US Army Corps
of Engineers
Los Angeles District
South Pacific Division

RILLITO RIVER, PIMA COUNTY, ARIZONA
EL RIO ANTIGUO
Draft Feasibility Study

Prepared by:

U.S. Army Corps of Engineers
Los Angeles District
South Pacific Division

In Coordination With:
Pima County
October 2004

CESPD-RP-S (1105) 12 May 2004

Memorandum for: Commander USACE (CEMP-SPD)

SUBJECT: Final Feasibility Report for Rillito River, Pima County, Arizona (El Rio Antiguo) (PWI #013544)

1. Reference: CESPL-DE memorandum dated 6 May 2004, SAB.

2. I concur in the conclusions and recommendations of the District Commander.

LEONARDO V. FLOR
COL, USA
Acting Commander

EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers is conducting a study of the Rillito River in the area known locally as El Rio Antiguo to identify, define and solve environmental degradation, flooding and related land and water resource problems. These efforts are proceeding in partnership with Pima County Flood Control, the non-Federal sponsor.

The El Rio Antiguo reach of the Rillito River, which is the study area, consists of that portion of the river extending from Craycroft Road at upstream end down to Campbell Avenue. The study area is located in Pima County, Arizona. The study boundary encompasses an area approximately 4.8 miles long varying from one mile to one-quarter mile wide, and encompassing approximately 1066 acres. The Rillito River aka Creek flows from east to west across the northern boundary of the City of Tucson from the confluence of Tanque Verde Creek and Pantano Wash to the Santa Cruz River 7.2 miles away (Figure S-1).

Although flood damages occur in some portions of the study area, previous Corps of Engineers flood control studies have demonstrated the lack of justification for further single-purpose flood damage reduction measures. The primary problem is the severe degradation and loss of riparian habitat along the Rillito River since the early 20th century. Along the El Rio Antiguo reaches of the Rillito, water once flowed perennially and supported substantial growth of cottonwoods, willows, and mesquites. Historical accounts of conditions on the Rillito approximately 100 years ago describe a tree-lined, narrow river with dense vegetation winding throughout the riverbed and vicinity. The river channel carried abundant water that supported early irrigation projects. In the 1850's, the river channel was lined with a continuous oasis of trees and grasses along the riverbanks and flood plain. The river path was obstructed by numerous beaver dams that ponded the water and encouraged the development of riparian wetlands.

Increasing appropriation of surface and ground water to support expansion of agriculture and growing urban populations resulted in the transformation of the Rillito from a river with perennial surface and subsurface flows to a dry wash with stabilized banks which flows only ephemerally in response to storm runoff. Because of this change, stands of native riparian habitat are rare in the study area, as they are throughout Pima County. Loss of riparian habitat is extremely significant in the arid southwest. Originally comprising a mere 1% of the landscape historically, over 95% of riparian habitat 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 adjacent parcels of undeveloped land in the El Rio Antiguo area and potential sources of water for restoration still exist. As long as this is true, there is an opportunity to accomplish significant 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.

The Federal planning objective for ecosystem restoration studies is to contribute to National Ecosystem Restoration (NER) through increasing the net quality and/or quantity of desired ecosystem resources. The specific objectives for environmental restoration within the study area have been identified as follows:

- Restore riparian vegetative communities within the river corridor to a more natural state.
- Increase the acreage of functional seasonal wetland habitat within the study area.
- Increase habitat diversity by providing a mix of habitats within the river corridor including the riparian fringe and buffer.
- Provide incidental flood control through ecosystem restoration to the extent that it does not impact the restoration object.
- Increase recreation and environmental education opportunities within the study area.

A number of measures were developed based upon those originally identified in the Reconnaissance Phase of the study, with additional potential measures added based upon the results of public involvement efforts and upon other similar studies in the region. Both restoration and recreation are addressed. To ensure no flood damage reduction opportunities were missed, the existing flood damages were identified. The average annual damages were not sufficient to support inclusion of flood control as a project purpose in development of detailed alternative plans. As the study continued, the set of measures was screened and refined. The initial conceptual alternatives were expanded into an array 20 alternatives that were subjected to analysis that is more detailed. Through this iterative process, a final array of 3 alternatives was produced. Additional refinement of those alternatives and subsequent analysis of costs and ecosystem restoration benefits relative to their effectiveness, acceptability, completeness, and efficiency led to the selection of the preliminary recommended plan. The proposed plan is illustrated in Figure S-1. It is characterized by:

- A set of terraces in the area known as the "Bend;"
- Cottonwood/willow, mesquite, shrub and grasses planted in the channel, in tributary mouths, and in water harvesting basins on the tributaries;
- A culvert and pipeline from upstream will allow water to flow behind the soil cement in 2-year and higher events to provide water to riparian plant communities along the north bank in the upstream portion of the study area;
- A high and low flow channel created to support a mesquite community and connect the Finger Rock Wash to the Rillito River;
- Water harvesting basins at each upstream tributary mouth; and
- A distribution system for effluent supporting planted vegetation until established and in dry periods.

The terraces will be constructed at the height of the 5, 10 and 20-year water surface elevations. The soil cement stabilized bank of the Rillito River will be cut down to the level of the lower terrace and the new banks between the terraces will be stabilized. The first terrace level will be restored desert wash (shrub-scrub) community. The second terrace level will be planted with cottonwood-willow community and the third terrace level will be planted with the mesquite

bosque community. The area above the third terrace will be contoured up to the current height of the upland area on its boundary.

Eight basins for water harvesting will extend from tributaries with swales, berms and vegetative gabions used to distribute water to plant communities. The tributary streambeds will be planted with cienega marsh vegetation up to the width of the natural channel.

A low flow channel will be stabilized with gabions and vegetation (mesquite and a bed of cienega marsh vegetation). The channel will be graded from base of Finger Rock Wash to three feet above the bed of the Rillito at the river mouth, and will capture lower flow events from Finger Rock. This channel will widen at the mouth to slow flows & mimic natural channels. The alignment will follow Roger Road and will capture flows from cut off channels entering at Palo Verde Road. Some higher flows will be diverted across the park to the Bend Basin using swales and berms. The channel will be sized to handle 1980 cubic feet per second (cfs), equivalent to the 10 yr flow, with 510 cfs breaking out for distribution across the park. A high flow channel will be established to convey flows in excess of the capacity of this system. Both channels are designed to support a mesquite bosque habitat.

Finally, flood flows beginning with the 2-year event will be directed behind the soil cement on the north bank downstream of Craycroft Road through a pipe and ditch system 1 foot in depth. Side slopes will vary from two vertical: 1 horizontal banks to 6 vertical: 1 horizontal. Side slopes stabilized with either vegetation, rock or soil cement. This system will inundate the existing and restored vegetation between Craycroft and Swan Roads.

Implementation of this alternative will result in the creation of 34.7 acres of desert wash habitat, 102.4 acres of mesquite woodlands, 95.5 acres of cottonwood-willow forest, and 3.5 acres of cienega. In addition, 47.9 acres of existing riparian habitat will be preserved and improved as part of the project. Although not maintained as part of the alternative, an additional 107 acres of the riverbottom will be incidentally improved because of increased water and seed sources. The resulting increase in ecosystem productivity has been characterized using an approach based on a functional assessment model. That characterization shows that the average functional capacity of the ecosystem in the project area will increase a barely functioning riverine system, to a moderately healthy functional level.

Environmental analyses conducted in accordance with the provisions of the National Environmental Protection Act (NEPA) indicate the likelihood of no lasting negative impacts from implementation of the recommended plan. The analyses identified a number of short term impacts associated with construction activities and concluded that these impacts could be mitigated through implementation of Best Management Practices (BMPs) designed to reduce or eliminate those impacts.

The non-Federal sponsor, Pima County Flood Control, has also expressed a desire to increase the passive recreation opportunities incidental to the restoration effort within the study area. The existing River Park is a popular passive recreational site. With the construction of the proposed ecosystem restoration measures, this reach will have increased visitation and will require additional recreational opportunities for the enjoyment and protection of the restored ecosystem.

The total first cost for construction of the environmental restoration portion of the recommended plan (based on October 2004 prices) is $63,852,500. Based upon the requirements of the Water Resources Development Act of 1986 (WRDA 86), as amended by Section 202 of WRDA 96,

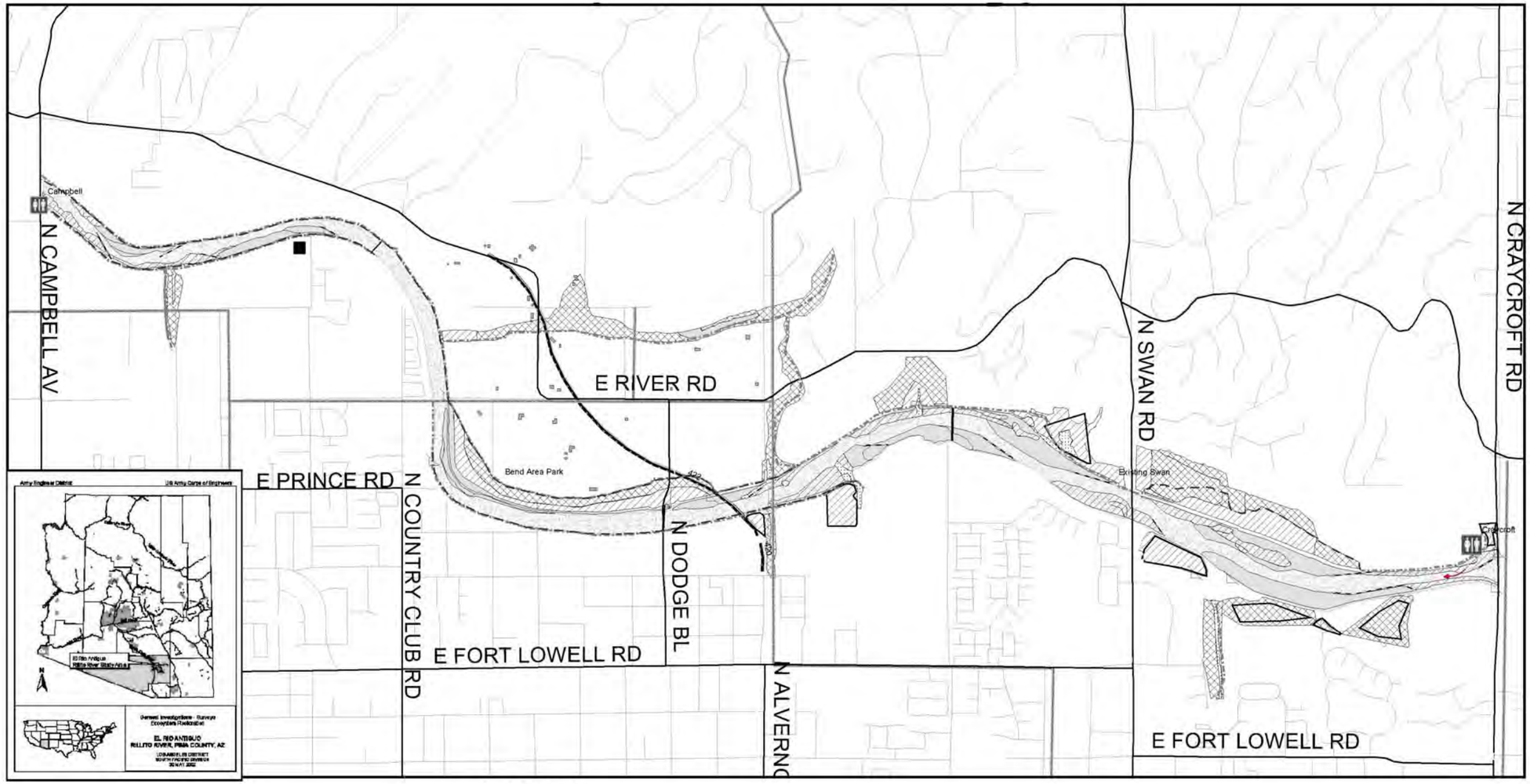
cost sharing for ecosystem restoration and flood control features would be 65 percent Federal and 35 percent non-Federal. Thus, the Federal share of the restoration cost would be $41,504,000 and the non-Federal share would be $22,348,500. Costs for Operation, Maintenance, Repair, Rehabilitation and Replacement (OMRR&R) include:

O&M Activities	Annual Cost
Invasives Control	$22,597
Patrol/Biological Survey/Replanting	$18,660
Plant Replacement	$19,096
Gabion Replacement (every 25 years)	$22,021
Reno Mattress Replacement (every 25 years)	$89,684
Irrigation System Maintenance	$44,223
Finger Rock Wash Cleanout	$6,344
Basins Cleanout	$159,000
Maintenance Road & Ramps	$9,800
O & M Subtotal	$391,425
Associated Water Costs	$851,932
Total	$1,243,357

The addition of recreation features was evaluated and justified. The recommended plan includes decomposed granite (DG) multipurpose trails, a pedestrian bridge, parking, and trail links that serve a recreation purpose by providing opportunities to a variety of recreational users. Comfort stations serve the basic safety needs of the recreational user. Warning signs are also added to direct pedestrians off the newly restored area guide pedestrians away from any potential danger. The recreation plan produces an increase in average annual recreation benefits of $299,000 at average annual cost of $191,500. This results in a benefit to cost ratio of 1.56 with net benefits of $107,500. The recreation plan has a first cost of $2,804.500. Cost sharing for recreation features is 50 percent Federal and 50 percent non-Federal. Fifty percent of the first cost of the recreation plan is $1,402,250 that increases the level of Federal financial participation by approximately 4%.

The cost for environmental education, public art, associated costs of water, and all operations and maintenance (O&M) costs for the recommended project would be the responsibility of the non-Federal sponsor. Annual costs for operation and maintenance are estimated at $20,300.

The total first cost of the recommended plan is $66,657,000 and the total operation and maintenance costs are $1,263,657. The Federal share of the recommended plan is $42,906,375 and the non-Federal share is $23,750,625. The analysis presented in this report shows that the selected plan is feasible and would provide environmental restoration and recreational benefits that serve the public interest. Plan features are consistent with proposals developed by pubic involvement work groups. The United States Fish and Wildlife service supports implementation of the selected plan.



1:13,000

0 0.25 0.5 1 Miles

Restored Vegetation

- COTTONWOOD/WILLOW FOREST
- MESQUITE BOSQUE
- CIENEGA
- SCRUBSHRUB

- Maintenance Turnaround
- Public Parking
- Potential Ramp Locations
- Campbell
- Craycroft
- Maintenance Road
- Recreational Trail
- upstream basins
- Historic Buildings
- Pedestrian Bridges
- floodway

PRIMARY FEATURES
1 set of terraces
8 upstream basins
12 gabions
Finger Rock Wash Riparian Corridors
RECREATION FEATURES
New ramp access to river
2 new pedestrian bridges
2 new comfort stations
Parking at Craycroft

Figure S-1 Alternative 2H, El Rio Antiguo
Rillito River, Pima County Arizona

Table of Contents

EL RIO ANTIGUO, PIMA COUNTY
DRAFT FEASIBILITY STUDY

Table of Contents

Page
CHAPTER I STUDY AUTHORITY 1
CHAPTER II STUDY PURPOSE, STUDY SCOPE, AND STUDY AREA II-1
A. Study Purpose II-1
B. Study Scope II-2
C. Study and Report Process II-2
D. Study Coordination II-3
E. Study Area II-4
Climate and Meteorology II-4
Population II-4
Existing Land Use II-5
Topography II-6
Geology II-7
CHAPTER III PRIOR STUDIES, REPORTS & EXISTING PROJECTS III-1
A. Existing USACE Reports III-1
B. Prior Studies or Reports by Other Agencies III-1
C. Existing and Current USACE Studies and Projects III-2
D. Community Master Plans III-2
CHAPTER IV PROBLEMS AND OPPORTUNITIES IV-1
A. Historical Conditions IV-1
B. Existing Conditions IV-3
Soils IV-5
Surface Water IV-6
Hydraulic Analysis IV-8
Sediment Deposition IV-8
Groundwater IV-8
Water Budget IV-10
Water Quality IV-12
Hazardous, Toxic, Radioactive Wastes (HTRW) IV-13
Biological Resources IV-14
Rillito River (Swan Wetlands) 1135 ..... IV-20
Habitat Evaluation IV-21
Cultural IV-42
Real Estate IV-42
Flood Damage IV-42
Recreation IV-47
C. Base Year Conditions IV-48
D. Expected Future Without-Project Conditions IV-48
Basic Assumptions IV-48

Population/Land Use IV-49
Water Quality/Supply IV-49
Hydraulic and Sedimentation Analysis IV-49
Wildlife Habitat IV-51
Flood Control IV-51
Recreation IV-51
E. Specific Problems and Opportunities IV-52
Degradation of Riparian Habitat IV-53
Area Flooding Problems IV-53
Water Quality IV-54
Water Quantity IV-54
Recreation IV-54
CHAPTER V PLAN FORMULATION V-1
A. Planning Objectives V-1
Federal Planning Objectives V-1
Specific Planning Objectives V-1
B. Planning Constraints V-2
Availability of Water V-2
Maintenance of Floodway Capacity V-2
Proximity of Recreation to Restoration V-2
Endangered Species V-2
C. Alternative Development and Evaluation Process V-2
D. Ecosystem Restoration Measures V-3
E. Preliminary Evaluation of Measures V-5
F. Preliminary Restoration Concepts V-6
1. Basins V-8
2. Channel and Bend Area Restoration V-9
3. Channel and Tributary Restoration Alternative V-9
No Action Alternative V-10
G. Alternative Plans – First Array V-10
Development V-10
Alternatives V-11
H. Evaluation of Alternative Plans V-16
Environmental Resources V-16
Hydraulics Effects V-17
Water Budget V-18
Costs V-18
Economics V-18
Associated Evaluation Criteria V-20
I. Alternative Plans – Final Array V-22
J. Selection of a Recommended Plan V-22
Comparison and Evaluation of Alternative Plans V-22
National Objectives V-22
NER Benefit Analysis of the Final Array V-23
Environmental Quality V-24
Regional Economic Development and Other Social Effects V-24

Selection of a Recommended Plan V-31
K. Recreation Plan V-31
CHAPTER VI DESCRIPTION OF THE PLAN SELECTED FOR RECOMMENDATION VI-1
A. Plan Description VI-1
Terraces VI-1
Basins VI-4
Finger Rock Wash Channels VI-9
Craycroft to Swan Pipe and Ditch Irrigation System VI-9
Additional Water Sources VI-12
Real Estate Plan VI-12
Costs of Recommended Plan VI-12
B. Project Outputs VI-13
National Ecosystem Restoration VI-13
National Economic Development VI-13
C. Associated Costs VI-13
D. Maintenance Considerations VI-13
E. Recreation Plan VI-14
F. Monitoring and Adaptive Management Plan VI-16
Purpose VI-17
Goal VI-17
Restored Habitats VI-17
Habitat & Wildlife Monitoring - Frequency and Protocol VI-18
Success Criteria, Reporting & Adaptive Management VI-19
CHAPTER VII Plan Implementation VII-1
A. Study Recommendation VII-1
B. Division of Plan Responsibilities VII-1
C. Cost Allocation VII-1
D. Current and Future Work Eligible for Credit VII-2
E. Institutional Requirements VII-2
F. Environmental Requirements VII-2
G. Non-Federal Requirements VII-5
H. Sponsorship Agreements VII-5
I. Procedures for Implementation VII-7
CHAPTER VIII Public Views and Comments VIII-1
A. Non-Federal Views and Preferences VIII-1
B. Views of the Non-Federal Sponsor VIII-1
C. Financial Analysis VIII-1
D. Summary of Study Management, Coordination, Public Views and Comments VIII-2
CHAPTER IX Conclusions IX-1
CHAPTER X Recommendations X-1
CHAPTER XI LETTERS OF SUPPORT AND FINANCIAL CAPABILITY XI-1

List of Tables

Table 2.1 Land Use Designations in the El Rio Antiguo Study Area..... II-5
Table 4.1 Rillito N-yr Peak Discharges IV-7
Table 4.2 Adjusted Tributary Discharges IV-8
Table 4.3 Water budget for the years 1995-2001 (rates are in ac-ft/yr) IV-12
Table 4.4 General Landfill Characteristics IV-14
Table 4.5 Vegetation Communities IV-16
Table 4.6 Arizona Riverine Model Functions..... IV-25
Table 4.7 Cover Type Acreages..... IV-32
Table 4.8 Land Use in the Study Area IV-32
Table 4.9 Hydrogeomorphic Functional Assessment Summary..... IV-34
Table 4.10 Functional Capacity Index Comparisons IV-37
Table 4.11 Functional Capacity Unit Comparisons IV-40
Table 4.12 Number of Structures in the Finger Rock Wash Area IV-44
Table 4.13 Total Estimated Damages by Event Finger Rock Wash..... IV-45
Table 4.14 Attendance Figures for Rillito River Parks..... IV-48
Table 4.15 ..... IV-50
Future Without Project PWAA's in the El Rio Antiguo Study Area IV-50
Table 4.16: Additional Park Facilities Needed to Achieve Guidelines IV-52
Table 4.17 Problems and Opportunities..... IV-52
Table 5.1 Basin Alternatives..... V-12
Table 5.2 Terrace Alternatives..... V-14
Table 5.3 Channel/Tributary Alternatives V-15
Table 5.4: Average Cost, Average Cost, CEA, ICA and HGM Rankings V-19
Table 5.5 Final Incremental Cost Analysis..... V-23
Table 5.6 Summary Comparison of Detailed Plans..... V-25
Table 6.1 Economic Cost Summary for the Recommended Plan..... VI-12
Table 6.2 Restoration Operation and Maintenance Costs..... VI-14
Table 6.3 Summary of Recreation Benefits and Costs VI-16
Table 7.1 Cost Apportionment Table..... VII-2

List of Figures

Figure 1.1 Location Map..... 2
Figure 1.2 House Resolution..... 3
Figure 2.1 Location Map..... II-9
Figure 2.6 Rillito River in 1936 (Photo provided by the Arizona Geological Survey)..... II-10
Figure 2.2 Study Area Vicinity..... II-11
Figure 2.3 Study Area Land Use..... II-12
Figure 2.4 Ownership Type II-13
Figure 2.5 Study Area Topography II-14
Figure 4.1 Lateral Migration of the Rillito Channel IV-4
Figure 4.2 Soil Cement was used to stabilize banks and prevent lateral migration..... IV-5
Figure 4.3 Gaps in Soil Cement Banks..... IV-5
Figure 4.6 Storm run-off from a typical 1year probability summer storm. IV-11
Figure 4.9 Invasive Plant Species IV-16

Figure 4.10 Swan Wetlands, Rillito 1135 ..... IV-21
Figure 4.11 Cottonwood/Willow Community IV-29
Figure 4.12 Remnant mesquite bosque east of Swan IV-30
Figure 4.13.Rillito River Bottom IV-31
Figure 4.14 Buffer Areas IV-32
Figure 4.16 Baseline Functional Capacity Index Results IV-35
Figure 4.17 Existing Conditions Scores Description IV-36
Figure 4.18 FCI Comparisons IV-38
Figure 4.19 Results for Baseline Functional Capacity Units IV-39
Figure 4.20 Functional Capacity Units IV-41
Figure 4.21 Finger Rock Wash flows IV-43
Figure 4.22 Frequent flows cause obstruction to traffic and home access. IV-43
Figure 4.23 100 year Floodplain in the Bend Area IV-46
Figure 4.4 Floodplain boundaries for the 2, 5, 10, 25 year events IV-55
Figure 4.5 Floodplain boundaries for the 50, 100 and 500 year events IV-56
Figure 4.7 Potential HTRW Sites IV-57
Figure 4.8 Vegetation Communities IV-58
Figure 4.15 Distribution of Vegetation Cover Types (PWAAs) in the study area IV-59
Figure 4.24 Recreation Resources IV-60
Figure 4.25 Tentative Plans for Rillito River Parks IV-61
Figure 5.24 All Plans Differentiated V-20
Figure 5.1 Alternative 1A - All Basins 4 ..... V-32
Figure 5.2 Alternative 1B - All Basins 1 ..... V-33
Figure 5.3 Alternative 1C – Upstream Basins 4 ..... V-34
Figure 5.4 Alternative 1D – Upstream Basins 1 ..... V-35
Figure 5.5 Alternative 1E – 2 Downstream Basins 4 ..... V-36
Figure 5.6 Alternative 1F – 2 Downstream Basins 1 ..... V-37
Figure 5.7 Alternative 1G – 1 Downstream Basin 4 ..... V-38
Figure 5.8 Alternative 1H - 1 Downstream Basin 1 ..... V-39
Figure 5.9 Alternative 2A – 2 Terraces 4 ..... V-40
Figure 5.10 Alternative 2B – 2 Terraces 1 ..... V-41
Figure 5.11 Alternative 2C – 1 Terrace 4 ..... V-42
Figure 5.12 Alternative 2D – 1 Terrace 1 ..... V-43
Figure 5.13 Alternative 2E – 2 Tergab 4 ..... V-44
Figure 5.14 Alternative 2F 2 Tergab 1 ..... V-45
Figure 5.15 Alternative 1G – 1 Tergab 4 ..... V-46
Figure 5.16 Alternative 2H – 1 Tergab 1 ..... V-47
Figure 5.17 Alternative 3A – Chanbar 4A V-48
Figure 5.18 Alternative 3B – Chanbar 1a V-49
Figure 5.19 Alternative 3C – Chanbar 4b V-50
Figure 5.20 Alternative 3D - Chanbar 1b V-51
Figure 5.21 Restored, Preserved & Created Functional Outputs Comparisons V-52
Figure 5.22 Restored, Preserved and Created FCI Comparisons V-53
Figure 5.23 Restored, Preserved and Created Acre Comparisons V-54
Figure 6.1 Recommended Plan VI-2
Figure 6.2 Recommended Plan Compared to Future WOP VI-3

Figure 6.3 Terrace Cross Section VI-5
Figure 6.4 Typical Basin Cross-Section VI-7
Figure 6.5 Finger Rock Wash Low Flow Channel VI-10
Figure 6.6 Craycroft to Swan Water System VI-11

Draft Environmental Impact Statement

Appendices and Technical Reports

Appendix A	Hydrology	(under separate cover)
Appendix B	Hydraulics	(under separate cover)
Appendix C	Groundwater and Water Budget	(under separate cover)
Appendix D	Design	(under separate cover)
Appendix E	Cost Estimating	(under separate cover)
Appendix F	Geotechnical	(under separate cover)
Appendix G	HTRW	(under separate cover)
Appendix H	Economics	(under separate cover)
Appendix I	Real Estate	(under separate cover)
Appendix J	Public Involvement	(under separate cover)
Appendix K	Habitat Analysis	(under separate cover)

List of Acronyms

ADWR – Arizona Department of Water Resources

AGFD – Arizona Game and Fish Department

CAP – Central Arizona Project

EAD – Estimated Annual Damages

EL – Environmental Lab

EQ – Environmental Quality

ERDC - Engineering Research and Development Center

ERR – Environmental Restoration Report

FCI – Functional Capacity Index

FCU – Functional Capacity Unit

FEMA – Federal Emergency Management Agency

HGM – Hydrogeomorphic Method

HTRW – Hazardous, Toxic and Radioactive Wastes

MBTA – Migratory Bird Treaty Act

NED – National Economic Development

NER – National Ecosystem Restoration

PCFCD – Pima County Flood Control District

PCDTFCD – Pima County Department of Transportation and Flood Control District

PED – Preliminary Engineering and Design

PWAA(s) – Partial Wetland Assessment Area(s)

SDCP – Sonoran Desert Conservation Plan

CHAPTER I
STUDY AUTHORITY

This report presents various alternatives to address flooding, environmental restoration and recreational opportunities on the Rillito River, Pima County, Arizona. The Rillito River is commonly called Rillito Creek and so named on most maps of the area. The study area is additionally called El Rio Antiguo (because of its cultural significance) to distinguish it from previous studies and projects with similar names. The Rillito is a significant tributary of the Santa Cruz River in the State of Arizona. A location map is presented in Figure 1.1.

The statutory authority for this project investigation and study is contained in the following enacted laws:

Section 6, Public Law 761, Seventy-fifth Congress, dated June 28, 1938, which reads:

" The Secretary of War is hereby authorized and directed to cause preliminary examination and surveys at the following locations..... Gila River and Tributaries, Arizona."

Additional authority was provided by House Resolution 2425, dated March 17, 1994 stating:

"… The Secretary of Army is hereby 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."

Authority for project implementation will be sought in an upcoming Water Resources Development Project as a separately authorized civil works project.

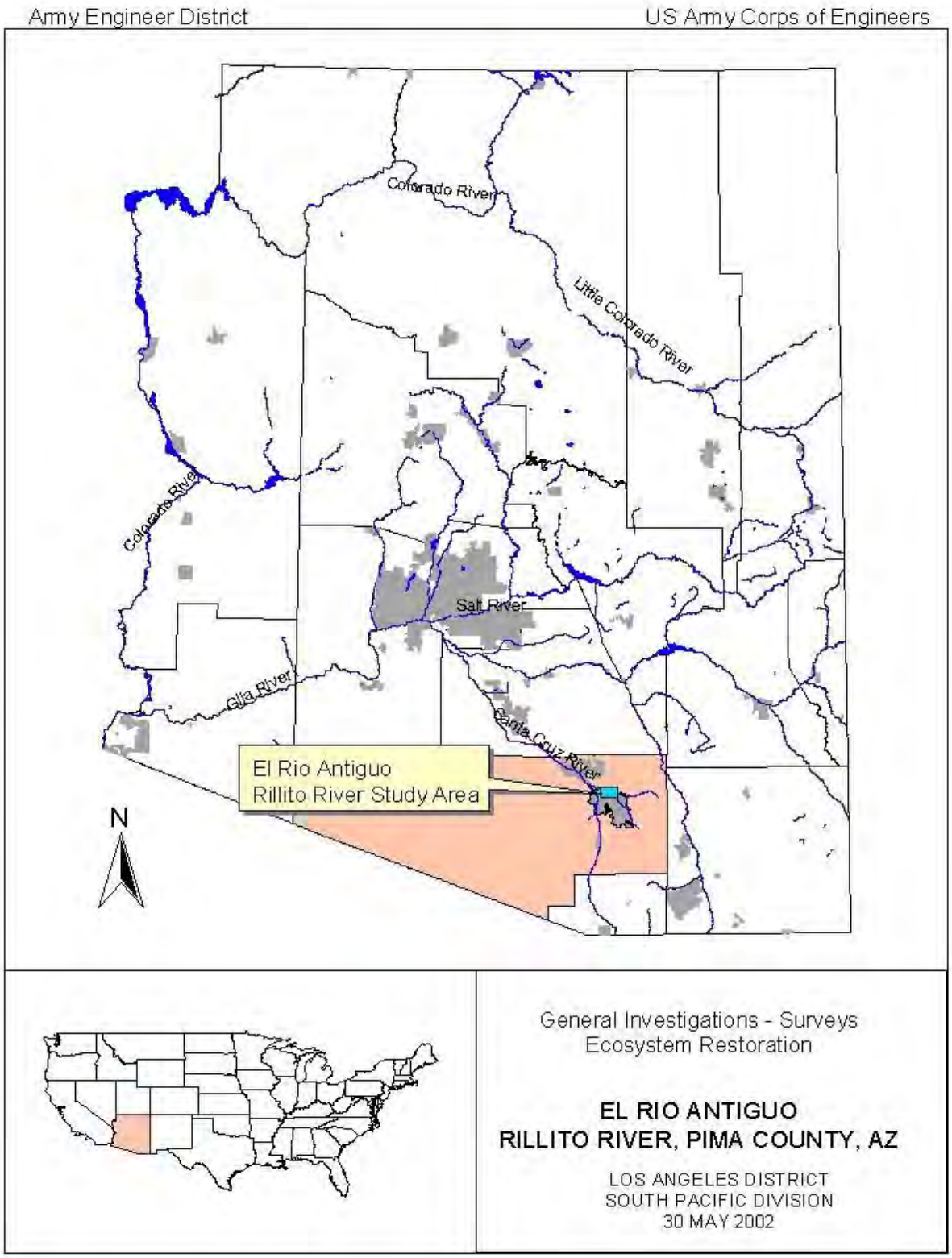


Figure 1.1 Location Map

U.S. House of Representatives

COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION

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

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

RESOLUTION

State of Arizona
Docket 2425

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

Adopted: May 17, 1994

ATTEST: NORMAN Y. MINETA, Chair

Figure 1.2 House Resolution

CHAPTER II
STUDY PURPOSE, STUDY SCOPE, AND STUDY AREA

A. Study Purpose

This feasibility study provides an interim response to the study authority. While the study authority includes floods control and other purposes, the House Report accompanying the appropriation focuses on ecosystem restoration. The El Rio Antiguo, Rillito River, Pima County, Arizona Feasibility Study is an ecosystem restoration study being conducted by the U.S. Army Corps of Engineers, Los Angeles District (Corps) and the Pima County Flood Control District (PCFCD).

This report details the planning process for determining existing conditions in the project area; forecasting the expected future without-project conditions; formulating plans to address the problems and opportunities inherent is those conditions and determining the plan that best addresses those problems and opportunities in the context of study goals and identified constraints. Conditions that exist at the time of the study are collectively called the existing or baseline condition. The future without-project condition is the same as the "no action" alternative, and describes what is expected to happen in the absence of Federal or non-Federal action. The no action alternative assumes the future will bring change, despite a lack of Corps participation. The future without a project depends closely on all aspects of long-term planning for urban needs as they are perceived at later dates and as conditions change. Future development would occur in accordance with existing plans by the City of Tucson General Plan, the Pima County Comprehensive Plan Update, and the Sonoran Desert Conservation Plan.

The future status of the significant natural, economic, and social resources described in the existing conditions, when forecast for the future conditions, provides the basis for comparing the effects of proposed projects with the no action alternative. Effects are compared over a 50-year period beginning with the project base year. The project base year is the first year in which a Federal project would produce benefits. The project base year for this study is 2008, and the future condition extends 50 years later to 2058.

Alternative plans were developed to improve and increase habitat values and diversify wildlife species as well as provide recreation and environmental education with potential incidental benefits associated with flood damage reduction, water quality and supply. This draft report is intended to document the process of plan formulation and evaluation while providing the basis for future completion of the complete decision document that presents the results of the feasibility phase of the General Investigation effort. This draft feasibility report is intended to provide a basis for future accomplishment of the following tasks:

- Provide a complete presentation of study results and findings of existing, baseline and future without project conditions so that readers can reach independent conclusions regarding the reasonableness of recommendations in the next study steps;
- Indicate compliance with applicable statutes, executive orders and policies; and
- Provide a sound and documented basis for decision makers at all levels to judge the recommended solution(s).

B. Study Scope

The proposed project offers an opportunity to restore critical riparian and cienega habitats that have been lost in the region due to water resource changes in Pima County. The opportunity exists to use knowledge gained from existing ecosystem restoration projects and utilize other water sources to expand and sustain riparian and cienega habitats along the watercourse.

Study efforts are being conducted in coordination with the Corps, the PCFCD, other federal agencies, state resource agencies, and concerned members of the public.

C. Study and Report Process

The Los Angeles District of the Corps of Engineers completed the first phase of the General Investigations study in September of 2001. The results and conclusions of the reconnaissance phase were presented in the Rillito River, Pima County 905b Report. This report established that there was a Federal interest in proceeding to a second, feasibility phase of the General Investigation to investigate the opportunities for providing habitat restoration in the area of Arizona specified as El Rio Antiguo, Rillito River, Pima County.

This report documents information and analyses from the reconnaissance report and incorporates the findings of the initial planning process that includes initial baseline assessment, future without project conditions projections and establishment of public involvement in the planning process.

In this report, the Corps of Engineers 6 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 were evaluated for effectiveness, efficiency, completeness, and acceptability. The impacts of alternative plans were 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 were compared. The public involvement program was used to obtain public input to the alternative identification and evaluation process. Cost effectiveness and incremental cost analysis were used to prioritize and rank ecosystem restoration alternatives. A benefit cost analysis was conducted to prioritize and rank recreational measures.
6. A plan was proposed for selection, and a justification for plan selection was presented.

Throughout the planning process for this project, public input has been solicited utilizing a variety of avenues including local newspaper articles, public information mailings, and coordination with special-interest groups, public workshops and formal public hearings. The

initial planning process began with a meeting November 13, 2001 to identify and review the primary issue areas involved in the El Rio Antiguo study area. Because of that initial meeting, further meetings were scheduled to establish a process for development of public involvement in planning for restoration of the El Rio Antiguo, Rillito River study area. Issues addressed included habitat restoration, water budget, water quality, wildlife habitat, recreation, environmental education and tributary flood control. The principal participants in this public workshop planning process were representatives from Federal, state, and local agencies, citizens from the local area, and other stakeholders. Factors taken into consideration in the planning process included:

- develop a plan based on good science,
- develop a plan that meets the needs of all of the stakeholders,
- develop a consensus plan, and
- develop an achievable plan.

The process that was adopted for the El Rio Antiguo Study effort was patterned after the Phoenix Tres Rios River Management Plan. The idea was to establish a series of workshops around the principal issue areas: restoration of riparian habitat, establishment of a wildlife corridor, water supply, water quality, and recreation. The first Work Group meeting was held May 8, 2002 and sixteen local residents attended. This core group of citizens committed to 7 months of meetings, field trips and hard work in order to document their ideas and input to the habitat restoration design. Seven monthly meetings and two group field trips were conducted May through November 2002. Primary concerns identified by the Work Group participants are:

- Access to Rillito River and existing trails
- The use of native vegetation for restoration
- The wise use of water
- Providing wildlife habitat
- The visual impact of the project
- Using interpretive signage
- Working with surrounding neighbors.

The issue of flooding arose only the context of a secondary effect of restoration actions such as water harvesting. After the workshops, ideas were synthesized into an alternative plan concept that included all of the community perspectives and would be acceptable to all participants. Subsequent plan formulation efforts integrated Work Group concepts wherever possible. Detailed information on the Work Group proceedings may be found in the Public Involvement Appendix.

D. Study Coordination

Formal and informal coordination occurred with a variety of Federal state and local agencies in addition to the public involvement efforts described above. Agencies contacted included the United States Fish and Wildlife Service (USFWS), the Arizona Department of Game and Fish (ADGF), the City of Tucson Parks, Tucson Water Department, City of Tucson Transportation, Pima County Department of Transportation, Pima County Cultural Resources, and Pima County Parks and Recreation. In addition to the above local stakeholders included the University of

Arizona Cooperative Extension, Pima Trails, local Homeowners Associations, Tucson Audubon Society, and Friends of the Rillito, a neighborhood group.

Representatives from USFWS and ADGF participated in development of the functional assessment model and its application. USFWS also participated in development of alternatives and their design. USFWS has prepared a Planning Aid Letter and is currently preparing a Coordination Act Report for this study.

E. Study Area

The study area is located in Pima County, Arizona. The Rillito flows from its beginning at the confluence of Tanque Verde Creek and Pantano Wash for a total of 12.2 river miles to the Santa Cruz River. The Rillito flows into the Santa Cruz River 7.6 miles downstream from the study area after flowing under Interstate 10. The Rillito drains the Southern side of the Santa Catalina Mountains that reach elevations over 9000 ft. It also brings waters from the Northern edge of the Rincon Mountains that reach elevations up to 7000 ft.

Figure 2.1 (Page II-9) presents the general project study area location and Figure 2.2 (Page II-11) shows the study area vicinity. The study area is within eastern Pima County, Arizona (See Figures 1.1, 2.1, 2.2). The study name, *El Rio Antiguo* (The Old River), has been adopted because it is the physical connection to the 19th century environmental resources in this region. The study extends along the Rillito between Craycroft Road downstream to Campbell Avenue for a project length of approximately 4.8 miles. The study area averages one mile wide, and encompasses approximately 1066 acres.

The study boundaries upstream and downstream were directed by Congress at the request of the sponsor. The upstream and northern boundaries were chosen for physical reasons. The upstream boundary at Craycroft Road is the headwater of the stream and the north bank boundary is the edge of the floodplain at the mountain front. The south bank boundary and the Campbell Avenue boundary were chosen because they are the perceived limits of opportunity for ecosystem restoration in this urbanized area.

Climate and Meteorology

The El Rio Antiguo study area is characteristic of the Sonoran desert: hot and dry. The average annual daily maximum temperature is 82°F. Average annual daily minimum temperature is 54°F. Average precipitation is approximately 12 inches per year with 46 per cent of the rainfall occurring during the monsoon season from July to September. There is potential for snowfall in the month of January.

Precipitation is normally divided between the summer and winter seasons. Summer storms are typically local, high-intensity thunderstorms, and generally occur from July to September. Storms on record have produced 5 inches of rainfall in a 24-hour period. Winter storms are typically widespread cyclonic storms with long duration, low-intensity rain.

Population

In 2000, the population in Pima County totaled approximately 843,746 people reflecting a growth rate of 26.5 per cent over the last decade. This total includes 332,350 households, with approximately 2.5 people per family. The City of Tucson accounts for 57 per cent of the population.

Existing Land Use

In Pima County, The San Xavier, Pascua Yaqui and Tohono O'odham reservations together account for ownership of 42.1 percent of county land. The state of Arizona owns 14.9 percent; the U.S. Forest Service and Bureau of Land Management, 12.1 percent; other public lands, 17.1 percent; and individual or corporate ownership, 13.8 percent. Pima County has two Enterprise Zones, one in South Tucson and portions of Tucson and the other in an unincorporated portion of the county just southwest of Tucson.

The Rillito flows along the northern boundary between the City of Tucson and unincorporated Pima County in an east-west direction. The study area currently contains a variety of land uses. It consists of mainly residential areas, rural type areas with agricultural uses, privately owned ranches, light industrial and commercial uses, as well as open space and public parks. There are no heavy industrial areas near the study area. Figure 2.3 (Page II-12) shows the land use in the El Rio Antiguo study area. Table 2.1 lists the corresponding acres of land use category in the study area.

Table 2.1 Land Use Designations in the El Rio Antiguo Study Area

Land Use	Acres
Residential	292.1
Agricultural	6.9
Commercial	9.4
Industrial	.9
Institutional	60.5
Lodging	.1
Governmental	87.2
Office	.9
Rural	88.7
Utilities	22.9
Vacant	291.9
Dedicated Open Space	20.2
Other	184.3
TOTAL	1066

Nearly one-half of the study area (476 acres) is publicly owned with the majority of public acreage (384) being held by Pima County. In addition to lands held outside the channel, the Pima County Department of Transportation and Flood Control District owns most of the land between the soil cement banks. That area includes the slightly elevated terraces and the low flow channel which experiences occasional water flow after periods of rain. Private ownership is predominant outside of the River. The distribution of public and private ownerships is depicted

in Figure 2.4. (Page II-13) To the north of the Rillito River, several properties support small privately owned livestock and ranch operations within the study area. In the area along the south of the Rillito River, an agriculture research facility is operated by the University of Arizona. The Tucson Electric Power North East substation is located adjacent to the Rillito River, by Dodge Boulevard. The area south of the Rillito River includes light industrial and commercial land uses. Development of shopping plazas and apartments has occurred south of the Rillito, near Swan Road. Light industrial and commercial land uses to the south of the Rillito River in the study area include closed landfills, formerly operated as sand and gravel operations.

A prominent land use feature in the Rillito River, as well as the surrounding area, is public and private recreation land uses. The Rillito River functions as a river park with trails. Several parks within close vicinity to the Rillito River and the El Rio Antiguo study area have typical park amenities and recreational opportunities.

Pima County has instituted a number of measures governing land use that would either directly or indirectly support restoration efforts in the study area or. These measures include: the Comprehensive Land Use Plan that guides overall land use density as enforced by the Zoning Code; the Sonoran Desert Conservation Plan that provides a comprehensive plan to preserve natural and cultural resources; the Environmentally Sensitive Lands Ordinance that establishes comprehensive policies and regulations for environmentally sensitive areas; the Floodplain Management Ordinance and associated regulations; Riparian Habitat Protection regulations; the Native Plant Preservation Ordinance that protects upland native vegetation; the Flood prone Land Acquisition Program that pursues acquisition of floodplain for public safety and open space; and the Open Space Acquisition Program that purses acquisition of property for protection natural and cultural resources

Topography

Pima County covers 9,184 square miles. Elevations range from 1,200 feet to the 9,185-foot peak of Mount Lemmon in the Santa Catalinas. The study area is on a Basin-and-Range valley floor called the Tucson Basin, with surface elevations of about 2,000 to 3,000 ft, and drainage to the northwest (Figure 2.1, page II-9). Block faulting produces a topography of sharp contrasts, in which isolated, almost parallel mountain ranges rise in stark contrast above low-lying desert plains.

Unless otherwise noted, use of the term floodplain refers to the floodplain associated with 500-year FEMA discharge. This area includes lands that would have been part of the riparian corridor historically maintained by the Rillito River. The study area floodplain is bounded to the north by the foothills of the Santa Catalina Mountain Range (Figure 2.5, page II-14). The floodplain is hilly to the north and cut by numerous small tributaries except at the “Bend”. This area is an alluvial fan at the confluence of the Finger Rock Wash with the Rillito. The “Bend” has been farmed in the past. It is flat and subject to flooding from the Finger Rock Wash and the Rillito River. The topography slopes away to the south of the Rillito but the study area is generally flat. The floodplain boundary to the south stays within the river's banks as it flows along the southern border of the Bend area but expands out to maximum widths of approximately 3,000 feet immediately downstream and upstream of that location.

Geology

Regional Geology

The study area is in the Basin and Range geomorphic province, which covers a large section of the southwestern United States and northern Mexico. This province is characterized by internal drainage, which is prevalent in the northern section and is found locally in the southern section. There are numerous types of geologic structures in the province, the most common of which is block faulting.

The Tucson Basin, a north-northwest-trending structural depression, is filled with 20,000 ft or more of Cenozoic-era deposits topped by a maximum of about 100 ft of Late Quaternary alluvial deposits, with the maximum thickness of alluvium along drainage channels. The alluvium is composed of sands, gravels, cobbles, silts, and clays. However, some of the basin areas are pediments—erosional surfaces cut into the edges of nearby uplands.

Study Area Geology

The Rillito River drainage basin is approximately 934 square miles. The main tributaries are Pantano Wash and Tanque Verde Creek. Pantano Wash drains desert and mountainous areas and Tanque Verde Creek drains primarily rural areas with some mountainous areas in the northeast part of the basin. The Rillito basin is within the Tucson Basin, which is underlain by several thousand feet of unconsolidated and semi-consolidated alluvial material.

The study area surface and near surface is composed of Pleistocene to Holocene-age river channel and floodplain deposits and terraces within the Rillito drainage channel and banks and on contiguous lands to the south. On the Rillito's north bank, only the youngest of the river channel, floodplain and terrace deposits are present. This is because the Rillito has been migrating northward, eroding what is north of it and depositing reworked sediment to the south. It is now at a position where it is or nearly is in juxtaposition with piedmont alluvium of the Santa Catalina foothills.

Faults and Seismicity

Faults. There are no faults occurring within the immediate vicinity of the study area. The closest fault to the study area is the Catalina detachment fault, 3 mi to the northeast, and its related splay, named the Finisterra fault, which is as close as 2.6 mi to the study area. Both are normal faults. Movement along the Catalina fault strongly deformed some of the late Oligocene to early Miocene sediments deposited at the base of the Santa Catalina Mountains, and to a lesser degree deformed younger, unconformably overlying Miocene sediments. Younger Pliocene geologic units along the Santa Catalina front are not deformed. Therefore, the fault has not been active since prehistoric times.

Seismicity. Seismicity was addressed previously by the Corps of Engineers in the Design Memorandum for soil-cement bank stabilization, in the bend area and at the confluence of the Santa Cruz River and the Rillito; those conclusions, drawn from numerous literature sources, also are applicable for the current study area:

- the study area is astride zone 1 and zone 2 (low to moderate seismic potential) on the Seismic Zone Map of the Contiguous States
- earthquakes with magnitudes greater than 4.0 on the Richter scale have been concentrated in this particular zone 2;
- earthquake intensities with Modified Mercalli shaking intensities greater than VI have been known in this particular zone 2 (on a scale of I - XII, with XII being the greatest shaking);
- estimated recurrence interval of surface-rupturing earthquakes (which can be among the most damaging to structures) has been 300 to 4,000 years (over the past 20,000 years);
- the strongest shaking intensity likely felt within the confines of the study area was intensity VII, resulting from the 130-mile-away, Sonora, Mexico earthquake of 1887, with its maximum shaking intensity of XII and estimated magnitude of 7.2; note that this earthquake caused landslides and rockfalls in the Santa Catalina Mountains and widespread damage to structures, even in Phoenix. Some smaller walls around the San Xavier Mission grounds collapsed at the time.

Channel Morphology

The Rillito was once at grade with a braided, meandering streambed and a broad floodplain. By 1936, farming practice had begun to have an effect on the floodplain. Finger Rock Wash was cut off from the Rillito and riparian vegetation was removed and replaced with agricultural fields. Comparison of aerial photos taken in 1936 (Figure 2.6, page II-10) to recent photos (Figure 2.2, page II-11) shows that the channel was at grade in 1936 with some remaining riparian areas and a much wider flood plain.

The river has since lost its connection to the floodplain due to channel degradation and incision. Today, the incised channel of the Rillito averages 250 feet in width and 4 to 7 feet in depth, but flooding and simultaneous lateral erosion and downcutting have increased widths to as much as 600 ft in places. Soil cement bank stabilization has been added along most of this reach of the Rillito. The mouths of tributaries and the area between Alamo Wash and Alvernon Wash are the only areas without such protection. The width of the stream narrows downstream from Alvernon Way to the western end of the study area at Campbell Avenue. The existing stabilized and incised channel conveys flood flows safely through the area. However, these channel conditions prevent the inundation of the floodplain that maintained the historic riparian community.

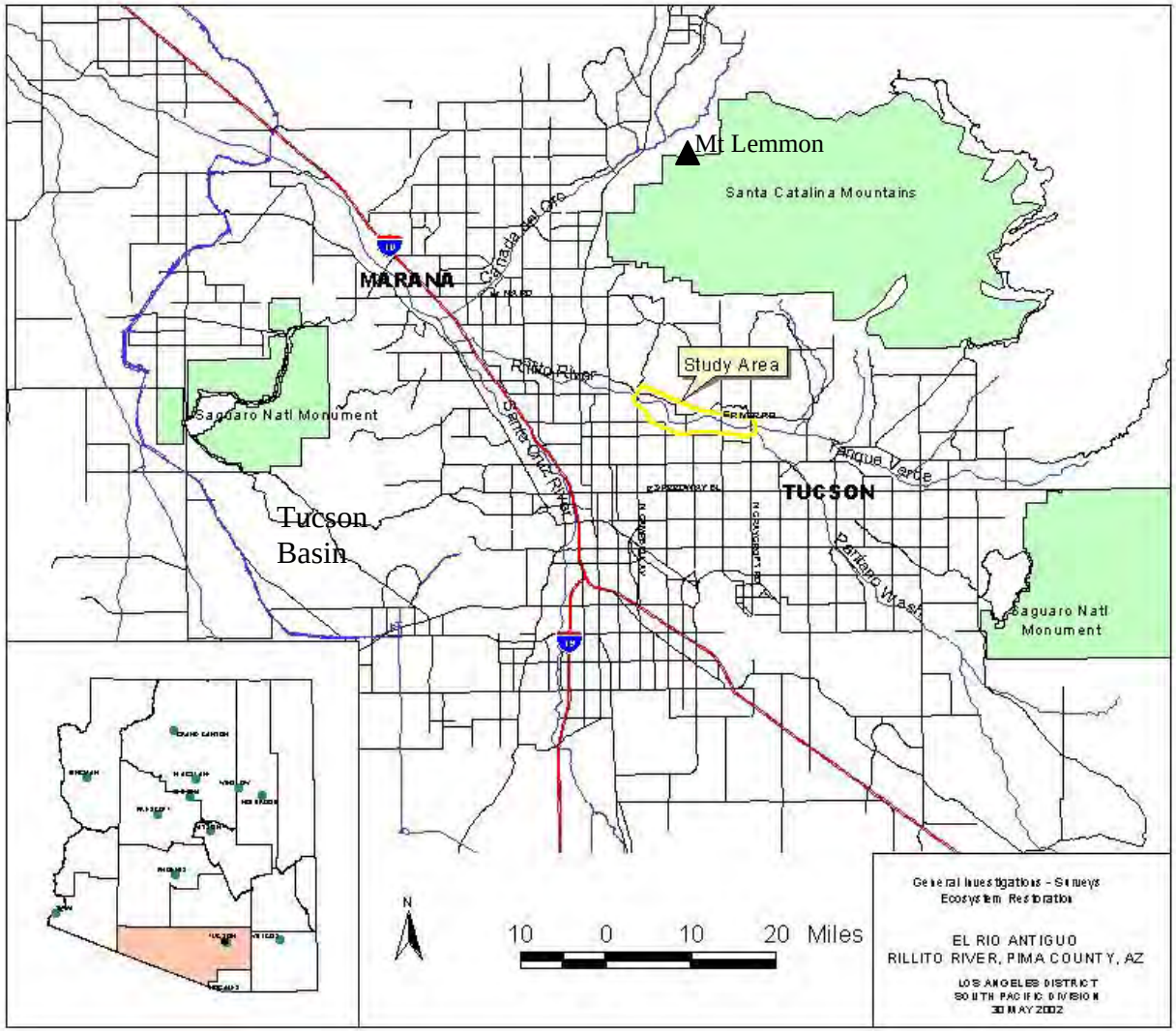


Figure 2.1 Location Map

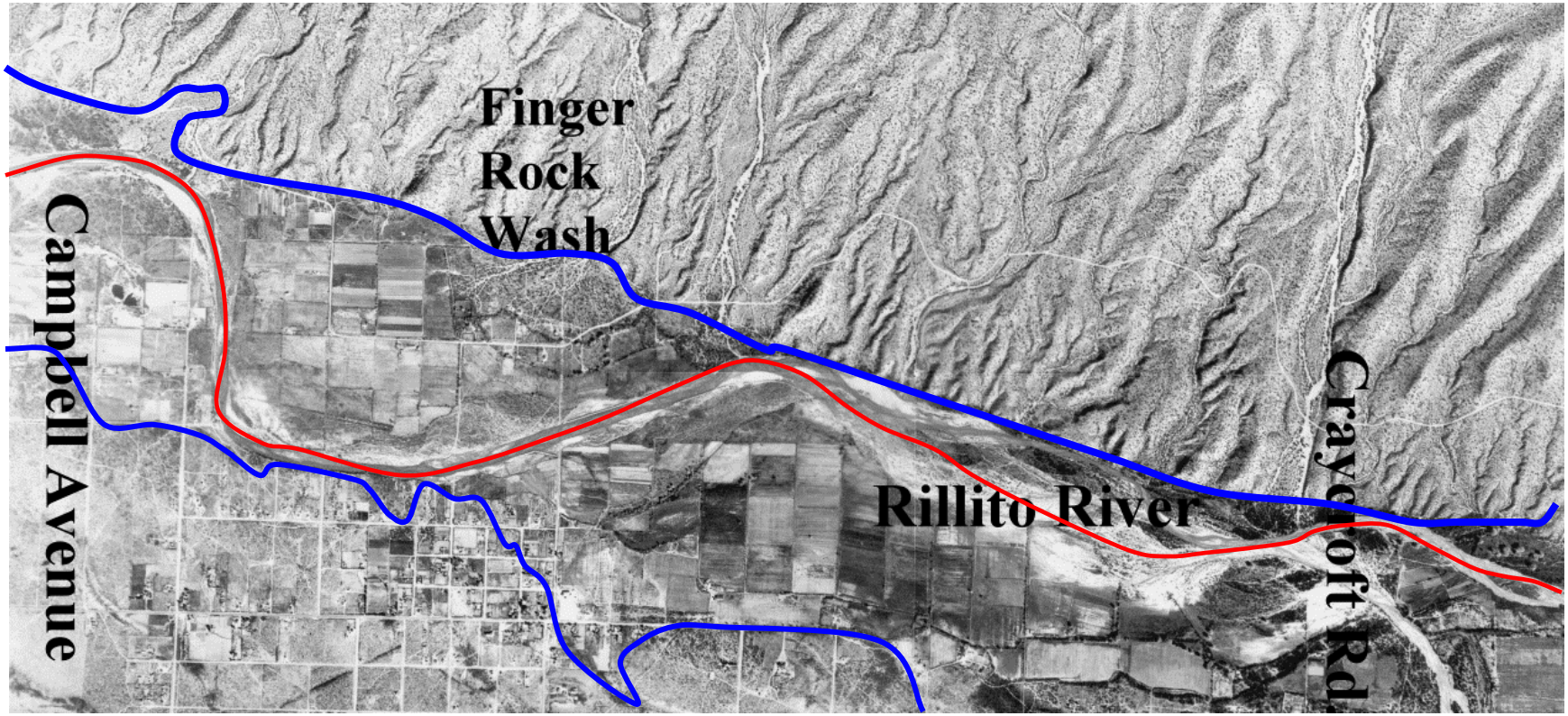


Figure 2.6 Rillito River in 1936 (Photo provided by the Arizona Geological Survey)

Note the braided nature of the stream, remaining riparian areas, and the wider floodplain. By 1936, the encroachment of agriculture has begun to influence the channel, reducing floodplain area, and channel meander. However, at the time of this photo, the channel still had some ability to meander across the floodplain (indicated by the blue lines). Today, the channel (indicated in red) is entirely confined, straightened, and unable to interact with its geologic floodplain.

