ALTERNATIVES EVALUATION REPORT
(Book 1 of 2)

El Rio Watercourse Master Plan and Area Drainage Master Plan

Contract FCD 2001C024
Stantec Project No. 82000240

Stantec

November 2005
Revised December 2005
Revised April 2006

FINAL REPORT

El Rio Watercourse Master Plan

Alternative Evaluation Report

Book 1 of 2

PREPARED FOR:

FLOOD CONTROL DISTRICT
of
Maricopa County

PREPARED BY:

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April 2006

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Project No. 8200240

CONTRACT FCD 2001C024

Flood Control District of Maricopa County

Stantec

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1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

The El Rio Watercourse Master Plan (El Rio WMP) study reach of the Gila River is unique among watercourses in Maricopa County. A shallow groundwater table and inflows from agricultural and industrial sources result in a diverse natural environment of high scenic quality and there is an overwhelming public opinion that the existing character of this reach of the river should be preserved, and if possible, enhanced. The Gila River is the largest river in the state after the Colorado River, with a contributing drainage area of approximately 46,000 square miles at the study limits. In recent times, this reach of the river has experienced several large flood events resulting in significant damage to property and infrastructure. This area is also one of the fastest growing areas in the country. It has grown in population by approximately 225 % in the last 14 years. In the past, traditional development practices associated with such rapid growth have looked to maximize developable area. Such practices often result in uncoordinated flood control measures.

1.2 PURPOSE

The purpose of the El Rio WMP is to examine the benefits, opportunities and impacts of a range of flood control management plans that address the flood and erosion hazards and impending development pressures while considering public safety, social, economic and environmental factors. The ultimate goal of this examination is to recommend a preferred watercourse master plan. Development of the plan is based on public coordination; hydrologic, hydraulic and sediment analyses; geomorphic evaluations and environmental and visual resource investigations.

The project is conducted in four phases. The first phase involves data collection and identification of flooding problems. The second phase is investigations and developing existing condition models. The third phase is alternative formulation and the final phase is the recommended alternative. The purpose of this report is to document the alternative formulation process through which elements of the preferred master plan are identified and evaluated, as well as the documentation of data, assumptions, procedures and criteria used in conducting analyses and evaluations of potential flood control alternatives.

1.3 DESCRIPTION OF STUDY AREA

The El Rio WMP study limits of the Gila River extend approximately 17 miles upstream from the State Route 85 bridge to just upstream of the Agua Fria River confluence as shown in Figure 1.0. The 100-year floodplain limits cover an area of approximately 17,000 acres. Of that, approximately 8,300 acres is floodplain fringe. Currently four bridges cross the river with a fifth bridge in the planning phases at the Cotton Lane Road alignment.

In general through the study reach, the southern bank of the river is tucked up against the Estrella Mountains and Buckeye Hills. The terrain along the south bank is generally quite steep with only a few pockets of developable land within the floodplain limits. The

land adjacent to the north bank of the river is predominantly composed of agricultural uses. Supporting the agricultural activities is an irrigation network consisting of canals operated and maintained by the Buckeye Water Conservation and Drainage District (BWCDD) and the Arlington Irrigation District (AID). The headworks for the BWCDD is a diversion structure located within the river bottom near the upstream study limits. This structure feeds the Buckeye Main Canal, the main delivery structure for the BWCDD. A portion of the Main Canal, the Extension Canal and numerous other laterals, tailwater ditches and associated structures lie within the 100-year floodplain limits. Water for the AID is supplied, in part, by the BWCDD system. The AID facilities that lie within the 100-year floodplain limits include the Arlington Main Canal, laterals, tailwater ditches and associated structures.

Agricultural return flows in combination with a shallow groundwater table and wastewater effluent provide sufficient water supply to support a diverse vegetative community and several unique species of wildlife. Native riparian vegetation along the study reach of the river includes stands of cottonwood and willow trees as well as cattail and bullrush that line open bodies of water. However, most of the vegetation within the study reach consists of dense, monotypical stands of salt cedar. Many of the open bodies of water are created by beaver dams. In addition to beaver, the river provides habitat for egrets and great blue herons and has suitable habitat for two endangered species; the southwest willow flycatcher and the Yuma clapper rail. Another unique feature of the study reach is the number of cultural sights that have been documented. The majority of those sites occur on the north bank and range from habitation sites to early irrigation facilities.

The river morphology in the study reach can be characterized as a compound channel that consists of a meandering low flow channel and a wider system of braided subchannels. The current limits of the compound channel have been identified by JE Fuller/Hydrology & Geomorphology (JEF, 2003). The limits are generally coincident with the limits of the Federal Emergency Management Agency (FEMA) floodway, which vary between 2,000 feet and 6,000 feet in width. Within the compound channel JEF defined an active channel that represents the limits in which the low flow channel migrates. Inspection of historic aerial photography and other data shows that the width and location of both the compound channel and the active channel have changed over time. Because of the geologic control (rocky outcrops) along the south bank, most of the variability in the river has been along the north bank.

Recently, agricultural activities have begun to encroach into the river floodplain and the historic lateral migration limits. At the same time, the native riparian vegetation is being replaced with dense stands of salt cedar. The combination of these factors is impacting the natural form and function of the river and the capacity to convey flood flows.

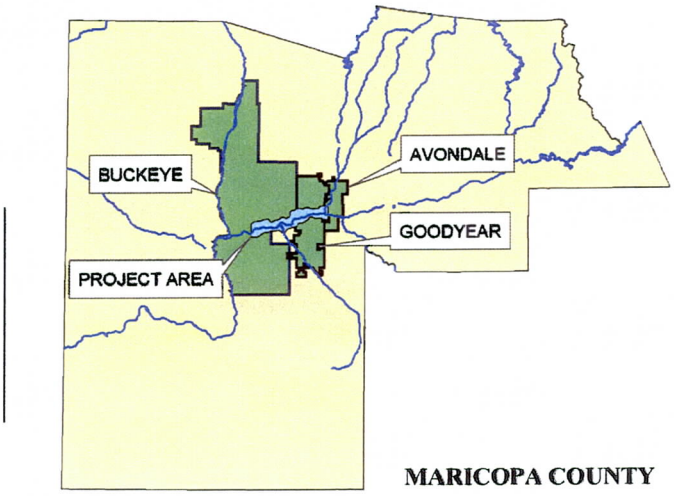

Figure 1 - Project Vicinity Map

1.4 PROJECT GOALS

The general concept for the El Rio Watercourse Master Plan (El Rio WMP) was developed in 1999 through the efforts of a multi-agency committee and is documented in a report entitled "The El Rio Vision, Multi-Agency Review and Response to Planning and Policy Opportunities on the Gila River." That concept was to prepare a comprehensive flood control management plan to be used by Maricopa County as well as the Town of Buckeye and the Cities of Goodyear and Avondale to help guide development along the river in order to provide a uniform and coordinated approach to floodplain management. The major goals of the El Rio WMP identified by the committee are:

- Restore and maintain the natural functions within the river corridor,
- Focus on multi-use facilities and functions,
- Maintain or enhance flood control elements or mitigate,
- Focus on public/private partnerships, and
- Link functional compatibility outside the riparian habitat limits.

The authority for the development of El Rio WMP is established in the Arizona Revised Statutes Title 48, Chapter 21 and the Floodplain Regulations for Maricopa County. The Flood Control District of Maricopa (District) contracted with Stantec Consulting Inc. and a team of subconsultants to assist in the development of this plan.

1.5 ACKNOWLEDGMENTS

The success of the El Rio Watercourse Master Plan development is due to the contributions of numerous individuals and the shared belief that through appropriate planning, public safety and quality of life can be improved for the citizens who live along or visit this reach of the Gila River. In addition, it should be noted that the vision and leadership provided by Maricopa County Council Members Max Wilson and Mary Rose Wilcox was instrumental in the success of this project. The input, perspective, and guidance of the following individuals and organizations is greatly appreciated.

Maricopa County Board of Supervisors

District 1, Fulton Brock
District 2, Don Stapley
District 3, Andrew Kunasek
District 4, Max W. Wilson (Chairman)
District 5, Mary Rose Wilcox

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Russ Miracle
Doug Williams
John Hathaway
Greg Jones
Bing Zhao
David Degerness
Theresa Pinto
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Diana Stuart
Melissa Lempke
Jen Pokorski
Jessica White

City of Avondale

Stephanie Karlin
Dan Davis

City of Goodyear

Joe Schmitz

Town of Buckeye

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Buckeye Water Conservation and Drainage District

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Maricopa County Planning and Zoning

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John Fuller
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M3 Research

Dave Garrett

Wass Gerke & Associates, Inc.

Roland Wass
Sara Gerke

2.0 DATA COLLECTION AND EXISTING CONDITION ANALYSIS

2.1 INTRODUCTION

Existing data was collected and analyzed as part of Phases I and II of this project. The results of those phases provided the baseline hydrologic, hydraulic, geomorphic, environmental, cultural and visual characteristics data for the identification and analysis of all planning elements and the development of evaluation criteria used to rank planning elements. Data and conclusions drawn from various existing condition analysis reports are utilized in the formulation and evaluation of flood control management alternatives. Reports prepared as part of those phases are separate documents referred to as attachments to this report. The following is a brief summary of the attachments.

2.1.1 Attachment 1 - Data Collection Report, Stantec, September 2005

The Data Collection Report provides a listing and brief description of all the data collected for the El Rio WMP. Type of data collected includes historical aerial and ground photographs, environmental surveys, current land use plans, general and area specific planning documents, vegetation, wildlife and cultural resource surveys, geologic and geomorphic data, hydraulic and hydrologic reports, floodplain delineations, topographic mapping, hydraulic models, as-built plans, drainage reports and site plans, design guidelines and drainage manuals.

2.1.2 Attachment 2 – Planning Element Analysis, Stantec, July 2003

The Planning Element Analysis report presents figures, descriptions and detailed tabulations of the key planning elements within the study limits. The key planning elements include:

- Land Ownership

  Most of the EL RIO WMP study area acreage is comprised of land held in private ownership. Approximately 19,303 acres or 63% of the project area is privately owned. Government owned land consists of 11,410 acres or 37% of the study area. The private land use is controlled by regulatory requirements; such as the General Plan Land Use Designations and Zoning Regulations which are found in each of the cities and the county. The distribution of land ownership in the project area is depicted in Figure 2.1.

- Land Use

  Based on the EL RIO WMP Composite Land Use Designations Map (Figure 2.2) presented in the Planning Element Analysis Report the breakdown of designated land use in the floodway, floodplain and overall EL RIO WMP study area includes an estimated 12,760 ± acres of designated Open Space land. The various city designations also include 1,418 ± acres as Water (equivalent to Open Space

Designation), which is generally found within the floodway and 203-acres of Public/Quasi-Public designated land. Combining the Open Space, Water and Public/Quasi Public designated land there are more than 14,381 ± acres of potential opportunity for river flood control facilities, as well as recreation, preservation, river restoration, heritage landscape character retention, multiple use focus and recreational amenities that link the El Rio project to the surrounding communities.

- Transportation and Infrastructure

  Within the El Rio study area future roadway improvements are under consideration, such as the potential extension of Hwy 303 with a bridge crossing on the Gila River and the Interstate 10 reliever. Based on conversations with the Planning and Zoning offices of Buckeye and Goodyear, the I-10 reliever may be located within the existing FEMA Effective Floodplain or in the area between MC 85 and the Gila River. In addition, with the build out and development of the larger proposed development projects, such as Estrella Mountain Ranch development, opportunities will increase as the transportation and infrastructure improvements are completed, making possible the development of adjacent lands. Notably Estrella Parkway / Rainbow Valley Road is planned to be improved ultimately from Southern Avenue to Ray Road, and a new bridge is planned along the Cotton Lane alignment. Optimally, transportation systems planning and land use planning work hand in hand. As land is developed and the transportation and infrastructure are improved, adjacent land becomes more economically viable and therefore more attractive for consideration by land developers for further development and improvement

- Sand and Gravel Mining

  Private land use within the floodway/plain of the EL RIO WMP includes several active or potential sand and gravel mining sites (Figure 2.3). Several individual operations exist. These include: American Aggregates, Rockland Materials, Gravel Resources, A and B Silica Sand Inc., Alleco Stone Company, Salt River Sand and Rock, Fort McDowell Yavapai Nation, Pioneer Landscaping Materials, Edward Kelton Construction, Phoenix Redi-Mix, and Buckeye Water Conservation and Drainage District.

  Sand and gravel mining property owners working in cooperation with the Flood Control District afford potential opportunities for a planned pattern of river material extraction and channel formation. During the alternative analysis phase of the EL RIO WMP project, particular attention will be focused on the plans, opportunities and constraints presented by sand and gravel mining operators in the floodplain. Care should be taken to locate the excavations so that they will not cause headcutting that might damage existing structures. These recommendations can be implemented through permitting and monitoring of private enterprise within the floodway/plain.

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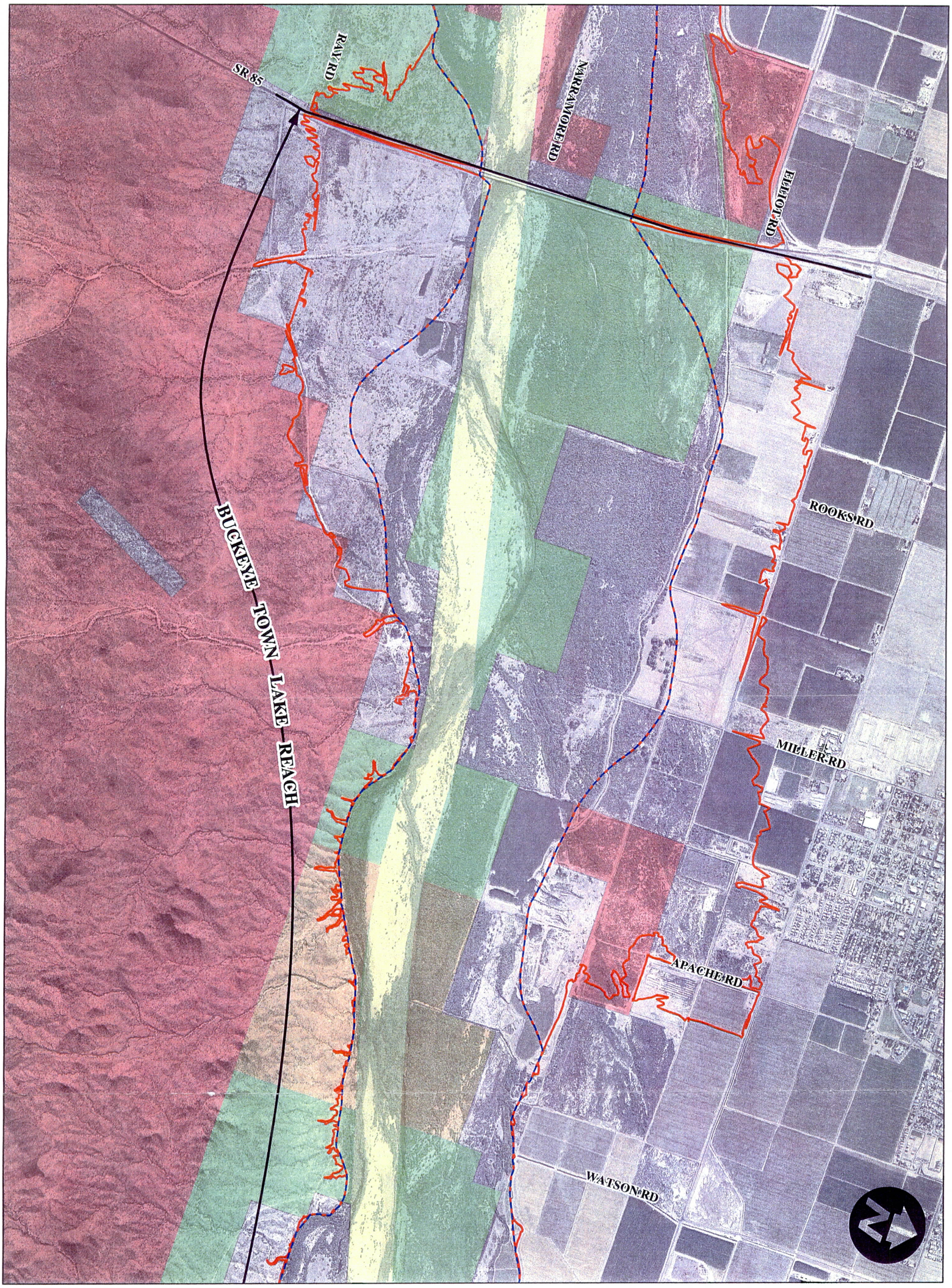

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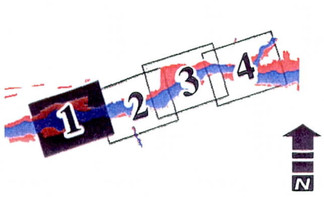
100-Year Flood Zone
- Floodway Boundary
- 100 Year Floodplain Boundary

Land Ownership
- Bureau of Land Management
- AZ Game & Fish
- Maricopa Co. Parks & Recreation
- AZ State Trust
- Private
- FCD Owned, Leased or Easement



EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.1 - LAND OWNERSHIP
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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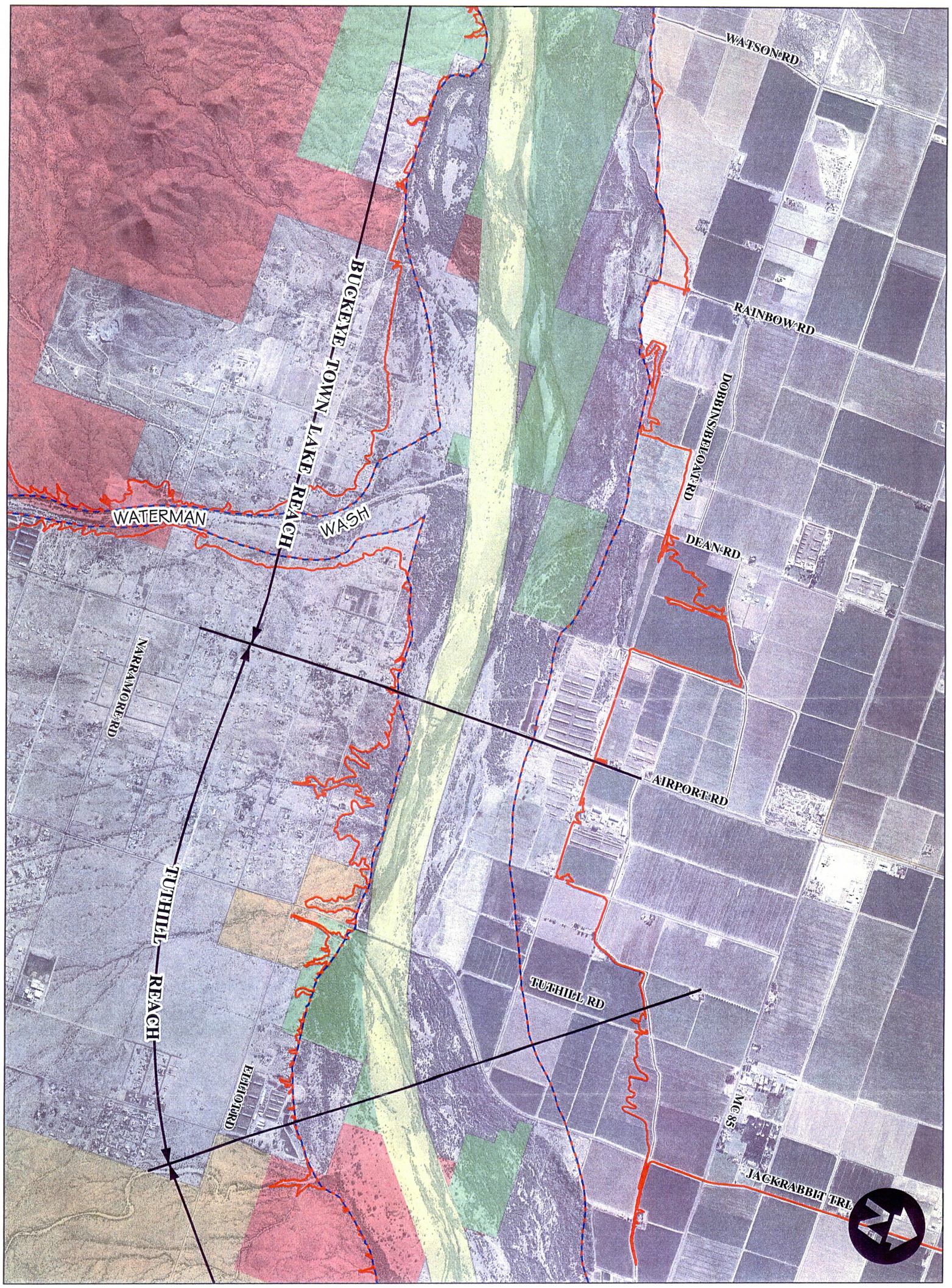

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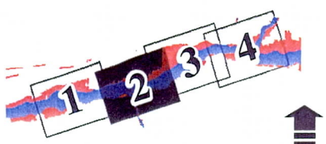

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EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.1 - LAND OWNERSHIP
SHEET 2 OF 4 (TUTHILL REACH)
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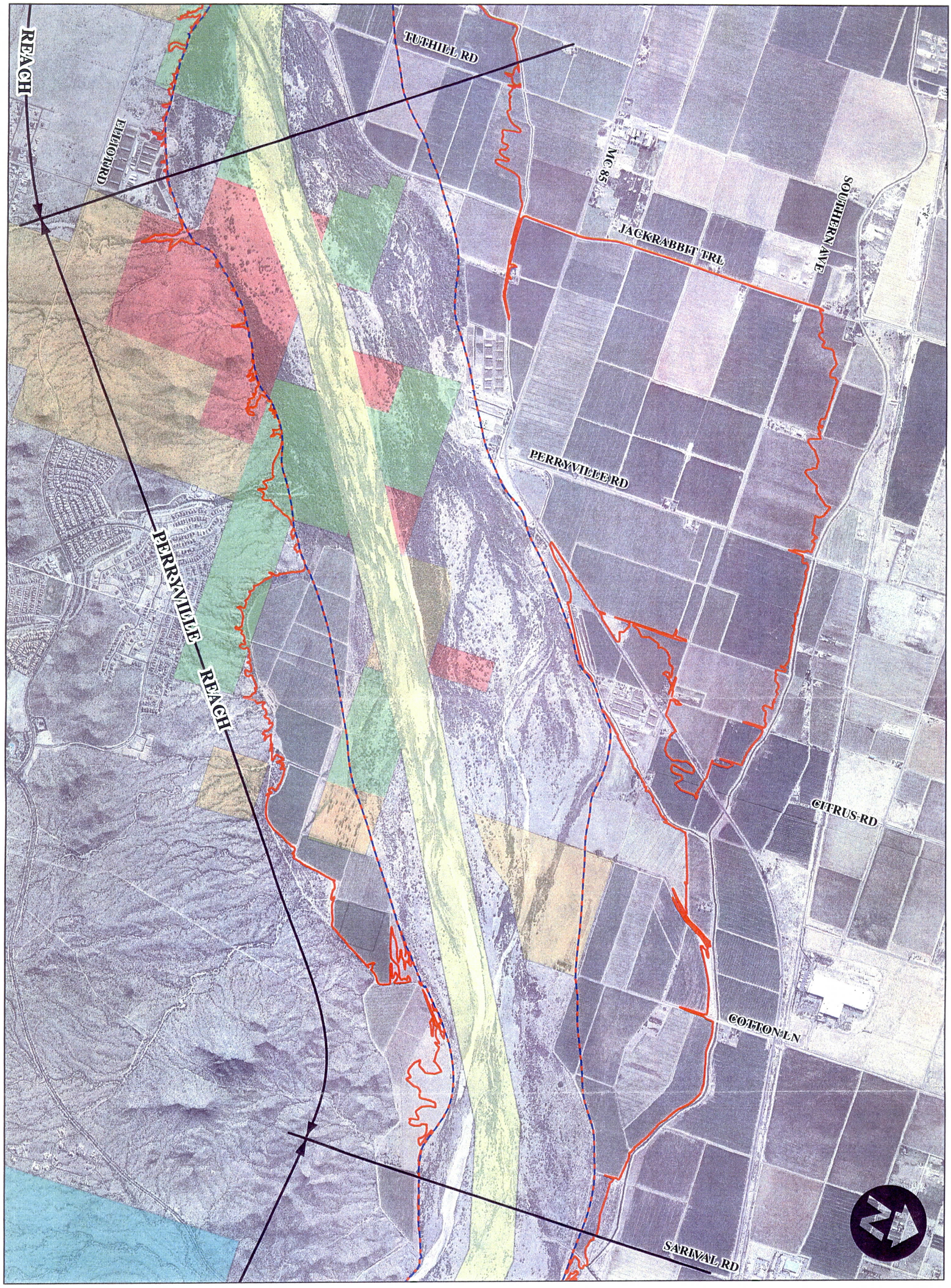

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Phoenix, AZ 85044

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- 100 Year Floodplain Boundary

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- AZ State Trust
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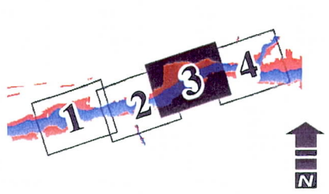

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.1 - LAND OWNERSHIP
SHEET 3 OF 4 (PERRYVILLE REACH)
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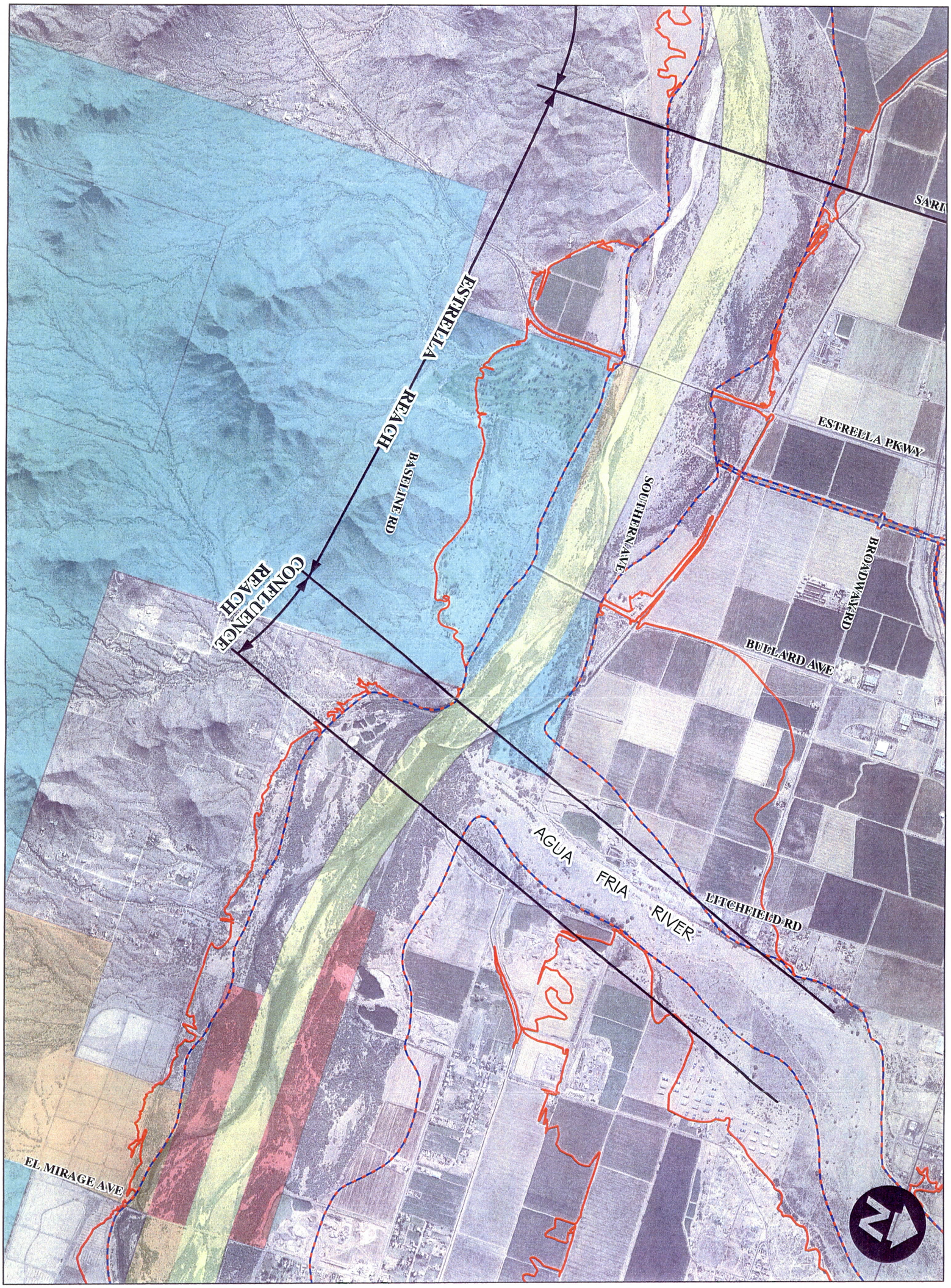

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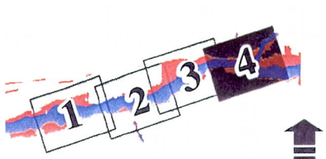

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.1 - LAND OWNERSHIP
SHEET 4 OF 4 (ESTRELLA REACH)
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1 Inch = 2000 Feet

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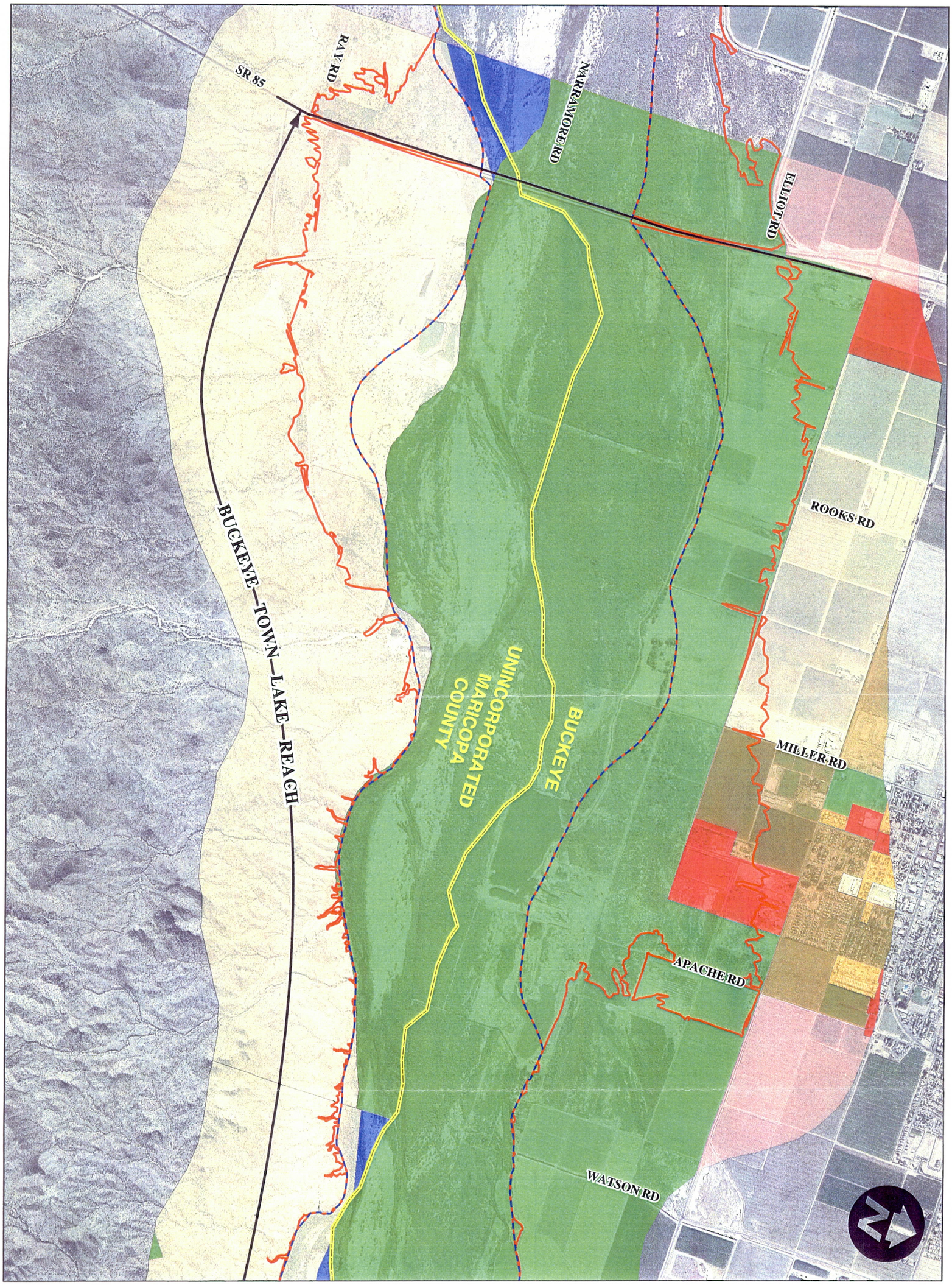

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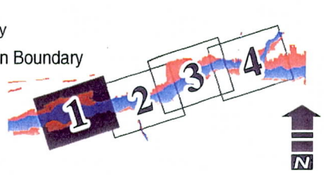
Composite Landuse

- 0 to 1 Du/Ac
- 1 to 2 Du/Ac
- 2+ Du/Ac
- 4+ Du/Ac
- Commerce
- Mixed Use
- Open Space
- Public/Quasi Public
- Water

- 10,000' Birdstrike Buffer (Goodyear Airport)
- buckeyeoldlimits

100-Year Flood Zone

- Floodway Boundary
- 100 Year Floodplain Boundary



EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.2 - COMPOSITE LAND USE
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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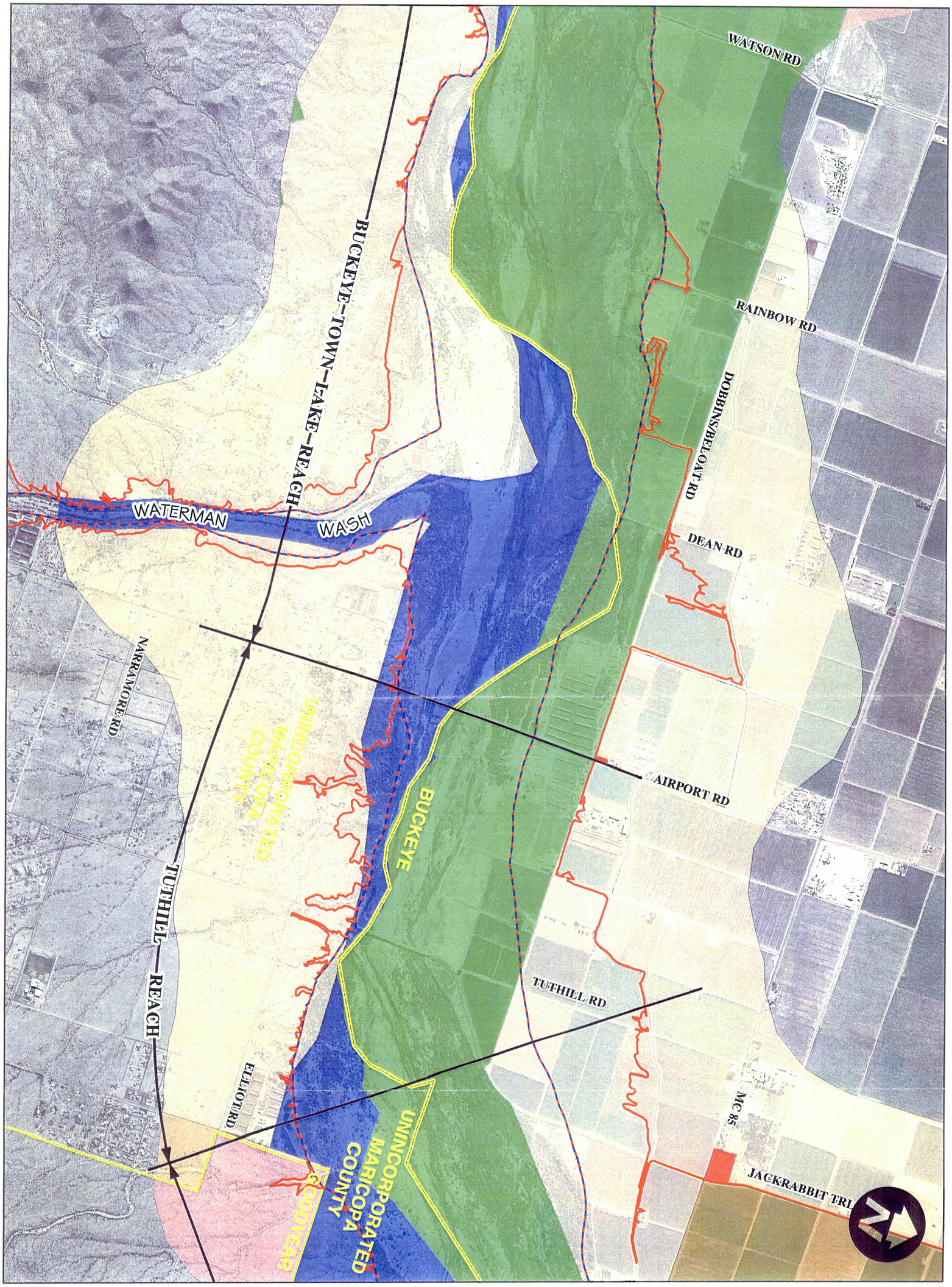

Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

Composite Landuse
- 0 to 1 Du/Ac
- 1 to 2 Du/Ac
- 2+ Du/Ac
- 4+ Du/Ac
- Commerce
- Mixed Use
- Open Space
- Public/Quasi Public
- Water

- 10,000' Birdstrike Buffer (Goodyear Airport)
- buckeyeoldlimits

100-Year Flood Zone
- Floodway Boundary
- 100 Year Floodplain Boundary

1 2 3 4

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EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.2 - COMPOSITE LAND USE
SHEET 2 OF 4 (TUTHILL REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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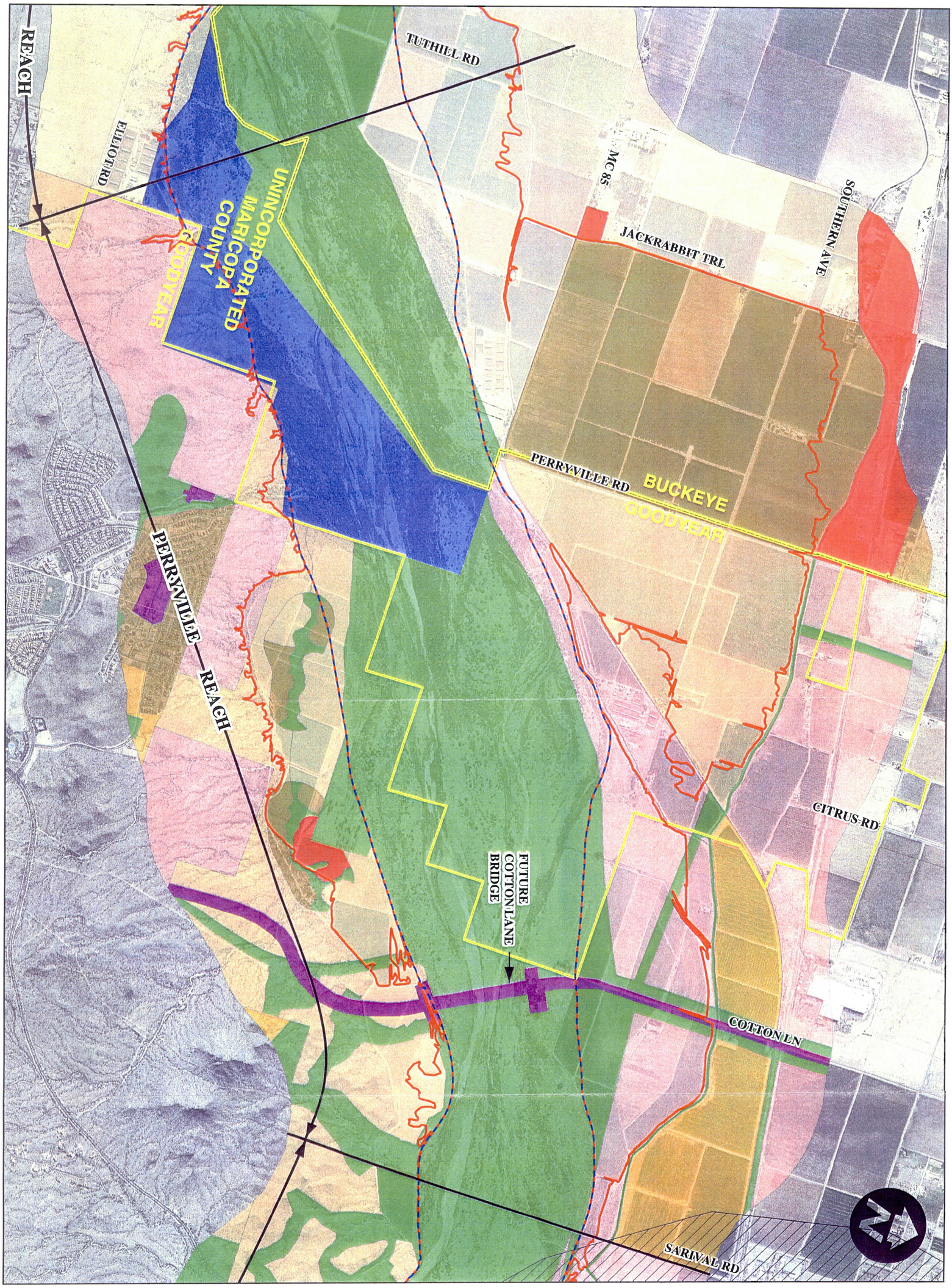

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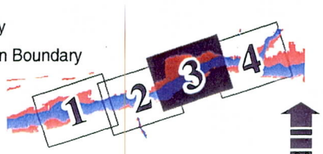

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.2 - COMPOSITE LAND USE
SHEET 3 OF 4 (PERRYVILLE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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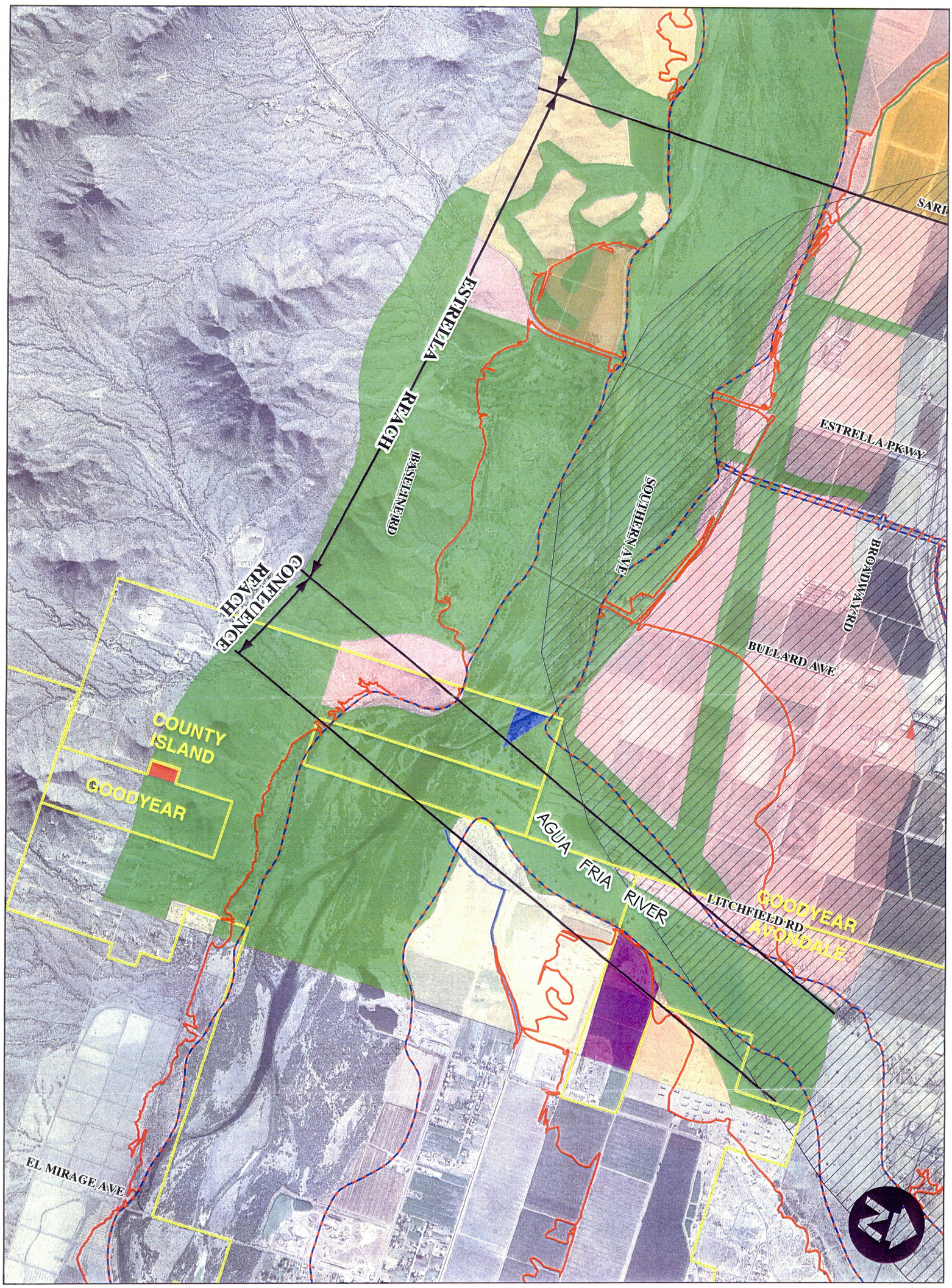

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- buckeyeoldlimits

100-Year Flood Zone
- Floodway Boundary
- 100 Year Floodplain Boundary

1 2 3 4

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EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.2 - COMPOSITE LAND USE
SHEET 4 OF 4 (ESTRELLA REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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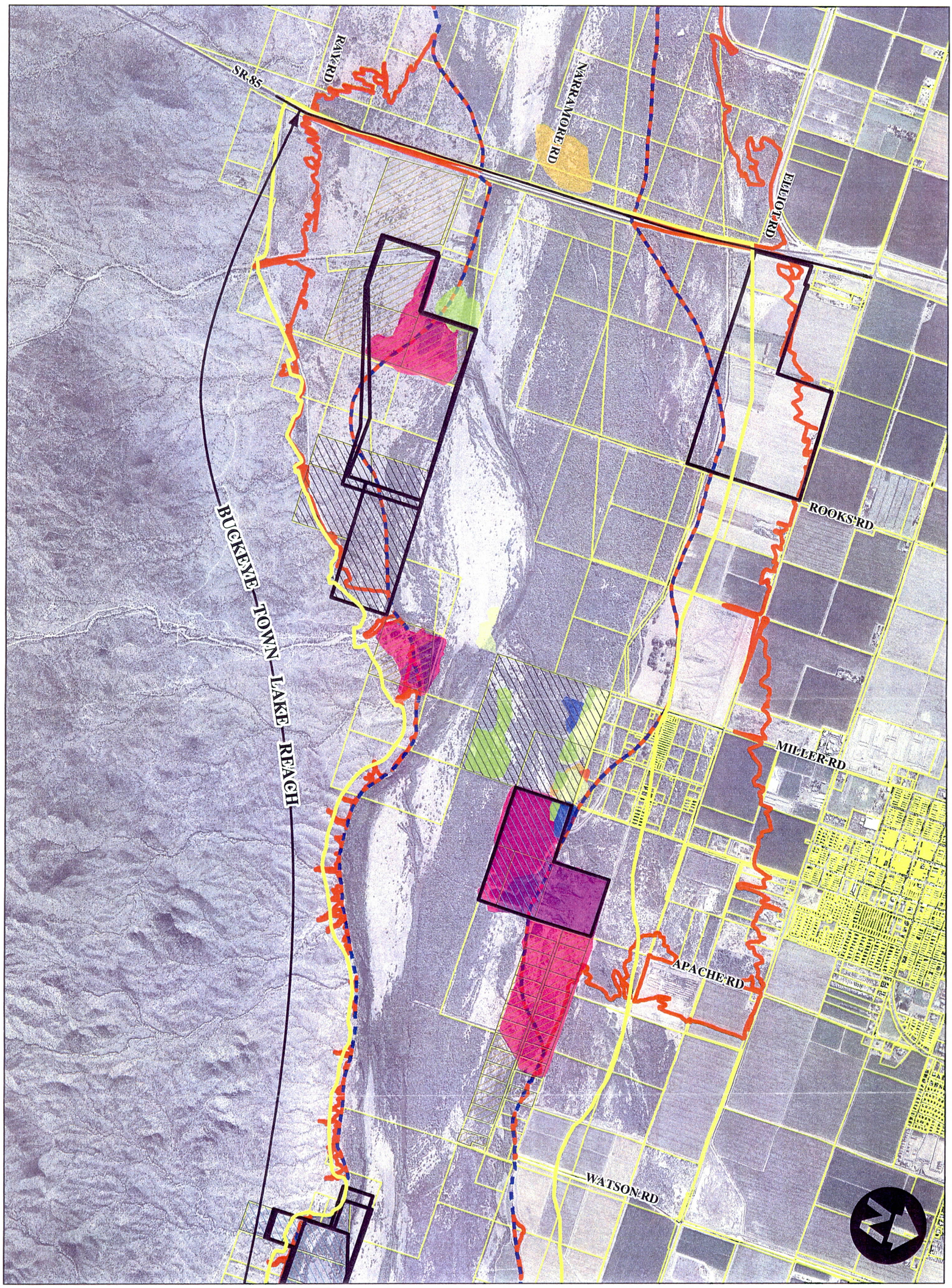

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8211 S. 48th St.
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Historic S & G Sites
- 1940s
- 1950s
- 1960s
- 1970s
- 1980s
- 1990s
- 2000s
- Erosion Hazard Area

New Application or Amendment to Application

Floodplain Use Permits
- Active
- Expired, In Process or No Permit
- Inactive

100- Year Flood Zones
- Zone AE
- Zone A
- Zone AH
- Floodway

1 2 3 4

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.3 - SAND & GRAVEL MINING OPERATIONS
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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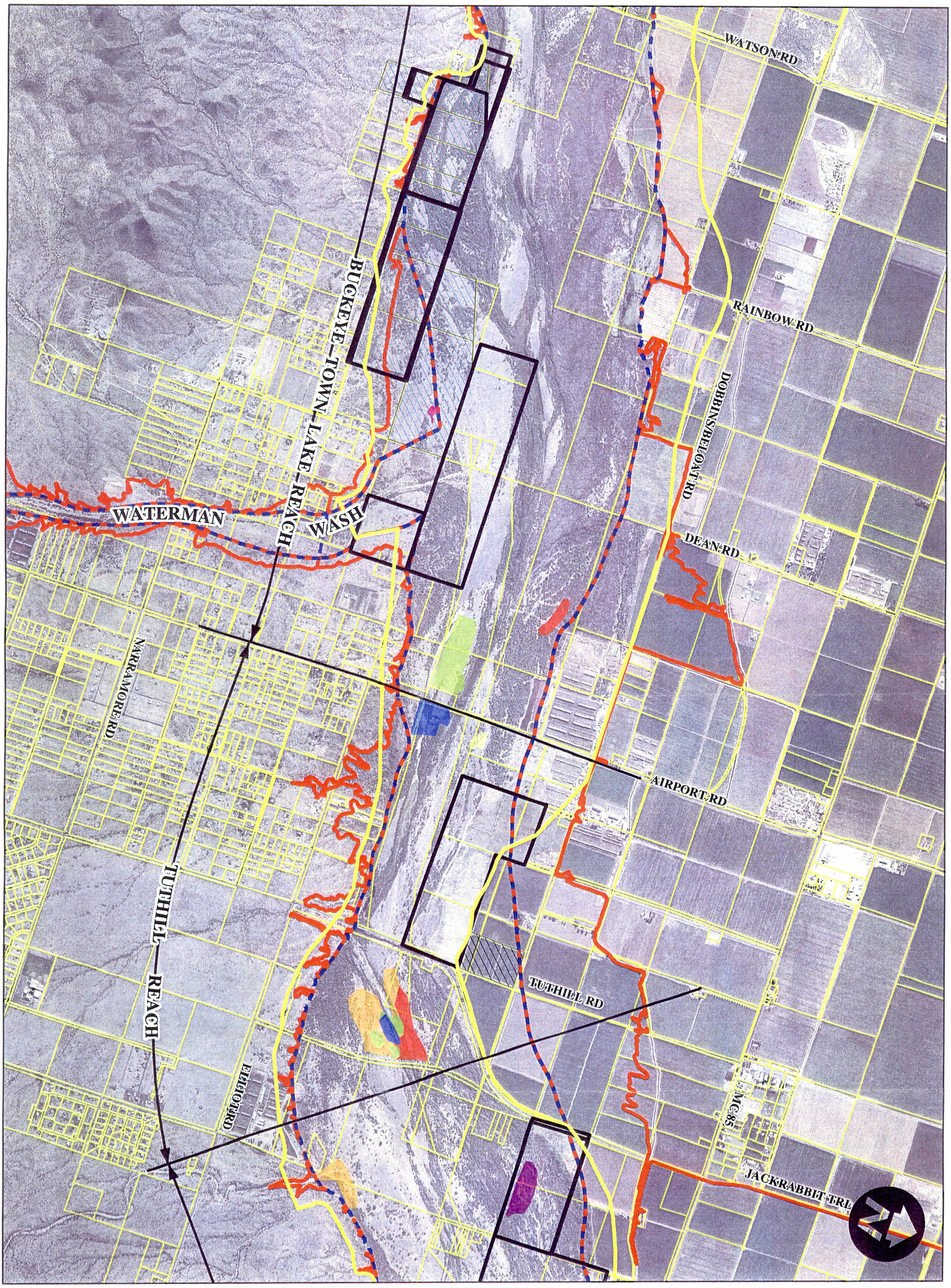

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100- Year Flood Zones
- Zone AE
- Zone A
- Zone AH
- Floodway

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EL RIO

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.3 - SAND & GRAVEL MINING OPERATIONS
SHEET 2 OF 4 (TUTHILL REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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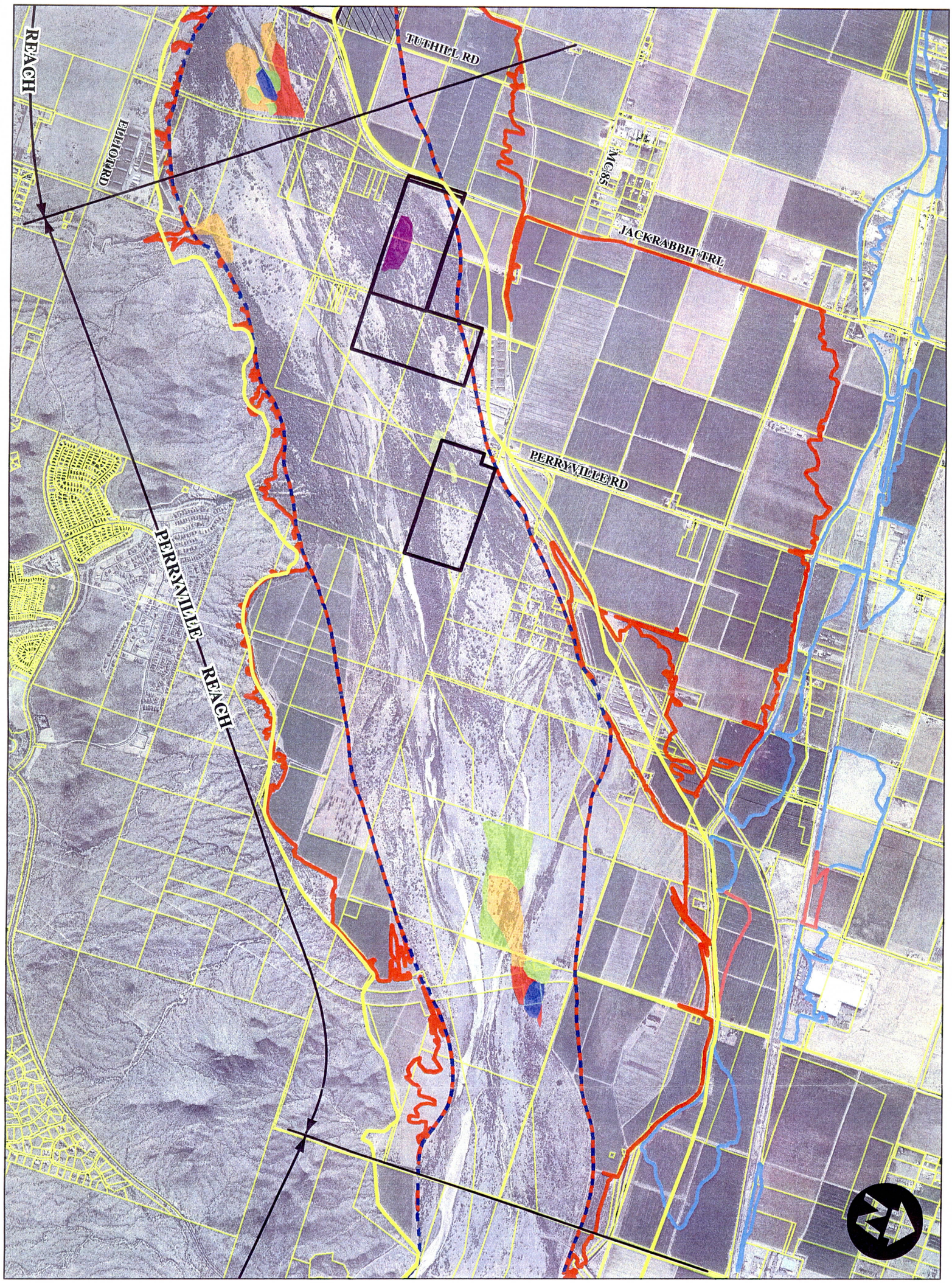

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- Inactive

100- Year Flood Zones
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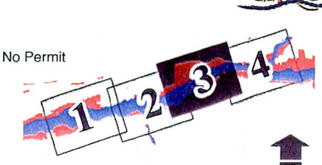
- Zone AH
- Floodway



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EL RIO

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.3 - SAND & GRAVEL MINING OPERATIONS
SHEET 3 OF 4 (PERRYVILLE REACH)
1 FEB 2006

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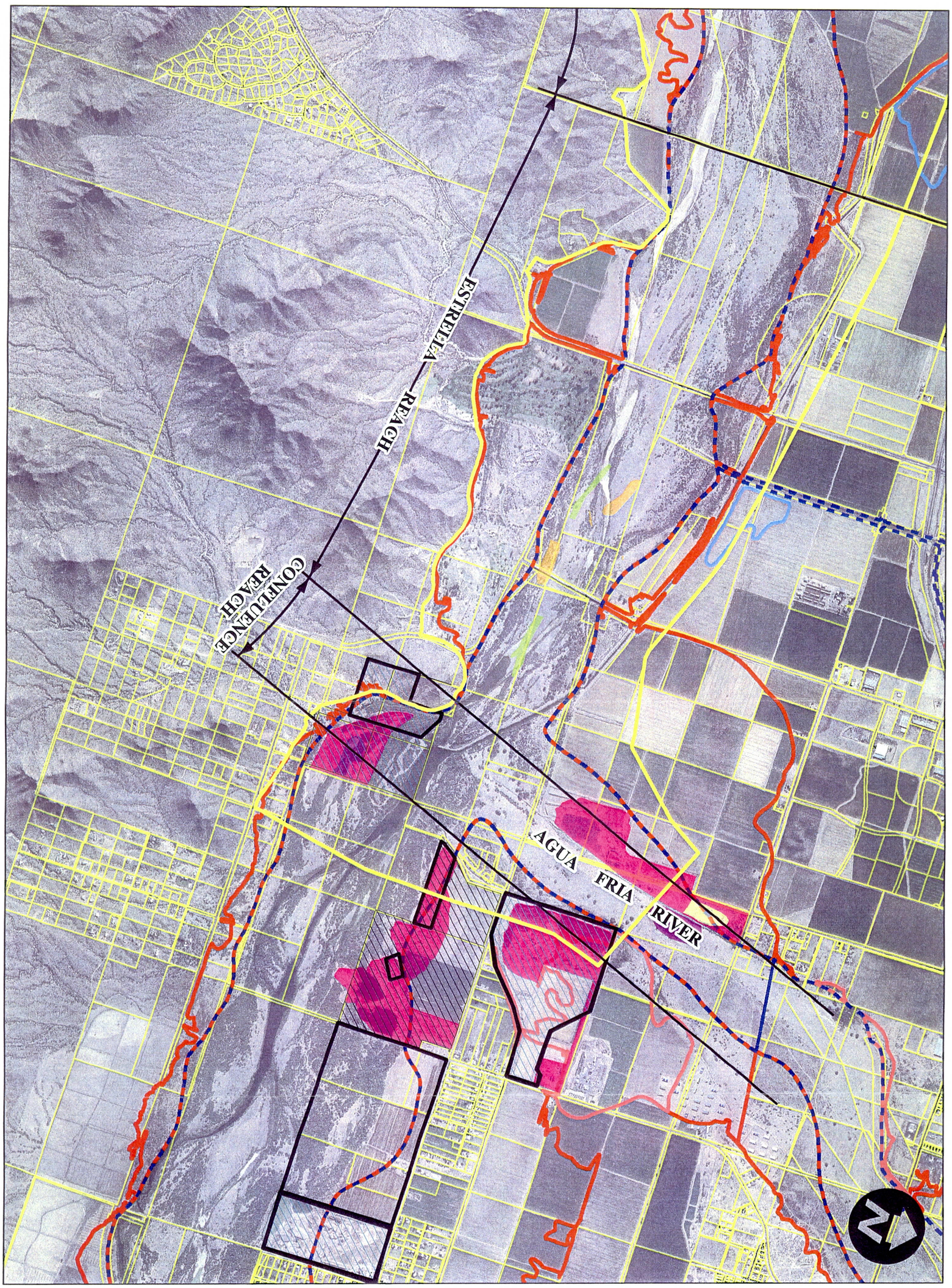

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EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.3 - SAND & GRAVEL MINING OPERATIONS
SHEET 4 OF 4 (ESTRELLA REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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2.1.3 Attachment 3 - Existing Condition Hydrology and Hydraulics Memorandum

The Existing Condition Hydrology and Hydraulics Memorandum presents data, figures, methodology descriptions and detailed tabulations of the key hydrologic and hydraulic elements and parameters that will be used in hydraulic and sedimentation evaluations of flood control management alternatives.

