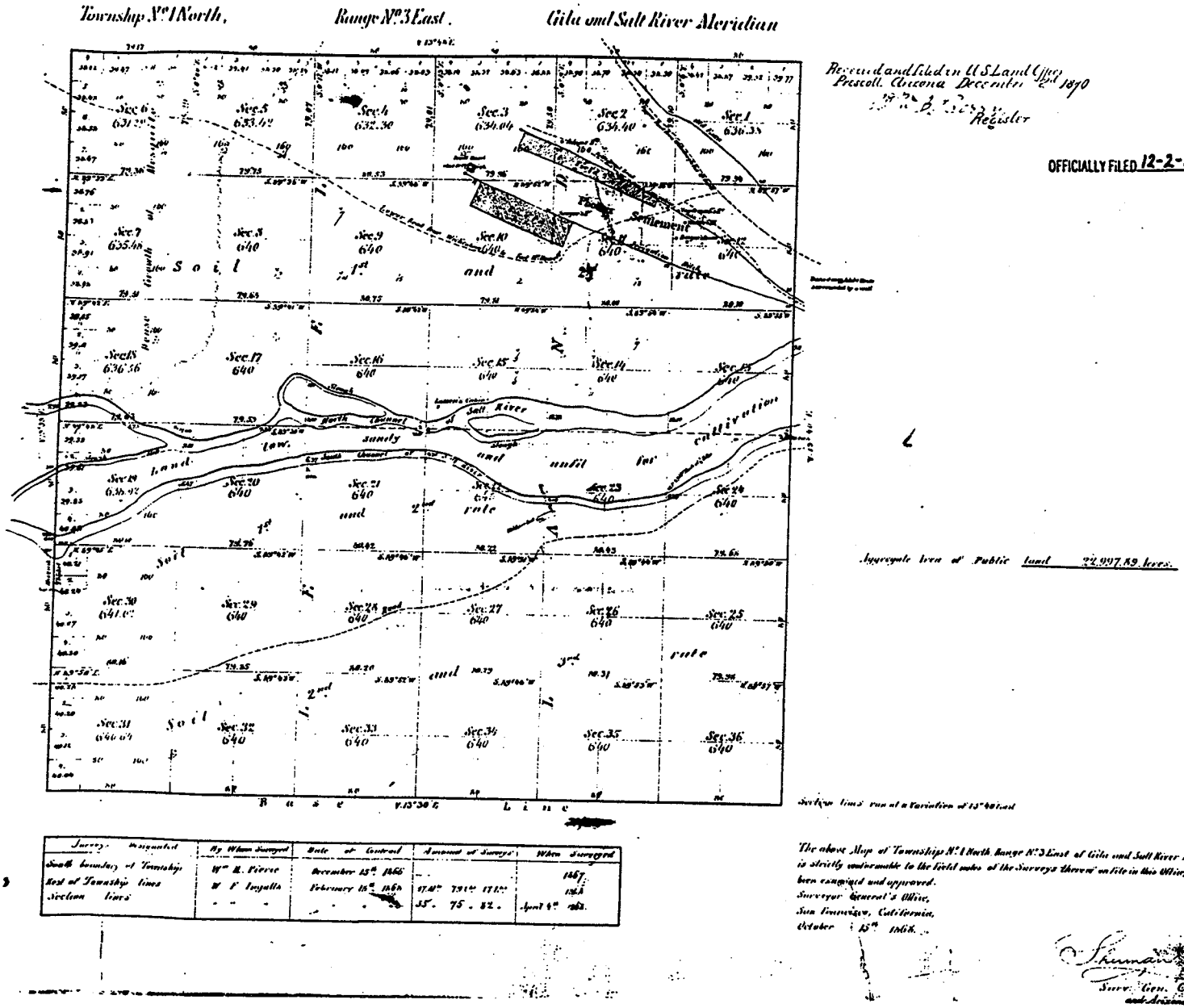
Surveyor General's Office,
San Francisco, California,
October 22nd 1868.

8.7.4 Country Club Drive Crossing to 40th Street Crossing



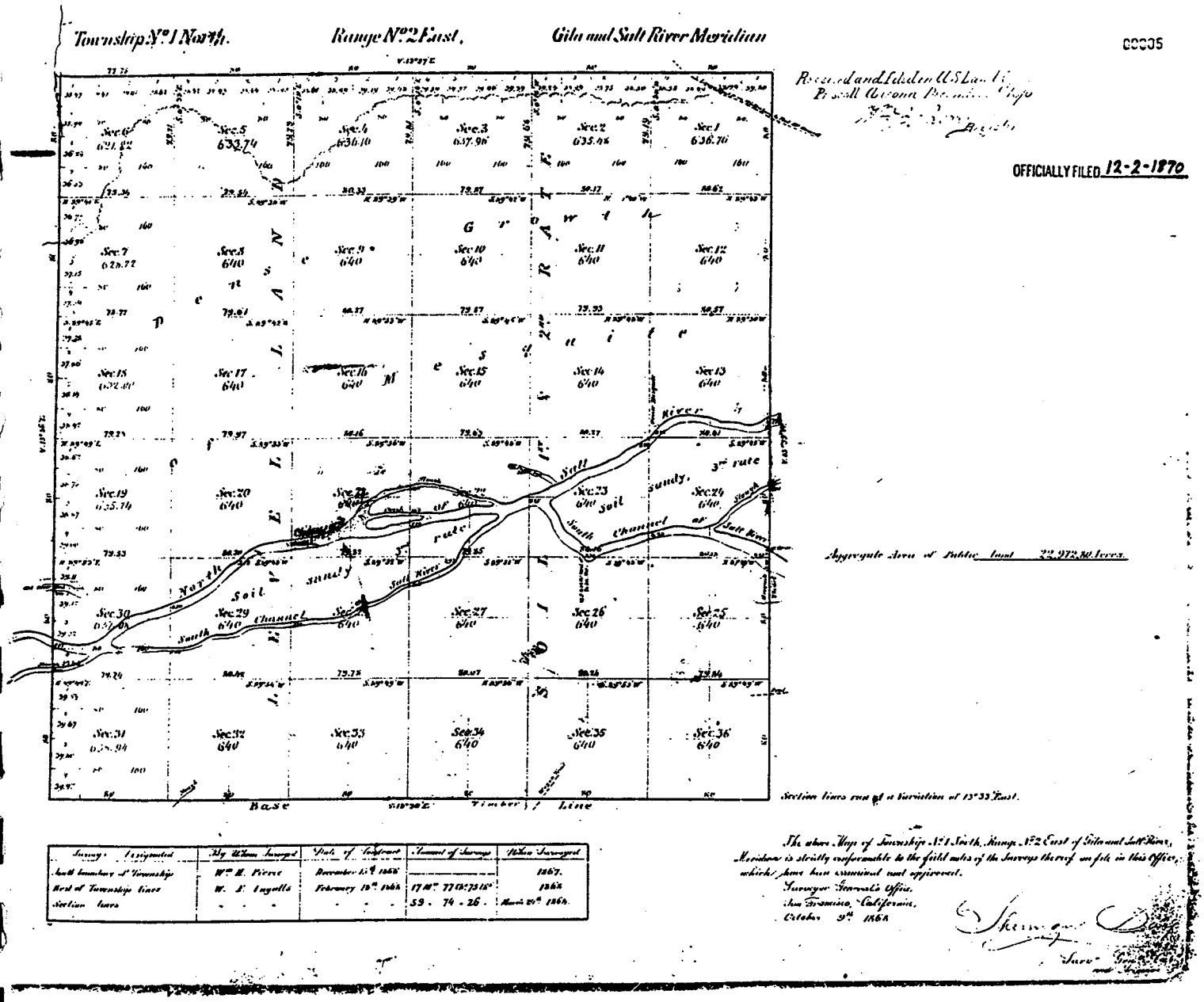
Surveys Designated	By whom Surveyed	Date of Contract	Amount of Surveys	When Surveyed
South boundary of Township	Wm B Pierce	September 15th 1866		1867
East of Township lines	W. F. Ingalls	February 16th 1869	17 M. 73 ch. 32 l.	1869
Section lines	- - -	- - -	60 " [illegible] "	April 20th 1868.

8.7.5 40th Street Crossing to 19th Avenue Crossing



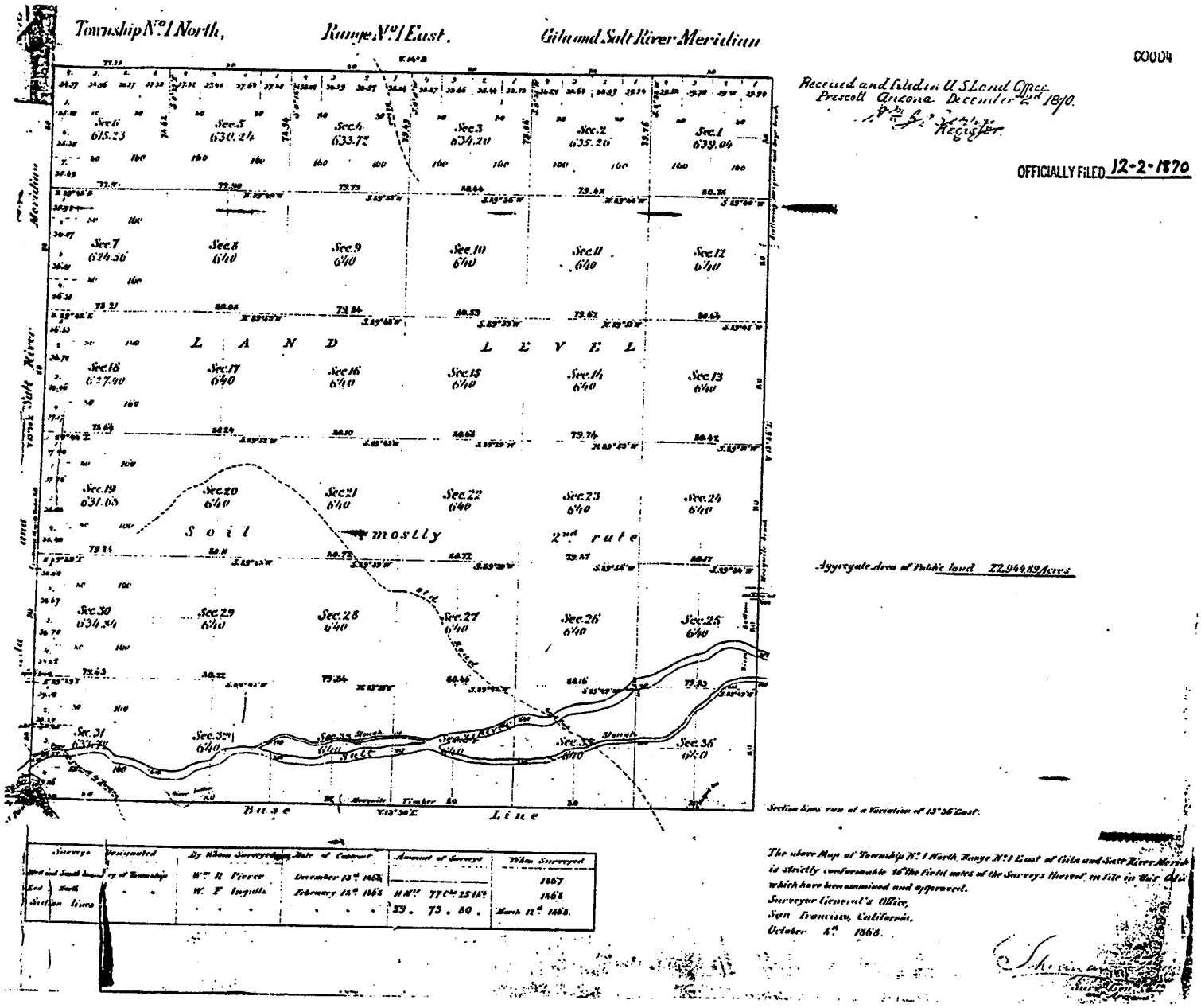
Surveys designated	By Whom Surveyed	Date of Contract	Amount of Surveys	When Surveyed
South boundary of Township	Wm. H. Pierce	December 15th 1866	--	1867
Rest of Township lines	W. F. Ingalls	February 16th 1868	47.40 79.00 17.00	1868
Section lines	- - -	- - -	35. 75. 82.	April 4th 1868

8.7.6 19th Avenue Crossing to 67th Avenue Alignment

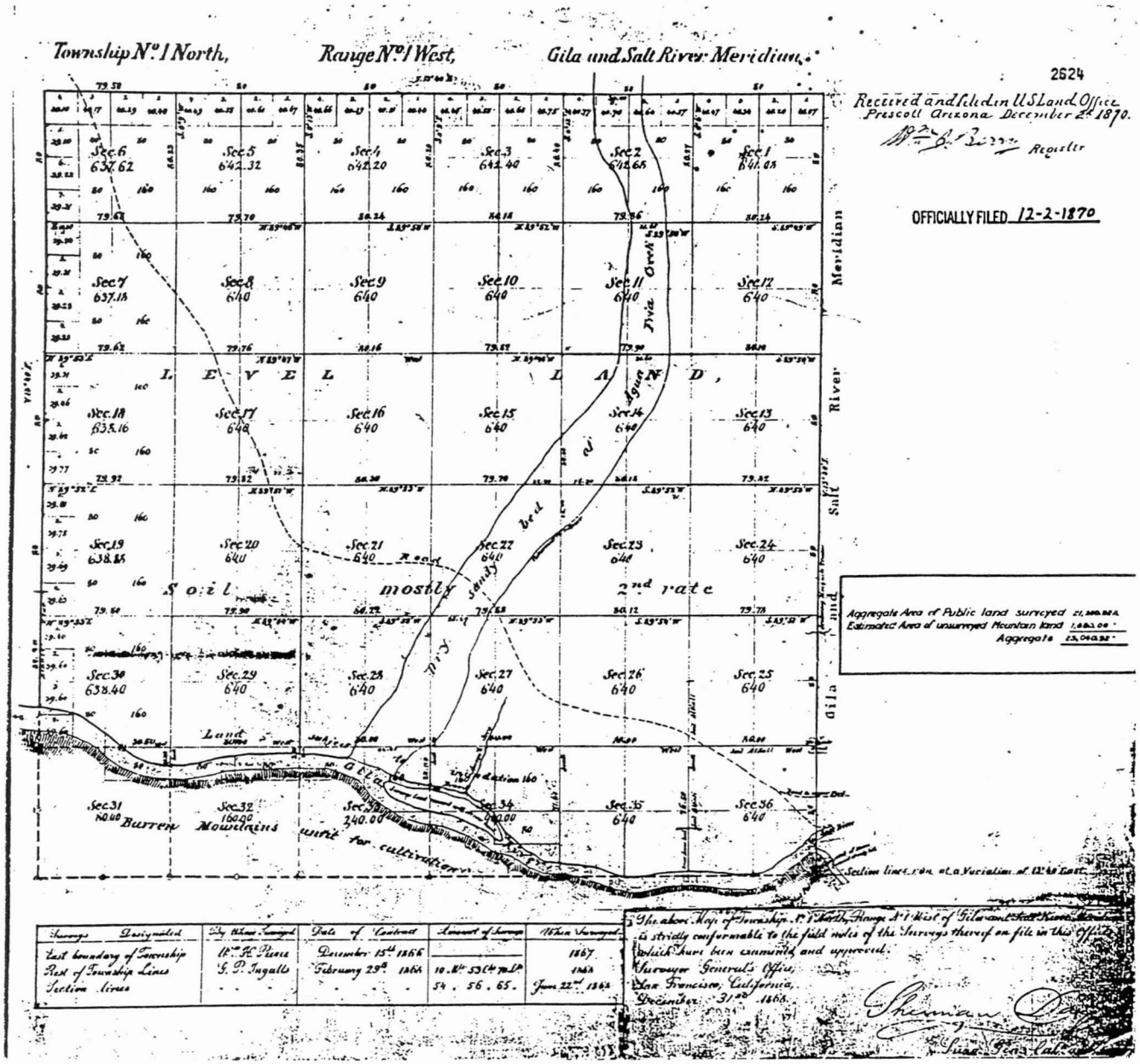


Survey: Designated	By Whom Surveyed	Date of Contract	Amount of Surveys	When Surveyed
South boundary of Township	Wm. H. Pierce	December 15th 1866		1867.
Rest of Township lines	W. E. Ingalls	February 15th 1868	17 M. 77 Ch. 73 lk.	1868
Section lines	- - -	- - -	59 . 74 . 26 .	March 20th 1868.

8.7.7 67th Avenue Alignment to 115th Avenue Crossing



8.7.8 115th Avenue Crossing to the Agua Fria River

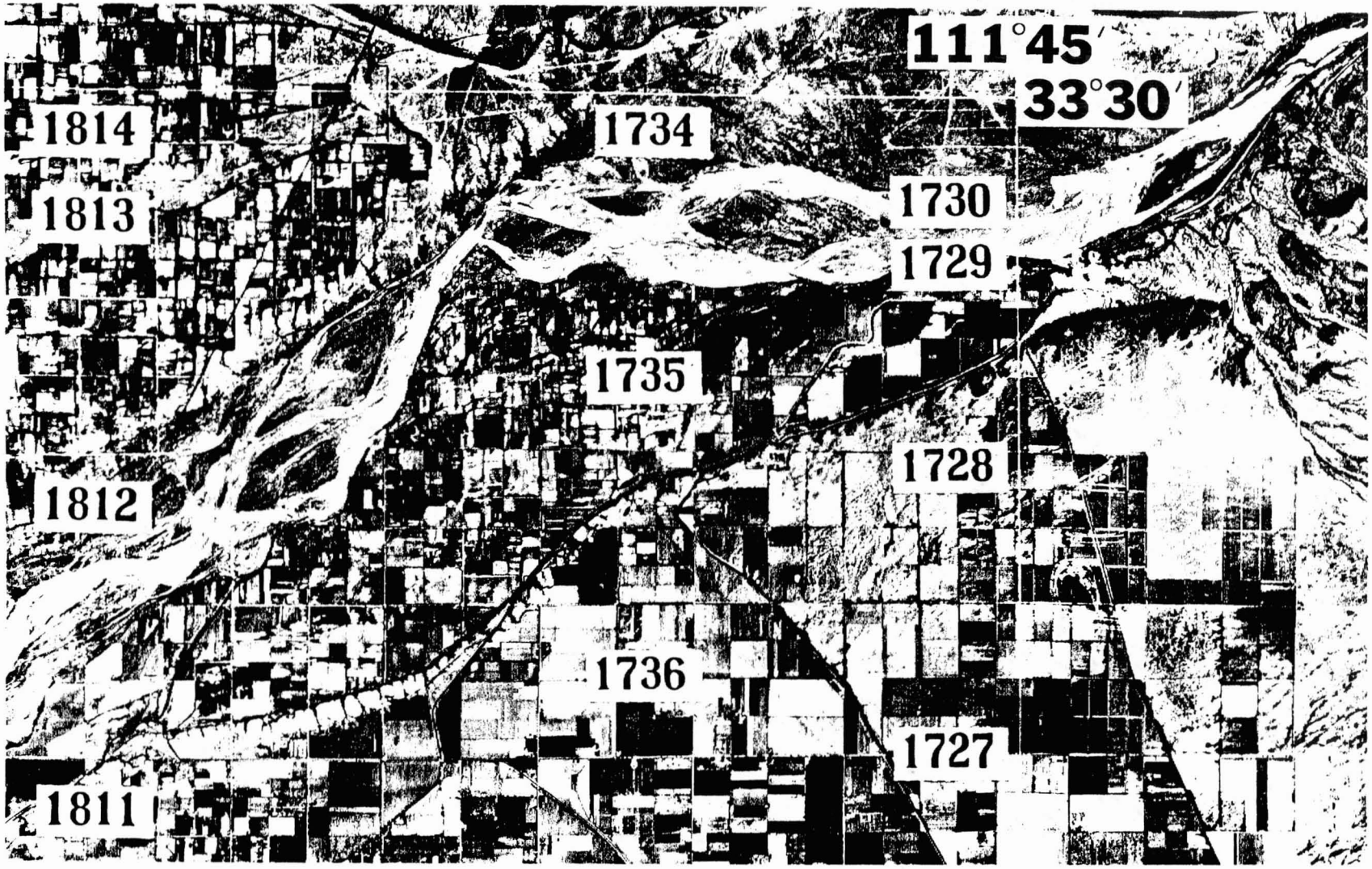


8.8 Aerial Photographs of the Lower Salt River, 1937

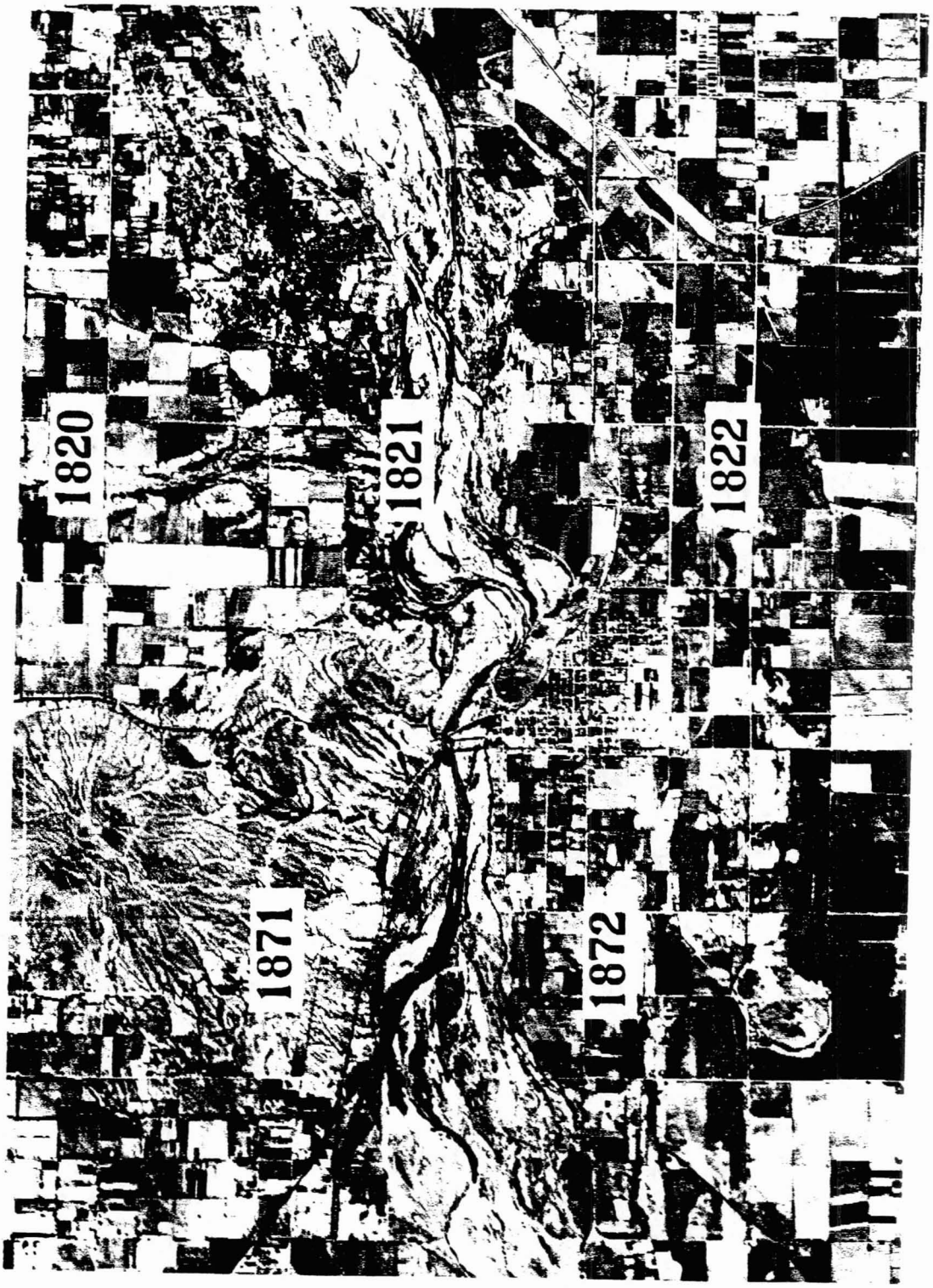
The following pages contain aerial photographic coverage of the entire study area taken in 1937. The negatives for the individual frames of aerial photography are stored in the U.S. National Archives, Washington, D.C., Document Record 114. The images on the following pages are taken from the photo index sheets which are constructed from groups of individual frames identified by black numbers in white rectangles. The index sheets are identified by the the 15' latitude and longitude identifers of the corners. The original index sheets had some overlap, and included the following sheets:

Sheet Number	Upper Left Corner	Lower Right Corner
1	112 Degrees, 00 Minutes West, 33 Degrees, 30 Minutes North	111 Degrees, 45 Minutes West, 33 Degrees, 15 Minutes North
2	112 Degress, 15 Minutes West, 33 Degrees, 30 Minutes North	112 Degrees, 00 Minutes West, 33 Degrees, 15 Minutes North
3	112 Degrees, 30 Minutes West, 33 Degrees, 30 Minutes North	112 Degrees, 15 Minutes West, 33 Degrees, 15 Minutes North

