US Army Corps of Engineers
Los Angeles District

Santa Cruz River, Paseo de las Iglesias
Pima County, Arizona

Final Feasibility Report and

Environmental Impact Statement

APPENDIX D
HABITAT ANALYSIS

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1. INTRODUCTION

The U.S. Army Corps of Engineers (the "Corps") is conducting a feasibility study in the Paseo de las Iglesias reach of the Santa Cruz River to identify, define and solve environmental degradation, flooding and related water resource problems. These efforts are proceeding in partnership with the Pima County Department of Transportation and Flood Control District, the non-Federal sponsor.

The Paseo de las Iglesias study area was defined in coordination with the non-federal sponsor based on factors including but not limited to jurisdictional boundaries, physical impediments (i.e., highways), and historical floodplain limits. The Paseo de las Iglesias study area is approximately 5005 acres and consists of a 7-mile reach of the Santa Cruz River and its tributary washes. Beginning where Congress Street crosses the river in downtown Tucson the study area extends upstream to the south along the river to the boundary of the San Xavier District of the Tohono O'Odham Nation (see Figure 1). The eastern study boundary is represented by Interstates 10 and 19. The western study area boundary is represented by Mission Road and the San Xavier District of the Tohono O'Odham Nation. The study area name, Paseo de las Iglesias, translates to "Walk of the Churches." The study area derives its name from the fact that it provides the physical and cultural connection between the 18^{th} century San Xavier Mission and the Mission San Augustin archeological site. This area is the cradle of modern day Tucson and has a lineage of continued habitation dating thousands of years before settlement of the area by the Spanish missionaries.

In the Southwest, riparian landscapes are invaluable. Although they represent less than 1% of the region's area (Knopf, F. L. 1989), a large proportion (75-80%; Gillis 1991) of vertebrate wildlife species depends on riparian areas for food, water, cover, and migration routes. Riparian zones also improve water quality because they filter sediments and nutrients; accumulated sediments in riparian zones store large amounts of water, which helps sustain stream flow during drier times.

It is important to note that the basic ecological premise behind ecosystem restoration is the recovery of limiting components, defined by their primary functional characteristics, be they water, soils and/or habitat structure. The primary goal of this study was therefore focused on the restoration of such functional components within the study area. To measure the success of the ecosystem restoration proposals, the best available science was brought to bear. In most ecosystem restoration studies, benefits are measured using quantifiable techniques rather than qualitative assessments. It was important then, that the technique selected to quantify benefits for the studies be repeatable, efficient and effective, as results could be questioned by outside interests, and the participating agencies could not afford to spend excessive quantities of time evaluating alternatives.

In previous ecosystem restoration studies, the Losa Angeles District primarily evaluated wildlife benefits using a technique referred to as modified Habitat Evaluation Procedures (mHEP). 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 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.

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. 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 (Smith et al. 1995).

The Hydro Geomorphic Assessment of Wetlands approach (HGM) was developed specifically to accomplish this task (Ainslie et al. 1999; Brinson 1993). HGM identifies groups of wetlands that function similarly using three criteria (geomorphic setting, water source, and hydrodynamics) that fundamentally influence how wetlands and riparian systems function.

For the purposes of this study, both the mHEP and HGM methodologies are presented herein to assess the Without and With Project Conditions.

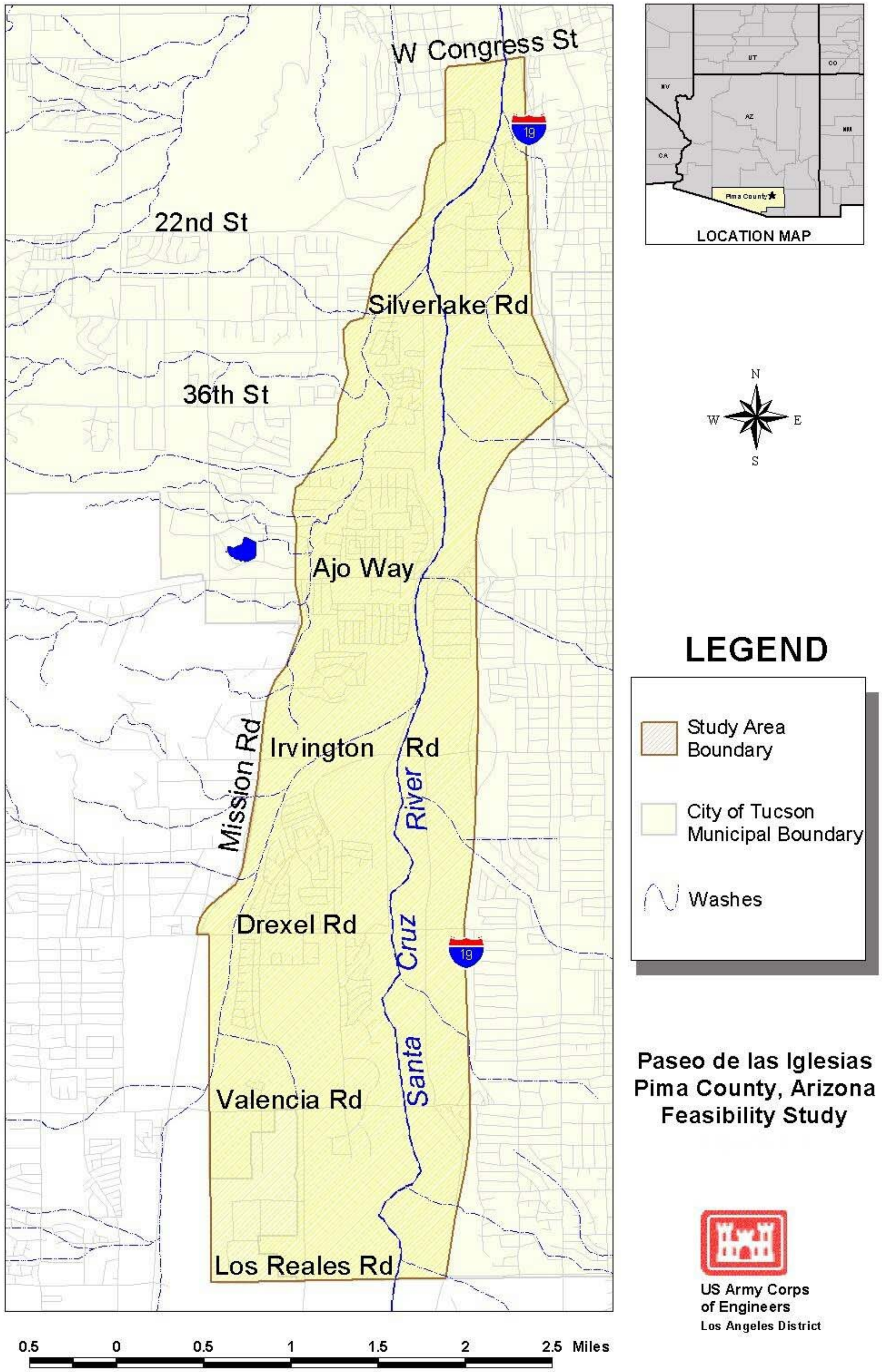


Figure 1: Paseo de las Iglesias Study Area

2. ECOSYSTEM RESTORATION EVALUATION METHODOLOGIES

2.1 Species-Based Habitat Indices

USACE presently uses the habitat unit concept to characterize the non-monetary outputs of ecosystems that must justify project costs. The concept is closely associated with development of the Habitat Evaluation Procedures (HEP) developed under the lead of the U. S. Fish and Wildlife Services (USFWS 1980a-c). HEP measures the effects of environmental change through a series of species-based Habitat Suitability Indices (HSI) developed for approximately 160 individual fish and wildlife species. The species-based HSI models rely on field measured habitat parameters, which are integrated into a single, probability-of-use index ranging from 0 to 1.0. HEP uses a simple multiplication product of impacted area in acres and HSI to calculate Habitat Units (HUs).

Species-based Habitat Suitability Index (HSI) models deployed in the traditional Habitat Evaluation Procedures (HEP) methodology are numerous, easy to use, are relatively inexpensive, but not immediately available or applicable to the arid southwest region, and do not capture all of the important habitat/ecosystem elements or all of the justifying value needed to restore ecosystems. Species-based HSI models are not scaled based on ecosystem integrity and should only be used to indicate a more naturally integrated ecosystem condition when the HSI value is known for the targeted restored condition. Few existing single-species HSI models satisfy these criteria well, but ecosystems might be characterized by new models for native dominant and keystone species, including dominant plant species and top-carnivore species, used in series with a few HSI models for rare species in the community. Several species-based HSIs might then "bracket" the community-habitat relationships satisfactorily, but the need for many new models offsets the main existing advantage.

2.2 Community-Based Habitat Indices

Existing community- based HSI models offer more promise than species-based HSI models because they are more efficient in capturing those habitat measures necessary for restoring ecosystem integrity and can be compared across a wide range of ecosystems for prioritization purposes (Stakhiv, et al. 2001). Community-based HSI models indicate relative ecosystem value more inclusively than species-based models because they link habitat more broadly to ecosystem components or functions. While species richness is relatively easy to link to habitat features in community-based HSI models, species richness may not predict the number of endangered species present in an ecosystem very well. Most species richness measures are limited to one to a few taxonomic categories, such as birds, fish, or aquatic insects. The taxonomic groups chosen for characterizing integrity may not characterize to fine enough degree the habitat needs of the endangered species. Complete models would need to account for this potential deficiency by assuring the diversity measure is inclusive of the vulnerable species or by including a separate relationship between vulnerable-species and habitat conditions. Again, each community would require a unique model of habitat-species relationships. Relatively few community prototype models have been developed, however, and most of the models would require considerable investment to cover the variety of ecosystems managed by the Corps.

2.3 Function-Based Indices

USACE's Environmental Laboratory (Engineer Research and Development Center, Vicksburg, MS) developed a similar approach to assessing the functional capacity of a wetland using standard wetland assessment protocols typically deployed in the regulatory arena. Referred to as the HydroGeoMorphic Approach (or HGM), an assessment model is developed and serves as a simple representation of functions performed by a wetland ecosystem (Ainslie et al. 1999). The model defines the relationships between one or more characteristics or processes of the wetland ecosystem or surrounding landscape and the functional capacity of a wetland ecosystem. Functional capacity is simply the ability of a wetland to perform a function compared to the level of performance in reference standard wetlands. The HGM methodology is based on a series of predictive Functional Capacity Indices (FCIs) – quantifying the capacity of wetlands to perform a function relative to other wetlands from a regional wetland subclass in a reference domain. Functional capacity indices are by definition scaled from 0.0 to 1.0. 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 in a reference domain. 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. FCI models combine VSIs in a mathematical equation to rate the functional capacity of a wetland on a scale of 0.0 (not functional) to 1.0 (optimum functionality). An HGM subclass model is basically an assimilation of several FCI models combined in a specific fashion to mimic a site's functionality. Users can review and select several FCI models to evaluate the overall site functionality. All FCI models are described using a single FCI formula (refer to the Single Formula Subclass Models section below). Some examples of HGM FCI models include floodwater detention, internal nutrient cycling, organic carbon export, removal and sequestration of elements and compounds, maintenance of characteristic plant communities, and wildlife habitat maintenance.

2.4 Process Simulation Models

Process simulation models are based (in theory) on ecosystem process and offer the greatest flexibility in use and management insight with respect to the output generated with incremental additions of restoration measures (Stakhiv, et al. 2001). Functional stability could in theory be analyzed directly. In terms of basic processes, similar principles operate across all ecosystems. However, process models rely on fundamental understanding of the way ecosystems operate and are extremely "information hungry". Much can be learned about how ecosystems work during assembly of process models, but the ultimate models for evaluating non-monetized environmental service are many years away even if research investment were substantially increased. The past objections to process models having to do with inadequate portability and computational capability are less likely to apply now. Even so, the details of resource partitioning into communities of different species richness and functional stability require much research and development. In the process of assembling such models, much more could be learned than from index models about managing ecosystem process for more reliable service delivery (sustainable development?) across all monetized and non-monetized services. Process simulation shows the most promise for incorporating tradeoff analysis within single model operations.

2.5 SELECTION OF THE HGM METHOD FOR THE ARIZONA STUDIES

In 2002, the Los Angeles District began the process of formulating alternative designs for the five Arizona Ecosystem Restoration Planning Studies (El Rio Antiguo on the Rillito River, Paseo de las Iglesias and Tres Rios del Norte on the Santa Cruz River, Rio Salado Oeste and VaShly'ay Akimel on the Salt River). The District partnered with the U. S. Army Engineer Research and Development Center (ERDC) Environmental Laboratory (EL), the U.S. Fish and Wildlife Service (USFWS), and the Arizona Game and Fish Department (AGFD) to ensure all stakeholder issues were considered.

Setting ecosystem restoration objectives and performance criteria on the holistic recovery of "non-use" benefits, such as wildlife habitat, hydrology and biogeochemical processes, was critical to the overall planning process for the studies. It is important to note that the basic ecological premise behind ecosystem restoration is the recovery of limiting components, defined by their primary functional characteristics, be they water, soils and/or habitat structure. The primary goal of the studies was therefore focused on the restoration of such functional components within the study area. To measure the success of the ecosystem restoration proposals, the best available science was brought to bear. In most ecosystem restoration studies, benefits are measured using quantifiable techniques rather than qualitative assessments. It was important then, that the technique selected to quantify benefits for the studies be repeatable, efficient and effective, as results could be questioned by outside interests. Many rapid assessment techniques were readily available to the Evaluation Teams in off-the-shelf formats in 2002, but for the various reasons described in the next section, HGM (HydroGeoMorphic Assessment of Wetlands) was selected to quantify the anticipated benefits gained by the proposed ecosystem restoration activities.

Again, HGM emphasizes 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. Although models used in a HEP methodology might be more appropriate to a riparian setting in this region, their overall evaluation of potential changes to the ecosystem dynamic are limited when capturing wetland functionality as a whole. The HGM 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. Available HEP models were limited to the habitat function in support of species richness, and might overlook key hydrologic influences experienced in high-flow periods.

2.6 Introduction To The HGM Process

Wetland ecosystems share a number of common attributes including relatively long periods of inundation or saturation, hydrophytic vegetation, and hydric soils. In spite of these common attributes, wetlands occur under a wide range of climatic, geologic, and physiographic situations and exhibit a wide range of physical, chemical, and biological characteristics and processes [Ainslie et al. 1999; Ferren, Fiedler, and Leidy (1996); Ferren et al. 1996a,b; Mitch and Gosselink 1993; Semeniuk 1987; Cowardin et al. 1979). 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. 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 (Smith et al. 1995).

The HydroGeoMorphic Assessment of Wetlands approach (HGM) was developed specifically to accomplish this task (Ainslie et al. 1999; Brinson 1993). HGM identifies groups of wetlands that function similarly using three criteria (geomorphic setting, water source, and hydrodynamics) that fundamentally influence how wetlands function. "Geomorphic setting" refers to the landform and position of the wetland in the landscape. "Water source" refers to the primary water source in the wetland such as precipitation, overbank floodwater, or groundwater. "Hydrodynamics" refers to the level of energy and the direction that water moves in the wetland. Based on these three criteria, any number of "functional" wetland groups can be identified at different spatial or temporal scales. For example, on a continental scale, Brinson (1993) identified five hydrogeomorphic wetland classes. These were later expanded to the seven classes described in Table 1 (Smith et al. 1995).

Table 1. HydroGeoMorphic Wetland Classes on a Continental Scale

HGM Wetland Class	Definition
Depression	Depression wetlands occur in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water. Depression wetlands may have any combination of inlets and outlets or lack them completely. Potential water sources are precipitation, overland flow, streams, or groundwater/interflow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression. The predominant hydrodynamics are vertical fluctuations that range from diurnal to seasonal. Depression wetlands may lose water through evapotranspiration, intermittent or perennial outlets, or recharge to groundwater. Prairie potholes, playa lakes, vernal pools, and cypress domes are common examples of depression wetlands.
Tidal Fringe	Tidal fringe wetlands occur along coasts and estuaries, and are under the influence of sea level. They intergraded landward with riverine wetlands where tidal current diminishes, and river flow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. The interface between the tidal fringe and riverine classes is where bi-directional flows from tides dominate over unidirectional ones controlled by floodplain slope of riverine wetlands. Because tidal fringe wetlands frequently flood and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. Tidal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent, and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh. *Spartina alterniflora* salt marshes are a common example of tidal fringe wetlands.
Lacustrine Fringe	Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water. Fringe table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. Surface water flow is bi-directional, usually controlled by water-level fluctuations resulting from wind or seiche. Lacustrine wetlands lose water by flow returning to the lake after flooding and evapotranspiration. Organic matter may accumulate in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are an example of lacustrine fringe wetlands.

Table 1. (cont.) HydroGeoMorphic Wetland Classes on a Continental Scale

HGM Wetland Class	Definition
Slope	Slope wetlands are found in association with the discharge of groundwater to the land surface or sites with saturated overland flow with no channel formation. They normally occur on sloping land ranging from slight to steep. The predominant source of water is groundwater or interflow discharging at the land surface.. Precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by down-slope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturated subsurface flows, surface flows, and by evapotranspiration. Slope wetlands may develop channels, but the channels serve only to convey water away from the slope wetland. Slope wetlands are distinguished from depression wetlands by the lack of a closed topographic depression and the predominance of the groundwater/interflow water source. Fens are a common example of slope wetlands.
Mineral Soil	Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large floodplain terraces Flats where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater.. They are distinguished from flat upland areas by their poor vertical drainage due to impermeable layers (e.g., hardpans), slow lateral drainage, and low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become organic soil flats. They typically occur in relatively humid climates. Pine flatwoods with hydric soils are an example of mineral soil flat wetlands.
Organic Soil Flats	Organic soil flats, or extensive peat lands, differ from mineral soil flats in part because their elevation and Soil Flats topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by overland flow and seepage to underlying groundwater. They occur in relatively humid climates. Raised bogs share many of these characteristics but may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peat lands are examples of organic soil flat wetlands.

Table 1. (cont.) HydroGeoMorphic Wetland Classes on a Continental Scale

HGM Wetland Class	Definition
Riverine	Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. Additional sources may be interflow, overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. In headwaters, riverine wetlands often intergrade with slope, depressional, poorly drained flat wetlands, or uplands as the channel (bed) and bank disappear. Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evapotranspiration. Peat may accumulate in off-channel depressions (oxbows) that have become isolated from riverine processes and subjected to long periods of saturation from groundwater sources. Bottomland hardwoods on floodplains are an example of riverine wetlands.

In many cases, the level of variability in continental-scale wetland hydrogeomorphic classes is still too immense to develop assessment models that can be rapidly applied while being sensitive enough to detect changes in function at a level of resolution appropriate to the planning process. For example, at a continental geographic scale the depression class includes wetlands as diverse as California vernal pools (Zedler 1987), prairie potholes in North and South Dakota (Kantrud et al. 1989; Hubbard 1988), playa lakes in the high plains of Texas (Bolen et al. 1989), kettles in New England, and cypress domes in Florida (Kurz and Wagner 1953; Ewel and Odum 1984).

To reduce both inter- and intra-regional variability, the three classification criteria (geomorphic setting, water source, and hydrodynamics) are applied at a smaller, regional geographic scale to identify regional wetland subclasses. In many parts of the country, existing wetland classifications can serve as a starting point for identifying these regional subclasses (Stewart and Kantrud 1971; Golet and Larson 1974; Wharton et al. 1982; Ferren, Fiedler, and Leidy 1996; Ferren et al. 1996a,b; Ainslie et al. 1999). In addition to the three primary classification criteria, certain ecosystem or landscape characteristics may also be useful for distinguishing regional subclasses in certain regions. For example, depression subclasses might be based on water source (i.e., groundwater versus surface water) or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels). Tidal fringe subclasses might be based on salinity gradients (Shafer and Yozzo 1998). Slope subclasses might be based on the degree of slope, landscape position, source of water (i.e., through-flow versus groundwater), or other factors. Riverine subclasses might be based on water source, position in the watershed, stream order, watershed size, channel gradient, or floodplain width. Examples of potential regional subclasses are shown in Table 2 (Smith et al. 1995; Rheinhardt et al. 1997).

Table 2. Potential Regional Wetland Subclasses in Relation to Geomorphic Setting, Dominant Water Source, and Hydrodynamics

Geomorphic Setting	Dominant Water Source	Dominant Hydrodynamics	Potential Regional Wetland Subclasses	
			Eastern USA	Western USA/Alaska
Depression	Groundwater or interflow	Vertical	Prairie pothole marshes, Carolina Bays	California vernal pools
Fringe (tidal)	Ocean	Bidirectional, horizontal	Chesapeake Bay and Gulf of Mexico tidal marshes	San Francisco Bay marshes
Fringe (lacustrine)	Lake	Bidirectional, horizonal	Great Lakes marshes	Flathead Lake marshes
Slope	Groundwater	Unidirectional, horizontal	Fens	Avalanche chutes
Flat (mineral soil)	Precipitation	Vertical	Wet pine flatwoods	Large playas
Flat (mineral soil)	Precipitation	Vertical	Peat bogs; portions of Everglades	Peatlands over permafrost
Riverine	Overbank flow from channels	Unidirectional, horizonal	Bottomland hardwood forests	Riparian wetlands

Regional Guidebooks include a thorough characterization of the regional wetland subclass in terms of its 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.

Designed to assess wetlands as a whole, the HGM technique focuses on a wetlands' structural components and the processes that link these components within a system (Bormann and Likens 1969). Structural components of the wetland and the surrounding landscape (e.g., plants, soils, hydrology, and animals) interact with a variety of physical, chemical, and biological processes. Understanding the interactions of the wetlands' structural components and the surrounding landscape features is the basis for assessing wetland functions and the foundation of the HGM Approach. By definition, wetland functions are the normal or characteristic activities that take place in wetland settings. Wetlands perform a wide variety of functions, although not all wetlands perform the same functions, nor do similar wetlands perform the same functions to the same level of performance. The ability to perform a function is influenced by the characteristics of the wetland and the physical, chemical, and biological processes within the wetland. Wetland characteristics and processes influencing one function often also influence the performance of other functions within the same wetland system. Examples of wetland functions evaluated with Functional Capacity Index (FCI) models are found in Table 3.

Table 3. Wetland functions measured in HGM and their value to the ecosystem

Functions Related to the Hydrologic Processes	**Benefits, Products, and Services Resulting from the Wetland Function**
Short-Term Storage of Surface Water: The temporary storage of surface water for short periods.	Onsite: Replenish soil moisture, import/export materials, and provide a conduit for organisms. Offsite: Reduce downstream peak discharge and volume, and help maintain and improve water quality.
Long-Term Storage of Surface Water: The temporary storage of surface water for long periods.	Onsite: Provide habitat and maintain physical and biogeochemical processes. Offsite: Reduce dissolved and particulate loading and volume, and help maintain and improve surface water quality.
Storage of Subsurface Water: The storage of subsurface water.	Onsite: Maintain biogeochemical processes. Offsite: Recharge surficial aquifers, and maintain base flow and seasonal flow in streams.
Moderation of Groundwater Flow or Discharge: the moderation of groundwater flow or groundwater discharge.	Onsite: Maintain habitat. Offsite: Maintain groundwater storage, base flow, seasonal flows, and surface water temperatures.
Dissipation of Energy: The reduction of energy in moving water at the land/water interface.	Onsite: Contribute to nutrient capital of ecosystem. Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality.
Functions Related to Biogeochemical Processes	**Benefits, Products, and Services Resulting from the Wetland Function**
Cycling of Nutrients: The conversion of elements from one form to another through abiotic and biotic processes.	Onsite: Contributes to nutrient capital of the ecosystem. Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality.
Removal of Elements and Compounds: The removal of nutrients, contaminants or other elements and compounds on a short-term or long-term basis through physical processes.	Onsite: Contributes to nutrient capital of the ecosystem. Contaminants are removed, or rendered innocuous. Offsite: Reduced downstream loading helps to maintain or improve surface water quality.
Retention of Particulates: The retention of organic and inorganic particulates on a short-term or long-term basis through physical processes.	Onsite: Contributes to nutrient capital of the ecosystem. Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality.

Export of Organic Carbon: The export of dissolved or particulate organic carbon.	Onsite: Enhances decomposition and mobilization of metals. Offsite: Supports aquatic food webs and downstream biogeochemical processes.
Functions Related to Habitat	**Benefits, Products, and Services Resulting from the Wetland Function**
Maintenance of Plant and Animal Communities: the maintenance of plant and animal community that is characteristic with respect to species composition, abundance, and age structure.	Onsite: Maintain habitat for plants and animals (e.g., endangered species and critical habitats) forest and agriculture products, and aesthetic, recreational, and educational opportunities. Offsite: Maintain corridors between habitat islands and landscape/regional biodiversity.

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. Consequently, wetland assessments using the HGM approach require the recognition by both the Assessment Team and the end user that this link (i.e., between wetland function and system integrity) is critical. One cannot develop criteria, or models, to maximize a single function without having potentially negative impacts on the overall ecological integrity and sustainability of the wetland system as a whole. For example, one should not attempt to create a wetland to maximize water storage capacity without the recognition that other functions (e.g., plant species diversity) will likely be altered from those similar wetland types with less managed conditions. This does not mean that a wetland cannot be developed to maximize a particular function, but that it will typically not be a sustainable system without future human intervention.

The HGM approach is characterized and differentiated from other wetland assessment procedures in that it first classifies wetlands based on their ecological characteristics (i.e., landscape setting, water source, and hydrodynamics). Second it uses reference sites to establish the range of wetland functions. Finally, the HGM approach uses a relative index of function (Functional Capacity Index or FCI), calibrated to reference wetlands, to assess wetland functions. In the HGM methodology, a Variable Subindex (VSI), is a mathematical relationship that reflects a wetland function's sensitivity to a change in a limiting factor or variable within the Partial Wetland Assessment Area or PWAA (a homogenous zone of similar vegetative species, geographic similarities, and physical conditions that make the area unique). Similar to cover types in HEP, PWAAs are defined on the basis of species recognition and dependence, soils types, and topography. In HGM, VSIs are depicted using scatter plots and bar charts (i.e., functional capacity curves). The VSI value (Y axis) ranges on a scale from 0.0 to 1.0, where a VSI = 0.0 represents a variable that is extremely limiting and an VSI = 1.0 represents a variable in abundance (not limiting) for the wetland.

Reference wetlands 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 (Ainslie et al. 1999). The use of reference wetlands to scale the capacity of wetlands to perform a function is one of the unique features of the HGM approach. Reference provides the standard for comparison in the HGM approach. Unlike other methods which rely on data from published literature or best professional judgment, the HGM 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. Since wetlands exhibit a wide range of variability, reference wetlands should represent the range of conditions within the reference domain. A basic assumption of HGM is that the highest, sustainable functional capacity is achieved in wetland ecosystems and landscapes that have not been subject to long-term anthropogenic disturbance (Smith et al. 1995). 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. However, 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 subindex. To assist the user, a list of key terms related to the reference wetland concept in the HGM methodology (Table 4).