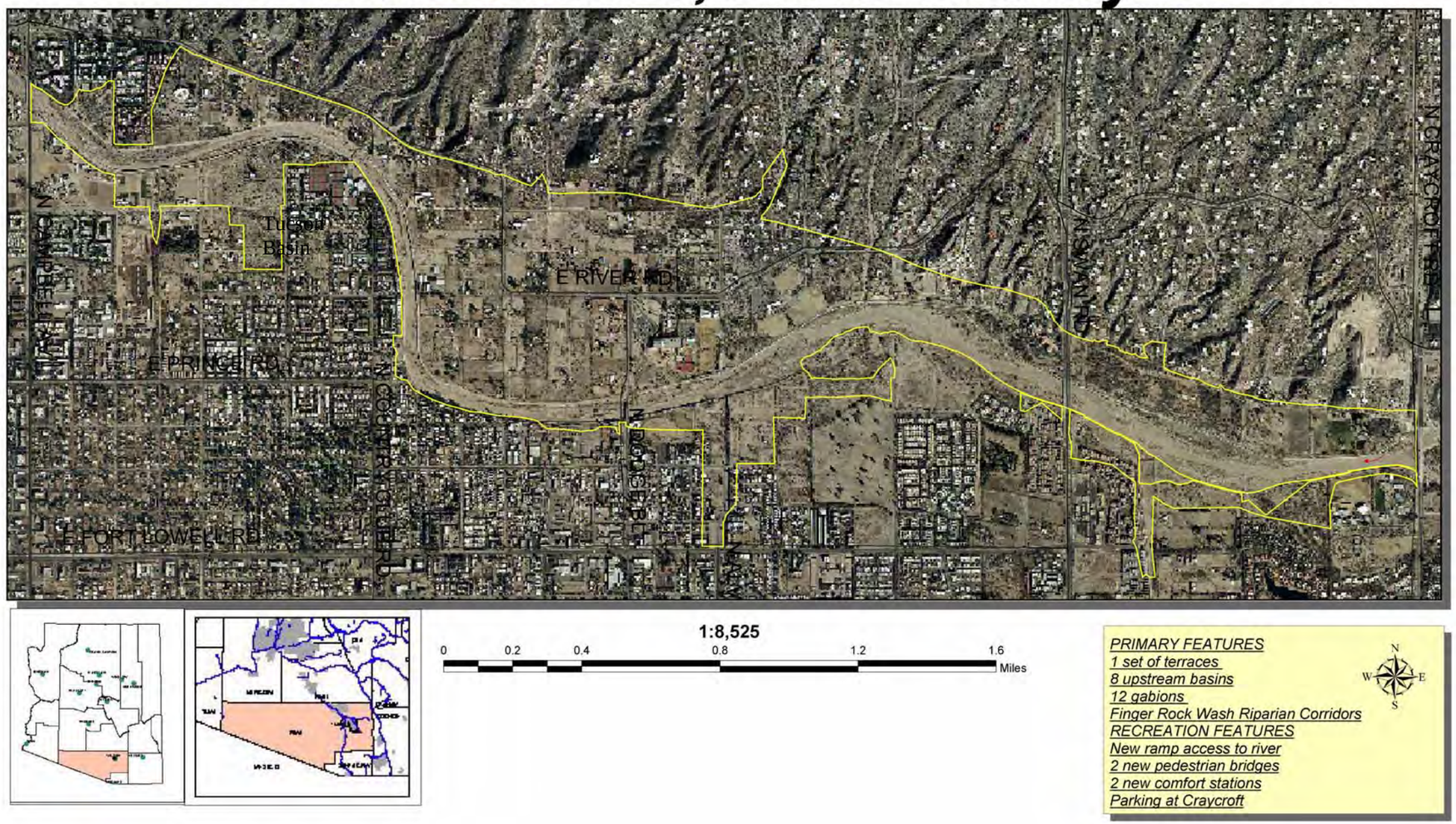


Figure 2.2 Study Area Vicinity

The study area sits at the northern edge of the City of Tucson and is highly developed to the south. The north and south boundaries represent the perceived boundaries for restoration potential. The north boundary runs along the edge of the floodplain at the mountain front. The southern study boundary encompasses open areas with potential availability.

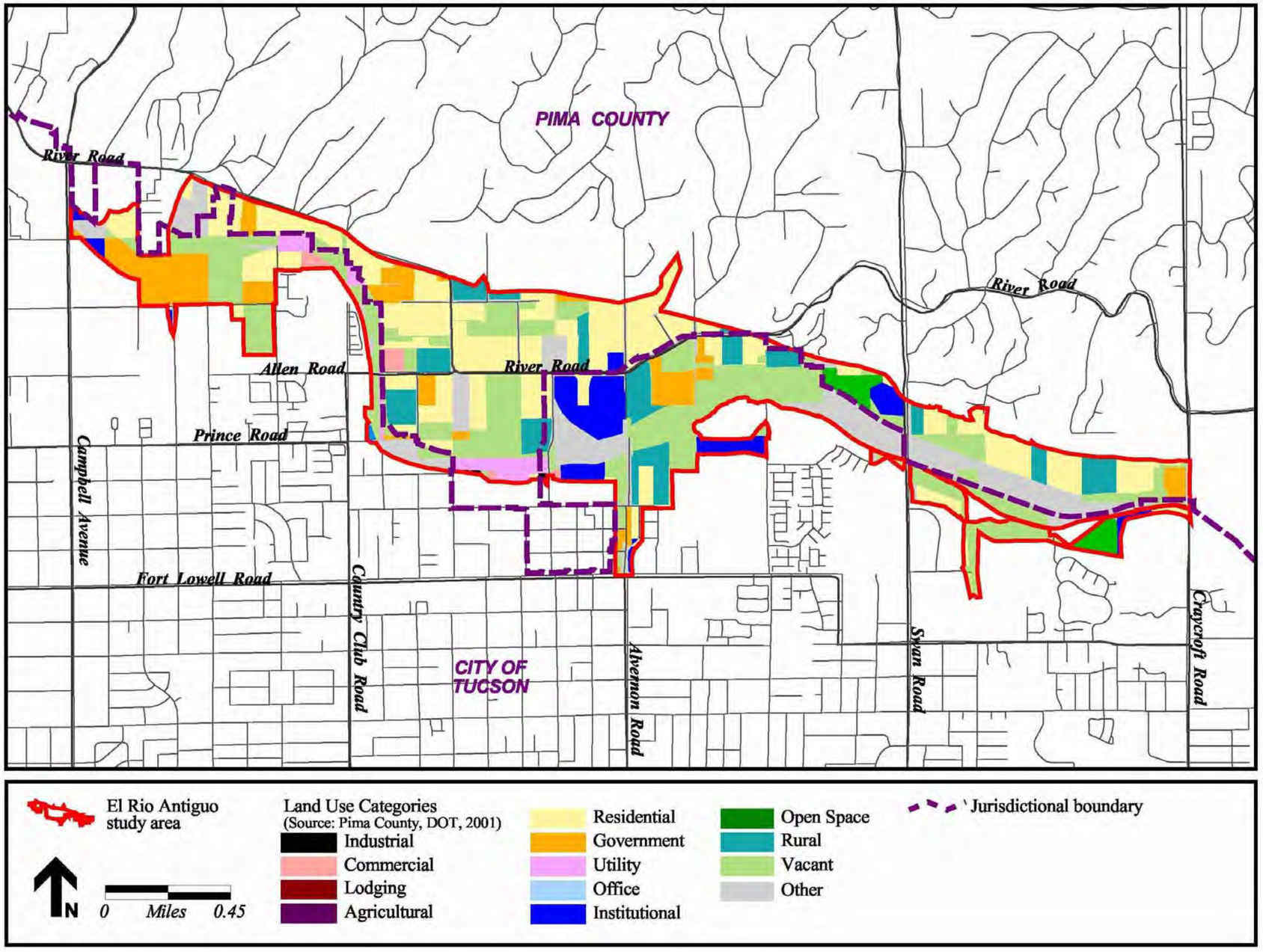


Figure 2.3 Study Area Land Use

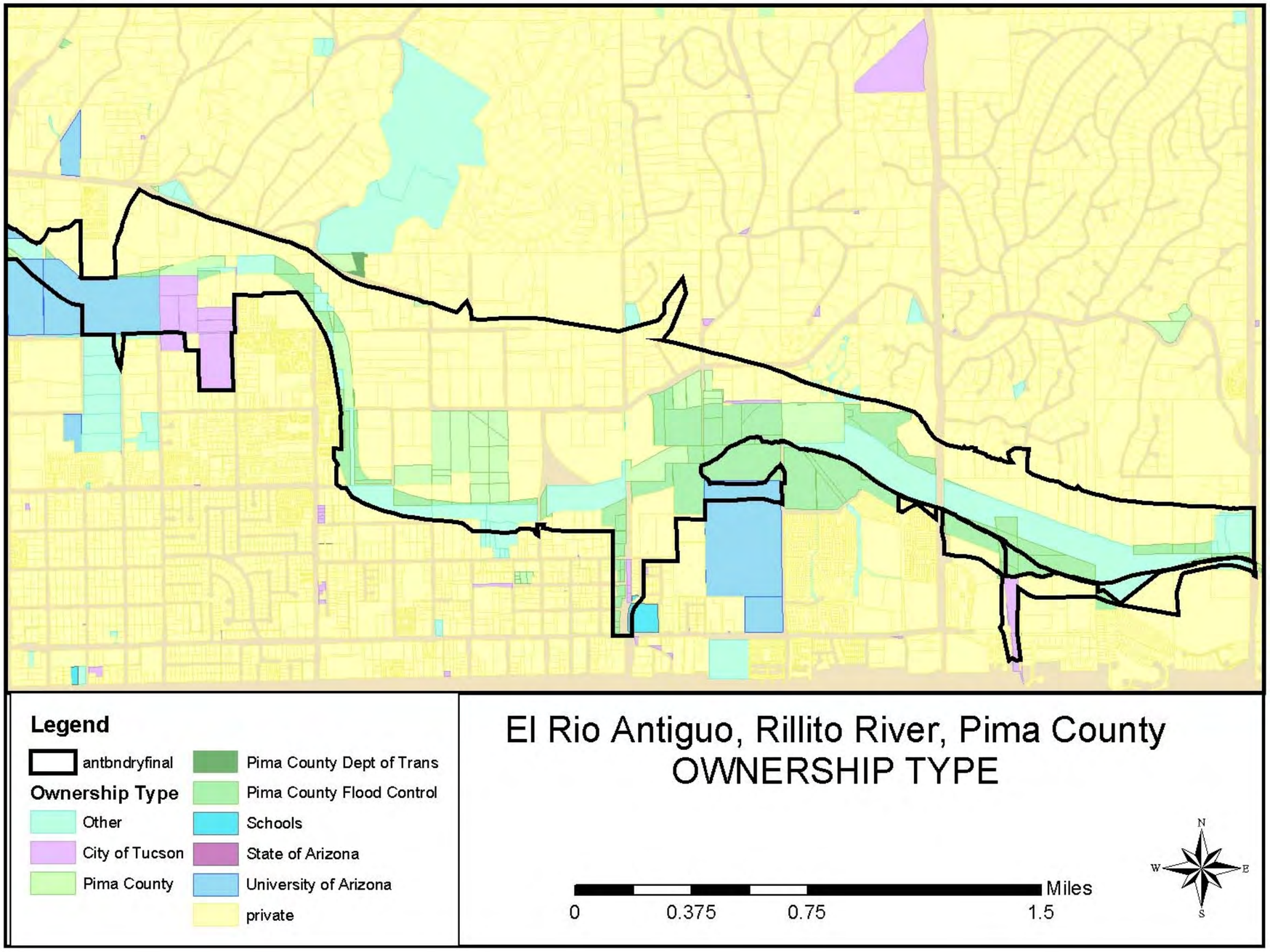
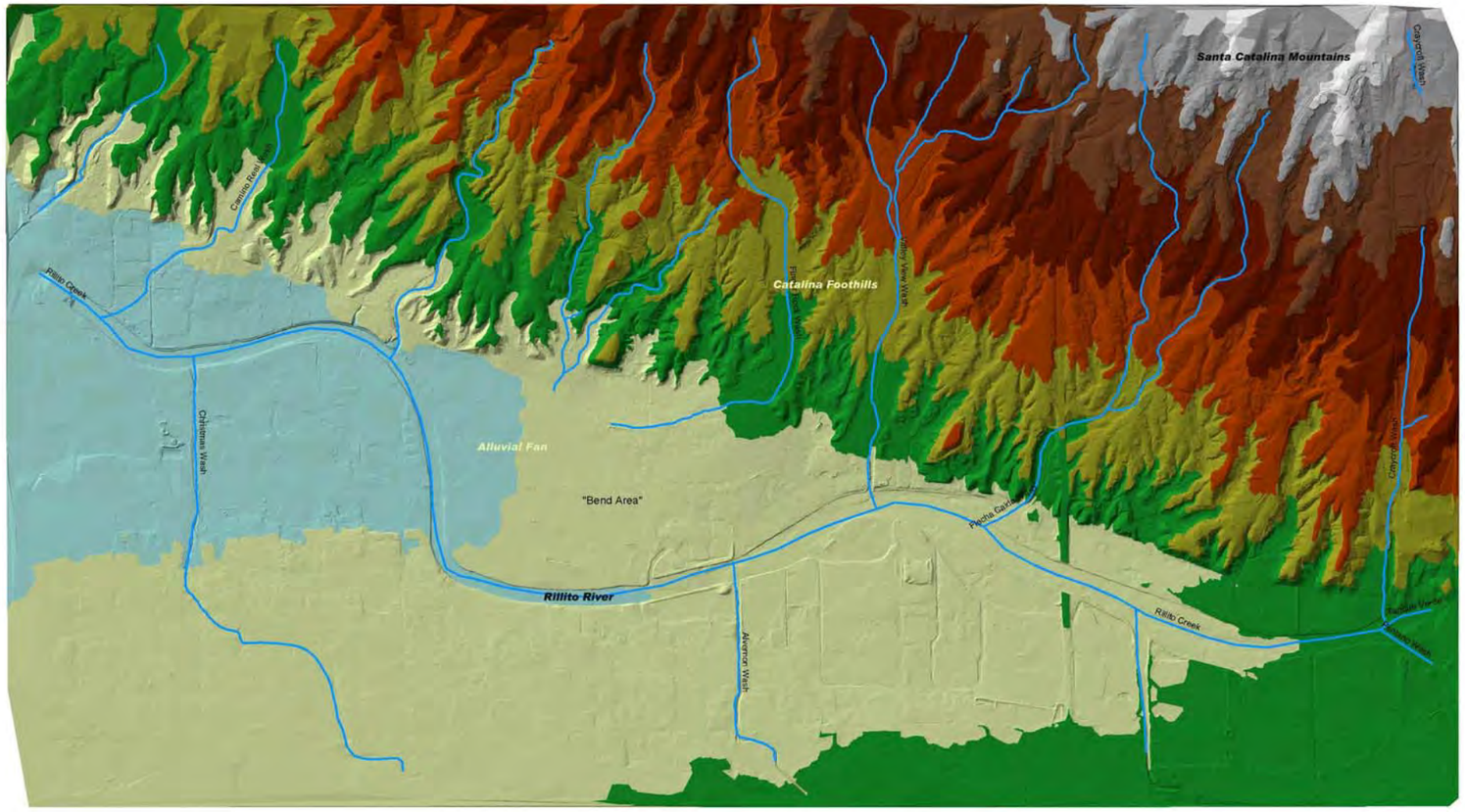


Figure 2.4 Ownership Type

El Rio Antiguo, Rillito River, Pima County, Arizona
TOPOGRAPHY



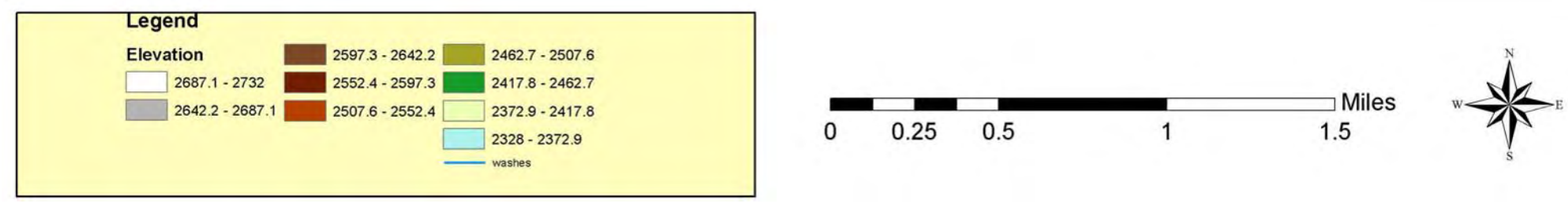


Figure 2.5 Study Area Topography

CHAPTER III
PRIOR STUDIES, REPORTS & EXISTING PROJECTS

A. Existing USACE Reports

1) *Gila River, Santa Cruz River Watershed, Pima County, Arizona,* U.S. Army Corps of Engineers, August, 2001. The purpose of this study is based on the Corps authorities to study watersheds and develop watershed management plans.

2) *Gila River and Tributaries, Arizona and New Mexico, Santa Cruz River Watershed Basin Final Reconnaissance Study, Arizona.* LA District, Corps of Engineers 1996.

3) *Gila River and Tributaries, Arizona and New Mexico, Design Memorandum Rillito River, Tucson, Arizona Bank Protection.* Los Angeles District, Corps of Engineers 1992.

4) *Survey Report & Environmental Assessment, Rillito River & Associated Streams, Tucson, Arizona,* U.S. Army Corps of Engineers, May 1986, revised 2/13/87. The purpose of this study was to investigate water resources related problems in and around Tucson, Arizona and to determine the need for and the feasibility of improvements to solve these problems.

5) *Lower Finger Rock Wash, Tucson, Pima County, Arizona,* Detailed Project Report Section 205, Los Angeles District, Corps of Engineers, September 1996. Lower Finger Rock Wash is a tributary of the Rillito River, which flows into the Bend area of the River.

6) *U S Army Corps of Engineers, Design Memorandum, Rillito River, Tucson, Arizona, Bank Protection.* US Army Corps of Engineers, Los Angeles District, Oct. 1992.

7) *General Design Memorandum for: The Rillito River bank protection, Campbell Avenue to Country Club Road:* a technical services report prepared by the Flood Control Design Section for the US Army Corps of Engineers, Los Angeles District, Aug. 1991.

B. Prior Studies or Reports by Other Agencies

1) Fonseca, J. and W. Melgin. 1996. Rillito Recharge Project. High Plains States Ground Water Demonstration Program U.S. Bureau of Reclamation.

2) U. S. Geological Survey. 1995. Quality of Surface Water and Ground Water in the Proposed Artificial-Recharge Project Area, Rillito Creek Basin, Tucson, Arizona. Water Resources Investigations Report 95-4270. P:26.

3) U. S. Geological Survey. 1994. Quality of Water and Chemistry of Bottom Sediment in the Rillito Creek Basin, Tucson, Arizona, 1986-92. U. S. Geological Survey Water Resources Investigations Report 94-4114. P:90.

4) England, A. S. and W. F. Laudenslayer. 1995. The California Desert: An Introduction to Natural Resources and Mans Impact, Volume II. *Birds of the California Desert. p:337.*

5) Camp Dresser & McKee, Inc. 1989. Rillito Creek Recharge Feasibility Study Interim Report Phase A Task 4, Environmental and Archaeological Characterization. Rillito Project Management Committee.

6) Ciolek-Torrello, R. S. and J. A. Homburg. 1990. Cultural Resources Surveys and Overviews of the Rillito River Drainage Area, Pima County, Arizona. Statistical Research Technical Series No. 20.

7) Statistical Research Inc. 2003. Little River: An Overview of Cultural Resources for the Rio Antiguo Feasibility Study, Pima County, Arizona.

8) Pima County Cultural Resources Office. 2001. National Register of Historic Places, Binghampton Rural Historic Landscape, Pima County, Arizona.

C. Existing and Current USACE Studies and Projects

1) Rillito River Section 1135 Ecosystem Restoration Project is currently in development of the Environmental Restoration Report (ERR) and is located on the south bank of the Rillito River within the same study reach. This Section 1135 project reduces the scope of the El Rio Antiguo, Rillito River Restoration Study to the north bank and those areas of the south bank not within the scope of the 1135 project. It was not included in this study because it has reached its final study stage with a completed Environmental Restoration Report (ERR). The study will soon be in the Preliminary Engineering and Design stage. Including it in the scope of the current study effort would seriously delay the completion of the 1135 project.

2) The Gila River and Tributaries, Arizona and New Mexico: Rillito River, Tucson, Arizona Phase II: Bank Protection: Craycroft Road to North Campbell Avenue. Completed. The Corps of Engineers was authorized in WRDA 1986 to construct this project for flood control and recreation purposes. Pima County was the local sponsor. The U.S. Army Corps of Engineers completed the Rillito River Bank Protection Project in 1996. With the construction of the Corps of Engineers/Pima County Soil Cement Bank Protection Project, in 1996, the 100-year flood on the Rillito River is contained within the river's banks along most of the study reach .Following completion of the bank stabilization portion of this million multiphase effort, the Corps began construction of the final phase of the project. Sixteen pedestrian bridges and various linear park improvements, extending from the Santa Cruz River to La Cholla Boulevard and from Alvernon Way to Craycroft Road were constructed. This phase of the project was completed in June 2000.

D. Community Master Plans

1) Pima County Comprehensive Plan. The purpose of the comprehensive plan is to conserve the natural resources of the county, to ensure efficient expenditure of public funds, and to promote health, safety, convenience, and general welfare of the public. The comprehensive plan includes the following guidelines related to aesthetic resources:

- Restore and preserve natural areas. This may include floodplain acquisition, purchase of development and water rights, and limitations on rezoning.
- Construct wetlands and riparian areas. This may include the use of reclaimed water or CAP water, and recharge projects.
- Preserve open space characteristics of development sensitive lands and promote

development that blends with the natural landscape and protects wildlife habitat. Extend visually the public land boundaries.

- Provide natural open space.

2) Sonoran Desert Conservation Plan. In 1998, Pima County Board of Supervisors launched the Sonoran Desert Conservation Plan (SDCP). The goal of the SDCP is to combine short-term actions to protect and enhance the natural environment and long-range planning to ensure that the natural and urban environments not only coexist, but also develop an interdependent relationship where one enhances the other. The SDCP includes the following guidelines related to aesthetic resources:

- Retain mesoriparian and riparian linkage areas (streambed and associated upland) at a minimum of 95 percent of their current level.
- Retain biological core areas at a minimum of 80 percent of their current level.
- Retain multiple use areas at a minimum of 75 percent of their current level

CHAPTER IV
PROBLEMS AND OPPORTUNITIES

Problems and opportunities were identified, defined, and assessed through coordination with local and regional agencies, the public involvement process, site assessments, interpretation of prior studies and reports, and review of existing water projects. An initial screening of problems and opportunities included habitat restoration, flooding and flood control, water conservation, and recreation. Specific problems and opportunities are based on an assessment of the existing and expected future without project conditions, as described in the following sections. Although flood damages occur in some portions of the study area, previous flood control studies have demonstrated the lack of justification for single purpose flood control measures. The opportunity exists to restore riparian habitat along the Rillito from Craycroft to Campbell Avenue. In general, riparian areas occur along stream banks where soils are fertile and water is abundant for at least some portion of the year.

The presence of a stream or river is the single factor that signifies riparian habitat. Riparian habitats are exceptionally significant in the arid southwest, and most exhibit the majority of the functions and values typically present in a wetland system. The majority of riparian areas in Arizona are narrow, linear strips. This is especially true within the more arid desert communities. These riparian zones function as wildlife corridors and oases with respect to the surrounding arid regions. The resulting microclimate within these areas provides habitat for species that would not otherwise survive the summer. In general, species diversity is higher in riparian areas than in the neighboring uplands. Overall, riparian habitats have declined by approximately 90% in the western United States, which further highlights the value of future restoration projects.

A. Historical Conditions

In order to have a complete understanding of historic conditions and the value of what has been lost it is necessary to consider the study area in the broader ecological context of the arid southwest. In the past, there were hundreds of locations across the southwest where waters flowed perennially or seasonally. These watercourses were often just the exposed tips of vast aquifers that rose upward to the earth's surface. The surface and subterranean waters created springs and riparian areas along rivers and streams scattered like islands of green across the arid southwestern landscape. Some of these areas were tiny, only a few acres or less in size, but others were thousands of acres of lush, nurturing habitat and travel corridors for local and migratory wildlife. Wildlife thrived in broad marshes and dense mesquite thickets, in galleries of stately cottonwoods and willows shading the flowing waters, in expansive meadows of native grasses and shrubs, and in the water itself, which teemed with fish, frogs, turtles, insects, and aquatic plants.

When the first people arrived in the southwest, a few thousand years ago, they used these riparian islands; first as migratory corridors and then to establish permanent settlements. When the first Europeans arrived in the late 1600's, they found the same ecosystem of riparian islands embedded in an arid landscape. They used the riparian areas as others had before – as highways and places to settle. One of the first places they settled was in the Santa Cruz River Valley. In the early 19th century, American beaver trappers ventured into Arizona in search of pelts to

supply the beaver hat fashion craze sweeping Europe. It took only a few trappers a few years to eliminate dam building beavers from the desert rivers. In mid century, wagon trains carrying American migrants to the gold fields of California passed through the region. As they had in the past, riparian islands provided an essential place to rest, hunt, graze livestock, and refill water barrels in preparation for long, dry stretches westward. Without these sanctuaries of freely flowing water and the habitat it supported, it is doubtful that any sizable groups could have traversed the region. In the late 19th century, substantial riparian areas remained in many parts of the Tucson area.

Along the *El Rio Antiguo* reaches of the Rillito, water once flowed perennially and supported substantial growth of cottonwoods, willows, and mesquites. Historical accounts of conditions on the Rillito approximately 100 years ago describe a tree-lined, narrow river with dense vegetation. The Rillito historically supported a dense riparian community along its banks. The river carried abundant water that supported early irrigation projects. In the 1850's, the river was lined with a continuous oasis of trees and grasses along the riverbanks and flood plain. The river path was obstructed by numerous beaver dams that ponded the water and encouraged the development of riparian wetlands.

The riparian plant species included cottonwood (*Populus fremontii*) and broad mesquite trees (*Populus juliflora*) with seep willow (*Baccharis glutinosa*), hackberry (*Celtis pallida*), and desert willow (*Chilopsis linearis*) as community members. Cottonwood and willow forests are typically found in depositional environments where fine-grained alluvial soils are located on floodplains. These forests commonly occur with other riparian communities because fluvial processes such as floodplain aggradation and channel meandering create environmental gradients and mosaics, in, for example, water table depth and inundation frequency, which favor diverse riparian species assemblages.

Mesquite bosques were a part of the mosaic. They were once the most abundant riparian community type in the Southwest. Mesquite bosques are usually found in the drier areas within the riparian continuum. Mesquite can be found in floodplains or low terraces several yards above the streambed, and up to 45 feet above the water table.

In addition to forest communities, the Rillito and associated streams were once known as "Cienegas de los Pimas." The water was in marshes with grass up to 6 feet tall in some places. Cienegas are plant communities that develop in Southwestern streams where groundwater perennially intersects the surface and where stream ecosystems are stable. Cienegas in this area were dominated by low sedges highly adapted to riparian soils. They were a unique addition to the landscape and were considered a climax aquatic habitat.

Prior to extensive pumping of groundwater in the Tucson Basin, the amount of water leaving the basin (stream flow, evaporation and transpiration) nearly equaled the amount entering and groundwater storage was nearly constant. Perennial streams and springs bubbled up where underground conditions created barriers to subsurface flow. Early settlement of the study area was justified due to the excellent water supply from the Tanque Verde Creek, Pantano Wash and Rillito Creek. Farmers and ranchers developed three ditches on the south side of the Rillito called the Bingham, Cole and Corbett Ditches. This water supply was a major consideration in the relocation of Fort Lowell to the south of Pantano Wash in 1873. On the north side of the Rillito, the Davidson Ditch, which later was developed into the Binghampton irrigation system for the Rillito Farms, was developed by the Mormon settlers. This irrigation system was built in

1901. With the constant supply of water, the Mormon settlement became largely self-sufficient, raising all of the crops to maintain their community. These crops included barley, alfalfa, corn, potatoes, tomatoes, beans, melons, pumpkins, cabbages, onions, peas, peaches, apricots, apples, blackberries, strawberries, grapes, quince, plums, walnuts, pigs, turkeys, ducks, chickens, and both dairy and beef cattle.

Throughout the 20th Century, groundwater pumping increased at a rate far greater than nature could replenish it. The Mormon community maintained the Binghampton irrigation system, until it was abandoned after the main canal was washed out in 1941. However, the system had already started to become less reliable in the 1920's due to lowering of the groundwater table. That prompted the drilling of wells to supplement of the surface water supply.

Although the immediate causes vary from place to place, the consequences of our exploitation of water in Tucson are repeated across the southwest. Today only a few vestiges of riparian islands remain. In most places in the Tucson basin, only desert plants exist unless artificial irrigation is supplied. The Rillito River now flows only in response to storm water runoff. Almost every watercourse in Tucson has dried up and been confined to concrete banks. Only a few places up in the surrounding mountains and foothills, such as the upper reaches of Tanque Verde Creek, and stretches of effluent streams downstream from sewage treatment facilities still stir the memory of what has been lost.

B. Existing Conditions

The Rillito system is very different today. Due to agricultural and rural development of the region, the Rillito had become a wide entrenched channel with vertical banks by 1900. Specific causes of erosion and habitat destruction were removal of flood plain grasses, overgrazing of cattle, erosion along cattle trails, and summer flooding due to the loss of beaver dam storage and riparian wetlands. Riparian communities have been eliminated or substantially reduced because of historic land clearing, wood gathering, erosion, and lowering of the groundwater table. The remaining modern mesquite bosque is tiny compared to pre-development bosques that extended for miles.

The Rillito River system had become extensively braided with wide channels and steep banks by 1941 (Figure 2.2). This braiding of the river was due in large part to the loss of riparian community that tended to stabilize the riverbanks during periods of high discharge. The cycles of drought and flooding stressed the riparian system and contributed to degradation and eroding of the banks. The erosion caused by denudation of the area led to movement of excessive amounts of sediment with each flood. Between 1941 and 1963, the Rillito channels narrowed and became less braided. It is possible that reduced stream flow intensity and sediment deposition in combination with some riparian recovery could have been significant factors in this trend toward channel narrowing.

The changes in more recent times are thoroughly documented. It is clear that lateral migration of the Rillito channel was a major channel morphology element. The Rillito channel has been straightened in numerous segments due to flood-induced lateral erosion (Figure 2.2 on page II-11, Figure 4.1). Straighter channels mean higher flow velocities. Higher flow velocities can result in downcutting of stream channels, which can be very serious, setting off wide-ranging cycles of erosion on tributaries and damage to infrastructure and environment, including draining

of local aquifers and destruction of ecosystems. Another cause of downcutting on the Rillito may have been sand and gravel mining downstream of the study reach.

Figure 4.1 shows lateral migration of the Rillito channel caused damage to infrastructure resulting in the need for the bank stabilization project recently completed by the Corps of Engineers on the Rillito. (Baker, V., 1998, Picture of the Rillito River near Prince Road downstream of the study area, Tucson, University of Arizona)

Figure 4.1 Lateral Migration of the Rillito Channel

The newest significant impact on channel morphology of the Rillito is soil-cement bank stabilization for flood-control purposes. As of 1984, soil-cement protection was being added to select, discontinuous locations on both banks of the Rillito. Soil cement protection is near continuous within the study area on both banks of the stream (See Figures 4.2 and 4.3). There is a gap in the soil cement on the south bank between Alamo Wash and Alvernon Wash where there was no threat to property requiring protection. That area has been incorporated into a Corps restoration study currently in progress. There are other gaps at tributary inlets that allow for some minor habitat development (Cover Photo).

Currently, the site conditions on the study area are moderately to severely degraded. There is no perennial stream flow and low quality habitat. The Rillito flows only in response to snow melt and storm flows. There is very little recharge resulting in greatly reduced groundwater levels. The depleted groundwater, soil cement banks and adjacent urbanization preclude the system from natural flow and species regeneration. The native vegetation is sparse and is being replaced by non-native species, such as tamarisk. No sensitive wildlife species are known to occur, nor is any habitat of sufficient quality present to support them. The variety of birds, reptiles, mammals, and amphibians is very low. Most of the bird species identified are those common to urban areas, and not riparian habitats. The lack of vegetation also has a negative impact on the visual aesthetics, provides no shade, and limits passive recreational opportunities along the river path.

Figure 4.2 Soil Cement was used to stabilize banks and prevent lateral migration.

Figure 4.3 Gaps in Soil Cement Banks

Soil cement has gaps to allow for inflows from tributaries. These areas are often bridged to allow for recreation along the banks.

Soils

The utility of local soils for accomplishing this study's environmental restoration goals are tied to groundwater levels and the high permeability of the uppermost soils. Two other factors impact a soil's ability to support plant growth. Both of these factors vary between soil classifications and can vary within each soil classification. The first factor is the amount of organic material in the

soil. The second factor is the presence of calcium carbonate cementation in the soil and the degree of calcium carbonate cementation that exists in the soil. Soils in which the calcium carbonate cementation is continuous do not allow for root growth and do not retain water. Cementation due to calcium carbonate deposits is known to occur in the study area in near surface deposits. However, cementation is not expected to be a problem for the concepts and locations to be evaluated within the study area.

In addition, soils with the potential to be collapsible have been identified in the study area; others, with the potential to be expansive also have been identified. The collapse phenomenon usually occurs when a soil that typically has been dry is wetted or saturated when under a load, as in the case of watering the new lawn or other plantings surrounding a new home that has been built on formerly pristine desert land. As the soil "collapses", the ground compacts and subsides. Damage, even severe damage, can occur if this is an area where weight of a building is bearing. For the study area concepts currently under consideration, the collapsible soils problem may ultimately be just a maintenance problem in areas where surface depressions may develop. It is even possible that the increased micro-topographic relief would increase the retention of water in such depressions and contributes to an increase ecosystem values.

Expansive soils demonstrate shrink and swell characteristics that can cause damage such as displaced walls. As a general example, concrete-block basement walls have been caved inward under the forces. Overall clay content and specific clay mineralogy are thought to be factors useful in identifying expansive soils characteristic. This problematic characteristic may be minimized by the in-situ gravel content of these same materials.

Nine soil series and classifications are present within the El Rio Antiguo project area. Arizo-Riverwash Complex 0-3% slopes and Glendale silt loam 0-3% slopes compose approximately 90% of the project area including nearly all of the river floodplain and adjacent upland areas. Other soil types on-site are confined to the edges of the project boundary and have already been developed. Arizo-Riverwash Complex soils are currently known to support riparian vegetation.

Surface Water

The Rillito and its tributaries are ephemeral and do not carry flow without precipitation. Stream flow in Rillito and its tributaries varies seasonally with storm type. In general, summer flows result suddenly from intense, localized thunderstorms and have high peak discharges, short duration and large suspended sediment concentrations. Winter flows have lower peak discharges and longer duration carrying smaller suspended sediment loads. Surface water sources available from Rillito (average annual volume of 10,135 acre-ft) and tributaries (average annual volume of 2,844 acre-ft) can also be used as potential water supply sources. Thus it seems that irrigation could be supplied by Rillito flows or tributary flows. However, a closer look at the variability of seasonal or monthly flows of the Rillito and tributaries indicates that, in a given month, the available flow can vary from zero (minimum) to the maximum (which is typically several times mean flow for that month). This monthly variation for the Rillito is documented in the Groundwater and Water Budget Appendix. The same variation is found on the tributaries. Availability of water from Rillito or tributaries is therefore subject to considerable uncertainty.

Design/regulatory discharges have been established and approved by various agencies including the Corps of Engineers for the Rillito. A 100-year design discharge of 32,000 cfs is currently used and approved by FEMA (Federal Emergency Management Agency), Pima County

Department of Transportation and Flood Control District (PCDTFCD), and the U.S. Army Corps of Engineers. Discharges for other frequencies are listed in the following table.

Table 4.1 Rillito N-yr Peak Discharges

Location	Drainage Area (sq. Miles)	Peak discharges in cfs			
		10-yr	50-yr	100-yr	500-yr
Above confluence with Santa Cruz	935	12,500	23,000	32,000	62,000
First Avenue	892	12,500	24,000	32,000	64,000

Substantial time has elapsed since publication of the FEMA Flood Insurance Study for the City of Tucson in dated January 6, 1988. In addition, a number of major (2nd, 4th, 8th, and 17th largest) and minor (1st and 4th smallest) annual peak flows have occurred during in the interval since publication. In order to confirm the validity of the FEMA discharge analysis a reevaluation was completed. Based upon a statistical analysis of the most recent systematic record for Rillito River near Tucson, the 100-year peak discharge (1% chance annual exceedance event) is approximately 30,000 cfs. The FIS value of 32,000 cfs is somewhat larger than the value determined from use of the full database plus a few estimated peak discharges. If the FIS peak discharge was considered as the 1% chance annual exceedance event for economic evaluation, then the without project channel has slightly more than 100-year capacity. It is unlikely that changes of this magnitude would significantly affect the analysis, but hydraulic and economic analyses will consider these variations when evaluating constructed improvements. See the Hydrology Appendix for additional detail regarding this analysis.

Several tributaries join the Rillito River reach between Craycroft Road and Campbell Avenue. Six tributaries joining the right (north) bank of the river reach are: Craycroft Wash, Flecha Caida Wash, Valley View Wash, Finger Rock Wash, Camino Real Wash and Campbell Wash. The left or south bank of the project reach receives flows from five tributaries: Alamo Wash, Bosque Creek, Hill Farm Wash, Christopher City Wash, Alvernon Wash and Christmas Wash. The drainage areas of the tributaries joining the north bank of the Rillito contain mountainous and foothill areas with steep slopes at the upper watersheds, while the lower watersheds are relatively flat with low-density mostly residential developments. In contrast, the tributaries joining the south bank of the Rillito drain highly urbanized areas within metropolitan City of Tucson, and have much flatter channel slopes. Discharges by tributary are listed in Table 4.2 below:

Of these tributaries, the washes with soil cement gaps and potential as restoration sites are Craycroft Wash, Flecha Caida Wash, Valley View Wash, Alamo Wash, Alvernon Wash Christmas Wash Camino Real and Columbus Wash. Finger Rock Wash discharges are as sheet flow on the alluvial fan at the Bend Area and then into the Rillito.

Table 4.2 Adjusted Tributary Discharges

Tributary	N-Year discharges in cfs				
	Q2	Q5	Q10	Q50	Q100
Craycroft Wash	234	600	1000	2350	3200
Flecha Caida Wash	154	380	620	1500	2100
Valley View Wash	275	680	1150	2800	3800
Finger Rock Wash	410	1260	1980	3500	4900
Camino Real Wash	176	440	740	1800	2450
Campbell Wash	210	520	850	2100	2800
Alamo Wash	985	1777	2600	5300	7000
Alvernon Wash	549	1050	1500	3000	3800
Christmas Wash	549	1050	1500	3000	3800

Hydraulic Analysis

The map in Figure 4.5 (Page IV-56) illustrates overflows for the 50, 100 and 500-year FEMA discharges. Figure 4.4 (Page IV-55) illustrates flows for the 2, 5, 10 and 25-year events. Note the similar floodplain boundaries on Figure 4.4. The channel is covered bank to bank in the entire study area in the 2-year event. The floodplain maintains the same boundaries within the channel for all events up to the 25-year event. In the 25-year event, there are some minor breakouts at tributaries and near Columbus Avenue. There are breakouts in the 50, 100 and 500-year events. In light of the recent hydrologic reevaluation, some of the overflows represent return intervals slightly different from their labeled values. For example, the 100-year overflow represents the 125-year overflow (expected probability).

Sediment Deposition

Sediment deposition over the Finger Rock Wash floodplain area during flood events was estimated at a debris yield of 84 acre-feet during a 100-year event. The average deposition depth is 0.30 feet for the 100-year event. Other flow events also have significant debris yields.

Channel bed changes for the Rillito were computed using HEC-6. Average annual bed change is between 2.08 ft and a negative 0.69 ft in the study area.

Groundwater

The alluvial units of the Tucson basin are from the Pantano Formation of Oligocene age, the Tinaja beds of Miocene and Pliocene age, the Fort Lowell Formation of Pleistocene, and the

surficial deposits of Pleistocene and Holocene age. The unconfined aquifer that underlies the Tucson basin is made up of these hydraulically interconnected sedimentary units. The Tucson aquifer is more than 2,000 feet thick and is composed mainly of loosely consolidated to moderately cemented silty sand to silty gravel.

The hydrogeologic system in the study area is characterized by periodic recharge along the ephemeral stream channel of the Rillito, groundwater flow to the south-southwest through basin-fill deposits, and discharge to municipality wells south and west of the study area (Groundwater Appendix, Figure 2). Periodic stream flow occurs in response to precipitation and snowmelt from the Santa Catalina and Rincon Mountains. Infiltration occurs through the highly permeable stream-channel deposits and flows down gradient through moderately to highly permeable basin-fill deposits.

The aquifer system consists of basin-fill deposits of alluvial sediments underlain by crystalline rocks. The main aquifer is the moderately to highly permeable Fort Lowell Formation. Highly permeable stream-channel deposits also are an important water-bearing unit where the deposits are saturated along the flood plain of the Rillito. Groundwater also flows through the upper Tinaja beds of moderate to low permeability. The lower Tinaja beds are much less permeable than the upper Tinaja beds and are an effective lower boundary of the groundwater flow system.

The Fort Lowell Formation typically consists of inter-bedded layers of clay, silt, sand, gravel and boulders. Thickness of individual beds averages 47 ft. Thickness of the unit exceeds 50 ft in places but generally is about 30 ft.

The most permeable unit is the stream-channel deposits of the young alluvium along Rillito River. The unit consists of sand, gravel, and boulders and minor amounts of silt and clay. Thickness of individual beds averages 20 ft .

Thickness of the lower Tinaja beds is poorly known because no wells are known to penetrate the unit. Lower Tinaja beds typically are comprised of mudstone and clay and contain inter-beds of sand, silt, and gravel. Upper Tinaja beds are the main water-bearing unit north of the flood plain of Rillito River and the south boundary of the area between Craycroft and Fort Lowell Roads. The unit typically consists of moderately consolidated sand, gravel, clay, and silt and typically is described as conglomerate or cemented sand and gravel.

The aquifer beneath the Rillito is characterized as high-yield, flowing to the northwest, paralleling the surface drainages in direction and slope. The aquifer in the Tucson Basin is defined as that part of the Ft. Lowell Formation that is saturated, plus the underlying, and presumably saturated upper Tinaja beds. PDTFCD staff has provided verification of this relationship between groundwater and the Ft. Lowell Formation: both the groundwater table and top of the Ft. Lowell were expected to be at about 30 ft in depth below the invert of the Rillito, at least in the central part of the study area in mid-year 2001. The overlying materials above the Ft. Lowell and groundwater table represent a vadose zone, which is important and discussed further in the Geotechnical Appendix.

Collectively, from these characteristics, we learn that both groundwater recharge and storm events can cause rapid rise in water levels, while groundwater pumping and seasonal dry periods can cause substantial decrease.

Water Budget

Area Water Sources

Area water sources include groundwater, storm runoff, and reclaimed water lines. The water budget analysis was generated based on total inflow and outflow in ac-ft/yr along the study reach of the Rillito River. Following is a short description of contributing factors in the water budget calculations.

Groundwater

For the purposes of this water budget, the most important aspects of groundwater are its depth and its interaction with the saturated zone. This zone is variable due its permeability, shallow depth to groundwater, variability during flow events, and pumping of groundwater. Essentially all recharge is through sandy channel bottom with very little recharge in overbank areas.

It is evident that groundwater pumping and seasonal dry periods can cause substantial decrease in groundwater levels in the Rillito, while both groundwater recharge and storm events can cause rapid rise in levels. Snowmelt from the Santa Catalinas also is known to cause groundwater elevations to rise to the invert in the Rillito. Determining precisely the allowable range for such fluctuation and maintaining water levels in that range will be crucial to the success of environmental restoration of plant communities along this reach of the river. Materials of the channel in the study area, as they are understood at this point in the study, appear to be less than ideal for sustaining high groundwater levels without regular recharge.

Depth to groundwater in 2001 was 16 to 45 feet in the Craycroft to Alvernon reach of the study area with potential to support established riparian vegetation. The downstream reach (Alvernon to Campbell Ave.) has depth to ground water levels of 120 to 160 feet.

Groundwater pumping is occurring for irrigation purposes. There are 24 pumping wells within the study area. All are privately owned and 13 are primarily used for irrigation purposes. Of these wells, five may have associated groundwater rights. Pump withdrawals are between 60 and 106 ac-ft per year.

Storm water Runoff

Storm water runoff from nine tributaries, the Tanque Verde and the Pantano contribute to surface flows in the Rillito. The Rillito itself flows an average of eleven times per year. A 2-year event flow entirely inundates the channel from bank to bank. There is some bank inundation occurring in the Bend Area at the 50-year event.

Figure 4.6 Storm runoff from a typical 1year probability summer storm.

Infiltration

An estimated 240 ac-ft per day was used for the El Rio Antiguo study area (approximately 5 miles) in the water budget calculations. Infiltration to the aquifer in the study area estimated at 2640 ac-ft per year. Highest infiltration rates are at Craycroft and infiltration decreases further downstream.

A major factor affecting the stream flow in Rillito River is channel infiltration losses. Previous studies have estimated that approximately half of the incoming runoff in the Rillito River and its tributaries infiltrates into the streambed. Estimates from these studies show approximately 5100 to 6800 acre-feet of annual runoff from Rillito River to the Santa Cruz River are potential sources available for recharge.

Reclaimed Water

An 8-inch lateral pipe transports reclaimed water across the river near Craycroft. Reclaimed water use is the area is primarily for turf irrigation purposes. Reclaimed water for the Rillito study area comes from Roger Road Water Reclamation Facility, located on Sweetwater Drive west of I-10, adjacent to the PCWMD Roger Road Water Pollution Control Facility. This plant treats sewage from the area of metropolitan Tucson lying generally to the southwest of Rillito River and Pantano Wash. The existing plant had a capacity of 9,000 ac-ft per year as of 1990. An expansion to 28,000 ac-ft per year was projected in the 1989-1999 Capital Improvement Plan

(CIP). Reclaimed water deliveries to the study area have been between1100 and 1400 ac-ft per year.

Evapotranspiration Losses

Based on typical evapotranspiration rate (ft/day), total loss in ac-ft/yr was used on water budget calculations. Transpiration was determined for the undisturbed and unoccupied areas acting as a protective barrier between urban areas and riparian areas. This variable (vegetation), subsequently referred to as buffer, transpires at approximately 0.005 ft/day, whereas the same types of vegetation near Riparian areas would transpire at an average rate of 0.016 ft/day. Based on the availability of water in irrigated soil and time of the year, transpiration rate for agricultural crops is 0.02 ft/day on the average. A rate of 0.02 ft/day was used to estimate evapotranspiration for agricultural crops for an average growing season of 8 months (240 days). Average evapotranspiration rate for vegetation in the Sonoran desert wash community, subsequently referred to shrub-scrub, was estimated at 0.016 ft/day in the active, or low flow channel. High evapotranspiration rates are likely at locations where depth to groundwater table is within 25 ft. A constant rate for all years was used in water budget analysis.

Table 4.3 summarizes the existing and base-year groundwater budget analysis for the Rillito River study reach. This data reflects inflow and outflows to the aquifer.

Table 4.3 Water budget for the years 1995-2001 (rates are in ac-ft/yr)

Year	**Inflow**		**Outflow**	
	Infiltration	Reclaimed water	Pumped withdrawal	Evapo-transpiration
1995	2640.00	1236.28	106.32	863.00
1996	2640.00	1352.18	60.60	863.00
1997	2640.00	1172.11	57.43	863.00
1998	2640.00	1098.39	70.57	863.00
1999	2640.00	1292.94	34.40	863.00
2000	2640.00	1433.48	61.58	863.00
2001	-	1380.68	-	-

Water Quality

Pollutants

A water quality sampling program was initiated in 1986 by the Rillito River Recharge program to document background quality for future use in evaluating pollution in the project area, because of recharge from urban runoff and river flow. Analysis revealed the existence of certain organic and inorganic constituents in some wells at concentrations potentially harmful to public health. Wells were identified within the study area of this report that contained water with

constituent concentrations of health concern such as nitrates, toluene, sulfonamides and other tentatively identified organics of public health concern. Resampling in June 1987, confirmed these findings.

USGS sampled wells to determine the variability of groundwater quality throughout the year. Water was found to have large values of pH, hardness (moderate hardness to hard), alkalinity, total dissolved solids concentration, and concentrations of calcium, sodium, and bicarbonate.

Reclaimed water used in the study area is available from the Roger Road Wastewater Treatment Plant. The water is non-potable but is available for irrigation and other commercial uses. The nitrogen and phosphorus concentrations are ideal for fertilization of plants. Reclaimed water quality information on twelve constituents for year 2000 and 2001 were obtained from Tucson Water and are available in the Groundwater Appendix.

Hazardous, Toxic, Radioactive Wastes (HTRW)

There are four areas within the Study Area with significant findings warranting further investigation (Figure 4.7, page IV-57). Significant findings indicate only the potential for the presence of HTRW. These areas include closed solid waste landfills and "wildcat dumps", properties within an area described as the Kleindale Industrial district, the University of Arizona (U of A) Campus Agricultural Center, and selected commercial and private properties located along the north bank of Rillito Creek.

Potentially hazardous materials.

Potential contaminants of concern identified included solvents, petroleum hydrocarbons, polychlorinated biphenyls (PCBs), pesticides, metals and asbestos. If parcels identified in areas of concern are included in the project area a Phase I Environmental Assessment is recommended to evaluate the potential impacts of any contamination within the project area in the absence of response actions.

Landfills

There are three known sanitary landfills near the study boundary. This boundary is established for data collection purposes only. Two of these sites are adjacent and are referred to as a single landfill (Columbus). The Columbus landfill lies adjacent to but not within the study boundary. Other sites identified as landfills or wildcat dumping areas are at the fringes of the study boundaries located at some distance from the Rillito. As previously summarized by the Corps of Engineers, these landfills have the following characteristics.

Table 4.4 General Landfill Characteristics

Name	Total Volume (yd^3)	Max. Depth	Type of Materials	Status
Columbus landfill #1 & 2	2,581,000	20 ft	"trash" (but see text below)	*abandoned; *obliterated by flood flows in 1960s but see text below); *concern is potential leachate if groundwater levels are raised
Walnut landfill	202,000	70 ft	"trash" (but see text below)	*abandoned; *concern is potential leachate if groundwater levels are raised.

To assess risk to a restoration project, site assessments including soil and groundwater sampling and some trenching into the debris in order to examine them would be in order. All have been undertaken regarding the Columbus landfill, determining that there was no groundwater contamination or strong evidence of landfill leachate. In addition, there was no evidence of methane production, TPH (total petroleum hydrocarbons) or other hazardous waste above regulatory levels, although there was evidence of asbestos containing materials in the landfill and spilled fuel on the surface. Boundaries were difficult to ascertain.

Biological Resources

Watersheds within Pima County and associated habitat have been significantly altered in the past one hundred years. Historically, many of the rivers flowed perennially and supported lush riparian vegetation and marsh habitat, including the Rillito. Prior to 1890, dense stands of cottonwood, willow, ash and walnut trees lined the Rillito. Mesquite bosques covered the floodplain terraces and beaver dams were common. It is estimated that eight-five to ninety-five percent of quality riparian habitat in Pima County has been lost over the past century. Remaining areas of riparian habitat are depicted in Figure 4.8 (Page IV-58).

Riparian systems provide important habitat for a wide variety of plants and animals. This is especially important in the Southwest where the upland habitats are typically dry and devoid of rich vegetation. Migratory birds, for instance, depend upon riparian areas for foraging and breeding areas. These strings of habitat, while encompassing less than one percent of the Southwest landscape, support a disproportionate number of wildlife species. It is estimated that seventy-five to ninety percent of all wildlife in the arid southwest is riparian dependent during some part of its life cycle. Degradation or loss of riparian habitat within Pima County has had great impacts on most resident species.

Historically, the Pantano Wash, Santa Cruz River, Cienega Creek and the Rillito River provided these islands of habitat in the Tucson Basin needed to support resident and migratory wildlife species. Human uses, such as agriculture, livestock grazing, groundwater pumping, and urbanization have depleted the groundwater in the Tucson watershed and reduced available riparian habitat.

The El Rio Antiguo study area falls within the Conservation Lands System (CLS) that is part of an updated comprehensive resource management plan for Pima County. Within the CLS, the majority of the site is identified as a Multiple Use Management Area. Multiple Use Management Areas are those areas defined by the SDCP by the occurrence of high potential habitat for three or more priority vulnerable species and special elements.

The east side of the project site, east of the midway point between Swan Road and Craycroft Road, is a designated Biological Core Management Area. Biological Core Management Areas are defined by the occurrence of high potential habitat for five or more priority vulnerable species, special elements (e.g., caves, perennial streams, cottonwood-willow forests), and other unique biological features. El Rio Antiguo is identified as potential habitat for 18 Sonoran Desert Conservation Plan Priority Vulnerable Species, including five bats, two small mammals, five birds, one amphibian, three reptiles and one plant species.

Vegetation Communities

Riparian Forests

Areas with ephemeral stream channels support xero-riparian vegetation such as mesquite and acacia. Shallow groundwater and areas of intermittent surface flow support meso-riparian vegetation such as mixed broadleaf forests of sycamore and ash. Wetlands and perennial watercourses support hydro-riparian vegetation such as cottonwood-willow forests. These riparian communities are extremely rich in species diversity, supporting several hundred species of plants and sustaining a rich food base for wildlife.

Riparian dependent plant communities are considered sensitive vegetation communities in the Southwest, particularly in Pima County. Sensitive plant species that could potentially occur on-site and are known to occur in the vicinity are listed in the Draft Environmental Impact Statement (DEIS). No federal or state listed species were observed. Four Pima County Protected Native Plant species were observed on the El Rio Antiguo project site. They are desert hackberry (*Celtis pallida*), western desert willow (*Chilopsis linearis* var. *arcuata),* Arizona fishhook barrel cactus (*Ferocactus wislizenii),* and velvet mesquite (*Prosopsis velutina).*

Riparian communities on the Rillito have been impacted by diversion of and reduction in stream flow, depletion of groundwater tables, competition by exotic plant species, the effects of grazing and fire, loss of floodplain function by undercutting caused by flood control activities, and encroaching urban and agricultural uses. The map of exotic and invasive species (Figure 4.9) within the study area shows the extensive competition that native species within the study area face.

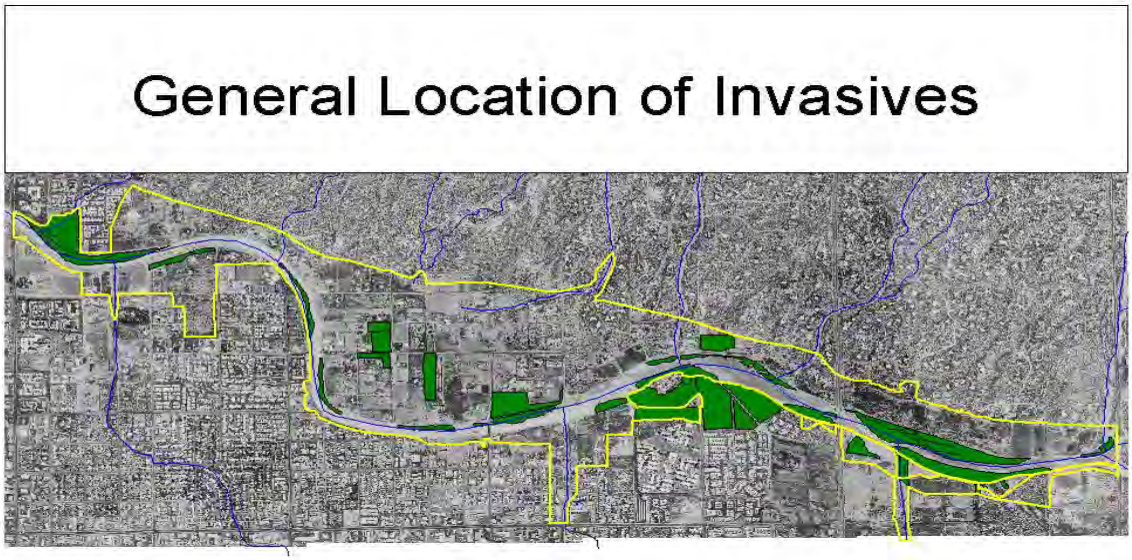


Figure 4.9 Invasive Plant Species

Invasive plants (in green) within the study reach threaten the survival of native species.

Vegetation communities present within the El Rio Antiguo study area include Sonoran desert scrub, mesquite bosque, Sonoran Deciduous swamp and riparian scrubland, and Sonoran interior strand habitat. Vegetation communities are based on the Brown, Lowe and Pase (1994) vegetation classification system. Other areas consist of developed and disturbed areas. Soil cement banks and the paved and gravel trails occur on the north and south side of the river and traverse a variety of habitat types that are primarily mapped within the Sonoran interior strand habitat. These habitat types are listed below in Table 4.5 and described in the DEIS. Cottonwood/willow habitat is found on less than 4 acres.

Table 4.5 Vegetation Communities

Vegetation Community	Acreage
Sonoran Desert Scrub, Palo verde - Cacti - Mixed Shrub Series	50
Sonoran Riparian and Oasis Forests, Mesquite Series	97
Sonoran Deciduous Swamp and Riparian Scrub, Mixed Scrub Series	20
Sonoran Interior Strand, Mixed Scrub Series	118
Current Low Flow Channel	63
Developed Urban	718
Total Acreage (includes Swan Wetlands Acreages)	1066

Wildlife

Species detected during the surveys are typical of the desert vegetation communities in the region. A complete list of the wildlife species detected on-site is provided the DEIS.