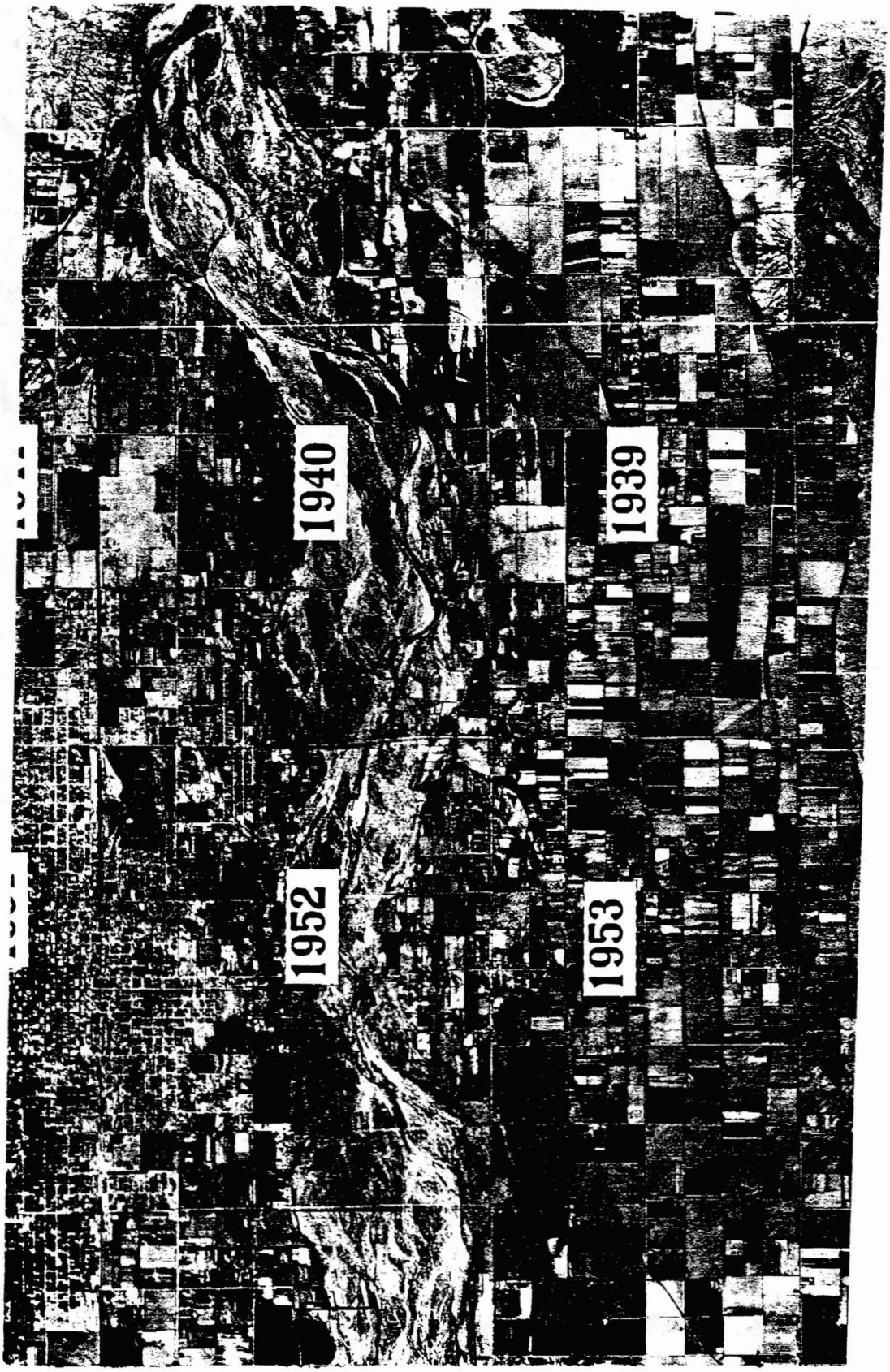
8.8.1 Granite Reef to Dobson Road



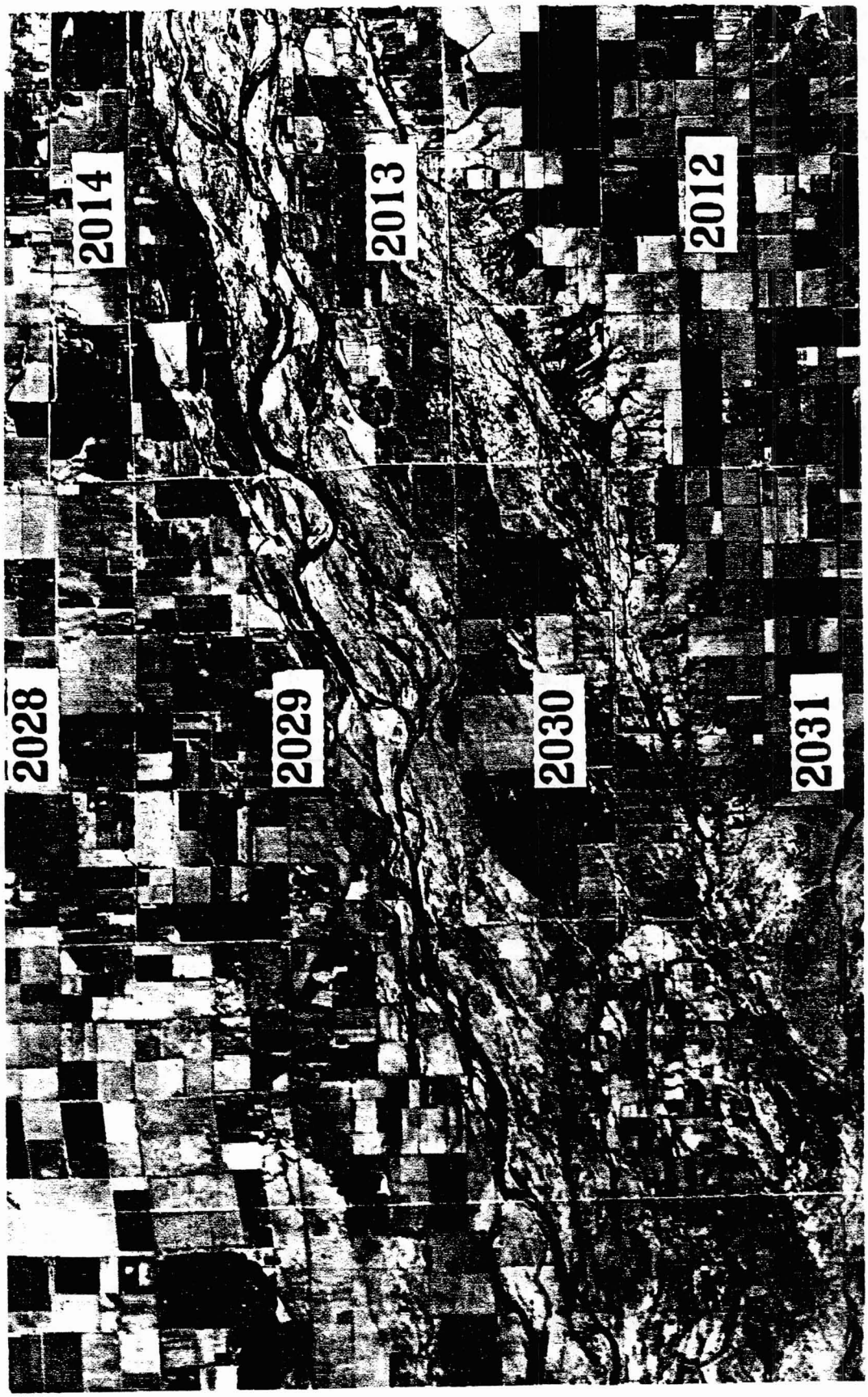
8.8.2 Dobson Road to 40th Street



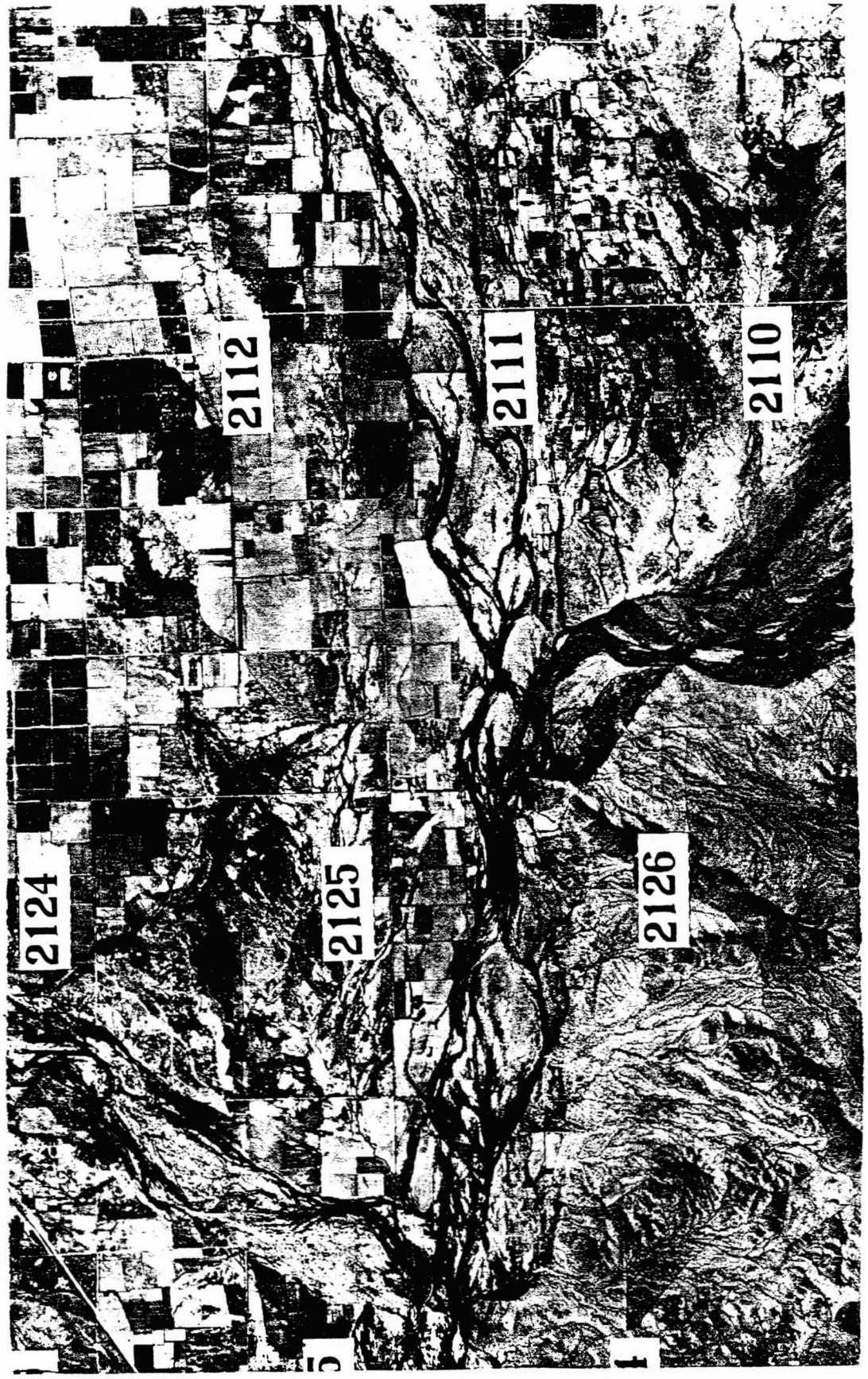
8.8.3 48th Street to 16th Avenue



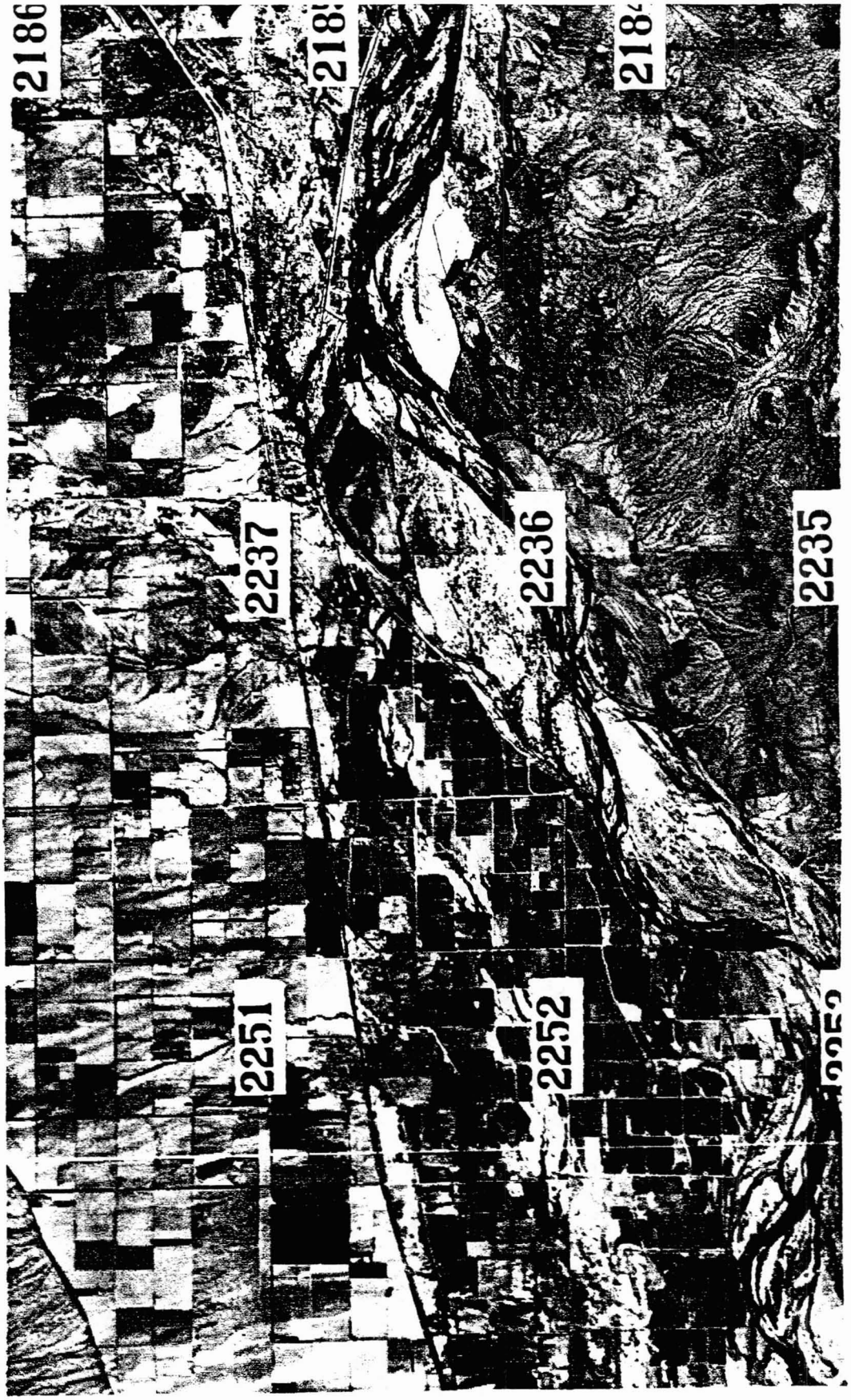
8.8.4 16th Avenue to 99th Avenue



8.8.5 99th Avenue to Litchfield Road



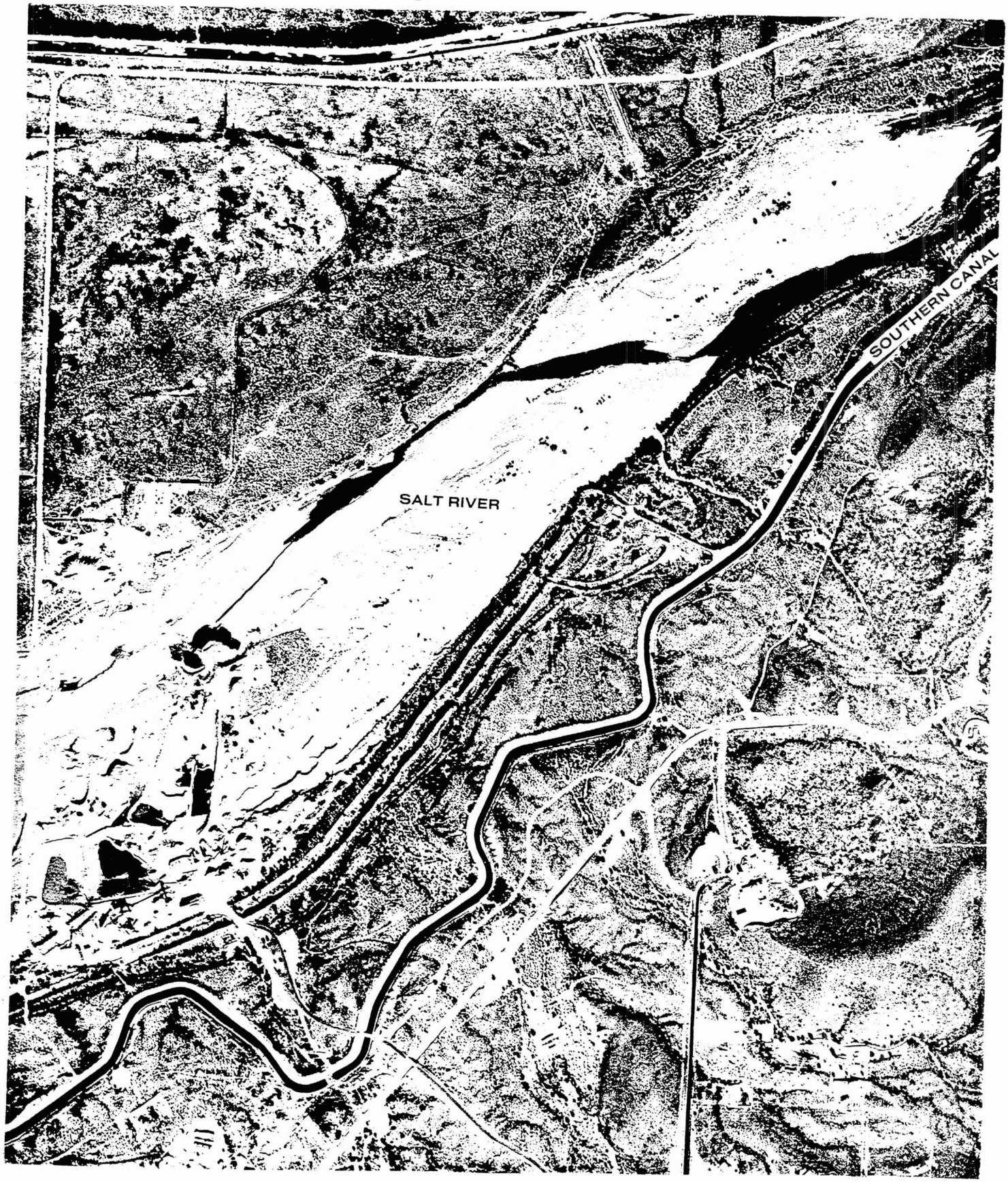
8.8.6 Litchfield Road to Airport Road



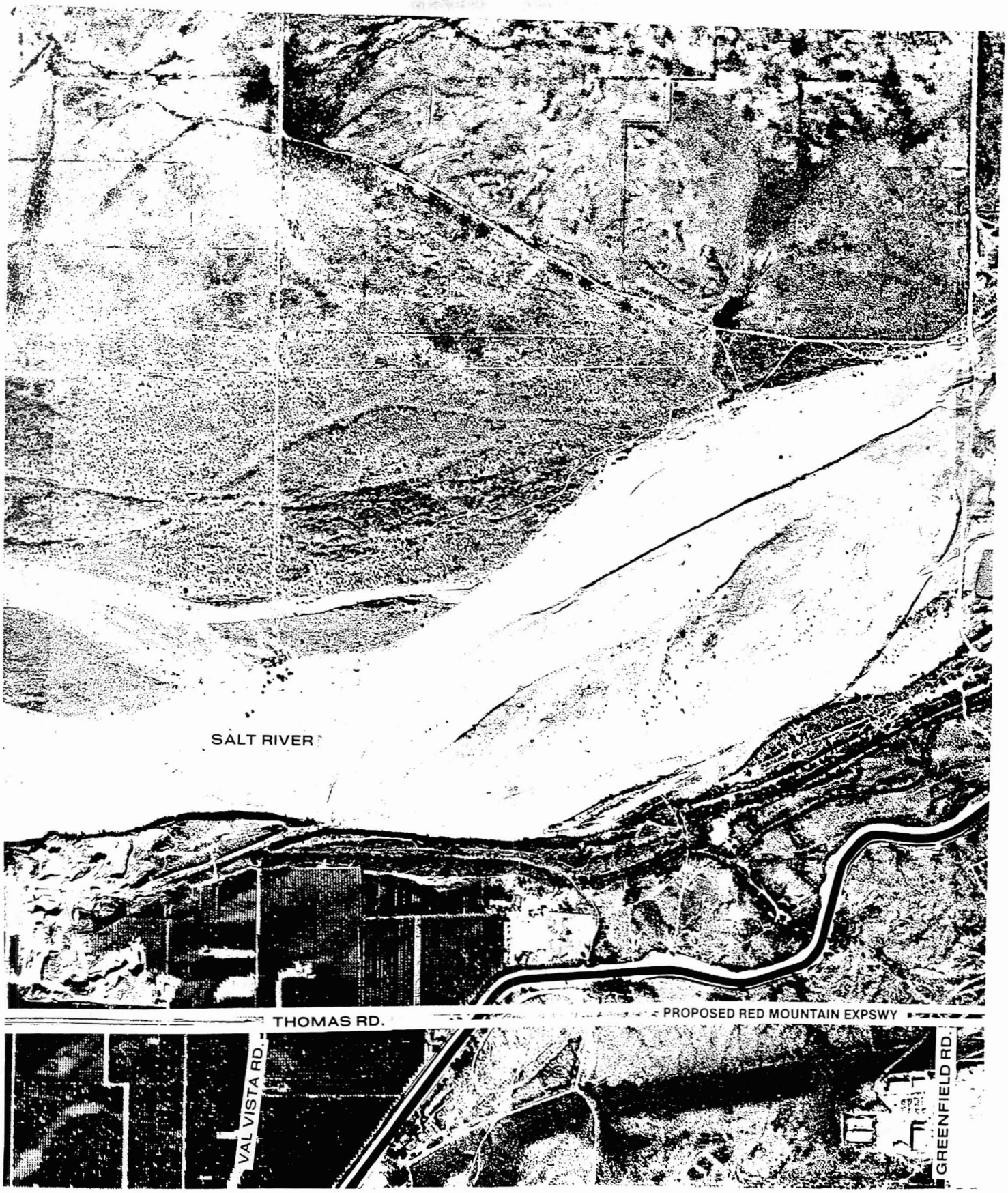
8.9 Aerial Photography of the Lower Salt River, 1987

The following pages contain portions of aerial photographs which, taken together, show the river in the entire study area with the exception of two segments that were not covered in the original photography: the river immediately downstream from Granite Reef Dam, and a segment of the channel upstream from the Country Club Crossing. The original photographs were taken by Rupp Aerial Survey, Inc. in 1987. In there original presentation, Rupp provided the photographs in large format book form, with the book designed such that on the right side of the open book, the photograph is displayed. On the left leaf, a map of the same area is show that includes property boundaries, ownership, and zoning designations.