- Hydrology

  Hydrologic analysis evaluates rainfall-runoff relationships for a given area (watershed) where the volume and rate (peak discharge) of runoff is estimated at specific locations. An understanding of the hydrology of an area is key in determining flood hazards and in identifying potential impacts to the subject reach of the Gila River. Peak discharges used in hydraulic and sediment transport analyses for the El Rio WMP were taken from the March 1996 U.S. Army Corps of Engineers report for the modifications to Roosevelt Dam entitled *Gila River Basin, Arizona, Section 7 Study for Modified Roosevelt Dam, Arizona, Hydrologic Evaluation of Water Control Plans, Salt River Project to Gila River at Gillespie Dam* and from the Federal Emergency Management Agency (FEMA) *Gila and Salt Rivers Flood Insurance Study* (Baker, 1999).

- Hydraulics

  Baseline hydraulic data for the El Rio Watercourse Master Plan is taken from *The Gila and Salt Rivers Flood Insurance Study* (Baker, 1999). That study, herein referred to as the FEMA Study, was authorized in 1992 by the Flood Control District of Maricopa County and extends from 1.4 miles downstream of State Route 85 on the Gila River to the Granite Reef Dam on the Salt River. Originally the downstream limits of the study were at Gillespie Dam on the Gila River. The original study was broken into 5 reaches. A change in scope resulted in the majority of the lower reach, Reach 1, being removed from the study. The remainder of Reach 1 was added to Reach 2. The El Rio Watercourse Master Plan (EL RIO WMP) study reach extends from State Route 85 to the confluence with the Agua Fria and Gila Rivers and lies entirely within Reach 2 of the FEMA Study. The data, procedures and results for Reach 2 of the FEMA Study were reviewed in regard to the purposes of EL RIO WMP.

- Breakout Area, Stantec, June 2004

  This Memo documents the preliminary hydraulic modeling conducted to estimate the discharge and extent of flooding hazard resulting from the failure of the Extension Canal and/or MC 85 where those facilities lie within the 100-year floodplain limits. The potential breakout was identified in the floodplain delineation study, but was not mapped. The peak breakout discharge was estimated to be 7,300 cfs. The resulting flood inundation area extends along a parallel path to the Gila River eventually returning to the river near the Town of Buckeye.

- Field Survey Comparison

  This memo describes comparisons of field survey data to the topographic mapping prepared as part of *The Gila and Salt Rivers Flood Insurance Study* (Baker, 1999).

2.1.4 Attachment 4 - Sedimentation Analyses, Book 1- El Rio Existing Condition Sedimentation Analysis and Book 2-El Rio Alternative Sedimentation Analysis, Stantec Consulting Inc. November 2005.

The primarily goal of the sediment transport analysis was to define the existing condition sediment transport characteristics of the river. The following objectives defined the approach to the analysis:

- Develop an understanding of the fluvial process of sedimentation within the El Rio project area for the period of record (from about 1921 through 2004) and for the 100-year flood event.

- Develop an understanding of how the present river would respond with no intervention if subjected to a sequence of floods similar to those of historic record plus a 100-year flood.

- Qualitatively identify tendencies for sedimentation that may occur in reaches of the study watercourse.

- Quantify magnitudes of sedimentation that may occur.

- Providing a sediment transport model that can be used to evaluate various structural and nonstructural flood management alternatives.

Conclusions cited in the report drawn from the existing condition analysis are:

1. The Gila River in the El Rio study area has the following characteristics:

   a) At low flows, generally less than about 35,000 cfs, the river is braided. Flow occurs in numerous small channels that intersect through a broad expanse of the river.

   b) At high flows, the river tends to be straight. During floods, the flow is concentrated in a relatively narrow main channel.

   c) The bed of the river is predominantly sand.

   d) The bed material is slightly coarser in the upper 8 miles, which is due to the inflow of gravel and cobble from the Salt River.

2. Floods in the El Rio study area are predominantly from the Salt River with a lesser contribution from the Gila River upstream of the confluence.

3. Sediment inflow to the El Rio study area has the following characteristics:

    a) The Salt River supplies a lower concentration of wash load due to the numerous storage dams on the Salt and Verde Rivers.

    b) The Salt River supplies a larger portion of coarse bed material (gravel and cobble) than the Gila River upstream of the confluence.

    c) The Gila River provides higher concentrations of wash load due to the lack of storage dams in the near vicinity on either the Gila River or the Santa Cruz River.

    d) The Gila River provides a greater concentration of sand load than the Salt River. The Gila River upstream of the confluence is a broad sand bed river. The Salt River upstream of the confluence is armored with gravel and cobble.

4. During floods, the majority of the sediment transport is in a relatively narrow channel through the broad floodplain.

5. The main channel of the Gila River is in near dynamic equilibrium; sediment inflow equals sediment outflow.

6. The HEC-6T model cannot accurately estimate the deposition of fine sand and silt in the highly vegetated overbank areas.

7. Erosion and sedimentation varies along the length of the river.

    a) Sedimentation is expected in the broad channel from station 189 to station 194.

    b) Overall erosion is expected in the river channel from station 185 to station 189 and for about 2 miles upstream of the SR 85 bridge.

    c) General scour of as much as 8 feet can be expected in the channel of the river during floods.

The volume of sediment passing through the El Rio study area during a 100-year sequence of floods is about 350 million tons or about 200,000 acre-feet. That volume agrees well with the Corps of Engineers estimate of sedimentation in Painted Rock Reservoir for the period from 1953 through 1993.

2.1.5 Attachment 5 – Lateral Migration Analysis Report, JE Fuller/Hydrology &Geomorphology, September 2005.

The primary purpose of the lateral migration analysis is to delineate a corridor width that would be required to preserve the pre-project channel form and function. That corridor,

referred to as the erosion hazard boundary or lateral migration zone (Figure 2.4), is based on extensive field observations and the interpretation and analysis of historic data. Information contained in that report includes figures illustrating the historical lateral movement of the river, discussions of the river morphology, identification of areas within the study reach subject to future lateral migration and/or long term scour and deposition and areas recommended for more detailed geomorphic investigations.

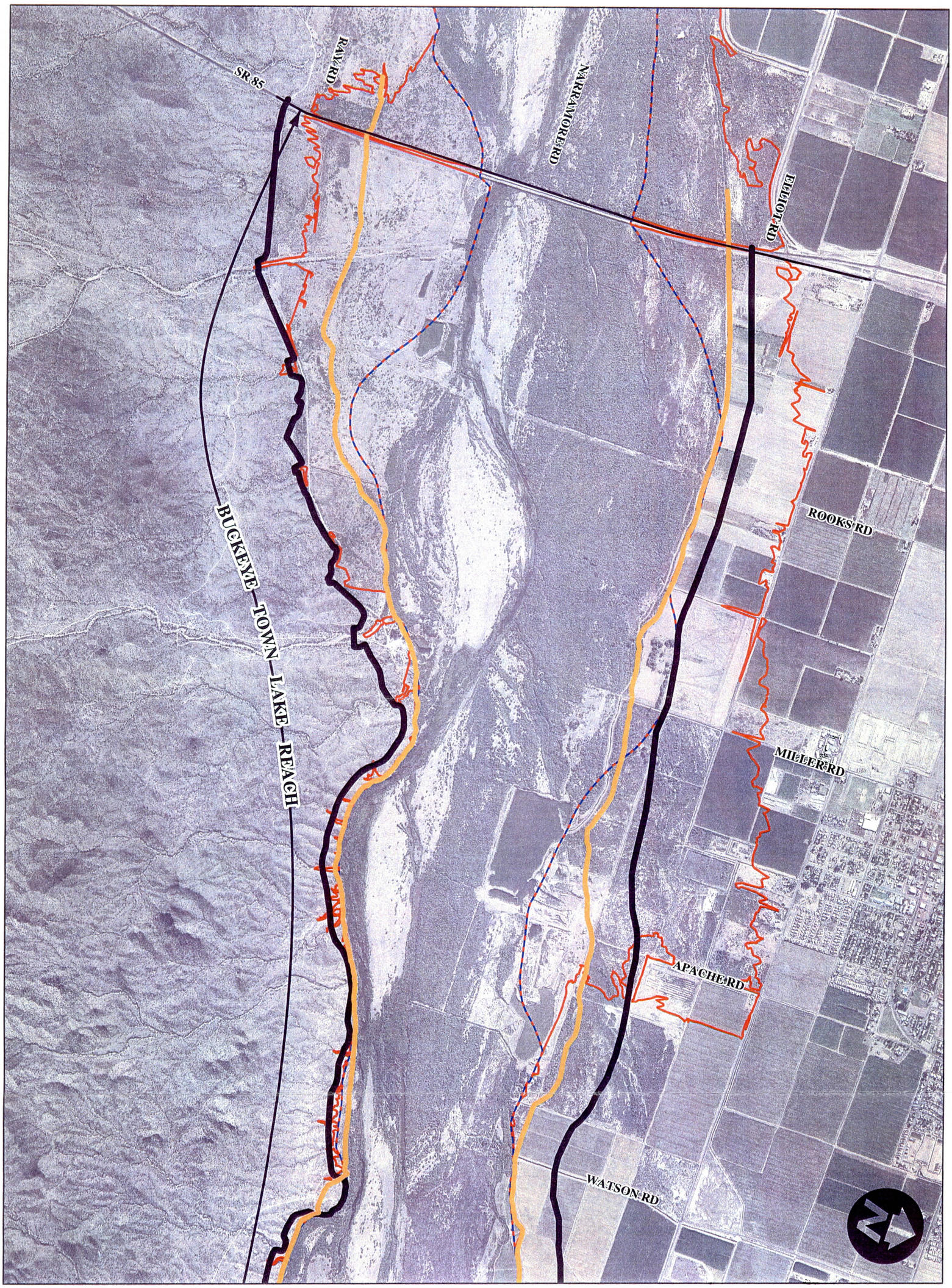
2.1.6 Attachment 6 – Groundwater Evaluation, HydroLogic Consultants, April 2003

The Groundwater Evaluation report discusses the physical conditions, processes and human factors relating to groundwater within the study reach. Groundwater elevation data were used to prepare contour maps of the water table elevations. Two contour maps were prepared. The first reflects current conditions within the study limits. The existing condition map shows that the depth to groundwater within the main channel of the river is generally less than 3 meters. Beyond the channel limits, but within the 100-year floodplain limits, the depth to groundwater is generally less than 10 meters with much of the western portion of the study limits (near the Town of Buckeye) being less than 3 meters. Outside of the floodplain limits, the depth to groundwater is generally between 3 and 10 meters. The second contour map depicts potential depths to groundwater during drought conditions. That map shows that during drought conditions, the depth to groundwater for most of the study reach would be greater than 10 meters with the exception of the western portion near the Town of Buckeye where depths would be between 3 and 10 meters. Also included in the report are discussions of the water budget along the study reach and the impacts of future development to the groundwater conditions.

2.1.7 Attachment 7 – Environmental Resources Report, Stantec; Wass Gerke & Associates, Inc; EcoPlan Associates, Inc. and Aquatic Consulting & Testing, Inc., July 2003

The Environmental Resources Report is a compilation of qualitative and quantitative evaluations of the physical, wetland, biological and anthropogenic resources within the study area. Wass Gerke & Associates prepared the physical and wetland resources section of the report. That section characterizes the water quantity and quality in regard to the riparian habitat that exists within the study reach as well as the potential for restoration and enhancement opportunities.

EcoPlan Associates, Inc. prepared the biological resources section of the report. That section documents the vegetative and wildlife surveys that were conducted within the study reach. The survey limits generally correspond to the FEMA floodway boundary, an area approximately 8,000 acres in size. Nine vegetative cover types were identified. Over 90-percent of the area surveyed is composed of salt cedar (54-percent) and cobble strand (38-percent). The surveys also identified suitable habitat for two endangered species, the Yuma clapper rail and the southwest willow flycatcher and several unique wildlife features such as beaver dams and lodges, great blue heron rookeries and egret roosts.



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Compound Channel
Lateral Migration Zone
100-Year Flood Zone
Floodway Boundary
100 Year Floodplain Boundary

1 2 3 4

N

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.4 - LATERAL MIGRATION ZONES
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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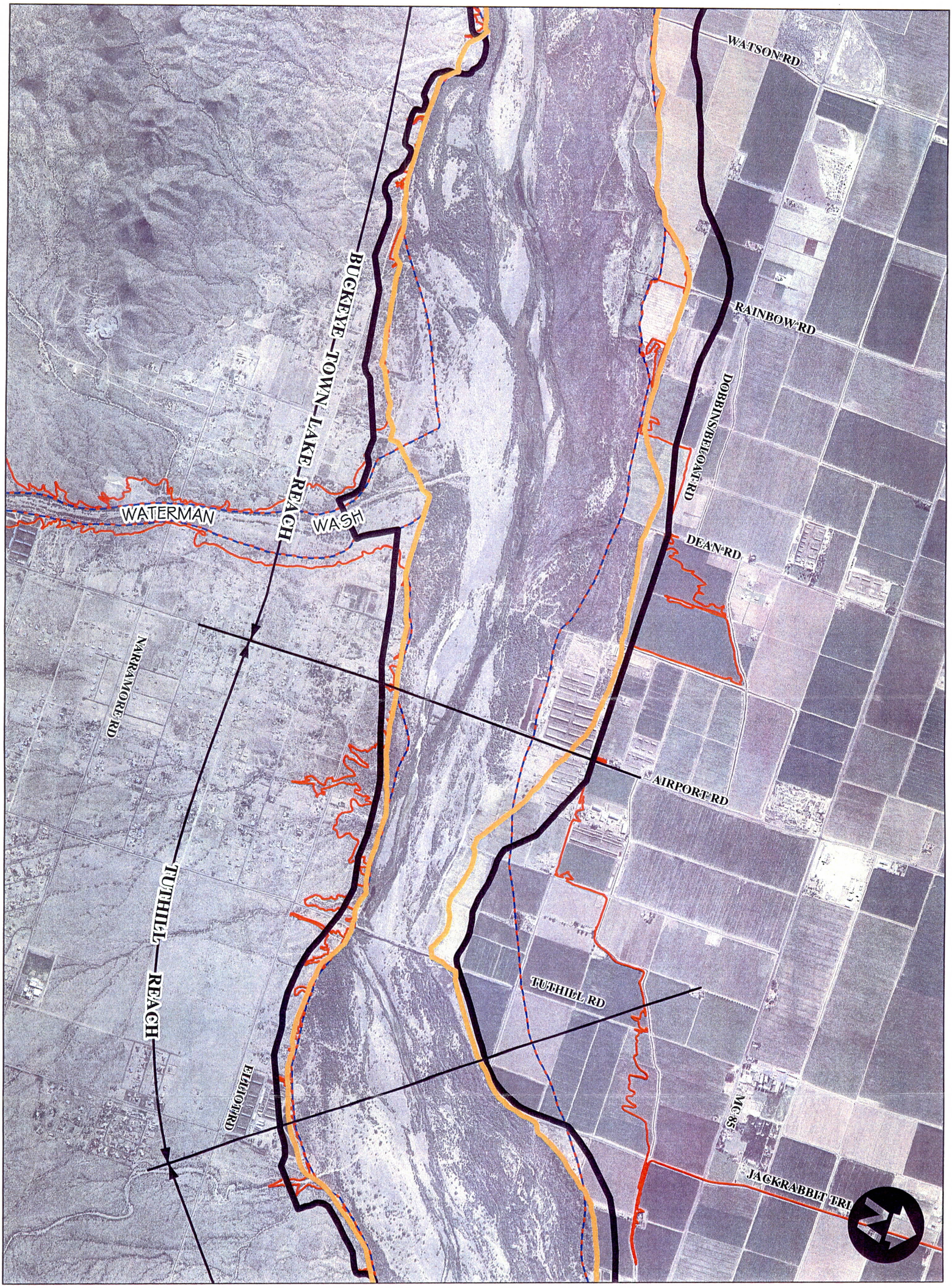

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Compound Channel
Lateral Migration Zone
100-Year Flood Zone
Floodway Boundary
100 Year Floodplain Boundary

1 2 3 4

N

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.4 - LATERAL MIGRATION ZONES
SHEET 2 OF 4 (TUTHILL REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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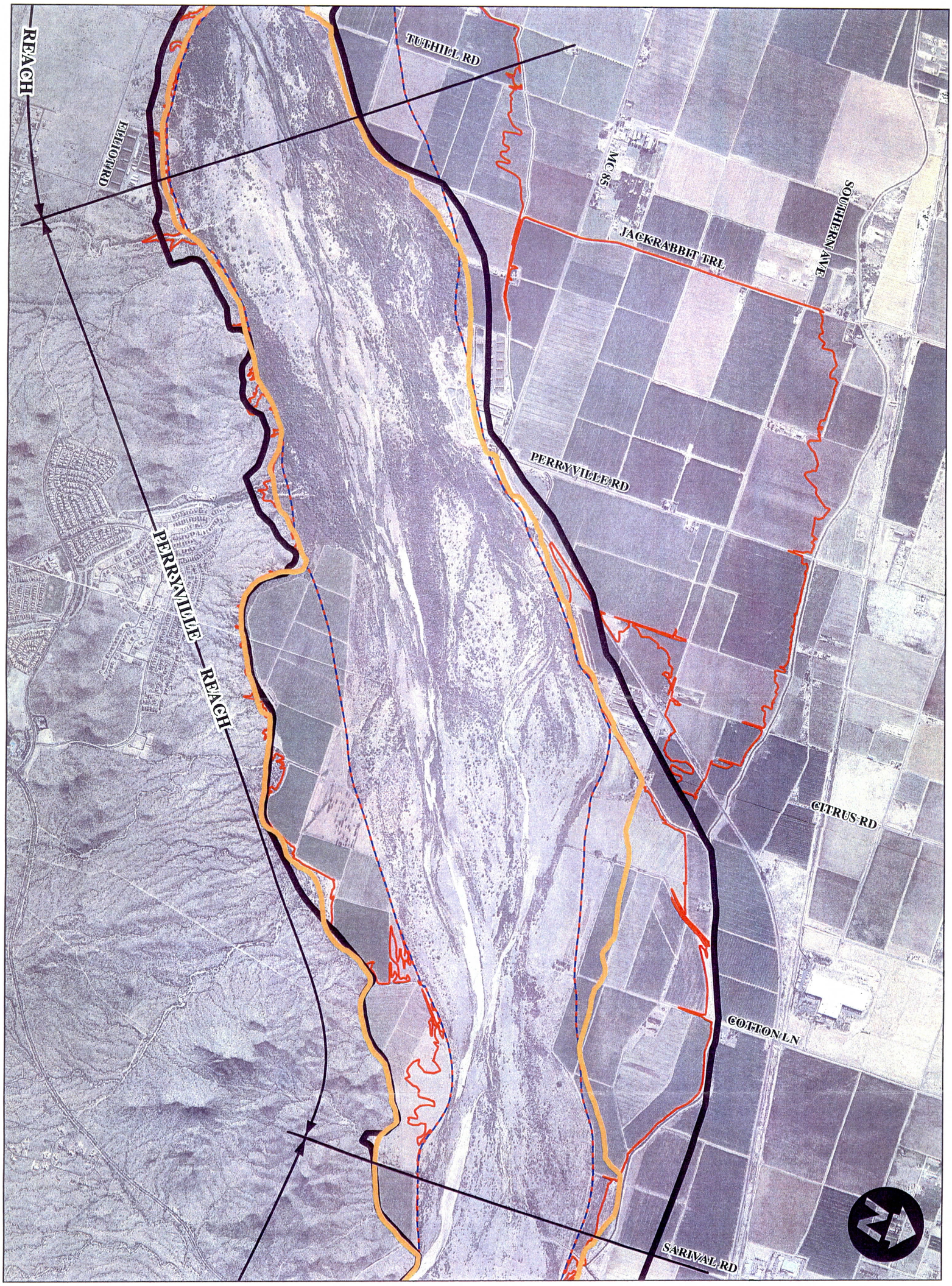

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EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.4 - LATERAL MIGRATION ZONES
SHEET 3 OF 4 (PERRYVILLE REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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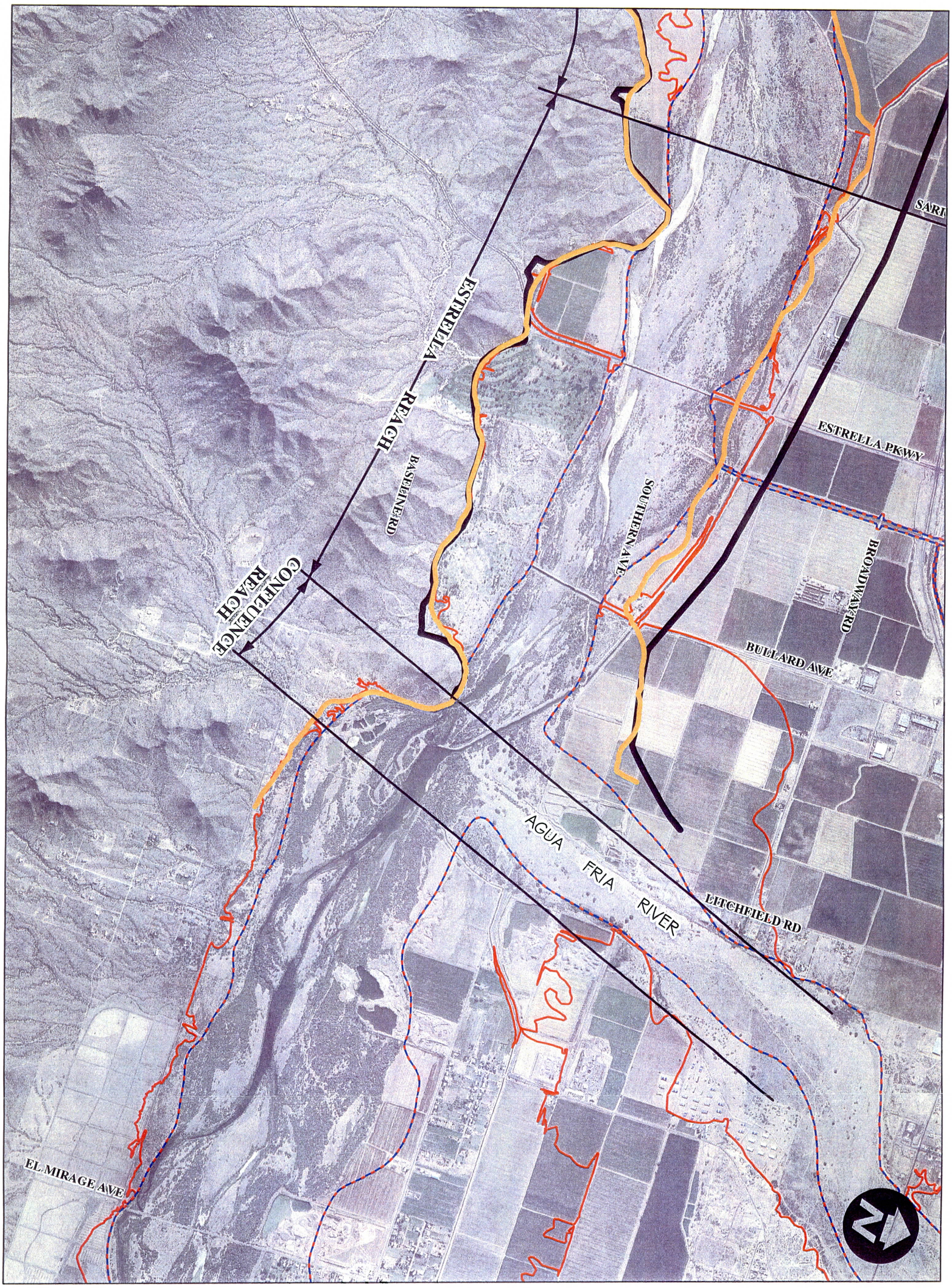

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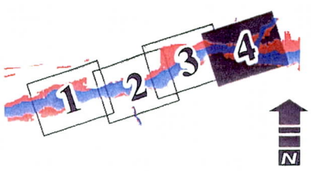

EL RIO WATERCOURSE MASTER PLAN

FIGURE 2.4 - LATERAL MIGRATION ZONES
SHEET 4 OF 4 (ESTRELLA REACH)
1 FEB 2006

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Aquatic Consulting & Testing Inc. prepared the nuisance insect and vector populations section of the report. That section presents the estimated populations of midge flies and mosquitoes in relation to potential breeding sites within the study reach as well as vector control recommendations.

Stantec prepared the anthropogenic section of the report. That section characterizes the features of the study area landscape that have been influenced by human activities. Those features include sources of surface water, cultural resource sites from historical and pre-historical civilizations, hazardous waste sites and solid waste sites. Potential opportunities and constraints to floodplain management activities due to those features are identified and discussed.

2.1.8 El Rio Landscape Management Guidelines

The aesthetic treatment of flood control elements primarily consists of placement of landscape fill on bank armoring and levee structural fill, and landscaping of the fill areas. Landscape guidelines are cited in the Report entitled "El Rio Landscape Management Guidelines" prepared by EDAW Inc.

2.1.9 Implementation Planning and Funding Strategies

M3 Research and CL Williams developed an implementation and funding strategies report. Their report entitled El Rio WMP Funding and Implementation Strategies describes possible implementation and funding process that could be applied to the El Rio WMP.

2.1.10 Visual Resources

The District contracted with BRW to provide a Scenery and Recreation Resources Data Collection Report and Analysis Report. The following excerpts summarize the report purpose and content.

Preservation of the natural landscapes of Maricopa County and protection of local community character are primary objectives that are identified in the Flood Control District Board approved Policy for Landscaping and Aesthetic Treatment of Flood Control Facilities. These objectives are accomplished by planning and designing flood protection facilities to complement and enhance the visual characteristics of the landscape settings in which they are located.

The identification and selection of flood protection methods that have the potential to complement the visual character of the El Rio is a key step to achieving the District's aesthetics policy objectives. Factors considered in the Scenery Resources are:

- Expected natural and man-made images within the El Rio locale
- All landscape within the El Rio locale have a defined, unique character

- Maintaining or enhancing existing scenic integrity within landscape settings is important to achieve District policy on the development of flood protection facilities within the County

- Landscapes that are the most diverse are typically the most valued by local communities

- All flood protection facilities have a definable character when compared to the landscape setting they are proposed to be developed within

- Landscape settings vary in their ability to absorb various methods of flood protection without the loss of their inherent character

- Flood protection methods vary in their ability to complement landscape settings

The Scenery Resources evaluations indicate that non-structural and soft structural flood control management strategies are compatible with the existing condition visual characteristics.

2.2 PLANNING REACHES

Due to the variability of conditions (topography, environmental, visual quality, etc) that exist throughout the study limits, the river was divided into planning reaches as shown in Figures 2.1 through 2.4. The reach limits were selected based on the existing hydrologic, hydraulic, geomorphic, environmental, cultural and visual characteristics identified during Phases I and II. Descriptions of some of the physical characteristics of each reach are presented below, additional information or details can be found in the attachments to this report

The most upstream reach is named the Confluence Reach. This reach encompasses the Agua Fria River confluence. The principle feature in this reach is the BWCDD headworks. The BWCDD headworks currently consists of an earthen diversion structure that feeds the BWCDD Main Canal. The diversion structure extends into the river from the north bank and forms a small, temporary storage pool. Over time, a unique habitat has developed around the storage pool that includes native riparian vegetation, and a Great Blue Heron Rookery.

The Estrella Reach extends approximately 2.5 miles downstream from the Confluence Reach to the Sarival Avenue roadway alignment. The primary feature defining this reach is the 10,000-foot bird strike zone for the Goodyear Airport. There are two bridged crossings in this reach, one at Bullard Avenue and the other at Estrella Parkway. Land ownership is a mix of private, state and county. The depth to groundwater within this reach is generally less than 3 meters and open bodies of water persist throughout the year. Vegetation within this reach consists of cobble strand and salt cedar. There are several documented cultural sites located throughout the reach on both sides of the river. The Alkali Ruin is the most extensive of the cultural sites extending nearly the entire length of the reach.

The Perryville Reach extends approximately 5 miles downstream from the Estrella Reach to the Jackrabbit Trail roadway alignment. This reach contains the proposed Cotton Lane Bridge and the flow breakout. Land ownership in this reach is a mix of private, state and federal. The depth to groundwater is generally less than 3 meters at the upstream of the reach and between 3 and 10 meters at the downstream end of the reach. Vegetation consists primarily of cobble strand and salt cedar and there is a great blue heron rookery. There are several documented cultural sites located throughout the reach on both sides of the river.

Downstream of the Perryville Reach is the 1.5 mile long Tuthill Reach. The Tuthill Reach is a relatively stable reach in regard to historic lateral migration. The Tuthill Bridge crosses the river in this reach. Land ownership is a mix of private and state, but is primarily private ownership. There are sustained open pools of water within this reach that contain a beaver dam and lodge. The small pools are lined with willow/salt cedar as well as cattail (designated as Marsh 2). Outside of those areas, the vegetation is predominately cobble strand with small areas of salt cedar. There are six documented cultural sites within this reach, the largest of which, Brewster Ruin, is partially located within the floodway.

The most downstream reach is the Buckeye Reach. This reach is approximately 7 miles in length, ending at the SR 85 Bridge crossing. Near the upstream end of this reach is the confluence with Waterman Wash. Land ownership in the reach is a mix of federal, state and private with the majority of ownership within the floodplain limits being state ownership. Most of the sand and gravel operations within the study limits occur in this reach. This reach has the greatest concentration of unique wildlife as well as the greatest diversity of vegetative types including large areas on very dense stands of salt cedar. This reach has several sustained open bodies of water and a very shallow groundwater table. There are numerous cultural sites located on both sides of the river.

3.0 FLOOD CONTROL MANAGEMENT ALTERNATIVES DEVELOPMENT AND EVALUATION

3.1 INTRODUCTION

The purpose of the El Rio WMP is to examine the benefits, opportunities, and impacts of a range of flood control management plans that address the flood and erosion hazards and impending development pressures in consideration of public safety, social, economic, and environmental factors and to recommend a preferred watercourse master plan. Development of the plan is based on public coordination; hydrologic, hydraulic and sediment analyses; geomorphic evaluations and environmental and visual resource investigations. Flood control management alternatives are evaluated based on how well each alternative meets the goals of the El Rio WMP.

The alternative formulation phase of El Rio WMP was performed as a stepwise process designed to arrive at an alternative that provides public safety from flood events up to the 100-year event and takes into consideration impacts to the environment. The intent of the process is to determine a Least Environmentally Damaging Practical Alternative (LEDPA). The LEDPA must consider public safety, social, environmental and economic impacts. A minimum of four alternatives is required by the scope of work to be evaluated in order to determine the LEDPA. Two of those alternatives are no action and least environmentally impacting alternatives.

The first step in the alternative formulation process is the identification of potential alternatives as well as environmental, social, implementation and design considerations. The second step is the analysis of the selected alternatives and the third step is the determination of a preferred alternative.

3.2 ALTERNATIVE IDENTIFICATION

3.2.1 General

Potential floodplain management alternatives as well as environmental and social enhancement opportunities and considerations, implementation issues and design considerations were identified during meetings involving the project team, the steering committee and project stakeholders. The alternatives that were identified ranged from a full structural approach, such as channelization, to an entirely natural watercourse managed through regulation and setbacks. Enhancement opportunities, implementation issues and design considerations that were identified were organized into a set of evaluation criteria to measure the effectiveness of the alternatives at meeting the project goals.

3.2.2 Project Alternatives

Alternatives identified in the various meetings are organized into four general alternative categories. Those categories are Full Structural, Soft Structural, Non-Structural and a No-Action Alternatives. Opportunities for environmental enhancements such as vegetation management exist for all alternatives. Details and analysis specific to

vegetation management are discussed in the Recommended Alternative Section of this report. The following are definitions/discussions of each alternative and/or general alternative category.

3.2.2.1 Structural Alternative

A structural alternative for the El Rio WMP is an alternative that provides armoring for bank stabilization. Typical construction materials associated with armoring for the structural alternative can include gabion mattresses, gunite, concrete, soil cement and rip rap. The channel bottom is not armored. Three variations of the structural alternative were evaluated.

The first, Structural Alternative 1 (Figure 3.1), allows for development encroachment into the floodplain to the approximate floodway limit. Due to physical constraints the alignment of the bank protection may deviate from the floodway alignment. The floodway limit typically defines the maximum amount of development encroachment allowed by the Federal Emergency Management Agency into the floodplain without redefining the floodway limits. This structural alternative consists of a channel with a natural bottom and bank stabilization. The alignment of Structural Alternative 1 is depicted in Figure 3.2.

Structural Alternative 2 is a variation of Structural Alternative 1. Structural Alternative 2 allows for a 2000-foot wide channel to be excavated. This alternative combines a 2,000-foot wide channel with floodplain encroachment to the approximate floodway limit. A typical section illustrating the general features of this alternative is provided as Figure 3.3. The 2,000-foot earthen, trapezoidal channel would be constructed within the limits of the active channel. The channel invert would not exceed the existing low flow channel invert. It is assumed that vegetation along the channel would be restored or allowed to re-establish to a natural condition. At the compound channel/floodway limits bank protection would be provided to prevent lateral migration. In some areas, the bank protection would be required to extend above the existing ground surface to meet District freeboard criteria. The bank protection could consist of any of the materials listed in the general alternative definition and would depend on local conditions such as depth to ground water and soil salinity. The alignment of Structural Alternative 2 is depicted in Figure 3.4.

Structural Alternative 3 (Figure 3.5) allows for encroachment in the floodway leaving a 2000-foot wide flood conveyance corridor. This variation would require community and FEMA approval. The encroachment could be accomplished through engineered fill with bank protection, construction of a levee or a combination of both depending on local conditions. The banks of the corridor would be lined with any of the material listed in the general alternative definition depending on local conditions. It is assumed that vegetative re-growth would be kept to a minimum. The alignment of Structural Alternative 3 is depicted in Figure 3.6.

3.2.2.2 Soft Structural Alternative

The soft structural alternative (Figure 3.7) is similar to the structural alternative with the exception that the bank protection is buried and landscaped. Bioengineered bank protection treatments could be utilized. The soft structural treatment can be applied to any of the three structural alternatives (Structural Alternative 1, 2 or 3) to provide aesthetic enhancements.

Landscape aesthetic treatments are intended to create features that fit the form and function of the existing landscape character. Typical landscape aesthetic treatments consist of variations in the form (alignment, profile, side slope etc.) of the structural element, use of color or textural patterns or the use of fill material to hide the structural element. Bioengineering treatments involve the use of vegetation for soil stabilization and the enhancement, both visually and functually, of structural elements. More detailed information of different types of Bioengineering treatments is provided in Appendix A.

3.2.2.3 Non-Structural Alternative

The non-structural alternative (Figure3.8) defines a corridor that allows the watercourse to function naturally, and does not permit development within that corridor. The non-structural alternative is managed and/or implemented by policies, ordinances, property acquisition, and multi-agency planning efforts. The non-structural alternative is defined by the limits of the 100-year floodplain or lateral migration zone whichever provides the widest setback. The alignment of the Non-Structural Alternative is depicted in Figure 3.9.

For the El Rio WMP, only the erosion hazard zone and the 100-year floodplain are considered for the non-structural management corridor. Because the potential erosion hazard limits identified as part of this project are based on existing conditions, this alternative would involve vegetation management. Vegetative management activities would involve thinning of the dense monotypical stands of salt cedar and the enhancement of existing areas of native riparian vegetation.

3.2.2.4 No-Action Alternative

The no-action (do nothing) alternative provides flood control management based on current federal, state, and local floodplain management regulations that allow encroachment into the floodway fringe. Typically under current regulations, encroachments into the floodway fringe are allowed in a piecemeal fashion without taking into consideration the effect of the encroachment or collective encroachments on the entire watercourse.

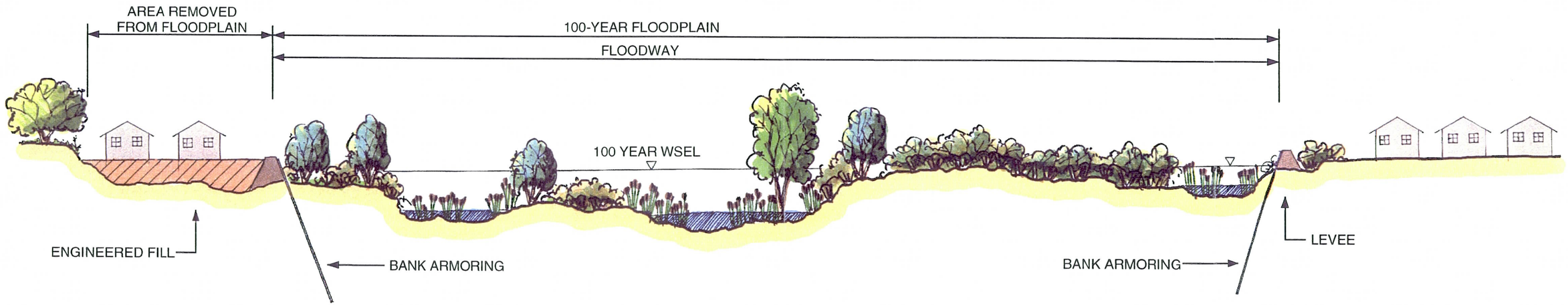
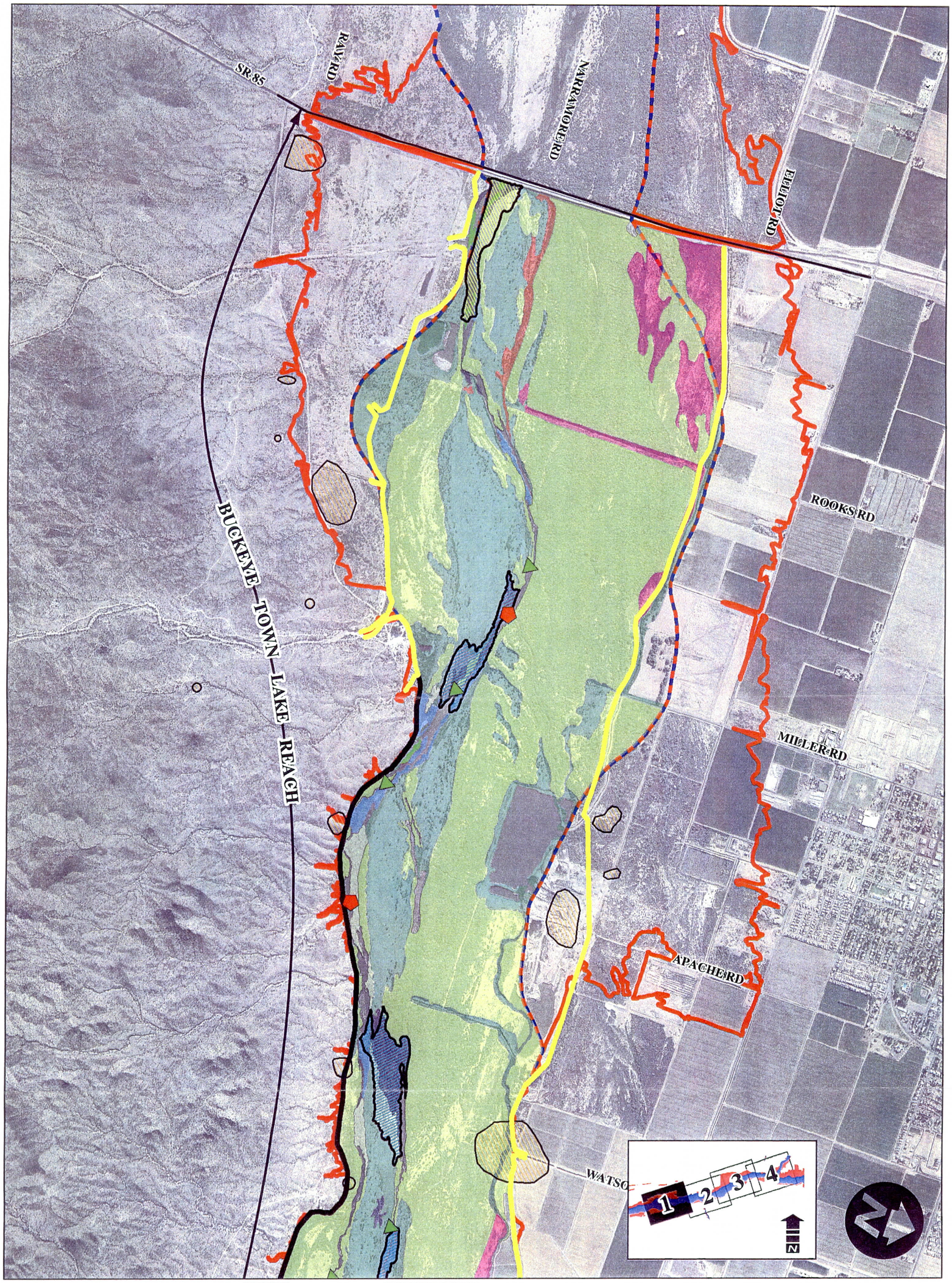


FIGURE 3.1 - STRUCTURAL ALTERNATIVE 1



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Phoenix, AZ 85009

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8211 S. 48th St.
Phoenix, AZ 85044

FLOOD ZONES
- ZONE AE
- ZONE A
- ZONE AH
- FLOODWAY

VEGETATIVE COMMUNITIES
- ARROWWEED WILLOW SALT CEDAR
- COTTONWOOD WILLOW
- MARSH 2
- SALT CEDAR COTTONWOOD WILLOW
- ARROWWEED WILLOW
- ATRIPLEX
- COBBLE STRAND
- SALT CEDAR
- WILLOW SALT CEDAR

UNIQUE WILDLIFE FEATURES
- BEAVER DAM
- EGRET ROOST
- BEAVER LODGE
- GREAT BLUE HERON ROOKERY
- ALIGNMENT OF BANK PROTECTION/LEVEE ALTERNATIVE ELEMENT
- ALIGNMENT OF LATERAL MIGRATION ZONE ALTERNATIVE ELEMENT

OPPORTUNITY AREAS
- MONITORING & MAINTENANCE
- MONITORING & MAINTENANCE/ENHANCEMENT
- ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

OTHER FEATURES
- AREA OF ARCHAEOLOGICAL INTEREST
- BIRDSTRIKE ZONE

EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.2 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 1
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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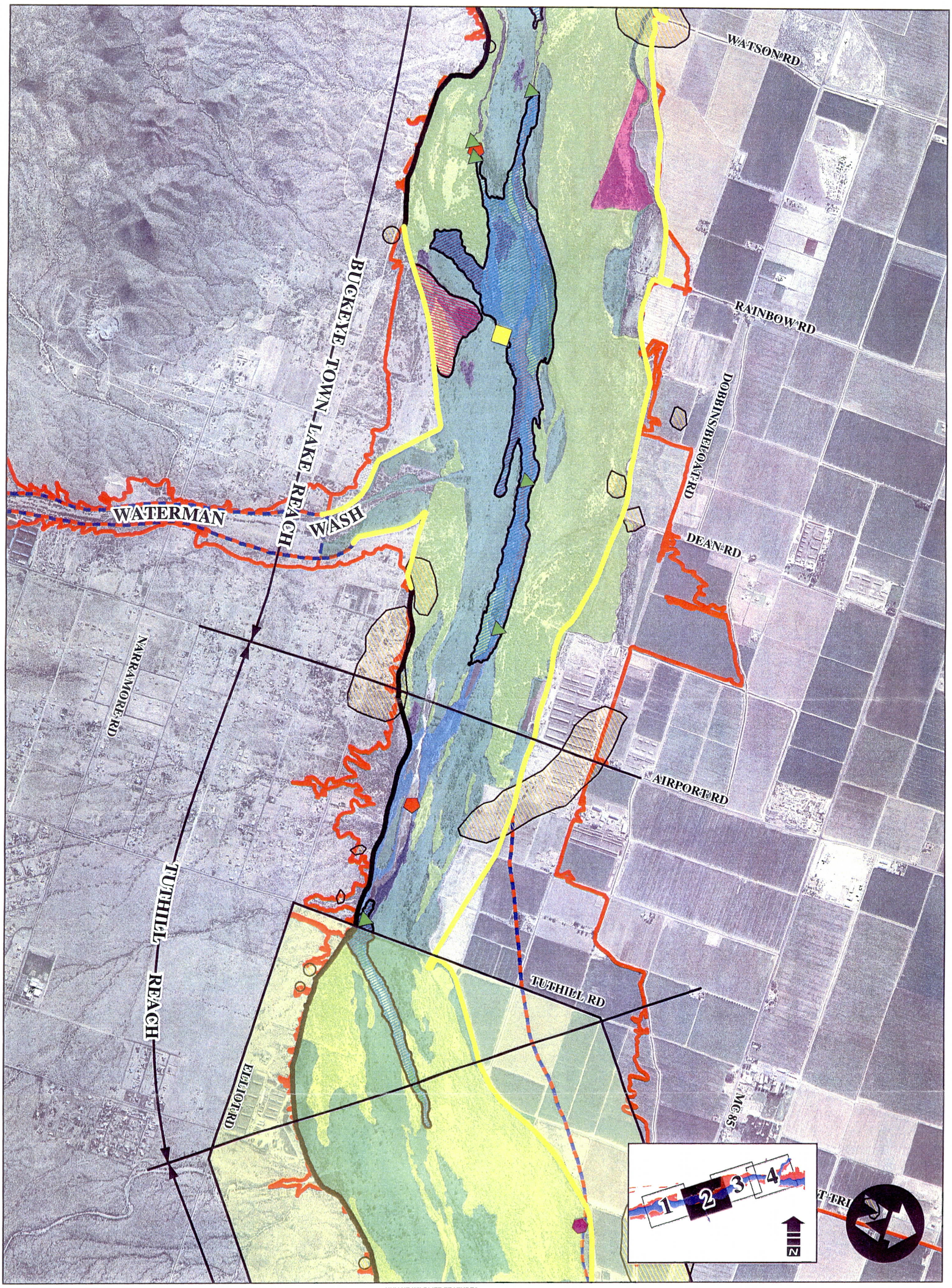

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- ALIGNMENT OF LATERAL MIGRATION ZONE ALTERNATIVE ELEMENT

OPPORTUNITY AREAS
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OTHER FEATURES
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- BIRDSTRIKE ZONE

EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.2 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 1
SHEET 2 OF 4 (TUTHILL REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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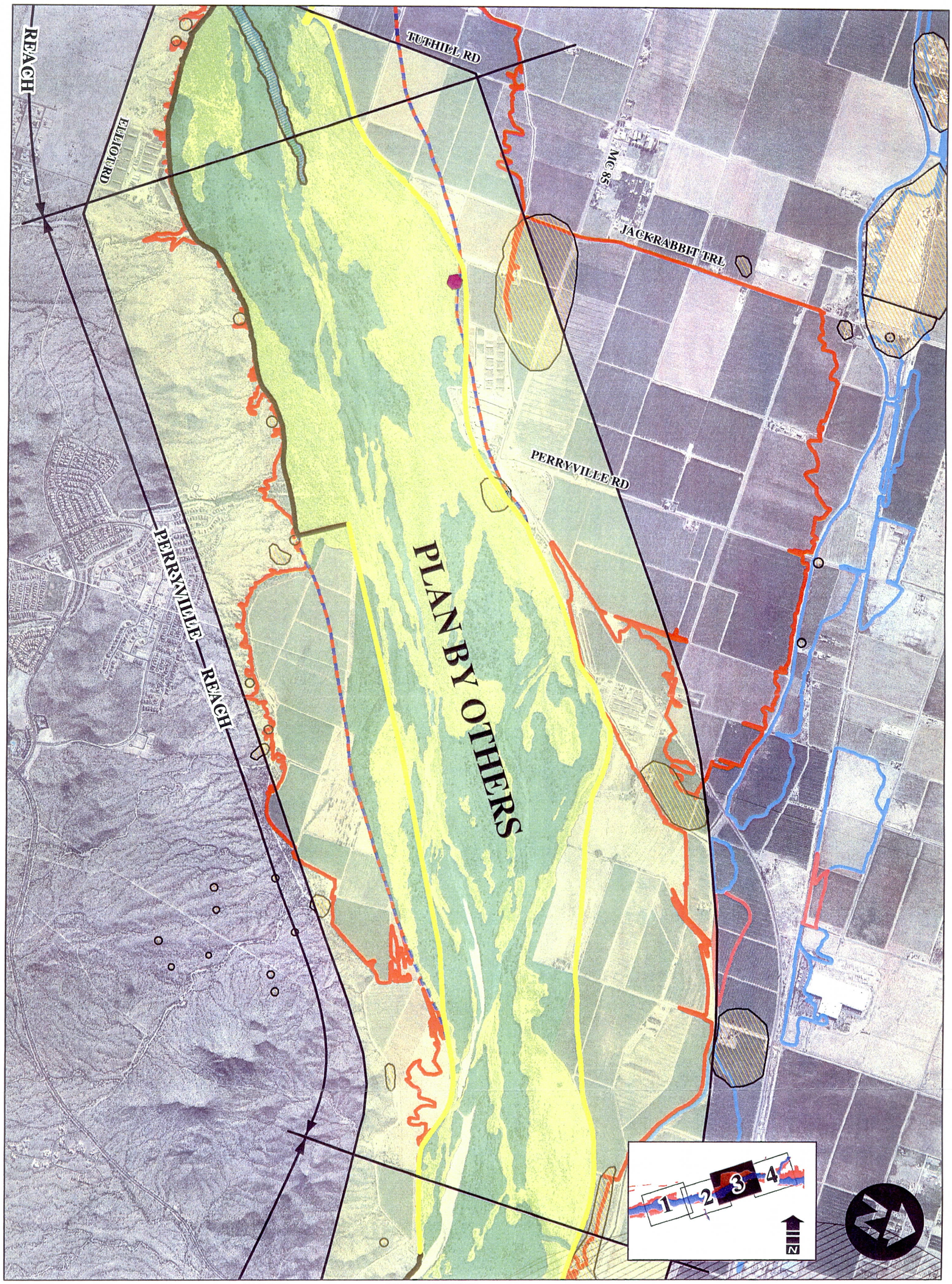

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OTHER FEATURES
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EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.2 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 1
SHEET 3 OF 4 (PERRYVILLE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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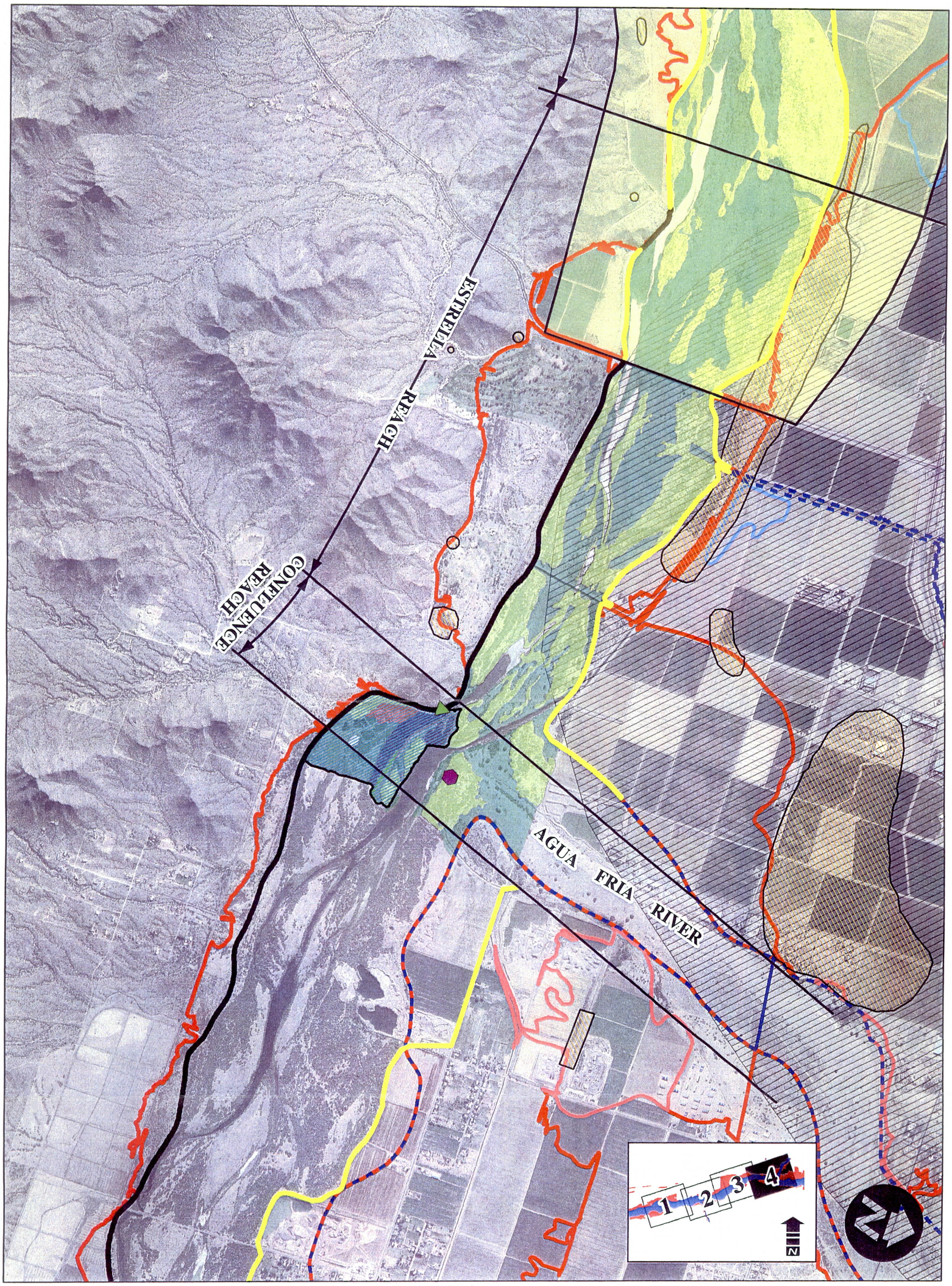

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FLOOD ZONES
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VEGETATIVE COMMUNITIES
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- ARROWWEED WILLOW
- ATRIPLEX
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UNIQUE WILDLIFE FEATURES
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- ALIGNMENT OF LATERAL MIGRATION ZONE ALTERNATIVE ELEMENT

OPPORTUNITY AREAS
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- MONITORING & MAINTENANCE/ENHANCEMENT
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OTHER FEATURES
- AREA OF ARCHAEOLOGICAL INTEREST
- BIRDSTRIKE ZONE

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FIGURE 3.2 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 1
SHEET 4 OF 4 (ESTRELLA REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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SOUTH BANK

NORTH BANK

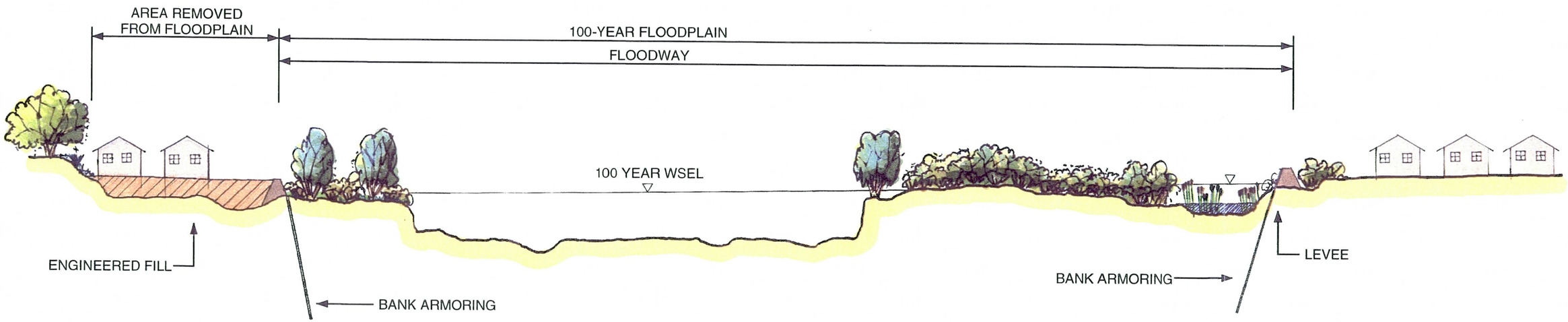
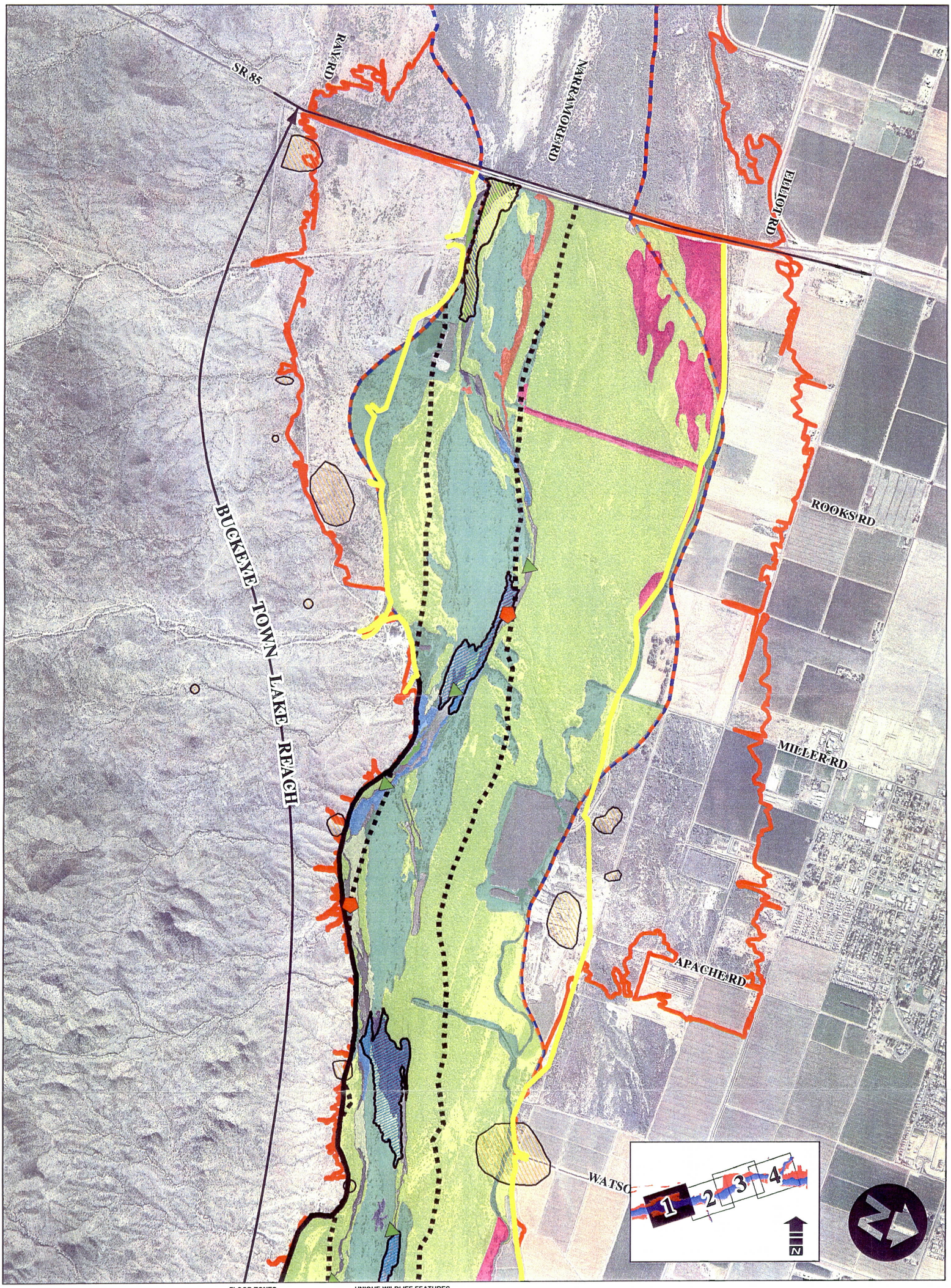


