US Army Corps
of Engineers
Los Angeles District

Tres Rios del Norte
Tucson, Arizona

Draft F3
Without-Project Conditions

August 2002

LOS ANGELES DISTRICT, CORPS OF ENGINEERS
PLANNING DIVISION, WATER RESOURCES BRANCH
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F3 EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers is conducting a study in the Tres Rios del Norte area to identify and define environmental degradation, flooding and related land and water resource problems and develop solutions. These efforts are proceeding in partnership with Pima County, the City of Tucson and the Town of Marana.

This report is for the purpose of meeting the Corps F3 milestone requirements. This includes identification of problems, opportunities, constraints, and planning objectives. For the F3 milestone, the key element is the development of the without project condition, which is equivalent to the no action plan. The without project condition consists of conditions in a base year, and a projection of how those conditions will change over a 50 year planning horizon. This includes projections on growth and development, land use changes, continuing decline of remaining riparian habitat, and the eventual re-allocation of effluent currently in the river to other uses. Chapter IV of this report details all of the areas of evaluation that comprise the without project condition.

In addition, a number of measures have been developed based upon those originally in the Project Management Plan (PMP), with additional potential measures added based upon other similar studies in the region. The original PMP included Areas of Evaluation, which were the culmination of an extensive almost year-long cooperative effort on the part of the 3 local sponsors to develop a consensus list of items, goals, objectives, and specific projects that would be desirable in the study area (Enclosure G to the PMP). These areas of evaluation have been included and correlated in this report to show how they match up with Corps measures, objectives, and potential for accomplishment under this study. Restoration, recreation, and flood damage reduction are addressed. As the study continues, the set of measures will be screened and refined. In addition, as alternatives are evaluated, there will be an iterative process of re-combining measures and developing additional alternatives until arriving at a recommended plan.

More detailed alternatives will be developed in the next step of the study process (F4 milestone) in accordance with Corps of Engineers feasibility criteria including, technical feasibility, economic efficiency, environmental compliance and public acceptability. The local sponsors will be integral to development of specific alternatives for evaluation and analyses.

The primary problem is the severe degradation and loss of riparian habitat along the Santa Cruz River since the late 19th century. In the study area, it has been estimated that a continuous corridor of approximately 7000 to 8000 acres of dense riverine riparian and floodplain riparian fringe habitat existed at that time, supported by perennial flows and a high groundwater table in the vicinity of the river. Increasing appropriation of surface and ground water to support expansion of agriculture and growing urban populations resulted in the transformation of the Santa Cruz from a river with perennial surface or subsurface flows to a dry wash which flows only ephemerally in response to storm runoff. As a result of this change, stands of native riparian habitat are rare throughout Pima County and specifically in the study area. Today, less than 500 acres of the original

riparian habitat remains, in a state of degraded quality and in isolated patches, and primarily supported by effluent flows from area waste water treatment facilities. Although a narrow band of riparian habitat has established along the effluent dominated low flow channel the health and continued existence of that habitat is by no means assured. The lack of stable natural channel morphology leaves the habitat at risk of being stranded by migration of the existing low flow channel carrying treated effluent during a flood event. In the future, it is expected that without-project, as growth and development pressures continue, the economic value of the effluent will increase to such a point that the owners of that water will no longer choose to discharge it into the river but will instead utilize it for other more economically rewarding purposes. This is projected to occur within a period of twenty five years. The remaining stands of riparian habitat will not survive without surface or groundwater. Other problems include flooding and erosion and inadequate recreation facilities.

Loss of riparian habitat is extremely significant in the arid southwest. Originally comprising a mere 1% of the landscape historically, over 95% has already been lost in Arizona. This type of river-connected riparian and fringe habitat is of an extremely high value due to it rarity. Arid Southwest riparian ecosystems are designated as a critically endangered habitat type. It has been estimated that 75 to 90 percent of all wildlife in the arid southwest is riparian dependent during some part of its life cycle. As a direct consequence of the extent of the lost or degraded riparian habitat the area has experienced a major reduction in species diversity and in the population of remaining species. In addition, destruction of native riparian habitat facilitates an increase in invasive plant species that are more tolerant of disturbed conditions. Such plants consume more water than native vegetation, placing additional strains on limited water supplies

At the present time there are still large parcels of vacant land in the Tres Rios del Norte area and the ultimate disposition and use of the effluent flows has not occurred. As long as this is true there is an opportunity to accomplish large scale restoration in the study area. Restoration alternatives have the potential to increase riparian habitat acreage and quality and thereby expand wildlife diversity and quantity, control invasive plant species and provide an ecological resource that is significant and valuable in the region.

In this report, planning objectives and constraints have been articulated. Numerous opportunities exist for restoration and related purposes including: groundwater recharge; improving water quality; land use planning and flood control; increasing recreation; creation of a river corridor and improving the efficient use of effluent for multiple purposes. Pima County, the Town of Marana and the City of Tucson are ready to begin the process of formulating and evaluating restoration alternatives for the Tres Rios del Norte area of the Santa Cruz River.

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FEASIBILITY STUDY

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CHAPTER I
STUDY AUTHORITY

General authorization for the Tres Rios del Norte Study is provided by the Flood Control Act of 1938 (for the Gila River and its tributaries – which includes the Santa Cruz River). The specific authorization for the Reconnaissance and Feasibility phases of the Tres Rios Del Norte Study are provided by House Resolution 2425 (HR 2425), dated May 17, 1994. HR 2425 states:

> *"… the Secretary of the Army is requested to review reports of the Chief of Engineers on the State of Arizona…in the interest of flood damage reduction, environmental protection and restoration and related purposes."*

The Energy and Water Development Appropriations Act of 2000 (Public Law 106-60, dated September 29, 1999 states: "The Committee recommendation includes $100,000 for the Corps of Engineers to evaluate opportunities for environmental restoration and related matters in Pima County, Arizona. This study is to proceed with particular reference to recommendations and findings included in the Sonoran Desert Conservation Plan, Pima County, Arizona, dated October 21, 1998."

A copy of the House Resolution follows as Figure 1.1

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U.S. House of Representatives

COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION

SUITE 2165 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
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COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C.

RESOLUTION

State of Arizona
Docket 2425

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

Adopted: May 17, 1994

ATTEST: NORMAN Y. MINETA, Chair

Figure 1.1 House Resolution

CHAPTER II
STUDY PURPOSE, STUDY SCOPE, AND STUDY AREA

A. Study Purpose

The Tres Rios del Norte, Tucson, Arizona Feasibility Study and Environmental Impact Statement is being conducted by the U.S. Army Corps of Engineers, Los Angeles District (Corps), the Pima County Flood Control District, the Town of Marana and the City of Tucson. The purpose of this study is to identify and define environmental degradation, flooding impacts and related land and water resource problems and develop solutions.

This report will describe the base year project area conditions and the project area future without-project condition. The future without-project condition is the same as the "no action" alternative and anticipates project area conditions in the absence of Federal action.

Alternative plans are being developed to provide for restoration, recreation, flood control, and related land and water resources planning. This report is intended to be a complete decision document that presents the results of both the reconnaissance and feasibility phases of the General Investigation effort. This feasibility report is intended to accomplish the following tasks:

- Present the study results and findings, including those developed in the reconnaissance phase, so that readers can reach their own conclusions regarding the report recommendations;
- Indicate compliance with applicable statutes, executive orders, and policies; and
- Establish a sound and documented basis for decisions makers at all levels to judge the recommended solution(s).

Note: This F3 document is an interim product to describe without project conditions. Alternative development will occur in the next stage of the study process.

B. Study Scope

The scope of this study consists of: 1) identifying problems and needs associated with loss of riparian habitat and related water resources; 2) formulating alternative measures for environmental restoration that produce National Environmental Restoration (NER) and National Economic Development (NED) benefits; and 3) identifying the opportunity and the role for Corps' participation in environmental restoration, recreation, flood control and related water resources planning.

C. Study and Report Process

The Los Angeles District of the Corps of Engineers completed the first phase of the General Investigations study in December of 2000. The results and conclusions of the first phase were presented in the Tres Rios del Norte, Arizona 905(b) analysis for the reconnaissance phase report. The reconnaissance report established Federal interest in proceeding to the second phase of the General Investigation Study, the feasibility phase.

D. Study Area

The Tres Rios del Norte study area is located in the upper Sonoran Desert in the Santa Cruz River Watershed. The Santa Cruz River headwaters are in the San Rafael Valley in southeastern Arizona. From its headwaters the river flows south into Mexico. After a 35-mile loop through Mexico, it reenters Arizona about six miles east of Nogales. The river continues northward to Tucson then northwest to its confluence with the Gila River 12 miles southwest of Phoenix.

The study area comprises an 18 mile reach of the Santa Cruz River to the North of Tucson. In that reach the Santa Cruz has it confluence with two of its major tributaries, the Rillito River and the Canada del Oro. It is from these features that the area derives its name, Tres Rios del Norte (three rivers of the north). The study area is situated within Pima County in the northwestern Tucson Metropolitan area, and through the Town of Marana. The area comprises nearly 20,000 acres of Marana, unincorporated Pima County and suburban Tucson. Approximately 65% of the study area is in the Town of Marana, 25% within Pima County and 10% in the City of Tucson. Tucson is the second largest city in Arizona and is the Pima County seat.

The study area was defined in coordination with the Pima County Flood Control District, the Town of Marana and the City of Tucson (Figure 2-1). The study area is bounded on the south by Prince Road, and on the north by North Sanders Road, West Moore Road and West Avra Valley Road. The western edge follows Silverbell Road north from Prince Road to a point just beyond its intersection with Scenic Drive. From there the western boundary parallels Scenic Drive for a distance of about one mile before turning west to Airline Road and north to West Avra Valley Road. The eastern boundary falls just to east side of Interstate 10 from Prince Road to Orange Grove Road. From Orange Grove Road to the northern limit the eastern boundary parallels I-10 at a distance of about one-half mile to the east with an eastward extension to include Arthur Pack Regional Park. The width of the study area varies from 2.2 to 6.9 miles over its 18 mile length.

The lower Santa Cruz River within the Tres Rios del Norte study area has perennial flow because of discharges from the Roger Road and Ina Road wastewater treatment plants. Riparian vegetation exists along the lower Santa Cruz River in response to wastewater discharge. Willow, cottonwood, and salt cedar seedlings are establishing but appear only

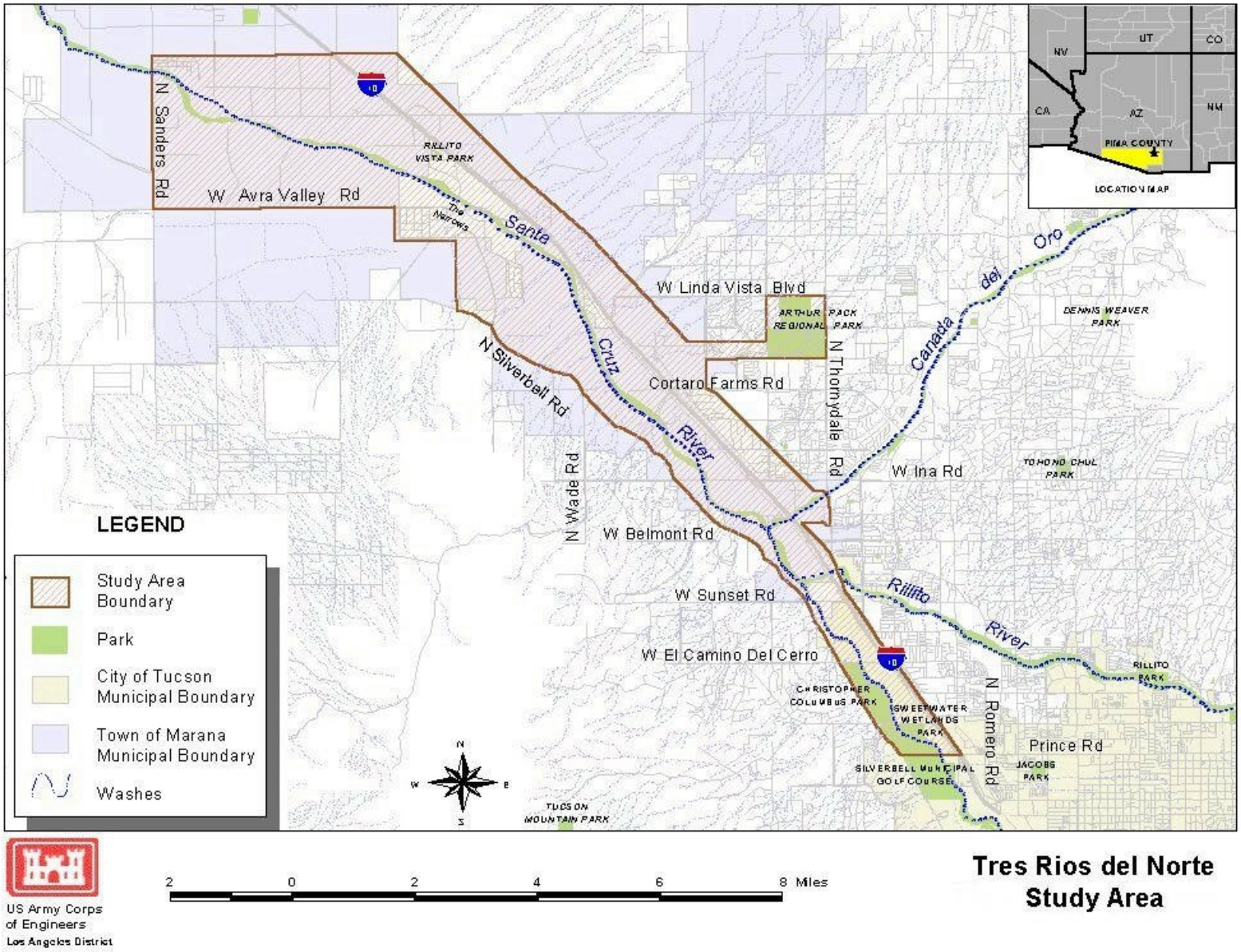

Figure 2.1 Location Map

in association with the narrow band of moist soil along the effluent channel. This habitat would cease to flourish if was deprived of the effluent based flows.

Existing Land Use

The Tres Rios del Norte study area is a mixture of urban residential, commercial, industrial, agricultural, and open space land uses. The most prominent feature of the Tres Rios del Norte study area is the Santa Cruz River. Prominent land use designations in the Tres Rios del Norte study area include vacant lands (public and private) and agriculture. Agriculture is a dominant land use in the northern portion of the study area (Marana). In general, public vacant lands in the north are owned by the State of Arizona, in the south by the City of Tucson, and in the middle of the study area by Pima County. More detailed information on land use, designations, zoning and ownerships is in Chapter IV of this report.

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CHAPTER III
PRIOR STUDIES, REPORTS & EXISTING PROJECTS

A. Prior Studies or Reports

Many studies have been conducted pertaining to water and related land resources within the study area. These studies have examined subject matter including development trends, environmental resources, water supply, groundwater recharge, wastewater management, flooding and erosion, geology, cultural resources, history, and recreation. The following is not intended to be a comprehensive list of previous reports, but to provide a sample of the types of studies that have been completed in the study area.

Arizona Stream Navigability Study for the Santa Cruz River (Gila River Confluence to the Headwaters) Final Report, Prepared by SFC Engineering Company for the Arizona State Land Department

Santa Cruz River Corridor Plan, October 2001, Town of Marana

Sonoran Desert Conservation Plan: Relationships Between Land and People – The Cultural Landscapes Approach in Archaeology and History (May 2000) Pima County

Overview of Traditional Cultural Places in Pima County (May 2000) Pima County

Preserving Cultural and Historic Resources – A Conservation Objective of the Sonoran Desert Conservation Plan, (May 1999) Pima County

Sonoran Desert Conservation Plan: Pygmy Owl Update (November 1999) Pima County

Final Documentation October, 1993 Flood Damage Report, Pima County Department of Transportation and Flood Control District

Pima County Flood Control District Comprehensive Program (December 1990), Pima County Department of Transportation and Flood Control District, Planning and Development Division

Pima County Flood Control District Comprehensive Program Report FY1990-91-FY1995-96 (January 1997), Pima County Department of Transportation and Flood Control District, Planning and Development Division

Santa Cruz River Alignment Recharge Study - Final Report (July 1986), Prepared by Pima Association of Governments for City of Tucson

City of Tucson General Plan (City of Tucson, November 2001).

Existing Conditions Hydrologic Modeling for the Tucson Stormwater Management Study (TSMS), Phase II, Stormwater Master Plan, Task 7, Subtask 7A3. prepared by Simons, LI & Associates, Inc. for the City of Tucson, November 1995.
Landfills and Waste Disposal Sites along the Lower Santa Cruz River - Final Report (February 1995) Prepared by Pima Association of Governments for Pima County Flood Control District

Landfills Along the Santa Cruz River in Tucson and Avra Valley – Final Report, Arizona (May 1995) Prepared by Pima Association of Governments for City of Tucson Office of Environmental Management

Arizona Stream Navigability Study for the Santa Cruz River (Gila River Confluence to the Headwaters) Final Report Prepared by SFC Engineering Company for the Arizona State Land Department

Sonoran Desert Conservation Plan: Mountain Parks (August 1999) Pima County

Pima County River Parks Master Plan (December 1996) Prepared by Planners Ink for Pima County Department of Transportation and Flood Control District

Sonoran Desert Conservation Plan Draft Report (October 1998), Pima County

Sonoran Desert Conservation Plan Update – Focus on Riparian Area (July 1999), Pima County

Reconnaissance Phase Study, 905(b) Analysis (September 2000) (*Includes Tres Rio del Norte and Agua Caliente)*, U.S. Army Corps of Engineers Los Angeles District

Gila River, Santa Cruz River Watershed, Pima County Arizona – Final Feasibility Report (August 2001), U.S. Army Corps of Engineers Los Angeles District

B. Existing Projects

There are no existing Federal projects within the study area. There are other Federal projects and studies in the vicinity of the study area. Those projects/studies are on the Santa Cruz River or its tributaries in or near the study area. They include the El Rio Antiguo Study on the Rillito River and the Paseo de las Iglesias Study upstream on the Santa Cruz River. Existing or planned features to add environmental restoration or recreation measures to these projects/studies have the potential to multiply the benefits of a project in the Tres Rios Del Norte area through linkage of the features.

Local improvements within the study area include projects for ground water recharge, bank protection, flood control, recreation, and transportation and other infrastructure.

C. Master Planning

This study is one component of an innovative locally initiated regional strategy to provide flood protection and restore and conserve area natural resources while balancing economic interests, satisfying laws and regulations, promoting ecosystem restoration, and accommodating future growth. Urban development in the Tucson Valley began over 200 years ago with farming communities located near the rivers for crop land irrigation. As a result of early development along the major rivers, structural flood control measures have been necessary to protect existing development in the urban core and along the Santa Cruz and other Rivers and tributaries in the region.

The Pima County Flood Control District recognized in 1979 the need to establish a regional flood control program to address countywide flood hazard. Since that time, the District has been successful in implementing flood control improvements and floodplain management regulations, however much remains to be done because comprehensive floodplain management is a relatively new land use concept in Pima County. Environmental restoration along watercourses and recreational amenities are an integral part of the regional strategy. For example, Pima County has acquired natural floodplain lands in order to preserve natural functions such as overbank flood storage, groundwater recharge, and habitat and wildlife corridors. The District has taken steps to preserve the Santa Cruz floodplain in areas such as Green Valley and Canoa Ranch, the Cienega Creek Natural Preserve, and other projects that complement the environmental restoration work along the urban rivers. The Sonoran desert Conservation Plan provides for integration of all these efforts by Pima County.

The City of Tucson owns a large portion of the water within the region, and has developed innovative strategies to begin to utilize water sources other than groundwater to fulfill its mission as a water provider to the population. More efficient use of available water sources would enable the Tucson region to continue to grow and prosper, while potentially reducing historic groundwater overdrafts that have led to the decline of riparian habitat.

The Town of Marana's Santa Cruz River Corridor Plan is designed to provide a framework to maximize economic and quality of life opportunities to ensure that the corridor becomes a major asset to the community, helping to define a sense of place and community pride. A laissez faire approach to planning can allow fragmented and unconnected patchwork of incompatible development and economic activities, and result in other problems. With vision, leadership, and thoughtful planning, the corridor can become a unifying element connecting the community, with much more positive outcomes.

With Pima County Flood Control District, Tucson Water Department, and the Town of Marana as the non-federal sponsors of the Corps' Tres Rios del Norte study, there are large scale opportunities to further a regional approach that provides linkages to existing and planned projects, promotes and facilitates beneficial land and water resources uses, restores environmental values and improve the quality of life, and provides a framework

for cooperation among local entities for the overall and enduring benefit of people of the region. Additional information regarding local master planning initiatives is presented below.

Sonoran Desert Conservation Plan

The Sonoran Desert Conservation Plan is a comprehensive, local planning initiative to conserve the County's most valued natural and cultural resources, while accommodating the inevitable population growth and economic expansion of the community.

In the most recent phase of this planning effort a Science Technical Advisory Team and staff of the County developed the concept for a differentiated biological reserve where Pima County biological resources are ranked in level of importance. That concept was applied to establish a framework for designing a Conservation Lands System for eastern Pima County. The Conservation Lands System is a first draft attempt to place value on conserving natural biological resources of the County. The intent of the master planning effort is to ultimately extend the system to the establishment of similar priorities for cultural and historic resources, ranching, riparian and mountain parks.

City of Tucson General Plan

The City of Tucson General Plan regulates planning and development activities within incorporated areas of the city in the vicinity of the Tres Rios del Norte study area. The Land Use Element identifies policies that, along with other elements of the General Plan, describe the City's vision for physical development by providing criteria for the location and intensity of future land uses (City of Tucson, November 2001).

The City of Tucson General Plan establishes "Livable Tucson Goals." These include:

- Infill and reinvestment, not urban sprawl which includes well-planned growth, the management of urban sprawl, and development within the city rather than just on its periphery.

- Abundant urban green space and recreation areas which include recreation and green space within the city such as neighbor and regional parks, common space, community gardens, bike and walking paths, linear and river parks, and trees and urban landscaping.

- Protection of the natural desert environment which includes protection of the Sonoran Desert ecosystem and protection of washes, hillsides, open space, and wildlife.

Town of Marana General Plan

The Town of Marana General Plan serves as the guiding document for future development with the town. The plan establishes a series of goals, objectives, and policies that direct development decisions. These goals are grouped into elements and focus on land use, economic development, public facilities and services, and circulation.

General Plan elements are translated into a series of implementation initiatives. These are presented as part of the Implementation Action Plan adopted by the Town and included in the General Plan. The Town of Marana has prepared a corridor plan for the Santa Cruz River Corridor within the town.

Santa Cruz River Corridor Plan, Town of Marana

The Mayor and Council mandated development of the plan as an amendment to the Marana General Plan. The overall goal of the plan is to ensure that the corridor becomes a major asset to the community.

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CHAPTER IV
PROBLEMS AND OPPORTUNITIES

A. Background, Historical Conditions and Problem Development

This section discusses the historical development of the conditions that have led to the current problems in the study area. Specific problems are detailed in the next section of the report.

Hydrology and Geomorphology

The Santa Cruz floodplain experienced a complex alluvial history culminating in a major cut and fill cycle between 500 and 300 years ago. Prior to the arrival of European settlers, the Santa Cruz River was a shallow stream occupying a broad flat floodplain covered with mature mesquite forests and cottonwood trees. In the Tres Rios del Norte study area, water flows were historically intermittent and subsurface.

Nearly all of the city of Tucson and its surrounding communities are located within the Tucson Basin. This broad valley is ringed by a number of mountain ranges that provide the origins for the numerous watercourses that transect the basin. Many of these rivers, creeks, and washes become tributaries that lead to the Santa Cruz River. The water of the river long served as a vital source of life for people, wildlife, and a robust riparian plant community. This green ribbon that traversed the Sonoran Desert, ran the entire length of the Tres Rios del Norte study area, and, historically, had been the primary artery for sustaining life and economic development in the Tucson Basin.

At the time of statehood (1912), the Santa Cruz River was still perennial in some of the reaches that had shown historic surface flows, but flows were becoming increasingly intermittent in most areas. As perennial surface waters disappeared so did the marshes, the mesquite woodlands and the cottonwood forests. South of San Xavier, the old wagon road that ran between Tucson and Nogales eroded into a deep channel by the1940s. The berm was eventually breached and captured the main flow of the Santa Cruz. Between 1953 and 1962, Tucson's main dump was at the base of Sentinel Peak. This landfill completely filled the confluence of the Santa Cruz River and the West Branch (a tributary to the Santa Cruz). A second landfill near Congress Street narrowed the river there. Constriction the channel led to dramatic downcutting of the riverbed. Much of the area's riparian vegetation had been cut for wood or lumber. Homes and farms, using increasing amounts of the scarce water, left little water to maintain the existing riparian growth. Figure 4.1 provides a dramatic illustration of changes in the character of the river from historic to modern times.

U.S. Geological Survey stream gage summaries (1907, 1912) indicate that all surface water flows were diverted at the Tucson gauging station by irrigation ditches. Agricultural uses in Tucson and San Xavier accounted for most of the diversion of the area's surface water with supplemental irrigation water coming from groundwater pumps. Other diversions, and groundwater pumping, also diminished flows on major tributaries to the Santa Cruz River, especially the Rillito River. In addition to the diversion of all surface water, growing numbers of

wells contributed to declines in the groundwater table. Today, the Santa Cruz River is an ephemeral stream that flows mainly as a result of seasonal storm events. Groundwater levels in the Tres Rios del Norte study area currently range from approximately 100 to 250 feet below the land surface.

These changes in the river/wash system have impacted the surface/groundwater interactions and sedimentation dynamics that are part of a natural flood regime and important for sustaining and regenerating riparian vegetation.

Historic Riparian Habitat

Like many rivers in the southwest, the Santa Cruz River once had an unstable channel that periodically changed location within a wide floodplain. Within this floodplain, the high water table once supported extensive riparian forests of mesquite, cottonwood, and willow while subsurface flows in low-lying areas supported biologically productive cienegas (marshlands). During the last century agriculture, flood control and development have gradually transformed the river and associated biological resources. Historic accounts of Tucson indicate that the Santa Cruz River flowed year round at San Xavier del Bac, and approximately 10 miles north near downtown Tucson. Near the former confluence of the Santa Cruz and the West Branch there was a natural Cienega (seep wetland)/wetland. Similarly, in the study area, the high water table once supported riparian forests of mesquite, cottonwood, and willow while subsurface flows in low-lying areas supported biologically productive cienegas. Extensive riparian forest remained in the area into the late 19th century. In fact, the town of Marana provides lasting evidence of those forests. The name Marana first appeared on Southern Pacific Railroad maps in 1890. Marana is a Spanish word meaning a jungle, a tangle or a thicket and was chosen as an appropriate name by the railroad workers as they hacked their way through the dense brush. Decades of timber harvesting, urbanization, and lowering of the water table have reduced mesquite and cottonwood woodlands in the floodplain adjacent to the Santa Cruz River to the few patches that remain today.

Loss of riparian habitat is considered extremely significant in the arid southwest. Originally comprising a mere 1% of the landscape historically, over 95% has already been lost in Arizona. This type of river-connected riparian and fringe habitat is considered to be of an extremely high value due to its rarity. Arid Southwest riparian ecosystems are designated as a critically endangered habitat type. Riparian systems provide important habitat for a wide variety of plants and animals, especially in the southwest where the upland habitats are typically dry and devoid of lush vegetation. These strings of habitat, while encompassing less than one percent of the southwest landscape, support a disproportionately high number of wildlife species. An estimated 75 to 90 percent of all wildlife in the arid southwest is riparian dependent during some part of its life cycle.

Historic growth

Historically, the Santa Cruz River was a perennial surface stream until early in the twentieth century, having stands of cottonwood trees and cienegas. This relatively lush environment encouraged the intermittent settlement of numerous areas of the Santa Cruz River basin. Human

habitation of the study area dates backs thousands of years and agriculture has a long history in the study area with evidence of maize cultivation over 2000 years ago. The Tohono O'odham Indians at San Xavier, and farmers at Tucson, used the surface waters of the river for irrigation. The Santa Cruz River served as an important transportation route for Native Americans, missionaries, Spanish explorers, colonizers, miners, cattlemen, and settlers. The river provided a well-established route from the south and the east into present day Arizona as far as Tucson, providing food and water for the traveler. The Tucson presidio, located south of the study area, was founded in 1775 adjacent to the river and formed the basis of the present city of Tucson.