Table 4. Reference Wetland Terms and Definitions

Term	Definition
Reference domain	The geographic area from which reference wetlands representing the regional wetland subclass are selected
Reference Wetland	A group of wetlands that encompass the known range of variability in the regional wetland subclass resulting from natural processes and disturbance and from human alteration.
Reference standard wetlands	The subset of reference wetlands that perform a representative suite of functions at a level that wetlands is both sustainable and characteristic of the least human altered wetland sites in the least human altered landscapes. By definition, the functional
Reference standard wetlands variable condition	The range of conditions exhibited by model variables in reference standard wetlands. By wetland variable definition, reference standard conditions receive a variable subindex score of 1.0.
Site potential **- Mitigation Project Context**	The highest level of function possible, given local constraints of disturbance history, land use, (mitigation project or other factors. Site potential may be less than or equal to the levels of function in reference context) standard wetlands of the regio
Project target **- Mitigation Project Context**	The level of function identified or negotiated for a restoration or creation project.
Project standards **- Mitigation Project Context**	Project standards Performance criteria and/or specifications used to guide the restoration or creation activities (mitigation context) toward the project target. Project standards should specify reasonable contingency measures if the project target is not

In the HGM approach, an assessment model is a simple representation of a function performed by the wetland ecosystem (Ainslie et al. 1999). It defines the relationship between one or more characteristics or processes of the wetland ecosystem or surrounding landscape and the functional capacity of a wetland ecosystem. Functional capacity is simply the ability of a wetland to perform a function compared to the level of performance in reference standard wetlands. The HGM methodology is based on a series of predictive Functional Capacity Indices (FCIs). An index of the capacity of wetland to perform a function relative to other wetlands from a regional wetland subclass in a reference domain. Functional capacity indices are by definition scaled from 0.0 to 1.0. 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 in a reference domain. 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. FCI models combine VSIs in a mathematical equation to rate the functional capacity of a wetland on a scale of 0.0 (not functional) to 1.0 (optimum functionality). An HGM subclass model is basically an assimilation of several FCI models combined in a specific fashion to mimic a site's functionality. Users can review and select several FCI models to evaluate the overall site functionality. All FCI models are described using a single FCI formula (refer to the Single Formula Subclass Models section below). Some examples of HGM FCI models include floodwater detention, internal nutrient cycling, organic carbon export, removal and sequestration of elements and compounds, maintenance of characteristic plant communities, and wildlife habitat maintenance.

Reference sites used for model calibration for Arizona Studies included The Nature Conservancy's Hassayampa River Preserve, the Verde River at the confluence with the Salt River, the 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 River confluence. These sites were recommended based on the following criteria: 1) they were reasonable sites considering current conditions, 2) they were in a similar regional Riverine subclass to the Santa Cruz River with similar elevation, topography, gradient, and stream order, 3) they represented important aspects of pre-historical conditions, and 4) 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. The goal in choosing these sites was that the hydrologic, biogeochemical and habitat characteristics be as undisturbed as possible.

HGM model variables represent the characteristics of the wetland ecosystem (and surrounding landscape) that influence the capacity of a wetland ecosystem to perform a function. HGM model variables are ecological quantities that consist of five components (Schneider 1994). These include: 1) a name, 2) a symbol, 3) a measure of the variable and procedural statement for quantifying or qualifying the measure directly or calculating it from other measurements, 4) a set of values [i.e., numbers, categories, or numerical estimates (Leibowitz and Hyman 1997)] that are generated by applying the procedural statement, and 5) units on the appropriate measurement scale. Table 5 provides several examples.

Table 5. Components of a typical HGM model variables

Name (Symbol)	Measure/Procedural Statement	Resulting Values	Units (Scale)
Redoximorphic Features (V_{REDOX})	Status of redoximorphic features/visual inspection of soil profile for redoximorphic features	Present/ Absent	unitless (Nominal Scale)
Floodplain Roughness (V_{ROUGH})	Manning's Roughness Coefficient (n) Observe wetland characteristics to determine adjustment values for roughness component to add to base value	0.01 0.1 0.21	unitless (Interval Scale)
Tree Biomass (V_{TBA})	Tree basal area/measure diameter of trees in sample plots (cm), convert to area (m), and extrapolate to per hectare basis	5 12.8 36	m^2/ha (Ratio Scale)

HGM model variables occur in a variety of states or conditions in reference wetlands (Ainslie et al. 1999). The state or condition of the variable is denoted by the value of the measure of the variable. For example, tree basal area, the measure of the tree biomass variable could be large or small. Similarly, recurrence interval, the measure of overbank flood frequency variable could be frequent or infrequent. Based on its condition (i.e., value of the metric), model variables are assigned a variable subindex. When the condition of a variable is within the range of conditions exhibited by reference standard wetlands, a variable subindex of 1.0 is assigned. As the condition deflects from the reference standard condition (i.e., the range of conditions that the variable occurs in reference standard wetland), the variable subindex is assigned based on the defined relationship between model variable condition and functional capacity. As the condition of a variable deviates from the conditions exhibited in reference standard wetlands, it receives a progressively lower subindex reflecting its decreasing contribution to functional capacity. In some cases, the variable subindex drops to zero. For example, when no trees are present, the subindex for tree basal area is zero. In other cases, the subindex for a variable never drops to zero. For example, regardless of the condition of a site, Manning's Roughness Coefficient (n) will always be greater than zero.

HGM combines both the wetland functionality (FCIs measured with variables) and quantity of a site to generate a measure of change referred to as Functional Capacity Units (FCUs). Once the FCI and PWAA quantities have been determined, the FCU values can be mathematically derived with the following equation: FCU = FCI x Area (measured in acres). Under the HGM methodology, one FCU is equivalent to one optimally functioning wetland acre. Like HEP, HGM can be used to evaluate further conditions and the long-term affects of proposed alternatives by generating FCUs for wetland functions over several TYs. 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 simulated, to promote environmental optimization.

2.7 HGM SOFTWARE

The vast number of calculations necessary to conduct the HGM analyses on a projects the size of the AZ Studies led the District to contact EL for technical assistance. Using the latest technological advancements, EL performed the necessary evaluations in less than three years. In addition to facilitating the application of HGM in the study, EL's biologists used the EXHGM (EXpert Hydrogeomorphic Approach to Wetland Assessments) software package to generate restoration benefits in a timely manner (refer to the software section later in this chapter). The EL team performed more than 2,500 iterations in the evaluations of the proposed designs in the wetland assessment described herein using the EXHGM software package.

EXHGM is a Microsoft Access© 2000 software package developed by EL to automate standard HGM calculations. EXHGM's programming architecture afforded the EL staff the opportunity to compare the resultant outputs of the two methodologies on similar platforms (i.e., results were reported in terms of units derived from quality and quantity calculations that could be reviewed in common software environments, namely Microsoft Excel and Microsoft Access formats). Again, the EXHGM the program should be viewed as a tool that can provide a rational, supportable, focused, and traceable evaluation of wetland functionality, and its application to the decision-making process is unquestionable. However, the user must understand the basic HGM tenets as defined in supporting literature (Brinson, 1993; Smith et al., 1995) prior to attempting application of the software. In other words, the user should not expect the EXHGM software to provide the only predictive environmental response to project development scenarios, and should understand the limitations of the methodology's response to predictive evaluations prior to its application.

The EXHGM program was designed to process large amounts of data quickly and efficiently, handling a large number of FCI models simultaneously. Each model can incorporate any number of cover types (or partial wetland assessment areas). Each cover type can include a large number of variables, and the user can incorporate as many life requisites or functions within each model as necessary. These capabilities support the examination of complex studies with large numbers of permutations. In some studies, it is not unusual to evaluate 10 - 15 FCI models (with more than 25 cover types) in an attempt to describe complex interdependencies (i.e., interrelationships) within the ecosystem. The large amount of tedious mathematical calculations necessary to compute HGM at this level requires a powerful tool to evaluate environmental output. EXHGM, enhanced by its abilities to communicate these activities in an organized fashion, can quickly accomplish this task. The number of permutations, processing speed, and program performances are limited only by the capacity of the user's hardware, where data storage becomes the limiting factor.

The EXHGM program allows the user to evaluate a large number of projected changes (future factors) across numerous years for each alternative design. Each package allows the user to assign future factors to each model for each year considered within the life of the project (i.e., each TY). This capability allows the user to manage forecasts across the long-term planning horizon, in an attempt to better reflect reality through the life of the project. Again, the number of permutations is limited only by the user's computer storage capacity. EXHGM evaluates any FCI-based model. In most instances, a wetland cannot be described using a single PWAA. A standard HGM tool must complete these computations, regardless of whether the model utilizes a single PWAA or multiple PWAAs. EXHGM can be used to calculate suitability for any single or multiple PWAA model whether the wetlands functionality is based on one or more multi-faceted functions.

The tool is capable of reevaluating FCI models as the user adapts previously created alternative designs to fit new situations. It is not necessary to reinvent FCI models, cover type interdependencies, or life requisite interrelationships once a standard evaluation configuration has been created. The software packages allow the user to open a previously created configuration and introduce change (e.g., adding field data, future factors, TYs, species, cover types, acreage quantities, etc.). This capability supports the software's utilization in a wide range of agency activities over the long term. For example, an alternative design developed to evaluate project impacts for a stream restoration study in the past, can be adapted to evaluate stream restoration projects throughout the region in the future. By simply altering the cover type composition of a previously developed EXHGM datafile, the software can account for regional variations, and quickly define functionality impacts. Thus, as projects are funded or evolve, EXHGM can be easily implemented with little effort devoted to modeling "setup."

3. HGM HABITAT EVALUATION

Based on the USFWS's Ecological Service Manual series on HEP (USFWS 1980a-c), and a series of protocols for HGM application developed by EL (Brinson 1993; Smith et al. 1995), there are 12 steps involved in the application HGM when assessing an ecosystem restoration project:

1) Build a multi-disciplinary Evaluation Team.
2) Define the project.
3) Determine goals and objectives.
4) Map Partial Wetland Assessment Areas (PWAA's).
5) Select, modify and/or create model(s).
6) Conduct field sampling.
7) Perform data management and statistical analysis.
8) Calculate Baseline Conditions.
9) Generate Without Project Conditions and calculate outputs.
10) Generate With Project Conditions and calculate outputs.
11) Develop Relative Value Indices and perform trade-offs
12) Report the results of the analyses.

The following sections describe these steps in further detail and discuss their various applications to the Paseo de las Iglesias Feasibility Study.

3.1 EVALUATION TEAM

An interagency, interdisciplinary team was formed to lead both the model selection/development phase of the project, and to establish the baseline and future without project conditions of the study area. Evaluation Team members for this study included representatives from the U. S. Army Corps of Engineers (USACE) Los Angeles District, USACE Environmental Laboratory (EL), U. S. Fish and Wildlife Service (USFWS), Arizona Game and Fish Department, Pima County Flood Control District, David Miller and Associates, and SWCA Environmental Consultants.

3.2 PROJECT DEFINITION

3.2.1 The Ecosystem Restoration Approach

By definition, an ecosystem can be described as an integrated unit, identified as a biotic community enjoined with its physical environment. Inherent within this definition, is the concept of a structural and functional system, unified through life processes. According to Stakhiv et. al., an ecosystem is characterized as a viable unit of the community and a interactive habitat (2001). Ecosystems then, are hierarchical and can be viewed as nested sets of open systems in which the physical, chemical, and biological processes form interactive subsystems. It is important to note that by definition ecosystems can be microscopic in size or can be as large as the biosphere. Thus, ecosystem restoration efforts can be directed at different sized ecosystems within the nested set, spanning multiple states, more localized watersheds or smaller complexes of habitat.

3.3 SETTING GOALS AND OBJECTIVES

In an attempt to generate quantifiable objectives for the study, the Evaluation Team set out specific ecosystem restoration goals, and developed a series of performance measures to assess the success of the ecosystem restoration designs.

3.3.1 Project Goals

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:

- Increase the acreage of functional riparian and floodplain habitat within the study area;
- Increase the wildlife and habitat diversity by providing a mix of riparian habitats within the river corridor, riparian fringe and historic floodplain;
- Provide passive recreation opportunities;
- Provide incidental benefits of flood damage reduction, reduced bank erosion, reduced sedimentation and improved surface water quality consistent with the ecosystem restoration; and
- Integrate desires of local stakeholders consistent with Federal policy and local planning efforts.

The Evaluation Team was asked to outline the primary arid riparian system and communities within the project area, generate a list of performance measures upon which restoration success could be measured, and select an evaluation tool to measure the success of restoration efforts within this system. Four major communities or systems were identified: 1) Cottonwood-Willow Forests; 2) Mesquite Woodlands, 3) River Bottom Areas (largely unvegetated, including emergent); and 3) Scrub-Shrub (e.g., Rabbit bush, Quail bush, Ironwood, and Saltbush).

3.3.2 Ecosystem Assessment Performance Measures (Objectives)

The goal of Civil Works ecosystem restoration activities is to restore significant ecosystem function, structure, and dynamic processes that have been degraded (Stakhiv et. al., 2001). Ecosystem level measures address the question of what are the appropriate compositions, structures, and functions of each ecosystem (Haufler et al. 2002). Ecosystem level measures define the "acceptable" range of conditions for any stand or reach in a landscape to qualify as "suitable" for contributing to the amount needed for adequate ecological representation. Function-related measures ensure that ecosystems "look right" and function appropriately to ensure conservation of biological diversity and ecosystem integrity. Performance measurement is required to understand the gap between actual and expected levels of achievement in ecosystem restoration initiatives and when corrective action may be warranted. The results indicated by a performance measure will generally be compared with expectations specified by a performance target (which might be based on a benchmark best practice, a technical standard or some specified progression from the baseline value). Therefore, performance measures should correspond with performance targets and indicate the extent to which the study's design is achieving these performance expectations. Performance measures are an important source of feedback for effective management.

Early in the evaluation process, the Evaluation Team reviewed the relevant ecosystem problems, and the study goals and objectives. They then generated a list of quantifiable ecosystem restoration success criteria (i.e., performance targets on the basis of restored acreages and functional lift) to gauge the success of the proposed alternatives, and compared these alternatives in an iterative fashion. Specifically, these performance targets focused on the existing wetland quantity and quality, but additionally expanded to incorporate proposed conditions of the region. For more details, refer to the individual study reports.

3.3.3 Project Life and Target Years.

Given these goals and objectives, the District designated a "Project Life" of 50 years for the study, and asked the Evaluation Team to develop a series of Target Years within this 50-year setting to generate projections of both Without Project and With Project activities. Target years for the studies therefore included TY0 (Baseline Conditions), TY1 (Year of Construction) and TY51 (End of Project) to capture this 50-year span. Two additional Target Years (11 and 26) were included to capture significant anticipated changes in vegetative cover and structure in the study area between TY1 and TY51.

3.4 PARTIAL WETLANDS ASSESSMENT AREA MAPPING

3.4.1 Cover Types

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

All four cover types or PWAAs were mapped within the study boundaries (See Figure 2). 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

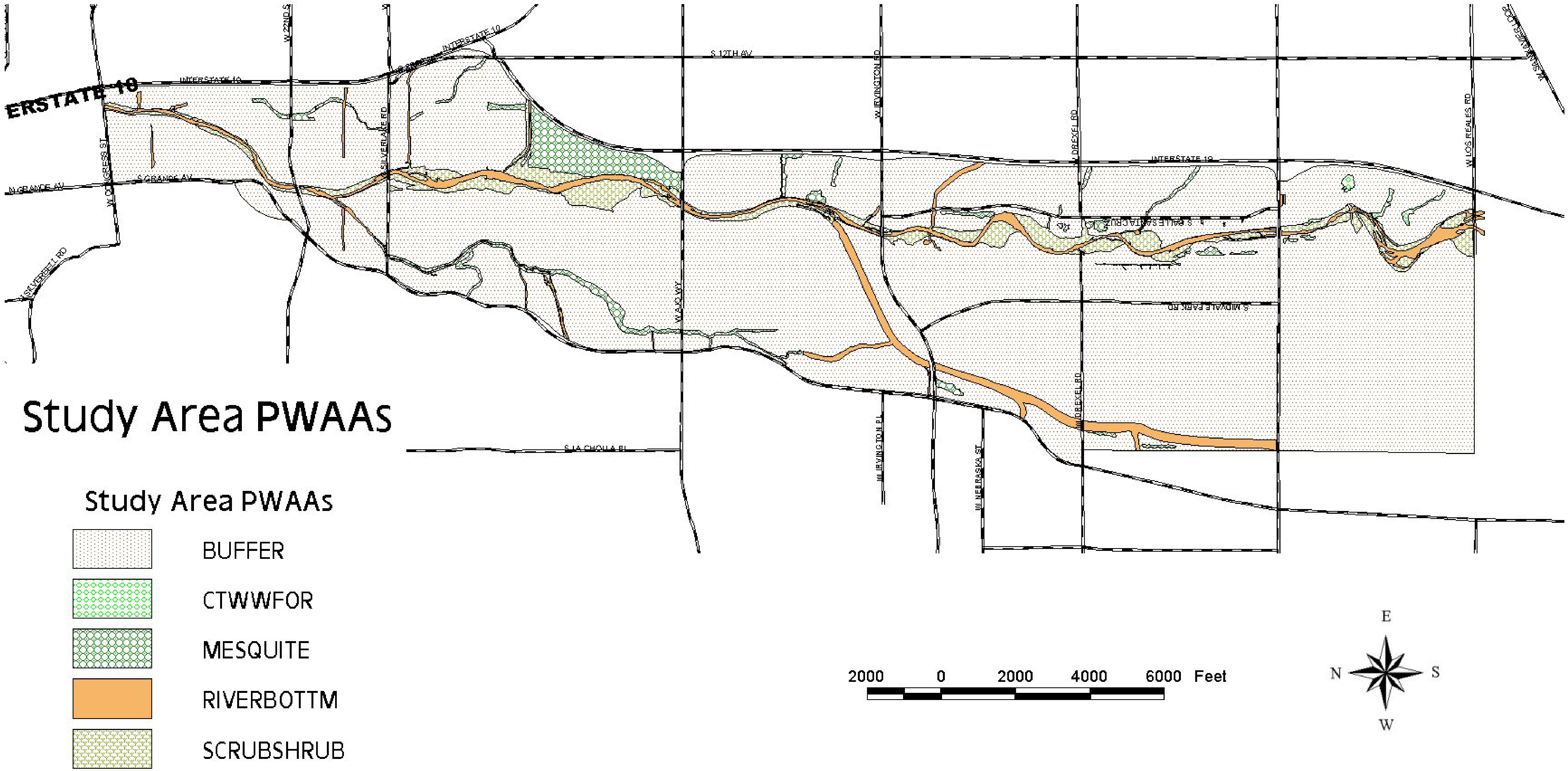


Figure 2: Partial Wetland Assessment Area Mapping for the Paseo de las Iglesias Study Area

on the study area, not with the intent that actual project features will be planned to that extent. Scattered remnants of natural vegetation remain, those cover types include mesquite, and scrub-shrub lands. Natural cienegas or seasonal emergent wetlands have disappeared from the study area. To evaluate the wetland conditions using HGM, the study area is divided into manageable sections and quantified in terms of acres.

The total study area includes 5005 acres.

TABLE 6: PWAA Mapping Acreages

COVER TYPE	ACRES
Cottonwood/Willow Forest	0
Mesquite Bosque	160
Riverbottom (includes low flow and grasses)	173
Scrub-shrub (Sonoran Desert Wash Communities)	256
Total	**589**

3.4.1.1 Cottonwood-Willow Forest

Cottonwood-willow forest is a 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. 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 parallel to the main direction of water flow that may occur in riverine flood channels and along the banks of streams.

In the Sonoran Desert, riparian areas nourish cottonwood-willow forests, one of the most rare 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 Santa Cruz River. Where it was once perennial it is now an ephemeral stream. This has contributed to the disappearance of cottonwood and willow habitat within the study area. Incasive species, such as Salt Cedar depicted below, have now moved into the river and continue to thrive.

Salt Cedar has invaded the study area

3.4.1.2 Scrub-Shrub Lands (Desert Wash)

Scrub-shrub is the name given to the desert wash plant community in the functional assessment model. This cover includes shrub-dominated communities common along the low flow channel of the river as well as those common to the floodplain fringe. A healthy scrub-shrub community supports a diverse plant and wildlife community. Various combinations of desert-wash species such as burro bush, rabbit bush, quail bush, saltbush, and occasionally creosote bush dominate them.

The existing scrub/shrub community occupies more acreage (256 ac.) than any other cover type within the study area. The majority of that acreage is on the low terraces elevated only slightly above the dry low flow channel of the Santa Cruz River. Compared to the reference sites and the model biodiversity for shrub-scrub, this cover type is severely lacking in diversity in the study area. 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.

Scrub-shrub lands are dominated by saltbush and often cobble and sand substrate.

3.4.1.3 River Bottom (Dry Flow Channels)

The River Bottom includes the low flow channel (dry), tributary channels, and the gravel and sand bars within the braided river channel totaling 173 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, low sedges and grasses dominate the plant community. This community type was once common, but no longer exists. Low flow channels and depressions within the river bottoms of the Santa Cruz River have been almost entirely eliminated. These features are unvegetated when present so the acres listed reflect areas where the cover type would be expected to occur. Due to the composition and lack of diversity within the project area dry river bottom, low flow channel, and emergent wetlands are all combined into this one cover type.

Santa Cruz River Low flow channel – Tres Rios del Norte

3.4.1.4 Mesquite Woodlands

Mesquite woodlands or "bosques" historically thrived over large areas within the river floodplain and on higher terraces of the river and were common into the 1940s. These communities have been nearly eliminated from the river ecosystem by a combination of anthropogenic activities (e.g., cutting for firewood) and an ever-lowering aquifer combined with an altered flood regime. Contiguous mesquite stands currently exist along the Old West Branch of the Santa Cruz River. Several smaller patches are scattered throughout the historic floodplain of the Santa Cruz. These small bosques generally consist of struggling trees that have been isolated from the river by soil cement banks and are threatened by urbanization. Together, these areas of mesquite-dominated woodlands total 160 acres.

Typical mesquite woodlands

3.5 SELECTING AND MODIFYING THE FCI MODELS

At the time of this study, very few HGM subclass models were published for distribution. EL was leading a research work unit under the Ecosystem Management and Restoration Research Program (EMRRP) for the development of HGM subclass models. After several interviews with District personnel regarding the wetland subclasses existing in the study area, EL facilitators identified the need to modify and existing subclass model developed in the District for the Santa Margarita Study for riverine overbank systems (Lee et al. 1997). A workshop was convened in May of 2001 to develop the model. Forty-nine local and regional experts attended and participated in five days of intensive model development. All federal state and local agencies as well as local and regional experts from Arizona State University, the University of Arizona, and private consultants participated in the model workshop.

3.5.1 FCI Model Selections

Initially, each workshop member was asked to identify wetland functions they deemed important to the success of the wetland subclass. USACE EL facilitators tallied votes, and the functions were ranked on the basis of votes. Ten functions were subsequently identified for the Paseo HGM subclass model:

1) Maintenance of Characteristic Dynamics
2) Dynamic Surface Water Storage/Energy Dissipation
3) Long Term Surface Water Storage
4) Dynamic Subsurface Water Storage
5) Nutrient Cycling
6) Detention of Imported Elements and Compounds
7) Detention of Particles
8) Maintain Characteristic Plant Communities

9) Maintain Spatial Structure of Habitat
10) Maintain Interspersion and Connectivity

These FCI functions were selected on the basis of their representation of ongoing critical ecosystem processes within the wetland subclass. Based on the expert's opinions, riverine overbank model was associated with the four dominant cover types or PWAAs (Cottonwood-Willow Forests, Mesquite Woodlands, River Bottom, and Scrub-Shrub).

3.6 FIELD SAMPLING

Basic site characterization, mapping and data collection are the first steps in inventorying an ecosystem restoration site (USACE 2000; Fischenich 1999). Characterization for the study area included gathering data on water quality, geochemistry, hydrology, fluvial geomorphology, substrate conditions, flora, and fauna, and to the greatest extent possible, identifications of underlying stressors in the region. In particular, land-use activities, physical habitat alterations, and invasive species were identified. In addition to the physical and chemical characteristics of the study area, land ownership and regulatory jurisdictions played an important role in determining opportunities for restoration. Much of this information was geographically based and stored in a Geographic Information System (GIS). As part of the basic site characterization, historical data on landscape-scale habitat conditions, land-use characteristics and ownership patterns was collected as well. Site- and landscape-level data were collected and historical data was obtained and reviewed. These datasets, in turn, were used to characterize the baseline conditions of the study area.

Several members of the Paseo Evaluation Team participated in the field sampling efforts initiated in the early spring months of 2001 and again in April of 2003. The 3-4 member field crews, facilitated by USACE personnel, included members from five (5) separate federal, state, and local agencies, experts from nearby universities, and consultants.

3.6.1 Variables Measured In the Field

A total of sixteen (16) FCI variables were measured during the field sampling efforts. These variables are described in detail in Table 7. Variables were sampled according to protocols listed in these tables.

3.6.2 Field Sampling Protocol

100-m transects were laid down within the boundaries of the four cover types within the study area and variables were measured using one-meter quadrats at 10 m intervals (i.e., ten sampling stops or stations per transect were made). In most instances, data collected on the cover type transects were averaged to generate a cover type score for the site. This strategy reduced the coefficients of variance (i.e., standard deviations of the field data). When class data was recorded (e.g. deacy and surface inflow class data), the modes were calculated instead of averages across transects within the cover type.

3.6.3 Variables Obtained Without Field Sampling

Some variables could be obtained through various historical records, aerial photos or mathematical calculations rather than through active field sampling. In addition, a total of 13 FCI variables were obtained from District resources and spreadsheet calculations. These variables are described in detail in Table 8.

Table 7: FCI Variables Measured in the Field Sampling Effort for the Wetland Assessment

VAR Code	Variable Description	Methodology, Techniques and Assumptions	Logic
AGSA	Algal Growth Coverage (%)	Percent of quadrat with algae, algal remnants, or water present.	Fxn 5: NUTRIENT & 6: ELEMENTS - Algal growth is an indicator for wetness at the surface. If there is water present long if enough for algal mats to grow, then the water is there long enough for vegetation to take up nutrients in the system.
BUFFCOV	Vegetation Cover in the Buffer Zone (%)	Measure percent cover of vegetation vs. bare ground within the quadrat.	Fxn 11: BUFFER - Buffer cover is important for protecting animals as they travel from wetland area to the uplands. Native vegetation is highly preferable over non-native vegetation.
CWD	Cover of Dead and Down Woody Debris Larger Than or Equal to 2.5" in Diameter (Coarse)	Percent of quadrat with coarse woody debris present.	Fxn 2: WATSTORENR - Coarse woody debris along with microtopography and trees serve as indicators of roughness as a substitute for Manning's n value. Fxn 5: NUTRIENT - Coarse woody debris in various stages of decay indicates that the function is on-going and sustainable. Fxn 7: DETPARTICL - Coarse woody debris provides surface roughness which reduces water velocity. This enables organic and inorganic particulates to settle and to be detained. Fxn 9: HABSTRUCT - Coarse woody debris detains coarse and fine particulate matter, and therefore, influences channel morphology (e.g. pool-riffle complexes). Coarse woody debris also provides energy sources and substrates for the microbial activity that is important in nutrient cycling and other biogeochemical processes. Coarse woody debris also provides habitat for a wide variety of invertebrates and vertebrates.
DECAY	Presence of Coarse Woody Debris in Various Stages of Decomposition	Class data: 0 = No data 1 = One Class present 2 = Two Classes Present 3 = Three Classes Present 4 = Four Classes Present 5 = Five Classes Present 6 = No coarse wood - variable is recoverable 7 = No coarse wood - variable is not recoverable Five stages of decay: 1 = Logs recently fallen, bark attached, leaves and fine twigs present, no fungi present 2 = Logs with loose bark, no leaves and fine twigs present, fungi may be present 3 = Logs without bark, few stubs of branches present, fungi may be present 4 = Logs without bark or branches, heartwood in advance state of decay, fungi may be present	Fxn 5: NUTRIENT - Coarse woody debris in various stages of decay indicates that the function is on-going and sustainable.