FIGURE 3.3 - STRUCTURAL ALTERNATIVE 2



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FLOOD ZONES
- ZONE AE
- ZONE A
- ZONE AH
- FLOODWAY

VEGETATIVE COMMUNITIES
- ARROWWEED WILLOW SALT CEDAR
- COTTONWOOD WILLOW
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- ARROWWEED WILLOW
- ATRIPLEX
- COBBLE STRAND
- SALT CEDAR
- WILLOW SALT CEDAR

UNIQUE WILDLIFE FEATURES
- BEAVER DAM
- EGRET ROOST
- BEAVER LODGE
- GREAT BLUE HERON ROOKERY
- ALIGNMENT OF BANK PROTECTION/LEVEE ALTERNATIVE ELEMENT
- ALIGNMENT OF LATERAL MIGRATION ZONE ALTERNATIVE ELEMENT
- 2000' CHANNEL ALIGNMENT

OPPORTUNITY AREAS
- MONITORING & MAINTENANCE
- MONITORING & MAINTENANCE/ENHANCEMENT
- ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

OTHER FEATURES
- AREA OF ARCHAEOLOGICAL INTEREST
- BIRDSTRIKE ZONE

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FIGURE 3.4 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 2
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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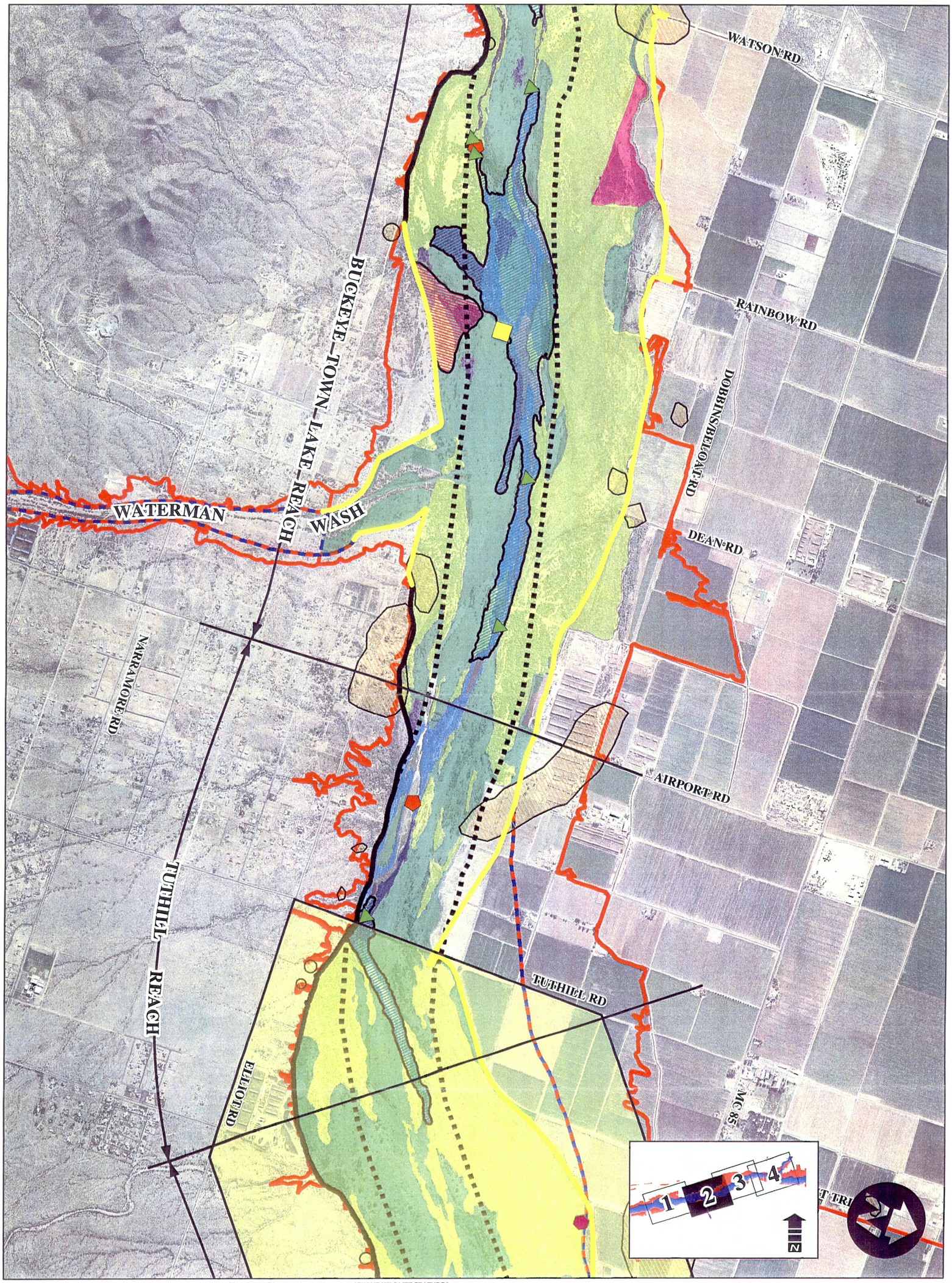

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FLOOD ZONES
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- ZONE A
- ZONE AH
- FLOODWAY

VEGETATIVE COMMUNITIES
- ARROWWEED WILLOW SALT CEDAR
- COTTONWOOD WILLOW
- MARSH 2
- SALT CEDAR COTTONWOOD WILLOW
- ARROWWEED WILLOW
- ATRIPLEX
- COBBLE STRAND
- SALT CEDAR
- WILLOW SALT CEDAR

UNIQUE WILDLIFE FEATURES
- BEAVER DAM
- EGRET ROOST
- BEAVER LODGE
- GREAT BLUE HERON ROOKERY

- ALIGNMENT OF BANK PROTECTION/LEVEE ALTERNATIVE ELEMENT
- ALIGNMENT OF LATERAL MIGRATION ZONE ALTERNATIVE ELEMENT
- 2000' CHANNEL ALIGNMENT

OPPORTUNITY AREAS
- MONITORING & MAINTENANCE
- MONITORING & MAINTENANCE/ENHANCEMENT
- ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

OTHER FEATURES
- AREA OF ARCHAEOLOGICAL INTEREST
- BIRDSTRIKE ZONE

EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.4 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 2
SHEET 2 OF 4 (TUTHILL REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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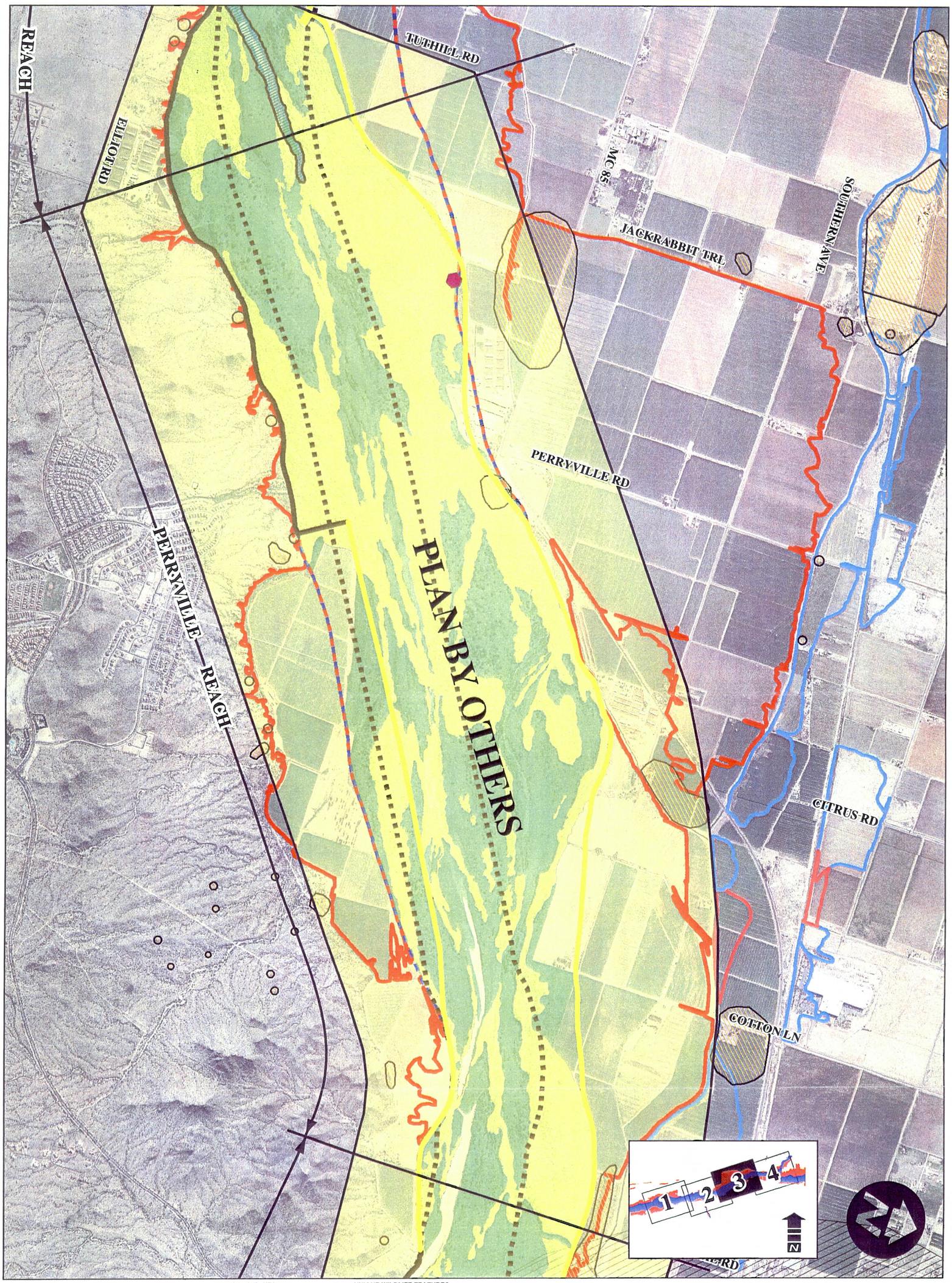

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- SALT CEDAR COTTONWOOD WILLOW
- ARROWWEED WILLOW
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- SALT CEDAR
- WILLOW SALT CEDAR

UNIQUE WILDLIFE FEATURES
- BEAVER DAM
- EGRET ROOST
- BEAVER LODGE
- GREAT BLUE HERON ROOKERY
- ALIGNMENT OF BANK PROTECTION/LEVEE ALTERNATIVE ELEMENT
- ALIGNMENT OF LATERAL MIGRATION ZONE ALTERNATIVE ELEMENT
- 2000' CHANNEL ALIGNMENT

OPPORTUNITY AREAS
- MONITORING & MAINTENANCE
- MONITORING & MAINTENANCE/ENHANCEMENT
- ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

OTHER FEATURES
- AREA OF ARCHAEOLOGICAL INTEREST
- BIRDSTRIKE ZONE

EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.4 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 2
SHEET 3 OF 4 (PERRYVILLE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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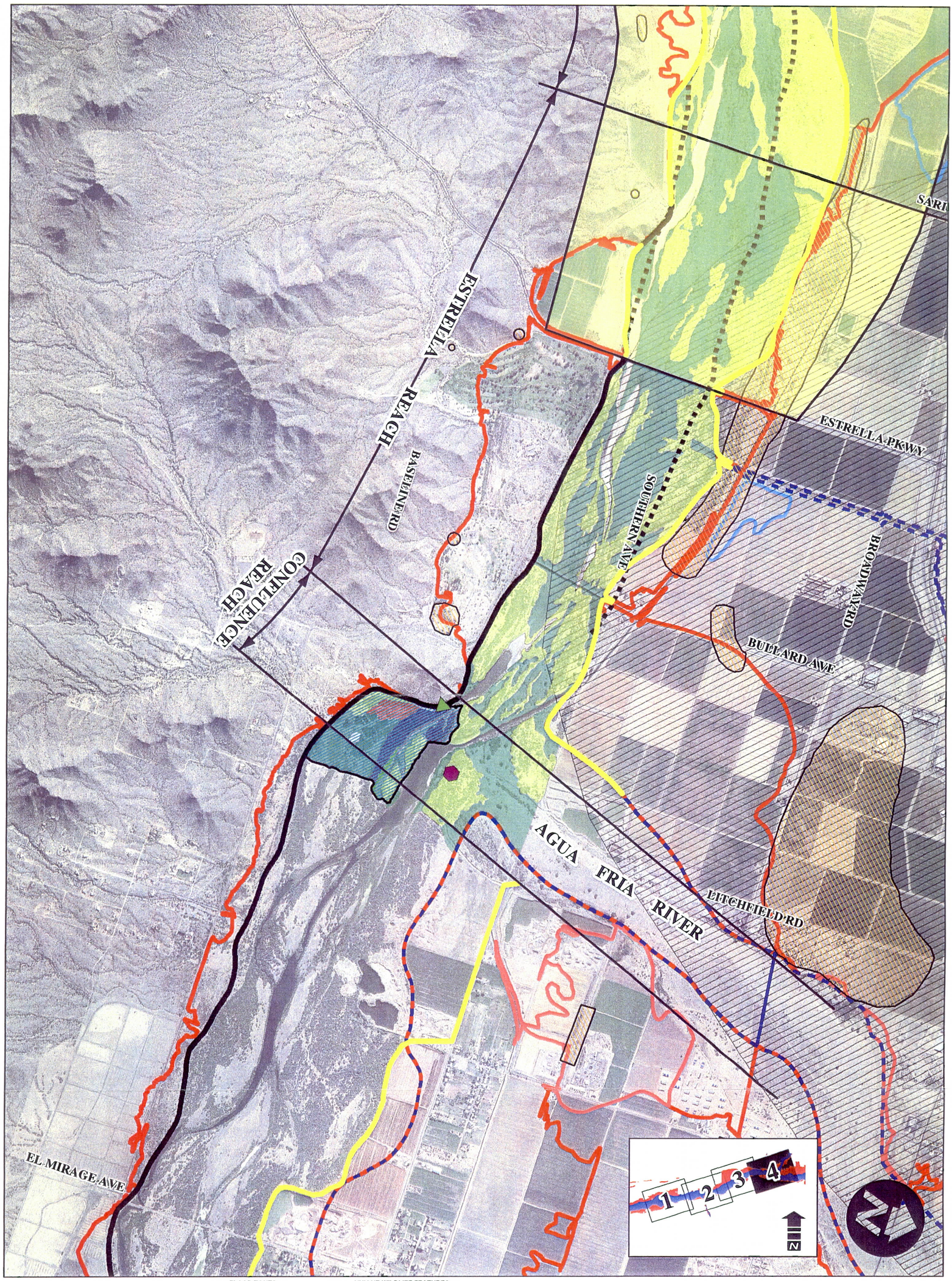

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FLOOD ZONES
- ZONE AE
- ZONE A
- ZONE AH
- FLOODWAY

VEGETATIVE COMMUNITIES
- ARROWWEED WILLOW SALT CEDAR
- COTTONWOOD WILLOW
- MARSH 2
- SALT CEDAR COTTONWOOD WILLOW
- ARROWWEED WILLOW
- ATRIPLEX
- COBBLE STRAND
- SALT CEDAR
- WILLOW SALT CEDAR

UNIQUE WILDLIFE FEATURES
- BEAVER DAM
- EGRET ROOST
- BEAVER LODGE
- GREAT BLUE HERON ROOKERY
- ALIGNMENT OF BANK PROTECTION/LEVEE ALTERNATIVE ELEMENT
- ALIGNMENT OF LATERAL MIGRATION ZONE ALTERNATIVE ELEMENT
- 2000' CHANNEL ALIGNMENT

OPPORTUNITY AREAS
- MONITORING & MAINTENANCE
- MONITORING & MAINTENANCE/ENHANCEMENT
- ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

OTHER FEATURES
- AREA OF ARCHAEOLOGICAL INTEREST
- BIRDSTRIKE ZONE

EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.4 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 2
SHEET 4 OF 4 (ESTRELLA REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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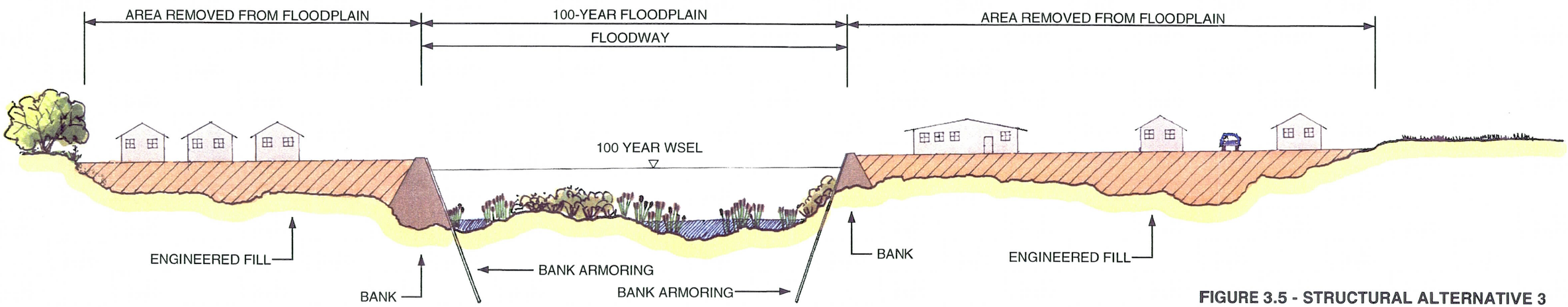
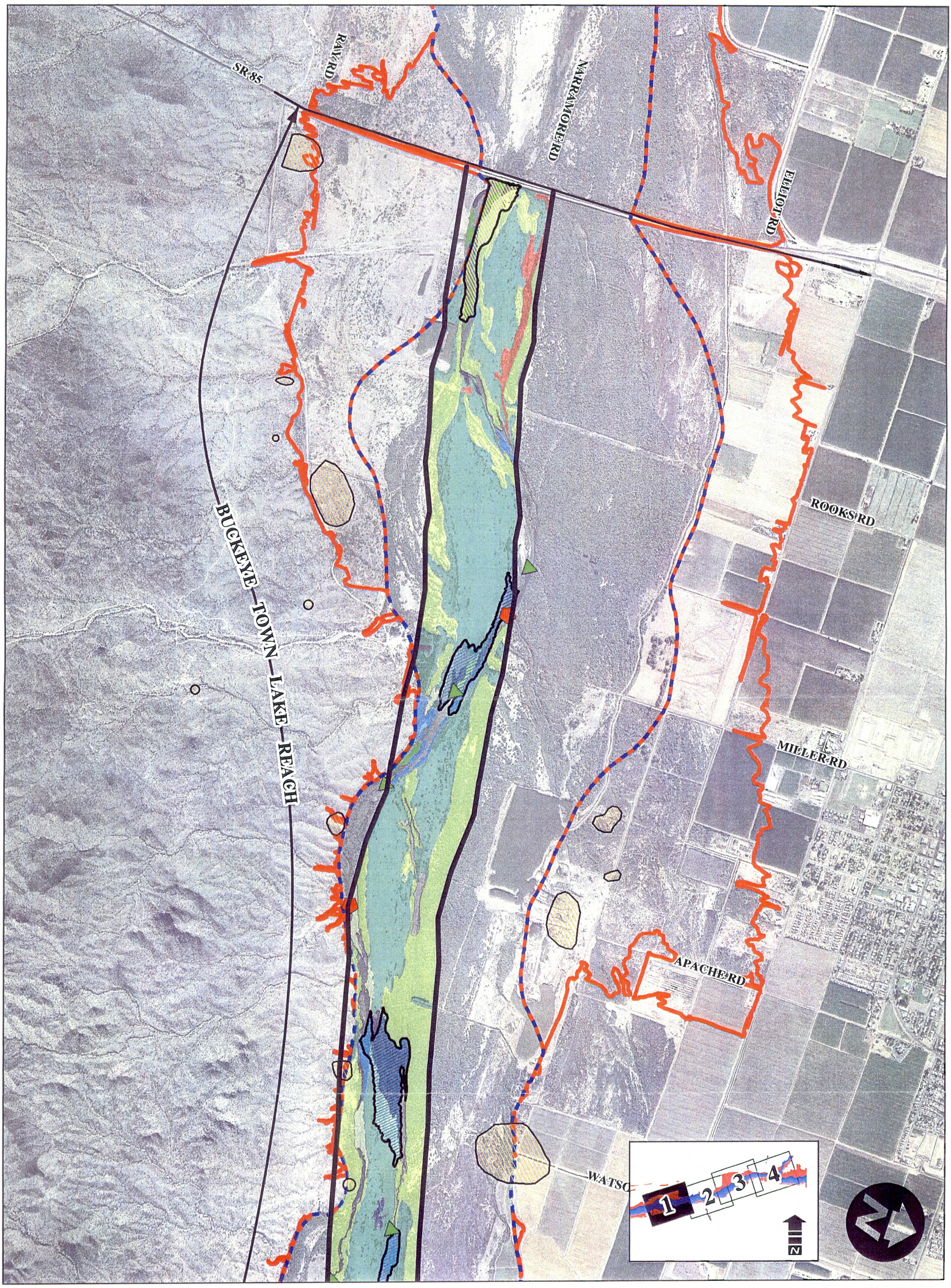


FIGURE 3.5 - STRUCTURAL ALTERNATIVE 3



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UNIQUE WILDLIFE FEATURES
- BEAVER DAM
- EGRET ROOST
- BEAVER LODGE
- GREAT BLUE HERON ROOKERY
- 2000' CORRIDOR

100-YEAR FLOOD ZONES
- Zone AE
- Zone A
- Zone AH
- Floodway

OTHER FEATURES
- AREA OF ARCHAEOLOGICAL INTEREST
- BIRDSTRIKE ZONE

VEGETATIVE COMMUNITY
- ARROWWEED WILLOW SALT CEDAR
- COTTONWOOD WILLOW
- MARSH 2
- SALT CEDAR COTTONWOOD WILLOW
- ARROWWEED WILLOW
- ATRIPLEX
- COBBLE STRAND
- SALT CEDAR
- WILLOW SALT CEDAR

OPPORTUNITY AREAS
- MONITORING & MAINTENANCE
- MONITORING & MAINTENANCE/ENHANCEMENT
- ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.6 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 3
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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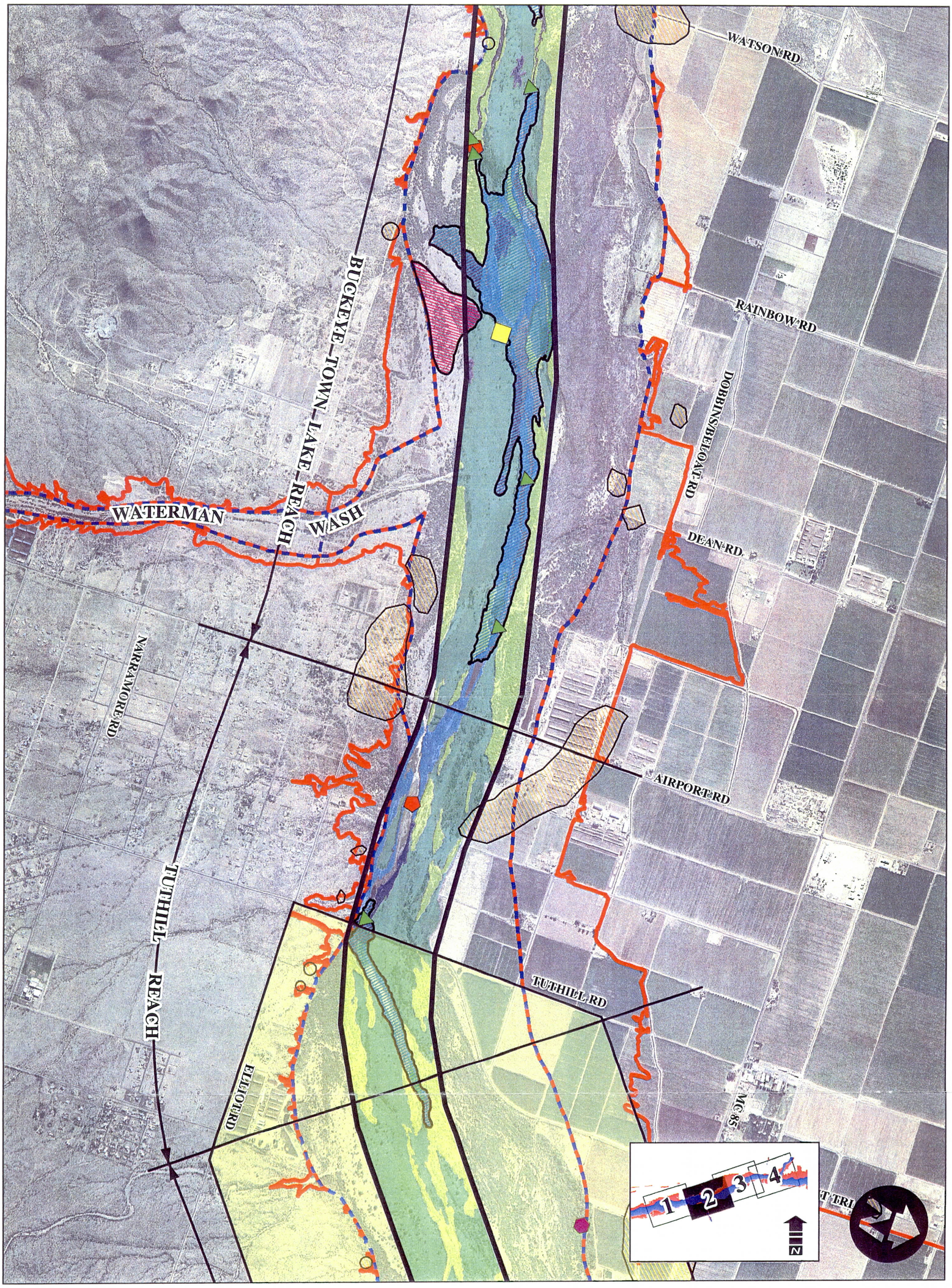

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Phoenix, AZ 85009

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Phoenix, AZ 85044

UNIQUE WILDLIFE FEATURES
- BEAVER DAM
- EGRET ROOST
- BEAVER LODGE
- GREAT BLUE HERON ROOKERY
- 2000' CORRIDOR

100-YEAR FLOOD ZONES
- Zone AE
- Zone A
- Zone AH
- Floodway

OTHER FEATURES
- AREA OF ARCHAEOLOGICAL INTEREST
- BIRDSTRIKE ZONE

VEGETATIVE COMMUNITY
- ARROWWEED WILLOW SALT CEDAR
- COTTONWOOD WILLOW
- MARSH 2
- SALT CEDAR COTTONWOOD WILLOW
- ARROWWEED WILLOW
- ATRIPLEX
- COBBLE STRAND
- SALT CEDAR
- WILLOW SALT CEDAR

OPPORTUNITY AREAS
- MONITORING & MAINTENANCE
- MONITORING & MAINTENANCE/ENHANCEMENT
- ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.6 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 3
SHEET 2 OF 4 (TUTHILL REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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FIGURE 3.6 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 3
SHEET 3 OF 4 (PERRYVILLE REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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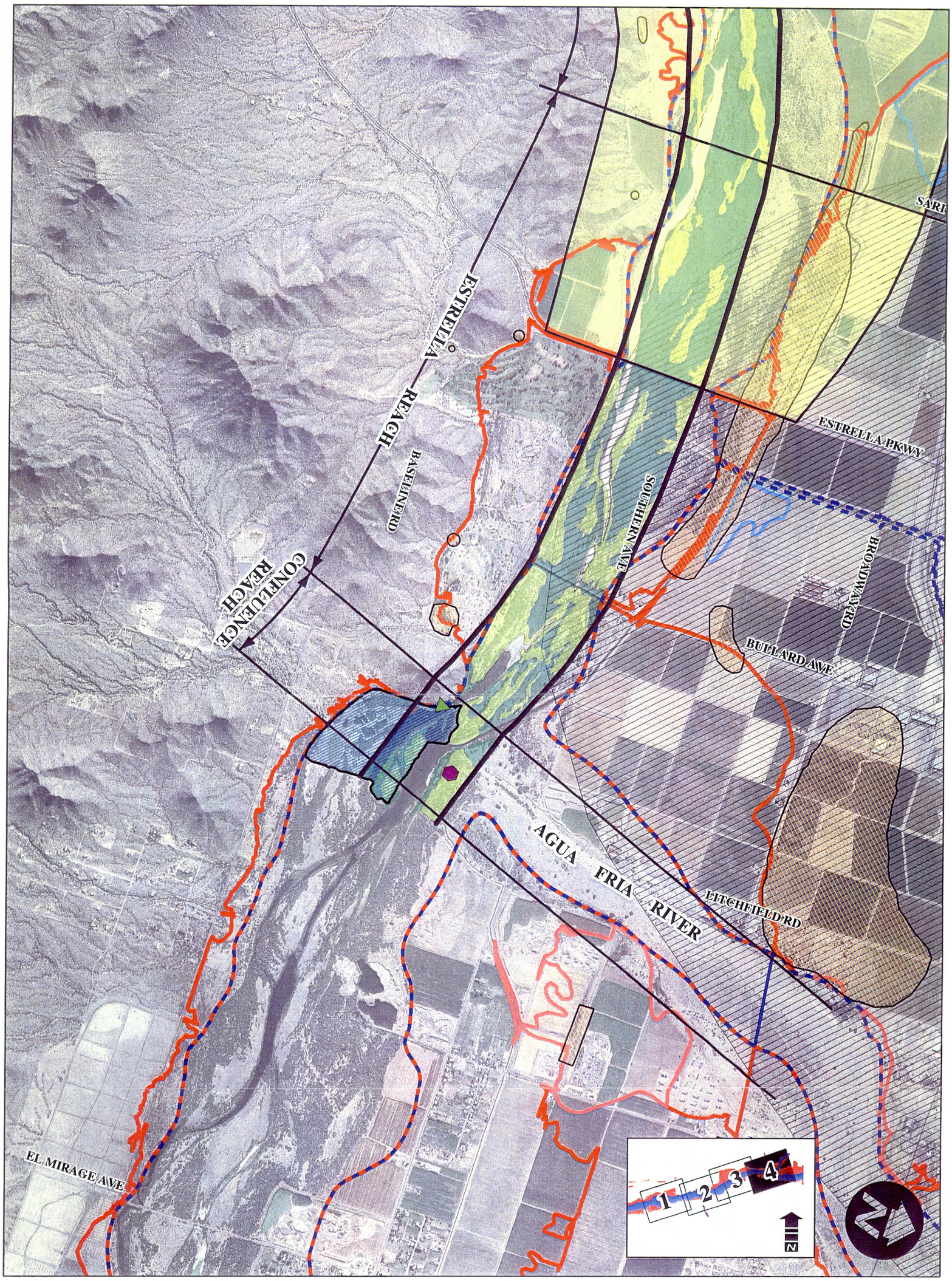

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FIGURE 3.6 - ALIGNMENT OF STRUCTURAL ALTERNATIVE 3
SHEET 4 OF 4 (ESTRELLA REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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SOUTH BANK

NORTH BANK

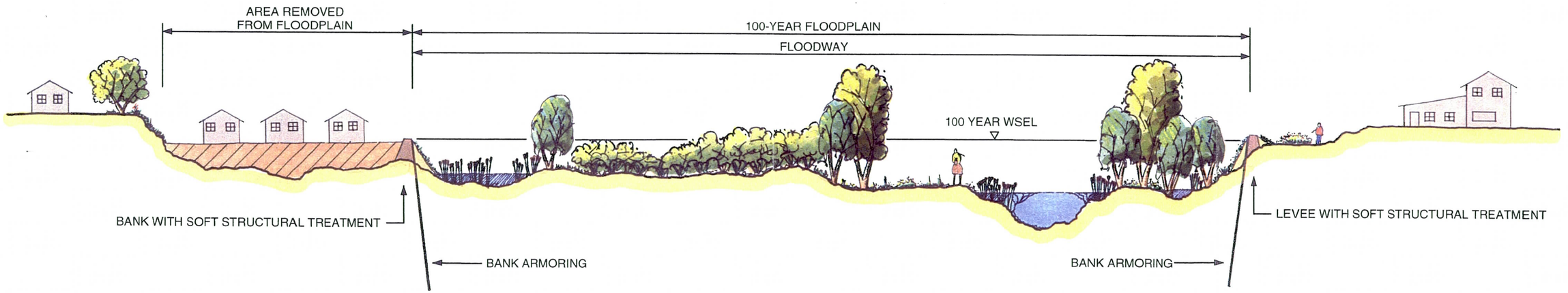


FIGURE 3.7 - SOFT STRUCTURAL ALTERNATIVE

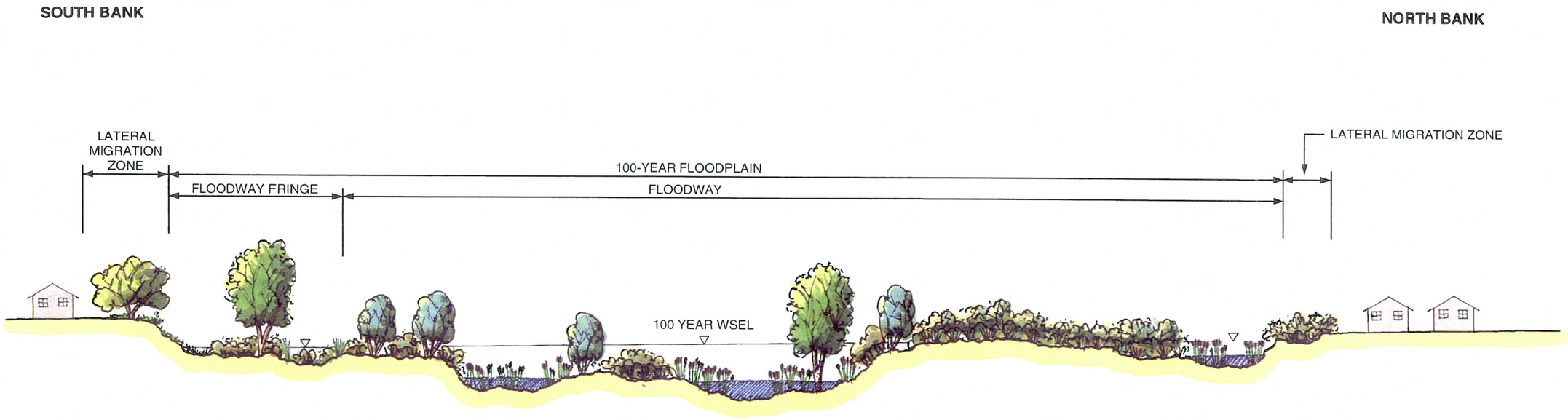
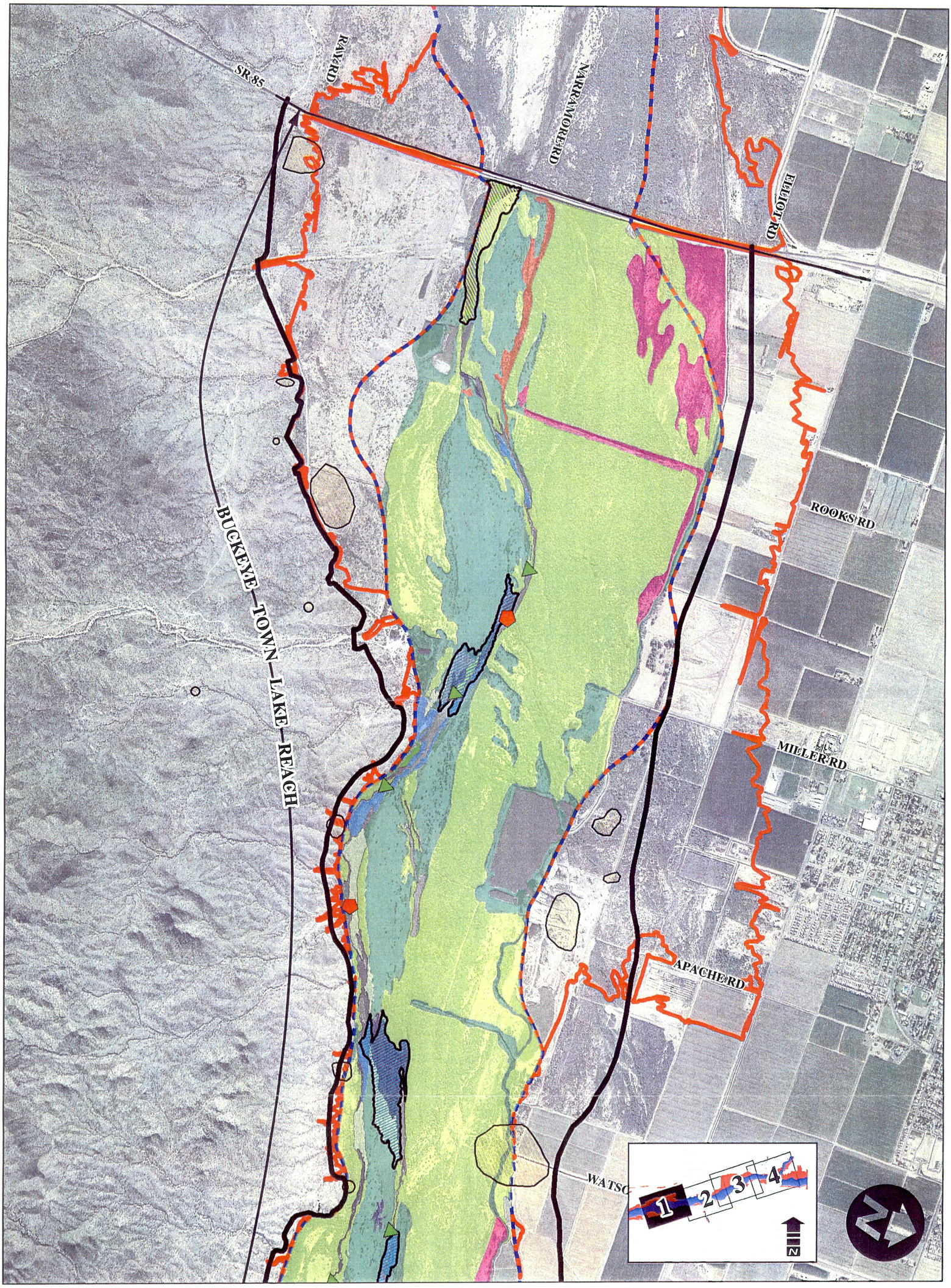


FIGURE 3.8 - NON-STRUCTURAL ALTERNATIVE



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UNIQUE WILDLIFE FEATURES
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- LATERAL MIGRATION AREA

100-Year Flood Zones
- Zone AE
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FIGURE 3.9 - ALIGNMENT OF NON-STRUCTURAL ALTERNATIVE
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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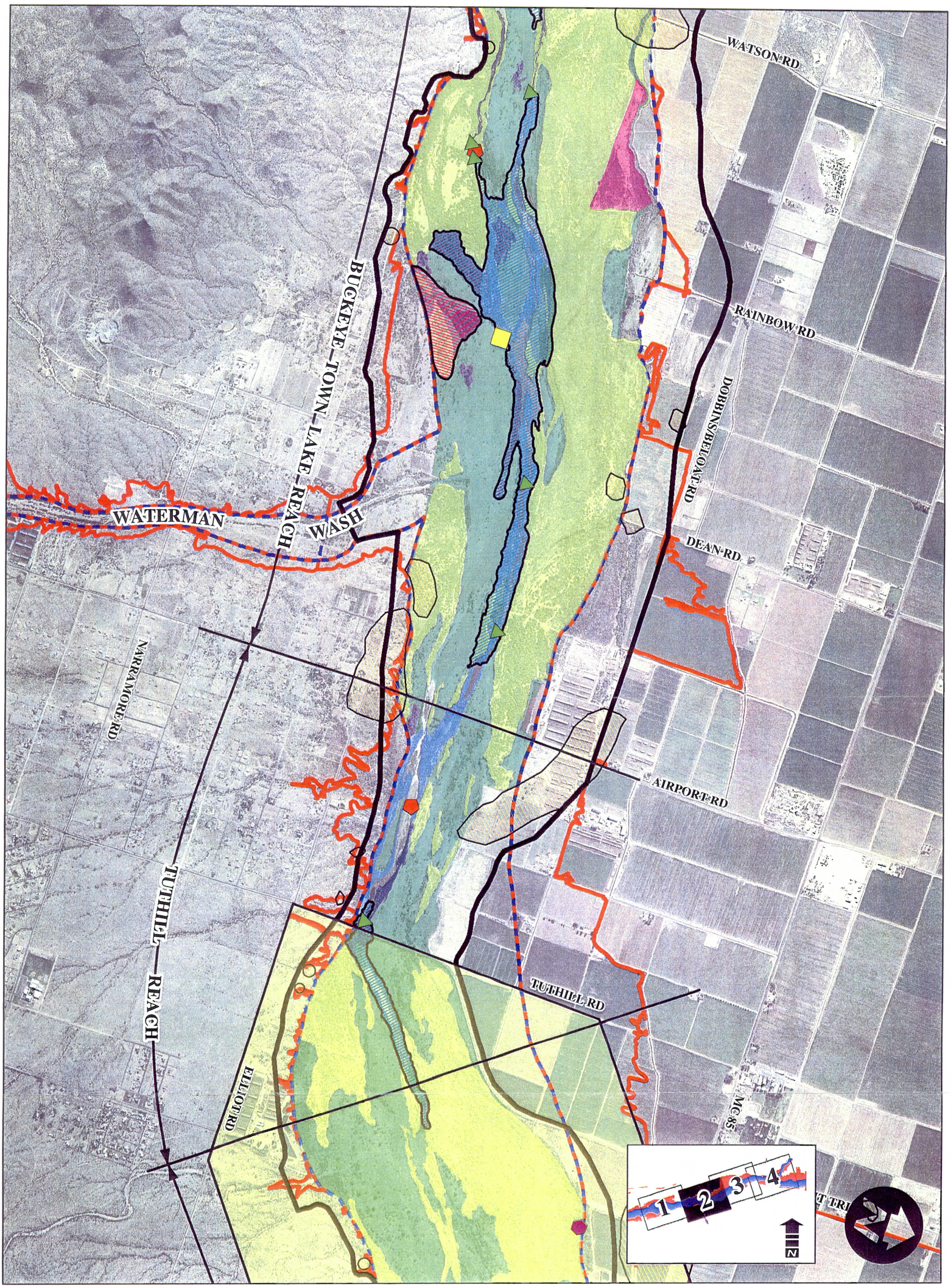

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FIGURE 3.9 - ALIGNMENT OF NON-STRUCTURAL ALTERNATIVE
SHEET 2 OF 4 (TUTHILL REACH)
1 FEB 2006

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1 Inch = 2000 Feet

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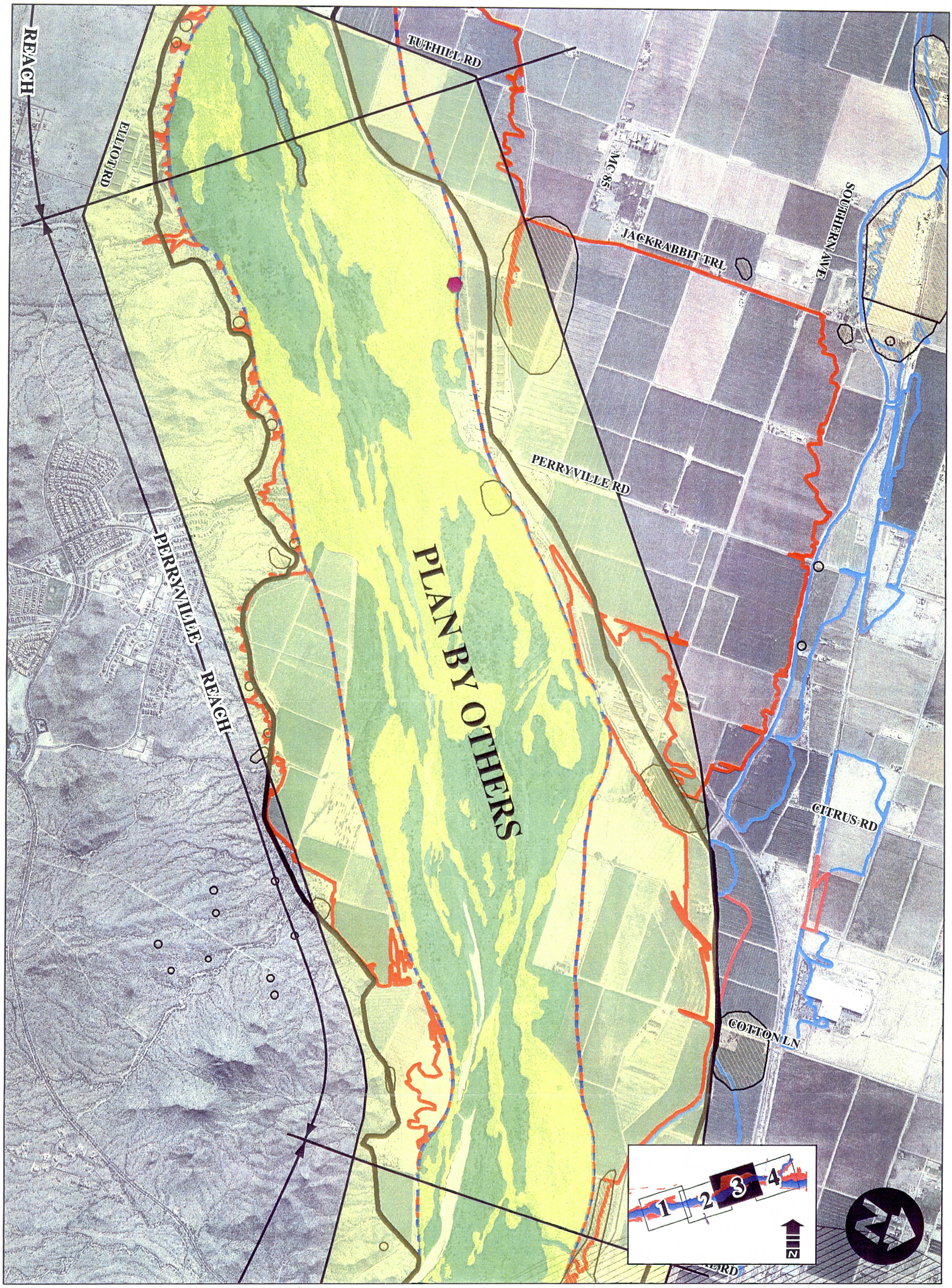

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EL RIO WATERCOURSE MASTER PLAN

FIGURE 3.9 - ALIGNMENT OF NON-STRUCTURAL ALTERNATIVE
SHEET 3 OF 4 (PERRYVILLE REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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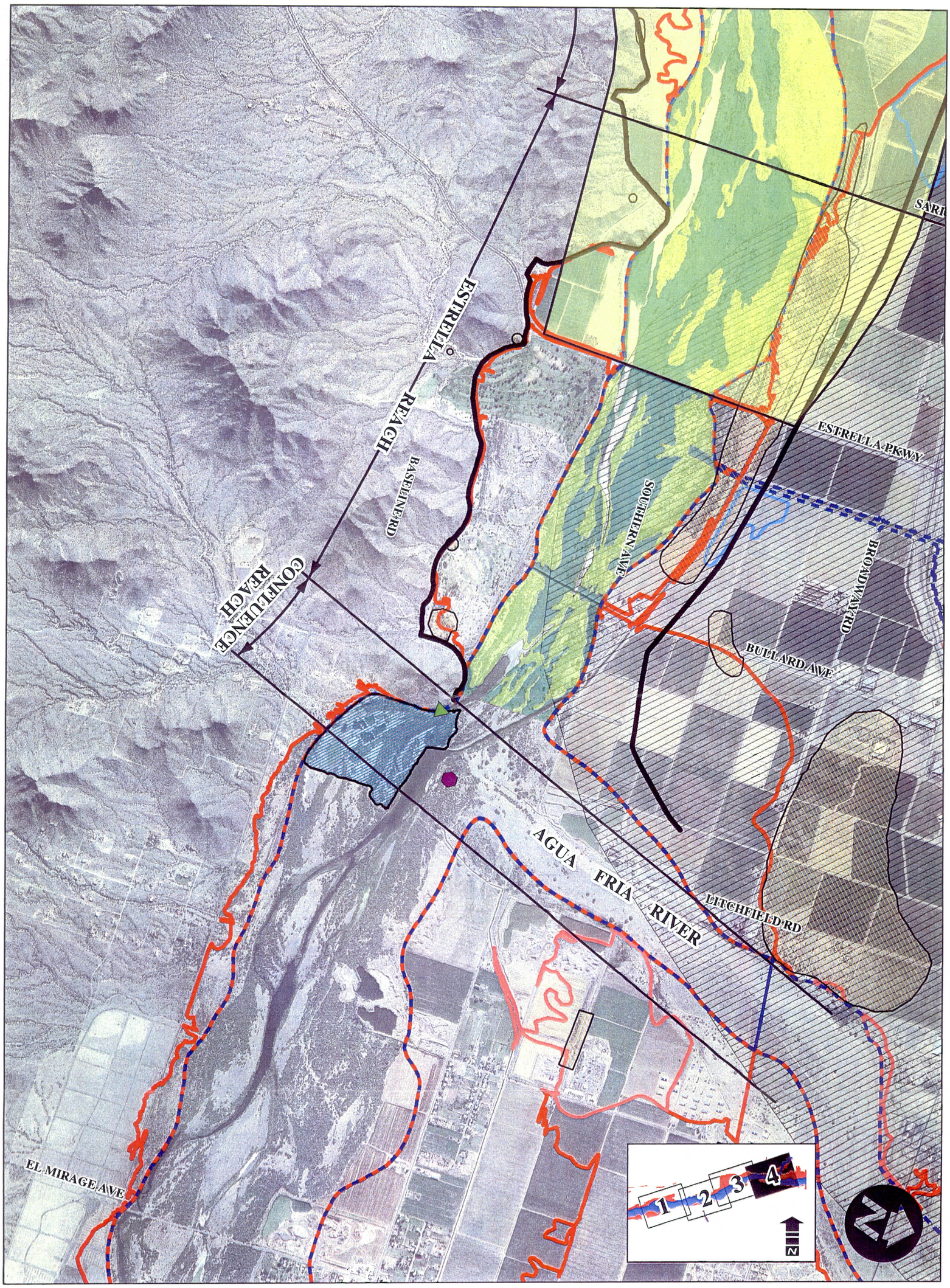

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FIGURE 3.9 - ALIGNMENT OF NON-STRUCTURAL ALTERNATIVE
SHEET 4 OF 4 (ESTRELLA REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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3.3 ALTERNATIVE EVALUATION

These potential alternatives were evaluated in order to identify which ones would be considered for further detailed analysis. The evaluation was based on generalized, "low resolution" hydraulic modeling and qualitative interpretations of the benefits and impacts in regard to the evaluation criteria. The evaluation of each alternative is presented on a reach-by-reach basis following the discussion of the hydraulic modeling conducted for the alternatives.

3.3.1 Hydraulic Analysis

Hydraulic modeling of the alternatives was accomplished by modifying the FEMA HEC-RAS model discussed in Attachment 3 - Existing Condition Hydrology and Hydraulics Memorandum. Modifications to that model are limited to changes in roughness coefficients and the use of the encroachment and the channel modification routines to represent the general features of the various alternatives. The modified models are provided digitally on CD in Appendix B. HEC-RAS project and plan names are listed in Table 3.1

Table 3.1 Alternative Analysis Hydraulic Model Summary

HEC-RAS Project Name	HEC-RAS Plan Name	Description
El Rio WMP Base File	FEMA - Floodplain/Floodway w/ levees	Baseline hydraulic data for the El Rio Watercourse Master Plan is taken from the Gila and Salt Rivers Flood Insurance Study (Baker, 1999).
El Rio WMP Base File	Base Model with KR Topo	Additional Base model for the EL RIO WMP - Includes cross sectional data from river station 188.69 to 194.20 prepared as part of the King Ranch development.
El Rio WMP Alternative Analysis	Structural Alternative 1	Levee alignment generally follows FEMA floodway boundary. Deviations occur at western end of study area to follow Arlington Canal (right overbank area) and natural terrain near Tuthill Road
2000-foot Chnl w/ Fdwy Levee Alternative	Structural Alternative 2	Levee alignment generally follows FEMA floodway boundary. 2,000-foot channel generally centered about station 20000.
El Rio WMP 2000 ft Floodway Corridor Alt	Structural Alternative 3	2,000-foot wide floodway corridor centered around geometry station 20,000. Manning's n-values are the same as in the base model

As stated previously, the soft structural alternatives are similar to the full structural alternative with the exception that the structural features are hidden or softened by landscape aesthetic or bioengineering treatments. For this level of analysis, it was assumed that landscape aesthetic and bioengineering treatments would have a negligible impact on the hydraulic characteristics given the magnitude in the dimensions of the proposed alternatives. Therefore, a single HEC-RAS model was used to represent both the full structural and soft structural options of the various alternatives.

For the floodway bank/levee alternative (Structural Alternative 1), the FEMA HEC-RAS model was adopted with minor changes. The bank/levee alignment for Structural Alternative 1 varies from the FEMA floodway alignment only at areas where topographic features (either manmade or natural) can be utilized to provided a sinuous bank alignment over a rigid one defined by the floodway alignment.

For the channelization alternative (Structural Alternative 2), the 2,000-foot channel alignment follows the FEMA model hydraulic baseline (station 200+00 in the cross sectional geometry). In general, the channel width is centered about the baseline. The profile of the proposed channel was adjusted so that the proposed channel invert generally was higher than the existing low flow invert elevation of the FEMA HEC-RAS model to facilitate utilizing the HEC-RAS channel modification rountine. The channel side slopes are set to 4 horizontal to 1 vertical. The roughness coefficient used for the proposed channel is 0.045. This value represents a mature condition that includes vegetation along the channel banks. Initial analysis of this alternative showed that in order to meet District freeboard criteria, the bank protection would extend above the natural ground elevation at the floodway boundary. This was modeled using the floodway encroachment stations.

Structural Alternative 3, the 2,000-foot conveyance corridor alternative was modeled using the Method 1 option of the HEC-RAS encroachment routine. The alignment for this alternative follows the FEMA model hydraulic baseline. In general, the 2,000-foot conveyance corridor is centered about the baseline. The existing geometry of the channel within the conveyance limits and channel roughness were not revised.

The non structural alternative is an alternative which is managed by lateral migration zones. Due to the unpredictability of channel geometry and vegetation changes due to lateral migration, flood hazard zones associated with the non-structural alternative are not quantified with a hydraulic model but are assumed to be consistent with Existing FEMA Flood Hazard Zones. Potential deviation from the FEMA Flood Hazard Zone is addressed qualitatively.

3.3.1.1 Hydraulic Analysis Results

Results of the hydraulic models for the Structure Alternatives (Alternatives 1, 2 and 3) are compared to the Base Hydraulic Model to determine the impact of the alternative on the hydraulic properties of the watercourse. Figures 3.10 through 3.18 depict the results of the comparison of the Base Model with Structure Alternative 1, Structure Alternative 2, Structure Alternative 3, and the Nonstructural Alternative. Figures depict changes in

top width, flow depth, and flow velocity for the 100-year event for each alternative relative to the same hydraulic properties calculated for the Base Hydraulic Model.

3.3.1.2 Conclusions

Conclusions that can be drawn from review of the comparison of specific hydraulic parameters are:

- Changes in top width occur for Structural Alternative 1, 2 and 3. Given that both Structural Alternatives 1 and 2 have the same bank/levee alignments the changes in top width are the same. The change in top width for Structural Alternatives 1 and 2 are a result of the elimination of the floodway fringe. The change in top width for Structural Alternative 3 is a result of encroachment not only into the floodway fringe but also in the floodway area.

- Minor changes in channel depth of flow are recognized in comparing the results of hydraulic models for Alternatives 1 and 2 relative to the base hydraulic model. Changes in flow depth for Structural Alternatives 1 and 2 are primarily a result of proposed encroachment to the floodway fringe. The comparison of depth of flow between the Base and Structural Alternative 3 show that there is a significant increase in flow depth (as much as 6 feet) due to the proposed encroachment into the floodway corridor.

- Changes observed in comparing output from the hydraulic models indicate that changes in velocity are similar to the flow depth changes that were observed. Changes in velocity for Structural Alternatives 1 and 2 are minor relative to the Base Model, however there are significant (4 to 6 fps) changes recognized when comparing channel flow velocity calculated for Alternative 3 relative to the Base Model. The significant change in velocity is a result of the proposed encroachment into the floodway corridor.

As mentioned earlier, due to the unpredictability of channel geometry and vegetation changes due to lateral migration, flood hazard zones associated with the non-structural alternative are not quantified with a hydraulic model but are assumed to be consistent with existing FEMA Flood Hazard Zones. Potential deviation from FEMA Flood Hazard Zones could occur at locations along the North Bank/Floodway Limit adjacent to the Buckeye Slough. (North Bank approximately between Miller and Perryville Roads) should the river channel migrate to the northern lateral erosion hazard limits there is a potential for split flow to occur. The split flow would ultimately drain to the Buckeye Slough, which is lower in elevation than the North Bank elevations.