During the late nineteenth and early twentieth century, a combination of conditions occurred which resulted in entrenchment of this river into a much deeper channel. In general, entrenchment of rivers is attributed to a combination of climate changes, man-made diversions along the river, overgrazing, and sometimes even geologic activity. The Santa Cruz River was broad and shallow until floods in 1887 caused the river to incise a water diversion channel. The ensuing incision of the floodplain caused a lowering of the water table and serious channel bank erosion. Even then, the river flowed until perennial flow disappeared in the late 1930s and 1940s due to groundwater pumping.

Settlement and growth patterns in the Tucson area have been shaped by natural as well as anthropogenic influences. Natural influences include topography and watercourses. Transportation routes, while anthropogenic in nature, are influenced by natural features as well. The four most prominent land use shaping features are topography, watercourses, transportation routes, and governmental lands. These features have affected and influenced natural, constructed, and administrative issues. Transportation routes evolved as overland routes, railroads, and highways. Administrative influences that have guided land use decisions include territorial and Arizona State Trust lands, Tohono O'odham Nation, Coronado National Forest, Santa Rita Experimental Range, Tucson Airport and Davis-Monthan Air Force Base, Saguaro National Park, and other public landed owned by county, state, and federal entities.

Historically, agriculture uses have predominated in the northern portion of the Tres Rios del Norte study area, particularly the Avra Valley area. Most of the agriculture has occurred on the west side of the River. Over the years, some farmland has been converted to urban areas. Marana began annexing large areas to the south and east of its traditional area, and has experienced substantial growth. Extensive urban lands are now also included in this town. Marana's population grew from a few thousand people in the 1980s to almost 15,000 in 2000. During the late 1970s and early 1980s sand and gravel mining were developed along the Santa Cruz River, particularly in the vicinity of Ina Road and Cortaro Road. Sand and gravel mining continues today along the Santa Cruz, and as the population increases, the demand for these construction and landscape materials also increases.

Santa Cruz River Perennial Flow North of Tucson, late 1800's

Santa Cruz River Bordering the Rodgers Road Wastewater Treatment Facility

Figure 4.1 Comparison of Historic and Present Conditions

Problem Identification

Decreasing Riparian Habitat

The primary problem is the severe degradation and loss of riparian habitat along the Santa Cruz River since the late 19th century. In the study area, it has been estimated that a continuous corridor of approximately 7000 to 8000 acres of dense riparian and floodplain riparian fringe habitat existed at that time, supported by perennial flows and a high groundwater table in the vicinity of the river. Increasing appropriation of surface and ground water to support expansion of agriculture and growing urban populations resulted in the transformation of the Santa Cruz from a river with perennial surface or subsurface flows to a dry wash which flows only ephemerally in response to storm runoff. As a result of this change, stands of native riparian habitat are rare throughout Pima County and specifically in the study area. Today, less than 500 acres of riparian habitat remains, in a state of degraded quality and in isolated patches, and primarily supported by effluent flows. Perennial base flow conditions, critical to the needs of native plants, no longer exist in the river/wash corridors through the study area.

As areas in and around the Santa Cruz watershed have been developed, much of the biological resources and habitat in the study area has been degraded significantly, displacing much of the riparian and floodplain fringe vegetation that once occupied the area. Degradation of the river, washes, and adjacent over bank areas, due to upstream development, modified stream morphology, and groundwater pumping has significantly altered the biologically rich Santa Cruz River. For example, the river lost at least six species of native fish, and one native plant. Mesquite bosque areas died when the water table dropped due to groundwater pumping. More recently, riparian vegetation has diminished through urban development and channelization. Sand and gravel operators removed huge quantities of sediment and garbage was dumped into the pits. Many of the incised channel banks are now lined with soil-cement bank stabilization to prevent erosion. Today, the Santa Cruz River is a well-defined, channelized and bank protected watercourse. The Santa Cruz River has been channelized through the Continental Ranch development between Cortaro Road and a point approximately 1.7 miles south of the Avra Valley Road bridge. This channelization contains a two-tiered channel. Periodic floods move the effluent channel away from established sites and a lack of water appears to be the cause of death for mature trees where the channel has shifted. Over the 18-mile-long Tres Rios del Norte study area, riparian resources vary as channel geomorphology and land use patterns change.

Rapid Growth and Development

The Tres Rios del Norte study area is now characterized by degraded rivers, washes, and adjacent over bank areas. The degradation is primarily due to upstream development and associated changes in stream morphology leading to significantly reduced native riparian plant species and wildlife habitat. The study area is a mixture of urban residential, commercial, industrial, agricultural, and open space land uses.

The Santa Cruz River is a well-defined, channelized, and, in some reaches, bank protected watercourse. Well-defined washes occur in the western portion of the study area coursing through the ridges of the Tucson Mountain foothills. Excessive groundwater pumping has lowered the water table so that the river now flows only in response to direct rainfall runoff or discharge of effluent from wastewater treatment facilities. Natural perennial base flow

conditions, critical to the needs of native plants, no longer exist in the river/wash corridors through the study area. Unsuitable existing bank conditions exist at many locations. Significant reaches of soil cement bank stabilization have been constructed in the southern and central portions of the study area. Man-made bank changes have resulted in a degraded but stable bank in many locations. Some locations, including residential areas, have been significantly impacted by increased flood flows.

Currently, the study area consists predominantly of vacant and agricultural lands with agriculture being dominant in the northern portions. Much of the vacant land is in or adjacent to the river. While those vacant lands present the opportunity for ecosystem restoration development pressures have increased in recent years. Developed land (residential, industrial and commercial) currently comprises the next largest land use category. Demographic projections (Table 4.1) support the likelihood of maintaining or expanding the rate of development in the study area. If restoration efforts are delayed the land needed for effective projects may not be available.

Table 4.1
Population Trends in Tucson and Pima County

Jurisdiction	1980	1990	1997	2000	% Increase (1980-2000)	% Annual Increase (1980-2000)	% Projected Growth (2000-2020)
Marana	1674	2187	6831	13,556	723.1%	36.2%	464.7%
Tucson	330,537	405,390	452,836	486,699	47.2%	2.4%	21.2%
Total Pima County	**531,443**	**669,139**	**789,650**	**843,746**	**58.8%**	**2.9%**	**43.0%**

Loss of Environmental Values

As the loss riparian habitat continues, associated environmental values decline as well. The loss of the continuous corridor, decreasing wildlife and plant species diversity, and loss of numerous other environmental values is directly tied to the decline in the riparian ecosystem. In addition to these impacts is the likely increase in invasive plant species that are more tolerant of disturbed conditions. As the stabilizing function of native plants is lost, and as development occurs, river banks must be engineering to control erosion. Loss of the aesthetic value of a natural river and its riparian plant community is another consequence.

Limited Water Availability in the Arid Southwest

Under Arizona law, the right to use surface water is acquired by appropriating the water to a beneficial use. Priority is established on a "first in time, first in right" basis. 45 A.R.S. § 151 et seq. For all practical purposes, all of the surface water in Southern Arizona has been appropriated and no additional water is available for appropriation.

In 1980, Arizona adopted the Groundwater Management Act ("GMA") which established a highly regulated system to control the withdrawal of groundwater within each Active

Management Area ("AMA").45 A.R.S. §401 et seq. The AMAs were created in regions where historically the groundwater resources had been over-pumped and the long-term availability of groundwater was threatened. The GMA established the Upper Santa Cruz Subbasin and Avra Valley Subbasin as the Tucson AMA. In an AMA, groundwater may only be withdrawn pursuant to a permit issued by the Arizona Department of Water Resources ("ADWR").

An exception is made for exempt wells—non-irrigation wells having a maximum pump capacity of not more than thirty-five gallons per minute. 45 A.R.S. § 454. An exemption is also made for wells that are part of a CERCLA (1980 Comprehensive Environmental Response, Compensation, and Liability Act, commonly referred to as "superfund") remedial action. 45 A.R.S. § 454.01. The local sponsors of the Tres Rios del Norte study do not support using mined groundwater for riparian habitat projects.

The Secretary of the Interior administers basic entitlements to Colorado River water through the issuance of delivery contracts, and the allocation of Central Arizona Project ("CAP") water to water users within the state. The Arizona Department of Water Resources ("ADWR") plays an advisory role to the Secretary in recommending these allocations; the Secretary customarily accepts these recommendations.

There is no agricultural water user in the Tucson AMA that holds a subcontract for CAP water. Several municipal water providers in the Tucson AMA have annual entitlements to Colorado River Water delivered through the CAP canal. In most circumstances, the municipal water providers are utilizing their CAP entitlements for the purposes of Assured Water Supply demonstrations.

Any entitlement that may be relinquished in the future by water providers not needing or desiring to demonstrate an Assured Water Supply will be transferred to other water providers in the AMA. Therefore, it is expected that such entitlements will not be available for use in any Tres Rios del Norte riparian habitat project.

Other Problems

In addition to the primary problems discussed above, there are some specific problem areas that are subject to flood and erosion damages. Furthermore, recreational facilities are not adequate to meet current demands.

B. Development of Baseline and Future Conditions

Purpose

Based upon the Identified Problems, evaluations and analyses were performed to better define the technical aspects that are related to the problems and potential solutions. The various technical disciplines collected, analyzed, and developed the information in the following sections. The planning and engineering considerations for developing the baseline and future conditions help to assess the opportunities and provide the means to evaluate the technical aspects of the alternatives in an interdisciplinary approach.

C. Baseline Conditions

Definition of Base Year

Base Year conditions are defined as those conditions which are expected to exist with the study area in the earliest year that a project could begin to produce NED/NER benefits. A thorough assessment and evaluation was conducted for current conditions for this study. A complete discussion of those conditions is referenced in the associated appendices to this report. This section focuses specifically on the without-project conditions in a base year of 2012. The future without-project condition, discussed in the next section, is a projection of how the base year without-project conditions are expected to change over the 50-year period of analysis (project life) to provide the baseline conditions against which developed alternatives can be compared and evaluated.

Reach Delineation

The reaches described below are illustrated in Figure 4.2 which follows this section.

Prince Road to Ina

Reach 1 begins at Prince Road in City of Tucson and ends at Ina Road in Town Marana. The major land uses in this reach include recreational uses on the west bank and industrial uses on east bank. On the west bank the recreational facilities include the Silverbell Golf Course and Christopher Columbus Park. The Silverbell Golf Course is an 18-hole course that features 9 lakes. The Christopher Columbus Park is a park in the City of Tucson that has lake and over 300 acres. The industrial uses along the east bank include industrial parks, sewage plants and gravel mines. The sewage plants include the Roger Road Plant and Ina Road Plant. East bank land uses also include the Sweetwater Wetland, a restored riparian habitat, and Ted Walker Sportpark which has significant facilities for baseball and soccer.

Ina Road to Cortaro

Reach 2 begins at Ina Road and ends at Cortaro Road in Town of Marana. Along the east bank of Santa Cruz land uses are predominantly industrial and gravel mining. Vacant land dominates the west bank of Santa Cruz in this reach. A major retail and commercial center is being developed at Cortaro Road.

Cortaro Road to the Narrows

Reach 3 begins at Cortaro Road and ends at Continental Narrows. The Narrows are located a short distance south of the Avra Valley Road bridge over the Santa Cruz. The Continental Ranch Development is located on the east bank of Santa Cruz in this reach. This development is largest housing development in Town of Marana. The majority of Marana's 13,556 residents live in the Continental Ranch Development. On the east bank of the Santa Cruz the major land uses include commercial development, gravel mining and a golf course. This reach of the river

has soil cement bank protection on both sides the capacity to convey flood flows exceeding the 100-year recurrence interval.

Narrows to Sanders Road

Reach 4 begins at Continental Narrows and ends at Sanders Road. The major land use in this rural area is agriculture. This reach also includes the old section of the Town Marana. Ora Mae Harn Park is located in the old section of the Town of Marana and has baseball and soccer fields. The Marana Northwest Regional Airport, a small regional airport, is located in Reach 4. The east bank of the river in this reach has a constructed levee protecting farmlands.

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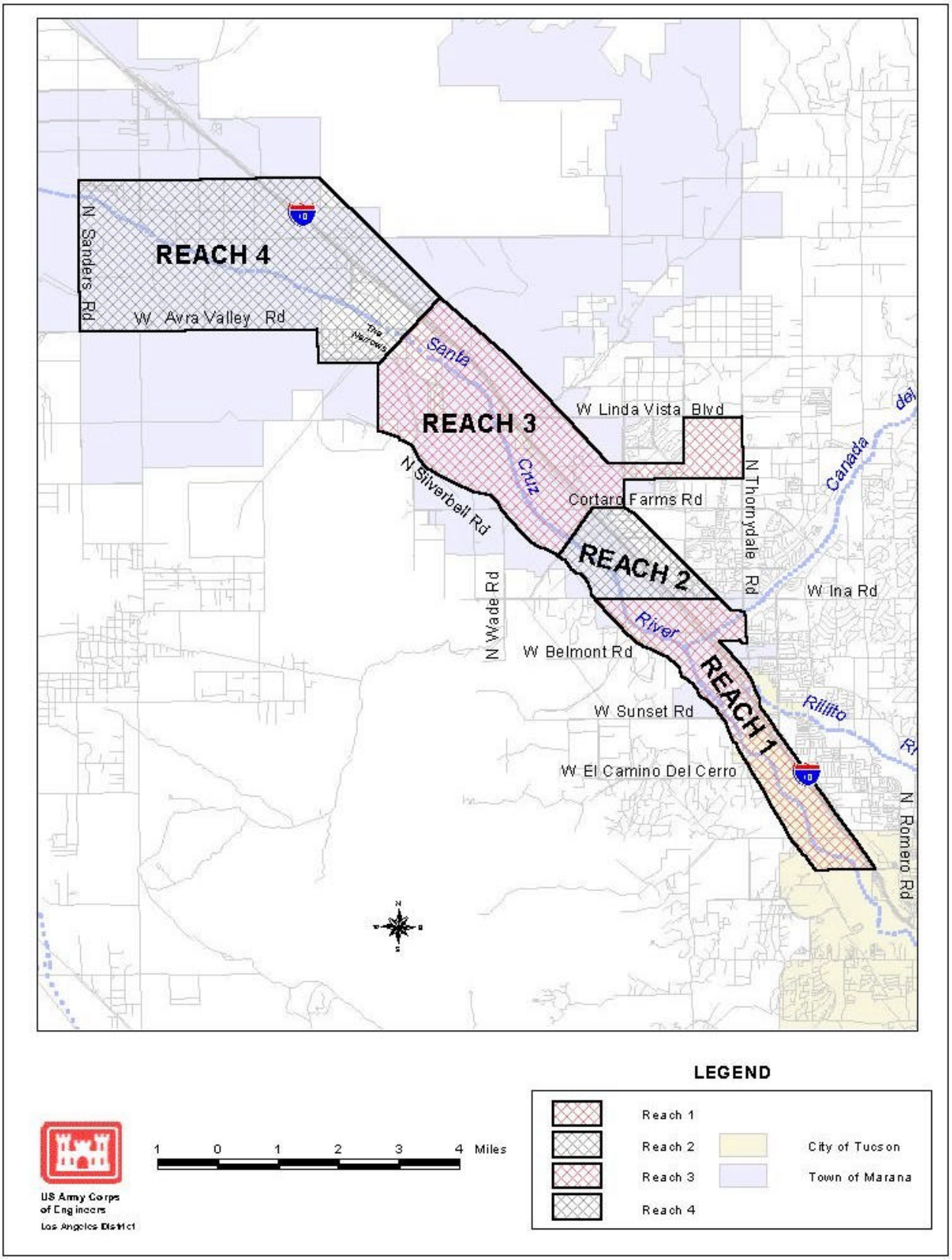

Figure 4.2 Study Reach Delineations

Land Use

Prominent land use designations in the Tres Rios del Norte study area include vacant lands and agriculture. Agriculture is a dominant land use in the northern portion of the study area. Agriculture in this area is mostly cotton, alfalfa, and some vegetable crops such as lettuce. Large areas classified as vacant include the Tres Rios riverbed and some adjacent floodplain areas. In general, vacant lands in the north are owned by the State of Arizona and in the south by the City of Tucson, while vacant areas in the center are owned by Pima County. Large areas of vacant land occur east of I-10 and north of Cortaro Farms Road in areas along Silverbell Road. Most of these vacant lands are privately owned. Figure 4.3 shows the land use in the Tres Rios del Norte study area.

Ownerships, acres

The Pima County Geographical Information System (GIS) identifies 7,026 parcels within the study area as of January 2002. Of those, 6568 are privately owned parcels with a total Full Cash Value (FCV) of $735,715,428. Portland Cement and Coca Cola are prominent owners of industrial facilities in the study area. West of I-10 and just north of Prince Road is the North Tucson Business Center.

The approximate land ownership boundaries between Pima County, the city of Tucson, and the town of Marana are shown in Figure 4.2 via highlighting of the areas in Tucson and Marana. In addition to County-owned lands, Pima County's jurisdiction (for flood control) includes the rivers and washes while the general areas surrounding the rivers and washes outside of County ownership are under the jurisdictions of Tucson and Marana.

Land Uses

The Tres Rios del Norte study area comprises approximately 19,800 acres and is a mixture of urban residential, commercial, industrial, agricultural, and open space land uses. Although this area is developing rapidly, open space remains the primary land use. The total of all open space land use designations (vacant and recreation) is 9606 acres or slightly more than half of the study area. Most of the vacant land is currently available for future development. A summary of current land use is presented in Table 4.2.

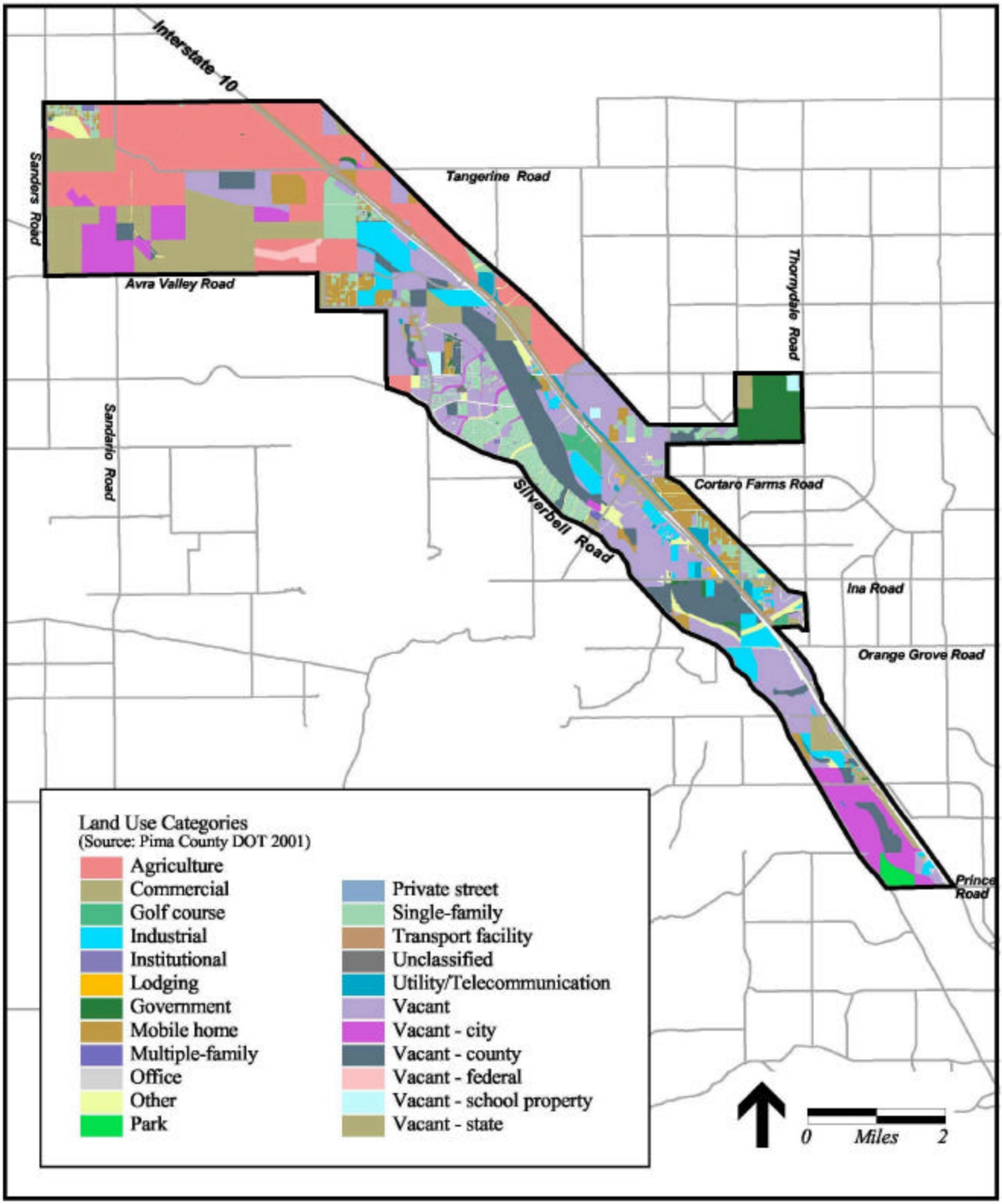

Figure 4.3 Land Use Categories

Table 4.2
Current Land Use

Land Use Designation	Acres
Commercial Industrial	1838
Residential	1898
Agricultural	4096
Recreational	227
Private - Vacant	3712
Public - Vacant	5668
Other	2365
Total	19,800

Commercial & Industrial

Industrial and commercial areas occur in many places along the river. They include Institutional, Office, Lodging and Misc. Government as well as the Commercial and Industrial land use categories. The total acreage of all these uses is 1838 or approximately 10 percent of the study area. Industrial land use includes sand and gravel operations, extraction pits, and wastewater treatment facilities.

(1) Sand and Gravel Mining

Numerous sand and gravel mining operations occupy the floodplain adjacent to the channel in the study area. On the east bank mining operations occupy the land between the channel and Interstate 10 (I-10) from Ruthrauff Road in the south to northern boundary a few hundred feet south of Canada del Oro. Other substantial areas on the east bank are between Ina Road and Cortaro Road, immediately north of Cortaro Road, and between Tangerine Road and the channel in the northern portion of the study area. Sand and Gravel mining operations on the west bank occupy the land between Silverbell Road and the channel from just south of Sunset Road to Orange Grove Road. The locations of existing Sand and Gravel mines area shown on Figure 4.4

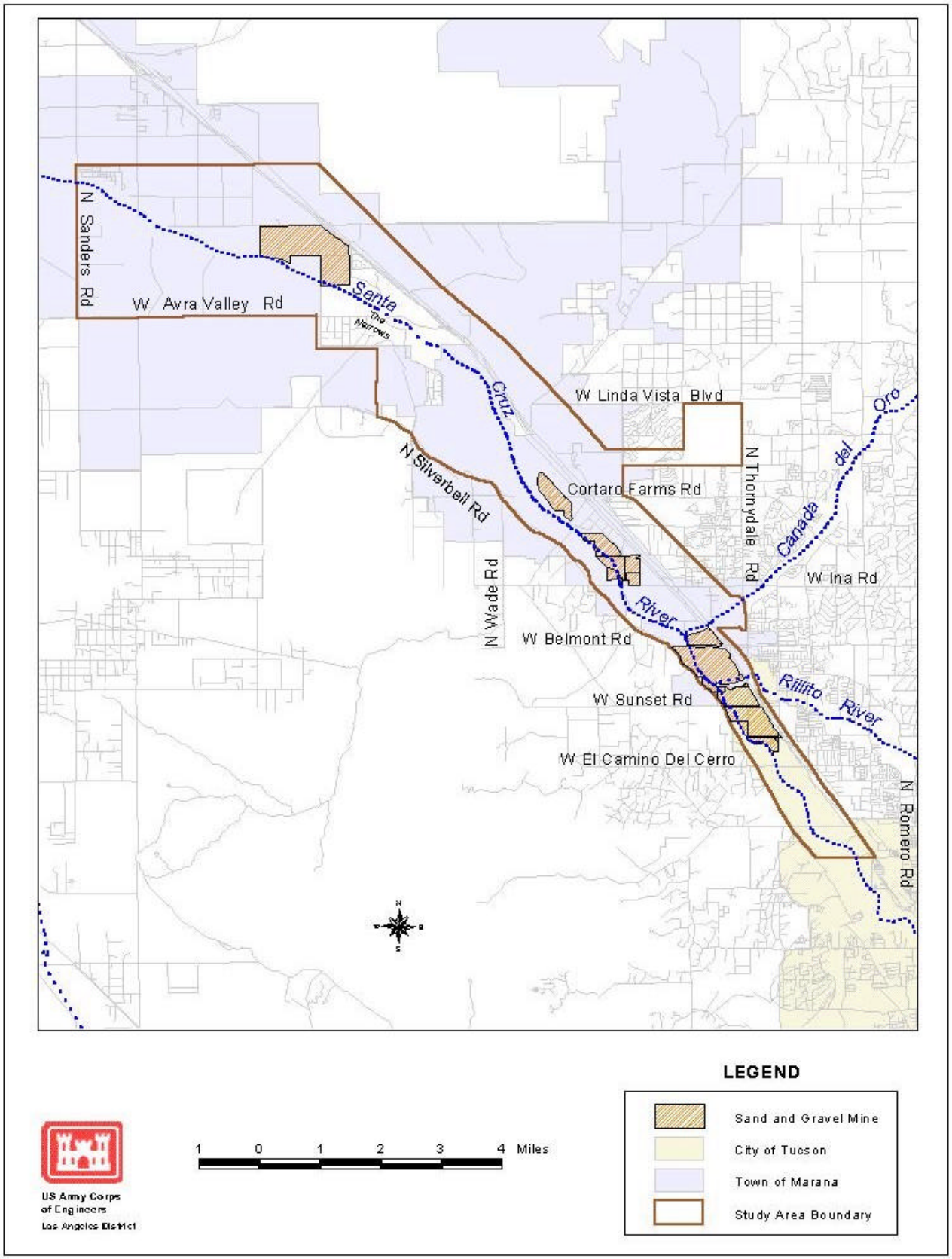

Figure 4.4 Sand and Gravel Mining Operations

Residential

Residential land use comprises 1898 acres or approximately 10 percent of the study area.

Agricultural

Agriculture comprises 4,096 acres and 21 percent of the study area. Agriculture in this area is mostly cotton, alfalfa, and some vegetable crops such as lettuce.

Recreational (Golf Courses, parks, etc.)

Recreation currently comprises 227 acres in the study area. There is a need for additional recreational facilities, and there is currently a high demand for recreation in the area.

Vacant - Private

Vacant private land (3712 acres) makes up approximately 19 percent of the study.

Vacant - Public

Vacant public lands comprise 5,668 acres in the study area, the largest category of land use at approximately 29 percent. Large areas classified as vacant lands include the Tres Rios riverbed and adjacent floodplain areas. In general, public vacant lands in the north are owned by the State of Arizona (2,462 acres), and in the south by the City of Tucson (1,290 acres), while vacant areas in the middle of the study area are owned by Pima County (1,740 acres).

Other Misc

Other Miscellaneous includes the Transport Facility, Utilities/Telecommunications, Private Street, Unclassified and Other land use designations. These areas comprise 2,365 acres of the study area with Unclassifed (1403 acres) being the largest sub-category.

Water Resources

Surface Water

Flood flows

Between Cortaro Road and Sunset Road, the only bank protection is a 1.5 mile stretch that protects the wastewater treatment plant. Between Cortaro Road and Avra Valley Road, the river is bank protected with a terraced cross section. Flood flows up to approximately the 10-year event are contained within a 350 - 400 foot wide low-flow channel. The 100-year event flow is contained within the soil cement banks with a top width that varies from 800 feet (near Cortaro Road) to 2,000 feet within the Continental Ranch Subdivision.

Runoff events are generally of short duration with flows lasting from a few hours up to a several days in the case low recurrence interval events. Flood flows originating in the upper reaches of

the river seldom make it to its confluence with the Gila River and most of the flood flow is diverted westward and the sediments are deposited. Discharge-frequency relationships are shown in Table 4.8 later in this chapter.

Effluent Flows

No local permanent water resources exist along the Santa Cruz River in the study area. Non-effluent flows occur only as a result of runoff from storms. Three water treatment facilities are located on the Santa Cruz River within the study area, the Roger Road Wastewater Treatment Plant, the Ina Road Water Pollution Control Facility, and the Rillito Wastewater Treatment Facility (Figure 4.5). Effluent released from the facilities currently provides a perennial flow in the Santa Cruz River within the Tres Rios del Norte study area. Approximately 57,200 acre-feet of effluent are discharged into the river annually

The Roger Road Wastewater Treatment Plant was established in 1951 and serves the Tucson area located south of the Rillito River. The facility currently discharges approximately 25,000 acre-feet per year into the Santa Cruz river. An additional 12,000 acre feet per year of treated effluent is delivered into the City of Tucson reclaimed water system for non-potable uses.

