Arroyo Colorado Habitat Restoration Plan

Developed by the Habitat Restoration Workgroup of the Arroyo Colorado Watershed Partnership and prepared by Kay Jenkins, Texas Parks and Wildlife Department, as a component of the Arroyo Colorado Watershed Protection Plan.

2006

This is a report of the Coastal Coordination Council pursuant to National Oceanic and Atmospheric Administration Award No. NA04NOS4190058.

This report is funded in part by grants/cooperative agreements from the National Oceanic and Atmospheric Administration and the Environmental Protection Agency. The views expressed herein are those of the authors’ and do not necessarily reflect the views of NOAA and EPA or any of their sub-agencies.
Table of Contents

List of Tables ........................................................................................................................................ v
List of Figures ......................................................................................................................................... vi

Introduction ............................................................................................................................................. 1
   Arroyo Colorado Habitat Restoration Workgroup .............................................................................. 1
   Goals .................................................................................................................................................... 2
   Study Area .......................................................................................................................................... 3

State of the Habitat ................................................................................................................................. 4
   Terrestrial Habitats ............................................................................................................................... 5
   Aquatic Habitats ................................................................................................................................... 16
   Historic and Current Monitoring Efforts or Studies of Fish and Wildlife Resources ......................... 23
      Non-Tidal Segment ............................................................................................................................ 23
      Tidal Segment ................................................................................................................................ 24
   Threats to Habitats Associated with the Arroyo Colorado .................................................................... 26
      Continued Loss of Wetlands and Riparian Areas ............................................................................... 26
      Continued Channel and Streambank Erosion ................................................................................... 27
      Invasive Plant Species ....................................................................................................................... 29
      Continued Dissolved Oxygen Problems in the Arroyo Colorado ....................................................... 30

Existing Habitat Conservation Plans and Efforts .................................................................................... 31

Institutional Framework ............................................................................................................................. 39
   Managing Entities and Policies of the Arroyo Colorado ....................................................................... 39
   Regulatory Programs Pertaining to Fish and Wildlife Resources ......................................................... 40
      Rivers and Harbors Act (1899) ........................................................................................................ 40
      Clean Water Act ............................................................................................................................... 40
      The Endangered Species Act (1973) ................................................................................................. 41
      Fish and Wildlife Coordination Act (1934) ...................................................................................... 41
      401 Water Quality Certification ........................................................................................................ 41
   Non-Regulatory Programs Beneficial to Fish and Wildlife Resources .................................................. 41
      Natural Resource Damage Assessment Program ............................................................................... 41
      Texas Parks and Wildlife Department's Kills and Spills Team (KAST) .............................................. 42

Toolkit of Strategies for Improving Water Quality and Fish and Wildlife

Habitat in the Arroyo Colorado .................................................................................................................. 43
   Habitat Feasibility Study ...................................................................................................................... 43
   Compilation and Summary of Relevant Literature and Data .................................................................. 43
   Development of the Preliminary Habitat Alternatives .......................................................................... 43
   Selection of Ten Strategies for Further Evaluation ............................................................................... 44
      Ponds (Strategy 1) ............................................................................................................................... 45
      Stormwater wetland systems using a series of wetland cells within small drainages and wetland swales (Strategy 2) ........................................................................................................ 45
Stormwater wetland treatment systems using extended detention shallow wetlands, pocket wetlands and pond/wetland systems (Strategy 3) ................................................................. 46
Bank/slope stabilization using bioengineering with vegetation for erosion control (Strategy 4) ........................................................................................................................................... 46
Filtration using vegetated filter strips (Strategy 5) ..................................................................... 46
Channels with wet swales or wetlands (Strategy 6) ..................................................................... 47
Constructed wetlands for tertiary treatment following an individual wastewater treatment plant (Strategy 7) ................................................................................................................... 47
Regional constructed wetlands polishing flows from multiple wastewater treatment plants in close proximity (Strategy 8) .............................................................................................................. 48
Large scale on-channel constructed wetland systems (Strategy 9) .............................................. 48
Large scale off-channel constructed wetland systems (Strategy 10) ........................................... 48
Final Technical Report (Toolkit) .................................................................................................. 50

Recommended Habitat Restoration Implementation Plan for the Arroyo Colorado ................................................................. 52

Conserve Existing Riparian and Wetland Habitats ........................................................................... 53
  Action 1 ......................................................................................................................................... 53
  Action 2 ......................................................................................................................................... 54
Reduce Channel and Streambank Erosion .......................................................................................... 54
  Action 3 ......................................................................................................................................... 54
  Action 4 ......................................................................................................................................... 55
  Action 5 ......................................................................................................................................... 55
  Action 6 ......................................................................................................................................... 55
  Action 7 ......................................................................................................................................... 55
Construct Wetlands to Improve the Water Quality in the Arroyo Colorado ........................................ 55
  Action 8 ......................................................................................................................................... 56
  Action 9 ......................................................................................................................................... 56
  Action 10 .......................................................................................................................................... 56
Factors Affecting the Selection of Recommended Actions .............................................................. 56
  Constructed wetlands for tertiary treatment of waste streams ......................................................... 56
  Ponds, bioengineering, vegetated filter strips and constructed wetlands for treatment of non-point source discharges ........................................................................................................ 58
  Large off-channel constructed wetlands for treatment of point source and non-point source pollutants ................................................................................................................................. 59
Funding Sources .................................................................................................................................. 59
Measuring Success ................................................................................................................................ 59

Acknowledgements .......................................................................................................................... 61

Literature Cited .................................................................................................................................. 62

Appendix A. Members of the Arroyo Colorado Habitat Workgroup .............................................. 69

Appendix B. Maps ................................................................................................................................ 70

  Map 1. The location of the Arroyo Colorado watershed in Hidalgo, Willacy and Cameron counties of South Texas. ................................................................................................................................. 70
Map 2. Land use in the watershed of the Arroyo Colorado in the Lower Rio Grande Valley, Texas......................................................................................................................................... 71
Map 3. The Texas Commission on Environmental Quality classified reaches (Segment 2202 and Segment 2201) and the zone of impairment in the Arroyo Colorado in the Lower Rio Grande Valley, Texas......................................................................................................................................... 72
Map 4. Pollutant loading by sub-basins (delineated for modeling purposes) of the Arroyo Colorado watershed in South Texas, based on data from Hydrologic Simulations Program-Fortran model runs by the Texas Commission on Environmental Quality for an 11-year period from January 1, 1989 through December 31, 1999, compiled by Alan Plummer Associates, Inc. and Crespo Consulting, Inc......................................................................................................................................... 73
Map 5. The ten ecoregions of Texas adapted from Gould (1975) used in conservation planning by Texas Parks and Wildlife Department. ......................................................................................................................................... 74
Map 6. The Tamaulipan Thornscrub Ecoregion recognized by The Nature Conservancy in its conservation efforts......................................................................................................................................... 75
Map 7. The Nature Conservancy’s identified conservation areas within the Gulf Coast Prairies and Marshes Ecoregion of Texas......................................................................................................................................... 76
Map 8. Federal and state properties in conservation as national wildlife refuges, state wildlife management areas and state parks within the Lower Rio Grande Valley region of Texas. ..... 77

Appendix C. Rare plants and animals potentially occurring within the watershed of the Arroyo Colorado in South Texas. ................................................................. 78

Appendix D. Selected marsh plants (freshwater and salt water) indigenous to Hidalgo and/or Cameron counties suitable for wetland creation and restoration projects. ........................................................................................................ 82

Appendix E. Common sources of funding used to support water quality and habitat conservation.......................................................................................................... 87
List of Tables

Table 1. Dominant species of vertebrates and invertebrates collected during a Texas Parks and Wildlife Department study in the tidal segment of the Arroyo Colorado from 2001-2003. ................................................................. 25

Table 2. The predominant invasive plant species known to occur in terrestrial and aquatic habitats associated with the Arroyo Colorado in Hidalgo, Willacy and Cameron Counties, Texas. ................................................................. 29

Table 3. Ten water quality improvement strategies selected by the Arroyo Colorado Habitat Restoration Workgroup for further evaluation by Alan Plummer Associates, Inc. ................................................................. 44
List of Figures

Figure 1. One of several Arroyo Colorado Habitat Workgroup meetings held at the Texas A&M-Kingsville Citrus Center in Weslaco, Texas.................................2
Figure 2. Characteristic vegetation of the Tamaulipan Biotic Province in South Texas and northern Mexico.................................................................6
Figure 3. A mangrove community (foreground), mudflats (center) and a loma (background) typically found in the Gulf Coast Prairies and Marshes Natural Area in South Texas.................................................................10
Figure 4. Riparian vegetation on the banks of the non-tidal segment of the Arroyo Colorado near Harlingen, Texas..............................................................14
Figure 5. Water from the Rio Grande is pumped into Willow Lake in Santa Ana National Wildlife Refuge in South Texas to restore hydrology to the resaca...........................15
Figure 6. Photographs of the pilot channel of the Main Floodway portion of the Arroyo Colorado in Hidalgo County, Texas; associated flood control levees are outside of the photographed areas.................................................................17
Figure 7. Llano Grande Lake located near Weslaco, Texas is an area where water in the Arroyo Colorado is impounded due to flood control structures................18
Figure 8. Oxbows, such as this one, were once part of the Arroyo Colorado but were cutoff when the tidal segment was straightened and deepened for navigation purposes in the 1930s and 1940s........................................................20
Figure 9. The Port of Harlingen turning basin located at the far upstream end of the tidal segment of the Arroyo Colorado in South Texas........................21
Figure 10. Urban development along the bank of a resaca located in Brownsville, Texas........................................................................................................26
Figure 11. Bank erosion in the tidal segment of the Arroyo Colorado exacerbated by overgrazing of the riparian zone and adjacent land........................................27
Figure 12. Bank sloughing occurs along the Arroyo Colorado due to the steep slopes maintained along the pilot channel.....................................................28
Figure 13. Egrets fly away from a drainage canal as the vegetation they were resting in is mechanically removed as part of typical maintenance activities on drainages located within the Arroyo Colorado watershed........................................28
Figure 14. Guineagrass (blooming grass in the foreground) can invade disturbed riparian areas in South Texas.................................................................30
Figure 15. A fish dieoff from low dissolved oxygen conditions resulting from a wastewater treatment plant upset that led to excessive algal growth in a drainage ditch in South Texas.................................................................30
Figure 16. Conceptual design of a regional or large-scale off-channel constructed wetland within the floodway levees for treatment of collective flows containing point source and non-point source discharges (APAI 2006).................................49
Figure 17. Conceptual design of a regional or large-scale off-channel constructed wetland outside the floodway levees for treatment of collective flows containing point source and non-point source discharges (APAI 2006).................................50
Introduction

The Arroyo Colorado Habitat Restoration Plan is the product of the efforts of the Arroyo Colorado Habitat Restoration Workgroup to develop and recommend strategies for habitat restoration that would reduce pollutant loadings to the Arroyo Colorado, improve assimilative capacity of the stream and/or mitigate existing physical conditions that contribute to poor water quality in the stream. Although the tidal segment (2201) of the Arroyo Colorado, located in the Lower Rio Grande Valley of Texas, has been designated for high aquatic use by the Texas Commission on Environmental Quality (TCEQ), it is currently included in the 2002 and draft 2004 Texas List of Impaired Waters prepared pursuant to the Clean Water Act, Section 303(d) because sometimes the dissolved oxygen concentrations are lower than the criterion established to assure optimum conditions for aquatic life in the tidal segment. The TCEQ completed the first phase of a Total Maximum Daily Load (TMDL) analysis (TCEQ 2003) and determined that historical modifications to the Arroyo Colorado and nutrient enrichment from both point source discharges and non-point source runoff were responsible for the low dissolved oxygen concentrations (TCEQ 2003). The TCEQ, under the leadership of Roger Miranda, assisted local efforts to develop a Watershed Protection Plan to address low dissolved oxygen problems in the Arroyo Colorado by funding the formation of a stakeholder group known as the Arroyo Colorado Watershed Partnership. This partnership is an expansion of the original TMDL stakeholder group. The efforts of the Arroyo Colorado Watershed Partnership and its six workgroups are facilitated through the leadership of Laura De La Garza, serving with the Texas Sea Grant College’s Texas Coastal Watershed Program as the Arroyo Colorado Watershed Coordinator.