Figure 3.10 Hydraulic Parameter Comparison-Top Width, Base Model to Structural Alternative 1 Model

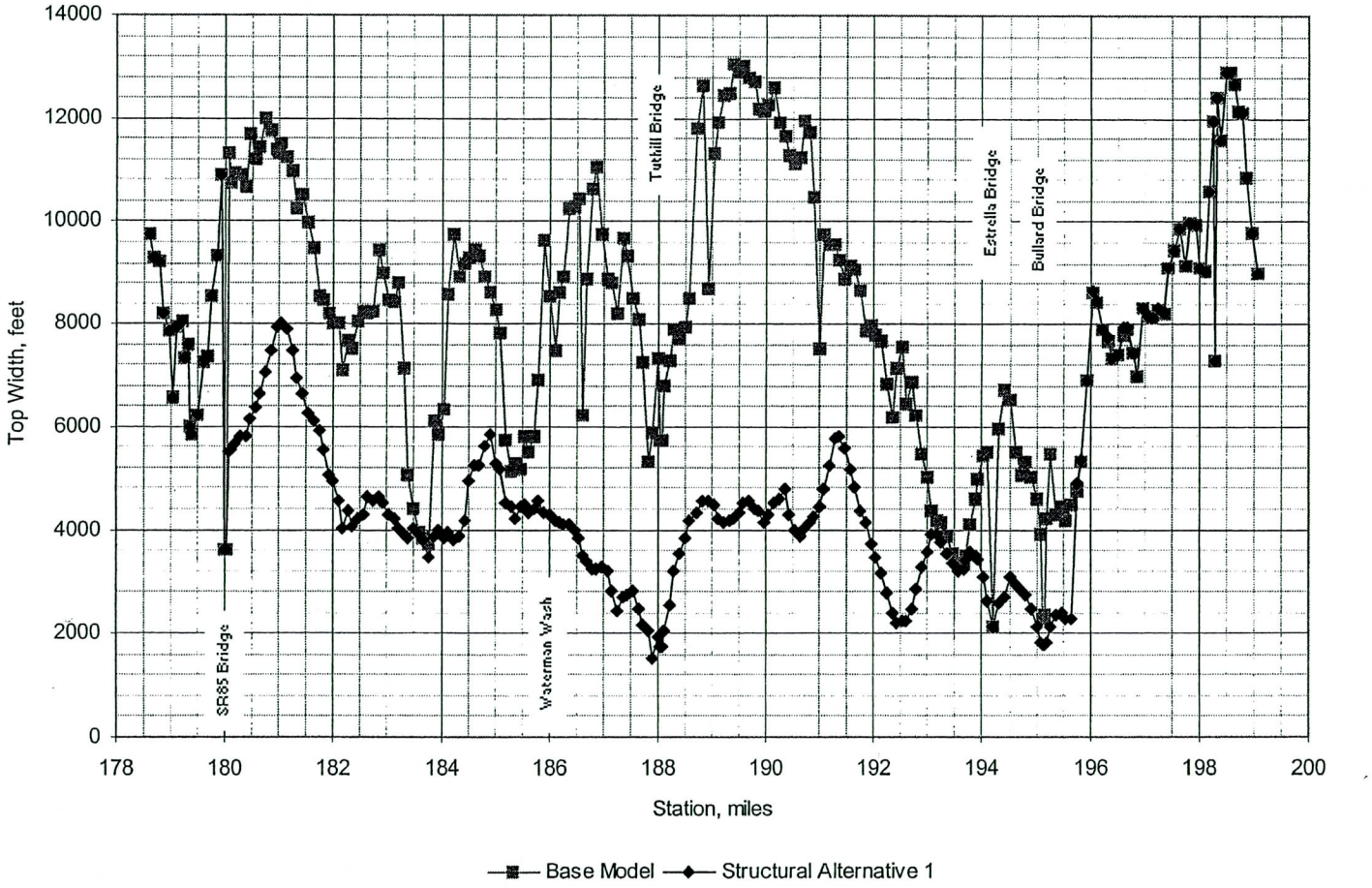


Figure 3.11 Hydraulic Parameter Comparison-Top Width, Base Model to Structural Alternative 2 Model

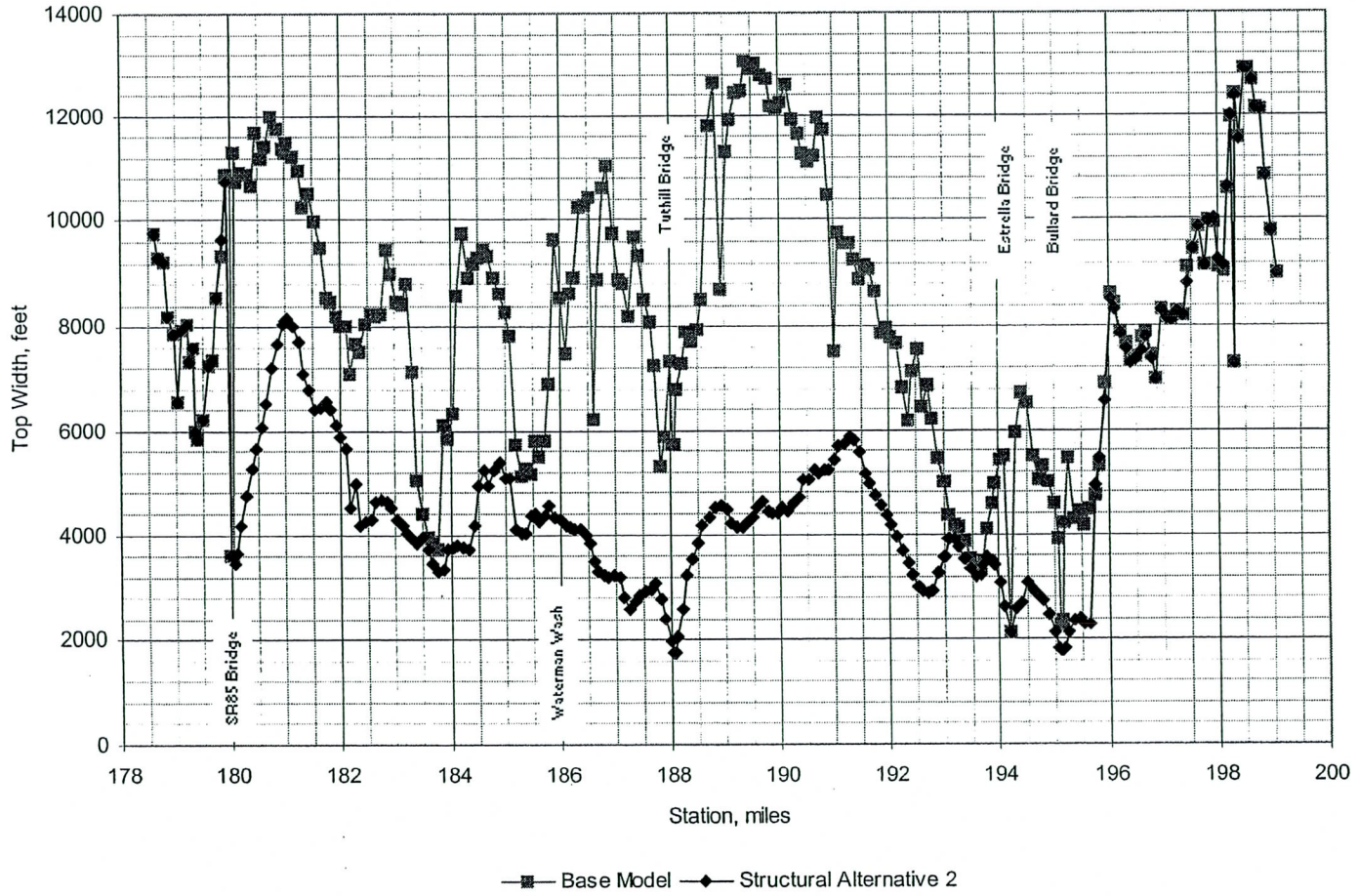


Figure 3.12 Hydraulic Parameter Comparison-Top Width, Base Model to Structural Alternative 3 Model

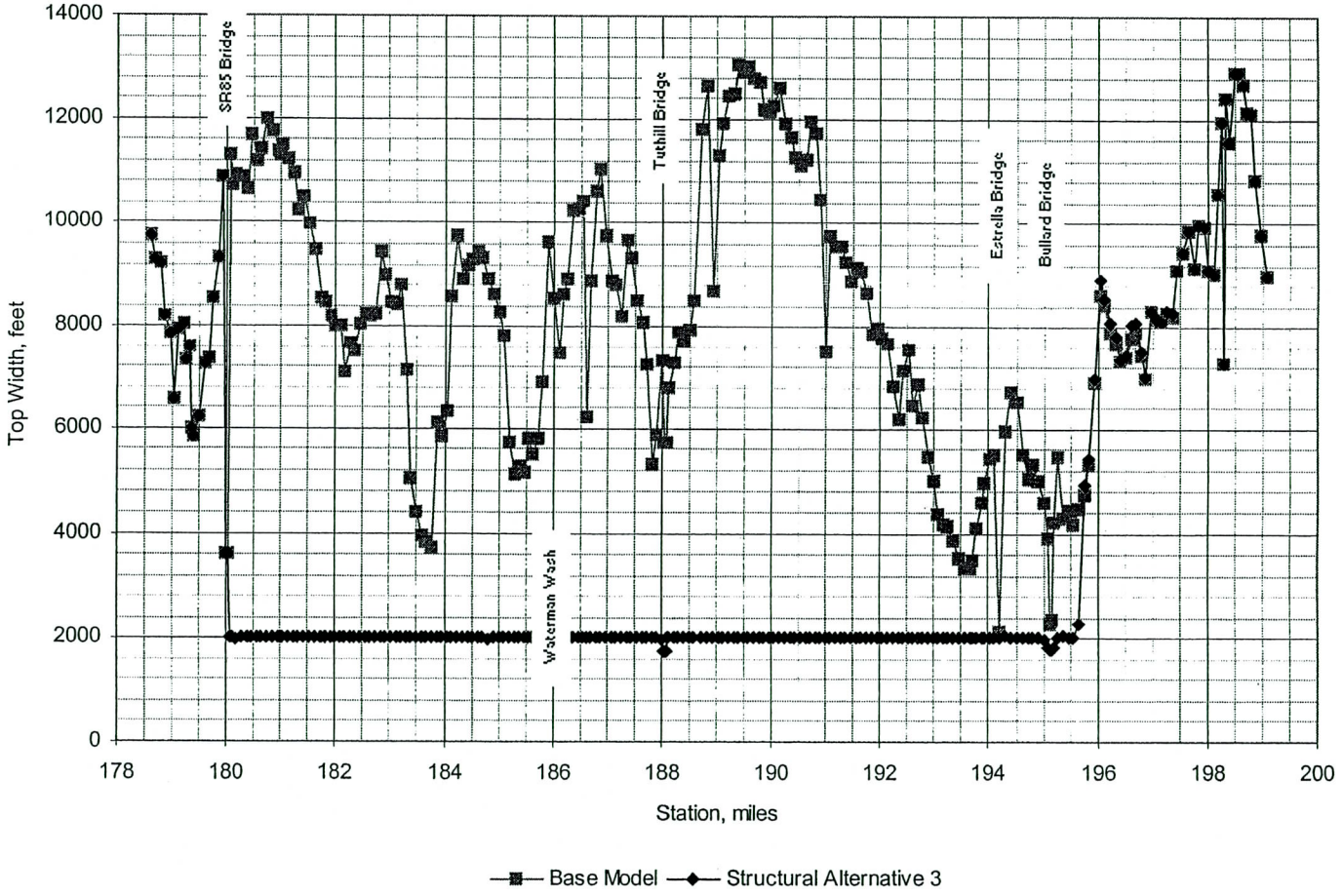


Figure 3.13 Hydraulic Parameter Comparison-Flow Depth, Base Model to Structural Alternative 1 Model

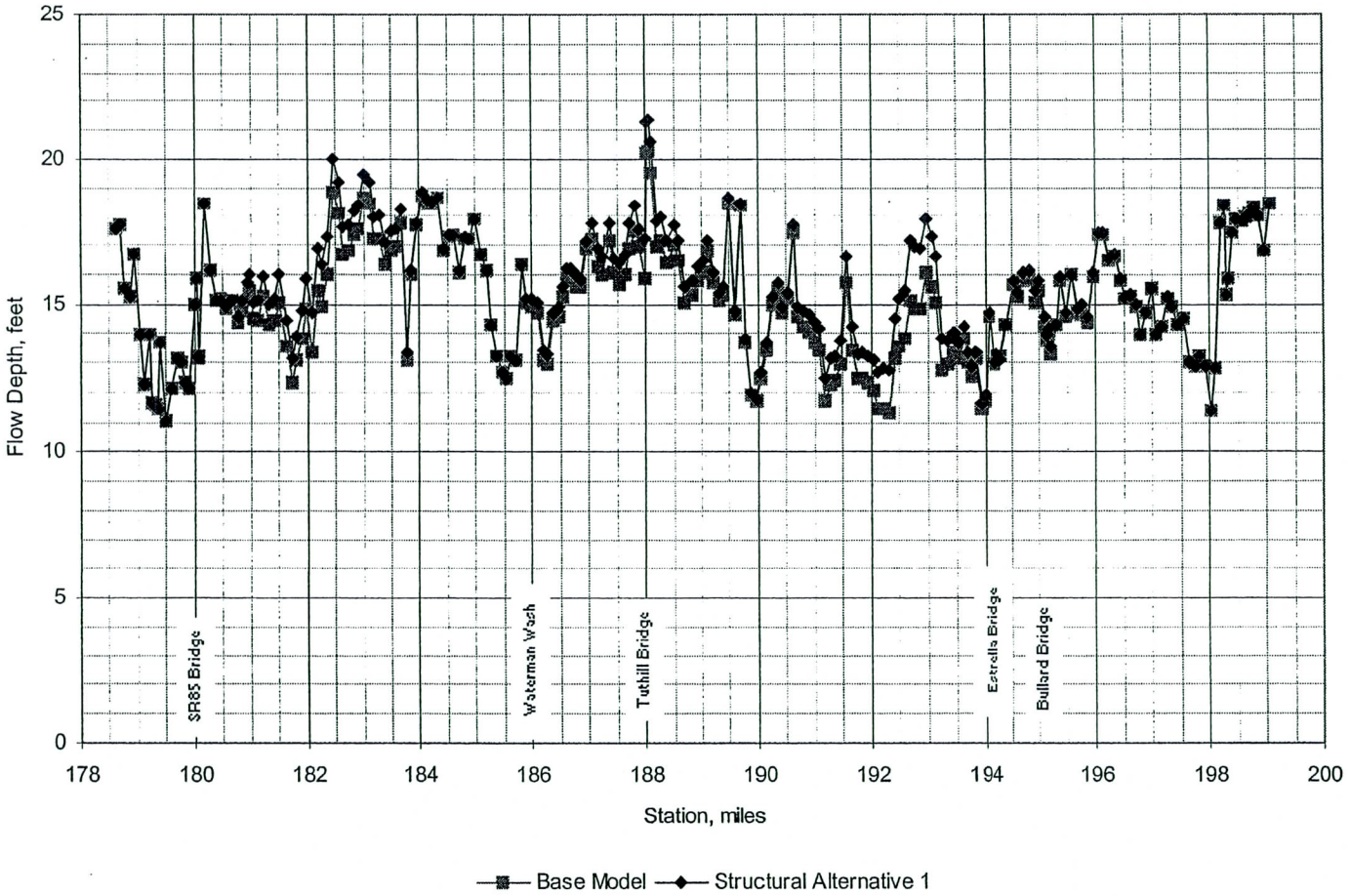


Figure 3.14 Hydraulic Parameter Comparison- Flow Depth, Base Model to Structural Alternative 2 Model

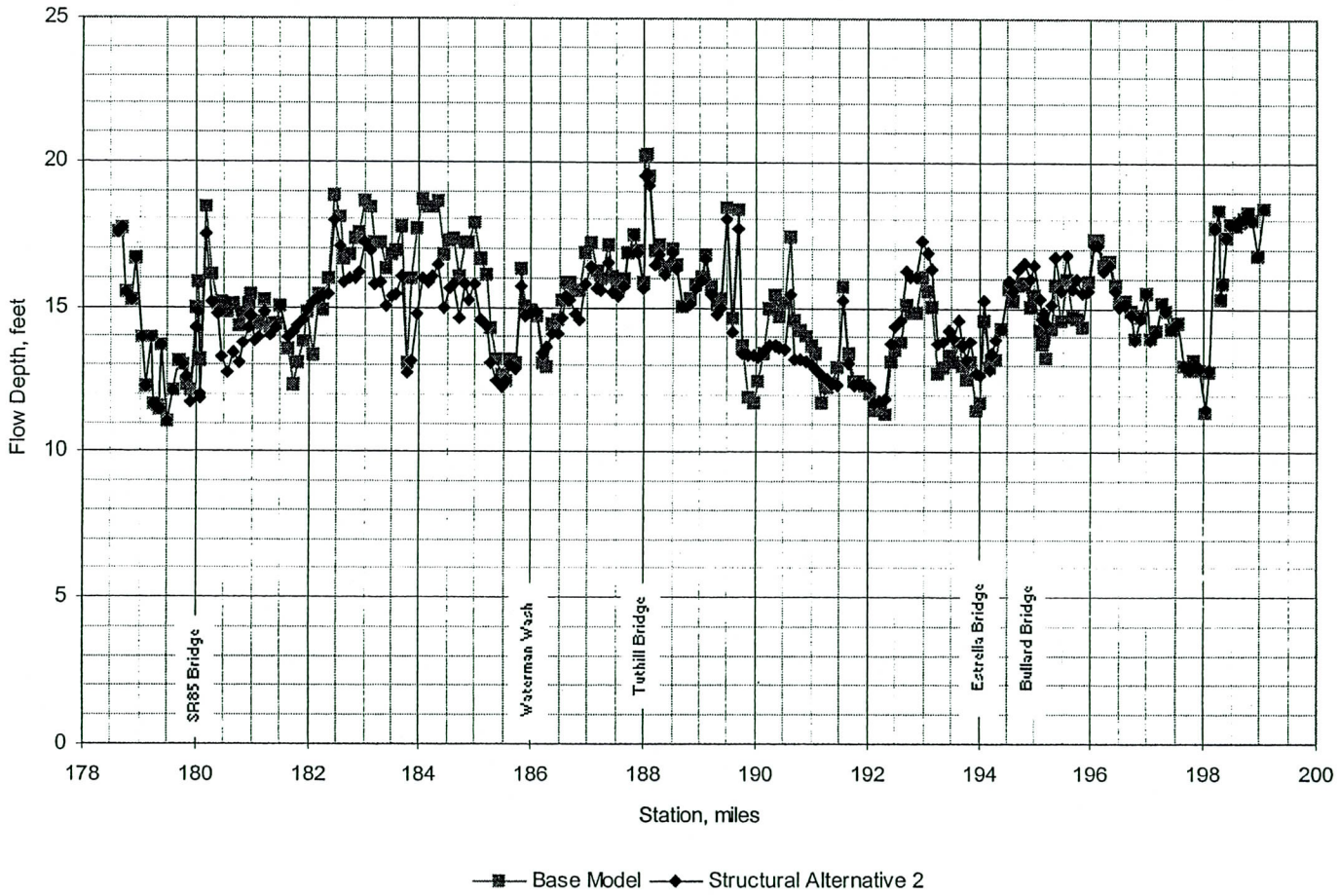


Figure 3.15 Hydraulic Parameter Comparison- Flow Depth, Base Model to Structural Alternative 3 Model

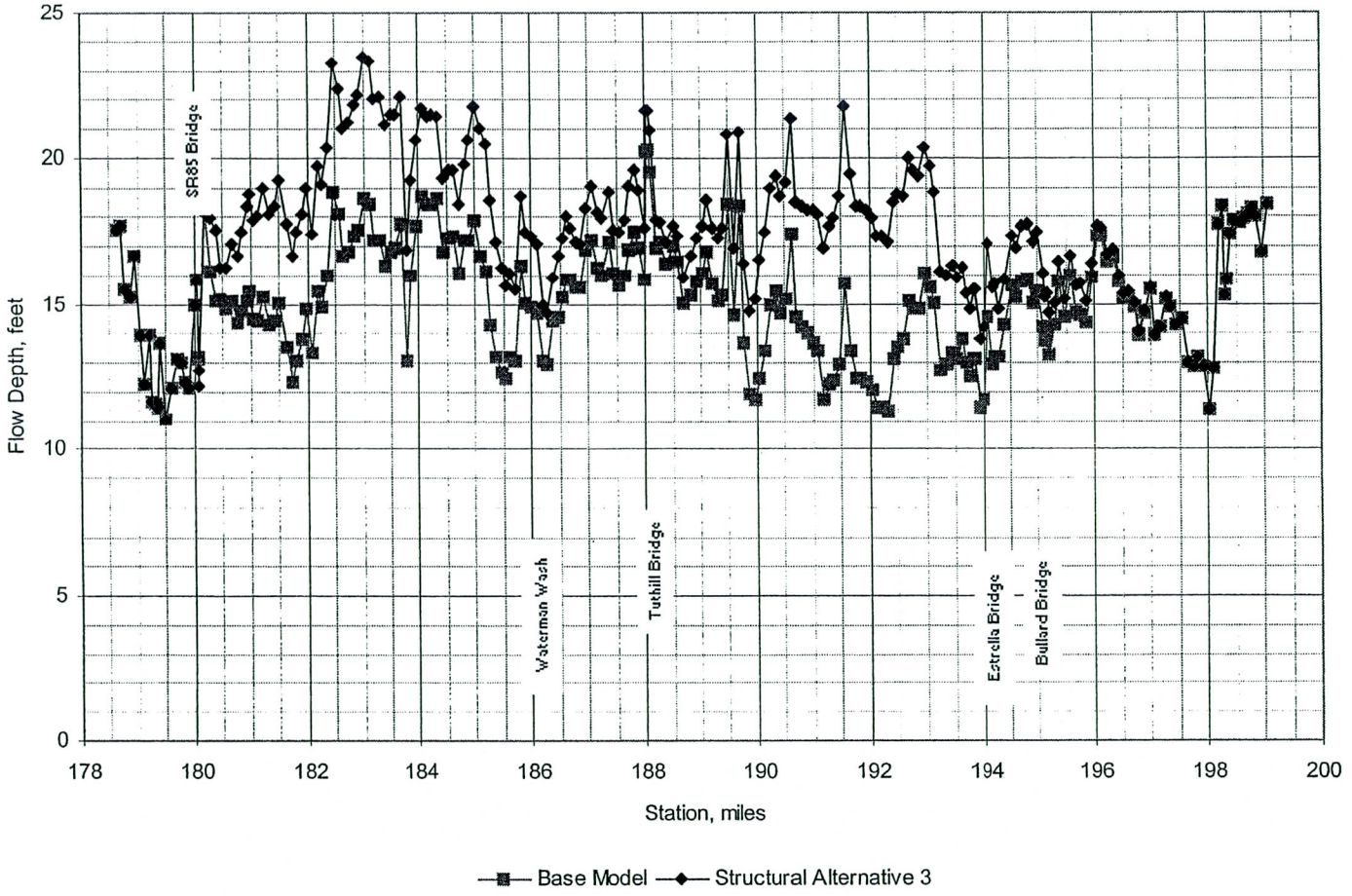


Figure 3.16 Hydraulic Parameter Comparison- Flow Velocity, Base Model to Structural Alternative 1 Model

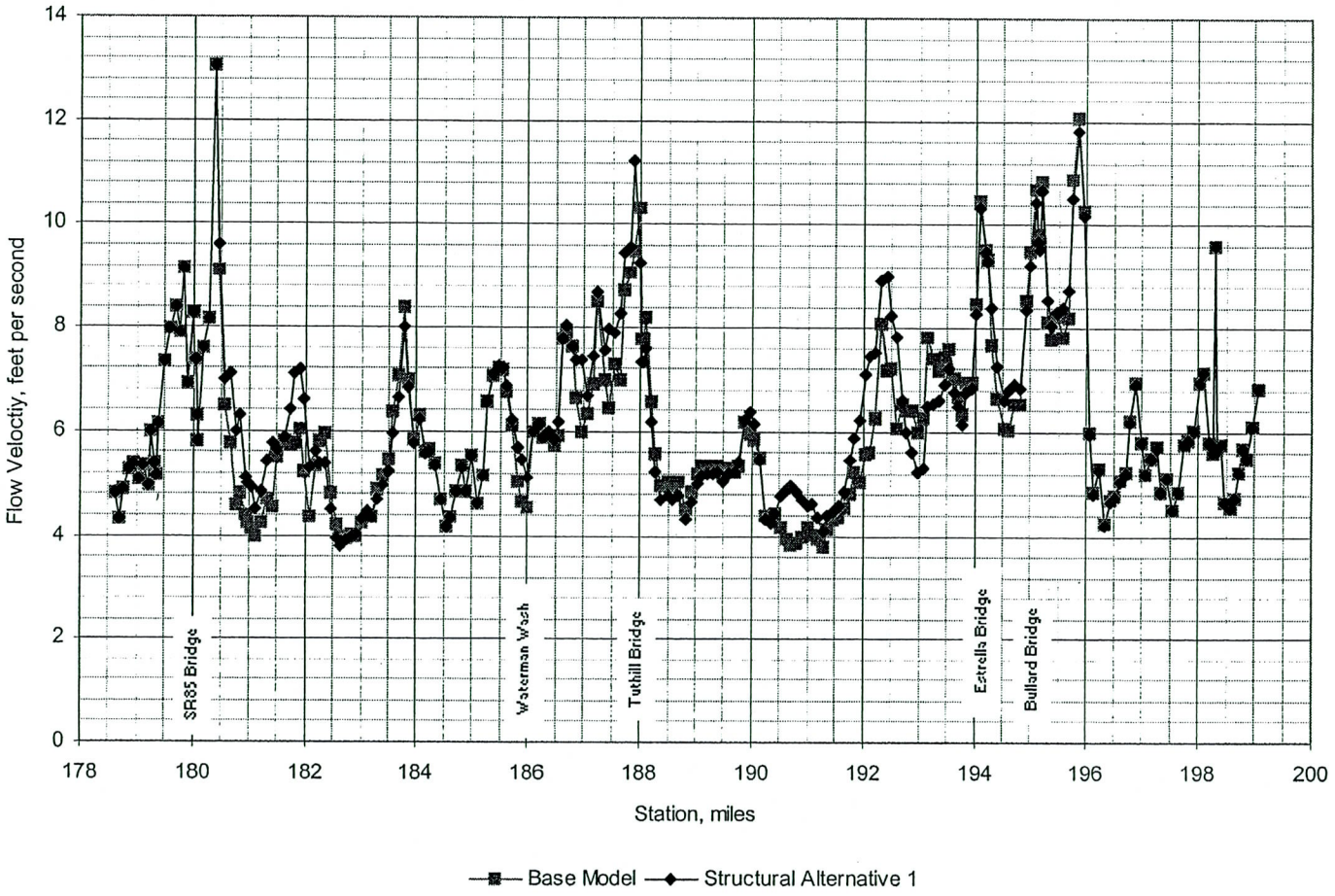


Figure 3.17 Hydraulic Parameter Comparison- Flow Velocity, Base Model to Structural Alternative 2 Model

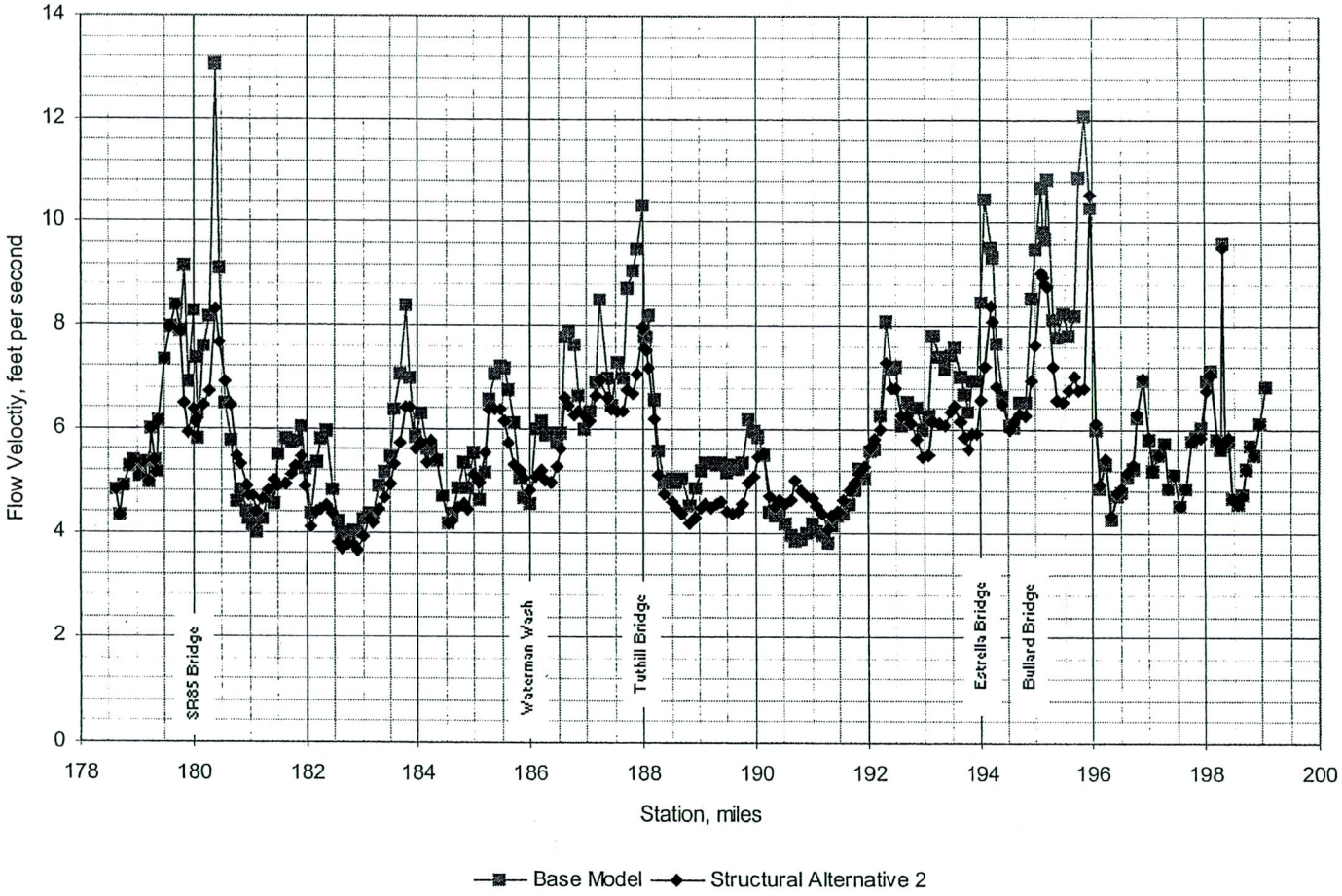
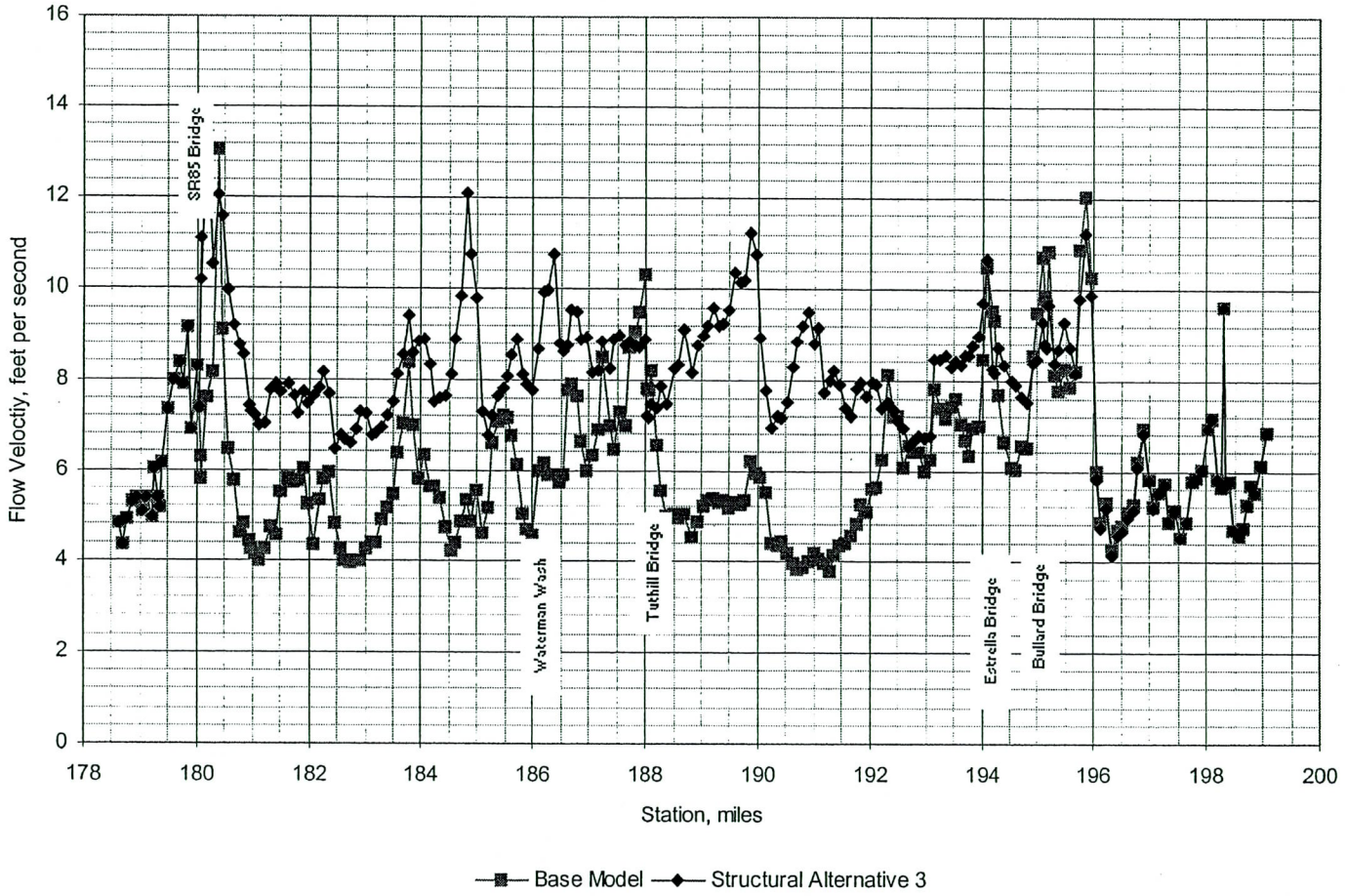


Figure 3.18 Hydraulic Parameter Comparison- Flow Velocity, Base Model to Structural Alternative 3 Model



3.3.2 Environmental and Cultural Resources Impacts

Environmental resources within the El Rio study area were divided into three major types, physical and wetland resources, biological resources, and human influence resources. Each of these major resources categories contains both opportunities and constraints for development of flood control management, plans, practices, and activities. Environmental and cultural resources were identified so that impacts of proposed flood control alternatives could be identified, and opportunities to preserve high quality habitat or enhance marginal habitat were also identified. Potential impacts to Environmental and Cultural Resources from Structural Alternatives 1, 2, 3 and the Non-Structural alternatives are depicted on Figures 3.2, 3.4, 3.6 and 3.9 respectively. Impacts of each alternative on identified environmental and cultural resources are summarized in Table 3.2.

Table 3.2 Environmental Impact Summary

Alternative	Impacts to Unique/Endangered Wildlife/Habitat	Impacts to Biological Resources	Impacts to Cultural Resources	Habitat Value Enhancements Opportunities
Full Structural				
Structural Alternative 1	Proposed structural features will not impact unique wildlife features	Impacts limited to Salt Cedar and Arrow Weed Willow vegetation communities along bank stabilization / levee alignments	Bank stabilization / levee alignments impact four cultural resource sites.	Abundant opportunity for enhancements between south and north bank alignments.
Structural Alternative 2	Channelization element will impact unique wildlife features	Channelization element will impact open water and Cottonwood / Willow and Marsh Vegetative Communities	Bank stabilization / levee alignments impact four cultural resource sites.	Habitat value enhancement opportunities are minimized with channelization effort.

Table 3.2 Environmental Impact Summary Cont.

Alternative	Impacts to Unique/Endangered Wildlife/Habitat	Impacts to Biological Resources	Impacts to Cultural Resources	Habitat Value Enhancements Opportunities
Structural alternative 3	Due to the degree of encroachment into the floodway corridor sustainability of unique wildlife features will be impacted.	Sustainability of open water and Cottonwood / Willow and Marsh Vegetative Communities within proposed floodway corridor will be diminished.	Bank stabilization / levee alignments impact four cultural resource sites.	Due to the degree of encroachment into the floodway corridor, habitat enhancement opportunities are greatly diminished
Non-Structural	Proposed alternative will not impact unique wildlife features	Proposed alternative will not impact vegetative communities	Possibility to lose cultural resource sites due to lateral migration.	Opportunity for enhancements occur between south and north lateral migration boundaries.

3.3.3 Opinion of Probable Construction Cost

3.3.3.1 Purpose

Preliminary estimates of construction cost are prepared for the structural alternatives, soft structural alternatives and the non-structural alternative. Cost estimates are used as an aid in the selection process of a recommended alternative. Cost estimates developed for each alternative reflect the proposed improvements developed from generalized hydraulic evaluations and are considered approximate. The value of land removed from the floodplain/erosion hazard zone by an alternative is estimated to determine the benefit of the proposed improvement.

3.3.3.2 Methodology

Quantities are calculated for earthwork (channel excavation, fill and/or levee fill), volume of bank armoring material required, and for land cost. Volume of fill material was determined by average end area calculations for cross-sections (cross sections from the HEC-RAS Model were utilized) taken through the proposed channel excavation, fill and/or levee fill area. Bank armoring quantities are determined by applying a typical section along the length of the improvement area. Estimating total scour at each

hydraulic cross section and then computing a reach average derived a toe-down depth for bank armoring. Scour depth estimated for all reaches. Fill quantities in the floodway and floodway fringe area are based on fill being placed to the calculated freeboard elevation.

Due to the presence of high ground water, dumped riprap was chosen over soil cement and/or gabion mattress or baskets for typical bank armoring material. It was assumed that the cost to dewater and, to place soil cement or gabion baskets on banks would be excessive. Dumped riprap quantities are based on a riprap installation technique in which toe material is installed in a trench above the water table. The trench is typically constructed below the adjacent channel invert elevation. During a scour event at the toe of slope, riprap would be launched into the forming scour hole checking river migration into the bank. Utilizing the proposed slope and estimated toe down depth, the volume of material provided in the toe trench is calculated by applying a 1.5 factor to the required riprap thickness. The size of the dumped riprap material was determined utilizing procedures cited in the Districts' Drainage Design Manual for Maricopa County, Hydraulics.

Table 3.3 lists a summary of unit cost utilized to determine cost estimates for each alternative. Given the level of design (conceptual) of the proposed alternatives, a cost contingency is applied to account for design details that are not taken into account at this stage. Contingency cost is estimated at 25 percent of the total construction cost of the proposed improvements.

3.3.3.4 Cost Estimate Results

Table 3.4 list a summary of constructions cost estimates of evaluated alternatives. Table 3.5 through Table 3.11 provide detail construction costs estimates for Structure Alternative 1, Soft Structural Alternative 1 Structure Alternative 2 Soft Structural Alternative 2, Structure Alternative 3, Soft Structural Alternative 3 and the Nonstructural Alternative, respectively.

Table 3.3 Summary of Unit Costs

DESCRIPTION	UNIT	UNIT PRICE
CONSTRUCTION		
Clear and Grub	AC	$1,000.00[1]
Channel Excavation	CY	$5.00[2]
Haul Excess Material	CY	$7.00[3]
Structural Fill (On-site)	CY	$6.00[4]
Structural Fill (Import)	CY	$10.00[5]
Dumped Riprap (D_{50}= 0.5')	CY	$60.00
Dumped Riprap (D_{50}= 0.75')	CY	$60.00
Dumped Riprap (D_{50}= 1.0')	CY	$60.00
Dumped Riprap (D_{50}= 1.25')	CY	$60.00
Dumped Riprap (D_{50}= 1.5')	CY	$60.00
Filter Fabric	SF	$1.00
PROPERTY		
Right of Way (within Floodplain)	AC	$25,000.00
Reclaimed Floodway Property	AC	($25,000.00)[6]
Property Acquisition- Floodplain	AC	$25,000.00
Property Acquisition- Non-Floodplain	AC	$50,000.00
ENVIRONMENTAL MITIGATION		
Hydroseed	AC	$2,000.00
LANDSCAPING		
Landscape Aesthetic Fill (On-site)	CY	$4.00
Landscape Aesthetic Fill (Import)	CY	$9.00
Plantings	AC	$4,500.00[7]
GENERAL REQUIREMENTS (percentage of subtotal)		
Contingency	LS	25.00%[8]
Engineer (Planning, Design and Geotech)	LS	10.00%
Mobilization	LS	3.00%
Supplemental General Conditions	LS	3.00%[9]
Const. Management (CQA Testing, Inspection and Eng. Support)	LS	8.00%

Table 3.3 Summary of Unit Costs Cont.

Table Footnotes

1) Doesn't include salvage of native plants. Clearing unit cost assumes that ground conditions are 50% Agriculture/Minor Vegetation (Clearing unit cost of $500.00 per acre) and 50% Salt Cedar (Clearing unit cost of $1500.00 per acre).

2) Assume material is placed on-site

3) Haul excess excavated material to an offsite location. Assumes no need locally for material.

4) Assume native material is acceptable for structural fill, with only minor processing

5) Includes furnishing approved aggregate, cement, mixing and placing, complete

6) Reclaimed land is assumed to gain $25,000/ac value when it is removed from the floodplain. No cost has been carried for providing fill to elevate the lands above the 100 year flood.

7) Estimate does not include irrigation, Plant pallet consists of 20/acre Screwbean Mesquite, 40/acre Velvet Mesquite and Hydroseeding

8) Accounts for unknown conditions as well as general conditions, temporary facilities, insurance,

9) Includes partnering allowance, permitting, public information and notification allowance, public sign

Table 3.4 Alternative Construction Cost Estimates Summary

Reach	No-Action	Non-Structural	Structural Alternative 1		Structural Alternative 2		Structural Alternative 3	
			Full Structural	Soft Structural	Full Structural	Soft Structural	Full Structural	Soft Structural
Estrella	---	$35,587,500	$8,631,750	$9,788,375	$34,912,125	$34,830,000	$136,225,000	$140,617,250
Perryville		NA	NA	NA	NA	NA	NA	NA
Tuthill	---	$6,218,750	$5,097,875	$6,364,875	$48,724,000	$48,564,750	$225,536,375	$225,953,000
Buckeye Town Lake	---	$80,468,750	$38,252,000	$43,727,875	$42,307,250	$42,188,125	$1,161,087,250	$1,166,141,750
Total Construction Cost	---	**$122,275,000**	**$51,981,625**	**$59,881,125**	**$125,943,375**	**$125,582,875**	**$1,522,848,625**	**$1,532,712,000**
Total Land Value Offset	---	$0	($134,550,000)	($134,550,000)	($118,042,500)	($118,042,500)	($254,650,000)	($254,650,000)
Total	---	**$122,275,000**	**($82,568,375)**	**($74,668,875)**	**$7,900,875**	**$7,540,375**	**$1,268,198,625**	**$1,278,062,000**

A 25% cost contingency is applied to all construction costs presented in the Table

Table 3.5 Construction Cost Estimate – Structural Alternative 1

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Estrella Reach (13,200 ft)	**$6,905,400**					
Clear and Grub		40	-	AC	$1,000.00	$40,000
Channel Excavation			-	CY	$5.00	$0
Haul Excess Material			-	CY	$7.00	$0
Structural Fill (On-site)			-	CY	$6.00	$0
Structural Fill (Import)		127,456	-	CY	$10.00	$1,274,600
Dumped Riprap (D50= 1')		73,346	-	CY	$60.00	$4,400,800
Filter Fabric		110,019	-	SY	$1.00	$110,000
Right of Way (within Floodplain)		40	-	AC	$25,000.00	$1,000,000
Property Acquisition			-	AC	$0.00	$0
Hydroseed		40	-	AC	$2,000.00	$80,000
Landscape Aesthetic Fill			-	CY	$9.00	$0
Plantings			-	AC	$4,500.00	$0
Reclaimed Floodway Property		153	-	AC	($25,000.00)	($3,827,800)
Tuthill Reach (10,560 ft)	**$4,078,300**					
Clear and Grub		29	-	AC	$1,000.00	$29,000
Channel Excavation				CY	$5.00	$0
Haul Excess Material				CY	$7.00	$0
Structural Fill (On-site)				CY	$6.00	$0
Structural Fill (Import)		138,871	-	CY	$10.00	$1,388,700
Dumped Riprap (D50= 0.5')		29,804	-	CY	$60.00	$1,788,200
Filter Fabric		89,411	-	SY	$1.00	$89,400
Right of Way (within Floodplain)		29	-	AC	$25,000.00	$725,000
Property Acquisition			-	AC	$0.00	$0

Table 3.5 Construction Cost Estimate – Structural Alternative 1 Cont.

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Hydroseed		29	-	AC	$2,000.00	$58,000
Landscape Aesthetic Fill				CY	$9.00	$0
Plantings				AC	$4,500.00	$0
Reclaimed Floodway Property		385	-	AC	($25,000.00)	($9,617,500)
Buckeye Reach (34,320 ft)	**$30,601,600**					
Clear and Grub		106	58	AC	$1,000.00	$164,000
Channel Excavation				CY	$5.00	$0
Haul Excess Material				CY	$7.00	$0
Structural Fill (On-site)				CY	$6.00	$0
Structural Fill (Import)		392,319	208,289	CY	$10.00	$6,006,100
Dumped Riprap (D50= 1')		212,468	112,793	CY	$60.00	$19,515,600
Filter Fabric		318,702	169,189	SY	$1.00	$487,900
Right of Way (within Floodplain)		106	58	AC	$25,000.00	$4,100,000
Property Acquisition			-	AC	$0.00	$0
Hydroseed		106	58	AC	$2,000.00	$328,000
Landscape Aesthetic Fill				CY	$9.00	$0
Plantings				AC	$4,500.00	$0
Reclaimed Floodway Property		1,390	891	AC	($25,000.00)	($57,040,800)

SUB-TOTAL	$41,585,300
CONTIGENCY (25%)	$10,396,325
TOTAL COST OF ALTERNATIVE	**$51,981,625**
TOTAL LAND VALUE OFFSET	($70,486,100)
TOTAL	**-$18,504,475**

Table 3.6 Construction Cost Estimate – Soft Structural Alternative 1

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Estrella Reach (13,200 ft)	**$7,830,700**					
Clear and Grub		46	-	AC	$1,000.00	$46,400
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		127,456	-	CY	$10.00	$1,274,600
Dumped Riprap (D50= 1')		73,346	-	CY	$60.00	$4,400,800
Filter Fabric		110,019	-	SY	$1.00	$110,000
Right of Way (within Floodplain)		46	-	AC	$25,000.00	$1,159,800
Property Acquisition		-	-	AC	$0.00	$0
Hydroseed		46	-	AC	$0.00	$0
Landscape Aesthetic Fill (Import)		72,471	-	CY	$9.00	$652,200
Plantings		42	-	AC	$4,500.00	$186,900
Reclaimed Floodway Property		153	-	AC	($25,000.00)	($3,827,800)
Tuthill Reach (10,560 ft)	**$5,091,900**					
Clear and Grub		35	-	AC	$1,000.00	$35,200
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		138,871	-	CY	$10.00	$1,388,700
Dumped Riprap (D50= 0.5')		29,804	-	CY	$60.00	$1,788,200
Filter Fabric		89,411	-	SY	$1.00	$89,400
Right of Way (within Floodplain)		35	-	AC	$25,000.00	$880,200
Property Acquisition		-	-	AC	$0.00	$0

Table 3.6 Construction Cost Estimate – Soft Structural Alternative 1 Cont.

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Hydroseed		35	-	AC	$0.00	$0
Landscape Aesthetic Fill (Import)		85,464	-	CY	$9.00	$769,200
Plantings		31	-	AC	$4,500.00	$141,000
Reclaimed Floodway Property		385	-	AC	($25,000.00)	($9,617,500)
Buckeye Reach (34,320 ft)	**$34,982,300**					
Clear and Grub		124	68	AC	$1,000.00	$192,600
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		392,319	208,289	CY	$10.00	$6,006,100
Dumped Riprap (D50= 1')		212,468	112,793	CY	$60.00	$19,515,600
Filter Fabric		318,702	169,189	SY	$1.00	$487,900
Right of Way (within Floodplain)		124	68	AC	$25,000.00	$4,816,200
Property Acquisition		-	-	AC	$0.00	$0
Hydroseed		124	68	AC	$0.00	$0
Landscape Aesthetic Fill (Import)		233,256	120,835	CY	$9.00	$3,186,800
Plantings		112	61	AC	$4,500.00	$777,100
Reclaimed Floodway Property		1,390	891	AC	($25,000.00)	($57,040,800)

SUB-TOTAL	$47,904,900
CONTIGENCY (25%)	$11,976,225
TOTAL COST OF ALTERNATIVE	**$59,881,125**
TOTAL LAND VALUE OFFSET	($70,486,100)
TOTAL	**-$10,604,975**

Table 3.7 Construction Cost Estimate – Structural Alternative 2

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Estrella Reach (13,200 ft)	**$27,929,700**					
Clear and Grub		646	-	AC	$1,000.00	$646,100
Channel Excavation		1,912,703	-	CY	$5.00	$9,563,500
Haul Excess Material		1,699,243	-	CY	$7.00	$11,894,700
Structural Fill (On-site)		213,460	-	CY	$6.00	$1,280,800
Structural Fill (Import)				CY	$10.00	$0
Dumped Riprap (D50= 0.75')		56,295	-	CY	$60.00	$3,377,700
Filter Fabric		84,442	-	SY	$1.00	$84,400
Right of Way (within Floodplain)		40	-	AC	$25,000.00	$1,002,500
Property Acquisition			-	AC	$0.00	$0
Hydroseed		40	-	AC	$2,000.00	$80,000
Landscape Aesthetic Fill			-	CY	$4.00	$0
Plantings			-	AC	$4,500.00	$0
Reclaimed Floodway Property		153	-	AC	($25,000.00)	($3,827,800)
Tuthill Reach (10,560 ft)	**$38,979,200**					
Clear and Grub		515	-	AC	$1,000.00	$514,800
Channel Excavation		3,003,619	-	CY	$5.00	$15,018,100
Haul Excess Material		2,862,157	-	CY	$7.00	$20,035,100
Structural Fill (On-site)		141,462	-	CY	$6.00	$848,800
Structural Fill (Import)		-	-	CY	$10.00	$0
Dumped Riprap (D50= 0.5')		28,494	-	CY	$60.00	$1,709,700
Filter Fabric		42,742	-	SY	$1.00	$42,700
Right of Way (within Floodplain)		30	-	AC	$25,000.00	$750,000
[illegible]				AC	$0.00	$0

Table 3.7 Construction Cost Estimate – Structural Alternative 2 Cont.

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Hydroseed		30	-	AC	$2,000.00	$60,000
Landscape Aesthetic Fill			-	CY	$4.00	$0
Plantings		-	-	AC	$4,500.00	$0
Reclaimed Floodway Property		385	-	AC	($25,000.00)	($9,617,000)
Buckeye Reach (34,320 ft)	**$33,845,800**					
Clear and Grub		1,679	57	AC	$1,000.00	$1,735,800
Channel Excavation		1,557,636	-	CY	$5.00	$7,788,200
Haul Excess Material		1,076,922	-	CY	$7.00	$7,538,500
Structural Fill (On-site)		319,319	61,395	CY	$6.00	$2,884,300
Structural Fill (Import)		-	-	CY	$10.00	$0
Dumped Riprap (D50= 0.5')		99,890	55,867	CY	$60.00	$9,345,400
Filter Fabric		149,834	83,801	SF	$1.00	$233,600
Right of Way (within Floodplain)		103	57	AC	$25,000.00	$4,000,000
Property Acquisition		-	-	AC	$0.00	$0
Hydroseed		103	57	AC	$2,000.00	$320,000
Landscape Aesthetic Fill		-	-	CY	$4.00	$0
Plantings		-	-	AC	$4,500.00	$0
Reclaimed Floodway Property		1,390	891	AC	($25,000.00)	($57,040,800)

SUB-TOTAL	$100,754,700
CONTIGENCY (25%)	$25,188,675
TOTAL COST OF ALTERNATIVE	**$125,943,375**
TOTAL LAND VALUE OFFSET	($70,485,600)
TOTAL	**$55,457,775**

Table 3.8 Construction Cost Estimate –Soft Structural Alternative 2

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Estrella Reach (13,200 ft)	**$27,864,000**					
Clear and Grub		655	-	AC	$1,000.00	$654,900
Channel Excavation		1,912,703	-	CY	$5.00	$9,563,500
Haul Excess Material		1,561,569	-	CY	$7.00	$10,931,000
Structural Fill (On-site)		213,460	-	CY	$6.00	$1,280,800
Structural Fill (Import)			-	CY	$10.00	$0
Dumped Riprap (D50= 0.75')		56,295	-	CY	$60.00	$3,377,700
Filter Fabric		84,442	-	SY	$1.00	$84,400
Right of Way (within Floodplain)		49	-	AC	$25,000.00	$1,222,700
Property Acquisition			-	AC	$0.00	$0
Hydroseed		49	-	AC	$0.00	$0
Landscape Aesthetic Fill (On-site)		137,674	-	CY	$4.00	$550,700
Landscape Aesthetic Fill (Import)		-	-	CY	$9.00	$0
Plantings		44	-	AC	$4,500.00	$198,300
Reclaimed Floodway Property		153	-	AC	($25,000.00)	($3,827,800)
Tuthill Reach (10,560 ft)	**$38,851,800**					
Clear and Grub		521	-	AC	$1,000.00	$521,100
Channel Excavation		3,003,619	-	CY	$5.00	$15,018,100
Haul Excess Material		2,774,716	-	CY	$7.00	$19,423,000
Structural Fill (On-site)		141,462	-	CY	$6.00	$848,800
Structural Fill (Import)		-	-	CY	$10.00	$0
Dumped Riprap (D50= 0.5')		26,591	-	CY	$60.00	$1,595,500
Filter Fabric		42,742	-	SF	$1.00	$42,700
Right of Way (within Floodplain)		36	-	AC	$25,000.00	$907,000

Table 3.8 Construction Cost Estimate – Soft Structural Alternative 2 Cont.

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Hydroseed		36	-	AC	$0.00	$0
Landscape Aesthetic Fill (On-site)		87,441	-	CY	$4.00	$349,800
Landscape Aesthetic Fill (Import)			-	CY	$9.00	$0
Plantings		32	-	AC	$4,500.00	$145,800
Reclaimed Floodway Property		385	-	AC	($25,000.00)	($9,617,000)
Buckeye Reach (34,320 ft)	**$33,750,500**					
Clear and Grub		1,695	57	AC	$1,000.00	$1,752,000
Channel Excavation		1,557,636	-	CY	$5.00	$7,788,200
Haul Excess Material		897,218	-	CY	$7.00	$6,280,500
Structural Fill (On-site)		319,319		CY	$6.00	$2,884,300
Structural Fill (Import)			-	CY	$10.00	$0
Dumped Riprap (D50= 0.5')		96,092	53,647	CY	$60.00	$8,984,300
Filter Fabric		149,834	83,801	SF	$1.00	$233,600
Right of Way (within Floodplain)		119	57	AC	$25,000.00	$4,405,600
Property Acquisition			-	AC	$0.00	$0
Hydroseed		119	57	AC	$0.00	$0
Landscape Aesthetic Fill (On-site)		179,704	-	CY	$4.00	$718,800
Landscape Aesthetic Fill (Import)		-	-	CY	$9.00	$0
Plantings		107	50	AC	$4,500.00	$703,200
Reclaimed Floodway Property		1,390	891	AC	($25,000.00)	($57,040,800)

SUB-TOTAL	$72,602,300
CONTIGENCY (25%)	$18,150,575
TOTAL COST OF ALTERNATIVE	**$90,752,875**
TOTAL LAND VALUE OFFSET	($70,485,600)
TOTAL	**$20,267,275**

Table 3.9 Construction Cost Estimate – Structural Alternative 3

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Estrella Reach (13,200 ft)	**$108,980,000**					
Clear and Grub		48	44	AC	$1,000.00	$91,800
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		5,445,000	4,705,000	CY	$10.00	$101,500,000
Dumped Riprap (D50= 0.5')		40,831	39,001	CY	$60.00	$4,789,900
Filter Fabric		61,246	58,501	SY	$1.00	$119,700
Right of Way (within Floodplain)			44	AC	$25,000.00	$2,295,000
Property Acquisition			-	AC	$0.00	$0
Hydroseed		48	44	AC	$2,000.00	$183,600
Landscape Aesthetic Fill (Import)		-	-	CY	$9.00	$0
Plantings		-	-	AC	$4,500.00	$0
Reclaimed Floodway Property		364	119	AC	($25,000.00)	($12,083,800)
Tuthill Reach (10,560 ft)	**$180,429,100**					
Clear and Grub		33	41	AC	$1,000.00	$74,000
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		13,985,000	3,015,000	CY	$10.00	$170,000,000
Dumped Riprap (D50= 1')		61,710	74,179	CY	$60.00	$8,153,300
Filter Fabric			111,268	SY	$1.00	$203,800
Right of Way (within Floodplain)			41	AC	$25,000.00	$1,850,000
Property Acquisition			-	AC	$0.00	$0

Table 3.9 Construction Cost Estimate – Structural Alternative 3 Cont.

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Hydroseed		33	41	AC	$2,000.00	$148,000
Landscape Aesthetic Fill		-	-	CY	$9.00	$0
Plantings		-	-	AC	$4,500.00	$0
Reclaimed Floodway Property		477	157	AC	($25,000.00)	($15,850,000)
Buckeye Reach (34,320 ft)	**$928,869,800**					
Clear and Grub		138	140	AC	$1,000.00	$278,000
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		70,556,726	16,937,797	CY	$10.00	$874,945,200
Dumped Riprap (D50= 1.5')		368,961	381,293	CY	$60.00	$45,015,200
Filter Fabric		553,441	571,939	SF	$1.00	$1,125,400
Right of Way (within Floodplain)		138	140	AC	$25,000.00	$6,950,000
Property Acquisition			-	AC	$0.00	$0
Hydroseed		138	140	AC	$2,000.00	$556,000
Landscape Aesthetic Fill		-	-	CY	$9.00	$0
Plantings		-	-	AC	$4,500.00	$0
Reclaimed Floodway Property		3,537	1,141	AC	($25,000.00)	($116,950,000

SUB-TOTAL	$1,218,278,900
CONTIGENCY (25%)	$304,569,725
TOTAL COST OF ALTERNATIVE	**$1,522,848,625**
TOTAL LAND VALUE OFFSET	($144,883,800)
TOTAL	**$1,377,964,825**

Table 3.10 Construction Cost Estimate –Soft Structural Alternative 3

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Estrella Reach (13,200 ft)	**$112,493,800**					
Clear and Grub		62	55	AC	$1,000.00	$116,600
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		5,445,000	4,705,000	CY	$10.00	$101,500,000
Dumped Riprap (D50= 0.5')		41,588	39,727	CY	$60.00	$4,878,900
Filter Fabric		61,246	58,501	SY	$1.00	$119,700
Right of Way (within Floodplain)		62	55	AC	$25,000.00	$2,914,100
Property Acquisition		-	-	AC	$0.00	$0
Hydroseed				AC	$0.00	$0
Landscape Aesthetic Fill (Import)		170,384	105,573	CY	$9.00	$2,483,600
Plantings		57	50	AC	$4,500.00	$480,900
Reclaimed Floodway Property		364	119	AC	($25,000.00)	($12,083,800)
Tuthill Reach (10,560 ft)	**$180,762,400**					
Clear and Grub		39	43	AC	$1,000.00	$82,300
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		13,985,000	3,015,000	CY	$10.00	$170,000,000
Dumped Riprap (D50= 1')		57,902	69,584	CY	$60.00	$7,649,200
Filter Fabric		92,565	111,268	SY	$1.00	$203,800
Right of Way (within Floodplain)		39	43	AC	$25,000.00	$2,058,700
Property Acquisition		-	-	AC	$0.00	$0

Table 3.10 Construction Cost Estimate – Soft Structural Alternative 3 Cont.