8.9.1 Vicinity of Higley Road Alignment

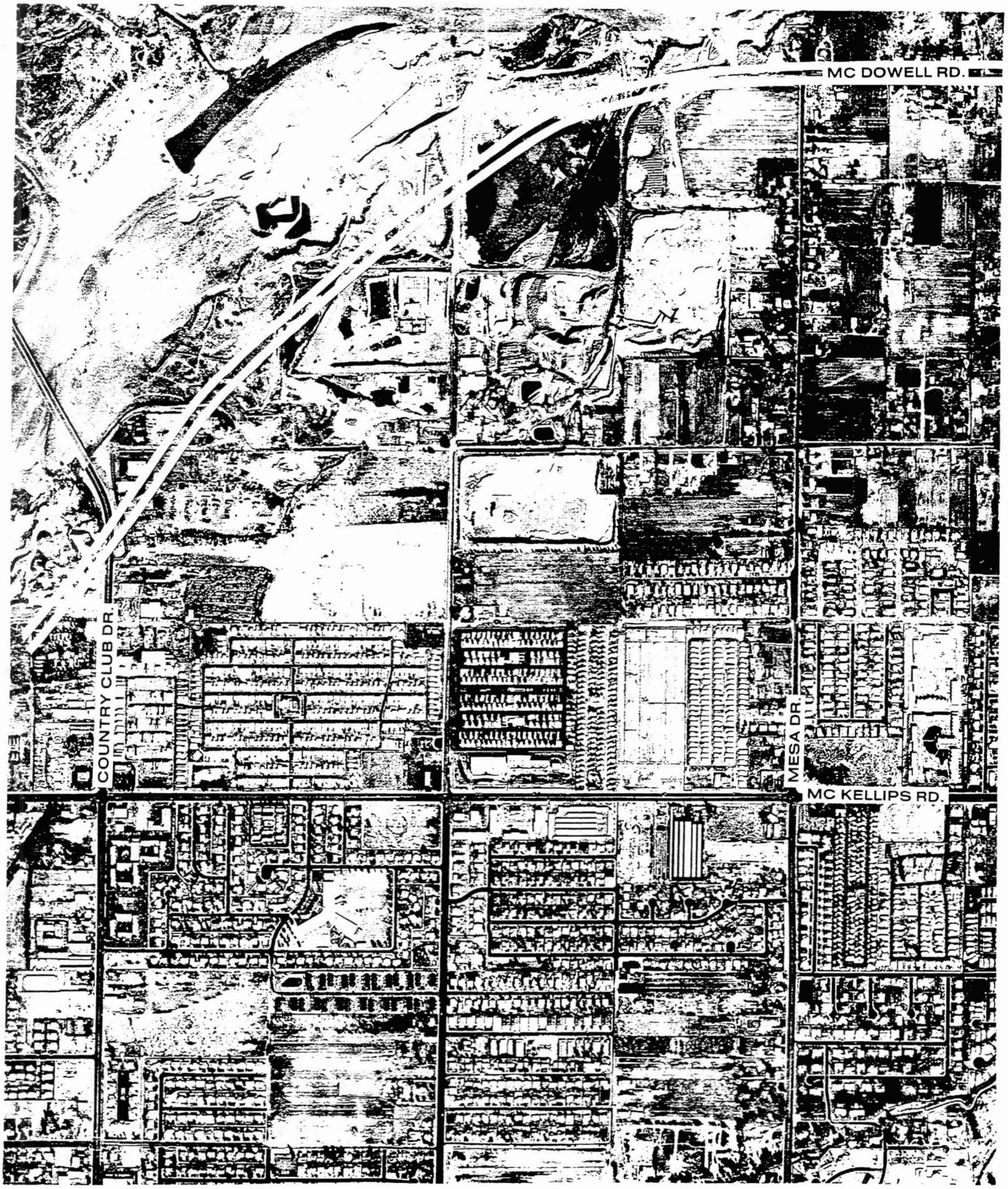


8.9.2 Vicinity of Greenfield Road Alignment

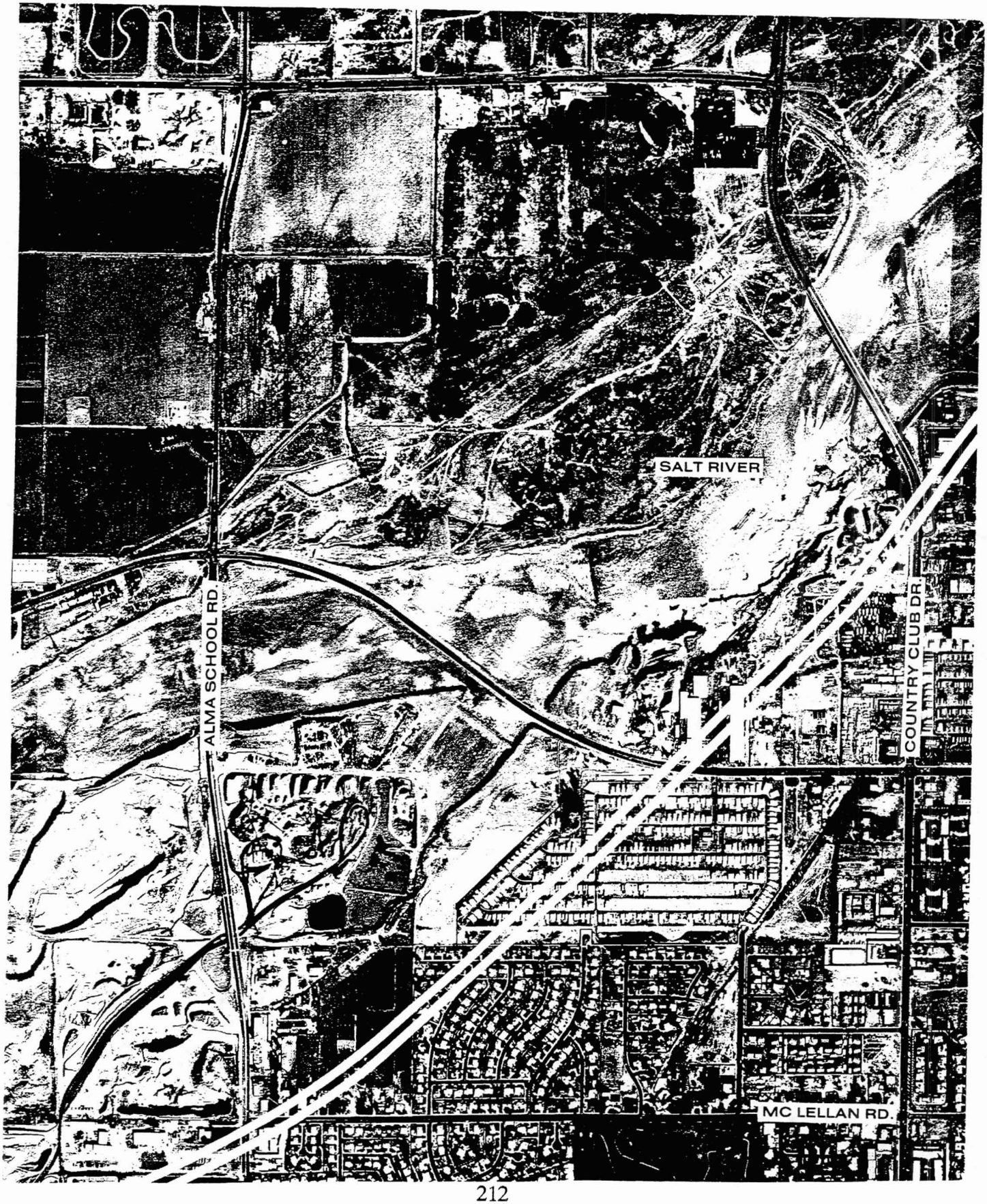


8.9.3 Vicinity of Lindsay Road Alignment

8.9.4 Vicinity of Center Street Alignment

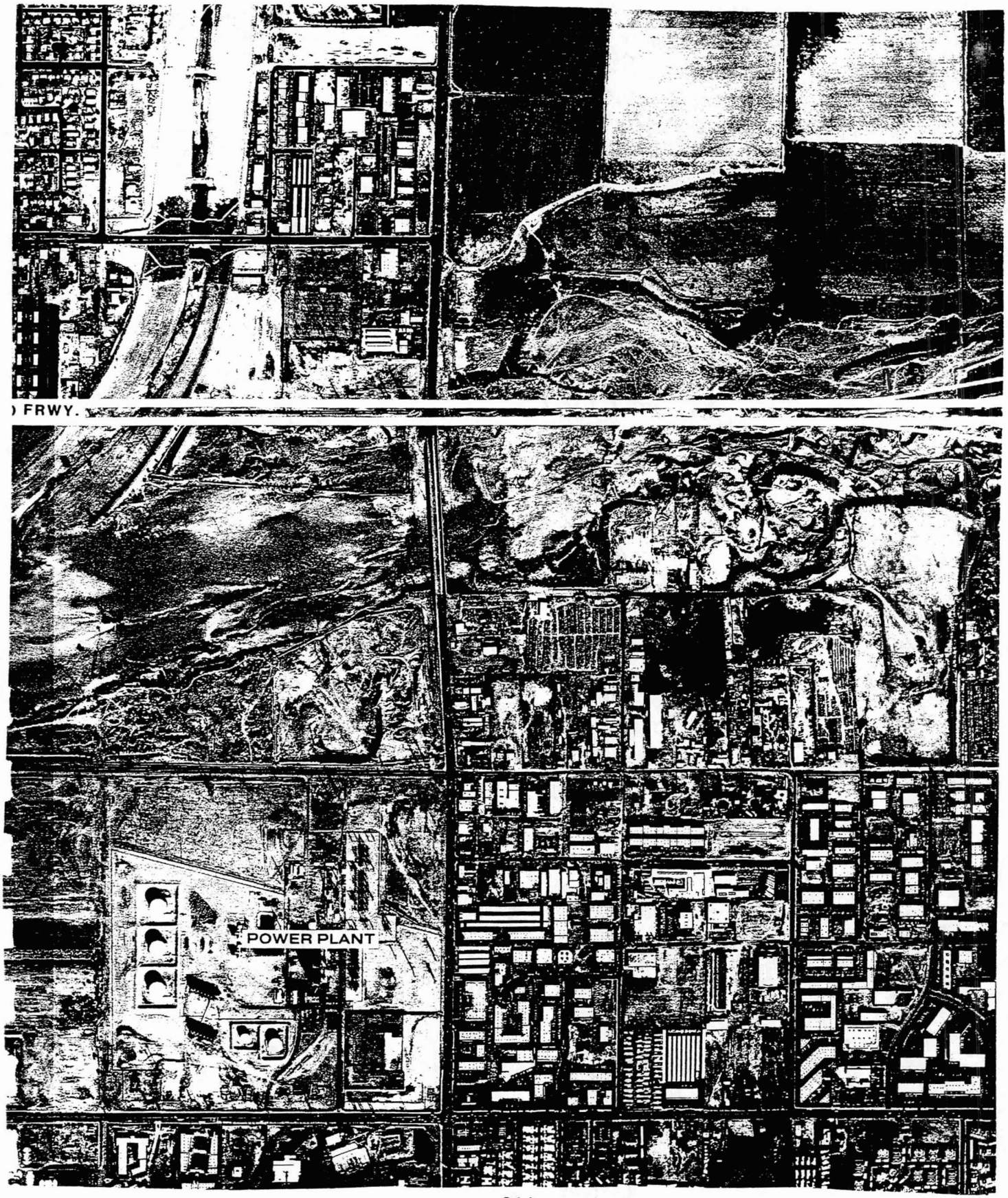


8.9.5 Vicinity of Alma School Road Crossing

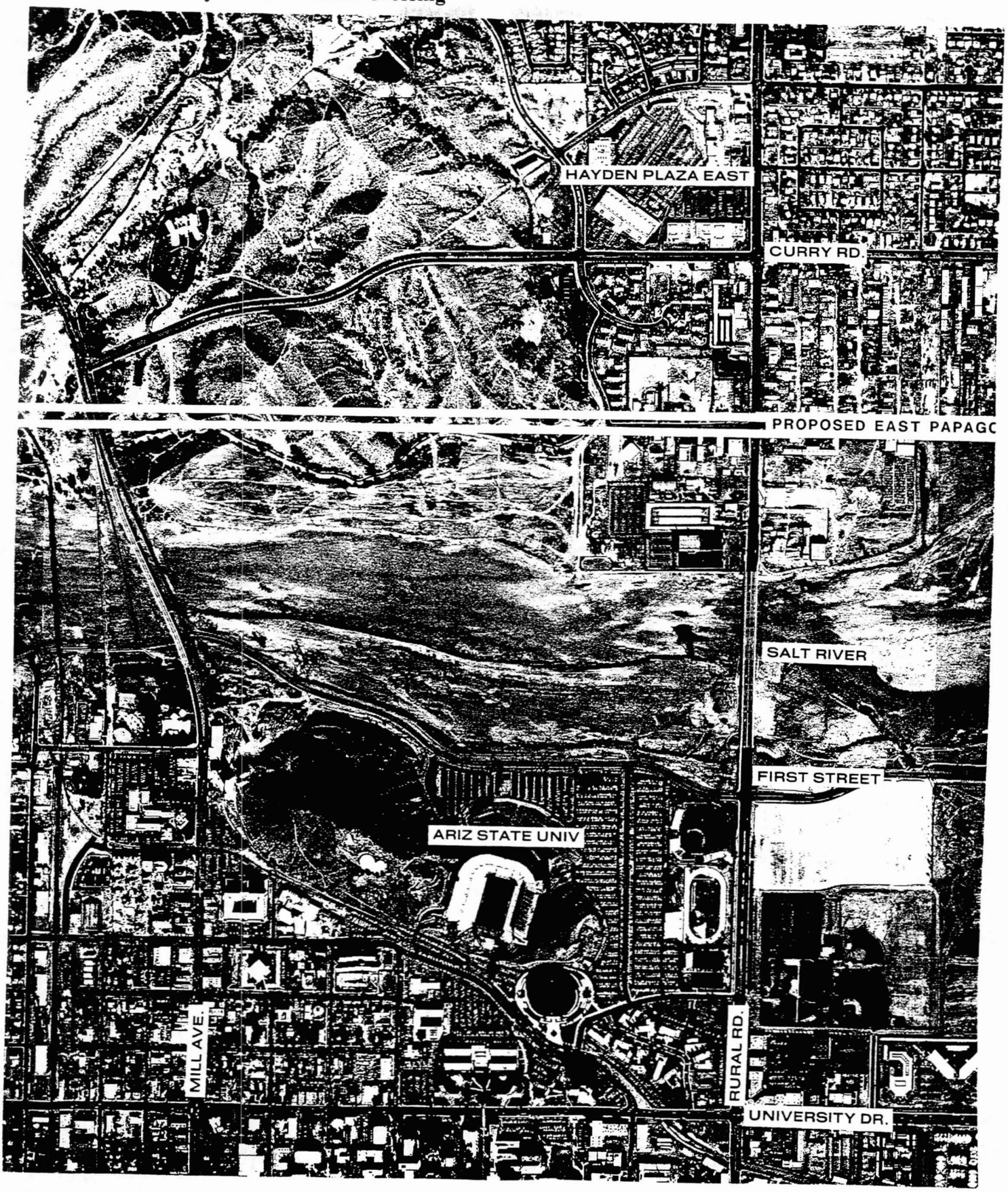


8.9.6 Vicinity of Dobson Road Alignment

8.9.7 Vicinity of McClintock Drive Crossing



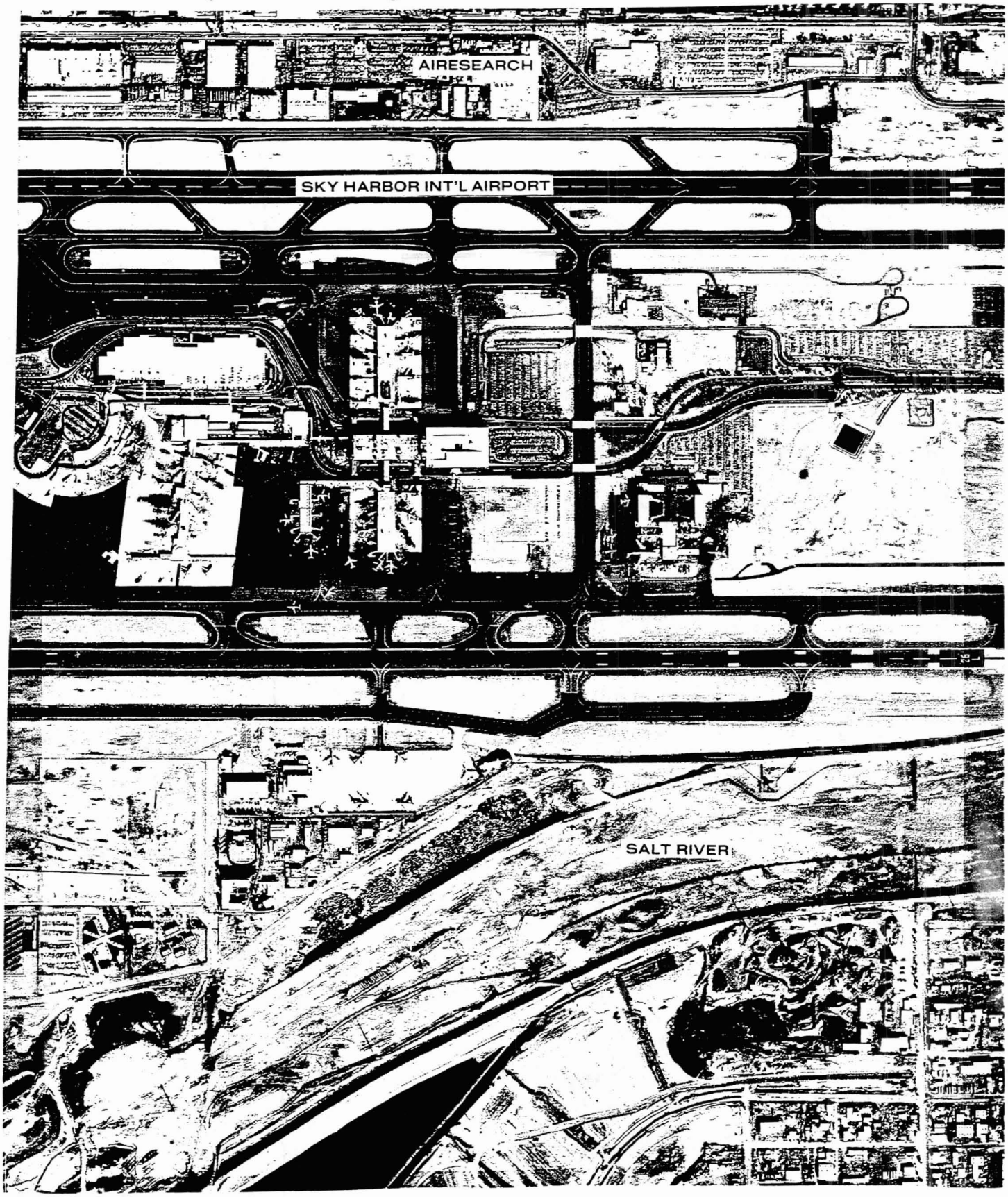
8.9.8 Vicinity of Mill Avenue Crossing



8.9.9 Vicinity of Priest Drive Crossing

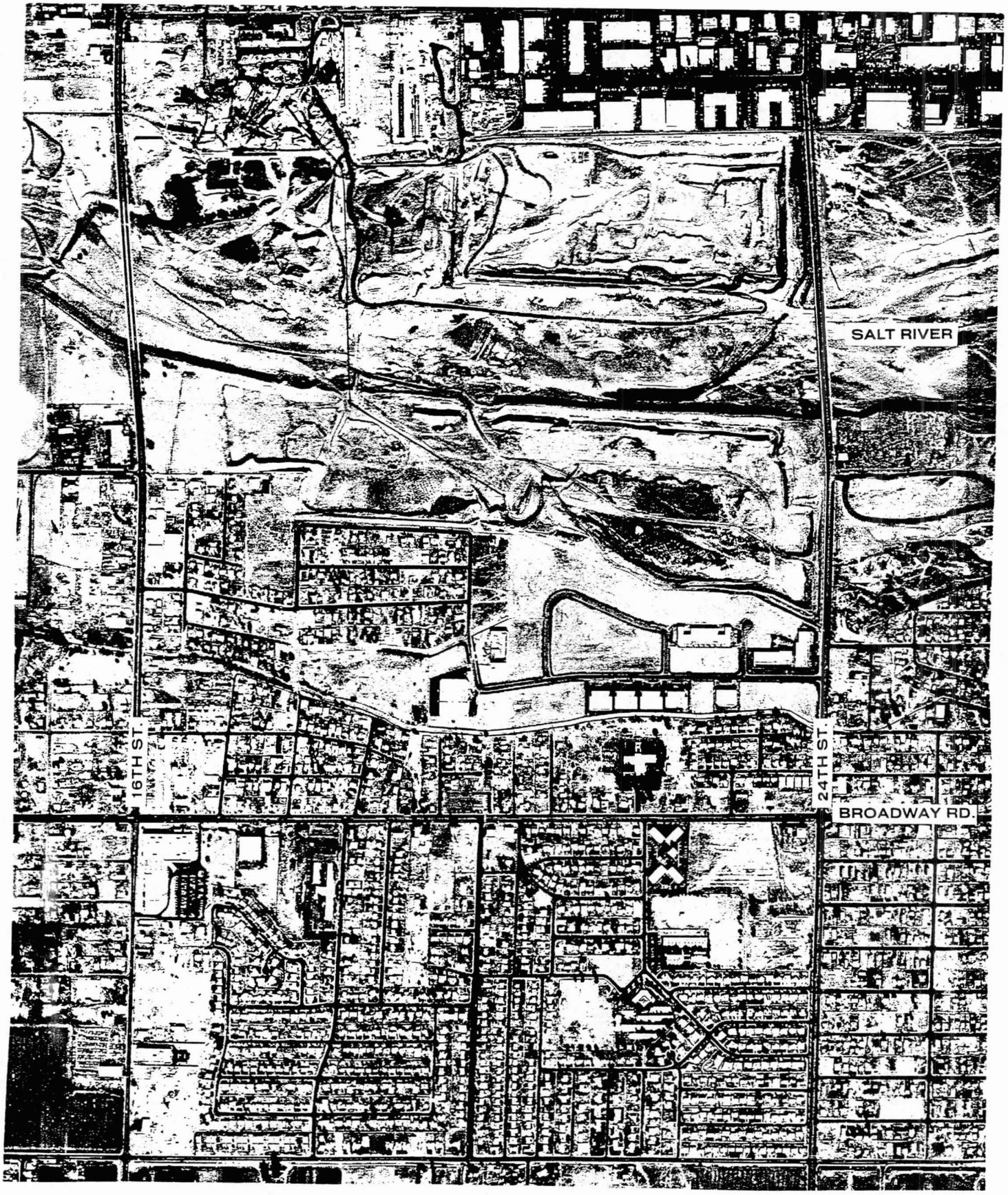
8.9.10 Vicinity of Hohokam Expressway Crossing