Arroyo Colorado Habitat Restoration Workgroup

Texas Parks and Wildlife Department (TPWD) began facilitating the Arroyo Colorado Habitat Restoration Workgroup’s efforts to develop a habitat restoration plan in June 2004 through an agreement with TCEQ. Funding to support TPWD’s contributions to the planning process was made possible through non-point source pollution funding provided by an Environmental Protection Agency (EPA) Clean Water Act Section 319 grant administered by TCEQ. Additional funding for a habitat restoration feasibility study to help the Habitat Workgroup’s efforts to develop the restoration plan was provided by a Texas Coastal Coordination Council, Coastal Management Program grant pursuant to National Oceanic and Atmospheric Administration (NOAA) Award No. NA04NOS4190058 administered by the Texas General Land Office. Participating members of the Arroyo Colorado Habitat Workgroup include staff from federal, state, and local governments and resource agencies, members of local nongovernmental organizations and interested citizens. The names of the participating members of the Arroyo Colorado Habitat Workgroup are provided in Appendix A.
Two Habitat Restoration Habitat Workgroup meetings, held on November 30, 2003 and February 16, 2004, were facilitated by TCEQ before TPWD began facilitating the workgroup meetings. Seven more workgroup meetings held on August 13, 2004, December 2, 2004, April 14, 2005, August 4, 2005, October 18, 2005, December 8, 2005, and January 19, 2006 were facilitated by TPWD. Meeting summaries from the Habitat Restoration Workgroup meetings and from the other workgroups’ meetings can be found on the Arroyo Colorado Watershed Partnership website (www.arroyocolorado.org) through a link to the TCEQ website. Electronic versions of this Arroyo Colorado Habitat Restoration Plan and the final technical report submitted by Alan Plummer and Associates, Inc. (APAI) on the habitat restoration and water quality improvement feasibility study conducted in 2005 (APAI 2006) are also available on the Arroyo Colorado Watershed Partnership website.

**Goals**

Workgroup members agreed that the Habitat Restoration Plan should provide the Arroyo Colorado Watershed Partnership stakeholders with information about the habitats associated with the Arroyo Colorado and its watershed, potential strategies for improving habitat in the watershed and water quality in the Arroyo Colorado, and sources of funding for implementing habitat improvement strategies. To assist the Arroyo Colorado Watershed Partnership with incorporating the Habitat Restoration Plan into the Arroyo Colorado Watershed Protection Plan, the Workgroup members decided to include a recommended implementation plan of strategies that have the potential to significantly reduce pollutant loadings into the Arroyo Colorado. The Habitat Workgroup established the goals listed below to guide the development of the Arroyo Colorado Habitat Restoration Plan.

- Describe the state of the terrestrial and aquatic habitats within the boundaries of the Arroyo Colorado watershed.
- Provide a toolkit of potential strategies for habitat improvement and water quality improvement in the Arroyo Colorado.
- Develop a recommended implementation plan of strategies that would improve water quality in the Arroyo Colorado.
- Develop monitoring plans for measuring success of implemented habitat restoration recommendations.

Study Area

The Arroyo Colorado Habitat Restoration Plan includes the Lower Rio Grande Valley area of South Texas that is contained within the boundaries of the Arroyo Colorado watershed (Map 1 in Appendix B). The term “Arroyo Colorado”, used in this document, includes the above tidal segment of the stream flowing from its headwaters west of Mission near Abram-Perezville in Hidalgo County to a point just south of the Port of Harlingen and the tidal segment that starts just south of the Port of Harlingen and ends downstream of where the dredged navigation channel enters the Lower Laguna Madre. West of the town of Mercedes the Arroyo Colorado is often referred to as the Main Floodway. Portions of Hidalgo, Cameron and Willacy Counties are included in the study area. The above tidal segment of the Arroyo Colorado is characterized by a steep walled pilot channel entrenched within a wide floodplain bounded by flood control levees, a lack of vegetation, and an absence of impoundments (TWC 1990) and is approximately 101.5 kilometers (63 miles) long. The tidal segment of the Arroyo Colorado is dredged and maintained as a navigable waterway connecting the Port of Harlingen to the Gulf Intracoastal Waterway and is approximately 42.1 kilometers (26 miles) long.

The drainage area, or watershed (Map 2 in Appendix B), of the Arroyo Colorado is approximately 1,828 square kilometers (706 square miles) bounded on the west and south by the drainage of the Rio Grande, on the north by drainage to the North Floodway and on the east by drainage to the Laguna Madre (TWC 1990). The watershed of the Arroyo Colorado is roughly long and narrow in shape and consists of nearly level land under intense development for agricultural and urban uses. Most of the land within the Arroyo Colorado watershed is in use for agricultural crop production and ranching. Primary agricultural crops include cotton, corn, sorghum, sugar cane, citrus, and a variety of vegetables (TAES 2000) cited by TCEQ (2003). Significant urbanization began in the late 1980s in areas along the Arroyo Colorado and continues today. Conversion of land to urban development is the principle land use change occurring in the Arroyo Colorado watershed (TCEQ 2003).
State of the Habitat


Scientists recognize that the Lower Rio Grande Valley is not an actual valley but a delta that gently slopes away from the Rio Grande (Jahrsdoerfer and Leslie 1988). The delta begins approximately 137 kilometers (85 miles) upstream of the mouth of the Rio Grande, and fans out symmetrically to include approximately 161 kilometers (100 miles) of the Gulf Coast (USFWS 1997). The Rio Grande originates in the Rocky Mountains of southwestern Colorado and its course runs approximately 3,033 kilometers (1,885 miles) through Colorado, New Mexico and Texas before emptying into the Gulf of Mexico near Brownsville, Texas. The Rio Grande delta disrupts the typical pattern of barrier islands and coastal lagoons found in the western Gulf of Mexico and it separates the Laguna Madre of South Texas from the Laguna Madre of northern Mexico (USFWS 1997).

The Arroyo Colorado, as a former distributary of the Rio Grande, runs a course roughly parallel to the lower most portion of the Rio Grande but at a distance of approximately 1 to 32 kilometers (0.6 to 20 miles) north of the river (TWC 1990). The Arroyo Colorado is situated within the delta of the Rio Grande on a land form that was produced by the deposition and accumulation of alluvial sediments carried to the coast by the ancestral Rio Grande system (TWC 1990). The region is characterized by its alluvial soils, absence of topographic relief, subtropical and semi-arid climate, unique natural vegetation and intense agricultural and urban development (TWC 1990). Information on the properties of the soils found within the watershed of the Arroyo Colorado and the surrounding area is available from the soil surveys produced for Hidalgo County (Jacobs 1981), Willacy County (Turner 1982), and Cameron County (Williams et al. 1977).

The combination of climate, geology, vegetation, and wildlife found in the Lower Rio Grande Valley is unlike that in any other region of the United States (Jahrsdoerfer and Leslie 1988). The weather in the Lower Rio Grande Valley is characterized by warm, humid air and moderate southeasterly winds produced by weather systems originating over the Gulf of Mexico. Monthly mean temperatures range from 16°C (60°F) in January to 29°C (84°F) in July and August, based on data collected at the Brownsville International Airport station during a 44 year period (TWC 1990). Normal mean precipitation is 63.7 cm (25.1 inches) per year, based on precipitation reported for the Brownsville International Airport, but more inland locations may receive as much as 30 percent less annual precipitation (TWC 1990). Annual rainfall is poorly distributed throughout the year with maximums occurring in late spring and early fall (TWC 1990).

The mangrove swamps, flats and marshes associated with the tidal portions of the Arroyo Colorado and the Rio Grande provide valuable feeding and nursery habitat for marine fisheries species and feeding habitat for avian species. The dense brush habitat and wetlands found in this region of Texas provide feeding, nesting, and cover habitat for many wildlife species. The
Rio Grande and the Arroyo Colorado and their associated riparian forests serve as corridors connecting the last remaining remnant tracts of undisturbed terrestrial habitats in the Lower Rio Grande Valley. The area supports an abundance of neotropical migratory songbirds, mammals, snakes, lizards and salamanders. It is also home to rare and unique plant and animal species, many of which reach the northernmost limits of their distribution in the Lower Rio Grande Valley (USFWS 1997). Several state and federally listed threatened and endangered species are found in the region including the ocelot (Leopardus pardalis) and the jaguarundi (Herpailurus yaguarondi). A complete list of rare plants and animals that potentially occur within the Arroyo Colorado watershed is provided in Appendix C.

Conservation and management of natural resources requires an understanding of the distribution and condition of those resources. Efforts to understand the natural world have spurred scientific studies and conservation plans directed at a variety of biological and ecological scales from individual species to large landscapes (Comer et al. 2003). Many agencies and organizations involved with conservation of natural resources have moved away from strategies that focus primarily on endangered species to more comprehensive approaches (Grossman et al. 1998). Knowledge of historic descriptions of the natural communities and understanding the results of status and trends analyses regarding the resources of an area help resource managers develop conservation priorities.

The state of the terrestrial and aquatic habitats section of this report provides a summary of the historic and recent accounts of the habitats occurring in the South Texas area. The accounts of the terrestrial habitats range in scale from descriptions of ecological divisions (coarse scale) to associations (fine scale). Only those natural communities or habitats expected to occur within the boundaries of the Arroyo Colorado watershed or the immediately adjacent area are described. Wetlands are included in the section on terrestrial habitats while the aquatic habitat section describes the managed channel of the Arroyo Colorado. Plant nomenclature follows that of Jones et al. (1997).

**Terrestrial Habitats**

The Arroyo Colorado watershed lies within the boundaries of the Tamaulipan Biotic Province described by Blair (1950). A biotic province, as defined by Dice (1943) is a considerable and continuous geographic area that may include more than one major ecosystem. Biotic provinces focus on uplands and they include freshwater communities but not marine communities. The Tamaulipan Biotic Province was originally mapped by Dice (1943) and modified by Blair (1950) to extend the northern boundary to the north and northeast. Blair’s extension of the northern boundary meant that the Tamaulipan Biotic Province incorporated the Arroyo Colorado watershed and other areas of South Texas not originally included by Dice (1943). The province is characterized by a dense growth of shrubs and small trees Dice (1943). Historical descriptions of the physical and biological characteristics of the Tamaulipan Biotic Province are summarized by Judd (2002).

Because of the unique vegetation characteristics of the Lower Rio Grande Valley, Blair (1950) designates the area as a separate biotic district from the rest of the Tamaulipan Biotic Province and called it the Matamoran Biotic District (Jahrsdoerfer and Leslie 1988). Judd (2002) reports that Blair (1950) identifies general vegetative patterns about the thorny brush plant communities found in the Matamoran Biotic District. He observes that the vegetation becomes less dense
from the coast westward and that plant species differ depending on the soil texture. Sandy soils support mesquite (*Prosopis glandulosa*) in open woodlands mixed with various grasses, while clay soils support a variety of thornscrub species in addition to mesquite. Blair (1950) notes that the thornscrub communities were more luxuriant in the Rio Grande delta region than further south in Mexico and that they were most luxuriant in the immediate floodplain of the Rio Grande. Blair (1950) also identifies coastal marshes dominated by Gulf cordgrass (*Spartina spartinae*) as a distinct plant community within the Matamoran Biotic District (Judd 2002).