DESCRIPTION	AMOUNT	QTY-North Bank	QTY-South Bank	UNIT	UNIT PRICE	SUBTOTAL
Hydroseed		39	43	AC	$0.00	$148,000
Landscape Aesthetic Fill		43,162	4,930	CY	$9.00	$0
Plantings		35	39	AC	$4,500.00	$0
Reclaimed Floodway Property		477	157	AC	($25,000.00)	($15,850,000)
Buckeye Reach (34,320 ft)	**$932,913,400**					
Clear and Grub		172	154	AC	$1,000.00	$278,000
Channel Excavation		-	-	CY	$5.00	$0
Haul Excess Material		-	-	CY	$7.00	$0
Structural Fill (On-site)		-	-	CY	$6.00	$0
Structural Fill (Import)		70,556,726	16,937,797	CY	$10.00	$874,945,200
Dumped Riprap (D50= 1.5')		351,870	363,635	CY	$60.00	$45,015,200
Filter Fabric		553,441	571,939	SY	$1.00	$1,125,400
Right of Way (within Floodplain)		172	154	AC	$25,000.00	$6,950,000
Property Acquisition		-	-	AC	$0.00	$0
Hydroseed		172	154	AC	$0.00	$556,000
Landscape Aesthetic Fill (Import)		385,421	68,880	CY	$9.00	$0
Plantings		159	142	AC	$4,500.00	$0
Reclaimed Floodway Property		3,537	1,141	AC	($25,000.00)	($116,950,000
SUB-TOTAL	$1,226,169,600					
CONTIGENCY (25%)	$306,542,400					
TOTAL COST OF ALTERNATIVE	**$1,532,712,000**					
TOTAL LAND VALUE	($144,883,800)					
TOTAL	**$1,387,828,200**					

Table 3.11 Construction Cost Estimate -Non Structural Alternative

DESCRIPTION	AMOUNT	QTY-North	QTY-South	UNIT	UNIT PRICE	SUBTOTAL
Estrella Reach (13,200 ft)	**$28,470,000**					
Property Acquisition- Floodplain		291	400	AC	$20,000.00	$13,820,000
Property Acquisition- Non-Floodplain		227	66	AC	$50,000.00	$14,650,000
Tuthill Reach (10,560 ft)	**$4,975,000**					
Property Acquisition- Floodplain		55	42	AC	$25,000.00	$2,425,000
Property Acquisition- Non-Floodplain		-	51	AC	$50,000.00	$2,550,000
Buckeye Reach (34,320 ft)	**$64,375,000**					
Property Acquisition- Floodplain		665	662	AC	$25,000.00	$33,175,000
Property Acquisition- Non-Floodplain		341	283	AC	$50,000.00	$31,200,000

SUB-TOTAL	$69,350,000
CONTIGENCY (25%)	$17,337,500
TOTAL COST OF ALTERNATIVE	**$86,687,500**
TOTAL LAND VALUE OFFSET	$0
TOTAL	**$86,687,500**

4.0 ALTERNATIVES SELECTION

4.1 CRITERIA AND PROCEDURE

Evaluation criteria and procedures for selection of a recommended alternative are adapted in part from evaluation criteria and procedures developed for the Cave Creek Watercourse Master Plan, Skunk Creek Watercourse Master Plan, and the North Peoria Area Drainage Master Plan projects previously completed by the District. The evaluations of the alternatives are based on weighted elements of four criteria. The criteria are Public Safety Impacts, Social Impacts, Environmental Impacts, and Economic Impacts. A weighting factor is developed that represents the "relative importance" of each element in the evaluation process. Weighting factors of 1 or 2 were utilized in the evaluation. A factor of 2 was utilized for evaluation criteria that are considered the most important. The Public Safety criterion receives a weighting factor of 2 whereas the other evaluation criteria receive a weighting factor of 1. A rating system is then used to measure the effectiveness of each alternative at meeting the elements of each criterion. The rating system ranges from 1 to 5. A value of 1 represents a "very low" rating at meeting the criterion, a value of 2 represents a "low" rating, a value of 3 represents a "moderate" rating, a value of 4 represents a "high" rating, and a value of 5 represents a "very high" rating. Rated values for each element are averaged to obtain a total value for the criterion.

4.1.2 Criteria Definitions

4.1.2.1 Public Safety Criterion

Historically, society has experienced loss of life and property due to flooding and riverbank erosion. The public safety criterion rates the function of the alternative to keep the public out of harm's way during a 100-year flood while minimizing adverse changes to the river that would result in potential downstream risks to life, property, and structures. The public safety criterion is based on evaluating the threat for loss of human life and possible damage to structures and property resulting from implementation of a given alternative. This criterion is an indicator of how well the proposed alternative will succeed in reducing or eliminating life threatening flood and erosion related hazards, as well as reducing the potential for flood and erosion related damage to public and private properties. The effectiveness of an alternative to satisfy this element must account for the following considerations:

River Mechanics

The following elements of river mechanics are taken into consideration when evaluating the public safety of an alternative:

River Hydraulics

The hydraulic conditions (such as velocity, depth, and water surface elevation) of the river due to a specific alternative shall not increase risk to public safety or to property.

Sediment Transport

The sediment transport in and through the reach as measured by sediment load, streambed aggradation or degradation, and tendencies for bank erosion shall not constitute a greater risk than occurs under existing conditions.

Erosion Hazards

An alternative shall mitigate the lateral migration potential of the river or account for this potential erosion hazard.

Flow Breakout

An alternative shall mitigate potential flow breakout. The 100-year peak discharge shall be contained within the flow conveyance limit of an alternative.

Tributary Inflow

Local runoff and tributary inflow shall be efficiently conveyed to the Gila River. Changes to the 100-year water surface elevation within the El Rio WMP study reach of the Gila River cannot create local flooding problems or flooding along tributaries or adjacent reaches of the Gila River.

4.1.2.2 Social Criterion

The evaluation of the social impact criterion is based on the effectiveness of each alternative in satisfying the four elements described below.

Community Acceptance

This element accounts for the input received from the public involvement process. The effectiveness of an alternative in meeting community acceptance is measured by the public's response to an alternative. A positive response results in a high score, whereas a negative response would result in a low score.

Multi-use Opportunities

This element is an indicator of the multi-use opportunities of an alternative. Examples of such uses included passive and active recreation, trails, and open space. The effectiveness of the criterion is based on the extent of multi-use opportunities that result from implementing a given alternative. Alternatives are assessed on their ability to accommodate multi-use trails/pathways, their compatibility with other potential recreation facilities in terms of access, and user's experience on the trail/pathway. The standard used to evaluate the alternatives is whether an alternative provides opportunity for recreation. Opportunity is equated to the amount of area potentially available for recreational activities-the greater the area, the higher the score.

Visual Resource and Aesthetic Compatibility

This element evaluates the relative degree of contrast between the various components of the alternatives and their setting in the landscape. Visual contrast is based on spatial dominance, visual compatibility, color, line, and form. An example that can be used to measure the compatibility of a given alternative is the construction of a wide concrete channel. Such a channel would spatially dominate the setting, have a high degree of contrast in terms of color, line, and form, and would not be visually compatible with the surrounding natural desert vegetation and landforms. A structure of this type would be given a low rating. Alternatives that do not include structural features or where the structural features of the alternative is mitigated with landscaping would be given high ratings.

Compatibility with Other Existing Plans

This element is an indicator of the compatibility of the proposed alternative with planning policies and guidelines cited in other existing planning documents. Planning documents reviewed are general land use plans and specific trail, park, recreation and open space plans developed by Maricopa County Planning and Zoning, Maricopa County Parks, the Cities of Avondale and Goodyear and the Town of Buckeye. The preferred land use types presented in the above mentioned planning documents are open space and both passive and active recreation. The amount of open space provided by an alternative is evaluated as a measure of a specific alternative's compatibility with existing planning documents. An alternative that is compatible with other plans would be rated high, while an alternative that is not would be rated low.

4.1.2.3.Environmental Criterion

The evaluation of the environmental impact criterion is based on the effectiveness of each alternative in satisfying the three elements described below.

Complexity of Environmental Permitting

Complexity of Environmental Permitting focuses on the acquisition of the US Army Corps of Engineers 404 Permits and 401 Water Quality Certifications. The alternatives are measured based on the potential for needing a 404 Permit, the level of 404 Permit required (Nationwide vs. Individual), and the level of mitigation necessary to gain federal approval to construct the alternative. To evaluate this element, it is assumed that alternatives with structural features will cause disturbance to the land within the Waters of the United States. The extent of an alternative's impact to the Waters of the United States is used as a measure of complexity to obtain a 404 Permit. As an example, constructing an alternative within the Waters of the United States that requires an Individual 404 Permit and 401 Water Quality Certification, and requires extensive mitigation measures to replace the relatively high-value habitat would receive a low rating.

Impact on Biological Resources

Impacts on biological resources account for the potential impact on biological resources by the proposed alternatives and how well the proposed management alternative will succeed in preserving or restoring (enhancement opportunity) the natural riparian environment found along the study watercourses. The most important indicator of this is the ability of a given alternative to preserve wildlife habitat or minimize disruption to existing habitat. An alternative with no biological resource impacts would rate high. Alternatives with extensive biological resource impacts would be rated low.

Impact on Cultural Resources

This element accounts for the potential impact on cultural resources by a given alternative. It is also an indicator of how well the alternatives will succeed in preserving cultural resources. An alternative that impacts known cultural resources would be rated low, while an alternative that impacts no cultural resources would be rated high.

4.1.2.4 Economic Criterion

The evaluation of the economic criterion is based on the effectiveness of each alternative in satisfying two elements that are described below.

Implementation Cost

This element represents the estimated cost of the proposed alternative to the public, either through increased development costs passed on to future residents of the area who will directly benefit from the improvements (local public) or the costs to the general public.

The cost for a structural alternative considers the cost of the structural improvements necessary to implement the proposed alternative (a positive cost) and the value of land that is protected from flooding and erosion hazards by the structural improvements (a negative cost, i.e., benefit). Added together, these costs represent the total net cost of the alternative.

The effectiveness of a given alternative is measured by the total net cost. The lower the net cost, the higher the rating for the alternative. Negative net cost is rated higher than positive net cost.

Maintenance Cost

This element accounts for the potential maintenance costs associated with the components of an alternative. It is assumed that such costs are proportional to the degree of effort required to sustain the function of the alternative over time. The

greater the degree of effort, the higher the potential maintenance cost. A high degree of effort to sustain an alternative results in low rating. Minor effort to sustain an alternative results in high rating.

The evaluation criteria was applied to the No Action, Non-Structural, Structural (3 variations) and the Soft Structural (3 variations) Alternatives for the Buckeye Town Lake, Tuthill and Estrella Reaches to determine how one alternative would rank against another. The Perryville Reach was not evaluated because it is part of the private King Ranch Development. The King Ranch Development is planning flood control measures for the Perryville Reach. The Confluence Reach was not evaluated because it is a transition reach between the Gila River and the Agua Fria River and the El Rio Project and the Tres Rios Project. The transition reach includes a lake at the location of the diversion structure for the Buckeye Water Conservation and Drainage District. A combination of the Structural, Soft Structural and Non-Structural Alternatives are required to address the opportunities and constraints associated with the Confluence Reach

Results of the alternatives evaluation on a reach by reach basis are summarized in Table 4.1. The soft structural alternative (as applied to Structural Alternative 1) was ranked as the number one alternative for each reach. Structural Alternative 1 (without the soft structural treatment) was ranked second, whereas the non-structural alternative was ranked third for each reach.

Table 4.1 Summary of Alternative Selection Evaluation Results

River Reach (from upstream to downstream)	**Alternatives** [1]							
	No Action Alternative	Non-Structural Alternative	Structural Alternative 1	Structural Alternative 1 with Soft Structural Application	Structural Alternative 2	Structural Alternative 2 with Soft Structural Application	Structural Alternative 3	Structural Alternative 3 with Soft Structural Application
Buckeye Town Lake	14.1	18.5	19.0	19.5	16.4	16.5	12.6	12.8
Tuthill	13.9	18.5	18.7	19.2	16.4	16.6	12.8	12.9
Estrella	13.9	17.9	18.6	19.0	16.7	16.9	13.0	13.3

1. Values in table are a summation of ranking values for each criteria used to evaluate an alternative. A value of 25 would be considered a perfect scour.

5.0 RECOMMENDED ALTERNATIVE REFINEMENT AND EVALUATION

5.1 RECOMMENDED ALTERNATIVE

The recommended alternative for all reaches with the exception of portions of the Perryville and Estrella Reaches is a combination of the soft structural alternative and the non-structural alternative. The alignment of the soft structural element of the recommended alternative closely follows the 100-year floodway alignment. The non-structural alternative will be applied to river segments located along the south bank where flow-resistant geologic formations occur and bank protection is not required. Along the south bank from approximately 3.9 miles downstream of the Estrella Road Bridge to the Estrella Road Bridge, the Plan displays improvements proposed by the King Ranch development. Along the north bank from approximately 3 miles downstream of the Estrella Road Bridge and from that point approximately 1 mile upstream, improvements displayed are from the King Ranch development.

The alignment of the recommended alternative and proposed resource enhancement elements are depicted on Figure 5.1 and on the Conceptual Plans and Details presented as Plates 1 through 4 (see Book 2). Figure 5.1 also depicts equestrian and multi-use trail systems and locations where trails could connect to the County's Regional Trail System.

5.2 RECOMMENDED ALTERNATIVE HYDRAULIC ANALYSIS

5.2.1 Purpose

Three main elements of the recommended alternative can potentially affect the hydraulic conditions of the study reach. They are encroachment of the floodplain to the levee/bank alignment, changes in type and distribution of vegetation within enhancement areas, and changes in topography due to sand and gravel excavation or due to the creation of open water/marsh areas.

Hydraulic models (HEC-RAS Plans) are developed to determine the worst-case scenario in terms of the effect of physical changes to the river system on hydraulic parameters. Each plan models an additional element of the recommended alternative so that incremental changes to hydraulic parameters due to specific changes in physical conditions will be realized

5.2.2 Methodology

Hydraulic modeling of the recommended alternative was accomplished by modifying the FEMA HEC-RAS model discussed in Section 3.3.1. Modifications to that model are limited to changes in roughness coefficients and the use of the encroachment routine to represent the general features of the recommended alternative. The geometry editor was also utilized to define potential sand and gravel excavations. Open water and shallow water areas depicted on Figure 5.2 between River Mile (RM) 180.09 and 183.02 were modeled as potential sand and gravel excavations.

Topographic information provided (September, 2005) by the King Ranch development for portions of the Estrella Reach were incorporated into the Base and Recommended Alternative Hydraulic Models. Changes to hydraulic conditions due to the incorporation of the new topography are discussed in Attachment 3.

A new Base HEC-RAS Plan was developed to reflect topography provided by the King Ranch Development. The plan is called "Base Model with KR Topo" and is located in the HEC-RAS project file named El Rio WMP Base File. The HEC-RAS Plans developed to model the recommended alternative will be compared against the "Base Model with KR Topo" Plan to determine changes in hydraulic conditions due to the recommended alternative.

Three separate HEC-RAS Plans were developed to model the effect of encroachment, changes in roughness coefficients due to vegetation/resource enhancement, and changes in topography due to inferred sand and gravel excavation. Descriptions of each HEC-RAS Plan are summarized in Table 5.1. HEC-RAS computer input and output files are provided in Appendix B.

Table 5.1 Recommend Alternative Hydraulic Model Summary

HEC-RAS Project Name	HEC-RAS Plan Name	Description
El Rio WMP Alternative Analysis	Proposed Levee and KR Improvements	Plan models proposed levee alignments that generally follow Effective FEMA floodway boundaries. Models also includes proposed King Ranch improvements as of September 23 2005 and updates to topography provided by King Ranch. Existing condition roughness coefficients are utilized.
El Rio WMP Alternative Analysis	Proposed Levee, Veg Enhance & KR Improvement	Elements of the plan are similar to those described above with the exception that roughness coefficients have been revised to reflect enhancement conditions.
El Rio WMP Alternative Analysis	Proposed Levee, New Veg & KR Improvement & S&G	In addition to floodplain encroachment and changes to roughness coefficients due to proposed vegetation enhancements potential sand and gravel excavations are modeled.

Revisions to roughness coefficients due to proposed vegetation/resource enhancements were accomplished by developing GIS shape files that delineated the distribution of the vegetation enhancements. Attributes to the shape files were created that reflect the Manning's roughness coefficients estimated for each vegetation enhancement type. The GIS shape files were then incorporated into the HEC-RAS models. Due to the limited extent of proposed cottonwood/willow corridors within the Atriplex Series a shape file

specific to the cottonwood willow corridor was not created. Between River Mile 188.69 and River Mile 194.21 future condition Manning's coefficients provided by the King Ranch development were incorporated into the models. In addition to estimating Manning's roughness coefficients for the El Rio recommended alternative, roughness coefficients were estimated for the Tres Rios project that is located just upstream of the El Rio Project at the confluence of the Agua Fria and Gila Rivers. Tres Rios roughness coefficients are based on potential vegetation enhancements (removal of Salt Cedar in river bottom and development of open water wetland areas). Figure 5.2 depicts the distribution of Manning's roughness coefficients utilized to model the recommended alternative. A summary of Manning's Roughness Coefficients and associated vegetation enhancement treatments are listed in Table 5.2.

For those areas in which the hydraulic cross section limits extend beyond the extent of the recommended alternative, roughness coefficients utilized in the FEMA model were used for areas in which flow may occur. At areas where flow would not occur an arbitrary value of 0.025 was assigned.

Table 5.2 Summary of Manning's Coefficients for Recommended Alternative

Vegetation/Resource Enhancement	Manning's Roughness Coefficients
Mesquite Bosque	0.15
Cobble Strand	0.030
Low Terrace (grasses, shrubs and forbs)	0.045
Cottonwood/Willow Enhancements	0.065
Riparian Wetland with Emergent Marshes	0.03
Open Water	0.03

Topographic data is revised to reflect potential sand and gravel operations along cross sections that intersect proposed open water areas that result from excavation. In order to define the minimum flow conveyance elevation, an overtopping elevation (the elevation at which flow will exit at the downstream end of a potential excavation) is estimated and coded as hard ground through the excavation..

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EL RIO WATERCOURSE MASTER PLAN

FIGURE 5.1 - RECOMMENDED ALTERNATIVE
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
8 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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BUCKEYE

MESQUITE BOSQUE

LEVEE ALIGNMENT

ROOKS RD

BUCKEYE TOWN LAKE OPEN WATER (DEEP)

AREA BETWEEN LEVEE ALIGNMENT AND FLOODWAY BOUNDARY WILL BE REMOVED FROM 100 YEAR FLOODPLAIN

EMPTY ACRES HORSE FACILITY

RIVER LOOP TRAIL ACCESS

ELLIOT RD

MILLER RD

BUCKEYE

COTTONWOOD WILLOW CORRIDOR

RIVER LOOP TRAIL ACCESS

APACHE RD

REGIONAL TRAIL ALIGNMENT

WATSON RD

NARRAMORE RD

LEVEE ALIGNMENT

EMERGENT MARSH

OPEN WATER (DEEP)

WETLANDS/OPEN WATER (SHALLOW)

COTTONWOOD WILLOW CORRIDOR

RAY RD

COBBLE STRAND

LATERAL MIGRATION LIMIT

SR-85

BUCKEYE TOWN LAKE REACH

COTTONWOOD / WILLOW ENHANCEMENTS

REGIONAL TRAIL ALIGNMENT

UNINCORPORATED MARICOPA COUNTY

OPPORTUNITY AREAS

MONITORING & MAINTENANCE
MONITORING & MAINTENANCE/ENHANCEMENT
ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

EXISTING 100-YEAR FLOODPLAIN
EXISTING 100-YEAR FLOODWAY
PURPLE TEXT INDICATES FEATURES CITED IN OTHER PLANNING DOCUMENTS

Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

BUCKEYE

RAINBOW RD

WATSON RD

AREA BETWEEN LEVEE ALIGNMENT AND FLOODWAY BOUNDARY WILL BE REMOVED FROM 100 YEAR FLOODPLAIN

LEVEE ALIGNMENT

COTTONWOOD WILLOW CORRIDOR

RIVER LOOP TRAIL ACCESS

DOBBINS/BELOAT RD

DEAN RD

REGIONAL TRAIL ALIGNMENT

LEVEE ALIGNMENT

GRASSES / SHRUBS / FORBS

AIRPORT RD

RIVER ACCESS

TURHEL RD

BUCKEYE

MC 85

JACKRABBIT TRL

BUCKEYE

COBBLE STRAND

LEVEE ALIGNMENT

COTTONWOOD / WILLOW ENHANCEMENT SITE

MESQUITE BOSQUE

BUCKEYE-TOWN-LAKE-REACH

WATERMAN WASH

MARSH / OPEN WATER CORRIDOR

LATERAL MIGRATION LIMIT

VISTA

ELLIOT RD

REGIONAL TRAIL ALIGNMENT

UNINCORPORATED MARICOPA COUNTY

TUTHILL REACH

NARRAMORE RD

EL RIO WATERCOURSE MASTER PLAN

FIGURE 5.1 - RECOMMENDED ALTERNATIVE
SHEET 2 OF 4 (TUTHILL REACH)
8 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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EL RIO

OPPORTUNITY AREAS

MONITORING & MAINTENANCE

MONITORING & MAINTENANCE/ENHANCEMENT

ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

EXISTING 100-YEAR FLOODPLAIN

EXISTING 100-YEAR FLOODWAY

PURPLE TEXT INDICATES FEATURES CITED IN OTHER PLANNING DOCUMENTS

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Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

Stantec

EL RIO WATERCOURSE MASTER PLAN

FIGURE 5.1 - RECOMMENDED ALTERNATIVE
SHEET 3 OF 4 (PERRYVILLE REACH)
8 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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BUCKEYE
GOODYEAR
UNINCORPORATED MARICOPA COUNTY
SOUTHERN AVE
JACKRABBIT TRL
MC 85
CITRUS RD
COTTON LN
SARIVAL RD
PERRYVILLE RD
TROHILL RD
ELLIOT RD

AREA BETWEEN LEVEE ALIGNMENT AND FLOODWAY BOUNDARY WILL BE REMOVED FROM 100 YEAR FLOODPLAIN
GOODYEAR MULTI-USE TRAIL
COTTON LANE BRIDGE ALIGNMENT
REGIONAL TRAIL ALIGNMENT
BANK STABILIZATION ALIGNMENT
REGIONAL MULTI-USE & EQUESTRIAN TRAIL
LEVEE ALIGNMENT
CHANNEL EXCAVATION
TRAIL HEAD
RIVER LOOP TRAIL
COBBLE STRAND
20 cfs LOW FLOW CHANNEL
BANK STABILIZATION ALIGNMENT
TRAIL HEAD
RIVER LOOP TRAIL
VISTA
TRAIL HEAD
VISTA
MITIGATION AREA
GOODYEAR MULTI-USE & EQUESTRIAN TRAIL
COMMUNITY CENTER
LATERAL MIGRATION LIMIT
LINEAR PARKS AND TRAILS
REGIONAL TRAIL ALIGNMENT
PERRYVILLE REACH
REACH
STA

OPPORTUNITY AREAS
MONITORING & MAINTENANCE
MONITORING & MAINTENANCE/ENHANCEMENT
ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

EXISTING 100-YEAR FLOODPLAIN
EXISTING 100-YEAR FLOODWAY
PURPLE TEXT INDICATES FEATURES CITED IN OTHER PLANNING DOCUMENTS

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Phoenix, AZ 85009

Stantec Consulting Inc.
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Phoenix, AZ 85044

EL RIO WATERCOURSE MASTER PLAN

FIGURE 5.1 - RECOMMENDED ALTERNATIVE
SHEET 4 OF 4 (ESTRELLA REACH)
8 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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REGIONAL MULTI-USE & EQUESTRIAN TRAIL
SAR
ESTRELLA PKWY
RIVER ACCESS
GOODYEAR MULTI-USE & EQUESTRIAN TRAIL
BROADWAY RD
BULLARD AVE
LEVEE ALIGNMENT
ESTRELLA BRIDGE
COBBLE STRAND
COTTONWOOD WILLOW ENHANCEMENT
LITCHFIELD RD
AVONDALE
GOODYEAR
AGUA FRIA RIVER
VISTA
TRAIL HEAD
EXISTING LEVEE
BULLARD AVE BRIDGE
SALT CEDAR MANAGEMENT R & D SITE
VISTA
BEGIN 20cfs LOW FLOW CHANNEL
INTERMITTENT FLOW
BUCKEYE WATER CONSERVATION AND DRAINAGE DISTRICT LAKE
TRAIL CONNECTION W/ ESTRELLA PARK TRAIL HEADS
INTERPRETIVE CENTER EDUCATION POD
FLOOD CONTROL LEVEE
CITY OF AVONDALE TRAIL SYSTEM
LATERAL MIGRATION LIMIT
VISTA
ESTRELLA REACH
CONFLUENCE REACH
UNINCORPORATED MARICOPA COUNTY
COTTONWOOD / WILLOW ENHANCEMENT SITE
AVONDALE EQUESTRIAN TRAIL
TRES RIOS PROJECT
GOODYEAR
AVONDALE
EL MIRAGE AVE

El Rio

OPPORTUNITY AREAS
MONITORING & MAINTENANCE
MONITORING & MAINTENANCE/ENHANCEMENT
ENHANCEMENT, RESTORATION OR POSSIBLE LAND EXCHANGE

EXISTING 100-YEAR FLOODPLAIN
EXISTING 100-YEAR FLOODWAY
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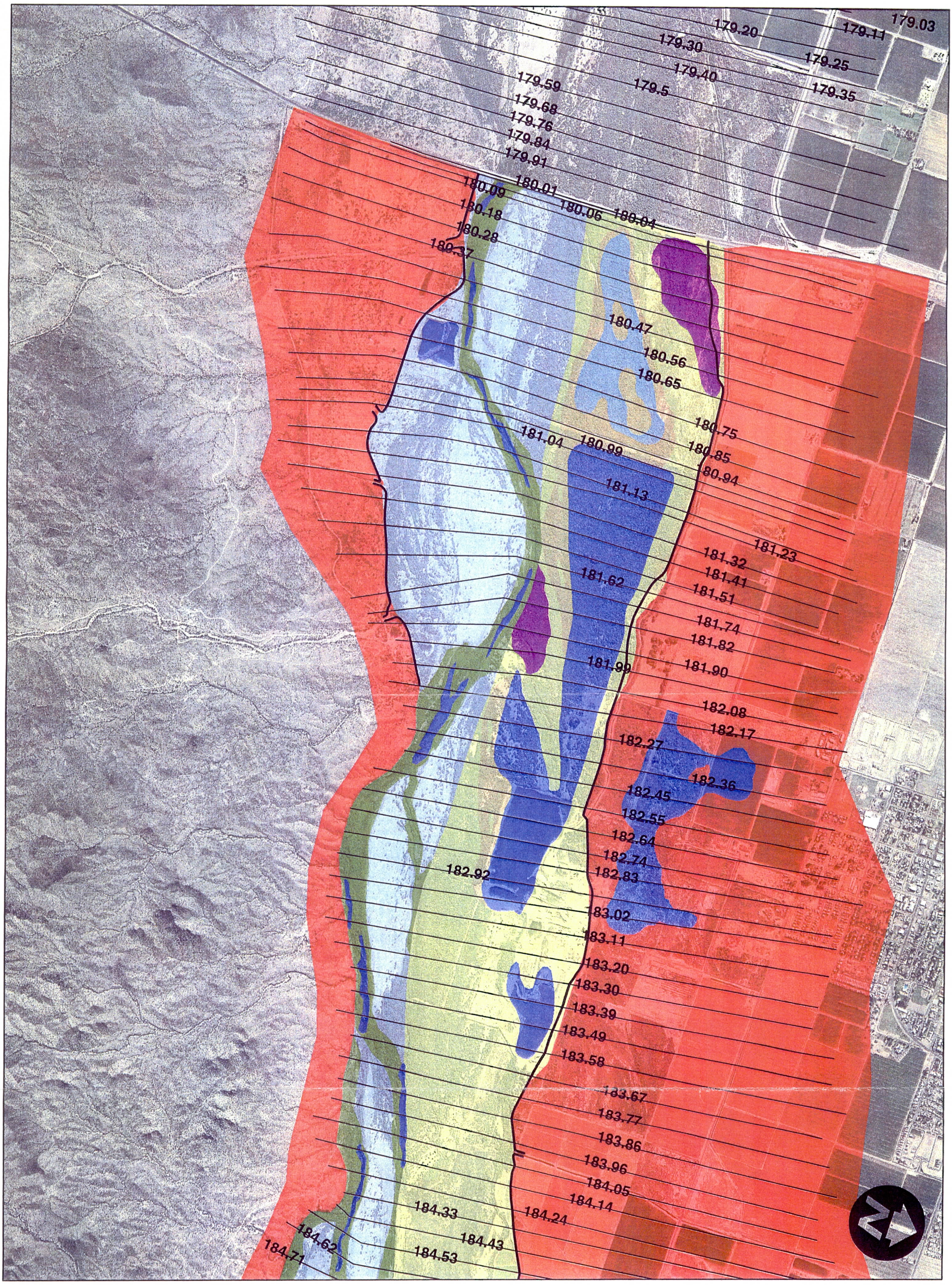
Phoenix, AZ 85044



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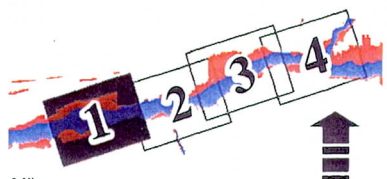
Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

N-Values

0.025	AGRICULTURAL	0.030	RIPARIAN AND EMERGENT MARSH
0.030	ATRIPLEX	0.065	COTTONWOOD/WILLOW ENHANCEMENTS
0.030	COBBLE STRAND	0.025	PARK
0.043	DESERT	0.032	PARK1
0.150	MESQUITE BOSQUE	0.030	SHALLOW WATER
0.150	SALT CEDAR	0.030	TRES RIOS
0.030	OPEN WATER	0.065	URBAN

181.90 HEC-RAS Cross Section w/ River Mile



EL RIO WATERCOURSE MASTER PLAN

FIGURE 5.2 - N VALUES
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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184.14
184.24
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184.43
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185
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185.19
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185.61
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185.81
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187.82
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188.04
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189.02
189.12
189.22
189.31
189.39
189.49
189.58
189.68
R.S. 188.69

Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

N-Values

0.025	AGRICULTURAL	0.030	RIPARIAN AND EMERGENT MARSH
0.030	ATRIPLEX	0.065	COTTONWOOD/WILLOW ENHANCEMENTS
0.030	COBBLE STRAND	0.025	PARK
0.043	DESERT	0.032	PARK1
0.150	MESQUITE BOSQUE	0.030	SHALLOW WATER
0.150	SALT CEDAR	0.030	TRES RIOS
0.030	OPEN WATER	0.065	URBAN

181.90 HEC-RAS Cross Section w/ River Mile

1 2 3 4

N

EL RIO WATERCOURSE MASTER PLAN

FIGURE 5.2 - N VALUES
SHEET 2 OF 4 (TUTHILL REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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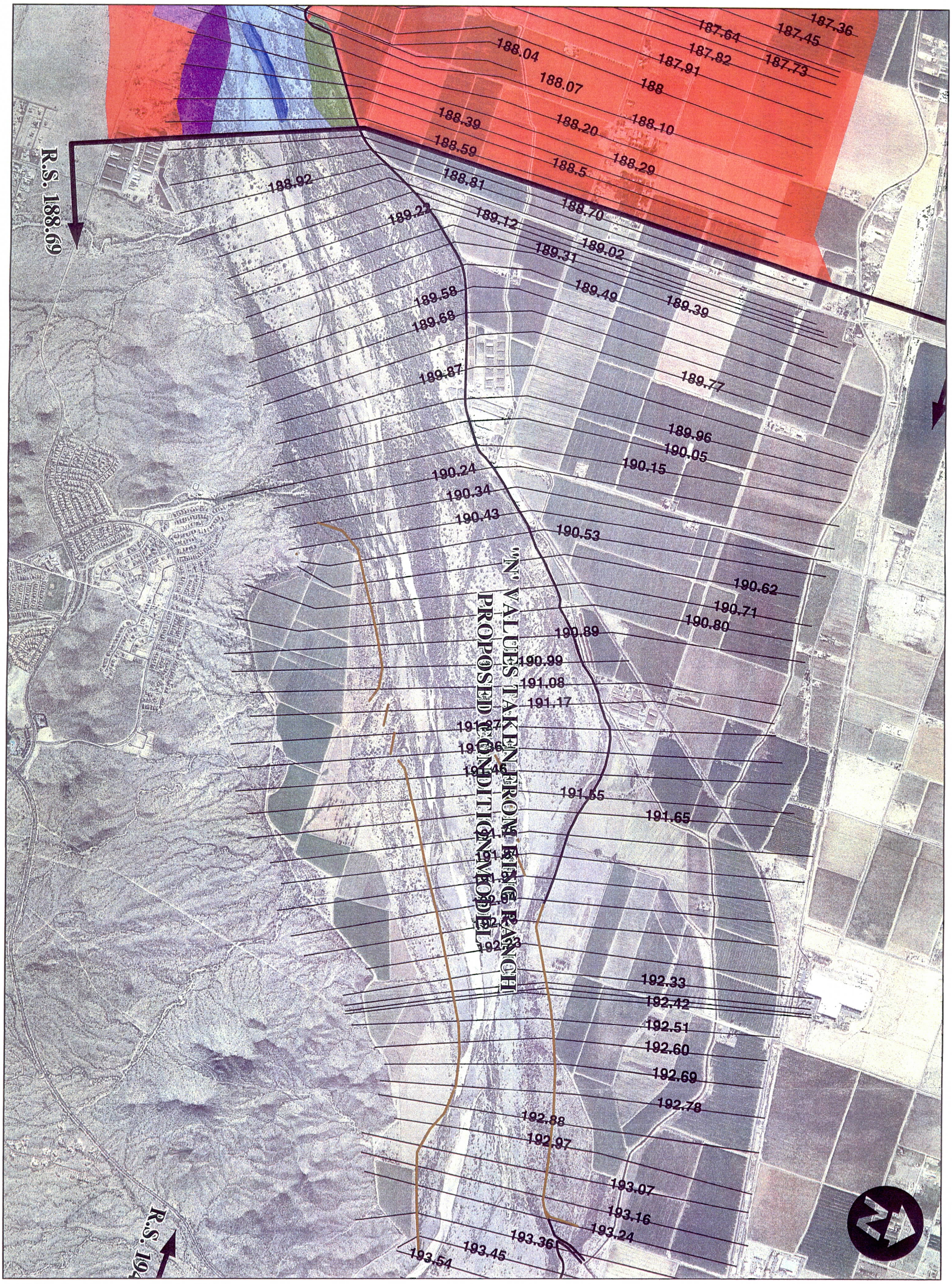

Flood Control District of Maricopa County
2801 W. Durango St.
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Stantec Consulting Inc.
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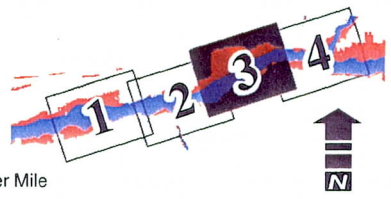
Phoenix, AZ 85044

N-Values

0.025	AGRICULTURAL	0.030	RIPARIAN AND EMERGENT MARSH
0.030	ATRIPLEX	0.065	COTTONWOOD/WILLOW ENHANCEMENTS
0.030	COBBLE STRAND	0.025	PARK
0.043	DESERT	0.032	PARK1
0.150	MESQUITE BOSQUE	0.030	SHALLOW WATER
0.150	SALT CEDAR	0.030	TRES RIOS
0.030	OPEN WATER	0.065	URBAN
		181.90	HEC-RAS Cross Section w/ River Mile



EL RIO WATERCOURSE MASTER PLAN

FIGURE 5.2 - N VALUES
SHEET 3 OF 4 (PERRYVILLE REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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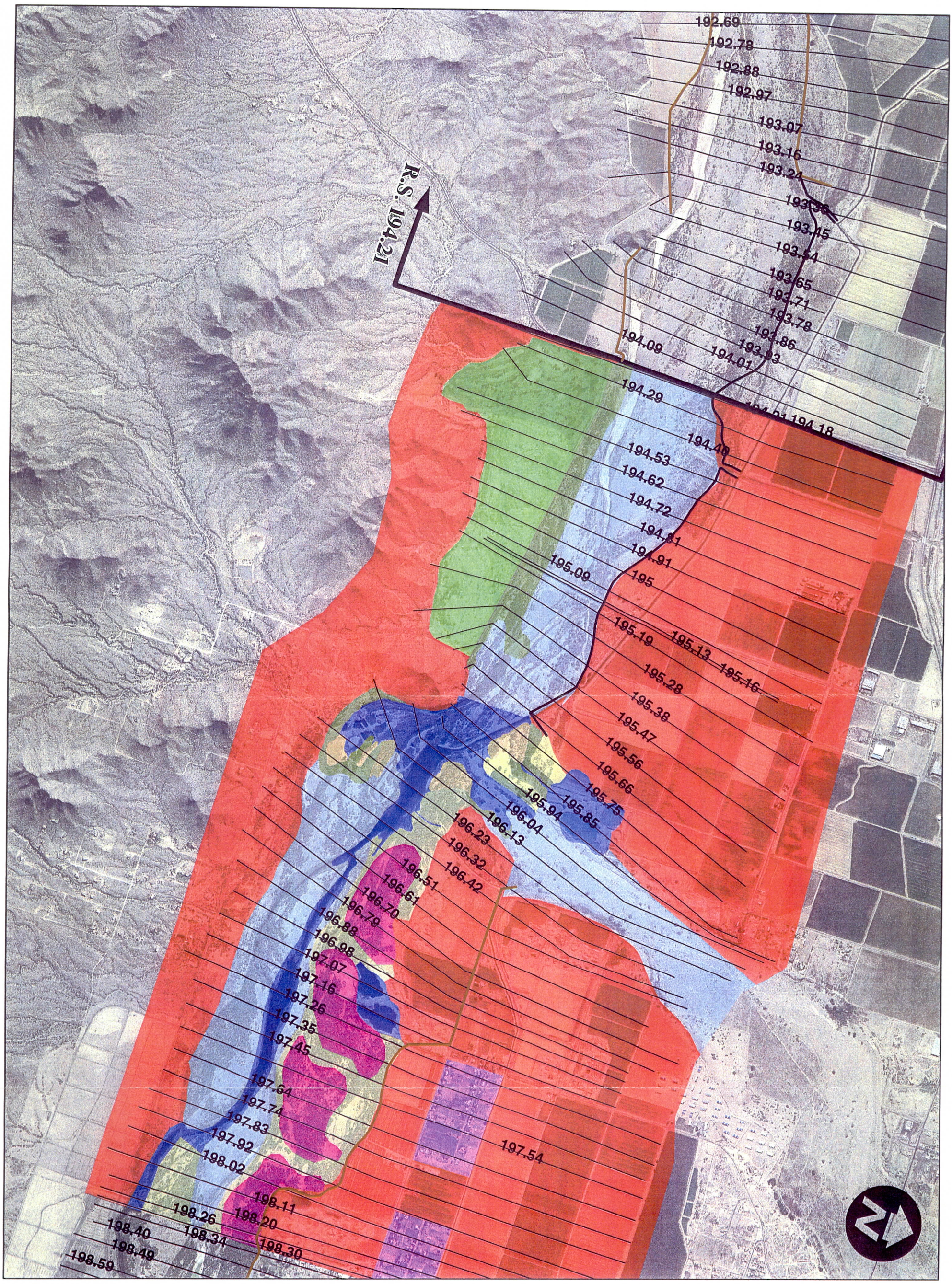

Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

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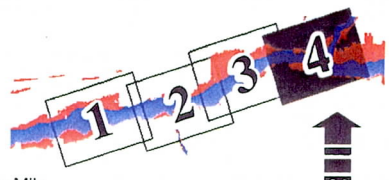
8211 S. 48th St.
Phoenix, AZ 85044

N-Values

0.025	AGRICULTURAL	0.030	RIPARIAN AND EMERGENT MARSH
0.030	ATRIPLEX	0.065	COTTONWOOD/WILLOW ENHANCEMENTS
0.030	COBBLE STRAND	0.025	PARK
0.043	DESERT	0.032	PARK1
0.150	MESQUITE BOSQUE	0.030	SHALLOW WATER
0.150	SALT CEDAR	0.030	TRES RIOS
0.030	OPEN WATER	0.065	URBAN
		181.90	HEC-RAS Cross Section w/ River Mile



EL RIO WATERCOURSE MASTER PLAN

FIGURE 5.2 - N VALUES
SHEET 4 OF 4 (ESTRELLA REACH)
1 FEB 2006

0 1,000 2,000 4,000
1 Inch = 2000 Feet

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5.2.3 Recommended Alternative Hydraulic Analysis Results

Results of the hydraulic models for the recommended alternative are compared to the Base Model to determine the impact of the alternative on the hydraulic properties of the watercourse

Figures 5.3 through 5.5 depict the comparison of the results from the Base Model with the results from the hydraulic models developed for the recommended alternative. As mentioned earlier, elements of the recommended plan were modeled in sequential steps. The major elements modeled are floodplain encroachment (referred to as Levee Only in the figures), floodplain encroachment and vegetation enhancements (referred to as Levee and Veg in the figures) and floodplain encroachment with vegetation enhancements and excavation due to sand and gravel operations (referred to as Levee, Veg and Excavation in the figures).

Figures depict changes in top width, water surface elevation, and flow velocity for the 100-year event for major elements of the recommended alternative relative to the Base Model.

5.2.4 Conclusions

Conclusions that can be drawn from the comparison of specific hydraulic parameters are:

- Encroachment to the floodway limit (Levee Only) resulted in significant changes to the overall floodplain width at locations where there was a floodway fringe. Changes in top width occur primarily due to encroachment into the floodplain. Revisions to roughness coefficients that reflect proposed vegetation enhancements (Levee and Veg) or channel geometry that reflected potential sand and gravel operations (Levee, Veg and Excavation) did not significantly increase or decrease floodplain widths.

- At locations in which there was a floodplain fringe that was encroached to the floodway limit, water surface elevations increased between 0 and 1 foot. Between river miles 181.62 and 182.36, the levee alignment encroachment extends beyond the floodway limit. At this location water surface elevations increased between 0.9 and 1.4 feet.

- Relative to the HEC-RAS Plan, that models the levee only (without revisions to roughness coefficients or cross section geometry), changes to water surface elevations due to changes in Manning's roughness coefficients range between 0.2 and 2.2 feet.

- Relative to the HEC-RAS Plan, that models the levee and revisions to roughness coefficients (without revisions to cross section geometry), changes to water surface elevations due to changes in cross section geometry that reflect potential sand and gravel operations range approximately between 0.4 and 1.6 feet.

- There is a slight increase and/or decrease in flow velocity due to encroachment into the floodplain with the levee alignment.

- The greatest velocity increases realized is 1 to 2 fps recorded between River Miles 180.65 and 181.04.

- The greatest change in velocity occurs at River Mile 180.37 in which a decrease in average velocity of 4.7 and 7.3 fps was recorded for the (Levee and Veg)Plan and the (Levee, Veg and Excavation) Plan, respectively. The decrease in velocity is due to changes in overbank conveyance. Due to the distribution of roughness coefficients and the location of the excavation, overbank, conveyance decreased at the expense of channel conveyance relative to the Base Model.

- The following general conclusions are offered from the review of the HEC-RAS Plans that modeled elements of the recommended alternative.

    - Changes in floodplain width are primarily a function of encroachment into the floodplain.

    - Revisions to Manning's roughness coefficients to reflect vegetation enhancements typically did not result in a significant change to floodplain width but did result in changes to the distribution of flow along a cross section which resulted in changes to velocity in the channel segment.

    - The effect of channel excavation in areas outside of the main channel results in similar conclusions derived from changes in roughness coefficients. Typically there are not significant changes to water surface elevations, however, the distribution of flow conveyance along a cross section is changed.

Figure 5.3 Top Width Comparison Existing Conditions Model to Recommended Alternative models

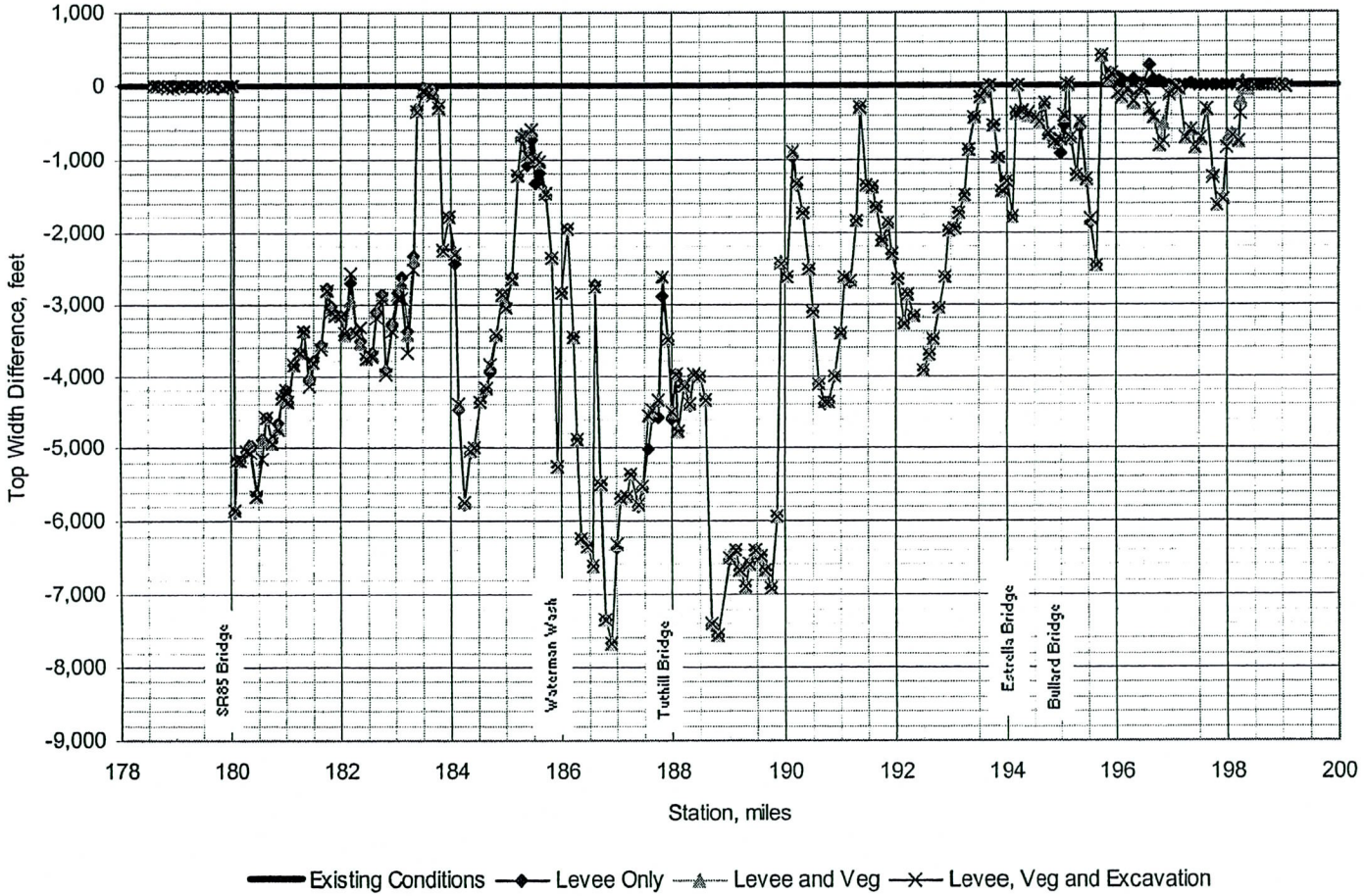


Figure 5.4 Water Surface Elevation Comparison Existing Conditions Model to Recommended Alternative models

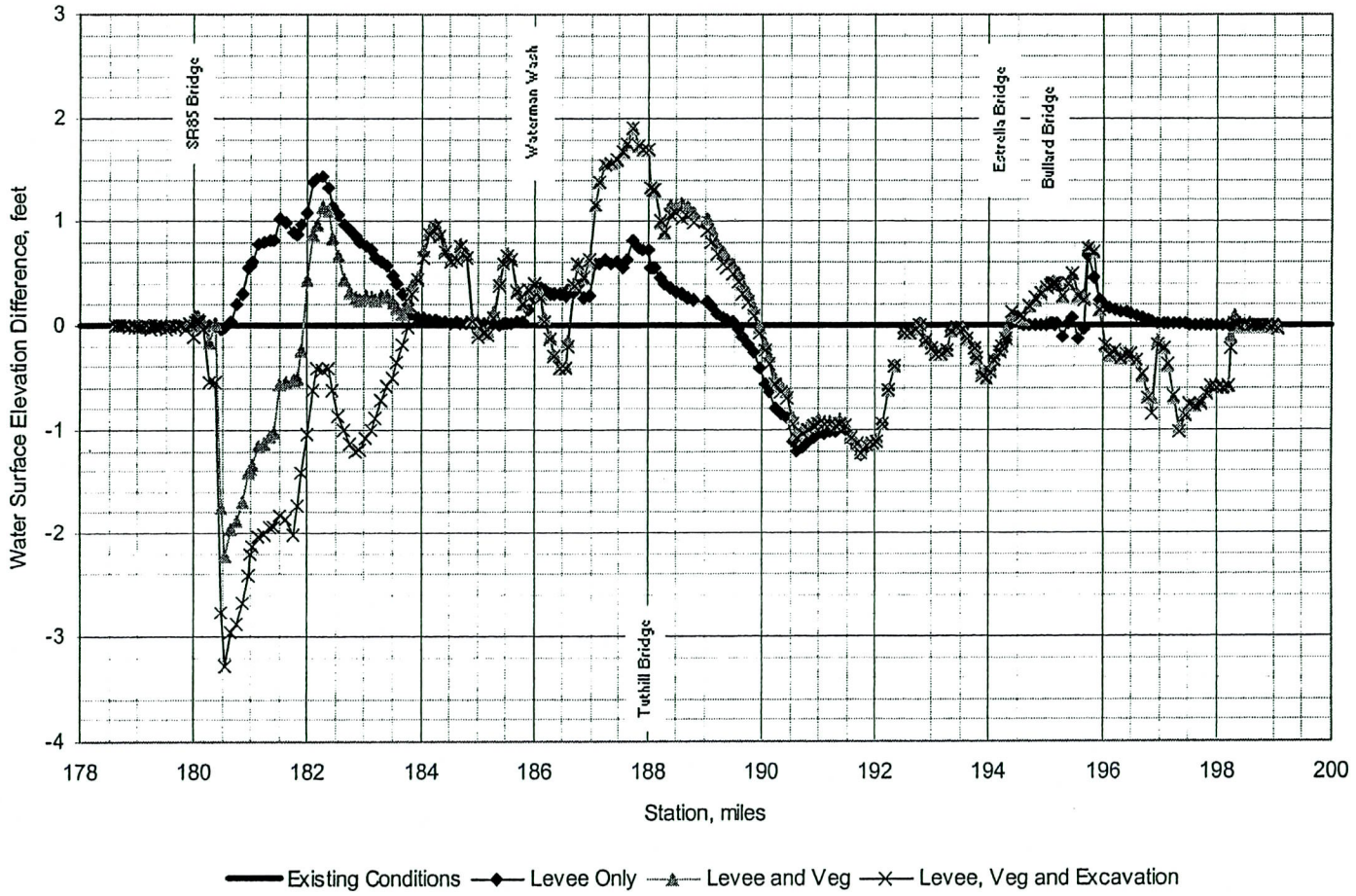
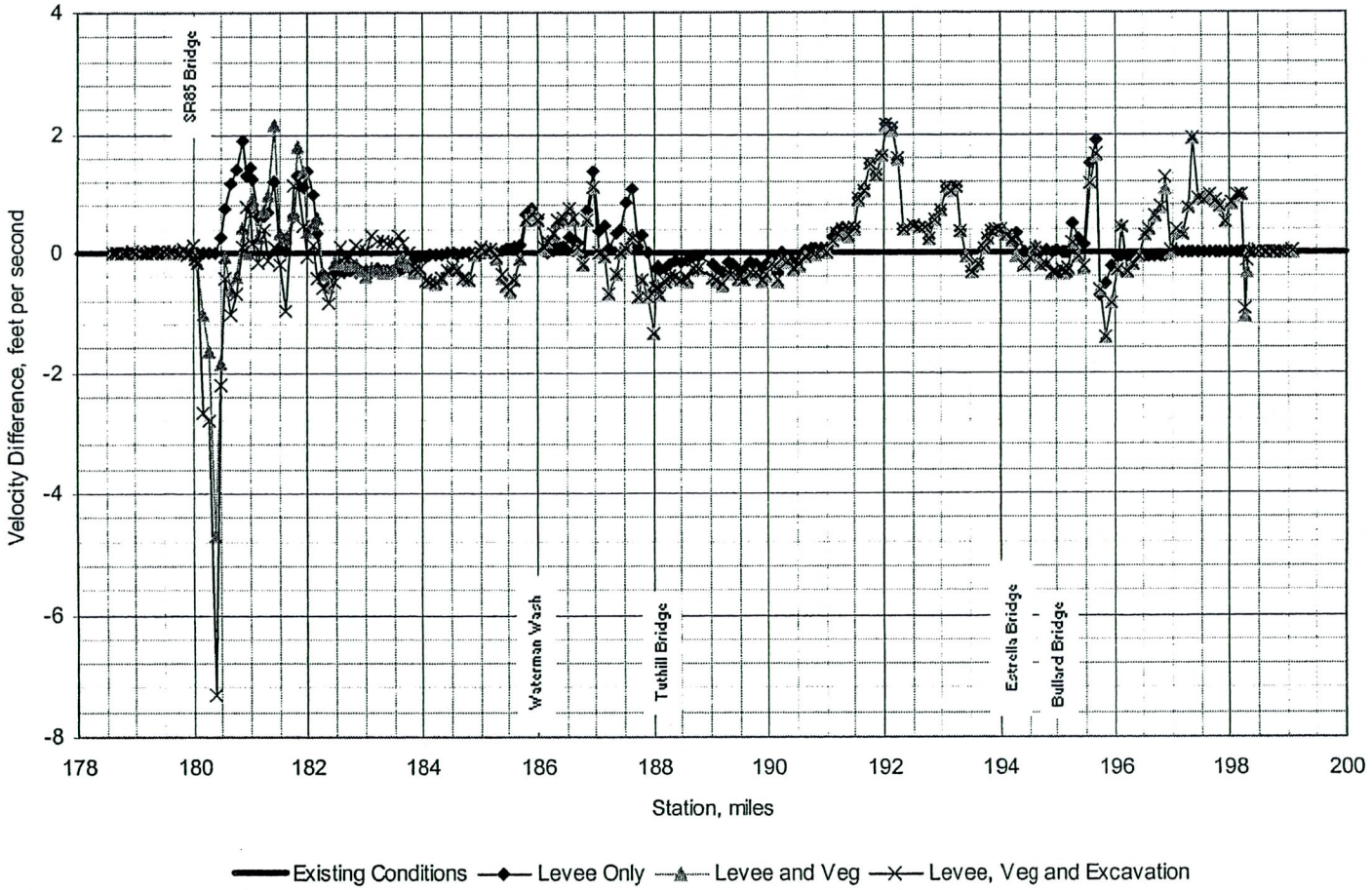


Figure 5.5 Velocity Comparison Existing Conditions Model to Recommended Alternative models



5.2.5 Opinion of Probable Cost Estimate

5.2.5.1 Purpose

Cost estimates developed for the recommended alternative reflect proposed improvements developed from generalized hydraulic evaluations and are considered approximate based on concept level engineering.. The construction cost estimates are developed for planning purposes. The value of land removed from the floodplain/erosion hazard zone by an alternative is estimated to determine the benefit of the proposed improvement.

5.2.5.2 Methodology

Quantities are calculated for earthwork (channel excavation, fill and/or levee fill), volume of bank armoring material required, and for land cost. Volume of levee fill material was determined by average end area calculations for cross-sections (cross-sections from the HEC-RAS Model were utilized) taken through the proposed channel excavation, fill and/or levee fill area. Bank armoring quantities are determined by applying a typical section along the length of the improvement area. Toe-down depth for bank armoring was calculated by estimating total scour at each hydraulic cross section and then computing a reach average.

The HEC-RAS model developed for the recommended alternative contains 3 plans. They are 1) Proposed Levee and King Ranch Improvements, 2) Prop Levee, Vegetation Enhancements and King Ranch Improvements and 3) Proposed Levee, Vegetation Enhancements, King Ranch Improvements and sand and gravel excavations. Description of each plan is provided in Table 5.1. Results from all plans are utilized to set the height (based on the plan that produced the greatest water surface elevation at a specific cross section) of the levee proposed in the recommended alternative and thus levee fill and bank protection quantities.

Due to the presence of high groundwater, dumped riprap was chosen over soil cement and/or gabion mattress or baskets for typical bank armoring material. It was assumed that the cost to dewater and, to place soil cement or gabion baskets on banks would be excessive. Dumped riprap quantities are based on a riprap installation technique in which toe material is installed in a trench above the water table. The trench is typically constructed below the adjacent channel invert elevation. During a scour event at the toe of slope, riprap would be launched into the forming scour hole checking river migration into the bank. Utilizing the proposed bank slope and estimated toe down depth, the volume of material provided in the toe trench is calculated by applying a 1.5 factor to the required riprap thickness. The size of the dumped riprap material was determined utilizing procedures cited in the Districts' Drainage Design Manual for Maricopa County, Hydraulics.

5.2.5.3 Opinion of Probable Construction Costs

Table 5.3 list detailed construction cost estimates for the recommended alternative for The Estrella, Perryville, Tuthill and Buckeye reaches. Construction cost estimates for the

Perryville and Estrella reaches do not include construction cost for proposed channel, bank protection, bridge and environmental mitigations improvements proposed by the King Ranch Development. Construction cost estimates does not include the cost for the construction of resource enhancement elements (see Section 6 Resource Enhancements). General cost contingencies are applied to the construction of the levee and associated bank protection. Levees, environmental mitigation (dust control), levee landscape aesthetics (soft structural treatment) construction cost are presented individually for each reach and as a project total. Table 3.3 lists a summary of unit cost utilized to determine cost estimates for each alternative.

The preferred recommended alternative for the Confluence Reach is primary an irrigation diversion structure and resources enhancements. Table 5.4 list a summary of unit cost utilized to determine cost estimates for the Confluence Reach. Table 5.5 list detail construction cost for the Confluence Reach.

Table 5.3 Recommended Alternative Construction Cost Summary

DESCRIPTION	AMOUNT	QTY -North Bank	QTY -South Bank	UNIT	UNIT PRICE	SUBTOTAL
1. Construction						
Estrella Reach (13,200 ft)	**$4,097,500**					
Clear and Grub		46	-	AC	$1,000.00	$46,100
Structural Fill (Import)		105,673	-	CY	$10.00	$1,056,700
Dumped Riprap (D50= 0.5')		47,535	-	CY	$60.00	$2,852,100
Filter Fabric		142,604	-	SY	$1.00	$142,600
Perryville Reach (24,816 ft)	**$5,231,900**					
Clear and Grub		52	-	AC	$1,000.00	$52,000
Structural Fill (Import)		153,290	-	CY	$10.00	$1,532,900
Dumped Riprap (D50= 0.5')		57,889	-	CY	$60.00	$3,473,300
Filter Fabric		173,666	-	SY	$1.00	$173,700
Tuthill Reach (10,560 ft)	**$3,451,200**					
Clear and Grub		32	-	AC	$1,000.00	$32,200
Structural Fill (Import)		141,641	-	CY	$10.00	$1,416,400
Dumped Riprap (D50= 0.5')		31,787	-	CY	$60.00	$1,907,200
Filter Fabric		95,362	-	SY	$1.00	$95,400
Buckeye Reach (34,320 ft)	**$27,663,200**					
Clear and Grub		116	61	AC	$1,000.00	$177,400
Structural Fill (Import)		425,053	228,013	CY	$10.00	$6,530,700
Dumped Riprap (D50= 1')		225,893	114,840	CY	$60.00	$20,444,000
Filter Fabric		338,839	172,260	SY	$1.00	$511,100
Construction Subtotal	**$40,443,800**					

Table 5.3 Recommended Alternative Construction Cost Summary Cont.

DESCRIPTION	AMOUNT	QTY- North Bank	QTY- South Bank	UNIT	UNIT PRICE	SUBTOTAL
2. Environmental Mitigation						
Estrella Reach (13,200 ft)	**$92,300**					
Hydroseed		46	-	AC	$2,000.00	$92,300
Perryville Reach (24,816 ft)	**$104,000**					
Hydroseed		52	-	AC	$2,000.00	$104,000
Tuthill Reach (10,560 ft)	**$64,300**					
Hydroseed		32	-	AC	$2,000.00	$64,300
Buckeye Reach (34,320 ft)	**$354,800**					
Hydroseed		116	61	AC	$2,000.00	$354,800
Environmental Mitigation Subtotal	**$615,400**					
3. Property Acquisition						
Estrella Reach (13,200 ft)	**$1,153,300**					
Right of Way (within Floodplain)		46	-	AC	$25,000.00	$1,153,300
Perryville Reach (24,816 ft	**$1,299,400**					
Right of Way (within Floodplain)		52	-	AC	$25,000.00	$1,299,400
Tuthill Reach (10,560 ft)	**$803,900**					
Right of Way (within Floodplain)		32	-	AC	$25,000.00	$803,900
Buckeye Reach (34,320 ft)	**$4,435,300**					
Right of Way (within Floodplain)		116	61	AC	$25,000.00	$4,435,300
Property Acquisition Subtotal	**$7,691,900**					

Table 5.3 Recommended Alternative Construction Cost Summary Cont.