8.9.11 Vicinity of 40th Street Alignment

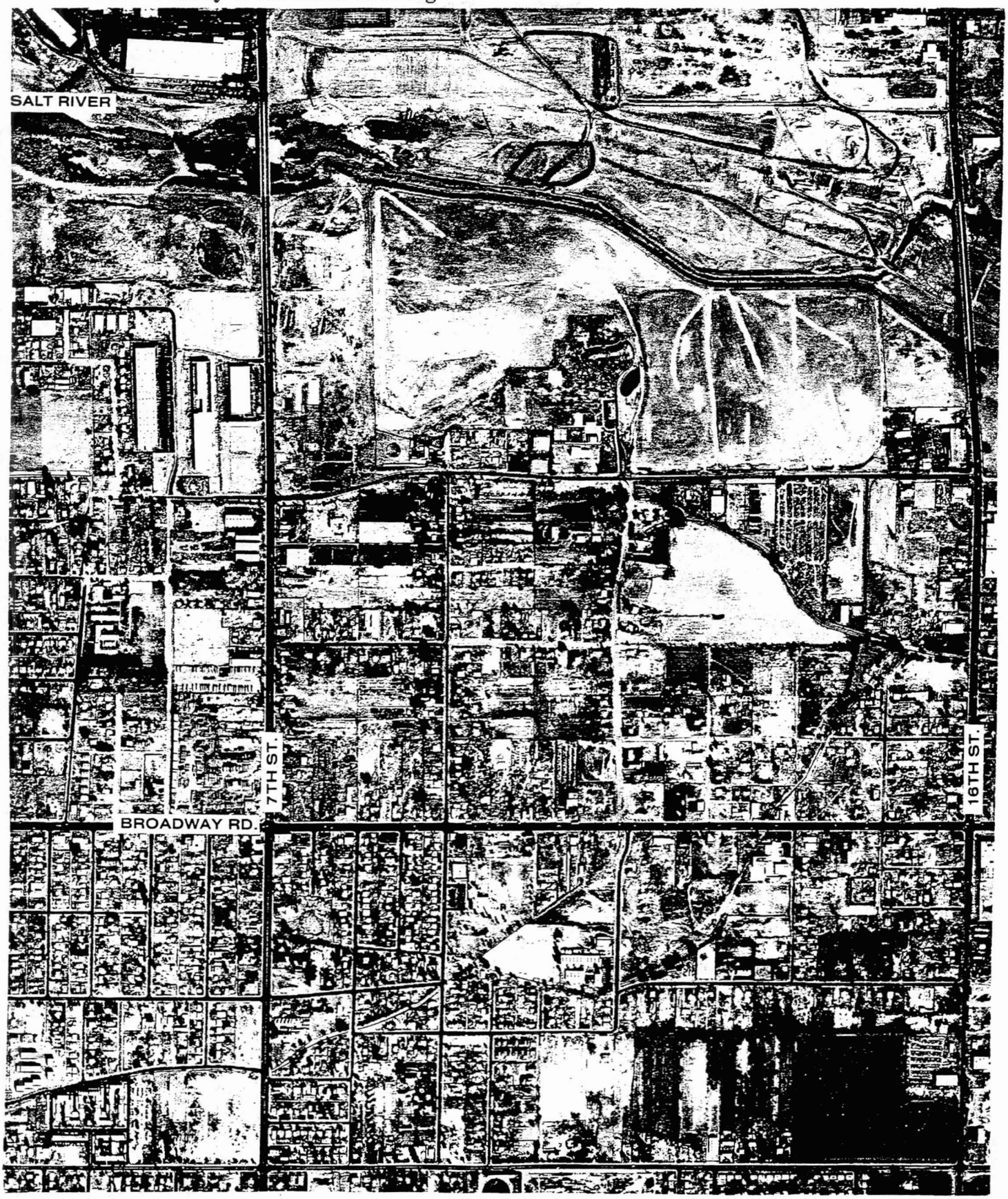


8.9.12 Vicinity of I-10 Freeway Crossing

8.9.13 Vicinity of 16th Street Crossing

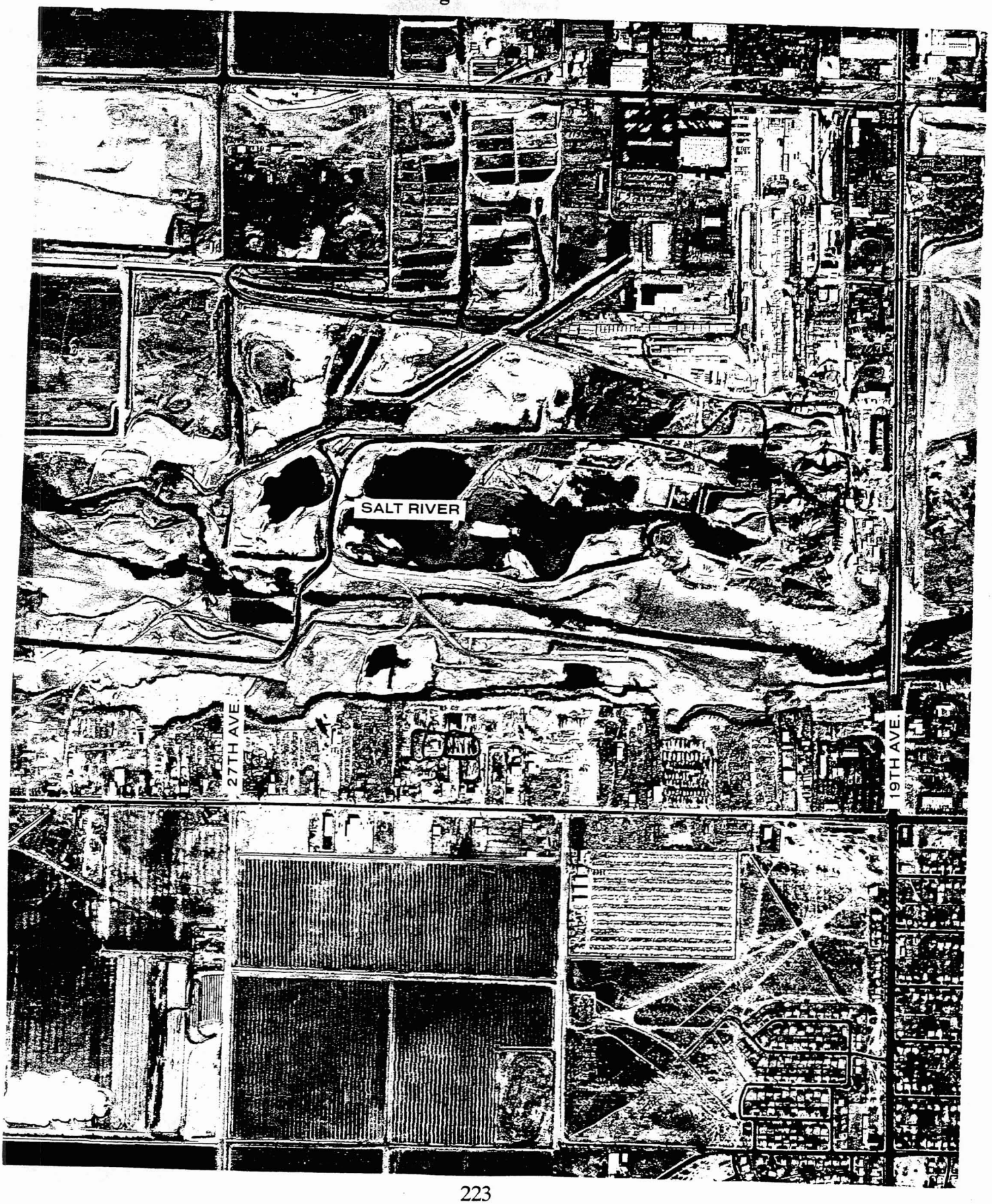


8.9.14 Vicinity of 7th Street Crossing



8.9.15 Vicinity of 7th Avenue Crossing

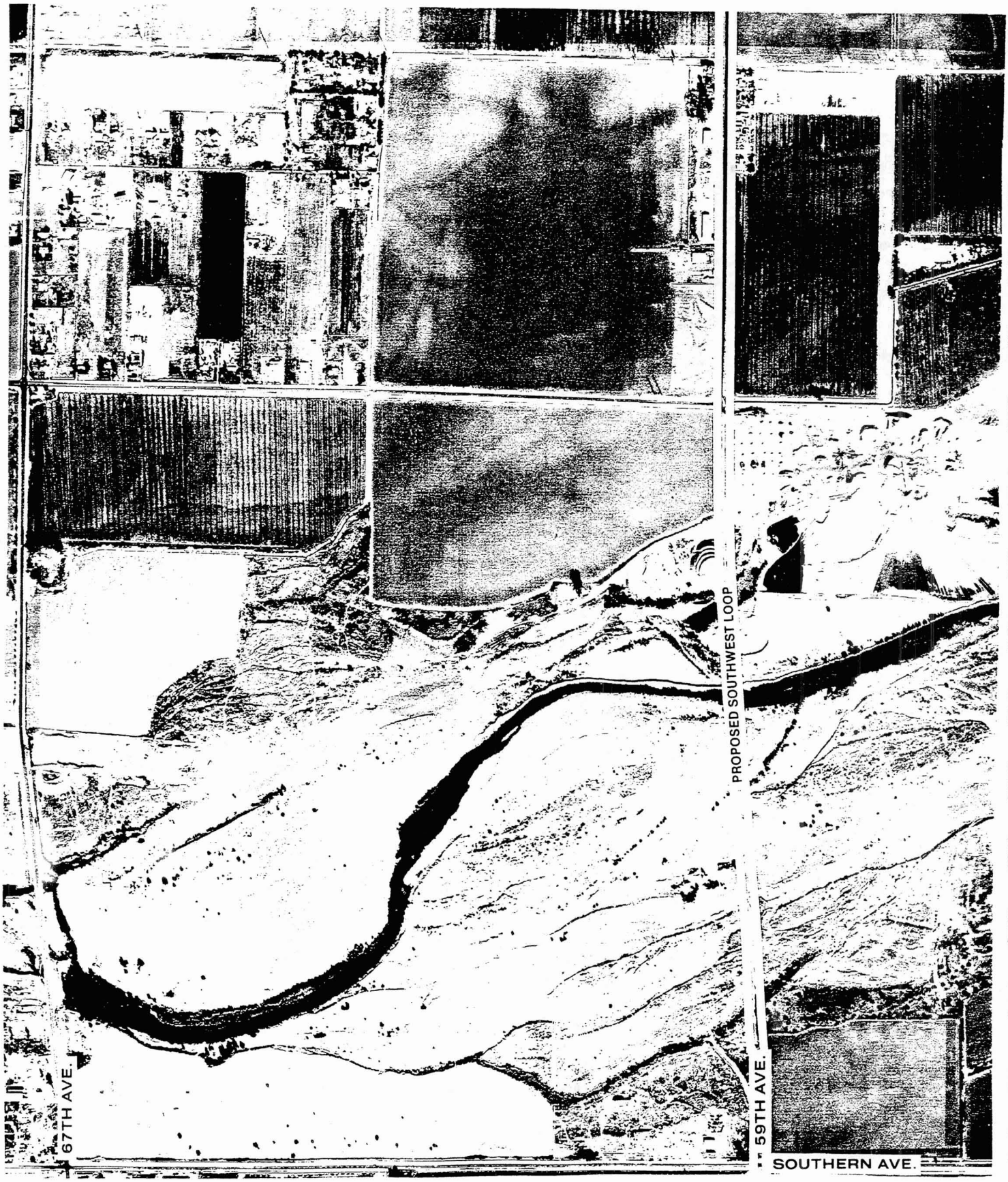
8.9.16 Vicinity of 27th Avenue Crossing



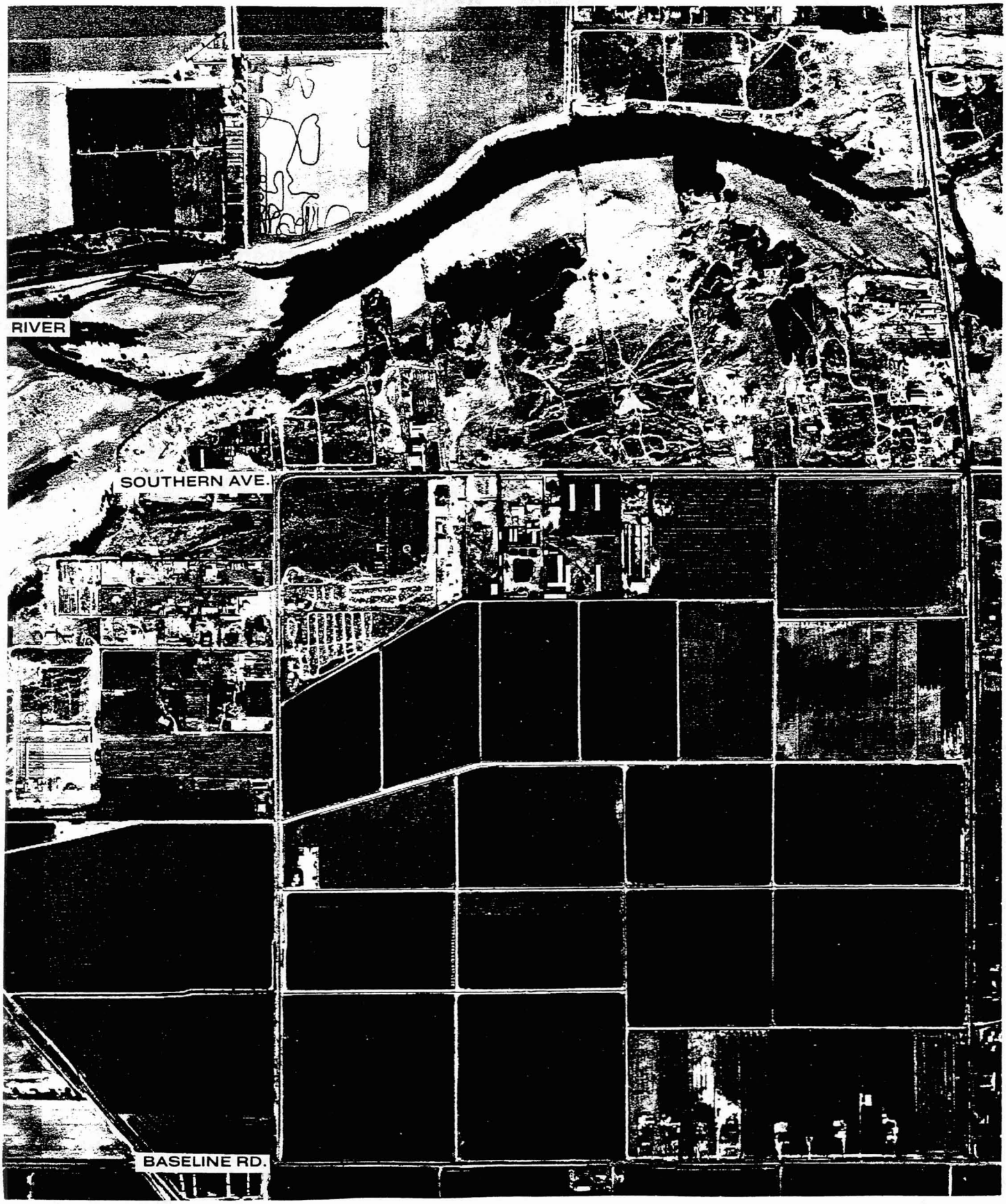
8.9.17 Vicinity of 43rd Avenue Crossing

8.9.18 Vicinity of 51st Avenue Crossing

8.9.19 Vicinity of 67th Avenue Crossing

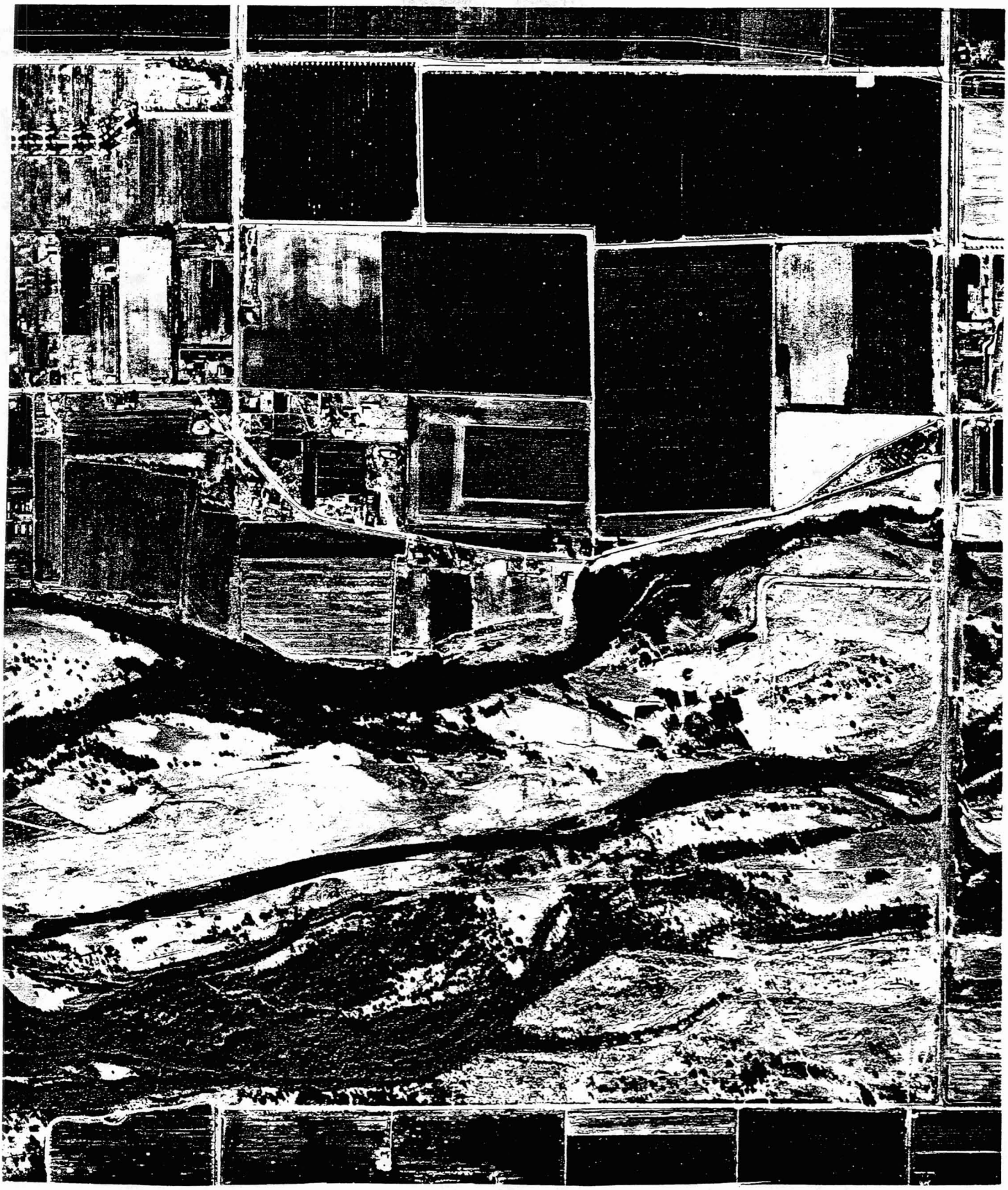


8.9.20 Vicinity of 75rh Avenue Alignment

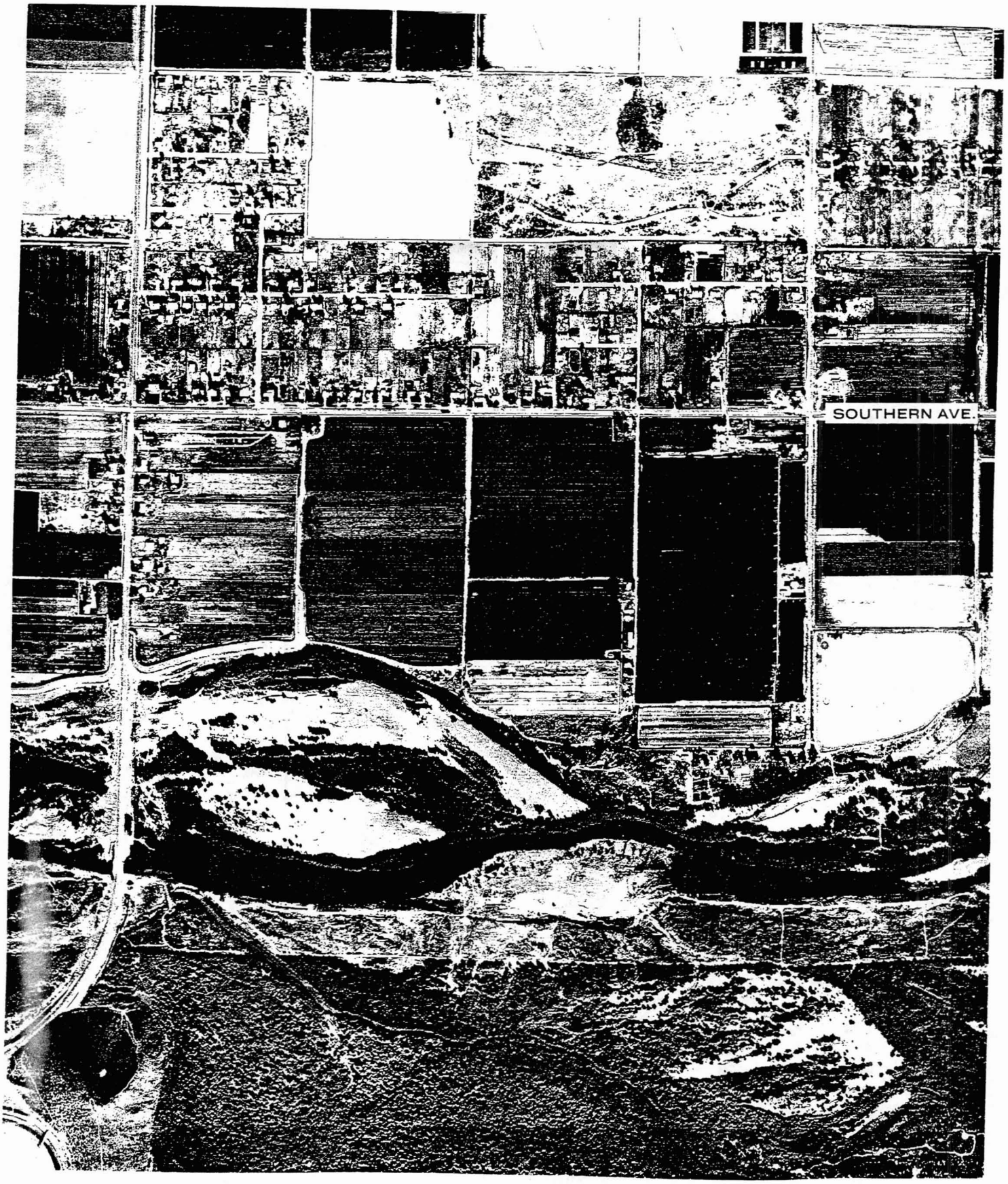


8.9.21 Vicinity of 91st Avenue Crossing

8.9.22 Vicinity of 99th Avenue Crossing



8.9.23 Vicinity of 115th Avenue Crossing



8.10 Discharge Data

8.10.1 Annual Peak Flows of the Salt River at Granite Reef Dam (Source: Salt River Project)

Year	Peak Flow (cfs)	Total Volume (a-f * 1000)
1891	285,000	2,050
1892	1,650	24
1893	37,000	179
1894	2,400	80
1895	80,000	620
1896	10,000	100
1897	35,000	204
1898	2,400	48
1899	5,500	68
1900	4,700	49
1901	11,000	240
1902	6,000	35
1903	22,000	215
1904	18,000	193
1905	65,200	1,442
1906	70,000	814
1907	50,000	517
1908	45,000	342
1909	13,000	258
1910	10,000	910
1911	57,000	1,575
1912	6,000	930
1913	3,500	127
1914	16,000	220
1915	19,000	670
1916	84,000	2,740
1917	28,000	500
1918	28,000	240
1919	46,000	363
1920	87,800	1,100
1921	17,000	122
1922	24,000	356
1923	43,000	343
1924	6,000	32
1925	6,200	28
1926	29,000	195
1927	50,000	454
1928	7,800	27
1929	17,000	78
1930	2,300	15
1931	23,000	120
1932	49,000	275
1933	225	0.5
1934	60	0.1
1935	6,900	90
1936	3,400	8
1937	37,000	400
1938	59,000	210
1939	500	3
1940	2,500	12
1941	32,000	880
1942	0	0

Year	Peak Flow (cfs)	Total Volume (a-f * 1000)
1943	1,300	4
1944	63	1
1945	300	1
1946	400	2
1947	162	1
1948	0	0
1949	300	2
1950	400	2
1951	4,400	16
1952	700	3
1953	32	0
1954	700	4
1955	1,600	6
1956	0	0
1957	400	2
1958	300	1
1959	2,000	17
1960	750	5
1961	125	0
1962	0	0
1963	250	1
1964	500	7
1965	64,000	200
1966	53,000	38
1967	3,000	12
1968	3,700	106
1969	91	0
1970	0	0
1971	0	0
1972	9,000	75
1973	22,000	1,240
1974	268	1
1975	120	0
1976	500	2
1977	0	0
1978	140,000	1,389
1979	88,000	1,997
1980	180,000	2,061
1981	0	0
1982	10,000	178
1983	45,000	1,744
1984	25,604	270
1985	16,500	772
1986	930	6
1987	2,500	30
1988	4,250	20
1989	250	0.5
1990	3,000	0.6
1991	7,000	90
1992	12,300	881
1993	125,000	4,091

8.10.2 Monthly Discharge of the Verde River Below Bartlett Dam (Source: U.S. Geological Survey)

Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1904				237	236	184	119	126	63	729	1625	482
1905	188	210	241	1420	7713	8781	5226	833	283	245	567	771
1906	544	3433	875	812	1202	5468	1029	247	150	234	743	211
1907	181	312	2641	2429	2619	3767	838	251	209	217	430	404
1908	614	375	323	306	1973	1395	301	443	146	462	880	356
1909	265	281	3129	1760	1459	2029	1258	200	135	379	1255	475
1910	160	221	354									
1914	204	339	306	957	3045	716	251	154	114	204	234	230
1915	327	270	652	1241	2448	3591	2180	2663	207	327	349	231
1916	177	249	393	8231	3766	5184	696	232	159	201	508	1296
1917	726	327	340	1222	1496	1760	6005	1253	234	417	727	389
1918	247	243	266	394	904	4613	355	160	137	191	545	190
1919	193	346	458	345	953	1560	1333	173	118	2126	906	471
1920	741	2850	2230	2235	8956	1883	1041	305	209	180	456	228
1921	241	463	342	315	335	522	236	167	126	296	1695	367
1922	442	288	1437	2594	2749	3279	1070	256	163	209	333	240
1923	185	283	1229	347	1222	2207	794	193	116	199	254	1929
1924	270	968	3500	994	358	523	1646	172	99	187	105	202
1925	228	212	433	298	329	413	452	204	124	204	354	1128
1926	779	341	368	298	293	720	4423	408	117	193	248	347
1927	246	215	432	320	7080	2029	809	195	202	259	474	1829
1928	279	297	424	480	1421	995	241	169	112	133	482	189
1929	263	275	303	320	412	1368	2140	149	116	164	581	390
1930	175	217	234	291	443	1341	545	175	99	312	624	283
1931	225	514	356	229	3019	639	252	246	97	161	779	376
1932	213	600	948	478	6454	3640	777	199	137	224	247	134
1933	292	208	294	382	364	726	299	344	148	182	164	321
1934	233	206	253	260	269	226	257	120	106	124	452	215
1935	166	267	317	1046	2236	1971	1000	183	114	120	592	485
1936	238	246	278	265	866	969	692	150	93	223	434	318
1937	211	312	291	461	6333	4076	1420	188	142	216	163	187
1938	205	215	262	272	406	4715	223	128	99	138	290	203
MEAN	305	503	771	1008	2302	2300	1223	345	141	305	564	480

8.10.3 Monthly Discharge of the Salt River at McDowell (Source: U.S. Geological Survey)

Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1904				185	170	164	132	117	64	418	1697	513
1905	269	176	192	2252	10168	14685	13704	5255	1547	568	591	930
1906	444	9954	2048	1661	1769	8011	5105	1642	645	508	897	379
1907	303	377	4819	3782	3207	4645	2489	883	570	421	1120	1180
1908	1182	979	554	411	3978	3898	1673	957	456	827	2190	1147
1909	391	375	3832	1203	3622	3055	3945	544	681	468	1220	2510
1910	485	1127	341									
MEAN PRE-1939	512	2165	1964	1582	3819	5743	4508	1566	661	535	1286	1110

8.10.4 Annual Peak Discharge of Indian Bend Wash at Scottsdale (Source: U.S. Geological Survey)

Year	Discharge (cfs)
1961	142
1962	0
1963	46
1964	41
1965	8.2
1966	147
1967	37
1968	679
1969	0
1970	419
1971	9.2
1972	4380
1973	3980
1974	0.9
1975	15
1976	603
1977	37
1978	933
1979	155
1980	57
1981	97
1982	47
1983	582
1984	901
MEAN 1961-1984	**555**

8.10.5 Significant Releases Into the Salt River at Granite Reef Dam (Source: Salt River Project)

Year	Peak Mean Daily Flow (cfs)	Dates	Total Releases	Total Days
1911	0		0	0
1912	0		0	0
1913	3,700	Feb. 26 - Mar. 16 Mar. 24-25 Apr. 1-9	3	30
1914	15,700	Jan. 28-30 Feb. 19 - Mar. 1 Dec. 19-26	3	21
1915	18,700	Jan. 30 - Feb. 6 Feb. 12-23 Mar. 18 - Apr. 6 Apr. 18 - May 24 Aug. 27 Sept. 3 Dec. 31	7	80
1916	79,100	Jan. 16 - May 15 Sept. 9-12 Oct. 8-10	3	128
1917	23,100	Jan. 20 - Feb. 2 Feb. 24 - Mar. 7 Apr. 18 - May 1	3	39
1918	28,400	Feb. 26-28 Mar. 8-16 Aug. 7-13	3	19
1919	46,200	Feb. 2-3 Mar. 28 - Apr. 4 July 14-22 Aug. 2-4 Nov. 26 - Dec. 3	5	30
1920	87,800	Jan. 5-9 Feb. 9-16 Feb. 20 - Apr. 16	3	58
1921	15,900	Jul. 25 Aug. 1-2 Aug. 22-23 Dec. 28-30	4	8
1922	24,100	Jan. 3-7 Feb. 10-15 Feb. 21-22 Mar. 17-30	4	17

Year	Peak Mean Daily Flow (cfs)	Dates	Total Releases	Total Days
1923	42,000	Mar. 5-13 Sept. 19-20 Nov. 11-14 Dec. 27-31	4	19
1924	5,990	Jan. 1-4 Apr. 3-4 Apr. 10-11	3	8
1925	6,200	Sept. 18-23 Oct. 7-8	2	8
1926	28,800	Apr. 15-17 Apr. 20-21	2	15
1927	49,800	Feb. 15 - Mar. 2 Sept. 13-15	2	18
1928	7,820	Feb. 5-9	1	5
1929	17,200	Apr. 5-9 Mar. 12-13	2	7
1930	2,290	Mar. 23-24 Aug. 9-10	2	4
1931	22,900	Feb. 13-19 Dec. 10-11	2	9
1932	48,700	Feb. 10 - Mar. 6 Mar. 10-14 Mar. 19-22	3	35
1933	0		0	0
1934	0		0	0
1935	6,827	Jan. 12-13 Jan. 16-17 Feb. 7-11 Feb. 15-16 Mar. 4-5	5	13
1936	4,000	Feb. 25	1	1
1937	36,891	Feb.7-11 Feb. 15-21 Mar. 13-21	3	21
1938	57,554	Mar. 1-8 Mar.13-14	2	10
1939	0		0	0
1940	2,495	Dec. 25 Dec. 30-31	2	3
1941	32,206	Feb. 8-9 Feb. 13-14 Feb. 17 - May 18	3	95
1942 through 1964	0		0	0