Important woody species characteristic of the Matamoran Biotic District identified by Blair (1950) and reported by Judd (2002) include retama (*Parkinsonia aculeata*), Texas ebony (*Chloroleucon ebano*), anacahuita (*Cordia boissieri*), and anacua (*Ehretia anacua*). Early studies on the vegetation of Texas that include the Lower Rio Grande Valley area include those by Bray (1906), Tharp (1939), Cottle (1931), Allred and Mitchell (1954), and Gould et al. (1960). Clover (1937) and Johnston (1955, 1963) describe the vegetation of the Lower Rio Grande Valley in detail (Judd 2002). Jahrsdoerfer and Leslie (1988) report that Clover (1937) designates the vegetation of the Lower Rio Grande Valley as Tamaulipan brushland and subdivides it into two broad groupings: mesquital and chaparral. Mesquital was originally an open savannah-like bosque of large trees with a grassland understory. The native grasses were removed due to heavy grazing that occurred in the region after European colonization began in 1749 leaving cacti, brush and stunted mesquite as dominant plants [(Clover 1937, Crosswhite 1980) cited by Jahrsdoerfer and Leslie (1988)]. Crosswhite (1980) describes chaparral as consisting of nearly impenetrable thicket of stiff, xerophytic, usually evergreen, brush (Jahrsdoerfer and Leslie 1988).

![Characteristic vegetation of the Tamaulipan Biotic Province in South Texas and northern Mexico.](image)

Figure 2. Characteristic vegetation of the Tamaulipan Biotic Province in South Texas and northern Mexico.

Two major vegetational areas in the Tamaulipan Biotic Province, the Gulf Prairies and Marshes and South Texas Plains, are recognized by Gould et al. (1960) cited by Judd (2002). Gould (1975) classifies most of the Lower Rio Grande Valley as a small part of the South Texas Plains vegetational area. The Gulf Coast Prairies and Marshes vegetational area is comprised primarily of grassland located on the eastern margin of the province adjacent to the Laguna Madre, while the South Texas Plains vegetational area is thought originally to have supported
savannah grassland in the inland portion of the province (Judd 2002). Contradicting theories that woody vegetation from Mexico encroached on grassland in South Texas, Johnston (1963) cited by Judd (2002) and Jahrsdoerfer and Leslie (1988) reports that thorny brush vegetation occurred in its present range when the first plant collector visited the region in 1828.

The LBJ School of Public Affairs (1978) describes eleven natural regions of Texas and describes South Texas Brush Country (equivalent to South Texas Plains), Gulf Coast Prairies and Marshes and a third natural region called Coastal Sand Plains, not previously recognized by Gould (1960), as the natural regions of South Texas. The South Texas Brush Country is further divided into three zones: Brush Country, Bordas Escarpment, and Subtropical Zone. The Gulf Coast Prairies and Marshes natural region is also subdivided into three zones: Dunes/Barrier, Estuarine Zone, and Upland Prairies and Woods (LBJ School of Public Affairs 1978). Natural regions occurring within the boundaries of the Arroyo Colorado watershed include portions of the Brush Country Zone and Subtropical Zone of the South Texas Brush Country region and the Estuarine Zone of the Gulf Coast Prairies and Marshes region. The Coastal Sand Plains region is located north of and outside of the boundaries of the Arroyo Colorado watershed.

Ecological communities are often classified at the state or regional level to help direct conservation priorities although efforts are ongoing to support the identification of regional and national ecological units (Grossman et al. 1998). Ecological communities represent a fine scale of classification and the communities are usually classified by vegetation type and expressed as associations of dominant plant species. Vegetation is readily measured and is an indicator of the ecological function of natural systems (Grossman et al. 1998). Jahrsdoerfer and Leslie (1988) describe two general types of brush habitats in the Lower Rio Grande Valley, Riparian and Scrub Forests and Upland Thornscrub and Thorn Woodland. The Riparian and Scrub Forests classification consists of several intergrading habitat types that are associated with the Rio Grande and that produce taller vegetation than surrounding areas (Jahrsdoerfer and Leslie 1988). It is also found along resacas, a local term used to describe former oxbows and river channels that are found throughout the Rio Grande delta. Upland Thornscrub and Thorn Woodland Brush habitats are more extensive in the Lower Rio Grande Valley but the densest areas are limited to the western half of Starr County (Jahrsdoerfer and Leslie 1988).

The United States Fish and Wildlife Service (USFWS) recognized 10 biotic communities in the Lower Rio Grande Valley during the development of the Land Protection Plan for the Lower Rio Grande Valley National Wildlife Refuge (USFWS 1983). The recognized communities include Chihuahuan Thorn Forest, Upper Valley Flood Forest, Barretal, Upland Thorn Scrub, Mid-Valley Riparian Woodland, Sabal Palm Forest, Clay Loma/Wind Tidal Flats, Mid-Delta Thorn Forest, Wooded Potholes and Basins, and Coastal Brushland Potholes (USFWS 1983). The descriptions of the ten communities, and an eleventh one, Ramaderos, recognized by Jahrsdoerfer and Leslie (1988) are summarized by the USFWS (1997). The eleven biotic communities were designated and prioritized for land acquisition purposes and therefore contain both similarities and differences from other published ecological descriptions of the area (USFWS 1997).

The Clay Loma/Wind Tidal Flats community is described as a matrix of clay dunes interspersed within saline flats, marshes and shallow bays bordering the Gulf of Mexico (USFWS 1997). Coastal Brushland Potholes describe areas of dense brushy woodland surrounding freshwater
ponds and shifting to low brush and grasslands around brackish ponds and saline estuaries near the Gulf of Mexico (USFWS 1997). Active and stable sand dunes are found in the Coastal Brushland Potholes community. The Sabal Palm Forest, also referred to as Boscaje de la Palma (USFWS 1983), includes remnant stands of riparian forest located along the Rio Grande south and east of Brownsville dominated by Sabal Palm (Sabal mexicana) (USFWS 1997). Mid-Valley Riparian Woodland is essentially tall, dense canopied bottomland hardwood including Rio Grande ash (Fraxinus berlandieriana), sugar hackberry (Celtis laevigata), black willow (Salix nigra), cedar elm (Ulmus crassifolia), Texas ebony and anacua (USFWS 1997).

Mid-Delta Thorn Forest once covered most of the Rio Grande delta and is comprised of mesquite, Texas ebony, coma (Sideroxylon celastrina), anacua, granjeno (Celtis pallida), and colima (Zanthoxylum fagara) (USFWS 1997). The dense thicket of the Mid-Delta Thorn Forest is a favored site for white-winged dove nesting colonies (USFWS 1997). It probably characterizes the habitat within the Arroyo Colorado watershed prior to European settlements. Remnant tracts of this habitat are usually small in size, normally less than 100 acres (USFWS 1983). Woodland Potholes and Basins are characterized by lighter soils and numerous small seasonal freshwater wetlands and playas (USFWS 1997). It also includes the unique large hypersaline lakes of La Sal Vieja, La Sal Blanca and La Sal del Rey that provide habitat for migrating shorebirds (USFWS 1997).

Upland Thorn Scrub is the most widespread habitat type in the Tamaulipan Biotic Province and occurs on higher and dryer sites to the north and west of the Rio Grande delta (USFWS 1997). The Barretal describes a community where a small tree related to citrus, known as barreta (Helietta parvifolia), occurs in the U.S. only on caliche hilltops along the Bordas Escarpment in Starr County (USFWS 1997). The Upper Valley Flood Forest occurs where the Rio Grande flood plain becomes narrower upstream of Mission, Texas with river bank stands of Rio Grande ash, cedar elm, sugar hackberry and black willow often shifting to mesquite, prickly pear and granjeno within a short distance from the river (USFWS 1997). Ramaderos are isolated riparian strips of dense brush that are associated with arroyos and smaller drainages within arid uplands that have higher moisture and deeper soils (USFWS 1997). Most of the remaining ramaderos are located in Starr County and serve as travel lanes and refuges for wildlife. The Chihuahuan Thorn Forest, also known as Falcon Woodlands, includes a narrow riparian zone and a desert shrub community that occurs along the Rio Grande below Falcon Dam (USFWS 1997).

Texas Parks and Wildlife Department mapped and categorized existing vegetation (habitat types) in Texas (McMahan et al. 1984) within the ecological areas recognized by Gould et al. (1960). The vegetation types described by McMahan et al. (1984) are depicted as associations of two or three dominant plants and listed according to a physiognomic designation including brush, parks, woods, forest, swamp, grassland and marsh. Brush refers to communities where woody plants, usually less than nine feet tall, are dominant and growing as closely spaced individuals, clusters or closed canopied stands with greater than 10% canopy cover. Parks are communities where woody plants, nine feet tall or greater, dominate and grow as clusters, or as scattered individuals within continuous grass or forbs (11%-70% woody canopy cover overall). Grassland describes communities where herbs are the dominant species and where the canopy of woody vegetation is 10% or less. Marsh refers to communities where the dominant vegetation is emergent herbaceous plants in inundated or periodically inundated areas and woody vegetation is generally lacking (10% cover or less of woody canopy).
Excluding crops, McMahan et al. (1984) describe twelve vegetation types in the South Texas Plains and Gulf Prairies and Marshes ecological areas. Four noncrop vegetation types have principal occurrences within the boundaries of the Arroyo Colorado watershed. Mesquite-Blackbrush (Acacia rigidula) Brush, Mesquite-Granjeno Parks, and Native or Introduced Grasses occur in both the South Texas Plains and the Gulf Prairies and Marshes ecological areas. The Smooth Cordgrass (Spartina alterniflora)-Marsh Saltgrass (Distichlis spicata)-Sea Ox-Eye (Borrichia frutescens) (saline) Marsh is a marsh-barrier island vegetation subtype occurring in the Gulf Prairies and Marshes ecological area (McMahan 1984) within the boundaries of the Arroyo Colorado watershed.

Diamond et al. (1987) develop a framework for classifying potential plant communities and ranking their rarity and need for protection. Their classification framework is modified from Driscoll et al. (1984) and UNESCO (1973) and has at its top level the plant community class, which is based on the dominant growth form. Recognized classes include forest, woodland, shrubland, dwarf shrubland, herbaceous vegetation, swamps, and marshes. Below class are subclasses that are based on morphological characteristics of dominant species or adaptation to temperature and water (Diamond et al. 1987). Below subclasses are series and associations and both are named for typical dominant or co-dominant species. According to Diamond et al. (1987) vegetation classification at the series level allows for some differences in species composition and dominance relationships among representative stands while associations are plant community types of definite floristic composition within a uniform habitat. Because conservation efforts generally concentrate on late seral stage plant communities, rather than on early or mid-successional communities, Diamond et al. (1987) describe and classify 78 late seral stage plant community types of Texas. Using the natural regions identified by the LBJ School of Public Affairs (1978), Diamond et al. (1987) provide the primary region of occurrence for each of the identified community types. They also rank the classified community types according to conservation needs as endangered (1), threatened (2), apparently secure (3) or secure (4).

A forest is a community formed by trees at least three meters tall and with a canopy of 61% or more, while a woodland community has a tree canopy of 26 to 60% (Diamond et al. 1987). Two forest series, Texas Palmetto (Sabal mexicana) Series and Sugarberry (Celtis laevigata/C. reticulata)-Elm (Ulmus sp.) Series, occur within the Subtropical Zone of the South Texas Brush Country Natural Area (Diamond et al. 1987). The Texas Palmetto community is also recognized by Clover (1937), Davis (1942), Odum (1971), and Benson (1979) although there is some disagreement on the historic extent of this plant community in Texas. Lockett and Read (1990) report an isolated population of Texas palmetto in Jackson County on the central coast of Texas. Clover (1937) provides a list of 81 plant species associated with the Texas Palmetto community and included the Boscaje de la Palma as a coastal climax community of the Lower Rio Grande Valley of Texas (Judd 2002).