DESCRIPTION	AMOUNT	QTY- North Bank	QTY- South Bank	UNIT	UNIT PRICE	SUBTOTAL
4. Levee Landscape Aesthetics						
Estrella Reach (13,200 ft)	**$2,896,600**					
Landscape Aesthetic Fill		290,944	-	CY	$9.00	$2,618,500
Planting		41	-	AC	$4,500.00	$185,800
Hydroseed		46	-	AC	$2,000.00	$92,300
Perryville Reach (24,816 ft)	**$3,205,000**					
Landscape Aesthetic Fill		323,118	-	CY	$9.00	$2,908,100
Planting		43	-	AC	$4,500.00	$192,900
Hydroseed		52	-	AC	$2,000.00	$104,000
Tuthill Reach (10,560 ft)	**$1,536,700**					
Landscape Aesthetic Fill		149,471	-	CY	$9.00	$1,345,200
Planting		28	-	AC	$4,500.00	$127,200
Hydroseed		32	-	AC	$2,000.00	$64,300
Buckeye Reach (34,320 ft)	**$10,004,200**					
Landscape Aesthetic Fill		648,856	344,576	CY	$9.00	$8,940,900
Planting		104	54	AC	$4,500.00	$708,500
Hydroseed		116	61	AC	$2,000.00	$354,800
Landscape Aesthetics Subtotal	**$17,642,500**					

Table 5.3 Recommended Alternative Construction Cost Summary Cont.

5. General Costs	$32,532,864	% of Total Cost		Total Cost	General Cost Subtotals
Contingency		25%	LS	$66,393,600	$16,598,400
Engineer (Planning, Design and Geotech)		10%	LS	$66,393,600	$6,639,360
Mobilization		3%	LS	$66,393,600	$1,991,808
Supplemental General Conditions		3%	LS	$66,393,600	$1,991,808
Const. Management (CQA Testing, Inspection and Eng. Support)		8%	LS	$66,393,600	$5,311,488

Reach	General Cost Subtotals by reach
Estrella Reach (13,200 ft)	$ 4,037,453
Perryville Reach (24,816 ft)	$ 4,821,747
Tuthill Reach (10,560 ft)	$ 2,869,489
Buckeye Reach (34,320 ft)	$ 20,804,175

6. Construction Cost Summary

Reach Subtotal Construction Cost Estimate without the Benefit of Reclaimed Floodplain Property	
Estrella Reach (13,200 ft)	**$ 12,277,153**
Perryville Reach (24,816 ft)	**$ 14,662,047**
Tuthill Reach (10,560 ft)	**$ 8,725,589**
Buckeye Reach (34,320 ft)	**$ 63,261,675**
PROJECT TOTAL (without benefit of reclaimed floodplain property)	**$ 98,926,464**

Table 5.3 Recommended Alternative Construction Cost Summary Cont.

7. Reclaimed Floodplain Property Benefit		QTY-North Bank		Unit	Unit Price	Subtotal
Estrella Reach (13,200 ft)	**($7,550,000)**					
Reclaimed Floodplain Property		151	-	AC	($50,000.00)	($7,550,000)
Perryville Reach (24,816 ft)	**($85,650,000)**					
Reclaimed Floodplain Property		1,713	-	AC	($50,000.00)	($85,650,000)
Tuthill Reach (10,560 ft)	**($19,150,000)**					
Reclaimed Floodplain Property		383	-	AC	($50,000.00)	($19,150,000)
Buckeye Reach (34,320 ft)	**($102,250,000)**					
Reclaimed Floodplain Property		1,391	654	AC	($50,000.00)	($102,250,000)
Reclaimed Floodplain Property Benefit Subtotal	**($214,600,000)**					

Reach Subtotal Construction Cost Estimate with the Benefit of Reclaimed Floodplain Property	
Estrella Reach (13,200 ft)	**$ 4,727,153**
Perryville Reach (24,816 ft)	**$ (70,987,953)**
Tuthill Reach (10,560 ft)	**$ (10,424,411)**
Buckeye Reach (34,320 ft)	**$ (38,988,325)**
PROJECT TOTAL (with benefit of reclaimed floodplain property)	**$ (115,673,536)**

Table 5.4 - Unit Cost for the BWCDD Lake and Diversion Structure

Description	Unit	Unit Price
Construction		
Clear and Grub	AC	$1,000.00 [1]
Excavation (earth)	CY	$3.00 [2]
Excavation (rock)	CY	$10.00 [3]
Structural Fill (Import)	CY	$10.00 [4]
Roller Compacted Concrete	CY	$80.00 [5]
Structural Concrete	CY	$400.00 [5]
Fuse Plug	CY	$4.00 [6]
Steel Sheet Piling	SF	$20.00 [7]
H Piling	LF	$75.00 [7]
Irrigation Head Gate	LS	$75,000.00 [8]
Sluice Gate	LS	$75,000.00 [8]
Dewatering	LS	$10,000.00
Mass Grading	CY	$2.00
Parking Facilities	AC	$100,000.00 [9]
Operation and Maintenance Road	LF	$15.00 [10]
Landscaping and Environmental Mitigation		
Hydroseed	AC	$2,000.00
Cottonwood and Willow	AC	$9,180.00 [11]
Wetland Marsh and Transition	AC	$6,471.00 [11]
Trail	LF	$6.00
Public Facilities	LS	$181,000.00 [12]

Table 5.4 - Unit Cost for the BWCDD Lake and Diversion Structure Cont.

Description	Unit	Unit Price
Right of Way and Property Acquisition		
Right of Way/Property Acquisition	AC	$25,000.00
General Requirements (percentage of subtotal)		
Contingency	LS	25.00%[13]
Engineer (Planning, Design and Geotech)	LS	10.00%
Mobilization	LS	3.00%
Supplemental General Conditions	LS	3.00%[14]
Const. Manag. (CQA Testing, Insptn. and Eng. Support)	LS	8.00%

Footnotes

1. Does not include salvage of native plants. Clearing unit cost assumes that ground conditions are 50% Agriculture/Minor Vegetation (Clearing unit cost of $500.00 per acre) and 50% Salt Cedar (Clearing unit cost of $1500.00 per acre)

2. Assume material is placed on-site

3. Assume rubber tired equipment is adequate and material is placed on-site

4. Includes furnishing approved material and placing

5. Includes furnishing approved aggregate, cement, mixing and placing, complete

6. Assume native material is acceptable for with only minor processing

7. Includes furnishing approved material and placing

8. Includes furnishing and installation of gate, electric service and access/maintenance facilities

9. Includes asphalt paving, striping, signage and gates

10. Includes compaction, grading and furnishing and placement of aprvd material for a width of 16 ft

11. Does not include irrigation or site preparation

12. Includes construction of 2 restrooms and 4 ramadas

13. Accounts for unknown conditions as well as general conditions, temporary facilities, insurance, performance bond, survey and as-builts

14. Includes partnering allowance, permitting, public information and notification allowance, public sign allowance and water management

Table 5.5 Engineering Cost Estimate for the BWCDD Lake and Diversion Structure

Description	Amount	Qty	Unit	Unit Price	Subtotal
Construction					
Diversion Structure	**$9,904,300**				
Clear and Grub		10.6	AC	$1,000.00	$10,600
Excavation (earth)		64,900	CY	$3.00	$194,700
Excavation (rock)		1,900	CY	$10.00	$19,000
Structural Fill (Import)		37,100	CY	$10.00	$371,000
Roller Compacted Concrete		71,400	CY	$80.00	$5,712,000
Structural Concrete		3,900	CY	$400.00	$1,560,000
Fuse Plug		28,000	CY	$4.00	$112,000
Steel Sheet Piling		83,000	SF	$20.00	$1,660,000
H Piling		1,400	LF	$75.00	$105,000
Irrigation Head Gate		1	LS	$75,000.00	$75,000
Sluice Gate		1	LS	$75,000.00	$75,000
Dewatering		1	LS	$10,000.00	$10,000
SRP Tailwater Ditch Extension	**$28,900**				
Clear and Grub		1.0	AC	$1,000.00	$1,000
Excavation (earth)		1,800	CY	$3.00	$5,400
Operation and Maintenance Road		1,500	LF	$15.00	$22,500
Parking Facilities	**$1,805,200**				
Clear and Grub		16.8	AC	$1,000.00	$16,800
Mass Grading		54,200	CY	$2.00	$108,400
Parking Facilities		16.8	AC	$100,000.00	$1,680,000
Construction Subtotal	**$11,738,400**				
Landscaping and Environmental Mitigation	**$967,500**				
Hydroseed		28	AC	$2,000.00	$56,800
Cottonwood and Willow		41	AC	$9,180.00	$376,400

Wetland Marsh and Transition		35	AC	$6,471.00	$226,500
Trail		21,132	LF	$6.00	$126,800

Table 5.5 Engineering Cost Estimate for the BWCDD Lake and Diversion Structure Cont.

Description	Amount	Qty	Unit	Unit Price	Subtotal
Public Facilities		1	LS	$181,000.00	$181,000
Right of Way and Property Acquisition	**$10,840,000**				
State Land		78	AC	$25,000.00	$1,940,000
BWCDD/BID		196	AC	$25,000.00	$4,900,000
Maricopa County Parks and Recreation		40	AC	$25,000.00	$1,000,000
Flood Control District of Maricopa County		120	AC	$25,000.00	$3,000,000
General Requirements (percentage of subtotal)	**$5,751,900**				
Contingency		25%	LS	$11,738,400	$2,934,600
Engineer (Planning, Design and Geotech)		10%	LS	$11,738,400	$1,173,800
Mobilization		3%	LS	$11,738,400	$352,200
Supplemental General Conditions		3%	LS	$11,738,400	$352,200
Const. Manag. (CQA Testing, Insptn. and Eng. Support)		8%	LS	$11,738,400	$939,100
PROJECT TOTAL	**$29,297,800**				

6.0 RESOURCE ENHANCEMENTS

6.1 RECOMMENDED ENHANCEMENTS

Resource Enhancements are those elements of the recommended plan that enhance the existing biological resources. Biological resource enhancements include development of higher quality habitat types (such as native cottonwood and willow) through conversion of poor quality types (such as salt cedar) where conditions are favorable. They may also include removal of non-native species by replacing them with open water, wetland marsh, and native riparian vegetation in areas where soil and water quality characteristics are favorable. Resources enhancements depicted on Figure5.1 include the following categories:

- Mesquite Bosque

  A tree and groundcover treatment recommended for terraced overbank areas. Area extent of this treatment should be minimized so that flow conveyance through the reach where it is applied is not reduced.

- Cobble Strand

  Application recommended generally within the channel bottom located away from the low flow channel. Vegetation treatment includes native shurbs and grasses.

- Low Terrace

  Enhancements consist of native shurbs and grasses located on terraces adjacent to channels. Terraces are generally 6 to 8 feet above low flow channels. Application would typically be applied between Cottonwood/Willow Corridors.

- Cottonwood/Willow Corridors

  Cottonwood/Willow Corridor treatments are applied adjacent to irrigation tail water ditches or low flow channels. The treatment consist of trees, riparian understory, ground cover, and in pockets adjacent to the low flow channels, aquatic plants.

- Cottonwood/Willow Enhancements

  Cottonwood/Willow Enhancement treatments are similar in content to Cottonwood/Willow Corridor treatment; however, the application of the treatment is along existing low flow open water channels that have plant species consistent with the prescription that is already established.

- Riparian Wetland with Emergent Marshes

  This treatment is applied to areas adjacent to open water. The application may be an element of a restoration effort associated with a sand and gravel operation where the water table is near the ground surface. The treatment would be located in shallow water around the excavation or adjacent to

islands in the open water area. The treatment could be combined with the Cottonwood/Willow prescriptions.

- Bioengineering

  Hollis (1997) states that "Bioengineering is the combination of biological, mechanical, and ecological concepts to control erosion and stabilize soil through the sole use of vegetation or in combination with construction materials, similar to engineered materials." Through the use of natural vegetation, bioengineering provides opportunities to enhance wildlife habitat, water quality and visual aesthetics. In areas where there is a resource, or resource enhancements adjacent to a low flow channel that has the potential to migrate laterally, bioengineering techniques are recommended to stabilize channel banks. Examples of bioengineering techniques are provided in Appendix A.

- Open Water

  Open water areas are proposed at locations where the ground water table is near the surface. Typically the creation of open water areas will require excavation. The excavation may be facilitated through sand and gravel mining.

Details such as vegetation type, density, distribution and community classification for each enhancement category are provided on the Conceptual Plan Detail Sheets (Plate 3 and Figure 5.1). Environmental Enhancement Implementation, Operation, and Maintenance Considerations Including Summary Results from the Soil and Water Quality Screening are located in Appendix C.

6.1.1 Recommended Enhancements Cost Estimates

The resource enhancement elements of the recommended alternative for the El Rio Watercourse Master Plan represent a major portion of the overall project. As such, it is important that the cost of implementing the enhancements be understood to the extent possible at this level of planning.

Development of a detailed cost estimate for the resource enhancement element of the recommended plan is not practical at this level of planning. Instead, a planning level cost estimate is prepared considering only a short list of anticipated bid items with an appropriate contingency for items that are not known.

6.1.1.1 Unit Costs

Bid items that are reasonable to expect for the implementation of the resource enhancement are clearing and grubbing of existing vegetation, the recommended plant pallet and excavation associated with the Cottonwood/Willow corridors. A contingency for unknowns of 25 percent will be added to the costs for resource enhancements. Unit costs for each of these bid items are taken from the same or similar items used in the alternative formulation and/or recommended alternative cost estimates for the flood

control features. Discussion of the unit costs for each of the bid items and associated considerations is provided in the following paragraphs. In addition to the specific bid items, general costs for engineering, mobilization, supplemental general conditions and construction administration are considered.

Clear and Grub – There is a tremendous range in the existing vegetative conditions in regard to estimating a clear and grub unit cost. For the flood control features of the recommended alternative, a unit cost of $1,000 per acre was used as an average of $500 per acre for agricultural areas and "minor" vegetation and $1,500 for salt cedar. For the resource enhancements, the "minor" vegetation and salt cedar unit costs are treated separately and related to the various recommended vegetation types. In general, Mesquite Bosque, Cottonwood/Willow, wetland marsh and open space Atriplex series enhancement areas are replacing dense stands of vegetation typically consisting of Salt Cedar. Therefore, a unit cost of $1,500 per acre is used for these areas. For the open space Cobble Strand enhancement areas, the existing vegetation density is mixed with large areas of no vegetation. Therefore, a unit cost of $500 per acre is used for those areas. The unit cost for both vegetative conditions does not include salvage of native plants.

Plant Pallet – Unit costs for the plant pallet are taken from Table 9 of Appendix C of the Recommended Alternative Report. The unit costs listed in that table include a 25 percent contingency. For consistency with other unit costs used in this cost estimate, the contingency is removed from the unit cost to be added to the total cost. Unit costs for each of the vegetative types of the recommended plant pallet are listed in Table 6.1. The unit costs listed in Table 5.1 do not reflect costs associated with site preparation, irrigation or other appurtenances.

Table 6.1
Plant pallet unit costs

Vegetation Description	Unit Cost with Contingency	Unit Cost without Contingency
Mesquite Bosque	$6,968.00	$5,226.00
Cottonwood/Willow	$9,180.00	$6,885.00
Wetland Marsh	$6,471.00	$4,853.25
Cobble Strand	$4,710.00	$3,532.50
Atriplex Series	$2,084.00	$1,563.00

Excavation – Unit cost for excavation of the Cottonwood/Willow corridor is the same as the excavation unit cost used for the BWCDD lake and diversion structure element of the recommended alternative. That unit cost is $3 per cubic yard.

6.1.1.2 Cost Estimate

Quantities used in the planning level cost estimate for the proposed resource enhancements of the recommended alternative are taken from Figure 12 and Plate 3,

Resource Enhancement Details of the Recommended Alternative report. For the Cottonwood/Willow corridor, excavation is based on a rectangular section 16 feet in width and 1.5 feet in depth. The acreage of Cottonwood and Willow trees assumes a corridor width of 100 feet.

The total estimated cost for the resource enhancements is approximately $47,500,000. For planning purposes, the cost estimated is broken down by reach in Table 6.2.

Table 6.2 Resources Enhancements Cost Summary

Resource Enhancment	Reach	Unit	Quantity	Unit Cost	Estimated Cost	Subtotal by reach
ATRIPLEX SERIES	**Buckeye**	AC	1,461	$ 1,563	$ 2,284,000	
COBBLE STRAND		AC	1,388	$ 3,533	$ 4,903,000	
COTTONWOOD/WILLOW		AC	646	$ 6,885	$ 4,448,000	
MESQUITE BOSQUE		AC	161	$ 5,226	$ 841,000	
WETLAND MARSH		AC	236	$ 4,853	$ 1,145,000	
EXCAVATION		CY	35,611	$ 3	$ 107,000	
C&G (SALT CEDAR)		AC	2,504	$ 1,500	$ 3,756,000	
C&G (OPEN SPACE)		AC	1,388	$ 500	$ 694,000	$ 18,178,000
ATRIPLEX SERIES	**Tuthill**	AC	77	$ 1,563	$ 120,000	
COBBLE STRAND		AC	415	$ 3,533	$ 1,466,000	
COTTONWOOD/WILLOW		AC	34	$ 6,885	$ 234,000	
C&G (SALT CEDAR)		AC	111	$ 1,500	$ 167,000	
C&G (OPEN SPACE)		AC	415	$ 500	$ 208,000	$ 2,195,000
COBBLE STRAND	**Perryville**	AC	1,854	$ 3,533	$ 6,549,000	
COTTONWOOD/WILLOW		AC	30	$ 6,885	$ 207,000	
C&G (SALT CEDAR)		AC	30	$ 1,500	$ 45,000	
C&G (OPEN SPACE)		AC	1,854	$ 500	$ 927,000	$ 7,728,000
COBBLE STRAND	**Estrella**	AC	816	$ 3,533	$ 2,883,000	
COTTONWOOD/WILLOW		AC	4	$ 6,885	$ 28,000	
WETLAND MARSH		AC	6	$ 4,853	$ 29,000	
C&G (SALT CEDAR)		AC	10	$ 1,500	$ 15,000	
C&G (OPEN SPACE)		AC	816	$ 500	$ 408,000	$ 3,363,000
COTTONWOOD/WILLOW	**Confluence**	AC	32	$ 6,885	$ 220,000	
WETLAND MARSH		AC	23	$ 4,853	$ 112,000	
C&G (SALT CEDAR)		AC	55	$ 1,500	$ 83,000	$ 415,000
Resource Enhancement Subtotal						*$ 31,879,000*
Contingency					*25%*	*$ 7,969,750*
Engineer (Planning, Design and Geotech)					*10%*	*$ 3,187,900*
Mobilization					*3%*	*$ 956,370*
Supplemental General Conditions					***3%***	***$ 956,370***
Const. Management (CQA Testing, Inspection and Eng. Support)					***8%***	***$ 2,550,320***
Resource Enhancement Total						**$ 47,499,710**

7.0 DESIGN GUIDELINES

7.1 INTRODUCTION

The following design/planning guidelines are presented to aid designers and planners in their efforts to implement the El Rio Watercourse Master Plan. The guidelines are in part from, and in addition to, guidelines and criteria presented in Maricopa County Drainage Design Manual Volume II-Hydraulics, State Standards developed by the Arizona Department of Water Resources and applicable Federal Emergency Management Agency design criteria.

7.2 DESIGN GUIDELINES FOR THE RECOMMENDED PLAN

7.2.1 Levee/Bank Armoring

Geomorphic and sediment transport evaluations indicate that the Gila River within the study reach has defined a conveyance corridor through the process of erosion and lateral migration. The corridor defines the area that is required for the river to convey flood flow and the sediment in a dynamic equilibrium state. Even though the river has defined a corridor in which the majority of its work is done, due to bank instability the opportunity for lateral migration exists.

Levee and/or bank armoring is required to limit lateral migration of the Gila River, to protect floodway fringe property from being inundated and to minimize encroachment of the natural river corridor so that the form, function and dynamic equilibrium of the river is maintained.

The proposed levee/bank protection alignment is consistent with the natural river corridor and generally follows the effective FEMA floodway limit. The following minimum guidelines should be addressed in the design of levee and bank armoring:

- *Design Event.* At a minimum, the 100-year peak discharge will be utilized as the design event for levee and bank protection design. A levee risk analysis and/or hydraulic evaluation for a greater event may be required. Designers shall contact the Flood Control Districts of Maricopa County for design/evaluation guidance.

- *Topographic Mapping.* Detailed topographic mapping will be required for the design reach and shall extend upstream and downstream of the project for hydraulic analysis purposes.

- *Hydraulic Analysis.* The hydraulic models developed for planning purposes for the El Rio recommended plan are based on dated topographic information. New topographic data and hydraulic analysis will be required for detailed levee and bank protection design. In addition to new topographic data, Manning's roughness coefficients shall be revised to be consistent with existing channel form and vegetation densities. If resource vegetation enhancements are an element of the project, roughness coefficients shall be consistent with proposed enhancements.

- *Alignment.* Deviation from the proposed levee/bank armoring alignment is not encouraged, however the plan recognizes that there may be special conditions which merit alignment adjustment. Hydraulic and sediment transport analysis are required to demonstrate that the alignment adjustments do not have adverse impacts to flow and sediment conveyance, both upstream and downstream. Alignment may impact jurisdictional waters of the United States. Impacts to the water of the US will be mitigated.

- *Bank Armoring.* The plan recommends dumped riprap for bank armoringdue to high groundwater in the project area. There are construction techniques favorable to the placement of riprap underwater over techniques for other conventional armoring types. In areas where ground water may not be a construction constraint, other bank armoring measures may be employed. In lieu of providing armoring to the toe down depth, placement of launchable riprap at the toe in a trench is proposed. Design procedures for riprap armor can be found in "The WES Stream Investigation and Streambank Stabilization Handbook" (October 1997).

- *Scour Calculations.* Scour depths calculated for the El Rio Watercourse Master Plan are for planning purposes only. Project specific total scour calculations based on new topographic, geotechnical and hydraulic data are required for all levee design. When a levee transitions to a bridge abutment, abutment scour shall be calculated.

- *Levee Freeboard.* The minimum levee height will be set at FEMA requirements or by a levee risk analyses, whichever is greater.

- *Levee Internal Drainage.* Design of levees will require a detailed evaluation and solution for offsite stormwater runoff and irrigation tail water that will accumulate on the landward side of a levee. Provisions to discharge this stormwater to the Gila River without adverse impacts to properties shall be made.

- *Levee Transitions.* Design of levees will require transitions to existing and future structures and will need to provide "key ins" when transitioning to natural ground (when project design reach does not tie into an existing levee). Example of structure transitions are:

    - At bridges

    - At tributary storm drain channels

    - At crossings of irrigation canals or drains

- *Planning and Construction.* Flood control management projects should be constructed in a manner that minimizes impacts to adjacent properties. The following design/implementation guidelines are offered so that adjacent properties are not impacted by a project:

- In areas where there is a floodway fringe that can be removed by the implementation of a levee, the lateral extent of the levee shall extend the total length of the floodway fringe area. This may require multi-landowner and agency coordination.

- In areas adjacent to sand and gravel operations, bank armoring and/or levee construction shall be done in advance of sand/gravel extraction by the sand and gravel operator.

- In the event that resource vegetation management will increase flow velocities in a reach that could result in increased lateral migration, bank armoring shall be in place in the subject reach prior to the construction of resource enhancements.

- *Landscape Aesthetic Treatments.* The recommended plan calls for landscape aesthetic treatment. The aesthetic treatment primarily consists of placement of landscape fill on bank armoring and levee structural fill, and landscaping of the fill areas. Landscape guidelines are cited in the Report titled "El Rio Landscape Management Guidelines" prepared by EDAW Inc.

7.2.2 Lateral Migration

7.2.2.1 Erosion Hazards

Areas located within the recommended erosion hazard zones developed as part of the El Rio Watercourse Master Plan may be subject to increased risks to public safety that warrant specific development restrictions. Given the level of detail used to develop the recommended erosion hazard zones, the developer/landowner is given the option of completing a more detailed erosion hazard zone evaluation. A typical scope of work for such an analysis is listed below:

7.2.2.2 Typical Scope of Work for Detailed Erosion Hazard Analysis

Channel stability, or the potential for lateral migration will be evaluated using the following types of analyses:

- Interpretation of Geologic Surfaces
- Historical Analyses
- Field Analyses
- Geomorphic Analyses
- Hydraulic and Empirical Analyses
- Sediment Transport Modeling

- Sediment Yield Analysis
- Sediment Gradation Analysis

Specific tasks likely to be conducted with each of these analyses are outlined below.

7.2.2.3 Technical Analysis Work Plan

Task 1 – Hydraulics Analysis

Hydraulic Data – HEC-RAS Models. Hydraulic data will be obtained from modeling prepared for the effective FEMA Flood Insurance Studies or new modeling prepared for this study. Specific tasks include the following:

- *Plot Cross Sections.* Cross section plots showing existing condition 2-, 10-, and 100-year water surface elevations will be prepared. If the future conditions flow rates change significantly from existing conditions flow rates, then water surface elevations and channel geometry will also be plotted for future conditions. Ineffective flow areas in cross sections will also be documented.

- *Prepare Plots of Hydraulic Data from HEC-RAS.* Plots of top width, hydraulic depth, flow cross section area, maximum flow depth, mean channel velocity, and other data, as needed, will be prepared. At minimum, data from the 100-year event will be plotted. Additional plots for the 10-year event may be made to estimate conditions for the dominant discharge.

- *Define Channel Subreaches.* Plots of HEC-RAS data will be used to define characteristic hydraulic reaches based on uniform flow sections, erosion prone sections (narrow width, high velocity), choke sections (short, constricted reaches), backwater sections upstream of choke sections, longitudinal profile, and potential grade controls. To eliminate potential data scatter between cross sections that may mask trends, running averages of hydraulic data will also be examined to help define reaches. Reach definition will be coordinated with results of geomorphic analyses described below.

Sediment Gradations. Sediment data for the channel bed and banks will be collected for use in hydraulic and geomorphic analyses. Specific tasks include the following:

- *Sediment Sampling.* Samples of bed sediments from representative locations at approximately one-mile increments throughout the study reach will be obtained for sieve analysis. In addition, surficial sediment size data will be estimated using pebble counts. Bank sediment data will be collected from detailed descriptions and photographic records. These supplemental bed and bank sediment data will be collected at cross sections spaced approximately 1,000 feet apart throughout the study reach. All sampling locations will be noted on a detailed exhibit.

- *Sediment Analysis.* Sediment gradations showing D90, D84, D50, D15, and D10 will be prepared for each sediment sample. Sediment gradations will be reviewed to verify that reach definitions are supported, and to quantify reach-averaged sediment gradation data. Bed, bank, and overbank sediment characteristics will be compared and quantified. Armored reaches will be identified. Size gradation for HEC-6T model input will be quantified for each subreach. Ranges of size gradation will be defined so that various scenarios of sediment transport analyses can be constructed to identify zones of potential aggradation or degradation, for use in sensitivity analyses of HEC-6T modeling.

Sediment Yield. Sediment supply to the study reach will be evaluated to quantify sediment sources outside the study limits. Specific tasks include the following:

- *Regional Sediment Yield Estimates.* SSediment yield estimates developed for the El Rio Sedimentation analysis shall be used (Alternative Evaluation report Attachment 4) in the development of HEC-6T model inflow boundary conditions.

- *HEC-6T Modeling.* Sediment yield estimates will be used as HEC-6T inflow boundary conditions, and will also be used to assess long-term impacts due to sediment accumulations in ponding areas or other backwater areas.

HEC-6T Modeling. HEC-6T models of existing and future (alternative) conditions developed for the El Rio Watercourse Master Plan will be serve as the base model. The base model will be revised to reflect site specific and current regional conditions such as detail topographic data or physical changes to the water course (both up stream and down stream of the subject site) that might have occured since the development of the El Rio Sedimentation models. The primary goal of the HEC-6T modeling is to estimate general sedimentation trends of aggradation or degradation, as reflected in a net sediment deficit or surplus. The HEC-6T model will be used to assess sediment transport and related channel stability for the 10-year, dominant channel forming discharge, 100-year flood discharge, and possibly an extreme catastrophic discharge event.

7.2.2.4 Task 2 – Lateral Stability Assessment

Interpretation of Geologic Surfaces. Geologic data will be used to identify and map recent geomorphic surfaces near the stream. The age and position of these surfaces will be used to constrain the rate of lateral and vertical movement over recent geologic time. Specific tasks include the following:

- Interpret aerial photographs.

- Select soil test pit locations.

- Describe soil profiles in soil test pits.

- Describe surficial soil characteristics.
- Inspect surfaces in field.
- Prepare geomorphic mapping.

Historical Analyses. Historical data will be used to identify historical patterns of channel behavior, historical impacts on the stream by humans, and past rates of lateral and vertical channel change. Historical data will be used to set the context for interpretation of existing conditions and prediction of future channel response. Specific tasks include the following:

- Collect historical maps and topography.
- Collect historical aerial and ground photographs.
- Digitize historical channel position.
- Determine rates and types of channel change from digitized channel plots.
- Measure historical channel characteristics (width, sinuosity, etc.).
- Plot and compare historical longitudinal profiles.
- Catalogue types of human impacts, plot locations.
- Prepare time line of watershed and channel changes.

Field Analyses. Field data will be collected to identify areas of channel instability, quantify channel and bank characteristics, and document existing channel conditions. Specific tasks include the following:

- Select index cross section spacing and locations.
- Measure channel characteristics at index cross sections.
- Measure bank characteristics at index cross sections.
- Document existing conditions with photographs and notes.
- Perform boulder counts for channel bed sediments.
- Describe soil pits excavated in the channel bottom.
- Collect sediment samples from the channel bottom for sieve analysis.

Geomorphic Analysis. A geomorphic description of the stream characteristics will be prepared to identify appropriate types of hydraulic and empirical analyses, identify

existing channel processes, and to predict trends in future channel behavior. Specific tasks include the following:

- Describe regional geologic history.
- Collect hydrologic data - peak discharge rates, flow duration curve, mean and monthly flow rates, annual flood series, flood history, climatic data, etc.
- Measure channel planform characteristics – channel pattern, meander features, pool and riffle spacing, width, slope, periodicity of narrow and wide reaches.
- Identify evidence of paleofloods.
- Identify stream analogs on adjacent watersheds.
- Evaluate tributary characteristics – drainage area, slope, sediment type, sediment yield, flow rates, location of confluence.
- Assess impacts of tributaries and tributary sediment load on main channel morphology.
- Apply applicable methodologies from *the District Piedmont Flood Hazard Assessment Manual* (Draft, August 1998, or most recent version) to identify surface ages and stability.
- Perform stream classification.
- Define stream reaches.

Hydraulic and Empirical Analyses. Engineering analyses based on hydraulic data obtained from a HEC-RAS model of the study reach will be performed to assess the potential for bank erosion and scour. These analyses will be used to determine whether a stream is stable, whether it is likely to experience bank erosion and/or scour, and what amount of lateral erosion is likely to occur. Where hydraulic data are required, the computations will be based on 2-, 10-, and 100-year reach-averaged hydraulic data. Specific tasks include the following:

- Revision of HEC-RAS model as described above.
- Define stream reaches using hydraulic data and physical stream characteristics.
- Determine reach-averaged hydraulic data.
- Compute allowable velocity.
- Compute scour depths (general, local, and long-term).

- Compute armoring potential & depth to armor.
- Compute equilibrium slope.
- Compute reach sediment continuity relationships.
- Apply Lane's relation to stream reaches.
- Apply regime equations to stream reaches.
- Apply hydraulic geometry relationships to stream reaches.
- Apply empirical channel geometry relationships to stream reaches.
- Apply appropriate regional lateral stability prediction methodologies – these may include the AMAFCA Prudent Line, ADWR State Standard 5-96, King County (WA) methodology, Rosgen bank assessment techniques, etc.

Impacts Analysis. The proposed development will be modeled to assess the potential downstream and upstream impacts, using the same procedures and methodologies listed above.

7.2.2.5 Final Product

The final product for these tasks will include a map showing the recommended erosion hazard zone boundaries and a final report. The final report will include the following:

- Discussion of assumptions and limitations of methodologies.
- Discussion of how the results of the various analyses were combined with the sediment transport modeling results, sand and gravel mining impact assessment analysis, and were translated into the erosion hazard zone(s).
- Recommendation for future updates of hazard zone boundaries.
- Recommendation for long-term monitoring.
- Recommendations for how to modify the erosion hazard boundaries and/or under what conditions development can occur within the boundaries.

7.2.3 Resource Vegetation Management

Type, distribution, and density of proposed resource vegetation management opportunities are depicted on Figure 5.1 and Plate 1. The plan recognizes that the implementation of the resources vegetation management elements will take place as budgets and funding partners are identified and developed and will not occur all at once. The type and distribution of vegetation management depicted on the Figure 5.1 are not-cast-in stone but are provided as seed ideas to be expanded on. The following general

guidelines, in addition to specifications listed on the Detail Sheets of the Conceptual Plans, are offered for the selection and implementation of a resource vegetation management:

- Protect highest quality habitat types such as wetland marsh, cottonwood, willow and other plant communities dominated by native species.
- Restore and enhance higher quality habitat types such as native cottonwood and willow through conversion of poor quality types such as salt cedar, where conditions are favorable
- Remove exotic species, replacing them with open water, wetland marsh, and native riparian in areas where conditions are favorable
- Enhance and upgrade lower quality upland habitat types where soil and water quality allow
- Enhancement should provide an increase in resource value (example – lineal extent of shoreline and/or emergent marsh area should be more extensive than existing condition)
- Soil characteristics shall be consistent with the characteristics required for the particular enhancement to achieve long-term sustainability
- Water source to support desired enhancement shall be identified
    - Fluctuation in groundwater table should be considered
    - Off site water sources to be used in drought conditions should be identified
- Water quality should be such that the desired enhancement is sustainable
- Hydraulic and sediment transport analysis are required to demonstrate that elements of the resource vegetation management project does not have adverse impacts to flow and sediment conveyance, both to upstream and downstream properties.
- A maintenance and operation plan shall be developed for the desired enhancement

Additional guidelines for resource vegetation management implementation, operation, and maintenance considerations including summary results from the soil and water quality screening and conceptual planting cost estimates are located in Appendix C.

Mosquito management considerations associated with resource vegetation management are located in Appendix D.

7.2.4 Sand and Gravel Excavation

The plan recommends at a minimum that Sand and Gravel Mining Guidelines (2003) developed by the District for a Floodplain Use Permit Application be used as a starting point for planning a Sand and Gravel Operation in the El Rio Planning Area. Polices developed by the District outlining the intent of the guidelines are as follows:

- Aggregate mines should be located outside of the regulatory floodway.
- Aggregate mines should be located outside of the erosion hazard zone.
- If aggregate mines are located within the regulatory floodway or erosion hazard zone and no structural flood control measures are provided, the maximum excavation depth should be no greater than the natural channel invert elevation shown on the effective floodplain delineation study or as established by the District.
- If aggregate mines within the floodplain or erosion hazard zone are excavated below the natural channel invert elevation shown on the effective floodplain delineation study or as established by the District, then engineered grade control structures shall be provided at any point where the 100-year flood could enter the excavation or engineered flood control structures shall be provided to prevent the 100-year flood from entering the excavation.
- Aggregate mining operations shall have no adverse floodplain or sedimentation impacts on any adjacent or off site property.
- Aggregate mining operations must have a reclamation plan that demonstrates long-term stability of the excavation and adjacent river system.
- Aggregate mining operations shall conform to the recommendations and policies specified in the approved watercourse master plan for the watercourse.
- Technical reports submitted in support of aggregate mining floodplain use permits shall be prepared by experienced Arizona-registered civil engineers with relevant expertise in hydrology, hydraulics, sediment transport, river mechanics, fluvial geomorphology, and local stream systems.

Sand and gravel operations can facilitate construction of open water areas, wetland and emergent marshes recommended by the El Rio Watercourse Master Plan. The plan offers the following guidelines for sand and gravel operation that occur within the Gila River floodplain.

- Sedimentation analyses conducted for the El Rio Watercourse Master Plan indicates that the potential for upstream headcutting from an excavation and downstream degradation of the channel bed occurs. The magnitude of the headcuts and degradation is dependent on the size of the excavation. Due to

this potential, sand and gravel operations are not recommended to occur within the main Gila River channel unless it is demonstrated that adjacent properties are not impacted by erosion. The main channel is defined as the limits of the active channel, which is presented in Attachment 5–Lateral Migration Analysis Report. Sand and gravel excavations adjacent to the main channel shall prevent capture of the main channel.

- Hydraulic and sedimentation analyses are required to demonstrate that potential upstream headcutting and downstream degradation are limited to occur within the property limits of the excavation and that the excavation has no impact to the river system. If this is not possible potential damages due to erosion as a result of the excavation must be mitigated with adjacent property owner/owners.

- Capture can occur when headcutting from the excavation propagates upstream to the main channel or when the main channel erodes laterally into the excavation.

- Sand and gravel excavations adjacent to proposed levee alignments shall construct the levee and associated bank armoring to prevent lateral migration of the river in a runoff event. Set backs of the excavation from the levee shall be consistent with setbacks presented in the District's Sand and Gravel Guidelines.

- A reclamation plan consistent with the intent of the recommended resource enhancement elements and design guidelines of the El Rio Watercourse Master plan shall be developed. Guidance for developing a recommendation plan are listed in the Districts, "sand & gravel reclamation guidelines (2004)".

7.2.5 Bridge Crossings

Bridge crossing shall be designed so that the disruptions to the natural sediment transport capabilities of the river are minimized. To minimize disruptions to the sediment transport capabilities of the river, the plan recommends that bridges span the floodway limits.

8.0 ENVIRONMENTAL PERMITS

At a minimum, any construction occurring as a result of the El Rio Watercourse Master Plan will require the following:

NPDES Storm Water Permit. The Clean Water Act Amendments of 1987 require that certain types of storm water discharges be permitted under the National Pollutant Discharge Elimination System (NPDES). Construction activities that disturb more than five acres are included in this program. Submittal of a Notice of Intent (NOI) as well as development of a Storm Water Pollution Prevention Plan (SWPPP) is necessary.

Section 404 Permit. This section of the Clean Water Act requires the issuance of a permit for the discharge of dredged or fill material into waters of the United States. Specific categories of activity may qualify for Nationwide permits, however, the maximum impact allowable under Nationwide permits is usually one-tenth of an acre. Projects causing more than this level of impact will require an Individual Permit.

9.0 IMPLEMENTATION PLANNING AND FUNDING STRATEGIES

9.1 INTRODUCTION

The El Rio WMP presents a comprehensive approach that includes engineering, environmental, landscape, social and economic considerations. Proposed improvements will result in flood protection for greater public safety along the river corridor. The plan also specifies increased recreation opportunity, improvements in environmental resources, as well as improved community resources. While these differing elements are seemingly distinct in purpose, they are proposed to be implemented in a coordinated fashion to best achieve specified overall goals.

The implementation and funding strategy is developed as part of the WMP, to assure that needed future actions for implementation are considered in the planning effort. The implementation and funding strategies incorporate key proposals for four differing elements: community outreach; program and policies, including governance and maintenance, security and liability; regulatory compliance; and funding opportunities.

Community Outreach

Community outreach in the implementation strategy includes education and participation efforts for stakeholders, elected officials and the public. The overall project will require a continued public and community outreach strategy through planning and implementation, to engage political, business, environmental, community and other interest groups in this rapidly developing area of the County.

Programs and Policies

This element outlines the policies and governance programs needed to ensure compliance with the WMP, oversee maintenance, and assume liability for the project. Programs and policies in the implementation strategy include adoption of the WMP by local governments as a guideline for future public and private development activity. Pilot projects are proposed to ensure transition from planning to full implementation. Public activities proposed include locating facilities such as a new lake, recreational corridors, visitor information areas, and transportation networks in conformity with the WMP. Implementation strategies and procedures are proposed to improve funding and completion of projects in a timely manner. Site development considerations such as location of commercial and residential facilities related to private development are recommended in accordance with WMP requirements.

Regulatory Compliance

Compliance with various laws and ordinances will be necessary for successful implementation of the WMP. These include federal laws such as the Endangered Species Act (ESA), the Clean Water Act (Section 404 permitting), and the National Environmental Policy Act (NEPA), state regulations such as the Arizona Pollutant

Discharge Elimination System program (AzPDES) and local floodplain and zoning ordinances. Both public and private activities must comply with these regulations and while they impose constraints on certain activities, they also present opportunities for implementation. Examples of these opportunities in coordination with the adopted WMP include restoration of certain reaches of the Gila River within the WMP area as part of required mitigation for Section 404 permitting of flood control or other construction activities. These restored areas would enhance wildlife habitat values and provide passive recreational opportunities to the public. Examples of these opportunities at the local government level may include requirements for erosion hazard setbacks, open space, and recreational amenities for future private developments at locations identified in the WMP.

Funding

Resources to fund capital flood protection and enhancement projects as well as maintenance activities need to be secured. The funding implementation strategy will require differing programs and selective funding from multiple sources. Funding considerations may be separated into flood control activities and watercourse enhancement activities and will draw on both public and private sources. Examples of how flood control facilities can be built using public funding include use of Flood Control District tax revenues and bond funding from local governments as budgeted in annual Capital Improvement Programs. In addition, cost sharing programs with federal agencies such as the Bureau of Reclamation and Army Corps of Engineers can be utilized. An example of such might be to utilize District and Town of Buckeye funds to construct a levee upstream of the Tuthill Road Bridge and utilize federal cost sharing dollars to conduct vegetation management activities in concert with the levee improvements. An example of how both flood control and recreation enhancements can be built by private funding includes construction of facilities by private developers as part of their project infrastructure and open space set-asides as required by local ordinances.

9.2 IMPLEMENTATION STRATEGY FOR COMMUNITY OUTREACH

Community outreach is a critical part of any major development project. It is especially important in the El Rio WMP because of the broad base of resources, communities, agencies, interest groups and other parties affected by the program.

The developed outreach effort has been structured from the start to support the overall planning, implementation and funding strategies for the program. That is, a continued focus has been maintained and should continue in outreach efforts to engage and inform the public and gain support for specific actions over the full term of the project.

Three general periods of outreach strategies are envisioned for the El Rio WMP as follows.

- Year 1-2 General community involvement and education during WMP development
- Year 2-5 Outreach to engage select supporters in pilot projects and form implementation and funding groups

- Year 4-10 Longer term outreach to sustain development programs

9.3 POLICIES AND PROGRAMS TO ENHANCE THE IMPLEMENTATION STRATEGY

The implementation strategy is enhanced greatly by local communities and regional groups collaborating on legal requirements, policies , and agreements that streamline adoption of elements of the program.

Most of the legal requirements pertain to permitting the proposed activities, especially as relates to actual site disturbance activities. For example, overlapping federal, state and local government requirements exist regarding assessment procedures on any development project for every activity performed, from disposal of waste to surveys for Threatened & Endangered Species. Increased flexibility in local and regional government policies in these areas can greatly improve implementation.

Establishment of policies, agreements, zoning regulations, etc. by local and regional government leadership can greatly prove El Rio WMP project implementation, especially in the near term. These can relate to zoning, permitting, joint approval of activities crossing multiple jurisdictions, joint approval of collaborative agreements on funding, support of pilot projects, etc.

Policy issues relate to specifications on how various project activities will be implemented. Policies often vary from agency to agency, especially from federal to state and local agencies. Often project directors, find themselves ensnarled in multi-agency policies that appear at cross purpose. Examples are policies relating to survey requirements regarding biological resource issues or cultural resource issues, prior to development.

Pilot programs can facilitate implementation of the larger El Rio WMP. Two pilots, an Educational Research &Development and Programmatic Demonstration pilots are outlined as part of the implementation strategy. The purpose of the Educational R&D pilot is to determine vegetation management techniques that will control salt cedar, improve flood conveyance and enhance wildlife habitat. The Educational R&D site is planned to open to the public in winter 2006.

The programmatic demonstration pilot incorporates all elements of the El Rio WMP: flood control, vegetation management, habitat enhancement, open water creation and recreational amenities. For further information on the program demonstration pilot, see *Project Proposal and Site Selection Report for the El Rio WMP Programmatic Pilot.*

9.4 AN IMPLEMENTATION STRATEGY FOR ADDRESSING LEGAL REQUIREMENTS

Compliance with federal, state and local laws and ordinances is critical to effective implementation of the WMP recommended alternative. Capabilities for compliance fully exist with the extensive federal, state and local partners involved in planning the El Rio WMP. However, explicit interest exists in having compliance and project activities move

forward in both an efficient and effective manner. This will become a challenge due to the extent of law and regulation that will impact the project. This includes federal laws such as the Endangered Species Act (ESA), the Clean Water Act (Section 404 permitting) and the National Environmental Policy Act (NEPA). Actions to respond to state regulations such as the Arizona Pollutant Discharge Elimination System program (AZPDES) and local flood plain and zoning ordinances will also be critical in the implementation strategy.

Proposed public and private development activities in the WMP project area must comply with these regulations, and while they impose constraints on certain activities, they also present opportunities for implementation. Examples of these opportunities in accordance with the adopted WMP include restoration of certain reaches of the Gila River as part of required mitigation for Section 404 permitting of flood control or other construction activities. These restored areas would also enhance wildlife habitat values and provide passive recreational opportunities to the public. Examples of these opportunities at the local government level may include satisfying requirements for erosion hazard setbacks through open space and recreational amenities for future private developments at locations identified in the WMP.

Completion of the WMP permits identification of many areas of compliance that will be necessary. However, some areas will not be obvious until actual project designs for specific areas are formulated.

9.5 DEFINING APPROACHES TO THE FUNDING STRATEGY

Funding the El Rio WMP will involve the broadest cross section of interests, stakeholders and partners. The El Rio WMP river segment is part of the greater biophysical and social system (Greater Gila River system), and funding the preferred alternative must create enhancements to the El Rio segment as well as the total system. Parties that have critical involvement with the larger system are being engaged, informed and approached for funding support of the El Rio segment.

Effective funding strategies for this type of project require support from partners who are not funding entities, as well as those who are approached for funding. Important in these are congressional, tribal, state, county and city leaders; regulatory agencies; members of the environmental community and members of business and agricultural communities. A developmental funding package for this size of project involves collaboration and partnerships with diverse federal/state/local entities because of broad objectives sought, and also because of the diverse interests along the corridor.

A funding strategy for implementing and maintaining the project must embrace fully all the above diverse groups across an extended time horizon. It must also present a logical approach for identifying viable funding entities and potential partnerships. Following are elements of the strategy proposed and currently being utilized for funding the WMP.

- Identify and design one or more potential demonstrations or pilots for implementation. Specify long-term strategy for implementation of the pilot projects which relates to the overall El Rio WMP.

- Utilizing the analysis of potential funding partners, develop a funding scenario for the pilot projects. Include specification of constraints, application procedures, and other requirements on direct funding as well as cost-share, land exchanges and other indirect funding options.

- Define activities included in the recommended alternative requiring funding support. Specify funding requirements across a 5-to 10-year timeline.

- Develop a matrix of potential funding entities that traditionally fund projects or project components in the recommended alternative, including the educational pilot and programmatic demonstration pilot components.

9.6 NEXT STEPS FOR IMPLEMENTATION

To maintain momentum after the planning phase is concluded, an El Rio Implementation Committee should be created. The purpose of the committee will be to direct the implementation process, to afford greater coordination among agencies and provide mediation in areas where needed.

The *El Rio Implementation Planning and Funding Strategies Report* has been developed as part of the planning process and can be used to guide the work of the Implementation Committee. The Report outlines a variety of funding and implementation mechanisms and strategies.

As part of the planning process, the El Rio project team and its stakeholders explored the strategies in the above-mentioned report along with dozens of other implementation mechanisms. The options were evaluated based on their ability to satisfy the four components of the implementation strategy: community outreach, programs and policies, regulatory compliance and funding.

One new option that was identified during the evaluation process was the possibility of the creation of a special district. A special district (similar in structure to a community facilities district) could provide cost-share on flood control improvements, fund enhancements, ensure compliance with the WMP, apply for and hold regulatory permits, assume ownership, liability and responsibility for improvements and provide maintenance and site security. In addition, the special district would efficiently facilitate coordination among multiple jurisdictions and provide a means to maintain project continuity.

Since a special district is a new approach, the project team and stakeholders developed a brief analysis of the special district option. The analysis (see *Implementation Mechanism White Paper*) appears as an appendix to the *El Rio Implementation Planning and Funding Strategies Report.*

APPENDEX A BANK PROTECTION TREATMENTS

BANK PROTECTION TREATMENTS MEMORANDUM

INTRODUCTION

The purpose of this memo is to present bank protection measures that could be considered for structural and non-structural solutions that would be employed to mitigate erosion in the study reach of the El Rio Watercourse Master Plan. Types of bank protection investigated include traditional hard structures such as soil cement, riprap and gabions that have long design lives (50 to 100 years (Hollis et al, 1997)) and recently developed bioengineering treatments for bank erosion control.

TYPICAL STRUCTURAL TYPE BANK PROTECTION

Historically structural type bank protection measures have been the preferred method of bank protection because of their long design life and because their performance has repeatedly been hydraulically evaluated resulting in a high degree of confidence in their structural integrity. Structural type bank protection measures are grouped into rigid and flexible types. Examples of rigid types are soil cement, concrete, and grouted riprap. Some disadvantages of rigid armor listed by Hollis et. al. (1997) are: 1) provision to drain ground water must be included in the design to prevent excess positive pore water pressures, 2) difficult or impossible to construct underwater 3) are environmentally insensitive and 4) being inflexible bank armor could heave or subside resulting in failure. Examples of flexible types of armor are riprap and gabion baskets or mattresses. These types of flexible armor may be considered unaesthetic, however environmentally esthetic treatments such as soil cover with vegetative plantings have been applied with gabions.

When a high degree of confidence (due to public safety or high property value), is needed in a structure's ability to resist erosive flow conditions structural type bank protection should be utilized. Examples of structural solutions historically utilized in Maricopa County are listed in Table 1.

Table 1 Examples of Structural Bank Protection Measures

Bank Protection Type	Description	Comments
Soil Cement	Soil is mixed with sufficient cement to create a durable channel lining without the use of reinforcement material (Biedenharn, 1997).	Soil cement, a rigid bank armor will withstand high erosive velocities and is usually less expensive to install than concrete or grouted riprap. The construction of rigid armor underwater is difficult (increasing the cost of construction) or impossible (Biedenharn, 1997). Excellent erosion control measure however lacks environmental esthetics. Is not conducive to habitat enhancement.
Riprap	Angular graded stone consisting of a wide range of stone size placed on graded bank slopes at an engineered thickness. The larger stones resist hydraulic forces with the smaller stones adding interlocking support. (Biedenharn, 1997).	Can be designed with a high degree of precision and confidence (Biedenharn, 1997). Tree or brush plantings within the riprap could create localized scour conditions that could lead to bank failure.
Gabion Mattress	Wire mesh rectangular baskets tied together to form a mattress that is typically placed on a 2:1(horizontal to vertical) or flatter slope.	Treatment has flexibility to adjust to scour or settlement and remain in contact with the bed and bank (Biedenharn, 1997). Amenable to reestablishing vegetation along banks.

Figure 1. Example of soil cement Bank Protection

Figure 2. Example of gabion basket with volunteer vegetation.

Figure 3. Example of gabion mattress with volunteer vegetation.

Figure 4. Example of gabion mattress. Apron to mattress has been undermined

Figure 5. Example of Dump Riprap.

BIOENGINEERING BANK PROTECTION

Hollis et. al. (1997) relates that over the last decades there have been increased demands placed on the Army Corp of Engineers to incorporated vegetation into their erosion control measures instead of the use of hard traditional measures. Bioengineering is being considered on many projects. Hollis (1997) states that "Bioengineering is the combination of biological, mechanical, and ecological concepts to control erosion and stabilize soil through the sole use of vegetation or in combination with construction materials, similar to engineered materials". Through the use of natural vegetation bioengineering provides opportunities to enhance wildlife habitat, water quality and visual aesthetics.

Assets of bioengineering cited by Hollis (1997) are:

- Vegetation root system can reinforce soil
- Vegetation will dampen waves or dissipate wave energy
- Vegetation will enhance water infiltration
- Vegetation will deplete soil water by uptake and transpiration

- Dense vegetation can dissipate the energy near the bank and induce deposition

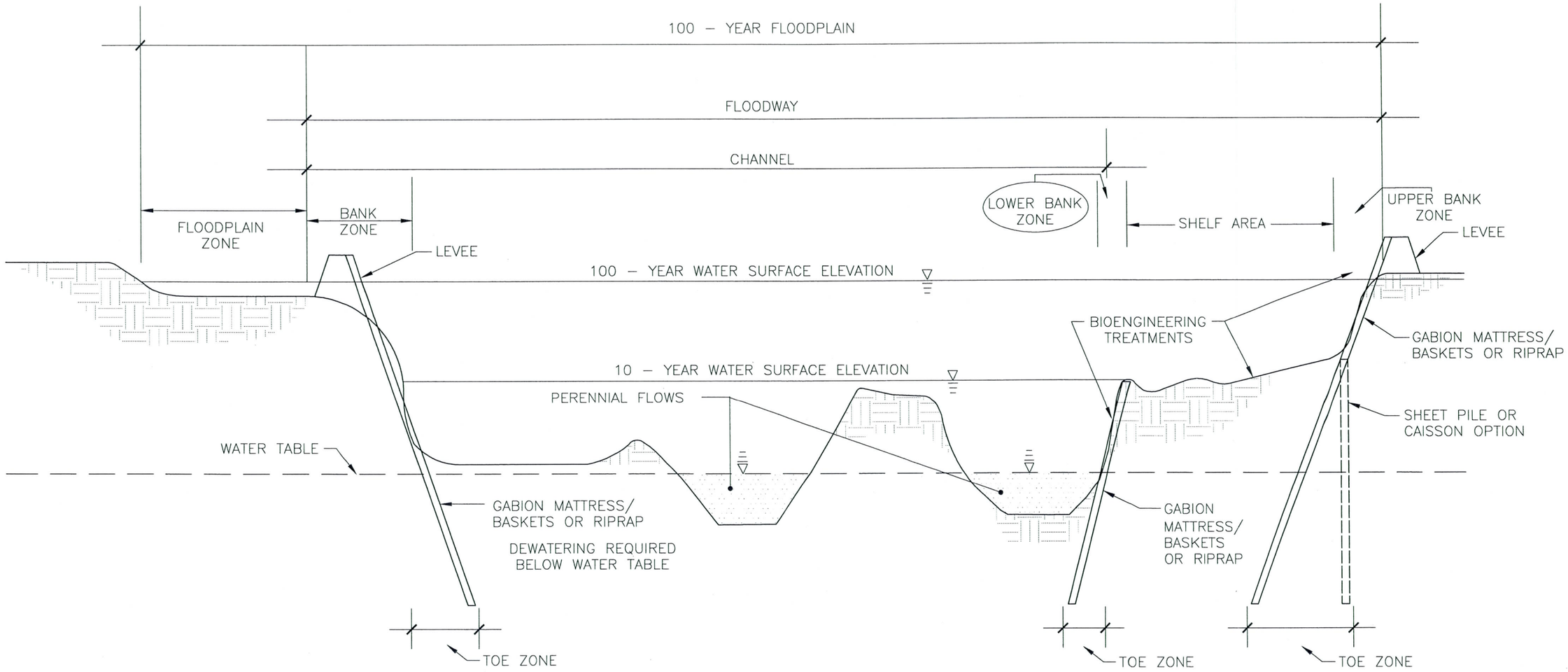
Limitations of bioengineering measures for bank erosion cited by Hollis (1997) are:

- Failure for vegetation to grow.
- Subject to undermining if tow down protection is not used
- Feeding on vegetation by wildlife and livestock diminishes erosion protection function.
- Lack of specific design guidance.
- Unknown performance conditions and failure thresholds.

Hollis et. al. (1997) recommends that bioengineering fixes should be arranged across a bank in elevation zones that delineate a plants or grouping of plants ability to withstand and dissipate the hydraulic conditions impinging on the bank. Bioengineering zones delineated by the COE for the upper Missouri River are the toe zone, splash zone, bank zone and terrace zone. The toe zone is a zone of high hydraulic stress located between the channel bed and the normal stage. Undercutting and bank failure occurs unless corrective measures are taken. The splash zone is exposed frequently to wave wash and erosive river currents and is located between normal high water and low-water stages. The splash zone section of the bank is typically inundated 6 months of the year. The bank zone is located above the normal high–water level and inundated for at least a 60-day duration once every 2 to 3 years. The groundwater elevation in the bank zone is typically near the soil surface due to its location to the normal stage surface. The terrace zone is located to the landward side of the bank and is subject to occasional flooding. Erosion with in the terrace zone can occur if the terrace is not covered with vegetation.

Features described to distinguish different bioengineering zones for the upper Missouri River are not applicable to the study reach of the Gila River. The Gila River morphology is defined primarily by channel forming events that included intermittent storm water runoff within the channel from events with a frequency up to and including the 10-year event and secondly by irrigation return flows, wastewater effluent, and high groundwater. The overall channel dimensions can be defined by the limits of the 10-year event and at locations is as much as 3000 feet wide. The 100-year floodplain which includes the area outside of the channel is as much as 6000 feet wide. The secondary flow (irrigation return and wastewater) to the river relative to storm water runoff is minor, amounting to less than 100 cfs and is typically confined to ponds and sinuous low flow channels located with in the channel banks. The secondary flow is perennial at locations where the ground water table is high. Dense vegetation with some diversity within the watercourse tends to be spatially associated with the secondary flow. Secondary flow supports the presence of the vegetation which influences hydraulic conditions that shape the morphology of the river.

The concepts of bioengineering zones can be applied to the study reach of the Gila River, however the zones will be different than what was developed for the upper Missouri River. A toe zone, upper and lower bank zones and a floodplain zone are proposed to define different erosion zones and possibly location of different types of erosion mitigation. Figure 6 depicts the different erosion zones in a cross section view. The toe zone is that area below the channel invert that is subject to scour. The vertical limit is set by estimating total scour at a specific location. Toe protection is applied at locations where the limits of undermining of channels banks and/or channel lateral migration needs to be set or controlled. The bank zone is subdivided into two zones, an upper zone and a lower zone. Typically the lower zone is the area along the bank between the channel bottom and the first break in slope (near the 10-year runoff event stage). The upper bank is typically defined as the area between the upper limits of the lower bank and the 100-year runoff event stage. Figure 7 depicts perennial in the toe zone. Figure 8 and 9 depict the lower bank zone and Figures 10 and 11 depict the upper bank zone. Along the northern bank of the study reach a shelf typically separates the upper banks. The bank zones are zones of high hydraulic stress that have erosive currents impinging on the zone. The lower bank zone is subject to more frequent stress than the upper zone. The floodplain zone is the landward area outside of the lower bank or upper bank that is inundated during a 100-year event. The shelf referred to above to as the area separating the upper and lower banks is within the floodplain area and is characterized by fine-grained floodplain deposits. The surface of the shelf can be relatively flat or undulating and irregular. During a 100-year event depth of flow in shelf areas are 5 to 8 feet where as in other floodplain areas the depth of flow is less than 5 feet.



→ → → SOIL MOISTURE DECREASE → → →

STRUCTURAL ARMORING

TOE ZONE, LOWER & UPPER BANK ZONE

SHEET PILE
CAISSON
RIPRAP
GABIONS

LOWER BANK ZONE

WETLAND PLANTS
COIR ROLL

BIOENGINEERING TREATMENTS

SHELF AREA

ARROW WEED (WATER TABLE 0–3 FEET FROM SURFACE)
SEEP WILLOW (WATER TABLE 0–3 FEET FROM SURFACE)
COYOTE WILLOW (WATER TABLE 3–10 FEET FROM SURFACE)
COTTONWOOD (WATER TABLE 3–10 FEET FROM SURFACE)

UPPER BANK ZONE

MESQUITE
SALT CEDAR
NATIVE GRASS
FORBS
SHRUBS

FIGURE 6

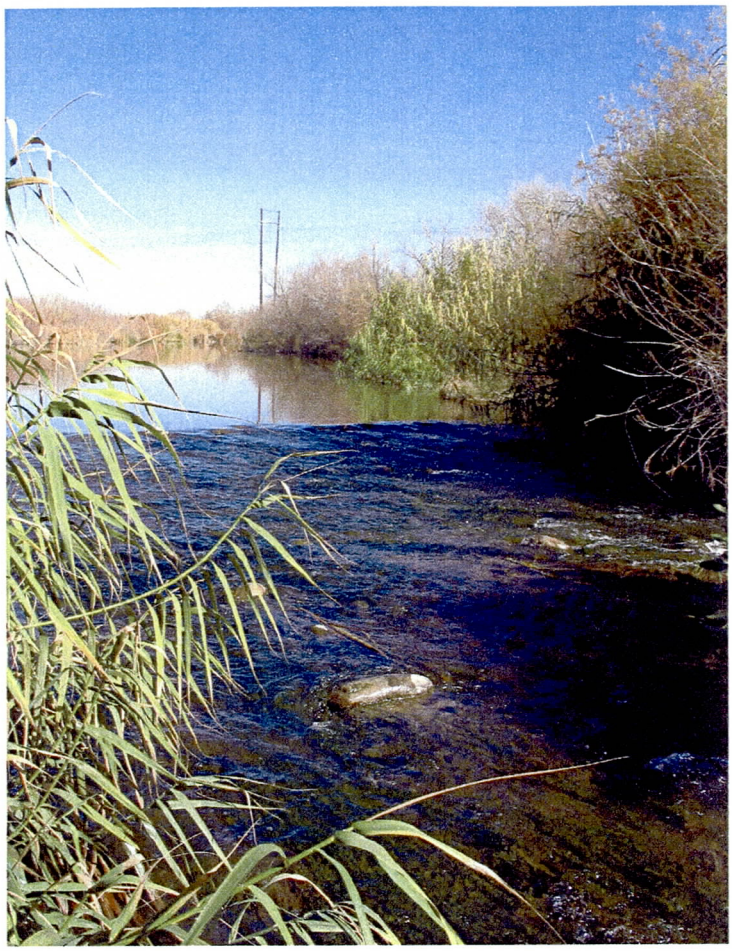


Figure 7. Perennial flow in the toe zone.