The Ina Road Water Pollution Control discharges approximately 32,000 acre-feet per year into the Santa Cruz River. This facility, established in 1977, serves the northern parts of the Tucson metropolitan area, Oro Valley, and a major portion of the Town of Marana.

Effluent Water Quality

Both the Rodgers Road and the Ina Road facilities are required to are required to monitor a number of parameters for compliance with NPDES (1999) and Aquifer Protection Permits (2001). Recent data for year 2000 discharge monitoring reports indicate that the effluent water quality is well within the NPDES and APP permit limits.

Extensive monitoring for dissolved oxygen was conducted from 1992 to 1994. Only two out of 228 samples failed to meet the established standard and those missed only narrowly. In 1998 sampling conducted by the United States Geological Service (USGS) on one out of twelve samples exceeded the standard for turbidity.

Ownership

As noted earlier, for all practical purposes, all of the surface water in Southern Arizona has been appropriated and no additional water is available for appropriation. The potential availability of water, especially effluent currently in the river, is dependent upon a complex legal and institutional framework and subject to negotiation between the owning parties. Consequently, the continued release of effluent is not assured.

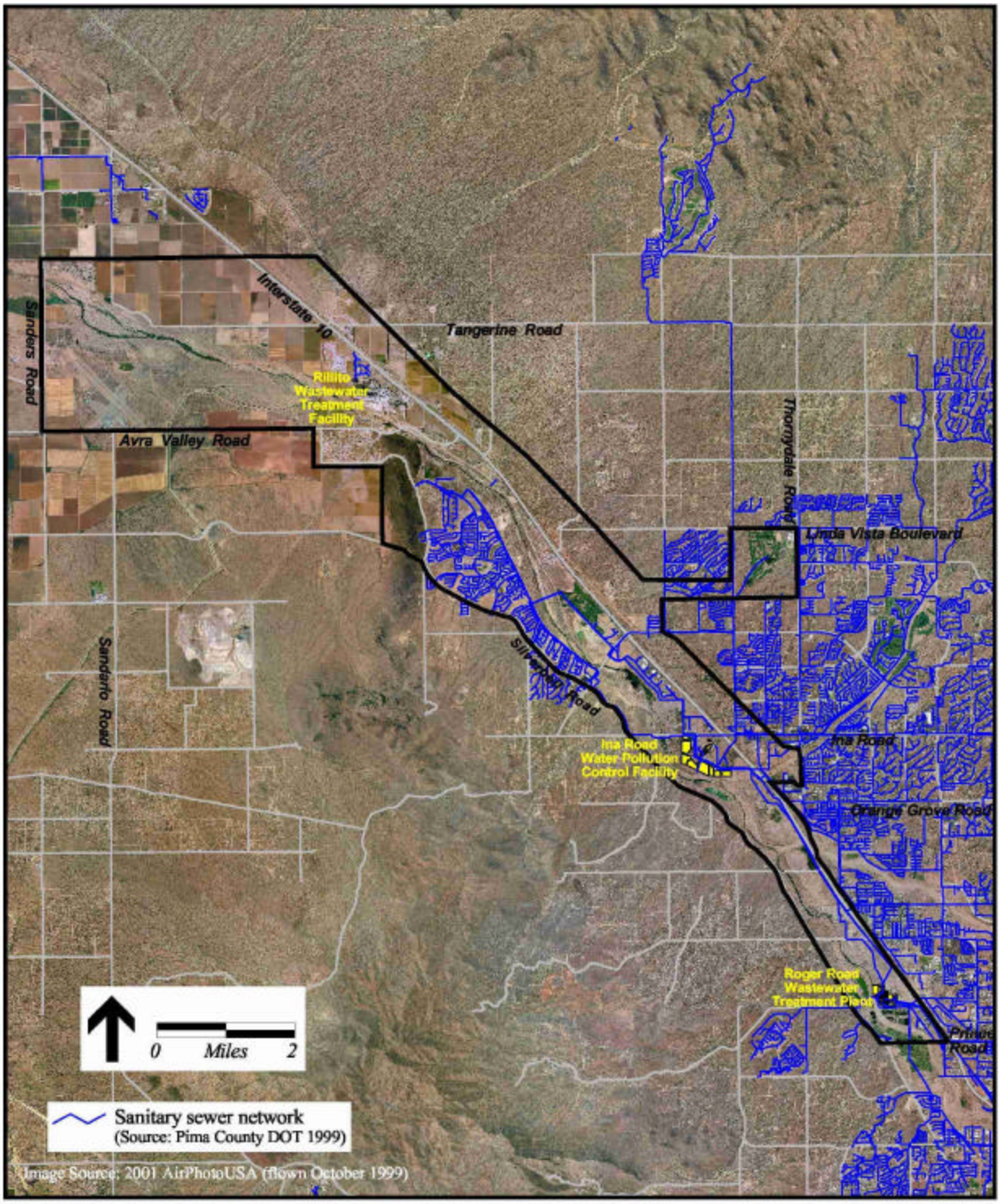

Figure 4.5 Wastewater Treatment Facilities

The Secretary of the Interior administers basic entitlements to Colorado River water through the issuance of delivery contracts, and the allocation of Central Arizona Project ("CAP") water to water users within the state. The Arizona Department of Water Resources ("ADWR") plays an advisory role to the Secretary in recommending these allocations; the Secretary customarily accepts these recommendations. There is no agricultural water user in the Tucson AMA that holds a subcontract for CAP water. Several municipal water providers in the Tucson AMA have annual entitlements to Colorado River Water delivered through the CAP canal. In most circumstances, the municipal water providers are utilizing their CAP entitlements for the purposes of Assured Water Supply demonstrations. Any entitlement that may be relinquished in the future by water providers not needing or desiring to demonstrate an Assured Water Supply will be transferred to other water providers in the AMA.

In 1989 the Arizona Supreme Court ruled in *Arizona Public Service v. Long*, 160 Ariz. 429, 773 P.2d 988 that the entity that treats wastewater to produce Effluent has the right to use that Effluent, including the right to sell or transfer it. So long as the treating entity chooses to dispose of Effluent by discharge into a stream bed, the Effluent "becomes and is water 'flowing in a stream' and under A.R.S. § 45-151 is subject to appropriation by downstream users." 773 P.2d 988 at 998. However, the treating entity is not obligated to continue such discharge and has no duty to continue the discharge to the benefit of downstream appropriators.

Water Budget

As discussed above, sources of water to support restoration projects is realistically limited to effluent releases and capture of runoff. Current releases of effluent from wastewater treatment facilities provided 57,200 acre-feet of water in 2000. However, continued delivery of this water to the river is not assured. The quantity of naturally occurring water in the study area is an important consideration to supplement effluent flows or partially replace them, in the event that these releases were to be reallocated to other uses.

Data concerning flows at tributary confluences is important since the receding flows potential quantities of storm water that might be harvested to support restoration efforts. The period of record for the Tucson gage located near the Congress Street bridge over the Santa Cruz River was evaluated to determine daily flows during different seasons. It was determined that an average daily flow of 1 cfs was exceeded during 17 to 43 percent of the period of record during the summer season (July-August-September). Average daily flows of 10 cfs, have been exceeded from 12 to 30 percent of period of the record. In the winter months (December through March) average daily flows of 1 cfs were exceeded in 7 to 14 percent of the period of record. Average daily flows of 10 cfs were exceeded in 5 to 8 percent of the period of record. During the remaining months (October-November, April-June) there was no flow in the river upwards of 92 percent of the record.

Annual flow for the Santa Cruz River at Cortaro for calendar years 1940 through 2000 ranged from 1,740 AF in 1956 to 184,600 in 1993; average annual flow for this period was 41,130 AF/yr. Average annual flow for calendar years 1991 through 2000 was 68,070 AF/yr. During that same period (1991 to 2000) effluent releases averaged approximately 52,000 AF/yr. The total runoff available for capture during those years averaged about 16,000 AF/yr. An idea as to the scale of restoration that could be supported by storm water harvesting can be gained by comparing the 16,000 AF/yr available for capture to the water demands of various riparian

habitats as presented in Table 4.3. The annual requirements of each habitat, independent of infiltration losses are estimated to be 9.73 AF/yr per acre for Cottonwood/Willow, 17.4 AF/yr per acre for Emergent Fresh Water Marsh and 3.0 AF/yr per acre for Mesquite and Scrubshrub.

Table 4.3
Restored Habitat Water Demands
(Acre-Feet per Acre)

Mon.	CottonWood/ Willow Consumption	CottonWood/ Willow Evapo-transpiration	Emergent Fresh Water Marsh Consumption	Emergent Fresh Water Marsh Evapo-transpiration	Mesquite/ Scrubshrub Consumption	Mesquite/ Scrubshrub Evapo-transpiration
Jan	.185	.183	.13	.29	.02	.05
Feb	.185	.258	.20	.44	.04	.07
Mar	.185	.417	.34	.76	.06	.13
Apr	.370	.550	.53	1.18	.10	.20
May	.370	.750	.74	1.64	.14	.27
Jun	.555	.825	.81	1.80	.15	.30
Jul	.555	.825	.76	1.69	.14	.28
Aug	.555	.750	.67	1.49	.12	.25
Sep	.185	.575	.50	1.11	.09	.19
Oct	.185	.442	.39	.87	.07	.14
Nov	.185	.275	.22	.49	.04	.08
Dec	.185	.183	.10	.22	.02	.04
Total	3.70	6.03	5.40	12.0	1.0	2.0

The annual runoff available for capture may seem substantial relative to the water demands of the restored habitats however, water losses to infiltration increase requirements by an order of magnitude. Several studies have been performed to evaluate the rate of recharge for both the Santa Cruz and Rillito Rivers (Wilson 1979; Katz 1987; Wilson and Newman 1987; Cluff et al. 1987). These studies attempted to evaluate the recharge rate using primarily empirical methods. The study by Katz indicated that the infiltration rates, volumes of recharge per day, and volumes of recharge per day normalized to stream length were computed. For the Santa Cruz, these figures were roughly 1.37 ft/day, 551 ac-ft/day, and 18 ac-ft/day/mi, respectively. For the Rillito River, the same figures were roughly 1.67 ft/day, 479 ac-ft/day, and 41 ac-ft/day/mi, respectively. The studies by Cluff, et. al., and Wilson and Newman, evaluate the effects of channel stabilization on infiltration and ground water recharge. These reports are available at the Pima County Flood Control District in-house library.

As shown by the above data, the timing and volume of runoff in the study area will not support large scale restoration. Ephemeral flows from several tributaries, in addition to ephemeral flows within the Santa Cruz River, currently support only minor isolated patches of riparian habitat (covering less than 5% of the river corridor). There can be considerable variation in the timing of these flows from the various tributaries and the main river. The lack of perennial flows, combined with the significant depth to groundwater (over 100 feet), results in an existing conditions water budget that is incapable of supporting greater areas of habitat. The primary

limiting factor for habitat is water. The capture and retention of the flow during "wet seasons" could result in an incremental increase in the amount of habitat that is supportable.

Groundwater

The principal groundwater sources in the Tucson basin occur in the sedimentary rocks and alluvium that form a single aquifer unit. The aquifer consists of the Pantano Formation, the Tinaja Beds, and the Fort Lowell Formation (from bottom to top). The Pantano Formation has small to moderate water yields. The Tinaja beds have small to water yeilds, frequently in excess of 1000 gallons per minute (gal/min). The Tinaja aquifer is within 350 feet of the ground surface throughout most of the basin.

Annual groundwater overdrafting has dramatically lowered the area's groundwater table. Due to the groundwater development during the last 50 years, the average depths to groundwater, a critical water source for native plants, have declined below the root zone of most riparian vegetation. The water table is over 100 feet below the riverbed except in a narrow band below the low flow channel established by the effluent releases.

Large-scale groundwater pumping in the Tucson basin began around 1900 and increased dramatically in the 1940s. Most of the groundwater pumped in the 1940s was used for irrigation. Later, groundwater pumpage was approximately equally divided among irrigation, municipal, and industrial uses. Continued groundwater pumping throughout the basin has lowered the regional water table and created areas of significant water level decline. The centers of greatest water-level decline are along the Santa Cruz River near Sahuarita and in the City of Tucson.

Depths

Due to multiple formations and perched water tables, depths to groundwater can range from less than 20 feet to about 170 feet below the ground surface along the Santa Cruz and Rillito Rivers. Water levels in the Tres Rios del Norte study area currently range from approximately 100 to 250 feet below the land surface. Within the study area, water levels are shallowest south of Avra Valley Road and deepest near the study area's northern boundary. Extensive groundwater pumpage for irrigation and municipal uses has caused long-term groundwater-level declines throughout much of the Santa Cruz River Basin. Recently, replacement of agricultural pumping with CAP water has resulted in water level rises north of Avra Valley Road. However, when compared to historic data, the water table has shown a net decline. These long-term water-level declines have resulted in aquifer compaction and associated land subsidence of up to 0.5 feet in the Santa Cruz River Basin.

Wells

More than 40 wells lie within the study area with a like number in close proximity to the study area boundaries. Total groundwater withdrawals from wells located within 10 miles of the Santa Cruz River were reviewed for the period of 1985-1999. The average annual withdrawal for that period was approximately 87,000 acre feet. More detailed information is provided in the Geotechnical Appendix and the Groundwater Appendix.

Groundwater Quality

Groundwater is the main source of drinking water in eastern Pima County. In general, groundwater in the Tucson AMA is of acceptable quality for most uses. Most groundwater resources meet Federal and state drinking water standards, though contaminant levels exceed primary safe drinking water standards in a few areas. Land uses such as landfills, irrigated agriculture, underground storage tanks, abandoned wells (wells no longer in service that have not been capped), wastewater treatment facilities, military facilities, mines, and industry and commerce have historically been linked to groundwater contamination in the basin (PAG 2001a). Volatile organic compounds (VOCs), nitrates, petroleum hydrocarbons, and heavy metals are among common groundwater contaminants known to be present in the Tucson area.

According to the Pima Association of Governments, there are 10 well known areas of groundwater contamination in eastern Pima County. Two of these areas are located within the Tres Rios del Norte study area, the El Camino del Cerro Water Quality Assurance Revolving Fund (WQARF) site and the Silverbell Jail Annex Miracle Mile WQARF site. Both are located in the southern portion of the study area.

The El Camino del Cerro WQARF site is located between the Santa Cruz River on the west, Shannon Road on the east, the Rillito River on the north, and El Camino del Cerro Road on the south. The closed El Camino del Cerro landfill occupies approximately 20 acres of land on the southwest portion of the site. Approximately 23 different VOCs and several trace metals have been detected in groundwater in the vicinity of the site. The extent and severity of groundwater contamination to the northeast of I-10 have not been completely determined (ADEQ 2001). The primary contaminants of concern found at the site include Tetrachloroethylene (PCE), trichloroethylene (TCE), vinyl chloride, and benzene (PAG 2001a).

The Silverbell Jail Annex Miracle Mile WQARF site is bounded roughly by Silverbell Road on the west, Sweetwater Road on the north, Fairview Road on the east, and Grant Road/Ironwood Hill Drive on the south. The closed Silverbell Jail Annex Landfill is located on the site at 3200 North Silverbell Road. The major source of contamination at this site is thought to originate underneath the south cell of the closed Silverbell Jail Annex Landfill. PCE and TCE are the two predominant VOCs detected at the landfill. Other VOCs routinely detected in monitor wells on the site include vinyl chloride, dichlorodifluoromethane, trichlorofluoromethane, methylene chloride, and dichloroethylene (ADEQ 2001).

Recharge Sites

Infiltration of storm runoff in the stream channels during the rainy seasons is the major source of recharge to the groundwater in the basin (Davidson 1973). Seepage of runoff along the mountain fronts constitutes the second largest source of recharge. This natural system recharges about 100,000 acre-ft/yr. However, there is currently a demand for 300,000 to 400,000 acre-ft annually. The resulting deficit is causing the water table to decline at an average annual rate of about 2.7 feet (PCDOT 1986).

Artificial groundwater recharge is an important tool currently used to help maintain a balance of Tucson's water use and supply. One method used during artificial groundwater recharge is the construction of dams, levees, and basins. These structures work by retaining water, allowing it

to infiltrate the top layers of soil and rock and percolate down to the underlying aquifer. Retaining structures can be constructed within the riverbed or in an area away from the river. Another method called direct injection converts existing water extraction wells to allow for the injection of water directly into the aquifer. Direct injection is the most certain method of recharge because water can be directed to a specific location within the aquifer.

There are numerous existing and proposed direct groundwater recharge projects and facilities located in the Tucson Basin. Several of these projects and facilities are located within the Tres Rios del Norte study area. They include the High Plains Effluent Recharge Project, the Avra Valley Recharge Project, the Lower Santa Cruz Replenishment Project, the Tangerine Road Basins, and the Lower Santa Cruz In-Channel Project, the Santa Cruz Managed Effluent Project, and the Sweetwater Effluent Basins.

Riparian Habitat

In areas lacking the perennial flow of provided by effluent releases the river is devoid of riparian habitat (Figure 4.6).

Figure 4.6 Looking SSW at Santa Cruz River Near Prince Road

North of the Roger Road wastewater treatment facility effluent flows support riparian habitat of cottonwood, willow, and salt cedar. The habitat is generally confined to a narrow strip less than 100 feet wide adjacent to the low-flow channel created by effluent flows. The habitat exists along this narrow strip due to the highly pervious soils in the river bottom which preclude infiltrating water from spreading laterally.

A large pond approximately (15 acres surface area) located just west of the Santa Cruz River–Canada del Oro River confluence and a half mile segment of the river to Ina Road provide suitable waterfowl habitat. At Ina Road a grade control structure was constructed to reduce channel downcutting. This structure flattens the slope and creates a lower-velocity zone that is favorable for riparian plant establishment. From Ina Road to Cortaro Farms Road, flooding of old sand and gravel borrow pits has created a complex of riparian forest, freshwater marsh, small ponds, and a meandering low-flow channel.

Figure 4.7 Old Sand and Gravel Pit Filled Up With Water

The continued existence of the habitat described above is completely dependent upon continued effluent releases.

Cover types descriptions, acreages (standard classification)

The vegetation communities within the Tres Rios del Norte study area generally vary from low to moderate-quality habitat and include Sonoran desert scrub (including creosotebush-bursage series, paloverde-cacti-mixed shrub series, saltbush scrub series), Sonoran riparian and oasis forests (including mesquite series, cottonwood-willow series, and salt cedar disclimax series), and Sonoran interior strand (including an annual series). Other areas mapped include agriculture, open water, developed, and disturbed places. Vegetation communities are depicted in Figure 4.8. The numbers following each habitat title correspond to the vegetation classification codes in Brown et al. (1994). The largest percentage of area (44%) is the developed, with the next largest (34.5%) being naturally vegetated areas and (19.5%) active agriculture. Acreages for all cover types are presented in Table 4.4. Additional detail regarding vegetative communities can be found in the EIS.

Table 4.4
Vegetation Communities

Vegetation Community	Acreage
Sonoran Desert Scrub (154.10)	2,112.7
Sonoran Desert Scrub, Creosotebush-Bursage Series (154.11)	706.1
Sonoran Desert Scrub, Paloverde-Cacti-Mixed Shrub Series (154.12)	2,093.7
Sonoran Desert Scrub, Saltbush Series (154.17)	527.3
Sonoran Riparian and Oasis Forests, Mesquite Series (224.52)	84.8
Sonoran Riparian and Oasis Forests, Cottonwood-Willow Series (224.53)	315.5
Sonoran Deciduous Swamp and Riparian Scrub (234.70)	549.5
Sonoran Deciduous Swamp and Riparian Scrub Salt Cedar Disclimax Series (234.72)	42.8
Sonoran Interior Strand (254.70)	287.6
Sonoran Interior Strand, Annual Series (254.72)	115.6
Active Agriculture (999.11)	3,851.8
Abandoned Agriculture (999.12)	97.4
Developed (999.21)	8,708.8
Open Water (999.30)	35.2
Mining Pond (999.32)	3.1
Streambed (999.41)	17.4
Developed Levee (999.42)	153.4
TOTAL ACREAGE	19,802.8

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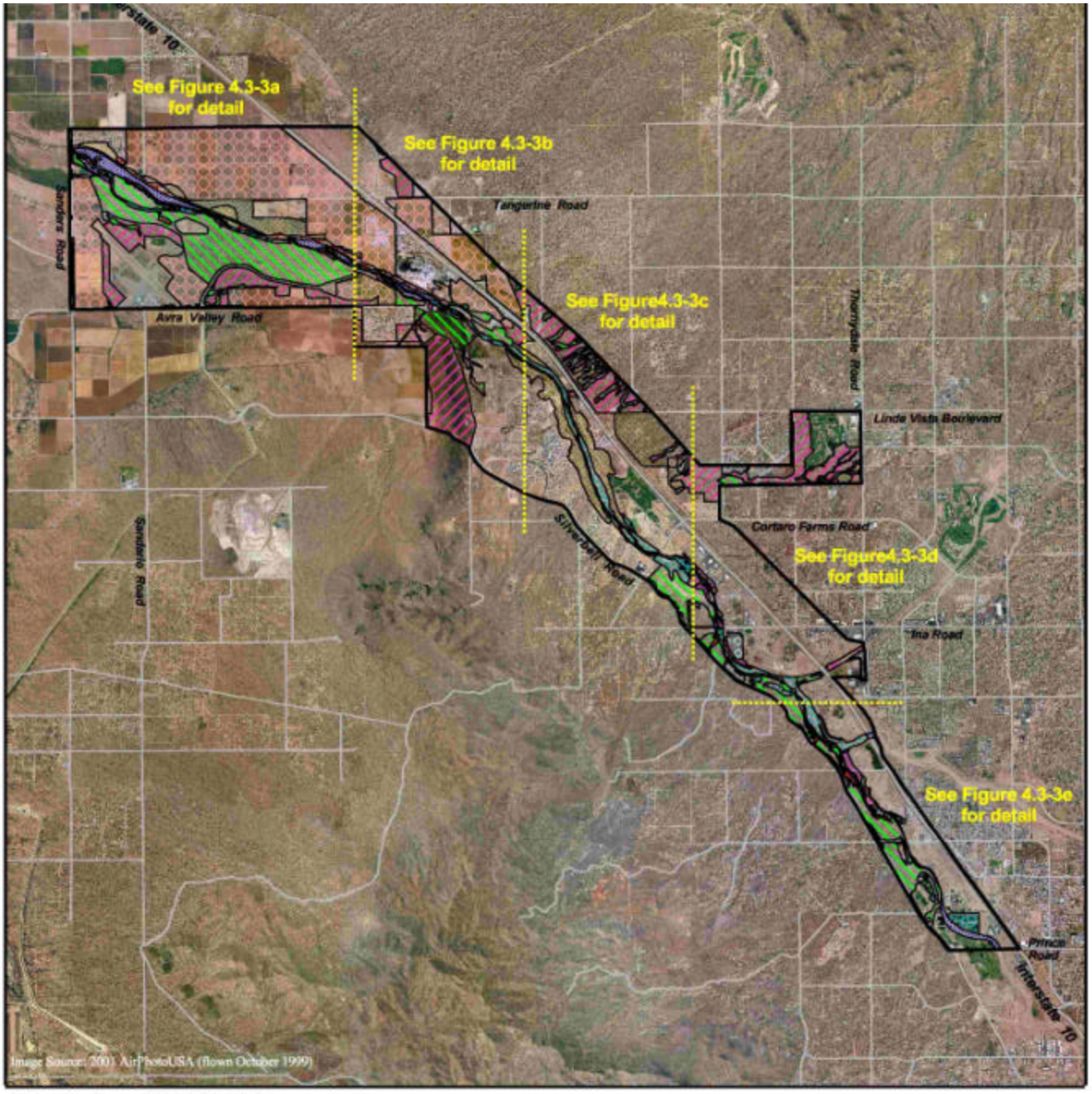

Vegetation Communities (BLP Code) (Source: RECON 2002)

- Sonoran Desert Scrub (154.10)
- Creosotebush-Bursage (154.11)
- Paloverde-Cacti-Mixed Scrub (154.12)
- Saltbush (154.17)
- Mesquite (224.52)
- Cottonwood-Willow (224.53)
- Sonoran Deciduous Swamp & Riparian Scrub (234.70)
- Saltcedar Disclimax (234.72)
- Sonoran Interior Strand (254.70)
- Sonoran Interior Strand, Annual (254.72)
- Active Agriculture (999.11)
- Abandoned Agriculture (999.12)
- Developed (999.21)
- Open Water (999.30)
- Mining Pond (999.32)
- Streambed (999.41)
- Developed Levee (999.42)

Detail Figures 4.3-3 a-e may be found in the EIS

Figure 4.8 Cover Types (standard classification)

Cover types descriptions. acreages (HGM)

Partial Wetland Assessment Areas (PWAAs) are homogenous zones of similar vegetative species, geographic similarities, and physical conditions that make the area unique. In general, PWAAs are defined based on species recognition and dependence, soils types and topography. Habitats evaluated within the study area will be classified as one of four PWAAs or as Buffer zone. These habitat delineations are illustrated in Figure 4.9.

Cottonwood-Willow Forest: Cottonwood-willow forest is representative of high-quality riparian habitat in Arizona. Riparian habitats are defined as habitats or ecosystems that are associated with adjacent bodies of water (rivers, lakes, or streams) or are dependent on the existence of perennial or ephemeral surface or subsurface water drainage. They are further characterized by having diverse assemblages of plant and animal species in comparison with adjacent upland areas. The cottonwood-willow riparian habitat is patchy in the study area and much of the original stands of this habitat have been replaced by the invasive and non-native salt cedar.

Mesquite Woodlands: Mesquite woodlands historically occurred over large areas within the river floodplain and on higher terraces of the river. These communities have been nearly eliminated from the river ecosystem by changes to natural processes. Currently, only small fragmented stands of scattered mesquite woodlands remain along the Santa Cruz River.

Scrub-Shrublands: Scrub-shrub lands are common and are present within the active channel of the river in the project study area. They are dominated by various combinations of burrobush, rabbitbush, quailbush, saltbush, and occasionally by creosote bush. Some of these areas have been highly disturbed and contain little or no vegetation cover.

Riverbottom (Low Flow Channels): These features are characterized by either seasonal or perennial open water, and are generally unvegetated when present. Vegetation, when present, consists of scattered patches of Bermuda grass, salt heliotrope, and sedges.

Other areas such as a buffer zone, urban areas, and desert areas will be tracked as part of the HGM modeling effort. All of the vegetation communities discussed under the standard classification system fall within one of the PWAAs or buffer zone. A summary of PWAA Classifications is presented below in Table 4.5.