A woodland community includes communities referred to as open forests or savannahs under different classification systems (Diamond et al. 1987). Two woodland series, Texas Ebony-Anacua Series and Mesquite-Huisache (Acacia minuata) Series, occur within the Subtropical Zone of the South Texas Brush Country Natural Area (Diamond et al. 1987). Shrubland refers to communities composed of shrubs from half a meter to three meters tall with a canopy cover of 26% or more. Four shrubland series are described for the South Texas Brush Country Natural Area (Diamond et al. 1987). A mainly evergreen shrubland, Cenizo Series, occurs in
the Brush Country Zone of the South Texas Brush Country Natural Area, as do two mainly
deciduous shrubland community types: the Blackbrush Series, and the Fern Acacia (*Acacia berlandieri*) Series. Another Mainly Deciduous Shrubland community type classified for the
Subtropical Zone of the South Texas Brush Country is the Texas Ebony-Snake-eyes
(*Phaulothamnus spinescens*) Series (Diamond et al. 1987).

Herbaceous vegetation communities are dominated by grasses, graminoids, or forbs with less
than 25% canopy cover of woody plants (Diamond et al. 1987). One medium tall grassland
community type, the Cane Bluestem (*Bothriochloa barbinodis*)-Mesquite Series, recognized by
Diamond et al. (1987), occurs in the Brush Country Zone of the South Texas Brush Country
Natural Area. The Gamagrass-Switchgrass Series (*Tripsacum dactyloides-Panicum virgatum*)
and Little Bluestem-Indiangrass Series (*Schizachyrium scoparium-Sorghastrum nutans*) are two
tall grassland series that occur in the Upland Prairies and Woods Zone of the Gulf Coast
Prairies and Marshes Natural Area (Diamond et al. 1987).

Swamps are forested or shrub-dominated wetlands, with standing water at the surface at least
50 percent of the year and hydric soils. One swamp, the Black Mangrove (*Avicennia
germinans*) Series, occurs in the Subtropical Zone of the South Texas Brush Country Natural
Area (Diamond et al. 1987). Marshes are herbaceous-dominated wetlands (Diamond et al.
1987). Four marsh communities occur in the estuarine zone of the Gulf Coast Prairies and
Marshes Natural Area. These communities include Rush (*Juncus* sp.)-Sedge Series, Gulf
Cordgrass (*Spartina spartinae*) Series, Marshhay Cordgrass (*Spartina patens*) Series, Saltgrass
(*Distichlis spicata*) and Smooth Cordgrass (*Spartina alterniflora*) Series. The Rush-Sedge
Series occurs in all of the natural areas of Texas (Diamond et al. 1987). The Smooth Cordgrass
Series is only located in the intertidal zone of the Estuarine Zone of the Gulf Coast Prairies and
Marshes Natural Area (Diamond et al. 1987).

Figure 3. A mangrove community (foreground), mudflats (center) and a loma (background)
typically found in the Gulf Coast Prairies and Marshes Natural Area in South Texas.
Lonard et al. (1991) cited by Judd (2002) describe four major habitats in the Lower Rio Grande Valley based on natural vegetation including River Floodplain, Coastal Prairies and Marshes, Barrier Island, and Brush-Grasslands. River floodplain habitat includes riparian forest along the banks of the Rio Grande and along resaca banks (Judd 2002). Dominant plant species in riparian forests include cedar elm, mesquite, Texas ebony, hackberry, anacua and Texas palmetto. Floodplain habitats still subject to flooding feature huisache, black willow, retama, hackberry, and Mexican ash (Judd 2002). Important woody species on resaca banks include retama, huisache, Texas ebony, black willow and black mimosa (*Mimosa asperata*) (Judd 2002). Brush-Grasslands habitat occurs in upland areas away from the Rio Grande and away from the coast (Judd 2002). Lonard et al. 1991 described the vegetation in this habitat as characterized by low trees, shrubs, cacti and yuccas of variable density with small grassy areas in open sites. Stratification occurs in the plant communities in the Brush-Grasslands habitat (Judd 2002). Overstory species include mesquite, huisache and Texas ebony. Understory species include cenizo, coyotillo (*Karwinskia humboldtiana*), granjeno, guajillo (*Acacia berlandeiri*), guayacan (*Guaiacum angustifolium*), common lantana (*Lantana horrida*), leatherstem (*Jatropha dioica*), lime pricklyash (*Zanthoxylum fagara*), lotebush (*Ziziphus obtusifolia*), narrowleaf forestiera (*Forestiera angustifolia*), border paloverde (*Parkinsonia texana var. macrum*), prickly pear (*Opuntia* spp.), anacahuita and blackbrush (Judd 2002). On soils with good drainage, many cacti are present, while in areas of deep sands, grasses are more abundant (Judd 2002). Grasses occur with mesquite scattered in small clumps (mottes) or as individuals within a savannah (Judd 2002).

The Texas Natural Heritage Program (Diamond 1993) revises and expounds on the Texas vegetation series classified by Diamond et al. (1987) and provides distribution information, important species, associated series, global conservation ranks and state conservation ranks for 90 plant communities of Texas. These vegetation series represent actual plant communities rather than potential plant communities. Series occurring within or adjacent to the boundaries of the Arroyo Colorado watershed include Black Mangrove Series, Blackbrush Series, Cane Bluestem-False Rhodesgrass (*Trichloris pluriflora*) Series, Cenizo Series, Glasswort-Saltwort (*Salicornia bigelovii/S. virginica-Batis maritima*) Series, Guajillo Series, Gulf Cordgrass Series, Marshhay Cordgrass Series, Mesquite-Granjeno Series, Mesquite-Huisache Series, Rush-Sedge Series, Saltgrass-Cordgrass Series, Smooth Cordgrass Series, Texas Ebony-Anacua Series, Texas Ebony-Snake-eyes Series and Texas Palmetto Series.

Lonard and Judd (2002) studied the riparian vegetation of the lower Rio Grande from the mouth of the river, in Cameron County, to near Falcon Dam in Starr County at seven locations. Dominant tree species identified at one or more of the sites include mesquite, sugar hackberry, cedar elm and anacua, while the dominant shrub throughout the riparian corridor is granjeno. The introduced guineagrass (*Panicum maximum*) and buffelgrass (*Pennisetum ciliare*) are the dominant species in the ground cover, displacing native species. These grass species and others from Asia and Africa were introduced in the 1950s by the U.S. Department of Agriculture and other agencies for erosion control and quickly took over the ground layer in areas that had experienced overgrazing.

et al. (1980) report that brackish marshes are common and occur because evaporation exceeds precipitation, prevailing southeasterly winds carry salt spray inland from the Laguna Madre and extremely high storm tides from tropical storms flow inland along drainage courses. Salt marshes occur in areas along the coast of the Laguna Madre. Clover (1937) cited by Judd and Lonard (2004) identifies 44 plant species associated with freshwater habitats but does not list species associated with brackish and salt marshes. White and Schmedes (1986) identify typical species of the three types of marsh habitats but do not provide a list of all species occurring in each kind of marsh. Lonard and Judd (1999) catalogue the vascular plant species found in fresh, brackish and salt marshes in the Rio Grande delta based on a survey of 27 marshes.

The Nature Conservancy in partnership with an international network of cooperating Natural Heritage Programs and Conservation Data Centers developed a classification framework for the vegetation of the United States, called the U.S. National Vegetation Classification (Grossman 1998). However, identifying the nation’s ecological communities at the finest level (based on plant associations) is still ongoing nationally (Grossman et al. 1998). Conservation assessments conducted on a coarse or global scale are often using ecoregions as a spatial planning framework (Comer et al. 2003). Ecoregions are regional landscapes defined by similar geology, landforms, climates and ecological processes (Comer et al. 2003). They contain geographically distinct assemblages of ecological systems that share a large majority of their ecological communities and function effectively as a framework for conservation at global and continental scales (Comer et al. 2003). Comer et al. (2003) report that ecoregions are classified by The Nature Conservancy (Groves et al. 2002) and World Wildlife Fund (Olson et al. 2001) for the Western Hemisphere. The Tamaulipan Thornscrub Ecoregion is used by NatureServe and The Nature Conservancy as a framework for biological diversity conservation efforts in South Texas and northern Mexico. The Tamaulipan Thornscrub Ecoregion represents about 18.8 million hectares (46.4 million acres) stretching from Del Rio to Goliad in Texas, and south to Muzquiz, Monterrey, and Cuidad, Victoria in Mexico and includes the South Texas Plains vegetational area of Gould (1960) and the Arroyo Colorado watershed.

Comer et al. 2003 present a working classification of terrestrial ecosystems in the United States where boundaries of ecosystems are defined in part based on the combination of existing plant communities and abiotic factors. This bio-ecosystem approach to defining ecological systems is receiving more widespread attention for conservation and resource management (Comer et al. 2003). Ecological systems are typically classified at a broader scale than individual plant communities at the association level (Comer et al. 2003). Ecological systems units link established vegetation classification associations using multiple factors that help to explain why they tend to be found together in a given landscape (Comer et al. 2003). Therefore ecological systems are more readily identified, mapped and understood as practical ecological units than most vegetation classification units such as alliances or associations (Comer et al. 2003). The nomenclature for ecological systems includes three primary components that communicate regional distribution, vegetation physiognomy and composition and/or environmental setting (Comer et al. 2003).

A preliminary list and descriptions of ecological systems occurring in the Tamaulipan Thornscrub Ecoregion are available from the Natural Heritage Central Databases (NatureServe 2003b) and in an unpublished internal report of The Nature Conservancy, Inc. (Elliott 2004). Descriptions of ecological communities, classified as vegetation alliances found in the Tamaulipan Thornscrub Ecoregion are also available from NatureServe (2003a). The Nature
Conservancy also identifies the Gulf Coast Prairies and Marshes Ecoregion in its planning efforts and it includes the far eastern portion of the Arroyo Colorado watershed. Descriptions of ecological communities found in the Gulf Coast Prairies and Marshes Ecoregion are available from NatureServe (2001). These communities are classified as vegetation associations.

Detailed descriptions of many of the plants growing in the Lower Rio Grande Valley are available in field guides including those by Everitt et al. (1999), Taylor et al. (1999), and Everitt and Drawe (1993). A key to the plants of the Rio Grande Delta, other than those in the grass family, is provided by Richardson (1995). Information regarding the distribution of the vegetation of the South Texas Plains region and its value to wildlife are also provided by some of the authors. A more general resource on woody vegetation of Texas including information regarding propagation of the plants and their cultural uses is provided by Vines (1960). Information regarding grasses and other herbaceous plants found in South Texas include Hatch and Pluhar (1993) and Lonard (1993). Descriptions of plants that can be found in the Gulf Prairies and Marshes and adjacent areas of Texas include those by Stutzenbaker (1999), Hatch et al. (1999), and Richardson (2002).

Human activities and land use have impacted the vegetation communities of the Tamaulipan Biotic Province. Spanish settlements were first established along the lower Rio Grande by José de Escandón beginning in 1749 (Best 2004). These early settlers brought in grazing animals including cattle, horses, mules and sheep to feed mostly in the pastures north of the Rio Grande and in 1757 the total population of these animals outnumbered the human population in the early settlements almost 50 to 1 (Best 2004). Historical accounts from the 1800s cited by Best (2004) of the habitats in South Texas include descriptions of a riparian forest belt from 5-6 to 30 miles wide on the United States side of the Rio Grande. Jahrsdoerfer and Leslie (1988) report that more than 95% of the original native brushland in the Lower Rio Grande Valley has been cleared and converted for agriculture and urban development. A review of aerial photographs of the Arroyo Colorado watershed area from the 1930s by TPWD staff revealed that most of the area was already cleared and in agricultural production at the time. Approximately 91% of Cameron County’s native woodlands were converted to agricultural development between the 1930s and 1983 (Tremblay et al. 2005).