Year	Peak Mean Daily Flow (cfs)	Dates	Total Releases	Total Days
1965	67,000	Apr. 20-23 Dec. 31	2	4 1
1966	53,000	Jan. 1-11 Feb. 12 - Mar. 4	2	33
1967	2,950	Dec. 19-20	1	2
1968	3,703	Feb. 14-19 Feb. 25 - Mar. 1 Mar. 10-15 Apr. 15-22	4	26
1969	0		0	0
1970	15,000	Sept. 5-6	1	2
1971	0		0	0
1972	10,000	Jun. 22 Oct. 6 Nov. 22 Dec. 26-31	4	9
1973	1,000 4,100 22,000	Jan. 1-8 Feb. 21-28 Mar. 2 - May 29	1 1 1	8 8 89
1974	0		0	0
1975	0		0	0
1976	0		0	0
1977	0		0	0
1978	95,800 110,000	Mar.1 - Apr. 10 Dec. 17 - Dec. 31	2 1	41 15
1979	87,500	Jan. 1 - June 3	4	154
1980	9,300 137,725	Jan. 20 - Feb. 12 Feb. 14 - June 2	1 2	13 78
1981	0		0	0
1982	8,970 3,159 6,385	Mar. 13-25 Mar. 29 - Apr. 10 Dec. 10-31	1 1 1	13 5 22
1983	30,000 45,000 11,200	Jan. 1 - May 31, June 3-16 Oct. 1 - Nov. 10 Dec. 25-31	6 1 1	165 41 7
1984	1,864 25,604	Jan. 1-19 Dec. 22-31	1 1	19 10
1985	16,500 1,730	Jan. 1 - May 15 Dec. 9-31	1 1	135 23
1986	4 930	Jan. 1-17 Mar. 28 - Apr. 8	1 1	17 12
1987	2,500	Feb. 22-27 Mar. 16 - Apr. 15	2	37

Year	Peak Mean Daily Flow (cfs)	Dates	Total Releases	Total Days
1988	907	Feb. 22-23, Feb. 26 - Mar. 2	2	8
	4,250	Apr. 21-22, Apr. 24-29	2	8
	800	Oct. 14-17	1	4
1989	250	Mar. 26-27	1	2
1990	3,000	Aug. 14-15	1	2
1991	7,000	Mar. 1 - Apr. 21	1	52
	1,015	Sept. 3-5	1	3
	400	Oct. 27-28	1	2
	50	Nov. 10-11	1	2
	1,050	Dec. 18-31	1	12
1992	13,100	Jan. 1 - June 20	1	172
	13,600	Aug. 22 - Sept. 7	1	17
	6,600	Dec. 29 - 31	1	3
1993	99,400	Jan. 1 - June 3	1	154

8.11 Water Quality Data

8.11.1 Surface Water Standards for Recreation and Wildlife (Source: Arizona State Department of Health Services, 1977)

Substance	Recreation and Aesthetic Limiting Concentration (ug/l)	Fish, Aquatic Life and Wildlife Limiting Concentration (ug/l)
Arsenic	50	50
Barium	1000	500
Cadmium	10	10
Chromium (Hexavalent)	50	50
Copper	1000	50
Cyanide	200	100
Lead	50	50
Mercury	5	5
Phenol	1	1
Selenium	10	10
Silver	50	50
Zinc	5000	500

8.11.2 Interpretation of Water Quality for Irrigation (Source: Salt River Project, Annual Water Quality Report, 1990)

Quality Parameter	Problems	Parameter Levels		
		No Problems	*Increasing Problems*	*Severe Problems*
Total Dissolved Solids (mg/l)	Salinity effects on crop yield	< 500	500-2000	> 2000
	Deflocculation of clay and reduction in infiltration rate	> 320	< 320	< 128
Boron (mg/l)	Specific ion toxicity	< 0.5	0.5-2.0	2.0-10
Chloride (mg/l)	Water absorbed by roots only	< 142	142-355	> 355
	Water also absorbed by leaves	< 106	> 106	
Nitrogen (mg/l)	May delay harvest time and adversely affect yield or quality of some crops	< 5.0	5.0-30	> 30
Bicarbonate as HCO3 (mg/l)	When water is applied by sprinklers, bicarbonates may cause white carbonate deposits on fruits and leaves	< 90	90-520	> 520

8.11.3 Drinking Water Standards for Organic Constituents (Source: Salt River Project, Annual Water Quality Report, 1990)

Substance	EPA MCL (ug/l)	Arizona Action Level (ug/l)
Volatile Organic Compounds (VOCs)		
Trichloroethene (TCE)	5.0	
Tetrachloroethylene (PCE)		1.0
1,1,1 Trichloroethane (TCA)	200.0	
Chloroform (CHLORO)	100.0	
Bromodichloromethane	100.0	
1,1 Dichloroethane	N/E	
1,2 Dichloroethane (1,2-DCA)	5.0	
1,1 Dichloroethylene (1,1 DCE)	7.0	
Methylene Chloride (METHCHL)		4.7
Benzene	5.0	
1,2 Diochloropropane	1.0	
Trichloroflurometh ane	1.0	
1,3 Dichlorobenzene	750.0	
Herbicides		
Dibromochloropropane (DBCP)		0.025

N/E = No Established Drinking Water Standard

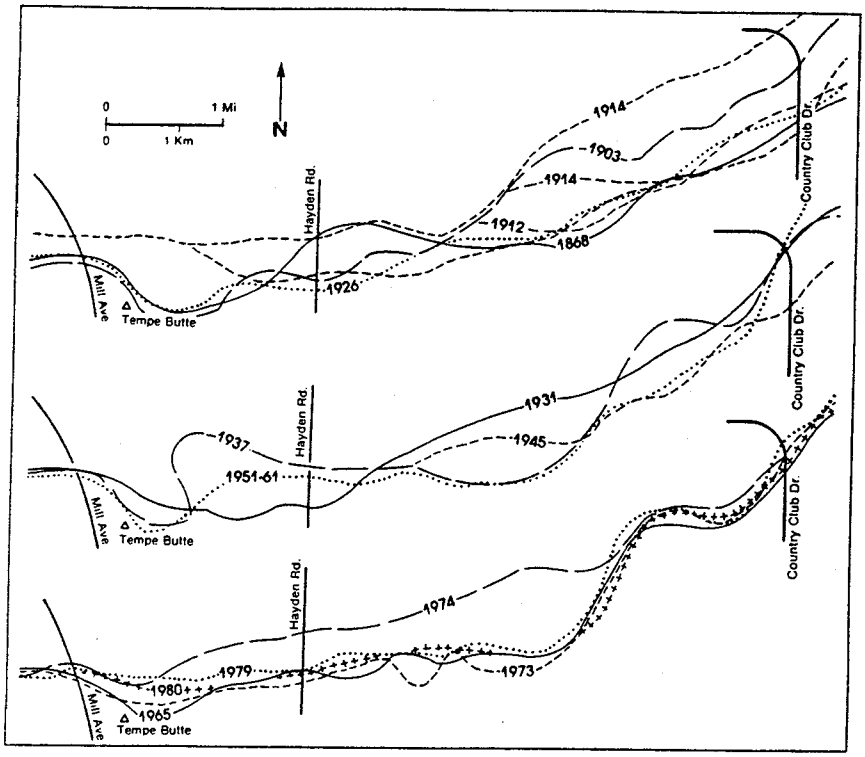
8.12 Additonal Data Sources for Hydrology and Water Quality

To Be Added in Final Report

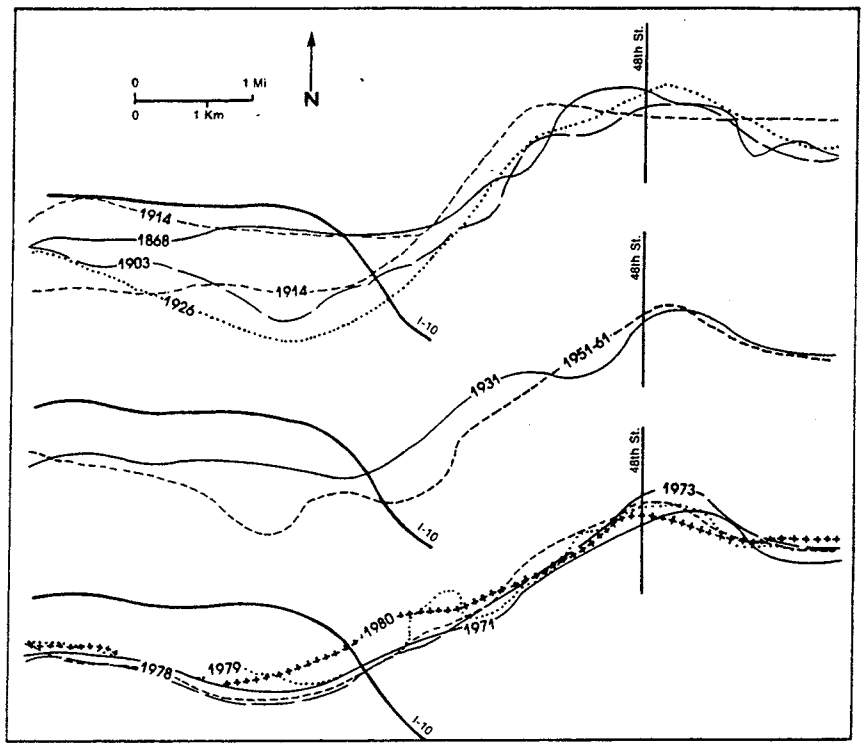
8.13 Historical Thalweg Maps

The following pages contain maps showing the location of the thalweg or low flow channel of the Salt River in the study area. The maps show locations for the period 1868, when accurate maps first became available, and 1980, immediately after the last major flood. They were published by Graf, 1982; 1983. The reach between Granite Reef Dam and Country Club Drive is not included because of lack of data.

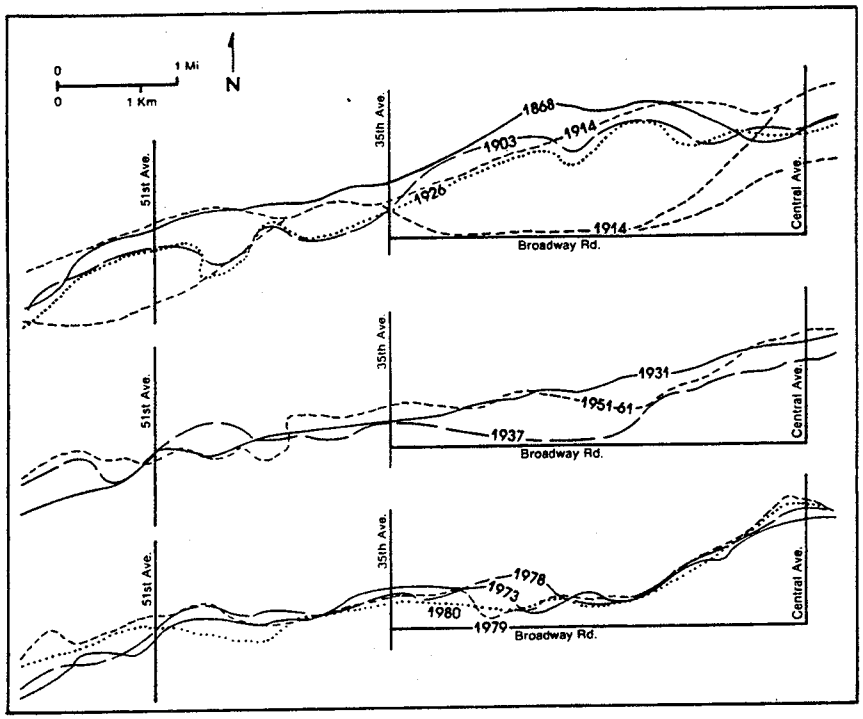
8.13.1 Country Club Drive to Mill Avenue



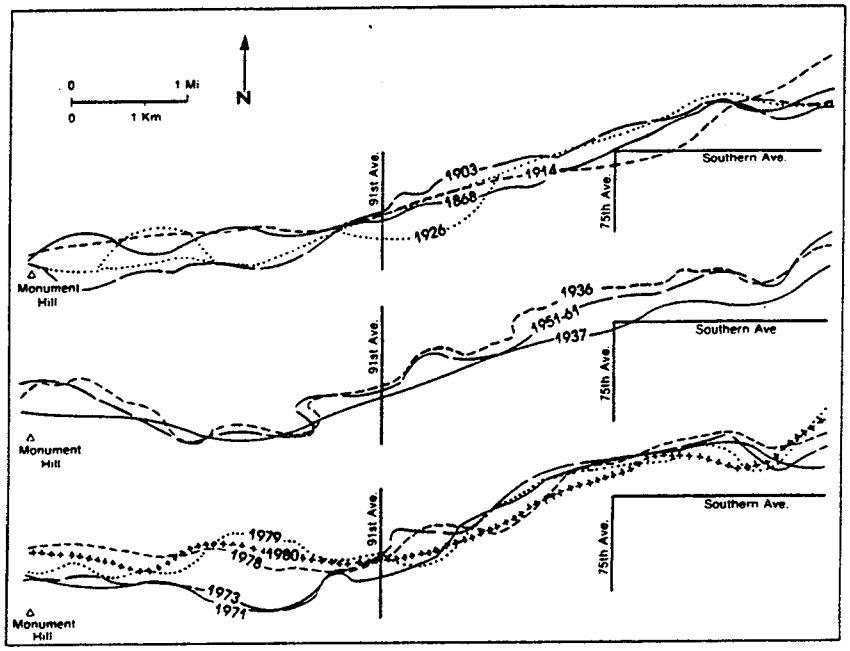
8.13.2 Mill Avenue to 7th Street



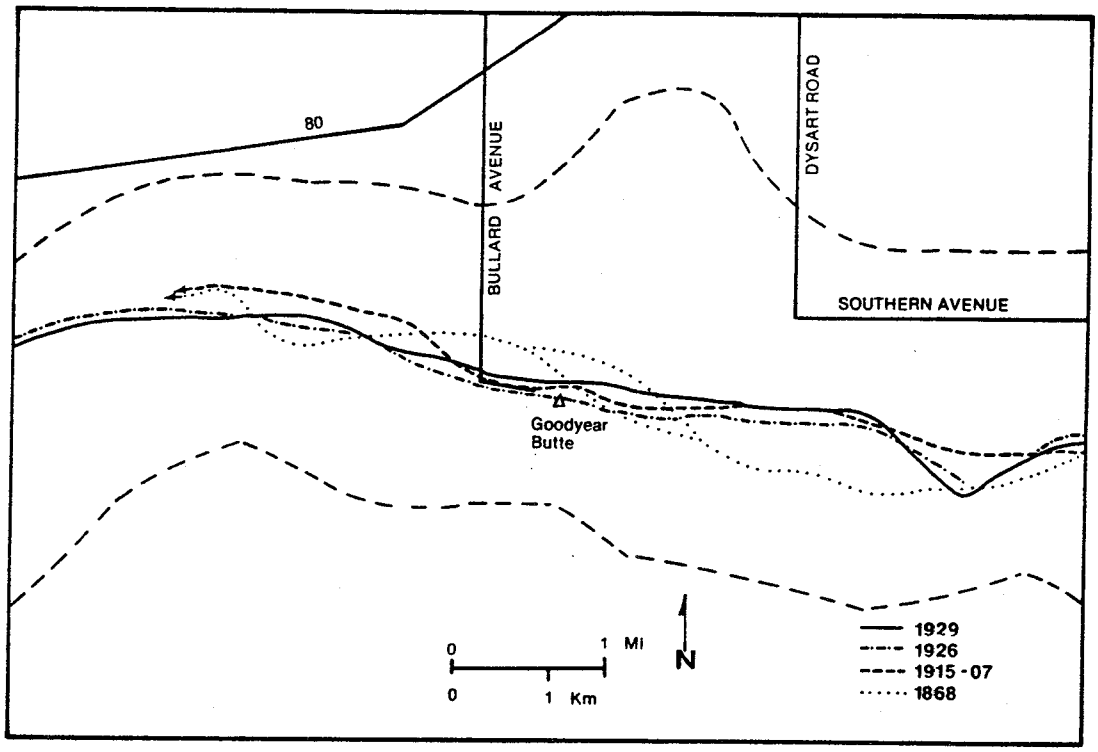
8.13.3 7th Street to 59th Avenue

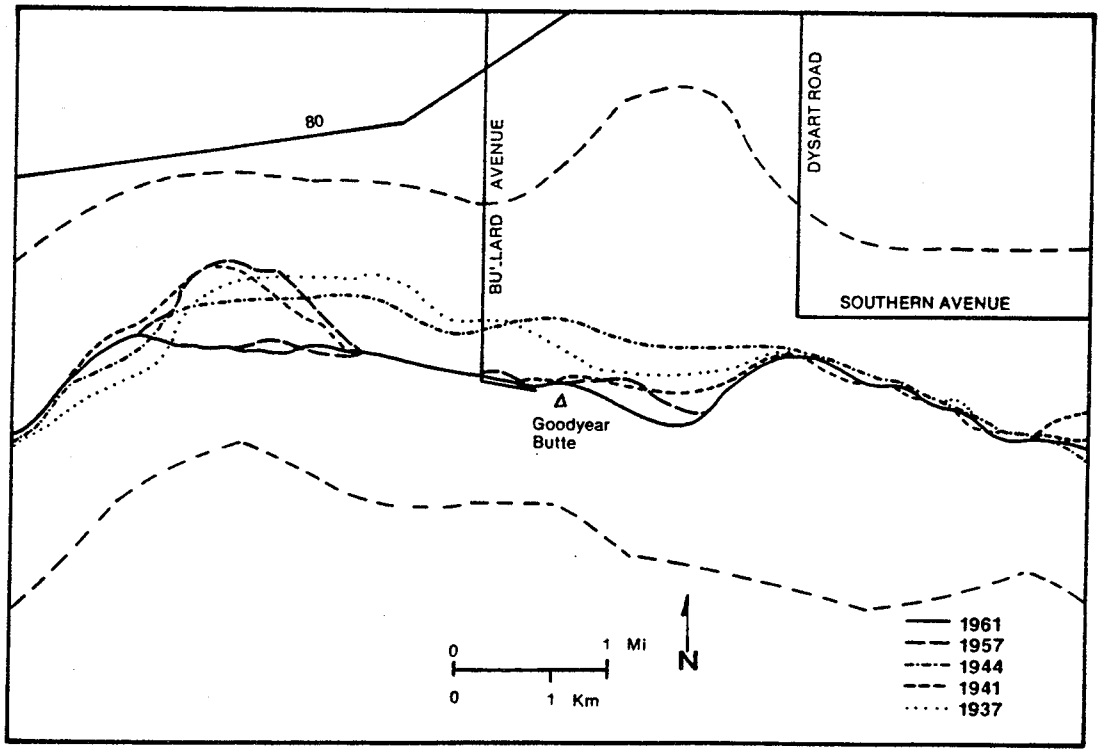


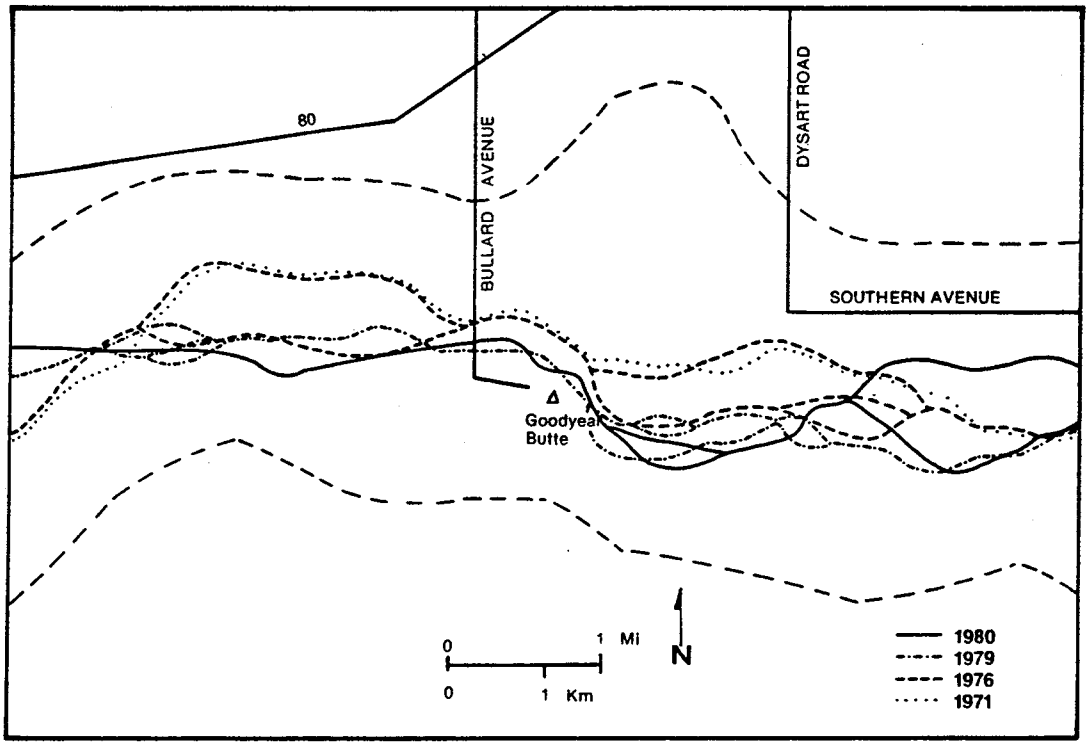
8.13.4 59th Avenue to 115th Avenue



8.13.5 115th Avenue to Sarival Avenue



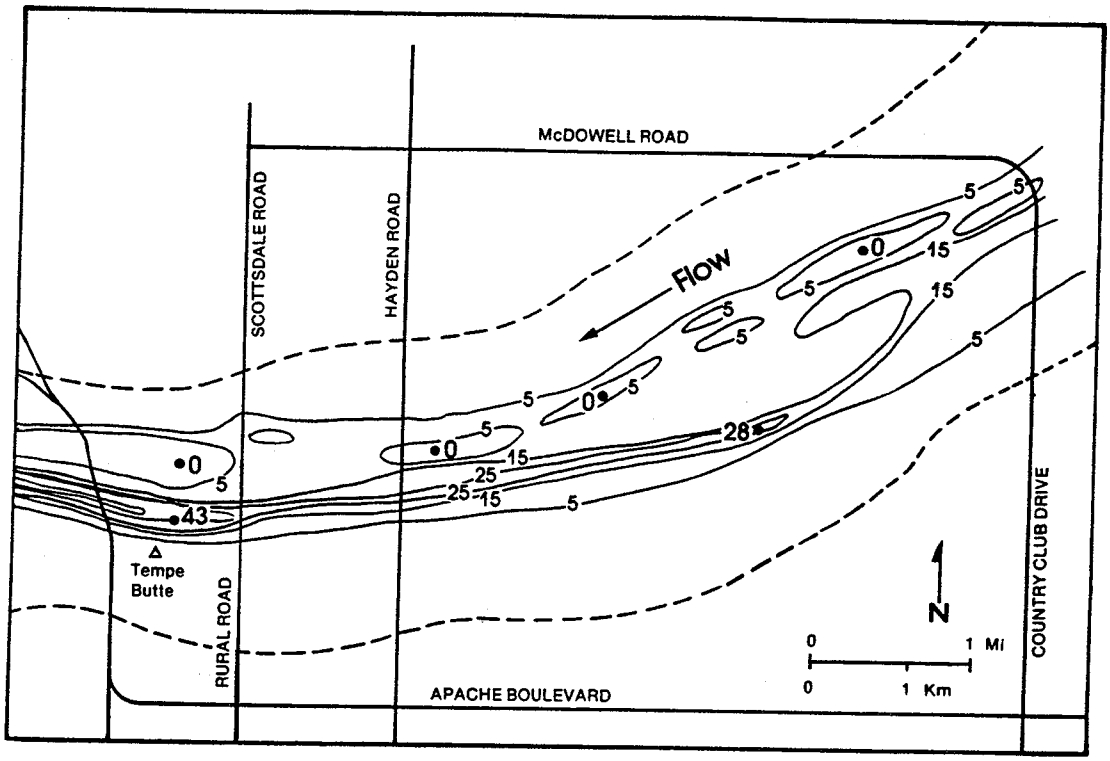



80
BULLARD AVENUE
DYSART ROAD
SOUTHERN AVENUE
Goodyear Butte
0
1 Mi
0
1 Km
N
1980
1979
1976
1971

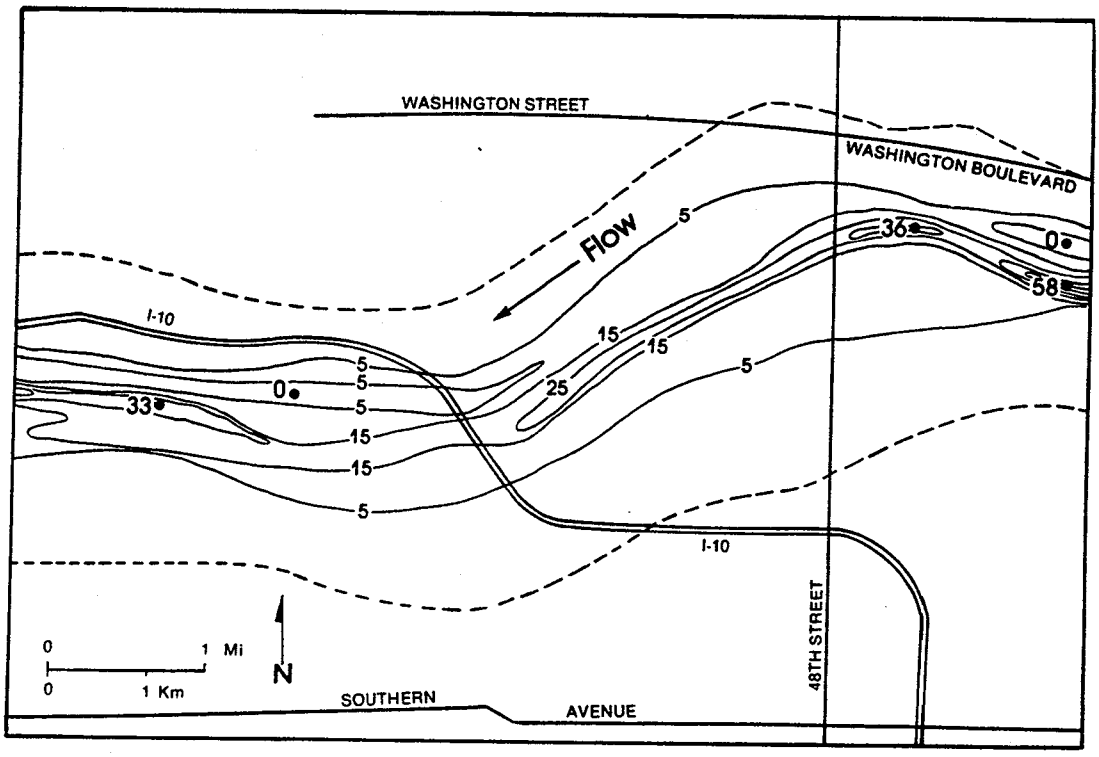
8.14 Thalweg Locational Probability Maps

The following pages contain thalweg locational probability maps based on the historical position maps presented in Appendix 8.13. The reach between Granite Reef Dam and Country Club Drive is not represented because of lack of data.