Figure 8. Example of lower bank zone.

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Figure 9. Example of lower bank zone.

Figure 10. Example of upper bank zone.

Figure 11. Example of upper bank zone.

Bank erosion bioengineering type solutions for the study reach should be applied at locations where a high degree of confidence in the solution to provided erosion protection is not required. Examples where the treatment may be applied would be adjacent to proposed wetland areas where the loss of vegetation due to a large runoff event would be acceptable or in areas where existing or proposed structures are located out of the erosion hazard zone. Examples of bioengineering solutions that may be applied to the study reach are listed in Table 2 and the erosion zones that the solution may be applied to are depicted in Figure 6.

Table 2 Types of Bioengineering Bank Erosion Control

Bioengineering Stream Bank Erosion Control	Description	Comments
Log, Rootwad and Boulder Revetments (Figure 12)	Boulders and logs with root masses attached placed in and on stream banks to provide stream bank erosion, trap sediment, and improve habitat diversity	Can be used with soil bioengineering systems and vegetative plantings to stabilize the upper toe zone/lower bank zone and ensure a regenerative source of stream bank vegetation. Life of application can be limited due to climate and species used (Stream Corridor Restoration, 1998). Can create local scour and erosion. Placement is labor and heavy equipment intensive.
Live Stakes (Figure 17)	Live woody cuttings which are tamped into the soil to root grow and create a living root mat that stabilizes the soil by reinforcing and binding soil particles together, and by extracting excess soil moisture.	Can be used to enhance conditions for colonization of local plant communities. Requires structural toe protection. Applicable in the lower bank zone and shelf area.

Table 2 Types of Bioengineering Bank Erosion Control (Cont.)

Bioengineering Stream Bank Erosion Control	Description	Comments
Joint Plantings	Live stakes tamped into joints or openings between rocks (riprap) which have previously been installed on a slope or while rock is being placed in the slope.	Survival rates can be low due to damage to the cambium or lack of soil/stake interface (Stream Corridor Restoration, 1998). Not applicable where filter fabric is used. Can create local scour, damaging structural integrity of bank stabilization measures
Vegetated Gabions (Figure 15)	Wire-mesh rectangular baskets filled with small to medium size rock and laced together to form a structural toe or near vertical wall. Live branch cuttings are placed on each consecutive layer between the rock filled baskets to take root, consolidate the structure and bind it to the slope.	Useful for stabilizing steep erosive slopes where a structural solution is required. Appropriate where channel side slopes must be steeper than what would be required for other structural stabilization measures such as riprap and gabion mattress's (Stream Corridor Restoration, 1998). Vegetation plantings may be problematic when filter fabric is used in conjunction with gabion baskets. Applicable in the upper and lower bank zones.

Table 2 Types of Bioengineering Bank Erosion Control (Cont.)

Bioengineering Stream Bank Erosion Control	Description	Comments
Dormant Post Plantings	Plantings of cottonwood, willow, poplar, or other species embedded vertically into stream banks to increase channels roughness, reduce flow velocities near the slope face and trap sediment (Stream Corridor Restoration, 1998).	Soil horizon for plantings must be a least 4 feet thick. Post plantings should penetrate into the water table. Livestock and beavers should be kept away form the plantings for the first growing season. Treatment is applicable in the lower part of the bank zone (Hollis et al, 1997) and shelf area.
Brush Mattress (Figure 16)	Combination of live stakes, live facines, and branch cuttings installed to protect stream banks. Contents of mattress eventually spouts and establishes numerous individual plants (Stream Corridor Restoration, 1998).	Placed in the lower zone above toe protection. After placement the brush mattress is covered with soil. (Hollis et al, 1997).
Bank Cribwalls (Figure 13)	Crib cells constructed with logs with, abutment logs extending into the bank for structural stability Used to protect streambanks at the toe while at the same time providing excellent overhead cover for fish (Hollis et al, 1997).	Labor intensive. Constructed in the toe zone/lower bank zone (Hollis et al, 1997).

Table 2 Types of Bioengineering Bank Erosion Control (Cont.)

Bioengineering Stream Bank Erosion Control	Description	Comments
Live Fascines (Figures 16 and 17)	Dormant branch cuttings bound together into cylinder shaped bundles and placed in trenches along the bank that parallel the stream course (Hollis et al, 1997).	Also referred to as wattling. Typically placed in the lower bank zone along with other bioengineering treatments.
Coir Rolls (Figure 14)	A roll of aquatic plants wrapped in coconut fiber or a biodegradable fabric. The fiber or fabric traps sediment as the plant roots develop.	Applicable in wet land areas within the upper toe zone and the lower bank zone.

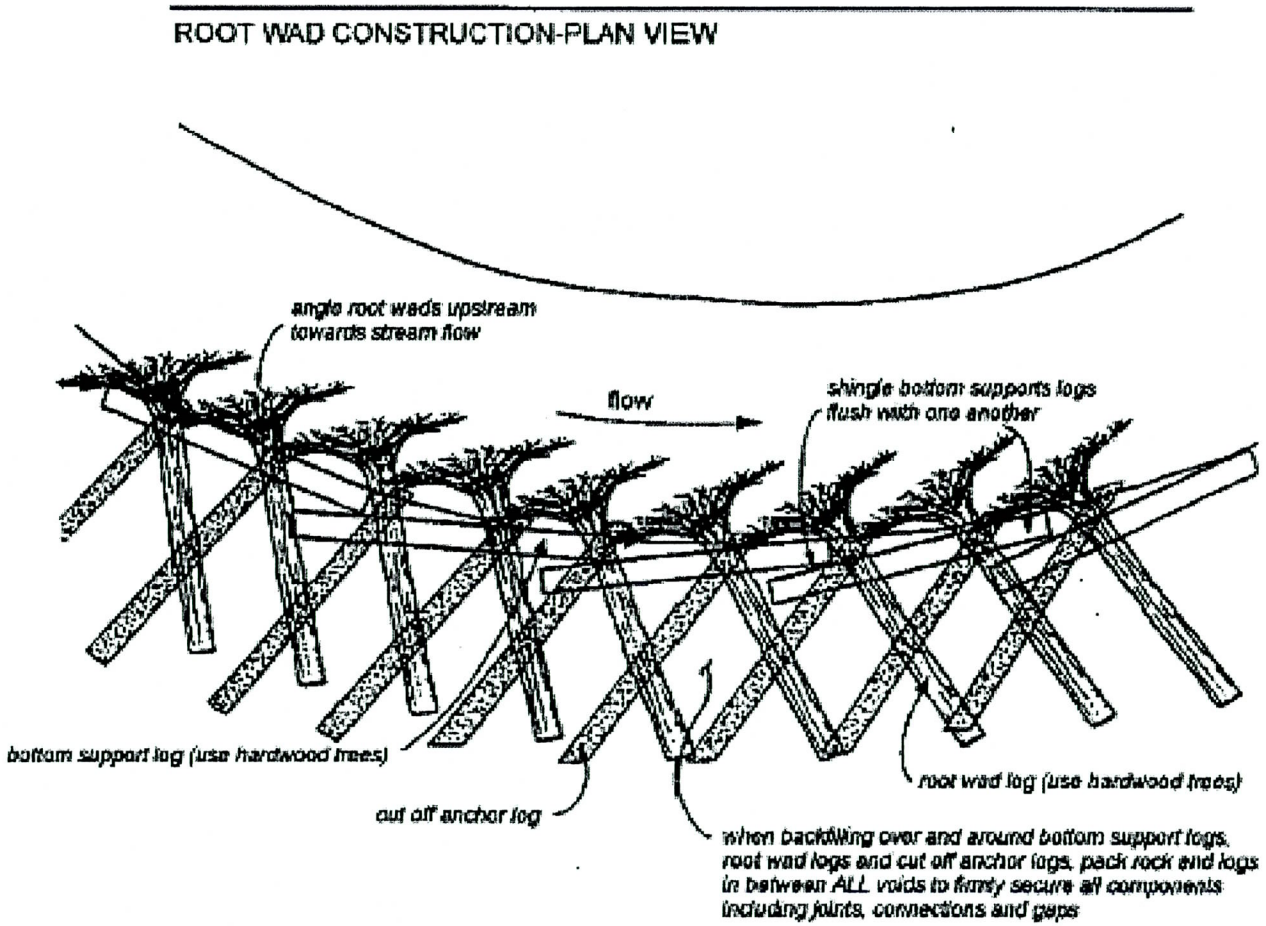


Figure 12. Schematic of root wad bank protection from (Hollis et al, 1997).

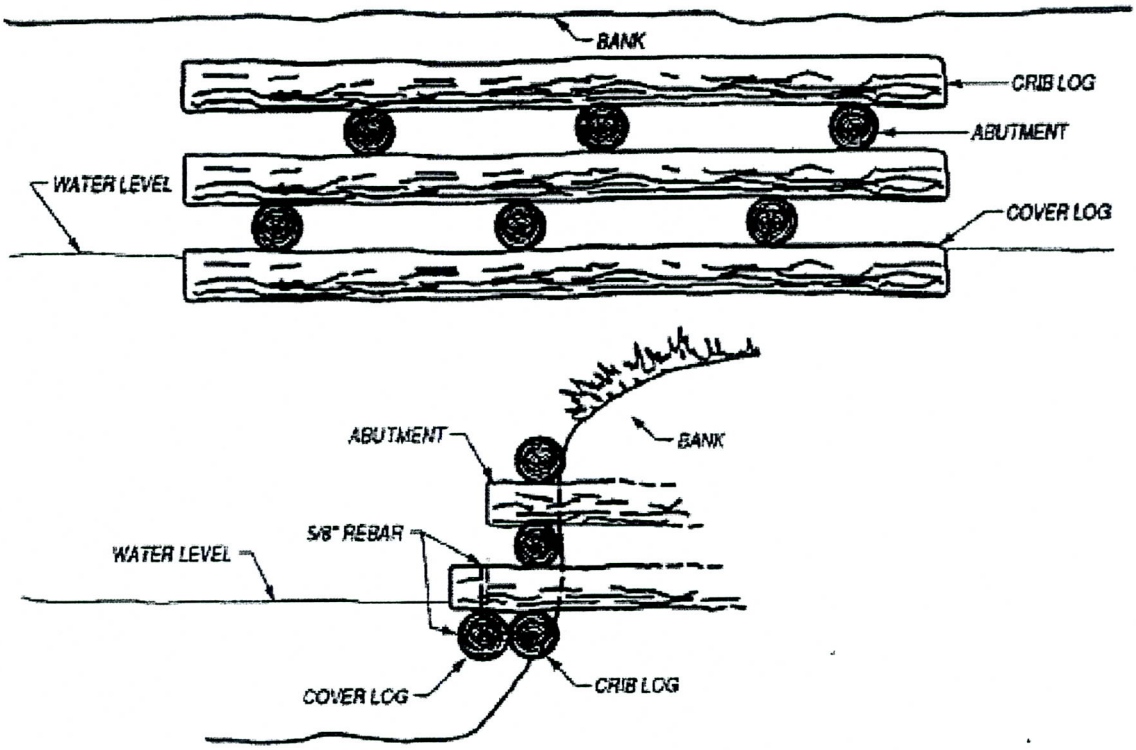


Figure 13. Bank crib with log cover schematic from (Hollis et al, 1997).

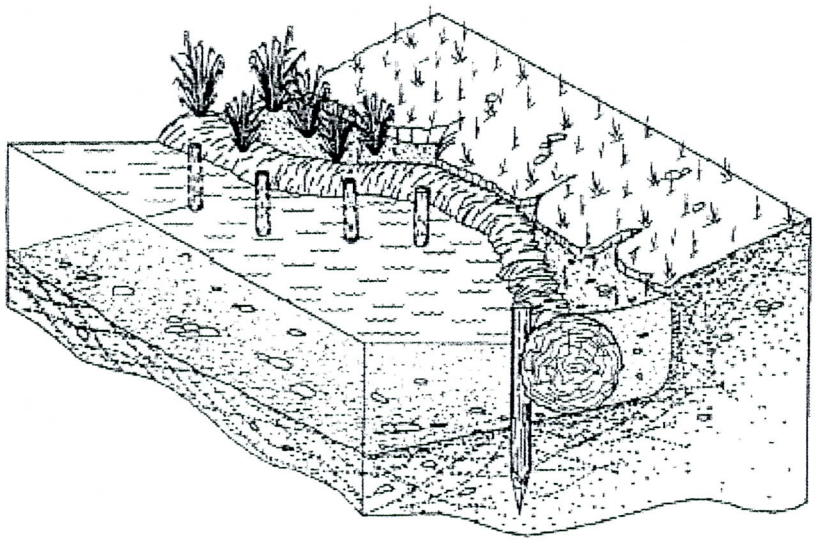


Figure 14. Example of a coir geotextile roll application from (Hollis et al, 1997).

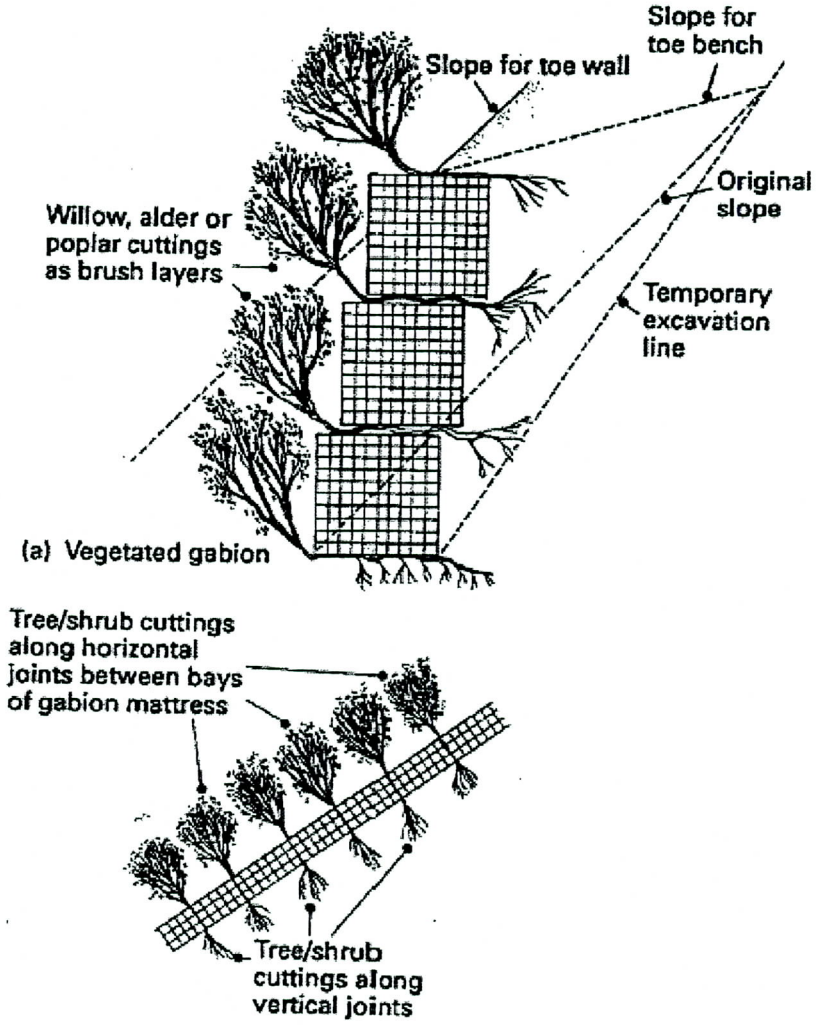


Figure 15. Gabions with tree cuttings (from Hollis et al, 1997).

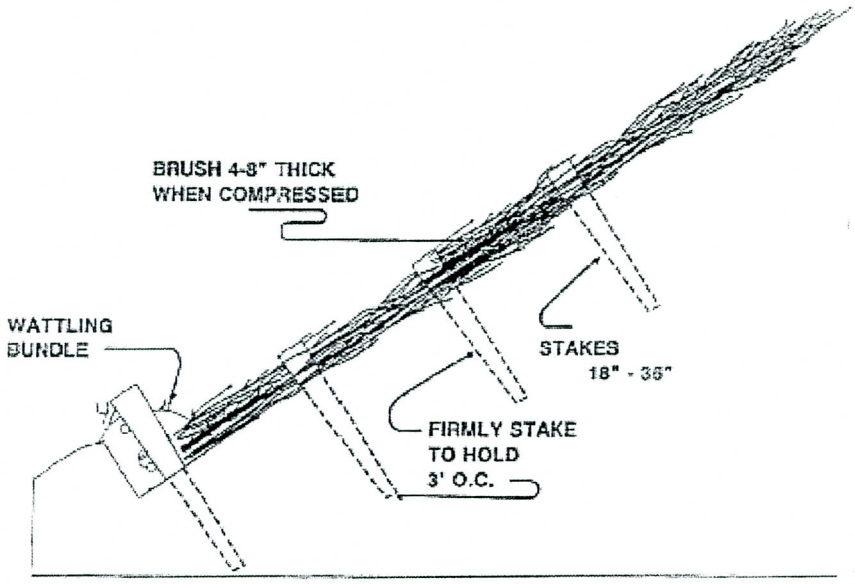


Figure 26a. Profile view.

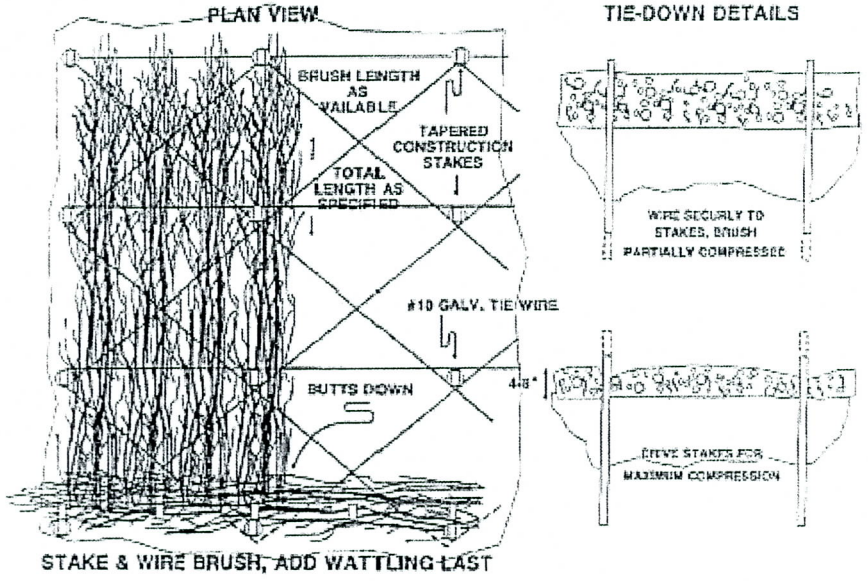


Figure 26b. Plan view.

Figure 16. Schematic of brush mattress and wattling (from Hollis et al, 1997).

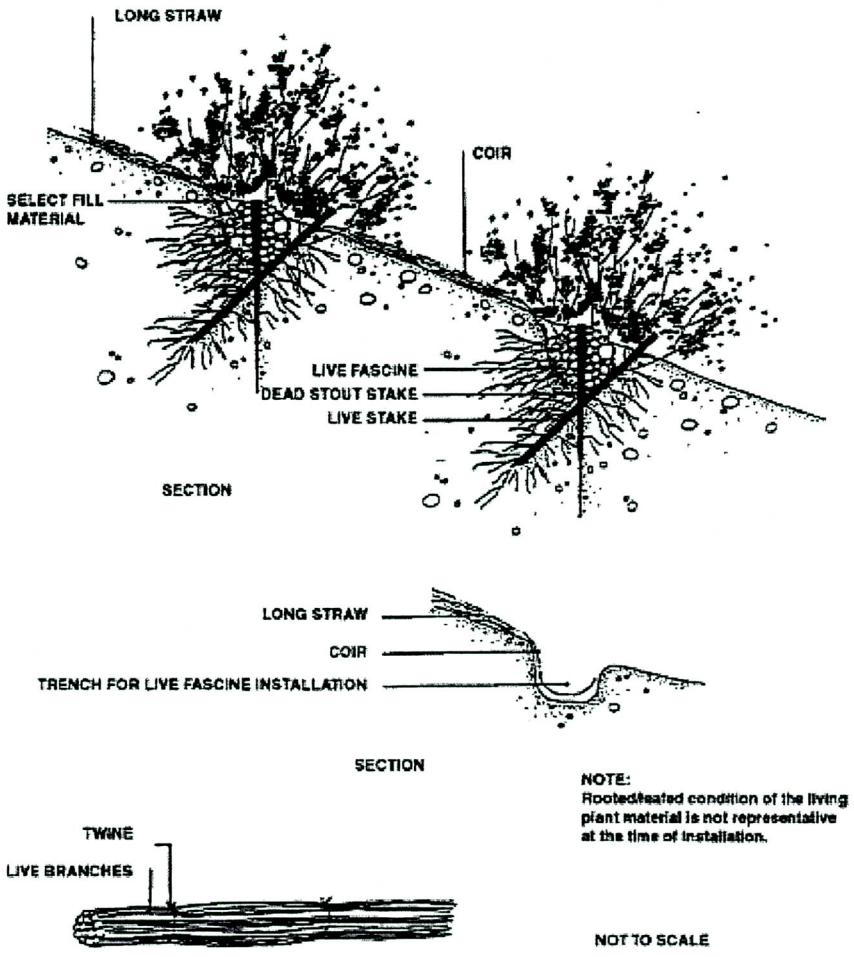
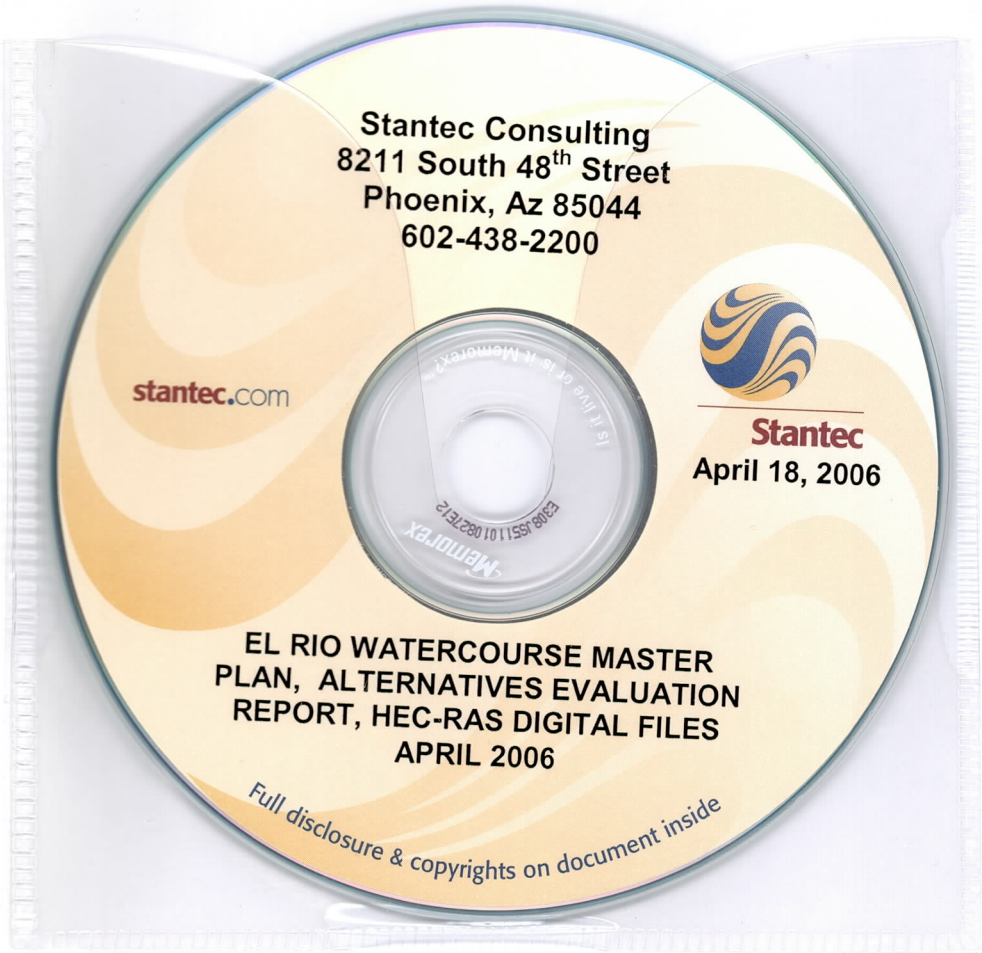


Figure 17. Schematic of live fascine bundles application (from Hollis et al, 1997).



APPENDIX B HEC-RAS DIGITAL FILE

APPENDIX C VEGETATION ENHANCEMENTS

Technical Memorandum

El Rio Water Course Master Plan: Environmental Enhancement Implementation, Operation, and Maintenance Considerations Including Summary Results from the Soil and Water Quality Screening and Conceptual Planting Cost Estimates

Final Report

Authors:

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Tempe, Arizona

WASS Gerke + Associates, Inc.

Phoenix, Arizona

Date: December 6, 2005

Introduction

The El Rio Water Course Master Plan includes in its recommendations that select Environmental Enhancement areas be considered when implementing the plan. These Enhancements will involve the creation of new habitat, replacement of exotic and invasive vegetation with suitable native stock, and the protection and augmentation of existing low to medium value habitat. Selected enhancements may also serve the role of erosion control and bank stabilization at sites. Such enhancements will include establishing terrestrial, wetland and aquatic plant communities in large areas which would likely take the form of the following vegetative features:

Cottonwood – Willow Corridors

Mesquite Bosque

Riparian Wetlands w/ Emergent Marsh Features

Open Conveyance – *Atriplex* Series (Fine Soils)

Open Conveyance – *Sacaton* Series (Coarse Soils)

Pond Edge Stabilization (Bio-engineering options)

There is much to consider when planning, designing, constructing, and operating landscape scale vegetation communities. It is paramount that the physical setting be such that the system is sustainable and allows for recruitment of species over the life of the project. This means that water supply, water quality, site soils and topography are designed to provide a platform that satisfies the needs for the vegetative community to be established. This is turn allows operators/managers of the systems to minimize maintenance costs in the long term while the system provides the habitat functions and roles intended.

This document is intended to provide a discussion of some of the issues to be considered when designing and implementing the Environmental Enhancements of the El Rio Water Course Master Plan. Much of the guidance presented is general in nature because the proposed Enhancements have not been designed nor have final locations been decided upon. The next section provides some thoughts on establishment and initial site layout. This is followed by a discussion of some operational concerns, including irrigation method and some thoughts on salt management. Next, some thoughts regarding long-term monitoring of the Enhancement areas are presented that can be used to gauge the health of the system(s) and to serve as a trigger for maintenance actions. A section regarding the results of preliminary soil and water quality screening in the proposed Enhancement Areas is presented with an all raw data provided in an appendix. Finally, per acre level of magnitude cost estimates are included for the proposed environmental Enhancement features.

Establishment and Layout

Several considerations should be kept in mind when laying out the Environmental Enhancement features. To the extent practicable (i.e. considering depth to groundwater and the ability to route surface waters for irrigation) working with the existing topography is a good choice and will often result in less earth moving which in turn reduces cost. Protection of existing desirable vegetation and landforms is paramount and good designs should adopt this premise.

When establishing riparian vegetation such as Godding's Willow (*Salix gooddingii*) and Fremont Cottonwood (*Populus fremontii*) or wetland/aquatic plants, water is key. Monitoring of restoration project features indicates that the most robust growth and sustainability is linked to adequate water supplies. These species only occur and persist naturally in moist and saturated soil conditions; hence the restoration designer and operator must ensure water deliveries for success to be achieved.

In areas where the depth to groundwater exceeds that needed to support cottonwood and willow growth, e.g., > 3.3 ft (1 m) for willows, > 10 ft (3 m) for cottonwoods; irrigation should be delivered via open channels. Such channels can be un-lined or partially lined depending on the amount of water available and the aerial extent of irrigated land. Irrigation using open channels is a method that allows delivery of water to specific plants and or zones. In addition, the conveyance way itself serves as a platform for the recruitment of volunteer plants which should be encouraged as long as they are desirable species. For newly installed material plant cottonwood and willow poles within 3.5 feet (1 m) of the open channels within moist to saturated soils.

The scale of water delivery features necessary to support cottonwood/willow can be as little as 12-inches wide and 12 inches deep, to several feet wide and deep. The frequency of delivery will likely be on the order of 75% wet and 25% of the time dry. Timing of irrigation deliveries can be adjusted (increased) to accommodate plant stress during dry months and subsequently reduced to match natural temporal rainfall/runoff patterns. In addition, irrigation delivery can be timed to optimize recruitment of desirable native vegetation, e.g. cottonwood willow, instead of less desirable species such as salt cedar.

The site should be laid out with future recruitment in mind. Initial plantings should be completed on the upwind side of the site first, if possible. If present, existing mature vegetation should be protected in place. Both the initially planted stock and any existing mature stock will serve as a seed source for subsequent years, especially if located on the upwind side of the site and if recruitment areas (areas of disturbed soil that can be irrigated) are prepared on the downwind side at appropriate time(s) of the year.

Due to the rapid growth of cottonwood and willow species, large containerized stock is not necessary. Dormant live cuttings or seed is recommended for establishing these species. Larger poles can be used to provide initial size-class diversity. As stands mature, additional poles can be planted or areas for recruitment by seed can be prepared.

Mesquite can be slower growing and to establish size-class diversity, large specimen tress can be planted in mesquite bosques or drier areas of riparian sites.

Most importantly, the managers of these enhancement areas must allow the vegetation to establish within and adjacent to the delivery channel. If adequate water is available, the channels can be extended or braided to increase the amount of irrigated land and hence increase the amount of riparian area.

The ground surface in open areas of the site(s) and those located under the canopy of trees should be left with shallow depressions. Such depressions will capture and pond water which in turn will encourage the development of herbaceous vegetation. To increase patch diversity, allow areas of xeroriparian species to exist on the drier portions of the Enhancement zones.

As with the riparian areas, the drier Mesquite Bosque enhancement features should be designed such that minimal earthwork is required and that existing desirable vegetation is protected in place. The new plantings should be laid out such that they compliment the existing vegetation and take advantage of existing site topography. The Bosque should be laid out as a mosaic of trees, open grass land, and interconnecting drainages. The use of long tube-pot saplings is encouraged for the majority of the Bosque tree material. To provide immediate size-class diversity, it is recommended that 4 to 5 large containerized

Mesquite trees per acre are interspersed among the long-tube pot grown starts. Hydroseeding or using plugs to establish grass lands that will provide conveyance capacity will compliment the enhancement area and add to its functionality within the floodplain and river corridor.

Again, periodic irrigation via either constructed or existing drainages is recommended because the delivery channel(s) itself will provide a platform for the establishment of moist soil and wetland plants. Such features add to the plant diversity and hence increase the overall habitat benefit of the Bosque. Further, the drainages will transport seed from stock growing within or upstream of the bosques which will promote the continued recruitment of plant species and add to the sustainability of the area over the life of the project.

Some of the enhancements will take the form of wetland marshes. These features will provide an important transition from the aquatic to the terrestrial environments. Initial layout of the wetland features should take into consideration water source location, depth to groundwater, and local topography. Cost savings will be realized if wetlands can be sited in areas that require minimal grading, e.g. existing depressions in the landscape, and do not have to be lined, e.g. connected to groundwater. Such features can also be used to replace large areas of *Tamarix* if wetland vegetation is established to preclude re-infestation, and/or water depths are maintained $\geq$ 3.5 feet. The location of wetland and aquatic features could be such that they serve as fire-breaks within the active channel or in the adjacent flood plain areas.

Open space, for the conveyance of flood flows are also recommended Environmental Enhancements in the El Rio project reaches. There are two variations proposed, one suitable for highly saline fine soils (Atriplex series), and one for more coarse-grained sands and gravels (Sacaton series). Such communities should be sighted in the more xeric portions of the project area and could likely be used to replace mono-typical stands of salt cedar in the floodway and floodplain areas. Atriplex communities are exceptional for erosion control, wildlife forage, and reclamation of saline lands.

Operations

Once the enhancements have been sighted, designed, and constructed, operational considerations will come into play. Many of the enhancements use vegetation adapted to periodic perturbations, e.g. flood and fire. Because the Gila River and its tributaries are highly controlled, these inputs of energy are absent and must be replaced by operations and maintenance activities. The following text provides the reader with some activities that could be used to increase the health and vigor of the communities as well as their overall sustainability while they mature.

A potential activity is to periodically excavate narrow strips (3 to 12-feet wide) of earth connected to the irrigation delivery channels to provide shore-bird habitat and to provide areas for volunteer tree species to establish. This activity should be conducted during the late spring and coincide with the seed fall from cottonwood and willow tree species.

Creation of flooded areas adjacent to / fed by the irrigation channels will allow for ground cover to develop in addition to deep watering riparian tree and shrub species. The frequency of flooding will depend upon the vegetation to be established and maintained in such areas. In all cases, standing water should not be allowed to persist for more than 36 hours in flood irrigation areas to prevent breeding of floodwater and stagnant water mosquitoes.

Assess the need to remove plants instead of immediately removing them from the site just because they have not been there historically. In some cases, the vegetation is serving a stabilization or habitat role, e.g. fan palms were not historically in the region, but now grow in moist areas and serve as refuge for myriad insect and birds species. The presence of species not historically present at the site may indicate that environmental conditions have changed or are changing. This observation should lead to investigation as this information may be used to assess the need for soil or irrigation water amendment, a change in vegetation coverage, and/or the need for other long-term vegetation fitness measures to be implemented at a site(s).

As such, the need to remove "weedy" species should be assessed considering a number of aspects. Flood control conveyance must be maintained and hence, the assumed vegetation densities and structure used to design flood control features should not be exceeded over the life of the project. If the "weedy" species do not compromise flood control goals, there might not be a reason to remove them, especially since "weeds" often provide functions such as erosion control, cover, food, and refuge for animals.

The same assessment should be done for all "volunteer" plants that may occur at the Enhancement areas. It is likely that such plants provide wildlife habitat and have functional roles on the landscape. Their removal should consider the benefits as well as the detriments, for example increased fire hazards, or when amount of volunteer plants change the character of the Enhancement. Again, such change in plant community could indicate that the environment has changed and hence favors the newly established "volunteers". Such change should be investigated and a cause(s) defined. It may be that the new suite of volunteers may be the "best" vegetative community for the site from a sustainability standpoint.

For the first several years after establishment, weed removal should be investigated prior to taking action. Such an investigation should develop an experimental protocol which would monitor the effects of species removal on habitat value, erosion control, and aesthetics. Finally, as long as they do not pose a danger to visitors, dead-snags, e.g. large cottonwood or willow trees that have expired, should be left in place to serve as habitat for raptors, owls, egrets, and herons.

If it is deemed necessary, e.g. poor fitness, lack of recruitment, loss of flood control conveyance, etc., vegetation can be removed from the enhancement areas. This can be accomplished using mechanical, chemical, or fire-related techniques. Mechanical removal refers to stem removal followed by root plowing and includes mowing, sawing, chaining, or ripping, hand pulling and bulldozing. Mechanical removal will result in large amounts of biomass needing to be disposed of either on or off-site. Obviously offsite disposal will increase O&M cost substantially. To help defray such costs, small amounts of biomass could be placed in debris piles around the site which adds to the overall diversity and complexity of the site. This in turn can increase the overall habitat value of the Enhancement area.

Chemical treatment will also result in biomass needing to be disposed of at off-site facilities due to potential unintended release of the chemical from decaying vegetation. Depending upon the plant species and aerial extent, several options for chemical treatments do exist. One should note that any herbicide application must be done by State certified applicators working for a licensed Qualifying Party. Large individual trees or clumps of large trees can be treated with high volume foliar spray methods. Smaller clumps or individual trees can be treated using low impact herbicide application to cut-stumps. For plants with stems in the 1 to 2 inch diameter size class, low dosage herbicide application to the basal area bark can be effective. For large areas, e.g. greater than 1 acre, consideration should be given to herbicide application by fixed wing aircraft or helicopters. The choice of method will dictate the costs and will often be site specific.

Fire has been used as a management tool for many years, and the opportunity to utilize this method in rehabilitating select vegetative features of the Enhancement areas should be explored. Although fire will not be a management tool in upland areas, it can be a particularly useful tool in rehabilitating overgrown emergent marsh areas.

Prescribed burns are typically used in the "habitat" management of wetland marsh systems for the following four reasons (Wright and Bailey 1982, Gordon et al. 1989):

1) To make new green shoots, roots, and rhizomes of grasses and sedges available to geese.

2) To expose fallen seed for ducks.

3) To make wetlands suitable for ducks, muskrats, and nutria by eliminating sour marsh conditions of flooded and decomposed organic matter, and impenetrable growth of climax species of plants such as common reed, bulrush, sawgrass, cordgrass, and cattail, and by promoting growth of seed producers.

4) To create deep pools and edge for nesting and feeding waterfowl.

In general, there are three classes of prescribed burns in wetlands, A) Surface/cover burns, B) Root burns, and c) Peat burns. Surface/cover burns are typically cool fires used to remove organic material. Root burns are much hotter and actually kill the roots. These are used to select for desirable species and eradicate, at least for some time period after the burn, undesirable species. The peat burns really won't apply here, but they are used to establish open-water areas in large peat bogs. The literature suggests almost any time of the year is suitable for burning, depending on objectives. In general, the best time to burn is immediately prior to the growth of desirable species although the goals and species specific reaction(s) to burning should be taken into account. For instance, cattail is controlled best by draining, burning, and re-flooding of the wetland during the summer (Mallik and Wein, 1986). On the other hand, the Kingman, AZ treatment wetlands are typically burned during late January to late February. As another example, prescribed marsh burns in the early spring provide succulent shoots and favor muskrat populations. Conversely, summer or fall marsh burns reduce muskrat densities by destroying house-building supplies (Daiber, 1986).

In any case, burned areas should be re-flooded immediately so that a vapor zone (approximately 3") will develop and protect the burned stubble which re-sprouts quickly. Marsh areas and the surrounding uplands should be burned on a rotating basis with no more than approximately 33% of the system burned at any one time.

Extensive burning should be avoided during and just prior to nesting seasons (typically February to August, but especially April, May, and June. Extensive burning should also be avoided in systems or areas subject to erosion problems. Finally, extensive burning is not recommended during drought years for systems that rely upon natural precipitation and/or runoff to satisfy the hydroperiod.

The following are just a few considerations necessary in conducting a prescribed burn.

1) Pre-Burn Preparation

    a. Site Preparation & Fire Breaks

    b. Equipment Considerations, e.g. use of foam retardants

2) Fuel

    a. Decision to burn is made 1-year in advance

    b. 1.1 to 2.2 mt/ha of fuel is desirable

3) Weather

    a. Air temperature < 15.5 °C

    b. Relative Humidity 20 to 40% unless winds are < 10 kph and air temperature is < 4.4 °C.

    c. Winds typically 10 to 24 kph and steady.

    d. Defer burning for at least 5 days after ≥ 0.25 cm of precipitation.

4) Smoke Management

5) Personnel

    a. Fire Teams

    b. Suppression Team

    c. Safety

6) Ignition Source

    a. Ground versus aerial

    b. Drip Torch - gasoline and diesel oil (3:1); kerosene and diesel oil (2:3); others?

7) Firing Patterns

    a. Fire Line

    b. Main Fire

    c. Spot Fires

8) Burn

a. Decision is made day before after reviewing a spot weather forecast

b. Notify Crews and Others

c. Stage during the morning of the proposed burn

d. Obtain another spot weather report

e. Set and observe test fires for fuel, burning patterns, and smoke management

f. Decision to burn is then reevaluated

9) Reporting

a. Detailed Report on conditions and results should be made after each burn event.

b. Photographs of area pre and post burning should be made.

c. Water quality monitoring

d. etc.

Monitoring Considerations

Once constructed, the El Rio Environmental Enhancements will require a monitoring component to guide management practices and maintenance activities. Several components should be looked at including flood conveyance capacity, vegetation fitness, soil quality, irrigation water quality, and wildlife usage. The following section provides some thoughts regarding the monitoring time frame and what could be monitored.

Monitoring of certain aspects should be initiated before the start of construction. Baseline soil chemistry and irrigation water quality should be developed based upon the parameters tested for in the El Rio Soil and Water Screening effort described later in this document. After construction, monitoring should be expanded to include the installed vegetation and any constructed features such as culverts, inlets, outlets, irrigation conveyances, piping and pumps. Rigorous monitoring should occur for the first three years after installation to fine tune the project facilities. One should continue to monitor the project site for at least five years. During this period, the site does not need to be as frequently or intensively monitored as it was during the initial phase. The aspects to be monitored include abiotic conditions, e.g. soil moisture, depth to water table (or depth to saturated soils), and stream flow rate and permanence in delivery channels and the main river channel. Monitor the electrical conductivity and nutrient content of soil and water

at various micro sites throughout the project area, at least annually for the life of the project.

Monitoring of the plant communities should also be conducted. Several parameters to consider include: tree height and mortality, tree density and seedling recruitment rate, herbaceous cover, vegetation volume, vegetation height, and plant species richness. The frequency of monitoring could be once or twice per year. One could also include monitoring at the ecosystem-level and focus on riparian functions such as litter decomposition.

Monitoring the abundance and species richness of animals such as insects and birds will help to assess whether the installed habitat is performing the intend functions. Such an effort could take the form of monitoring the reproductive success of select bird species, to ensure that the habitat is not serving as a population 'sink'. Or, identify a particular indicator of riparian habitat quality (such as particular taxa) and focus monitoring efforts on those species

Since the El Rio Environmental Enhancements will be subject to flooding, fire, etc. it is advisable to develop a procedure for monitoring the impacts of such events to aid in rehabilitating the site if necessary. As such it is recommended that a mechanism be developed that allows a team to rapidly monitor the impacts in response to environmental extremes, such as after a flood event, fire, extreme drought, or extreme high temperatures.

The Enhancement areas will likely be frequented by humans for a number of activities that can be deemed desirable and un-desirable. It is advisable to monitor usage by people and to assess the benefits they derive from visiting such a feature. Monitoring visitation will also help to gage the need for rubbish removal, the propensity of illegal dumping and the need to regulate the number of people or locations that they visit.

Finally monitoring efforts should be coordinated such that groups monitoring animals are aware of efforts by groups monitoring hydrology and vegetation to ensure interaction and communication among the various scientists and environmental managers responsible for the site(s).

El Rio Enhancement Area(s) Soil and Water Quality Screening Results

Screening of water and sediment quality at selected Environmental Enhancement locations within the El Rio reach of the Gila River was conducted in order to assess the sustainability of anticipated aquatic, riparian, or desert adapted vegetative features to be located therein. There were significant unknowns as to where such features will be implemented, as such, a screening level of effort was conducted at seven (7) sites (see Figure 1 for map sites and general locations of where samples were taken). Five (5) corresponded to the enhancement sites shown on the project Enhancement Area Maps, while two were water supply. In addition, water was sampled from the Arlington Canal immediately upstream of the MC 85 Bridge and from Gila River stream flow at Map location 3. Table 1 provides the Map number and brief description of all sample

locations. Global positioning coordinates are provided for all sampled sites in Appendix A.

Table 1. El Rio Water Course Master Plan Environmental Enhancement Water and Soil Screening Sites.

Map Number	Description	Sample Type (S or W)
1	Existing Salt Cedar – Planned Mesquite Bosque	Soil
2	Existing Salt Cedar – Planned Wetland Marsh & Pond	Soil
3	Existing Salt Cedar – Planned Wetland Marsh & Pond	Soil
4	Water Supply, N. Bank at Watson Rd.	Water
5	Existing Cottonwood/Willow – Planned Augmentation Area	Soil
6	Water Supply, N. Bank at Dean Rd.	Water
7	Salt Cedar R&D Site	Soil
1	Arlington Canal at M.C. 85 Bridge	Water
3	Gila River Flow	Water

Water Sampling Results

Water was sampled using a "grab" technique from four locations (see Table 1 above) and analyzed for conventional chemical parameters including organic compounds and selected heavy metals. These data are summarized below in Table 2 and the following text will provide a cursory discussion of the results. Raw data is included as an Appendix to this document.

Table 2. El Rio Water Quality Screening Data Results Summary.

	Site			
	Arlington Canal @ MC 85	Gila River Flow	Watson Rd.	Dean Rd.
Parameter	**1**	**3**	**4**	**5**
General Chemistry				
Conductivity (mmhos/cm = dS/m)	4.660	6.160	5.450	2.370
pH	7.7	7.9	8	7.7
TDS (mg/L)	3070	3900	3530	1380
NH_4-N (mg/L)	0.22	0.3	0.12	0.9
TKN (mg/L)	2.34	2.71	0.81	2.13
NO_2+NO_3-N (mg/L)	9.82	0.41	8.73	3.85
Total Nitrogen (mg/L)	12.16	3.12	9.54	5.98
Total Phosphorous (mg/L)	0.663	0.148	0.585	1.3
Organic Compounds				
Chlorinated Herbicides (8151A)	ND	ND	ND	ND
EDB/DBCP (EPA 504)	ND	ND	ND	ND
Carbamate Pesticides (EPA 531.3)	ND	ND	ND	ND
Chlorinated Pesticides (EPA 608)	ND	ND	ND	ND
Heavy Metals (Total)				
Al (mg/L)	0.8	< 0.5	0.8	0.8
As (mg/L)	0.008	0.007	0.006	0.006
Be (mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
Cd (mg/L)	< 0.002	< 0.002	< 0.002	< 0.002

Table 2. Cont. El Rio Water Quality Screening Data Results Summary

	Arlington Canal @ MC 85	Gila River Flow	Watson Rd.	Dean Rd.
Co (mg/L	< 0.01	< 0.01	< 0.01	< 0.01
Cr (mg/L)	< 0.01	< 0.01	< 0.01	< 0.01
Cu (mg/L)	< 0.01	0.01	< 0.01	< 0.01
Fe (mg/L)	0.73	0.05	0.71	0.67
Mo (mg/L)	0.03	< 0.02	0.03	0.04
Ni (mg/L)	< 0.01	< 0.01	< 0.01	< 0.01
Pb (mg/L)	0.003	< 0.002	< 0.002	< 0.002
Se (mg/L)	0.002	< 0.002	0.002	< 0.002
V (mg/L)	0.02	< 0.01	0.01	< 0.01
Zn (mg/L)	0.02	< 0.01	0.02	0.02

Notes: ND = Non Detected; < = Less than

Conductivity (ECw)

Considering agricultural irrigation guidelines, the water sources investigated during the screening effort can all be considered in the moderate to severe range with respect to plant salinity hazard (Morris and Devitt, 1991). As seen in Table 2, ECw ranges from 2.4 at Dean Rd. to a high in the Gila River of 6.2 and typical agricultural irrigation guidelines state a moderate hazard exists with ECw in the range of 1.5 to 3.0. Values greater than 3.0 can cause severe salinity hazards to plants.

Total Dissolved Solids (TDS)

The conductivity results are supported by the TDS data as they also can be classified as having the potential to cause moderate to severe salinity stress for most agricultural crops (Morris and Devitt, 1991). The highest TDS water source was associated with the Gila River flow (3900 mg/L), while the source with the lowest TDS concentration was from the Dean Road outfall.

pH

If the source water pH is too high, there is a potential that micronutrients such as iron, manganese, and zinc may be unavailable. The source waters for potential El Rio Enhancement areas can be classified as suitable for most irrigation requirements (6.5 to 8.4). As seen in Table 2, the source waters are all slightly alkaline with the Watson Rd. outfall the highest at a pH of 8.0; the lowest was 7.7 measured at both the Dean Rd. and Arlington Canal sites.

Nutrients (Nitrogen and Phosphorous)

The most prevalent form of nitrogen found during the screening efforts was nitrite (NO_2) and nitrate (NO_3) collectively referred to as NOx. These nitrogen forms are of concern in the environment because infants ingesting more than 10 mg/L of NO_3-N can suffer from Methanoglobonemia commonly known as "Blue-Baby" syndrome. As such, the State of Arizona has an Aquifer Protection Permit Limit of no more than 10 mg/L Total Nitrogen. As seen in Table 2, the 10 mg/L limit is exceeded in the Arlington Canal sample. Watson Rd. is also very close to the limit at 9.5 mg/L. The total Nitrogen in these two discharges could be significantly reduced by wetland treatment, especially since the form of nitrogen in NOx. Ammonia nitrogen is low in all sources.

Phosphorous was detectable in all source waters sampled but was not present at > 1.0 mg/L. This was an interesting result given that phosphorous concentrations discharged from upstream wastewater treatment facilities can be as high 3.5 to 4.0 mg/L. With respect to the Enhancement areas the levels of phosphorous detected in the screening efforts are not of concern.

Organic Compounds

In all, four classes of organic compounds were tested for in each of the water sources. In all cases, no organics were detected at or above the method detection limits.

Heavy Metals (Total)

Fourteen heavy metals were analyzed for in the source waters. Beryllium, Cadmium, Cobalt, Chromium, and Nickel were not detected at any water sampling location. Lead (3.0 ug/L) was only detected in the Arlington canal.

Of the metals that were detected several can pose toxicity to the plants themselves or to organisms feeding on the plants. Aluminum (Al) concentrations of less than 1.0 mg/L will not cause problems even in the long-term, however at concentrations ≥ 20 mg/L it is only advisable to use the water for short-term irrigation. The current sampling effort produced Al concentrations that ranged from < 0.5 (Gila River Flow) to 0.8 mg/L (Arlington Canal, Watson Rd., and Dean Rd.). As such, from an aluminum standpoint, all sources of irrigation are likely suitable.

Arsenic (As) was way below concern levels for most crops in that they ranged from 0.006 to 0.008 mg/L. For the irrigation of plants, concern over As typically occurs when the concentration is > 1.0 mg/L. However, there is also the concern for impacts to biota. Again, this typically is of concern at higher concentrations. As such, water features within the El Rio should be designed to minimize evaporative concentration and allow for periodic flushing of the system(s).

Copper (Cu) can cause plant distress at relatively low concentrations. Long-term irrigation is feasible if Cu concentrations are in the range of 0.20 mg/L or less. If Cu concentration is 5.0 mg/L or greater, this water should only be used for irrigation on a short-term basis. The El Rio screening effort found Cu at detectable levels (0.01 mg/L) in only one of the water sample locations, the Gila River flow and it does not appear to be a concern for use with the Enhancements.

Although an essential element for most plants, iron (Fe) in excess can cause plant distress and even toxicity. Iron levels of 5.0 mg/L or lower are suitable for long-term irrigation, while concentrations up to 20 mg/L should only be used for the short-term. The screening efforts resulted in a range of iron concentrations from 0.05 mg/L in the Gila River flow to 0.73 mg/L in water from the Arlington Canal, and hence will not be problematic.

Molybdenum (Mo) is not naturally occurring but is a product of industrial products. It is a trace nutrient required for plants, but has a maximum exposure level of 0.01 mg/L. The water quality data shows slightly higher values, 0.03 – 0.04 mg/L. It is not toxic to plants at normal concentrations in soils and water. However, it can be toxic to animals (typically livestock) that forage on plants grown in soils with high concentrations. This may be of concern for the bird population that forages on plants. Molybdenum should remain on the monitoring list should water quality continue to be monitored.

Selenium (Se) was detected in two of the four water samples at the concentration of 0.002 mg/L. This is below the levels at which the irrigation water would not be usable in the long-term (0.050 mg/L). However, there is also the concern for impacts to biota. Again, this typically is of concern at higher concentrations. As such, water features within the El Rio should be designed to minimize evaporative concentration and allow for periodic flushing of the system(s).

Vanadium (V) was found in two of the four water samples; 0.02 mg/L was found in the Arlington Canal and 0.01 mg/L was found in the Watson Road discharge. Vanadium is an industrial metal and V compounds unless otherwise known, are usually considered toxic. Vanadium compounds in some industrial smoke pollution may cause lung cancer and industrial regulations exist to keep exposure to V_2O_5 dust under control. Vanadium is also a necessary dietary component for rats and chicks. No information was available for other environmental consequences.

Zinc (Zn) was present in 3 of the 4 water samples taken at a concentration of 0.02 mg/l. Zn is the most common element in the earth's crust and natural occurrences in the crust

can result in high concentrations. The partial body contact can be in the range of 40 mg/L. As such, at the concentration found during the screening effort, Zn is not likely to pose any problems associated with constructing or operating the enhancement areas.

Soil Screening Results

A total of 48 sites were sampled within the 4 El Rio Enhancement areas and the Salt Cedar Research and Development site. Soil pH and electrical conductivity measurements were made and textural classification assessed at each of the 48 sites on discrete samples obtained at the surface, 12-inches, and 24-inches below the surface. The collected soil samples were combined into composite samples representing the Environmental Enhancement areas. Table 3 provides a listing of composite sample names and corresponding map numbers. General chemical analyses were conducted by Aquatic Consulting and Testing, Inc. Tempe, AZ, while organic analyses were performed by Del Mar Analytical Laboratories, Irvine CA.

Table 3. El Rio Water Course Master Plan Soil Screening Composite Locations.

Composite Sample ID	Enhancement Description	Map Number
S5-Comp	Mesquite Bosque	1
S12-Comp	Wetland Marsh / Pond	1 & 2
S17-Comp	Mesquite Bosque / Wetland Marsh / Pond	2
S39-Comp	Wetland Marsh / Pond	3
S28-Comp	CW/W Augmentation	5
S48-Comp	Salt Cedar R&D	7

Soil pH and conductivity measurements were obtained from each of the depth stratified samples. A cursory review of the data set indicates a slight gradient in conductivity that decrease with depth. This is especially evident in areas away from the main flow path and currently occupied by stands of *Tamarix*. However, in a few cases notable increases in conductivity occurred with increasing depth; suggesting that salt laden materials have been buried or the salt front was pushed deeper by infiltration. The pH seemed relatively constant over the 24 inch sample range. Due to the large number of samples, for presentation in this report, pH and conductivity data were reduced to average, minimum, and maximum values that correspond to the composite sample ID's and Map number shown in Table 3 above. Table 4 provides the pH summary results while Table 5 provides the conductivity values. All raw data are provided in the Appendix.

Table 4. El Rio Soil Screening Summary pH (S.U.) Results.

Enhancement Area Map Number	Minimum	Maximum	Average
1	7.2	10.3	8.4
1 & 2	7.9	8.5	8.2
2	6.7	8.8	7.7
3	7.3	9.0	8.0
5	7.2	9.6	8.3
7	6.7	9.6	7.4

As expected in desert southwest soils, the pH is on the alkaline side of the scale. Only two samples were slightly acidic and these were associated with the burned salt cedar area (Map # 2), and the Salt Cedar R&D site (Map # 7). Average pH values are in the range that will accommodate most of the plant species proposed for the Enhancement areas.

Table 5 El Rio Soil Screening Conductivity (dS/m) Results Summary.

Enhancement Area Map Number	Minimum	Maximum	Average
1	0.68	71.30	16.20
1 & 2	2.68	8.04	5.34
2	0.16	35.70	3.78
3	0.04	2.02	0.26
5	0.03	4.80	1.07
7	0.03	1.05	0.19

The highest soil conductivities were obtained in the areas currently occupied by salt cedar and *Atriplex* communities. These areas are located in the N.E. Quadrant and upstream of the Gila River and M.C. 85 Bridge. As one moves towards the centerline of the River and in general upstream, the conductivity falls. It is likely that the conductivity can be reduced by flushing the soils with lower TDS irrigation water, adding soil amendment(s), or by removing the top 12 to 24 inches or more. In Map Areas 1 and 2, current soil conductivity may limit re-vegetation efforts to those based on salt tolerant plant communities such as Atriplex, or Mesquite Bosque associations. Wetland marsh and wetland ponds would be suitable. Based upon the Sodium Absorption Ratio (SAR) data shown in Table 6 for the same areas, the influx of fresh water and high SAR, the wetland bottom will be prone to sealing, which may obviate the need for liner systems.

Table 6. El Rio Soil Screening SAR and Trace Total Metal Summary Results.

Parameter	S5-Comp Map 1	S12-Comp Maps 1&2	S17-Comp Map 2	S39-Comp Map 3	S28-Comp Map 5	S48-Comp Map 7
SAR	515	37.8	25.4	15.1	3.1	6.5
Boron (mg/Kg)	39	48.4	38.4	30.7	18	15.2
Copper (mg/Kg)	13.7	26.9	25.8	21.1	11.9	7.8
Iron (mg/Kg)	1530	2030	2160	1900	1080	756
Manganese (mg/Kg)	208	290	231	204	133	104
Zinc (mg/Kg)	28.7	50	48.5	41.7	23.6	16.3

High concentrations of sodium in irrigation water may adversely affect soil structure and reduce the soil hydraulic conductivity in fine-textured soils. Unlike the salinity hazard, excessive exchangeable sodium does not impair the uptake of water by plants, but does impair the infiltration of water into the soil. The growth of plants is, thus, affected by an unavailability of soil water or poor aeration. The degree to which sodium will be

adsorbed by a soil is a function of the proportion of sodium to the divalent cations (Ca^{++} and Mg^{++}), and is usually expressed by the sodium adsorption ratio (SAR).

The SAR values found during the sediment screening efforts ranged from 3.1 to 515. The 515 value is suspect, although it was obtained in the northeast quadrant of the Gila River and MC 85 where soil conductivity values were found to be highest. If one removes the 515 value from the results, the SAR ranged from a maximum of 37.8 to a minimum of 3.1 with an average SAR of 17.6. These are elevated SARs that could indicate potential soil structure problems, e.g. poor drainage, if low TDS water is used for irrigation.

Calcium carbonate tends to precipitate in soils and is related to the Langlier index of the irrigation water. An adjusted SAR value can be calculated which takes into account the effects of precipitation and dissolution of calcium carbonate in the soil as related to the concentration of $CO_3^{--} + HCO_3^-$.

The hydraulic conductivity of the soil is also affected by the salt concentration of the soil solution. In general, the higher the salt concentration of the soil solution, the higher the soil hydraulic conductivity will be for a given SAR. Ayers and Tanji (1981) classified irrigation water with respect to its effect on soil structure and hydraulic conductivity, taking both SAR_{adj} and the salt concentration into account. They developed the classification shown in the following Table 7.

Table 7. Classification of Irrigation Water Using SAR_{adj} and C_i (reproduced from Bouwer and Idelovitch, 1987)

	C_i		
SAR_{adj}	**No Problems**	**Slight to Moderate Problems**	**Severe Problems**
0 – 3	> 580	130 – 580	< 130
3 – 6	> 830	160 – 830	< 160
6 – 12	> 1,280	220 – 1,280	< 220
12 – 20	> 1,980	580 – 1,980	< 580
> 20	> 3,580	1,150 – 3,580	< 1,150

The available data for the El Rio Enhancement area irrigation water source(s) did not provide alkalinity values and as such, SAR_{adj} values have not been computed for the irrigation source water. However, if one considers the unadjusted SAR values for the

Enhancement site locations corresponding to Map Numbers 1, 2, and 3 (37.8, 25.4, and 15.1) which are likely to be fed irrigation water from the Arlington Canal and/or the Gila River (3070 – 3900 mg/L), Table 7 indicates that there could be Slight to Moderate to No Problems utilizing this irrigation water with respect to reducing the hydraulic conductivity of the underlying soils. The Enhancement Area located by Map number 5 (CW/W augmentation) is currently fed by the Gila River base flow and potentially the Dean Rd. irrigation outfall. The Dean Rd. outfall water conductivity is 1380 mg/L while the Gila River water conductivity was 3900 mg/L. The high TDS concentration of the proposed irrigation waters, coupled with the Map 5 SAR of 3.1, indicates that No Problems with respect to reducing the hydraulic conductivity of the soils is expected there. The same situation exists at the Map 7 Salt Cedar R&D site.