Table 4.5
HGM Partial Wetland Assessment Area Classifications for the Tres Rios del Norte Study Area

Code	PWAA Description	Baseline Acres	Percent
AGCROP	Farms and Croplands - Dairy, Cotton and Alfalfa	3,865.7	19.5
BUFFER	Existing Buffer Zones – Mesquite, Ironwood, Rabbitbush, Quailbush, Cat-claw, Acacia, Palo verde and Creosote	2,771.8	14.0
CTWWFOR	Existing Cottonwood-Willow Forests in the Active Channel	315.2	1.6
DESERT	Desert Areas - Bare Earth, Cacti, Rabbitbush and Acacia	2520.6	12.7
MESQUITE	Existing Mesquite Woodlands on Terraces and in the Active Channel	72.8	0.4
OPENWATER	Existing Open Water Areas in the Active Channel - Inactive Sand and Gravel Operations	38.4	0.2
PARKS	Parks and Recreation Areas	598.2	3.0
RIVERBOTTOM	Existing River Bottom Areas in the Active Channel - Largely Unvegetated (Includes Emergents)	54.9	0.3
SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel	683.1	3.5
SCRUBSHRUB	Existing Scrub-Shrublands in the Active Channel - Rabbitbrush, Quailbrush, Ironwood and Saltbush	1,123.4	5.7
SOILCEMENT	Existing Soil Cement Areas on the Slopes of the Active Channel	153.4	0.8
URBAN	Existing Residential, Industrial and Transportation Avenues	7,605.3	38.4
TOTAL		19,802.8	

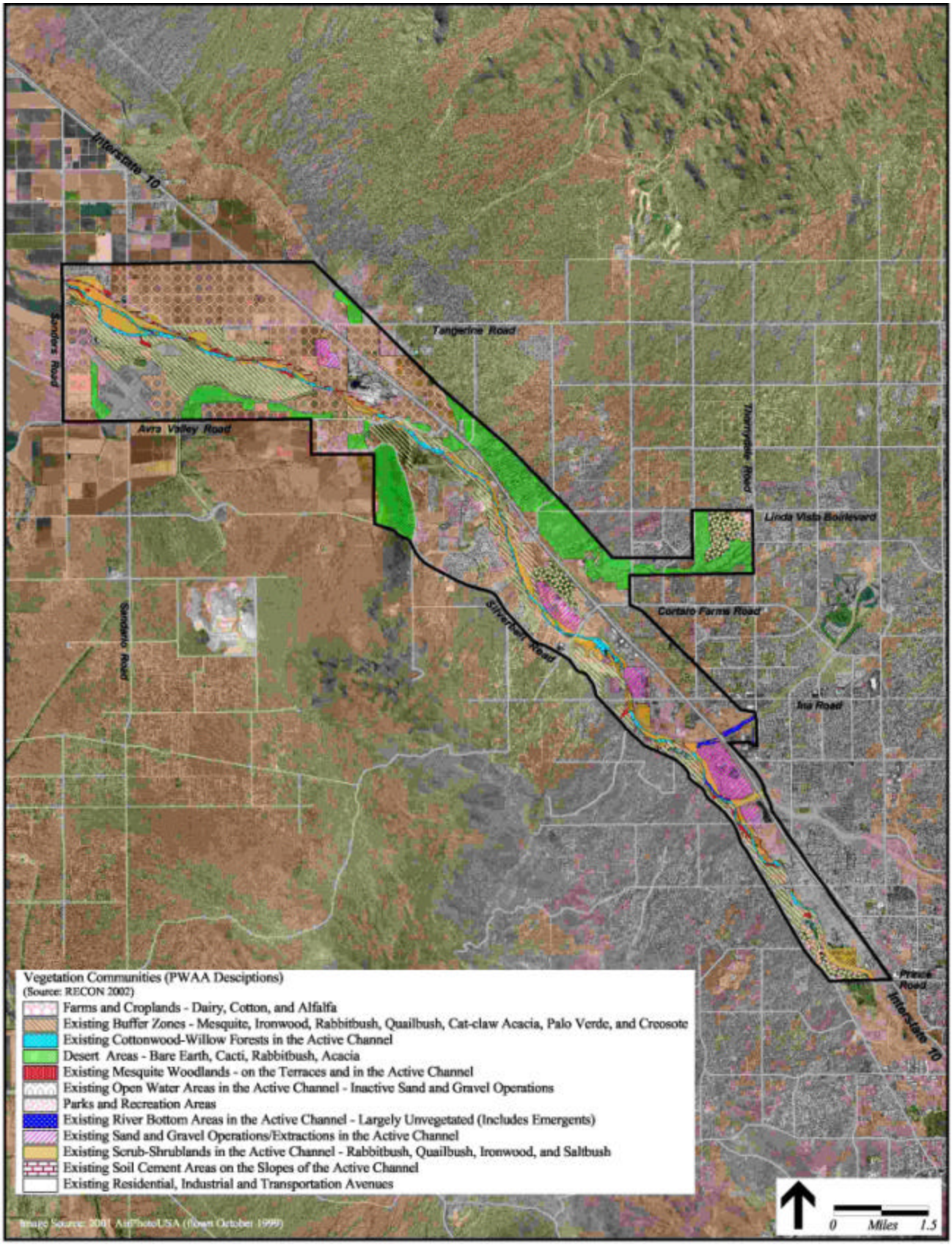

Figure 4.9 Cover Types (HGM)

HGM Modeling Description

In arid regions biological resources are typically concentrated along riparian systems. This feasibility study relies on the results of a Hydrogeomorphic Approach to Wetlands Assessment Methodology (HGM) to yield quantitative descriptions of biological resources along and adjacent to the Santa Cruz River in the study area. HGM was chosen for its broad analysis of processes and conditions necessary for support of riparian habitat. Riparian components including size, substrate characteristics, and species composition will be considered in quantification of the biological resource function and value.

An HGM approach treats the biota of an area as being the outcome of an ecological process. It also merges these biological events with hydrologic and geologic process at work in a region. Wetlands under this method are measured in terms of functional capacity. This concept is based on the inherent capacity of a wetland to perform a function under its physical, chemical, and biological components, and the level of functioning is determined by interactions between the wetland and surrounding environment. The inherent capacity of a wetland is dynamic and its functional capacity is based on an assessment model defining the relationship between the ecosystem and landscape scale variables and functional capacity. The assessment method develops a Functional Capacity Index (FCI).

The FCI is a quantitative estimate of functional capacity for a wetland. The ideal goal of an FCI is to quantify and produce an index that reflects functional capacity at the site. The results of an FCI analysis can be quantified based on a standard 0-1.0 scale, where 0.00 represents the lowest functional capacity for the wetland and 1.0 represents highest. The Functional Capacity Unit (FCU) is a measure of the ability of a wetland to perform a certain function and is calculated by multiplying an FCI by the corresponding wetland area that is producing that FCI (i.e., FCI x acreage = FCU). When evaluating and comparing alternative ecosystem restoration plans or scales of plans, the with project FCU will be compared to the future without project FCU. The net change in FCU represents increases in the biological function of the ecosystem directly attributable to the implementation of alternative plans.

Applying the HGM approach, the Santa Cruz River was classified as Riverine Overbank. The Santa Cruz River is also characterized regionally as arid and Southwestern. As such, the functions developed in an existing Riverine Overbank Subclass model were modified for Arizona low gradient rivers to be applied in the standard (HGM) approach for this study.

The model for Arizona was further calibrated in a workshop with the Environmental Lab (EL) of the Engineering Research and Development Center (ERDC). Workshop participants included the Los Angeles District Corps, local sponsor representatives from the City of Phoenix, City of Tucson, Town of Marana, Pima County Flood Control District, and Salt River Pima Maricopa Community, Arizona Game and Fish Department, U.S. Fish and Wildlife Service, and representatives from the scientific community. Field sampling results based on the calibration of the model during the workshop will be available for analysis of alternatives. The functions were developed in a Workshop by a committee consisting of Pima County, Corps of Engineers, ERDC, U. S. Fish and Wildlife Service, Arizona Game and Fish Department, and recognized representatives from the scientific community.

HGM Results

In the previous Table 4.5, HGM Partial Wetland Assessment Area Classifications for the Tres Rios del Norte Study Area, several cover types, acreages, and their percentage of the study area were delineated. The HGM model is only applied to those specific areas that are within the riparian zone, including the fringe areas characterized as buffer. The model is applied to the following cover types:

- Cottonwood-Willow - Baseline Acres: 315
- Mesquite - Baseline Acres: 72.8
- Scrub Shrublands - Baseline Acres: 1123.4
- River Bottom - Baseline Acres: 54.9
- Buffer - Baseline Acres: 2771.8

Existing riparian habitat within the river is classified according its type, and not included as river bottom, for example. Buffer areas are characterized by their immediate adjacency to the river as part of the river corridor/riparian fringe/floodplain. Acreages are determined from detailed GIS mapping.

For developing the modeling parameters, a group of over 50 people participated in a conference to evaluate and develop the model. The group included representatives from the Corps of Engineers Plan Formulation, Environmental Resources, Hydrology and Hydraulics functions; the local sponsors and their technical experts; the United States Fish and Wildlife Service, Arizona Game and Fish Department, University of Arizona, Arizona State University, and recognized experts in the fields of hydrology, geomorphology, biology, botany, and riparian ecology, and other fields. They evaluated specific variables applicable to each cover type, arriving at a total of 26 independent variables. After defining these variables, the group developed the mathematic relationships of the 26 variables into a total of 11 functions meant to describe and capture the essential elements of Southwest Sonoran Arid Desert Riparian Ecosystems.

The modeling methodology applies each developed function to each cover type to be modeled. The HGM model includes a total of four Hydrology and Geomorphology functions, three Nutrient Functions, and four Biological Functions. The functional areas are meant to delineate a complete picture of what actually contributes to a functioning, healthy ecosystem. Detailed explanations of the each function, its composition, application, and computation are provided in the HGM Appendix. The 11 functions are listed below.

- Function 01: Maintenance of Characteristic Channel Dynamics
- Function 02: Dynamic Surface Water Storage/Energy Dissipation
- Function 03: Long Term Surface Water Storage
- Function 04: Dynamic Subsurface Water Storage
- Function 05: Nutrient Cycling
- Function 06: Detention of Imported Elements and Compounds
- Function 07: Detention of Particulates
- Function 08: Maintain Characteristic Plant Communities
- Function 09: Maintain Spatial Structure of Habitat
- Function 10: Maintain Interspersion and Connectivity
- Function 11: Maintain Protection Zone from Urban Encroachment

The analysis of each cover type in terms of its ability to perform each function results in the assignment of a Functional Capacity Index (FCI) for each function. Each cover type, therefore will have a total of 11 FCI's. It is important to note that the model tracks the 11 functions for each modeled cover type separately; the purpose of this is to keep track of how the all various factors (hydrologic, geomorphic, biologic, nutrients and others) affect the overall function of the riparian zone. Essentially the model breaks a variety of complex factors down into definable units that can be tracked and compared.

The existing habitat was evaluated and Functional Capacity Indices were developed to represent the baseline condition. The results of that analysis are presented below in Table 4.6.

Table 4.6
Baseline PWAA Functional Capacity Indices

Cover Type	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Cottonwood-Willow Forest	.17	.37	.25	.50	.53	.44	.24	.49	.23	.13	-
Mesquite Woodlands	.17	.37	.25	0.0	.23	.31	.20	.41	.14	.13	-
Scrub-Shrublands	.17	.31	.25	0.0	.15	.22	.19	.21	.15	.13	-
Wetlands	.17	.40	.25	.50	.78	.49	.27	.58	.29	.13	-
Buffer	-	-	-	-	-	-	-	-	-	-	.75

FCIs range from 0 to 1, with values approaching 1 being indicative of greater function and desirability. FCIs towards the lower end of the scale indicate less quality. The basic units (currency) for the HGM model consist of the index, multiplied times the acres, in order to develop a Functional Capacity Unit (FCU). The FCU is dependent on both the quality and quantity of the cover type being modeled. This is similar to HEP, except that, in HGM, FCIs are generated for each of the eleven essential functional areas.

In evaluating the indices in the table above, it is clear that in most of the functional areas, the existing habitat in the study area is of generally low quality. Only one functional index out of the 55 reaches .5 and one reaches .78, with the remainder on the lower ranges of quality. Healthy, robust riparian habitat generally has indices in many of the functional areas of .65 or greater. These FCIs indicate habitat that is under stress, in isolated patches and in decline.

These indices were applied to the existing acreage of each cover type to develop the Functional Capacity Units (currency) for the baseline condition. This data is shown in the Table 4.7 below.

Table 4.7
Baseline PWAA Functional Capacity Units

Cover Type	Acres	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Cottonwood-Willow Forest	315.2	54	117	79	158	167	139	76	154	72	41	0
Mesquite Woodlands	72.8	12	23	18	0	20	23	15	30	10	9	0
Scrub-Shrublands	1123.4	191	348	281	0	169	247	213	236	169	146	0
Wetlands	54.9	9	22	14	27	43	27	15	32	16	7	0
Buffer	2771.8	0	0	0	0	0	0	0	0	0	0	2079

The above table indicates that the existing low quality FCIs, multiplied times a limited number of remaining acres, results in the displayed FCUs. As a means of comparison, consider that if one assumes a historic, healthy contiguous riparian corridor of approximately 7000 acres, with an average functional index in each of the 11 functions of only .65, each entry in the above table would be 4550. What the modeling illustrates is that the baseline conditions are seriously degraded from healthy, functioning conditions.

These values allow us see the gap between potential and actual functionality of riparian habitat in the study area, even without having reference to changes in acreage. Each FCU has a theoretical maximum value equal to the number of acres of the habitat type the FCI is applied to. By comparing the existing FCU to the acreages one can see the potential for dramatic gains in functionality, independent of the mere adding of acreage.

Environmental

Biological Resources

Sensitive Plants

Sensitive plant species that could occur on-site and are known to occur in the vicinity are listed in Table 4.3-4 of the EIS. No federal or state listed plant species were observed. Six sensitive plant species were recorded on or close proximity to the Tres Rios del Norte study area. Arizona Game and Fish occurrence records indicate two sensitive species were observed within two miles of the study area. These species are discussed below.

- Tumamoc globeberry (***Tumamoca macdougalii***). Tumamoc globeberry is a perennial vine in the cucumber family (Cucurbitaceae). Tumamoc globeberry was observed in 1987 within the study area. This species has been identified by the Pima Association of Governments as a "priority and vulnerable" species.
- Western desert willow (***Chilopsis linearis* var. *arcuata*).** Western desert willow is a Pima County protected native plant. A large shrub or small tree in the bignonia family

(Bignoniaceae), desert willow has dark scaly brown bark and narrow light green unserrated leaves. Desert willows were scattered throughout the Santa Cruz River channel and the floodplain.

- Arizona fishhook barrel cactus (***Ferocactus wislizenii)*.** Arizona fishhook barrel cactus is a Pima County protected native plant. A member of the cactus family (Cactaceae), Arizona fishhook barrel cactus can reach a maximum height of 11 feet and be up to 2 feet in diameter. A few Arizona fishhook barrel cacti were identified in the paloverde-cacti mixed scrub community on-site.
- Velvet mesquite (***Prosopsis velutina)*.** Velvet mesquite is a Pima County protected native plant. A deciduous large shrub or small tree in the pea family (Fabaceae), velvet mesquite has dark brown bark that separates into narrow strips along the trunk, with greenish yellow leaves along four-inch cylindrical spikes. Velvet mesquite is the dominant species of the mesquite bosques on-site and is present in the paloverde-cacti mixed scrub community. A few smaller velvet mesquite occur in the streambed within the Sonoran riparian scrub habitat.
- Thornber fishhook cactus (***Mammillaria thornberi*).** This Arizona Department of Agriculture salvage restricted species can only be collected with a permit. This small cactus blooms from April to September, has pink flowers with white edges, and is found in the paloverde-cacti mixed scrub series. This species was recorded in Avra Valley in 1985 within one mile of the Tres Rios del Norte study boundary.
- Sparseleaf hermannia (***Hermannia pauciflora*).** This herbaceous perennial that grows on dry rocky slopes between 2,400 and 4,280 feet can reach a height of 12 inches. The yellow or orange flowers can bloom anytime between February and June and September whenever soil moisture is adequate (AGFD 2000a). This U.S. Forest Service Region 3 sensitive species was recorded in 1966 within two miles of the Tres Rios del Norte study boundary.

Sensitive Wildlife

Based on historic sightings, four sensitive wildlife species are known to occur within or near the Tres Rios del Norte study area. These species include the rufous-winged sparrow (*Aimophila carpalis*) and federally endangered cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*). These two Pima County priority and vulnerable species are discussed in the Biological Appendix to the EIS. Additional sensitive species include:

- Fulvous whistling duck (***Dendrocygna bicolor*).** The fulvous whistling duck is a medium-sized duck that can weigh up to two pounds and is between 18 and 22 inches long. The southern United States is the extreme northern range of this species that is commonly found in Mexico and Central and South America (SDH 2001). This U.S. Forest Service Region 3 sensitive species was recorded in 1995 within the central part of the Tres Rios del Norte study area near Ina Road. The ponds and marshes within the study area provide foraging opportunities for this species.
- Black-bellied whistling duck (***Dendrocygna autumnalis*).** The black-bellied whistling duck is a close relative of the fulvous whistling duck and can reach up to 16 inches in length. Like the fulvous whistling duck the southern United States is at the extreme northern end of this species' range. Called the black-bellied whistling duck for its habit of nesting in burned-out tree cavities and resulting soot-covered breast, this duck also nests on the ground in marsh areas (SDH 2001; Wild Texas 2002). This Arizona Game and

Fish Wildlife of Special Concern in Arizona species was recorded near the southern edge of the study boundary near Prince Road in 1980. The marshes of the Sweetwater wetlands provide foraging and breeding opportunities for this species.

- Cave myotis (*Myotis velifer*). This bat species can grow to between 3.5 and 4 inches in length and typically roosts in caves, tunnels, and mine shafts and under bridges. The cave myotis typically feeds on small moths and flying ants by foraging between six and fifteen feet above the ground just above the top of vegetation (AGFD 1997b). This U.S. Forest Service Region 3 sensitive species was recorded before 1960 within one mile of the Tres Rios del Norte study boundary. Foraging and roosting opportunities for this species currently exist within the Tres Rios del Norte study area.

Cultural Resources

Approximately three-quarters of the cultural resources study area have been previously surveyed for archaeological deposits. As a result of these investigations, 246 archaeological sites have been recorded within the cultural resources study area. One hundred fifty-one of these are prehistoric, 51 have both historic and prehistoric components, and 43 are historic sites. Eighteen of the recorded prehistoric archaeological sites and seven of the recorded historic archaeological sites are considered major resources. The term "major" refers to those sites that have the potential to or have already contributed significantly to the understanding of prehistory or history in the Tucson Basin and southern Arizona region. Of the 25 major archaeological sites recorded in the cultural resources study area, 12 occur within the current Tres Rios del Norte study area.

NEPA Compliance

The cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*) a Federally endangered species known to occur in the study area. One USFWS Candidate Species for listing, the Yellow-billed Cuckoo (Coccyzus americanus) is also known to occur in the area.

Fish and Wildlife Coordination Act, as amended: Coordination efforts with the USFWS and the State of Arizona Game and Fish (AGFD) are in process and will continue through the feasibility study. Formal coordination is integral to the feasibility study.

Endangered Species Act of 1973, as amended: As required by Section 7 of this Act, the Corps requested a list of threatened, endangered, proposed, and candidate species known to occur within the proposed project areas. All pertinent species information is addressed and incorporated in the Environmental Appendix. A fully coordinated Environmental Impact Statement (EIS) will be prepared during this feasibility study.

Sensitive Areas: Several sensitive areas exist. Examples include a large pond approximately (15 acres surface area) located just west of the Santa Cruz River–Canada del Oro River confluence and a half mile segment of the river to Ina Road that provide suitable waterfowl habitat; and the area from Ina Road to Cortaro Farms Road, where flooding of old sand and gravel borrow pits has created a complex of riparian forest, freshwater marsh, small ponds, and a meandering low-flow channel. Like the river near the Ina Road sewage discharge outfall, this segment also supports productive waterfowl habitat.

Recreation

Parks

Within and surrounding the Tres Rios del Norte study area are a variety of recreation facilities and parks, including the open space and unimproved trails associated with the Santa Cruz River. Both private and public facilities are present. Additionally, there are several pedestrian and equestrian trails that follow foothills washes down to connect with the Santa Cruz River and the Tres Rios del Norte study area.

Recreation facilities in the study area include parks and golf courses. Golf courses include Arthur Pack Park and the Links at Continental Ranch, located between the Santa Cruz River and I-10 in the central portion of the study area, and the Silverbell golf course, located along the southern boundary of the study area. Park areas include open space areas with native vegetation, and many hiking trails along washes. While many golf courses in the area use groundwater, Arthur Pack golf course uses effluent for irrigation. The Silverbell golf course is west of the river in the vicinity of Prince Road, the southern boundary of the study area.

Private Recreational Facilities

- The Sportspark is a privately operated recreational facility located at the southwest corner of Ina Road and the Interstate 10 (I-10) frontage road. This facility has lighted ball fields, is open to the public, and is used frequently by softball, baseball, and volleyball leagues. In the past, a water park with slides and pool was operated as part of the Sportspark, but that component is now closed.
- The Links at Continental Ranch is an 18-hole course designed after the traditional Scottish courses with a moderately high use of turf. It is located north of Cortaro Road, between the I-10 frontage and a sand and gravel operation that flanks the east bank of the Santa Cruz River. It is privately operated, but open to the public.

Public Recreational Facilities

- Christopher Columbus Park, Silverbell Lake, and Silverbell Golf Course. This City of Tucson regional park and golf course is located between Silverbell Road and the west bank of the Santa Cruz River, just west of the Roger Road Wastewater WWTP and effluent release point. Treated wastewater from the Roger Road WWTP is used to fill the lake and irrigate the 18-hole public golf course. There is direct access to and from the adjacent linear trails along the soil cement bank of the river. Facilities and activities at the park include: boating, sailboarding, fishing, model airplane facility, model boat facility, off-leash dog run area, picnic ramadas and sites, playground, and restrooms.
- Ted Walker Park. This is a Pima County District Park with baseball fields, soccer field, restrooms, drinking water, and saguaro garden. It is located between the I-10 frontage and the Santa Cruz River, just north of the confluence with the La Canada del Oro Wash. The maintenance trail along the soil cement banks provide access to the Santa Cruz River
- Santa Cruz River Linear Park. Maintenance trails along the soil cement bank portions of the Santa Cruz River riverbed provide pedestrian and bicycle access along the river

corridor. However, this section of the river has not been developed as a parkway with irrigated plants, benches, drinking fountains, or other amenities.

- Arthur Pack Park. Approximately two to three miles east of the Santa Cruz River is Pima County's Arthur Pack Regional Park. This is a 505-acre urban park bounded by Linda Vista Boulevard on the north, Thornydale Road on the east, the Camino de Oeste alignment on the west, and a section of Hardy Road on the south. Adjacent to the northeast corner of the park is the Mountain View High School complex. Adjacent to the northwest corner of the park is an undisturbed 60-acre tract of state trust land. The Park's facilities are Americans with Disabilities Act (ADA) accessible and include lighted baseball and football/soccer fields, reservable ramadas, basketball court, concession building, picnic area, playground, hiking/walking paths, restrooms, and drinking water. Adjacent to the west of these facilities is Arthur Pack Golf Course, an 18-hole public golf course with a pro shop and restaurant.
- Rillito Vista Neighborhood Park and Recreation Center. This facility is located at 8820 W. Robinson Road near the town of Rillito. The park has ramadas, a volleyball court, lighted basketball court, picnic area, playground, restrooms, drinking water, and a daycare center. The facility is operated by Tucson Metropolitan Ministries.
- Ora Mae Harn Park. Marana currently has one public park. Its location is outside and approximately one mile north of the Tres Rios del Norte study area boundary. Ora Mae Harn Park is located on 44 acres of land at the corner of Lon Adams and Barnett Road, across from Town Hall and the Police Station. Park amenities at Ora Mae Harn Park include the following: 3 lighted ball fields, 1 lighted soccer field, 7 covered ramadas, complete with grills, lighting, and electrical outlets, 2 lighted tennis courts, 1 lighted basketball court, large soccer/multi-use field, 1 outdoor swimming pool, 3 lighted covered playground areas and a community recreation center
- Marana Northwest Regional Airport. Marana's airport has one 4,200-foot lighted and paved runway and one 3,000-foot unlighted paved runway. This facility is used by recreationists for small aircraft flights, parachuting, gliding, and hang gliding.

The locations of existing parks in the study are shown in Figure 4.10.

Trails

There are numerous watercourses that drain into the Santa Cruz River. These range from the large tributaries of La Canada del Oro Wash and the Rillito River to smaller washes that convey flows from the Tucson Mountains and from the Tortolita Mountains. Historically these washes have provided important pedestrian, equestrian, and wildlife routes to and from the Santa Cruz River from adjacent areas.

Trails and washes that are important links of the Pima County Trails Master Plan and fall within the study area include the following (Pima County 1996):

- Primary Trails: Greasewood Loop, Trails End Wash, Sweetwater Wash, Belmont Road, Wildhorse Wash, Picture Rocks Wash, Wild Burro Wash, Gas Pipeline, Roger Wash, Idle Hour Wash, Yuma Mine Trail, Silverbell Road and CAP Canal Line.
- Secondary Trails: Joplin Lane/Cortaro Farms Road and El Camino de Manana Wash.

One of the primary regional trails, the CAP Canal Line Trail (currently being developed) connects with the Wild Burro Wash Trail near Tangerine Road, and when complete will link Tucson Mountain Park with Tortolita Mountain Park (Pima County 2000). The trail network indicated above is shown in Figure 4.10.

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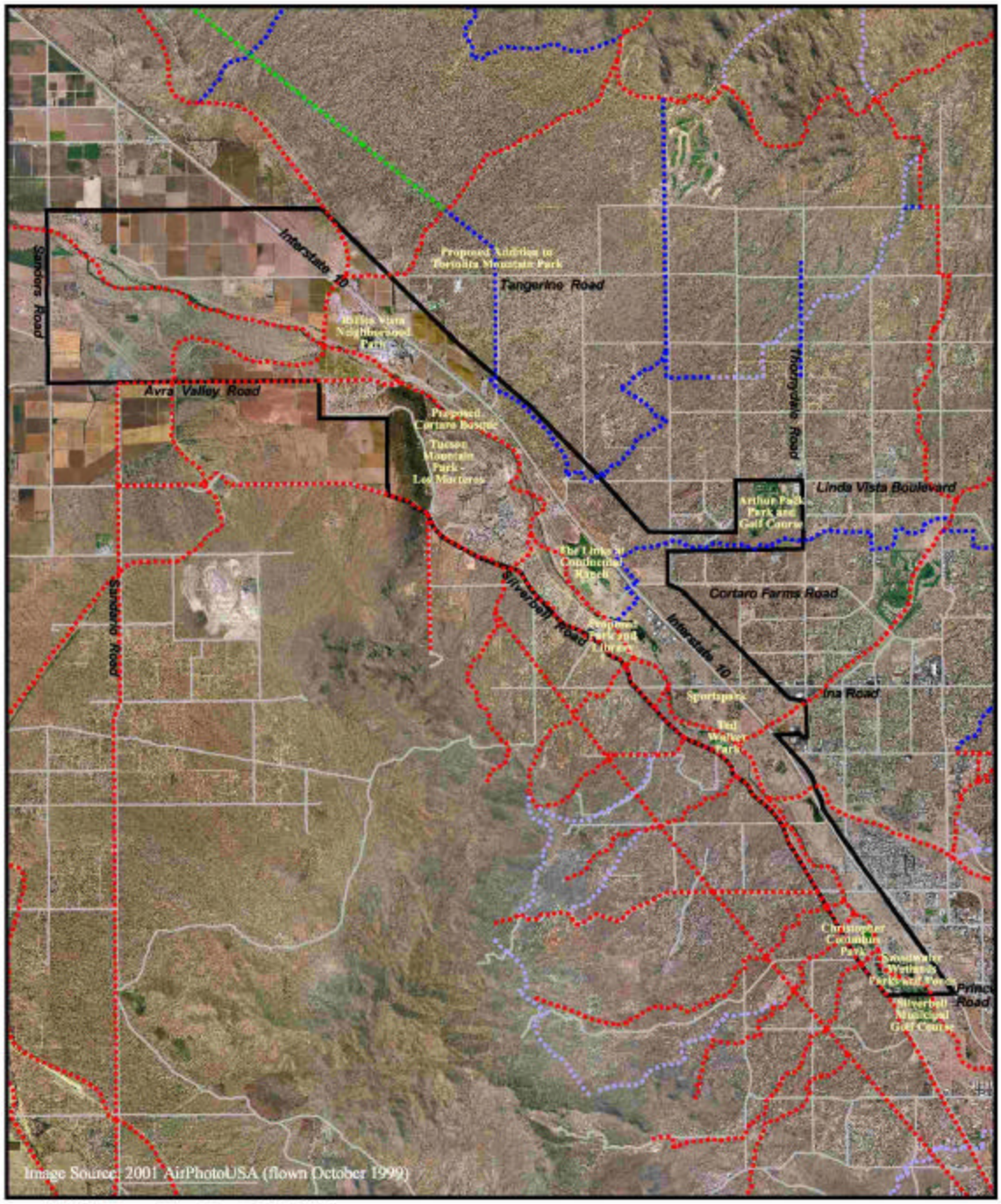

Trails (Source: Pima County DOT 1996)
- Primary
- Secondary
- Local
- Unclassified

0 Miles 2

Figure 4.10 Recreation Facilities in the Tres Rios del Norte Study Area

Other

The City of Tucson's eighteen-acre Sweetwater Wetlands near Prince Road and I-10 opened in March 1998, with park-like facilities for the public (benches, sidewalks, bridges, restrooms and interpretive signage). Countless species of birds, reptiles, amphibians and mammals are known to occur there. The Sweetwater Wetlands and Recharge Project is a constructed wetland on the west side of Tucson near I-10 and Prince Road that has been designed to accomplish three main functions (University of Arizona 2002). Since the site began receiving water in April 1997, members of the Arizona Game and Fish Department and the Tucson Audubon Society have documented more than 120 bird species there – compared to less than 15 species documented at the site prior to ground breaking. The facility can be utilized as an ecological classroom for all ages since it is open and free to the public seven days a week from dawn to dusk. The path along the top of the eastern soil cement bank of the Santa Cruz River is immediately adjacent to and accessible from the Sweetwater Wetlands.

The Marana Northwest Regional Airport. has one 4,200-foot lighted and paved runway and one 3,000-foot unlighted paved runway. This facility is used by recreational flyers for small aircraft flights, parachuting, gliding, and hang gliding.