FWD	Cover of Dead and Down Woody Debris Smaller Than in Diameter (Fine)	Percent of quadrat with fine woody debris present.	Fxn 5: NUTRIENT -Fine woody debris in various stages of decay indicates that the function is on-going and sustainable. Fxn 7: DETPARTICL -Fine woody debris provides surface roughness which reduces water velocity. This enables organic and inorganic particulates to settle and to be detained. Fxn 9: HABSTRUCT - Fine woody debris provides energy sources and substrates for the microbial activity that is important in nutrient cycling and other biogeochemical processes.
INVASIVES	Presence/Absence of invasive species.	Denote the presence or absence of invasive species.	Fxn 8: PLANTS - A healthy plant community comprises a high percentage of native, non-invasive plants. As a system becomes disturbed, sensitive native species are out-competed by invasive, non-native species.
LITTER	Cover of Leaf Litter and Other Detrital Matter (%)	Percent of quadrat with litter cover present	Fxn 5: NUTRIENT and Fxn 6: ELEMENTS - Litter/detrital layer of debris provides energy and substrate for microbial processes which result in the conversion of elements and compounds. Fxn 9: HABSTRUCT - The litter layer is important for cover, food and nesting of various vertebrates and invertebrates.
SPECRICH	Species Richness	Count (and if possible identify) the number plant species present	Fxn 8: PLANTS - Some measure of plant species diversity is needed, if one is to assess the function of maintaining characteristic plant communities. Riparian ecosystems can be species -rich. Maintaining regional biodiversity is a key riverine function.
SURFIN = SURFINRILL + SURFINLAT	Surface inflow to wetland via sheetflow.	Class data: 0=No data 1=Any of the following are present & similar to reference standard: rills on adjacent upland slopes; lateral tributaries entering floodplain and infiltrating 2=Both indicators, present & less than the reference standard 3=Both indicators, absent & some sedimentation occurs on wetland surface 4=Both indicators, absent & channelization prevents sedimentation on wetland surface	Fxn 6: ELEMENTS - When precipitation rates exceed soil infiltration rates, overland flow in uplands adjacent to riverine wetland may be a water source. Indicators include the presence of fill and rearrange litter on the uplands leading to the floodplain.

TOPO = MICROTOPO + MACROTOPO	Macro (large scale) and microtopographic (small scale) relief. Macrotopography generally refers to large-scale features such as secondary channels and in channel ponds. Microtopography generally refers to small-scale features such as pit-and-mound and hummock-and-hollow patterns.	Class data for FPA: 0 = No data 1 = Macro and microtopo. relief 2 = Homogenous surfaces with macro and microtopo. relief 3 = Homogenous surface & lacks macro and microtopo. relief 4 = Steep bank, recoverable 5 = Steep bank, not recoverable	Fxn 2: WATSTORENR & Fxn 3: WATSTORLNG - Topographic features such as pits and ponds, provide areas that can store surface water as well as provide roughness. Fxn 7: DETPARTICL - Macro- and microtopographic relief provide surface roughness and complexity to the system. Flowing water must move into, over, through, or around these features. Velocity is reduced allowing particulates to be detained. Fxn 8: PLANTS, Fxn 9: HABSTRUCT and Fxn 10: INTERSPERS- Topological complexity offers a variety of ecozones and ecotones that supply the habitat needs of -, wetland-, and edge-adapted species.
TVV	Abundance as measured through vegetation volume.	Record the number of decimeter hits within each meter interval. A hit is defined as any vegetation within a 10-dm radius of the rod, per vertical decimeter. These estimations can be based on comparisons with lower intervals where hits can be directly measured.	Fxn 2: WATSTORENR - Coarse vegetative along with microtopography and trees serve as indicators of roughness as a substitute for Manning's n value. Fxn 5: NUTRIENT - Vegetative cycle nutrients through soil and water nutrient uptake, biomass accumulation and litter production. Fxn 6: ELEMENTS - Vegetative are long-term sinks for elements and compounds. Fxn 7: DETPARTICL - Vegetative slow the velocity of water which must move around them and provide roughness to the system. The roughness dissipates hydrologic energy and allows for particulates to be detained. Fxn 8: PLANTS - Vegetative density, as determined from reference standards, is characteristics of healthy system. Vegetative density will alter with various degrees of perturbation.
VEGSTRATA	Number of Vegetation Layers present	Record the number of layers present. Layers include: Tall (>10 m) broad-leaved tree Short broad-leaved tree Tall microphyllous tree Short microphyllous tree Tall (>1 m) broad-leaved shrub Short broad-leaved shrub Short (<1 m) microphyllous shrub Short microphyllous shrub Vine Epiphyte Bunch grass Non-bunch grass Forb Lichens or biotic soil crusts	Fxn 9: HABSTRUCT - As the number of vegetation layers at a site increases, so do the number of niches for bird species. The use of 1 meter height increments may provide a more sensitive measure of this diversity-related structural property than does the use of only 3 layers (e.g., ground, shrub, tree).
WIS	Wetland indicator score	Record wetland indicator score for species identified in SPECRICH. Scores are as follows: 1 = OBLIGATE 2 = FACULTATIVE WET 3 = FACULTATIVE 4 = FACULTATIVE UPL 5 = UPLAND	Fxn 8: PLANTS - A healthy wetland plant community comprises a high percentage of wetland, native, non-invasive plants. As a system becomes disturbed, sensitive native species are out-competed by non-wetland, invasive, non-native species.

CANHERB	Herbaceous Canopy Cover (%)	Percent of quadrat with herbaceous cover present	Fxn 8: PLANTS - In arid regions, the abundance or biomass of vegetation is a key factor influencing animal abundance and diversity. For example, bird species abundance and diversity in arid regions increases with vegetation volume. Vegetation volume provides a 3-dimensional measure of abundance and serves as a rough surrogate for above-ground vegetation biomass. It thus provides more information about structural habitat value than does 2-dimensional cover estimates.
CANSHRUB	Shrub Canopy Cover (%)	Percent of quadrat with shrub cover present	Fxn 8: PLANTS - In arid regions, the abundance or biomass of vegetation is a key factor influencing animal abundance and diversity. For example, bird species abundance and diversity in arid regions increases with vegetation volume. Vegetation volume provides a 3-dimensional measure of abundance and serves as a rough surrogate for above-ground vegetation biomass. It thus provides more information about structural habitat value than does 2-dimensional cover estimates.
CANTREE	Tree Canopy Cover (%)	Percent of quadrat with tree cover present	Fxn 8: PLANTS - Tree density, as determined from reference standards, is characteristics of healthy system. Tree density will alter with various degrees of perturbation.

Table 8: FCI Variables Obtained From Other Methods

VAR Code	Variable Description	Methodology, Techniques and Assumptions	Logic
BUFFLENGTH	Area with Sufficient Buffer Length (%)	Landscape Variable Class data: 0 = No data 1 = 100% of the reach has a right & left bank buffers 2 = Only 1 side of the reach has 100% buffering 3 = 75% of the reach has right & left bank buffers 4 = Only 1 side of the reach has 75% buffering 5 = 50% of the reach has right & left bank buffers 6 = Only 1 side of the reach has 50% buffering 7 = 25% of the reach has right & left bank buffers 8 = Only 1 side of the reach has 25% buffering 9 = 0% of the reach has right & left bank buffers	Fxn 11: BUFFER - Buffer serves as a protective zone against urban encroachment to the riverine wetland, therefore the longer the buffer the more protection.
BUFFWIDTH	Width of Buffer Zone (m) (i.e., Distance to nearest Human Disturbance)	Landscape Variable Class data: LANDUSE =1.0 and BUFFWIDTH=1.0 (100m for perrenial streams or 50m for ephemeral streams), score = 1.0 LANDUSE<1.0 and BUFFWIDTH<1.0, score = LANDUSE x BUFFWIDTH LANDUSE = 0 and BUFFWIDTH=1.0, score = 1.0 Curve depends on type of flow in channel. For perennial flows, (San Pedro, Tumacocori, Hassayampa, Salt River, Paseo, Tres Rios del Norte, Oeste) curve is 0,0,100,1	Fxn 8: PLANTS - A healthy plant community comprises a high percentage of native, non-invasive plants. As a system becomes disturbed, sensitive native species are out-competed by invasive, non-native species. Fxn 9: HABSTRUCT - Coarse woody debris detains coarse and fine particulate matter, and therefore, influences channel morphology (e.g. pool-riffle complexes). Coarse woody debris also provides energy sources and substrates for the microbial activity that is important in nutrient cycling and other biogeochemical processes. Coarse woody debris also provides habitat for a wide variety of invertebrates and vertebrates. Fxn10: INTERSPERS - Contiguous vegetation cover offers both horizontal and vertical connectivity throughout the riverine system. Fxn 11: BUFFER - Buffer serves as a protective zone against urban encroachment to the riverine wetland, therefore the wider the buffer the more protection.
CONTIG	Contiguous Vegetation Cover Between Wetlands and Uplands (%)	Landscape Variable	Fxn10: INTERSPERS - Contiguous vegetation cover offers both horizontal and vertical connectivity throughout the riverine system.
DEPSATSED	Depth of Saturated Sediments (m)	Class data for CTWWFOR: 0 = No data 1 = 0 m 2 = 1 - 3 m 3 - > 3 m Class data for MESQUITE: 0 = No data 1 = 0 m 2 = 1 - 7 m 3 = > 7 m Class data for RIVERBOTTM 0 = No data 1 = 0 m 2 = 001 - 025 m 3 = > 025 m	Fxn 4: WATSTORSUB - Availability of water storage beneath the wetland surface. Storage capacity becomes available due to periodic drawdown of water table.

FPA	Floodprone area	Landscape Variable Class data: 0 = No data 1 = FPA not clearly modified 2 = FPA is confined on one side 3 = FPA is confined and >1.5X bankful width 4 = FPA is confined and <1.5X bankful width, recoverable 5 = FPA is confined and <2X bankful width, not recoverable 6 = Concrete Channel	Fxn 1: CHANNELDYN - The erosion, transportation, and deposition of sediment is a function of stream velocity and sediment diameter. Constrictions of the stream channel and/or FPA may result in increased velocity and, therefore, may result in increased sediment entrainment and transport. Further, widening of the stream channel and/or FPA may result in decreased velocity and, therefore, may result in decreased sediment entrainment and transport. Fxn 2: WATSTORENR - Dynamic surface water storage and energy dissipation are functions of surface area and surface roughness. FPA is often straightened, confined, and cleared, and these activities result in a loss of surface area and surface roughness. Fxn 7: DETPARTICL - Unconfined and unmodified FPAs generally provide greater roughness and greater surface area, reducing hydrologic energy and allowing particulates to be retained.
FREQ	Frequency of Inundation	Class data: 0 = No data 1 = Perennial Flow 2 = Intermittent 3 = Saturated (Q1) 4 = Temporarily flooded seasonal high (Q2) 5 = Temporarily flooded bankful (Q10) 6 = Temporarily flooded large flood (Q25) 7 = Temporarily flooded major flood (Q100) 8 = Temporarily flooded super flood (>Q100)	Fxn 2: WATSTORENR & Fxn 3: WATSTORLNG - Fxn 6: ELEMENTS - Without flooding from overbank flow, there would be little opportunity for waterborne materials on streams to be removed by biogeochemical processes operating on floodplain wetlands. For an unaltered site that receives flooding at a 2 - to 5-year intervals, the 2- to 5-year intervals would score a 1.0: an annual flooding regime would be inappropriate for that site and would score less than 1.0.
LANDBUFF	Computation only	Landscape Variable Class data: LANDUSE =1.0 and BUFFWIDTH=1.0 (100m for perrenial streams or 50m for ephemeral streams), score = 1.0 LANDUSE<1.0 and BUFFWIDTH<1.0, score = LANDUSE x BUFFWIDTH LANDUSE = 0 and BUFFWIDTH=1.0, score = 1.0	Fxn 8: PLANTS - A healthy plant community comprises a high percentage of native, non-invasive plants. As a system becomes disturbed, sensitive native species are out-competed by invasive, non-native species. Fxn 9: HABSTRUCT - Coarse woody debris detains coarse and fine particulate matter, and therefore, influences channel morphology (e.g. pool-riffle complexes). Coarse woody debris also provides energy sources and substrates for the microbial activity that is important in nutrient cycling and other biogeochemical processes. Coarse woody debris also provides habitat for a wide variety of invertebrates and vertebrates. Fxn10: INTERSPERS - Contiguous vegetation cover offers both horizontal and vertical connectivity throughout the riverine system. Fxn 11: BUFFER - Buffer serves as a protective zone against urban encroachment to the riverine wetland, therefore the wider the buffer the more protection.

LANDUSE	Type of Adjacent Landuse	Landscape Variable Class data: 0 = No data 1 = Active sand and gravel operations 2 = Commercial/ Industrial 3 = Paved roads 4 = Multi-family residential (apartments and duplexes) 5 = Single-family residential (individual houses) 6 = Gravel roads, dirt roads, bike paths, and infrequently visited structures 7 = Inactive sand and gravel operations 8 = Agricultural cropland 9 = Open space (parks, golf course, etc) 10 = Pristine, uninhabited areas	Fxn 8: PLANTS - A healthy plant community comprises a high percentage of native, non-invasive plants. As a system becomes disturbed, sensitive native species are out-competed by invasive, non-native species. Fxn 9: HABSTRUCT - Coarse woody debris detains coarse and fine particulate matter, and therefore, influences channel morphology (e.g. pool-riffle complexes). Coarse woody debris also provides energy sources and substrates for the microbial activity that is important in nutrient cycling and other biogeochemical processes. Coarse woody debris also provides habitat for a wide variety of invertebrates and vertebrates. Fxn10: INTERSPERS - Contiguous vegetation cover offers both horizontal and vertical connectivity throughout the riverine system. Fxn 11: BUFFER - Buffer serves as a protective zone against urban encroachment to the riverine wetland, therefore the wider the buffer the more protection.
PORE	Soil pore space available for storing subsurface water. Performance is related to soil texture and permeability.	Class data: 0 = No data 1 = Soil texture is sand-sandy loam; no restrictive layer 2 = Soil finer than sand-has restrictive layer 3 = Soil texture is finer restrictive layer 4 = Modal soil profile highly compacted in the upper 24" 5 = Non-porous layer	Fxn 3: WATSTORLNG - A sand-sandy loam soil provides both high pore space and high permeability so water can quickly seep below surface therefore decreasing the long term surface storage. Fxn 6: ELEMENTS -
Q	Alterations of Hydroregime	Class data: 0 = No data 1 = No additions, diversions, or damming of flow affecting the assessment area (e.g. water harvesting, farming practices, stormwater management, etc) 2 = Evidence of additions, diversions, or damming of flow, BUT no evidence of significant impacts to channel pattern, dimension, and profile 3 = Evidence of additions, diversions, or damming of flow, AND there is evidence of changes in vegetation abundance; No evidence of increase sediment or scour 4 = Evidence of additions, diversions, or damming of flow, AND there is evidence of increase sediment or scour 5 = Evidence of additions, diversions, or damming of flow, AND there is evidence of significant impacts to channel pattern, dimension, and profile; Variable is recoverable 6 = Permanent alterations to hydroregime are evident; Variable is not recoverable	Fxn 1: CHANNELDYN - Alterations of the assessment area hydroregime can result in changes in discharge, bedload, vegetation, bank stability, and attendant channel morphology.
SED	Extent of sediment delivery to the water/wetland from culturally accelerated sources.	0 = No data 1 = No Culturally Accelerated Sources of Sediment Input 2 = Culturally Accelerated Sources Present and Little or No Evidence of Culturally Accelerated Sediment Delivery 3 = Culturally Accelerated Sources Present and Evidence of Culturally Accelerated Sediment Delivery 4 = Culturally Accelerated Sources, Evidence of Sediment Delivery - Causing Extreme Change in Channel Morphology and/or Vegetation Morphology	Fxn 1: CHANNELDYN - Fxn 7: DETPARTICL - Rates of sediment accumulation that exceed normal background rates indicate that the function is not sustainable.

SUBIN	Subsurface flow into the water/wetland via interflow and return flow.	Class data for adjacent areas: 0 = No data 1 = Undistributed, subsurface flow evident 2 = Undisturbed & subsurface flow is observed 3 = Disturbed soils and plant communities 4 = Utilized for agricultural activities 5 = Fill 6 = Impervious 7 = Concrete channel	Fxn 3: WATSTORLNG - Subsurface flow into the water/wetland, either from adjacent lands or upstream sources, is water that can be stored. Fxn 6: ELEMENTS - Subsurface flow into the water/wetlands increases soil moisture and can sustain it during times of lower flow.
SURFIN = SURFINRILL + SURFINLAT	Surface inflow to wetland via sheetflow.	Class data: 0=No data 1=Any of the following are present & similar to reference standard: rills on adjacent upland slopes; lateral tributaries entering floodplain and infiltrating 2=Both indicators, present & less than the reference standard 3=Both indicators, absent & some sedimentation occurs on wetland surface 4=Both indicators, absent & channelization prevents sedimentation on wetland surface	Fxn 6: ELEMENTS - When precipitation rates exceed soil infiltration rates, overland flow in uplands adjacent to riverine wetland may be a water source. Indicators include the presence of fill and rearrange litter on the uplands leading to the floodplain.
TOPO = MICROTOPO + MACROTOPO	Macro (large scale) and microtopographic (small scale) relief. Macrotopography generally refers to large-scale features such as secondary channels and in channel ponds. Microtopography generally refers to small-scale features such as pit-and-mound and hummock-and-hollow patterns.	Class data for FPA: 0 = No data 1 = Macro and microtopo. relief 2 = Homogenous surfaces with macro and microtopo. relief 3 = Homogenous surface & lacks macro and microtopo. relief 4 = Steep bank, recoverable 5 = Steep bank, not recoverable	Fxn 2: WATSTORENR & Fxn 3: WATSTORLNG - Topographic features such as pits and ponds, provide areas that can store surface water as well as provide roughness. Fxn 7: DETPARTICL - Macro- and microtopographic relief provide surface roughness and complexity to the system. Flowing water must move into, over, through, or around these features. Velocity is reduced allowing particulates to be detained. Fxn 8: PLANTS, Fxn 9: HABSTRUCT and Fxn 10: INTERSPERS- Topological complexity offers a variety of ecozones and ecotones that supply the habitat needs of -,
TRIB	Presence of connected tributaries	Landscape Variable Class data: 0 = No data 1 = All tributaries (channel and riparian corridor) are unmodified and connect to the mainstem 2 = Some tributaries are modified (consolidated, redirected, or channelized) but still connected to the mainstem 3 = Tributaries are highly modified/channelized, OR not connected to the mainstem	Fxn 10: INTERSPERS -

3.7 DATA MANAGEMENT AND STATISTICAL ANALYSIS

All data management for variables, functions, and field sampling was performed by the USACE Environmental Laboratory and then input into ExHGM software for statistical analysis and quality control.

3.8 PASEO DE LAS IGLESIAS BASELINE CONDITIONS

Once the baseline inventory was conducted, and both the variable means/modes and the cover type acreages were determined, the baseline conditions in terms of Functional Capacity Units (FCUs) were generated. Strictly speaking, the means/mode values for each variable were applied to the Variable Subindex graphs as dictated by the model documentation. For example, if the percent of ground cover in the CTWWFOR PWAAs at Site X was 50 percent on average, the value "20" was entered into the "X-axis" on the Variable Subindex curve below, and the resultant VSI score (Y-axis) was recorded (VSI = 1.0).

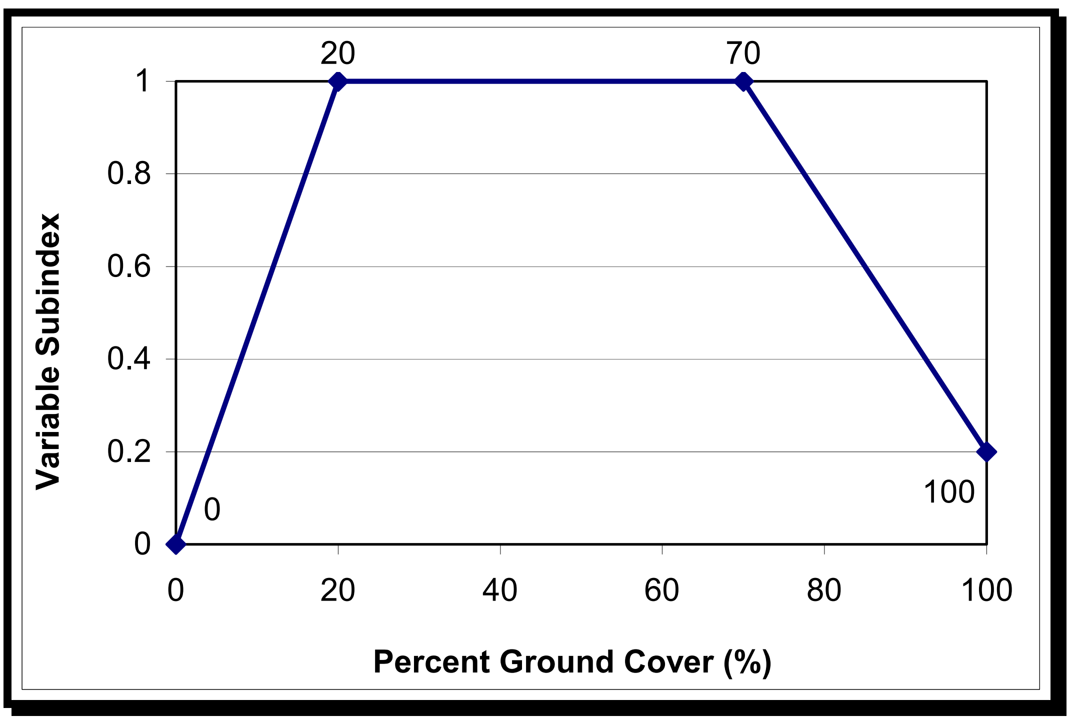


Figure 3: Example Variable Subindex (VSI) curve

The process was repeated for every associated variable and PWAA per model. The individual VSI scores were then entered into the HSI formula on a PWAA-by-PWAA basis, and individual PWAA FCIs were generated. Each answer, referred to as the PWAA FCI was then weighted by the relative area (RA)[1] of the PWAA, and

[1] Relative Area: In HGM, the relative area is a mathematical process used to "weight" the various applicable PWAAs on the

combined with the answers from the remaining associated PWAAs in an additive fashion. The model's formula was considered to be the sum of the PWAA FCIs as follows:

$$\mathbf{FCI_{Subclass\ Model} = \sum \left(PWAA\ FCI\ x\ RA\right)_X}$$

where : PWAA FCI = Results of the PWAA FCI calculation,
X = Number of PWAAs associated with the model, and
RA = Relative area of each PWAA.

The final step was to multiply the FCI result against the habitat acres (i.e., PWAA acres associated with the model). The final results, referred to as Functional Capacity Units (FCUs), quantified the quality and quantity of the wetland conditions at the site at TY0 (Baseline). The details of baseline results are fully documented in each project's reports. The distribution of these Cover Types is illustrated in Figure 2 with acreages listed in Tables 9 and 10. The total study area includes 5005 acres.

Table 9: Mapped Cover Type Acreages

COVER TYPE	ACRES
Cottonwood/Willow Forest	0
Mesquite Bosque	160
Riverbottom (includes low flow and grasses)	173
Scrub-shrub (Sonoran Desert Wash Communities)	256
Total	**589**

Non-riparian cover designations within the study area are tabulated in the Table 10 below:

TABLE 10: Mapped Non-PWAA Cover Types

COVER TYPE	ACRES
AGCROP	416
DESERT	237
DITCHES	99
PARK	86
SOIL CEMENT	21
URBAN	3557
Total	**4416**

basis of quantity. To derive the relative area of a model's PWAA for the study, the following equation was utilized:

$$\text{Relative Area} = \frac{\text{PWAA Area}}{\text{Total Area}}$$

where: PWAA Area = only those acres assigned to the PWAA of interest
Total Area = the sum of the acres utilized in the model

3.10.1 *Baseline Functional Capacity Indices (Ecosystem Quality)*

As previously noted, 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 (i.e., existing) FCI and FCU conditions measured within the study area are shown in Table 11 below and illustrated in Figures 4 and 5. Definitions of each function were provided in Table 3 earlier in this chapter. FCIs were applied to study area cover types to calculate FCUs. These results show that riparian and wetland habitats within the study area have low functional values and are therefore highly degraded.

TABLE 11: Baseline Functional Assessment Summary

Function Name	Weighted Functional Capacity Index (FCI)	Applicable Acres	Baseline Functional Capacity Units (TY0 FCUs)
Fxn 01: Maintenance of Characteristic Dynamics	0.200	589	118
Fxn 02: Dynamic Surface Water Storage/Energy Dissipation	0.692	589	408
Fxn 03: Long Term Surface Water Storage	0.188	589	111
Fxn 04: Dynamic Subsurface Water Storage	0.000	589	0
Fxn 05: Nutrient Cycling	0.339	589	200
Fxn 06: Detention of Imported Elements and Compounds	0.297	589	175
Fxn 07: Detention of Particles	0.329	589	194
Fxn 08: Maintain Characteristic Plant Communities	0.168	589	99
Fxn 09: Maintain Spatial Structure of Habitat	0.204	589	120
Fxn 10: Maintain Interspersion and Connectivity	0.197	589	116

Functions 1 through 4 are hydro-geomorphic functions. The hydro-geomorphic 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. As shown below, all but one of the FCIs for these functions are extremely low for the study area:

- *Function 1, Maintenance of Characteristic Dynamics,* is 0.20 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 high value that is most likely a result of the relatively wide channel in the unprotected reaches.
- *Function 3, Long Term Surface Water Storage* scored low as a result of modification of the flood prone area, construction of soil cement, disappearance of perennial flow and 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 groundwater 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, culturally accelerated sediment sources upstream, and lack of organic input sources within the study area.

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, low percentages of contiguous vegetation cover between the riverbed and uplands, and modifications to tributary connections to the Santa Cruz.

Figure 4 illustrates the baseline functional level of the Paseo de las Iglesias study area. All indices show that the site is functioning poorly from an ecosystem standpoint. The average FCI is 0.26 for Paseo de las Iglesias study area. The lowest rated Reference Site, the Salt River, was rated at 0.57 (see Figure 6).

To compare Functional Capacity Units (FCUs) between the reference site(s) and the study area, the FCI for each reference site was multiplied times the same acreage per PWAA that exists in the Paseo de las Iglesias study area. When the Paseo de las Iglesias site is compared to the Arizona reference sites (see Figure 7), the area has a much lower functional capacity index for desirable cover types. This illustrates the inability of the habitat within this reach to sustain itself. The average across the eleven functions for the existing conditions in the study area is 154 AAFCUs, compared to the results for the Salt River Reference Site (the least productive of the five reference sites), which was 333 AAFCUs.