Historical accounts of early Texas settlements describe the area between the Rio Grande and the Nueces River, north of the Rio Grande delta on the Eolian sand plain where the elevation is about 6 meters (20 feet) higher than the delta area, as open grasslands interspersed with shrubs and low mesquite trees (Best 2004). The conversion of these former savannahs or prairies to brushlands or shrublands is the subject of debate among early ecologists. Archer et al. (1988) cited by Best (2004) agreed with Johnston (1963) that the current woody flora in this region of Texas has likely been present all along, but perhaps restricted to escarpments, ridges, drainages and riparian zones. Livestock is credited with dispersing the seeds of woody plants from the parent plants to the disturbed (grazed) grasslands [(Archer et al. 1988) cited by Best (2004)]. Overgrazing and the control of wildfires resulted in the dominance of shrubs and trees in these former grasslands (Best 2004). The transition of soil types and moisture regimes from the Rio Grande delta to the Eolian sand plain is gradual and Best (2004) describes the natural community that occurred in this transition zone as “subtropical shrub savannah”. The historical upland vegetation in this area ranged from dense shrubland with a grass understory near the delta to open grassland with few shrubs near the sand plain (Best 2004).
Historically, the banks of the Arroyo Colorado above tidal were probably dominated by mesic woodland sub-tropical plant communities, remnants of which can be found today along some portions of the Rio Grande and its former channels. These communities have a relatively high canopy dominated by Texas ebony and anacua, a dense shrub layer dominated by brasil (*Condalia hookeri*), and a sparse ground layer dominated by plant litter. The course of the Arroyo Colorado runs through some of the most urbanized and/or intensively farmed land in the Rio Grande Valley (see Map 2 in Appendix B), yet some of the most diverse vegetation remaining in the Rio Grande Valley occurs along the banks in small, dense stands of native brush. Ecological systems recognized by The Nature Conservancy of Texas found along the Arroyo Colorado are Lower Rio Grande and Tamaulipan Riparian Woodlands and Forests and Tamaulipan Mesquite Woodlands (Elliott 2004).

The Lower Rio Grande and Tamaulipan Riparian Woodlands and Forests community describes woodlands and forests having canopies reaching 15 m (50 feet) in height (Elliott 2004). They are typically dominated by sugar hackberry, cedar elm, Rio Grande ash and/or mesquite (Elliott 2004). The Chihuahuan Thorn Forest, Upper Valley Flood Forest and Mid-Valley Riparian Forest biotic communities recognized by USFWS (1997), the description of the riparian zone at Salineño by Lonard and Judd (2002), and the Sugarberry-Elm Series described by Diamond (1993) would all be represented in the Lower Rio Grande and Tamaulipan Riparian Woodlands and Forests (Elliott 2004).

The Tamaulipan Mesquite Woodlands system is similar to shrub dominated ecological systems in the Tamaulipan Thornscrub Ecoregion, but differs from them due to the presence of a woody canopy with a height of 3 – 6 m (10 – 20 feet) typically dominated by mesquite (Elliott 2004). This ecological system is widespread and common throughout the ecoregion. The Ramaderos, and Mid-Delta Thorn Forest biotic communities of USFWS (1997), and Diamond’s (1993) Mesquite-Granjeno Series are represented in the Tamaulipan Mesquite Woodlands ecological system (Elliott 2004). Of note is the presence of a few small and scattered occurrences of *Ayenia limitaris*, a federally-listed endangered plant, in remnant tracts of brush along the Arroyo Colorado. Several rare plant species, such as *Adelia vaseyi* and *Tillandsia baileyi*, appear to be more common in remnant brush tracts along the Arroyo Colorado than in other areas of the Rio
Arroyo Colorado
Habitat Restoration Plan

Grande delta (Carr 2002). Two endangered communities classified by Diamond et al. (1987) potentially occurring within the boundaries of the Arroyo Colorado watershed are the Texas Palmetto Series and Texas Ebony-Anacua Series. Another community, the Texas Ebony-Snake-eyes Series is ranked threatened (Diamond et al. 1987) and also potentially occurs within the boundaries of the Arroyo Colorado watershed.

Prior to construction of dams on the Rio Grande to create water reservoirs and the construction of floodways and levees to control floodwaters, the Rio Grande overflowed its banks annually depositing new sediment and moving water into a variety of meander channels in the delta (Judd and Lonard 2004). The water supply and flood control projects constructed on the Rio Grande and in its delta beginning in the 1920s have eliminated floodwaters as a source of water to the wetlands in the delta and these wetlands now depend on rainfall alone as a source of water inflow (Jahrsdoerfer and Leslie 1988, Judd and Lonard 2004). Freshwater wetlands are the least commonly occurring wetland in the delta due to low annual rainfall and the absence of river overflow from the Rio Grande (Judd and Lonard 2004).

Figure 5. Water from the Rio Grande is pumped into Willow Lake in Santa Ana National Wildlife Refuge in South Texas to restore hydrology to the resaca.
Aquatic Habitats

Maps from the early 1900s of the Lower Rio Grande Valley region of South Texas indicate the source of the Arroyo Colorado located near the town of Mercedes, Texas. However the presence of small oxbow lakes (resacas) indicates that at one time the Arroyo Colorado was a distributary channel of the Rio Grande and branched from the river below what is now the city of Mission, Texas (Bryan 1971) and flowed northeastward, eventually draining into the Laguna Madre. It is thought to have flowed intermittently before agricultural and urban development brought about modifications to the channel and flow. The upper two-thirds of the Arroyo Colorado are underlain by alluvium consisting mostly of mud deposited by the Rio Grande, while the lower one-third is underlain by barrier island deposits, mostly sand with some silt and clay. Almost all of the deposits underlying the Arroyo Colorado are of Holocene origin except for a short distance in the lower one-third of its course where the Beaumont Formation, of Pleistocene origin abuts the northern and western banks of the Arroyo Colorado (Brown et. al. 1980).

The Arroyo Colorado has been modified to carry flood waters from the Rio Grande and the Lower Rio Grande Valley to the Laguna Madre. Today, the Arroyo Colorado, as recognized by the Texas Commission on Environmental Quality (TCEQ), extends 138 kilometers (86 miles) from southwest of the City of Mission, Texas, northeastward to the Laguna Madre (TCEQ 2003). The TCEQ has classified two reaches of the Arroyo Colorado based on the physical characteristics of the stream (Map 3 in Appendix B). Segment 2202, the Arroyo Colorado above tidai, extends from FM 2062 near Mission in south-central Hidalgo County to a point 100 meters (328 feet) downstream of Cemetery Road, south of the Port of Harlingen, in east-central Cameron County (TCEQ 2003). The far western portion of the Arroyo Colorado above tidal is part of a floodway system that diverges from the Rio Grande at the Anzalduas Dam. This western upstream portion of the Arroyo Colorado, beginning near Mission, is identified on U.S. Geological Survey topographic maps of the area as the Main Floodway until it reaches the Mercedes area.

Flood control projects in the Lower Rio Grande Valley that eventually led to the construction of the Main Floodway began when Cameron and Hidalgo counties began constructing a system of protective levees in 1925 to protect farmlands and urban developments, based on a plan proposed by the U.S. Bureau of Reclamation. The counties were unable to maintain the completed works and the need for international cooperation between the U.S. and Mexican governments became evident. In 1932, the two federal governments adopted a plan for implementing an international project for flood protection. The U.S. Section of the International Boundary Commission, now the International Boundary and Water Commission (IBWC), utilized the existing levees built earlier by the counties, through a memorandum of agreement with the two counties, and extended, raised and strengthened them as part of the Lower Rio Grande Flood Control Project.

Under an international agreement with Mexico, the International Boundary Commission built a river floodway and constructed two diversion dams, Anzalduas and Retamal, to permit diversion of the Rio Grande floodwaters into interior floodways (USFWS 1997). Both countries agreed to divert 2,973 cubic meters/second (105,000 cubic feet/second) of Rio Grande floodwaters through their respective interior floodways (IBWC 1993). The United States diverts its share of
the Rio Grande floodwaters to the interior floodway at the Anzalduas Dam, upstream of Hidalgo, Texas, while Mexico diverts its share of the floodwaters at Retamal Dam, south of Donna, Texas (USFWS 1997). On the United States side of the Rio Grande, the flood control project consists of about 164 kilometers (102 miles) of levees along the Rio Grande and about 270 kilometers (168 miles) of levees flanking the interior floodway system that includes the Main Floodway (considered part of the Arroyo Colorado by TCEQ and in this plan), the Arroyo Colorado and the North Floodway (IBWC 1991).

The International Boundary Commission rectified the pilot channel of the Main Floodway from Rincon Road near Granjeno to FM 1015 near Mercedes during the 1930s and 1940s. Today the pilot channel of the Main Floodway component of the Arroyo Colorado originates west of the City of Mission near FM 2062 where it first receives stormwater runoff and irrigation return flows (TWC 1990). It is also near the headwaters of the Main Floodway that floodwaters from the Rio Grande are diverted at Anzalduas Dam through natural and manmade features, known as the Banker Floodway, to the Main Floodway (TWC 1990). The Main Floodway portion of the Arroyo Colorado is designed and maintained to convey a maximum flow of approximately 2,973 cubic meters/second (105,000 cubic feet/second).

Figure 6. Photographs of the pilot channel of the Main Floodway portion of the Arroyo Colorado in Hidalgo County, Texas; associated flood control levees are outside of the photographed areas.

The Main Floodway flows into Llano Grande Lake, a shallow depression located southwest of the City of Mercedes in southeast Hidalgo County (TCEQ 2003), and divides into the North Floodway and the Arroyo Colorado. The North Floodway was constructed by the International Boundary Commission in 1942 as part of the Lower Rio Grande Flood Control Project and it splits off of Llano Grande Lake at its northern end. The North Floodway drains the vast majority of Willacy County, a significant portion of northern and eastern Hidalgo County, and a small portion of northwestern Cameron County (TCEQ 2003). The North Floodway empties into the Laguna Madre north of the dredged Arroyo Colorado mouth. The North Floodway has a high channel bottom and therefore does not receive any flow from Llano Grande except during flood conditions (Matlock and Demich 1999). The flood control features at this site are used to divert a significant portion of flood waters conveyed by the Main Floodway to the North Floodway during flood events. The Arroyo Colorado downstream of Llano Grande can carry a maximum
flow of 595 cubic meters/second (21,000 cubic feet/second), while the North Floodway can carry 2,378 cubic meters/second (84,000 cubic feet/second). When flow in the Arroyo Colorado exceeds 40 cubic meters/second (1,400 cubic feet/second), the flood waters are divided between the Arroyo Colorado and the North Floodway (Matlock and Demich 1999). The last time flood waters were diverted to the North Floodway was in 1988 during flooding associated with Hurricane Gilbert.

Llano Grande Lake is described by TWC (1990) as a natural resaca, created as part of the ancestral, now abandoned, river course of the Rio Grande. However, Matlock and Demich (1999) report that Llano Grande Lake was created when a siphon structure (El Fuste siphon) associated with the flood control project dammed the flow in the area and created a backwater. The siphon is used to convey irrigation water from the Rio Grande underneath the Arroyo Colorado to the communities and agricultural producers north of the Arroyo Colorado. Regardless of its origin, Llano Grande functions as a large settling basin, collecting much of the upstream sediment load transported in the Main Floodway (TCEQ 2003). There are many outlets for the flow in Llano Grande Lake, including a bypass channel, the Arroyo Colorado, and the North Floodway (Matlock and Demich 1999). During normal flow the Arroyo Colorado diverges from Llano Grande Lake as the most downstream outflow (Matlock and Demich 1999). The bypass channel diverges from the lake approximately 2.7 kilometers (1.7 miles) upstream of the Arroyo Colorado divergence (Matlock and Demich 1999). The bypass channel or pilot channel routes most of the flow from the Main Floodway around the impounded water in Llano Grande to the Arroyo Colorado downstream of the flood control structures (TWC 1990).