Geotechnical

Topography

The study area is located near the central portion of the Tucson basin, a broad 1,000 square mile (sq.mi.) valley in the Santa Cruz River drainage basin. The topography of this basin is typical of the Basin and Range Physiographic Province. Northwestward trending, steep, rugged fault block mountains border the broad, gently northwest sloping alluvium-filled valley. The basin is about 50 miles long and is approximately 20 miles wide in the southern and central parts, narrowing to 4 miles wide at the northwest outlet. The basin is bounded on the north and east by the Tortolita, Santa Catalina, Tanque Verde, Rincon, Empire and Santa Rita Mountains, and on the west by the Tucson, Black and Sierrita Mountains. The mountains on the west side of the basin range from 3,000 to 6,000 feet elevation. The mountains on the north and east side of the valley range from 6,000 to 8,000 feet elevation, with peaks rising to elevations of 9,400 feet. The metropolitan City of Tucson resides at the approximate center of this basin at an elevation of about 2,400 feet.

Geology

The complex geological history of Arizona has resulted in the formation of three geologic physiographical provinces. The three provinces consist of the Colorado Plateau (in the northern area of the state), the Basin and Range Province (encompassing southern and western Arizona), and the Central Highlands or Transitional Zone (encompassing the central part of the state). The Santa Cruz River Basin lies within the Sonoran Desert of the Basin and Range Physiographic Province. The north to northwest trending alluvial basin is characterized by a semi-arid to arid broad valley.

The present relief of the Santa Cruz River Basin is a direct result of a period of regional uplifting due to block faulting that took place during the late Tertiary (63 to 2 million years ago) or early

Quaternary (2 million years ago to present). The Basin and Range province in southwestern Arizona has been considered tectonically inactive since that period. Concurrent with the uplifting of the regional mountains, large amounts of alluvium from the surrounding mountains have been deposited within the basin (at the center of the Santa Cruz River basin, bedrock is currently buried by more than 11,000 feet of alluvial sediments).

Soils

The alluvial sediments deposited within the basin have been divided into four geologic units that are, in descending order of depth: surficial or recent alluvial deposits, the Fort Lowell Formation, the Tinaja Beds, and the Pantano Formation. The surficial deposits occupy the streambed channels and are generally less than 100 feet thick. The coarse surficial deposits allow the infiltration of surface water to recharge the underlying units.

The alluvial deposits in the study area consist mainly of recent stream channel and floodplain deposits. These alluvial basin sediments are generally gravel and gravelly sand. Locally, the sediments in the study area are sand to sandy silt of fluvial origin. Lithified sediments do not crop out along the Santa Cruz River and generally they should not be present within excavation depths of the channel for structure installation, though such formations do approach the riverbed elevation in the vicinity of 22nd Street.

The material encountered within the stream banks was typically a fine sandy silt. This material is not layered and has little plasticity but is cemented. There are very few cobble-sized rocks intermixed within this sandy silt material. The stability of the existing native stream banks is marginal due to the existence of two conditions. One, the natural cementation of the soils allows the banks to stand at a near vertical inclination at many locations along the reaches of the study area. The vertical banks, when impacted by the any significant stream flow, are susceptible to being undercut at the toe and collapsing into the stream channel. The undercutting occurs mainly by water breaking down the weak cementation present in the silty material. The second condition is piping. Either surface or subsurface water flowing over the streambanks or through the streambanks via groundwater remove the fine-grained material and form large cavities or cave-like structures in the face of the stream bank. This reduces the stability of the banks as stream flows interact with the cavities in the bank and can cause mass wasting as the created cavities enlarge and collapse. The distribution of soil types in the study area is illustrated in Figure 4.11.

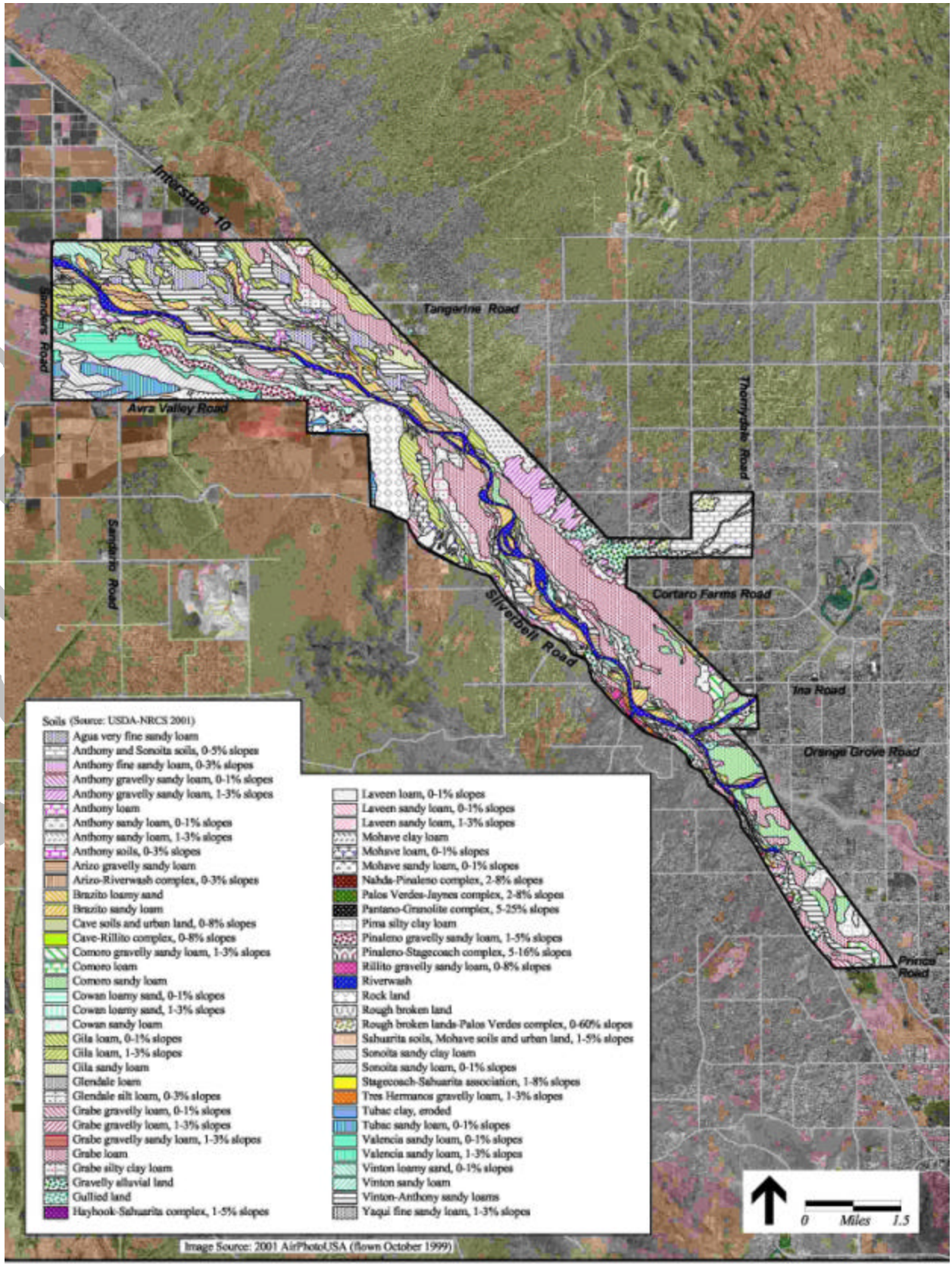

Figure 4.11 Soils in the Tres Rios del Norte Study Area

Landfills

Within the Tres Rios del Norte study area there are five closed solid waste landfills, two active construction debris landfills, one active waste tire collection site, and one active municipal solid waste landfill. The locations of these landfills is illustrated in Figure 4.12. A brief description of each site is provided below:

a. Arizona Portland Cement Company Landfill. This currently active landfill is operated by the APCC for the disposal of construction debris and materials.

b. Cortaro Landfill. The Cortaro Landfill, which is closed, was operated by Pima County from approximately 1965 to 1967. The site occupies approximately 20 acres and has a depth of approximately 10 feet. No ground water contamination has been indicated at this time.

c. El Camino del Cerro Landfill. This closed landfill, which is a state superfund site, is owned and was operated by Pima County. It was established in an abandoned sand and gravel pit and reportedly received garbage and trash from 1973 to 1978.

d. Silverbell Jail Annex Landfill. This closed landfill, which is also a state superfund site, is owned and was operated by the city of Tucson. It received municipal solid waste from 1966 until at least 1975 and possibly as late as 1977.

e. Marana #1 Landfill. This closed landfill was reportedly operated by Pima County from 1969 to 1972. The site occupies approximately 5 acres and has a depth of approximately 8 feet. No ground water contamination has been indicated where the site is estimated to be at this time.

f. Marana #2 Landfill. This closed landfill was operated by Pima County from approximately 1972 to 1978. The site occupies approximately 40 acres and has a depth of approximately 25 feet. No ground water contamination has been discovered down gradient of this site.

g. Ina Road Landfill Facilities. This active landfill site is recorded by Arizona Department of Environmental Quality (ADEQ) as two separate facilities: the Ina waste tire facility and the Ina construction debris facility. These facilities are owned by Pima County. The landfill originally operated from the early 1960s to 1973. In 1977 the facility reopened and currently accepts only inert construction debris and materials such as rock, broken concrete, and clean soil. Tires for recycling are accepted at an off-site facility.

h. Tangerine Landfill. This active landfill opened in March of 1983 as "the first modern-era environmentally sound (lined) sanitary landfill" (Pima County 2002). This landfill receives municipal solid waste from throughout the region. Its current projected life expectancy is to the year 2010.

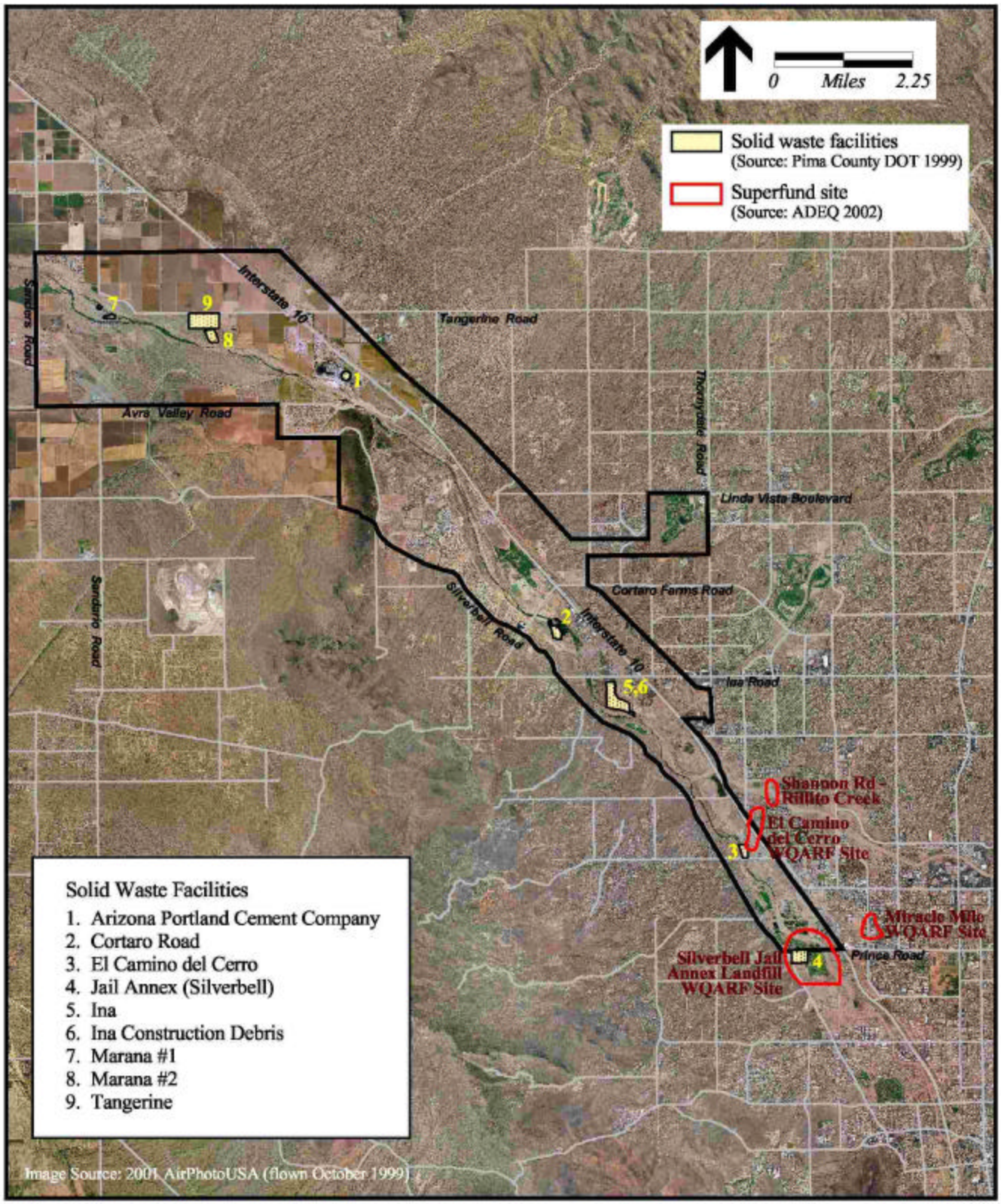

Figure 4.12 Solid Waste Facilities in the Tres Rios del Norte Study Area

HTRW & Phase I sites

The National Priority List (NPL) is the Environmental Protection Agency's (EPA's) list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial response under Superfund. There are no NPL sites or known extensions of contaminant plumes within or adjacent to the Tres Rios del Norte study area.

There are no Department of Defense (DOD) sites or known extensions of contaminant plumes within or adjacent to the Tres Rios del Norte study area.

The ADEQ established a Registry of sites in Arizona where groundwater or soil contamination is present and which qualify for funds from the Water Quality Assurance Revolving Fund (WQARF). There are two WQARF sites within the study area: the El Camino del Cerro Landfill site and the Silverbell Jail Annex Landfill site Figure 4.12.

- The El Camino del Cerro landfill, owned and operated by Pima County, was used for the disposal of municipal and solid waste from 1973 to 1978. No records were kept regarding the type of refuse deposited in the landfill, which was open 24 hours a day. In 1982, Pima County initiated the first of three phases of the Landfill Environmental Studies Program to determine the environmental effects of two selected landfills, the El Camino del Cerro landfill and the Ina Road Sanitary landfill. Remedial investigations have been conducted by Pima County in the vicinity of the landfill and northeast of I-10. The Decision Record for listing the El Camino del Cerro site on the WQARF Priority List was signed by the ADEQ Director, May 23, 1995.
- The Silverbell Jail Annex Landfill (the landfill) is located at 3200 North Silverbell Road in northwest Tucson. The landfill is a closed municipal solid waste landfill owned and operated by the City of Tucson (the City). The landfill is made up of two unlined cells which comprise approximately 40 acres. The south cell received wastes between 1966 and 1973 and is approximately 26 acres. The north cell received wastes between 1973 and 1977 and is approximately 14 acres. Neither cell accepted hazardous waste though landfill access was not strictly controlled. The south cell has been covered with soil. The north cell has been covered and re-vegetated and now underlies the Silverbell Golf Course. In the fall of 1983, groundwater was found to be contaminated at the Tra-Tel Mobile Home Park supply well to the east of the site. The city began conducting subsurface investigations in 1983 at the landfill and ADEQ began conducting groundwater investigations in 1985 at the Miracle Mile site. Tetrachloroethylene (PCE) and trichloroethylene (TCE) were found at levels which exceeded Aquifer Water Quality Standards. The city submitted a Letter of Intent to ADEQ proposing the remedial action which would be taken at the Landfill. The landfill at that time was incorporated within the Miracle Mile site boundaries.

Additional details regarding these sites can be found in the EIS Section 4.10.

Economics

Flood Damages

The study area has experienced flooding in the past that caused major damage to the transportation and the infrastructure for water and sewage. Since the last major flood event that occurred in 1993, some land has changed from agriculture to residential. The Continental Ranch Development that is located from Cortaro Road to Avra Road has added almost 3,000 homes in the 500-year flood plain.

Flood damage reduction projects have reduced the threat of future flood damages. Within the Tres Rios del Norte study area the Santa Cruz River has been channelized and its banks soil cemented for protection against damage from erosion of flood events between the southern study area boundary a point approximately one-fourth of a mile north of Camino del Cerro. The Santa Cruz River has also been channelized through the Continental Ranch development between Cortaro Road and a point about 1.7 miles south of the Avra Valley Road bridge. The channelization is designed to contain a 100-year flood within a two-tier channel. Moreover, the upper tier is only inundated during 10-year or greater floods (Pima County 2000). Some small additional areas of bank protection have been constructed in the northern portion of the study area. Figure 4.21 shows the areas of channelization or bank protection.

Pima County has also constructed an approximately six-mile-long levee along the east bank of the Santa Cruz River between the north end of Continental Ranch and Sanders Road. This levee project is also shown in Figure 4.21. The overbank floodplain area on the west side of the river adjacent to this levee is being left unmodified to provide overbank storage capacity that will act to decrease downstream flood peaks (Pima County 2000).

A narrow 100-year floodplain is now characteristic of the river in the southern and central portions of the study area. Channel widths range from 100 to 500 feet and the 100-year discharge is conveyed by the channel through the study area. The river in the northern portion of the Tres Rios del Norte study area generally has a more natural meandering course and a broader floodplain.

A preliminary hydraulic evaluation was completed for the baseline conditions. The evaluation shows almost no commercial or residential development is in the 100-year floodplain. The 100-floodplain covers mostly recreational facilities and vacant land. However, the evaluation shows that the delineation of the 500-year flood would cover an area that includes about 3,000 homes, industrial parks, and major transportation links like Interstate 10.

October 1977 Flood Event

Silverbell Golf Course, located along the Santa Cruz River near the Roger Road alignment, suffered damages estimated at $230,000.

October 1983 Flood Event

Considerable damage occurred to both public and private property. Numerous bridges and at-grade crossings along the Santa Cruz River, Rillito River, Pantano Wash and Canada del Oro Wash were damaged or destroyed. An office complex and several apartment buildings along the Rillito River were substantially damaged or completely destroyed as a result of riverbank erosion and avulsion. Numerous power lines along the Santa Cruz and Rillito Rivers were damaged when the foundations of the support towers, some of which were located within the riverbeds, were undermined by erosion. In the Town of Marana, approximately 20 residences were destroyed by erosion along Cortaro Road. Also, the flooding in the old section Town of Marana by Sanders Road damaged private structures, private businesses, and agricultural crops. The bridges at Ina Road, Cortaro Road, Avra Valley Road, and Sanders Road were damaged in this flood event. Minor damage also occurred to the Marana wastewater treatment facilities and the Ina Road landfill was severely damaged.

In response to the flood damage, a mitigation plan was developed to repair the damage and provide flood control works to reduce future damage. The plan combined Federal, state and local funding into a $105.8 million program.

January 1993 Flood Event

Within Pima County, flooding occurred along the Santa Cruz River with most damage occurring in the Green Valley and Marana areas. Large tracts of pecan groves in Green Valley and farmland in Marana were inundated. The flood event of 1993 caused significant channel instability, resulting in areas of significant bank erosion and areas of significant sedimentation. Shifting of the channel caused considerable damage to the roadway approaches and bank protection at the Ina and Cortaro Road bridge crossings of the river. The Trico Road bridge crossing north of Tucson was completely in-filled with sediment and a new channel course was cut by the river north of the bridge. Considerable erosion damage occurred along the Tanque Verde Creek, a major tributary to the Santa Cruz River and along the Agua Caliente Wash, a tributary to the Tanque Verde Creek. Erosion damage along the Agua Caliente Wash was dramatic and rendered the area east of the wash inaccessible (except by air) for a period of days. Most segments of the river within the Tucson metropolitan area were of sufficient capacity to pass the flood flows without damage. However, the January 1993 flood was particularly hard on the northeast part of the Tucson metropolitan area where many unimproved segments remained.

Socioeconomics

Three primary areas of employment in Pima County are in education, government, and military. Sources of employment in the educational sector include the University of Arizona, Pima County Community College, and the Tucson Unified School District. Government offices offer employment in the state, county and city level. Two military establishments provide further employment opportunities. They are Davis-Monthan Air Force Base and Raytheon Missile Systems Company. All three areas of employment generally require a higher percentage of professional and technical skills as well as some college education. This helps to explain why 24.7 percent of the people employed in Pima County are employed in professional and technical occupations.

This demand for higher paying jobs, combined with steady population growth, may explain why Pima County has enjoyed a low unemployment rate as much as 1.4 and 1.8 percentage points lower than Arizona and the United States. In 1998, local unemployment was 2.7 percent compared with 4.1 percent for Arizona and 4.5percent for the United States.

Construction of housing units has been increasing over the last decade. 348,508 housing units were constructed in Pima County in 1999 to accommodate population expansion in the area. This figure is up from 298,207 in 1990. In fact, the 1999 American Community Survey Profile for Pima County, Arizona, indicated that about 21 percent of the housing stock has been constructed in the past ten years. Most of the newer homes, in master planned communities, are reasonably priced compared to other metropolitan areas. The average cost of a new single family home is about $109,102, a primary factor making the overall cost of living in Pima County among the lowest of major U.S. metropolitan areas.

Hydrology and Hydraulics

Climate and Seasons

The climate in the Santa Cruz River Basin is typically desert in character with short, mild winters and long, hot summers. High diurnal temperature variations are characteristic of the region. Temperature extremes range from about 12° Fahrenheit in the winter to 122° Fahrenheit in the summer. The prevailing winds are from the east and are usually light, although severe windstorms occur at rare intervals. Mean annual precipitation ranges from 11 inches in the valleys to over 37 inches at elevations greater than 8000 feet NGVD. Studies conducted in the Tucson vicinity show an extremely low percentage (about 1%) of the rainfall appears as runoff, generally evaporating or returning to groundwater. Precipitation occurs in two distinct seasons of the year; summer (late June, July, August, September, and into October; and winter - December, January, February, and March.

Monsoon Season

Summer rains in the form of thunderstorms originating in moist air that flows into Arizona from the Gulf of Mexico generally occur in middle to late afternoon and are usually of local extent. Approximately 80% of the thunderstorms over the basin occur in the summer months. Floods associated with summer thunderstorms can be extremely flashy (up to 3 hours) and are of short duration.

Cyclonic Season

Some general summer storms do occur during the period July through September. They are associated with an influx of tropical maritime air originating over the Gulf of Mexico or the south Pacific Ocean and entering the area from a southeast or a southwest direction. Usually the influx of tropical air is caused by the circulation about a high-pressure area centered in the southeastern United States, but occasionally is caused by remnants of a tropical hurricane. There is often relatively heavy precipitation for periods of up to 24 hours and showers may continue

intermittently for as long as 3 days. Flooding commonly covers a wide area with durations of about 24 hours.

Frontal Season

Winter precipitation is normally associated with the passage of cyclonic storm centers originating in the Pacific Ocean, which commonly are a result of interaction between polar Pacific and tropical Pacific air masses. Some snow falls at the higher elevations, but the effect on flood flows is negligible. Individual storms usually are of several days' duration and wide areal extent, with slow and steady intensity. Winter floods from these storms are of longer duration with lower flood crests.

Floods can occur from heavy thunderstorms, but are typically of short duration (lasting up to three hours). The frequently occurring 2-year, 6-hour event in Tucson is about 1.5 inches of rainfall. The extreme 100-year, 6-hour event is about 3.6 inches in Tucson. Occasionally, longer-term summer storms occur, associated with tropical storms from the Gulf of Mexico or the Pacific Ocean. These storms may provide heavy precipitation for up to 24 hours, causing longer lasting flood events (24 hours or more). The 2-year, 24-hour event is about 1.8 inches in Tucson. The more extreme 100-year, 24-hour event is about 4.6 inches in Tucson. The mountainous areas may receive up to 5.5 inches during a 100-year event. Winter storms provide lesser amounts of precipitation and are associated with frontal storm systems from the Pacific Ocean.

Runoff

While all surface flows in the study are ephemeral, storm flows can be of significant magnitude. The Santa Cruz River flood of 1983 was estimated at approximately 53,000 cfs at Tucson. This discharge is 1.8 times the previously estimated 100-year (regulatory) discharge of 30,000 cfs at Tucson. As a result of that flood, the validity of the 30,000 cfs estimate had been called into question by local regulatory agencies. Several new estimates had been prepared, ranging from 30,000 cfs to 100,000 cfs. Historically, the flood frequency estimates by the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), the Federal Emergency Management Agency (FEMA) and some local jurisdictions were at odds with one another. This has the effect of resulting in a loss of opportunity for the various entities to work together on floodplain management and flood control projects toward common goals.

Investigations aimed at resolving these differences were conducted as part of the Corps' Gila River, Santa Cruz River Watershed Study (August 2001). The analysis conducted for that study separated annual peak flow data into three sub-populations: summer thunderstorms (generally occurring from June through August), dissipating tropical cyclones (generally occurring in September and October) and winter storms (generally occurring from November through March). That analysis resulted in discharge frequency estimates which more closely approximated local estimates.

The estimated frequency discharges relationships for Tucson and Cortaro Road used for development of the existing condition Hydraulic model are presented in Table 4.8 below. These values match the values that resulted from the analysis discussed above with the exception that the current study uses a slightly higher value for the 20 year frequency.

Table 4.8
Santa Cruz River: Discharge Frequencies Used for the Study Area
(cubic feet per second)

Location	Drainage Area sq. mi.	500-yr	100-yr	50-yr	20-yr	10-yr	5-yr
Tucson	2,222	120,000	55,000	35,000	20,000	14,000	9,500
Cortaro Rd	3503	150,000	66,000	45,000	28,000	19,000	13,000

There are over 70 natural washes and artificial drains which deliver runoff to the Santa Cruz River in the study reach. Detailed information regarding the flow rates of each drain for various frequency events is provided in the Hydrology Appendix.

Tributary Hydrology summaries

Annual flow for the Cañada Del Oro Wash below Ina Road for calendar years 1996 through 2000 ranged from 220 AF in 1999 to 2,420 AF in 2000; average annual flow for this period was 950 AF/yr. Annual flow for the Rillito River at La Cholla Boulevard for calendar years 1996 through 2000 ranged from zero AF in 1997 to 23,672 AF in 2000; average annual flow for this period was 9,520 AF/yr.

There are 78 in-flows to the Santa Cruz River in the study area not including Canada del Oro and the Rillito River. These include natural washes, storm drains and discharge from detention basins. The tributaries have drainage areas ranging from less than .1 square miles up to nearly 10 square miles. There is a broad range of discharge values associated with these tributaries. Discharges associated with the 2-year recurrence interval event vary from 38 cubic feet per second (cfs) to 856 cfs. Discharges associated with the 100-year recurrence interval event range from 194 cfs up to 9,258 cfs. Detailed information regarding the flow rates of each drain for various frequency events is provided in the Hydrology Appendix.

Historic Flooding in the study area

The four most severe flooding events in recent history occurred in 1977, 1983, 1990 and 1993.

<u>October 1977 Flood Event</u>

In the 1977 flood approximately 12 to 14 inches of precipitation fell near Nogales and resulted in a peak discharge on the Santa Cruz River at Tucson of approximately 23,700 cubic feet per second (cfs). It was estimated that the 1997 flood flow on the Santa Cruz River at Tucson was a 25-year recurrence interval event.

<u>October 1983 Flood Event</u>

This flood caused record flooding throughout Pima County, particularly along the Santa Cruz Valley. The peak discharge on the Santa Cruz River at Tucson was estimated to be 53,080 cfs, correlated to a 100-year recurrence interval event.

July 1990 Flood Event

The flood event led to a state declaration of Pima County as a disaster area.

January 1993 Flood Event

Peak flows for the 1993 event were not published for the Santa Cruz River at Cortaro. Subsequent Corps studies have estimated the peak to be 40,000 cfs, slightly less than a 50-year recurrence interval event (45,000 cfs)

Floodplain delineations

The 5-, 10-, 20-, 50-, 100-, and 500-year flood events were simulated for the Santa Cruz River. The floodplains associated with these discharges were and are illustrated in Figures 4.13 through 4.20. The l00-year floodplain is narrow with few structures within its boundaries.