Currently, no sensitive wildlife species are known to occur in the El Rio Antiguo study area. A few historic occurrences (from 1893 to 1981) of Mexican garter snake (*Thamnophis eques megalops*), cactus ferruginous pygmy owl, western yellow-billed cuckoo, and occult little brown bat are documented within one mile of the study area; however, the majority of habitat for these species has been developed.

Historical records indicate the presence of a few sensitive species in the general vicinity of the study area. During the development of the SDCP, modeled potential habitat and priority conservation areas were designated for all priority vulnerable species within the Plan's jurisdiction. Eighteen species were identified to have potential to occur in the El Rio Antiguo study area. These include amphibians, reptiles, birds, and small mammals.

Amphibians

Most amphibians require moisture for at least a portion of their lifecycle, with many requiring a permanent water source for habitat and reproduction. Terrestrial amphibians are adapted to more arid conditions and are not completely dependent on a perennial or standing source of water. No amphibians were detected on-site. The ephemeral nature of the Rillito likely precludes amphibians from inhabiting the site.

The El Rio Antiguo study area is within an area identified by the SDCP as a critical landscape linkage for amphibians. Habitat restoration efforts within the El Rio Antiguo study area will expand the suitable habitat and create an important corridor for the lowland leopard frog.

The lowland leopard frog (*Rana yavapaiensis*) is designated as a USFWS Species of Concern, an AGFD Wildlife of Special Concern, a USFS Region 3 Forester Priority Sensitive Species, and a SDCP Priority Vulnerable Status 2 Species. Populations of this species typically occur in aquatic systems (prefers small to medium streams over ponds and other aquatic habitats) with surrounding Sonoran Desert Scrub, Semi-desert Grassland, or Medrean Evergreen Woodland upland vegetation communities.

Reptiles

The diversity and abundance of reptile species vary with habitat type. Many reptiles are restricted to certain vegetation communities and soil types, although some of these species will also forage in adjacent communities. Sensitive reptile species with potential to occur within the study area are the Mexican garter snake (*Thamnophis eques megalops*), the Tucson shovel-nosed snake (*Chionatis occipitalis klauberi*), and the giant spotted whiptail (*Cnemidophorus burti stictogrammus*).

The Mexican garter snake is designated as a USFWS Species of Concern, an AGFD Wildlife of Special Concern, a USFS Region 3 Forester Priority Sensitive Species, and a SDCP Priority Vulnerable Category 2 Species. Habitat for the Mexican garter snake includes permanent marshes, ponds, cienegas, and Sonoran riparian forests and woodlands. SDCP potential habitat modeling considers the entire El Rio Antiguo study area to be medium potential habitat for the Mexican garter snake. The study area is also a SDCP critical landscape linkage for this species. The present lack of perennial water in the Rillito means during much of the year the site does not

provide habitat for this species. Habitat restoration within the El Rio Antiguo study area could augment high potential habitat located immediately upstream and provide an important habitat linkage to the Santa Cruz River.

The Tucson shovel-nosed snake is designated as a SDCP Priority Vulnerable Status 1 Species. It was eliminated from much of this area due to habitat loss from agriculture and urban development. The species is most abundant in flat and sparsely vegetated areas with fine, wind-blown sand. Associated vegetation includes creosote, desert grasses, desert forbs, cactus, and mesquite. According to the SDCP, this species has a moderate potential to occur within the study area based on suitable habitat. The preservation and enhancement of mesquite habitat associated with Rillito River between Craycroft and Alvernon Roads will increase habitat quality for this species.

The giant spotted whiptail is designated as a USFWS Species of Concern, a USFS Region 3 Forester Priority Sensitive Species, and a SDCP Priority Vulnerable Status 2 Species. Currently in Pima County, the giant spotted whiptail has been recorded from the Santa Catalina, Santa Rita, and Baboquivari Mountains. Giant spotted whiptails are found in lower Sonoran (chiefly riparian areas) and upper Sonoran life zones, in mountain canyons, arroyos, and mesas in arid and semi-arid regions, entering lowland desert along stream courses. The species is found in dense shrubby vegetation, often among rocks near permanent and intermittent streams, and in grassy areas within riparian habitats. The El Rio Antiguo study area is within a SDCP critical habitat linkage and a potential habitat restoration area for this species. Habitat restoration associated with El Rio Antiguo will provide suitable habitat for the giant spotted whiptail.

Birds

The diversity of bird species within an area varies with respect to the character, quality, and diversity of the vegetation communities present. The low to moderate quality habitat associated with the El Rio Antiguo site presently, precludes a high diversity of species using the site. Many birds common to urban areas were observed.

Sensitive bird species with potential to occur within the El Rio Antiguo study area include Swainson's hawk (*Buteo swainsoni*), the Western yellow-billed cuckoo (*Coccyzus americanus ssp. Occidentalis),* Abert's towhee (*Pipilo aberti vorhiesi),* the Western burrowing owl (*Speotyto cunicularia hypugaea*), and the Rufous-winged sparrow (*Aimophila carpalis).*

Swainson's hawk is an Arizona species of special concern, an USFS sensitive species and is covered by the MBTA. Swainson's hawks are not known to occur in the El Rio Antiguo study area. Suitable nesting habitat is not present. SDCP potential habitat modeling identifies the majority of the study area as a medium potential habitat for Swainson's hawks to occur. Habitat restoration along the Rillito will provide roosting and foraging habitat for this species; however, nesting habitat is unlikely.

The western yellow-billed cuckoo is petitioned for listing as federally endangered, is a USFS Sensitive, is an AGFD Wildlife of Special Concern and a SDCP Priority Vulnerable species. This subspecies of the yellow-billed cuckoo is believed to have been once widespread and locally common in California and Arizona. Its present distribution in Pima County is at Cienega Creek, Arivaca Creek, San Pedro River, Tanque Verde Wash, Rincon Creek, and the Green Valley pecan orchards. The western yellow-billed cuckoo inhabits mature Sonoran riparian deciduous forest, Cottonwood-Willow Series, and Sonoran riparian scrub in well-developed

mesquite bosques. SDCP potential habitat modeling for the western yellow-billed cuckoo suggests high quality habitat is located in the river bend area of the project (between Dodge and Country Club Roads) and in upland habitat between Alvernon and Craycroft. However, the river bend area has been developed and no mature cottonwood riparian forests occur in the study area. Potential habitat remains east of the study area. Habitat restoration associated with the El Rio Antiguo project will benefit this species.

Abert's towhee is listed as a migratory bird under the Migratory Bird Treaty Act and is a Priority Vulnerable Species under the SDCP. Abert's towhee historically ranged from southern Utah, Nevada and southeastern California to southeastern Arizona. Abert's towhee prefers riparian deciduous woodland and riparian scrubland with a dense under story of shrubs. Its range has contracted due to loss of suitable riparian habitat. Rillito River is mapped as medium to high potential habitat for Abert's towhee in the SDCP. The limited riparian forest and mesquite bosque communities in the study area are degraded and generally have little to no under story or groundcover species. This offers only low potential habitat for Abert's towee. Habitat restoration in the study area will benefit this species.

The western burrowing owl is a SDCP Priority Vulnerable Species. Burrowing owls are uncommon residents of grasslands, open areas in desert scrub, pastures, and the edges of agricultural lands. The SDCP identifies two areas within the El Rio Antiguo study area that have a high potential for the western burrowing owl. Both areas have been developed. Soil cement stabilization and recreational activity mean most of the project provides low potential habitat for this species. Habitat creation and enhancement will increase foraging opportunities for this species.

The rufous-winged sparrow is a SDCP Priority Vulnerable Species and is locally uncommon species in Pima County. The SDCP identifies two areas within the El Rio Antiguo study area that have a moderate potential for rufous-winged sparrow. The western most area located in the river bend area located west of Dodge Street has been developed. Portions of the moderate potential habitat between Alvernon and Craycroft remain intact, but are substantially reduced. Urbanization along the Rillito likely precludes this species from occurring in the study area. Habitat restoration will increase habitat for this species.

Mammals

Sensitive species of mammal with potential to occur within the study area include the Western red bat (*Lasiurus blossevillii)*, the western yellow bat (*Lasiurus xanthinus=ega*), the California leaf-nosed bat (*Macrotus californicus*), the pale Townsend's big-eared bat (*Plecotus townsendii pallescens*), the Arizona shrew (Sorex arizonae) and Merriam's mouse (*Peromyscus merriami*).

The western red bat is an AGFD Wildlife Species of Special Concern, a USFS Sensitive Species and is a SDCP Priority Sensitive Species. SDCP identifies portions of the El Rio Antiguo study area as moderate potential habitat for the western red bat. There is a low potential for the western red bat to occur in the study area due to the limited availability of suitable roosting and foraging habitat in and adjacent to the Rillito. Habitat restoration and enhancement will increase foraging and roosting opportunities for this species.

The western yellow bat is an AGFD Wildlife Species of Special Concern and a SDCP Priority Vulnerable Species. The SDCP modeling identifies the upland habitat of the El Rio Antiguo study area as high potential habitat and the creek itself as medium potential habitat. There is a

low potential for this species to occur in the study area due to the limited availability of cottonwood trees, or other roosting habitat. Habitat restoration and enhancement will increase foraging and roosting opportunities for this species.

The California leaf-nosed bat is a Federal Species of Concern, a USFS Sensitive Species, an AGFD Wildlife Species of Special Concern, and a SDCP Priority Vulnerable Species. The SDCP identifies the eastern portion of the study area as moderate potential habitat and the majority of the site as low potential habitat. No roosting habitat is available on-site. There is a low potential for this species to forage on-site in the desert washes and streambed. Habitat restoration and enhancement will improve foraging opportunities for this species but would not be expected to improve roosting habitat.

The pale Townsend's big-eared bat is a Federal Species of Concern, an AGFD Wildlife of Special Concern, and SDCP Priority Vulnerable Species. According to the SDCP, low to moderate potential habitat occurs in the study area. There are limited suitable roosting sites on the El Rio Antiguo site. There is a low potential for this species to forage on-site. Habitat restoration and enhancement will improve foraging opportunities for this species but would not be expected to improve roosting habitat.

The Arizona shrew is designated as a USFWS Species of Concern, an AGFD Wildlife Species of Special Concern, a USFS Region 3 and 5 Forester Priority Sensitive Species, and a SDCP Priority Vulnerable Status 2 Species. The El Rio Antiguo study area supports low to high potential habitat for the Arizona shrew according to the SDCP. A lack of cover and woody debris means that there is a low potential for this species to forage and nest within the study area. Habitat creation and enhancement associated with the El Rio Antiguo project will improve foraging and nesting opportunities for this species.

Merriam's mouse is AGFD Wildlife of Special Concern and a SDCP Priority Vulnerable Species. The SDCP identifies small areas of moderate and high potential habitat for this species in the eastern portion of the project area just west of Craycroft Street, most of which has been developed or disturbed. Habitat creation and enhancement associated with the El Rio Antiguo project is expected to provide critical habitat for this species.

Rillito River (Swan Wetlands) 1135

The 1066 acres included in the El Rio Antiguo study area encompasses but does not include a 60.7 acre project area for the Swan Wetlands 1135 study. Any project implemented because of this study will not include habitat values for the Swan Wetlands 1135 project, but will improve its connectivity and interspersion with upstream and downstream areas. This project will implement water harvesting and irrigation to improve habitat from East of Columbus Avenue to Craycroft Road on the south bank of the Rillito in the area shown on the map below:

Figure 4.10 Swan Wetlands, Rillito 1135

Habitat Evaluation

Evaluation Methodology

Several evaluation methodologies were considered for habitat evaluation. No suitable evaluation methodology existed for Southwestern riparian systems and it was determined that one would have to be developed from existing methods. The first method considered was the Habitat Evaluation Procedure (HEP) developed in the 1970's and early 1980's by the U.S. Fish and Wildlife Service (USFWS). This procedure was developed in cooperation with other agencies as a non-monetary evaluation procedure for project planning. That process has been used and modified since then for both impact assessment and planning habitat restoration and management projects. Ecological Services Manuals describe the procedure and process in detail (USFWS 1980a-c). The Habitat Evaluation Procedure (HEP) is an objective, reliable and well-documented process used nationwide to generate environmental outputs for all levels of proposed projects and monitoring operations in the natural resources arena. When applied

correctly, HEP provided an impartial look at environmental effects and delivers measurable products to the user for comparative analysis. HEP guidebooks focus on individual species. No guidebooks exist for evaluation of species habitat within the El Rio Antiguo, Rillito River area.

To evaluate habitats for planning purposes without existing guidebooks, the District primarily evaluated wildlife benefits using a technique referred to as modified Habitat Evaluation Procedures (mHEP) (Tetra Tech, Inc. 2002). The basic premise of this modified procedure focused on a field reconnaissance approach where biologists surveyed a study site to familiarize themselves with the current conditions of the study area. The field reconnaissance resulted in a numeric index used to characterize the value of the existing habitat. The solution was often efficient; however, the results were often not repeatable and clearly subjective. In other words, a new team of experts visiting the site could derive a wholly different set of HSI values for the communities, and baseline conditions would appear much worse or much better than this initial study predicts.

This analytic approach attempted to measure the result of a restoration without directly evaluating the components producing that result. It is important to note that the basic ecological premise behind ecosystem restoration is the recovery of limiting components such as water, soils, and/or habitat structure, defined by their primary functional characteristics. The primary goal of the study is therefore focused on the restoration of such functional components within the study area while the environmental metric (mHEP) considered only the outcome. In most ecosystem restoration studies, benefits are measured using quantifiable techniques rather than qualitative assessments. It is important then, that the technique selected to quantify benefits for this study is repeatable, efficient and effective, as results could be questioned by outside interests. A functional assessment approach was chosen for habitat evaluation on the Rillito because of its broader analysis of processes and conditions necessary for support of riparian habitat as well as in recognition that hydrogeomorphic processes are primary drivers of the ecosystem. To measure the success of the ecosystem restoration proposals, this method was chosen in order to bring the best available science to bear.

The functional assessment examines habitat based on physical and biological parameters. This methodology assesses the functions associated with the range of physical and chemical attributes comprising habitat of wetland ecosystems. It also incorporates a structural index based on a set of species identified for the specific model application. Models used in a HEP methodology might be more appropriate in some riparian settings but their overall evaluation of potential changes to the ecosystem dynamic are limited when capturing wetland functionality as a whole. A functional approach has one important advantage over the HEP methodology (HSI models in particular) in that it is more inclusive of all ecosystem functions relevant to ecosystem services. Hydrology and geomorphic conditions are the primary drivers governing riverine ecosystems. Available HEP models are limited to the habitat function in support of species richness, and might overlook key hydrologic and geomorphic influences on the ecosystem. Use of a functional assessment tool includes assessment of both abiotic and biotic functions. Therefore, a functional assessment tool based on HGM methodology was developed for use in planning studies at sites in the riverine overbank systems of the Sonoran Deserts of Arizona.

Functional Assessment Modeling for Arizona Riverine Systems

The variability of wetlands makes it challenging to develop assessment methods that are both accurate (i.e., sensitive to significant changes in function) and practical (i.e., can be completed in

the relatively short time frame available for conducting assessments). Existing "generic" methods, designed to assess multiple wetland types throughout the United States, are relatively rapid, but lack the resolution necessary to detect significant changes in function, particularly in an arid climate. One way to achieve an appropriate level of resolution within the available time frame is to reduce the level of variability exhibited by the wetlands being considered.

The HydroGeoMorphic Assessment of Wetlands approach (HGM) was developed specifically to accomplish this task for regulatory purposes by the Engineering Research and Development Center of the Corps of Engineers. HGM identifies groups of wetlands that function similarly using three criteria (geomorphic setting, water source, and hydrodynamics) that fundamentally influence how wetlands function.

Regional Guidebooks include a thorough characterization of the regional wetland subclasses in terms of geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process. Classifying wetlands based on how they function narrows the focus of attention to a specific type or subclass of wetland, the functions that wetlands within the subclass are most likely to perform, and the landscape/ecosystem factors that are most likely to influence how wetlands in the subclass function. This increases the accuracy of the assessment, allows for repeatability, and reduces the time needed to conduct the assessment.

No regional guidebooks exist for Arizona Riverine riparian areas, so a functional assessment model was developed for plan formulation purposes using HGM. Since there is not a regional guidebook completed specifically for the arid riverine environment in Arizona, existing HGM models were modified to develop a functional assessment tool for planning purposes. The riverine over bank subclass for low gradient streams is the most applicable to the environment. Draft Guidebooks for the Santa Margarita Watershed and San Luis Rey Watershed were reviewed for information.

A workshop was held to bring together regional experts and seek their input on modifying the model to be applicable to Arizona Rivers. Workshop participants included the Environmental Lab (EL) of the Engineering Research and Development Center (ERDC), the Los Angeles District Corps staff, 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.

The resulting model included eleven functions that have been calibrated by data gathered in the field at five reference sites and five study sites in Riverine settings in the Arizona Sonoran Deserts. The development of this model is discussed in the Draft Environmental Impact Statement and the resulting model is summarized below.

Functional Assessment Currency

Wetland functions represent the currency or units of the wetland system for assessment purposes, but the integrity of the system is not disconnected from each function, rather it represents the collective interaction of all wetland functions. Functional capacity is simply the ability of a wetland to perform a given function compared at the level that it is performed in reference standard wetlands. It was decided to use the same type of currency or index for this functional model as is used in HGM. The HGM methodology assesses wetland function based on a series

of predictive Functional Capacity Indices (FCIs). To quantify each function an index was developed to indicate functional level as compared to a reference site representative of the best functional capacity likely to be attainable in an Arizona climate. An index of 1.0 indicates that a wetland performs a function at the highest sustainable functional capacity, the level equivalent to a wetland under reference standard conditions. An index of 0.0 indicates the wetland does not perform the function at a measurable level and will not recover the capacity to perform the function through natural processes. In summary, FCI models rate the functional capacity of a wetland on a scale of 0.0 (not functional) to 1.0 (optimum functionality). Indices for each function are included in the Habitat Analysis Appendix.

Functional Assessment combines both the wetland functionality (FCIs measured with variables) and wetland quantity to generate a measure of change referred to as Functional Capacity Units (FCUs). Subcategories of wetlands are identified to further increase the resolution of the model. Those subcategories or cover types are referred to as Partial Wetlands Assessment Areas or PWAA. The functions developed for the Arizona riverine functional assessment model are displayed in Table 4.6, below. The index associated with each of these functions is computed based the values obtained from field measurements of the variables determined to have an effect on each function. In computing the index for a function the variables included in that function are weighted to reflect their relative importance and the way the variables interact using addition, multiplication, division or exponential relationships. For example, in Function 1 (Maintenance of Characteristic Dynamics) each variable is equally weighted and additive, while in Function 2 multiplies Frequency by Flood prone Area averaged with that to the average of topography, vegetative volume and coarse woody debris and then takes that to the ½ power or square root. Each functional capacity index is first calculated for each PWAA. The resulting indices are then weighted by the relative area of each PWAA and those scores are summed to generate the site index for a function.

Once the FCI and PWAA acreages have been determined, the FCU values can be mathematically derived with the following equation: FCU = FCI x Area (measured in acres). Under the functional assessment methodology, one FCU is equivalent to one optimally functioning wetland acre. Functional assessment modeling can be used to evaluate future conditions and the long-term effects of proposed alternatives by generating FCUs for wetland functions over several Target Years, or years of interest during the project life. In such analyses, future wetland conditions are estimated for both Without Project and With Project conditions. Projected long-term effects of the project are reported in terms of Average Annual Functional Capacity Units (AAFCUs) values. Based on the AAFCU outcomes, alternative designs can be formulated, and trade-off analyses can be conducted, to promote environmental optimization.

Table 4.6 Arizona Riverine Model Functions

Functions Related to Hydrologic and Hydraulic Processes	Description	Reference Standard (1.0)
Fxn 1: Maintenance of Characteristic Dynamics (V[Q] + V[FPA] + V[SED])/3	Physical processes and structural attributes that maintain characteristic channel dynamics. These include flow characteristics, bedload, in-channel coarse woody debris, and potential coarse woody debris inputs, channel dimensions, and other physical features (e.g. bank vegetation, slope).	SED -No culturally accelerated sources of sediment, FPA - the flood prone area is unmodified, and Q -no additions, diversions, or damming of flow affecting the assessment area (e.g. water harvesting, farming practices, storm water management, etc)
Fxn 2: Dynamic Surface Water Storage and Energy Dissipation (V[FREQ]*V[FPA])+((V[TOPO]+V[TVV]+V[CWD])/3)/2) ^(1/2)	Dynamic water storage and dissipation of energy at bankfull and greater discharges. These are a function of channel width, depth, bedload, bank roughness (coarse woody debris, vegetation, etc.), presence and number of in-channel coarse woody debris jams, and connectivity to off channel pits, ponds, and secondary channels.	FPA -The flood prone area is unmodified, TOP0-there is macro and micro topographic relief, FREQ-perennial flow, TVV-Abundant vegetation of PWAA type, and CWD – 9 – 15%
Fxn 3: Long Term Surface Water Storage (((V[TOPO]*V[FREQ])^(1/2)) * (((1-V[P0RE])+V[SUBIN]/2))^(1/2)	The capability of a wetland to temporarily store (retain) surface water for long durations; associated with standing water not moving over the surface. Water sources may be overbank flow, overland flow, and/or channelized flow from uplands, or direct precipitation.	TOP0-there is macro and micro topographic relief, FREQ-perennial flow, PORE – sandy loam with restrictive layer, SUBIN – undisturbed soils and direct evidence of subsurface flow
Fxn 4: Dynamic Subsurface Water Storage V[DEPSATSED]	Availability of water storage beneath the wetland surface. Storage capacity becomes available due to periodic draw down of water table.	DEPSATSED - 1 M for CTWWFOR, 1-7 m for MESQUITE, 0 m for EMERGENTS
Functions Related to Biogeochemical Processes	**Description**	**Reference Standard (1.0)**
Fxn 5: Nutrient Cycling ((V[TVV]+(3*V[AGSA])/4)+((V[DECAY]*((V[LITTER]+V[FWD]+V[CWD])/3))^(1/2))))/2	Abiotic and biotic processes that convert elements from one form to another; primarily recycling processes.	TVV-Abundant vegetation of PWAA type, AGSA – High percentage of algae on ground surface, DECAY- 3 coarse woody debris classes present, LITTER – 28-46% litter cover, CWD – 9-15%, and FWD - 38-63 % fine wood debris

Fxn 6: Detention of Imported Elements and Dissolved Compounds (((V[FREQ] +V[SURFIN]+V[SUBIN])/30+((V[AGSA]+V[LITTER] +(1-V[PORE]))/3)+V[TVV])/3	The detention of imported nutrients, contaminants, and other elements or compounds.	FREQ-perennial flow, PORE – sandy loam with restrictive layer, SUBIN – undisturbed soils and direct evidence of subsurface flow, AGSA - High percentage of algae on ground surface, TVV-Abundant vegetation of PWAA type, LITTER – 28-46% litter cover, and SURFIN - Any of the following indicators are present and similar to the reference standard: rills on adjacent upland slopes; lateral tributaries entering floodplain and not connected to the channel.
Fxn 7: Detention of Particles ((2*V[FPA])+V[TOPO]+((V[CWD]+V[FWD] +V[SED]+V[TVV])/4))/4	Deposition and detention of inorganic and organic particulates (>0.45 um) from the water column, primarily through physical processes.	FPA -The flood prone area is unmodified, TOP0-there is macro and micro topographic relief, SED -No culturally accelerated sources of sediment, FWD - 38-63 % fine wood debris, and CWD – 9-15%
Functions Related to Habitat	**Description**	**Reference Standard (1.0)**
Fxn 8: Maintain Characteristic Plant Communities (((V[SPECRICH] +V[WIS] +V[INVASIVES])/3)*((V[CANHERB] +V[CANSHRUB]++V[CANTREE])/3))/3))^(1/2)	Species composition and physical characteristics of living plant biomass. The emphasis is on the dynamics and structure of the plant community as revealed by the species of trees, shrubs, seedlings, saplings, and herbs and by the physical characteristics of the vegetation.	INVASIVES – low % of invasives, SPECRICH – high number of species by PWAA, WIS –obligate wetland species present, CANHERB – 30 – 40% herbaceous cover, CANSHRUB – 41-68% shrub cover , and CANTREE – 53-88% tree cover
Fxn 9: Maintain Spatial Structure of Habitat (V[VEGSTRATA]+((V[CWD]+V[FWD]+V[LITTER])/3))/2	The capacity of a wetland to support animal populations and guilds by providing heterogeneous habitats.	FWD - 38-63 % fine wood debris, and CWD – 9-15% , LITTER – 28-46% litter cover, and VEGSTRATA – similar vegetative layers to reference site
Fxn 10: Maintain Interspersion and Connectivity (V[FREQ] +V[TOPO]+V[CONTIG]+V[TRIB])/4	The capacity of the wetland to permit aquatic organisms to enter and leave the wetland via permanent of ephemeral surface channels, over bank flow, or unconfined hyporheic gravel aquifers. The capacity of the wetland to permit access of terrestrial or aerial organisms to contiguous areas of food and cover.	FREQ-perennial flow, TOP0-there is macro and micro topographic relief, CONTIG – high % contiguous vegetation cover between waters/wetlands and uplands, and TRIB - All tributaries (channel and riparian corridor) are unmodified and connect to the mainstem
Fxn 11: Maintain Characteristic Buffer (V[LANDBUFF]+V[BUFFLENGTH]+V[BUFFCOV])/3	Maintain adjacent plant communities in order to provide protection from urban encroachment.	LANDBUFF - Reach has a 15 m right bank buffer & a 15 m left bank buffer or greater, BUFFLENGTH - 100% of the reach has a right & left bank buffers, and BUFFCOV – high percent cover of native vegetation vs. bare ground and/or non-native vegetation with in the quad rat

Reference Sites

Reference sites are wetland sites selected from a reference domain (a defined geographic area), selected to "represent" sites that exhibit a range of variation within a particular wetland type, including sites that have been degraded/disturbed as well as those sites with minimal disturbance. The use of reference wetlands to scale the capacity of wetlands to perform a function is one of the unique features of the functional assessment approach. The reference wetlands provide the standard for comparison in the functional assessment approach. They function as the physical representation of wetlands from the region that can be observed and measured repeatedly. Unlike other methods which rely on data from published literature or best professional judgment, the functional assessment approach requires identification of wetlands from the same regional subclass and from the same reference domain, collection of data from those wetlands, and scaling of' wetland variables to those data. If no true reference wetlands exist in a region, their probable conditions are estimated by regional experts. Reference wetlands can aid in design for wetland restoration by providing comparative standards.

Since wetlands exhibit a wide range of variability, reference wetlands should represent the range of conditions within the reference domain. A basic assumption of a functional assessment approach is that the highest, sustainable functional capacity is achieved in wetland ecosystems and landscapes that have not been subject to long-term anthropogenic disturbance. It is further assumed that under these conditions the structural components and physical, chemical, and biological processes within the wetland and surrounding landscape reach a dynamic equilibrium necessary to achieve the highest, sustainable functional capacity. Reference standards are derived from these wetlands and used to calibrate variables. It is also necessary to recognize that many wetlands occur in less than standard conditions. Therefore, data must be collected from a wide range of conditions in order to scale model variables from 0.0 to 1.0, the range used for each variable sub index.

Reference sites for model calibration included The Nature Conservancy's Hassayampa River Preserve, the Verde River at the confluence with the Salt River, Santa Cruz River at Tumacocori, the San Pedro River at the San Pedro National Riparian Conservation Area, and Tanque Verde Wash upstream of the Rillito confluence. These sites were recommended by the Model Development Workshop attendees based on the following criteria: they were reasonable sites considering current conditions, they were in a similar regional Riverine subclass to the Rillito River with similar elevation, topography, gradient, and stream order, they represented important aspects of pre-historical conditions, and they were uniform across political boundaries. Model attendees agreed that no truly ideal reference site exists and restoration to the ideal was not achievable due to inability to remove all stressors. Stressors at these reference sites include upstream dams, urbanization, groundwater pumping, diversions, and grazing. To set a more attainable goal, data from the sites would be combined and curves generated based on a reference standard developed from the sites would consider confidence intervals, standard deviations, mode, or averages, depending on the data. There was acknowledgement by all that optimal FCI scores (0.9, 1.0) were not likely to occur.

The goal in choosing these sites was that the hydrologic, biogeochemical and habitat characteristics be as undisturbed as possible in the following ways.

Hydrology has channel characteristics (channel pattern, sinuosity, and width) that are not significantly altered by human disturbances that cause changes in hydro-regime (flood

frequency, duration, or magnitude) or sediment transport. The sediment transport, channel morphology, width, and sinuosity patterns are natural. Vegetation is present to resist flow downstream, and topographic relief and subsurface water flow is available to promote surface water storage. If the river system had been altered in the past, the system has attained a stable condition for those characteristics and is no longer undergoing change. The depth of saturated sediment is near the surface.

Biogeochemical characteristic reflect natural processes. A range of vegetation types, and sediment combined with suitable topographic relief and a minimum of human structure, to support detention of particulates should be present. Sufficient water flow through the wetland (surface and subsurface) must be evident as well as a substrate with enough silt to adsorb elements and supply of organic materials. In addition, there should be evidence of decaying of woody vegetation and algal growth indicating nutrient cycling occurring within the wetland.

Habitat characteristics of the reference site should reflect historic conditions. One hundred percent of plant species must be vascular plants. Guild representatives must include a wide variety of growth forms (trees, shrubs, vines, grasses, forbs, algae, and lichens). Plant vertical configuration, foliage profile, must represent a variety of layers. All age classes of trees (seedlings, saplings, and trees) must be represented. There must be an abundance trees, shrubs, and herbaceous vegetation. Invasive plant species must be absent. Vegetation provides vertical and horizontal connectivity the length of the system. Leaf litter, fine woody debris, and coarse woody debris must be abundant. The site must have macro- and micro-topographic relief. The river channel should exhibit deposition and erosion of soils creating a wide flood plain characteristic of the area. Undisturbed subsurface flow must be evident. The flood flow should mimic the climatic/natural regime. Groundwater and the managed water supply must be appropriate to establish and maintain a diverse cover type. The flood prone area is undisturbed. Surface hydraulic connections exist between the bank full channel and the flood prone area. Surface water will pond for more than one day. All tributaries are unmodified and connected to the main stem. Land adjacent to the project is undeveloped. A wide protective buffer that extends the entire length of the site with native vegetation as the predominant plant source is evident.

Cover Types

Habitats evaluated within the study area were classified as one of four Partial Wetland Assessment Areas (PWAAs) or cover types significant for Arizona riverine systems. Cover types are primarily based on vegetation cover. These are Cottonwood/Willow, Mesquite, Scrub/Shrub (Desert Wash Community) or Riverbottom (potential emergent wetlands or cienega). These are homogenous zones of similar vegetative species, geography, and physical conditions that make the PWAA unique. In general, cover types are defined based on species recognition and dependence, soil types and topography. Other areas such as a buffer zone, urban areas, and desert areas will be tracked but not evaluated.

Cover types for this study were mapped within the study boundaries. Note that the mapping of these cover types adjacent to the channel was completed for planning purposes and in order to consider the effects of adjacent land use on the study area, not with the intent that actual project features will be planned to that extent. Figure 4.15 (Page IV-59) depicts cover types and land use found within the project area. Scattered remnants of natural vegetation remain, those cover

types include cotton-willow forest, mesquite, and scrub-shrub lands (Figure 4.15). Natural cienegas or seasonal emergent wetlands have disappeared from the study reach.

Cottonwood/Willow Forests

Cottonwood-willow forest is representative of high-quality hydro riparian habitat in Arizona. Riparian habitats are defined as habitats or ecosystems that are associated with rivers 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. These plant species are also found in habitats that are narrow, linear strands of vegetation oriented in the main direction of water flow that may occur in the riverbed and along the banks of streams. In the Sonoran Desert, riparian areas nourish cottonwood-willow forests, one of the rarest and most threatened forest types in North America. An estimated 90% of these critical wet landscapes have been lost, damaged or degraded in the last century. This loss threatens at least 80% of Arizona wildlife, which depends upon riparian habitats for survival. The growth of Tucson and surrounding areas, past land uses such as farming, grazing, gravel mining, and pumping of groundwater have altered the Rillito. Where it was once perennial and fed by springs, it is now an ephemeral stream. This has contributed to the decline of cottonwood and willow species within the study area. The Cottonwood/Willow cover type includes the individual remnants of the former cottonwood and willow communities that once existed on the Rillito and a few volunteers. The structural types of the few stands of cottonwood/willow within the study area (3.4 acres) show evidence of disturbed and early successional conditions. These conditions are consistent with past histories of water diversion, infrequent severe floods and land clearing. These trees are in areas associated with tributary mouths and storm drains. Fremont's cottonwood and Gooding's willow were dominant canopy species in the cottonwood-willow associations in the study area and remnants of both still exist.

Figure 4.11 Cottonwood/Willow Community

A Remnant community located mouth of Flecha Ciada Wash in the Rillito River (May 2002).

Mesquite Bosques

Mesquite woodlands historically occurred over large areas within the river floodplain and on higher terraces of the river and were common into the 1940s and 50s. These communities have been nearly eliminated from the river ecosystem by a combination of anthropogenic activities and altered hydrology. Currently, only one stand of mesquite woodlands remains on the Rillito River east of Swan Road outside of the soil cement banks (13.5 acres). This small bosque consists of struggling trees that have been isolated from the Rillito by soil cement banks and are threatened by urbanization. Mesquite is common throughout the region, but has been reduced to remnant patches rather than the extensive bosques once seen throughout the region.

Figure 4.12 Remnant mesquite bosque east of Swan

Note: This bosque struggles to survive urban encroachment. Shrub/scrub communities primarily composed of burro brush dominate the channel (September 2002)

Desert Wash Communities (Scrub shrub)

Scrub-shrub is the name given to the desert wash plant community in the functional assessment model. This cover is common within the active channel of the river. A healthy scrub-shrub community supports a diverse plant and wildlife community. The existing scrub-shrub community is presently dominated by burro bush (59 acres). The cover is severely lacking in diversity. Many of these areas have been highly disturbed in the past from the construction of bank protection, off road vehicle traffic, illegal dumping, and gravel mining activities and are severely lacking in diversity as well as threatened by invasive species.

Riverbottom (Cienega)

The Riverbottom includes the low flow channel, tributary channels, the gravel, and sand bars within the channel (155 acres). The Riverbottom should include emergent vegetation and the unique Southwestern cienega types of vegetation. The cienega is applied in North American areas with Hispanic history to a broad spectrum of marshy and swampy areas. In the Southwest,

and particularly in a seasonal cienega, the plant community is dominated by low sedges and grasses. This community type once common on the Rillito no longer exists.

The Rillito riverbottom has been disturbed by gravel mining operations (now prohibited on the Rillito). Low flow channels and depressions within the river bottoms of the Rillito River have been almost entirely eliminated. These features are generally unvegetated when present. Vegetation, when present, consists of scattered patches of Bermuda grass, salt heliotrope, and sedges. Due to the composition and lack of diversity within the project area river bottom, low flow channel, and emergent wetlands are all combined into this one cover type.

Figure 4.13.Rillito River Bottom

Note that the Riverbottom is largely un-vegetated and more barren that it was in the past due to past land uses in the area and in the River itself (Nov 2001).

Buffer

The buffer cover type consists of unoccupied lands that create a protective barrier between habitat areas and urban areas. It was measured for length, width and nativeness. About one third of the study area is currently classified as buffer. Over two thirds of the existing protective buffer is expected to become urban and disappear in the without project condition by 2058.

Figure 4.14 Buffer Areas

Buffer areas may be former sand and gravel sites or abandoned fields (Aug 2002)

The distribution of these Cover Types is illustrated in Figure 4.15 (Page IV-59) with acreages listed in Table 4.7 and 4.8. Total study area includes 1066 acres. This includes 230 acres of riparian vegetation and the riverbottom and 349 acres of buffer.

Table 4.7 Cover Type Acreages

COVER TYPE	ACRES
Cottonwood/Willow Forest	3.4
Mesquite Bosque	13.5
Riverbottom(includes low flow and grasses)	154.5
Scrub/Shrub (Sonoran desert wash communities)	58.6
Buffer	349.4
Total	579.4

Other land uses within the study area are tabulated in the table 4.8 below:

Table 4.8 Land Use in the Study Area

LANDUSE	ACRES
AGCROP	125.4
DITCHES	5.2
PARK	20.9
SOILCEMENT	22.4
URBAN	312.7
Total	486.6

Baseline Functional Capacity Indices (Ecosystem Quality)

As noted above, functional capacity indices are scaled from 0.0 to 1.0. An index of 1.0 indicates that a PWAA performs a function at the highest sustainable functional capacity, the level equivalent to a wetland under optimum conditions. An index of 0.0 indicates the wetland does not perform the function at a measurable level and will not recover the capacity to perform the function through natural processes. Baseline (Existing) conditions measured within the El Rio Antiguo study area are shown in Table 4.9 below and illustrated in Figures 4.11 and 4.12 (Pages IV-29 and IV-30). Definitions of each function follow Table 4.9. FCIs were applied to study area cover types, excluding buffer, to calculate FCUs for functions 1through 10 (230 acres which is the total acreage of existing Riverine wetland vegetation). Only the FCI for Function 11 was applied to the buffer acres (349 acres of existing buffer). Each of these Cover Types is in a degraded condition with severely limited acreages of riparian cover types and limited diversity. These results show that riparian and wetland habitats within the study area have low functional values and are therefore highly degraded, except in the case of Function 11 that assesses the effectiveness of the Buffer or protective zone. However, most of the buffer is expected to disappear from the study area.

Functions 1-4 are hydro-geomorphic functions. The hydrogeomorphic characteristics of a Riverine ecosystem are the primary ecosystem drivers—these include flow regime, geophysical setting, intermediate-scale geomorphic processes, and anthropogenic impacts that interact and vary in importance across spatial scales in controlling stream environments and shaping biotic communities. The FCIs for these functions are extremely low for the study area. Function 1, Maintenance of Characteristic Dynamics is 0.036 because of the effects of channelization, modification of the channel with soil cement, past farming practices and artificially accelerated input of sediment from upstream development. Function 2, Dynamic Surface Water Storage/Energy Dissipation, has a very low score as a result of modification of the flood prone area, lack of macro and micro topographic relief that was most likely caused by intense sand and gravel operations in the past on the Rillito as well as construction of soil cement, disappearance of perennial flow and lack of vegetation to slow and retain flows as well as lack of coarse, woody debris. Function 3, Long Term Surface Water Storage scored low for similar reasons as well as lack of a restrictive soil layer to slow infiltration and lack of subsurface flow. Function 4, Dynamic Subsurface Water Storage, had the lowest score possible because of the depth to ground water levels due to pumping of groundwater in the Tucson Basin.

Functions 5 to 7 reflect the biogeochemical processes or the availability of nutrients in the ecosystem. Function 5, Nutrient Cycling, was very low with the study area due because of the lack of sources of organic material. Function 6, Detention of Imported Elements and Compounds, was extremely low due to lack of perennial flow, lack of a restrictive soil layer, lack of organic sources and a disconnected floodplain due to soil cement banks. Function 7, Detention of Particles, was very low due to modification of the flood prone area throughout the study area, lack of micro and macro-topographic relief, culturally accelerated sediment sources upstream, and lack of organic input sources within the study area.

Table 4.9 Hydrogeomorphic Functional Assessment Summary

Function Name	Weighted Functional Capacity Index (FCI)	Existing Functional Capacity Units (TY0 FCUs)
Fxn 01: Maintenance of Characteristic Dynamics	0.036	8.34
Fxn 02: Dynamic Surface Water Storage/Energy Dissipation	0.178	40.91
Fxn 03: Long Term Surface Water Storage	0.137	31.56
Fxn 04: Dynamic Subsurface Water Storage	0.000	0.00
Fxn 05: Nutrient Cycling	0.136	31.38
Fxn 06: Detention of Imported Elements and Compounds	0.079	18.10
Fxn 07: Detention of Particles	0.154	35.33
Fxn 08: Maintain Characteristic Plant Communities	0.141	32.33
Fxn 09: Maintain Spatial Structure of Habitat	0.176	40.44
Fxn 10: Maintain Interspersion and Connectivity	0.324	74.61
Fxn 11: Maintain Protection Zone from Urban Encroachment	0.581	202.94

Functions 8 to 11 are related to the habitat within the ecosystem. Function 8, Maintain Characteristic Plant Communities, scored low because of the percent of invasives measured, the low number of plant species, the lack of obligate wetland species present and the low percentages of tree, shrub and herb canopy. Function 9, Maintain Spatial Structure of Habitat, scored low because of its low number of vegetation layers, and lack of organic debris and litter. Function 10, Maintain Interspersion and Connectivity also scored low due to lack of perennial flow, very little macro and micro-topographic relief, low percentages of contiguous vegetation cover between the channel and uplands, and modifications to tributary connections to the Rillito. This score was slightly higher because most tributaries are still connected to the stream, but ephemeral flows, modifications to the channel (i.e. soil cement) disconnecting it from the floodplain, and the lack of connection to Finger Rock Wash kept the scores low. Function 11, Maintain Characteristic Buffer, scored moderately high for existing conditions, but about two-thirds of the buffer is expected to be lost to urbanization over the next decade.

Figure 4.16 below illustrates the functional level of the El Rio Antiguo study area. Nearly all indices show that the site is poorly functioning. Figure 4.17 provides additional descriptive detail to explain the index values depicted in Figure 4.16. The average FCI is .177 for El Rio Antiguo and .499 for Tanque Verde Creek.

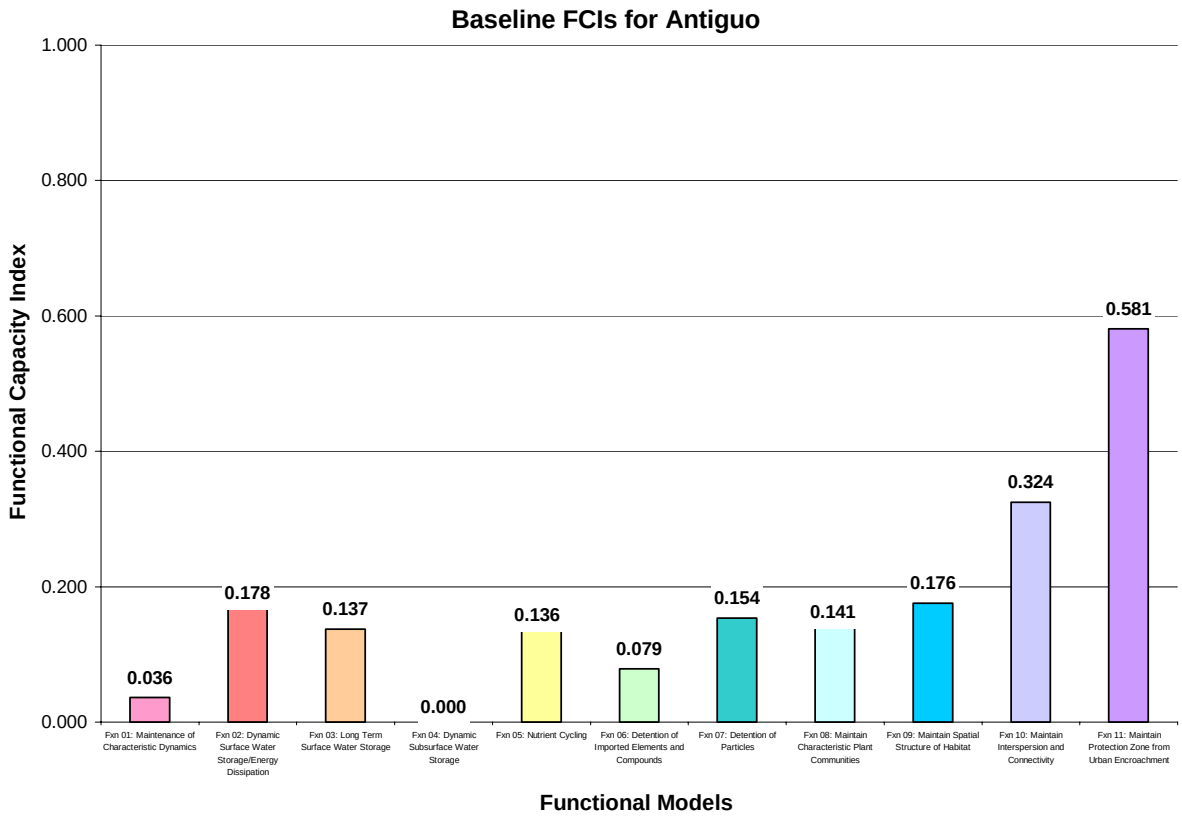


Figure 4.16 Baseline Functional Capacity Index Results

When compared to the functional capacity indices for Arizona reference sites the El Rio Antiguo study area is clearly functioning at a very low capacity. This is illustrated in Figure 4.18 and in Table 4.10 following. In a healthy ecosystem, it is assumed that there is sufficient acreage of each cover type to maintain system function. Functional Capacity Units are calculated by multiplying cover type acreage times the functional capacity index indicating the health of that acreage

To compare Functional Capacity Units between the reference site and the study site the FCI for each reference site was multiplied times the same acreage per PWAA that currently exists in the El Rio Antigo site. When the El Rio Antiguo site is compared to the Arizona reference sites, the El Rio Antiguo area has a much lower functional capacity index for desirable cover types (See Figures 4.16 and 4.18). This illustrates the inability of the habitat within this reach to sustain itself.

Function	**Fxn 1:** Channel Dynamics	**Fxn 2:** Dynamic Surface Water Storage and Energy Dissipation	**Fxn 3:** Long Term Surface Water Storage	**Fxn 4:** Dynamic Subsurface Water Storage	**Fxn 5:** Nutrient Cycling	**Fxn: 6** Detention of Imported Elements and Dissolved Compounds
Existing Conditions Score	0.036	0.178	0.137	0.00	0.136	0.079
Description – All functions are low due to limited acres and limited diversity.	Extremely low or very poorly functioning - due to the effects of channelization, past farming practices and artificially accelerated sediment inputs	Extremely low or very poorly functioning - due loss of connection to the floodplain, lack of micro or macro topographic relief most likely caused by past sand and gravel operations, disappearance of perennial flow, low vegetation volume and lack of coarse woody debris	Extremely low or very poorly functioning - for reasons similar those cited for Fxn 2 as well as for the lack of a restrictive soil layer to slow infiltration	The study area does not perform this function to a measurable level and will not recover through natural processes due to high depth to groundwater	Extremely low or very poorly functioning - due to lack of sources of organic materials	Extremely low or very poorly functioning - due to lack of a restrictive soil layer, lack of perennial flows, lack of organic sources and a loss of connection to the floodplain.

Function	**Fxn 7:** Detention of Particles	**Fxn 8:** Maintain Characteristic Plant Communities	**Fxn 9:** Maintain Spatial Structure of Habitat	**Fxn 10:** Maintain Interspersion and Connectivity	**Fxn 11:** Maintain Characteristic Buffer
Existing Conditions Score	0.154	0.141	0.176	0.324	0.581
Description –	Extremely low or very poorly functioning - due to a lack of perennial flow, the lack of restrictive soil layer, a lack of organic sources and a loss of connection to the flood plain	Extremely low or very poorly functioning – due to a high percentage of invasive plants with low diversity of plant species, a lack of obligate wetland species, and a low percentage of tree, shrub or herbaceous canopy	Extremely low or very poorly functioning - due to low number of vegetative layers and lack of organic debris or litter	Fair to moderately low functioning - despite a lack of perennial flow, a low percent of contiguous vegetation between the riverbottom and uplands, only ephemeral flows and modifications to the channel because of the maintenance of a connection to tributaries	Although the study area performs this function at a moderately high level due to continuous River Park and undeveloped lands it is expected to decrease by 2/3 to a low or poorly functioning score due to future development pressures

Figure 4.17 Existing Conditions Scores Description

Table 4.10 Functional Capacity Index Comparisons

	Baseline FCIs					
Function	**Hassayampa**	**Salt River**	**San Pedro**	**Tanque Verde**	**Tumacacori**	**Antiguo**
Fxn 01: Maintenance of Characteristic Dynamics	1.000	0.617	1.000	1.000	0.745	0.036
Fxn 02: Dynamic Surface Water Storage/ Energy Dissipation	0.604	0.856	1.000	0.763	0.745	0.178
Fxn 03: Long Term Surface Water Storage	0.619	0.499	1.000	0.433	0.527	0.137
Fxn 04: Dynamic Subsurface Water Storage	0.500	0.007	0.537	0.157	0.409	0.000
Fxn 05: Nutrient Cycling	0.524	0.416	0.466	0.317	0.560	0.136
Fxn 06: Detention of Imported Elements and Compounds	0.555	0.432	0.616	0.414	0.519	0.079
Fxn 07: Detention of Particles	0.875	0.713	0.837	0.728	0.649	0.154
Fxn 08: Maintain Characteristic Plant Communities	0.632	0.453	0.451	0.221	0.479	0.141
Fxn 09: Maintain Spatial Structure of Habitat	0.513	0.400	0.288	0.252	0.405	0.176
Fxn 10: Maintain Interspersion and Connectivity	0.752	0.431	1.000	0.539	0.745	0.324
Fxn 11: Maintain Protection Zone from Urban Encroachment	0.667	0.667	1.000	0.667	0.667	0.581
Average FCI	**0.66**	**0.50**	**0.74**	**0.50**	**0.59**	**0.18**

This table compares the difference between each of the functional capacity indices of the Arizona reference sites selected for comparison in this model and the study site. No Arizona site was fully functional. The last line in the table shows the average functional capacity for each reference site in comparison to El Rio Antiguo. The average functional capacity of the reference sites arranges from moderately healthy (.50) to good (.50 -.66) or even very good (.74) while the study site is functioning at a very poor level (.18).

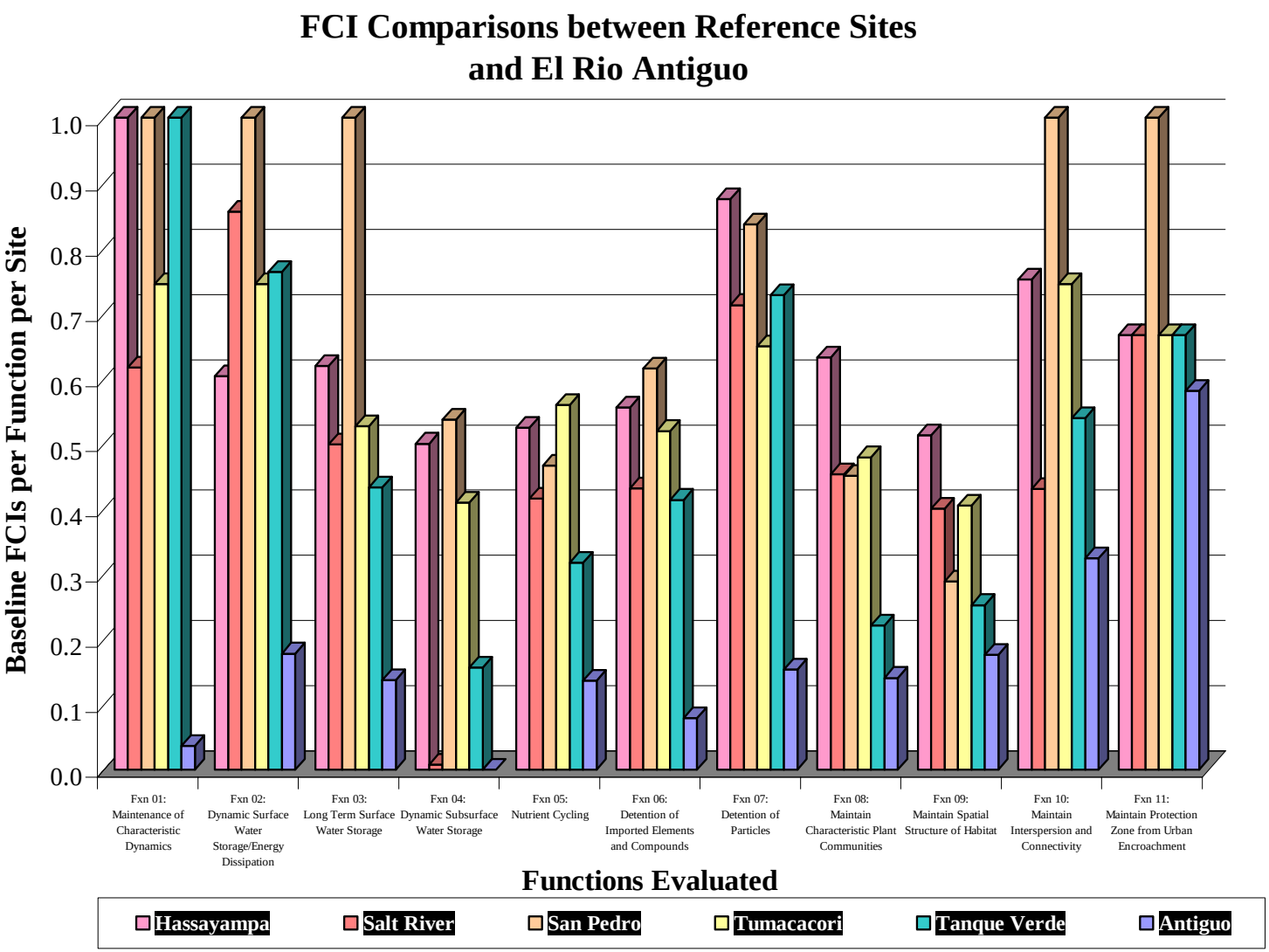


Figure 4.18 FCI Comparisons

Comparisons to Reference sites Existing Results for Functional Capacity Units

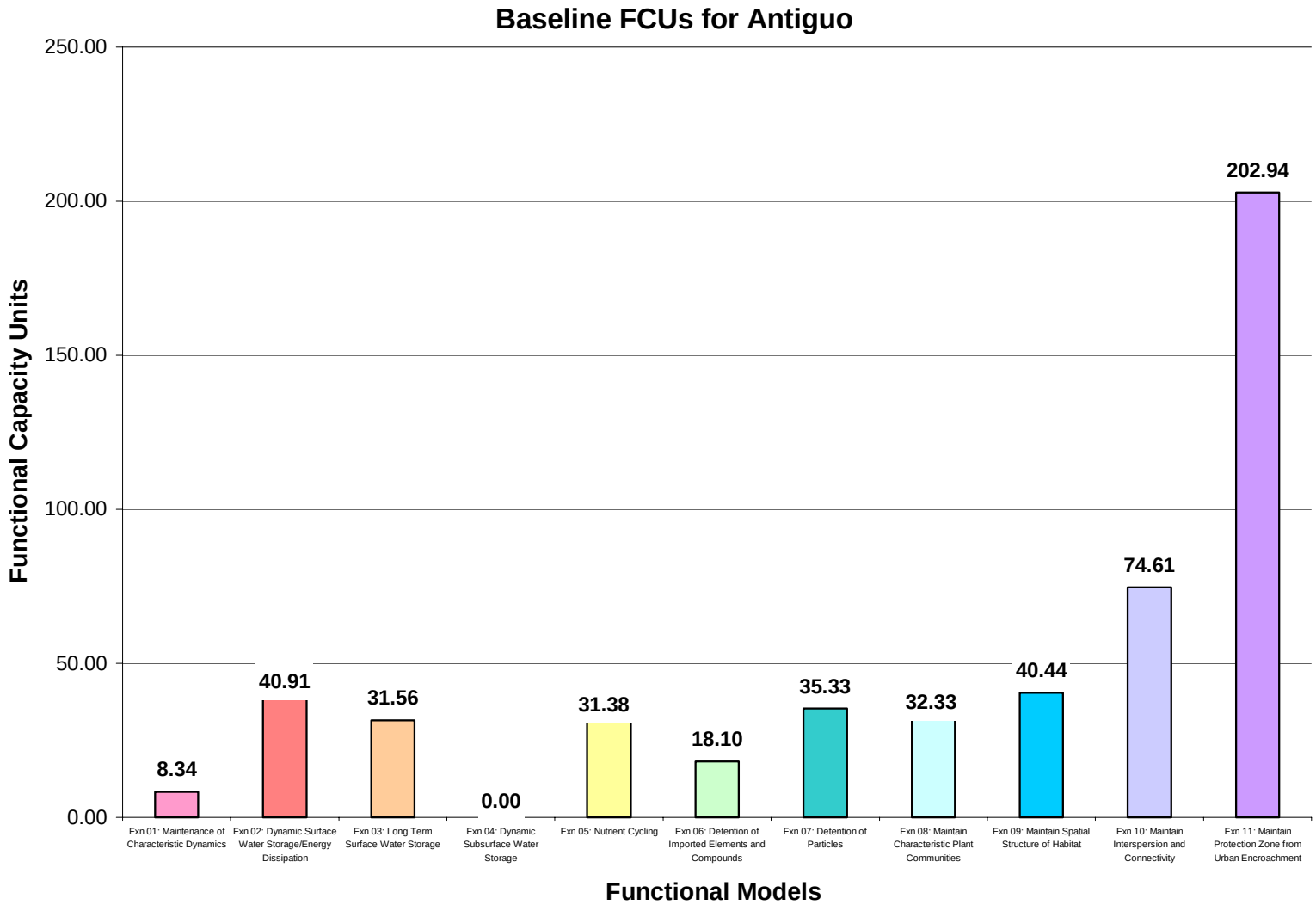


Figure 4.19 Results for Baseline Functional Capacity Units

Functional capacity at the reference sites is 2 ½ to 4 times higher than at the study site using consistent acreages.