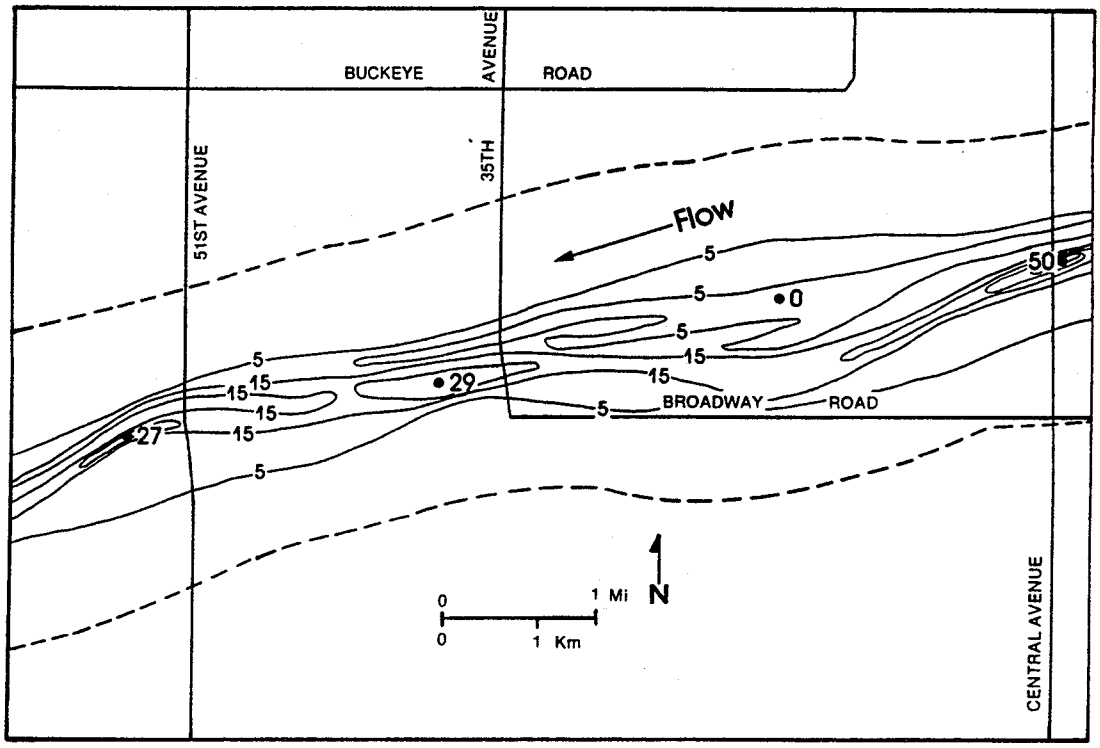
8.14.1 Country Club Drive to Mill Avenue



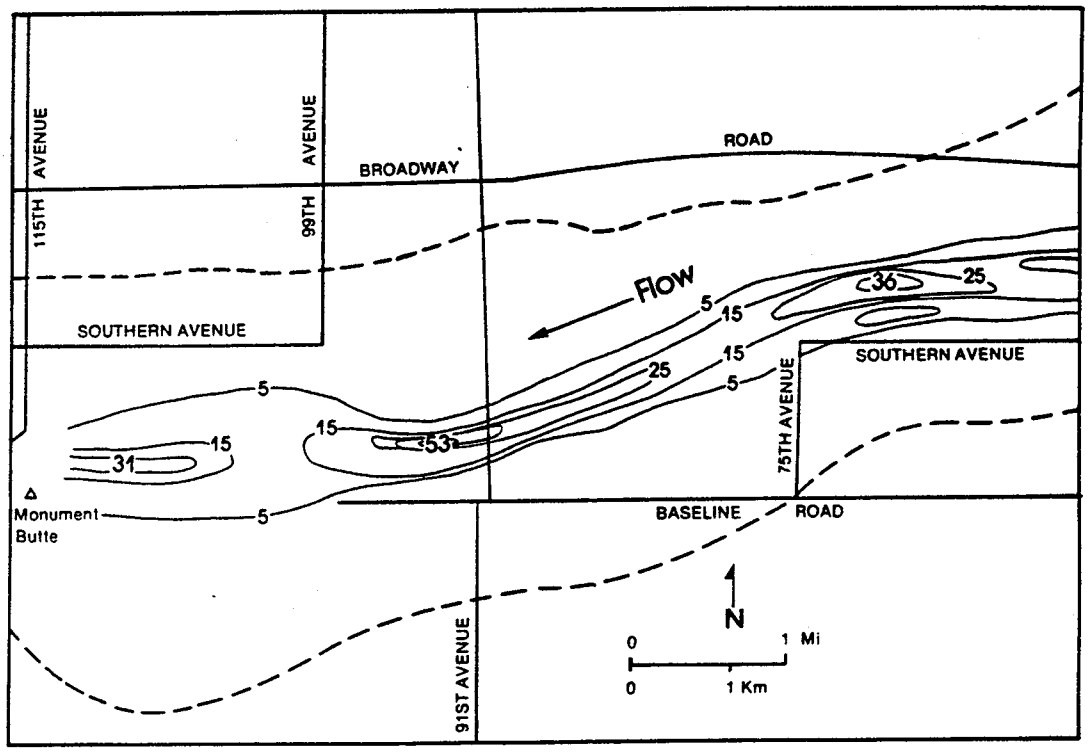
8.14.2 Mill Avenue to 7th Street



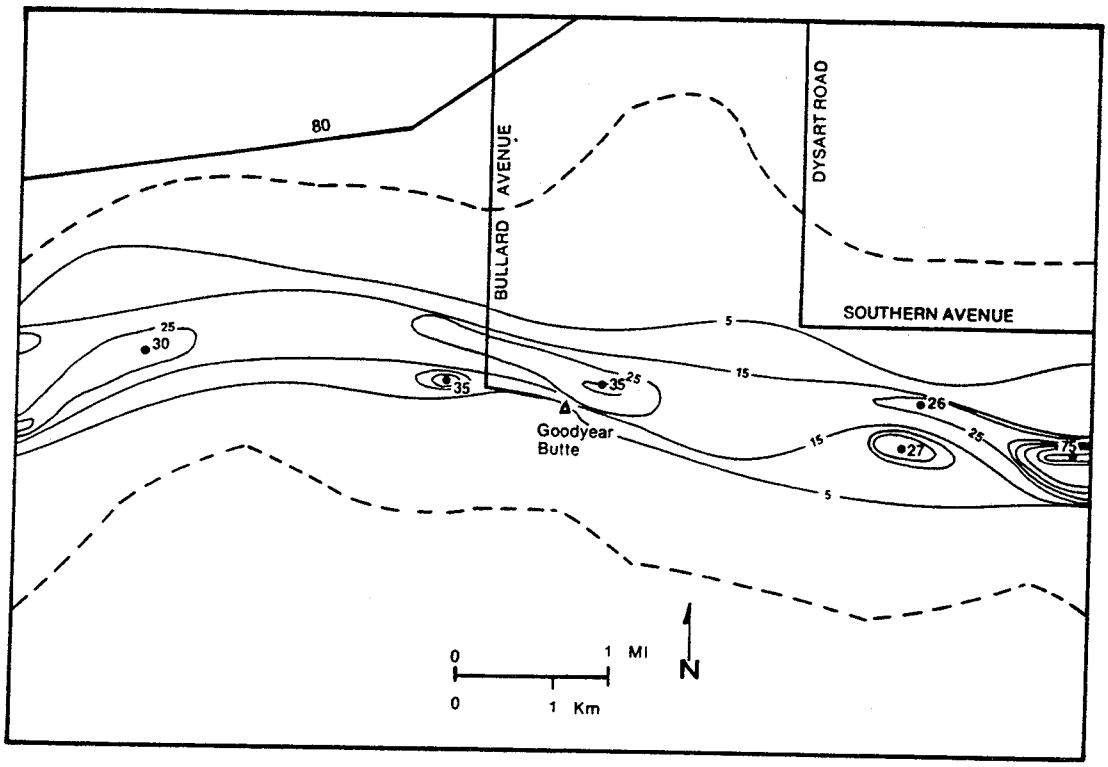
8.14.3 7th Street to 59th Avenue



8.14.4 59th Avenue to 115th Avenue



8.14.5 115th Avenue to Sarival Avenue



8.15 Conceptual and Philosophical Basis for Envrionmental Restoration

8.15.1 National Context for the Corps of Engineers

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 Salt 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.

8.15.2 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 Salt 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 Salt 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.

8.15.3 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.

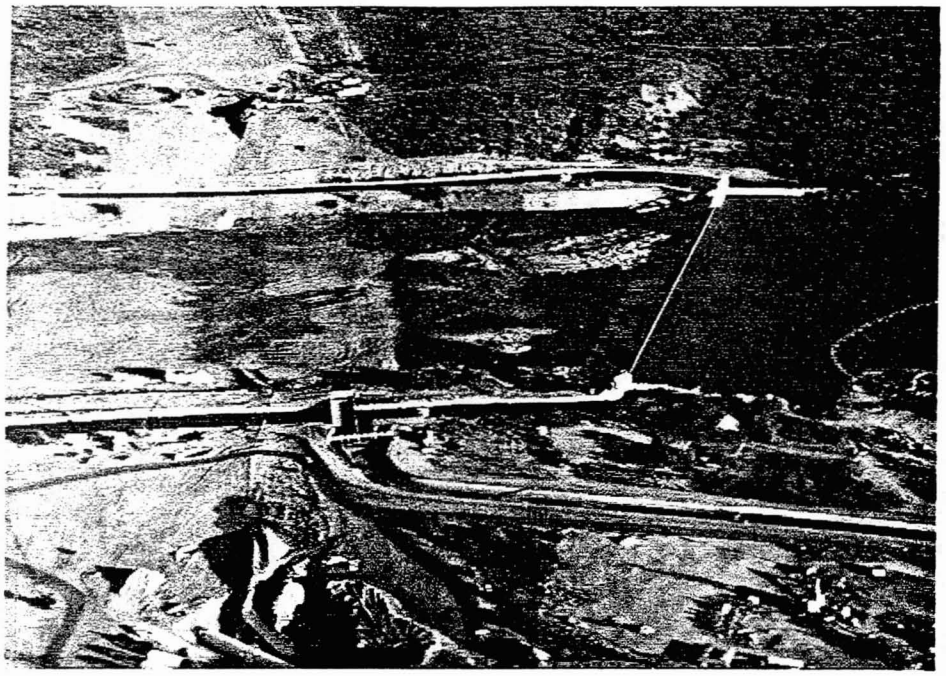
The 1968 Wild and Scenic Rivers Act also codified definitions of naturalness specifically for rivers. Section 16(a) of the act defines a river as "a flowing body of water or estuary or a section, portion, or tributary thereof, including rivers, streams, creeks, runs, kills, rills, or small lakes." The 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.

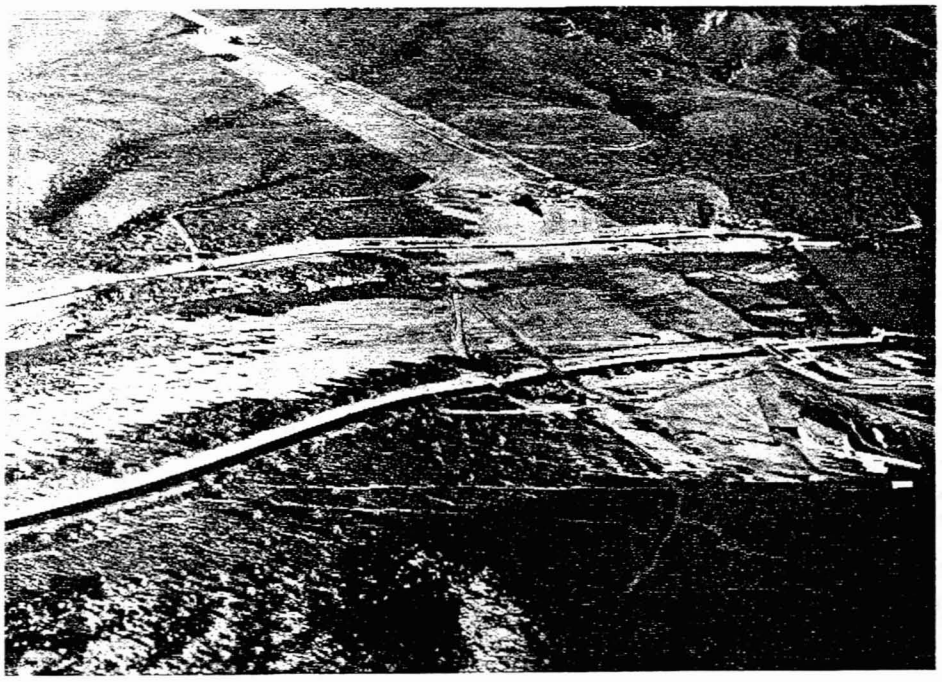
3. **Recreational** river areas: those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines and that may have undergone impoundment or diversion in the past."

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 Salt 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.

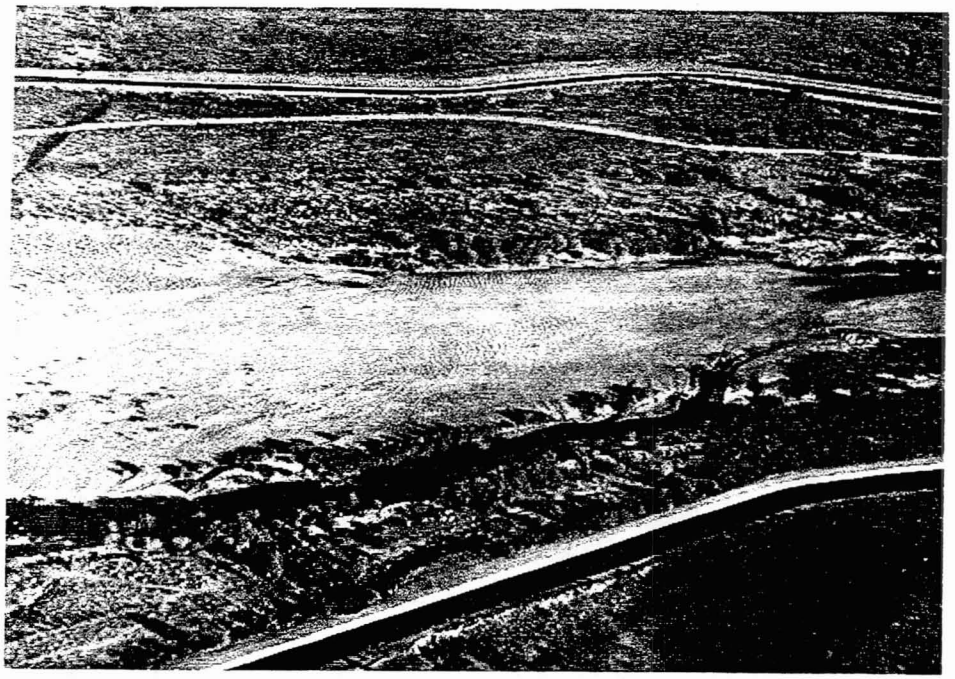
The Wilderness Act and the Wild and Scenic Rivers Act define their classifications based on holistic ecosystems. The classification of the subdivisions of ecosystems, the physical, chemical, and biological components, on a naturalness scale is also possible, and perhaps more useful from a management 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.



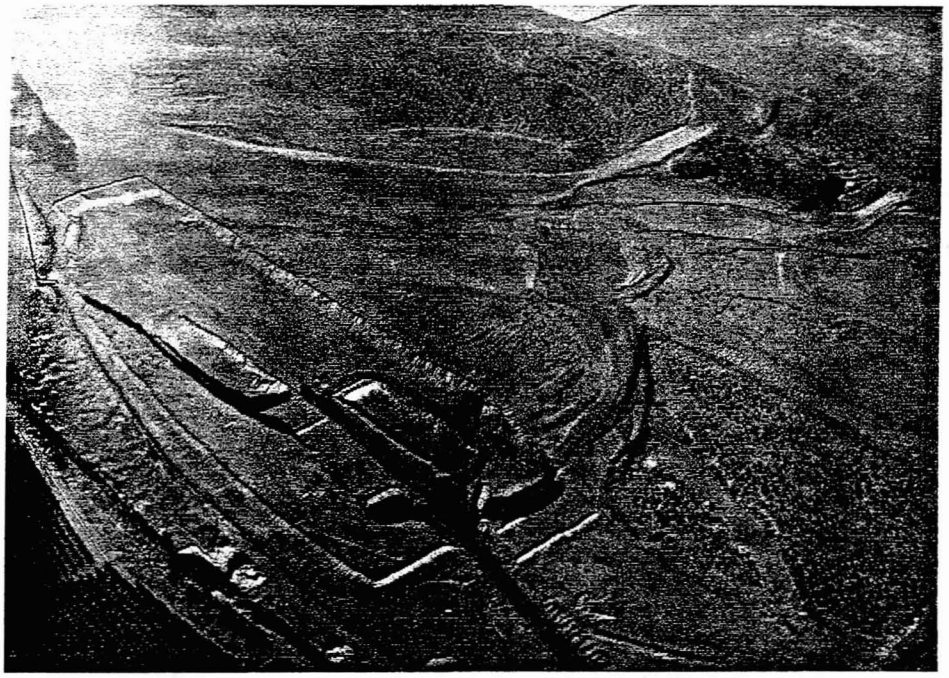
8.15.1 Looking north over the Salt River at Granite Reef Dam (W. L. Graf Photo 126-4, October 6, 1994).



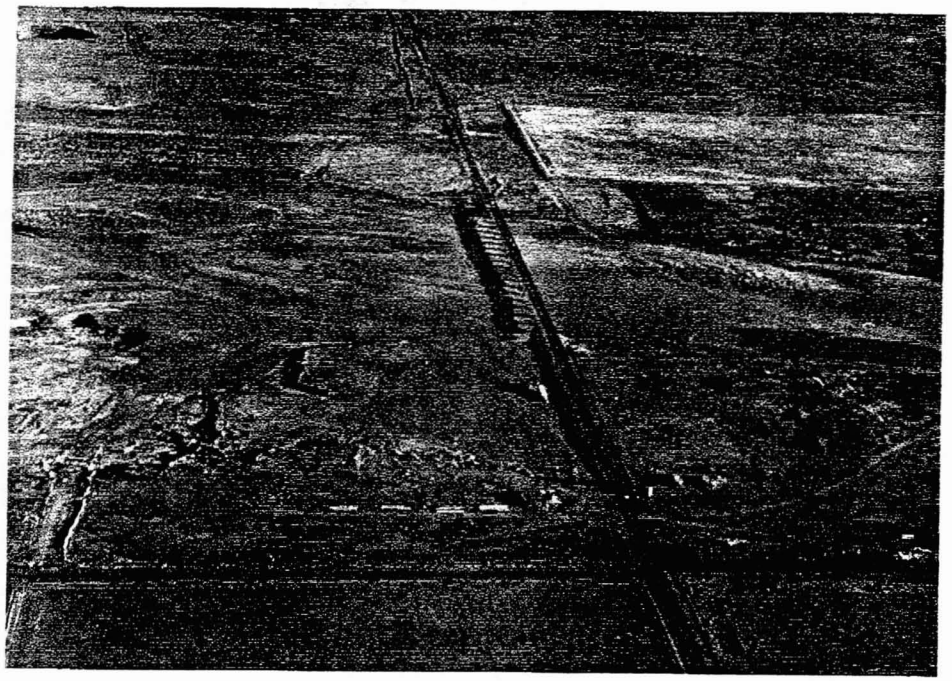
8.15.2 Looking north over the Salt River immediately below Granite Reef Dam with riparian vegetation at the left (W. L. Graf Photo 126-5, October 6, 1994).



8.15.3 Looking north over the Salt River about 2 miles below Granite Reef Dam, with giant ripple marks in channel sand deposits (W. L. Graf Photo 126-6, October 6, 1994).

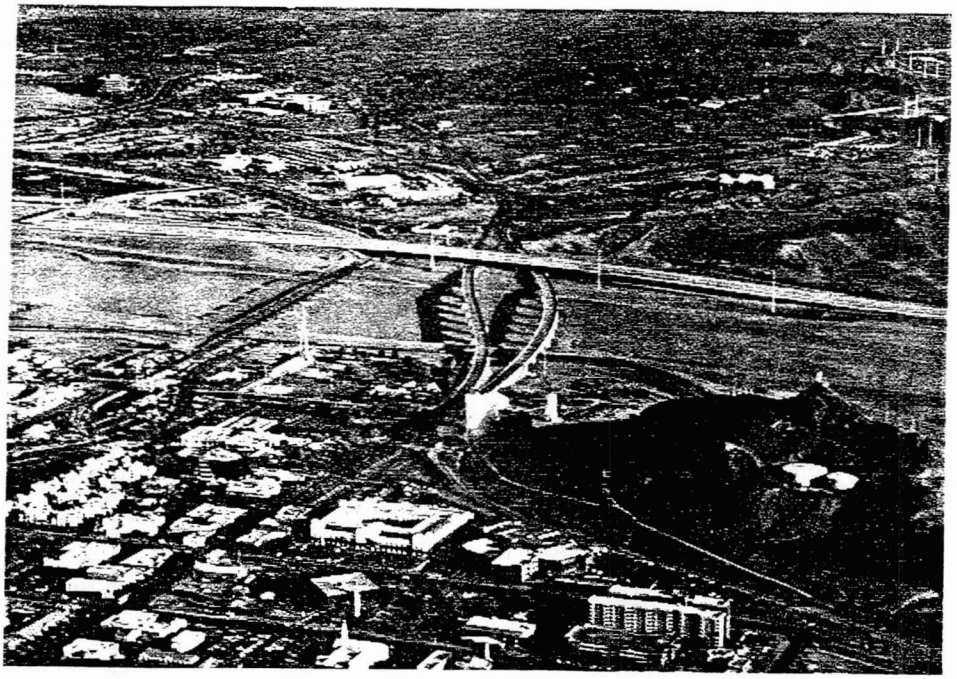


8.15.4 Sand and gravel mine on the south side of the Salt River, 2 miles upstream from Gilbert Road Bridge (W. L. Graf Photo 126-7, October 6, 1994).

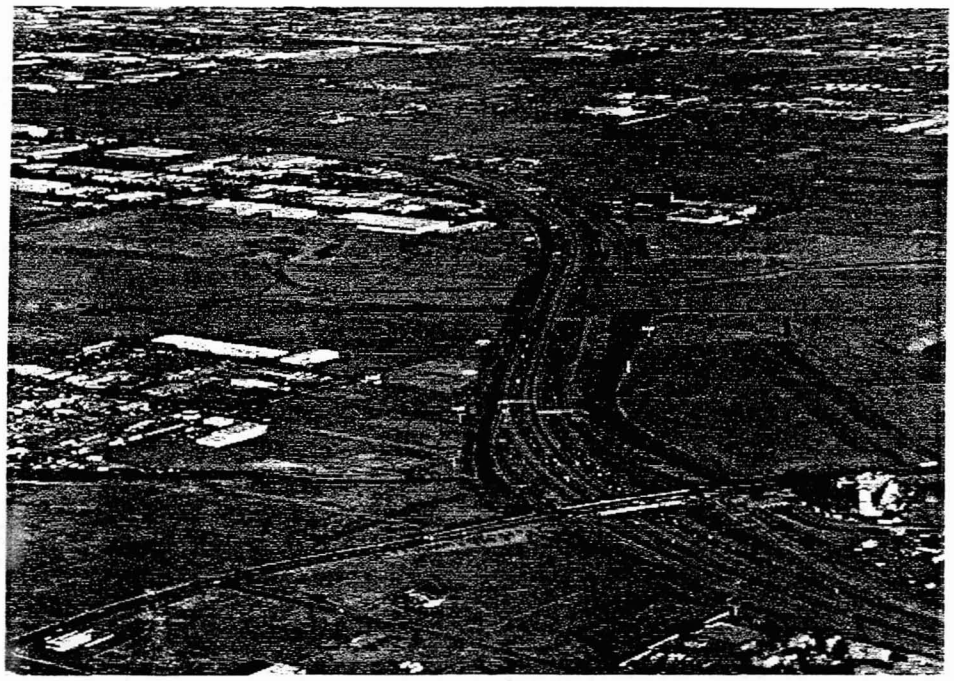


8.15.5 Looking north across the Salt River at the Gilbert Road Bridge (W. L. Graf Photo 126-8, October 6, 1994).

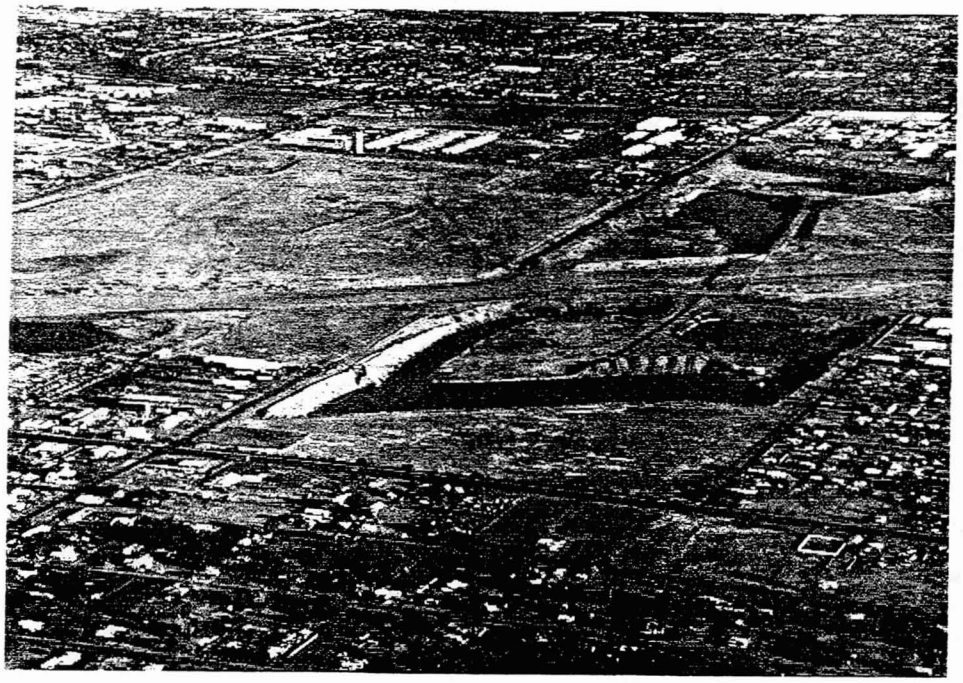
8.15.6 Looking north across the Salt River at the downstream end of the Tri-City Landfill, with numerous sand and gravel mines (W. L. Graf Photo 126-9, October 6, 1994).