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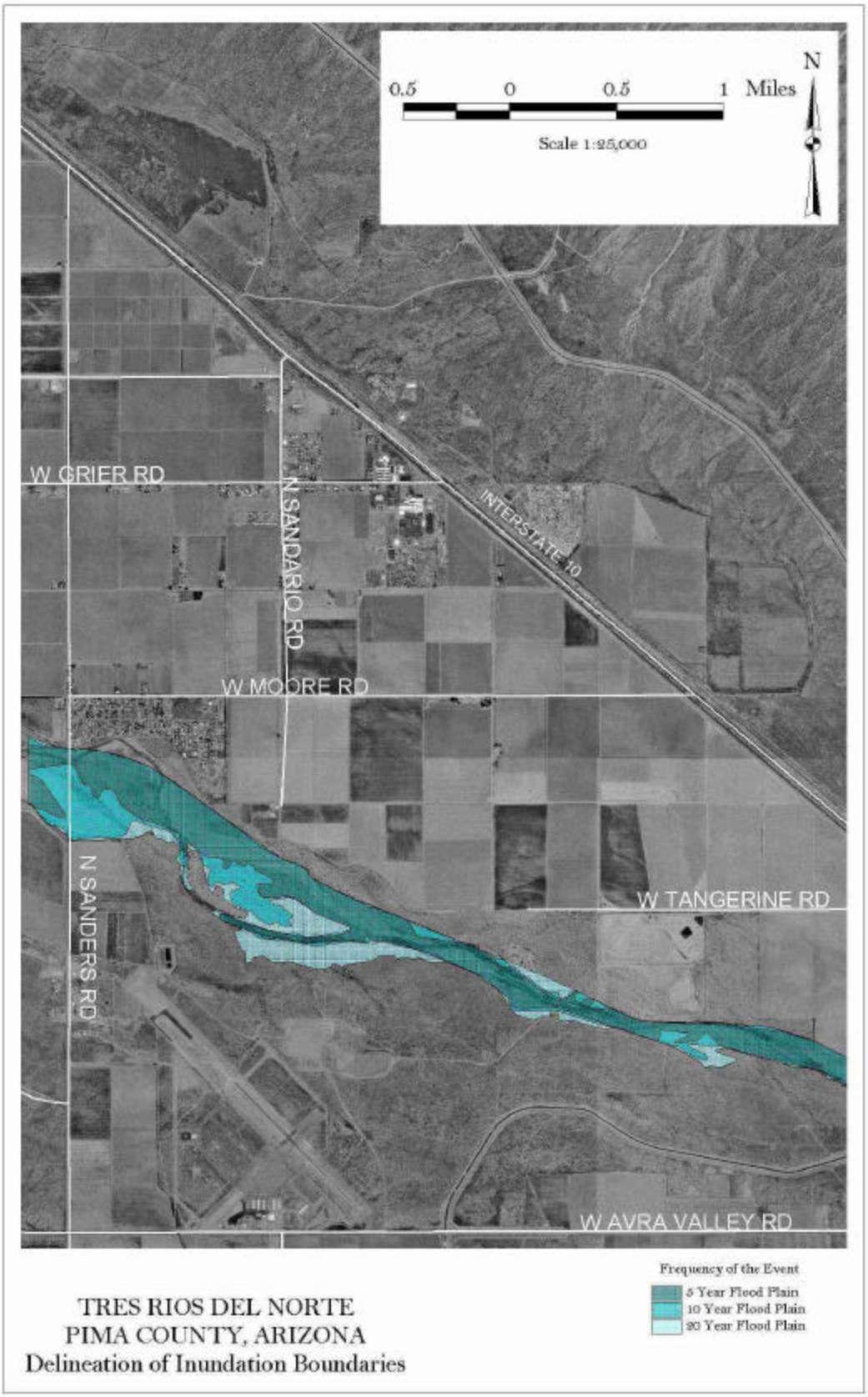

Figure 4.13 5,10 & 20-year Floodplains (1 of 4)

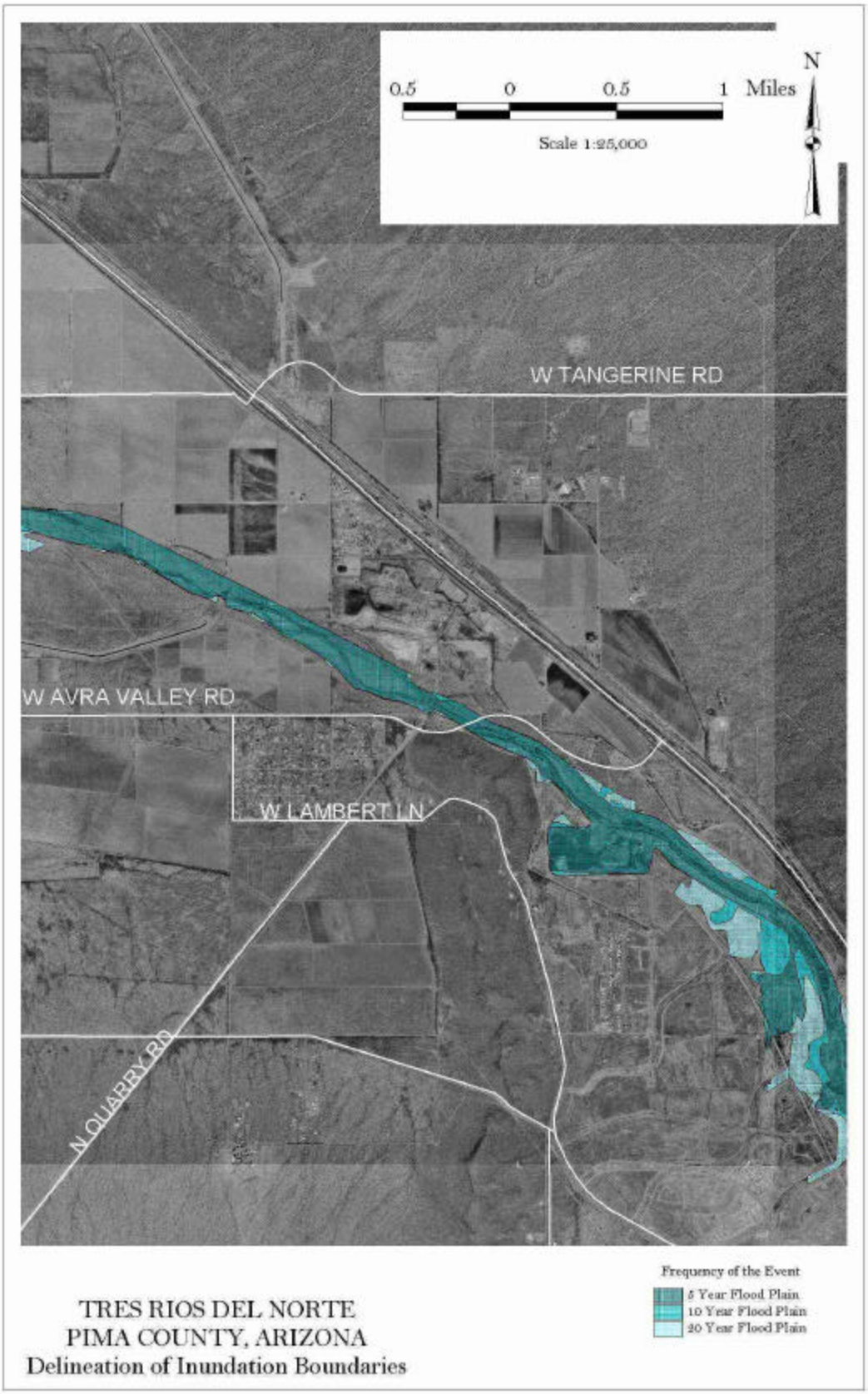

Figure 4.14 5,10 & 20-year Floodplains (2 of 4)

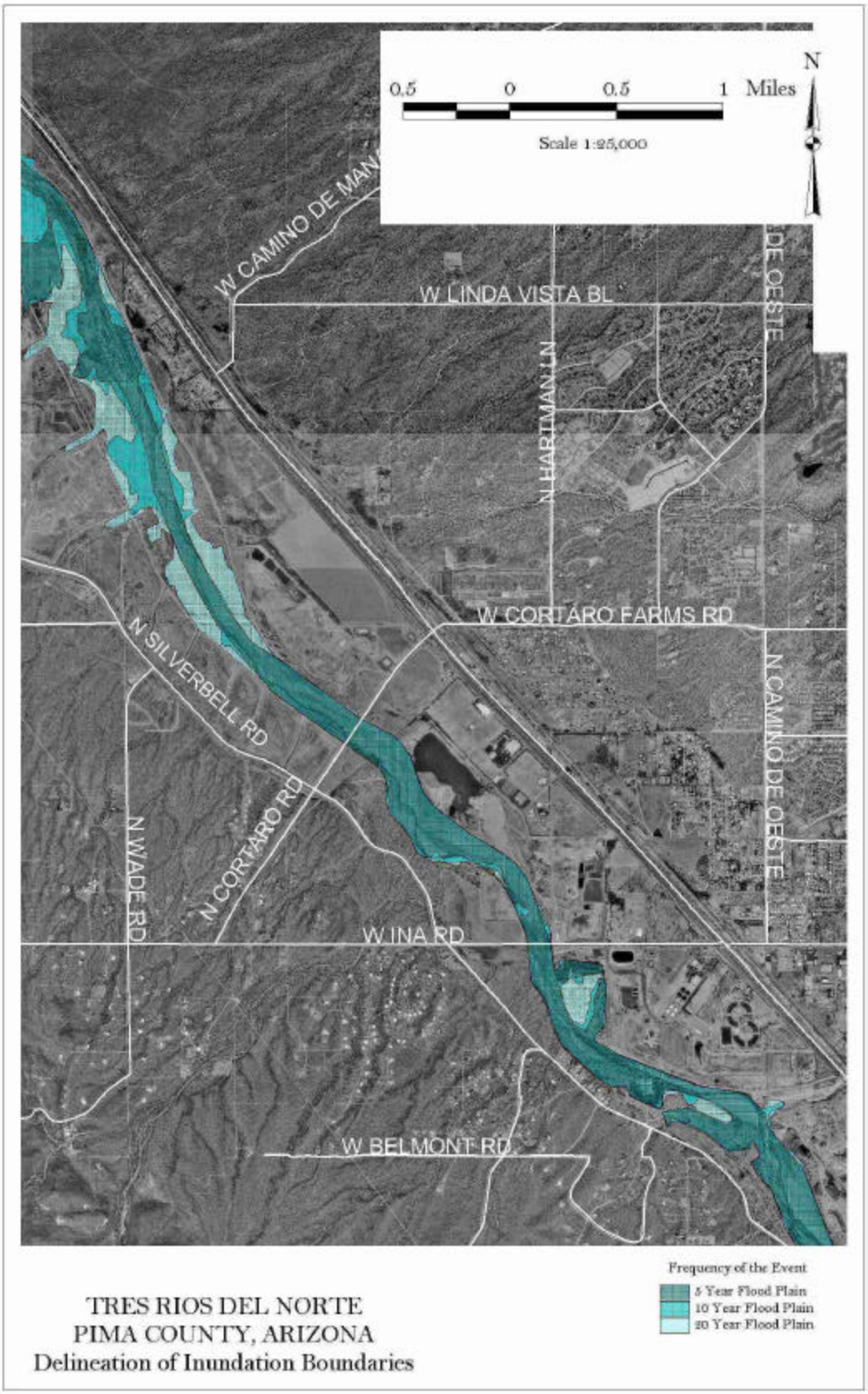

Figure 4.15 5,10 & 20-year Floodplains (3 of 4)

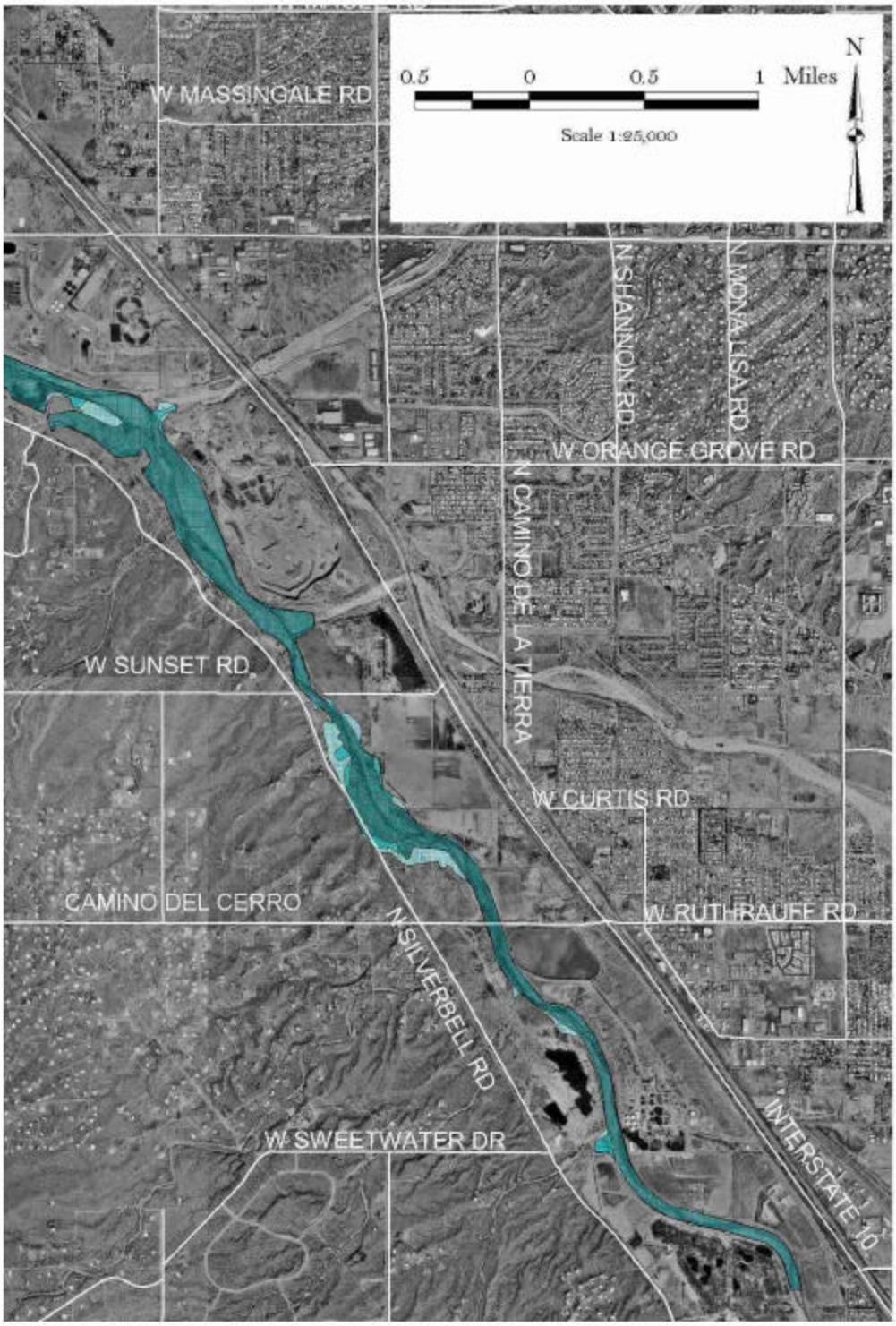

Figure 4.16 5,10 & 20-year Floodplains (4 of 4)

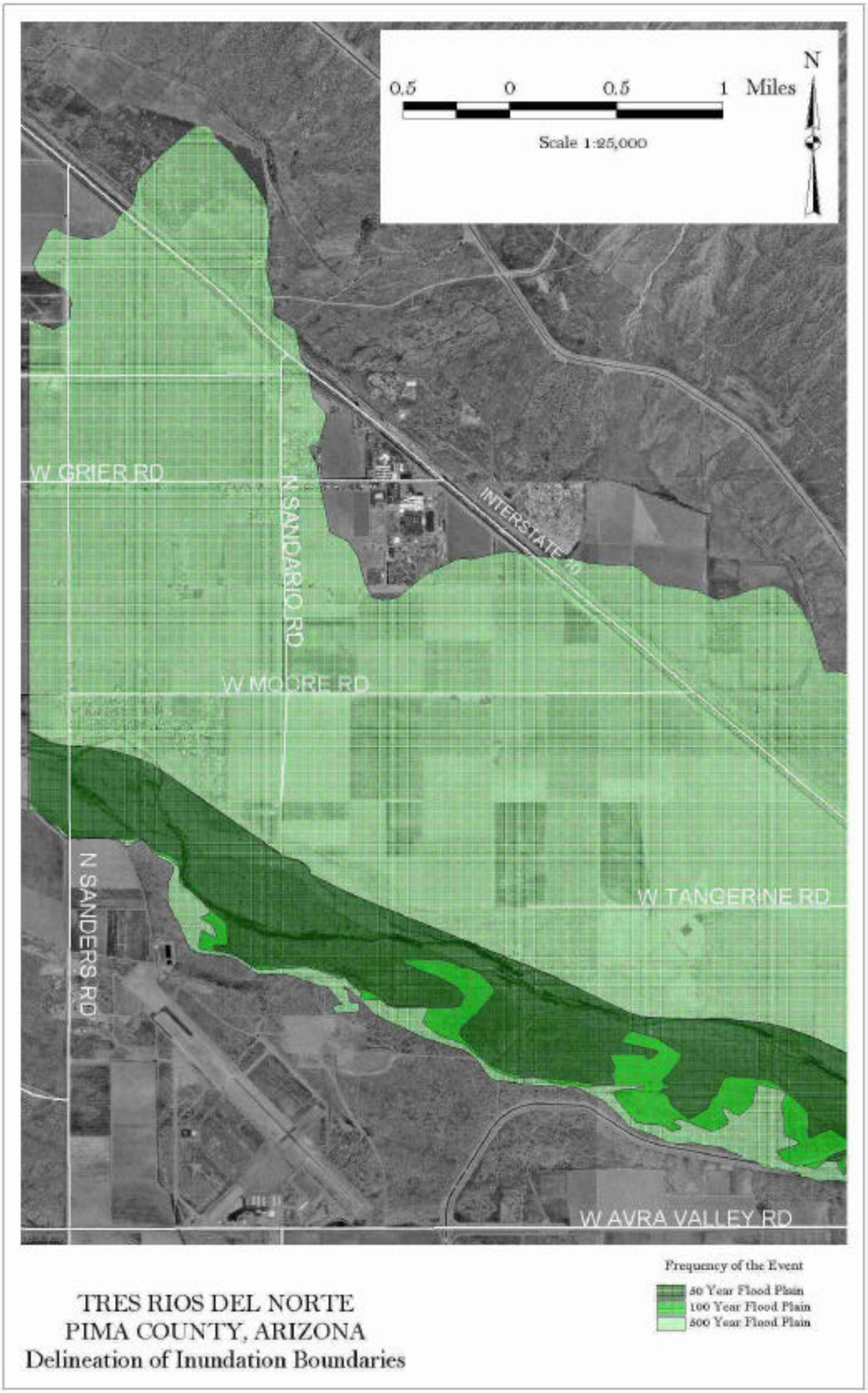

Figure 4.17 50,100 & 500-year Floodplains (1 of 4)

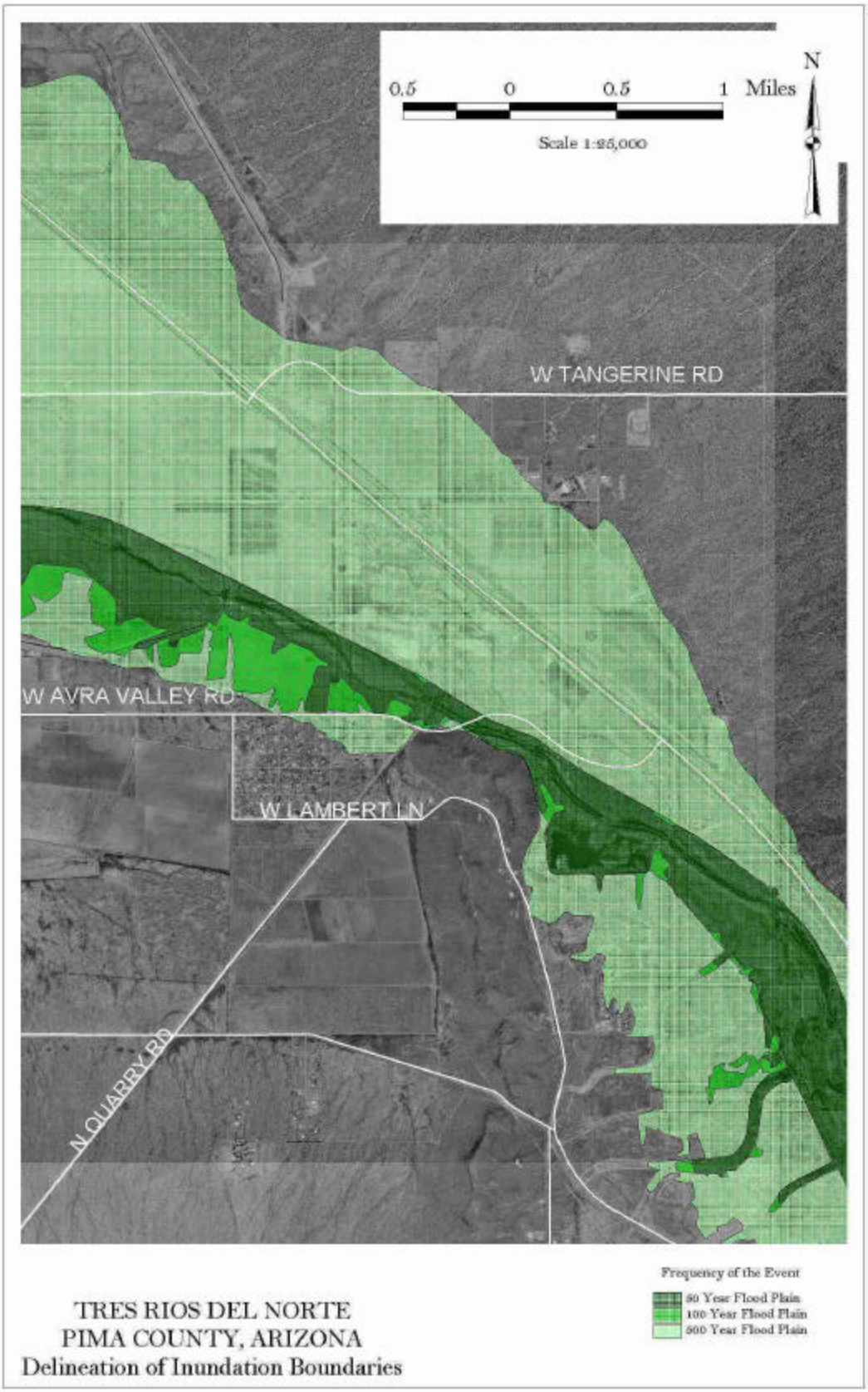

Figure 4.18 50,100 & 500-year Floodplains (2 of 4)

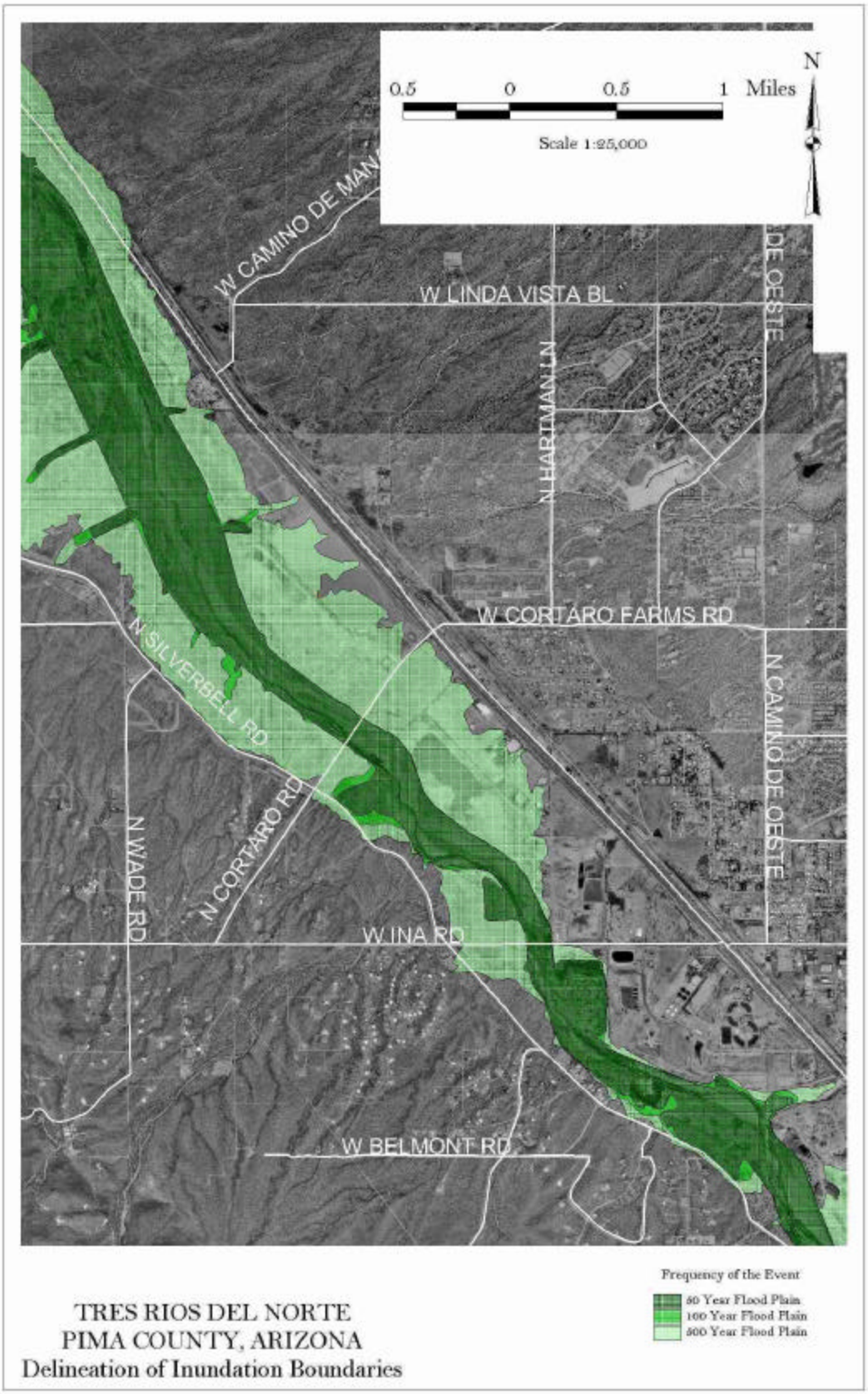

Figure 4.19 50,100 & 500-year Floodplains (3 of 4)

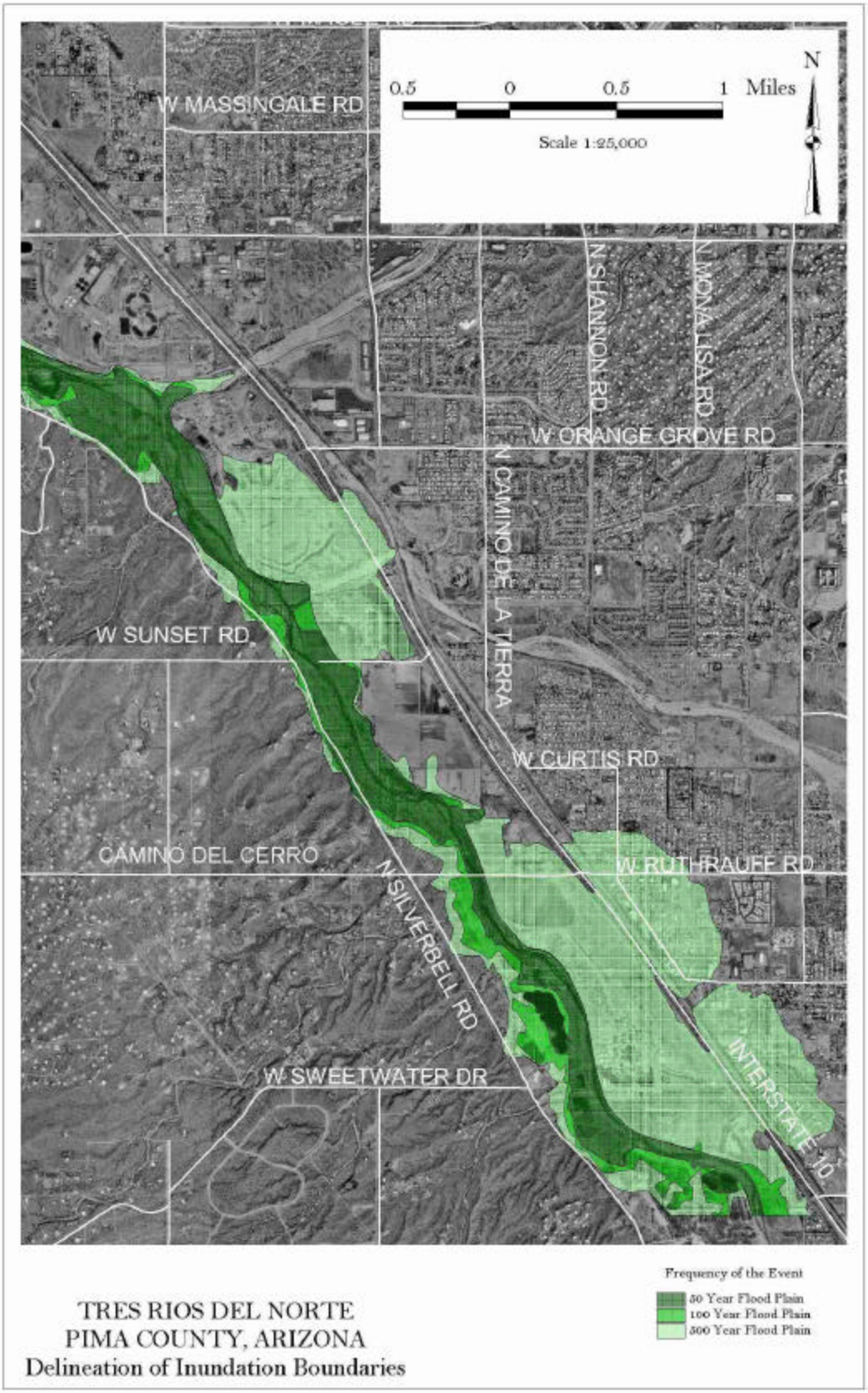

Figure 4.20 50,100 & 500-year Floodplains (4 of 4)

Channel Character

Sedimentation

The reach of the Santa Cruz River extending south of Trico-Marana Road (outside of the present study area) to Avra Valley Road has been relatively stable. No significant aggradation or degradation has been identified along this reach. Some degradation is occurring along the south end of the continental ranch reach in the vicinity of Cortaro Road. Recently, a five-foot drop in the channel was protected from further deterioration by a grade control structure. The degradation is believed to be due to perennial sewage effluent flows which have been gradually and continuously degrading the bed elevation. Due to an abundant sediment supply from the Rillito River and Cañada del Oro Wash, the Santa Cruz River transitions from an incised channel configuration to a more shallow, narrower cross-sectional area. The reach has shifted laterally up to 2,400 feet, in part due to sand and gravel excavations that have collapsed or diverted flow during flood events. The general channel instability in that reach, however, is historic.