When the El Rio Antiguo site is compared to the Arizona reference sites, the El Rio Antiguo area has a much lower acreage of desirable cover types. This illustrates the inability of the habitat within this reach to sustain itself. The average across the eleven functions for the study reach is 46.9 AAFCUs while results for the Tanque Verde reference site were 122 AAFCUs (Table 4.11). In a riverine system with perfect function, the score for the study area would have been 230 AAFCUs. Due to the impossibility of removing stressors such as urbanization and increasing depths to groundwater, it would not be possible to attain. However, a score similar to Tanque Verde and the Salt River would be possible as these sites are near urbanized areas with similar stressors.

Table 4.11 Functional Capacity Unit Comparisons

	Baseline FCUs					
Function	**Hassayampa**	**Salt River**	**San Pedro**	**Tanque Verde**	**Tumacacori**	**Antiguo**
Fxn 01: Maintenance of Characteristic Dynamics	230.00	141.83	230.00	230.00	171.40	8.34
Fxn 02: Dynamic Surface Water Storage/ Energy Dissipation	138.81	196.90	230.00	175.56	171.40	40.91
Fxn 03: Long Term Surface Water Storage	142.38	114.75	230.00	99.59	121.20	31.56
Fxn 04: Dynamic Subsurface Water Storage	115.00	1.70	123.45	36.05	94.15	0.00
Fxn 05: Nutrient Cycling	120.59	95.70	107.23	72.93	128.71	31.38
Fxn 06: Detention of Imported Elements and Compounds	127.73	99.26	141.57	95.12	119.46	18.10
Fxn 07: Detention of Particles	201.36	163.91	192.41	167.37	149.34	35.33
Fxn 08: Maintain Characteristic Plant Communities	145.42	104.20	103.66	50.74	110.18	32.33
Fxn 09: Maintain Spatial Structure of Habitat	118.00	92.05	66.32	58.05	93.21	40.44
Fxn 10: Maintain Interspersion and Connectivity	172.89	99.09	230.00	123.98	171.40	74.61
Fxn 11: Maintain Protection Zone from Urban Encroachment	232.933	232.93	349.40	232.93	232.93	202.94
Average FCU	**158.65**	**122.03**	**182.19**	**122.04**	**142.13**	**46.90**

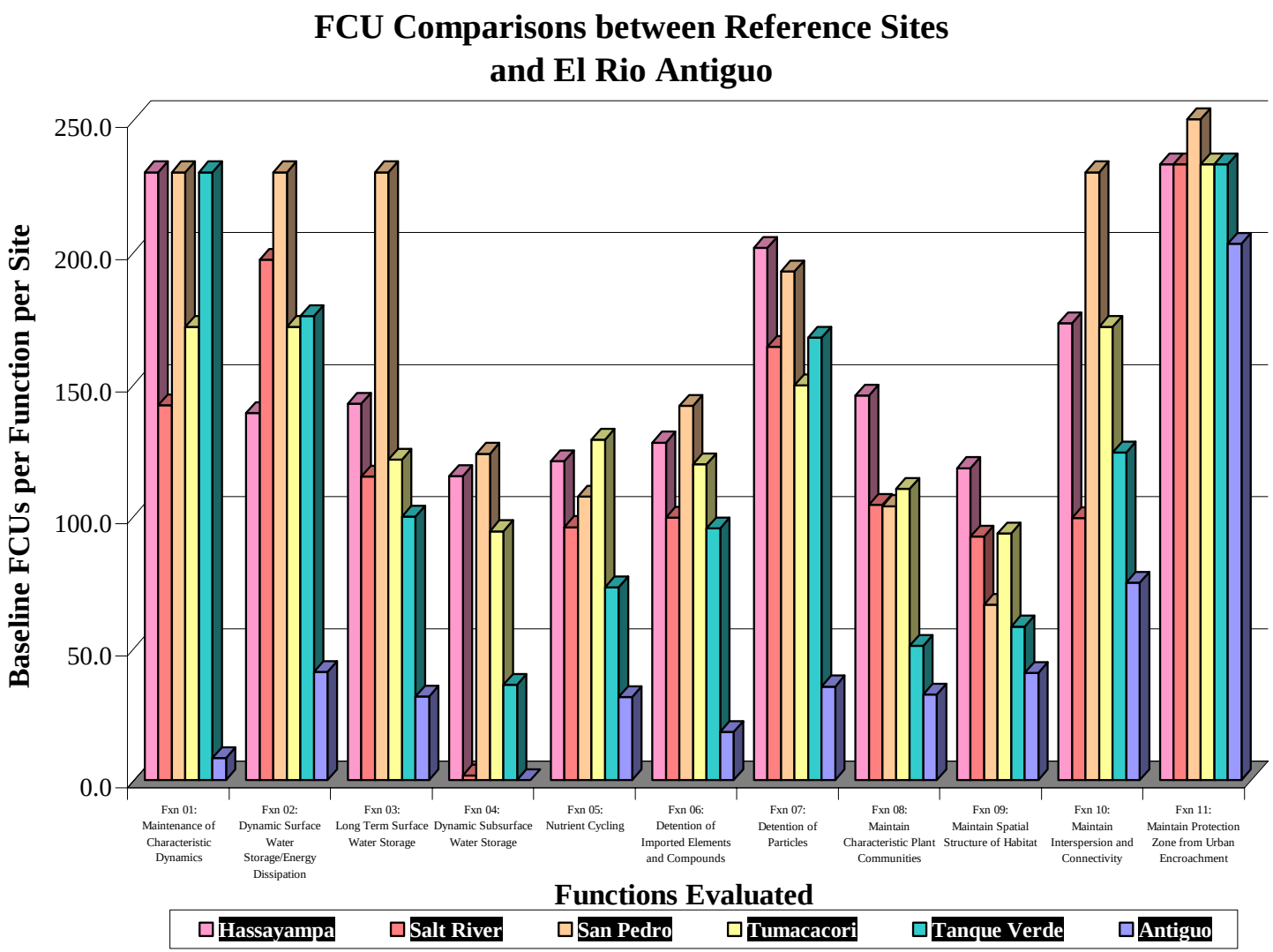


Figure 4.20 Functional Capacity Units

FCU for El Rio Antiguo are in blue and Tanque Verde units are in aqua.

Cultural

Given the sensitivity of the study area, the potential for impacts on cultural resources is high. A literature search and cultural resources overview of the proposed project area (area of potential effects [APE]) was performed. This search indicates that over 50 percent of the APE has been surveyed by archaeologists. These surveys have recorded 14 cultural sites within the APE. At least two sites are eligible for listing in the National Register of Historic Places, including AZ BB:9:18 (ASM) (prehistoric pit house) and AZ BB:9:302 (ASM) (Davidson Flume). A third site, AZ BB:9:238 (ASM) (historic Mormon settlement of Binghampton)was listed in the National Register of Historic Places on May 1, 2003. The remainders of sites have not been evaluated for eligibility to the National Register. The sites are considered potentially eligible. In consultation with Pima County and interested Native American tribes, ecosystem restoration measures will be developed in an attempt to avoid impacts to resources eligible for listing in the National Register. If there are any unavoidable impacts, and a cultural resource is determined eligible for the National Register, mitigation will be implemented prior to construction. Mitigation measures will be codified in a memorandum of agreement negotiated with Pima County and interested Native American nations.

Real Estate

The surrounding land to the north is hilly and frequently cut by desert washes. Land use is primarily residential ranging from large residential acreage to apartments and condominiums. There are some agricultural uses and vacant land. To the south, the land is flat and general land uses in the study area consist of residential uses, agricultural and agribusiness uses, light industry, business use including semi-public areas and public areas.

Flood Damage

Flooding in the El Rio Antiguo study area is primarily contained within the channel for the 100 yr event. Flood damage reduction studies and construction projects have recently been completed by the Corps of Engineers on the Rillito to the extent that was economically justified Residual Rillito flooding occurs along the south bank near County Club Road and on the south bank near Dodge Boulevard (Figures 4.4 and 4.5 on pages IV-55 and IV-56). Due to the proposed restoration of the El Rio Antiguo, incidental flood benefits might be expected at an area called the Finger Rock Wash area; therefore, a limited flood damage assessment has been conducted for this specific area. It is located on the north side of the Rillito River between Valley View Wash to the east and Country Club Road to the west. This area floods from both the Rillito River and Finger Rock Wash. Rillito flooding in the Finger Rock Wash area is expected to remain approximately the same but if there are any increases in flood depths due to restoration in the area, a mitigation plan will be devised. Finger Rock Wash, on the other hand, may have some notable incidental flood reduction benefits due to possible restoration in the area.

Figure 4.21 Finger Rock Wash flows

Figure 4.22 Frequent flows cause obstruction to traffic and home access.

Inventory of Floodplain Structures

Table 4.12 presents the number of structures by category within the 500-year FEMA floodplain in and adjacent to the Finger Rock Wash aka Bend Area. The principle flood problem in this area is the result of the lack of a channel(s) capable of conveying flows from Finger Rock Wash to the Rillito. Structures were counted in the field then verified through aerial maps to account for structures by parcel. The 100-year floodplain in this area is depicted in Figure 4.23.

Table 4.12 Number of Structures in the Finger Rock Wash Area

Category	Number of Parcels
SFR	78
MH	1
MFR	
Mixed	8
Commercial	
Nursery	12
Public	
Government	9
Religious	5
Total	107

The estimated depreciated value of structures in this area is $8,556,747. Content values were estimated using content ratios were then derived as a percentage of corresponding replacement values of structures. Total Finger Rock Wash area content value is $4,381,083.

Structure and Content Damage Evaluation

These stage damage functions are the results of analysis of inundation depths for each structure as determined by subtracting the first floor elevation from the appropriate average flood depth. These flood depths were assigned to their representative cross-section. Structure and content damages were estimated as a percentage of total structure and content values.

The resulting estimate of without-project expected annual damage is shown in Table 4.13.

Table 4.13 Total Estimated Damages by Event Finger Rock Wash

	Finger Rock Wash
Structure	
5 Yr	$185,722
10 Yr	$660,928
50 Yr	$1,050,584
100 Yr	$1,330,506
500 Yr	$1,727,168
EAD	$150,124
Content	
5 Yr	$102,821
10 Yr	$383,962
50 Yr	$579,042
100 Yr	$723,172
500 Yr	$915,203
EAD	$84,336
Total EAD	$234,459

Emergency Clean-Up Costs

Emergency clean-up costs in the study area were based on an estimate derived in the January 1993 Flood Damage Summary Report by Pima County Department of Transportation and Flood Control District due to a limited amount of information available concerning emergency response along the Rillito. The equivalent annual damages to residents due to flooding in the Finger Rock Wash areas were $30,631.

Traffic Damages Due to Floods

According to this analysis, the flooded areas could cause temporary closures of River Road between Country Club Road and Valley View Wash. River Road carries 20,200 vehicles per day near Dodge Boulevard. Detour miles approximate 1.5 miles. Potential damage resulting from delays is $10,695 per year. In addition, vehicle operation cost can be derived from total detour miles. At an operation cost of 0.32 cents per mile, the potential annual damage is $9,696. Annual traffic delay cost and vehicle operation cost equals $5,314 at an interest rate of 5.875 % and with a non-damaging event of approximately a 2-year.

Total Damages

Average annual flood damages from all categories total $270,494. Prevention of all of these damages would provide economic justification for a flood control project with an implementation cost slightly greater than $4,000,000. The implementation cost that could be supported would be reduced by the annual costs to operate and maintain the project.

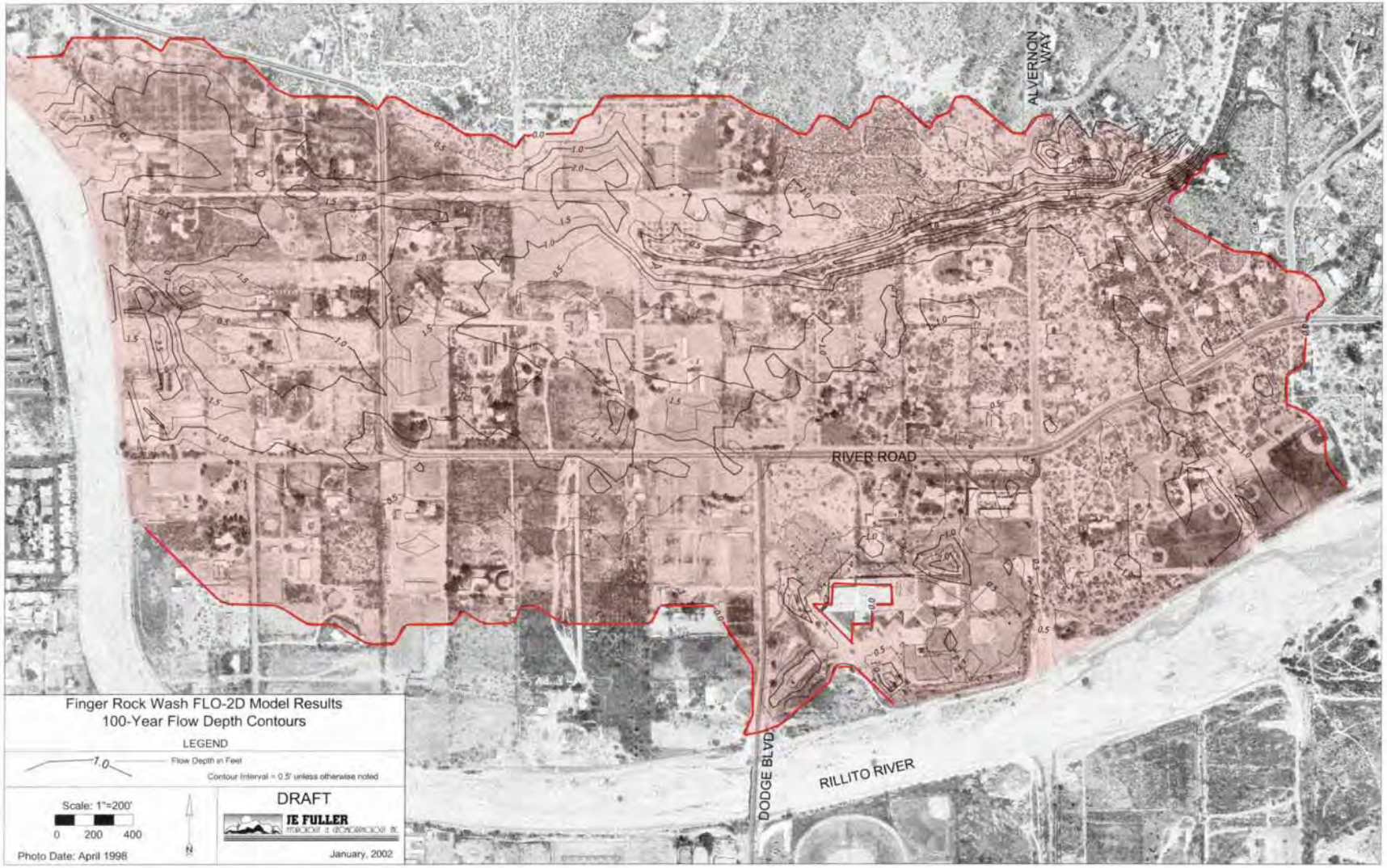


Figure 4.23 100 year Floodplain in the Bend Area

Recreation

Currently, several recreational opportunities exist in Pima County and near the El Rio Antiguo study area. Within Pima County, several areas are considered dedicated open space, which have unique environmental and physical qualities. These include:

- mountains and foothills,
- rivers and washes,
- canals,
- significant desert vegetation,
- wildlife habitat, and
- cultural resources.

The topography and river basins contribute to the natural attributes of the region, and the dedication of the riverbed and banks along the Rillito River to the bank stabilization project contributed to guaranteeing future public access to nature preserves, trails, scenic areas, picnicking spots, and recreational venues. Much of this dedicated open space exists in the form of regional parks and passive open areas.

There are several parks in the area (Figure 4.24, page IV-60). They are Fort Lowell Park, La Madera Park, McCormick Park, North Central Park, Murphey Multi-Use Field, George Mehl Foothills District Park and the Rillito River Park. Each of these parks serves the community in different ways. Fort Lowell Park is located at 2900 N. Craycroft Road and is a metro park. The area of the park is 58.94 acres. La Madera Park is classified as a neighborhood park with an area of 5.19 acres. McCormick Park is located at 2950 N Columbus Boulevard and is a community park. This community park is about 17.97 acres in area. North Central Park, a community park, is located at 3861 N Cactus Boulevard. The park is 38.65 acres. Murphey Multi-Use Field is located at 4550 N Camino Escuela. The park offers baseball, softball, and soccer fields. George Mehl Foothills District Park is located at 4001 E River Road. This park offers baseball and soccer fields, restrooms, a playground, and ramadas.

The Rillito River Park in particular serves the entire El Rio Antiguo area. The overall goal of the park is to establish a continuous river trail that will link up to a system of trails (some not yet developed) along the Santa Cruz River, Rillito River, Tanque Verde Creek, Pantano Wash, and Canada del Oro Wash.

The potential benefits of this river park include:

1. the development of a continuous interconnected corridor networking the metropolitan area
2. the creation of a portion of a region-wide trail system that will integrate with other established and integrated trails
3. the opportunity to maintain and enhance wildlife corridors
4. the implementation of multi-objective management of the riverbed and banks for visual, recreational, natural, and cultural resources
5. the establishment of a cohesive sense of regional distinction
6. the creation of educational and interpretive opportunities
7. the enhancement of property values, economic development, and tourism
8. the encouragement of alternative modes of transportation that can reduce vehicular use

and air pollution in the community.

The data shows attendance figures increased for the Rillito River Park from 1999 to 2000 (Table 4.14). One possible explanation for the increase in attendance for Rillito River Park might be due to the recent enhancement of the Rillito River Park. Possibly, individuals have chosen to recreate along the larger improved park.

Table 4.14 Attendance Figures for Rillito River Parks

Month	***Rillito Park Campbell Avenue***			***Rillito Park Children's Memorial Park***			***Rillito Park 1st Avenue***		
	1999	2000	2001	1999	2000	2001	1999	2000	2001
January	2,478	5,173	5,730	20,332	12,473	10,467	9,936	8,790	8,468
February	1,598	5,470	6,018	14,957	15,359	13,388	10,748	11,961	9,473
March	1,014	7,789	7,749	14,394	17,857	16,546	7,729	10,236	13,274
April	7,243	3,208	5,303	24,057	Broken	7,465	1,613	12,699	9,891
May	1,562	6,704	5,962	11,718	6,889	Broken	4,309	4,341	6,000
June	7,979	6,486	5,473	2,694	5,754	12,745	2,193	4,696	5,705
July	2,041	2,991	1,021	8,266	2,268	10,165	2,701	3,464	5,575
August	2,873	4,204	3,581	8,209	4,240	10,195	4,086	3,236	7,467
September	111	4,847	4,695	7,361	7,771	4,153	5,708	5,511	11,170
October	1,626	6,327	3,096	11,838	Broken	Broken	Broken	6,327	5,166
November	542	2,798	3,370	7,683	4,391	Broken	1,098	5,790	Broken
December	8,331	9,030	6,573	13,623	19,621	Broken	10,284	7,331	18,764
Totals	37,398	65,027	58,571	145,132	96,623	85,124	60,405	84,382	100,953

C. Base Year Conditions

Base Year conditions are defined as those conditions that are expected to exist with the study area in the earliest year that a project could begin to produce NER/NED benefits. The Base year for this study is 2008. A thorough assessment and evaluation was conducted for current conditions for this study. Base year conditions are expected to be essentially the same as existing conditions except for expected changes due to River Road realignment. A complete discussion of those conditions is referenced in the associated appendices to this report.

D. Expected Future Without-Project Conditions

The future without-project condition is a projection of how the base-year without-project conditions are expected to change over the 50year period of analysis to provide the basis against which alternatives could be developed, compared and evaluated. The future without-project conditions were identified in order to define and describe the most likely future conditions that are expected without a Federal project. The without-project condition was developed through meetings, discussions, and workshops with representatives from public agencies, water districts, resource experts, private citizens, and other interested stakeholders.

Basic Assumptions

It is assumed that the ecosystem restoration project between Craycroft and Swan Road, developed in the Rillito River Riparian Study (locally called Swan Wetlands) will be in place prior to construction of this project. 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. The earliest projected year that a Corps of Engineers project could begin to be operational is 2008. This is the first year (base year) that benefits could begin to accrue.

Population/Land Use

Regional population is expected to increase in the future. The Pima County Association of Governments (PAG) projects that:

- the county's population will grow to over 1million people by the year 2010, and
- by 2050 the county is expected to have a population of approximately 1.6 million people

The forecast increase in population will exert associated land use and development pressure upon the study area. It is expected that more urban development will replace the existing farmland and open areas. Because of development pressures and the availability of vacant land, zoned commercial and residential, population will continue to increase along this reach of the Rillito River, regardless of project status.

Currently, only 20 of the more than 300 vacant acres in the study area are identified as Dedicated Open Space. Much of the vacant land is already zoned residential or commercial and can be expected to develop in the near future. Given this location and the history of past development in the metropolitan area, the future without-project conditions suggest that as privately held land develops for commercial and residential uses (highest and best use based on market demand), adjacent publicly owned areas, currently available for restoration and associated recreational amenities, will come under increased development pressure.

The likely development condition described above is reflected in the projections for future cover types by acres presented below in Table 4-15. This development would greatly reduce, if not preclude, the opportunity for ecological restoration that currently exists. It would also lead to a decrease in both the quantity and quality of existing riparian habitat.

Water Quality/Supply

The quantity and quality of water available for riparian areas is expected to continue to decline as water is allocated to other uses within the study area. As a result, surface runoff will become an increasingly important source of water to support riparian habitat. Because of the extreme variability in the availability of surface runoff, the impact of declining water supply on habitat will be more pronounced.

Hydraulic and Sedimentation Analysis

Average annual bed changes due to sedimentation are between 2.08 and negative .69 ft in the Rillito (See Table 12 in the Hydraulics Appendix). Banks have been stabilized with soil cement and are not expected to change over the project life. However, the Finger Rock Wash has a high debris yield for all events. Therefore, the Bend Area is expected to continue to aggrade. This will result in continuing associated clean-up costs to the area

Functional Assessment of Future Without Project Conditions

In order to assess the future without project condition for the 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 be present under 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, this development is expected to reduce existing buffer zones. Although the acreage of scrub-shrub communities is forecast to remain in place, the quality of that habitat will further degrade. All other riparian plant communities will be eliminated during the period of analysis.

Table 4.15

Future Without Project PWAAs in the El Rio Antiguo Study Area

Code	Baseline Acres	Year 1 Acres	Year 6 Acres	Year 26 Acres	Year 51 Acres
AGRICULTURE/CROP LAND	126	126	0	0	0
BUFFER	349	349	276	117	117
COTTONWOOD/WILLOW FOREST	3	3	1	0	0
DITCHES	5	5	3	3	3
MESQUITE	14	14	7	0	0
NEW BUFFER	0	0	0	0	0
NEW COTTONWOOD/WILLOW FOREST	0	0	0	0	0
NEW RIVER BOTTOM	0	0	2	3	3
NEW SCRUB SHRUB	0	0	0	0	0
PARKS	21	21	55	55	55
RIVERBOTTOM	154	154	154	154	154
SCRUB SHRUB	59	59	59	59	59
SOIL CEMENT	22	22	22	22	22
URBAN	313	313	487	653	653

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 lost acreages of riparian and mesquite habitat result in the complete loss of the functions those habitats perform as part of the riparian corridor. In general, the FCI for each of the functions analyzed remained the same or declined slightly. The decline in average FCI applied to the reduced acres of riparian habitat resulted in a reduction from the current 47 FCUs to 34 FCUs at the end of the period of analysis. This can be compared to FCUs of 230 for the existing riparian acreages and 349 for Buffer acreages based on the assumption that the current habitat area were fully returned to pre-settlement conditions with an FCI of 1.0 for all functions.

Wildlife Habitat

If the No Project Alternative is chosen site conditions will continue to degrade. Tamarisk infestation is likely and, coupled with continued adjacent land use, could result in an even greater decline in groundwater levels and reduce the water available to native vegetation. Storm water and snowmelt would not be allowed to recharge groundwater, as it would be quickly utilized by the tamarisk. The resulting monotypic stands of vegetation, will further limit wildlife diversity. Another consequence of Tamarisk infestation is the creation of saline soils beneath its canopy, further reducing the likelihood of native plant establishment. Infestation by arrundo is also a potential problem.

If invasives are not controlled, the without project condition will include a reduction in groundwater recharge. Both the quantity and quality of existing native trees and shrubs would be reduced and reestablishment would be unlikely. Vegetation would appear similar to the most degraded areas in the existing condition. No sensitive species habitat would develop and no sensitive species would be likely to establish. In fact, the variety of birds, reptiles, mammals, and amphibians would most likely decrease. Remaining bird species identified would be those common to urban areas, and not riparian habitats. The lack of vegetation would continue to have a negative impact on the visual aesthetics, provide no shade, and limit passive recreational opportunities along the river path.

Flood Control

Total Earned Annual Damages (EAD) for structure loss in the study area are estimated at $234,549. The EAD for emergency response to residents due to flooding along Finger Wash are $30,631. Annual traffic delay costs and vehicle operation costs equal $5,314. The total EAD, or average annual damages, expected to occur in the future without project are $270,494. All are expected increase at an interest rate of 5.875%.

Recreation

Future river parks are planned for Tanque Verde Creek and Pantano Wash. Design work has been completed for sections of River Park along Canada del Oro from Thornydale Rd. to Magee Rd., along Tanque Verde Creek from Sabino Canyon to Tanque Verde Rd. and along Pantano Wash from Tanque Verde Rd to Golf Links Rd. Together the Santa Cruz, Rillito, Tanque Verde Creek, and Pantano Wash river parks will function as one large unified trail system. In addition, The City of Tucson has planned for the development of four parks along or near the El Rio Antiguo segment of the Rillito River. Most will be linked to the main Rillito River Park and will create a network of recreational experience areas.

Despite these plans, the current and projected ratio of park acres per 1,000 of population in the area is lower in most cases than the National and City Guidelines. A lack of sufficient recreation resources exists for all the types of parks except for metro and regional parks. Currently, existing metro parks have met population needs in the core/mid-city area but not the edge/future city region. Regional parks have also met demand for the core/mid city area but not the edge/future city. Unless a significant number of recreation facilities are built, the projected population growth for as early as 2010 will make the existing deficit and surplus of parks depending on facility types become lower (Table 4.16).

Table 4.16: Additional Park Facilities Needed to Achieve Guidelines

Facility Type	COT Core/Mid-City 2010	COT Edge/Future City 2010	Total 2010	Existing 2001	Needed to Fill Demand 2010
Mini Park	N/A	N/A	N/A	5 acres	N/A
Neighborhood Park	1,041 acres	366 acres	1,408 acres	515 acres	893 acres
Community Park	1,250 acres	439 acres	1,689 acres	504 acres	1,185 acres
Metro Park	1,250 acres	513 acres	1,762 acres	1,450 acres	312 acres
Regional Park	417 acres	293 acres	709 acres	619 acres	90 acres
Total	3,957 acres	1,611 acres	5,568 acres	3,093 acres	2,480 acres
Multi-Use Path	27.77 miles	9.76 miles	37.53 miles	10.00 miles	27.53 miles

The Rillito River area has become a popular recreation area. Pima County Parks and Recreation and The City of Tucson have tentative plans for park facilities within the Rillito River Riparian (Swan Wetlands 1135) study area and the El Rio Antiguo study area. Figure 4.25 (Page IV-61) illustrates those tentative plans.

E. Specific Problems and Opportunities

Table 4.17 presents a summary of the problems and opportunities in the study area. These issues are discussed in detail below.

Table 4.17 Problems and Opportunities

Problem	Associated Opportunity
Regional and local ecosystem degradation	Ecosystem restoration - natural riparian habitat
Flooding problems, including the need to provide protection to private and public property	Incidental reduction in flood damages associated with ecosystem restoration measures
Water quality problems, from point and non-point sources	Improve water quality through filtering effect of restored riparian areas
Water quantity problems, such as low groundwater levels, and limited water supplies	Increase water quantity as improved ecosystems are known to decrease depth to groundwater through increased water recharge
Limited local recreation	Increase passive recreation opportunities

As discussed in Sections II.E and III.D, Pima County has instituted a number of measures governing land use that would either directly or indirectly assist restoration efforts in the study

area. These measures, while not mandating restoration, enhance opportunities for both the implementation and maintenance of such projects.

Degradation of Riparian Habitat

The natural riparian ecosystem has been degraded within the study area for the following reasons:

- Degradation of the river, washes, and adjacent over bank areas, due to development, and modified stream morphology, has significantly reduced native riparian plant species and wildlife habitat.
- Perennial base flow conditions, critical to the needs of native plants, no longer exist in the river/wash corridors through the study area.
- Natural flood events characterized by broad shallow overflows and periodic channel migration have been replaced by managed flows through narrow entrenched floodways less that are not conducive to establishment of riparian ecosystems,
- Population encroachment and associated appropriation of natural resources, including groundwater, has increased stresses to the system,
- Exotic species and invasives such as salt cedar, desert broom, various species of aster, and arrundo are becoming a threatening presence in the channel.

Urbanization has changed the river's hydrology, greatly favoring the presence of invasive plant species that are tolerant of extremes such as low soil moisture and higher soil salinity. Native riparian species such as cottonwood and willow are unable to tolerate the high salinity levels in the surrounding soils. Moreover, due to salt cedar's broad seed dispersal window, prolific seed production, effective seed dissemination, rapid growth, and early maturation, it has an advantage over native vegetation, often disrupting reproduction of the desirable native flora. These exotics compared posses little value as habitat for native wildlife. Another danger posed by exotics is that, as they increase in density their presence increases the probability and intensity of catastrophic wildfires. The resulting catastrophic wildfires result in high mortality rates of native vegetation and ultimately stimulate successional growth towards monotypic stands of invasive vegetation. In a worst case scenario the functional capacity of the resulting riparian habitat would approach zero.

The opportunity exists to restore a more natural riparian ecosystem through river management and the establishment of more native riparian species. Opportunities exist for selective removal of invasives to encourage a more diverse native habitat. These opportunities will not exist indefinitely. In fact, as noted in discussing the future without project condition, increased development in the next few decades will eliminate much of the land available for restoration while increasing the demand for water needed to sustain it.

Area Flooding Problems

Minor flooding occurs in the study area. Flooding from Finger Rock Wash occurs as sheet flow across the Bend Area. While the 1% Rillito River flood event is primarily contained within the channel, there is damage to habitat. Potential damages are as follows:

- flood flows cause damage to cultural resources and residential areas in and around the Finger Rock Wash portion of the study area

- flood flows can destroy valuable habitat through inundation and scouring effects

The opportunity exists to design restoration areas that would concentrate Finger Rock Wash flows to sustain and protect the restored habitat communities.

Plans for realignment of River Road in the Bend Area and a new bridge across Alvernon have prompted purchase of properties that will be impacted. This is site of the former town of Binghamton. Current plans include preservation of the farming character of the site, refurbishing of historic buildings and removal of some residences in the area with the creation of a park emphasizing horse facilities. There is an opportunity to use flood flows to irrigate the park and support native riparian habitats in this area.

Water Quality

Different stressors on the area water quality have also been identified. Stressors are sources of water that could affect the quality of the surface water and groundwater in the El Rio Antiguo study area. These stressors include:

- flood flows,
- storm water runoff , and
- groundwater outflow

The opportunity exists to improve water quality from many of the stressors listed above through natural filtration in constructed cienegas as components of an overall restoration project.

Water Quantity

A variety of water quantity issues exist in and around the El Rio Antiguo study area, as follows:

- There is no longer sufficient flow in the Rillito River to support riparian habitat to the extent that it once existed in this area because upstream urbanization, channelization and historical agricultural stressors have eliminated the perennial flow that existed historically.
- Soil Cement Banks prevent access to overbank flows by riparian vegetation communities now stranded on the banks.

The opportunity exists to provide water to restore riparian habitat through storm water harvesting, irrigation until plants are established, irrigation for maintenance during drought years, and potential structural improvements in the El Rio Antiguo area. The extent to which restoration in the study area is possible largely depends on the amount of water that is or becomes available following consideration of existing water demands. The plan formulation process takes advantage of information developed during documentation of the without-project condition to site cienega areas in locations where channel excavation can harvest storm water flows and groundwater is within reach of a mature riparian community.

Recreation

As the population of the Tucson metropolitan area grows, the demand for recreation will increase as well. The Tucson area lacks sufficient recreation resources. Unless a significant number of recreation facilities are built, the projected population growth will make the existing deficit become worse. The opportunity exists to provide high quality recreation in the form of environmental education, hiking, biking, picnicking, bird watching, and horseback riding.

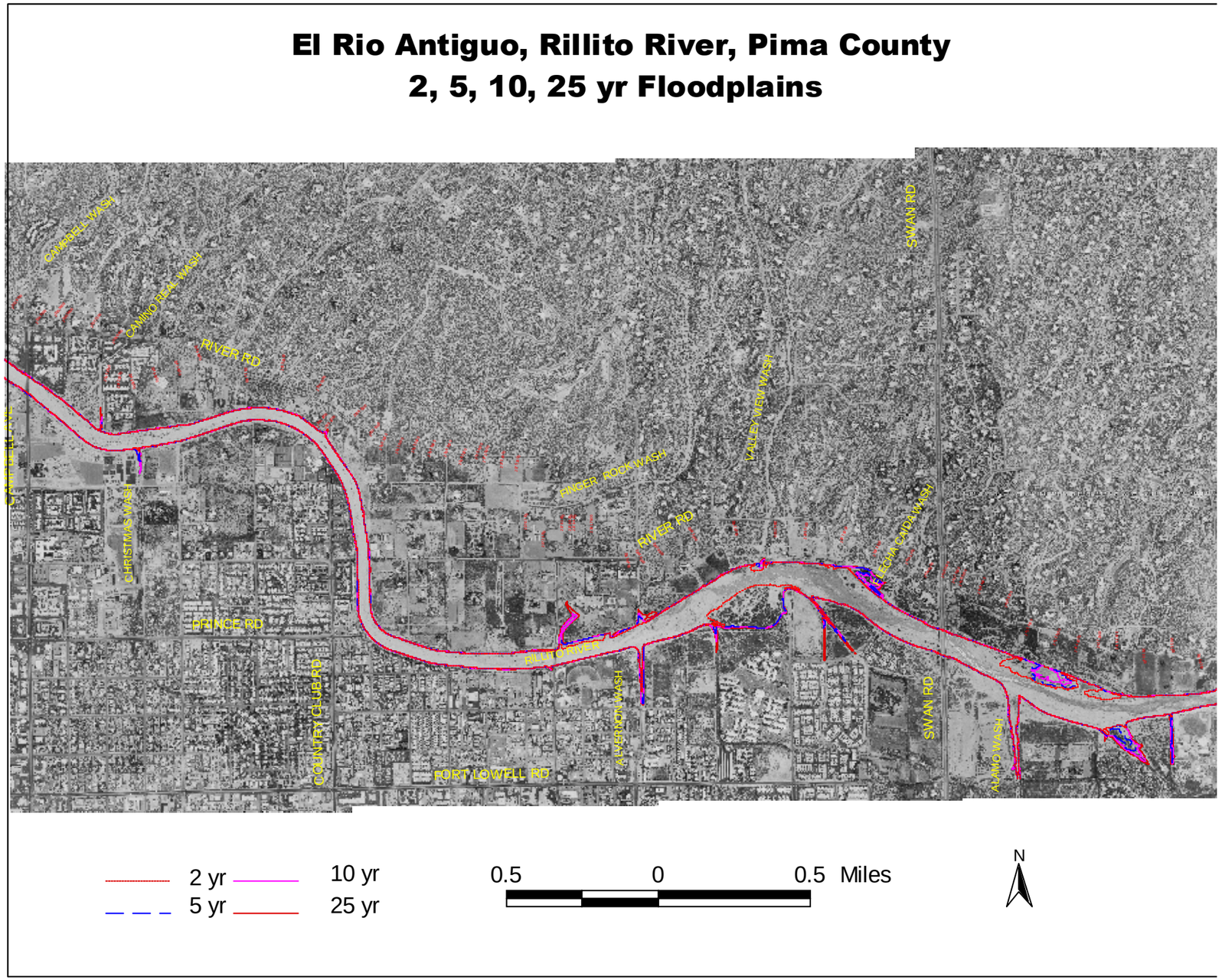


Figure 4.4 Floodplain boundaries for the 2, 5, 10, 25 year events

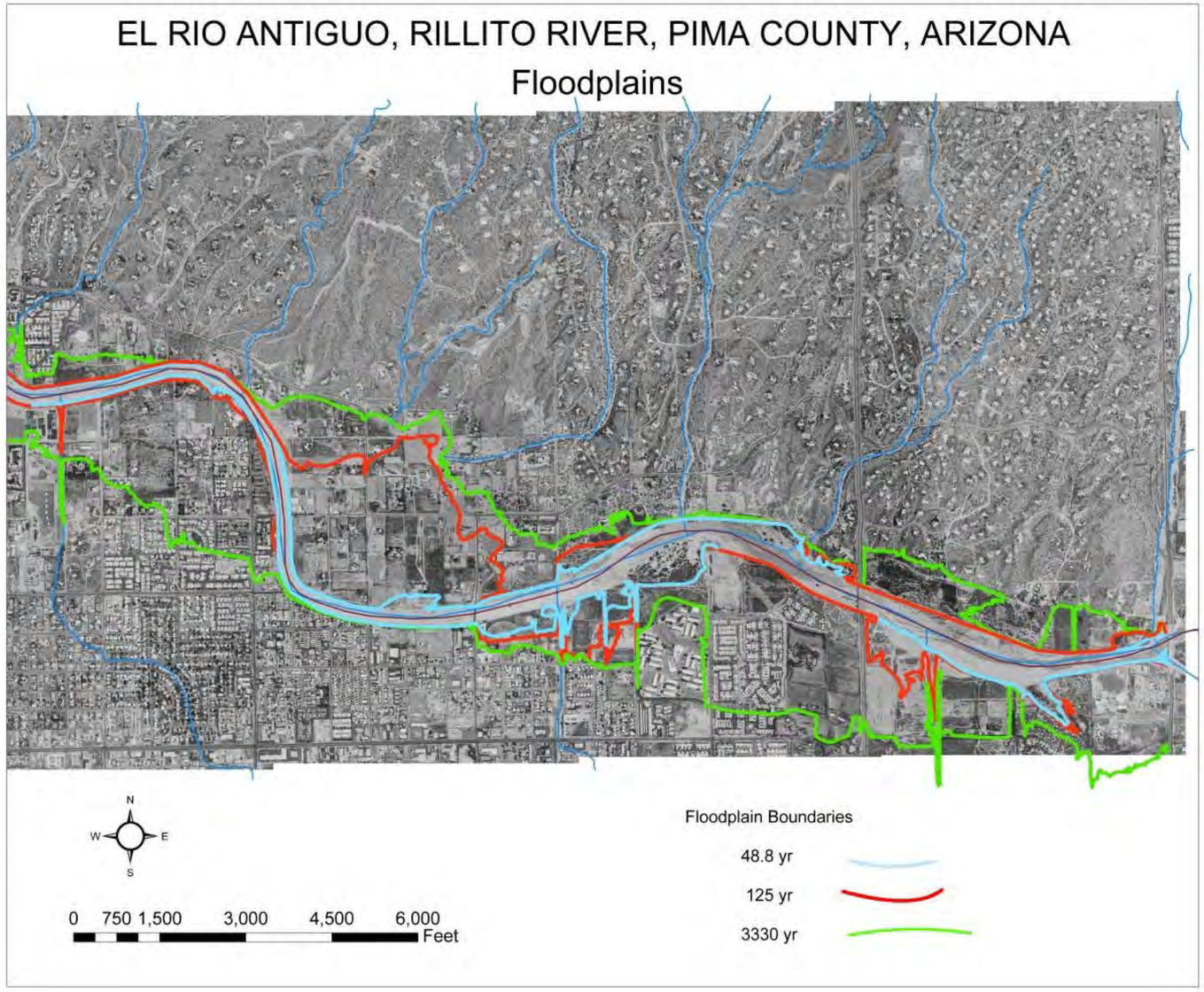


Figure 4.5 Floodplain boundaries for the 50, 100 and 500 year events

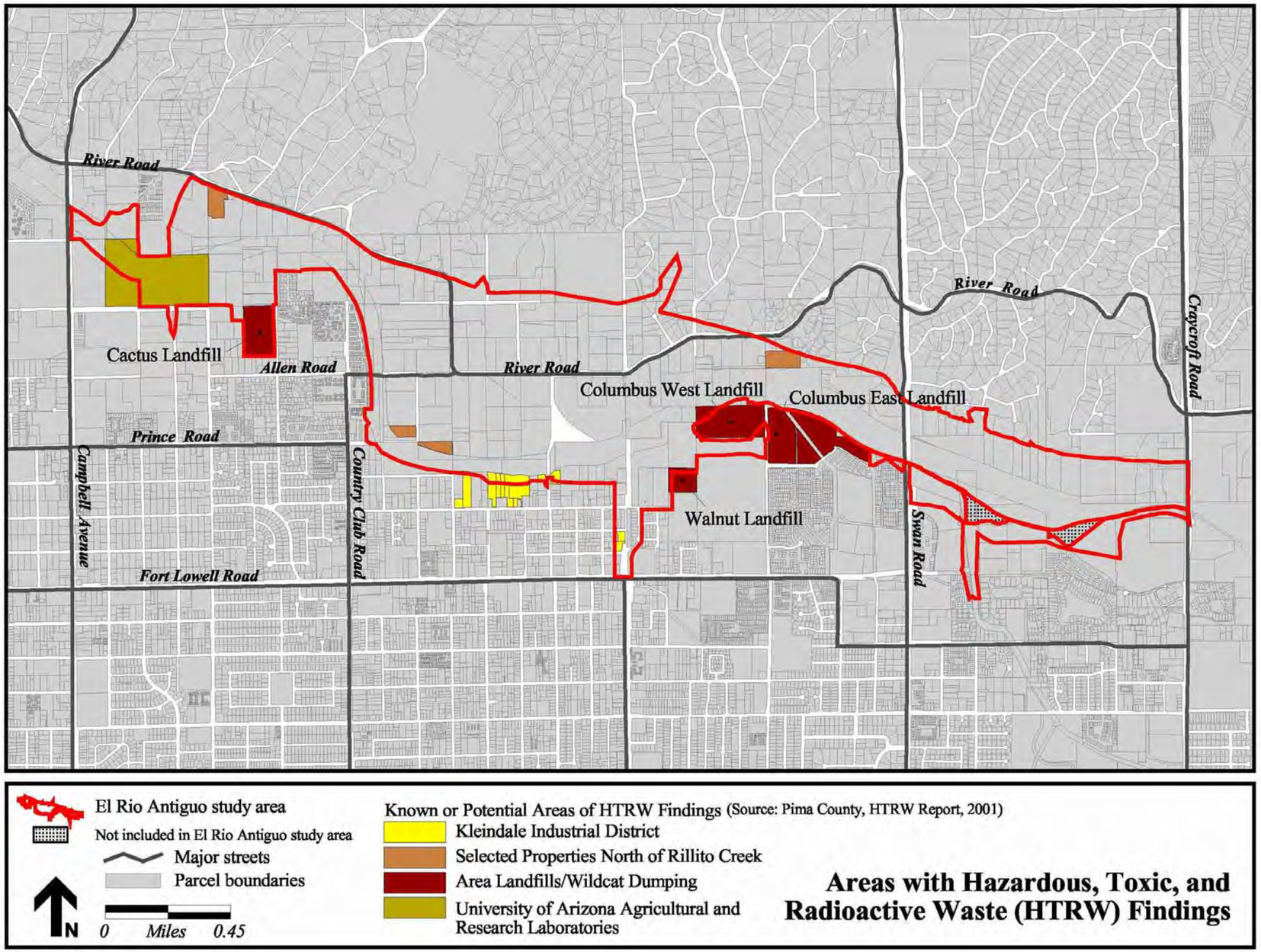


Figure 4.7 Potential HTRW Sites

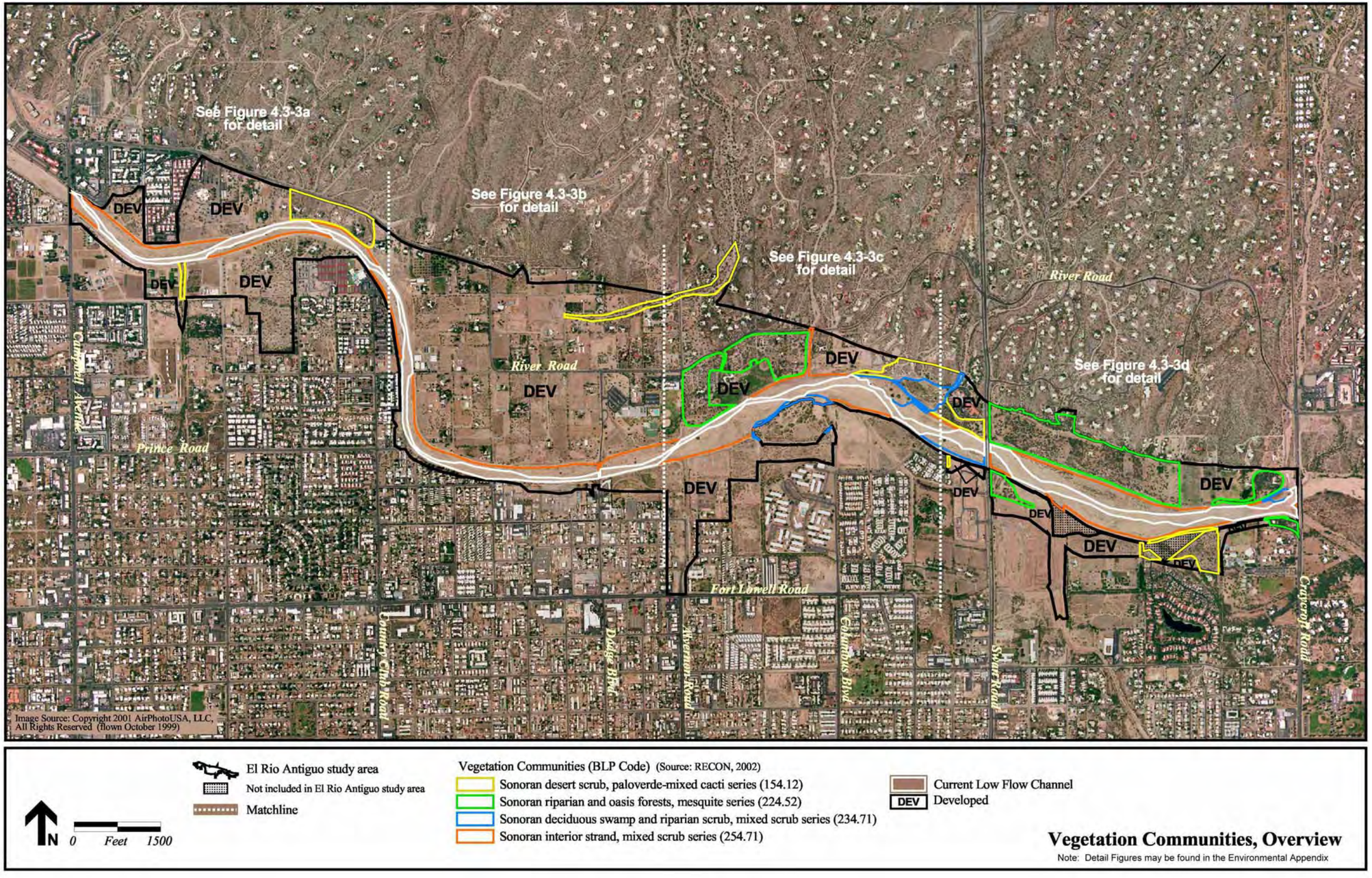


Figure 4.8 Vegetation Communities

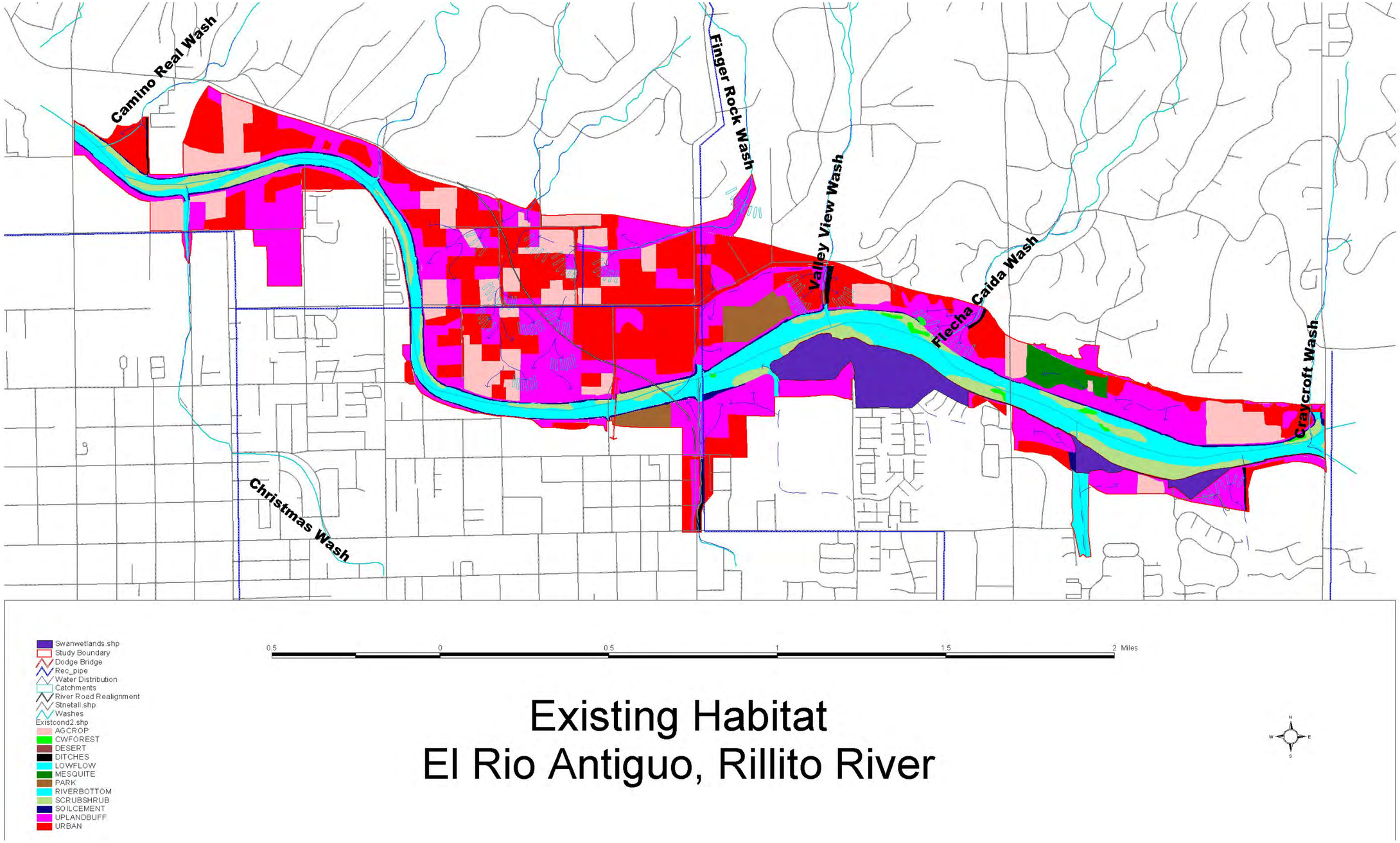


Figure 4.15 Distribution of Vegetation Cover Types (PWAAs) in the study area

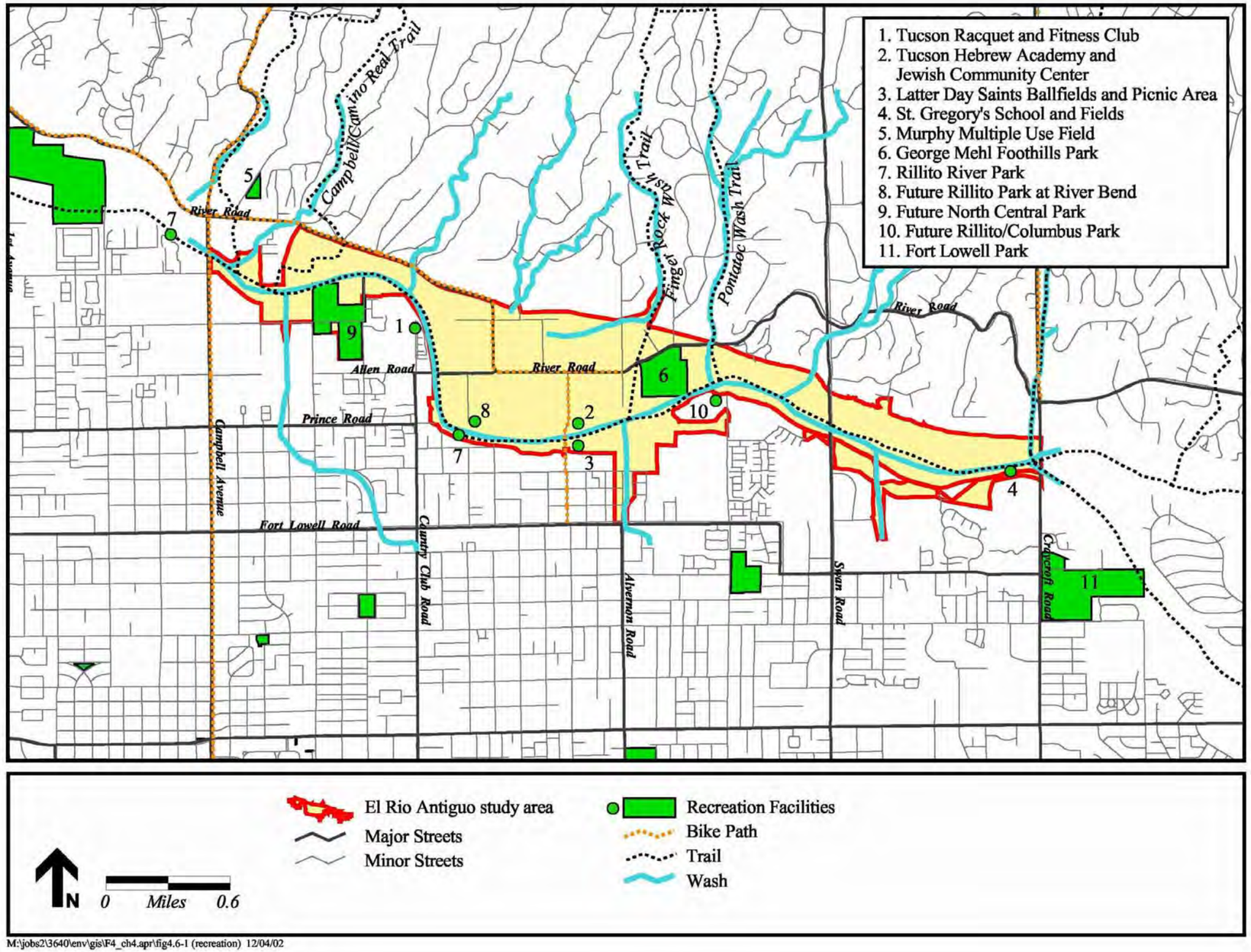


Figure 4.24 Recreation Resources

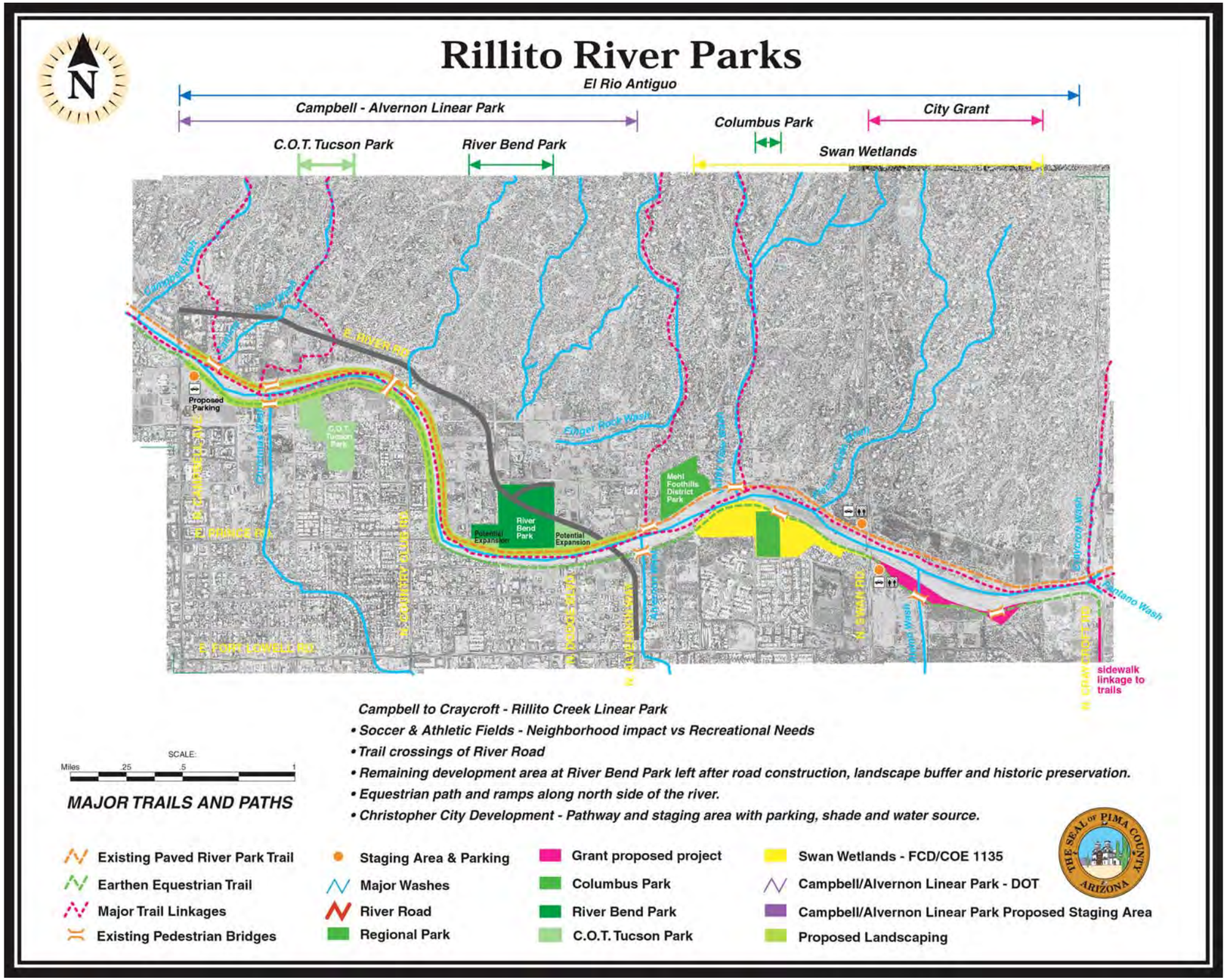


Figure 4.25 Tentative Plans for Rillito River Parks

CHAPTER V
PLAN FORMULATION

A. Planning Objectives

Federal Planning Objectives

Principles and Guidelines state that the Federal objective of water and related land resources project planning is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders and other Federal planning requirements. Water and related land resources project plans shall be formulated to alleviate problems and take advantage of opportunities in ways to contribute to this objective. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units.