Figure 7. Llano Grande Lake located near Weslaco, Texas is an area where water in the Arroyo Colorado is impounded due to flood control structures.
Segment 2202, or the above tidal segment of the Arroyo Colorado, includes the Main Floodway, Llano Grande Lake and the Arroyo Colorado downstream to its intersection with the tidal segment, but not the North Floodway. Downstream of Llano Grande Lake, near Mercedes, Texas, the Arroyo Colorado, above tidal, continues as a modified natural channel until it reaches the tidal segment (TWC 1990). In a study of the nutrient status of the Arroyo Colorado, Matlock and Demich (1999) report that the Arroyo Colorado and bypass channel in the Mercedes area are soft bottom channels with vegetated banks that are typically two meters (6.6 feet) high and in a continual state of sloughing, with masses of vegetation and soil moving down as blocks of material. The channels range from 10 to 20 meters (98.4 to 196.9 feet) wide and at base flow are about one meter (3.3 feet) deep (Matlock and Demich 1999).

Two small hydraulic weirs or drop structures were constructed by the IBWC across the pilot channel of the Arroyo Colorado just downstream of Llano Grande Lake and the El Fuste siphon (TWC 1990). The structures have a dual purpose of normalizing flow across a rapid elevation change and thus reducing erosion at the sites, and trapping a portion of the sediment load carried by the Arroyo Colorado from upstream (TWC 1990). Hydraulically, the structures have the effect of slowing the rate of flow and of increasing flow width and depth (TWC 1990). The water in the pilot channel of the Arroyo Colorado free-falls 3 meters (10 feet) as it flows over the structures (TWC 1990).

Despite the moderate slope of the channel bottom, hydraulic conditions within the Arroyo Colorado under low-flow conditions are considered to be generally favorable to rapid, unrestricted flow due to the configuration of the pilot channel, lack of vegetation, extensive channelization of the route and the absence of major impoundments (TWC 1990). Daily average flows in the Arroyo Colorado have been measured by the IBWC at the El Fuste Siphon near Mercedes since October 1965 and at the bridge crossing of U.S. Highway 83 near Harlingen since October, 1969 (TWC 1990). The critical low-flow is used in modeling projections and is computed as the average flow for a continuous 7-day period with a return period of 2 years (TWC 1990). The critical low-flow for the El Fuste station is 2.1 cubic meters/second (74.9 cubic feet/second) and for the U.S. Highway 83 station it is 4.7 cubic meters/second (167.1 cubic feet/second) for the period of record (TWC 1990).

The reported average, maximum, and minimum flows for the period of record are 5.6 cubic meters/second (199.1 cubic feet/second), 1648.3 cubic meters/second (58,200.0 cubic feet per second), and 0.7 cubic meters/second (25.7 cubic feet/second) for the El Fuste station (TWC 1990). The flows for the period of record for the U.S. Highway 83 station are 8.0 cubic meters/second (284.0 cubic feet/second) average, 118.9 cubic meters/second (4,198.4 cubic feet/second) maximum, and 2.0 cubic meters/second (69.2 cubic feet/second) minimum (TWC 1990). Flow velocities observed in the Arroyo Colorado range from 0.21 meters/second (0.68 feet/second) to 0.49 meters/second (1.61 feet/second) (TWC 1990). Measured flow width for the Arroyo Colorado ranges from 4.9 meters (16.1 feet) to 33.7 meters (110.6 feet) wide and calculated flow depth ranges from 0.09 meters (0.30 feet) to 1.9 meters (6.1 feet) (TWC 1990).

Segment 2201, the Arroyo Colorado tidal, starts at a point 100 meters (328 feet) downstream of Cemetery Road, south of the Port of Harlingen, and extends to its confluence with the Laguna Madre in Cameron and Willacy Counties (TCEQ 2003). This segment includes the Port of Harlingen turning basin. In 1933, the International Boundary Commission implemented Federal Project #5 which involved cutting five channels and straightening the Arroyo Colorado from
below Harlingen to its mouth at the Laguna Madre. The channel construction and straightening projects cut off some of the former bends in the original stream channel.

Figure 8. Oxbows, such as this one, were once part of the Arroyo Colorado but were cutoff when the tidal segment was straightened and deepened for navigation purposes in the 1930s and 1940s.

The U.S. Army Corps of Engineers (USACE) was authorized to construct the Laguna Madre section of the Gulf Intracoastal Waterway (GIWW) in 1945 and construction was completed in 1951 (USACE 1975). The GIWW provides shallow-draft navigation between the Rio Grande Valley and interconnecting waterways along the Gulf Coast to Florida. The tidal segment of the Arroyo Colorado (Segment 2201) is referred to as the Gulf Intracoastal Waterway – Tributary Channel to Harlingen, Texas and is 40 kilometers (25 miles) long. It was constructed from 1947 to 1951 and was opened to navigation in 1951. The Arroyo Colorado Navigation District of Cameron and Willacy Counties granted a perpetual easement in 1947 to the USACE to use specific placement areas for the dredged material from the GIWW and the Tributary Channel to the USACE (USACE 1975). Although the USACE did some straightening and bend-easing of the navigation channel, several of the larger oxbows were already bypassed during earlier federal projects implemented by the International Boundary Commission in the 1930s.
As part of the navigation project, from river kilometer 11 (mile 7) to the mouth, the old bed of the Arroyo Colorado was bypassed completely, and a new channel was completed to the Gulf Intracoastal Waterway in the Laguna Madre, approximately 34 kilometers (21 miles) north of Port Isabel, Texas (Bryan 1971). The authorized depth of the Tributary Channel to Harlingen is 3.66 meters (12 feet) below Mean Low Tide (Corps of Engineers Datum). Also authorized are 0.6 meters (2 feet) of advanced maintenance dredging and 0.3 to 0.6 meters (1 to 2 feet) of overdepth dredging, so the channel could be dredged to -4.9 meters (-16 feet) Mean Low Tide. The authorized width of the bottom cut of the channel is 38 meters (125 feet). The bottom cut dimensions of the turning basin at the Port of Harlingen, located at the far upstream end of the tidal segment, are 122 meters (400 feet) by 152 meters (500 feet), with a 61-meter (200-foot) transition where it narrows from 122 meters (400 feet) to 38.1 meters (125 feet). The authorized depth of the Port of Harlingen Turning Basin is 4.3 meters (14 feet) below Mean Low Tide (Corps of Engineers Datum). Also authorized are 1.2 meters (4 feet) of advanced maintenance dredging and 0.3 to 0.6 meters (1 to 2 feet) of overdepth dredging, so the basin could be dredged to -5.5 meters (-18 feet) Mean Low Tide.

Figure 9. The Port of Harlingen turning basin located at the far upstream end of the tidal segment of the Arroyo Colorado in South Texas.

Other than the Rio Grande itself, the Arroyo Colorado is the only other natural watercourse of significance in the entire Rio Grande delta area. The Arroyo Colorado and the North Floodway provide most of the “fresh” water that enters the Lower Laguna Madre (Bryan 1971). Perennial flow in the Arroyo Colorado is sustained mainly by municipal wastewater discharges and irrigation return flows, supplemented by agriculture and urban runoff on a seasonal basis (TCEQ 2003). Tidal fluctuation in the tidal segment of the Arroyo Colorado is approximately 0.21 meters (0.69 feet) (TWC 1990). According to calculations from flow data for an 11-year period from January 1, 1989 through December 31, 1999, from the Hydrologic Simulations Program-Fortran (HSPF) model used by the Texas Commission on Environmental Quality, average flows in the Arroyo Colorado at the downstream end of the above tidal segment (2202), are 230 MGD for all flows and 152 MGD for dry weather flows during the critical period of May through October (APAI 2006).

The Arroyo Colorado provides multiple uses for the region’s human population. It serves as a floodway, a conveyance for wastewater, an inland transportation route and a recreational area, providing boating and fishing opportunities to the Rio Grande Valley residents and visitors (Bryan 1971, TWC 1990 and TCEQ 2003). The tidal segment of the Arroyo Colorado is one of
Arroyo Colorado
Habitat Restoration Plan

very few brackish water areas in the Lower Laguna Madre of Texas and provides a nursery ground for marine species of the region (Bryan 1971). The tidal segment of the Arroyo Colorado was designated with a high aquatic life use by the state of Texas and has associated dissolved oxygen (DO) criteria that must be met in accordance with the Texas Surface Water Quality Standards (TCEQ 2003). The tidal segment of the Arroyo Colorado is currently included in the 2002 Texas Clean Water Act Section 303(d) List and Draft 2004 303(d) List because sometimes the dissolved oxygen concentrations are lower than the criteria established to assure optimum conditions for aquatic life in the upper 11.4 kilometers (7.1 miles) of the tidal segment (TCEQ 2003). This portion of the tidal segment of the Arroyo Colorado is referred to as the zone of impairment (see Map 3 in Appendix B).

The Texas Commission on Environmental Quality completed the first phase of a Total Maximum Daily Load (TMDL) analysis in 2002 and used a Hydrologic Simulations Program-Fortran (HSPF) model to study the pollutant loadings and dissolved oxygen dynamics in the tidal segment of the Arroyo Colorado (TCEQ 2003). One conclusion of the TMDL study was that even reductions of up to 90 percent in the loadings of constituents of concern into the Arroyo Colorado will not achieve the TMDL endpoint target, which is defined as a 90 percent rate of compliance with the DO criteria currently applied (24-hour average DO of 4.0 milligrams/liter and a 24-hour minimum DO of 3.0 milligrams/liter) (TCEQ 2002). A second conclusion of the TMDL analysis is that a significant volume of poorly treated and essentially untreated wastewater enters the Arroyo Colorado between the cities of Mission and Rio Hondo along with nutrients, biochemical oxygen demand (BOD), and sediment from agricultural non-point sources (TCEQ 2002).

Elevated nutrient levels in the tidal portion of the Arroyo Colorado contribute to periodic low DO levels. The wide diurnal fluctuations in DO (from 0 milligrams/liter to super-saturated DO concentrations) observed in the tidal segment of the Arroyo Colorado are characteristic of an algal-dominated water body (APAI 2006). The algae produce oxygen during the day and consume oxygen during the night. The TCEQ divided the Arroyo Colorado watershed into 14 sub-basins (Map 4 in Appendix B) for modeling purposes. Based on the results of the TCEQ modeling effort, on data from an 11-year period from January 1, 1989 through December 31, 1999 (TCEQ 2003), charts showing the loads in pounds/year of nitrate and ammonia, phosphate and total suspended solids by sub-basin were developed for the sub-basins upstream of or adjacent to the zone of impairment (APAI 2006) (see Map 4 in Appendix B).