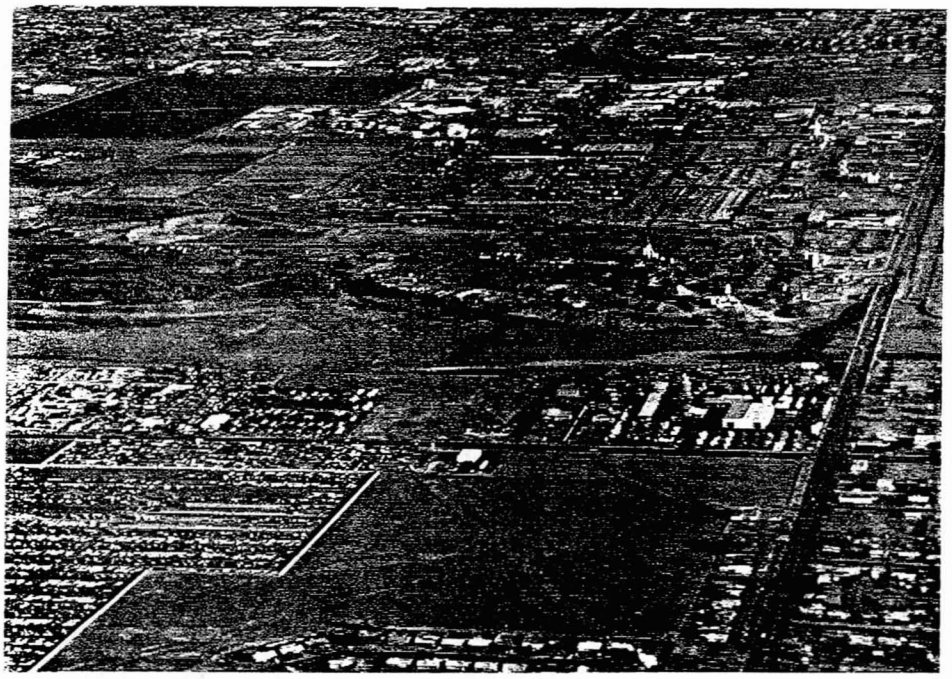
8.15.7 Looking north across the Salt River at the Mill Avenue Bridge, with Tempe Butte at the lower right (W. L. Graf Photo 126-12, October 6, 1994).



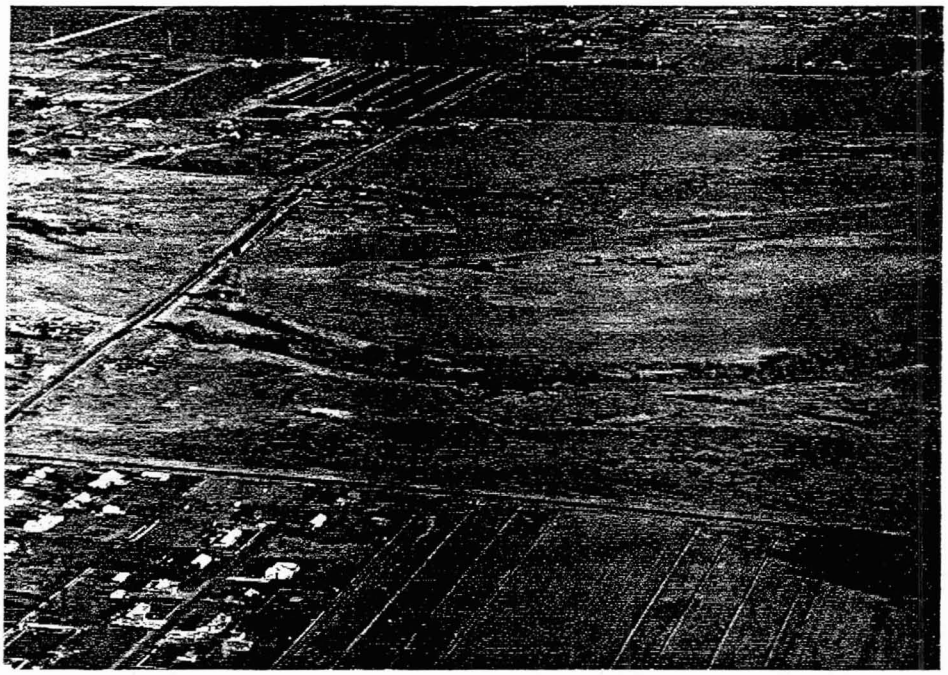
8.15.8 Looking north across the Salt River at the Interstate 10 Bridge, with the 48th Street Drain (W. L. Graf Photo 126-13, October 6, 1994).



8.15.9 Looking north across the Salt River at the 16th Avenue alignment showing abandoned sand and gravel mines (W. L. Graf Photo 126-14, October 6, 1994).



8.15.10 Looking north across the Salt River at the 19th Avenue Bridge (W. L. Graf Photo 126-15, October 6, 1994).



8.15.11 Looking north across the Salt River at the 67th Avenue Crossing (W. L. Graf Photo 126-16, October 6, 1994).

8.15.12 Looking north across the Salt River at the 83rd Avenue alignment, with the 91st Avenue Waste Water Treatment Plant at the top of the view (W. L. Graf Photo 126-17, October 6, 1994).

8.15.13 Looking north across the Salt River at the 91st Avenue Crossing, with the 91st Avenue Wastewater Treatment Plant at the top of the view (W. L. Graf Photo 126-18, October 6, 1994).

8.15.14 Looking north across the confluence of the Salt and Gila rivers. The Gila River has two channels, a constructed one at the left and a natural meandering one at the right (W. L. Graf Photo 126-20, October 6, 1994).

8.15.15 Looking north across the Gila River at the Agua Fria confluence, with the Buckeye Heading at the middle left (W. L. Graf Photo 126-21, October 6, 1994).

8.15.16 Looking north across the Gila River at "Goodyear Butte," with the Agua Fria at the right and the Bullard Avenue Bridge at the left (W. L. Graf Photo 126-22, October 6, 1994).

APPENDIX F

ALTERNATIVE TECHNICAL DETAILS

SEEPAGE RATES AND WATER DEMAND FOR ALTERNATIVES

Tempe Cienega, Alternatives A and B

The initial seepage rate could be as high as one foot per day. After establishment of a saturated subsurface plume below the pond, and installation and operation of collection galleries, steady-state seepage in the lake and wetland areas will be reduced. Based on studies by the City of Tempe, long-term seepage is expected to be approximately 0.2 feet/day, on the average. Actual seepage may be less due to the presence of a subsurface bedrock layer. Seepage will be controlled by subsurface collection galleries which will collect water and return it to the pond by pumping.

Water demands will include 1) maintenance of the 20-acre pond from evaporation and seepage, 2) wetland and riparian habitat demands for the Salt River habitat and 3) wetland and mesquite bosque habitat demands for Indian Bend Wash. The following Table summarizes some of the design criteria for creating a 20-acre pond in the Salt River.

With respect to the hydrophytic (wetland) vegetation, riparian (cottonwood/willow) vegetation and mesquite bosque, the following assumptions are made as a basis for evaluating water supply needs:

- Transpiration water requirement by each habitat type is based on information provided in the habitat analysis:

  Wetland = 4.0 feet per year
  Riparian (cottonwood/willow) = 4.6 feet per year
  Mesquite bosque = 2.4 feet per year;

- Seepage and evaporation losses for the wetland and riparian vegetation are the same as for the open-water pond (See Table below); and

- Seepage and evaporation losses for the mesquite bosque are negligible.

Water Demand For Maintaining a 20-Acre Pond in the Salt River at Tempe Cienega in Alternative A.[1]

Parameter	Quantity
Surface Area	20 acres
Evaporation 6 ft/yr	120 ac-ft/yr
Seepage Area	20 acres
Seepage loss 0.2 ft/day[2] (12 ft/year)	1,460 ac-ft/year (240 ac-ft/year)
Total Pond losses	1,580 ac-ft/year (360 ac-ft/year)
Total Pond Demand	1.41 MGD (0.32 MGD)

1 The pond is assumed to be 5 feet deep. Total pond volume = 100 acre feet.

2 Reference Rio Salado Technical Memorandum No. 8 by CH2MHILL 1992. This is an initial seepage rate estimated for Tempe Town Lake. Plugging by silts over time is expected to reduce the seepage rate over time. For purposes of this report, a long-term seepage rate of twice the evaporation rate is used. These figures are in parenthesis in the table.

Water Demand For Maintaining Riparian Habitat at Tempe Cienega in Alternative A.				
Parameter	Area (Acres)	Water Use (Feet per Year)	Total Water Demand (Acre Feet/ Year)	Total Water Demand (Million Gallons/Day)
SALT RIVER COMPONENT				
Wetland	4	22.0	88	0.08
Riparian Vegetation	15	22.6	339	0.30
Subtotal	19	22.5[1]	427	0.38
INDIAN BEND WASH COMPONENT				
Wetland	18	22.0	396	0.35
Mesquite Bosque	4	2.4	10	0.01
Subtotal	22	18.4[1]	406	0.36
Total	41	20.3	833	0.74

[1] This number is obtained by proportion, not by direct addition.

The total water requirement for maintaining a pond in the Salt River at Tempe Cienega ranges from 1.06 to 2.15 million gallons per day. The 2.15 mgd is an initial rate that will decrease over the course of the first year to a stable 1.06 mgd.

Tempe Cienega will be supplied by groundwater supplemented by the Salt River and local storm drains entering the Salt River. Well #6, west of the Indian Bend Wash and South of McKellips Road (Figure 6.6 of the main report) currently has more than sufficient capacity (3 mgd) to

provide all of the water needs for the Tempe Cienega and riparian habitat at the Indian Bend Wash and Salt River. This well is currently not being used and could easily be converted to use for Tempe Cienega. This well will be the primary source of water for Tempe Cienega.

Salt River flows will supplement groundwater sources. Average annual spills from Granite Reef Dam into the Salt River are approximately 247,000 acre feet. This is far in excess of the 2,000 acre feet maximum required annually to maintain the Tempe Wetland pond and riparian area within the Salt River. However, Granite Reef spills are highly seasonal and there is no opportunity for offsite storage of these flows for later release into the restoration area. The inflatable dam, on-site, will obstruct flows in the Salt River channel. The dam will cause a ponding depth of up to six feet (total ponding volume = 450 acre feet (in addition to the permanent pond. Flows in excess of six feet will pass over the structure and continue downstream. Flood-related impacts will be avoided by deflating the dam for river discharges in excess of the 10-year flood. Local storm drains such as the Price Road drain also provide an opportunity for a water supply, but this is also seasonal.

Lago de Vida, Alternative A

Seepage into the river channel will be controlled by subsurface collection galleries which will collect water and return it to the wetland headwaters by pumping. Seepage rates have not been investigated as they have at Tempe. It has been estimated that initial seepage along the Salt River could be as much as 1 foot per day. This rate is used as a maximum and will be determined during the feasibility study.

After establishment of a saturated subsurface plume below the pond, and installation and operation of collection galleries, steady-state seepage will be significantly lower than the initial maximum. For purposes of this study, a steady-state seepage rate of twice the evaporation rate is assumed.

The Table below provides a summary of the estimate of water requirement for the wetland habitat within the Salt River channel. Water requirement assumptions are the same as for Tempe Wetland.

Water Demand For Maintaining Wetland and Riparian Habitat in the Salt River at Lago de Vida, Alternative A.

Parameter	Area (Acres)	Water Use (Feet per Year)	Total Water Demand (Acre Feet/ Year)	Total Water Demand (Million Gallons/Day)
Bank Riparian Vegetation	40	22.6	904	0.81
Wetland	240	22.0	5,280	4.72
Total	280	22.1[1]	6,184	5.53

[1] This number is obtained by proportion, not by direct addition.

The total water requirement for Lago de Vida is approximately 5.53 million gallons per day depending upon infiltration.

Water supply will be groundwater supplemented by Phoenix City storm water flow and Salt River flood releases. It has been assumed for purposes of this study that the availability of shallow-water aquifer is expected to increase over the next ten years due to the reduction in agriculture. Pumping of this shallow aquifer would not cause any significant adverse effects.

Storm drains 11-20 and 33-39 produce an annual runoff of 7,200 acre feet. This volume is sufficient to supply the wetlands, but the timing of the runoff is such that large volumes are produced in short periods of time. There is no runoff at all during most periods of the year. To compensate for the flashy nature of runoff discharges, runoff will be collected in off-channel storage basins for later release at a controlled rate. Nevertheless, groundwater pumping will be

required to supplement the supply from runoff. For purposes of this study it can be assumed that the required rate of groundwater pumping to satisfy the minimum needs of the wetland is 7,088 acre-feet (5.53 mgd).

Lago de Vida in Alternative B

Seepage in the lakes will be controlled subsurface collection galleries which will collect water and return it to the pond by pumping. Seepage rates have not been investigated as they have at Tempe. It has been estimated that initial seepage along the Salt River could be as much as 1 foot per day. This rate is used as a maximum.

Collection galleries will be used to control seepage and return infiltrated water to the lake and wetland. After establishment of a saturated subsurface plume below the pond, and installation and operation of collection galleries, steady-state seepage will be significantly lower than the initial maximum. For purposes of this study, a steady-state seepage rate of twice the evaporation rate is assumed.

The Table below summarizes some of the design criteria for creating a 120-acre series of lakes along the Salt River near Central Avenue.

Water Demand For Maintaining a 120-Acre Lake at the City of Phoenix in the Vicinity of Central Avenue, Alternative B.[1]	
Parameter	Quantity
Surface Area	120 acres
Evaporation 6 ft/yr	720 ac-ft/yr
Seepage Area	120 acres
Seepage loss 12 ft/yr[2] (1 ft/day/ft[3])	1,440 ac-ft/yr (43,800 ac-ft/year)
Total Lake losses	2,160 ac-ft/yr (44,520 ac-ft/year)
Total Lake Demand	1.93 MGD (39.74 MGD)

1 The lake is assumed to be 10 feet deep. Total lake volume = 1,200 acre feet.

2 After the lake is filled, a plume of seepage will form between the lake bottom and the groundwater. After formation of the plume, and counting seepage recovery through underground collection galleries, effective loss to seepage will be significantly reduced over the initial infiltration rate. A seepage rate of twice the evaporation rate is assumed.

3 This is considered a worst-case, initial seepage rate for the unlined lake. The long-term seepage rate, after approximately one year, should be less than this.

The Table below provides a summary of the estimate of water requirement for the marsh habitat within the Salt River channel adjacent to the lakes. Water requirement assumptions are the same as for Tempe Wetland.

Water Demand For Maintaining Wetland and Riparian Habitat in the Salt River at Lago de Vida, Alternative B.				
Parameter	Area (Acres)	Water Use (Feet per Year)	Total Water Demand (Acre Feet/ Year)	Total Water Demand (Million Gallons/Day)
Bank Riparian Vegetation	40	22.6	904	0.81
Wetland	120	22.0	2,640	2.36
Total	160	22.2[1]	3,544	3.17

[1] This number is obtained by proportion, not by direct addition.

The total water requirement for Lago de Vida, including the lake and vegetated (river) portions ranges from 5.10 to 42.91 million gallons per day depending upon infiltration.

Water supply will be groundwater supplemented by Phoenix City storm water flow and Salt River flood releases. The lakes will be supplied entirely by pumped groundwater from the shallow aquifer table. The availability of the shallow-water aquifer is assumed to increase over the next ten years due to the reduction in agriculture. Therefore, pumping of this water is expected not to cause significant adverse effects.

Assuming an initial, worst-case water requirement of 39.74 million gallons per day, a maximum of 42 wells, pumping at 1,000 gallons per minute (16 hours per day), will be required to begin filling the lake. The actual initial requirement can be reduced by collection galleries which will collect infiltrated water and return it to the lake. Approximately 40 wells are available within the Lago de Vida Riparian Restoration area for this purpose (Figure 1). After equilibrium conditions have been established, the lake water requirement will be reduced to 1.93 mgd, which can be supplied by three wells pumping at 1,000 gallons per minute.

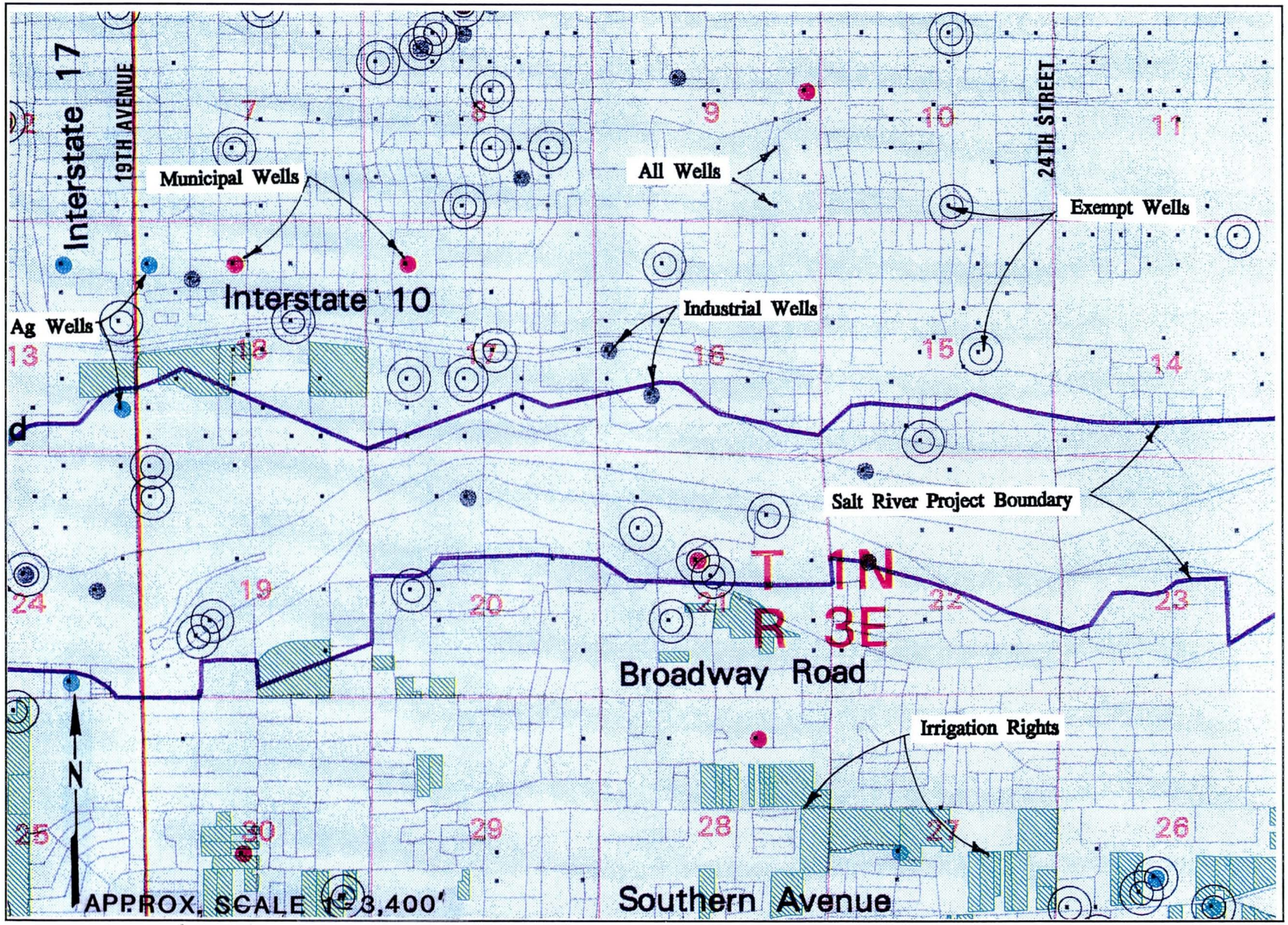


Figure 1 Present Well Locations at Lago de Vida.

The wetlands will be supplied by stormwater inflows supplemented by groundwater pumping. Drains 11-20 and 33-39 produce an annual runoff of 7,200 acre feet. This volume is sufficient to supply the wetlands, but the timing of the runoff is such that large volumes are produced in short periods of time. There is no runoff at all during most periods of the year. To compensate for the flashy nature of runoff discharges, runoff will be collected in off-channel storage basins for later release at a controlled rate. Nevertheless, groundwater pumping will be required to supplement the supply from runoff. For purposes of this study it can be assumed that the required rate of groundwater pumping to satisfy the minimum needs of the wetland is 3,544 acre-feet (3.17 mgd). Four wells, pumping at a rate of 1,000 gpm, will be more than sufficient to supply the wetland water demand.

The total water requirement for Lago de Vida, including the wetland and lakes, ranges from a long-term minimum of 5.10 mgd to an initial, worst-case 42.91 mgd. The wetland will be supplied by groundwater which could produce more than enough to maintain the vegetation. Assuming that no surface water is available, the maximum-possible long-term requirement from groundwater is 5.10 mgd, which is equivalent to 24 feet of water per year over the 240-acre area.

Landfill Considerations

There are two landfills near Lago de Vida. The first is Del Rio Landfill, which was a municipal dump on the south side of the river. It is closed, capped and has riprap protection against the 100-year flood on the Salt River. The second is west of Central Avenue and north of the river. It is owned by Union Rock and Materials, contains refuse, and is closed. Monitoring from both landfills indicates VOC contamination from an off-site source. No remediation is currently taking place other than monitoring.

The infiltration of an unlined lake is expected to be extensive. By allowing the water to infiltrate and be recirculated through pumping, the potential for the lake to go stagnant or anaerobic is reduced . However, with an unlined lake, special consideration must be given to the effect of infiltration on the groundwater table elevation which may result in seepage of water into nearby

landfills. A brief analysis was conducted to determine whether the lake water would impact the Del Rio Landfill. The results follow.

During the first year of operation, the infiltration rate of the lake could be approximately 1 ft/day. This infiltration rate will gradually decrease as the bottom of the lake is silted in. During this period, project wells placed between the Del Rio and Central Avenue Landfills and the Salt River will remove the infiltrated water before it reaches the landfills. Without such removal of infiltrated water, it would reach the landfills.

After about a year, the infiltration rate will decline until it is about 0.2 ft/day or less. Figure 2 illustrates elevation information and depicts the mound of groundwater that would be created beneath the lake assuming an infiltration rate of 0.2 ft/day. With an infiltration rate of 0.2 ft/day, a ten foot groundwater mound would develop under the proposed lake. This mound, with a slope of 50 ft/mi, would be reduced to 5 feet at the Del Rio Landfill, 600 feet from the lake. With a groundwater elevation of 1005.5 feet, the mound would not affect the landfill. However, when the Salt River flows, the water table rises into the landfill, with or without project.

Water Quality Benefits, Lago de Vida in Alternative A

Removal of Nitrates is a main water quality design goal for Rio Salado. The Table below provides preliminary sizing of wetlands for removal of nitrates of concentrations 45 mg/l as are present in the City of Phoenix at Central Avenue.

Sizing of Wetlands for Initial Nitrate Removal for Various Inflows (Concentration of 45 mg/l).