Ecosystem restoration is also one of the primary missions of the Corps of Engineers Civil Works Program. The Corps objective is to contribute to National Ecosystem Restoration (NER) through increasing the net quality and/or quantity of desired ecosystem resources. NER measurements are based upon changes in ecological resource quality as a function of improvement in habitat quality or quantity and expressed quantitatively in physical units or indexes (not monetary units).

The purpose of this Feasibility Study is to determine if environmental restoration in this reach of the Rillito River in Pima County, Arizona meets the Federal objectives stated above. This was accomplished by developing and evaluating measures and alternatives in order to recommend an implementable solution. Recreation was considered in formulation when the associated measures contributed directly to the restoration objective. To be consistent with the Federal objectives, any recommended solution presented in the Feasibility Report must address environmental restoration measures that result in an increase in net value to the NER.

Specific Planning Objectives

Specific planning objectives were identified for this feasibility effort through coordination with local and regional agencies, the public involvement process, site assessments, review of prior studies and reports, and review of existing water projects. The specific objectives for environmental restoration within the study area have been identified as follows:

- Restore riparian vegetative communities within the river corridor to a more natural state.
- Increase the acreage of functional seasonal wetland habitat within the study area.
- Increase habitat diversity by providing a mix of habitats within the river corridor including the riparian fringe and buffer.
- Provide incidental flood control through ecosystem restoration to the extent that it does not impact the restoration object.
- Increase recreation and environmental education opportunities within the study area.

B. Planning Constraints

In order to develop environmental restoration alternatives that will best meet the established objectives, consideration of the existing constraints must be made. The following planning constraints have been identified for consideration in developing alternatives.

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.

Maintenance of Floodway Capacity

Restoration of riparian habitat cannot be done in such a way that it would substantially reduce the capacity of the Rillito or its tributary washes to convey damaging flood flows.

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.

Endangered Species

The study area is located in an urban area that is not known to contain endangered or threatened species. 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.

C. Alternative Development and Evaluation Process

The El Rio Antiguo, Rillito River, Pima County feasibility study process involves successive iterations of alternative solutions to the defined ecosystem degradation problem. Those solutions are based upon the study objectives and designed to address the opportunities while remaining within the limitations imposed by the 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 a reasonable certainty of addressing the problem, and conform to Corps of Engineers technical standards, regulations, and policies;

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

*Economic Feasibilit*y: 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, measures were developed to satisfy the four feasibility criteria. Measures are utilized address the defined problems. In selecting the measures to be evaluated for this study, specific consideration was given to public input and suggestions, Corps experience with similar restoration opportunities, technical considerations based upon the characteristics of the area, and flood control considerations for improving or maintaining the existing level of protection.

D. Ecosystem Restoration Measures

Wide varieties of measures were identified for use in developing alternatives. Key assumptions for development of restoration measures are as follows:

1. A base year of 2008 with analysis out to a future year of 2058.
2. Future growth will be limited to City of Tucson south of the study area
3. The Rillito River Section 1135 /Swan Wetlands will be completed.
4. The River Road realignment & Alvernon bridge construction will be completed as planned.
5. Recreation plans for the study area will be coordinated with this study.

The initial list of measure included:

***Delivered Water Sources**:*

- Central Arizona Project (CAP) water. The CAP delivers Colorado River water from Arizona's allocation to various locations 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).
- Treated Effluent (Reclaimed water)

***Natural Water Sources**:*

- Passive capture would involve grading/contouring of restoration areas to promote capture of local runoff.
- Active capture would involve pumping storm flows from channels to small basins for recharge or subsequent irrigation use.

***Low Flow Channel**:*

- Reconfiguration and/or deepening of the existing low channel with modifications to encourage meandering could be accomplished to promote maintenance and/or expansion of existing in-channel habitat areas.

***Terracing**:*

- Creation of terraces above the channel invert in the Bend Area in conjunction with lowering of soil cement offers opportunities for habitat restoration that maintains a connection to the channel.

Islands/ Sand Bars/ Oasis

- Modify channel inverts to promote formation of sand bars and associated habitat.

Modify Confluence/Distribute Incoming Flows

- Confluences of tributary washes with the Rillito River could be modified to mimic naturally occurring fans or deltas that 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.

Soil Cement Removed

- Soil cement could be removed and replaced with banks laid back and stabilized by vegetation.

Soil Cement Modified

- Soil cement could be modified in the Bend Area and at tributary inlets to allow restoration of banks to a more natural state.

Drop Structures/Weirs

- Placement of semi-permanent structures with associated weirs in the channel to aid in channel low flow stabilization and create seasonal pools.
- Placement of structures and weirs in or near tributaries for water harvesting.

Elements Conducive to Wildlife

- Restore a mix of habitat to promote wildlife diversity.

Recreation Components

- Passive recreation associated with restored areas including trails, viewing areas, and signage.

- Establishment of equestrian 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 in the Bend Area to provide instruction on cultural resources and native ecology.

Land Acquisition

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

Flood Control

- Bioengineer flood control channel and sediment basin in the Bend Area to alleviate Finger Rock Wash flooding and debris flows. Include culverts to allow for flows under new alignment of River Road and to allow for wildlife passage under the road.

Berm or Wall along Buffer

- Construct a low berm or wall in areas where damages might be induced because of restoration features or where it will benefit wildlife and the riparian areas to have a barrier between the restored areas and restoration features.

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.

Flood irrigation behind soil cement

- Allow flood flows to irrigate through a culvert, pipe or ditch system behind soil cement to maintain existing plant communities isolated from the river.

E. Preliminary Evaluation of Measures

Each measure 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 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 that were carried forward were then combined in various configurations to form a preliminary set of alternatives, which was then subjected to a more rigorous evaluation against the criteria. Some measures became alternatives, while other measures were combined to form alternatives.

Preliminary Plans Eliminated from Further Consideration

Alternatives such as detention were considered and rejected by an earlier Corps study. That study suggested a potential Federal interest for a concrete flood control in the Finger Rock Wash area however; it met with significant public opposition. This opposition resulted from the strong desire of local residents to maintain a natural wash. Average annual damages of $270,494 were identified for the Finger Rock Wash area. Based on the earlier study, channelization to convey Finger Rock flows to the Rillito was considered the least expensive flood control measure. Preliminary costs for channelization of 100-year flood flows were estimated to be $7,505,000 with average annual costs (excluding O&M) of $468,000. This would result in a Benefit to Cost ratio of .55. Based on this analysis flood control measures in the Bend Area were eliminated from further consideration.

Soil cement removal, drop structures or weirs in the main channel to create pools, use of CAP water sources, and open water measures were not carried forward. Soil cement removal was eliminated because its removal and features to mitigate for the loss of its flood control benefit are cost prohibitive. Damages resulting from unstable banks were documented in earlier Corps studies and provided justification for the Corps Rillito flood control project. That study determined that construction of stabilized banks using soil cement was the most cost effective solution to the Rillito flood threat. Vegetative bank stabilization in lieu of soil cement banks was not considered technically feasible without expanding the channel into existing development. Such a plan would result in unacceptably high real estate costs and would be likely to encounter significant public opposition from area residents.

Open water measures in the channel were eliminated because the public would find them unacceptable and therefore they are do not meet public feasibility criteria. There is a strong opposition throughout the Tucson area to creation of mosquito habitat near residential areas. In addition, open water measures are seen as wasteful of water and do not produce substantial ecosystem benefits. Finally, CAP water as a source was also eliminated because delivery of the water would be cost prohibitive.

F. Preliminary Restoration Concepts

Measures were assembled into preliminary alternatives by the planning team that included members from the Sponsor, the Los Angeles Corps, ERDC, USFW, and biological consultants. Inclusion of benefits for restoring the inter-relations between biogeochemical, hydrogeomorphic and biological functions, particularly connectivity and interspersion, precluded associating outputs with measures because it required analysis of each alternative as a whole system. The

plan formulation team formulated ecosystem alternatives that combined the measures in ways to improve the function of the ecosystem.

Through an iterative process, groupings of measures were formulated into preliminary alternatives and conceptual designs. The team began alternative development with a single comprehensive ecosystem restoration alternative. Other conceptual alternatives arose based on the use of varying measures located at the bend, in the channel or at tributaries. The process considered potential water sources, reconnection of the disconnected tributary (Finger Rock Wash), locations for removal of soil cement to allow for more natural hydraulic function, water harvesting potential, areas where plant communities might survive, buffering of the restored plant communities, education, cultural and historical issues, biological diversity, potential land acquisition, vector control, flood damage reduction and water supply issues.

The team based alternative formulation on these considerations, the nature of ecosystem function as a whole, comparison to reference sites, and the following assumptions:

- River Road realignment will be completed
- Rillito/Swan Wetlands Section 1135 will be complete.
- Swan Wetlands will not be included in the study area analysis to avoid possibility of double counting benefits.
- Upstream and downstream reaches had different characteristics. Craycroft to Alvernon has higher groundwater and wider channel; measures in the channel are more likely to be viable in this upstream reach than Alvernon to Campbell, which is narrower with low groundwater.

Three preliminary restoration concepts were developed from the measures that survived screening. These concepts consisted of groups of design measures applied to project reaches. These examples demonstrated the likelihood of formulating feasible alternatives for ecosystem restoration in the study area and provided the basis for development and analysis of detailed alternatives. The preliminary concepts were varied with respect to water requirements, habitat focus and total scale. The three restoration concepts had several common features. Elements incorporated in each plan include:

Reach 1

In-channel restoration in Reach 1 would encourage a low flow channel built within the banks. This meandering channel would be lined with native grasses, desert wash vegetation, cottonwood/willow galleries and appropriate under-story vegetation.

Reach 2

Reach 2 would have in-channel re-vegetation with a diverse mix of desert wash vegetation to include desert hackberry and desert willow. Terracing in widest areas within the channel could be included within the soil cement and planted with mesquite communities.

Buffer

Additional land may be purchased to provide a wider buffer with native plant community re-vegetation and for terracing. Protective buffer areas may be planted with mesquite and acacia communities particularly along the 50-foot right of way in the River Park to promote habitat connectivity and a wildlife corridor between upland and riparian areas. Berms or floodwalls would be added at the outside edge of the buffer. These measures would be used where increasing n-values induce overbank flows that may cause flood damages to developed areas or where there is a need for a barrier between restored and developed areas. Berms could be vegetated with appropriate native vegetation.

Distinctive elements of each set of design measures are listed below.

1. Basins

This approach focused on excavation of basins with weep holes or weirs in the bend area and downstream or upstream basins, primarily where tributary washes empty into the Rillito. It included modification of bank protection, in channel restoration, buffer improvements and tributary side/drain restoration with basins for storm water harvesting and biannual flooding through a culvert into restored habitat and existing mesquite areas. It would include active and passive capture of storm water as well as a commitment of delivered water sources

Bend Area

One or more basins would be excavated in the Bend Area to capture/store water and provide planting areas for restoration. Re-vegetation on excavated areas will be graded from cottonwood/willow on the lowest level to mesquite communities to desert wash vegetation at the highest level from the river.

Flows from Finger Rock Wash approximately upstream to Sutton Lane would provide water for storm water harvesting. This water would fan out over restoration features with trails and recreation (possible horse staging area) located in non-inundated areas. It would include both a high flow and low flow channel. The low flow channel would carry the 10-year event and the high flow channel aligned approximately along the Alvernon alignment will carry larger events. Both will support mesquite communities.

Tributary Inlets/Side Drains

Soil cement banks would be reconfigured at tributary inlets with laid-back banks to create a more natural bank and connection between the Rillito and each tributary. Additional basins would be placed at tributary confluences. Tributaries would be re-vegetated as discussed below:

- Craycroft Wash. Harvest storm water. Re-vegetate with mesquite, cottonwood/ willow, sycamore, hackberry, & ash graded to desert wash habitat upstream on tributary
- West of Swan Rd. Large side drain fan on south banks would be reconfigured to allow for improved cottonwood/willow habitat
- Behind/around Swan Wetlands/Rillito 1135 area. Restore

mesquite/cottonwood/willow and desert wash communities

- Walnut to Alvernon. Revegetate with mesquite bosque community.
- Alvernon Wash to Ft Lowell. Revegetate with cottonwood/willow community after redesign of concrete channel to softer channel configuration.
- U of A Farms/Christmas Wash. Restore cottonwood/willow community. This would require acquisition of lands or a conservation easement.

Small side drains would be reconfigured to allow storm water and nuisance flows to be utilized to establish desert wash communities with hackberry and desert willow. Larger side drains would be re-vegetated with cottonwood/willow as appropriate.

2. Channel and Bend Area Restoration

This alternative includes modification of bank protection, in channel restoration, buffer improvements and tributary side/drain restoration. It would include active and passive capture of storm water as well as a commitment of delivered water sources and flooding through a culvert into existing mesquite areas.

Bend Area

Soil Cement Banks would be lowered on the inside or north bank of the Bend Area with terracing that protects the realigned River Road. Revegetating on terraced areas would be graded from desert wash on the lowest level, to cottonwood/willow on the second level, to mesquite communities at the highest level from the river.

Flows from Finger Rock Wash approximately upstream to Sutton Lane would provide water for storm water harvesting. This water will fan out over restoration features with trails and recreation (possible horse staging area) located in non-inundated areas. It would include both a high flow and low flow channel. The low flow channel would carry the 10-year event and the high flow channel approximately along the Alvernon alignment would carry larger events. Both will support mesquite communities.

3. Channel and Tributary Restoration Alternative

This alternative includes in-channel restoration, buffer improvements and tributary side/drain restoration. It would include active and passive capture of storm water as well as a commitment of delivered water sources. It would also include flooding through a culvert into existing mesquite areas.

Tributary Inlets/Side Drains

Soil cement banks would be reconfigured at tributary inlets with laid-back banks to create a more natural bank and connection between the Rillito and each tributary. Fans or Deltas would be engineered to allow for establishment of riparian communities with a better success rate for survival in higher flood flows. Tributaries would be re-vegetated as discussed below:

- Craycroft Wash. Harvest storm water. Re-vegetate with mesquite, cottonwood/

willow, sycamore, hackberry, & ash graded to desert wash habitat upstream on tributary

- West of Swan Rd. Large side drain fan on south banks would be reconfigured to allow for improved cottonwood/willow habitat.
- Behind/around Swan Wetlands/Rillito 1135 area. Restore mesquite/cottonwood/willow and desert wash communities
- Walnut to Alvernon. Revegetate with mesquite bosque community.
- Alvernon Wash to Ft Lowell. Revegetate with cottonwood/willow community after redesign of concrete channel to softer channel configuration.
- U of A Farms/Christmas Wash. Restore cottonwood/willow community. This would require acquisition of lands or a conservation easement from the University.

Small side drains would be reconfigured to allow storm water and nuisance flows to be utilized to establish desert wash communities with hackberry and desert willow. Larger side drains will be re-vegetated with cottonwood/willow as appropriated.

No Action Alternative

The No Action Plan is analyzed to provide a basis from which to assess the advantages and disadvantages of the other study alternatives. Under this alternative, the Corps of Engineers would take no action to provide ecosystem restoration within the study area, nor to develop plans with potential incidental benefits associated with flood damage reduction, recreation, and water quality and supply.

G. Alternative Plans – First Array

Development

The three original concepts (basins, terrace, and channel/tributary restoration) were varied to produce a wider array of restoration possibilities. Different numbers and locations of basins were considered such as creating either one or two basins in the bend area. The number and location of terraces was varied and different combinations of terraces were considered both with and without channel restoration measures. Finally, the improvement of existing buffer with native plantings and the creation of new buffer were considered. Through this process, the original three sets of design measures were expanded to create 20 alternatives.

All alternatives included water-harvesting basins, although the number and location varied. In addition, all alternatives had the same set of measures to direct recreation activities away from areas restored habitat. Two measures were common to nearly all the alternatives. Eighteen of the twenty alternatives included habitat restoration in newly established of high and low flow channels for Finger Rock Wash. Sixteen of the twenty alternatives included measures to facilitate establishment and maintenance of a low flow channel while restoring habitat throughout the channel. Half of the alternatives included the restoration of habitat in new and existing buffer areas adjacent to restored riparian habitat while the other half neither added new buffer nor improved existing buffer.

Alternatives

Basins Alternatives

There are eight basins alternatives. Four have buffer and four do not. Each basin alternative includes establishment of high and low flow channels for Finger Rock Wash. They also include channel restoration measures with 12 gabions to encourage meandering, low flow channel in the bend area, and various planting of communities including cottonwood willow, mesquite, desert wash and emergents in the river channel. The main concept of the basins alternatives are a series of alternatives that focus on the excavation of basins with weep holes in the bend area, or downstream basins, and upstream basins, primarily where the washes empty into the Rillito. Basins were designed and located to exploit opportunities for storm water harvesting and, by virtue of their design, provide habitat areas that could be efficiently irrigated using surface flow systems that mimic natural flood inundation. The downstream basin alternatives were varied to examine implementing one basin in the bend area, or implementing two basins in the bend area. This may be desirable to avoid cultural resource impacts. Planted areas include establishment of new riparian habitat as well as improvement of existing riparian areas. These planted areas will be irrigated. The features particular to each alternative are listed in Table 5.1 and illustrated in Figures 5.1 through 5.8 (Pages V-32 to V-39).

Table 5.1 Basin Alternatives

Alternative	Name	Description	Gross Investment/ Avg. Annual Cost (Including O&M)	Net Increase in Average Annual FCU
1A	All Basins 4	Two basins in the Bend Area Eight upstream basins Expanded and improved buffer areas	 $83,459,038 $6,698,102	 110
1B	All Basins 1	Two Basins in the Bend Area Eight upstream basins	$74,180,005 $6,115,399	 107
1C	Upstream Basins 4	8 upstream basins Expanded and improved buffer areas	$73,267,605 $5,559,134	 81
1D	Upstream Basins 1	8 upstream basins	$61,438,988 $4,817,726	 78
1E	2 Downstream Basins 4	Two basins in the bend area Expanded and improved buffer areas	$78,114,225 $6,142,332	 96
1F	2 Downstream Basins 1	Two basins in the bend area	$70,061,831 $5,636,805	 95
1G	1 Downstream Basin 4	One basin in the bend area Expanded and improved buffer areas	$81,211,239 $6,464,390	 105
1H	1 Downstream Basin 1	One basin in the bend area	$71,207,435 $5,839,046	 103

Gross investment in Table 5.1 includes costs of real estate, construction and interest during construction. Operation and Maintenance (O&M) includes the costs of annual O&M activities and the annualized costs of periodic O&M activities.

Terrace Alternatives

There are eight terrace alternatives. Four have buffer and four do not. Each basin alternative includes establishment of high and low flow channels for Finger Rock Wash. The terrace alternatives will include a high and low flow channel in the bend area, the eight upstream basins (with weep holes), primarily where the washes empty into the Rillito. Basins were designed and located to exploit opportunities for storm water harvesting and, by virtue of their design, provide habitat areas that could be efficiently irrigated using surface flow systems that mimic natural flood inundation. Four of the terrace alternatives do not have any channel restoration measures (gabions), which may be desirable from an engineering perspective in order to avoid any impact to existing grade control structures in the Rillito. The other four terrace alternatives have 12 gabions in the channel for restoration. The terrace alternatives are differentiated from the other alternatives by the concept of implementing a series of terraces in the bend area. Terraces will be cut in to the existing soil cement bank at the height of flow during a five-year flood event (approximately four to five feet above the river bottom). The second terrace will be constructed to accommodate flows during a 10-year event and a third terrace will accommodate flows during a 20-year flood event. The first terrace, which will be 75 feet wide at the widest point, will be planted with plant species typical of desert wash vegetation communities. The second terrace will be planted with cottonwood willow vegetation and will be approximately 200 feet at its widest point. Plants typical of a mesquite bosque will be planted on the upper third terrace. The third terrace will be approximately three feet higher than the second terrace and be approximately 150 feet at its widest point. A reinforced 2:1 slope will be used between the second and third terrace and the upland side of the third terrace will be contoured up to the current height of the adjacent upland area on its boundary. The terraces will occupy the location of the previously described Dodge and Bend Basins. The two sets of terrace alternatives were varied to examine implementing one set of terraces in the bend area, or implementing two sets of terraces in the bend area. This may be desirable to avoid cultural resource impacts. All eight terrace alternatives include various planting of communities including cottonwood willow, mesquite, and desert wash vegetation in newly created PWAAs, as well as existing PWAAs. These planted areas will be irrigated. The features particular to each alternative are listed in Table 5.2 and illustrated in Figures 5.9 through 5.16 (Pages V-40 to V-47). Gross investment in Table 5.2 includes costs of real estate, construction and interest during construction. Operation and Maintenance (O&M) includes the costs of annual O&M activities and the annualized costs of periodic O&M activities.

Table 5.2 Terrace Alternatives

Alternative	Name	Description	Gross Investment/ Avg. Annual Cost (Including O&M)	Net Increase in Average Annual FCU
2A	2 Terraces 4	Two Terraces in the Bend Area		
		Eight upstream basins	$92,629,044	
		Expanded and improved buffer areas	$7,017,413	91
2B	2 Terraces 1	Two Basins in the Bend Area	$82,261,778	
		Eight upstream basins	$6,367,282	89
2C	1 Terrace 4	1 terrace in the Bend Area		
		8 upstream basins	$83,734,449	
		Expanded and improved buffer areas	$6,431,114	92
2D	1 Terrace 1	1 terrace in the Bend Area	$72,600,586	
		8 upstream basins	$5,733,371	90
2E	2 Tergab 4	Two Terraces in the Bend Area		
		Eight upstream basins		
		Rillito Low Flow Channel Restoration	$93,996,838	
		Expanded and improved buffer areas	$7,133,857	125
2F	2 Tergab 1	Two Terraces in the Bend Area		
		Eight upstream basins	$86,091,612	
		Rillito Low Flow Channel Restoration	$6,644,239	123
2G	1 Tergab 4	One Terrace in the Bend Area		
		Eight upstream basins		
		Rillito Low Flow Channel Restoration	$86,311,311	
		Expanded and improved buffer areas	$6,622,899	122
2H	1 Tergab 1	One Terrace in the Bend Area		
		Eight upstream basins	$75,682,207	
		Rillito Low Flow Channel Restoration	$5,956,681	120

Channel/Tributary Restoration Alternatives

The channel and tributary restoration alternatives focus on the restoration of plant communities in the river channel and tributary areas. Eight gabions will be placed in the channel, along with three inflatable barriers. The inflatable barriers will be near existing grade control structures in the Rillito, and be placed at more of a perpendicular angle, to direction of flow compared to the gabions being placed at approximately a 45-degree angle. In addition, the inflatable barriers will help to maintain the low-flow channel location, directing flow away from establishing channel vegetation, create a meandering lower velocity channel in the sandy bottom and slow lower flows down to potentially hydrate channel vegetation. The inflatable barriers will be deflated during periods of flood flows equal to or exceeding the 10-year flood event. Other measures to be implemented under the channel restoration alternatives are the eight upstream basins with weep holes or weirs, both the high- and low-flow channels in the bend area, and various planting efforts including enhancement of existing PWAAS with plantings in cottonwood willow, mesquite, desert wash vegetation, cienega emergents in the tributary areas along the Rillito, and buffer communities. These planted areas will be irrigated. The features particular to each alternative are listed in Table 5.3 and illustrated in Figures 5.17 through 5.20 (Pages V-48 to V-51). Gross investment in Table 5.3 includes costs of real estate, construction and interest during construction. Operation and Maintenance (O&M) includes the costs of annual O&M activities and the annualized costs of periodic O&M activities.

Table 5.3 Channel/Tributary Alternatives

Alternative	Name	Description	Gross Investment/ Avg. Annual Cost (Including O&M)	Net Increase in Average Annual FCU
3A	Chanbar 4a	Three inflatable barriers		
		Low flow channel gabions		
		Finger Rock Wash Channels		
		Eight upstream basins	$75,439,886	
		Expanded and improved buffer areas	$5,931,028	101
3B	Chanbar 1a	Three inflatable barriers		
		Low flow channel gabions		
		Finger Rock Wash Channels	$71,612,192	
		Eight upstream basins	$5,689,400	100
3C	Chanbar 4b	Three inflatable barriers		
		Low flow channel gabions		
		Eight upstream basins	$55,799,984	
		Expanded and improved buffer areas	$4,479,881	80
3D	Chanbar 1b	Three inflatable barriers		
		Low flow channel gabions	$47,606,432	
		Eight upstream basins	$3,966,086	78

H. Evaluation of Alternative Plans

The evaluation of alternatives involves the consideration of the plan success in meeting planning objectives in the context of identified constraints. The following discussions address the differences and similarities between the alternatives and the baseline conditions. Details of these topics are addressed in the Environmental, Cost Estimating and Economic Appendices. The four national accounts are also considered in the comparison and evaluation of alternative plans, as are the associated evaluation criteria.

Environmental Resources

Remembering the thousands of acres of southwest riparian habitat that has been lost over the last century; taking into consideration the critical role that such habitats play in the life cycle of nearly all southwestern wildlife; and recalling the threat posed by development to many remaining riparian areas; it is difficult to overestimate the importance the restored acres.

The functional outputs for the Alternative 1A through 1H - Basins range from 78 AAFCUs to 110 AAFCUs. The outputs for Alternatives 2A through 2H - Terrace and Terrace with gabions range from 89 to 125 AAFCUs and are the best functional producers overall. The outputs for Alternatives 3A through 3D – Channel Restoration with barriers – range from 78 to 101 AAFCUs. Alternative 2E restores the highest number of acres and Alternative 3D restores the least number of acres. The top three functional (for hydrogeomorphic, biogeochemical and biological function) alternatives are Alternative 2E - two sets terraces with gabions, Alternative 2F - two sets terrace with gabions, Alternative 2H – 1 set of terraces with gabions,. The single terrace alternatives result in restoration of 277 acres of riparian habitat while the two terrace alternatives restore 284 acres. These alternatives would produce net AAFCU gains of 124, 123, 121 and 120 respectively. Figure 5.21 (Page V-52) shows a graph of AAFCUs per function for the terrace with gabions for channel restoration alternatives. The fourth ranking biologically productive alternative is included (Alternative 2H – 1terrace without gabions) . The red line across the graph represents the average net AAFCU for all 20 alternatives. From the red line on the graph, it is easy to see that the top four biological plans exceed the average net AAFCU for the study, as well as the AAFCU for many of the targets.

Figure 5.22 (Page V-53) shows the FCIs for top biological alternatives, as well as others. The red line on the graph represents the average FCIs of all 20 alternatives. The functions that fall short of the average FCI for all three alternatives are: Function 1 (channel dynamics), Function 3 (long-term water storage) and Function 10 (interspersion and connectivity). It should be noted that in this setting channel dynamics would be impossible to restore without entirely removing soil cement, and that long term effects of groundwater pumping cannot be alleviated. Interspersion and connectivity are also difficult to entirely restore because of the effects of urbanization. It is worth noting that these top biological alternatives had the highest FCI for these functions of any of the alternatives. Despite this limitation, the alternatives did produce an average FCI around 0.4, a good functioning level, compared to the poor level of around 0.1 for the baseline conditions, which is quite a dramatic increase, and would make a significant increase in the functioning and health of this riverine ecosystem.

Increases in restored vegetation communities are shown in Figure 5.23 (Page V-54). The acreage of existing cottonwood community to be restored is low, approximately three acres. However, the acreage of new cottonwood communities that will be established exceeds 100 acres

for the top two alternatives and is just less than 100 acres for the third and fourth. Similarly, the existing mesquite community acres are low for the three alternatives, around 13 acres. In contrast, the alternatives include approximately 103 acres of newly restored mesquite communities. For the scrub/shrub (Desert Wash) community, the existing areas to be restored the acreage of new restored communities are both roughly 35 to 40 acres. The acres for existing riverbottom (Cienega) include the bare area, where as the new riverbottom communities focus only on restored emergent vegetation. This cover type will encompass about 10 acres. A small area when compared to the other restored communities. It is reasonable to expect that increasing organic matter and seed sources in the channel will cause natural development of cienegas in areas that will not be planted within the channel. All of these gains must be considered in comparison to a future without project condition in which all cottonwood, and mesquite habitats have been eliminated from the area within 30 years. In addition, desert wash habitat would continue to degrade.

It is reasonable to expect that there may be both short and long-term changes to biological resources because of the implementation of alternatives. Possible short-term impacts may include, but are not limited to, temporary disturbance to vegetation communities and species including the temporary displacement or inadvertent killing of wildlife during construction. Implementation of mitigation measures during construction may avoid or at least minimize this. No adverse impacts are expected to federally listed species, since none are expected to occur in the area.

Beneficial impacts go beyond the increase in the amount and quality of native riparian vegetation detailed above. While no federally listed species currently occur in the area there are four USFWS Species of Concern, four USFS Sensitive Species and seven SDCP sensitive species who would directly benefit from the restoration of these habitats. These include six mammals, three reptiles, one amphibian and five birds. In addition to benefiting locally resident sensitive species, the restored areas will provide additional resting and forage habitat for the many migratory bird species that pass through the Santa Cruz Basin.

The lowest rated of the top four biological alternatives achieves a nine percent increase in output over the next best alternative. However, although the top four alternatives may be placed in rank order their functional outputs are relatively close.

Hydraulics Effects

Early iterations of the economic analysis showed that the final array of alternatives would be drawn from six of the twenty alternatives in the second array. Those alternatives were; Alternative 2 H -1 tergab 1, Alternative 2G -1 tergab 4, Alternative 2F -2 tergab 1, Alternative 2G- 2 tergab 4, Alternative 3D -chanbar 1b and Alternative 3C - chanbar 4b.

The hydraulic model of the study area was modified to reflect with project conditions for each of these alternatives. Detailed results of the modeling can be found in the Hydraulic Appendix. None of the alternative models produced clear evidence of induced damages resulting from project impacts. Any increases water surface elevations were substantially less than the contour interval of the map upon which the resulting 100-year floodplain was to be plotted. Additional analysis was conducted to resolve this issue and it was determined that none of the top four biological alternatives posed a risk of inducing increases in flood damages.

Water Budget

A water budget was prepared for each alternative. Consumption was not projected for riverbottom (Cienega) because all alternatives assume this cover type will only occur seasonally in response to the presence of harvested storm water.

The total annual volume of secondary effluent produced at the nearby treatment plans is 74,000 acre-feet (28,000 AF at the Ina Road plant and 46,000 AF at the Roger Road plant). Surface water sources available from the Rillito (average annual volume of 10,135 AF) and tributaries (2,844 AF) represent potential supplemental water sources. However, given the variability of seasonal or monthly flows, the actual surface water available in any given month can vary from zero to volumes in excess of what could be harvested. Due to this variability, irrigation systems have been designed to meet all consumptive needs of the vegetation using reclaimed water.

Costs

Preliminary costs were developed for each alternative. Cost estimates utilized a contingency of twenty-five percent of the alternatives' First Cost and allowed ten percent of the First Cost for engineering and design. One percent and six and one-half percent of first costs were used in estimating engineering and design during construction and construction management. The Gross Investment for an alternative includes the first cost added to the other costs defined above plus interest during construction calculated at the current 5.875 % interest rate, October 2003 price levels.

Gross Investment costs for the alternatives ranged from a low of $47,606,432 to a high of $93,996,838. Average Annual Costs, including Operation Maintenance Repair Rehabilitation and Replacement ranged from $3,966,086 to $7,133,857. The top four alternatives ranked by cost were also the four lowest alternatives ranked by biological output (Table 5.4). Details of cost estimates for other alternatives can be found in the Cost Estimating Appendix.

Economics

First, the results of the habitat assessment were compared using Cost Effectiveness Analysis (CEA). When comparing alternatives using CEA, those alternatives that produce increased levels of output (AAFCUs) for the same or lesser costs were considered "effective" solutions and were retained. These alternatives were compared based on cost efficiency (i.e. those alternatives that produce similar levels of output (AAFCUs at a lesser expense). The "efficient" solutions were submitted to Incremental Cost Analysis (ICA) (i.e. determining changes in costs for increasing levels of outputs). Once evaluated, through a computer program called IWR-Plan, on the basis of cost effectiveness and incremental cost analysis, the best buy solutions were determined (those that are both cost effective and incrementally effective).

The results of the ICA are displayed in Table 5.4 below along with rankings of average cost (annual costs per AAFCU), average annual cost, CEA, and Functional Assessment. The top average cost and incrementally effective and efficient solution evaluated was Alternative 2H (1-terrgab-1). The second and third ranked average cost and incrementally effective and efficient solutions were Alternative 2F (2-terrgab-1) and Alternative 2E (2-terrgab-4). Based on the Incremental Cost Analysis, the three best buys were carried forward into the final array. Alternative 2G was cost effective, but has slightly lower output and is more costly per unit than 2F (see black dot on graphic Figure 5.24). Alternative 2G was not a "Best Buy Plan", therefore, 2G was not carried forward into the final array.

Table 5.4: Average Cost, Average Cost, CEA, ICA and HGM Rankings

Average Cost Ranking	*Average Annual Cost*	*Cost Effectiveness Analysis (CEA) (Ranked By Average Cost)*	*ICA Ranking*	*Functional Assessment Ranking*	*Alternative*	*Average Net AAFCUs*	*Average Annual Cost ($M)*	*Average Cost (Cost Per AAFCU) ($M)*
2	1	**2**		19	CHANBAR-1B (3d)	78	3.97	.0509
1	10	**1**	**1**	4	1-TERRGAB-1 (2h)	120	5.96	.0497
3	17	**3**	**2**	**2**	2-TERRGAB-1 (2f)	123	6.64	.0540
5	2	5		18	CHANBAR-4B (3c)	80	4.48	.0560
4	16	4		**3**	1-TERRGAB-4 (2g)	122	6.62	.0543
7	20	7	**3**	**1**	2-TERRGAB-4 (2e)	125	7.13	.0570
8	11			6	ALLBASINS-1 (1b)	107	6.12	.0572
6	8	6		8	1-DWNBASINS-1 (1h)	103	6.84	.0567
9	6	8		10	CHANBAR-1A (3b)	99	5.69	.0575
10	9			9	CHANBAR-4A (3a)	101	5.93	.0587
11	5	9		12	2-DWNBASINS-1 (1f)	95	5.64	.0594
12	18			5	ALLBASINS-4 (1a)	110	6.70	.0609
15	7			16	1-TERRACE-1 (2d)	90	5.73	.0637
13	15			7	1-DWNBASINS-4 (1g)	105	6.46	.0615
14	3			20	UPBASINS-1 (1d)	78	4.82	.0618
16	12			11	2-DWNBASINS-4 (1e)	96	6.14	.0640
19	13			15	2-TERRACE-1 (2b)	89	6.37	.0716
18	14			13	1-TERRACE-4 (2c)	92	6.43	.0699
17	4	10		17	UPBASINS-4 (1c)	81	5.56	.0686
20	19			14	2-TERRACE-4 (2a)	91	7.02	.0771

A scatter plot of plans is shown in Figure 5.24 below. Cost effective, non cost effective, and best buy plans differentiated. Alternatives are labeled for only the cost effective and best buy plans.

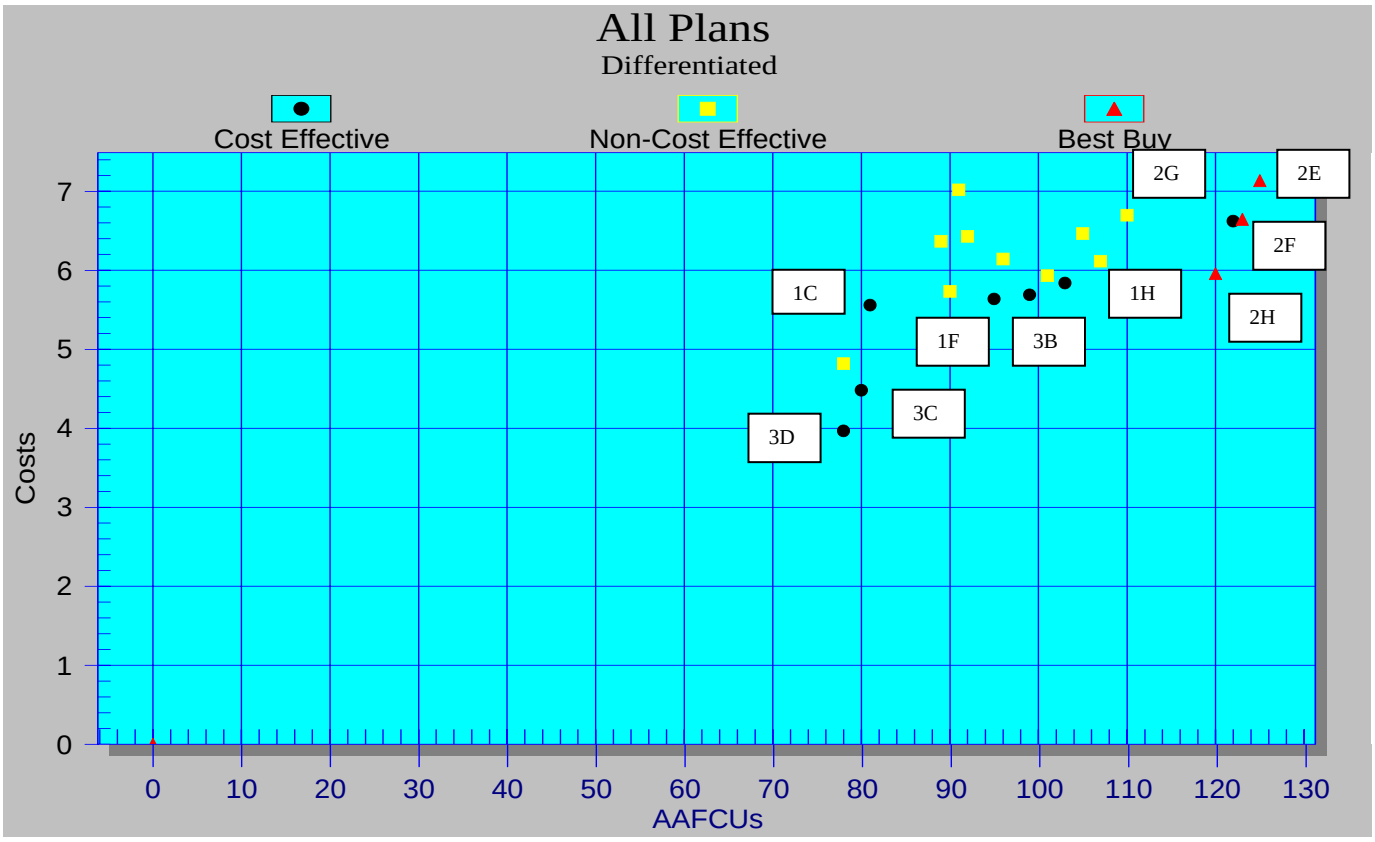


Figure 5.24 All Plans Differentiated

Associated Evaluation Criteria

The selection of alternative plans for the final array required a combination of decision-making factors. For ecosystem restoration, the decision-making process attempts to incorporate human needs and values with our best understanding of the natural environment, recognizing a complex blend of social, economic, political and scientific information. Both quantitative and qualitative information is used including information about outputs, costs, significance, acceptability, completeness, effectiveness, partnership context, and reasonableness of costs. Policy and Guidance screening criteria are shown below.

Completeness: Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.

1. Plans have been formulated to ensure that investments necessary to ensure realization of planned effects have been identified.
2. Costs of the investments have been thoroughly detailed by management measure and include: first costs, real estate costs, contingency, PED, engineering during construction, construction management, adaptive management, interest during construction, and OMRRR.

Therefore, the completeness of all plans in the final array is a result of accurately detailing all expected costs to accurately assess each element and allowing for extraneous factors by including an appropriate contingency.

Effectiveness: Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities. In other words, it contributes to the attainment of the planning objectives.

Planning objectives are listed as follows:

- Restore riparian vegetative communities within the river corridor to a more natural state.
- Increase the acreage of functional seasonal wetland habitat within the study area.
- Increase habitat diversity by providing a mix of habitats within the river corridor including the riparian fringe and buffer.
- Provide incidental flood control through ecosystem restoration to the extent that it does not impact the restoration object.
- Increase recreation and environmental education opportunities within the study area.

Efficiency: Efficiency is the extent to which an alternative plan is the most cost effective means to alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment.

IWR-Plan uses two techniques address the question: is the alternative worth it in the cost evaluation process? First, the results of the habitat assessment were compared using Cost Effectiveness Analysis (CEA). When comparing alternatives using CEA, those alternatives that produce increased levels of output (AAFCUs) for the same or lesser costs were considered "effective" solutions and were retained. These alternatives were compared based on cost efficiency (i.e. those alternatives that produce similar levels of output (AAFCUs at a lesser expense). The "efficient" solutions were submitted to Incremental Cost Analysis (ICA) (i.e. determining changes in costs for increasing levels of outputs). Once evaluated, through a computer program called IWR-Plan, on the basis of cost effectiveness and incremental cost analysis, the "best buy" solutions or alternatives resulting in the most output for the least cost were revealed (those that are both cost effective and incrementally efficient).

Plans 1C, 3C and 3D did not meet the criteria for completeness as determined by the study team, the sponsor and participating agency experts. While they raised overall function slightly, change in functional capacity was from very poorly functioning to poorly functioning and had the least gain in acres of all the proposed alternatives. Therefore, from a functional, biological perspective these alternatives were incomplete. Plans in the Cost Effective and Efficient Array meeting all the criteria for completeness were Alternative 1H, 2E-G, and 3B. Of these cost effective, efficient and complete alternatives, three were shown to be "best buy" solutions.

Acceptability: Acceptability is the workability and viability of the alternative plan with respect to acceptance by State, local entities and the public. Acceptability should also be compatible with existing laws, regulations, and public policies. The plans in the final array have features consistent with those identified as desirable by public work groups. These plans are also expected to comply with existing laws, regulations, and public policies.

I. Alternative Plans – Final Array

Based on the incremental analyses of the alternatives in the first array three alternatives were carried forward into the final array from which the recommended plan was selected. These plans were the "Best Buy" plans as illustrated in Figure 5.24.

These alternatives were:

Alternative 2H (1-terrgab-1): This alternative focuses on the implementation of only one set of terraces in the bend area, along with a low/high flow watercourse (FRW). Eight upstream basins will be implemented. In addition, under this alternative, there will be 12 gabions in the river channel for additional restoration efforts. Plant communities will include creation of new PWAAS as well as enhancement of existing PWAAS with plantings in Cottonwood-Willow, Mesquite, Scrub/Shrub, and Riverbottom. These planted areas will be irrigated.

Alternative 2F (2-terrgab-1): This alternative focuses on the implementation of two sets of terraces in the bend area, along with a low/high flow watercourse (FRW). Eight upstream basins will be implemented. In addition, under this alternative, there will be 12 gabions in the river channel for additional restoration efforts. Plant communities will include creation of new PWAAS as well as enhancement of existing PWAAS with plantings in Cottonwood-Willow, Mesquite, Scrub/Shrub, and Riverbottom.

Alternative 2E (2-terrgab-4): This alternative is the same as Alternative 2F (2-terrgab-1), except that new buffer areas will be created, and existing buffer areas will be enhanced with plantings.

J. Selection of a Recommended Plan

Comparison and Evaluation of Alternative Plans

The comparison and evaluation of alternatives involves the consideration of the effects that the plans will have on planning objectives and constraints. The following discussions address the differences and similarities between the alternatives and the baseline conditions. The four national accounts are also considered in the comparison and evaluation of alternative plans, as are the associated evaluation criteria.

National Objectives

In the 1970 Flood Control Act, Congress identified four equal national accounts for use in water resources development planning. They are national economic development (NED); regional economic development (RED); environmental quality (EQ); and social well being (OSE, other social effects). Policy in the 1970's regarded making contributions to only two of these, NED and EQ, as national objectives. Now only contributing to NED remains a national objective. However, these four categories of plan effects remain important considerations of water resource projects. The four categories, known as the System of Accounts and suggested by the U.S. Water Resources Council, address long-term impacts, defined in such a manner that each proposed plan can be easily compared to the no action plan and other alternatives. The Federal objective is taken from the "Economic and Environmental Principles and Guidelines for Water

and Related Land Resources Implementation Studies" also known as Principles and Guidelines or P&G. The P&G are one of the most important sources of Corps planning guidance.

"The Federal objective of water and related land resources planning is to contribute to national economic development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements."

Contributions to national economic development (NED) are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation. Recommended ecosystem restoration measures do not need to exhibit net NED benefits, but will be based on non-monetary outputs compatible with the P&G selection criteria. Although alternatives may produce incidental NED benefits, for this study, the NED account is replaced with the National Ecosystem Restoration (NER) account. Ecosystem restoration has become one of the primary missions of the Civil Works program. The National Ecosystem Restoration plan (NER) is the option with the greatest net ecosystem restoration benefits. The NER objective is to contribute to the Nation's ecosystems through restoration, with contributions measured by changes in the amounts and values of habitat. The four accounts used to compare the alternative plans have been modified to include the NER account, and the EQ, RED and OSE accounts.

NER Benefit Analysis of the Final Array

The NER account displays the monetary costs and the non-monetary benefits related to each alternative plan. The NER plan is identified by examining the net average annual functional capacity units (AAFCUs) for each alternative versus the net average annual costs for the alternative. Determination of the NER plan is typically the primary decision-making factor for identification of the recommended plan. The incremental cost analysis indicates that alternatives listed in Table 5.5 are cost effective and efficient incrementally. Alternative 2H (1-terrgab 1) ranks tenth based on average annual cost ($6.0 million) but ranks fourth in biological productivity and, at a cost of $49,700 annually per AAFCU, it ranks first. Alternative 2F (2-terrgab-1) will cost an extra $688,000 annually to produce 3 extra AAFCUs for an incremental cost of $229,000 per extra AAFCU. Alternative 2E (2-terrgab-4) will cost an additional $490,000 on an average annual basis and produce only 2 additional AAFCUs for an incremental cost of $245,000 on an average annual basis per additional AAFCU.

Table 5.5 Final Incremental Cost Analysis

Alt.	***AAFCUs***	***Annual Cost*** ($Millions)	***Average Cost ($Millions)***	***Incremental Cost ($Millions)***	***Incremental Output***	***Incremental Average Cost ($Millions)***
1-TERRGAB-1 (2h)	120	$5.96	$.0497	$5.9567	120	$.049639
2-TERRGAB-1 (2f)	123	$6.64	$.0540	$.6876	3	$.229186
2-TERRGAB-4 (2e)	125	$7.13	$.0570	$.4896	2	$.244809

Alternatives 2E, 2F and 2H are scaled variations of the same alternative. .Even though all of these Alternatives are very close in AAFCUs and rank among the top for biological productivity, Alternative 2H (1-terrgab-1) ranks first incrementally and fourth biologically. Incremental average costs more than quadruple from $49,700 to $229000 per AAFCU from Alternative 2H (1-terrgab-1) to Alternative 2F (2-terrgab-1). The jump increases for Alternative 2E (2-terrgab-4) at $245,000. Each incremental average cost jump among the tergab alternatives produced decreasing incremental outputs (3and 2). The three alternatives have nearly the same level of function at .49 and .50 so the higher output simply reflects the small increase in acres in 2F and 2E. Given the negligible increase in functionality, the small increase in area restored and the large increase in the incremental average costs selection of alternatives 2F or 2E is not warranted. Therefore, Alternative 2H is the NER plan.

Environmental Quality

The alternatives are forecast to have positive long-term impacts when compared to the no action alternative. They could have short-term negative impacts due to construction activities however; these could be mitigated through implementation of Best Management Practices. Environmental analysis detected no notable differences between Alternatives 2E, F and H with respect to impacts on water quality, air quality, noise, habitat, wildlife or endangered species. In addition, no differences were identified in alternative impacts to cultural resources and aesthetics. However, the plans do differ with respect to the number of acres restored and the ecosystem function restored (AAFCUs).

Regional Economic Development and Other Social Effects

None of the alternatives is forecast to have any quantifiable long-term effects on employment, causing growth or public health and safety when compared to the no action alternative. The plans are differentiated with respect to their annual operating costs and so have different effects on Local Government Finance as well as on Relocations Required and Open Space. When compared to the no action alternative, implementation of any of the alternatives, in concert with other proposed restoration actions, may help to sustain tourism related to bird watching and enjoyment of the environment. Implementation of any of the alternatives is expected to have positive long-term impacts on recreation and traffic, as detailed in the economic analysis.

These account and rankings for achievement of contributing to the four national accounts of the No Action Alternative, Alternatives, 2E, 2F and 2H are shown in Table 5.6 below. Although some of the variables are the same for each alternative, they have been included to preserve the distinction between the alternatives and the No Action Plan. Alternatives 1H, 2G, and 3C were not “Best Buy” plans and therefore, Alternatives 1H, 2G and 3C were not carried forward into the final array.

Table 5.6 Summary Comparison of Detailed Plans

	No Action	Alternative 2e	Alternative 2f	Alternative 2h
1. PLAN DESCRIPTION	No Action/Without Project Condition	2 Sets of terraces, known as the "Bend" Eight upstream basins Rillito low and high flow channel restoration Expanded and improved buffer areas Buffer areas enhanced with plantings 12 in-channel gabions for additional restoration Cottonwood/Willow, mesquite, shrub and grasses planted in the channel, in tributary mouths, and in water harvesting basins on the tributaries	2 sets of terraces, known as the "Bend" Eight upstream basins Rillito low flow channel restoration 12 in-channel gabions for additional restoration Cottonwood/Willow, mesquite, shrub and grasses planted in the channel, in tributary mouths, and in water harvesting basins on the tributaries	Set of terraces, known as the "Bend" 8 upstream basins A high and low-flow channel that supports mesquite habitat and joins the Finger Rock Wash with the Rillito River A distribution system for effluent supporting planted vegetation until established and in dry periods. 12 gabions Cottonwood/Willow, mesquite, shrub and grasses planted in the channel, in tributary mouths, and in water harvesting basins on the tributaries
2. IMPACT ASSESSMENT				
A. Environmental Quality (EQ)				
(1) Air Quality	Normal air quality levels created by business, traffic, and industrial activities. Ranks 4th.	Temporary air quality decrease due to construction. This will be mitigated through the implementation of Best Management Practices. However, this alternative may have positive long-term impacts when compared to the no action alternatives. Ranks 1st.	Temporary air quality decrease due to construction. This will be mitigated through the implementation of Best Management Practices. However, this alternative may have positive long-term impacts when compared to the no action alternatives. Ranks 1st.	Temporary air quality decrease due to construction. This will be mitigated through the implementation of Best Management Practices. However, this alternative may have positive long-term impacts when compared to the no action alternatives. Ranks 1st.
(2) Water Quality	Existing water quality is poor due to the high levels of certain pollutants. Ranks 4th.	Water quality may decrease temporarily due to construction. Best Management Practices will be implemented for mitigation. However, positive impacts over current conditions may occur in the long-term. Ranks 1st.	Water quality may decrease temporarily due to construction. Best Management Practices will be implemented for mitigation. However, positive impacts over current conditions may occur in the long-term. Ranks 1st.	Water quality may decrease temporarily due to construction. Best Management Practices will be implemented for mitigation. However, positive impacts over current conditions may occur in the long-term. Ranks 1st.
(3) Acres Restored	N/A Ranks 4th.	Projected increase of 345 acres. Ranks 1st.	Projected increase of 289 acres. Ranks 2nd.	Projected increase of 284 acres. Ranks 2nd.

Table 5.6: Summary Comparison of Detailed Plans for Rillito River, Arizona				
	No Action	**Alternative 2e**	**Alternative 2f**	**Alternative 2h**
(4) Incidental Acres Improved	N/A Ranks 4th.	Estimated increase of 107 acres of improved riverbottom. Ranks 1st.	Estimated increase of 107 acres of improved riverbottom. Ranks 1st.	Estimated increase of 107 acres improved riverbottom. Ranks 1st.
(5) Wildlife Habitat	Area is potential habitat to 18 Pima County Species of Interest. Vegetation is sparse and habitat is degraded in most places. Ranks 4th.	Wildlife habitat may decrease during construction, however, mitigation of Best Management Practices will be implemented. Wildlife habitat quality will improve with plantings and water in the long-term (see Acres restored and Incidental Acres Improved). Ranks 1st.	Wildlife habitat may decrease during construction, however, mitigation of Best Management Practices will be implemented. Wildlife habitat quality will improve with plantings and water in the long-term (see Acres restored and Incidental Acres Improved). Ranks 2nd.	Wildlife habitat may decrease during construction, however, mitigation of Best Management Practices will be implemented. Wildlife habitat quality will improve with plantings and water in the long-term (see Acres restored and Incidental Acres Improved). Ranks 2nd.
(6) Overall Ecosystem Function Restored (AAFCUs)	N/A Ranks 4th.	Overall projected net gain of 125. Ranks 1st.	Overall projected net gain of 123. Ranks 2nd.	Overall projected net gain of 120. Ranks 3rd.
(7) Cultural Resources & Historic Properties	Archeologists have counted 14 sites over the area of potential effects (APE). Three of the fourteen are eligible for the National Register. Ranks 4th.	Complete avoidance of these resources may be unsuccessful during the construction period. Therefore, a Memorandum of Agreement would be negotiated with the Arizona State Historic Preservation Officer and interested Native American Tribes. All archaeological, cultural and historic properties will be preserved as best as possible and the re-contour in the bend will add a historic appearance. Ranks 1st.	Complete avoidance of these resources may be unsuccessful during the construction period. Therefore, a Memorandum of Agreement would be negotiated with the Arizona State Historic Preservation Officer and interested Native American Tribes. All archaeological, cultural and historic properties will be preserved as best as possible and the re-contour in the bend will add a historic appearance. Ranks 1st.	Complete avoidance of these resources may be unsuccessful during the construction period. Therefore, a Memorandum of Agreement would be negotiated with the Arizona State Historic Preservation Officer and interested Native American Tribes. All archaeological, cultural and historic properties will be preserved as best as possible and the re-contour in the bend will add a historic appearance. Ranks 1st.

Table 5.6: Summary Comparison of Detailed Plans for Rillito River, Arizona				
	No Action	**Alternative 2e**	**Alternative 2f**	**Alternative 2h**
(8) Aesthetics	The views from and of the study area include: from the northern river boundary - the Santa Catalina Foothills; from the Foothills, the Rillito River, featuring natural washes, and recreation areas along the river; from the southern boundary, a bustling metropolitan area, and; from the Dodge Boulevard Bridge, a Tucson Electric Power Substation. The view of the river is characterized by soil cement, Sonoran mixed scrub and weeds, debris (household trash, tires, etc) and utility poles. These conditions would continue and possibly increase. Ranks 4th.	During construction, aesthetics may be adversely affected, however, many of these areas are not highly visible and are short-term. The implementation of 2e would eventually result in improved aesthetic views of riparian vegetation. This alternative would have the largest increase in restored acres and therefore the greatest area of visually pleasing habitat. Ranks 1st.	During construction, aesthetics may be adversely affected, however, many of these areas are not highly visible and are short-term. The implementation of 2f would eventually result in improved aesthetic views of riparian vegetation. This alternative has the second most restored acres and therefore would have the second largest area of visually pleasing habitat. Ranks 2nd.	During construction, aesthetics may be adversely affected, however, many of these areas are not highly visible and are short-term. The implementation of 2h would eventually result in improved aesthetic views of riparian vegetation. This alternative has the second largest amount of restored acres and therefore would have the third largest area of visually pleasing habitat. Ranks 2nd..
B. National Economic Development (NED)				
(1) NER Avg. Annual $/AAFCU (2) Incidental Flood Control Benefits (3) Recreational Benefits (4) CEA Ranking (5) 1st Costs (6) Total Average Annual Costs	N/A N/A N/A N/A N/A N/A Ranks 4th	$57,000 $270,404 $298,860 3 $88,946,000 $7,133,857 Ranks 3rd	$54,000 $270,404 $298,860 2 $81,466,000 $6,644,000 Ranks 2nd	$49,700 $270,404 $298,860 1 $71,682,000 $5,957,000 Ranks 1st
C. Regional Economic Development (RED)				
(1) Local Government Finance for O&M	No changes in financing. Ranks 1st.	Largest financial increases for O&M. Ranks 4th.	Second highest financial increases for O&M. Ranks 3rd.	Third highest financial increases for O&M. Ranks 2nd.
(2) Tourism	No changes. Ranks 4th.	Increased habitat may bring increased tourism due to increased wildlife viewing opportunities and improved aesthetics. Ranks 1st.	Increased habitat may bring increased tourism due to increased wildlife viewing opportunities and improved aesthetics. Ranks 2nd.	Increased habitat may bring increased tourism due to increased wildlife viewing opportunities and improved aesthetics. Ranks 2nd.