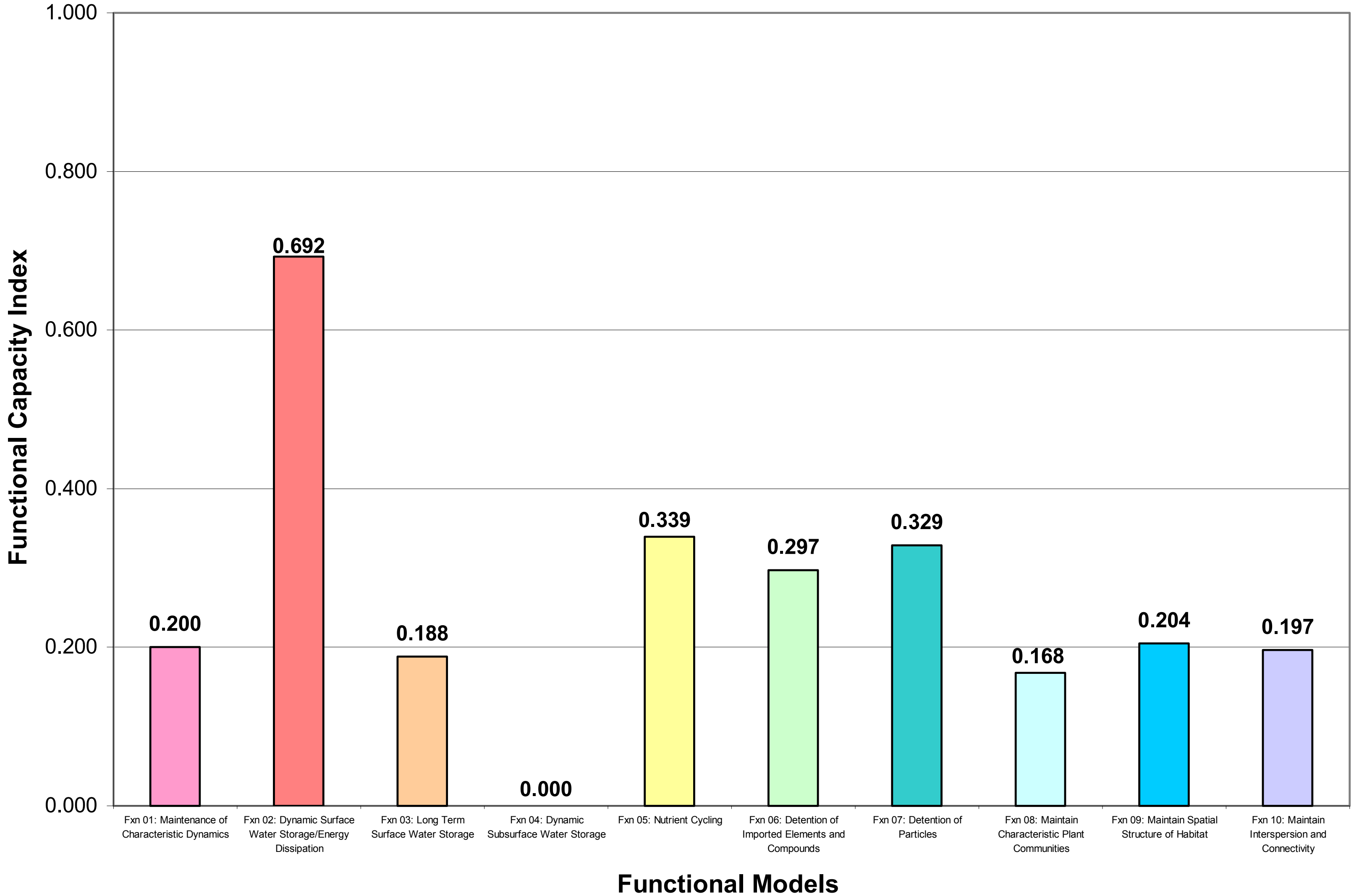


FIGURE 4: Baseline Functional Capacity Index Results

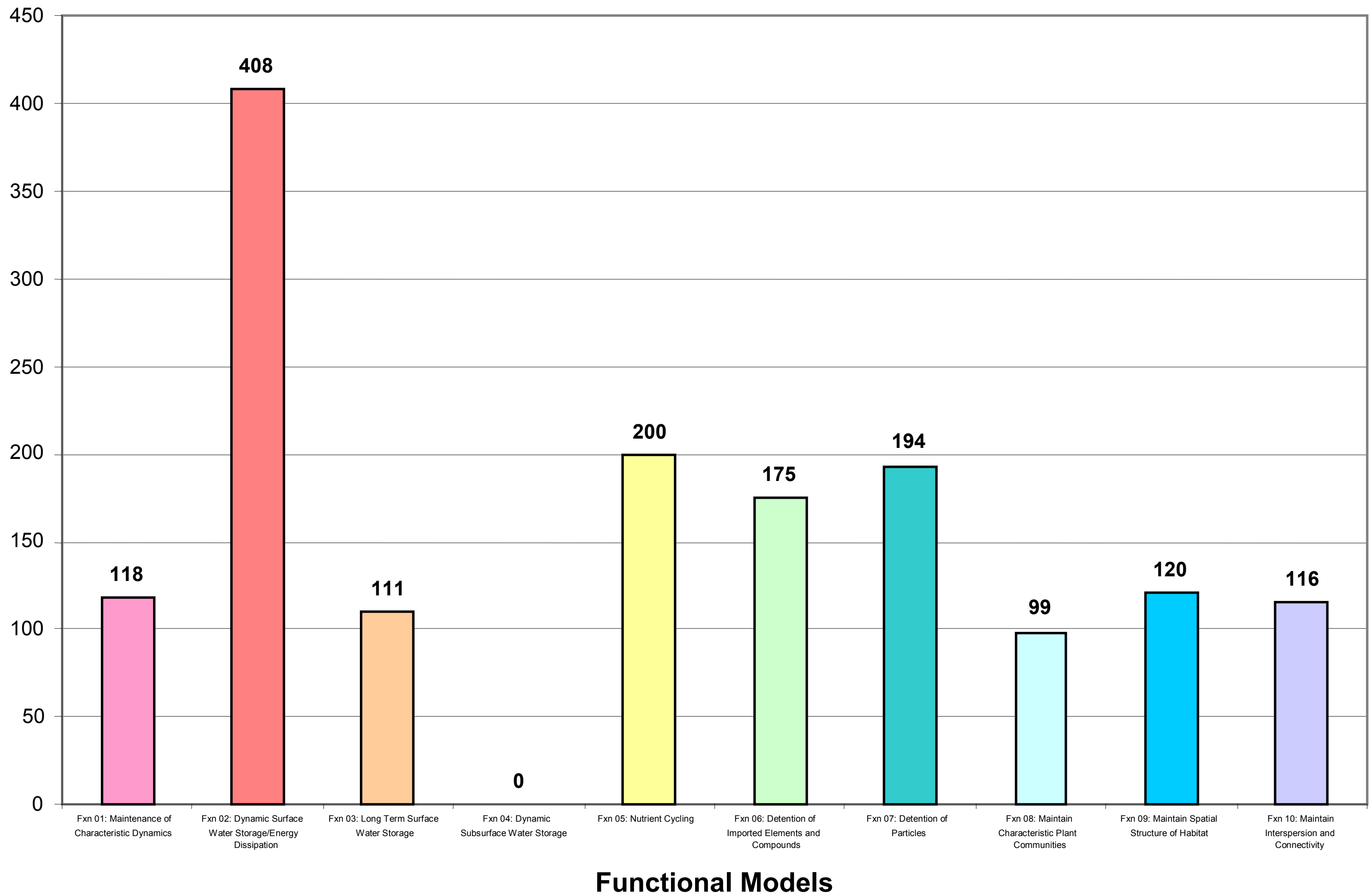


Figure 5: Baseline Average Annual Functional Capacity Units

Figure 6: FCI Comparisons between Reference Sites and Paseo de Las Iglesias

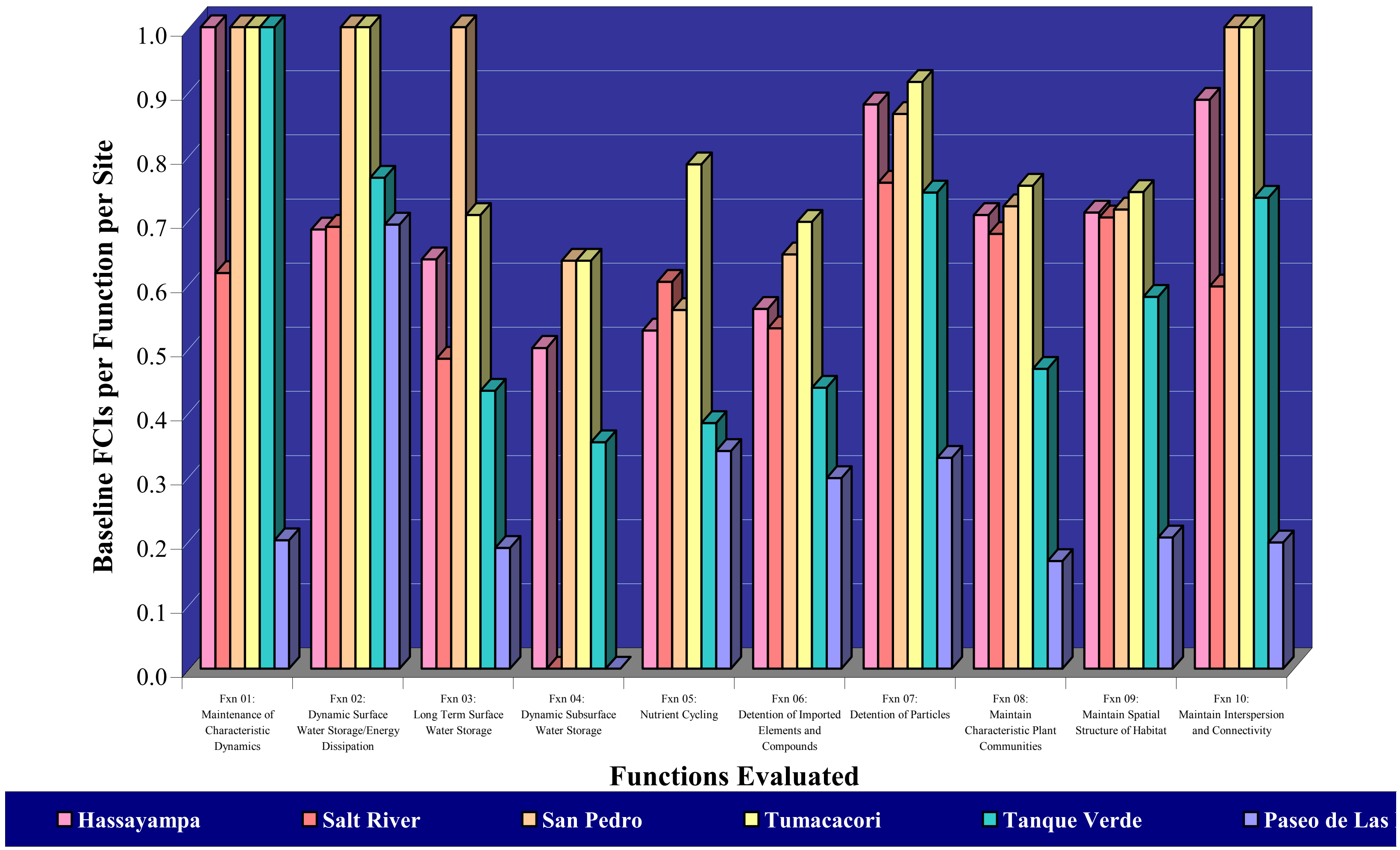
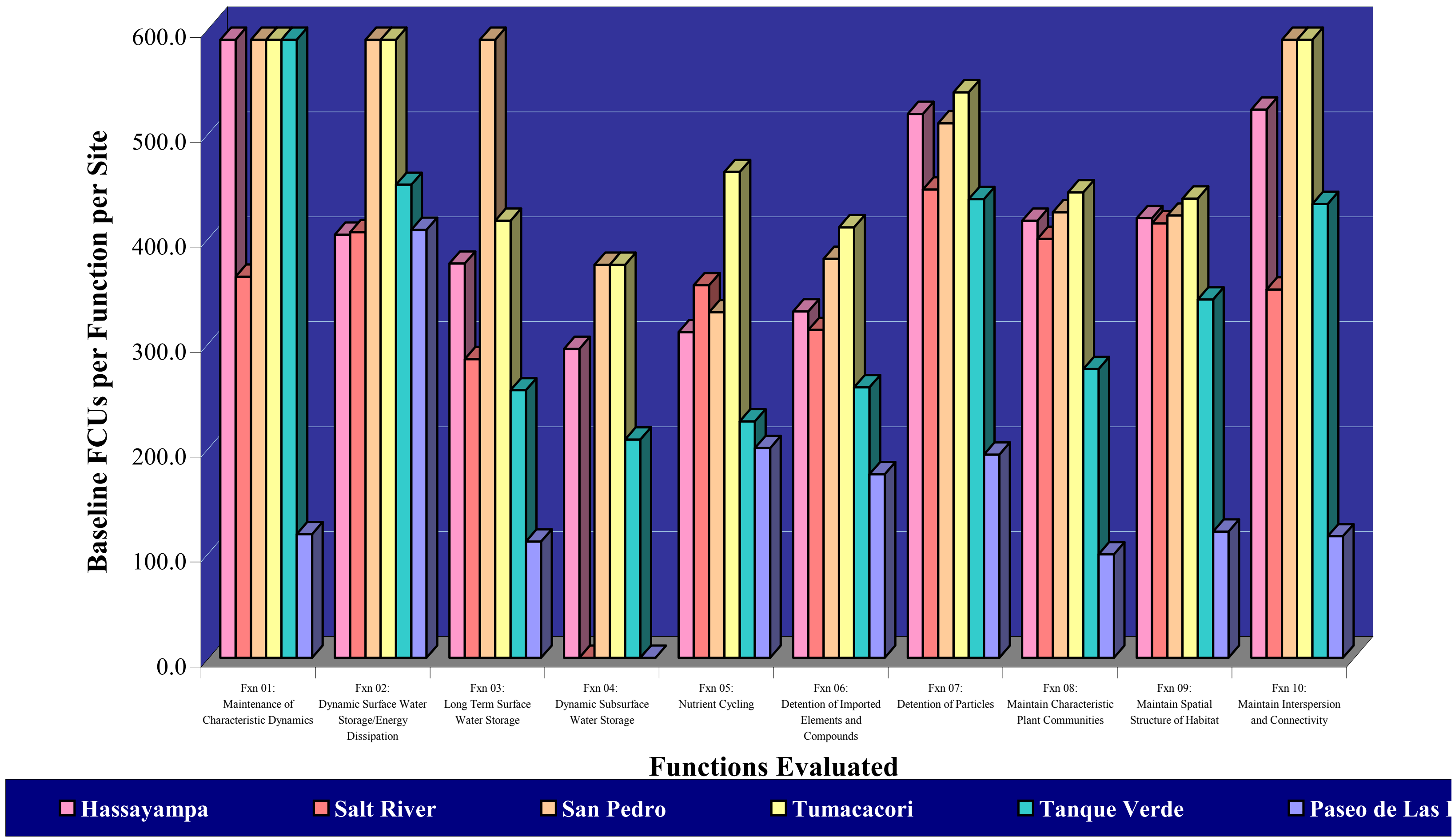


Figure 7: FCU Comparisons between Reference Sites and Paseo de Las Iglesias



3.9 WITHOUT PROJECT CONDITIONS

To develop plans for a community or region, it becomes necessary to predict both the short-term and long-term future conditions of the environment (USACE 2000). Forecasting, the process of developing these predictions, is undertaken to identify patterns in natural systems and human behavior, and to discover relationships among variables and systems, so that the timing, nature, and magnitude of change in future conditions can be estimated. Though many forecasting methods can be used in a standard assessment application such as HGM, a judgment-based method, supported by the scientific and professional expertise of the evaluation team, is often relied upon to forecast the effectiveness of ecosystem restoration alternatives, rate project performance, and determine many other important aspects of both Without Project and With Project conditions.

The Without Project condition is universally regarded as a vital and important element of the evaluation (USACE 2000). No single element is more critical to the planning process than the prediction of the most likely future conditions anticipated for the study area if no action is taken as a result of the study. It is important to note that by definition, the "No Action Alternative" is the Without-Project condition that describes the future that society would have to forego if action was taken. Conversely, the Without-Project condition is the result when no action is taken. When formulating plans the No Action Alternative must always be considered. In essence, this requires that any action taken be more "in the public interest" than doing nothing. The Without-Project condition becomes the default recommendation.

The Without Project description must adequately describe the future (USACE 2000). Significant variables, elements, trends, systems, and processes must be sufficiently described to support good decision-making. Without Project descriptions must be rational. Forecasts must be based on appropriate methods, and professional standards must be applied to the use of those methods. Accuracy is an important element of a rational scenario. All future scenarios should be based on the assumption of rational behavior by future decision-makers and must make sense. Scenarios should not rely on an unlikely series of events or irrational behavior. A good scenario must pass the test of making common sense. Without Project conditions are not "before-and-after" comparisons. Without Project conditions are not mere extensions of existing conditions, and should be oriented toward comparing alternative future scenarios. The Without Project condition must be inclusive in the sense that it is subjected to rigorous review and comment as part of the public participation process (and throughout the coordination and review process).

3.9.1 Without Project Condition Functional Capacity Results

As a result of development pressures and the availability of residentially-zoned land, population will continue to increase along this 7-mile reach of the Santa Cruz River, regardless of project status. Without-project, the riverbanks will most likely be soil cemented, thus greatly decreasing native vegetation growth and the floodplain area. In addition, the use of soil cement would increase the amount of developable land in the study area and result in increased residential and non-residential development adjacent to the River. This development would greatly reduce, if not preclude, the opportunity for ecological restoration and that would accrue from an integrated program of water resources and riparian restoration.

Increased development will reduce or eliminate ecosystem restoration opportunities. Over the past century, a reduction in vegetation adjacent to the river has resulted in a detrimental loss of wildlife habitat. For the Without Project Condition, this trend is expected to continue at an accelerated rate, due to the pressures of urbanization and competing demands on water and other resources within the region and study area.

This loss of value is reflected in the decrease of the average Functional Capacity Index for the study area from 0.26 in the base year to 0.18 in Year 51. The future Without Project Condition Functional Capacity Indices (FCI) is presented graphically in Figure 8.

Figures 9 presents the Without Project FCI comparisons between the reference sites and the study area in Target Year 51.

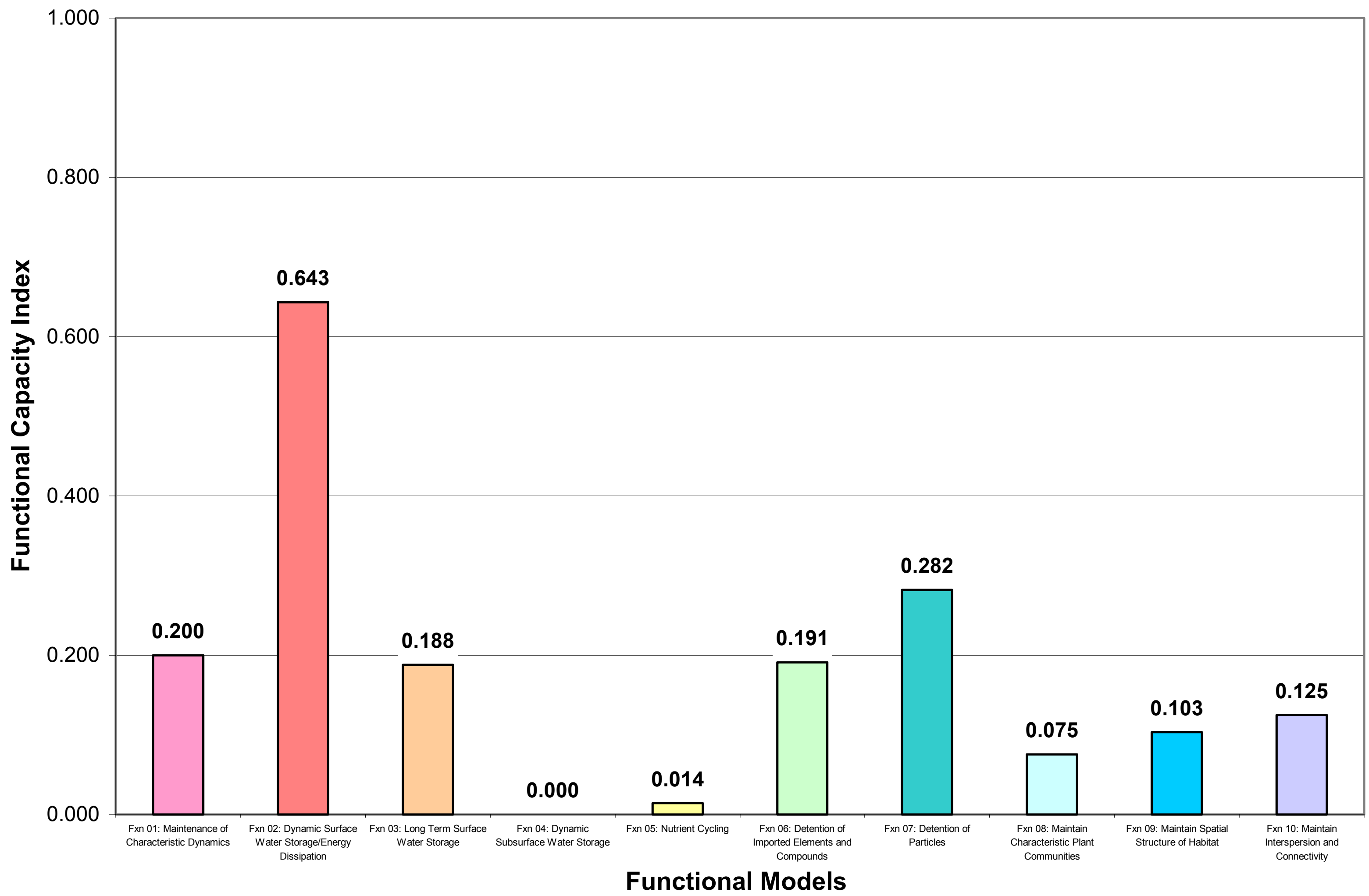
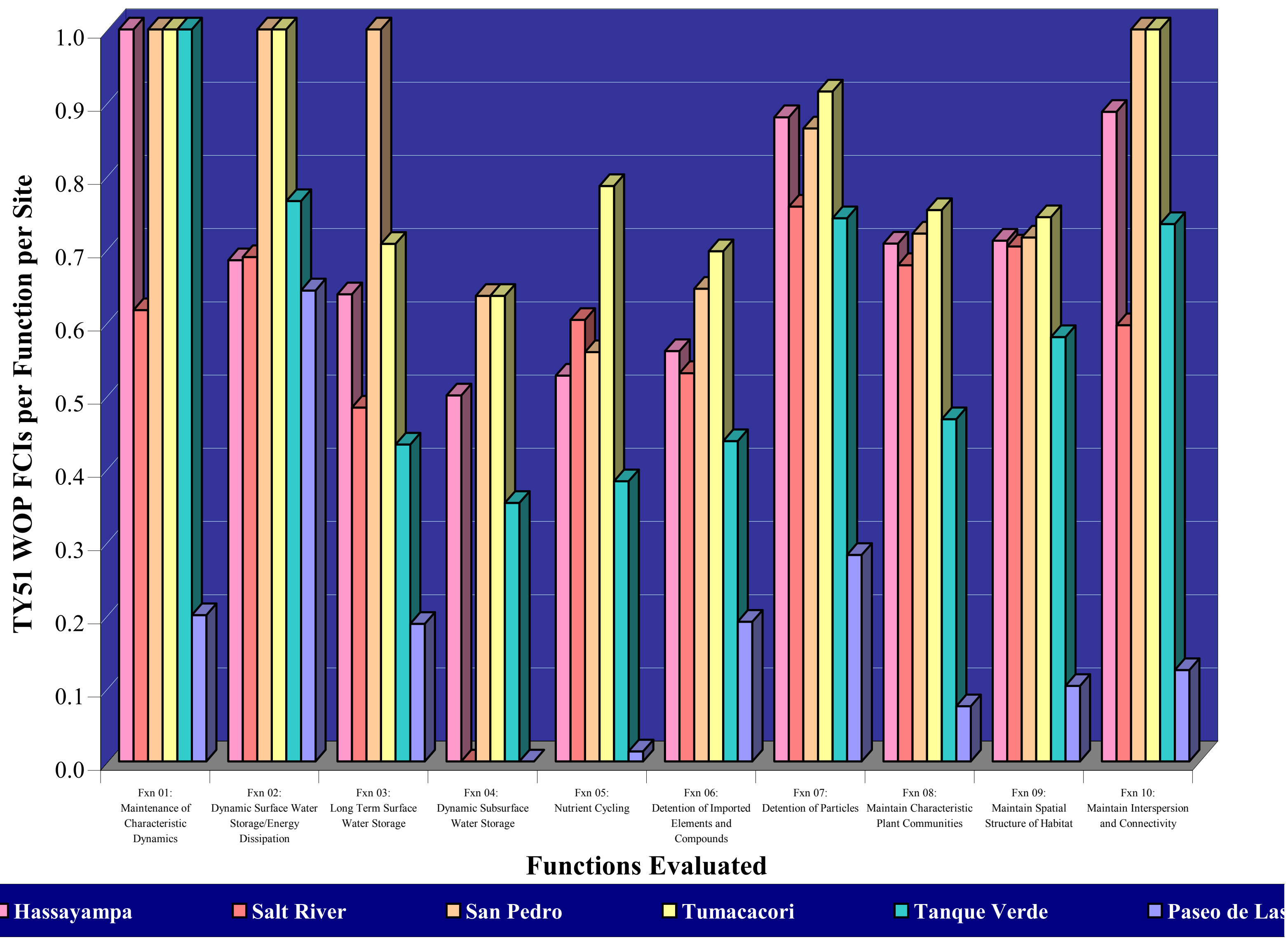


Figure 8: Future Without Project FCIs for Paseo de las Iglesias

Figure 9: WOP FCI Comparison of Paseo de las Iglesias and Reference Sites



3.9.2 Annualized Units for the Without Project Condition

Most federal agencies use annualization as a means to display benefits and costs, and ecosystem restoration analyses should provide data that can be directly compared to the traditional benefit:cost analyses typically portrayed in standard evaluations of this nature. Federal projects are evaluated over a period of time that is referred to as the "life of the project" and is defined as that period of time between the time that the project becomes operational and the end of the project life as dictated by the construction effort or lead agency. However, in many cases, gains or losses in wildlife habitat may occur before the project becomes operational and these changes should be considered in the assessment. Examples of such changes include construction impacts, implementation and compensation plans, and/or other land-use impacts. Ecosystem restoration analyses incorporate these changes into their evaluations by using a "period of analysis" that includes pre-start impacts. However, if no pre-start changes are evident, then the "life of the project" and the "period of analysis" are the same. In HGM, Functional Capacity Units (FCUs) are annualized by summing FCUs across all years in the period of analysis and dividing the total (cumulative FCU) by the number of years in the life of the project. In this manner, pre-start changes can be considered in the analysis. The results of this calculation are referred to as Average Annual Functional Capacity Units (AAFCUs), and can be expressed mathematically in the following fashion:

$$\text{AAFCUs} = \sum \text{Cumulative FCUs} \div \text{Number of years in the life of the project}$$

where: Cumulative FCUs =

$$\sum (T_2 - T_1)\left[\left((A_1 F_1 + A_2 F_2) \div 3\right) + \left((A_2 F_1 + A_1 F_2) \div 6\right)\right]$$

and where:
T_1 = First Target Year time interval
T_2 = Second Target Year time interval
A_1 = Area of available wetlands at beginning of T_1
A_2 = Area of available wetlands at end of T_2
F_1 = FCI at beginning of T_1
F_2 = FCI at end of T_2

This is a generalized formula and requires that the FCI and area of the available habitat for each target year. The numbers "3" and "6" are constants derived from the integration of FCI x Area for the interval between any two target years. This formula is applied to the time intervals between target years. The formula was developed to precisely calculate cumulative FCUs when either FCI or area or both change over a time interval. The rate of change of FCUs may be linear (either FCI or area change over the time interval) – the formula will work in either case.

Although the characteristics of this environmental decline will vary within the study area, the overall effect will be the reduction of existing habitat value. The study area AAFCUs for the Without Project Condition are shown in Figure 10. Figure 11 presents a comparison between the reference sites and the study area for the Without Project AAFCUs.

The accompanying reduction trend in Function Capacity Units from 154 to 71 is presented in Figure 12.