Erosion

Within the Tres Rios del Norte study area, erosion ranges from slight to severe and is dependent upon rainfall within the region as well as slope, geomorphology, and land use. Short, locally intense summer thunderstorms often result in flows that may locally cause erosion in the side washes and occasional overbank flood deposits. Highly turbid flows (high concentrations of suspended and bedload sediment) normally occur during these storm runoff events.

Existing Bank Protection

Within the Tres Rios del Norte study area the Santa Cruz River has been channelized and its banks soil cemented for protection against damage from erosion of flood events between the southern study area boundary a point approximately one-fourth of a mile north of Camino del Cerro. The Santa Cruz River has been channelized through the Continental Ranch development between Cortaro Road and a point about 1.7 miles south of the Avra Valley Road bridge. This channelization contains the 100-year floodplain within a two-tiered channel. The upper tier is inundated with flow only during floods with a return period greater than 10 years.

Bank protection within the northern segment of the study area is limited. The area experiences greater erosion and, historically, has been prone to extensive flooding, particularly as evidenced during the October 1983 and January 1993 floods. For example, during the 1983 flood, three people died in Marana due to flood-related accidents and residences, businesses, agricultural fields, and public transportation infrastructure suffered extensive damage.

Pima County has constructed a levee along the east bank of the Santa Cruz River between the north end of Continental Ranch and Sanders Road (a total distance of approximately six miles). The overbank floodplain area on the west side of the river across from the levee as well as along both overbanks north of Sanders Road presently functions to provide overbank storage capacity. This storage capacity acts to decrease downstream flood peaks. Existing improvements are illustrated in Figure 4.21.

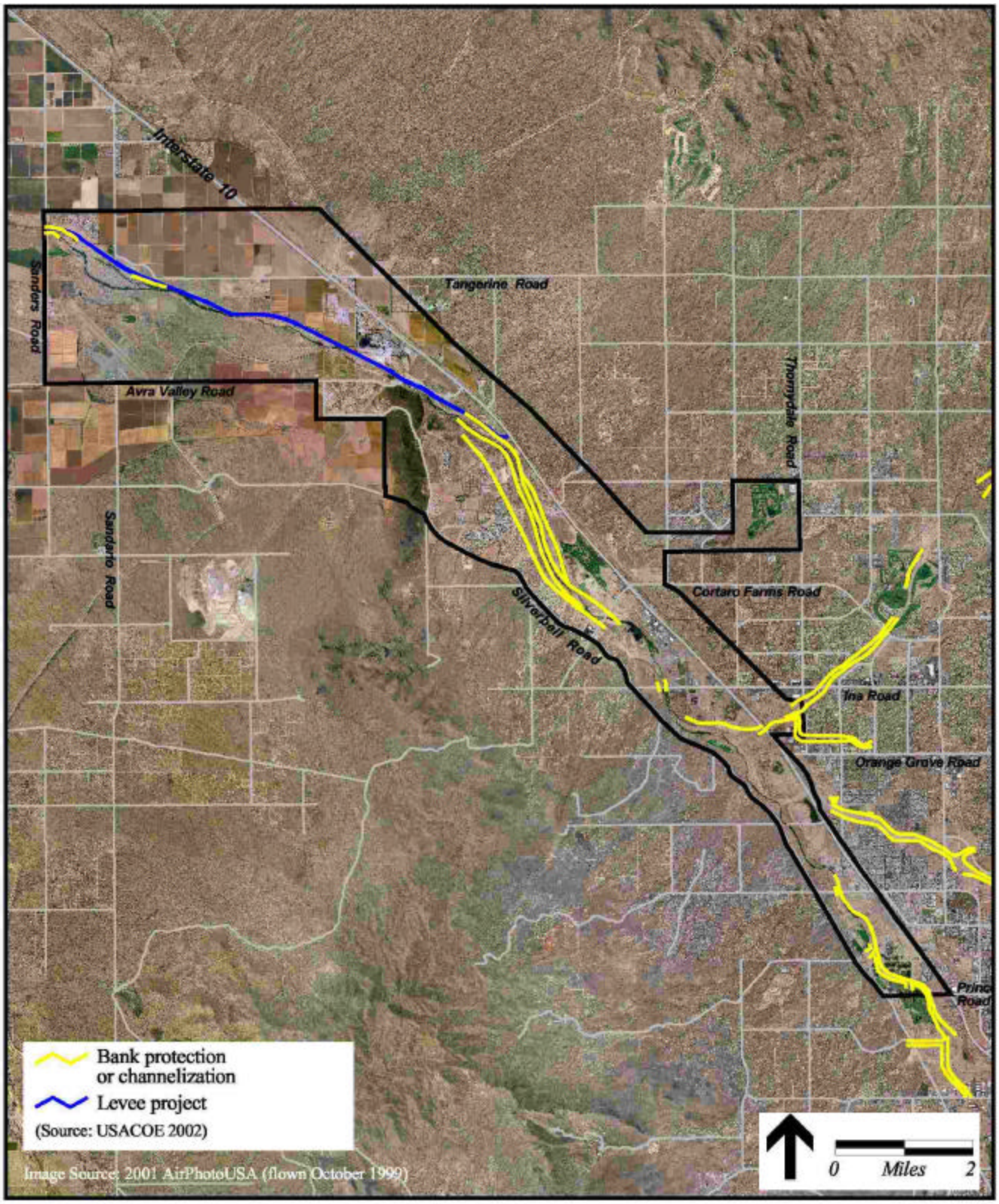

Figure 4.21 Bank Protection in the Tres Rios del Norte Study Area

D. Future Without Project Conditions

Definition of Future Without Project Conditions

The future without-project conditions for the 50-year planning horizon were identified in order to define and describe the most likely future conditions that are expected without a Federal project. The future without project condition is estimated starting at the base year 2012 (the earliest year a Corps project would become operational) conditions that are then projected 50 years into the future to year 2062. Projections utilize reasonable assumptions of how the base year conditions may change in the absence of any Federal project. The base and future year without-project condition is used to compare and evaluate any proposed alternative measures.

Basic Assumptions

It is assumed that no new ecosystem restoration or flood control projects will be in place prior to construction of a Federal project. In the event that a new feature is constructed by local interests prior to such authorization, the feature may be considered as an integral and compatible part of the Federal plan if prior approval is obtained.

Land Use

Given this location and the history of past development in the metropolitan area, the future without-project conditions suggest the following scenario. Initial development pressures will focus on privately held vacant and agricultural lands. Agricultural lands currently protected by the six mile long levee are especially susceptible to conversion to residential use over the next 50 years. As privately held land develops for commercial and park industrial uses (highest and best use based on market demand), adjacent publicly owned areas, currently available for restoration of upland habitat, preservation of cultural resources, and associated recreational amenities, will come under increased development pressure. Real estate values will rise in response to market demand. In order to maximize development acreage in areas adjacent to the River, a conventional, engineered solution for bank protection and erosion control (i.e., soil cement) would likely be implemented, and there would be minimum development setbacks from the River. (according to local land use codes, setbacks can be reduced following bank protection). As development occurs impervious ground cover will increase reducing both available land for native habitat and infiltration of runoff (Table 4.9)

Although this development scenario may include trail and recreation amenities as mitigation for bank protection, the River's corridor would likely have lost any remaining natural resource value.

Increased development will not only reduce or eliminate restoration opportunities. Over the past century, a reduction in vegetation adjacent to the River has resulted in an exponential loss of wildlife habitat. Without-project, this trend is expected to continue at an accelerated rate, due to the pressures of urbanization and competing demands on water and other resources within the region. Although the characteristics of this environmental decline will vary within the study area, the overall effect will be the reduction of existing habitat value.

Table 4.9
Land Use Trends

Land Use Designations	2012 Acres	2062 Acres
Commercial & Industrial	1838	7185
Residential	1898	7100
Agricultural	4096	500
Recreational	227	400
Private - Vacant	3712	0
Public - Vacant	5668	2000
Other	2365	2615

Population/Demographics

As a result of development pressures and the availability of residentially-zoned land, population will continue to increase along this 18-mile reach of the Santa Cruz River, regardless of project status. Without-project, the riverbanks will most likely be soil cemented, greatly decreasing native vegetation growth in the floodplain area. In addition, the use of soil cement would increase the amount of developable land in the study area and result in increased residential and non-residential development adjacent to the River. This development would greatly reduce, if not preclude, the opportunity for ecological restoration and that would accrue from an integrated program of flood control and riparian restoration.

Water Resources

Surface Water

Surface water flows will continue to be effluent dominated in the study area. In the future, it is expected that without-project, as growth and development pressures continue, the economic value of the effluent will increase to such a point that the owners of that water will no longer choose to discharge it into the river but will instead utilize if for other economic purposes. The majority of this reallocation is projected to occur within a period of approximately twenty-five years. The volume of those flows will initially increase reaching an estimated 60,000 AF/yr by 2012. As development continues and water increases in value effluent will increasingly be allocated for other purposes. By 2032 the volume of effluent releases will have decreased to an estimated 50,000 AF/yr and within 5 years (2037) effluent flows are estimated to have decreased to only 10,000 AF/yr. Only nominal flows are expected by 2062.

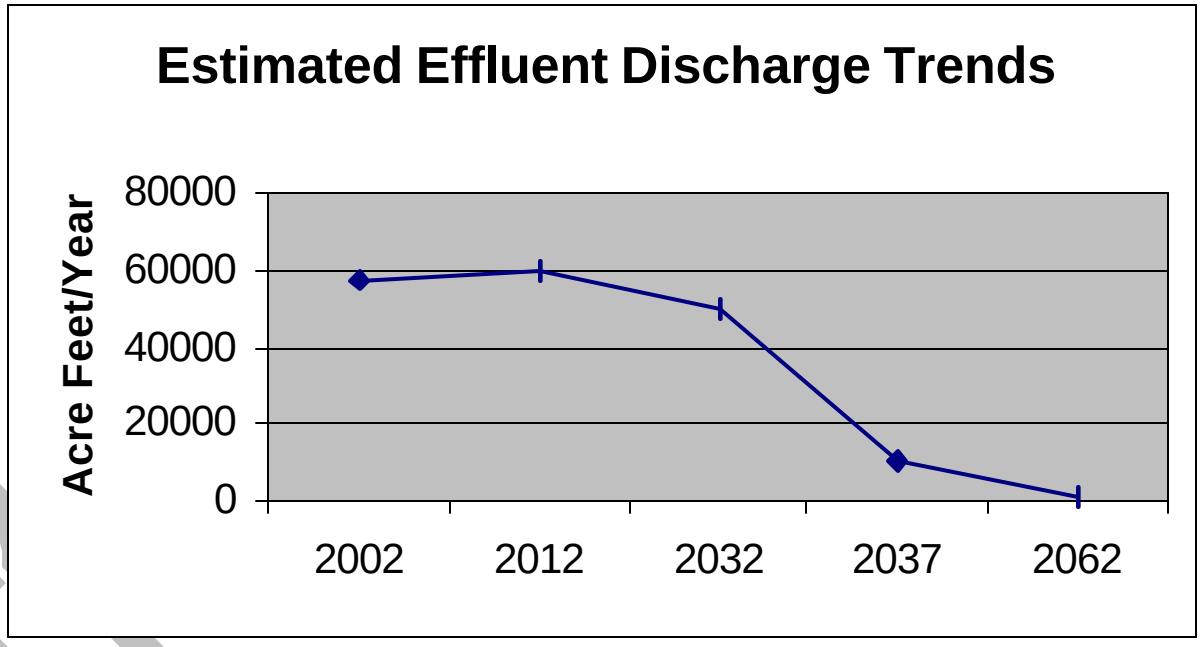

Figure 4.22 Estimated Effluent Trends

Groundwater

Groundwater pumping to meet future demand is expected to continue.

Riparian Habitat

The narrow band of riparian habitat supported by effluent flows will continue to exist proportionally in relation to the effluent releases. However, movement of the effluent dominated low flow channel due to periodic flood events combined with the lack of supporting ground water near the surface will preclude the normal development of the habitat.

Specifically, the future without project environmental conditions in the study area include:

- All open water will eventually be eliminated;
- Park lands will increase slightly;
- Mesquite vegetation will continue to decline as development proceeds;
- Cottonwood/Willow habitat will convert to scrub shrub as less water is available; and
- Scrub shrub vegetation will only be present in the active channel.

Due to the loss of effluent releases, it is anticipated that all remaining cottonwood/willow habitat and the remaining mesquite patches will be lost by within 25 years.

HGM Future Without Project Conditions

In order to assess the future without project condition for the 5 cover types being modeled, it is essential to develop not only trends in the acreages that may be present, but also to develop estimates of the quality of the habitat that is expected to present under those future conditions. The team developed the estimates that are displayed in the table below.

In general, it is recognized that agricultural and vacant lands are expected to develop into residential and other urban uses over the 50 year planning horizon. In addition, existing buffer zones are expected to be eliminated as part of this development. As effluent releases decline towards zero, the modeled riparian habitats will also decline to zero. Lesser quality scrub-shrub communities are expected to increase slightly in acreage and the "riverbottom" category is expected to increase as the vegetation currently existing in association with the low flow (effluent) channel declines. In general, the table below illustrates the conversion of agricultural and vacant lands into developed lands, and the eventual loss of the limited remaining riparian habitat as water (effluent) declines due to diversion to more economically rewarding allocations. The acreages shown are then analyzed with the expected future FCIs to estimate the change in FCUs in the study area without project. Of note is the interim acreage changes in future years 1, 6, 26, and 51. These interim points are all assessed by the future modeling in order to estimate time trends of the changes that are occurring.

Table 4.10
HGM Future Without Project PWAA Classifications for the Tres Rios del Norte Study Area

Code	Baseline Acres	Year 6 Acres	Year 26 Acres	Year 51 Acres
AGCROP	3,865.7	3,285.9	1,932.9	0
BUFFER	2,771.8	2,144.6	2,144.6	0
CTWWFOR	315.2	283.7	0	0
DESERT	2520.6	2,520.6	2,520.6	2,520.6
MESQUITE	72.8	72.8	36.4	0
OPENWATER	38.4	34.6	0	0
NEWBUFFER	0	0	0	0
NEWCTWWFOR	0	0	0	0
NEWRIVERBOTTOM	0	0	0	0
NEWSCRUBSHRUB	0	0	0	0
PARKS	598.2	598.2	791.5	791.5
RIVERBOTTOM	54.9	90.3	426.7	444.9
SANDGRAVEL	683.1	941.7	1,391.4	1,391.4
SCRUBSHRUB	1,123.4	1,123.4	1,141.6	1,391.4
SOILCEMENT	153.4	153.4	143.4	153.4
URBAN	7,605.3	8,553.8	10,672.5	13,341.2

As noted earlier in the report, the eleven functions developed for application to each cover type are:

- Function 01: Maintenance of Characteristic Channel Dynamics
- Function 02: Dynamic Surface Water Storage/Energy Dissipation
- Function 03: Long Term Surface Water Storage
- Function 04: Dynamic Subsurface Water Storage
- Function 05: Nutrient Cycling
- Function 06: Detention of Imported Elements and Compounds
- Function 07: Detention of Particulates
- Function 08: Maintain Characteristic Plant Communities
- Function 09: Maintain Spatial Structure of Habitat
- Function 10: Maintain Interspersion and Connectivity
- Function 11: Maintain Protection Zone from Urban Encroachment

Future without project habitat was estimated and Functional Capacity Indices were modified to represent the future without project condition at various years throughout the planning horizon. The end results of that analysis are presented below in Table 4.11.

Table 4.11
Future Without Project PWAA Functional Capacity Indices

Cover Type	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Cottonwood-Willow Forest	0	0	0	0	0	0	0	0	0	0	-
Mesquite Woodlands	0	0	0	0	0	0	0	0	0	0	-
Scrub-Shrublands	.17	.31	.25	0	.15	.22	.19	.18	.15	.13	-
Wetlands	.17	.30	.09	0	.08	.17	.19	.22	.11	.13	-
Buffer	-	-	-	-	-	-	-	-	-	-	

The lost acreages of riparian and mesquite habitat result in the complete loss of the functions those habitats perform as part of the riparian corridor. This is clearly indicated by the future FCI's. In general, no acreage is equivalent with no function in any of the 11 functional areas. These FCIs are indicative of areas that have no water in the river and development right up to banks with soil cement erosion protection for developed areas (similar to developed reaches outside the immediate study area). FCIs in such heavily urbanized developed conditions tens to be towards the extreme lower end of the quality scale. The future results FCIs shown in the above table are consistent with current (2002) conditions in other areas in the region that are heavily developed. These indices were applied to the expected acreage of each cover type in 2062 to develop the Functional Capacity Units for the future without project condition. This data is shown in the Table 4.12 below.

Prior to consideration of the lost acreages of riparian woodlands the complete loss of the functions those habitats perform as part of the riparian corridor is seen in the revised FCI's. These indices were applied to the expected acreage of each cover type in 2062 to develop the

Functional Capacity Units for the future without project condition. This data is shown in the Table 4.12 below.

Table 4.12
Future Without Project PWAA Functional Capacity Units

Cover Type	Acres	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Cottonwood-Willow Forest	0	0	0	0	0	0	0	0	0	0	0	0
Mesquite Woodlands	0	0	0	0	0	0	0	0	0	0	0	0
Scrub-Shrublands	1159.8	197	360	290	0	174	255	220	209	175	151	0
Wetlands	449.9	78	133	40	0	36	76	85	98	49	58	0
Buffer	0	0	0	0	0	0	0	0	0	0	0	0

As can be seen, along with the loss of certain habitat types comes the complete loss of the majority of functions and a much degraded FCU for the remaining habitat. The analysis helps illustrate that, while some acreages of habitat may remain, the quality is extremely low as well.

In comparing the historic and baseline conditions, it should be noted that historic conditions could produce conservative entries in each cell of the table in excess of 4550. Under the previously displayed baseline conditions no single entry is over 348 (with the exception of buffer which is 2079 under baseline and zero above). This represents a weighted average decline of greater that 90% from historic to baseline. In the future without project condition, with the complete loss of buffer, mesquite, and cottonwood willow FCUs (as projected by the team) and the decline in remaining FCUs, the relative numerical comparisons to baseline conditions produced by the modeling appear reasonable in terms of the relative qualities and acreages over time.

Environmental

Biological Resources

Development has already consumed much of the upland habitat within the Santa Cruz River floodplain. As a result of this development, portions of the river have been stabilized with soil cement banks and levees. As development increases so will the demand for flood control. Construction of additional soil cement banks and levees would channelize the river and increase stream velocities, erosional scouring, streambed downcutting, and the level of disturbance to native vegetation. Increased disturbance would favor non-native tamarisk, which would be expected to displace native species (as has already occurred in the lower Colorado River). Monotypic stands of non-native vegetation would further limit wildlife diversity.

Cultural Resources

Under the No Action alternative, no direct impacts on cultural resources are anticipated. However, it is possible that cultural resource sites may be disturbed or destroyed either through future human actions or through natural processes such as erosion or flood events.

Recreation

Many factors contribute to make the proposed riparian habitat areas along Tres Rios Del Norte study area attractive in terms of their potential to meet unmet demand for passive recreation through combination with adjacent facilities. Those factors include:

1. *Recreation Experience*--Proposed general recreation activities for the study area include trails for hiking, biking, and jogging. Among the activities identified, most have significant unmet demand.

2. *Availability of Opportunity*--The proposed facilities will provide an opportunity for many urban individuals to recreate close to their homes, work, and downtown.

3. *Carrying Capacity*--Pima County has experienced rapid population growth. Pima County's Metropolitan Statistical Area (MSA) population is 843,746 at year 2000 and is expected to reach 1,518,000 by year 2025—a difference of 674,254 over 25 years. With this increase in population comes an increased demand for recreational facilities.

4. *Accessibility*--According to 43% of the Arizona Trails 2000 survey respondents, loss of access to trails is the top three most important issues facing trails today.

5. *Environmental*--As demonstrated earlier, there are several recreation areas located in the study area. Of these sites, only the Sweetwater Wetlands provide a thriving riparian area.

In the future without project condition no recreational opportunities that may be proposed under the other alternatives, such as equestrian, bicycling, and hiking trails, and recreational rest stops would be implemented. Even without the proposed project, future recreational resources in the Tres Rios del Norte study area are likely to expand over time as new parks are designed and developed. Recreation demand in the study area is expected to grow steadily in the future due to regional population growth and increased tourism.

There are several planned parks within the study area. In Marana, a 16.5-acre site in Continental Ranch development is being developed as a neighborhood park. There is also a small private park and recreation area planned within the Saguaro Springs subdivision, southwest of Avra Valley and Silverbell Roads. A new park plan has been developed for the area immediately northeast and adjacent to the Coyote Trails Elementary School. The town of Marana also supports the development of a hiking, biking, and equestrian trail along the Santa Cruz River. Larger parks and facilities that are planned or under consideration include the following:

- *Silverbell/Cortaro Park* The most significant of the parks that are currently being planned is the proposed Marana District Park on 48.8 acres southeast of Cortaro and

Silverbell Roads. This park site was donated to the Town of Marana by private developers of residential and commercial properties nearby (*Arizona Daily Star* 2001). Marana is investing more than $4 million in this park site, which contains historic and prehistoric cultural resources.

- *Cortaro Bosque* This park is planned as an 80-acre revegetation area on the floodplain terraces along the west bank of the Santa Cruz River, south of Avra Valley Road (Pima County 1999).

The future needs for these parks, trails and recreational areas can be supported through a discussion of recreational demand and the unit day value method. Details of the recreational analysis are incorporated in the Economic Appendix. Although new parks and recreational facilities are planned for the area, their development may not be as focused on enhancing the riparian system within the Santa Cruz River to the extent that the proposed project is intended to.

Geotechnical

The following determinations have been made regarding the future without project geotechnical conditions:

- Subsurface conditions would not impact the construction of engineered bank stabilization measures.
- Seismicity is not a constraint on the implementation of a project in the Paseo de las Iglesias study area.
- Soils will support a variety of habitats

Landfills and HTRW, Phase I sites

The landfills and other sites will continue to be cleaned up and remediated. Some may eventually be made available for future development .

Economics

As noted earlier, existing development does not warrant detailed accounting of annualized economic damages. Benefits accruing from reduction in damages to future development cannot be used to provide economic justification for flood control projects.

Hydrology and Hydraulics

Runoff

For the next 20 years, it is anticipated that average annual population growth within the city limits of Tucson will increase slightly to 2.3 percent. In contrast, annual growth in Pima County will decrease by 1 percent. Although the following 30 years will continue to see a decline in the growth rate for both the City and County (a projected annual increase of 1.6 and 1.2 percent, respectively), the region's growth will be steady and positive. The anticipated population of Tucson in 2020 is 711,812. This will result in more than 97,800 new dwelling units or approximately 4,800 dwelling units, on average, per year for the next twenty years. Between the

years 2020 and 2050 it is anticipated that population in this area will level off due to final build out of vacant land currently zoned for residential.

Consideration of increases/decreases in watershed runoff was made in order to predict study area discharge for the year 2062 without-project condition. The magnitude of anticipated future growth in Tucson was investigated based on the City's development plans. The increase in runoff due to an increase in urbanization is reflected in the discharge-frequency values for the Santa Cruz River in the future, without-project condition. The smaller flood events (5, 10-, 25-year) experience a greater percentage increase in discharge due to increased development.

Floodplain delineations

Discharges will increase in the study vicinity due to anticipated build out of developable lands. However, the increases in volumes of discharges in the future without-project condition are insufficient to significantly affect the base year floodplain. Increased volumes of runoff, while contained within existing channels may lead to increased flow velocities and greater channel instability.

Channel Character

Future conditions along the Santa Cruz River channel are expected to remain nearly the same as the current conditions, although the main river channel may continue to deepen and meanders may continue to increase. The development of additional impervious surfaces along portions of the river may lead to an increased flow rate for the river following a rain event. A substantial amount of urban development is anticipated to occur in the areas along the Santa Cruz River, especially near the town of Marana. As development of areas without bank protection becomes economically viable, bank and erosion protection will be constructed to permit those areas to develop. Sediment and soil transport is anticipated to continue in the river channel.

E. Opportunities

Environmental Restoration

Opportunities for large-scale ecosystem restoration exist within the study area. Restoration of riparian zones could be accomplished either in or directly adjacent to the Santa Cruz River and its major tributary washes. Specific opportunities may include:

- Creating new water bodies or utilizing existing ones for restoration sites
- Planting riparian species
- Enhancing/widening stream courses
- Establishment of Mesquite bosques adjacent to stream courses in the riparian floodplain fringe
- Establishment of linkages to other projects to provide a continuous restoration corridor

Water Resource Management

Water resource management opportunities include:

- Storm water harvesting
- Groundwater recharge
- Provide a point of disposal for localized runoff
- Using effluent more efficiently within the study area
- Modifying the current distribution of treated effluent to expand habitat areas

Land Management

- Make maximum use of vacant lands for restoration
- Utilize sand and gravel mining areas as they are retired

Recreation

The opportunity exists to provide recreational resources in conjunction with any Federal project implemented for flood control purposes. In addition, limited passive recreational opportunities may be provided adjacent to restored habitat areas. Maintaining open space (recreation facilities) adjacent to restoration sites could help promote successful restoration in that it precludes the stress to habitat and wildlife associated with more intensive land use in adjacent areas. In general, facilities would likely consist of trails and interpretative signage.

Flood Control

Flood control opportunities consist of structural and non-structural measures that could be implemented in association with environmental restoration features. Among those measures is the potential to purchase flood prone structures and remove them from the flood plain to reduce future flood damages. Finally, the opportunity exists to formulate a project that addresses multiple purposes by, for example, providing storage for local runoff in a manner which facilitates groundwater recharge and helps to support habitat restoration.

F. Without Project Summary

Under the Without-Project Condition there will not be sufficient water to support expansion of existing areas of riparian and associated floodplain fringe habitats. In fact, as development continues throughout the Santa Cruz watershed and effluent flows are reallocated, loss of riparian and floodplain fringe habitat is likely to accelerate and many native species may be increasingly confined to isolated pockets of suitable environments. Furthermore, the lack of native riparian and associated floodplain fringe habitat will mean the absence of many species of native wildlife from the area.