Table 5.6: Summary Comparison of Detailed Plans for Rillito River, Arizona				
	No Action	**Alternative 2e**	**Alternative 2f**	**Alternative 2h**
D. Other Social Effects (OSE)				
(1) Life, Health, and Safety	No change. Ranks 4th.	Improvement in trails and increased number of ramps will increase health and safety. Ranks 1st.	Improvement in trails and increased number of ramps will increase health and safety. Ranks 1st.	Improvement in trails and increased number of ramps will increase health and safety. Ranks 1st.
(2) Displacement of croplands, orchards and grazing (No replacement of residences, businesses or industries is expected.)	No change. Ranks 1st.	Requires the most acres. Ranks 4th.	Requires the second most acres. Ranks 2nd.	Requires the second least amount of acres. Ranks 2nd.
(3) Community Cohesion	No change. Ranks 4th.	The community favors restoration over the no action alternative and therefore any alternative is more cohesive than the No Action Alternative. Ranks 2nd.	The community favors restoration over the no action alternative and therefore any alternative is more cohesive than the No Action Alternative. Ranks 1st.	The community favors restoration over the no action alternative and therefore any alternative is more cohesive than the No Action Alternative. Ranks 1st.
(4) Recreation	No change. Ranks 4th.	Increases carrying capacity of existing trail system and increase accessibility. Also restores habitat that expands recreation opportunities. Ranks 1st.	Increases carrying capacity of existing trail system and increase accessibility. Also restores habitat that expands recreation opportunities. Ranks 1st	Increases carrying capacity of existing trail system and increase accessibility. Also restores habitat that expands recreation opportunities. Ranks 1st
3. Plan Evaluation				
A. Contribution to Planning Objectives				
(1) Restore wildlife species habitat for threatened, endangered, and sensitive species and species of concern within the study area.	None Ranks 4th.	Alternative includes restoration/new plantings of cottonwood-willow forests, mesquite woodlands, river bottom, cienega, and scrub-shrub land. Ranks 1st.	Alternative includes restoration/new plantings of cottonwood-willow forests, mesquite woodlands, river bottom, cienega, and scrub-scrublands. Ranks 1st.	Alternative includes restoration/new plantings of cottonwood-willow forests, mesquite woodlands, river bottom, cienega, and scrub-scrublands. Ranks 1st.
(2) Restoration of El Rio Antiguo to a more natural condition through the planting of plant species that are native to and occurred historically in riparian streams and washed in the region	None Ranks 4th.	Restoration includes over 100 acres of new cottonwood-willow forests, about 40 acres new buffer zones, about 100 new acres of mesquite bosque, 10 new acres of new riverbottom, cienegas, and about 35 new acres of scrub-shrub. Ranks 1st.	This alternative includes about 100 acres of new cottonwood-willow forests, about 100 new mesquite bosque acres, almost 10 new acres of riverbottom, or cienegas, and about 35 new acres of scrub-shrub. Ranks 2nd.	The 2h alternative is expected to produce over 90 new acres of cottonwood-willow forest, over 100 new acres of mesquite bosque, about 5 new acres of riverbottom, or cienegas, and about 40 new acres of scrub-shrub. Ranks 2nd.

Table 5.6: Summary Comparison of Detailed Plans for Rillito River, Arizona				
	No Action	**Alternative 2e**	**Alternative 2f**	**Alternative 2h**
(3) Increase the acreage of functional seasonal wetland habitat within the study area.	No Increase. Ranks 4th.	This alternative is projected to increase riverbottom, cienegas, by 9 acres. Ranks 1st.	This alternative is projected to increase riverbottom, cienegas, by 9 acres. Ranks 1st.	This alternative is projected to increase riverbottom, cienegas, by 7 acres. Ranks 1st.
(4) Increase recreation opportunities to the extent that they protect or do not impact restoration	No Increase. Ranks 4th.	Alternative connects new trails to existing trails and guides recreation away from sensitive areas. Ranks 1st.	Alternative connects new trails to existing trails and guides recreation away from sensitive areas. Ranks 1st.	Alternative connects new trails to existing trails and guides recreation away from sensitive areas. Ranks 1st.
(5) Provide incidental flood control through ecosystem restoration to the extent that it does not impact the restoration object	None. Ranks 4th.	Incidental flood damage reduction results from restoration features in the Finger Rock Wash area. Ranks 1st.	Incidental flood damage reduction results from restoration features in the Finger Rock Wash area. Ranks 1st.	Incidental flood damage reduction results from restoration features in the Finger Rock Wash area. Ranks 1st.
B. Response to Planning Constraints				
(1) Limited availability of water to support establishment and maintenance of healthy riparian habitats	NA Ranks 1st.	Sufficient reclaimed water will be provided and water-harvesting methods will be committed to establish and sustain vegetation. This alternative requires 1546 acre-feet/year of reclaimed water. In many years, water harvesting will reduce the required volume of reclaimed water. Ranks 4th.	Sufficient reclaimed water will be provided and water-harvesting methods will be committed to establish and sustain vegetation. This alternative requires 1462 acre-feet/year of reclaimed water. In many years water harvesting will reduce the required volume of reclaimed water Rank 3rd	Sufficient reclaimed water will be provided and water-harvesting methods will be committed to establish and sustain vegetation. This alternative requires 1410 acre-feet/year of reclaimed water. . In many years water harvesting will reduce the required volume of reclaimed water Ranks 2nd.
(2) Restoration cannot be done in a way that it would substantially reduce the capacity of the Rillito or its tributary washes to convey damaging flood flows.	N/A Ranks 1st	Alternative includes channel widening along the Bend, flood flows diverted at Craycroft to behind soil cement, and vegetation washes out with major flood events. Ranks 1st	Alternative includes channel widening along the Bend, flood flows diverted at Craycroft to behind soil cement, and vegetation washes out with major flood events. Ranks 1st	Alternative includes channel widening along the Bend, flood flows diverted at Craycroft to behind soil cement, and vegetation washes out with major flood events. Ranks 1st
(3) Project must be formulated to avoid impacts from existing and planned recreational facilities in adjoining areas	N/A Ranks 1st	Meets concern, plus, additional recreation is planned that will direct recreation away from sensitive areas. In addition, trail linkages are planned for existing trails to minimize trail blazing. Ranks 1st	Meets concern, plus, additional recreation is planned that will direct recreation away from sensitive areas. In addition, trail linkages are planned for existing trails to minimize trail blazing. Ranks 1st	Meets concern, plus, additional recreation is planned that will direct recreation away from sensitive areas. In addition, trail linkages are planned for existing trails to minimize trail blazing. Ranks 1st

Table 5.6: Summary Comparison of Detailed Plans for Rillito River, Arizona				
	No Action	**Alternative 2e**	**Alternative 2f**	**Alternative 2h**
(4) Cannot jeopardize the continued existence of threatened or endangered species or to destroy or adversely modify their habitat. Furthermore, restoration may attract T&E species. Project 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.	N/A Ranks 1st	The new habitat will wash away with flood events, which will not adversely impact the ability to preserve flood control functions and maintenance of the channels. In addition, the increased habitat should provide species alternative habitat should a flood event occur. Ranks 1st	The new habitat will wash away with flood events, which will not adversely impact the ability to preserve flood control functions and maintenance of the channels. In addition, the increased habitat should provide species alternative habitat should a flood event occur. Ranks 1st	The new habitat will wash away with flood events, which will not adversely impact the ability to preserve flood control functions and maintenance of the channels. In addition, the increased habitat should provide species alternative habitat should a flood event occur. Ranks 1st
Summary Total Points	78	36	36	34

Selection of a Recommended Plan

After consideration of the National Objectives and other associated evaluation criteria, Alternative 2H (1-Tergab-1) is selected as the recommended plan. Alternative 2H was selected because:

1. It rated first for average cost and ICA and fourth for biological output. It was not only incrementally effective and efficient it was biologically strong.
2. Incremental average costs more than quadruple from $49,700 to $229,000 per AAFCU from Alternative 2H (1-terrgab-1) to Alternative 2F (2-terrgab-1). The jump is even greater for Alternative 2E (2-TERRGAB-4) at $245,000. Each incremental average cost jump among the Alternatives 2H, 2F and 2E produced decreasing incremental outputs (3and2).

This plan causes an incidental reduction of flooding caused by Finger Rock. However, flood depths from Rillito River will remain approximately the same under this plan, but if any increased depths from Rillito result from the restoration project, flooding will be mitigated

A recreation plan is included with a B/C ratio of 1.46. This plan complements the restoration plan by helping to minimize human interference and adds to the established park in a beneficial way that promotes and protects restoration goals.

From a partnership context and acceptability aspect, Alternative 2H best meets the objectives of the study sponsor, Pima County Flood Control and Transportation District. Alternative 2H appropriately addresses the balance between ecosystem restoration and the need to maintain the existing level flood protection.

K. Recreation Plan

As discussed in the Existing Conditions section of this report, the Rillito River Park (constructed as part of the US Army Corps of Engineers Rillito River Bank Protection Project) already exists. It runs the entire length of the El Rio Antiguo study area and acts as a primary trail linking several local parks in the area. The park facilities include: an exercise course, multiple use trails for pedestrian, equestrian, and bicyclists, restrooms, parking and an art project.

Even though the Rillito River Park already exists along the El Rio Antiguo, changes can be made to the park to increase recreation value, direct human activity away from restoration measures and perhaps increase visitation along the Rillito River and Finger Rock Wash area. Decomposed granite (DG) multipurpose trails, a pedestrian bridge, parking, and trail links serve a recreation purpose by providing opportunities to a variety of recreational users. Signs interpret the environment thereby enhancing recreation experience of the user. Comfort stations serve the basic safety needs of the recreational user. Other changes to the park can serve the ecosystem restoration purpose by reducing safety and maintenance concerns stemming from the project. All road segments and ramps designated as maintenance provide access to areas in case of emergencies such as flooding and fire. Access will also provide a means to maintain vegetation in the newly restored area and park facilities. Warning signs are also added to direct pedestrians off the newly restored area and guide pedestrians away from any potential danger. Detailed information regarding the costs and benefits associated with the Recreation Plan are presented in Chapter VI, Description of the Plan Selected for Recommendation.

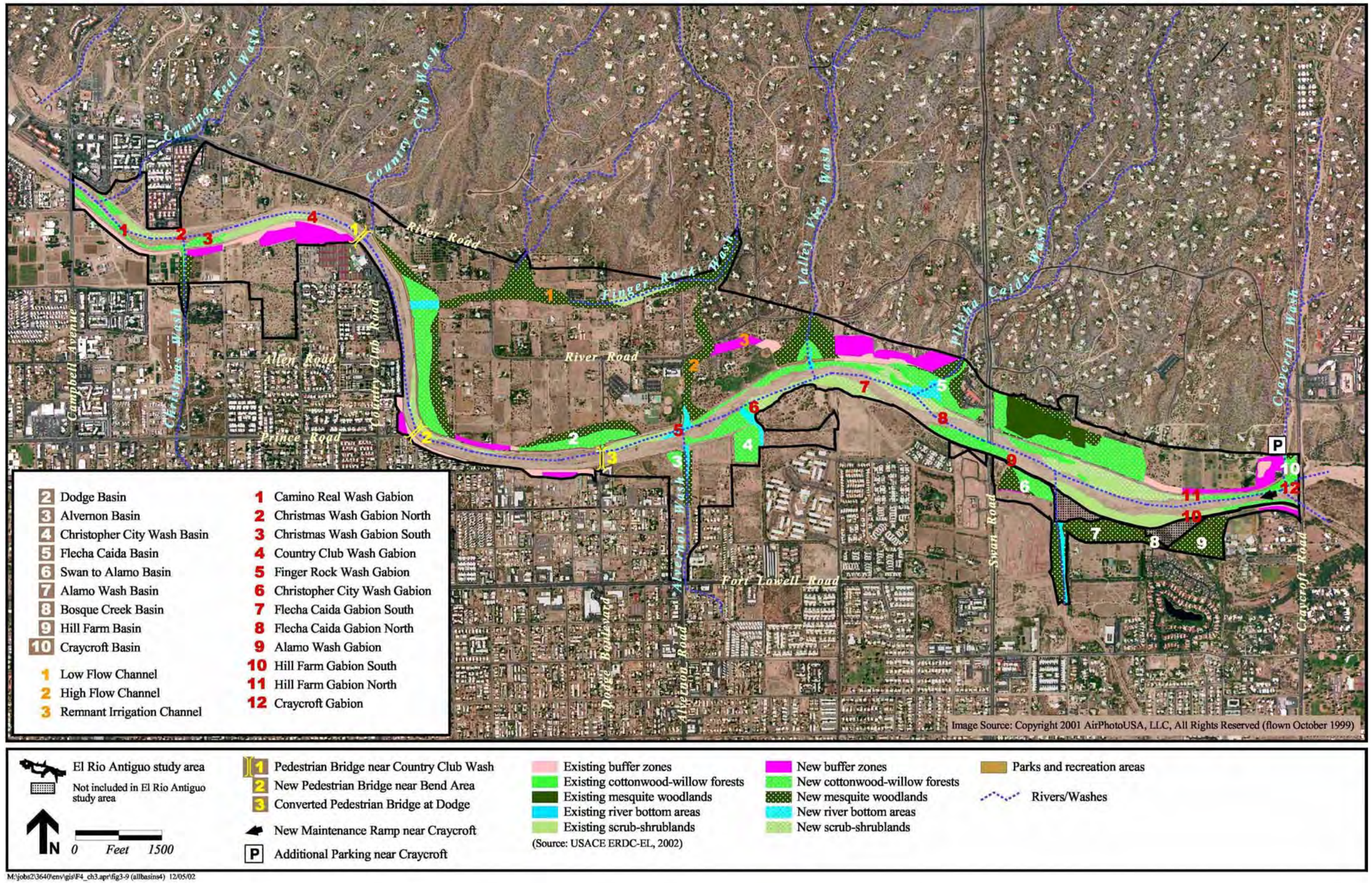


Figure 5.1 Alternative 1A - All Basins 4

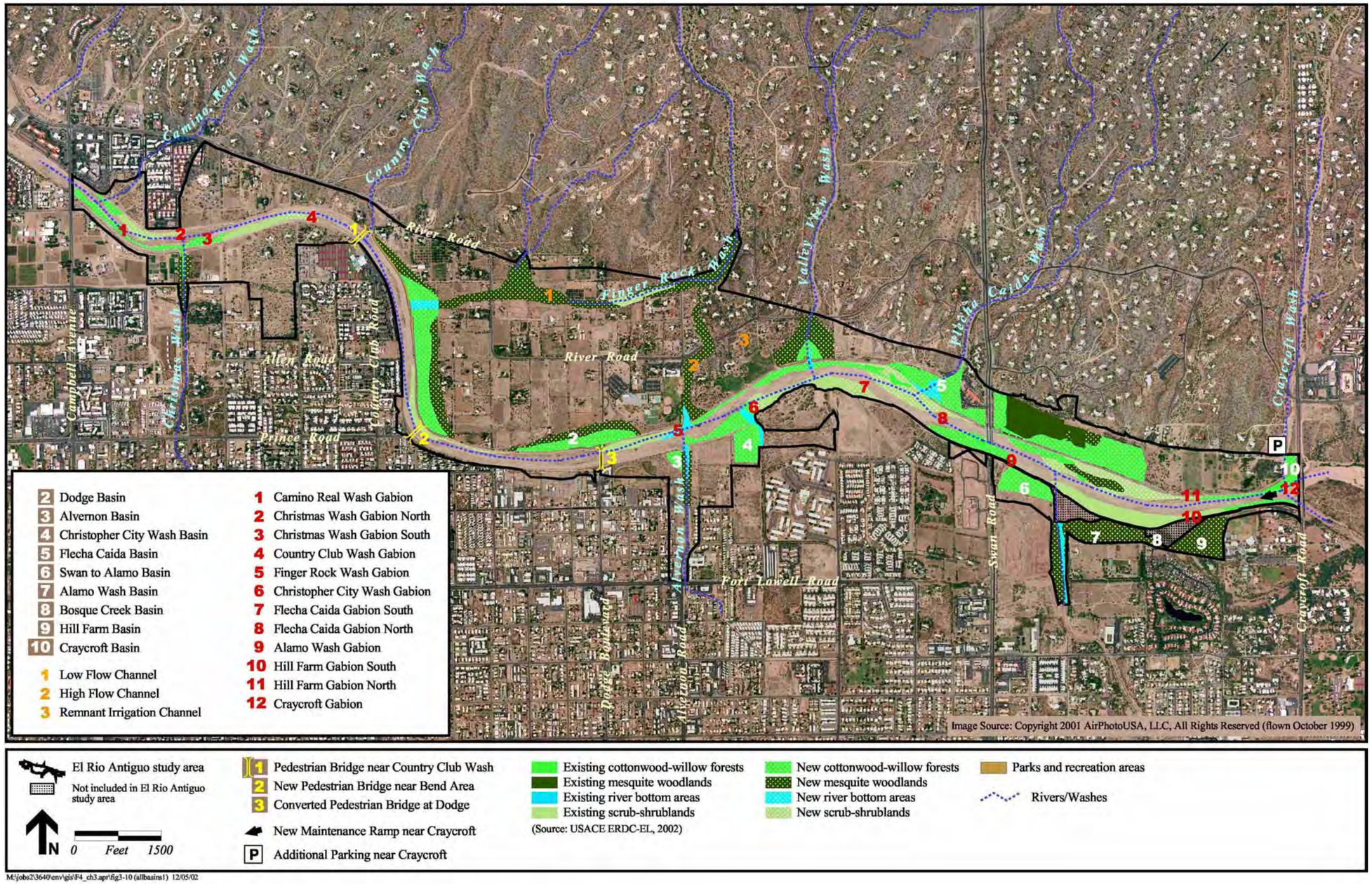


Figure 5.2 Alternative 1B - All Basins 1

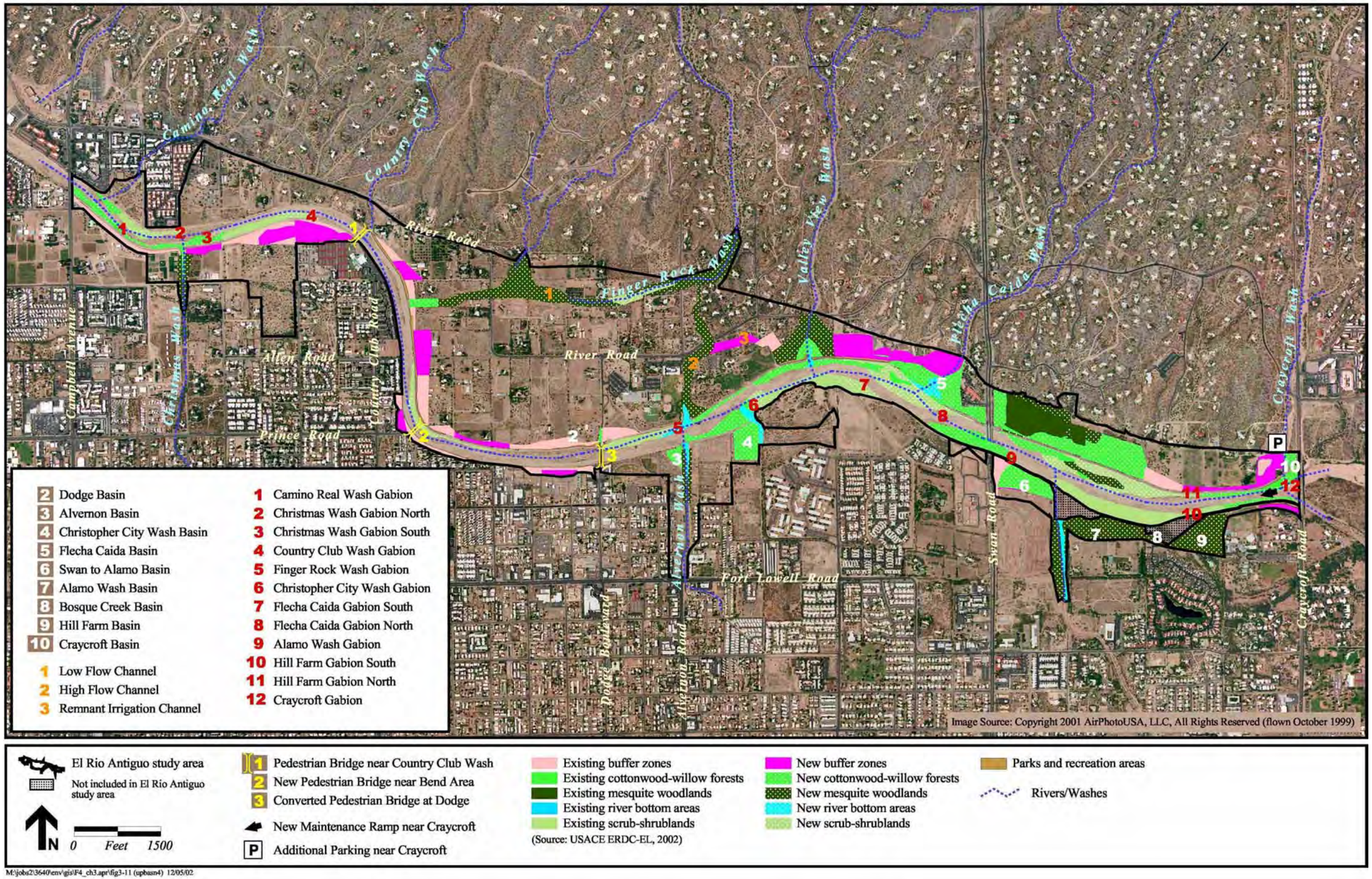


Figure 5.3 Alternative 1C – Upstream Basins 4

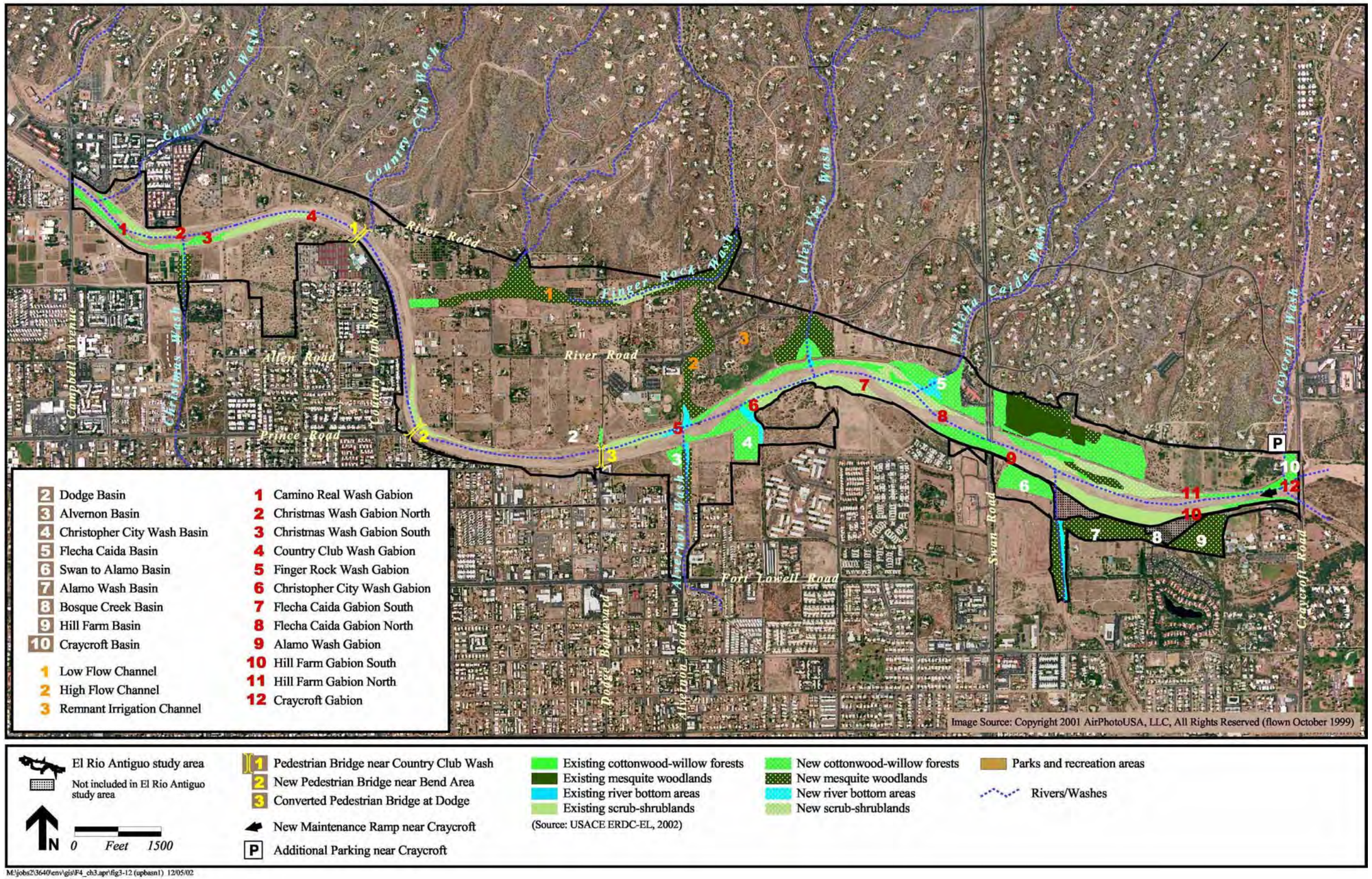


Figure 5.4 Alternative 1D – Upstream Basins 1

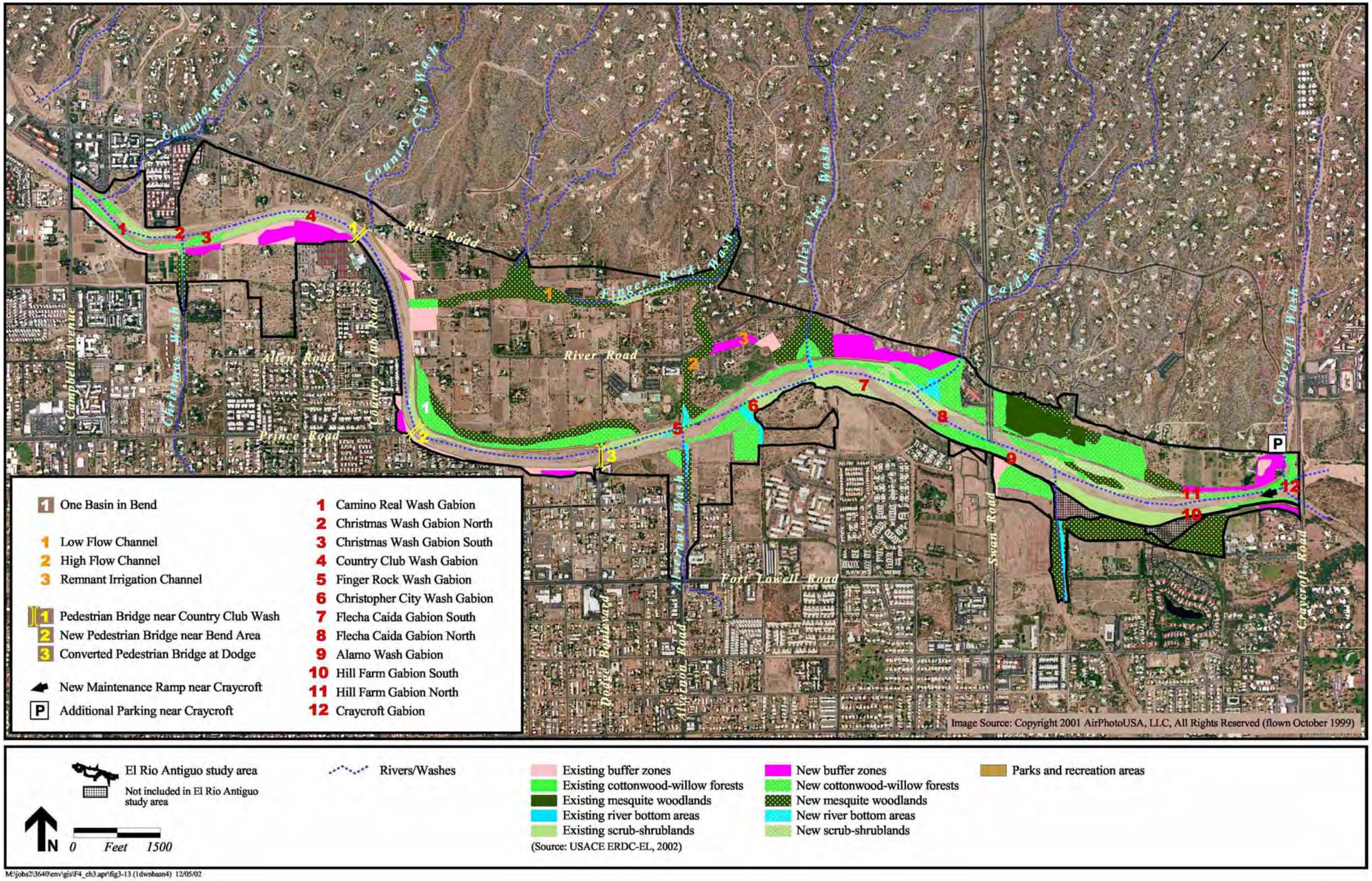


Figure 5.5 Alternative 1E – 2 Downstream Basins 4

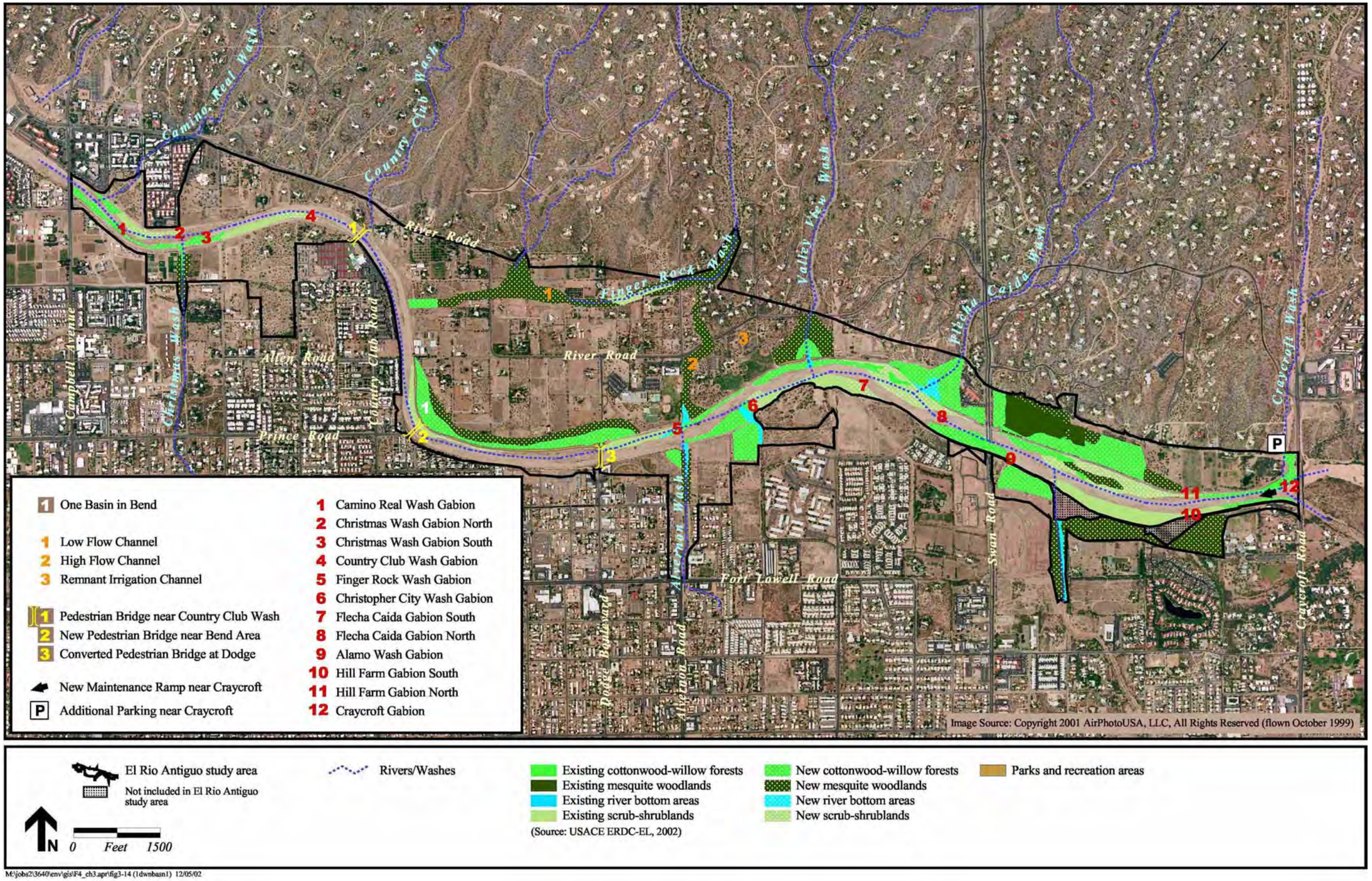


Figure 5.6 Alternative 1F – 2 Downstream Basins 1

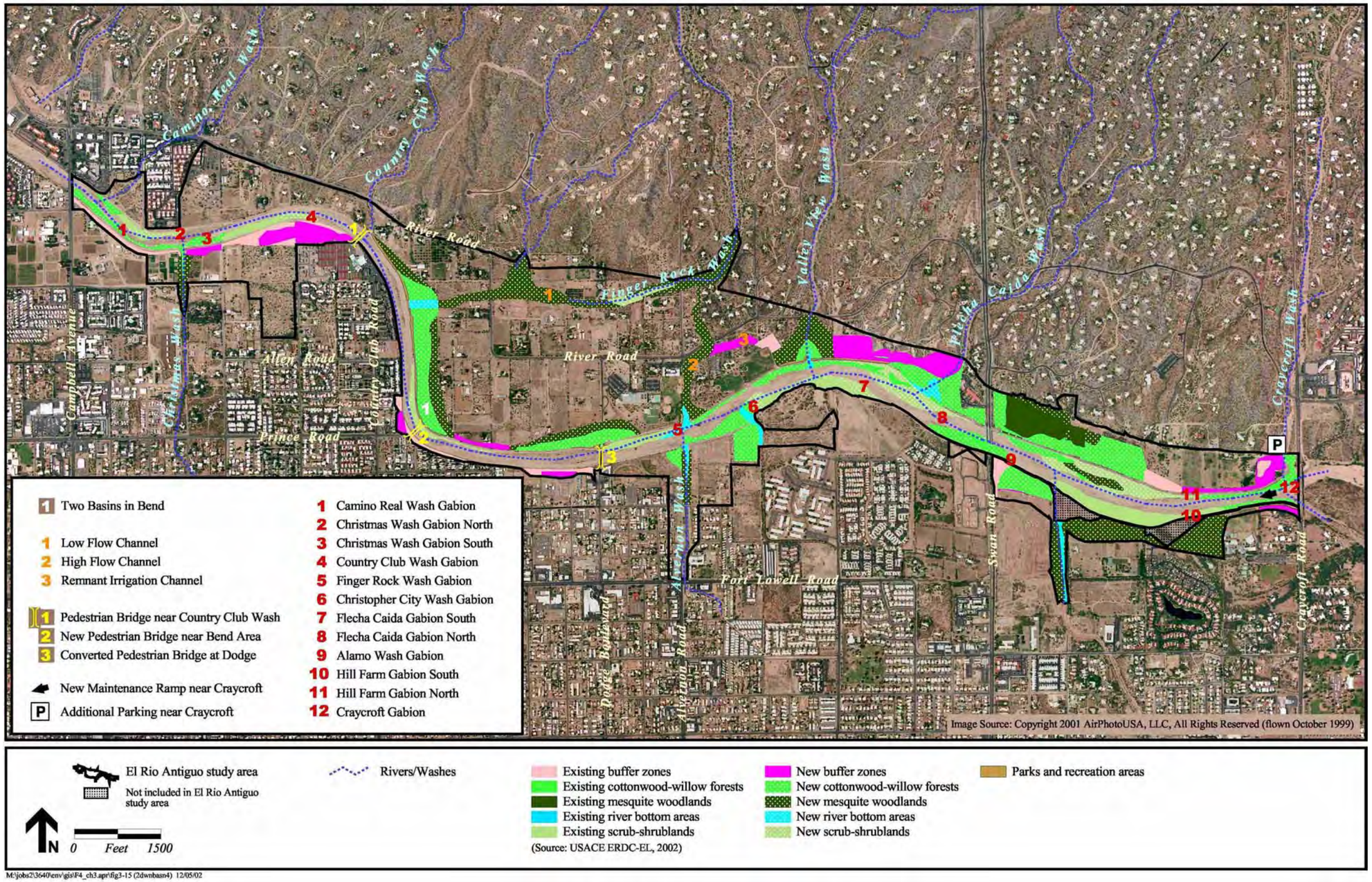


Figure 5.7 Alternative 1G – 1 Downstream Basin 4

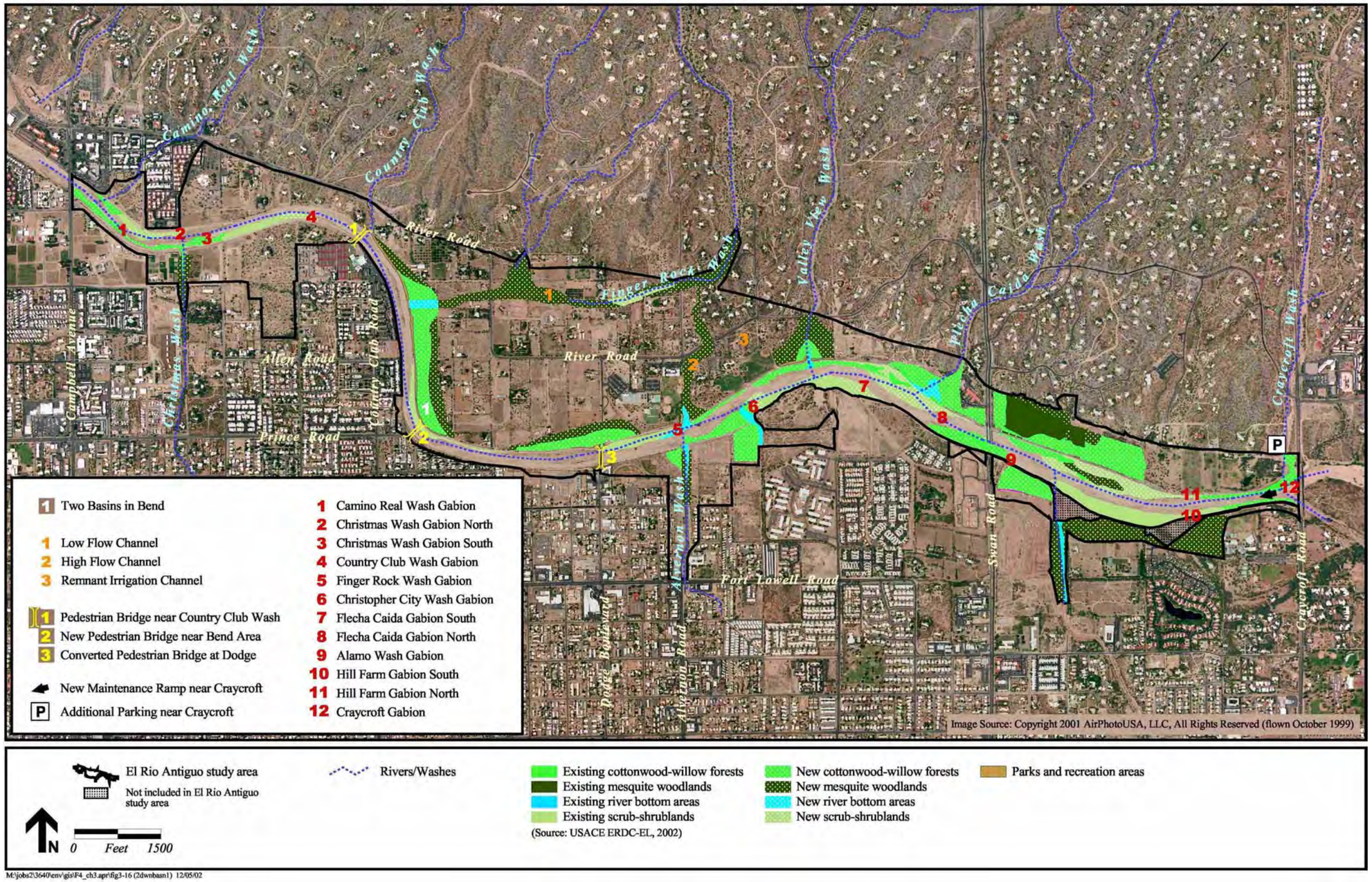


Figure 5.8 Alternative 1H - 1 Downstream Basin 1

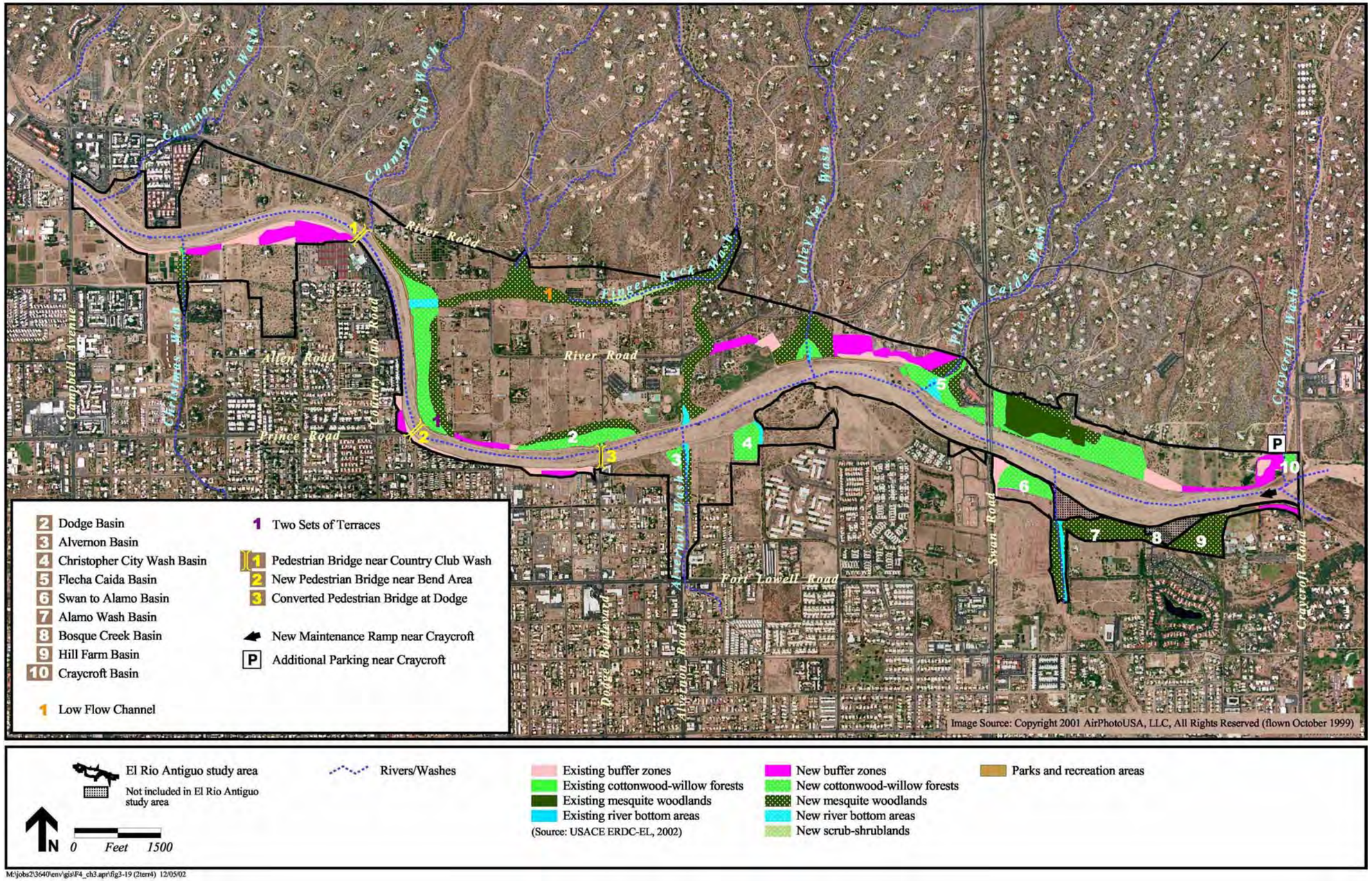


Figure 5.9 Alternative 2A – 2 Terraces 4

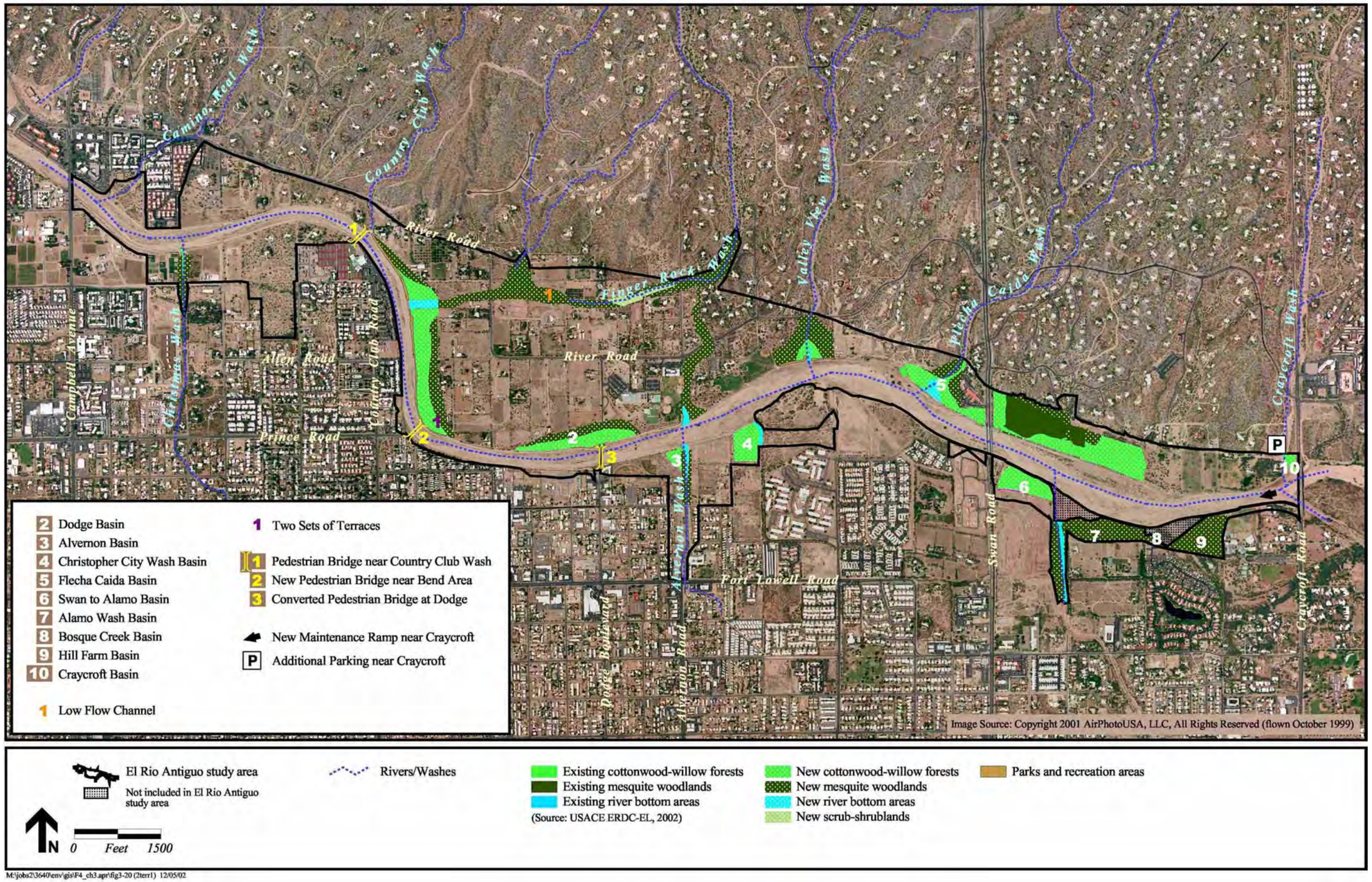


Figure 5.10 Alternative 2B – 2 Terraces 1

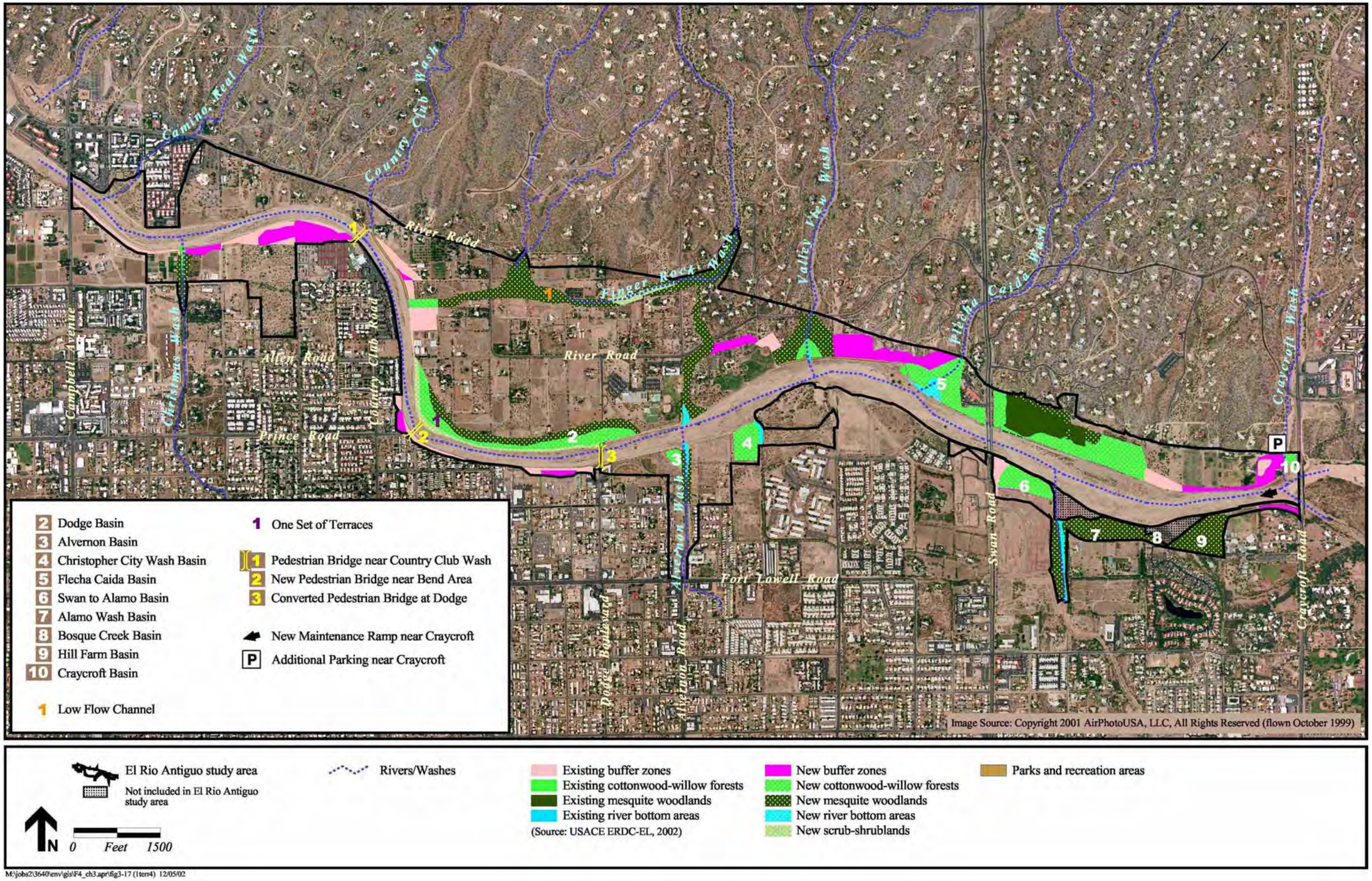


Figure 5.11 Alternative 2C – 1 Terrace 4

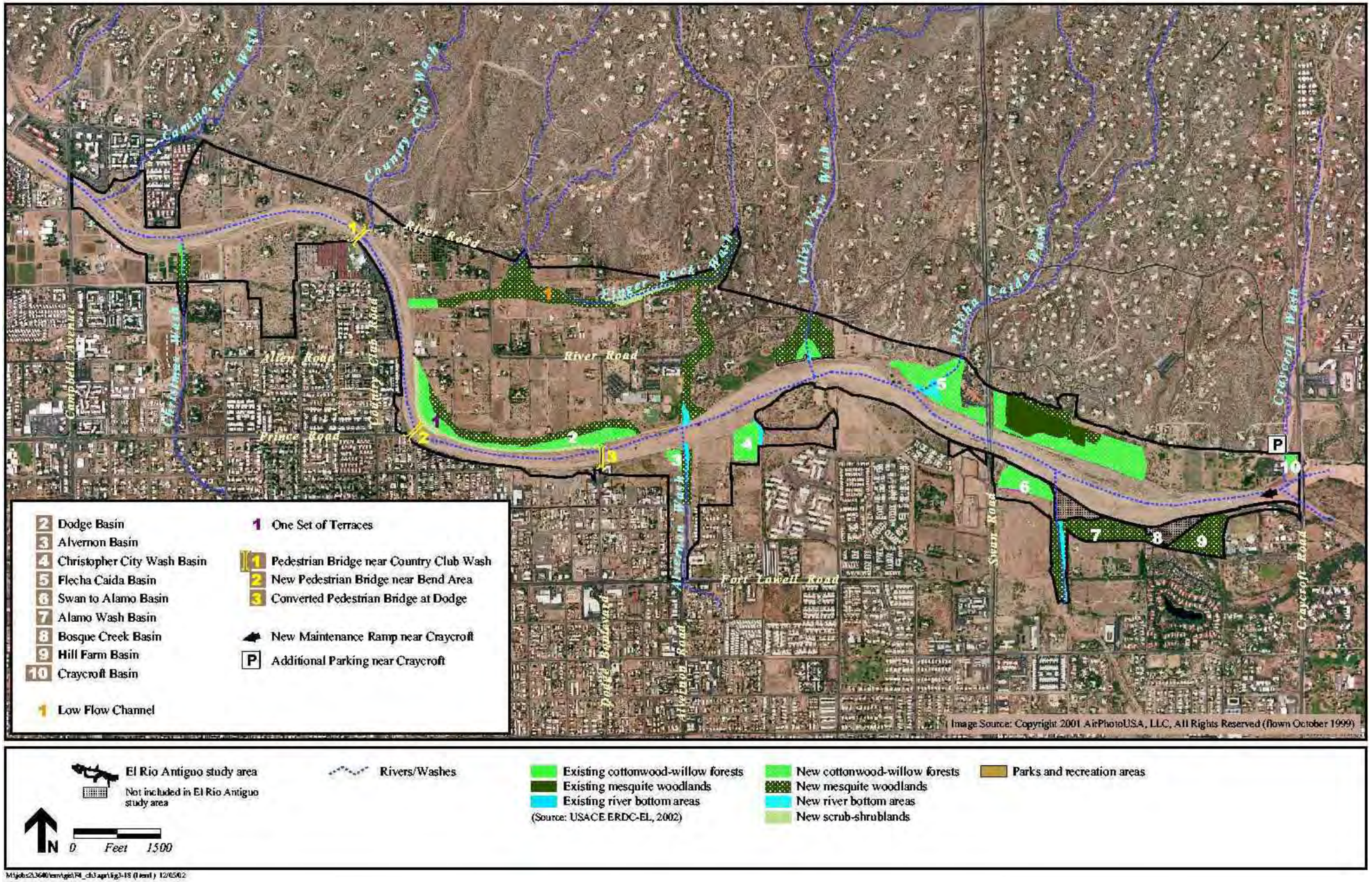
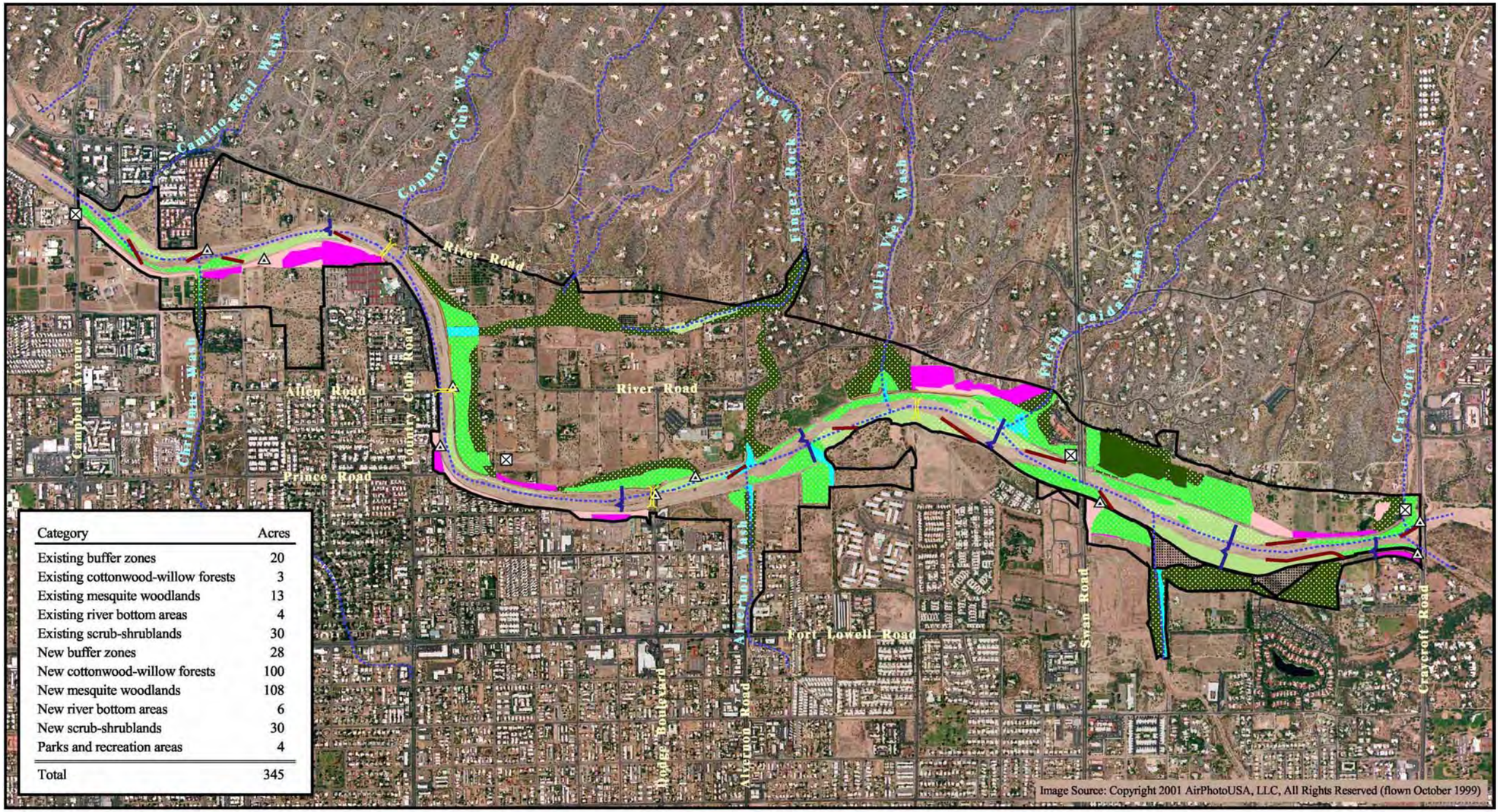