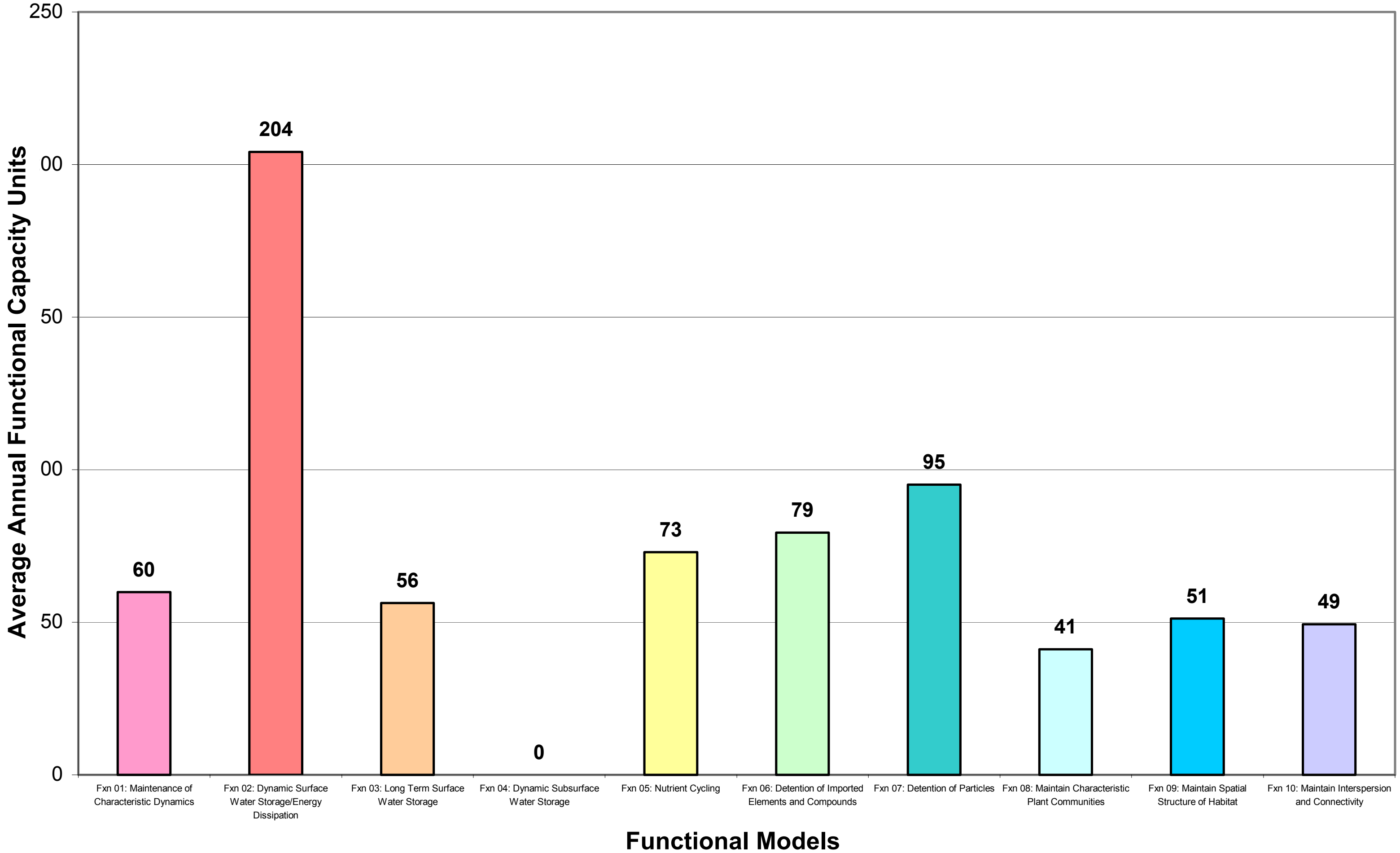
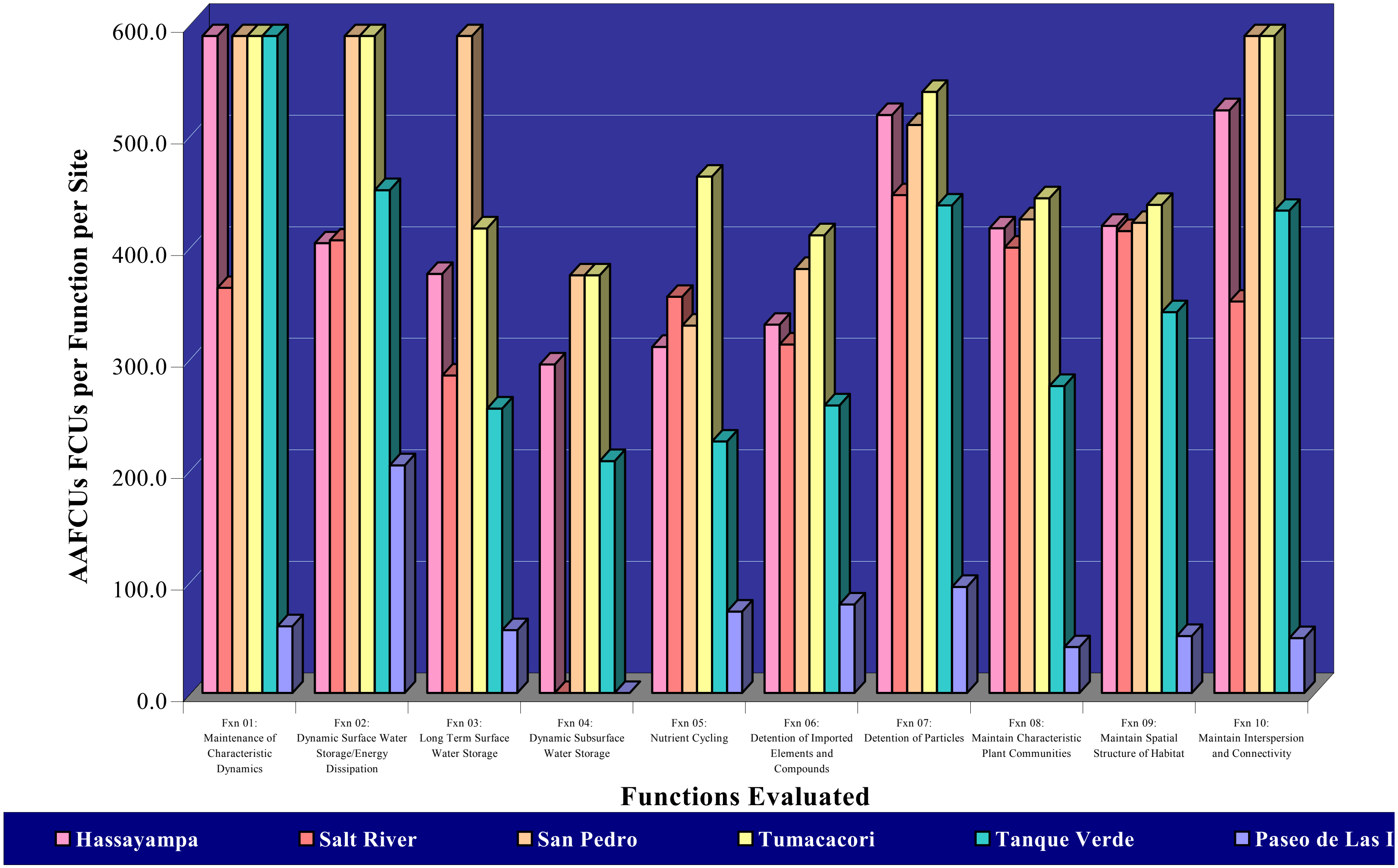


Figure 10: Future Without Project AAFCUs

Figure 11: WOP AAFCU Comparisons between Reference Sites and Paseo de Las Iglesias



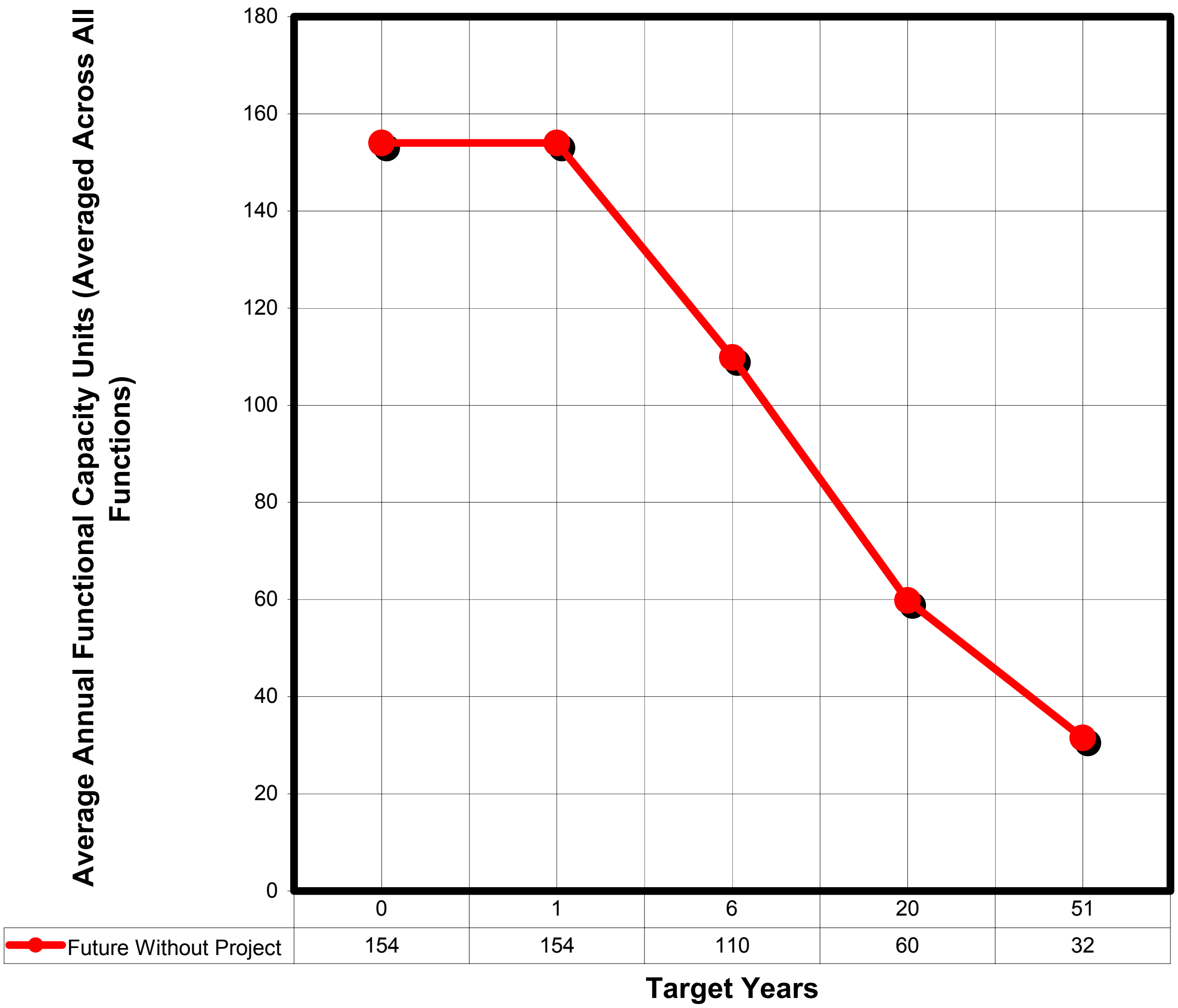


Figure 12: Trend in AAFCU's for the Without Project Condition7

3.10 WITH PROJECT CONDITIONS AND OUTPUTS

Throughout plan formulation, the Evaluation Team met on a regular basis to develop projection trends for each alternative. Alternatives were dropped from the analysis if their approaches were incongruous with the overall “restoration concept”; if their designs were impossible to achieve due to conflicting relationship with flood conveyance; or if the results were thought to be biologically unproductive. Various design and operation/maintenance activities were discussed in detail, and the outcomes of each were incorporated into the forecasting.

3.10.1 Alternative Development

Water to support restoration was identified as one of the most limiting constraints because of its scarcity and cost. The next greatest limiting factor was land that could be dedicated to restoration. In fact, the last four of the constraints identified deal with land use or land cost issues. Although water and land to support restoration were identified as principal limiting constraints, this analysis determined to evaluate what could be accomplished if significant areas of land and substantial volumes of water were available. This approach allows decision makers to weigh the relative cost of the biologic outputs resulting from commitment of substantial volumes of water when evaluating plans for implementation. Alternatives were developed to focus on varying levels of water supply and varying amounts of available land in order to ensure consideration of the effects of these two resources on plan costs and outputs.

The awareness of the importance of water availability as a constraint on plan formulation was evident in the earliest stages of alternative development. The process began with three broad concepts for restoration that were characterized by high, medium and low water demand. Another attribute of these concepts was that the level of engineering effort increased along with water demand. Those became the starting point for development of an initial array of alternatives.

In the process of developing the initial array of alternatives the low water concept was replaced by a “Xeroriparian” concept. The team felt that development of restoration features to be supported entirely by rainfall and harvesting of runoff ensured a viable minimum project as well as providing a basis for assessing the gains produced by differing levels of irrigation. As alternative design proceeded the team recognized that the Xeroriparian features would need irrigation for a short period during the initial establishment of habitat and could need supplemental water during periods of extended drought. However, these alternatives have no requirement for regular irrigation. In addition to the Xeroriparian concept features were also placed into Mesoriparian and Hydroriparian groups. In this way groups of features were aligned with the major different riparian communities as associated with the frequency and duration of the presence of water.

The concept of differing levels of engineering effort was explored but was not found to provide a sufficiently distinct set of alternatives. This concept was replaced with the idea of associating the riparian feature groupings with a geomorphic setting. The project area was divided into three regions; the active channel, the adjoining terraces and the historic floodplain. The active channel refers to the area where water flows most frequently and where perennial flow would be found if it existed. The terraces are the adjacent land features, which are elevated only slightly above the active channel. Lower terraces might be flooded by a 2-5 year event and the upper terraces would be flooded by a 5-10 year event. The historic floodplain is the area adjacent to the entrenched channel of the Santa Cruz River. Although it has been cut off from the river due to down cutting resulting from human activities, in the past this is the area that would have been flooded by infrequent events in the range of 10 year and greater.

Using the concepts of riparian communities and geomorphic setting a matrix of grouped features was created. This matrix is included as Table 12. The matrix allowed initial consideration of every potential combination of feature groups, including no action, to create forty-seven potential alternatives. Preliminary screening of these alternatives was accomplished applying three factors that embodied the planning objectives and constraints identified in the early stages of the study. The specific goals identified for this study are to:

- Increase the acreage of functional riparian and floodplain habitat within the study area;
- Increase the wildlife and habitat diversity by providing a mix of riparian habitats within the river corridor, riparian fringe and historic floodplain;
- Provide passive recreation opportunities;
- Provide incidental benefits of flood damage reduction, reduced bank erosion, reduced sedimentation and improved surface water quality consistent with the ecosystem restoration; and
- Integrate desires of local stakeholders consistent with Federal policy and local planning efforts.

Based on these goals, alternatives were screened out that:

- Failed to provide sufficient area of diverse habitat
- Were inconsistent with the natural progression of riparian communities
- Were likely to produce unacceptable impacts on flood conveyance

The first criteria is relatively straightforward. In applying the first criteria both the number of cover types restored and the total acreage restored were taken into consideration. The second criteria, consistency with natural progression merits some explanation. It is based on the fact that hydroriparian communities occur where water flows at all, or nearly all times of the year; mesoriparian communities experience frequent prolonged water flow and xeroriparian communities experience infrequent flows of shorter duration. In geomorphic terms, hydroriparian plants are most often found adjacent to the active channel or in the adjoining lower terraces. Mesoriparian plants would be found in the lower or upper terraces and xeroriparian would be found in the upper terraces or the historic floodplain. While diminished flows might lead to drier communities occurring nearing the active channel one would never expect to find hydroriparian plants in the historic floodplain or to find a drier community near the channel with a wetter one above it at a greater distance from the channel.

As used in this analysis, the active channel includes primary low flow and any channel braids or back waters that would be inundated when the low flow channel filled. With a few exceptions described later, alternatives that violated this "natural logic" were eliminated. The terraces refer to those areas elevated above the active channel but below the tops of the soil cement banks and their natural counter parts while the historic floodplain takes in the areas adjacent to the embanked river that were historically part of the Santa Cruz River's riparian ecosystem.

Finally, while the Santa Cruz River channel has substantial capacity to convey flood flows, the growth of thick stands of vegetation throughout the channel would reduce that capacity and run a high risk of inducing flooding as a result. Therefore, alternatives that would create extensive new vegetation in both the terraces and the active channel were eliminated.

Application of these screening criteria resulted in elimination of thirty-three of the forty-seven possible alternatives. The results of this screening are presented in Table 13 and those alternatives eliminated from further consideration are gray shaded.

Table 12: Alternative Features Matrix

	Active Channel Features	Floodplain Terrace Features	Historic Floodplain Features
No Action* (Without Project) *Listed items are anticipated consequences rather than measures to be implemented as in the other rows.	1. Continued instability of channel due to erosion. 2. Continued refuse dumping. 3. Continued degraded habitat.	1. Continued erosion loss of lower terraces creating cliff-like banks. 2. Eventual application of soil cement on unprotected banks armoring entire reach.	1. With expanded soil cement bank protection, continued historic floodplain encroachment by development.
Xero-Riparian (Establishment & Emergency Irrigation)	1. Construct aquitards upstream of existing and new grade control structures. 2. Divert low flow from New West Branch into remnant headwaters of Old West Branch. 3. Plantings of riparian grasses/shrubs	1. Water harvesting from local runoff. 2. Create tributary aquitard deltas with two-tiered aquitards. 3. Plantings on terraces and aquitards.	1. Amend soil with nutrients, moisture trapping, contouring. 2. Water harvesting from local runoff. 3. Replace steep banks with stabilized planted terraces
Meso-Riparian (Irrigation)	1. Construct and provide supplemental irrigation to aquitards upstream of existing and new grade control structures. 2. Introduce periodic flow into the Old West Branch just upstream of its confluence with the Enchanted Hills Wash and on other tributaries downstream of that point. 3. Plantings of riparian grasses	1. Create tributary single-tiered aquitard deltas. 2. Irrigate and plant terraces with mesquite along upper terrace. 3. Stabilize active channel banks by establishing thickly rooted mesquite at the edge of the lower terraces.	1. Amend soil with nutrients, moisture trapping, contouring. 2. Plant and irrigate historic floodplain. 3. Replace steep banks with stabilized planted terraces
Hydro-Riparian (Perennial Flow With Irrigation)	1. Restore perennial flow with multiple points of distribution into the main Santa Cruz and tributary channels. 2. Plant cottonwood-willow bundles at edges of perennial flow where erosion protection needed. 3. Construct perennial channel features (e.g., pools, runs, and riffles).	1. Create tributary aquitard deltas with hydraulic link to perennial flow. 2. Irrigate and plant low terraces with riparian grasses to maintain flood conveyance and discourage colonization by invasive species. 3. Irrigate and plant upper terraces with mesquite/cottonwood-willow.	Hydro Riparian plants do not occur in areas of the floodplain that are not subject to frequent inundation. Even so, measure 3 from the mesoriparian floodplain is carried forward to mitigate greater erosion risks associated with increased channel roughness in combinations where "No Action" is paired with Perennial Flow.

Table 13: Alternative Screeening

Active Channel	Terraces	Floodplain	Screen Out	Reason
No Action	Xero	Xero	Yes	Fails to provide sufficient habitat diversity
No Action	Xero	Meso	Yes	Not Consistent with Natural Pattern
No Action	Xero	No Action	Yes	Fails to provide sufficient habitat diversity
No Action	Meso	Xero		
No Action	Meso	Meso		
No Action	Meso	No Action	Yes	Fails to provide sufficient habitat diversity
No Action	Hydro	Xero	Yes	Not Consistent with Natural Pattern
No Action	Hydro	Meso	Yes	Not Consistent with Natural Pattern
No Action	Hydro	No Action	Yes	Not Consistent with Natural Pattern
No Action	No Action	Xero	Yes	Fails to provide sufficient habitat diversity
No Action	No Action	Meso	Yes	Fails to provide sufficient habitat diversity
Xero	No Action	No Action	Yes	Fails to provide sufficient habitat diversity
Xero	No Action	Xero	Yes	Fails to provide sufficient habitat diversity
Xero	No Action	Meso	Yes	Not Consistent with Natural Pattern
Xero	Xero	No Action	Yes	Fails to provide sufficient habitat diversity
Xero	Xero	Xero		
Xero	Xero	Meso	Yes	Not Consistent with Natural Pattern
Xero	Meso	No Action	Yes	Not Consistent with Natural Pattern
Xero	Meso	Xero	Yes	Not Consistent with Natural Pattern
Xero	Meso	Meso	Yes	Not Consistent with Natural Pattern
Xero	Hydro	No Action	Yes	Not Consistent with Natural Pattern
Xero	Hydro	Xero	Yes	Not Consistent with Natural Pattern
Xero	Hydro	Meso	Yes	Not Consistent with Natural Pattern
Meso	No Action	No Action	Yes	Fails to provide sufficient habitat diversity
Meso	No Action	Xero	Yes	Not Consistent with Natural Pattern
Meso	No Action	Meso	Yes	Not Consistent with Natural Pattern
Meso	Xero	No Action		
Meso	Xero	Xero		
Meso	Xero	Meso	Yes	Not Consistent with Natural Pattern
Meso	Meso	No Action		
Meso	Meso	Xero		
Meso	Meso	Meso		
Meso	Hydro	No Action	Yes	Not Consistent with Natural Pattern
Meso	Hydro	Xero	Yes	Not Consistent with Natural Pattern
Meso	Hydro	Meso	Yes	Not Consistent with Natural Pattern
Hydro	No Action	No Action		
Hydro	No Action	Xero	Yes	Not Consistent with Natural Pattern
Hydro	No Action	Meso	Yes	Not Consistent with Natural Pattern
Hydro	Xero	No Action		
Hydro	Xero	Xero		
Hydro	Xero	Meso	Yes	Not Consistent with Natural Pattern
Hydro	Meso	No Action	Yes	Too much reduction in conveyence
Hydro	Meso	Xero	Yes	Too much reduction in conveyence
Hydro	Meso	Meso	Yes	Too much reduction in conveyence
Hydro	Hydro	No Action		
Hydro	Hydro	Xero		
Hydro	Hydro	Meso		

As can be seen in Table 12, combinations of the four riparian categories with the three geomorphic regions form groups of management measures that designate alternatives. The combinations detailed in Table 12 are labeled with letters in this section for simplicity. The letters used are N for no action, X for xeroriparian, M for mesoriparian and H for hydroriparian. Each letter represents a row from the Alternative Features Matrix with the order of the letter aligned to the columns. For example, alternative HMN would be the result of combining hydroriparian active channel features and mesoriparian terrace features with no action in the historic floodplain. A brief description of each alternative remaining after prescreening is provided below. (For more detail, view Table 13 for reasons why thirty-three out of forty-seven possible alternatives were screened out of consideration).

No Action Within Active Channel

Alternatives NNN, NMX, and NMM remain after all combinations were made with no action remaining constant in the active channel. NNN calls for no action in the active channel, no action in the terraces, and no action in the historic floodplain. NMX implements no features in the active channel, a mesoriparian environment in the terraces, and xeroriparian features for the historic floodplain. NMM does nothing within the channel but implements mesoriparian action for both the terraces and historic floodplain.

NNN is considered the no action option and is one of the alternatives required by USACE in order to comply with the requirements of NEPA. No Action assumes that no project would be implemented by the federal government or by local interests to achieve the study area planning objectives. No action also takes into account the future without project condition likely to occur over the period of study. The No Action Plan forms the basis from which all other alternative plans are measured.

NMX and NMM, the two other remaining alternatives with no action in the active channel, represent a departure from the screening criteria. These alternatives are not consistent with natural patterns likely to occur given a mesoriparian environment in the terraces because one would normally find a hydoriparian or mesoriparian plant community in the active channel if flow were frequent enough to support a mesoriparian community on the terraces. However, they remain within consideration because of the need to avoid unacceptable reductions in flood conveyance. By leaving the active channel undisturbed, this has the least possible impact to conveyance.

Common features of both alternatives include:

1. The construction and planting of water harvesting bains at the confluences of 11 tributaries. The aquitard features would involve excavating in the area where the tributaries enter the terraces. Excavation would be to a depth of approximately four feet, a liner membrane would be laid, and the excavated area would be filled with layers of appropriately sized gravel covered with granular fill.

2. The implementation of a permanent irrigation system for mesoriparian areas. Permanent irrigation would combine construction of feeder pipelines to move water through the project area with use of open channels and level spreaders to distribute water at specific locations. In some cases, such as the tributary aquitards, a simple outflow would be sufficient.

3. The installation of temporary irrigation for xeroriparian areas and stabilized terraces in areas with steep unprotected banks.

4. The amendment of soil would be common to both mesoriparian and xeroriparian areas with the latter having additional surface treatments to improve the grounds ability to concentrate rainfall.

5. The cutting back into the historic floodplain would create gentler and more stabile slopes and would modify reaches of steep natural banks. The method of stabilization would be a function of the amount of land available for the new terrace area. Where available land is not a constraint banks will be graded at a 5-foot horizontal to 1-foot vertical slope and planted. Vegetated slopes of this grade are considered stable. A different treatment will be used in areas where there is not enough land to create a 5:1 slope but sufficient space exists to create slopes between 5:1 and 2:1. In those cases the banks will be laid back to the minimum slope that can be fit into the available space. These slopes will also be vegetated however; a geotextile layer will be installed prior to planting to ensure slope stability. In areas where insufficient space exists to accommodate 2:1 slopes placement of rip rap or soil cement may be necessary for bank protection. Such applications will be decided on a case-by-case basis.

6. The restoration or enhancement of 1,119 acres of habitat. Both NMX and NMM are dominated by xeroriparian shrub (shrubscrub) and mesquite with a few small pockets of cottonwood-willow. NMX is comprised of 693 acres of xeroriparian shrub, 416 acres of mesquite and ten acres of cottonwood-willow. In NMM the addition of irrigation to the historic floodplain reverses the dominance xeroriparian plants producing 638 acres of mesquite, 471 acres of shrubscrub and 10 acres of cottonwood-willow.

A difference between NMM and NMX is that for NMX there is no permanent irrigation in the historic floodplain. Two features added to compensate for this are the addition efforts at surface treatment and the creation of a number of shallow depressions to concentrate local run-off.

Xeroriparian Within Active Channel

One alternative including xeroriparian features in the active channel was carried forward. This alternative, XXX, pairs xeroriparian channel features with xeroriparian restorations on the terraces and in the historic floodplain

Features of alternative include:

1. The construction of a low flow diversion to direct water from the New West Branch back into the Old West Branch.

2. The construction of aquitards on the upstream side of six existing grade structures. The implementation of aquitard features would involve excavating upstream of each grade control structure to a depth of approximately four feet, placing a liner membrane, and filling the excavated area with layers of appropriately sized gravel covered with granular fill. The areas would be seeded with riparian grasses and would be maintained as emergent marsh with larger shrubs or medium sized trees periodically cut back to preclude significant impacts on flood flows. The aquitards would be expanded in size since, without irrigation, plants would be much more dependent on water harvesting.

3. The diversion of low flows would be accomplished by placing a diversions structure in the New West Branch channel to pond low flows through the bank to the newly excavated reach of channel between the NWB bank and remaining OWB channel.

4. The soil amendment of terrace and floodplain areas would include finish grading to provide micro-topography suitable for concentration of rainfall along with placement of rocks and coarse woody debris to facilitate moisture retention and provide sun and wind shade. Also, the off channel areas to concentrate local runoff would be created in the floodplain.

5. The restoration of 1,125 acres of habitat. It is dominated by 867 acres of xeroriparian shrub (Shrub Scrub) with 252 acres of Mesquite and 6 acres of emergent marsh (riverbottom).

Mesoriparian Within Active Channel

Five alternatives including mesoriparian features in the active channel were carried forward. Each of these alternatives places mesoriparian measures in the channel in combination with terrace and floodplain measures described above. They are MXN, MMN, MXX, MMX, and MMM.

Two of the five-mesoriparian channel alternatives (MXN and MMN) have mesoriparian habitat within the channel and no restoration in the historic floodplain. The difference is the treatment of the terraces. One plan calls for xeroriparian while the other calls for mesoriparian restoration treatment for the terraces. Both plans produce only 199 acres of restored or enhance habitat. MXN restores or enhances 6 acres of emergent marsh, 174 acres of xeroriparian shrub and 19 acres of mesquite while MMN restores the same 6 acres of emergent marsh with the remaining 193 acres consisting of mesquite.

The other three alternatives (MXX, MMX and MMM) have mesoriparian restoration within the channel for all three plans while two plans have xeroriparian treatment in the floodplain and two plans have mesoriparian improvements along the terraces. One plan has mesoriparian areas in the floodplain while the remaining plan has xeroriparian treatment along the terraces. All three plans produce 1,125 acres of restored or enhanced habitat. Alternative MXX is dominated by 862 acres of xeroriparian shrub with 257 acres of mesquite and 6 acres of emergent marsh. MMX is predominantly xeroriparian shrub at 688 acres with 421 acres of mesquite, 10 acres of cottonwood-willow and 6 acres of emergent marsh, MMM continues the trend with mesquite becoming dominant at 643 acres, 466 acres of xeroriparian shrub, 10 acres of cottonwood-willow and 6 acres of emergent marsh.