Boron in Soil

Boron was only measured in the soil composite samples. The findings show the presence of Boron in the range of 15.2 mg/kg soil – 48.4 mg/kg soil. Boron tends to adsorb to soils and can range from 10 mg/kg soil – 300 mg/kg soil. The typical average is 30 mg/kg soil. As seen in Table 6, Boron concentrations in the Enhancement area soils ranged from 18 mg/Kg (Map 5) to 48.4 mg/Kg (Map 1 & 2).

Boron is released into the environment through borate-containing fertilizers and herbicides, through the burning of wastes, crops, wood, and fossil fuels, and through sewage sludge disposal (including land application). As such, one might expect elevated Boron concentration downstream of agricultural discharges.

Boron can accumulate in aquatic and terrestrial plants, but does not increase in concentration through the food chain. This would provide an opportunity for plant uptake and removal in the marsh and terrestrial plants. Boron desorption studies may be recommended to determine the concentration of boron that could be desorbed in the selected plan features.

Most importantly Boron in water is toxic to sensitive plants when delivered in the irrigation water. Boron in excess of 2 mg/L can cause plant health problems, such as deformities in leaves. Given the evidence of Willow stress within and immediately downstream of the El Rio project reach, it is strongly recommended that boron concentrations be measured and determined in the water sources to ensure non-toxic concentrations are being delivered to the system.

Copper in Soil

Copper concentrations in the Enhancement Area(s) soils ranged from a low of 7.8 mg/Kg at the Map 7 R&D site to 26.9 mg/Kg near the boundary of Map numbers 1 & 2. There are no specific ion effects for copper for most terrestrial plants, however, toxicity can occur at fairly low concentrations of copper to algae and some aquatic plants.

Manganese and zinc are present in large quantities in the earths crust. The concentration of these elements in the El Rio soil screening appear normal and will likely not be a factor in plant establishment and/or maintenance.

Soil Organic Chemical Analysis Results

The six (6) composite samples were split and a portion analyzed for organic compounds that are typically associated with agricultural activities. In all 22 organic chemical were tested for and only two were detected; 4,4'-DDT and its daughter product 4,4'-DDE. This is a concern for the Enhancement areas and prior to final design, a more thorough characterization of the proposed Enhancement Areas is warranted and recommended.

A summary of the organic chemical analyses results are provided in Table 8 below. Upon inspection of the table one will note the presence of values for Decachlorobiphenyl and Tetrachloro-m-xylene. These two compounds were run by the laboratory to fulfill its QA/QC program and were not found in the environmental samples delivered.

DDT and DDE in Soil

Both DDT and DDE were extensively used as pesticides in the U.S. through the 1970s. Additionally as DDT breaks down DDE can be a degradation by-product. This could result in the increased concentrations of DDE over DDT (S17; 7.3 µg DDT/L to 21 µg DDE/L, and S39; 8 µg DDT/L to 42 µg DDE/L). Both DDT and DDE will strongly adsorb to soil particles and are not easily transported to groundwater. DDT will evaporate from soil and surface water and can be broken down by sunlight and microorganisms in soil and water. Once DDT and DDE are trapped in a soil system that is not exposed to sunlight, degradation can be extremely slow. Half of DDT present in soil can be expected to breakdown between 2 – 15 years.

DDT and DDE bioaccumulate in the fatty tissue of fish and are known endocrine disruptors resulting in concerns for fish and birds reproductive systems. As such, careful characterization should be conducted prior to habitat establishment. This may add significant cost to the construction of portions of the Enhancements as proper disposal of contaminated sediments may be needed.

Table 8. El Rio Soil Screening Organic Chemical Result Summary.

		Composite Sample Location					
	Composite ID	S5-Comp	S12-Comp	S17-Comp	S39-Comp	S28-Comp	S48-Comp
	Map Number	1	1 and 2	2	3	5	7
Method	Parameter						
EPA 3545	4,4'-DDD	ND	ND	ND	ND	ND	ND
EPA 3545	4,4'-DDE	5.2	5.8	21	42	ND	ND
EPA 3545	4,4'-DDT	ND	ND	7.3	8	ND	ND
EPA 3545	Aldrin	ND	ND	ND	ND	ND	ND
EPA 3545	alpha-BHC	ND	ND	ND	ND	ND	ND
EPA 3545	beta-BHC	ND	ND	ND	ND	ND	ND
EPA 3545	Chlordane	ND	ND	ND	ND	ND	ND
EPA 3545	Decachlorobiphenyl	27.4*	27.2*	28*	25.4*	26.8*	26.5*
EPA 3545	delta-BHC	ND	ND	ND	ND	ND	ND
EPA 3545	Dieldrin	ND	ND	ND	ND	ND	ND
EPA 3545	Endosulfan I	ND	ND	ND	ND	ND	ND
EPA 3545	Endosulfan II	ND	ND	ND	ND	ND	ND
EPA 3545	Endosulfan sulfate	ND	ND	ND	ND	ND	ND
EPA 3545	Endrin	ND	ND	ND	ND	ND	ND
EPA 3545	Endrin aldehyde	ND	ND	ND	ND	ND	ND
EPA 3545	Endrin ketone	ND	ND	ND	ND	ND	ND
EPA 3545	gamma-BHC (Lindane)	ND	ND	ND	ND	ND	ND
EPA 3545	Heptachlor	ND	ND	ND	ND	ND	ND
EPA 3545	Heptachlor epoxide	ND	ND	ND	ND	ND	ND
EPA 3545	Methoxychlor	ND	ND	ND	ND	ND	ND
EPA 3545	Tetrachloro-m-xylene	23.5*	24.2*	25.5*	23.7*	23.4*	24.2*
EPA 3545	Toxaphene	ND	ND	ND	ND	ND	ND

Notes: ND = Non-Detect; * Compounds used for Lab QA/QC, Not found in project soils.

Soil Textural Classification

All soil samples were assessed with respect to their textural class. A complete listing is available in the Appendix to this document. In general, the Enhancement site soils ranged from sands to loamy silts. In Map area 1, loamy sand, sand, silty clay loam, loamy sand, and silty loam are all represented. In the border region of Map Areas 1 and 2, the soil textural classes present included silty clay loam, loamy sand, and sandy clay loam. In Map area 3, soils classed out as sandy clay, loamy sand, and silty clay loam, while in Map area 5 the soils included primarily sand with some loamy sand, and sandy clay loam. The R&D site sampling indicated that the majority was sand with sandy clay loam and loamy sand also represented.

Summary

The El Rio Environmental Enhancement areas soil and water screening indicated several areas of concern. The presence of DDT and DDE in the soils may impact proposed aquatic and wetland features for a period of time after construction. High conductivity of both soils and irrigation water sources will confine the re-vegetation efforts to using salt tolerant species in many of the overbank locations in Map Areas 1 and 2. Options exist which might allow the establishment of less salt tolerant species by using soil amendments or flushing the site soils with lower TDS waters.

Based upon the screening results it is recommended that all irrigation water sources be analyzed for Boron. The relatively high concentrations found in the soils may indicate that Boron is entering the system as a result of anthropogenic activities. Boron can be highly toxic to crop plants and may also be toxic to native vegetation.

Preliminary Planting Cost Estimates for the El Rio Environmental Enhancements Plant Palettes

The following section provides level of magnitude per acre planting cost estimates for vegetation communities that could be established within the Environmental Enhancement Areas. Due to the significant amount of unknowns, the cost estimates include a 25% contingency. The following Table 9 provides a summary of these costs, while a full breakout is provided in the Appendix.

Table 9. Conceptual Level per Acre Cost Estimates for the Planting of the El Rio Environmental Enhancements.

Vegetation Description	Per Acre Planting Cost Estimate
Mesquite Bosque	$ 6,968
Cottonwood and Willow Corridor	$ 9,180
Wetland Marsh and Transition	$ 6,471
Open Space Cobble Strand (Coarse Soils)	$ 4, 710
Open Space Atriplex Series (Fine Soils)	$ 2, 084

The cost estimates above are based solely upon the cost of planted materials with a 6 month warranty period. Costs do not reflect overall site preparation, irrigation, or other appurtenances. In the case of the wetland marsh, it was assumed that plantings would take the following percentage of one acre. Transitional (bank zone) will occupy 15%, Emergent Marsh I is 25%, Emergent Marsh II 25%, Floating plants 20%, and Submerged plants would occupy 15%.

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APPENDIX D MOSQUITO MANAGEMENT

El Rio Watercourse Master Plan

Technical Memorandum: Mosquito Management Considerations

Final Report

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Date: December 6, 2005

Technical Memorandum: Mosquito Management Considerations

Introduction

The El Rio Watercourse Master Plan proposes to protect high quality wetland, riparian, and riverine habitats located within or immediately adjacent to the Gila River from its confluence with the Agua Fria River downstream to the MC 85 bridge. In addition to protecting these areas, engineered wetland and riparian areas are proposed to enhance the project reach. These enhancements will serve to improve water quality, increase the presence of wetland and riparian habitat, and provide a platform for environmental education and passive recreation. Although the creation and or protection of existing high quality wetland and riparian habitat will serve as a regional ecotourism and hence economic engine, both the existing and planned habitat features may at times support the breeding of mosquitoes. Such conditions can impact those visiting and residing near the project. As such, the owners/operators must keep mosquito management in mind during the design and implementation of the project. Prior to or coincident with construction, it is recommended that an integrated pest management plan be developed and followed for the life of the project.

Mosquitoes are an integral component of many aquatic/wetland systems and their shear numbers indicate some importance as a food source for desirable fauna. Certain mosquito species may at times also serve as vectors of serious human and animal pathogens. Some level of mosquito breeding will occur in engineered treatment wetlands systems, but these populations can be controlled through proper design, operation, and management. As such, the owner/operator of treatment wetlands must consider mosquito management throughout the development of the project and for the life of the facility. This is especially important in urban areas where the juxtaposition of the treatment wetland to outdoor recreation, commercial, or residential areas may be very close.

Most successful mosquito control strategies utilize the concept of an integrated pest management plan or IPM. In the United States mosquito control has evolved from merely reliance upon insecticide applications for controlling adult mosquitoes to an integrated plan that includes surveillance, source reduction, larvicide, and biological control. Public relations and education are also important aspects (Rose, 2001).

In short, the plan should focus on monitoring adult mosquitoes in and around the constructed wetland /riparian areas until zones are established within the wetlands that would be favorable for mosquito breeding. In existing wetland and riparian areas, these zones are likely already established and should be identified for possible larval sampling.

The first areas of interest should be located along the north bank of the river due to the juxtaposition of residential, agricultural, livestock, and commercial areas. Focusing on the adults at this stage will allow the development of baseline populations and species information. As the vegetation matures, it is recommended that juvenile monitoring be undertaken. If monitoring shows increases in adult or larval mosquitoes, then appropriate steps can be taken to reduce their numbers e.g., vegetation maintenance, stocking of mosquito fish, and/or prudent use of target specific mosquito larvicides.

The remainder of this document will discuss the water quality improvements that wetlands provide in light of the fact that they do provide areas where mosquitoes can breed. Next, the risk associated with mosquitoes is discussed including the species that are present in Arizona and the specific diseases that they can transmit. Actual mosquito monitoring data obtained this year from the El Rio project is also presented and discussed. The document ends with a presentation of IPM elements that could be enacted in the reach.

Wetland Treatment

The water "treatment" capabilities of wetlands were recognized very early by biologists and ecologists, but the engineering community did not consider them viable treatment systems until relatively recently. Some of the earliest research concerning pollutant removal in wetlands was conducted in Plon, Germany by K. Seidel and R. Kickuth (Seidel, 1976). They investigated the role aquatic plants play in water purification and in particular, the treatment of phenol and dairy wastewater using bulrush. Since that pioneering work, both natural and constructed wetlands have been examined for their pollutant removal/transformation capabilities using a variety of contaminated waters, including storm water runoff. In 1972 R.H. Kadlec and associates investigated the use of a natural wetland (Houghton Lake, MI) to treat municipal wastewater (Kadlec and Knight, 1996). In 1973, fish-processing waste was discharged to a freshwater marsh to investigate for nutrient removal (USEPA, 1999). In the late 1970's to late 1980's treatment wetland form and vegetation was studied. B.C. Wolverton used gravel-based subsurface flow wetlands to treat municipal wastewater for subsequent reuse and for removal of priority pollutants. In the 1980's Tom Debusk conducted pilot scale studies to look at vegetation issues, as did Ramesh Reddy and Smith (1987). In summary, three decades of research has demonstrated that wetlands provided predictable levels of water quality improvement (Ewel and Odum 1984, Kadlec and Tilton, 1979, USEPA 1999).

Engineered wetlands are now used routinely treat a variety of wastewaters including domestic and municipal wastewaters, storm water runoff, agricultural tailwater, and industrial process waters from food processing facilities, pulp and paper mills, petroleum refineries, landfills, and mining operations. Thousands of such facilities exist worldwide and the principals used for there design have been described at length (Kadlec and Knight 1996, Vyzmazal et al. 1998, USEPA 1999).

Surface flow treatment wetlands designed solely for water quality improvements may also have significant potential for providing areas conducive to mosquito breeding. Often times such systems receive lagoon effluents and other partially treated wastewaters with the goal of improving the quality to full secondary standards. Such systems may pose the greatest potential for mosquito breeding because of the combination of high strength wastewaters and dense emergent vegetation. Conversely, multipurpose treatment wetlands designed to provide ancillary benefits such as wildlife habitat and passive recreation often incorporate design features that are not favorable for mosquito breeding. Such features include deep, open water areas, diverse vegetation, and the ability to rapidly dewater vegetated areas. Open water areas are not likely to support mosquito production, but will support fish and aquatic invertebrates that assist in controlling

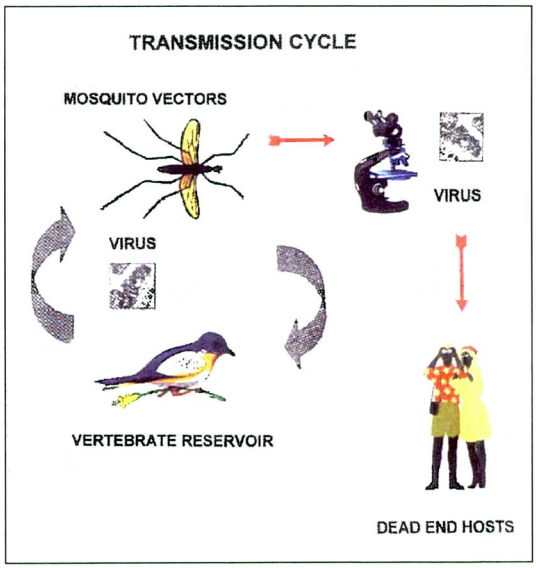
mosquito populations. The majority of mosquitoes will exploit heavily vegetated littoral zones that can be designed such that they permit relatively easy access for mosquito monitoring and control agents.

Permanently flooded habitats, with a diverse invertebrate and vertebrate fauna, generally produce fewer mosquitoes than newly or intermittently flooded habitats which lack predators (Russel 1999). For colonizing mosquito species such as *Culex tarsalis* that usually track newly created or disturbed sites for egg laying, this is especially true. Surface flow treatment wetlands appropriately designed to include wildlife benefits typically have permanently flooded habitats that support a diverse population of invertebrates and vertebrate species. A general conclusion from those areas that contain both surface flow treatment wetlands and un-impacted natural wetlands is that adequately designed and properly managed treatment wetlands do not pose any greater mosquito threat than the existing natural wetlands (Davis 1984, Carlson and Knight 1987). Further, surface flow treatment wetlands receiving pretreated wastewaters typically have production rates similar to natural wetlands.

Additional Mosquito Breeding Habitats

In addition to municipal treatment wetlands, many land uses and natural landscape features can provide habitat for mosquito development. Abandoned swimming pools, irrigated agriculture, ruderal land with shallow isolated pools, dump sites, and ephemeral wetland areas can all serve as potential and significant mosquito breeding habitat.

Risk from Mosquitoes



A mosquito management plan begins with an understanding of the risks that mosquitoes pose. This understanding should include knowledge of the life cycles for the mosquito species that can be present in a given geographic location, coupled with the knowledge of what pathogens can be present and how these pathogens can be transmitted by mosquito species. A typical outbreak of mosquito-borne disease would generally include; 1) introduction of the pathogen by host/reservoir (e.g., migratory birds), 2) pathogen activity in the mosquito species vector taking blood meals from the reservoir host, and 3) transmission from the mosquito species vector to the dead-end host for the virus (e.g., humans, horses, etc.). The size of the mosquito species vector population, the survival of infected adult species to permit multiple blood meals, and the propensity of mosquitoes to feed on different vertebrate host species are among the important factors influencing dynamics of disease outbreaks (Walton, 2000). If either the pathogen or the mosquito species vector is not present, there is little risk of mosquito-borne disease.

Mosquito-Borne Diseases

There are over 2500 species of mosquitoes throughout the world with about 200 species occurring in the United States (Floore, 2004). Mosquito-borne diseases are a major public health problem internationally with as many as 2.7 million people dying each year as a result of pathogens spread through mosquito vectors (FAMVIN, 2005). The World Health Organization (WHO) estimates that 300 to 500 million cases of malaria per year are caused by protozoan parasite(s) of the genus *Plasmodium,* which are transmitted primarily by *Anopheles sp.* mosquitoes. The majority of these cases occur in Sub-Saharan areas in Africa, Central and South America, Hispaniola, the Indian Subcontinent, Southeast Asia, the Middle East and Oceania where the parasites and mosquitoes are present together (WHO, 2002). According to the WHO, more than half the deaths occurred in 6 countries (China, Democratic Republic of Congo, Ethiopia, India, Nigeria, and Pakistan).

In 1999, 1,540 cases of malaria and 90 cases of dengue fever and were reported in the United States (CDC, 1999), this represents between 0.00054% - 0.00032% of the total yearly cases of malaria based on the WHO annual number of cases. A CDC study, 1963-2001, documented 123 deaths from malaria in the U.S. 118 of those deaths occurred between 1979 and 1998 (Journal of Forensic Sciences, 2003). This is an increase of 26% (1,227 cases) from 1998 (CDC, 1999). A survey of available literature estimates that the United States averages about 1200 to 1400 cases per year over the past 10 years. Most American cases develop in travelers who recently returned from parts of the world where malaria is widespread.

Two competent mosquito vectors, *Aedes aegypti*, recently renamed *Ochlerotatus aegypti* and *Aedes albopictus* can transmit dengue. From 1977 to 1994, a total of 2,248 suspected cases of imported dengue were reported in the U. S. (LACWVCD, 2004). By 1997, dengue had become the most important mosquito-borne viral disease affecting humans. The WHO estimates that there may be 50 million cases of dengue infection worldwide every year. The Dengue hemorrhagic fever (DHF) case fatality rate is approximately 5%. These malaria and dengue cases are frequently associated with tourists or immigrants who acquire their infection abroad, incubate during travel, and then become ill upon arrival in the United States, or relapse a previous infection (Rose, 2001). For example, an outbreak of 28 *Plasmodium vivax* malarial cases among undocumented agricultural workers was not detected until cases occurred among the resident population in San Diego in 1986 (Maldonado et al., 1990). Another example was an outbreak in a Houston neighborhood with immigrants from countries with Malaria transmission.

Reported cases of other mosquito-born diseases are rare in the U.S., but five main virus agents of encephalitis have caused outbreaks; eastern equine encephalitis (EEE), La Crosse (LAC) encephalitis, St. Louis encephalitis (SLE), western equine encephalitis (WEE), and West Nile virus (CDC, 2001). These encephalitis diseases have accounted for a combined annual U.S. average (1964-2000) of 218 reported cases per year, excluding West Nile (See Table 1) and 2,988 cases per year including West Nile. In Arizona, the combined annual average for these diseases is less than one case per year (excluding West Nile) and 203 including West Nile.

Mosquitoes in the Southwestern United States are known to transmit at least 10 arthropod borne viruses (arboviruses), but only western equine encephalomyelitis (WEE), St. Louis encephalitis (SLE), and West Nile viruses have caused widespread illness in humans and are likely to be transmitted by mosquitoes associated with wetlands (Reeves 1990). Eastern Equine Encephalitis is rare in humans with 221 cases reported in the U.S. from 1964 to 2004 (CDC, 2005). Most of these cases were east of the Mississippi.

West Nile (WNV) virus was first detected in New York State in 1999 (62 cases). In 2000, WNV was detected in 12 northeast and Mid-Atlantic States with 21 persons infected (U.S. Department of Health and Human Services, 2004). In 2001, WNV expanded into the south included 27 states. The geographic range expanded greatly in 2002 (4,156 cases) and 2003 (9,858 cases) ending up at the front range of the Rockies. As of October 1, 2004, WNV had expanded into 47 states and Puerto Rico with 1,821 human cases reported (CDC, 2005). In the U.S. since 1999, WNV human, bird, veterinary or mosquito activity has been reported to the CDC's ArboNet from all states except Alaska, Hawaii, and Oregon (CDC, 2005). The ArboNet is a national, electronic surveillance system established by the CDC to assist states in tracking WNV and other mosquito-borne viruses. From 1999 through 2004, there have been 16,637 human cases in the U.S. with 654 deaths with 60 mosquito species having been found in WNV positive mosquito pools. During that time, Arizona had 404 human cases with 17 deaths (CDC, 2005). The first diagnosed case in Arizona was during 2003 (ADHS, 2005). The first and majority (94%) of the deaths that have occurred in Arizona took place during 2004. This year, as of September 9, 2005, Arizona has reported 31 human WNV cases (one death) and one St. Louis encephalitis case. Arizona had its first WNV death this year on September 5, 2005 (ADHS, 2005).

Last year, West Nile Virus cases dropped significantly (75%) in the United States from 9,862 (264 deaths) in 2003 to 2,470 (88 deaths) in 2004. Other potentially local and important diseases transmitted by mosquitoes include: Dengue fever, dog heartworm, and Malaria; although Dengue and Malaria are not endemic to Arizona (ADHS 2005). There were 2 imported cases of Dengue in Arizona during 2002 (ADHS 2005). On September 3, 2005, the CDC reported 2004 and 2005 malaria cases in the United States at 10 and 6, respectively (CDC, 2005). The mosquito species responsible for Dengue and yellow fever, *Aedes aegypti*, has been spreading into southern Arizona and was recently found in Tempe (ADHS, 2005). Yellow fever only occurs in Africa and South America (CDC, 2005).

TABLE 1

Selected Occurrence of Encephalitides in the U.S. from 1964 through 2004

Disease	Incidence	[a] Nationwide Annual Average (cases/y)	[a] Arizona Annual Average (cases/y)	[a] Arizona Annual Maximum (cases/y)	Arizona 2000 - 2005 (cases/y)	Comments
Eastern Equine Encephalitis (EEE)	Consistent annual average	5	0	0	0	200 cases in the United States from 1964 through 2000
La Crosse (LAC) Encephalitis	Consistent annual average	75	0	0	0	No reported cases in AZ from 1964 - 2000
St. Louis Encephalitis (SLE)	Intermittent epidemic transmission	128	0.78	5 (1966, 1983)	5[f]	29 reported cases in Arizona from 1964 through 2000
West Nile Virus		2,773[b]	202[d]	391 (2004)[e]	391 (2004)[e]	16,637 reported cases in U.S. from 1999 - 2004
Western Equine Encephalitis (WEE)[c]	Intermittent epidemic transmission	17	0.05	1 (1966&1981)	0	640 confirmed cases nationally 1964 – 2000. Two reported cases in AZ from 1964 - 2000
Encephalitis Total		**218**			**0**	

[a] Includes years 1964 through 2000.

[b] 16,6637 cases over 6 years

[c] 1964 through 2000

d 2003 through 2004 (404 cases)

e Reflects January 1, 2004 through June 21, 2005 reported to ArboNet; 31 cases in 2005 (ADHS, 2005)

f 2003 all from Maricopa County; 1 case during 2005 (ADHS, 2005)

Source: CDC, 2005

Mosquito Species of Concern in Arizona

Mosquito species found in treatment wetlands can be classified based on their egg laying and hatching behavior. Females of some species lay their eggs directly on the water surface or on the leaves of aquatic plants (marsh breeding). The eggs hatch usually within a few days and do not need an external hatching stimulus. These behavioral traits are characteristic of mosquitoes of the following genera (or subgenera): *Anopheles, Coquillettidia, Culiseta, Culex, Mansonia,* and *Uranotaenia*. By contrast, the eggs of floodwater mosquitoes in the genera *Aedes* and *Psorophora* normally are deposited on moist soil or debris on the shore and around aquatic systems and do not hatch until submerged by rising water levels (Mattingly, 1971). These differences in egg laying and hatching have major impacts on the types and species found in treatment wetlands.

Systems with minimal or infrequent water level fluctuations seldom generate severe floodwater mosquito problems. On the other hand, permanent or semi permanent aquatic systems, especially those containing emergent or floating plants in nutrient-rich wastewater, may provide suitable habitats for the immature stages of several species that deposit their eggs on the water surface or aquatic vegetation.

There are over 40 known species of mosquitoes residing in Arizona. Approximately 20 species within the genus *Aedes* and 12 species within the genus *Culex* make up the majority of Arizona mosquito species. Mosquitoes known to occur within the Arizona are listed below and include:

Species	Species	Species
Culex tarsalis	*Aedes dorsalis*	*Aedes trivittatus*
Culex quinquefaciatus	*Aedes epactius*	*Aedes varipalpus*
Culex erythrothorax	*Aedes fitchii*	*Aedes vexans*
Culex thriambus	*Aedes implicates*	*Anopheles franciscannus*
Culex restuans	*Aedes increpitus*	*Anopheles hermsi*
Culex apicalis	*Aedes infirmatus*	*Culiseta incidens*
Culex arizonensis	*Aedes monticola*	*Culiseta inornata*
Culex coronator	*Aedes muelleri*	*Culiseta particeps*
Culex nigripalpus	*Aedes nigromaculis*	*Orthopodomyia kummi*
Culex peus	*Aedes papago*	*Orthopodomyia signifera*
Culex territans	*Aedes pullatus*	*Psorophora columbiae*
Aedes aegypti	*Aedes purpureipes*	*Psorophora discolor*
Aedes burgeri	*Aedes sollicitans*	*Psorophora signipennis*
Aedes cataphylla	*Aedes taeniorhynchus*	

Culex tarsalis is the most notable as the principal vector of SLE, WEE, and WNV in Arizona. *Culex quinquefaciatus*, is considered to be a vector for WNV and a secondary vector of SLE and WEE. Although *Culex erythrothorax* is found naturally infected with SLE virus, it is generally not considered a vector for SLE. Instead, it is considered a

potential vector for WNV. *Culex stigmatosoma* may act as an enzootic amplifier of SLE (secondary vector). *Anopheles hermsi* be a competent vector for malaria. *Culex thriambus* and *Culex restuans* are potential vectors for WNV. *Aedes albopictus* is a potential vector for dengue fever, WNV, and other encephalitis viruses. Lastly, *Ochlerotatus sierrensis* is a canine heartworm vector. All of the above-mentioned mosquito species require standing water for egg laying and as such, could breed if conditions are appropriate in the El Rio area.

The SLE arbovirus has a primary enzootic cycle in the Southwest involving *Culex tarsalis* and birds in the orders Passiformes (e.g. house finches, house sparrows) and Columbiformes (e.g. mourning doves, common ground doves) (McLean and Bowen, 1980; Mitchel et al., 1980). After amplification in the primary cycle, secondary SLE vectors include *Culex quinquefaciatus* and possibly *Culex stigmatosoma.* The WEE arbovirus primary enzootic cycle also involves *Culex tarsalis* and birds of the orders Passiformes, Columbiformes, and additionally the order Galiformes (e.g., Gambel's and California quail). The WNV arbovirus primary enzootic cycles involves mosquitoes from the genus *Culex sp.* and has been found to involve more than 70 bird species with notable infections in members of the bird family Corvidae. WNv has also been identified in the floodwater species *Psorophora* in Arizona. Symptoms of all three viruses are similar and range from unapparent to mild flu-like to meningitis to encephalitis. Arizona marsh-breeding mosquito species associated with SLE, WEE, West Nile virus, and malaria are summarized in Table 2.

TABLE 2
Arizona Marsh Breeding Mosquito Species Representing Vector Potential

Disease	Mosquito Species Vector	Reservoir/Host Species
St. Louis Encephalitis (SLE)	*Culex tarsalis, Culex quinquefaciatus*[a], *Culex stigmatosoma*[a], *and Culex erythrothorax*[b]	house finches, house sparrows, mourning doves, common ground doves
Western Equine Encephalitis (WEE)	*Culex tarsalis*	house finches, house sparrows, mourning doves, common ground doves, Gambel's and California quail
West Nile Virus	*Culex sp.* And Unknown Others[c]	Infection has been reported in > 70 bird species. Primary Surveillance Focused On Corvid Birds (Crows, jays, ravens, magpies and related birds. These and other species of birds have developed illness when infected with WN virus).
Malaria	*Anopheles freeborni, Anopheles hermsi, Anopheles punctipennis*	Humans; Primarily International Travelers and Immigrants

[a] May act as an enzootic amplifier of SLE viruses in nature

[b] Naturally infected with SLE viruses, but generally not considered a vector

[c] May include floodwater mosquitoes of the genus *Psorophora*

Although multiple species of mosquitoes that occur in the Arizona area are capable of transmitting arbovirus to humans, SLE, WEE, and WNV demonstrate low percentages of clinically apparent cases (e.g. infected persons showing symptoms) and of those apparent cases, low mortality rates. This information is summarized in Table 3.

TABLE 3
Arizona Marsh Breeding Mosquito Species Representing Vector Potential

Disease	% or Number of Clinically Apparent Cases	% Mortality
St. Louis Encephalitis (SLE)	< 1%	3-30%[c]
Western Equine Encephalitis (WEE)	0.2 – 1.0%[a]	< 3%[a]
West Nile Virus	328[a]	7%[d]
Malaria	1,540 cases[b]	0.5 approx.[b]

[a] Resien and Monath 1989

[b] U.S. reported cases with onset symptoms during 1999 (CDC, 1999)

[c] GLACVCD, 2005

[d] 4% mortality rate based upon 16 fatalities from 391 total human cases of WNV reported in Arizona as of the end of 2004 (ADHS, 2005). Nationally, the mortality rate is approximately 4%, based upon 654 fatalities from 16,637 total cases of WNV in the U.S. as of the end of 2004.

Dog heartworm is also endemic in Arizona, where coyotes provide a natural reservoir. Over 70 species of mosquitoes can support the worm (*Dirofilasia immitis*) including representatives of the species *Culex*, *Aedes*, and *Anopheles*.

El Rio Mosquito Monitoring Results

Adult mosquito density data were collected from October 9 through November 16, 2002 and again from September 29 through October 19, 2005 in support of a baseline assessment for the project boundaries. A total of 23 different sites were monitored each year. Standard taxonomic references were used for identifying the species of mosquito collected (Neilsen and Reese 1961, Chapman 1966, McDonald 1973, Bohart 1978, Darsie and Ward 1981). Narrative descriptions and GPS coordinates of the site locations are presented in Table 4. Species identifications and counts are presented in Tables 5a (2002) and 5b (2005).

Table 4

Survey Trap Locations

Site No	Location description	Latitude	Longitude
01	Estrella Parkway & Gila River	33.23.695	112.23.537
02	Tuthill Bridge @ Gila River south	33.21.302	112.29.226
03	Airport Road south @ Gila River	33.21.302	112.30.271
04	Waterman Wash	33.20.100	112.30.708
05	Bullard Avenue @ Gila River	33.23.642	112.30.466
06	Jackie Meck Lake 1	33.23.566	112.22.466
07	Jackie Meck Lake 2	33.23.393	112.21.999
08	Jackie Meck Lake 3	33.23.317	112.21.810
09	Jackie Meck Lake 4	33.23.242	112.21.743
10	Jackie Meck Lake 5	33.23.172	112.21.682
11	Jackie Meck Lake 6	33.23.147	112.21.536
12	Dean Road @ Gila River	33.21.593	112.31.327
13	Rainbow Road @ Gila River	33.21.560	112.32.373
14	Buckeye Wastewater Treatment Plant	33.21.566	112.34.936
15	Miller Road @ Gila River	33.20.861	112.35.448
16	East of Miller Road in Gila River	33.20.880	112.35.049
17	Eagle Mountain Road west	33.20.478	112.32.125
18	Eagle Mountain Road east	33.20.490	112.31.941
19	Gila River 1	33.21.041	112.31.429
20	Gila River 2	33.20.922	112.32.341
21	Gila River 3	33.21.140	112.31.017
22	West of Highway 85	33.19.924	112.37.508
23	East of Highway 85	33.19.913	112.37.361

Table 5a

Number of Mosquitoes and Species by Location 2002

Site No.	Total mosquitoes	*Aedes vexans*	*Anopheles franciscani*	*Culex tarsalis*	*Culex quinquefa.*	*Culex restuans*	*Culiseta inornata*
01	34	30	0	4	0	0	0
02	88	0	0	88	0	0	0
03	78	0	1	74	0	3	0
04	40	0	0	40	0	0	0
05	9	0	0	8	0	0	1
06	83	0	0	83	0	0	0
07	151	0	0	151	0	0	0
08	187	0	0	187	0	0	0
09	218	5	1	212	0	0	0
10	221	3	0	218	0	0	0
11	202	1	0	201	0	0	0
12	22	1	1	18	0	0	2
13	21	2	0	19	0	0	0
14	102	0	0	102	0	0	0
15	67	4	0	59	0	0	4
16	200	3	0	187	0	0	10
17	15	0	0	9	0	0	6
18	7	1	0	2	1	0	3
19	16	0	0	7	3	0	6
20	4	0	1	1	0	0	2
21	7	0	1	4	0	0	2
22	3	1	0	1	0	0	1
23	1	0	0	0	0	0	1

Despite sampling after the typical period of maximum mosquito density had passed during 2002, collections still contained as many as 221 mosquitoes per trap night. Six species of mosquitoes were identified; all are considered stagnant water forms. A total of 15 of the 23 samples exceeded 20 mosquitoes per night. ADHS and Maricopa County Vector Control consider a total of 20 or more mosquitoes per night indicative of potential health risk. *Culex tarsalis*, the most competent vector of many arboviruses, was the most commonly collected mosquito.

Table 5b

Number of Mosquitoes and Species by Location 2005

Site No.	Total Mosquitoes	*Aedes vexans*	*Anophele franciscan*	*Culex tarsalis*	*Culex quinqu*	*Culex Inornat*	*Psorophor Columbiae*
01	235	5	1	219	0	0	0
02	1350	0	0	1350	0	0	0
03	320	0	0	299	15	0	5
04	32	0	0	27	3	0	2
05	66	0	0	66	0	0	0
06	19	0	0	19	0	0	0
07	10	0	0	9	1	0	0
08	8	0	1	5	2	0	0
09	26	0	1	23	0	0	2
10	2	0	0	2	0	0	0
11	40	0	1	201	0	0	1
12	135	0	0	74	0	21	40
13	40	0	0	23	0	0	17
14	13	0	0	12	0	1	0
15	19	0	0	18	0	1	0
16	4	0	0	4	0	0	0
17	24	0	0	20	4	0	0
18	13	0	0	10	3	0	0

Table 5b Cont.

Site No.	Total Mosquitoes	*Aedes vexans*	*Anophele franciscan*	*Culex tarsalis*	*Culex quinqu*	*Culex Inornat*	*Psorophor Columbiae*
19	**44**	7	1	33	0	3	0
20	**30**	1	1	19	0	9	0
21	**16**	0	0	15	0	1	0
22	**17**	12	0	5	0	0	0
23	**8**	1	0	7	0	0	0

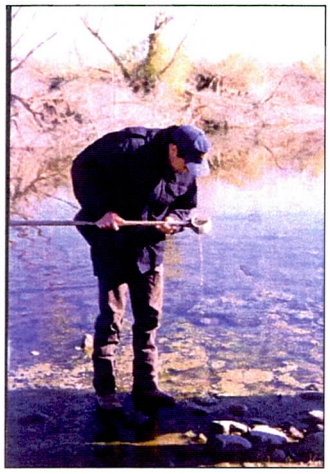
Although 2005 data were collected the during the peak of autumn mosquito breeding season and following a very wet winter and spring, total counts per trap were in the same range as 2002. The exception was at Tuthill Bridge where the count exceeded 1000 mosquitoes in one trap night. Six species were again collected, but *Culex restuans* was replaced *by Psorophora columbiae*, a floodwater form. A total of 12 of 23 collections exceeded 20 per trap night, a reduction from the 15 obtained in 2002. As in 2002, the mosquito that most typically dominated collections was *Culex tarsalis*.

El Rio Mosquito Integrated Pest Management Plan Elements

Surveillance and Mosquito Monitoring

An understanding of the problem is essential to a successful vector control program. As such, the owner/operator of a treatment wetland should establish a coordinated mosquito-monitoring program prior to construction of the treatment wetland so that baseline mosquito populations can be defined in the proposed project area and an assessment of the impact the wetland has on mosquito population dynamics as a result of the project can be measured. The ongoing monitoring plan should, at a minimum, characterize breeding areas, type, number, and sex of mosquitoes in a given locality. For instance, one needs to know if the mosquitoes being caught are competent vectors of concern and if they are "marsh-breeders", "container breeders", or flood water species which deposit eggs in moist sediments. This in turn will allow one to gauge if the adults caught could be breeding within the wetland or are born elsewhere and travel to the wetland. In addition, monitoring information can provide early notification if a health threat exists, or if it is merely a nuisance condition. This information coupled with the mosquito monitoring and arbovirus surveillance in wild birds, sentinel chicken flocks, and vector-borne pathogens in mosquitoes conducted by the Maricopa County Vector Control and others can then be used to generate the appropriate management response(s).

Larval Mosquito Monitoring



Larval sampling consists of "dipping" with a standard apparatus (pole w/ a cup on one end) at fixed and high probability locations throughout a problem area. In most cases, field personnel will have to literally "hunt" the mosquito larvae because of inherent flight responses and the structure of the habitat(s) they prefer. Most marsh-breeding mosquitoes (*Culex sp.*) will typically seek shelter in dense vegetation such as lodged bulrush/cattails or in dense grasses along shorelines or in overly watered turf areas, whereas container breeders such as *Aedes aegypti* (Dengue Fever) can be found in water holding cavities, dog-dishes, old tires, and even in irrigation valve-boxes. Floodwater species (*Psorophora* sp., etc.) will likely breed in areas where only periodic inundation occurs such as in surrounding agricultural fields or in turf areas where over watering in poorly drained areas occurs.

Method – Larval Dipping

Many techniques exist to collect larvae and the given effectiveness for each method will differ. As such, a single method should be used and the differences in techniques should be minimized among those individuals collecting samples (Knight et al, 1999). A quick dipping technique as described by Collins and Resh (1989) is adequate for most mosquitoes and can be used when dense emergent vegetation is present. If more than one

individual is to conduct the larval monitoring it would be advisable to compare dipping techniques so that samples are collected in a standardized manner.

Location(s) – Larval Dipping

After newly constructed wetland system(s) have begun to stratify into (or, for existing systems after one can identify) distinct ecological zones e.g., open-water, emergent mash, and chemical gradients in the water column, 5 to 10 permanent field stations should be established within a given wetland area. Within each field station zone, replicate samples can be taken after every 5 or 10 steps if wading, or every 30 feet if boating, such that a total of 25 dips are made in each zone. This often results in taking groups of samples within a 5 to 10 m area and should result in 125 to 250 dips per sample visit per basin. The individual samples can be combined, concentrated and the organisms preserved with a 70% to 100% ethanol solution for identification.

Sample Frequency – Larval Dipping

At a minimum, sampling for mosquito larvae should be conducted at intervals that are less than the time necessary for the mosquito species of interest to develop from the 1st instar stage to adult. Because it is more ecologically sound and cost-effective to control the immature stages than dispersing adults, the sample frequency should really be less than the standard generation time. As such, larval sampling frequency should be weekly during the warm months, March through October, and once a month during November through February.

Larval Counting & Reporting

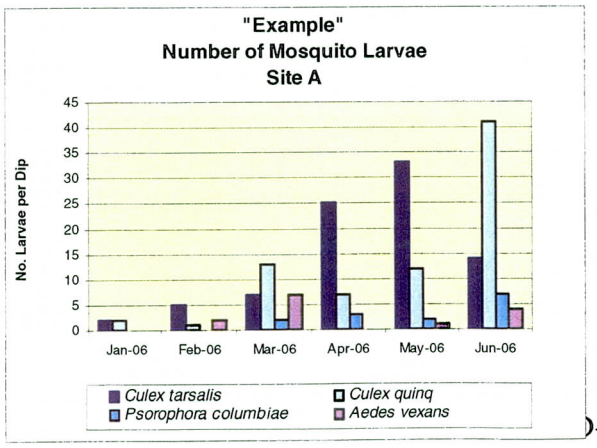
Ideally, larval counts should include enumeration of individuals in each life stage, 1st through 4th instars, and pupae. If control methods include the use of ingested larvicides, the presence of older instars and pupae may be used to determine the need to increase dose, frequency, and basin coverage, or method.

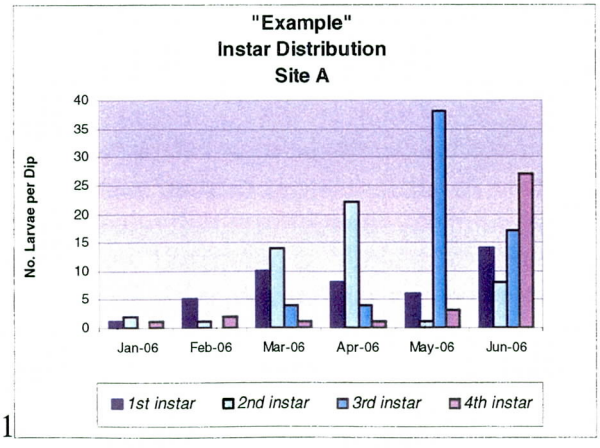
Reporting

Number of larvae per dip in each basin

Total number of larvae obtained per basin per sampling event

Number of 1st – 4th instars and number of pupae in each basin





Adult Mosquito Monitoring

Trap Selection & Placement

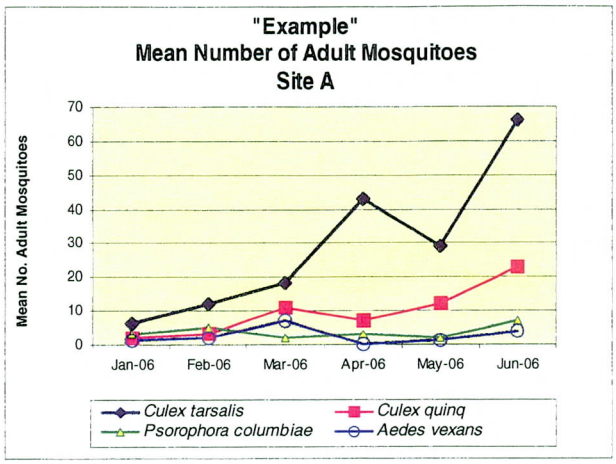
Adult mosquito monitoring can be done using several methods and commercially available traps. Some use colors or highly organic water as attractants, whereas others use a light source or CO_2. Host-seeking, gravid, and resting adults can be selected for based upon perceived needs and budget. For marsh breeding and floodwater species, Encephalitis Vector Survey (EVS) CO_2 baited traps have proven very successful and economical for collection of host-seeking adults (Rohe and Fall, 1979). Since mosquito activity is subject to many factors, e.g. trap placement, wind, humidity, it is advisable to develop a routine adult monitoring program which utilizes several trap locations for a given problem area. For instance, 10 traps are set out on a weekly basis to monitor adult mosquito populations at the Tres Rios Demonstration Project facilities, while six traps are used on a monthly basis in the Rio Salado full-scale project area.

Certain wetland and riparian features associated with the El Rio Project will be or are currently located in close proximity to residential housing which often includes landscape features that mosquitoes will use to rest in and for food sources such as trees, shrubs, and turf areas. In such a setting, adult mosquito trap placement should be focused around the transition from the marsh vegetation to elevated vegetation (Trees) in the terrestrial areas. On any given trap-night, 5 to 10 EVS traps should be affixed to permanent stakes adjacent to the vegetated areas such that the trap opening is approximately five feet above the ground surface. To provide an indication of mosquito source(s) and direction, four peripheral EVS traps could be placed approximately one mile outside the wetland facility of interest in all directions and/or data collected by others incorporated into this characterization of mosquito populations.

Adult Mosquito Monitoring - Operation and Frequency

EVS traps should be operated from late afternoon until early morning and such a time period will define a "trap-night". At the onset of the monitoring efforts, trapping adult mosquitoes once a month should be adequate to establish baseline numbers. As development encroaches upon the river corridor, adult monitoring will become the backbone of the IPM plan. As such, it is recommended that weekly placement of the traps should be conducted during the months of February through November and once a month in December and January. Mosquitoes caught at each trap should be transferred into 1-gallon zip-loc plastic bags for transport to counting and identification facilities. Enumeration should include the number of females, number of males, and identification to genus and species.

Tables presenting the results of raw number of females and males should be presented for each species of mosquito successfully trapped (see Table 5a and 5b for examples). To allow rapid evaluation of the change in abundance of adult mosquitoes, the mean number of each species collected per "trap-night" should be calculated and plotted over time.



Arbovirus Monitoring - Operation and Frequency

Assays that detect disease-causing agents and pathogens in field populations make it possible to monitor the spread of disease, to identify areas where there is risk at contacting the disease, and to efficiently target arthropod control measures. By monitoring infection rates and viral activity in nature, it may be possible to predict the threat of epidemic transmission of disease. While growth in virus cell culture or PCR-based molecular methods remain the standard, rapid and simple specific diagnostic tools make virus detection faster and cost-effective.

Because arbovirus screening is useful to identify immediate need for larvicide or adulticide use and public health notification, pooled mosquito samples should be tested for arbovirus at least monthly and more frequently during the peak mosquito breeding season. Similarly, dead corvids may be tested to determine the extent of virus in the bird population that typically acts as the virus source for female mosquitoes. Two test kits are widely available for use: VecTest® and RAMP®.

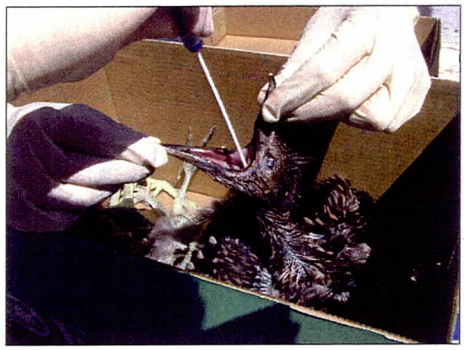
The VecTest WNV, SLE, and WEE Antigen Panel Assay is a rapid immunochromatographic assay intended for the qualitative determination of virus in infected mosquitoes. Monoclonal antibodies against SLE, WNV, and WEE have been employed to develop enzyme-linked immunosorbent assays (ELISA) that assess the risk and identification of disease vectors. The VecTest Panel Assay is a rapid wicking assay that identifies the presence or absence of viral antigens specific to the specific virus. The test provides rapid results without specialized equipment. The test is based on a dual monoclonal antibody sandwich principle. A ground mosquito extract is test with a dipstick. Antigen present in the solution binds with a gold sol label. The complex migrates to a test zone containing immobilized viral antibodies and forms a dye complex. Formation of the dye in a specific zone corresponds to presence of a specific antigen. Mosquitoes normally collected for monitoring purposes may be immediately tested, stored dried, or homogenized and frozen at -20C. The latter technique is advisable if the samples may undergo any cell culture or PCR confirmation analyses (see below).

The RAMP® West Nile Virus (WNV) Test is a highly sensitive, fluorescent immunoassay, pre-screening test used for identifying WNV in mosquitoes and corvids. It is based on a Rapid Measurement Platform (RAMP) technology that incorporates an internal control that is measured concurrently with the test sample to compensate for sample and operator variability.

The RAMP WNV Test has been independently validated by the US Center for Disease Control (CDC) and Canadian National Microbiology Lab (NML) to confirm 80% in correlation to PCR and 96% in correlation to ELISA.

Mosquitoes are collected, speciated and mixed with RAMP proprietary buffer. A sample is taken and added to a WNV test cartridge. The cartridge is allowed to dry for 90 minutes, and then inserted into the RAMP reader. As the sample migrates along a test strip, fluorescent dye-coated latex particles coated with antigen-specific antibodies bind to antigen if present. The RAMP reader measures fluorescence emitted by the complexes bound in the Detection and Internal Control zones. A quantitative result is displayed after 1 minute, which can be stored in the reader's memory, printed or uploaded to a computer.

In Corvids a throat swab is collected and mixed with RAMP proprietary buffer. An aliquot is taken and added to a WNV test cartridge. The cartridge is allowed to dry for 90 minutes, and then inserted into the RAMP reader. A quantitative result is displayed after 1 minute, which can be stored in the reader's memory, printed or uploaded to a computer.



A portion of ground mosquito extract from screening tests or separate split portions of collected mosquitoes may be frozen and transferred to the Arizona Department of Health Services (ADHS) for a full panel PCR or cell culture confirmation. ADHS provides this service free of charge on a monthly basis from about April through October.

Adult and Larval Mosquito Population Data Collection Materials

Mosquito Larvae - Equipment List:

Standard Dipper, Volume = 250 ml or 500 ml

Screened Concentrator Cup or Similar Means of Concentrating collected larvae

Sample Bottle (500 mL glass) for preserving instars and pupae

Ethanol as a preservative

Ice-Chest and Ice for transport to count/ID facility

Adult Mosquito - Equipment List:

10' metal t-posts or similar for trap placement, Quantity = 10 - 20

EVS CO_2 – Baited Adult Mosquito Traps, Quantity = 10 - 20

Dry-Ice, 5lbs. per trap, Quantity = 50 – 100 lbs. per trap night

1-Gallon Zip-Lock plastic bags

Permanent Marking Pen(s)

Mosquito Control: Biological, Larvicide, and Adulticide

Mosquito control along the El Rio should focus on larvae and pupae control using vegetation management and biological methods (mosquito predators and larvicides). Vegetation management can be a potent mosquito control technique. In problematic areas receiving nutrient enriched waters, up to 1/3 of the vegetation could be cleared on an annual basis using fire, chemical, or mechanical means. Most importantly, all cut biomass should be removed as quickly as possible from the wetland basins. If left to decompose on its own, the dead cut vegetation can provide a nutrient rich broth attractive to egg-laying mosquitoes as well as provide areas where fish and other macroinvertebrates can not access. A vegetation management plan coupled with biological controls such as fish can be an effective part of the overall El Rio IPM plan.

Mosquito fish have been one of the most effective biological methods of controlling mosquitoes for over forty years (VCD, 2002). Biological control also includes natural predators (e.g., dragonfly nymphs and predatory macroinvertebrates) that eat larvae and pupae. Highly target specific larvicides that have minimal impact on non-target organisms and the environment should also be utilized. The compartmentalization of treatment wetland system (e.g. emergent marsh surrounded by open water), as well as access around the basins that can accommodate mosquito control equipment, allow for very direct mosquito control focused on small areas rather than more expensive and less direct basin wide applications of mosquito control agents (Walton, 2002). Adulticides should not be part of routine mosquito control activities, but could be utilized in the event of a disease outbreak in the region.

Biological Control

It is likely that the diverse assemblage of aquatic, riparian, and terrestrial vegetation in and around the El Rio existing and proposed wetland/riparian facilities will encouraged development of a robust population of macroinvertebrates that include predacious diving beetles, damselflies, and dragonflies to assist in reducing mosquito larvae. Biological control of larvae provided by these predatory species can be supported through introduction of fish that feed on mosquito larvae. The potential exits to utilize the Gila topminnow (*Poeciliopsis occidentalis*) even though it is a listed species in the State of Arizona. The Gila topminnow is reported to feed on mosquito larva but is out-competed by the mosquito fish (*Gambusia affinis*). If the Gila topminnow is used, removal of

Gambusia from the system would probably be necessary. *Gambusia* is currently used for mosquito control in the many treatment wetlands throughout Arizona and the United States. For instance, Gambusia is a primary component of vector management efforts at the Tres Rios, Rio Salado, and Sweetwater wetland facilities. Further, Maricopa County routinely stocks *Gambusia* in abandoned swimming pools to manage mosquito production.

The name mosquito fish *(Gambusia affinis)* is derived from its voracious appetite for mosquito larvae. The species has been introduced into waters of almost every continent, and many oceanic islands. The hearty fish can withstand environmental extremes including temperatures ranging from 33°F to 107°F (Knight et al., 1999), a bonus for systems residing in the desert southwest where water temperatures can exceed 90 °F during the summer. *Gambusia* can survive at a pH range of 5 to 9.5, and is known to occur in cooling ponds with salinities as high as 15 parts per thousand. Successful reproduction has been noted in waters with a chemical oxygen demand (COD) ranging from 40 to 150 mg/l and survival is possible in waters with a COD as high as 200 mg/l (Coykendall, 1980; Meisch, 1985). It takes approximately 24 days for young to develop, and broods range from a few young to more than 300. A single female may produce up to 5 broods in a single lifetime (Krumholz, 1948). The predatory activities of *Gambusia* are not restricted to mosquito and other insect larva, but include the young fish of its own and other species, including listed species. As such coordination with Arizona Game and Fish is recommended prior to introducing this species.

Mosquito Larvicides

Two *Bacilli* (*Bacillus thuringiensis* variety *israelensis* (*Bti*) and *B. sphaericus* (*Bs*)), which are microbial agents formulated as crystalline bacterial spores that are ingested by mosquito larvae and cause the cell walls of the larval digestive system to burst (VCD, 2002), are currently registered for use against mosquitoes in much of the United States. *Bs* is more effective against mosquitoes in organically enriched waters such as wastewater effluents but has a narrower host range. *Bs* is very effective in controlling *Culex sp.* mosquitoes and according to the product label is reported to control several other mosquito species including *Aedes vexans, Aedes melanimon, Aedes stimulans, Aedes nigromaculis, Aedes triseriatus, Aedes solilicitans, Anopheles quadrimaculatus,* and *Coquillettidia perturbans. Bti* controls a broader spectrum of mosquito species and can be used to control chironomids such as midge fly larvae.

Bacillus toxins are target specific and are safe to humans and other nontarget organisms under current application rates and modes of contact (Walton and Mulla, 1992). A possible pitfall of *Bs* is the potential for mosquito targets to develop immunity to the mosquitocidal toxins. *Bti* contains multiple toxins whereas *Bs* contains only one. To mitigate the possibility of developing a resistance to *Bs* at the Tres Rios Demonstration Wetlands facilities, *Bti* is applied in lieu of, or in combination with *Bs* once a month during peak mosquito seasons. On the forefront is the development of an agent that combines the *Bs* mosquitocidal toxin with those of *Bti* (Federici et al., 2003). Since both agents are currently registered with the USEPA, it is thought that regulatory approval will

be expedited and the new agent will be introduced on the commercial market in the near future (Walton, 2002).

Application of the granular larvicides in a slurry form is often done mechanically from truck-mounted equipment or can be applied aerially over larger sites. Both methods allow more complete basin coverage and enhanced penetration of densely vegetated areas, which will result in significantly reduced larval counts. Currently available land-based broadcast equipment can effectively reach approximately 175-ft. If emergent zones occur at a greater distance from shore, application can be effected from a boat or aircraft. It typically takes 24 - 72 hours after treatment for complete larval mortality and the residual appears to control larval development for a period of 3 to 25 days post application, with less rapid mortality rates and longer residual control associated with *Bs*.

Another type of larvicide uses a juvenile hormone, methoprene, to prevent maturation of mosquito larvae. The chemical prevents the mosquito from maturing beyond the pupa stage; the time in its development when it ceases to feed. Ultimately the larva starves and dies. The material does not need to be consumed. If properly dosed and applied, the chemical is directly absorbed by larvae present in the environment.

Methoprene has a very low toxicity to non-target organisms and is toxic to fly (Dipteran) larvae. Thus, the material will also help manage midgefly and blackfly larvae. Commercial products come in both liquid and solid (granule or briquet) formulations.

One of the advantages of methoprene is its ability to maintain efficacy over a long period of time. Methoprene is very resistant to photo- and thermal degradation. Granular products remain effective up to 30 days, and 30-and 150-day efficacy briquets are available. Because of these characteristics, methoprene is an excellent choice for semi-permanent pools or ponds, and areas or structures frequently wetted by storm waters or other runoff. Pellets or briquets can be placed in these areas where the larvicide will remain inactive until wetted. If the area dries rapidly, the remaining material does not decompose readily and will be reactivated when re-wetted.

Mosquito Adulticides

Adulticides will not be part of routine mosquito control activities, but could be utilized in the event of a disease outbreak in the region. Adulticide application still has a place in integrated pest management plans to reduce adult mosquito populations during times of disease outbreaks or when extreme numbers of nuisance mosquito are present even though this activity may cause anxiety in the general public (Rose, 2001). Human exposure in residential areas is uncommon because of the very low application rates (such as 1 oz. per acre), ultra low volume methods and treatment is typically conducted in the early morning under low wind and moderate temperature conditions when people are indoors (Rose, 2001). Adulticides are immediately effective, but is not entirely selective to mosquitoes hence mosquito predators and vegetation may be adversely impacted. Control efforts within the El Rio project will focus on source reduction (prudent wetland design and operation) and larval control. Adulticide application would only be used in the event of a true public health threat due to adult mosquito populations in the project area.

If necessary, ultra low volume (ULV) fogging is a method employed to control outbreaks of adult mosquitoes. There are several compounds to choose from including sumithrin, pyrethrin, malathion, and permithrin. Recent studies indicate that adulticides applied at mosquitocidal dosages are not acutely toxic to common freshwater insects and aquatic invertebrates (Lawler et al., 1997). However, ULV application of malathion was used as an adulticide at the Tres Rios Constructed Wetlands Demonstration project in 1996, and was found to be toxic to the test organism, *Cerriodaphnia dubia* (Wass 1996, unpublished manuscript). The need has not since arisen for adulticide application since the 1996 event at Tres Rios, but if such actions were again needed at the site either a sumithrin based agent that has been used successfully at the Sweetwater Wetlands in Tucson, AZ, or a pyrethrin based agent would be selected.

Public Relations and Education

Many agencies around the country have developed public education campaigns to help spread information on vector control. The El Rio Project features will provide an opportunity to educate the local community regarding the benefits of wetlands, such as water quality improvement and habitat creation in the urban environment. Additionally, a public outreach component which focuses upon educating the public about mosquitoes and vector control can assist staff in conducting their integrated pest control efforts. Such a program is also invaluable as it serves as a basis for the community to understand when management steps are necessary and the means used to achieve mosquito control. Other communities have used the following methods to implement such programs:

- Websites
- Public services announcements (television and radio)
- Hotlines
- Door to door distribution of pamphlets
- Booths at local events
- Info in utility bills
- School programs (mosquito biology)

The objective is to inform the public about mosquitoes, their life cycles, and ways they can help reduce levels. The public needs to know how to get information about what to do, and who can help. Proper education produces an informed public who can understand life cycles of mosquitoes, and the effectiveness of vector control strategies.

In Alameda County, California, the Mosquito Abatement District sets up booths at the county fair and home and garden shows to help educate the public. In addition they have developed an education program for the schools that includes classroom presentations, educational materials, research projects, and grants). A focus of the grants is to educate on wetland research, restoration, and preservation activities.

Leon County Mosquito Control, in Florida, produces annual public service announcements aired on radio and television. The have also developed the Mosquito Hawk Education Program a public education program for 4th graders. Leon County also issues a brochure to new homeowners educating them on mosquito abatement strategies.

In Saginaw County Michigan, the Saginaw County Mosquito Abatement District has an extensive education program including a short story contest for elementary schools entitled "the Adventures of the Great Mosquito Detective." The commission also airs a 13-minute video on the local public access channel during summer months. The commission believes "By understanding the mosquito's life cycle, breeding habits, and methods of prevention and control, the public can be an integral factor in creating a more comfortable, disease-free environment." (www.scma.org)

As part of the El Rio Project facilities, it is recommended that a public outreach and education component be developed. This program should draw on information and tools developed for use in existing local programs or such as those discussed above, but it should be tailored to the information needs, expectations, and perceptions of those living in or expected to frequent the wetland facilities.

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