Q (MGD)	1	5	10	30	60	90
SA (acres)	18	92	184	550	1100	1700
W (ft)	56	280	560	1700	3350	5000 +

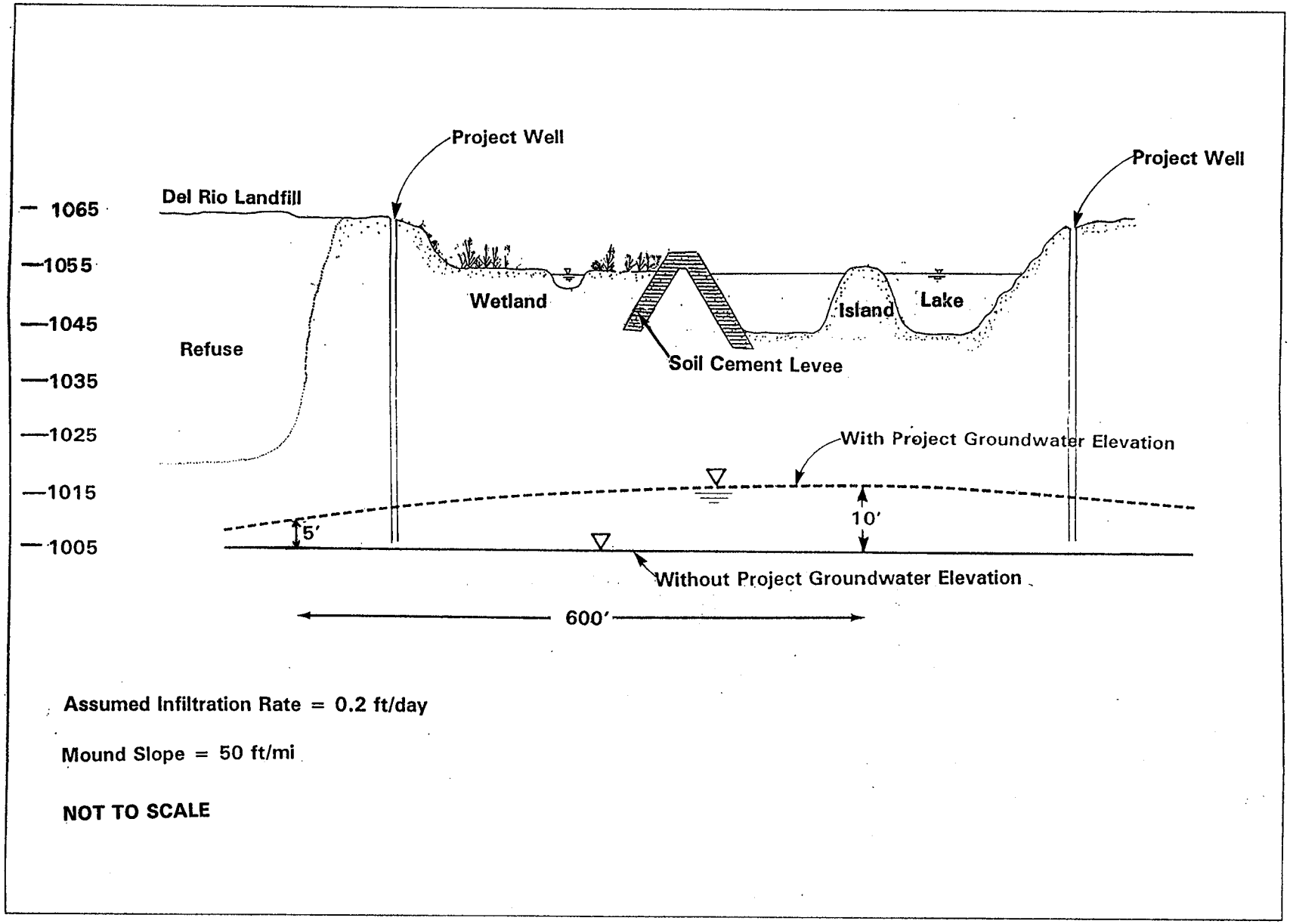


Figure 2 **Effects of Lago de Vida Lake Infiltration on Groundwater Elevation near the Del Rio Landfill**

Based upon the rate of removal of nitrates at a concentration of 45 mg/l, a 240-acre wetland could treat as much as 14,400 acre-feet of year for nitrates. This volume is twice the average amount of urban storm runoff entering from drains 11-20 and 33-39.

Water Supply and Quality, Tempe Rio Salado in Alternative B

Water supply options range in capital cost from under $500,000 to over $20,000,000. Operations and maintenance costs for these options range from nothing to over $2,000,000 per year. The supply costs do not include the basic costs of waste water treatment.

The options range from direct reuse of reclaimed water produced at the Kyrene WRF (or the proposed North WRF) to extensive additional treatment schemes combined with aquifer storage and recovery systems. The additional levels of treatment provided for the reclaimed water directly affect the water quality of the lake.

The City will be constructing two water reclamation plants. Together, they will produce millions of gallons of water per day. This will make water available for recreational use without using the City's allotted groundwater. In fact, excess water should be available for irrigation of landscaping, playing fields and golf courses. In the future, this water could be used for recharging our groundwater supply by allowing it to filter through the ground.

Seepage Control. Three general methods to reduce seepage from the lake were considered:

- Lining the lake, thus reducing seepage through the bottom and sides of the lake.
- Constructing cutoff walls along the lake boundary, thus reducing the seepage through the aquifer beneath the lake.
- Collecting the seepage with wells, and returning the pumped water to the lake

The liner and slurry wall techniques have a much higher construction cost (from $14 to $20,000,000, depending on depth) but low maintenance cost (Assuming the liner is placed below

the scour depth, there would be no replacement cost.). The pumped seepage recovery system has a relatively low capital cost ($4,500,000), but a high annual cost ($200,000) associated with energy costs for pumping, maintenance of equipment, and the more intensive groundwater monitoring that would be required.

Stormwater Quality. During the initial phase of the Rio Salado project, local data on storm water quality from urban areas were obtained from the City of Tempe, Arizona Department of Transportation, FCDMC, and the City of Mesa. These data indicate that local wet-weather samples contain higher levels of total suspended solids, biological oxygen demand, organic nitrogen, nitrate, ortho-phosphorous, and copper, compared to median urban data reported by the EPA. The local wet-weather samples contain lower concentrations of lead and zinc, and nearly equal concentrations of total phosphorous compared to median urban data.

The pollutant concentrations from the dry-weather samples were typically lower than the wet-weather samples. The data appear to indicate that dry-weather flows contribute a much smaller pollutant load compared to wet-weather flows. The data also suggest that detention storage in the Price Road Tunnel may provide some pollutant removal, especially for heavy metals. Copper, lead, and zinc concentrations from tunnel samples were below detection limits in dry-weather samples. One grab sample taken from the Price Road Tunnel, however, showed extremely high fecal coliform concentration, exceeding 90,000 CFU/100 ml. This sample may indicate high variability of storm water quality from individual sources.

Stormwater Management Options. A range of stormwater management options were evaluated. The options included wet detention ponds, dry retention ponds, and bypass and diversion devices. The range of cost is $33,300,000 to $11,420,000. The lower cost is estimated for a lake supplied by either the Kyrene WRF of future North WRF. The higher cost is related to a lake supplied by SRP. The alternatives are based on intercepting and diverting a portion of the runoff that would otherwise enter the lake. Additional system components include constructing an upstream dam to retain nuisance runoff and detain large flows, and a plan to continually de-water the Price Road Tunnel to reduce the impacts of stale discharges from the tunnel. if the selected supply

option entails an urban SRP reservoir, and SRP requires that all stormwater is diverted around the lake, a more conservative design incorporating a higher capacity bypass would be needed.

APPENDIX G

FLORA AND FAUNA IN INDIAN BEND WASH AREA PRIOR TO DEVELOPMENT

PREDOMINATING FLORA AND WILDLIFE SPECIES THAT OCCUPIED THE INDIAN BEND WASH AREA PRIOR TO DEVELOPMENT

TREES

Common Name	Scientific Name
Cottonwood	Populus fremontii
Desert willow	Chilopsis linearis
Mesquite	Prosopis juliflora
Blue Palo verde	Cercidium floridum
Yellow Polo verde	Cercidium microphyllum

SHRUBS

Arrowweed	Pluchea sericea
Burrobrush	Hymenclea salsola
White bursage	Franseria dumosa
Brittlebush	Encelia farinosa
Broom baccharis	Baccharis sarothroides
Catsclaw acacia	Acacia greggii
Creosote bush	Larrea divaricata
Crucifixion thorn	Holacantha emoryi
Desert Thorn	Lycium torreyi
Desert salt bush	Atriplex polycarpa
Four-wing saltbush	Atriplex canescens
Quailbush	Atriplex lentiformis
Haplopappus	Haplopappus heterophyllus
Seepwillow	Baccharis glutinosa
Salt cedar	Tamarix pentandra
Tree tobacco	Nicotiana glauca
Yucca	Yucca elata

HERBACEOUS VEGETATION

Buckwheat	Eriogonum spp.
Buffalo gourd	Cucurbita foetidissima
Desert sunflower	Gersea canescens
Cocklebur	Xanthium saccharatum
Evening primrose	Oenothera sp.
Filaree	Erodium cicutarium
Fiddle-neck	Amsinckia intermedia
Desert-mallow	Sphaeralcea ambigua

Jimsonweed	Datura meteloides
Pigweed	Amaranthus spp.
Russian thistle	Salsola kali
Sand verbena	Verbena gooddingii
Nightshade	Solanum xantii
Alkali-sacaton	Sporobolus airoides
Black drop-seed	Sporobolus cryptandrus
Drop-seed	Sporobolus pulvinatus
Bristlegrass	Setaria lutescens
Big galleta grass	Hilaria rigida
Johnson grass	Sorghum halepense
Salt grass	Distichlis stricta

CACTI

Barrel cactus	Ferocactus sp.
Cholla and pricklypear	Opuntia spp.
Fishhook cactus	Mammillaria spp.
Sahuaro	Cereus giganteus

AMPHIBIANS AND REPTILES

Common Name	Scientific Name
Couch's spadefoot	Scaphiopus couchi
Western spadefoot	Scaphiopus hammondi
Colorado River toad	Bufo alvarius
Woodhouse's toad	Bufo woodhousei
Great plains toad	Bufo cognatus
Desert tortoise	Gopherus agassiz
Gila monster	Heloderma suspectum
Banded gecko	Coleonyx variegatus
Collard lizard	Crotaphytus collaris
Leopard lizard	Crotaphytus wislizeni
Chuckwalla	Sauromalus obesus
Zebra-tailed lizard	Callisaurus draconoides
Desert spring lizard	Sceloporus magister
Long-tailed brush lizard	Uta graciosa
Tree lizard	Uta ornata
Side-blotched lizard	Uta stansburiana
Desert-horned lizard	Phrynosoma platyrhinos
Western whiptail	Cnemidophorus tigris
Western blind snake	Leptotyphlops humilis

Black-necked garter snake	Thamnophis cyrtopsis
Checkered garter snake	Thamnophis marcianus
Coachwhip	Masticophis flagellum
Desert patchnosed snake	Salvadora hexalepis
Gopher snake	Pituophis catenifer
Glossy snake	Arizona elegans
Common kingsnake	Lampropeltis getulus
Southwestern lyre snake	Trimorphodon lambda
Night snake	Hypsiglena torquata
Arizona coral snake	Micruroides euryxantus
Western diamond-backed rattlesnake	Crotalus atrox
Mohave rattlesnake	Crotalus scutulatus
Sidewinder	Crotalus cerastres

BIRDS

Common Name	**Scientific Name**
Turkey vulture	Cathartes aura
Sharp-skinned hawk	Accipiter striatus
Cooper's hawk	Accipiter cooperii
Ferruginous hawk	Buteo regalis
Harris hawk	Parabuteo unicinctus
Red-tailed hawk	Buteo jamaicensis
Sparrow hawk	Falco sparverius
Pigeon hawk	Falco columbarius
Prairie falcon	Falco mexicanus
Gambel's quail	Lophortyx gambelii
White-winged dove	Zenaida asiatica
Inca dove	Scardafella inca
Morning dove	Zenaidura macroura
Ground dove	Columbigallina passerina
Road runner	Geococcyx californianus
Short-eared owl	Asio flammeus
Screech owl	Otus asio
Great-horned owl	Bubo virginianus
Elf owl	Micrathene whitneyi
Burrowing owl	Speotyto cunicularia
Poor-will	Phalaenoptilus nuttallii
Lesser night hawk	Chordeiles acutipennis
Costa's hummingbird	Calypte costae
Red-shafted flicker	Colaptes cafer
Gilded flicker	Colaptes chrysoides
Gila woodpecker	Centurus uropygialis
Ladder-backed woodpecker	Dendrocopos scalaris
Western kingbird	Tyrannus verticalis

Ash-throated flycatcher	Myiarchus ciner ascens
Say's phoebe	Sayornis saya
Hammond's flycatcher	Empidonax hammondii
Western flycatcher	Empidonax difficilis
Vermillion flycatcher	Pyrocephalus rubinus
Horned lark	Eremophila alpestris
Common raven	Corvus corax
Bridled titmouse	Parus wollweberi
Verdin	Auriparus flaviceps
White-breasted nuthatch	Sitta carolinensis
House wren	Troglodytes aedon
Bewick's wren	Thryomanes bewickii
Cactus wren	Campylorhynchus brunneicapillus
Rock wren	Salpinctes obsoletus
Mockingbird	Mimus polyglottos
Bendire's thrasher	Toxostoma bendirei
Curve-billed thrasher	Toxostoma curvirostre
Western bluebird	Sialia mexicana
Mountain bluebird	Sialia currucoidus
Bluegray gnatcatcher	Polioptilla caerulea
Black-tailed gnatcatcher	Polioptila melanura
Ruby-crowned kinglet	Regulus calendula
Cedar waxwing	Bombycilla cedrorum
Phainopepla	Phainopepla nitens
Loggerhead shrike	Lanius ludoricianus
Starling	Sturnus vulgaris
Bell's vireo	Vireo bellii
Orange-crowned warbler	Vermivora celata
Lucy's warbler	Vermivora luciae
Audubon's warbler	Dendroica auduboni
Yellow warbler	Dendroica petechia
MacGillivray's warbler	Oporornis tolmiei
Wilson's warbler	Passer domesticus
House sparrow	Wilsonia pusilla
Western meadowlark	Sturnella neglecta
Hooded oriole	Icterus cucullatus
Bullock's oriole	Icterus bullockii
Brewer's blackbird	Euphagus cyanocephalus
Red-winged blackbird	Agelaius phoeniceus
Brown-headed cowbird	Molothrus ater
Summer tanager	Piranga rubra
Cardinal	Richmondena cardinalis
Blue grosbeak	Guiraca caerulea
Lesser Goldfinch	Spinus psaltria

Lawrence's goldfinch	Spinus lawrencei
House finch	Carpodacus mexicanus
Green-tailed towhee	Chlorura chlorura
Abert's towhee	Pipilo aberti
Lark bunting	Calamospiza melanocorys
Vesper sparrow	Pooecetes gramineus
Lark sparrow	Chondestes grammacus
Black-throated sparrow	Amphispiza bilineata
Sage sparrow	Amphispiza belli
Gray-headed junco	Junco caniceps
Chipping sparrow	Spizella passerina
Brewer's sparrow	Spizella breweri
Lincoln's sparrow	Melospiza lincolnii
White-crowned sparrow	Zonotrichia leucophrys

APPENDIX H

GEOTECHNICAL APPENDIX

Salt River
Rio Salado

1. Regional Geology. The project area is in the Phoenix basin of the Salt River Valley. Metropolitan Phoenix is located geomorphically within the Gila Lowland Section of the Sonoran Desert Subprovince, a part of the Southern Basin and Range Physiographic Province. This province is characterized by broad, gently sloping, connected alluvial valleys (basins) bounded by moderately high northwest to southeast trending, rugged mountains (ranges). During late Miocene time, the mountain ranges were extensively dissected and uplifted by northwest to southwest and east to west trending sub-parallel normal faults. The basins are very thick alluvial areas now covering the disconnected portions of the mountain ranges formed by downdropped normal faulting. Numerous low-lying isolated hills (inselbergs), which project above the valley surfaces, represent peaks of former mountain ranges that are now almost completely buried by Salt River Valley alluvial material.

   The mountain ranges that border the project area consist mostly of Tertiary aged sedimentary and volcanic rocks that lie unconformably upon an ancient Precambrian igneous and metamorphic basement complex. The complex is composed predominantly of igneous granite and diorite, metamorphosed schist, gneiss and volcanics. The Tertiary rocks are made up of volcanic basalt, andesite and rhyolite and sedimentary sandstone, siltstone and conglomerate.

   The Phoenix basin consists of Quaternary and upper Tertiary sediments that constitute the valley fill. They consist mostly of poorly to well consolidated and unconsolidated gravel, sand, silt, and clay, representing several environments and ages of deposition. The total thickness of the alluvial materials range from near zero meters (0 ft) along the mountain fronts to 3,000 meters (9,000 ft) under the valley interior.

2. Local Geology and Topography. The Rio Salado project extends approximately 48 km (30 mi) east and west along the Salt River, which flows west into the Phoenix Basin from the Superstition and Goldfield mountain ranges. The Salt River floodplain spreads approximately 1.5 km within the gentle, flat slopes of the Basin, but is restricted to less than 1/2 km (1/4 mi) near Tempe Butte inselberg, west of Tempe. The project is narrowest near Tempe Butte, which is bounded to the north by Camelback Mountain and the south by South Mountain.

   The predominant surface materials within the Rio Salado project area consist of Quaternary aged river and sheet wash deposited alluvium and slope deposited colluvium.. Thick layers of alluvium have accumulated within the major streams, tributaries and flood plains of the Salt River. Streambed alluvium is flanked, covered and underlain by thinner layers of wind and sheet wash deposited alluvium and bedrock colluvium.

Quaternary sediments consist of: 1) 83-117 meters (250-350 ft) of stream and river deposited sand, gravel and boulders interbedded with irregular silt, sand and gravel lenses; and 2) 1.5-75 meters (5-225 ft) of loose to dense silt, sand, clay and gravel alluvium and calcified to uncalcified colluvium.

Sediments of the Salt River reach their maximum thicknesses east and west of Tempe Butte gap, in the city of Tempe. At the gap streambed deposits are less than 75 meters (225 ft) thick. A significant exposure of Precambrian aged granite occurs in patches at the streambed surface along a 2.5 km (1.5 mi) length of the channel just west of the gap.

Upper Tertiary age river terrace deposits greater than 1,000 meters (3,000 ft) thick are found 33-117 meters (100-350 ft) beneath Quaternary alluvium. The Terrace sediments also lie exposed 1.5-117 meters (5-350 ft) above the Salt River channel beyond the project boundaries (near perimeters of the Salt River flood plain). The terraces consist of thick calcified and noncalcified sand and gravel. The terrace sediments overlie thick Tertiary sedimentary and volcanic rocks beneath the basin and inter face with Tertiary rocks along mountain ranges and inselbergs. The very thick Precambrian basement complex underlies basin alluvium at maximum depths of greater than 1,000 meters (3,000 ft) or greater.

3. Faulting. Faults in central Arizona are generally short, discontinuous, normal faults, some of which have been interpreted to displace Quaternary formations. Most fall within the Jerome-Wastach Structural zone, a 75 km (45 mile) wide band which extends from Utah into Mexico. In Utah, the zone is associated with current earthquake activity and displays evidence of abundant Quaternary faulting. In Arizona, the one includes the Main Street Fault in the northwest corner of the state and the Verde Fault located approximately 90 km (55 miles) north of the Rio Salado. Both faults are considered to be potentially active. Because of their distance from the project, ground accelerations from maximum credible events would be less than 0.1g.

4. Seismicity. n evaluation of the geologic and seismic conditions within a 162-km (100 mi) radius of the project area indicated that the proposed project is in an area of low seismicity as referenced in Zone 1 of the Seismic Zone Map of the Contiguous States (U.S. Army, Corps of Engineers, 1983). About 30 earthquakes with maximum epicentral intensities between ii and vi on the Modified Mercalli Intensity Scale (MM) have occurred within a 162-km radius of the project area from 1870 through 1980. The seismic historical record for the last 124 years indicates that only one major damaging earthquake (1887 Sonora, Mexico) has occurred and was located outside the 162-km radius.

The historical 1887 7.2M Sonora, Mexico earthquake was located more than 411 km (255 mi) from Tempe, AZ, and expressed 50 kilometers (31 mi) of surface rupture with 3 meters of normal displacement, causing rockfall in the project area. The most recent (1974) events, located about 24 km (15 miles) northeast of the project area, had recorded Richter magnitudes of only 2.5 and 3.0.

5. Groundwater. The project area overlies portions of the principal aquifer within the Phoenix Basin that consists of Quaternary and Upper Tertiary alluvium.

The Basin groundwater flow moves generally east to west, from the Salt River toward a major cone of depression near Luke Air Force Base, approximately 24 km (15 mi) west of Phoenix. To a lesser extent, groundwater also flows in a northwestward direction toward a second cone of depression in the Deer Valley area.

Recharge to the groundwater basin is derived from seepage of irrigation waters, streamflows, rainfall, and underflow of groundwater. Recharge from streamflow and rainfall is minor, and the amount of recharge from irrigation seepage and underflow has not been high enough to offset progressive lowering of the water table.

Long-term groundwater withdrawal, since the 1940's, has resulted in a general decline in water levels from 67-100 meters (200-300 ft) throughout the Phoenix Basin. However, water-level declines have usually been less than 16.5 meters (50 ft) near the Salt River. The overall trend indicates a progressive decline in water levels westward from the project area toward Luke Air Force Base, approximately 24 km (15 mi) west of Phoenix. To a lesser extent, groundwater also flows in a northwestward direction toward a second cone of depression in the Deer Valley area.

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6. Subsidence. Available information suggests that subsidence in the project area has not occurred. Ground failure in the form of (pumping) subsidence and earth-fissures has occurred in other areas of the Phoenix Basin. The closest ground failure occurrences to the project area are near Luke Air Force Base, where 1 to 3 feet of subsidence has been measured and exhibits the shape of a 3.2 km (2 mi) diameter "bowl" depression.

Earth-fissures and subsidence are both produced by groundwater (pumping) withdrawal, whereby ground (soil) compresses (subsides) because it has lost the support of water within its pores. Earth-fissures develop when the soil subsides differentially and pulls apart.

The Phoenix area will continue to be affected by subsidence because of groundwater overdraft.

7. Previous Exploration. Limits of the project area were explored in 1957 by drilling 5 power-auger soil holes with 45.7 cm (18-inch) diameters. The exploratory borings ranged in depth from 5-7 meters (15 to 21 ft). Soil was also examined by logging 4 vertical sections in 4 gravel pits. The thickness of these sections ranged from 4.5-15 meters (13.5 to 45 ft). The materials encountered during the exploration were predominantly granular.

8. Stone Sources. Two rock borrow sites have been identified as source of construction material and are available for use, in the event an engineering design is proposed for the Rio Salado project. The two rock quarries are less than 16 km (10 mi) from the site and have produced stone for previous Corps flood control projects at the Arizona Diversion Canal and Indian Bend Wash areas. Rocks from both quarries exhibit an excellent service record and are capable of producing hard granite and durable greenschist rock that meet District specifications for stone.

APPENDIX I

LOCAL SUPPORT

City of Tempe
P.O. Box 5002
31 East Fifth Street
Tempe, AZ 85280
602-350-5225

Neil G. Giuliano
Mayor

Dennis J. Cahill
Vice - Mayor

P. Ben Arredondo
Councilman

Lewis
iman

Carol E. Smith
Councilman

Linda Spears
Councilman

Joseph P. Spracale
Councilman

January 10, 1995

Colonel Michal Robinson
U.S. Army Corps of Engineers
300 N. Los Angeles Street
Los Angeles, California 90012

RE: Rio Salado Reconnaissance Study; R4 Draft Report

Dear Colonel Robinson:

On behalf of the City of Tempe, I want to thank you and your staff for the deleterious effort demonstrated in the Rio Salado Reconnaissance Study.

We have reviewed the R4 Draft Report and believe that it accurately states the problem areas within the Salt River and Indian Bend Wash drainage systems. As you may be aware, the City of Tempe has been actively involved with the Rio Salado Project area for over 30 years. In a short time, your staff has developed a document that is both technically correct and clearly illustrates the need for federal assistance within this region.

The City is interested in exploring further the opportunities discussed within the Reconnaissance Study. We feel very strongly that this is a project that is of immediate importance to our citizenry. Be assured that Tempe is ready to work with the Corps in developing a framework that advances this project to construction.

Sincerely,

Neil G. Giuliano

Neil G. Giuliano
Mayor

City of Phoenix
OFFICE OF THE MAYOR

SKIP RIMSZA
Mayor

200 West Washington Street, 11th Floor
Phoenix, Arizona 85003-1611
602-262-7111
FAX: 602 495-5583

Winner of the Carl Bertelsmann Prize

January 10, 1995

Mr. Robert S. Joe, Chief
Planning Division
U.S. Army Corps of Engineers
Los Angeles District Office
300 North Los Angeles Street
Los Angeles, CA 90012

Dear Mr. Joe:

It is with great pleasure that I write to you regarding the next phase of the partnership between the City of Phoenix and the Corps of Engineers to develop the Salt River (Rio Salado). We are committed to move forward with the Feasibility Study pending approval of the Reconnaissance Report by the Corp of Engineers. Due to previous commitments, neither myself or our city manager, Frank Fairbanks will be able to join you in San Francisco this week. However, you have my full support. The City will be represented by Peter Atonna, Deputy Planning Director.

We are continuing our alliance with the City of Tempe in this venture. The City is committed to the regional partnership of realizing the Rio Salado as an environmental restored habitat. Further, Arizona State University, in cooperation with Phoenix and Tempe, has committed to organize a symposium on the project and provide a briefing paper that will tie the history of the project to the current economic, political and environmental issues facing the metropolitan region.

Phoenix City Council will be discussing the project in further detail this spring. Thank you for the continued leadership of the Corps of Engineers in the effort to realize the environmental potential of the Salt River. I believe that its restoration as a waterway and habitat for indigenous wildlife will have multiple benefits for the City of Phoenix for generations to come.

Sincerely,

Skip Rimsza
Mayor

0036ltr

Recycled paper

THE STATE OF ARIZONA

GAME & FISH DEPARTMENT

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

Governor
Fife Symington

Commissioners:
Chairman Elizabeth T. Woodin, Tucson
Arthur Porter, Phoenix
Nonie Johnson, Snowflake
Michael M. Golightly, Flagstaff
Herb Guenther, Tacna

Director
Duane L. Shroufe

Deputy Director
Thomas W. Spalding

October 31, 1994

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

Re: Rio Salado Reconnaissance Study

Dear Mr. Dixon:

I am writing in reference to our conversations and participation in the Rio Salado 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 and wildlife associated recreation associated with the developing metropolitan area. The Department has been pleased to participate and contribute in-kind efforts to that undertaking. We believe that our contributions to date have been significant.

You have inquired about the Department's willingness to be a potential cost-share partner in a potential Rio Salado 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 a potential feasibility project is quite large by our standards. We are uncertain how much of the cost-share burden we could support, however we are anxious to explore financing opportunities with you and the participating cities. 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