The major changes in channel features from the one outlined for the xeroriparian alternatives consists of deletion of the diversion to the Old West Branch since irrigation reduces the need to establish this link; introduction of irrigation water into the lower reach of the Old West Branch and irrigation of the grade control aquitards. The irrigation would not be constant but would consist of adding water to extend the flow period following natural events. In this way the volume and duration of flow in these areas would be increased to mimic mesoriparian conditions.

Hydroriparian Within the Active Channel

Six alternatives including hydroriparian features in the active channel were carried forward. Three of the six alternatives (HNN, HXN and HHN) involve no action in the historic floodplain. The differences occur in the treatment of the terraces. One plan calls for no action, the second plan calls for xeroriparian, and the third plan calls for hydroriparian restoration in the terraces. HNN produces 319 restored acres with 122 acres of mesquite, 69 acres of cottonwood-willow, 69 acres of riparian shrub and 59 acres of emergent marsh. HXN produces 507 restored or enhanced acres with 243 acres of riparian shrub, 136 acres of mesquite, 69 acres of cottonwood-willow and 59 acres of emergent marsh. HHN produces 487 restored or enhanced acres with 181 acres of riparian shrub, 168 acres of mesquite, 79 acres of cottonwood-willow and 59 acres of emergent marsh. The other three alternatives are HXX, HHX and HHM. Three use xeroriparian treatment in the floodplain while one uses mesoriparian treatment. Two apply restoration of the terraces by xeroriparian treatment and two by hydroriparian treatment. HXX produces 1247 restored acres with 867 acres of riparian shrub, 253 acres of mesquite, 69 acres of cottonwood-willow and 59 acres of emergent marsh. HHX produces 1227 restored or enhanced acres with 805 acres of riparian shrub, 284 acres of mesquite, 79 acres of cottonwood-willow and 59 acres of emergent marsh. HHM produces 1227 restored or enhanced acres with 577 acres of riparian shrub, 512 acres of mesquite, 79 acres of cottonwood-willow and 59 acres of emergent marsh.

Implementation of these alternatives involves replacing the channel features with a perennial flow channel. It would require grading the active create low flow averaging six feet in width and one-half foot in depth. Grading would also create depress ional areas on each side of the low flow channel about ten feet in width where soil saturation conditions resulting from infiltration would be conducive to emergent marsh. Finally, a band of cottonwood-willow varying in width from ten to twenty feet would be positioned adjacent to the emergent marsh to further utilize infiltrating water from the perennial channel.

Because of the conveyance impacts that would result from the creation of perennial flows, terrace features are limited to either xeroriparian or hydroriparian. In the xeroriparian terrace features, both upper and lower level terraces would include finish grading to provide micro topography suitable for concentration of rainfall along with placement of rocks and coarse woody debris to facilitate moisture retention and provide sun and wind shade. In the hydroriparian terrace features, the upper level terraces are irrigated and planted with mesquite and pockets of cottonwood-willow. The lower terraces would be planted with riparian grasses and would be maintained as xeroriparian shrub with larger shrubs or medium sized trees periodically cut back to retain cross-sectional area for conveyance of larger flood flows.

Finally, the alternatives including no action in the historic floodplain include the stabilized terraces described for the xeroriparian and mesoriparian floodplain. While this measure produces significant restoration benefits, it is carried forward her to mitigate greater erosion risks associated with increased channel roughness.

3.10.2 With Project Condition Functional Assessment

With the general trends of the Without Project Condition (i.e. the No Action Alternative) in mind, the study team developed acreage and variable projections for the fourteen proposed alternatives. When possible, the Team offered suggestions to enhance the alternatives given the goals and functions.

The most producing alternative was HHM (519 AAFCUs). The second and third highest alternatives were HXX (491 AAFCUs) and HHX (490 AAFCUs). The least productive alternatives were MMN (115 AAFCUs) and MXN (62 AAFCUs) the restoration alternative calls for mesoriparian approach taken in the active channel, xeroriparian approach deployed in the floodplain terraces, and no action being taken in the historic floodplain. No alternative resulted in a loss of functionality.

Trends over a 50-year period for all alternatives, including No Action, are presented in Figure 13. As a general rule, the Team assumed that much of the land made for the project would be converted to productive riparian settings, and the existing Mesquite would diminish from urban development. Alternatives that incorporated the deployment of harvesting basins as well as those alternatives that opted for a vegetative watercourse were assumed to have high habitat quality. Regardless of the manner in which it was achieved, the Team assumed vegetative growth, and the health of wildlife would increase appropriately. The Team also attempted to capture the vegetative succession of this area in increments over time (low quality early in the life of the project, and higher quality later in the life of the project). By restoring, developing, and protecting these areas, the Team assumed the habitat would be buffered from human disturbance factors, thereby improving the overall value of the habitat in the urban setting.

The overall HGM results for each alternative are summarized in Table 14. The results show that alternative HHM (the restoration alternative calls for hydroriparian approach in the active channel and in the floodplain terraces and mesoriparian approaches deployed in the historic floodplain) produced the highest net AAFCUs across the suite of functions.

Table 14: With Project Functional Assessment Results

RANK	ALTERNATIVE	AAFCUs
1	H-H-M	519
2	H-X-X	491
3	H-H-X	490
4	M-M-M	454
5	N-M-M	451
6	M-M-X	409
7	X-X-X	406
8	M-X-X	402
9	M-X-X	375
10	H-H-N	194
11	H-X-N	188
12	H-N-N	155
13	M-M-N	115
14	M-X-N	62

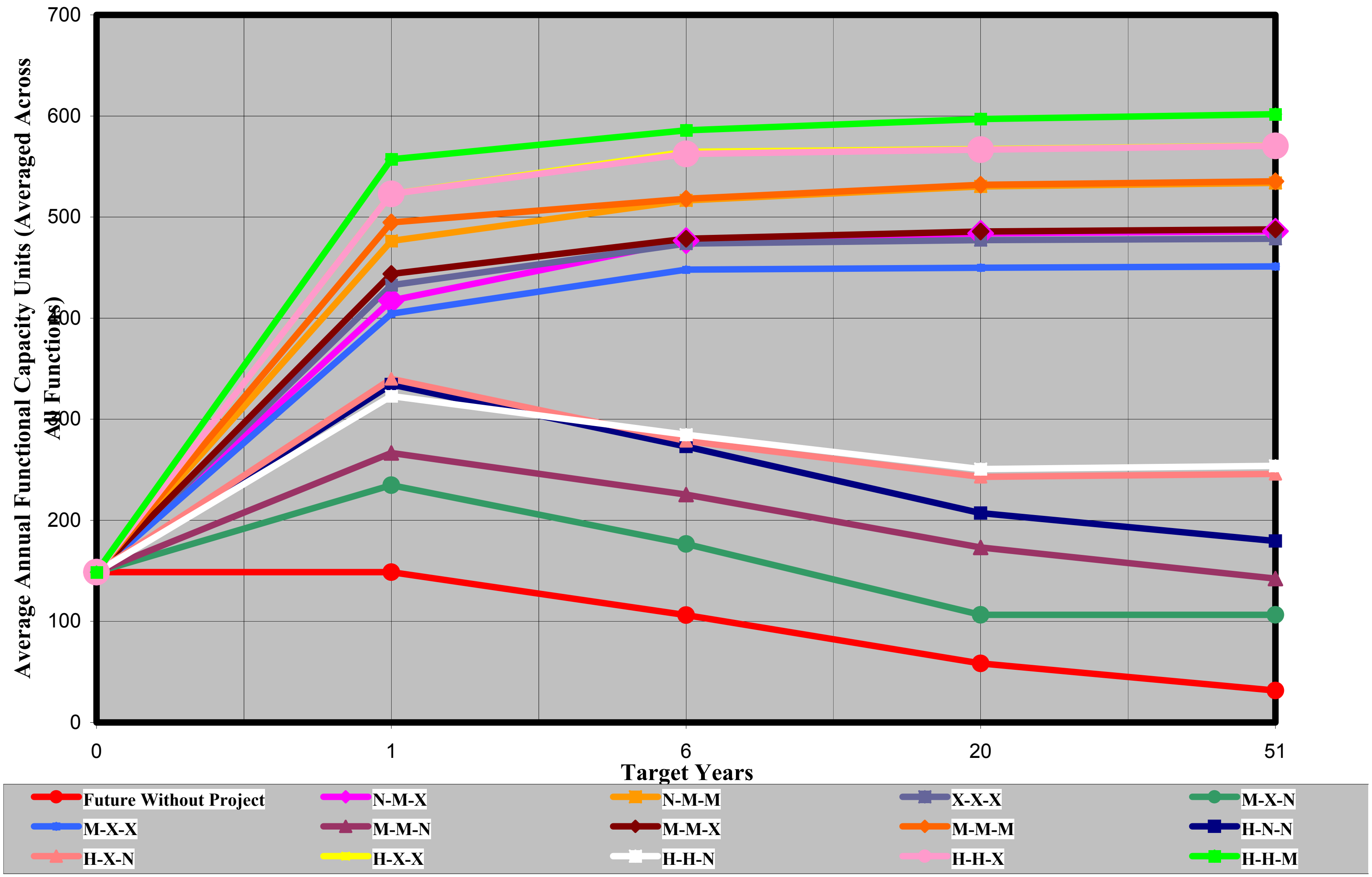


Figure 13: Trends in AAFCUs for Alternatives Evaluated

3.11 RELATIVE VALUE INDICES AND TRADE-OFFS

3.11.1 General Discussion

The "best" alternatives cannot be selected from among a set of "good" alternatives unless there is a means in which to compare them. It is only by comparison that an alternative is no longer "good enough," or that a "good" alternative becomes the "best" alternative. The purpose of the comparison step is to identify the most important criteria alternatives can be evaluated against, and compare the various alternatives across those criteria. Ideally, the comparison of alternatives concludes with a ranking of alternatives or some identification of the best course of action for the decision-makers. When all the important alternative designs are measured in the same units (e.g., ecological units, acres, dollars etc.), the comparison can be simple. More realistically, alternative designs are measured in a combination of dollars, ecological units, acres, housing relocations, water quality changes, noise levels, navigation safety, changed erosion rates, or a host of other tangible or intangible units. When this occurs, planners have to advise decision-makers about trade-offs (i.e., value judgments). Trade-offs are made throughout the planning process, throughout all screening activities, but they take on special significance as the study team, decision-makers and other stakeholders move toward selecting the best, most likely alternative future for a society. These trade-offs are first made regarding the individual alternatives under evaluation. The question is asked: "Is it good enough to warrant further consideration?" Alternative designs can be dropped from further analysis for a variety of reasons including cost ineffectiveness, design inconsistencies, and biological unproductiveness to name a few. Afterwards, trade-offs are considered across, and among, all the alternatives. Trade-offs are undertaken when contrasting outputs are encountered. For example, Alternative 1 may be less costly, but restores fewer wetlands than Alternative 2, a more costly design that restores significantly more wetland acres.

Trade-off analysis is a multi-criteria evaluation method commonly used by USACE when it is impossible (or not desirable) to express all alternative effects in a single metric - more than one evaluation metric can be considered (i.e., HEP, HGM, and costs together) in a trade-offs analysis (Edmunds and Letey 1973). Trade-offs enable planners to account for the entire gamut of differing (but relevant) criteria when comparing alternatives. Trade-offs can be as simple, or as complex, as necessary to afford the greatest suite of comparisons. In a simple application, trade-offs can frequently rely on professional judgment. Planners "trade-off" alternative contributions to objectives based on their own accumulated technical expertise, general experience, and specific knowledge of the study area (including stakeholder views and values). In essence, planners sit down and develop an alternative with "a little more of this" and "a little more of that," where the trade-offs made tend to be of a subjective nature. However, more quantifiable approaches exist to conduct trade-off analyses in a controlled environment.

Simple weighting is a sophisticated and simple approach to trade-offs that can be used when there are no apparent "winning" or dominant alternatives among those compared. In HGM, models are selected to emphasize the importance of specific functions, and can be "traded-off" by incorporating a weighting scheme into the calculation of final FCUs. By applying Relative Value Indices (RVIs) to the resultant outputs, function priorities can be characterized, and mathematical "weights" can be applied to HGM activities accordingly. In the overall scheme of project design, RVIs serve as prisms to concentrate attention on those changes that will impact the area's significant resources. The determination of "value" is a somewhat subjective exercise in the HGM process, but the HGM methodology provides avenues of documentation and justification necessary to support decisions in this arena (USFWS 1980b). Thus, RVIs can be used to perform trade-offs among functions, or simply to "level" the playing field.

3.11.2 Trade-Offs Decisions

Subsequent to the HGM modeling results of the 14 alternatives, the Study Team performed an exercise to evaluate the effects of Relative Value Indexing (RVI). The models were then rerun for: 1) Functions 2, 4 , and 8 only, 2) water functions only, 3) soils/biochemical functions only, and 4) habitat functions only. The results in the rankings of the alternatives are presented in Table 15 below:

Table 15: Trade-Off Comparison of Results

Rank	No Trade-Offs: Alt. (AAFCUs)	Fxns. 2, 4, & 8 Only	Water Fxns. Only	Soil Fxns. Only	Habitat Fxns. Only
1	H-H-M (519)	H-H-M (502)	M-M-M (601)	H-X-X (645)	H-X-X (372)
2	H-X-X (491)	H-H-X (465)	N-M-M (594)	H-H-X (632)	H-H-X (366)
3	H-H-X (490)	H-X-X (458)	H-H-M- (589)	H-H-M (629)	H-H-M (317)
4	M-M-M (454)	M-M-M (445)	M-M-X (493)	M-X-X (591)	N-M-M (134)
5	N-M-M (451)	N-M-M (443)	N-M-X (486)	M-M-X (588)	M-M-M (127)
6	M-M-X (409)	M-M-X (390)	X-X-X (481)	M-M-M (585)	N-M-X (126)
7	N-M-X (406)	N-M-X (387)	H-H-X (466)	X-X-X (580)	M-M-X (119)
8	X-X-X (402)	X-X-X (384)	H-X-X (466)	N-M-X (580)	X-X-X (117)
9	M-X-X (375)	M-X-X (348)	M-X-X (411)	N-M-M (579)	M-X-X (111)
10	H-H-N (194)	H-H-N (184)	H-H-N (233)	H-X-N (233)	H-H-N (110)
11	H-X-N (188)	H-X-N (182)	H-X-N (217)	H-H-N (226)	H-X-N (105)
12	H-N-N (155)	H-N-N (145)	H-N-N (189)	H-N-N (186)	H-N-N (77)
13	M-M-N (115)	M-M-N (113)	M-M-N (160)	M-M-N (122)	M-M-N (47)
14	M-X-N (62)	M-X-N (55)	M-X-N (63)	M-X-N (97)	M-X-N (26)

The RVI analysis did not significantly alter the rankings of the 14 alternatives when compared to the original model results using all ten functions. Weighting with the water and soils/biochemical functions only did increase the outputs (AAFCUs) slightly, however using only the habitat functions, the outputs decreased significantly.

Based on the results of the RVI exercise, the Study Team decided that all ten functions should be weighted equally and trade-offs analysis was not applied to the results.

3.12 HGM RESULTS AND ECONOMIC ANALYSIS

3.12.1 Economic Analysis Process

Between 1986 and 1987, the Headquarters' Office of the U.S. Army Corps of Engineers (USACE) provided policy directing Corps Districts to perform a type of cost analysis referred to as Incremental Cost Analysis (ICA) for all feasibility-level studies. The required ICA is, in effect, a combination of both a Cost Effectiveness Analysis (CEA) and Incremental Effectiveness Analysis (ICA). Together, the CEA/ICA evaluations combine the environmental outputs of various alternative designs with their associated costs, and systematically compare each alternative on the basis of productivity. Cost effectiveness analyses focus on the identification of the least cost alternatives and the elimination of the economically irrational alternatives (e.g., alternative designs which are inefficient and ineffective). By definition, inefficient alternative designs produce similar environmental returns at greater expense. Ineffective alternative designs result in reduced levels of output for the same or greater costs. The incremental cost analysis is employed to reveal and interpret changes in costs for increasing levels of environmental outputs.

In 1990, USACE issued Engineer Regulation 1105-2-100 (U.S. Army Corps of Engineers 1990) directing planners, economists, and resource managers to conduct CEA/ICA for all recommended mitigation plans. Later, in 1991, USACE produced Policy Guidance Letter Number 24 that extended the use of cost analysis to projects that restored fish and wildlife habitat resources (U.S. Army Corps of Engineers 1991). In the Corps' Engineering Circular 1105-2-210, the incorporation of cost analysis was declared "fundamental" to project formulation and evaluation (U.S. Army Corps of Engineers 1995). To facilitate the inclusion of these basic economic concepts into the decision-making process, USACE published two reports detailing the procedures to complete both incremental and cost effective analysis (Orth 1994; Robinson et al. 1995). Based on these reports, there were nine steps that should be completed to evaluate alternative designs based on CEA/ICA. These were as follows:

A. Formulate all possible combinations of alternative designs by:

1. Displaying all outputs and costs.
2. Identifying filters, which restrict the combination of alternative designs.
3. Calculating outputs and costs of combinations.

B. Complete a cost effective analysis by:

4. Eliminating economically inefficient alternative designs.
5. Eliminating economically ineffective alternative designs.

C. Develop an incremental cost curve by:

6. Calculating the average costs.
7. Recalculating average costs for additional outputs.

D. Complete an incremental cost analysis by:

8. Calculating incremental costs.
9. Comparing successive outputs and incremental costs.

In the ICA terminology, an alternative design is considered the With Project condition (i.e., "Build A Dam," "Develop a Wetland," "Restore the Riparian Zone," "Management Plan A," etc.). Under an alternative design, a series of scales (i.e., variations) can be defined which are modifications or derivations of the initial With Project conditions (i.e., "Develop 10 acres of Low Quality Wetlands," "Develop 1,000 acres of High Quality Wetlands", etc.). Often, these scales are based on differences in intensity of similar treatments and can, therefore, can be "lumped" under an alternative design class or category. During the first steps of CEA/ICA, all possible combinations of alternative designs and their scales are formed. As a general rule, intra-scale combinations (i.e., combinations of variations within a single alternative design) are not allowed - these activities would occupy the same space and time.

In most instances, CEA/ICA results are displayed in tables, scatter plots, and/or bar charts. These illustrative products assist decision-makers in the progressive comparisons of alternative design costs, and the increasing levels of environmental outputs. Before a user makes a decision based upon the outputs generated by the CEA/ICA, they must determine whether cost thresholds exist which limit production of the next level of environmental output (i.e., cost affordability). In addition, factors such as curve anomalies (i.e., abrupt changes in the incremental curve), output targets, and output thresholds can influence the selection of alternative designs. All detailed information and results of the CEA/ICA analyses are presented in the Appendix H, Economics of the Paseo de las Iglesias Feasibility Report.

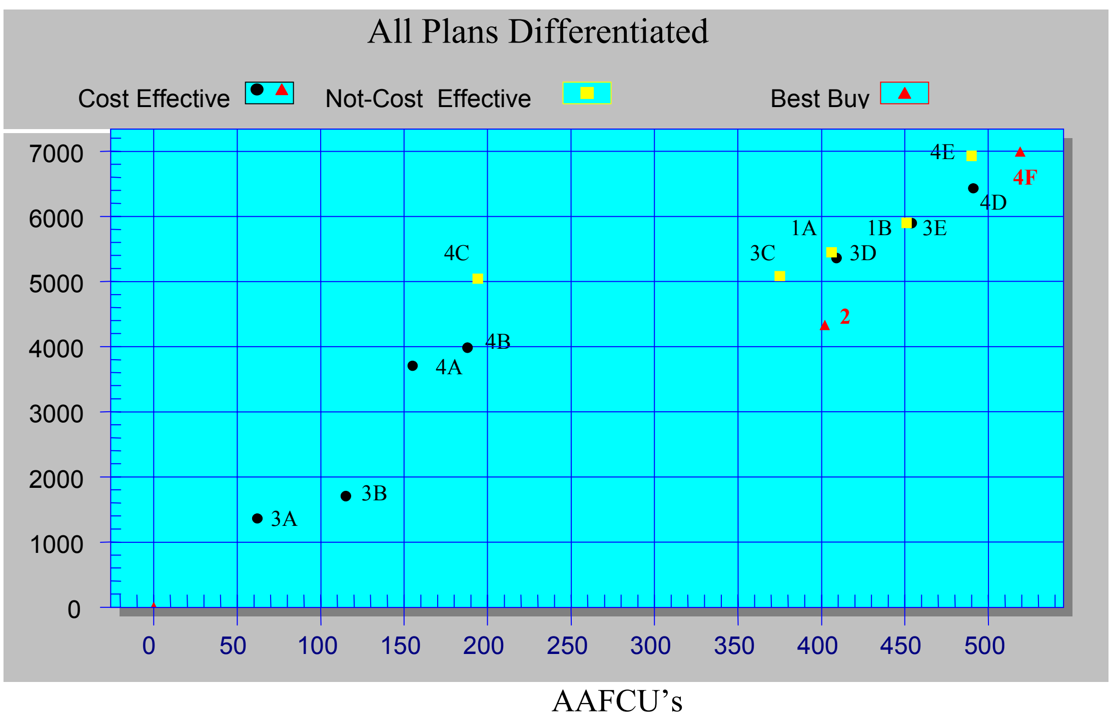
3.12.2 Incremental Cost Analysis (ICA) Overview

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, in turn, compared on the basis of 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 revealed (those that are both cost effective and incrementally effective).

3.12.3 Final Array of Alternatives:

The top average cost alternative and incrementally effective and efficient solution evaluated was XXX. The second ranked average cost and cost effective plan was MMM; however. The third ranked average cost plan was not cost efficient and effective as shown in the CEA ranking and did not rank as a best buy plan.

Figure 14: All Plans Differentiated
(CEA Plans and Best Buy Plans Labeled)



The incremental cost analysis indicates that alternatives listed in Table 14 are cost efficient and cost effective. Of the best buy plans, XXX is the least costly to build at $4,330,533 but also produces the least amount of AAFCUs (402) at $10,770 per AAFCU. HHM will cost an additional $2,645,644 on an average annual basis and produce 117 additional AAFCUs for an incremental cost of $22,610 on an average annual basis per additional AAFCU. This means HHM can be implemented for only 117 more units but the incremental cost per additional incremental AAFCU will be more then twice XXX at $10,770.

XXX has the least average cost, is the ICA best buy and is cost effective. It produces 402 AAFCUs and is ranked 8th place in the HGM. XXX rates 5th overall in total average annual cost. On the other hand, HHM is the largest plan at 14th place overall in total average annual cost. It is 7th place in average cost and 5th place in cost effective analysis. It is the second best buy plan.

The two alternatives identified by cost effectiveness and incremental cost analyses represent the extremes of the water requirements for the analyzed alternatives. The selection of a either a restoration alternative utilizing almost no water or one utilizing nearly 9,000 acre-feet per year would potentially pose problems with respect to public acceptability. Residents have expressed a desire for restoration beyond what might be accomplished without irrigation however; there are a number of restoration sites under study and committing such a large volume to a single project would most likely be opposed by local citizens. In addition to public acceptability, there would be a substantial fiscal burden and complex political agreements associated with committing 9,000 acre-feet per year to a single restoration project.

For these reasons a third alternative, Alternative 3E, was added to the final array despite the fact that it was not a "Best Buy". The primary reason for selecting Alternative 3E is that it comes closest to presenting a mid-point in water demand between Alternatives 2A and 4F. Alternative 3E restores mesoriparian habitat to the project area with pockets of hydroriparian plantings. Alternative 3E, with an annual water budget of just under 2,000 acre-feet, provides a substantial reduction from 4F while still committing enough water to sustain mesoriparian plant communities. In addition, although Alternative 3E is incrementally more expensive that Alternative 4F, it ranks second for cost effectiveness with a cost of $12,598 per average annual functional capacity unit.

4. HEP EVALUATION

4.1 CROSSWALKS BETWEEN HEP AND HGM

Ecosystems are generally characterized in terms of their structural components and the processes that link these components (Bormann and Likens 1969). Structural components of the ecosystem and the surrounding landscape, such as plants, animals, detritus, soil, and the atmosphere, interact through a variety of physical, chemical, and biological processes such as the movement of air and water, and the flow of energy and nutrients. Understanding how the structural components of the ecosystem, and the surrounding landscape are linked together by processes is the basis for assessing ecosystem functions. Since modified HEP was used in past District studies, and HGM is a more recent development for these ongoing studies, it is important to address similarities in their approaches to measuring ecosystem integrity, and discuss the use of multiple tools in evaluations of this magnitude. It is also important to validate the use of these two tools in an ecosystem setting, to assure users that the success of ecosystem restoration studies in the future can be evaluated effectively and efficiently using a combination of the HEP and HGM methodologies.

As one might expect, the HEP and HGM approaches are quite similar, varying only in matters of terminology and assessment focus. Probably the most important issue to address when approaching a HEP or HGM study is the communication of results in scientific syntax to the applicants and users. To that end, Table 16 has been included here to demonstrate crosswalks between terms used in HEP and "sister" terms used in the HGM application process.

Table 16: Terminology crosswalks between the HEP and HGM methodologies

Parameters	HEP Terminology	HGM Terminology
Measurable parcel of land defined by its vegetative cover, soils, and topography	Cover Type (CT)	Partial Wetland Assessment Area (PWAA)
An attribute or characteristic of landscape (or the surrounding landscape) that influences the capacity of wetland to perform a function or the suitability of the area to support a species or community	Variable	Variable
The index that rates the variable relative to optimum conditions. Both Indices are, by definition, scaled from 0.0 to 1.0.	Suitability Index (SI)	Variable Subindex (VSI)
A mathematical aggregation of the Variable Indices used to describe the interrelationships among variables that define the suitability or functionality of the site.	Habitat Suitability Index (HSI)	Functional Capacity Index (FCI)
The product of the quality of the site (determined by the HSI or FCI) multiplied by the quantity of the site. Unit = Quality Index X Quantity	Habitat Unit (HU)	Functional Capacity Unit (FCU)
Target Years are units of time measurement that allow users to anticipate and direct significant changes (in area or quality) within the project (or site).	Target Year (TY)	Target Year (TY)
The measure of future habitat conditions estimated for both baseline (Without Project) and design (With Project) conditions. Projected long-term effects of the project are reported in terms of average annual units. Average Annual Units = For each Target Year . . . Average Quality X Average Quantity	Average Annual Habitat Unit (AAHU)	Average Annual Functional Capacity Unit (AAFCU)
A technique deployed to emphasize the value or priority of the results in a "weighting" fashion.	Relative Value Index (RVI)	Relative Value Index (RVI)

The distinguishing difference between the HEP and HGM methodologies is the biological component they each were designed to assess. HEP was designed to interpret the effects of environmental change through a species or community-based habitat suitability relationship across the landscape - a habitat maintenance function in the ecosystem setting. Although the HEP technique was not initially developed to assess additional ecosystem functions, combinations of HSI models in the HEP methodology indirectly measure ecosystem functionality across terrestrial and aquatic systems. In other words, HSI model parameters correlate closely with measures of ecosystem integrity such as improved water quality (i.e., turbidity, pH, salinity, and temperature - factors in many fish HSI models), patchiness and/or disturbance (i.e., distance to cover and water, riparian zone widths, human disturbance - factors of many bird and mammal HSI models) and both plant community and wildlife habitat maintenance (a factor of all the HSI models developed). Of course, HSI models are limited because they define only animal habitats as they pertain to physical and chemical characteristics of the landscape. HSI models do not, for example, include geomorphic setting, water source, and hydrodynamics - features that that directly relate to aquatic ecosystem integrity. But a combination of well-chosen species- or community-based models can be deployed to capture and reflect change in ecosystem functions across the site.

The model selection process can "make" or "break" an ecosystem study, and it is extremely important that the selection process focuses on the study's performance measures (i.e., success criteria), community incidence and architecture, and model parameters directly contributing to the ecosystem function. To do this, it has been suggested that habitat evaluation teams select guild representative models rather than game species models. A guild representative is, by definition, an animal (or plant) that belongs to a group of functionally similar species with comparable habitat requirements whose members interact strongly with one another. If results indicate a decline in a guild representative's habitat, it is assumed that species within this guild will be subject to same decrease in habitat suitability, and the guild as a whole will decline. Thus, species HSI models should be selected as representatives of an identifiable guild.