CHAPTER V

PLAN FORMULATION

A. Study Methodology

This chapter presents the plan formulation rationale used during this feasibility study. The Corps of Engineers six step planning process specified in ER 1105-2-100 was used to develop, evaluate, and compare the array of candidate plans that have been considered. Steps in the plan formulation process include:

1. The specific problems and opportunities to be addressed in the study were identified, and the causes of the problems were discussed and documented. Planning goals were set, objectives were established, and constraints were identified.
2. Existing and future without-project conditions were identified, analyzed and forecast. The existing condition resources, problems, and opportunities critical to plan formulation, impact assessment, and evaluation were characterized and documented.
3. The study team formulated alternative plans that address the planning objectives. An initial set of alternatives was developed and will be evaluated at a preliminary level of detail.
4. Alternative project plans will be evaluated for effectiveness, efficiency, completeness, and acceptability. The impacts of alternative plans will be evaluated using the system of accounts framework (NED, EQ, RED, OSE) specified in the Principles and Guidelines and ER 1105-2-100.
5. Alternative plans will be compared. A benefit-cost analysis will be conducted to prioritize and rank flood damage reduction alternatives. Cost effectiveness and incremental cost analysis will be used to prioritize and rank ecosystem restoration alternatives. The public involvement program will be used to obtain public input to the alternative identification and evaluation process.
6. A plan will be selected for recommendation, and a justification for plan selection will be prepared.

B. Planning Objectives

Federal Planning Objectives

Planning objectives and constraints provide a framework for the development of alternative plans. As planning objectives for this investigation, it is in the Federal interest to:

- contribute to National Ecosystem Restoration (NER) through restoration of degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition.
- contribute to National Economic Development (NED) through the reduction of flood hazards

NER contributions result from creating new habitat or increasing the value of existing habitat and are measured in terms of non-monetary outputs. NED contributions include increases in the net value of national output of goods and services and can be measured in terms of monetary outputs such as reductions in flood damages and emergency response costs.

Specific Planning Objectives

Specific planning objectives were developed to guide formulation of a restoration plan. Those objectives are:

- Restore wetland and riparian vegetative communities within the river corridor to a more natural state, using the historic riparian ecosystem in the area as a target for measurement purposes.
- Increase the acreage of functional riparian habitat within the resource
- Minimize disturbance-type impacts to restored areas
- Minimize potential for sediment and organic matter accumulation in restored areas (low maintenance design)
- Increase habitat diversity by providing a mix of habitats within the river corridor including the riparian fringe
- Reduce flood damages in specified areas

C. Planning Constraints

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions that should not be violated. The planning constraints identified in this study are as follows:

Availability of Water

A principal constraint on any restoration project is the limited availability of water to support establishment and maintenance of healthy riparian habitats. Existing federal, state, county, tribal and private water laws, and agreements will impact plan formulation and implementation. Proposed project must take into account ownership/control of effluent and surface water rights.

Maintenance of Floodway Capacity

Restoration of riparian habitat cannot be done in such a way that it would substantially reduce the capacity of the Santa Cruz or its tributary washes to convey damaging flood flows. Any increase in flood hazard to private property that would result from project activities must be identified and offset. The project must not impact the safety of existing bridges.

Federal Aviation Administration (FAA)

Coordination is required with the FAA to minimize bird strikes within 5-mile radius of airports. The FAA has regulations that oppose open water within 10,000 feet of the airport operational taxiway.

Proximity of Recreation to Restoration

Projects must be formulated in such a way as to avoid impacts from existing and planned recreational facilities in adjoining areas.

Cultural Resources

The study area contains numerous cultural resource sites which must be considered in development of any specific plan.

Endangered Species

The cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*) a Federally endangered species known to occur in the study area. One USFWS Candidate Species for listing, the Yellow-billed Cuckoo (Coccyzus americanus) is also known to occur in the area. Any potential project would be required under the Endangered Species Act to not jeopardize the continued existence of threatened or endangered species or to destroy or adversely modify their habitat. Furthermore, ecosystem restoration projects may potentially attract endangered or threatened species. Projects should be sited so that their habitation by those species does not adversely impact the ability to preserve the flood control functions and maintenance of the channels.

Local Acceptability

Any plan must be acceptable to local residents and consistent with local planning efforts.

Displacement of People

The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 requires any local sponsor acquiring land for a project involving the Federal government to comply with the provisions of this act.

Vector Control

Incorporate vector control into the design, operation, and maintenance aspects of the project. The introduction of water bodies could provide increased opportunities for mosquito breeding.

Rapid Growth

The steady growth in the area creates increasing competition for water and land resources needed for ecosystem restoration. The study area is an urbanizing setting and it is recognized that restoration efforts will not be able to achieve completely historic ecosystem conditions.

Real Estate

Real Estate costs can significantly affect project costs. Since right-of way costs may not be uniform with respect to location within the study area or width of acquisition, real estate costs represent a constraint on the location and dimensions of potential alternatives. Existing federal, state, county, tribal and private land ownership, including sand and gravel ownership and leases, will impact real estate appraisals and acquisitions.

Landfills

Landfills and associated issues will need to be incorporated into plan formulation efforts.

County and City Lands

The Town of Marana, City of Tucson and Pima County own lands that could be affected by any project in the study area.

D. Alternative Development Rationale

The alternatives are developed for the purposes related specifically to the requirements for a Corps of Engineers Feasibility Report. As such, the alternatives described in this feasibility report are not proposals for actual construction, nor are they of sufficient design detail to be constructed. Following the completion of the feasibility report, EIS,

and project authorization by Congress, if such action occurs, detailed design analysis and preparation of plans and specifications would take place. Alternatives were formulated to address a comprehensive Federal project for ecosystem restoration to:

a. Comply with NEPA and other environmental laws and regulations;

b. Restore a variety of riparian and associated floodplain fringe habitats;

c. Provide an acceptable means of capturing storm water and utilizing it to help support appropriate water budgets to restore habitat areas;

d. Maintain or enhance existing conveyance of peak discharges and ensure that the system of storm water collection would not increase flood flows or worsen flooding conditions downstream in the existing developed areas;

e. Address specific flooding characteristics within the floodplain and major contributing washes;

f. Produce NER benefits and potentially contribute to the National Economic Development Account (NED);

g. Provide decision makers with information that could be utilized to help determine the balance between construction costs, real estate costs, and social issues and concerns;

h. Provide a framework for responding to future urban development in the floodplain, consistent with Executive Order 11988;

i. Match existing and proposed improvements where possible to take advantage of local improvements and to be consistent with the future master planning efforts of the local community.

E. Alternative Development and Evaluation Process

The Tres Rios del Norte feasibility study process involves developing and refining, through successive iterations, alternative solutions to the defined ecosystem degradation problem. Solutions are evaluated based upon the degree to which they address study objectives and take advantage of identified opportunities while remaining within the limitations imposed by the identified constraints. The general feasibility criteria that are required to be met are as follows:

- *Technical Feasibilit*y: Solutions must be technically capable of performing the intended function, have the ability to address the problem, and conform to Corps of Engineers technical standards, regulations, and policies;

- *Environmental Feasibility*: Solutions must comply with all applicable environmental laws, including the National Environmental Policy Act;

- *Economic Feasibility*: Solutions must be economically justifiable in that the economic benefits or, in the case of ecosystem restoration NER (non-monetary) benefits, must exceed the economic costs, in accordance with applicable regulations, policies, and procedures; and

- *Public Feasibility*: Solutions must be publicly acceptable as evidenced by a cost sharing non-Federal sponsor and further documented through an open public involvement process that incorporates the public's input into the formulation of the solutions.

Initially, specific measures were developed to satisfy the four feasibility criteria. Measures are stand alone features that address the defined problems. There are numerous measures that can be utilized to restore habitats depending upon site location, technical considerations, environmental conditions, and a host of other factors. In determining the set of measures to be evaluated for this study, consideration was given to public input and suggestions, Corps experience with similar restoration opportunities, technical considerations based upon the specifics of the area, and flood control considerations for improving or maintaining the existing level of protection.

F. Ecosystem Restoration Measures

A wide variety of measures were identified during the Reconnaissance Phase for use in developing alternatives. In some cases, multiple variations of measures were enumerated. The initial list of measure included:

- Delivered Water Sources: A water supply and distribution system to reestablish the surface (base flow) and groundwater hydrology of the river required to support other objectives. Potential sources of delivered water include:

  1. Central Arizona Project (CAP) water. The CAP delivers Colorado River water from Arizona's allocation to various location in the state including Tucson. CAP allocations available for importation into the Tucson Active Management Area total 192.2 MGD (215,333 acre-feet/year).
  2. Acquisition and transfer of Type 2 water rights. Three types of rights are derived from past individual water use; these are referred to as "grandfathered rights." Those rights are irrigation grandfathered rights, type 1 non-irrigation grandfathered rights, and type 2 non-irrigation grandfathered rights. The right is based on historical pumping of groundwater for a non-irrigation use and equals the maximum amount pumped in any one year between 1975 and 1980. Examples of non-irrigation uses include industry, livestock watering and golf courses. Type 2 rights are the most flexible because they can be sold separately from the land or well. In addition, the owner of a Type 2 right may, with ADWR approval,

withdraw groundwater from a new location within the same AMA. It is possible to lease a portion of a Type 2 right, but if the right is sold, it cannot be split; instead, the entire right must be sold.

3. Treated Effluent (Reclaimed water) discharges from the Roger Road and Ina Road Wastewater Treatment Plants, storm-drains and other interior drainage tributaries.

- Natural Water Sources: Natural sources are limited to seasonal flood flows in the Santa Cruz River and tributaries. Potential ways accessing this water source include grading/contouring of restoration areas to promote passive capture and pumping storm flows from channels to small basins for recharge or subsequent irrigation use.

- Low Flow Channel: Reconfiguration of the existing low channel or modifications to stabilize it could be accomplished to promote maintenance and/or expansion of existing in-channel habitat areas.

- Open Water: Year-round or seasonal pools or channel reaches with flowing water could be established to support restoration of aquatic habitat and benefit migratory waterfowl.

- Laid Back Banks/Channel Widening (changing bank angle): Reducing steepness of existing banks could create a wider and more natural channel. This measure could be applied in a variety of ways if sufficient right-of-way was available to accommodate the measure.

- Terracing: Creation of terraces above the channel invert but below the existing top of bank offers opportunities for habitat restoration which maintains a connection to the channel with less risk of damage from flood events.

- Islands/ Sand Bars/ Oasis: Modify channel inverts to create islands of riparian habitat at elevations that would not be affected by frequent floods. Modify channel inverts to promote formation of sand bars and associated habitat.

- Modify Confluence/Distribute Incoming Flows: • Confluences of tributary washes with the Santa Cruz River could be modified to mimic naturally occurring deltas which have the effect of distributing flows over a wider area and thereby support more habitat.

- In-Channel Vegetation: Establish riparian habitat areas in the channel, possibly in association with channel widening.

- Bank Vegetation: Vegetate banks to restore to a more natural state and reduce erosion.

- Floodplain vegetation: Vegetative communities such as Sonoran Riparian Deciduous Forest and Woodlands and Sonoran Deciduous Riparian Scrub typically are established in the floodplain fringe that experiences less frequent inundation. Reestablishment of these habitats within the river corridor would provide additional habitat diversity and linkages.

- Create Mesquite Bosque: Mesquite trees would be established at higher elevations from the river bottom. These areas would include terraces and over-bank areas. Low-water use irrigation or site conditions would need to be implemented in order to establish and maintain the mesquite trees. Once established, mesquite trees are expected to not require continuous water supply or maintenance.

- Cottonwood/Willow Gallery: Plant and establish cottonwood and willow tree communities along the wetted perimeter, fringe area locations within the river; around existing water areas, created wetlands and flowing water.

- Wetlands/Cienega Creation: Wetlands/cienega would be established at appropriate locations, in order to create a diverse and high value project habitat. Appropriate locations for wetlands would typically involve river backwater areas, ponded water locations, or previously occurring natural springs.

- Incorporate Existing Ponds: Utilize existing open water area, created by abandoned gravel mining operations, to create habitat and recreation areas. The habitat and recreation would take advantage of the existing open water value to further increase project outputs.

- Create Base Flow: This feature will return a perennial environment to the study area. This linear feature would also support appropriate plant and aquatic communities.

- Restore Desertscrub Community: Re-establish desertscrub plant communities along the degraded floodplain fringe of the river corridor, emphasizing saltbush-wolfberry and mesquite associations as components.

- Berms/ Debris/ Obstruction Removal: Berms, debris, and other obstructions to natural flow conditions exist at various points in the study area. Removal of these would promote a better distribution of naturally occurring flows and support habitat restoration.

- Soil Cement Removal: Soil cement could be removed in some reaches to allow restoration of banks to a more natural state.

- Palisades/Fence Jetties: Modification of channel inverts/banks would promote habitat establishment and reduce bank erosion through placement of low structures angled out from banks to slow flows and catch sediment.

- Drop Structures/Weirs: Placement of semi-permanent structures with associated weirs to aid in channel stabilization and create seasonal pools.

- Erosion Protection for Restored Areas: Placement of natural or engineered bank stabilization would limit erosion damages to restored areas.

- Elements Conducive Wildlife/Fish: Restore a mix of habitat sited in such a way as to be more beneficial to native wildlife/fish.

- Vector Control: Incorporate mosquito control measures as an integral part of the selected plan design and maintenance.

- Clean-Up: Clean-up debris and reshape the bank and channel, where manmade changes have occurred, to create a suitable restoration substrate.

- Improve physical and chemical conditions of existing flows.

G. Flood Control Measures

The feasibility study identified a variety of flood control measures which could be used to meet the planning objectives. The broad categories of flood damage reduction measures investigated are discussed below. Evaluation of structural and non-structural solutions or measures is required by law for any study having a flood control purpose.

Structural Measures

- Levee/Channel: Evaluate flood control levees and/or channel improvements to improve conveyance capacity at flood problem locations.

- Bank Stabilization: Bank protection at selected locations on the Santa Cruz River.

Non-Structural Measures

- Relocation of Existing Structures: Existing structures could be purchased to allow floodplain residents to move away from the floodplain. Purchased structures could be removed. The areas would be allowed to flood naturally, and could provide flood control benefits in addition to primary restoration benefits.

- Land Acquisition: Purchase or obtain conservation easements for land that possesses valuable habitat or has a high potential for successful habitat restoration.

H. Related Measures

Measures were identified to address other local planning objectives in association with restoration and flood control measures.

- Recreational Corridor: Incorporate trails and other passive recreational features in support of the other restoration management measures. Establishment of Equestrian and off-road vehicle areas in neighboring sites to reduce the likelihood of impacts to restored areas from those activities.

- Agricultural Education Components: Establish associated interpretative centers to provide instruction on historic agricultural practices.

- Cultural Education/ Interpretation/ Ecological Interpretation: Establish associated interpretative centers to provide instruction on cultural resources and native ecology. Incorporate cultural resources mitigation features, as required, as part of the recommended plan.

Recreation and Cultural Resources mitigation are recognized adjuncts Corps flood control and restoration projects.

I Areas of Evaluation

Initial Areas of Evaluation were identified through coordination with the Sponsors and other interest groups. The Areas of Evaluation are the culmination of an extensive almost year-long cooperative effort on the part of the 3 local sponsors to develop a consensus list of items, goals, objectives, and specific projects that would be desirable in the study area.

These areas were grouped into the following elements: Riparian Habitat Restoration; Groundwater Recharge and Water Supply; Flood Control; Recreational, Educational and Cultural; and General Projects. These areas of evaluation have been included and correlated in this report (Table 5.1 to follow) to show how they match up with Corps measures, objectives, and potential for accomplishment under this study. Restoration, recreation, and flood damage reduction are addressed. As the study continues, the set of measures will be screened and may change to some degree. In addition, as alternatives are evaluated, there will be an iterative process of re-combining measures and developing additional alternatives until arriving at a recommended plan. A brief description of each element follows.

Riparian Habitat Restoration Elements (R)

1. Identify and evaluate existing and potential high value riparian habitat. Develop a plan as appropriate to protect, enhance and restore these sensitive locations.

2. Evaluate upgrading the existing Constructed Ecosystem Research Facility operated by the University of Arizona in cooperation with Pima County Wastewater Management.

3. Evaluate the City of Tucson's Silverbell Lake Wildlife Habitat project located at Columbus Park.

4. Evaluate the wetlands located on City-owned land on the southeast corner of El Camino del Cerro bridge and the Santa Cruz River.

5. Evaluate introducing native grasses and shrubs to the El Camino del Cerro landfill cap. Plant on top of the landfill and contour the surface.

6. Evaluate restoring disturbed and eroded areas on the west overbank between El Camino del Cerro Road and Ina Road.

7. Evaluate opportunities and constraints for discharging treated effluent into the Canada del Oro Wash near the Ina Road Wastewater treatment facility, or other tributaries of the Santa Cruz River, to initiate riparian habitat.

8. Evaluate opportunities at the existing pond, on the west bank of the Santa Cruz River, near the confluence of the Santa Cruz River and Canada del Oro Wash.

9. Evaluate establishing a salvage and propagation native plant nursery and restore native vegetation at the old borrow pit area southeast of the Ina Road Bridge adjacent to the Ina Road treatment facility (Ina Road Triangle property).

10. Identify and evaluate restoring disturbed areas on both sides of the low flow channel from Cortaro Road to Avra Valley Road.

11. Identify viable wildlife travel corridors between the Tucson Mountains and the Tortolita Mountains. Areas of special interest would include the connectivity of Saguaro National Park with Arthur Pack Park (through Hardy Wash).

12. Evaluate corridor linkage facilities (e.g. oversized box culverts) to permit wildlife to safely traverse Silverbell Road at various drainage crossings.

13. Evaluate extending habitat restoration through drainage ways 2-10 in Continental Ranch areas for multipurpose flood/erosion control in the area.

14. Evaluate opportunities and constraints for creating wetlands, riparian forests (cottonwood/willow or mesquite bosque) and/or bird sanctuaries at suitable locations within the project reach including the old ADOT pit at the north end of Continental Ranch near Milligan Road.

15. Survey existing habitat for Huachuca Water-Umbel and evaluate potential reintroduction of this species.

16. Evaluate the regeneration of native vegetation within the main channel of the Santa Cruz River adjacent to the effluent flow or adjacent to managed or constructed groundwater recharge projects.

Groundwater Recharge And Water Supply Elements (GW)

Off-Channel

1. Evaluate expanding the City of Tucson's off-channel effluent recharge facilities on the east bank near the Roger Road Wastewater Treatment Plant or on the west bank in the vicinity of Columbus Park.

2. Evaluate the feasibility of an effluent and/or Central Arizona Project (CAP) water recharge project at the New West facility.

3. Evaluate the Marana West Side Effluent Reuse Pipeline Project as a recovery system and distribution network to insure water supply for habitat restoration and other uses, such as irrigation.

4. Evaluate the Phase II Lower Santa Cruz Replenishment Project.

In-Channel

5. Evaluate cooperative Santa Cruz Managed Recharge and Recovery north of Ina Road.

6. Evaluate in-channel 'constructed' recharge projects between the outfalls of the Roger Road and Ina Road Wastewater Treatment Plants, including additional recovery wells and distribution pipelines.

7. Evaluate a dual effluent channel within the Continental Ranch/Santa Cruz River low flow channel to allow the accrual of constructed recharge credits, help protect existing soil cement bank stabilization along this reach, and enhance riparian habitat through this corridor.

8. Evaluate inflatable dams. One possible location is approximately 4,400 ft. downstream of Cortaro Road crossing, on the Santa Cruz River.

Flood Control Elements (F)

1. Evaluate the Gardner Lane/Roger Road Wastewater facility drainage improvements. Extension of two 54-inch reinforced concrete pipes under the

Southern Pacific Railroad mainline and construction of a conveyance system for this runoff to the Santa Cruz River.

2. Evaluate the Ruthrauff Area/El Camino del Cerro landfill drainage improvements. Conveyance of runoff from the Ruthrauff Road area at Interstate 10 to the Santa Cruz River.

3. Evaluate soft bank protection on the west bank bend 1,800 feet to 5,600 feet downstream of the El Camino del Cerro bridge.

4. Evaluate some form of bank stabilization on the east bank between El Camino del Cerro bridge and Sunset Road. This section would infill between two existing sections from approximately 1,300 feet to 4,000 feet downstream of El Camino del Cerro bridge.

5. Evaluate some form of bank stabilization for approximately 5,600 ft., along the east bank of the Santa Cruz River between the Rillito Creek and the Canada del Oro Wash.

6. Evaluate three actions for the Santa Cruz River downstream of Cortaro Road: (1) Excavate two 15,000 feet long low flow effluent channels near the middle of the channel to relocate effluent flows away from the existing soil cement banks, enhance in-channel vegetation and promote ground water recharge; (2) Construct a series of grade control structures to protect the existing bank stabilization, enhance in-channel vegetation and promote ground water recharge; and (3) Rehabilitate both sides of the existing bank protection from Cortaro Road to the downstream end of the bank protection.

7. Evaluate the potential for sand and gravel pits, located along the banks of the Santa Cruz River, to be breached by erosion during flooding events. Analyze the threats to roads, highways and bridges, major utilities, and public and private property. Evaluate and implement techniques to prevent catastrophic breaches of large sand and gravel pits, during major flooding events, to minimize head cutting and channel degradation.

8. Evaluate implementing the drainage solutions prepared in the ADOT I-10 General Plan from Ruthrauff Road to Tangerine Road.

9. Evaluate grade control structures. These minimize channel degradation and promote riparian wetlands. Possible locations include:

- on Canada del Oro Wash near Interstate 10.
- at the Cortaro Road Bridge on the Santa Cruz River.
- 3,700 feet downstream of Cortaro Road on the Santa Cruz River; possible rubber dam site.
- at the future Twin Peaks Boulevard crossing on the Santa Cruz River.

- at the Avra Valley Road Bridge on the Santa Cruz River.
- along tributaries draining from the Tucson Mountains.

Note: A grade control structure is not proposed at the El Camino del Cerro Bridge on the Santa Cruz River due to landfill issues.

10. Evaluate opportunities and constraints for generating hydroelectric power at grade control structures.

11. Floodprone Land Acquisition:

(1) For the Santa Cruz River between El Camino del Cerro and Cortaro Road; acquire all private property forming the main channel and its west bank to Silverbell Road. This includes the Casas Arroyo subdivision.

(2) For the Santa Cruz River between Avra Valley Road and Sanders Road, acquire private property on the west bank.

Acquisition of these properties would serve multiple purposes including: flood control, recreation (Anza Trail), habitat preservation, groundwater recharge and recovery, and archeological preservation.

<u>Recreational, Educational, And Cultural Elements (RE)</u>

River/Linear Park (west bank)

1. Evaluate a river trail on the west bank of the Santa Cruz River connecting the City's existing Columbus Park to Sanders Road to the north. The trail will be seamless matching Pima County and Marana trail standards. The trail would be a part of the Juan Bautista de Anza National Historic Trail system

2. Integrate existing or planned projects on the west bank with the proposed trail system. Hubs or destinations could include:

- Columbus Park
- Marana District Park
- Cortaro Mesquite Bosque
- Los Morteros Heritage Park
- Marana High Plains Recharge

River/Linear Park (east bank)

3. Evaluate a river park concept with trail on the east bank of the Santa Cruz River from Prince Road to Sanders Road. The trail would interconnect to the Rillito Creek and the Canada del Oro Wash river park systems.

4. Integrate existing or planned projects on the east bank with the proposed trail system. Hubs or destinations could include:

- Sweetwater Wetlands
- Ina Road nursery
- Levee park.

Archaeological, Historical and Educational Sites

5. Evaluate educational and cultural opportunities within the Marana District Park site located near Cortaro Road and the Santa Cruz River.

6. Evaluate the Los Morteros Heritage Park, Anza Campsite, and Point of the Mountain Stage Station located north of Continental Ranch.

7. Evaluate interpretive signs at the 'Nine Mile Water Hole' and at the settlement of 'Laguna' on the west bank of the Santa Cruz River.

8. Evaluate preserving in-place the archeological sites within the project reach. The signs and exhibits could be along the river park trails or associated with flood control and riparian projects with reference to a proximate site.

9. Evaluate incorporating archaeology research and interpretation facilities.
10. Evaluate and implement conversion of flood prone land to enhance open space and to preserve Marana's heritage.

<u>General Projects (GP)</u>

1. Assess and evaluate vector control issues for every project with a surface water feature.

2. Evaluate existing use of sand and gravel operations and future uses such as recharge, recreation, and habitat restoration. Evaluate flood control given these uses.

3. Evaluate uses for the floodway lands on south/west side of Santa Cruz River which are compatible with the Marana Airpark.

4. Evaluate rehabilitating and restoring the area behind the levee. Identify compatible uses for this protected area of land

Each element has been aligned with the measures it supports. The results of that analysis are presented in Table 5-1 below.

Table 5.1
Elements Grouped by Measure

Plan Formulation Measures	Associated Elements
Ecosystem Restoration	
Delivered Water Sources	R3, R7, GW1-GW-8, F1, F2, F6, F9, GP2, F6
Natural Water Sources	
Low Flow Channel	R16, F6
Open Water	R8
Laid Back Banks/Channel Widening	F3-5
Terracing	F4-5
Islands/Sand Bars/Oasis	R1
Modify Confluence/Distribute Incoming Flows	R7
In-Channel Vegetation	R1, R7, R10, R13, R16
Bank Vegetation	R1, R113, R14
Floodplain Vegetation	R1, R3, R5, R6, R8, R9, R13
Create Mesquite Bosque	R1, R3, R9, R13, R14, GP3-4
Cottonwood Willow Gallery	R1, R3, R7, R9, R10, R13, R14, R16, F6
Wetlands/Cienega Creation	R1, R4, R7-9, R13, R14 , R16, F6, F9
Incorporate Existing Ponds	R1, R8, R14,
Create Base Flow	GW3, GW6-8, F6
Restore Desertscrub Community	R3, R5, F11, GP 3-4
Berms/Debris/Obstruction Removal	
Soil Cement Removal	
Palisades/Fence Jetties	
Drop Structures/Weirs	GW-6, GW-8, F6, F9
Erosion Protection for Restored Areas	F3-5
Elements Conducive to Wildlife/Fish	R11, R12, R14, R15
Vector Control	GP-1
Clean-Up	
Improve Condition of Existing Flows	R2, R10, F2
Flood Control	
Levee/Channel	F1, F11, GP2, GP-3
Bank Stabilization	R13, GW7, F3-8,
Relocation of Existing Structures	
Land Acquistion	F11, GP2
Related Measures	
Recreation Corridor	F11, RE 1-10, GP-2
Agricultural Education Components	
Cultural Mitigation/Interpretation/ Ecological Interpretation	F11, RE 5-10
Not Aligned	F10

Based upon the groupings in the above table, it appears that locally desired elements are largely compatible with the Corps Plan Formulation measures.

J. Preliminary Evaluation of Measures

Each measure, along with its associated elements, was evaluated in terms of the feasibility criteria. All criteria must be adequately met since any one criterion can serve to eliminate a measure from further consideration. Those measures/elements satisfying all the criteria were carried forward for additional development and evaluation while those that were shown not to meet the criteria were eliminated from further consideration.

Measures/elements that were carried forward will be combined in various configurations to form a preliminary set of alternatives, which will be subjected to a more rigorous evaluation against the criteria.

Restoration Measures

Based upon feasibility criteria, all of the identified restoration measures were carried forward for Plan Formulation in development of the alternatives. None could be eliminated at the preliminary screening level.

Flood Control Measures

Flood Control is a minor component of the feasibility study. Identified flood control measures were evaluated in the context of the restoration objectives and for the potential to provide additional flood control benefits. In many cases, flood control measures and restoration measures can be complimentary. The initial evaluation of flood control measures is discussed below.

Relocation

Land purchase for restoration is already being carried forward for alternatives, and any incidental flood control benefits will be evaluated.

Structural Measures

Levees: Levees can provide significant levels of protection in a cost effective manner, however, there are disadvantages such as increases of flood stages, real estate and access considerations, higher environmental impacts, and the potential for failure or overtopping. Economic analysis indicates a lack of sufficient benefits to support levee construction. Levees as a flood control measure are not carried forward for additional consideration in the formulation of alternatives.

Bank Protection: Soil cement or vegetative stabilized banks may offer protection from erosion for restored areas within the Santa Cruz River channel, additionally, in the formulation of alternatives that widen the existing channel and provide floodplain terraces; bank stabilization measures may be needed in order not to induce flood and erosion damages from a restoration project. The measure is carried forward as a restoration measure and incidental flood control benefits will be evaluated for specific appropriate areas. Bank stabilization as a single purpose flood control measure may also be evaluated for specific areas as part of a Locally Preferred Plan (LPP)

Related Measures

Measures/elements relating to recreation and cultural mitigation were carried forward for incorporation, as appropriate, with restoration and flood control measures.

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