The average total nitrogen concentration at the downstream end of the non-tidal portion of the Arroyo Colorado (just upstream of the zone of impairment) is 5.4 milligrams/liter for all flow data and 4.9 milligrams/liter for dry weather flows during the critical period of May through October (APAI 2006) based on loadings calculated from the HSPF modeling conducted by the TCEQ for 11 years of data from 1989-1999 (TCEQ 2003). The total nitrogen load is dominated by non-point source loadings from urban and agricultural runoff and from irrigation return flows. Other significant sources of total nitrogen include municipal and industrial point-source discharges, land application of permitted discharges, non-point source wastewater from colonias, and wastewater from septic systems (APAI 2006). Total nitrogen loadings by land use category per acre per year for the Arroyo Colorado watershed are presented by APAI (2006). Sub-Basins contributing large loads of nitrate and ammonia based on the HSPF modeling conducted by the TCEQ are Sub-Basins 3, 7, 8 and 9 (see Map 4 in Appendix B).
Based on the loadings calculated from the HSPF modeling conducted by the TCEQ for 11 years of data from 1989-1999, total phosphorus concentrations are 0.7 milligrams/liter for all flow data and 0.8 milligrams/liter for dry weather flows during May through October (APAI 2006). Average total phosphorus is a concern in all but the lowermost 17 kilometers (11 miles) of the non-tidal segment of the Arroyo Colorado (APAI 2006). Significant loads of total phosphorus are contributed by point-source discharges and non-point sources including urban areas, land application of permitted discharges, non-point source wastewater from colonias and septic systems, and agricultural cropland (APAI 2006). Sub-basins contributing large loads of phosphate include Sub-Basins 2, 8 and 9 (see Map 4 in Appendix B).

Average concentration of biochemical oxygen demand at the downstream end of the non-tidal segment of the Arroyo Colorado, based on the loadings calculated from the HSPF modeling conducted by the TCEQ for 11 years of data from 1989-1999, is 4.0 milligrams/liter (APAI 2006). The average concentration of BOD in dry weather flows from May through October is 2.6 milligrams/liter. According to the HSPF modeling, 23 percent of the BOD entering the Arroyo Colorado comes from municipal wastewater facilities (APAI 2006). Other significant sources of BOD loads are non-point sources including urban runoff, land application of permitted discharges, non-point source wastewater from colonias and septic systems, and runoff and irrigation return flows from agricultural lands. Significant loading of BOD occurs within the Arroyo Colorado due to the excessive growth of algae and the resulting cycling of algal biomass within the channel (APAI 2006).

Sediment loads to the Arroyo Colorado are dominated by non-point source loadings from agricultural and urban land as a result of storm runoff. However, suspended sediment loads occur during dry weather flows due to the significant loading contributed by municipal and industrial point-source discharges (APAI 2006). In-channel erosion of the pilot channel of the Arroyo Colorado is a source of sediment loading. Excessive algal growth, due to high nutrient levels, also contributes to suspended solids in the Arroyo Colorado (APAI 2006). Total loadings of suspended solids by land use category per acre per year for the Arroyo Colorado watershed are presented by APAI (2006). Sub-basins contributing large loads of total suspended solids include Sub-Basins 4, 7, 8 and 9 (see Map 4 in Appendix B).

Habitat alterations, including modification of hydrology, dredging, streambank destabilization, and the loss or degradation of wetlands, contribute to impaired water quality in streams and rivers (EPA 2005). The combined impacts of physical modifications, placement of dredge materials, and loss of riparian habitat are thought to be exacerbating low dissolved oxygen (DO) concentrations in the tidal segment of the Arroyo Colorado (TCEQ 2003). The straightening, widening and deepening of the tidal segment of the Arroyo Colorado to facilitate barge traffic effectively reduces velocity of the stream flow which reduces circulation and lowers re-aeration rates of the water column. Removal of sand bars and woody debris also removes potential areas of turbulence which would facilitate re-aeration of the water column (APAI 2006).

Historic and Current Monitoring Efforts or Studies of Fish and Wildlife Resources

Non-Tidal Segment - There has been limited sampling of fish and benthic macroinvertebrates in the non-tidal segment of the Arroyo Colorado. Samples were collected by the Texas Commission on Environmental Quality and Texas Parks and Wildlife Department in 1987 and 1994. Overall biological characteristics in this reach were fair.
Reporting the results of the 1987 study, Davis (1989) states that the benthic macroinvertebrate “community structure was considered poor, with pollution-tolerant species predominating and sensitive species absent.” Game fish were generally poorly represented in the fish community. Twenty-one species of benthic macroinvertebrates and 25 species of nekton were collected. Oligochaetes and chironomids were numerically dominant in the benthic community. Gizzard shad and Mozambique tilapia were the numerically dominant fish collected. Several estuarine species of fish were collected near the boundary with the Arroyo Colorado tidal segment. One of the primary limiting factors was poor physical habitat, fairly homogeneous fine-grained sediment which does not offer adequate protection or diversity for benthics and lack of significant pools which limits the presence of larger fish. Toxicity, particularly by residual chlorine from wastewater treatment plant discharges, was also slightly limiting macroinvertebrates and fish.

During the 1994 study, macrobenthos and fish communities again exhibited depressed community integrity (Davis et al. 1995). Analysis suggested a slight degree of toxicity affecting the community. Nineteen species of benthic macroinvertebrates were collected with the community numerically dominated by chironomids and amphipods. Twenty-four species of fish were collected with striped mullet numerically dominant.

**Tidal Segment** – More studies dealing with the biology and water quality of the Arroyo Colorado have been conducted in the tidal segment of the stream. Bryan (1971) cites an ecological survey of the Lower Laguna Madre from 1953-1959 reported by Breuer (1962) and a water quality survey of the Arroyo Colorado reported by Herrera and Classen (1966).

Bryan (1971) conducted a study from 1966-1969 to determine what role the Arroyo Colorado plays in providing nursery habitat for important fishes and crustaceans. Bryan (1971) also determined the relative abundance of vertebrate and invertebrate species, recorded hydrographic data, and developed a checklist of the organisms found. The study, found that the lower portion of the Arroyo Colorado provides nursery habitat for marine species of the region. Juvenile menhaden (*Brevoortia* sp.), red drum (*Sciaenops ocellata*) and white shrimp (*Litopenaeus setiferus*) were the most numerous of the economically important species found during the two-year study (Bryan 1971). Juvenile brown shrimp (*Farfantespenaeus azteca*) and blue crab (*Callinectes sapidus*) were also sampled to a lesser degree in the tidal segment of the Arroyo Colorado (Bryan 1971). Adult species sampled in the study included spotted seatrout (*Cynoscion nebulosus*), red drum, black drum (*Pogonias cromis*), sheephead (*Archosargus probatocephalus*) and southern flounder (*Paralichthys lethostigma*) (Bryan 1971). Adults of these species were concentrated in the lower 19 kilometers (12 miles) of the tidal segment (Bryan 1971). An annotated list of organisms collected in the study is provided by Bryan (1971). A major flood event, associated with Hurricane Beulah in September 1967, occurred during the sampling period and Bryan (1971) provides data on biological and hydrographic conditions of the tidal segment of the Arroyo Colorado prior to and following the flood.

Gorham-Test (1998) sampled 10 sites in the tidal segment of the Arroyo Colorado as part of a Regional Environmental Monitoring and Assessment Program (R-EMAP) Study of three small estuarine systems in Texas to address the ecological health of the estuaries by identifying benthic community structure, fish community structure and fish pathologies, measuring toxicity of sediments, and measuring concentrations of various pollutants in the sediments in 1993. The
study determined that the Arroyo Colorado benthic community structure values indicate stressed communities and degraded environmental conditions in comparison to the other two sites sampled (East Bay Bayou in Galveston Bay and the Rio Grande tidal area) (Gorham-Test 1998). The report also states that fish and shrimp mean abundances and species richness values were poorest in the Arroyo Colorado than the other two sites and the low values are attributed to low dissolved oxygen concentrations (Gorham-Test 1998).

The Coastal Fisheries Division of the Texas Parks and Wildlife Department (TPWD) conducted a study of aquatic organism relative abundance and distribution and their relationship to water quality in the Arroyo Colorado from 2001-2003. Twelve otter trawl and six bag seine samples were collected monthly at sites along the Arroyo Colorado using a stratified random sample design. Water temperature, salinity and dissolved oxygen were measured at each sampling station. Otter trawls, 5.7 meters wide with 38 millimeter stretched mesh, were towed in mid-channel in alternating directions. Bag seines, 9.1 meters long with 19 millimeter stretched mesh in wings and 13 millimeter stretched mesh in bag, were pulled parallel to the shoreline in randomly selected directions. Water temperature, salinity and dissolved oxygen were measured using YSI model 85 and model 55 meters. Measurements were taken within 1 meter of the bottom for trawls and at the surface for bag seines. One hundred five species of vertebrates and invertebrates were collected with nine species composing 80 percent of the catch by number (Table 1).

Table 1. Dominant species of vertebrates and invertebrates collected during a Texas Parks and Wildlife Department study in the tidal segment of the Arroyo Colorado from 2001-2003.

<table>
<thead>
<tr>
<th>Vertebrates</th>
<th>Invertebrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf menhaden</td>
<td><em>Brevoortia patronus</em></td>
</tr>
<tr>
<td>Spot</td>
<td><em>Leiostomus xanthurus</em></td>
</tr>
<tr>
<td>Atlantic croaker</td>
<td><em>Micropogonias undulatus</em></td>
</tr>
<tr>
<td>Pinfish</td>
<td><em>Lagodon rhomboides</em></td>
</tr>
<tr>
<td>White mullet</td>
<td><em>Mugil curema</em></td>
</tr>
<tr>
<td>Hardhead catfish</td>
<td><em>Arius felis</em></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>White shrimp</td>
<td><em>Litopenaeus setiferus</em></td>
</tr>
<tr>
<td>Brown shrimp</td>
<td><em>Farfantepenaeus aztecus</em></td>
</tr>
<tr>
<td>Grass shrimp</td>
<td>Genus <em>Palaemonetes</em></td>
</tr>
</tbody>
</table>

A plot of number of organisms and dissolved oxygen by river kilometer during July – September 2001-2003 shows that levels of dissolved oxygen below 2.0 ppm occurred from river kilometer 15 (mile 9.3) upstream through river kilometer 40 (mile 24.9) (Port of Harlingen). The plot also indicates that aquatic organism utilization (all species) is affected by low dissolved oxygen levels. Data for this study reside in the TPWD Coastal Fisheries Database and reports are in progress. Information on this study may be obtained from the Texas Parks & Wildlife Department, Brownsville Field Station, 95 Fish Hatchery Road, Brownsville, TX 78520, 956-350-4490.
Threats to Habitats Associated with the Arroyo Colorado

Continued Loss of Wetlands and Riparian Areas – Wetlands and riparian areas help control the delivery of pollutants to receiving waterbodies by minimizing pollutants available at the source, reducing the flow rate of runoff to allow for deposition of pollutants or infiltration of runoff, or remediating or intercepting pollutants through chemical or biological transformation (EPA 2005). In the Texas Comprehensive Wildlife Conservation Strategy, (TPWD 2005b), TPWD recognized that the most significant conservation challenges to both freshwater and saltwater systems in Texas are reduced water quality and decreased water quantity. Point source and non-point source pollution contribute to nutrient loading and directly threaten native fish and wildlife species that rely on clean water (TPWD 2005b). Wetlands and riparian areas are nature’s filters for removing pollutants from runoff from adjacent uplands to the receiving waterbodies. However, about half of Texas’ historic wetlands acreage has been converted to other uses to meet society’s demand for food, fiber, housing and other development (TPWD 1997).

Freshwater wetlands and resacas in the Lower Rio Grande Valley once thrived with annual flooding from the Rio Grande, but the water supply and flood control projects constructed since the 1920s eliminate floodwaters as a source of water to the wetlands in the delta, and natural resacas are now dependent on rainfall alone as a source of water inflow (Jahrsdoerfer and Leslie 1988). Resacas and other depressional freshwater wetlands (potholes) are habitat for waterfowl, shorebirds, wading birds, and several species of mammals, fish and invertebrates, including the state-listed threatened black-spotted newt and lesser Rio Grande siren (TPWD 1997). The riparian areas bordering remaining natural resacas often contain the same forest and woodland vegetation communities that were once prevalent throughout the Rio Grande delta, especially along the river and its distributaries. Resacas and their associated riparian areas are prime habitat for the federal and state listed endangered ocelot and jaguarundi (TPWD 1997). Resacas and riparian areas often serve as corridors connecting remnant tracts of thornscrub habitat.