In addition, model selection should be based on sensitivity of the species or community to the proposed changes. Thus, identification of proposed actions, and limiting factors within a model must be reviewed and compared prior to model selection. Although results are tallied in terms of habitat change to the specific species (or community), projected change is derived at the variable level. In other words, the team does not project a decline in habitat suitability for Species A. Instead, the evaluation team generates estimated changes on a variable-by-variable basis given a proposed project design (i.e., water depth will decrease, herbaceous vegetation will increase by 25 percent, the forested wetlands will expand by 15 percent, etc.) regardless of species or community association. Thus ecosystem functions (floodwater detention, habitat maintenance, characteristic plant community maintenance, etc) are inadvertently captured in the application of a species-based or community-based HSI model. To this end, HSI models can be relied upon to measure at least some, but obviously not all, ecosystem functions in both terrestrial and aquatic systems (including wetlands), the primary function being Maintenance of Wildlife Habitat, and secondarily the Maintenance of Characteristic Plant Communities.

HGM, on the other hand, was specifically designed to assess wetland functions rather than individual wildlife species requirements. Strictly speaking, HGM applications are limited to wetlands defined as areas with less than one meter of standing water present. Thus, HGM was not designed to evaluate all systems within the ecosystem. However, HGM is a powerful tool that can define the normal, or characteristic, activities that take place in a wetland ecosystem setting. As wetlands perform a wide variety of simple and complex activities based on their physical, chemical, and biological attributes, HGM has been designed to measure functional capacity. The combination of HGM, with its functional assessment approach, and HEP, with its coverage of both aquatic and terrestrial settings, can blanket the entire study area, capturing changes in ecosystem activities across the landscape. Maintenance of ecological integrity, the function that encompasses all of the structural components and processes in an aquatic and/or terrestrial ecosystem, can therefore be assessed using a combination of HEP and HGM.

4.2 HABITAT EVALUATION PROCEDURE METHODS

HEP has been used for the past few decades as a planning and evaluation tool to document the quality and quantity of available habitat for selected wildlife species under baseline and future conditions. HEP was developed by the U.S. Fish and Wildlife Service (USFWS) for use in impact assessment and project planning (USFWS 1976, 1980). HEP provides a quantification of wildlife habitat based on two variables:

1) The Habitat Suitability Index (HSI), a unitless number between 0 and 1, where 0 represents no habitat and 1 represents optimum habitat or ideal conditions. If several patches of similar habitat are included in a study area, the HSI is calculated for each, then an average HSI is assigned to the habitat type.

2) The total area of each habitat type within the study area.

The HSI (or average HSI) for each habitat type is multiplied by the total area of the habitat type to derive a score for Habitat Units (HU). Then, HUs for all habitat types within the study area are summed, to yield total HU for the study area under either baseline or future conditions. In some cases, an Average Annual Habitat Unit (AAHU) is derived, which is the total number of HUs gained or lost as a result of a proposed action, divided by the life of the action. Comparison of HUs and AAHUs can be used to support selection of project alternatives.

The first generation HEP used vegetation cover types, and evaluated existing or projected conditions with regard to ideal conditions (USFWS 1976). The second generation HEP used a compilation of HSIs for selected species of fish and wildlife (USFWS 1980). The HSI value is derived from an evaluation of the ability of key habitat components to supply the living requisites of the selected species, comparing existing habitat conditions and optimum habitat conditions. Optimum conditions are those associated with the highest potential densities of the species within a defined geographic area. The HSI value obtained from this comparison thus becomes an index to carrying capacity for those species. Usually several species of interest are selected for the HEP, and the final values used are aggregate values for all evaluation species.

HSIs were developed for many species of fish and wildlife (Table 17). Only a few species for which HSIs have been developed are known to occur, or are likely to occur, within the study area of Paseo de las Iglesias. Available HSI models are indicated in Table 17. Of these species, American Coot, Marsh Wren, Red-winged Blackbird, Yellow Warbler, and Yellow-headed Blackbird are not likely to occur regularly under current conditions, but are expected to migrate to the area if appropriate conditions are created for them. Of the other species known or likely to occur in the study area, the Bobcat, Brewer's Sparrow, and Lark Bunting are transients or migrants in the area, and the available HSIs are for specific breeding populations. Thus, the available HSIs are not suitable for application in evaluating the Paseo de las Iglesias project alternatives. Development of HSIs for appropriate species is beyond the scope of this analysis.

Table 17: Habitat Suitability Index Models Currently Available

Species with * are currently known to occur in the study area; species underlined are considered likely to occur following completion of the project, depending on alternative selected.
Source: U.S. Geological Survey 2003

- Alewife and Blueback Herring
- American Alligator
- American Black Duck (wintering)
- American Coot
- American Eider (breeding)
- American Oyster, Gulf of Mexico
- American Shad
- American Woodcock (wintering)
- Arctic Grayling Riverine Populations
- Arizona Guild and Layers of Habitat
- Atlantic Croaker
- Baird's Sparrow
- Bald Eagle
- Barred Owl
- Beaver
- Belted Kingfisher
- Bigmouth Buffalo
- Black Bear (Upper Great Lakes)
- Black-Bellied Whistling Duck
- Black Brant
- Black Bullhead
- Black-Capped Chickadee
- Black Crappie
- Black Duck (Wintering)
- Black-Shouldered Kite
- Black-Tailed Prairie Dog
- Blacknose Dace
- Blue Grouse
- Blue-Winged Teal
- Bluegill
- Bobcat
- Brewer's Sparrow*
- Brook Trout
- Brown Pelican (eastern)
- Brown Shrimp
- Brown Thrasher
- Brown Trout
- Bullfrog
- Cactus Wren*
- Canvasback (breeding habitat)
- Carp, Common
- Catfish,
  - Channel
  - Flathead
- Chinook Salmon
- Chum Salmon
- Clapper Rail
- Coho Salmon
- Common Carp
- Common Shiner
- Creek Chub
- Croaker, Juvenile Atlantic
- Cutthroat Trout
- Diamondback Terrapin
- Downy Woodpecker
- Drum, Red (larval and juvenile)
- Eastern Cottontail
- Eastern Meadowlark
- Eastern Wild Turkey
- English Sole (juvenile)
- Fallfish
- Ferruginous Hawk
- Field Sparrow
- Fisher
- Flounder, Southern and Gulf
- Forster's Tern
- Fox Squirrel
- Gadwall (breeding)
- Gizzard Shad
- Gray Partridge
- Gray Squirrel
- Great Blue Heron
- Great Egret
- Greater Prairie Chicken
- Greater Sandhill Crane
- Greater White-Fronted Goose (wintering)
- Green Sunfish
- Gulf Menhaden
- Hairy Woodpecker
- Inland Silverside
- Inland Stocks of Striped Bass
- Juvenile Atlantic Croaker
- Juvenile English Sole
- Juvenile Spot
- Lake Trout
- Lark Bunting*
- Laughing Gull
- Least Tern
- Lesser Scaup (breeding)
- Lesser Snow Goose (wintering)
- Lewis' Woodpecker
- Littleneck Clam
- Longnose Dace
- Longnose Sucker
- Coolwater & Coldwater Reservoirs
- Mallard (Mississippi Valley)
- Marsh Wren
- Marten
- Mink
- Moose, Lake Superior Region
- Mottled Duck
- Muskellunge
- Muskrat
- Northern Bobwhite
- Northern Pike
- Northern Pintail (Gulf Coast wintering)
- Osprey
- Paddlefish
- Pileated Woodpecker
- Pine Warbler
- Pink Salmon
- Red-Winged Blackbird
- Redbreast Sunfish
- Redear Sunfish
- Redhead (wintering)
- Roseatte Spoonbill
- Ruffed Grouse
- Sharp-Tailed Grouse
- Shelter-Belt Community
- Shortnose Sturgeon
- Slider Turtle
- Slough Darter
- Smallmouth Bass
- Smallmouth Buffalo
- Snapping Turtle
- Snowshoe Hare
- Southern and Gulf Flounders
- Southern Red-Backed
- Southern Kingfish
- Spotted Bass
- Spotted Owl
- Spotted Seatrout
- Striped Bass, Coastal
- Swamp rabbit
- Turkey
- Veery
- Walleye
- Warmouth
- Western Grebe
- White Bass
- White Crappie
- White Ibis
- White Shrimp
- White Sucker
- White-Fronted Goose (wintering)
- White-Tailed Deer
- Williamson's Sapsucker
- Wood Duck
- Yellow Perch
- Yellow Warbler*
- Yellow-Headed Blackbird*

Also considered for this analysis was the "Arizona Guild and Layers of Habitat Models" (Short 1984). This approach was specifically developed for western Arizona, near but outside of the region of the Paseo de las Iglesias project. Enough similarity between the two regions exists, however, so that the figures developed by Short might be applicable to the Paseo study area. Short's approach compares structural diversity (i.e., number of vertical layers of habitats, such as tree canopy, tree bole, shrub midstory, understory, etc) of habitat *X* to riparian forest (cottonwood-willow, the cover type with the highest number of layers) as a standard. The HSI tends to increase as habitat structure becomes more complex, and habitats with greater structural diversity receive higher HSIs. The more closely a cover type resembles cottonwood-willow, the higher the HSI. This approach does not show changes that would occur in a vegetation community, such as Sonoran Interior Strand Mixed Riparian Shrub, that has limited structural diversity. The Paseo de las Iglesias project intends to improve the shrub community in ways that do not include structural diversity, such as changes in density, contiguity, and self-maintenance of vegetation. Because these qualities are important components of the baseline conditions and of the proposed alternatives in the Paseo de las Iglesias project, Short's approach is not appropriate for use in this case.

Due to limitations of the aforementioned HSI models, an alternative approach, based on the first generation (1976) HEP approach, was selected for this study. This approach, which is described below, is more appropriate than the other available methods for the particular conditions of the study area and for the project alternatives considered.

Vegetation communities in the Paseo de las Iglesias study area were delineated using the definitions of Brown, Lowe, and Pase (Brown 1980, 1994), which is the standard used by most biologists in this region (see following section). Areas of similar vegetation conditions were delineated in the field on aerial photographs. Subsequently, the aerial photographs were digitized, and area calculations for each vegetation community were made using Arcview 3.2. Baseline conditions were evaluated for each community within the study area, based on the degree to which they approximate current concepts of healthy, pristine, natural conditions for each vegetation community as a functional ecosystem. A linear rating scale of habitat suitability (i.e., Habitat Suitability Index, or HSI) ranging from 0.0 to 1.0 was created based on specifically defined criteria (see Table 18). Within the study area, discrete areas of each community were evaluated based on these criteria. An average HSI for each community was then calculated for at least five locations (where five or more were available). By multiplying the average HSI value by the total measured area of each cover type, a single value was calculated to obtain Habitat Units (HU) for that community. Without Project and With Project conditions were estimated for the expected vegetation communities and conditions 50 years post project. Within the study area, undisturbed vegetation conditions are no longer present to serve as a standard for comparing existing vegetation communities. Consequently, evaluating the degree to which current conditions approximate ideal natural conditions was based on current vegetation communities outside the study area.

Table 18: Habitat Suitability Index Criteria

Value	Condition
1.0	Natural condition for the vegetation community, with mature individuals of long-lived species and a full age-class range of the native species appropriate to the site. Either natural reproduction of the community is occurring, or natural succession is proceeding to an appropriate subsequent seral stage. The vegetation community is consistent with the natural processes of climatic, fluvial, geological, and ecological processes. All expected native species of plants and animals are present. No invasive non-native species are present. There is no evidence of anthropogenic disturbance. The area is as large as natural processes permit, and is not fragmented by areas that have had natural vegetation removed by human activities.
0.7-0.99	Near natural condition for the vegetation community, with some mature individuals of long-lived species and representation of a range of age classes of the native species appropriate for the site. The vegetation community is consistent with the natural process of climatic, fluvial, geological, and ecological processes. Most expected species of native plants and animals are present. Invasive non-native species are not established. Evidence of anthropogenic disturbance is limited and does not obviously impact the vegetation community. The area is as large as natural processes permit, but has been somewhat fragmented by areas that have had natural vegetation removed by human activities.
0.5-0.69	Remnants of the natural condition of vegetation remain and are obvious to the trained eye. Some mature individuals of long-lived species are present, and there is some evidence of successful continuing reproduction and maturation of the community. The community is generally consistent with natural processes, although it may show effects of anthropogenic disturbance that impacts the vegetation community. The community may be dependent upon some level of maintenance for survival. Larger species of native animals are absent and unlikely to occur. Some invasive non-native species have become established in small areas, but do not dominate the community. The area may be small and isolated from other areas of similar vegetation.
0.3-0.49	Natural vegetation community is not obvious because few remnants are present. Few or no individuals of long-lived species are present or there is little or no evidence of successful reproduction and maturation of the community. The community is clearly subject to anthropogenic influence, and may be dependent upon active maintenance for survival. Some expected species of native plants and animals are present, but others are absent, including larger animal species. Invasive non-native species have become extensively established and may have become dominant.
0.2-0.29	Natural vegetation community is difficult to ascertain, but some native plant and animal species are present. The community has been obviously impacted by human activities, and has diversity and density limited by direct impacts. Invasive non-native species are the dominant, or at least a very important, component of the area.
0.1-0.19	Small and isolated patches of native vegetation are present, with intervening areas of no vegetation or weedy growth including invasive non-native species. Native plants and animals are few, and consist only or primarily of opportunistic species or species with extremely broad habitat selection.
ess than 0.1	Natural vegetation has been removed and has not become re-established. Non-native vegetation is present, but very limited in extent. Few native plants and animals are present, and consist only or primarily of opportunistic species or species with extremely broad habitat selection or (animals) are just passing through.

4.3 BASELINE MODIFIED HEP ANALYSIS:

Species considered in establishing the HSI's included any species or habitat community of interest to any regulatory or management agency of the Federal, State or local government. These included species listed by the U.S. Fish and Wildlife Service as Threatened, Endangered, or Candidate species, and species designated as Wildlife Species of Special Concern in Arizona (WSCA) by the Arizona Game and Fish Department that are known or likely to occur in the study area. In addition, species currently included as Priority Vulnerable Species in Pima County's Sonoran Desert Conservation Plan are considered. Priority Vulnerable Species are those 55 species that Pima County has determined are at risk or have been extirpated but have potential to be reintroduced within the county.

The results of the mHEP analysis of existing conditions in the study area indicate that the majority of the existing natural habitat has an average HSI of 0.4 on a scale where 1.0 indicates the best quality habitat and less than 0.1 indicates a complete lack of natural vegetation. Table 19 summarizes the results of the modified mHEP analysis. Distribution of the BLP cover types is shown in Figure 15.

TABLE 19: Modified HEP Analysis Results

BLP Code	Vegetation Classification to Series Level	Acres in Study Area	% of Study Area	Habitat Suitability Index (Average)	Habitat Units
154.1	Sonoran Desertscrub Biome				
154.12	Paloverde-Mixed Cacti Series	237	4.7	0.73	173
154.17	Saltbush Series	96	1.9	0.57	54.7
224.5	Sonoran Riparian Deciduous Forest and Woodlands Biome				
224.52	Mesquite Series (includes 234.71 Mixed Scrub Series of Sonoran Deciduous Riparian Scrub Biome)	160	3.2	0.60	96
234.7	Sonoran Deciduous Riparian Scrub Biome				
234.72	Saltcedar Disclimax Series	87	1.7	0.40	34.8
254.7	Sonoran Interior Strand Biome				
254.71	Mixed Shrub Series	261	5.2	0.50	130.5
300	Cultivated and Cultured Uplands				
314.1	Urban: Residential, commercial, and industrial	3045	60.8	0.20	609
314.15	Recreational (=maintained park)	86	1.7	0.30	25.8
364.1	Sonoran Vacant or Fallow lands	934	18.7	0.10	93.4
400	Cultivated and Cultured (or Anthropogenic water dependent) wetlands				
414.12	Urban Drainage	99	2.0	0.20	19.8
Total Study Area		**5005**	**100**	**0.25**	**1251**

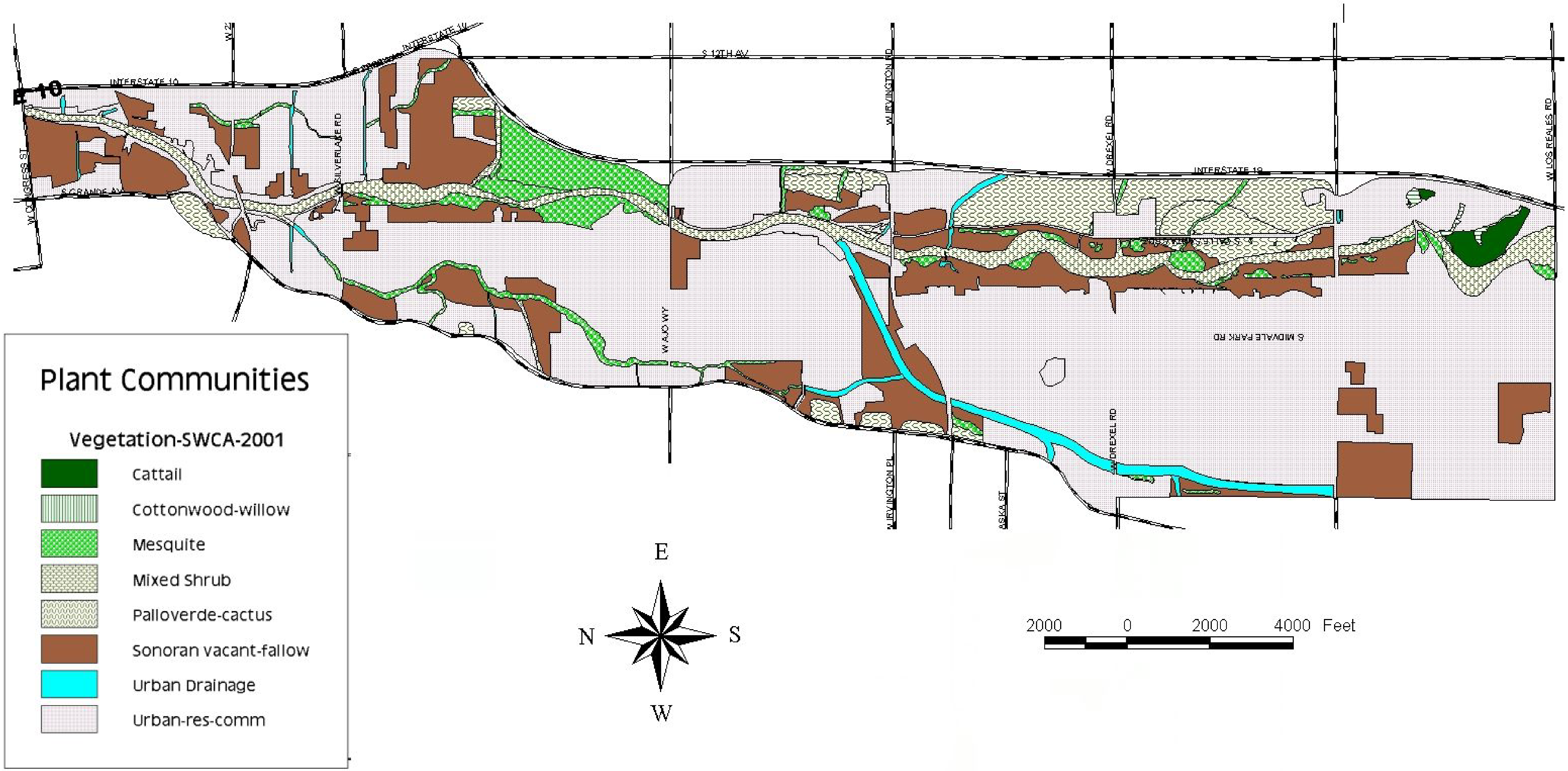


Figure 15: BLP Plant Communities Mapping for the Paseo de las Iglesias Study Area

4.4 HABITAT EVALUATION PROCEDURE (MHEP) FOR WITH PROJECT CONDITIONS

4.4.1 Purpose

A habitat restoration project, called the Paseo de las Iglesias project, is being planned by the Los Angeles District of the U.S. Army Corps of Engineers (USACE), with the Pima County Department of Transportation and Flood Control District as the local sponsor, for a seven-mile reach of the Santa Cruz River in Tucson, Arizona. One of the purposes of the planning process is to identify the most economically practicable and ecologically sustainable means to achieve restoration objectives in the study area. This modified Habitat Evaluation Procedure (mHEP) analysis is one component of the planning process.

4.4.2 Study Area

The study area consists of approximately 5,005 acres of urban and disturbed land on both sides of the Santa Cruz River, a frequently disturbed, deeply entrenched ephemeral channel. Urban development and intensive alteration of natural landscapes have effectively isolated the river channel from natural biological communities. Current on-going disturbances include channel bank erosion, urban development, active and inactive agricultural fields and landfills, off-road vehicle use, soil cement lined banks, wildcat dumping, and transient camps. Due to extensive, basin-wide groundwater pumping, the river that has dried up and the former aquatic and riparian communities have vanished. Remnant mesquite (*Prosopis velutina*) bosques are represented only in diminished, isolated pockets of stunted trees sprouting from cut stumps. Non-native plant species, including saltcedar (*Tamarix ramosissima*) and Athel tamarisk (*T. aphylla*), have replaced most of the native cottonwood (*Populus fremontii*) and willow (*Salix gooddingii*) riparian communities. No portion of the study area is without some impacts of human activity. Within the study area, approximately 1,200 acres of vacant lands associated with the river have been tentatively identified where restoration activities may occur.

4.5 VEGETATION COMMUNITIES

This section describes vegetation communities present within Paseo de las Iglesias study area currently and those that are proposed to be created under proposed alternatives. Baseline descriptions are based on field reconnaissance conducted in 2002 and 2003.

Sonoran Desertscrub

Sonoran Desertscrub is the characteristic upland community in the region. It is typified by open to dense stands of drought and heat tolerant deciduous trees and shrubs that have small leaves, and often thorns. Vegetation density and diversity is often related to local conditions. Within the study area, this biome forms two distinctive vegetation series, which are distributed as isolated outcrops between roads and developed areas: Paloverde-Mixed Cacti and Saltbush. Dominant woody perennial species include creosote bush (*Larrea tridentata*) on gravely soils and fourwing saltbush (*Atriplex canescens*) on silty soils. Currently the Sonoran Desertscrub community represents approximately 6.6 per cent of the study area, and it has been generally disturbed by human activities. Multiple dirt roads and wildcat dumpsites and the establishment of invasive non-native species such as buffelgrass and red brome degrade this community. The average HSI for this community at baseline is 0.65.

Sonoran Riparian Deciduous Forest and Woodland

This vegetation community is typically encountered along perennial or intermittent drainage ways and springs, where vegetation is able to tap shallow subsurface water. It consists of two associations, cottonwood-willow and mesquite.

Cottonwood-willow: Historically this community was dominant within the study area, but it has been eliminated as a result of human activities over the past century and has not been present for several decades. It is generally considered to be the most important, and among the rarest, of wildlife habitat types in the southwestern U.S. (Brown 1994). Most of the historic cottonwood-willow forest that historically existed in the region was eliminated in the twentieth century as a result of water use projects and declining water tables. Fremont cottonwood and one or more species of willows (e.g. *Salix gooddingii*) are the dominant tree species. Other species commonly occurring in this community are velvet ash (*Fraxinus pennsylvannica* var. *velutina*), netleaf hackberry (*Celtis laevigata* var. *reticulata*), velvet mesquite, and the exotic tamarisk (*Tamarisk chinensis*). Common shrubs include: lotebush (*Zizyphus obtusifolia*), singlewhorl burrobush (*Hymenoclea monogyra*), wolfberry (*Lycium* spp.), desert broom (*Baccharis sarothroides*) and others.

Mesquite: In addition to mesquite, common plant species in the Mesquite Woodland are catclaw acacia (*Acacia constricta*), blue paloverde (*Parkinsonia florida*), pitseed goosefoot (*Chenopodium berlandieri*), lotebush, fourwing saltbush, and various species of forbs, grasses, and vines. In the study area, mesquite trees in some remaining stands are relatively large, reaching heights between 10 and 20 feet. None, however, approach the 60-foot height of those trees that existed pre-settlement. Furthermore, the existing trees are not regenerating. Despite their comparatively small size, however, the remaining mesquite trees in the study area, especially where they occur in dense stands, provide important habitat for wildlife. The baseline average HSI for this community is 0.50.

Sonoran Deciduous Riparian Scrub

This vegetation community is primarily limited to the areas adjacent to washes, but an example is also found within the Santa Cruz River bed. In the study area, the Sonoran Deciduous Riparian Scrub Biome is represented by a Saltcedar Disclimax series, which is present primarily in the areas formerly vegetated by Sonoran Riparian Deciduous Forest and Woodland. This vegetation type has limited structural diversity and is dominated by plant species that are adapted to xeric conditions, in particular non-native invasive species such as Athel tamarisk and saltcedar, which form open to dense stands. Typically, trees in this series are less than 20 feet tall and are regularly subjected to intensive flood events. Other common species occurring within this vegetation type within the study area are Bermudagrass (*Cynodon dactylon*), camphorweed (*Heterotheca subaxillaris*), western tansymustard (*Descurania pinnata*), and Jerusalem thorn (*Parkinsonia aculeata*). The baseline average HSI for this community is 0.40.

Sonoran Interior Strand Mixed Shrub

This vegetation community is found within the Santa Cruz River mainstem and associated wash channels where it is subject to frequent flood events and regular scouring. It includes the existing low-flow channels, because the areas of vegetation change rapidly as a result of flow events. Scattered patches of vegetation, some of which may be quite dense, typically characterize Strand habitats. Vegetation primarily consists of shrubs that are well adapted to occasional flooding. Soils are usually sand and gravel, with small silt deposits and very low organic content. Common species in this community include many that are also associated with scrubland communities, such as saltbush, lotebush, singlewhorl burrobrush, and desert broom. Also found in this vegetative community are annuals, short-lived perennials, and invasive species, such as Adonis blazingstar (*Mentzelia multiflora*), camphorweed, Canadian horseweed (*Conyza canadensis*), common sunflower (*Helianthus annuus*), desert horsepurselane (*Trianthema porulacastrum*), western tansymustard, and buffelgrass (*Pennisetum ciliare*). The baseline average HSI for this community is 0.50.

Sonoran Interior Marshland

Emergent vegetation in this community varies from pure stands of saltgrass (*Distichilis spicata*) and bulrush (*Scirpus* spp.) to more commonly dense stands of reed (*Phagmites australis*) and/or southern cattail (*Typha domingensis*). Scrubland vegetation such as saltcedar, quailbush (*Atriplex lentiformes*) and mesquite typically border the marshland. Understory vegetation consists of whorled marshpennywort (*Hydrocotyle verticillata*), spearmint (*Mentha spicata*) and a variety of rushes and grasses. This community is no longer present within the study area, but was historically an important component of the landscape.

Cultivated and Cultured Uplands

This broad category encompasses areas where most native vegetation has been removed as a result of past or ongoing human activity. Non-native landscaping plants are an important, and in many cases the only, component of the vegetation. This category includes residential properties, building sites, landscaped recreation areas, agricultural areas, closed landfills, and other disturbed areas. Based on ecological and aesthetic characteristics, the Cultivated and Cultured Upland community can be subdivided into the following subcategories: Urban Land, Recreational Land, Sonoran Vacant or Fallow Land, and Urban Drainages.

Urban Land (Residential, Commercial, and Industrial): Much of the land in this category is essentially devoid of native vegetation, or, where vegetation does occur, it is usually sparse and scattered. As a general rule, the current condition of vegetation can be classified along the following continuum (from greatest impact to least impact): industrial, commercial, heavy residential, and light residential (Brown 1980). Included in Urban classification are horse properties and small agricultural fields around houses. Common plant species include velvet mesquite, burroweed (*Isocoma tenuisecta*), Jerusalem thorn, prickly Russian thistle (*Salsola tragus*), native and nonnative grasses, and numerous ornamentals and cultivars. Included among the ornamentals is a large stand of fan palms located on the west side of the river, between Irvington Road and Ajo Way, in a large mobile home park. The average baseline HSI for this community is 0.20.