Figure 5.12 Alternative 2D – 1 Terrace 1



Category	Acres
Existing buffer zones	20
Existing cottonwood-willow forests	3
Existing mesquite woodlands	13
Existing river bottom areas	4
Existing scrub-shrublands	30
New buffer zones	28
New cottonwood-willow forests	100
New mesquite woodlands	108
New river bottom areas	6
New scrub-shrublands	30
Parks and recreation areas	4
Total	345

El Rio Antiguo study area
Not included in El Rio Antiguo study area
Rivers/Washes
N
0 Feet 1500
Existing or proposed bridges
Access ramps
Comfort stations
Grade control
Gabion
Existing buffer zones
Existing cottonwood-willow forests
Existing mesquite woodlands
Existing river bottom areas
Existing scrub-shrublands
Parks and recreation areas
New buffer zones
New cottonwood-willow forests
New mesquite woodlands
New river bottom areas
New scrub-shrublands
(Source: USACE ERDC-EL, 2002)

M:\jobs2\3640\env\gis\F4_ch3.apr\fig3-21 (2terrgab4) 04/07/03

Figure 5.13 Alternative 2E – 2 Tergab 4

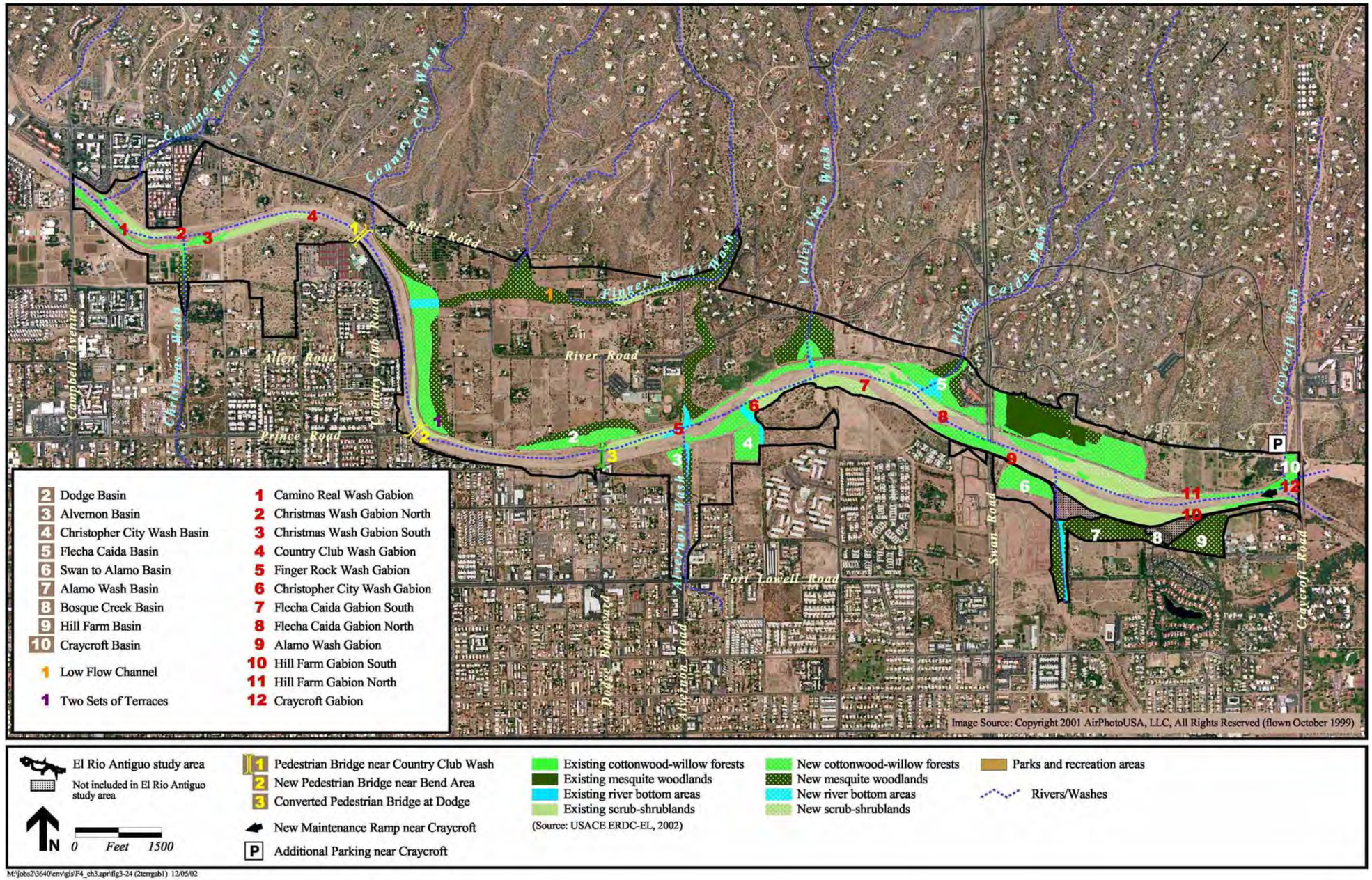


Figure 5.14 Alternative 2F 2 Tergab 1

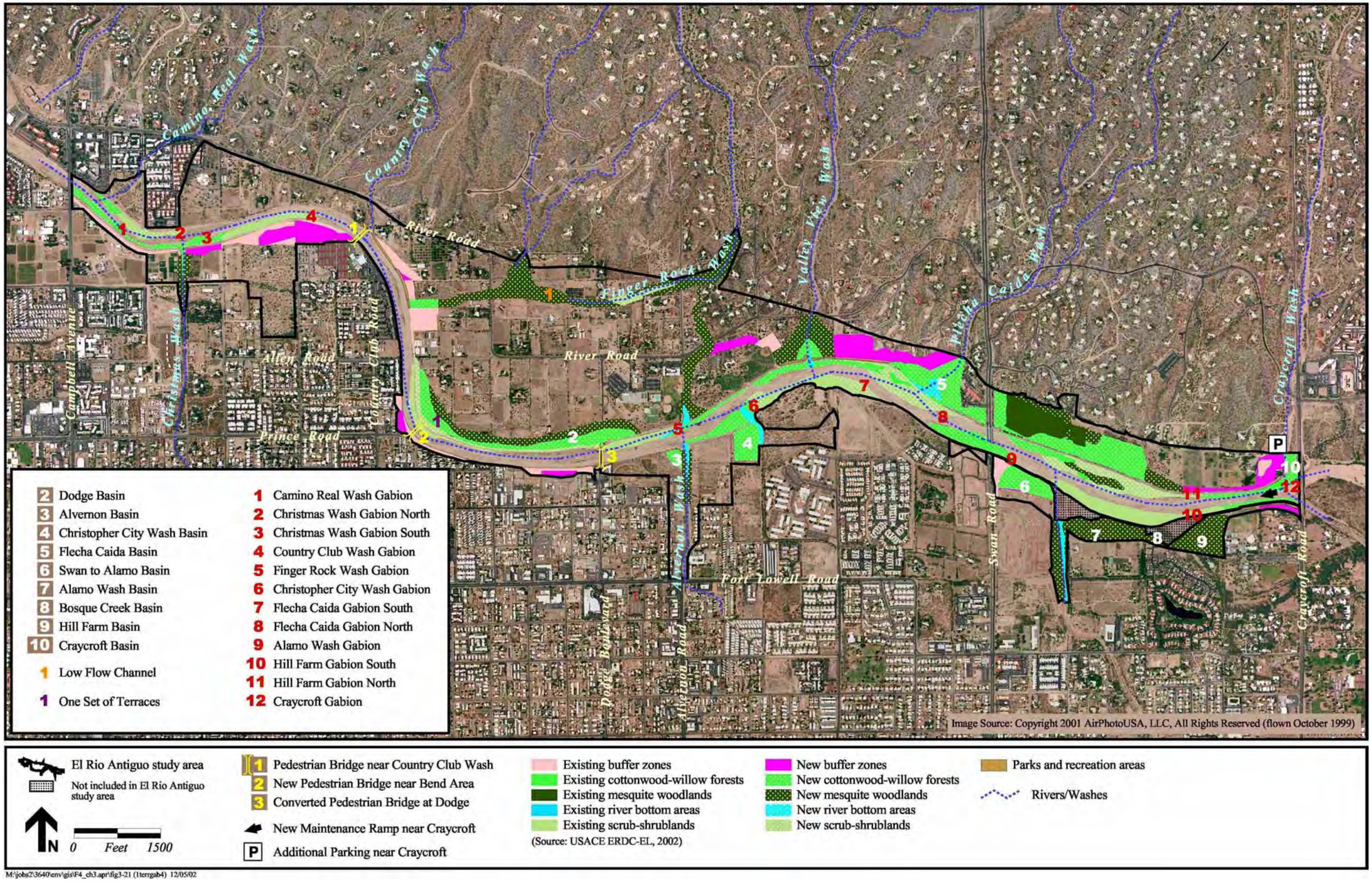


Figure 5.15 Alternative 1G – 1 Tergab 4

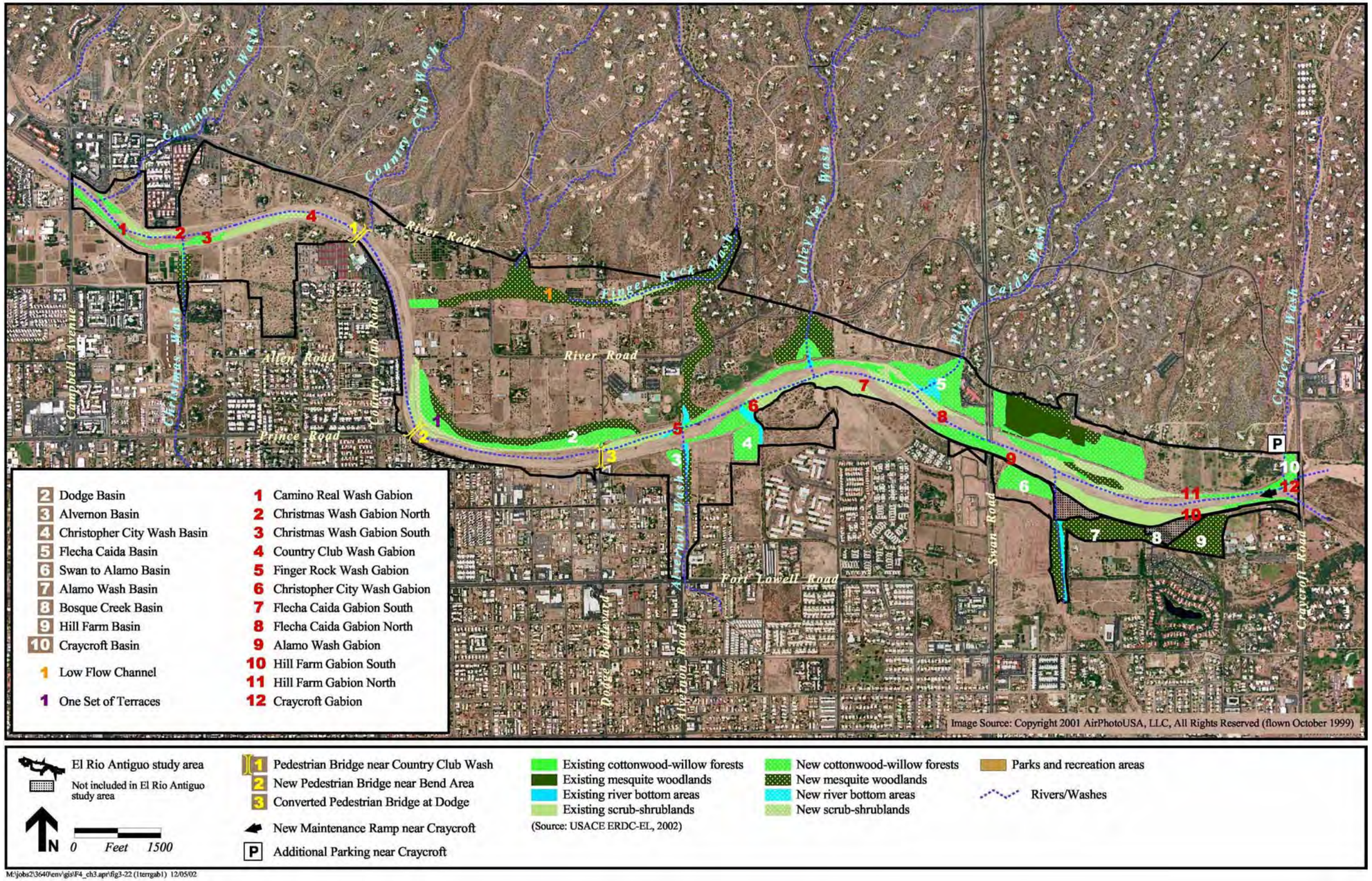


Figure 5.16 Alternative 2H – 1 Tergab 1

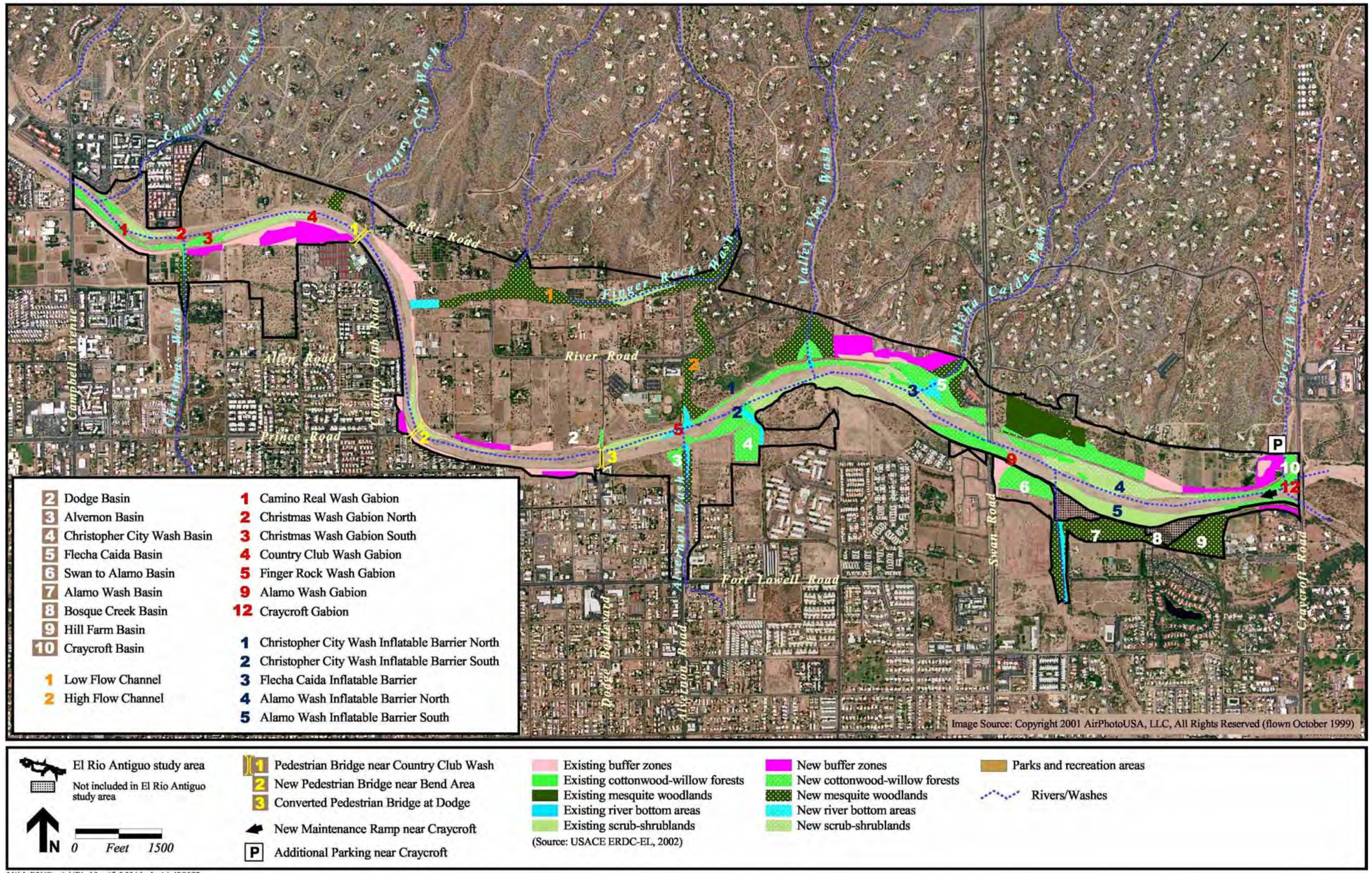


Figure 5.17 Alternative 3A – Chanbar 4A

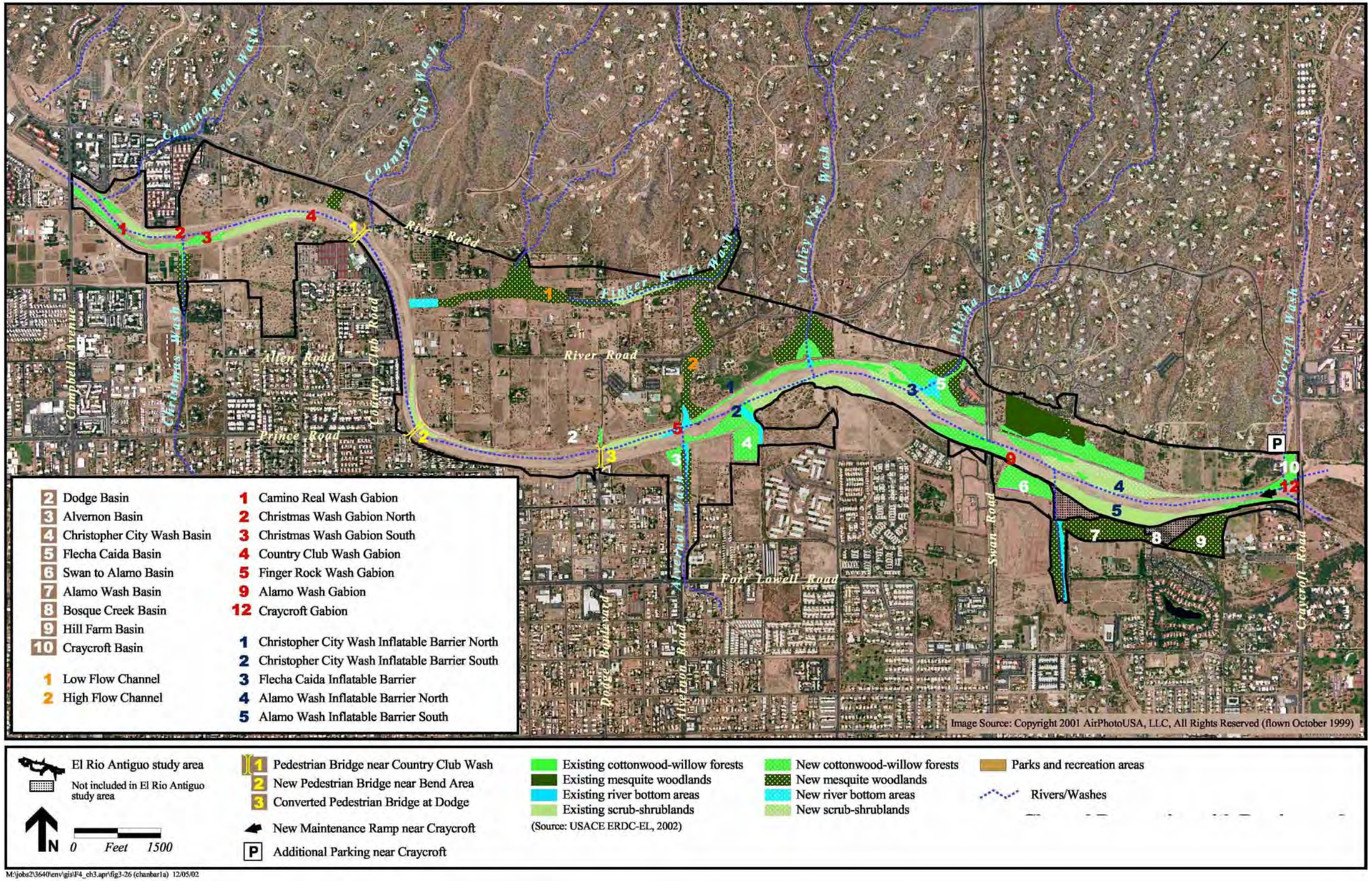


Figure 5.18 Alternative 3B – Chanbar 1a

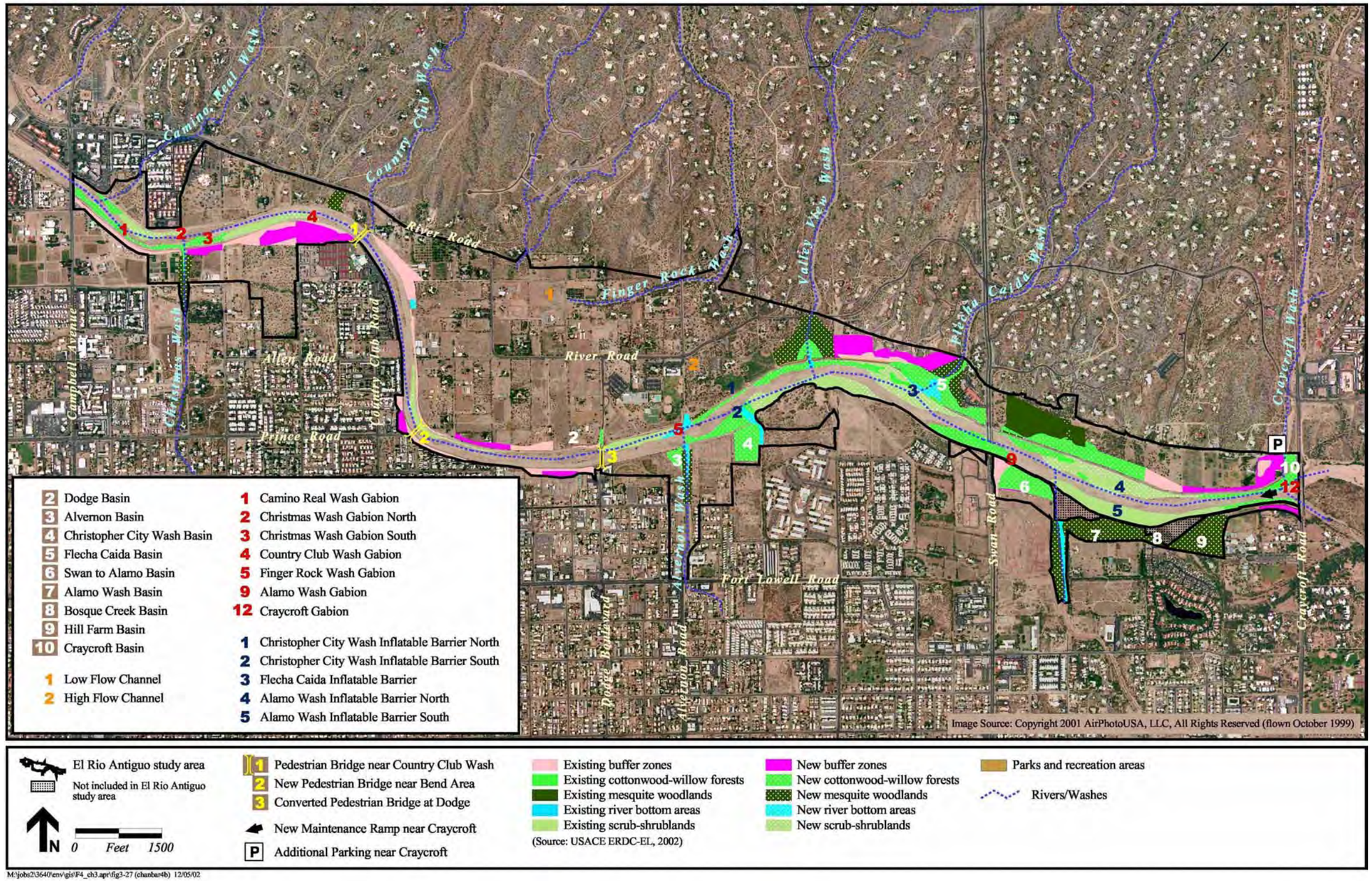


Figure 5.19 Alternative 3C – Chanbar 4b

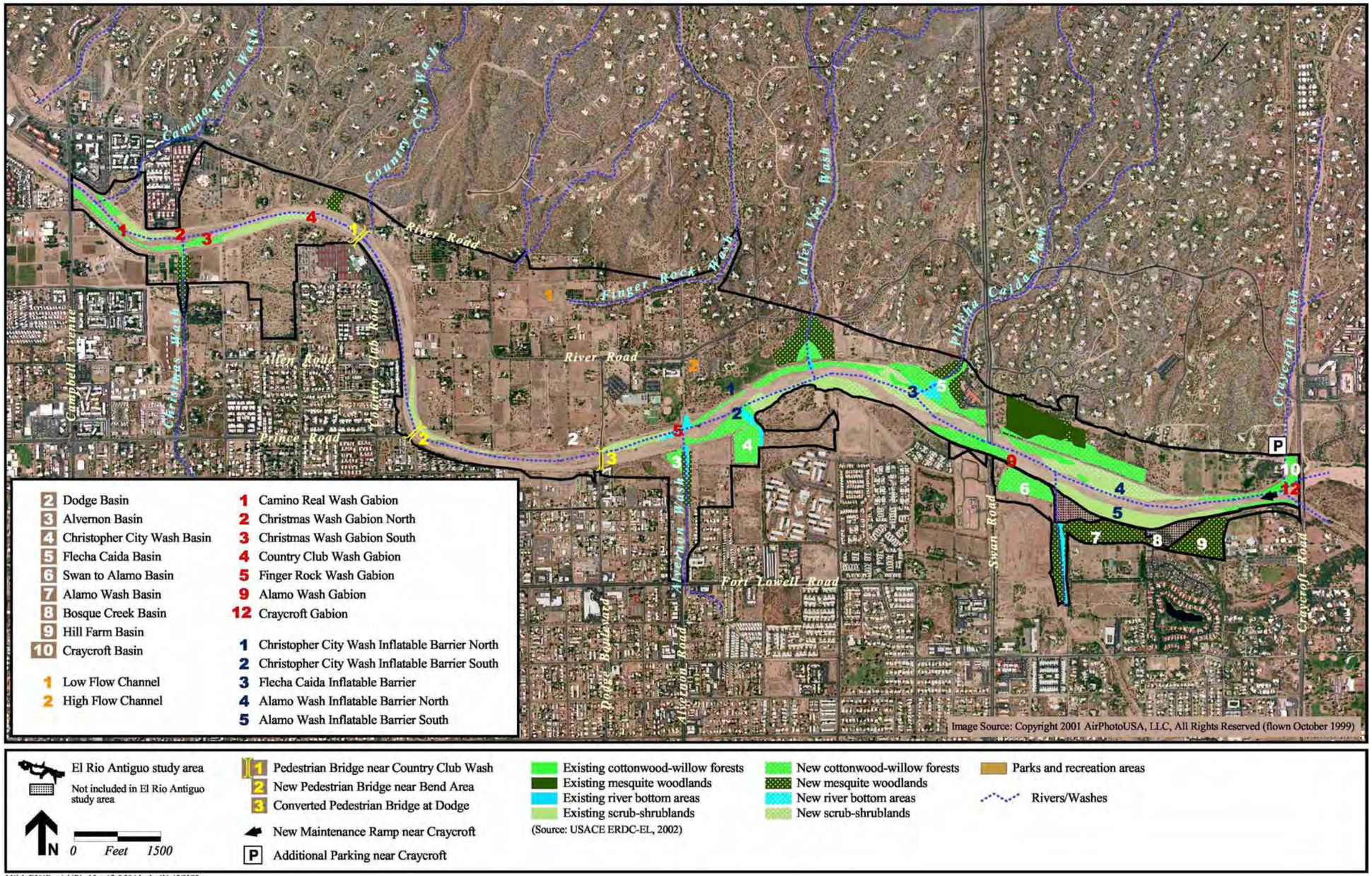


Figure 5.20 Alternative 3D - Chanbar 1b

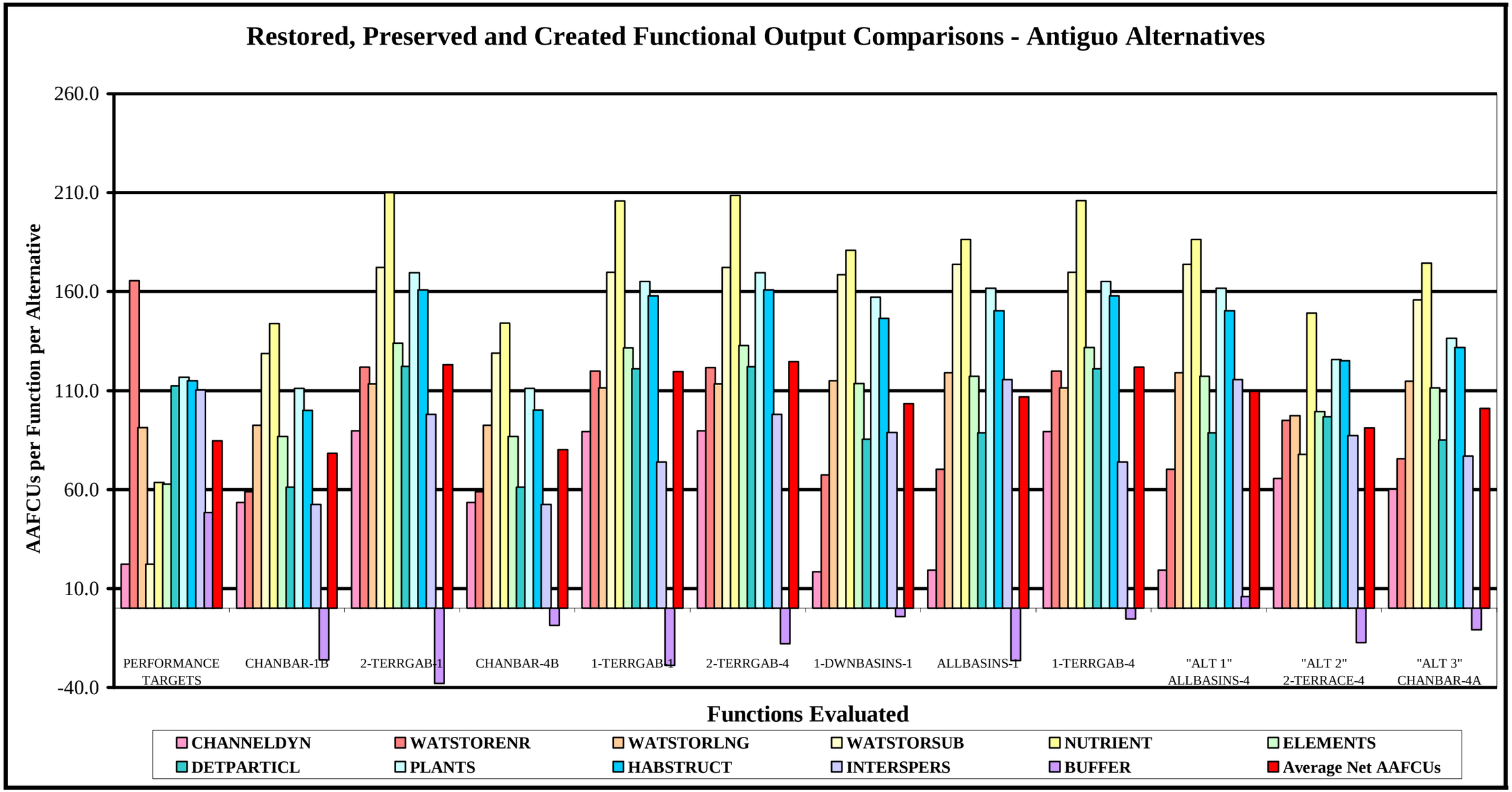


Figure 5.21 Restored, Preserved & Created Functional Outputs Comparisons

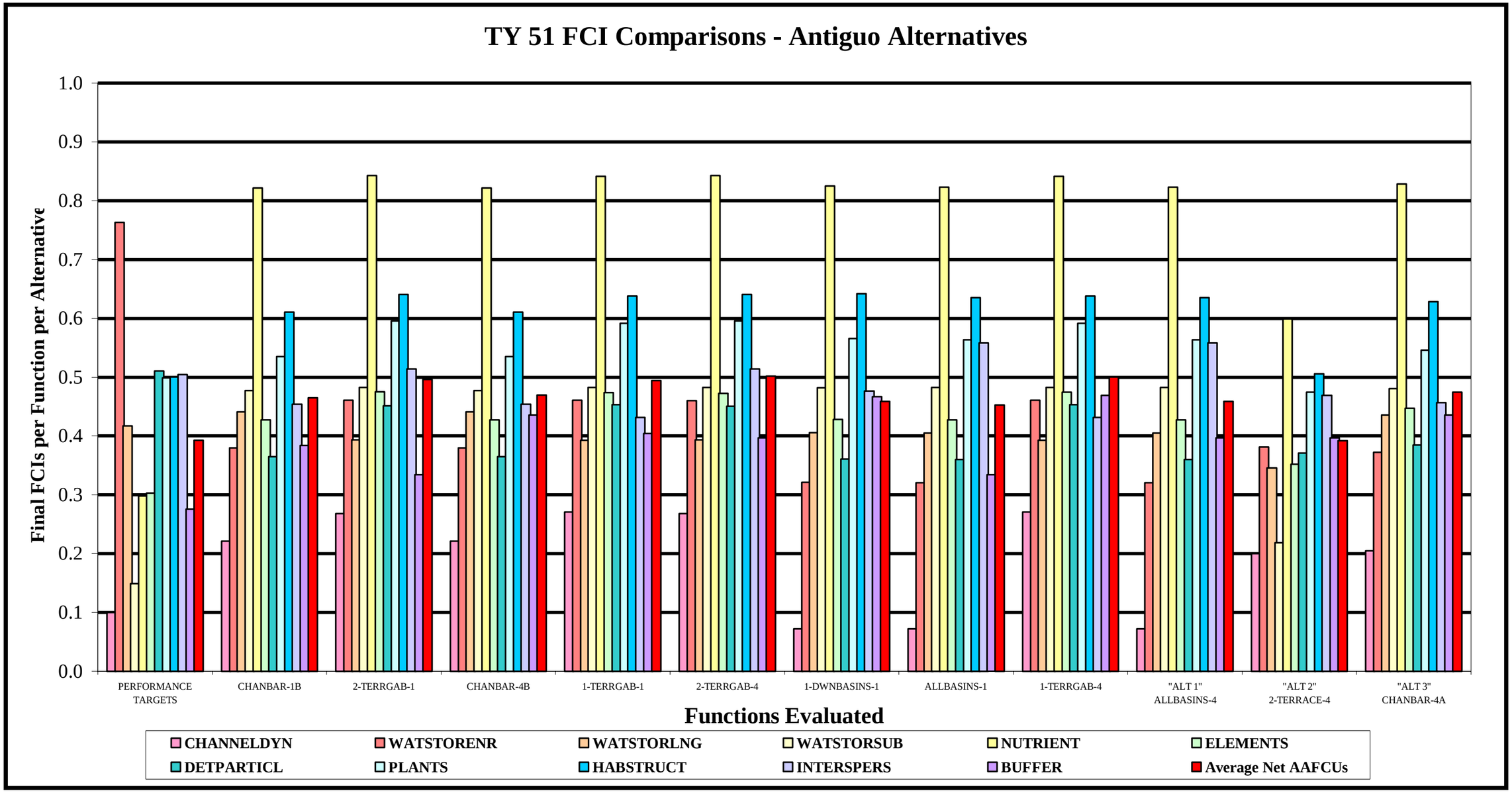


Figure 5.22 Restored, Preserved and Created FCI Comparisons

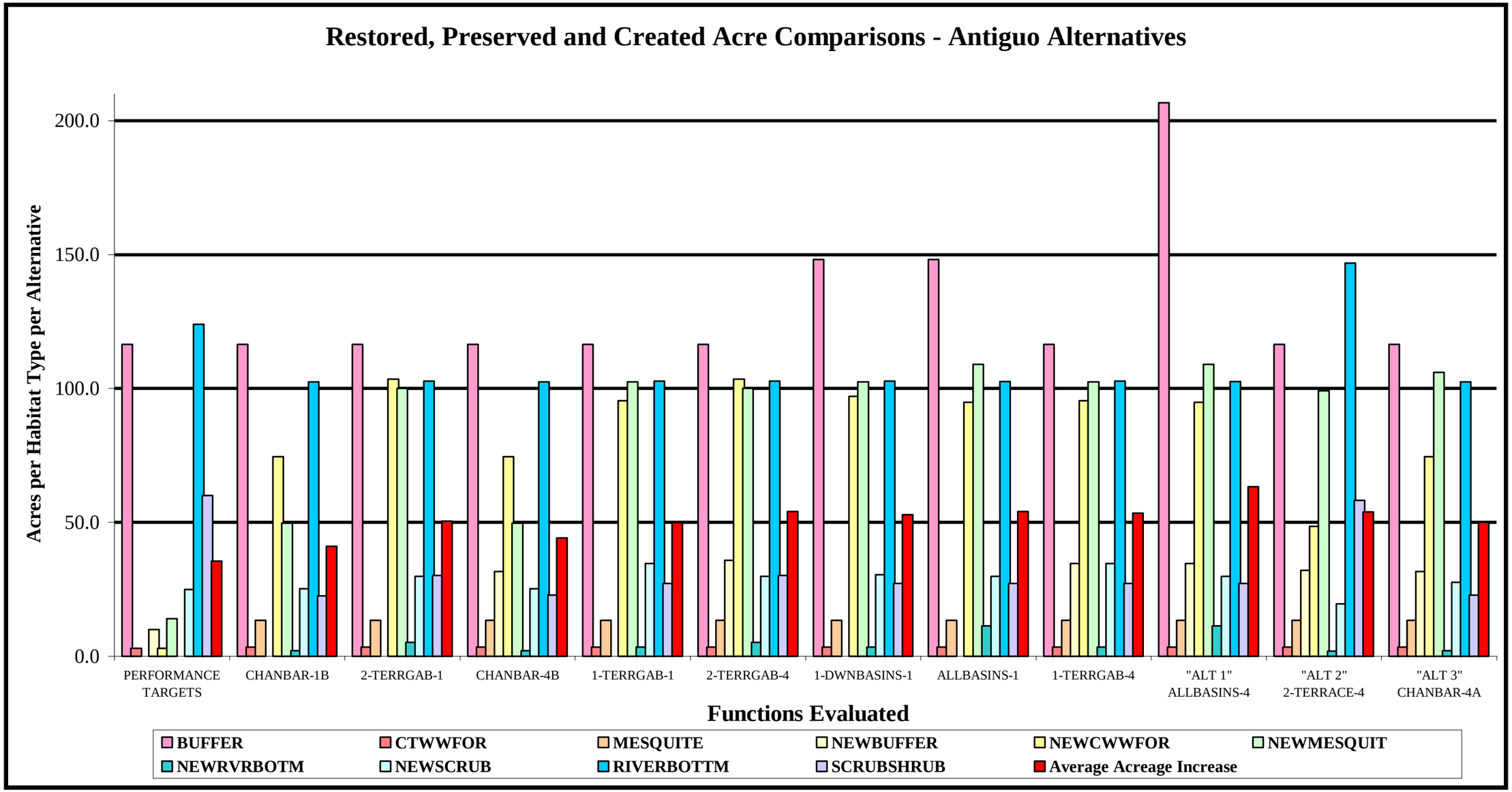


Figure 5.23 Restored, Preserved and Created Acre Comparisons

CHAPTER VI
DESCRIPTION OF THE PLAN SELECTED FOR RECOMMENDATION

A. Plan Description

The recommended plan, selected from those discussed in the previous chapter, is Alternative 2H – 1 Terrace without buffer. The plan is show in Figure 6.1 and the expected increase in the ecosystem function assessed is shown in Figure 6.2. Alternative 2H is expected to increase all ecosystem functions assessed to a moderate to excellent function except protective buffer. The protective buffer function is expected to decrease in both the without project and with project condition from a high to a moderate level of function. Specific plan features include:

Terraces

A single set of terrace will be cut into soil cement at the Bend Area for an approximate length of 4200 feet as shown in Figure 6.1. The first terrace will be cut into existing soil cement beginning at the flow height of the 5-year flow. A second level of the terrace will be at the height of a 10 year flow and a third level will be at a 20-year flow level. The first terrace level is 75 ft wide (at widest point) restored desert wash (shrub-scrub) communities slope to the next terrace 3ft at 4/1 slopes. The second terrace level is planted with cottonwood/hackberry/willow community and is up to 200 ft wide. The third terrace level is 3 ft higher with 3/1 slopes on Rillito side and is 150 feet wide at widest point. It is planted with Mesquite bosque community. This last terrace will be contoured up to the current height of the upland area on its boundary as shown on mapping. Detailed information regarding design of the terraces and other design features can be found in the Design Appendix.

Terraces will be irrigated with flood irrigation using effluent and will receive overflows from the Finger Rock Wash and the Rillito River. Overflows from Finger Rock Wash low flow channel will be directed across the Bend Park through “Mormon” style ditches and then through a graded system of berms and swales through the various plantings. The bridge at Dodge Road will be removed as a part of this ecosystem terrace measure after construction of Alvernon Bridge. This will discourage vehicle traffic or recreation through the restoration features, and improve the hydraulic regime by removing a constriction in the Bend area. A typical cross section is illustrated in Figure 6.3.

This design measure will improve the ecosystem functions assessed in the study area except buffer. It is expected to improve the hydrogeomorphic function of the project area. Terracing will improve flow characteristics through this currently narrow portion of the river by increasing the flood prone area and channel capacity. Terracing in combination with flood irrigation and provisions for flooding from Finger Rock Wash across this area will reconnect the channel with its floodplain in this area. Terracing and the berm and swale-grading plan will improve surface water storage and dynamic energy dissipation by improving micro topographic relief and increasing coarse woody debris. It will also dissipate more flood energy through the widened channel and increased vegetation. While the perennial flow is not restored, increased frequency of inundation from irrigation and water harvesting of tributary flows should increase soil moisture. Increased vegetation density and coarse wood debris should slow flood flows and allow for increased soil moisture and plant intake. Subsurface water storage will be improved as

Alternative 2H

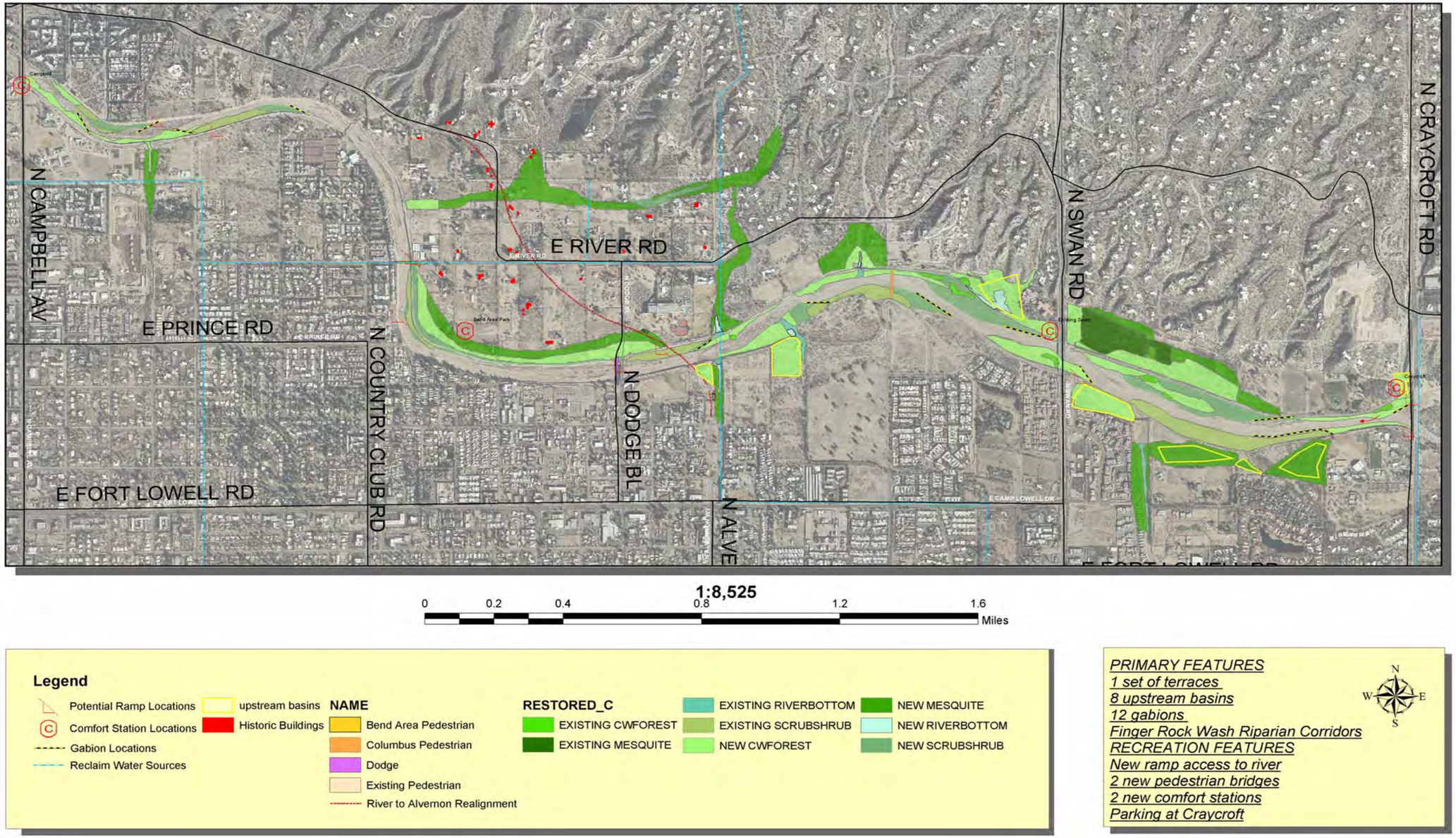


Figure 6.1 Recommended Plan

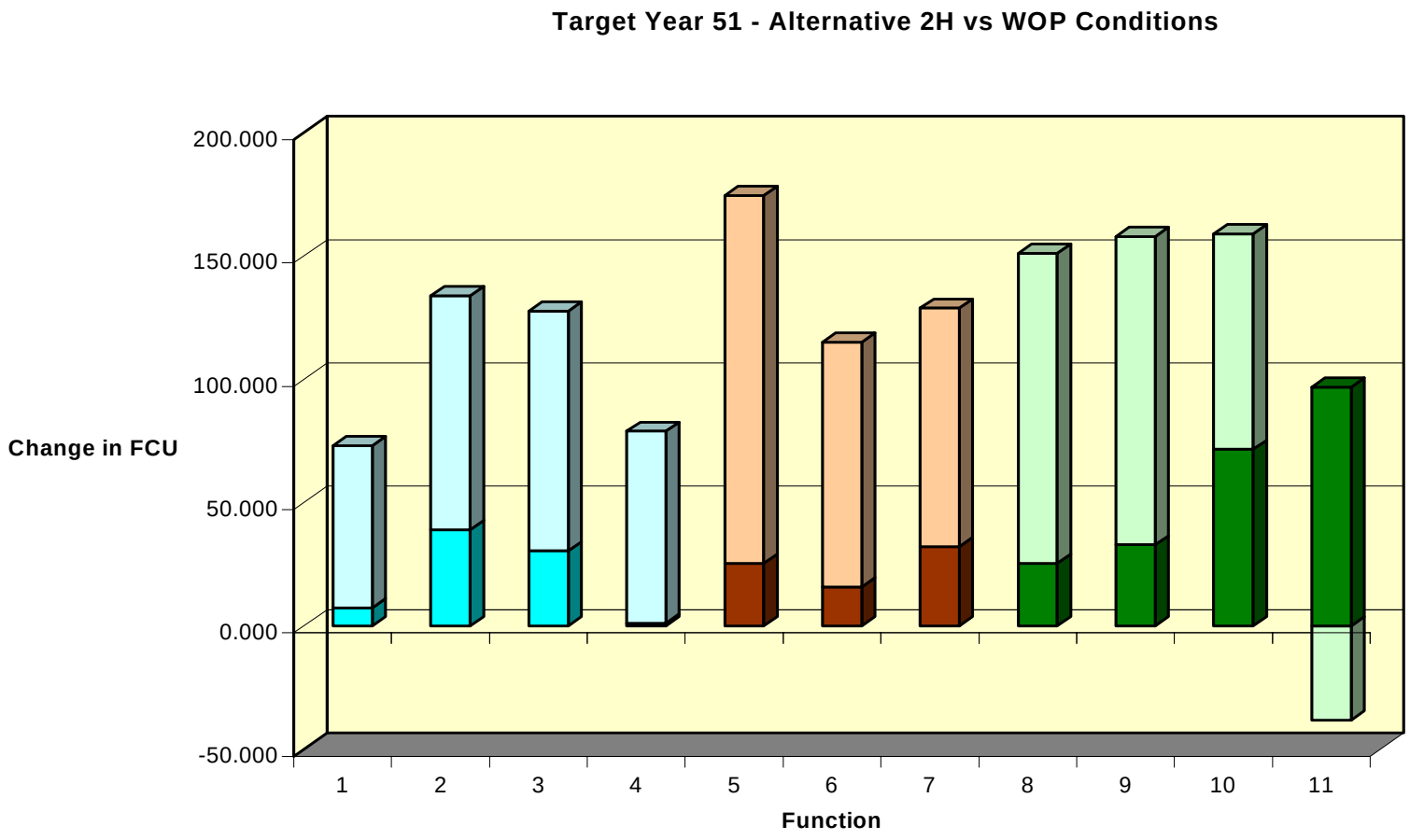


Figure 6.2 Recommended Plan Compared to Future WOP

Hydrologic functions are shown in blues. Biogeochemical Functions are shown in browns and Habitat Functions are shown in Greens.

- Net Hydrologic Change Alt 2H
-WOP Hydrologic Conditions

- Net Biogeochemical Change Alt 2H
-WOP Biogeochemical Condition

-Net Habitat Change Alt 2H
-WOP Habitat Condition

irrigation and directed flood flows will increase soil moisture thus decreasing depth to saturated sediments for plant maintenance.

Terracing will also improve biogeochemical functions as increased vegetation densities at this location will provide more classes of decay, coarse and fine woody debris percentages should increase and there should be an increase in percentage of litter cover. Surface and subsurface flows will be increased as well as potential for development of sediment layers creating restrictive soil lenses that will retain moisture. Potential for increased algal development on the surface also will be increased.

Habitat Functionality will be increased by terracing as it will allow plants to use Rillito and Finger Rock flood flows as a water source, will permit increased access of terrestrial and aerial wildlife to a more contiguous area of food and cover.

Basins

Eight basins for water harvesting will be excavated at tributary confluences with the Rillito and contoured with swales, berms and vegetative gabions used to distribute water from tributary flows to plant communities (Figure 6.4). The tributary streambeds will be planted with cienega marsh vegetation up to the width of the natural channel and with Mesquite or Cottonwood Communities. Basins will be sited to avoid impacts to and, potentially offer protection for Cultural Resources. Plant communities will be supported by flood irrigation for establishment and to alleviate drought conditions if they occur.

Water harvesting basins will improve the function of the ecosystem hydrologically, bio-geochemically and biologically in several ways. The basins will reduce annual operation and maintenance costs by reducing the volumes of reclaimed water needed for irrigation. They increase hydrogeomorphic function by slowing and retaining flows within the system for longer periods, increasing retention of potential woody debris inputs, increasing the flood prone area and increasing micro topographical relief. They should also reduce input from accelerated sources of sediment and trap sediments that may help develop a more restrictive soil layer thus increasing soil moisture, and decreasing depth to saturated sediments. Biogeochemical and habitat function may increase because of the basins due to a greater possibility for development of algal mats, presence of more decay classes and an increase in retention of woody debris and litter cover on the basin floor. Another effect of these processes should be an improvement in the quality of storm water runoff reaching the Rillito River channel.

Alvernon Basin

1. This basin is located at the confluence of the Rillito and Alvernon Wash.
2. It will be approximately 1 acre in size as shown on Figure 6.1.
3. The basin is tapered from entry of Alvernon Wash to a depth of 3 feet on the Rillito side.
4. The basin is planted with a Cottonwood Willow community.
5. The 3 ft edge of the basin will have a 4/1 slope.

Christopher City Wash Basin

1. The basin is located at the east end of Swan Wetlands 1135 area.
2. It will cover approximately 6 acres as shown on Figure 6.1.
3. It will follow the design seen at Bosque Creek.
4. The basin is planted with a Cottonwood Willow forest community.

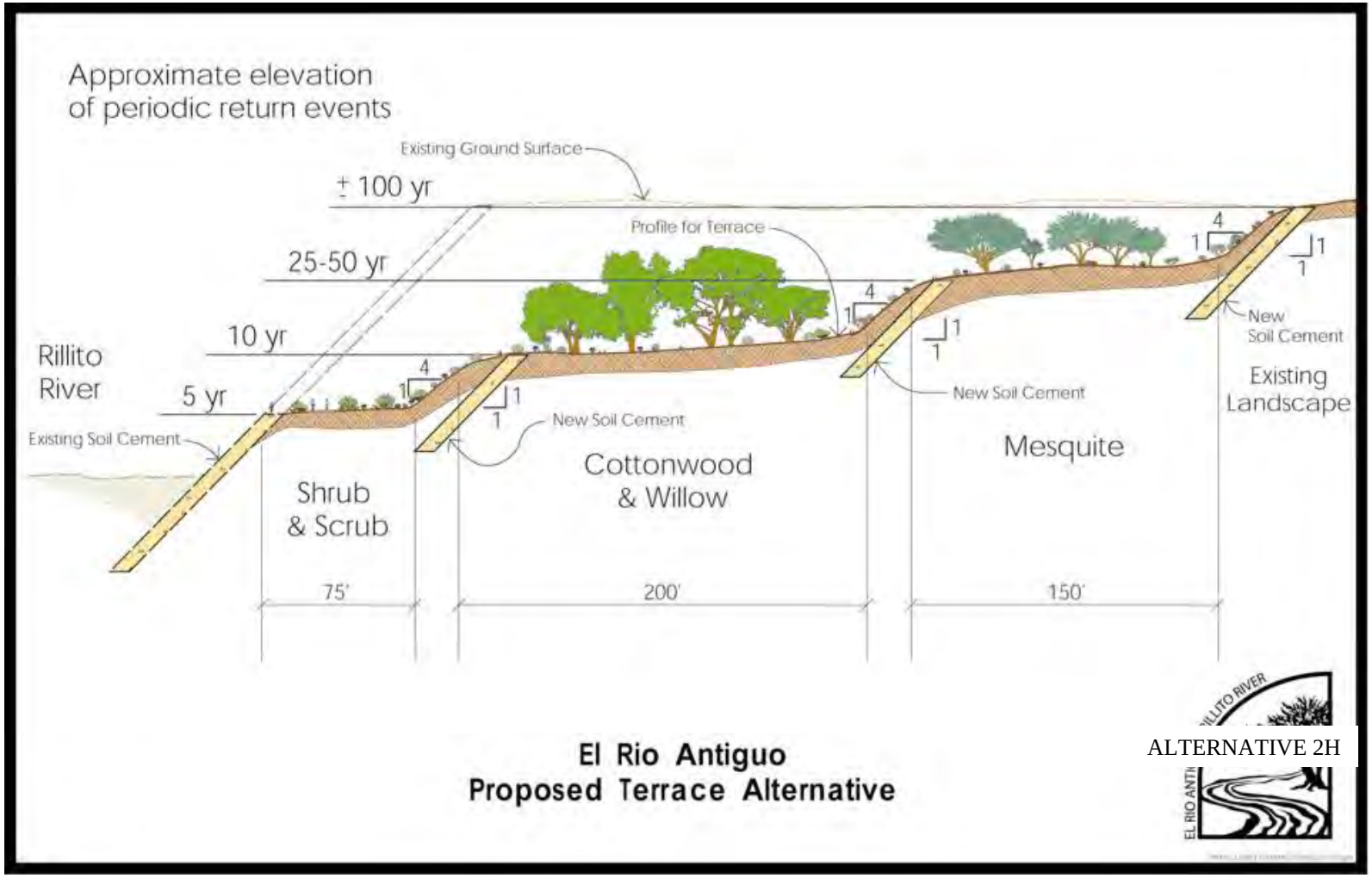


Figure 6.3 Terrace Cross Section

Typical cross sectional view of Terraces reconfiguring soil cement to increase channel width and flood prone area in the "Bend."