Recreational Land: Recreational lands consist of parks, including the Santa Cruz River Park and two small urban parks. This classification is composed of a wide array of vegetation types, ranging from predominantly nonnative landscaped trees and shrubs to comparatively natural vegetation that is actively maintained. Vegetation structure and density is highly variable. Common plants found on recreational lands include olive (*Olea europaea*), gum (*Eucalyptus* sp.), Goodding's willow, netleaf hackberry, Chinaberrytree (*Melea azederach*), tuna cactus (*Opuntia ficus-indica*), European fan palm (*Chamaerops humilus*), velvet ash (*Fraxinus velutina*), Florida hopbush (*Dodonea viscosa*), velvet mesquite, creosote bush and whitethorn acacia. The average baseline HSI for this community is 0.30.

Sonoran Vacant or Fallow Land: Historically, vacant or fallow lands were part of the upper terrace and/or floodplain of the Santa Cruz River, and many of them were used for agricultural production. During the 1950's and 1960's, however, most of these areas were retired from agricultural production. Today, these areas consist of fallow agricultural fields, closed landfills, inactive gravel pits, and other areas that have been recently disturbed but are not currently being used for other purposes. Most of these lands are owned by either the City of Tucson or Pima County. Most woody perennial vegetation has been removed from these lands. The most commonly established plant species are velvet mesquite, Jerusalem thorn, Athel tamarisk, burroweed, and a variety of native and non-native grasses and forbs. The average baseline HSI for this community is 0.10.

Urban Drainages: Urban drainages are drainage ways or conveyance channels for urban runoff that are maintained as part of the City's floodwater drainage system. Many of these drainages may originally have been natural washes, but have undergone bank stabilization and channel modification. Others are entirely artificial in origin. They are currently impacted by flooding, channel maintenance activities, transient camps, and wildcat dumping. Urban drainages are now vegetated primarily by non-native species and escaped cultivars, although remnant patches of native vegetation remain. In the study area, common plant species include Jerusalem thorn, camphorweed, Bermudagrass, red brome (*Bromus rubens*), mesquite, rough cocklebur, African sumac, and desert broom. The average baseline HSI for this community is 0.20.

4.6 ALTERNATIVES CONSIDERED

Alternatives were developed through a planning process that included input from a team of planners, ecologists, hydrologists, engineers, floodplain managers, and cost accountants. The process included a Hydrogeomorphic (HGM) Analysis and Incremental Cost Analysis (ICA), which are described in separate reports. The alternatives considered herein for comparative purposes and applied only to the No Action Alternative, the Hydric Alternative (HHM) and the Xeric Alternative (XXX), which were selected as the top two "Best Buy" alternatives by the HGM and ICA process and represent the broadest range of restoration efforts.

4.6.1 No Action Alternative

The USACE is required to consider the option of "no action" as one of the alternatives in order to comply with the requirements of NEPA. No Action assumes that no project would be implemented by the federal government or by local interests to restore or manage native vegetation in the study area and achieve the other planning objectives of the Paseo de las Iglesias project.

In the absence of a restoration project within the study area, there would be continued development of urban land along the river corridor. This would further degrade the existing habitat, and prevent future restoration from being practical, feasible, or cost effective. Both public and private interests have prepared numerous development concepts for this area, primarily because of its marketable location along the Interstate 19 (I-19) corridor. If river restoration does not occur, it is anticipated that development will significantly alter the existing vegetation. In order to maximize development acreage in areas adjacent to the river, a conventional, engineered solution for bank protection and erosion control (i.e., soil cement) would likely be implemented. In addition, the use of soil cement would increase the amount of developable land in the study area and result in increased residential and non-residential development adjacent to the river.

Native biotic communities that are regionally declining will be lost in the study area under the No Action alternative. Native plant species diversity will probably decrease, although an increase in invasive non-native and cultivated species will probably occur, so there will likely be an increase in total species diversity. Species that are regionally rare and sensitive to human impacts will decrease or be eliminated. After 50 years or less, the study area will have lost all vestiges of the historically natural dominant vegetation communities, and they will likely never recover in this area. No new stands of cottonwood-willow and no new marshland will develop within the study area. The mesquite community will continue to degrade as a result of insufficient water to support growth to tree stature, lack of a flood regime that fosters establishment and growth of seedlings, and woodcutting of remaining trees. Most of the mesquite community will be replaced by urban development. The Sonoran desertscrub community will continue to deteriorate as a result of human impacts, including development of the overbank areas as well as impacts by off-road vehicles, equestrians, and fires. Soil cement banks will prevent establishment and survival of native riparian plants. The Sonoran interior strand mixed shrub community will deteriorate as a result of increased erosion and disturbance by human activities, and by increased flood velocity and frequency resulting from the increase in impermeable surface on the watershed and soil cementing the banks. In all communities, increased disturbance will favor the establishment of non-native plant species.

4.6.2 Hydric Alternative

This alternative calls for creation of 79 acres of new cottonwood-willow community and 59 acres of Sonoran Interior Marsh, with provision of sufficient water to sustain growth to maturity. Land for the newly created cottonwood-willow and marsh communities will be taken from existing Sonoran interior strand, mixed scrub (128 acres) and urban drainage (10 acres). The cottonwood-willow and marsh communities will not be naturally self-regenerating or self-sustaining, but will depend on irrigation water because there are no practicable alternatives that can restore natural flood processes and a natural groundwater level sufficient to sustain these communities. Because of this dependence on irrigation and maintenance, the cottonwood-willow and marsh communities HSI cannot exceed 0.69. A total of 160 acres of the existing mesquite community will be retained, and an additional 352 acres of mesquite will be planted, bringing the total mesquite community to 512 acres. Land for newly created mesquite will be taken from vacant and fallow land (352 acres). Survival and recruitment of mesquites and other component species of this community will be enhanced by the provision of water beyond the natural background supply and improvement of soil. Trees will be able to grow to large stature because sufficient water will be provided by irrigation and water harvesting to sustain them. Dependence on irrigation and other maintenance limits the potential HSI to 0.69. . Native mixed shrub (128 acres) in the interbank area will be preserved and enhanced by reduction of erosion, water harvesting, interplanting with additional native species characteristic of this community, and exclusion of disturbance by off-road vehicles. The addition of 449 acres of planted mixed shrub will bring the total for this community to 577 acres under this alternative. Land for the newly created mixed shrub community will come from Sonoran desertscrub (65 acres), vacant and fallow land (373 acres), and urban drainage (11 acres). This community is expected to have an HSI of 0.99 because it will be naturally sustained.

Under this alternative all of the native plant communities will be retained and enhanced or recreated in a pattern that differs somewhat from the historic pattern, but is sustainable with maintenance and addition of water.

4.6.3 Xeric Alternative

This alternative involves irrigation only for establishment and emergency (drought) survival of plants. This alternative does not support a new cottonwood-willow community. It includes creation of six acres of marsh at aquitards (water retaining structures at strategic locations). Land for the marsh will come from existing strand mixed shrub community. The marsh will not depend on irrigation, but will capture natural rainfall runoff. However, it will be dependent upon occasional maintenance following floods. The HSI for the marsh, therefore, cannot exceed 0.69. All (160 acres) of the existing mesquite community will be retained, and 92 acres of new mesquite will be planted, bringing the total mesquite community to 252 acres. Land for the newly created mesquite community will come from existing urban drainage (10 acres) and vacant and fallow land (82 acres). Survival and recruitment of mesquites and other component species of this community will be enhanced by the provision of water beyond the natural background supply (only when needed in drought emergencies), for establishment of new plantings, and by water harvesting methods. Trees will be able to grow to larger stature than under current conditions because sufficient water will be provided by irrigation and water harvesting to sustain them. Dependence on irrigation and other maintenance limits the potential HSI to 0.69, but the limited irrigation compared to the Hydric Alternative suggests a HSI of 0.60 would more accurately describe this community under this alternative. . Native mixed shrub (159 acres) in the interbank area will be preserved and enhanced by reduction of erosion, water harvesting, interplanting with additional native species characteristic of this community, and exclusion of disturbance by off-road vehicles. The addition of 708 acres of planted mixed shrub will bring the total for this community to 867 acres under this alternative. The expected HSI for this community is 0.99 because it will be naturally sustained. Land for the newly created mixed shrub community will be taken from existing urban vacant and fallow agricultural land (556 acres), Sonoran desertscrub (65 acres) and Sonoran deciduous riparian scrub (87 acres).

Under the Xeric Alternative, all of the native plant communities will be retained and enhanced or recreated in a pattern that differs somewhat from the historic pattern, but is sustainable with minimal maintenance and without addition of water except to establish plantings and sustain vegetation during extreme drought conditions.

4.7 RESULTS

Results of the HEP analysis of the baseline and alternative conditions at 50 years after the project is completed are shown in Table 20. The results indicate that both of the action alternatives are clearly better than the No Action Alternative and an improvement over baseline conditions. It is counterintuitive that the Xeric Alternative ranks slightly higher than the Hydric Alternative using this method of analysis. The HUs for the Hydric Alternative are, perhaps, deceptively undervalued because the HSIs are limited to 0.69 for the cottonwood-willow and marsh communities. This value is the best fit to the criteria in Table 19, because these communities will be dependent upon the artificial addition of water and other maintenance. However, it should be recognized that the wildlife values of these communities would be very high, as long as water and maintenance are provided. There is a difference in HSI for mesquite between the two action alternatives. The mesquite community will mature more rapidly under the Hydric Alternative than under the Xeric Alternative, and the trees will be larger and probably of greater value to many species of wildlife. However, the HSI will not exceed 0.69 because the mesquite community will be dependent upon maintenance and irrigation. Also, the high value for the Strand, Mixed Shrub community, 0.99 under both alternatives, favors the Xeric Alternative, which has more of this community than the Hydric Alternative has.

Other approaches to defining HSI may result in different values. It appears that the HGM modeling process may differentiate between the alternatives with greater precision and accuracy than is possible with this HEP approach and HSI criteria.

Table 20: Vegetation Classification, Areas, Habitat Suitability Indices (H.S.I.), and Habitat Units (HU) within Study Area Under Three Alternatives

	Baseline			No Action Alternative			Hydric Alternative			Xeric Alternative		
Vegetation Classification	Acres	H.S.I.	HU	Acres	H.S.I.	HU	Acres	H.S.I.	HU	Acres	H.S.I.	HU
Sonoran Desertscrub	33	0.65	216.5	--	--	--	--	--	--	--	--	--
Mesquite	60	0.50	80.0	--	--	--	512	0.69	353.3	252	0.60	151.2
Riparian Scrub (saltcedar)	7	0.40	34.8	--	--	--	--	--	--	--	--	--
Strand (Mixed Shrub)	61	0.50	130.5	173	0.50	86.5	577	0.99	571.2	867	0.99	858.3
Urban	045	0.20	609.0	4212	0.20	842.4	3424	0.20	684.8	3484	0.20	696.8
Recreational	6	0.30	25.8	86	0.30	25.8	86	0.30	25.8	86	0.30	25.8
Vacant or Fallow lands	34	0.10	93.4	354	0.10	35.4	200	0.10	20.0	200	0.10	20.0
Urban Drainage	9	0.20	19.8	180	0.20	36.0	68	0.20	13.6	110	0.20	22.0
Cottonwood-Willow	-	--	--	--	--	--	79	0.69	54.5	--	--	--
Sonoran Interior Marshland	-	--	--	--	--	--	59	0.69	40.7	6	0.69	4.1
Total	5005		1209.8	5005		1026.1	5005		1763.9	5005		1778.3

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6. GLOSSARY

Alternative

In HEP analyses, this is the "With Project" condition commonly used in restoration studies. An Alternative can be composed of numerous activities, measures and/or options some examples of Alternatives include:

Alternative 1: *Plant food plots, increase wetland acreage by 10 percent, install 10 goose nest boxes, and build a fence around the entire site.*

Alternative 2: *Build a dam, inundate 10 acres of riparian corridor, build 50 miles of supporting levee, and remove all wetlands in the levee zone.*

Alternative 3: *Reduce the grazing activities on the site by 50 percent, replant grasslands (10 acres), install a passive irrigation system, build 10 escape cover stands, use 5 miles of willow facines along the stream bank for stabilization purposes.*

Average Annual Habitat Units (AAHUs)

A quantitative result of annualizing Habitat Unit (HU) gains or losses across all years in the period of analysis.

AAHUs = Cumulative HUs ÷ Number of years in the life of the project, where

Cumulative HUs =

Sum $(T_2 - T_1)[((A_1 H_1 + A_2 H_2) / 3) + ((A_2 H_1 + A_1 H_2) / 6)]$
and where:

T_1 = First Target Year time interval
T_2 = Second Target Year time interval
A_1 = Area of available habitat at beginning of T_1
A_2 = Area of available habitat at end of T_2
H_1 = HSI at beginning of T_1
H_2 = HSI at end of T_2

Average Annual Functional Capacity Units (AAFCUs)

A quantitative result of annualizing Functional Capacity Unit (FCU) gains or losses across all years in the period of analysis.

AAFCUs = Cumulative FCUs ÷ Number of years in the life of the project, where:

Cumulative FCUs =

$$\text{Sum } (T_2 - T_1)[((A_1 F_1 + A_2 F_2) / 3) + ((A_2 F_1 + A_1 F_2) / 6)]$$

and where:

T_1 = First Target Year time interval
T_2 = Second Target Year time interval
A_1 = Area of available wetland assessment area at beginning of T_1
A_2 = Area of available wetland assessment area at end of T_2
F_1 = FCI at beginning of T_1
F_2 = FCI at end of T_2

Baseline Condition

In the habitat assessment and planning analyses, baseline is the point in time before proposed changes, and is synonymous with Target Year (TY = 0).

Compensation

Also referred to as mitigation, in terms of wildlife habitat value loss, functional capacity loss, or environmental impacts, these are the methods or actions by which the inflicting agency or group offsets the unavoidable loss, of or damage to, these resources due to the proposed action.

Cost Effectiveness Analysis (CEA)

An economic analysis completed to determine the least-cost, economically rational, alternatives. Economically rational alternatives are, by definition, both the efficient and effective alternatives. The results of a cost effectiveness analysis are often displayed in tables, bar charts and scatter plots.

Cover Type

A homogenous zone of similar vegetative species, geographic similarities and physical conditions that make the area unique. In general, cover types are defined on the basis of species recognition and dependence.

Ecosystem — An ecosystem is a biotic community, together with its physical environment, considered as an integrated unit. Implied within this definition is the concept of a structural and functional whole, unified through life processes. Ecosystems are hierarchical, and can be viewed as nested sets of open systems in which physical, chemical and biological processes form interactive subsystems. Some ecosystems are microscopic, and the largest comprises the biosphere. Ecosystem restoration can be directed at different-sized ecosystems within the nested set, and many encompass multi states, more localized watersheds or a smaller complex of aquatic habitat.

Effective Alternatives — When comparing alternatives, these alternatives produce increased levels of outputs (AAHUs from HEP or AAFCUs from HGM) for the same or lesser costs.

Efficient Alternatives — When comparing alternatives, these alternatives produced similar levels of output (AAHUs from HEP or AAFCUs from HGM) at a lesser expense.

Equivalent Optimal Area (EOA) — The concept of EOA is used in HEP when the composition of the landscape, in relation to providing life requisite habitat, is an important consideration. An EOA is used to weight the value of the Life Requisite SI to compensate for this inter-relationship. For example, for optimal wood duck habitat conditions, at least 20 percent of an area should be composed of cover types providing brood-cover habitat. If an area has less than 10 percent in this habitat, the suitability is adjusted downward.

Existing Condition — Also referred to as the Baseline Condition, the Existing Condition is the point in time before proposed changes, and is designated as Target Year TY = 0 in the analysis.

Field Data — In HEP and HGM, this information is collected on various parameters (i.e., variables) in the field, and from aerial photos, following defined, well-documented methodology. An example is the measurement of percent herbaceous cover, over ten quadrats, within a riparian forest cover type. The values recorded are each considered "field data." Means of variables are applied to derive suitability indices and/or functional capacity indices.

Functional Capacity Index Model (FCI)

In the HGM, an FCI Model is a quantitative estimate of functional capacity for a wetland. The ideal goal of an FCI model is to quantify and produce an index that reflects functional capacity at the site. The results of an FCI analysis can be quantified on the basis of a standard 0-1.0 scale, where 0.00 represents low functional capacity for the wetland, and 1.0 represents high functional capacity for the wetland. An FCI model can be defined in words, or mathematical equations, that clearly describe the rules and assumptions necessary to combine functional capacity indices in a meaningful manner for the wetland.
For example:

$$FCI = (VSI\ V_1 * VSI\ V_2) / 4,$$

where:

$VSI\ V_1$ is the Variable Subindex (VSI) for variable 1;
$VSI\ V_2$ is the VSI for variable 2

Functional Capacity Units (FCUs)

A quantitative environmental assessment value considered the biological currency in HGM. Functional Capacity Units are calculated by multiplying the area of available wetland (quantity) by the quality of the wetland based on functionality. Quality is determined by measuring limiting factors describing wetland function, and is represented by values derived from Functional Capacity Indices (FCIs).

FCU = AREA X FCI.

Changes in FCUs represent potential impacts or improvements of proposed actions.

Future Factor (FF)
A unit of quality change, used to define the anticipated changes in mean field data, by target year, on a variable-per-cover type basis, rather than on a species-by-species basis. FF values are multiplicative factors (1.0, 1.5, 0.5, etc.), directly multiplied against the mean baseline condition, to allow project managers an opportunity to forecast changes over time on the site or project. For example, if the project manager anticipates a 50 percent increase in height of grass in the grassland cover type between TY_0 and TY_1, the baseline FF = 1.0, and the increase is an additional FF = 0.5, thus the overall FF = 1.0 + 0.5 = 1.5. In most instances, FFs less than 1.0 represent decreases in quality at the site, and FFs greater than 1.0 represent increases in quality at the site. Of course, this change is dependent upon the relationship between the species, the function, the cover type or PWAA, and the suitability index/functional capacity index for the model.

Guild
A group of functionally similar species with comparable habitat requirements whose members interact strongly with one another, but weakly with the remainder of the community. Often a species HSI model is selected to represent changes (impacts) to a guild.

Habitat Suitability Index Model (HSI)
In HEP, an HSI Model is a quantitative estimate of habitat conditions for an evaluation species or community. The ideal goal of an HSI model is to quantify and produce an index that reflects carrying capacity at the site. The results of an HSI analysis can be quantified on the basis of a standard 0-1.0 scale, where 0.00 represents low quality habitat for the species/community and 1.0 represents high quality habitat for the species/community. An HSI model can be defined in words, or mathematical equations that clearly describe the rules and assumptions necessary to combine suitability indices in a meaningful manner for the species.
For example:

$$HSI = (SI\ V_1 * SI\ V_2) / 4$$

where:
$SI\ V_1$ is the SI for variable 1;
$SI\ V_2$ is the SI for variable 2

Habitat Units (HUs) A quantitative environmental assessment value, considered the biological currency in HEP. Habitat Units are calculated by multiplying the area of available habitat (quantity) by the quality of the habitat for each species or community. Quality is determined by measuring limiting factors for the species (or community), and is represented by values derived from Habitat Suitability Indices (HSIs).

HU = AREA X HSI.

Changes in HUs represent potential impacts or improvements of proposed actions.

Increment In cost analyses, this term represents the change in cost divided, by the change in outputs between those solutions that survive the cost effectiveness filtration of alternatives. An increment then, is used to answer the question: "Is it worth it to take the next leap in cost?" Increments are displayed in bar charts and tabular reports.

Incremental Cost Analysis (ICA) An economic analysis is completed to reveal and interpret changes in costs for increasing levels of outputs (e.g., AAHUs from HEP or AAFCUs from HGM). The results of an incremental cost analysis are often displayed in bar charts and tables.

Independent Alternatives These alternatives can be implemented alone or in concert with their dependent alternatives.

Ineffective Alternatives When comparing alternatives, these alternatives produce <u>reduced</u> levels of output (AAHUs from HEP or AAFCUs from HGM) for the same or greater costs.

Inefficient Alternatives When comparing alternatives, these alternatives produced <u>similar</u> levels of output (AAHUs from HEP or AAFCUs from HGM) at a greater expense.

Life Requisite Suitability Index (LRSI)
In HEP, an LRSI is a mathematical equation that reflects a species' or community's sensitivity to a change in a limiting life requisite component within the habitat type. In HEP, LRSIs are depicted using scatter plots and bar charts (i.e., life requisite suitability curves). The LRSI value (Y axis) ranges on a scale from 0.0 to 1.0, where an LRSI = 0.0 means the factor is extremely limiting and an LRSI = 1.0 means the factor is in abundance (not limiting) in most instances.

Limiting Factor
A variable whose presence/absence directly restrains the existence of a species or community in a habitat. A deficiency of the limiting factor can reduce the quality of the habitat for the species or community, while an abundance of the limiting factor can indicate an optimum quality of habitat for the same species or community.

Measure
The act of physically sampling variables such as height, distance, percent, etc., and the methodology followed to gather variable information (i.e., see "Method" below). In some economic terms, a "measure" is considered a hierarchy of alternatives that can be subdivided further into scales or increments.

Method
In HEP or HGM applications, this is the mode/protocol followed to collect and gather field data. It is important to document the relevant criteria limiting the collection methodology. For example, the time of data collection, the type of techniques used, and the details of gathering this data should be documented as much as possible. An example of a method would be:

> *Between March and April, run five random 50-m transects through the relevant cover types. Every 10-m along the transect, place a 10-m^2 quadrat on the right side of the transect tape and record the percent herbaceous cover within the quadrat. Average the results per transect.*

Multiple Formula Model (aka Life Requisite Model)	In HEP, there are two types of HSI Models, the Single Formula Model (refer to the definition below) and the Multiple Formula Model. In this case a multiple formula model is, as one would expect, a model that uses more than one formula to assess the suitability of the habitat for a species or a community. If a species/community is limited by the existence of more than one life requisite (food, cover, water, etc.), and the quality of the site is dependent on a minimal level of each life requisite, then the model is considered a Life Requisite Model. In order to calculate the HSI for any Life Requisite Model, one must derive the value of a Life Requisite Suitability Index (see definition below) for each life requisite in the model – a process requiring the user to calculate multiple LRSI formulas. This multi-formula processing has led to the name "Multiple Formula Model" in HEP.
Non-Additive Situations	These situations occur when the combination of alternatives results in non-cumulative outputs or costs. Often this condition arises when environmental, economic and/or management factors contradict summative outcomes. For example, if the implementation of two separate alternatives can save on mobilization and demobilization costs, the project manager can reduce the overall combined cost to reflect this savings. The solution is considered "non-additive." This information is included in the cost analyses.
Non-Combinable Situations	These situations occur when mutually exclusive alternatives exist in the project. Often this condition arises when environmental, economic and/or management factors contradict combinable outcomes. For example, the alternative "construction of a new highway through the Florida Everglades" will conflict with the alternative "preservation and enhancement of the existing wetlands, precluding any development." If the only alternatives are to provide protection to the wetlands, or build the highway, these two alternatives are deemed "non-combinable" on the basis of environmental incompatibility. This information is included in the cost analysis evaluations.
Partial Wetland Assessment Area (PWAA)	A homogenous zone of similar vegetative species, geographic similarities and physical conditions that make the area unique. In general, PWAAs are defined on the basis of species recognition and dependence, soils types and topography.

Plans of Interest These situations occur when an outside qualitative factor directly influences the decision to implement an alternative, regardless of its environmental productivity or cost effectiveness. Several factors (i.e., political importance, aesthetic implications, environmental significance, community support, etc.) can compel decision-makers to evaluate alternatives that would have been eliminated under normal situations because of their ineffectiveness. For example, a "green belt" solution replacing a concrete channel through a business district might not be cost effective, or environmentally productive, but the co-sponsor (i.e., the local business association) can insist this alternative be evaluated as part of the project. This alternative is now considered a "Plan of Interest" alternative in cost analyses.

Project Manager Any biologist, economist, hydrologist, engineer, decision maker, resource project manager, planner, environmental resource specialist, limnologist, etc., who is responsible for managing a study, program, or facility.

Relative Value Index Is a value that is used to adjust AAHUs/AAFCUs to accommodate social, economic, ecological and political considerations? Judging criteria for relative values are defined by the decision-making team. Relative weights are calculated for each criterion, and then each evaluation model is rated against each criterion.

RVI = relative weight * value assigned to each evaluation model.

Relative Area In HEP and HGM, the relative area is a mathematical process used to "weight" the various applicable cover types on the basis of quantity. To derive the relative area of a model's cover type, the following equation can be utilized:

$$\text{Relative Area} = \frac{\text{Cover Type Area}}{\text{Total Area}}$$

where:

Cover Type Area = only those acres assigned to the cover type (or PWAA) of interest
Total Area = the sum of the acres utilized in the model.

Scale (1) In some geographical methodologies, the scale is the defined size of the image in terms of miles per inch, feet per inch, or pixels per acres; (2) scale can also refer to variations of the alternative in some cost analysis software packages.

Single Formula Model In HEP, there are two types of HSI Models, the Single Formula Model and the Multiple Formula Model (refer to the definition above). In this instance, an HSI model (or an FCI model in HGM) is based on the existence of a single life requisite requirement (or single wetland function requirement in HGM), and a single formula is used to depict the relationship between quality and carrying capacity (or functional capacity in HGM) for the site.

Site The location upon which the project manager will take action, evaluate alternatives and focus cost analysis.

Solutions In cost analysis, this is the alternative (see definition above.)

Spreadsheet A type of computer file or page that allows the organization of data (alpha-numeric information) in a tabular format. Spreadsheets are often used to complete accounting/economic exercises.

Suitability Index (SI) In HEP, an SI is a mathematical equation that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type. In HEP, SIs are depicted using scatter plots and bar charts (i.e., suitability curves). The SI value (Y-axis) ranges on a scale from 0.0 to 1.0, where an SI = 0.0 means the factor is extremely limiting, and an SI = 1.0 means the factor is in abundance (not limiting) for the species/community (in most instances).

Target Year (TY)
A unit of time measurement used in HEP, that allows the project manager to anticipate and direct significant changes (in area or quality) within the project (or site). As a rule, the baseline TY is always TY = 0, where the baseline year is defined as a point in time before proposed changes would be implemented. As a second rule, there must always be a TY = 1, and a TY = X_2. TY_1 is the first year land- and water-use conditions are expected to deviate from baseline conditions. TY_{X2} designates the ending target year. A new target year must be assigned for each year the project manager intends to develop or evaluate change within the site or project. The habitat conditions (quality and quantity) described for each TY are the expected conditions at the end of that year. It is important to maintain the same target years in both the environmental and economic analyses.

Trade-offs
Are used to adjust the AAHUs/AAFCUs by considering human values. There are no right or proper answers, only acceptable ones. If trade-offs are used, outputs are no longer directly related to optimum habitat.

Variable
A measurable parameter that can be quantitatively described, with some degree of repeatability, using standard field sampling and mapping techniques. Often, the variable is a limiting factor for a species (or community), used in the development of SI curves and measured in the field (or from aerial photos) by personnel, to fulfill the requirements of field data collection in a HEP or HGM application. Some examples of variables include: height of grass, percent canopy cover, distance to water, number of snags in 0.4 hectare or average annual water temperature.

Variable Subindex (VSI)
In HGM, a VSI is a mathematical equation that reflects a wetland function's sensitivity to a change in a limiting factor (i.e., variable) within the PWAA. In HGM, VSIs are depicted using scatter plots and bar charts (i.e., functional capacity curves). The VSI value (Y-axis) ranges on a scale from 0.0 to 1.0, where a VSI = 0.0 represents a variable that is extremely limiting and a VSI = 1.0 represents a variable in abundance (not limiting) for the wetland.

With Project Condition
Also referred to as the alternative, this is the condition of the site after an alternative is implemented.

Without Project Condition	Sometimes referred to as the Baseline condition, or the Existing condition, this is the expected condition of the site without implementation of an alternative; referred to as the "No Action" condition in planning studies. The habitat conditions at TY 0 always refer to the pre-existing conditions.