Flecha Caida Basin.

1. The basin extends to the river, is triangular and is as shown in the mapping.
2. It will be approximately 6 acres as shown on the map.
3. The basin is tapered from the entry of Flecha Caida Wash to a depth of 3 feet just behind the soil cement and sandbar. (A groin protects the sandbar on the upstream Rillito side). The 3 ft edge of the basin has a 2/1 slope.
4. The basin has an interior triangle of Cottonwood/Willow Forest surrounded by a Mesquite Bosque Community with an interior strand of cienega.
5. This area already acts as a water harvesting basin, but has been filled with construction debris. It will need to be re-excavated.
6. This basin follows the weir design seen at Bosque Creek.

Swan to Alamo Wash Basin

1. The basin extends from Swan Rd. to Alamo Wash.
2. The basin area will be approximately 7 acres as shown on mapping
3. Basin plant community will be Cottonwood/Willow forest.
4. Basin is tapered from entry of tributary to three feet depth on Rillito River side with 2/1 slopes.
5. This area is already partially excavated by Rillito flooding prior to construction of bank stabilization.
6. Weep holes will allow basin to empty into the Rillito.

Alamo Wash Basin

1. The basin extends from Alamo Wash to boundaries of study area polygon as shown on mapping.
2. The basin area is approximately 5 acres as shown in Figure 6.1.
3. Basin plant community is Mesquite bosque.
4. Basin is tapered from entry of tributary to 3 ft depth on Rillito River side with 4/1 slopes and weep holes allow drainage into the Rillito from the basin.

Bosque Creek Basin

1. The existing basin will be enlarged to include teardrop area between road & existing basin near Bosque Creek.
2. The basin floor tapers from wash entry to 3 ft depth toward River with 4/1 slopes.
3. The basin will be approximately 1 acre as shown on mapping.
4. The basin will support a Mesquite Bosque community.

Hill Farm Basin

1. This basin follows the design of Bosque Creek Basin.
2. The basin floor tapers from wash entry to 3 ft depth toward River with 4/1 slopes.
2. It cover approximately 5 acres as shown on Figure 6.1 and will support a Mesquite Bosque plant community.

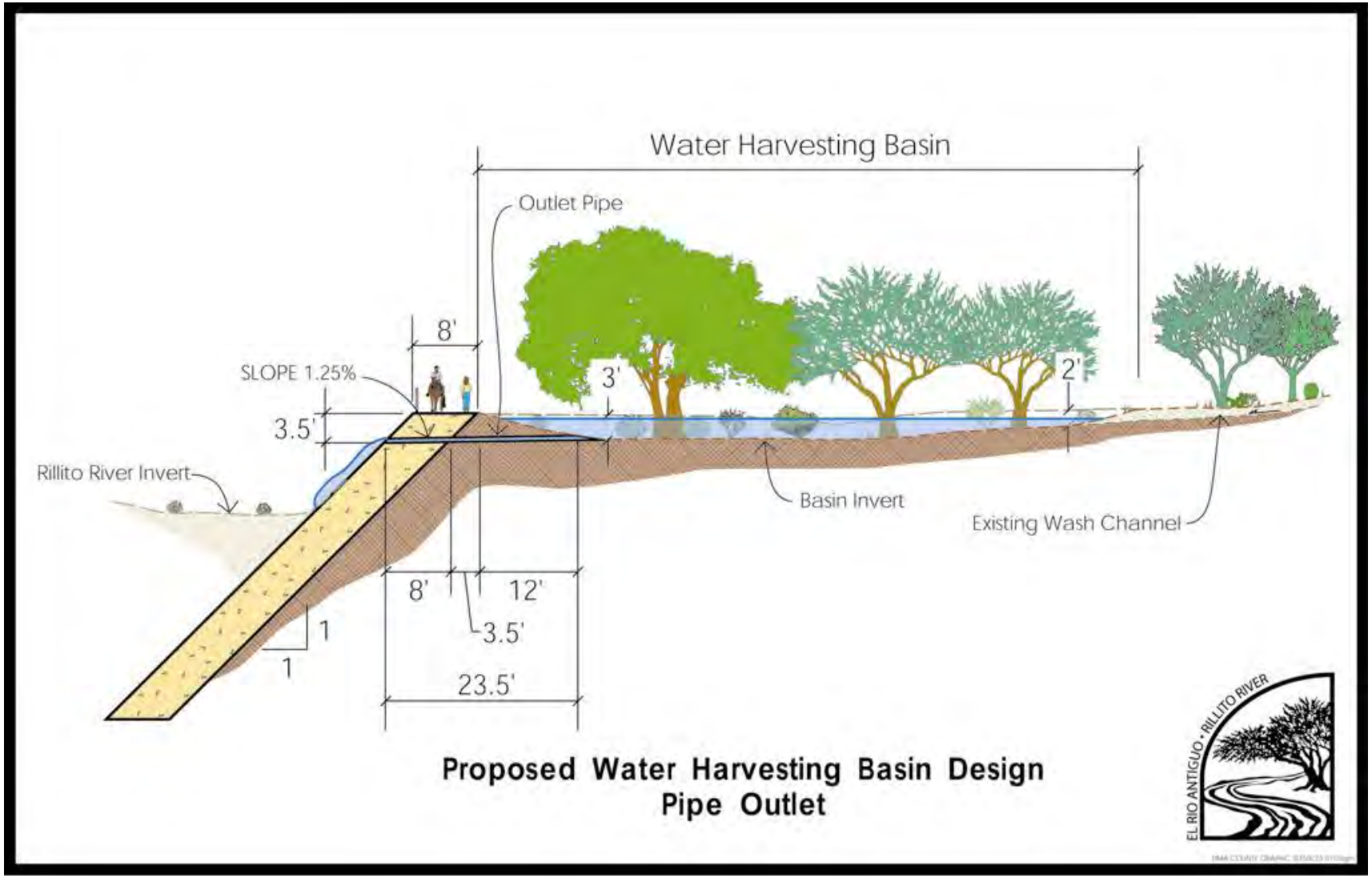


Figure 6.4 Typical Basin Cross-Section

Typical water harvesting basin cross-section using weep hole or pipe outlets. See Design Appendix for plan view of a typical basin and weir design.

Craycroft Basin

1. The basin floor will require removal of cement in bottom of channel and backfill to decrease gradient as the tributary enters the Rillito.
2. A barrier will be constructed at the tributary mouth with weep holes to allow for slow drainage into the Rillito.
3. A maintenance ramp nearby will allow for access to the Rillito streambed as well as for horse and foot traffic.
5. Gabion will protect Cottonwood/Willow community plantings in the streambed
5. Parking is provided at this site (5 spaces along Craycroft & 5 spaces in front of rescue property.
7. The basin will be approximately 1 acre as shown on mapping

Plant Communities:

Each plant community will be planted at a high density with the expectation of some die off. It is expected that the stronger plants will survive in a more natural configuration than could be designed for the original planting scheme. Each community and the river bottom will be seeded with native grasses to encourage cienega development. A grading plan will be developed that will allow irrigated flows to reach the planted area mimicking naturally occurring low flow events. Plant communities will increase all ecosystem functions assessed for this study. They will increase Hydrogeomorphic function by slowing flows and increasing the amount of time water is retained within the system allowing for a more sustainable habitat. This will also reduce depth to saturated sediment, organic matter contribution for nutrients, increase litter and woody debris, increase flow frequency through flood irrigation, and increase species diversity and biomass. This is expected to increase use of the area by wildlife and the use of this corridor as a connection between other habitats. Tree, shrub and herb canopies will increase creating greater structural diversity within each plant community.

Mesquite Communities:

Mesquite Bosque communities will include Mesquite, Desert Willow, Blue Palo Verde, Wolfberry, Graythorn, and Hackberry. It will be approximately 115.9 total acres across the project area with an expected water use of 4.0 acre-feet of water per year per acre. Plantings will be done at a high density with the expectation of some die out. 240 five gallon shrubs per acre will be planted along with 70 fifteen gallon trees per acre and the area will be seeded with native grasses. (115.9 Acres)

CW Forest Communities:

Cottonwood and Willow communities will include Fremont Cottonwood, Gooding's Willow, Sycamore, Ash, Arizona Walnut and Hackberry. Approximately 98.9 acres will be planted in this community type with an expected water need of 8.5 acre-feet of water per year per acre. Eighty-five fifteen-gallon trees will be planted per acre, and 250 shrubs in five-gallon containers will be planted per acre.

Desert Wash (Scrub/shrub) Communities:

Sixty-two acres of Desert Wash or strand communities in the river bottom and tributaries will be planted and maintained. Plant communities will include Wolfberry, Graythorn, Hackberry, Seep Willow, Bursage and Saltbush. Water needs are expected to be 3.0 acre-feet of water per year per acre. Plantings will use five-gallon container plants.

Cienega (Riverbottom):

Over seven acres of cienega grasses will be planted with native grasses at tributary mouths. The rest of the river bottom will be seeded with native grasses. These areas will not be irrigated. They are expected to survive on ancillary water from irrigation of other plantings and natural flows.

Finger Rock Wash Channels

A low flow channel stabilized with a Reno mattress and vegetation (Mesquite with interior Cottonwood/hackberry/willow forest & bed of cienega marsh vegetation) grading from base of Finger Rock Wash to three feet above the bed of the Rillito at mouth entering river) will capture lower flow events from Finger Rock to support a Mesquite Bosque. This channel will widen at the mouth to slow flows & mimic natural channels. The alignment will follow Roger Road and will capture flows from cut off channels entering at Palo Verde Road. Higher flows will be diverted across park to Bend Basin using swales, berms, etc. The channel should be able to handle 1980 cfs (10 yr flow) with 510 cfs breaking out for distribution across the park as shown on mapping. The high flow channel has an effective flow without a second larger channel to convey flows between the 10 and 100-year flow. This channel will also be stabilized with a Reno mattress and vegetation (primarily Mesquite community). It will support additional Mesquite Bosque. These two channels will reconnect the Finger Rock Wash to the Rillito providing a vital wildlife corridor between the Santa Catalinas and the Tucson Basin (Figure 6.5).

The high and low flow channels contribute to improvement of Riverine function by reconnecting the tributary to the river, creating a potential wildlife corridor and habitat for wildlife, increasing macro and micro topographic relief, directing tributary flows into habitat, creating potential for retention of soils that will provide a restrictive layer and better soil moisture retention. These features will also decrease depth to saturated sediment as Finger Rock Wash as flows are slowed and used by the Mesquite. In addition, flood irrigation will be used for establishment of plants and during periods of drought.

Craycroft to Swan Pipe and Ditch Irrigation System

This measure allows flood flows from the Rillito, and from small foothill basins to be used in the lower elevation areas behind the soil cement between Craycroft Road and Swan Road on the north bank of the river. A culvert and pipe system will be constructed through the soil cement at the 2-year event flow level. Using gravity pressure through the pipe, the water will flow into a 1 foot deep ditch and then be allowed to overflow through a system of berms and swales across the proposed restoration areas of Cottonwood Willow forest and Mesquite Bosque as shown in plan view in Figure 6.1 and in more detail in Figure 6.6. Excessive flows will drain through the existing culvert under Swan Road and out into the Rillito at the confluence with Flecha Caida Wash.

This feature will improve ecosystem function by providing flood flows to additional portions of the floodplain that were cut from the Rillito by construction of soil cement bank stabilization. It will also decrease depth to saturated sediment in the area, increase the flood prone area, detain nutrients, increase micro topographic relief, allow the area to support additional plant communities and increase habitat areas for wildlife.

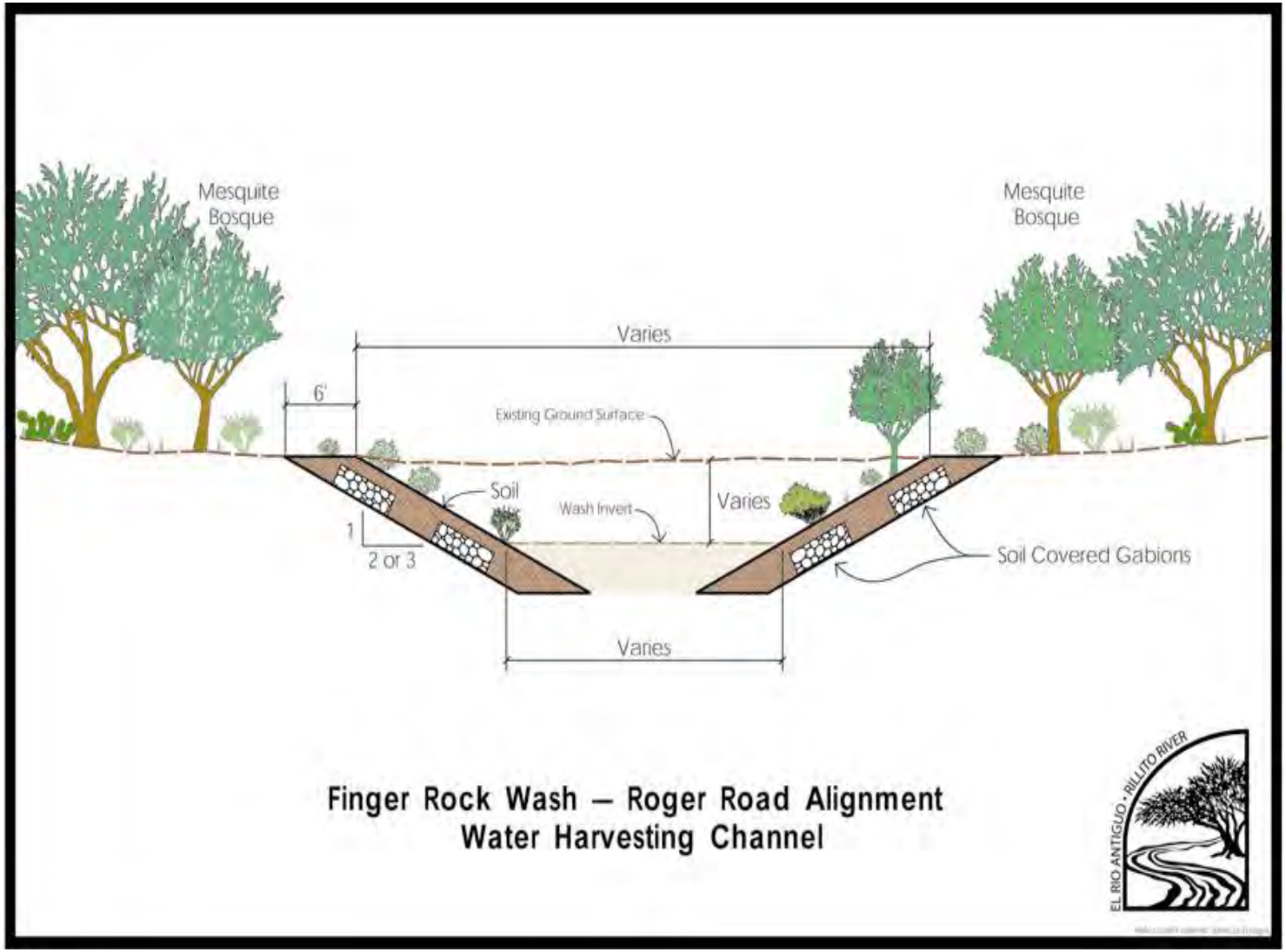


Figure 6.5 Finger Rock Wash Low Flow Channel

Cross sectional view of Finger Rock Wash low flow channel supporting a Mesquite Bosque and reconnection of this tributary with the channel of the Rillito for wildlife and flood flows. The high flow channel will be similarly constructed.

Figure 6.6 Craycroft to Swan Water System

Detail view of Craycroft to Swan pipe and ditch watering system. Flood flows from irrigation or natural floods will flow across the restored areas through a system of berms and swales. Excessive flood flows will drain through an existing culvert under Swan Road and existing weirs between Craycroft and Swan.

Additional Water Sources

Reclaimed water accessed from existing reclaimed waterlines as shown on mapping will be distributed through an irrigation system in all restored areas. This system will use flood irrigation (most commonly seen in agricultural settings) and direct the water through the plants using a system of swales and berms. The cultural landscape will be maintained by using Mormon ditch style irrigation through Binghampton to Bend Area terracing.

Flood flows beginning with the 2 year event will be directed behind the soil cement below Craycroft through a pipe and ditch system stabilized with vegetation. This system will inundate the existing and restored vegetation between Craycroft and Swan Roads. Design details are included in the Design Appendix.

Real Estate Plan

A Real Estate Plan has been developed and is included in Appendix I. A real estate cost estimate has been prepared for Alternative 2H and has been used in the MCACES analysis provided in the Cost Estimating Appendix.

Costs of Recommended Plan

The recommended plan has an estimated Total First Cost of 63,582,500. The First Cost is determined adding construction costs to real estate costs to arrive a "First Cost" and applying a contingency factor plus factors for design, engineering during construction, construction management and adaptive management to the First Cost. Details concerning costs of the recommended plan are presented in Table 6.1 below.

Table 6.1 Economic Cost Summary for the Recommended Plan

Cost Type	Amount
First Costs	
Construction & Real Estate	$48,546,500
Construction Costs	$26,446,500
Real Estate Costs	$22,100,000
Contingency at 25%	$6,611,500
PED at 10%	$4,150,000
EDC at 1%	$527,500
Construction Mgmt at 6,5%	$2,149,000
Adaptive Management at 3%	$1,868,000
Total First Costs	$63,852,500
Recreation First Cost	$2,804,500
Total First Cost	$66,657,000

B. Project Outputs

National Ecosystem Restoration

The selected plan produces 120 AAFCUs at a cost of $44,100 per unit. This output is indicative of modest size healthy arid region riparian ecosystem. As noted earlier in the report, such ecosystems are increasingly rare and are necessary to provide critical habitat for many native and migratory species.

National Economic Development

Incidental flood damage reduction benefits of $223,888 result from implementation of the Finger Rock Wash restoration features. Other incidental benefits from flood reduction are emergency response cost and traffic delay and vehicle operation cost. They are $30,631 and $5,314 respectively. In addition, recreation benefits detailed in the Economic Appendix total $298,860. Total benefits resulting from implementation of the recommended plan equal $558,693.

C. Associated Costs

For as long as the project remains authorized, the non-Federal sponsor must provide sufficient water for construction, operation and maintenance of the project. The cost of providing such water is an associated non-Federal cost of the project and 100 percent of these costs will be paid by the non-Federal sponsor. These costs are currently estimated at $852,000 annually. These costs are not shared as part of the total project costs.

D. Maintenance Considerations

The features of the El Rio Antiguo project are subject to damage by recurrent flood flows and periods of inundation. This will result in the need for periodic maintenance to insure successful habitat restoration. Operation and maintenance costs will include periodic channel clearance, control of invasive plant species, pumps and irrigation maintenance. Operation and maintenance also include periodic replanting of habitat areas damaged by flood flows and periodic replacement of gabions and the horse ramp and

In compliance with authorizing legislation and cost-sharing requirements the non-Federal sponsor must assume responsibility for operation and maintenance of project features for as long as the project remains authorized. Maintenance and operation of the project will generate the following costs.

Table 6.2 Restoration Operation and Maintenance Costs

O&M Activities	Annual Cost
Invasives Control	$22,597
Patrol/Biological Survey/Replanting	$18,660
Plant Replacement	$19,096
Gabion Replacement (every 25 years)	$22,021
Reno Mattress Replacement (every 25 years)	$89,597
Irrigation System Maintenance	$44,223
Finger Rock Wash Cleanout	$6,344
Basins Cleanout	$159,000
Maintenance Road & Ramps	$9,800
O&M Subtotal	$391,425
Associated Cost (Water)	$851,932
Total	$1,243,357

E. Recreation Plan

The Recreation Plan proposed in conjunction with the recommended restoration plan consists of decomposed granite (DG) multipurpose trails, a pedestrian bridge, parking, and trail links that serve a recreation purpose by providing opportunities to a variety of recreational users. Comfort stations will serve the basic safety needs of the recreational user. Other changes to the park can serve the ecosystem restoration purpose by reducing safety and maintenance concerns stemming from the project. All road segments and ramps designated as maintenance provide access to areas in case of emergencies such as flooding and fire. Access will also provide a means to maintain vegetation in the newly restored area and park facilities. Warning signs are also added to direct pedestrians off the newly restored area and guide pedestrians away from any potential danger. These changes will provide a unique opportunity for resource-based recreation and environmental education.

With the recreation improvements identified and described above, the unit day value (method described in the recreation component of this report under the Existing Condition) can be derived by selecting point values for recreation criteria and with the input of the US Army Corps of Engineers, LA District and local government agencies. These values are then applied to projected visitation. Because visitation figures have already been adjusted for double counting and projected over fifty years using a relationship to projected population growth, they will be used as a basis. However, further adjustments will be made to account for changes in visitation due to the construction of the project. These adjusted visitation figures will again be compared to capacity limits established by the National Recreation Parks Association.

The recreation criteria described in the Economic Appendix remain the same for the with project condition. The only changes will include impacts of the proposed recreation improvements to the Rillito River Park and Finger Rock Wash trail segment. They include:

1. ***Recreation Experience***--Same as Without Project Condition
2. ***Availability of Opportunity***--Same as Without Project Condition
3. ***Carrying Capacity***--As previously discussed, Pima County will experience rapid population growth. To accommodate this increase in population an

additional 10-space parking lots, along with areas for two comfort stations are being proposed for the Rillito River Park. DG multipurpose trail segments will also enhance carrying capacity along Rillito and Finger Rock Wash. Along Finger Rock Wash, the only recreational feature being added is a DG multipurpose trail along the restored Finger Rock Wash area. These proposed facilities would allow for future population growth.

4. ***Accessibility***—The addition of a pedestrian bridge which will cross the Rillito River near Prince Road will increase the access in the "bend area" since there currently are no cross bridges located in the "bend area." This will provide easy and quick accessibility across the river to four future parks (described in Future Recreation Facilities section of this report). They are Campbell Alvernon Linear Park, Rillito Park at River Bend, Rillito Park at Columbus Boulevard District Park, and North Central Natural Resource Park. Trail links at several areas along Rillito River Park are proposed which include access for multipurpose recreational use.
5. ***Environmental--*** Restoration features would increase passive opportunities for wildlife viewing, aesthetic experience, and education. Recreational trails, signs, and access will be located to allow for recreation activities in such a way as to discourage interference and recreation in habitat areas.

The increase in the monetary value of the recreation experience derived from the Unit Day Value analysis of the changes in the recreation experience was applied to the projected visitation to calculate the economic benefits resulting from the recreation plan. That value was determined to be $298,860.

The US Army Corps of Engineers, Los Angeles District prepared the following cost estimates for the recreation project improvements. Estimated First Cost of the recreation plan is $2,804,500. Details regarding recreation costs may be found in the Cost Estimating Appendix. The average annual cost of the recreation plan was computed to be $171,020. Annual operations and maintenance costs for the recreation plan are estimated to be $20,300. Thus, the total average annual cost of the recreation plan is $191,320. Table 6.3 summarizes the economic analysis of the recreation plan. Details regarding the analysis of the recreation plan may be found in the Economic Appendix.

Table 6.3 Summary of Recreation Benefits and Costs

Benefits	
Recreation Value Without the Recreation Plan	$490,643
Recreation Value With the Plan	$789,503
Net Benefits of the Recreation Plan	$298,860
Costs	
Average Annual Costs	$171,020
OMRRR	$20,300
Total Average Annual Costs	$191,320
Benefit to Cost Ratio	1.56
Net Benefits	$107,540

F. Monitoring and Adaptive Management Plan

Uncertainty and variability are inherent in water resources planning. Therefore, the consideration of risk and uncertainty is important in water resources planning. Situations of risk are conventionally defined as those in which the potential outcomes can be described in reasonably well known probability distributions. In situations of uncertainty, potential outcomes cannot be described in objectively known probability distributions. Risk and uncertainty arise from measurement errors and from the underlying variability of complex natural, social, and economic situations. The degree of risk and uncertainty generally differs among various aspects of a project. It also differs over time, because benefits from a particular purpose or costs in a particular category may be relatively certain during one time period and uncertain during another.

Some risk and uncertainty are assumed in nearly every aspect of a water resources project. The variability of outcome associated with the recommended plan does not fit the definition of risk. That variability is better characterized as uncertainty in that the potential outcomes cannot be described in known probability distributions.

A higher than normal amount of uncertainty exists regarding landscape scale ecosystem restoration in the arid southwest. This is because very few such projects have been completed and those that have of recent origin. Given the lack of precedent and scarcity of empirical data regarding restoration of Sonoran riparian systems, there is a great degree of uncertainty regarding a number of aspects of the design, construction and operation of the recommended alternative. Uncertainty exists regarding:

- The volumes and frequency of application to be used for irrigation
- The densities of initial plantings and the associated success rates
- The frequency of flood events and their impacts on restored habitat
- The design of the drainage features for water harvesting basins

- The design of channel stabilization measures
- Planned invasive plant management activities and schedules
- Planned sediment management activities and schedules

Due to the number of project elements subject to uncertainty and the high degree of uncertainty associated with them a Monitoring and Adaptive Management Plan will be established to evaluate the effectiveness of the restoration measures implemented in this project and make adaptive changes, if required, to obtain project objectives. The cost of the adaptive management action will be limited to 3 percent of the total project cost excluding monitoring costs.

Purpose

The purpose of the Monitoring and Adaptive Management Plan is to provide a mechanism to evaluate the effectiveness of the restoration measures implemented in this project and implement adaptive changes, if required to obtain project objectives. As outlined in EC 1105-2-210 (par., 21.b.), the Monitoring Plan is intended to ascertain whether: the project is functioning as per project objectives; adjustments for unforeseen circumstances are needed; and changes to structures or their operation or management techniques are required.

The Monitoring and Adaptive Management Plan will provide a description of: the habitats to be restored, the density and composition of the plantings to restore habitat, surveys to monitor the expected, natural re-introduction of native wildlife into the restored habitats, the performance criteria and monitoring protocol to evaluate success of the restoration effort, adaptive management actions (or maintenance activities) that may be performed to ensure a successful restoration effort, and reporting requirements.

The Monitoring and Adaptive Management Plan covers monitoring and adaptive management actions during the first 5 years after initial construction. (After the first 5 years, monitoring and/or adaptive management becomes the responsibility of the Local Sponsor.) Note that during the preconstruction engineering and design [PED] phase, more specific monitoring details [e.g., exact monitoring transect locations, reference site locations, more specific performance/success criteria, more specific monitoring protocols, etc...] may be added to this Monitoring and Adaptive Management Plan.)

Goal

The goal of this effort is to restore riparian vegetation typical of the Sonoran desert to obtain habitat values consistent with those predicted in the Habitat Analysis Appendix. It is expected that the habitat value of the Constructed Wetlands will have good to above average quality. It is also expected that the restored habitat will be suitable for native wildlife. The quality of the habitats (i.e., average or high) is expected to dictate the abundance or density of wildlife.

Restored Habitats

A description of: the habitats to be restored, the density and composition of the plantings to restore habitat along with a quantitative discussion of the surveys to monitor the restoration is

provided earlier in this chapter. Since only the wetlands constructed on the overbank are located outside of the 100-year flood zone, most restoration features have the potential to be impacted by long periods of flood inundation and subject to be uprooted during significant high flows - as would any natural riparian ecosystem. Monitoring protocols defined below will assist in determining whether replanting of the various habitats are needed following flood events. Prior to active restoration commencement, an assessment of the chosen restoration sites will be conducted to determine their suitability for the establishment and regeneration of native riparian plants. During pre-construction surveys, the recommended restoration site plant assemblages will be reviewed for their appropriateness for project.

Habitat & Wildlife Monitoring - Frequency and Protocol

Habitat (Vegetation) Monitoring

Cottonwood/Willow Riparian Corridors

For the first 6 months after planting the site, it would be monitored monthly; thereafter, the site would be monitored every other month for a year. The site will remain free of all non-native shrubs throughout this 18-month period. Should the survival rate of plantings indicate that the species composition is less than prescribed, replanting will be undertaken to ensure that the species composition is maintained.

All plantings shall have a minimum of 80% survival the first year and 100% survival the second and third years and/or attain 40% cover after 5 years. Ninety percent cover is expected in the Riparian Corridors after 10 years. There will be zero tolerance of exotic shrubs the first 5 years. If the survival and cover requirements are not met during the initial 5 years, the Corps is responsible for replacement planting to achieve these requirements. (Note that the replacement planting cost would be a cost-shared project cost for the first 5 years.)

After 5 years, the non-Federal Sponsor will be responsible for maintaining the restoration sites for the remaining life of the project. The species composition shall be maintained throughout the life of the project. Site monitoring would be performed yearly throughout the life of the project (also see Section 5, below).

All of Cottonwood/Willow Habitat will be planted in the flood-prone lower terraces. It should be regularly affected by flooding events (as typical of natural cottonwood/willow habitats). The Cottonwood/Willow sites will be evaluated after large storm events to determine the need for revegetating.

Mesquite Bosques

The monitoring frequency outlined for the Cottonwood/Willow Riparian Corridor restoration sites would be followed for the Mesquite Bosque sites.

Riparian Shrub

The monitoring frequency and percent survival outlined for the Cottonwood/Willow Riparian Corridors will be followed for the riparian shrub lands. All of the riparian scrublands will be in the in the floodplain. It should be regularly affected by flooding events (as typical of riverine

open water areas). The sites will be evaluated after large storm events to determine the need for revegetating.

Wildlife Monitoring

Restored habitats are expected to support native wildlife. The good quality riparian shrub lands, mesquite bosques and cottonwood/willow habitats are expected to support the diverse assemblage of wildlife that are associated with these habitat-types. Monitoring of wildlife abundance and diversity is proposed to assess whether habitats actually attract and support significant populations of a wide variety of native wildlife, as expected.

Bird surveys will be performed in the restored Cottonwood/Willow Riparian Corridors during each of the four seasons for the first 5 years following construction. The abundance/ diversity of bird species will be used as an indicator of whether wildlife habitat has developed as predicted and supporting a diverse assemblage of native avifauna. After the first five years, summer/spring bird surveys will be performed every other year to document the abundance and diversity trends. Small mammal trapping (live or snap) will be conducted during the summer for the first five years to document the diverse species expected to re-colonize restored habitats.

Success Criteria, Reporting & Adaptive Management

Success Criteria

The success or failure of the restoration effort will be measured against two parameters that should indicate whether the goal of this restoration effort is being achieved. They are: 1) whether the plant species compositions and/or percent cover requirements outlined for the various habitat types are met, 2) whether native wildlife re-colonize the restored habitats, and 3) whether the restoration sites naturally regenerate. Monitoring will occur as identified above. Monitoring reports would be prepared jointly at the end of the year by the Corps and the Local Sponsor during the first 5 years after initial construction. The need to adjust the constructed project will be based on the results of the monitoring reports. If the restored habitats achieve the plant species composition identified and achieve a diverse native wildlife assemblage, no modifications will be made. After the first five years, the non-Federal Sponsor will prepare the Monitoring Reports.

Monitoring Reports and Adaptive Management

The Corps and/or the non-Federal Sponsor will be responsible for collecting monitoring data and preparing annual Monitoring Reports. A Technical Committee consisting of, at least, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, and Arizona Department of Game and Fish, will assist in collection of monitoring data, review monitoring data results, and providing recommendations of possible adaptive management measures.

The Technical Committee will recommend adaptive management measures to the existing project's design should habitat not achieve the identified goal and objectives. If designed vegetation species composition are not achieved: replanting, additional irrigation, and/or removal

of vegetation (especially exotics) may be necessary. (Note that the use of herbicides should only be used if options that are more natural are unsuccessful.)

Annual Monitoring Reports and any adaptive management measures recommended by the Technical Committee will be forwarded to an Executive Committee, which will consist of, at least, a representative of the non-Federal Sponsor and the U.S. Army Corps of Engineers. The Executive Committee will decide whether to adopt adaptive management measures recommended by the Technical Committee.

Cost Estimates for alternatives described in this report included funds for Monitoring and Adaptive Management at the rate of 3 percent of the alternatives first cost.

CHAPTER VII
Plan Implementation

This chapter summarizes the cost-sharing requirements and procedures necessary to implement the restoration features of the selected plan.

A. Study Recommendation

The Selected Plan is an ecosystem restoration project that provides incidental flood control and recreation benefits. Because of its positive environmental contribution, the selected plan is recommended.

B. Division of Plan Responsibilities

The Water Resources Development Act (WRDA) of 1986 (P.L. 99-662) as amended and other statutes and administrative policies have established the basis for the division of Federal and non-Federal responsibilities in the construction, maintenance and operation of Federal water resource projects accomplished under the direction of the Corps of Engineers. This is discussed in detail below.

C. Cost Allocation

Cost sharing for construction of this project would be in accordance with current statutes whereby for environmental restoration projects, the non-Federal sponsor would provide all lands, easements and rights-of-way and dredged material disposal areas, provide relocations of bridges and roadways; provide alteration of utilities which do not pass under or through the project's structure; and maintain and operate the project after construction. All water rights and costs associated with providing water to the project shall be borne by the non-Federal sponsor. The value of this water has been estimated at $852,000 annually. Additional studies and analysis of the selected plan will be accomplished during Preconstruction Engineering and Design (PED). Because of these studies, additional necessary project features may be identified that could be part of the Federal cost sharing for this project. In this event, Federal project cost sharing would be adjusted in accordance with the terms that will be included in the Project Cooperation Agreement.

Corps guidance (PGL No. 36 and *59)* specifies that the level of financial participation in recreation development by the Corps at an otherwise justifiable project may not increase the Federal cost of the project by more than ten percent. This cost would be cost shared between the Corps and the non- Federal sponsor. Recreation costs are cost shared on a 50%/50% basis between the Corps and the non-Federal sponsor. Table 7.1 presents a summary of apportionment of project first costs between Federal and non-Federal interests for the Recommended Plan using current (2003) price levels

Table 7.1 Cost Apportionment Table

Rillito River, Pima County, Arizona
Ecosystem Restoration Project
(Costs x $1000)

Item	Allocation		
	Federal	**Non-Federal**	**Total**
Construction* (Construction, S&A, PED/EDC, Contingency)	41,504	248.5	41,752.5
Construction LEERDs* (Lands and credits, easements, rights-of-way, relocations and disposal sites		22,100	22,100
Total First Cost (Percentage of total cost)	41,504 65	22,348.5 35	63,852.5
Recreation Costs	1,402.25	1,402.25	2,804.5
Total First Costs	42,906.25	23,750.75	66,657

* Does not include IDC nor annual O&M, the latter of which is fully a non-Federal Cost

D. Current and Future Work Eligible for Credit

There is no current or future work planned or in construction which is part of the Corp' Selected Plans, or which would be eligible for Section 104 credit.

E. Institutional Requirements

Upon implementation of the cost-shared project, the non-Federal sponsor will prepare the following preliminary financial analysis:

(1) Assess project-related yearly cash flows (both expenditures and receipts where cost recovery is proposed), including provisions for major rehabilitation and operational contingencies and anticipated but uncertain repair costs resulting from damages from natural events;

(2) Demonstrate ability to finance their current and projected-future share of the project cost and to carry out project implementation operation, maintenance, and repair/rehabilitation responsibilities;

(3) Investigate the means for raising additional non-Federal financial resources including but not limited to special assessment districts; and

(4) Complete any other necessary steps to ensure that they are prepared to execute their project-related responsibilities at the time of project implementation.

In addition, as part of any Project Cooperation Agreement, the non-Federal sponsor would be required to undertake to hold and save the Federal Government free from damages due to construction, operation, and maintenance of the project, excluding damages due to the fault or negligence of the Federal Government or its contractors.

F. Environmental Requirements

The Selected Plan could result in discharge of fill material into waters of the United States during the period of construction. It also may result in discharges associated with operation and

maintenance activities. A Section 404(b)(l) evaluation has been prepared to address practicable alternatives. An NPDES permit will also be required for any water discharged to the river.

The EIS includes a 404(b)(1) analysis as part of the feasibility study. It is anticipated that the Corps would receive a 404(r) exemption for the project, when Congress approves the project report and authorizes the project.

The EIS includes a 404(b)(l) analysis as a part of the overall feasibility study. Based on this analysis, the feasibility report recommends that the project should receive a 404(r) exemption, when Congress authorizes the project. The 404(r) exemption would cover both the construction period and the operation and maintenance activities, for as long as the project remains authorized.

The Arizona Department of Environmental Quality (ADEQ), an agency of the state responsible for water quality, was contacted to coordinate the process in accordance with ER1105-2-100. A letter in response from ADEQ was received March 23, 2004, which states the proposed restoration project should comply with State surface water quality standards and that it should not have a negative impact upon the physical, chemical or biological integrity of the Rillito River. It further states that the State of Arizona concurs with the 404(r) exemption for State 401 Water Quality Certification (See Appendix _ of the EIS).

The report and EIS both include a description of the required O&M activities, including timing, and any required mitigation that will be needed, for as long as the project remains authorized. These activities will be incorporated into an O&M manual that will be provided to the non-Federal sponsor at the end of construction.

The non-Federal sponsor will not need to obtain a Section 404 permit for future O&M activities if the non-Federal sponsor carries out the O&M activities as specified in the O&M manual, without deviation. Anytime during the life of the project should O&M requirements need to be modified or should there be a change in conditions not anticipated during this feasibility study, then an appropriate NEPA document will need to be prepared to modify the O&M manual and determine the need for any mitigation or 404 permit for O&M activities.

Under direction by the Corps and Pima County, Statistical Research, Inc. performed a literature search and cultural resources overview of the proposed project area (area of potential effects [APE]) through the Arizona State Museum (ASM) (O'Mack et al. 2002). This search indicates that over 50 per cent of the APE has been surveyed by archeologists. These surveys have recorded 14 archeological sites within the project APE. At least two sites are eligible for the National Register of Historic Places (NRHP) including AZ BB:9:18 (prehistoric pithouse) and AZ BB:9:302 (Davidson Flume). In 1992 the Corps determined AZ BB:9:18 (ASM) and AZ BB:9:238 (ASM) to be eligible for listing in the NRHP. In 1995, the Corps determined AZ BB:9:302 (ASM) eligible for the NRHP. In 2003, the historic town of Binghampton (AZ BB:9:238 ASM) was listed in the NRHP. The remainder of the recorded sites within the study area is undetermined as to NRHP eligibility, unless destroyed. Sites described as destroyed are subject to confirmation via a field check. Many of the sites in the study area can be considered potentially eligible for listing in the NRHP.

Given the project's association with the Rillito River floodplain, the overall archeological sensitivity and potential are very high. Therefore, complete avoidance of all cultural resources by project alternatives may be unsuccessful. Preliminary project designs involving water

conveyance indicate potential adverse effects to the historic setting associated with the historic town of Binghampton (AZ BB:9:238 ASM), which listed in the National Register of Historic Places (NRHP). Proposed planting along the riverbank at Binghampton may not be an adverse effect since trees were planted historically in the same context. A determination of effect will not be made however, until more detailed plans are available, and after consideration of buried prehistoric resources along the bank of the river, in consultation with tribes and Pima County.

The remainder of known resources is potentially avoidable by the project. The floodplain may contain buried resources, however. If additional sites cannot be avoided, they will be evaluated regarding eligibility for the National Register. All NRHP sites that will be impacted by project constructed will be mitigated. Environmental Commitments are:

1. Qualified archeologists will perform a survey of previously unsurveyed areas within the project's area of potential effects, including Finger Rock Wash. Subsurface exploration to determine the presence/absence of buried cultural deposits may also be necessary.

2. If cultural resources cannot be avoided, they will be evaluated regarding eligibility for listing in the National Register of Historic Places.

3. Identification, evaluation, and mitigation studies will be coordinated with Pima County and interested Native American Indian Tribes.

4. Archeologists from Pima County and the Corps will participate in the design of water conveyance features across the landform associated with the historic town of Binghampton in an effort to minimize adverse effects.

5. Since it is likely that National Register listed or eligible properties will be adversely affected by the project (i.e. Binghampton), a Memorandum of Agreement will be negotiated with the Arizona State Historic Preservation Officer (SHPO), Pima County, and interested Native American Indian tribes. An archeological site treatment plan will also be developed in consultation with the SHPO, Pima County and interested Native American Indian tribes.

Compliance with the National Historic Preservation Act of 1966 (36 CFR 800): In accordance with 36 CFR 800, regulations implementing Section 106 of the National Historic Preservation Act, a records search has been performed. Corps identification and evaluation studies will be coordinated with Pima County and interested Native American Indian tribes. The Corps' determinations of eligibility and effect will be coordinated with the Arizona State Historic Preservation Officer (SHPO). Proposed project features that currently involve AZ BB:9:238 (ASM) (Binghampton) indicate that it is likely that National Register listed or eligible properties will be adversely affected by the project. Therefore, a Memorandum of Agreement (MOA) will be negotiated with the Arizona SHPO, Pima County, and interested Native American Indian tribes. An archeological site (historic properties) treatment plan will be developed in consultation with the SHPO, Pima County, and interested Native American Indian tribes as stipulated in the MOA. Until the field studies, consultation, and determinations of resource eligibility and project effect are completed, the project does not comply with the Act.

Coordination: Arizona State Historic Preservation Officer (SHPO) - A letter will be sent to the SHPO with our determination of eligibility and effect in accordance with 36 CFR 800.4(d). All supporting documentation required under 36 CFR 800.11(d) will be sent to the SHPO. This

includes the draft EIS. The draft EIS will also be sent to the following for comment along with all identification, evaluation, and mitigation studies:

Pima County - Ms. Linda Mayro/Mr. Roger Anyon, County Archeologists

Tohono O'odham Nation - Mr. Peter Steere, Program Manager, Cultural Affairs Department

Hopi Tribe - Mr. Leigh Kuwanwisiwma, Cultural Preservation Office

Pascua Yaqui - Ms. Amalia A.M. Reyes, Language and Culture Preservation Specialist

Other requirements relating to the Arizona Game & Fish Department and the Arizona Department of Environmental Quality would need to be addressed by the non-Federal sponsor.

G. Non-Federal Requirements

The presently estimated non-Federal share of the total first cost of the project is $23,750,750, which includes $22,100,000 in estimated LERRDs credits and $1,650,750 in non-Federal contribution.

In addition, maintenance and operation of the environmental restoration project is estimated to cost the non- Federal sponsor $1,263,657 annually.

Requirements of non-Federal cooperation are specified below:

a. Provide 35 percent of the separable project costs allocated to environmental restoration and 50 percent of the separate project costs allocated to recreation, as further specified below:

(1) Enter into an agreement that provides, prior to execution of a project cooperation agreement for the project, 25 percent of design costs;

(2) Provide, during construction, any additional funds needed to cover the non-federal share of design costs;

(3) Provide all lands, easements, and rights of way, including suitable borrow and dredged or excavated material disposal areas, and perform or assure the performance of all relocations determined by the Government to be necessary for the construction, operation, and maintenance of the project;

(4) Provide or pay to the Government the cost of providing all retaining dikes, waste weirs, bulkheads, and embankments, including all monitoring features and stilling basins, that may be required at any dredged or excavated material disposal areas required for the construction, operation, and maintenance of the project; and

(5) Provide, during construction, any additional costs as necessary to make its total contribution equal to 35 percent of the separable project costs allocated to environmental restoration and 50 percent of the separable project costs allocated to recreation.

b. For so long as the project remains authorized, operate, maintain, repair, replace, and rehabilitate the completed project, or functional portion of the project, including mitigation features, at no cost to the Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and any specific directions prescribed by the Government in the OMRR&R manual and any subsequent amendments thereto.

c. Give the Government a right to enter, at reasonable times and in a reasonable manner, upon land which the local sponsor owns or controls for access to the project for the purpose of inspection, and, if necessary, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the project.

d. Comply with Section 221 of Public Law 91 611, Flood Control Act of 1970, as amended, and Section 103 of the Water Resources Development Act of 1986, Public Law 99 662, as amended, which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non Federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element.

e. Hold and save the Government free from all damages arising for the construction, operation, maintenance, repair, replacement, and rehabilitation of the project and any project related betterments, except for damages due to the fault or negligence of the Government or the Government's contractors.

f. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project to the extent and in such detail as will properly reflect total project costs.

g. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601 9675, that may exist in, on, or under lands, easements or rights of way necessary for the construction, operation, and maintenance of the project; except that the non Federal sponsor shall not perform such investigations on lands, easements, or rights of way that the Government determines to be subject to the navigation servitude without prior specific written direction by the Government.

h. Assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or rights of way that the Government determines necessary for the construction, operation, or maintenance of the project.

i. To the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project and otherwise perform its obligations in a manner that will not cause liability to arise under CERCLA.

j. Prevent future encroachments on project lands, easements, and rights of way that might interfere with the proper functioning of the project.

k. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public law 91 646, as amended by title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100 17), and the Uniform Regulations contained in 49 CFR part 24, in acquiring lands, easements, and rights of way, and performing relocations for construction, operation, and maintenance of the project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said act.

l. Comply with all applicable Federal and State laws and regulations, including Section 601 of the Civil Rights Act of 1964, Public Law 88 352, and Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600 7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army".

m. Provide the non-Federal share of that portion of the costs of mitigation and data recovery activities associated with historic preservation, that are in excess of 1 percent of the total amount authorized to be appropriated for the project, in accordance with cost sharing provisions of the agreement;

n. Not use Federal funds to meet the non-Federal sponsor's share of total project costs unless the Federal granting agency verifies in writing that the expenditure of such funds is authorized.

o. Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.

H. Sponsorship Agreements

The Pima County Flood Control District has provided a Letter of Intent acknowledging sponsorship requirements for the El Rio Antiguo Project (included in Chapter XI, Letters of Support and Financial Capability). Prior to the start of construction, the non-Federal sponsor will be required to enter into an agreement with the Federal Government that it will comply with Section 221 of the Flood Control Act of 1970 (P.L. 9 1-61 1), and the Water Resources Development Act of 1986 (P.L. 99-662) as amended.

I. Procedures for Implementation

Future actions necessary for authorization and construction of the selected plans are summarized as follows:

(1) This report will be reviewed by the Headquarters of the U.S. Army Corps of Engineers, Washington, D.C.

(2) The Chief of Engineers will seek formal review and comment by the Governor of the State of Arizona and interested Federal agencies.

(3) Following State and Agency review, the report will be sent to the Assistant Secretary of the Army for Civil Works.

(4) Upon approval of the Assistant Secretary, the report will be forwarded to the Office of Management and Budget (0MB) to obtain the relationship of the project to programs of the President.

(5) The final report of the Chief of Engineers will then be forwarded by the Assistant Secretary of the Army for Civil Works to Congress.

(6) Congressional review of the feasibility report and possible authorization of the project would follow.

(7) Pending project authorization for construction, the Chief of Engineers could include funds where appropriate, in his budget requests for preconstruction engineering and design of the project. The objective is to ready each project for a construction start established with the feasibility study.

(8) Following receipt of funds, preconstruction engineering and design would be initiated and surveys and detailed engineering designs would be accomplished.

(9) Following Congressional authorization of the project, plans and specifications would be accomplished by the District Engineer.

(10) Subsequent to appropriation of construction funds by Congress, but prior to construction, the local sponsor would enter into a binding agreement to furnish the required cooperation. This agreement is the Project Cooperation Agreement (PCA).

(11) Bids for construction would be initiated and contracts awarded.

CHAPTER VIII
Public Views and Comments

A. Non-Federal Views and Preferences

The non-Federal views and preferences regarding environmental restoration were in general obtained through coordination with the non-Federal sponsor and with various local and regional agencies and organizations, neighborhood associations, and the general public. These coordination efforts consisted of a series of public meetings held during the reconnaissance and feasibility study phases, though surveys, through the maintenance of a 'point- of-contact' with whom any interest could discuss matters, and a mailing list by which invitations to public meetings were distributed. Announcements for public meetings were made in local newspapers indicating the date, time, place, and subject matter.

B. Views of the Non-Federal Sponsor

The Pima County Flood Control District has expressed willingness in continuing to be the non-Federal sponsor for project implementation. The County has indicated its support for the project and a willingness to assume cost-shared financial obligations for its implementation.

The non-Federal sponsor fully supports the results of the feasibility study. The non-Federal sponsor's interest in implementing environmental restoration solutions for the El Rio Antiguo area is reflected in the many previous studies and reports prepared by the County and by their willingness to enter into a cost-shared feasibility study to determine Federal interest.

There currently exists within the community, and with the non-Federal sponsor, significant interest for providing environmental restoration solutions for the El Rio Antiguo area. This is demonstrated by their desire to pursue environmental restoration options for the project, and their willingness to accommodate Federal guidance in the selected plan. The DEIS addresses existing resources and potential impacts to these resources from implementation of the desired environmental restoration alternative. It indicates that the selected plan would have temporary impacts to environmental resources associated with construction activities. These impacts are mitigable through adoption of Best Management Practices that reduce or eliminate the impacts. This is discussed in detail in the DEIS.

Locally preferred options within the study area are consistent with the Selected Plan. The non-Federal sponsor has related its acceptance of the selected plan and is willing to accept the Corns of Engineers identified NER plan as the Locally Preferred Plan.

C. Financial Analysis

Further project engineering, design, and construction would be conducted in accordance with the cost-sharing principles provided by the Water Resources Development Act of 1986, as amended. The non-Federal sponsor has indicated its ability and willingness to participate in the planning, engineering and design of the selected plan, and to participate in construction of the project. The statement of financial capability is provided in Chapter XI, Letters of Support and Financial Capability.

D. Summary of Study Management, Coordination, Public Views and Comments

The study team was a multi-disciplinary group that consisted of several functional elements of the Corns and the non-Federal sponsor. The study team included study and project managers, engineers, hydrologic and hydraulic engineers, groundwater specialists, environmental specialists, cost estimators, designers, appraisers, economists, materials, geotechnical specialists, real estate specialists, and landscape architects.

Formal and informal coordination occurred with a variety of Federal state and local agencies in addition to the public involvement efforts described above. Agencies contacted included the United States Fish and Wildlife Service (USFWS), the Arizona Department of Game and Fish (ADGF), the City of Tucson Parks, Tucson Water Department, City of Tucson Transportation, Pima County Department of Transportation, Pima County Cultural Resources, and Pima County Parks and Recreation. In addition to the above local stakeholders included the University of Arizona Cooperative Extension, Pima Trails, local Homeowners Associations, Tucson Audubon Society, and Friends of the Rillito, a neighborhood group.

Representatives from USFWS and ADGF participated in development of the functional assessment model and its application. USFWS also participated in development of alternatives and their design. USFWS has prepared a Planning Aid Letter and is currently preparing a Coordination Act Report for this study.

Throughout the planning process for this project, public input has been solicited utilizing a variety of avenues including local newspaper articles, public information mailings, and coordination with special-interest groups, public workshops and formal public hearings. The initial planning process began with a meeting November 13, 2001 to identify and review the primary issue areas involved in the El Rio Antiguo study area. Because of that initial meeting, further meetings were scheduled to establish a process for development of public involvement in planning for restoration of the El Rio Antiguo, Rillito River study area. Issues addressed included habitat restoration, water budget, water quality, wildlife habitat, recreation, environmental education and tributary flood control. The principal participants in this public workshop planning process were representatives from Federal, state, and local agencies, citizens from the local area, and other stakeholders.

The process established a series of workshops around the principal issue areas: restoration of riparian habitat, establishment of a wildlife corridor, water supply, water quality, and recreation. The first Work Group meeting was held May 8, 2002 and began 7 months of meetings, field trips and hard work in order to document their ideas and input to the habitat restoration design. Seven monthly meetings and two group field trips were conducted May through November 2002.

After the workshops, ideas were synthesized into an alternative plan concept that included all of the community perspectives and would be acceptable to all participants. Subsequent plan formulation efforts integrated Work Group concepts wherever possible. Detailed information on the Work Group proceedings may be found in the Public Involvement Appendix.

CHAPTER IX
Conclusions

The major conclusions of the El Rio Antiguo Ecosystem Restoration Feasibility Study to date are:

a. Developmental pressures combined with increasing appropriation of groundwater and surface water flows have been the most significant contributors to increasing degradation and loss of riparian habitat along the Rillito River in the last century. Future without project conditions will see the loss of the remaining pockets of habitat as adjacent vacant lands develop. The local species of concern, as well as birds migrating along the Pacific Flyway, will lose much of their forage base and will be much more vulnerable to terrestrial disturbances and predation.

b. Alternative measures developed to address the study objectives and constraints include construction of vegetated terraces to reconnect portions of the floodplain with the Rillito, placement and planting of water harvesting basins at tributary confluences, creation of vegetated water harvesting channels connecting Finger Rock Wash with the Rillito, planting of a low area on the north bank between Craycroft Road and Swan Road and irrigation of the planted areas.

c. The recommended plan will result in a total increase of 120 average annual functional capacity units at a total average annual cost of $5,292,700, an average annual cost of $44,100 per average annual functional capacity unit.

d. The total first cost of implementing the plan is $66,657,000 ($63,852,500 environmental restoration and $2,804,500 recreation). The Federal share is currently estimated at $42,906,250 (41,504,000 environmental restoration and $1,402,250 recreation). Annual Operation and Maintenance costs are estimated to be about $1,243,357 and are a 100% non-Federal responsibility.

e. The County of Pima is the Sponsor for the feasibility study and fully supports the recommended plan as the locally preferred plan. The Sponsor is willing and able to cost-share in the PED phase and are willing to participate in the cost sharing for the construction of the project.

f. The resource agencies and local interests also support this project.

CHAPTER X
Recommendations

I recommend that the plan described herein for environmental restoration, flood control, and recreation, be authorized for implementation as a Federal project. The total first cost of the project is currently estimated at $66,657,000 under October 2004 prices. The Federal share is currently estimated at $42,906,250.

I recommend that the Corps of Engineers participate in cost-shared monitoring and minor modifications, as maybe required to ensure success of the project, as identified and described within the Monitoring and Adaptive Management Plan.

My recommendation is subject to cost sharing, financing, and other applicable requirements of Federal and State laws and policies, including Public Law 99-663, the Water Resources Development Act of 1986, as amended by Section 210 of Public Law 104-303, the Water Resources Development Act of 1996, and in accordance with the required items of local cooperation identified in Chapter VII which the non-Federal sponsor must agree to prior to project implementation.

The plans presented herein are recommended with such modifications thereof as in the discretion of the Commander, HQUSACE, may be advisable.

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding. However, prior to transmittal to the Congress, the non- Federal sponsor, the State, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

Richard G. Thompson
Colonel, US Army
District Engineer

CHAPTER XI
LETTERS OF SUPPORT AND FINANCIAL CAPABILITY

As required by Section 905 of the Water Resources Development Act, of 1986 a financial capability statement from Pima County will be included in the final report to show non-Federal cost sharing capability and intent.

PUBLIC WORKS
pima county

John M. Bernal,
Deputy County Administrator

PIMA COUNTY
Public Works Administration
100 N. Stone Ave., Suite 300
Tucson, Arizona 85701

Website: www.co.pima.az.us
Tel.: 520.205.8350
fax: 520.205.8360

December 4, 2003

Colonel Richard G. Thompson
United States Army Corps of Engineers
915 Wilshire Boulevard, Suite 14P00
Los Angeles, California 90017

Re: El Rio Antiguo, Rillito River Ecosystem Restoration
Feasibility Study
Pima County, Arizona

Letter of Support for El Rio Antiguo

Dear Colonel Thompson:

Pima County, as local sponsor, extends its support of the recommended plan contained in the El Rio Antiguo, Rillito River Ecosystem Restoration Feasibility Report as an appropriate measure to restore riparian habitat to the Rillito River. A majority of Pima County's habitat has been lost due to urban development and groundwater usage in the Tucson basin. This restoration project is consistent with the county's overall goal of protection and restoration of our natural resources and will augment the Sonoran Desert Conservation Plan.

Pima County is prepared to move forward, as the local sponsor, with the U.S. Army Corps of Engineers to design and construct the El Rio Antiguo, Rillito River Ecosystem Restoration project. The project is located in Pima County, along the Rillito River between Craycroft Road and Campbell Avenue. Anticipating Congressional authorization of the project, the county is prepared to commit to its local share of 35% of preconstruction engineering and design (PED).

Pima County will assume its obligation to acquire all Lands, Easements, Rights of way, Relocations, and Disposal areas and upon completion, operate and maintain the project. We are prepared to meet our financial obligations to ensure completion of this project and look forward to executing an agreement for the Design phase of El Rio Antiguo project.

Sincerely,

John M. Bernal
Deputy County Administrator – Public Works