In urban areas of the Lower Rio Grande Valley, many resacas have been modified to serve as water supply storage systems, stormwater retention areas and/or amenities within developments. The shorelines are often bulkheaded and the water levels are artificially maintained at high levels year round. In addition, the riparian zones of resacas located in urban areas have been cleared to construct homes and other development and the natural plant communities have been replaced with nonnative landscapes.

Figure 10. Urban development along the bank of a resaca located in Brownsville, Texas.
Continued Channel and Streambank Erosion - High and steep cut-banks occur regularly along the Arroyo Colorado. Erosion is a natural process along riverine systems and accounts for changes in natural river courses, but it also contributes to pollutant loading in those systems. Erosion can be exacerbated by adjacent land uses including the clearing of woody vegetation on or near the banks for development, crop production, roads/trails and livestock grazing. When the riparian area is no longer intact, it cannot intercept and slow runoff from adjacent uplands and gullies start forming, reducing the integrity of the streambank. Channel and streambank erosion along the drainages leading to the pilot channel of the Arroyo Colorado, and along the pilot channel itself, is contributing to low water quality in the Arroyo Colorado from non-point source pollutants and is also contributing to the loss of riparian habitats.

Figure 11. Bank erosion in the tidal segment of the Arroyo Colorado exacerbated by overgrazing of the riparian zone and adjacent land.

Habitat alterations, including modification of hydrology, dredging, streambank destabilization, and the loss or degradation of wetlands, contribute to impaired water quality in streams and rivers (EPA 2005). Degradation of the riparian zone and modifications to the channel lead to erosion as intact chunks of soil and vegetation slough off the banks into the channel. Removal of the vegetation within and along the drainage ditches and the Arroyo Colorado pilot channel through herbicide applications or by mechanical means also leads to erosion problems, as well as contributes non-point source pollutants. Drainage districts and the International Boundary and Water Commission own easements for the drainage ditches and the pilot channel of the Arroyo Colorado and they maintain their respective channels to carry anticipated flood flows. These easements, in most cases, are too narrow to allow modifying the channel configurations so that the stream banks could support adequate vegetation.
Figure 12. Bank sloughing occurs along the Arroyo Colorado due to the steep slopes maintained along the pilot channel.

Figure 13. Egrets fly away from a drainage canal as the vegetation they were resting in is mechanically removed as part of typical maintenance activities on drainages located within the Arroyo Colorado watershed.
Invasive Plant Species – Invasive plant species, both native and introduced, occur in terrestrial and aquatic habitats associated with the Arroyo Colorado and the Lower Rio Grande Valley. Invasive species often have a negative impact on native plant and wildlife populations. Common reed (*Phragmites australis*) and giant reed (*Arundo donax*), which occur along the banks of the Arroyo Colorado, spread so quickly that they form expansive monospecific stands, decreasing plant diversity and excluding species having more value to wildlife over large areas. Individual plants of other species either directly, through allelopathic qualities as in tamarisk (*Tamarix* sp.) and buffelgrass (*Pennisetum ciliare*); or indirectly, through competition for water and/or light, as with Brazilian pepper (*Schinus terebinthifolius*) and tamarisk, exclude other plant species from occurring either near or under them. Other invasive species, though they do not exclude other plants, reduce the vigor and density of desirable native species around them through resource competition, e.g., guineagrass (*Panicum maximum*). Invasive plant species, particularly exotics, generally provide lower quality habitat (including food, cover, and nesting sites) for native wildlife species than do non-aggressive native plant species. Some of the most common invasive plant species found in the Lower Rio Grande Valley area are provided in Table 2.

Table 2. The predominant invasive plant species known to occur in terrestrial and aquatic habitats associated with the Arroyo Colorado in Hidalgo, Willacy and Cameron Counties, Texas.

<table>
<thead>
<tr>
<th>Plant Species</th>
<th>Native (N) or Introduced (I) to Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upland Grasses</strong></td>
<td></td>
</tr>
<tr>
<td>bermudagrass (<em>Cynodon dactylon</em>)</td>
<td>I</td>
</tr>
<tr>
<td>buffelgrass (<em>Pennisetum ciliare</em>)</td>
<td>I</td>
</tr>
<tr>
<td>guineagrass (<em>Panicum maximum</em>)</td>
<td>I</td>
</tr>
<tr>
<td>King Ranch bluestem (<em>Bothriochloa ischaemum</em>)</td>
<td>I</td>
</tr>
<tr>
<td><strong>Upland Trees/Shrubs</strong></td>
<td></td>
</tr>
<tr>
<td>black mimosa (<em>Mimosa pigra</em>)</td>
<td>N</td>
</tr>
<tr>
<td>black willow (<em>Salix nigra</em>)</td>
<td>N</td>
</tr>
<tr>
<td>Brazilian pepper (<em>Schinus terebinthifolius</em>)</td>
<td>I</td>
</tr>
<tr>
<td>Chinaberry (<em>Melia azedarach</em>)</td>
<td>I</td>
</tr>
<tr>
<td>Chinese tallow (<em>Sapium sebiferum</em>)</td>
<td>I</td>
</tr>
<tr>
<td>jara (<em>Baccharis salicifolia</em>)</td>
<td>N</td>
</tr>
<tr>
<td>retama (<em>Parkinsonia aculeata</em>)</td>
<td>N</td>
</tr>
<tr>
<td>Roosevelt willow (<em>Baccharis neglecta</em>)</td>
<td>N</td>
</tr>
<tr>
<td>salt cedar (<em>Tamarix sp.</em>)</td>
<td>I</td>
</tr>
<tr>
<td>tree morning glory (<em>Ipomoea carnea</em>)</td>
<td>I</td>
</tr>
<tr>
<td>tree tobacco (<em>Nicotiana glauca</em>)</td>
<td>I</td>
</tr>
<tr>
<td><strong>Transitional Grasses</strong></td>
<td></td>
</tr>
<tr>
<td>common reed (<em>Phragmites australis</em>)</td>
<td>N</td>
</tr>
<tr>
<td>giant cane (<em>Arundo donax</em>)</td>
<td>I</td>
</tr>
<tr>
<td><strong>Wetland and Aquatic Plants</strong></td>
<td></td>
</tr>
<tr>
<td>cattail (<em>Typha domingensis</em>)</td>
<td>N</td>
</tr>
<tr>
<td>hydrida (<em>Hydrida verticillata</em>)</td>
<td>I</td>
</tr>
<tr>
<td>water hyacinth (<em>Eichhornia crassipes</em>)</td>
<td>I</td>
</tr>
</tbody>
</table>
Continued Dissolved Oxygen Problems in the Arroyo Colorado – The pollutants associated with the point source and non-point source discharges into the Arroyo Colorado contribute to low dissolved oxygen conditions that lead to fish kills in the Arroyo Colorado. Texas Parks and Wildlife Department investigates fish and wildlife kills in Texas and information regarding those investigations is available from the Texas Parks and Wildlife Department Water Quality Coordinator in the Austin office at 512-912-7095 or from the Regional Kills and Spills biologist in the Corpus Christi office at 361-825-3246 or online at http://www.tpwd.state.tx.us/landwater/water/environconcerns/kills_and_spills/.

There were 42 fish kills documented by Texas Parks and Wildlife Department in the above tidal andtidal segments of the Arroyo Colorado from 1976-2004. The general sources of the mortality events vary and are attributed to agriculture (7), aquaculture (1), industry (12), municipal (5), natural processes (8), unknown (4), and weather (5). However, the direct cause of the fish kills is low dissolved oxygen in the water column in 34 out of the 42 events. Most of the documented fish kills occurred in the tidal segment of the Arroyo Colorado. The larger fish kills that resulted in the death of over 1 million fish per event occurred in the zone of impairment in the upper portion of the tidal segment.

Figure 15. A fish dieoff from low dissolved oxygen conditions resulting from a wastewater treatment plant upset that led to excessive algal growth in a drainage ditch in South Texas.
Existing Habitat Conservation Plans and Efforts

Extensive losses and degradation of terrestrial and aquatic habitats in the Lower Rio Grande Valley have been documented. Threats to the remaining habitats and their functions and values continue as human development expands in the region. Water quality problems occur in rivers and streams throughout the United States. For these reasons there have been several national, state and local efforts initiated to conserve important habitats and to protect and restore water quality. Federal, state and local resource agencies and conservation groups have recognized the significance of the habitats in the Lower Rio Grande Valley, and its freshwater and estuarine resources, to the health and well-being of the wildlife and citizens of the area and have developed conservation plans and implemented habitat conservation projects throughout the region. Habitats already under conservation are excellent reference sites for guiding restoration of degraded or destroyed habitats. Existing habitat conservation activities relevant to the Arroyo Colorado are summarized below.

The Texas Coastal Management Program (CMP) was authorized by state legislation passed in 1989 and amended in 1991 to develop a long-term plan for management of uses affecting coastal resources with other state agencies. The resulting plan, the Texas Coastal Management Plan, was developed by the Texas General Land Office (GLO) and approved by the National Oceanic and Atmospheric Administration (NOAA) in 1996 (GLO 1996). The first goal in the Texas Coastal Management Plan is to protect, preserve, restore, and enhance the diversity, quality, quantity, functions, and values of coastal natural resource areas (CNRAs). Included in the coastal natural resource areas are “waters under tidal influence” defined as “those waters in the state that are contained behind coastal barrier islands and within bays and estuaries and rivers to the inland extent of tidal influence”, coastal wetlands under specific circumstances, and many other coastal habitats that are not specifically relevant to the Arroyo Colorado.

In 2002, the U.S. Secretary of Commerce, was directed by Congress to establish a Coastal and Estuarine Land Conservation Program (CELCP) “for the purpose of protecting important coastal and estuarine areas that have significant conservation, recreation, ecological, historical, or aesthetic values, or that are threatened by conversion from their natural or recreational state to other uses,” giving priority to lands which can be effectively managed and protected and that have significant ecological value. The State of Texas, with the Texas General Land Office serving as the lead agency, is developing a state CELCP plan that will include elements required by NOAA, establish priorities for land acquisitions and describe the process the state will use to solicit, select and nominate projects for CELCP funding. The boundaries of the state CELCP will include the eighteen coastal counties. The lands and values that have been identified for protection in the state CELCP include the coastal natural resource areas identified in the Texas Coastal Management Plan (GLO 1996); and other habitats including three relevant to the Lower Rio Grande Valley. The three include habitats for rare, threatened, or endangered species, Texas Ebony-Anacua forests, and tidal/non-tidal waters on rivers and streams.

Texas Parks and Wildlife Department developed the Land and Water Resources Conservation and Recreation Plan to guide its efforts in conserving the state’s natural and historic heritage and in providing public access to the outdoors (TPWD 2005a). The plan establishes priority habitat types and ecoregions based on the conserved status, threat and biological value. Of the ten ecoregions (Map 5 in Appendix B) identified by Gould (1975) and used in TPWD’s planning
effort, three were identified as high priority (Tier 1) for TPWD efforts and the Arroyo Colorado watershed is within two of those ecoregions: the Gulf Coast Prairies and Marshes and the South Texas Plains. Texas Parks and Wildlife Department’s conservation priorities for the Gulf Coast Prairies and Marshes focus on inland prairies and coastal woodlands that are more prevalent in coastal areas north of the Arroyo Colorado watershed. However, for the South Texas Plains ecoregion, the Land and Water Resources Conservation and Recreation Plan identifies, as a conservation priority, protecting the remaining fragments of brush in the Lower Rio Grande Valley and protecting and restoring corridors between these habitats (TPWD 2005a).

High priority habitats identified in the Land and Water Resources Conservation and Recreation Plan (TPWD 2005a) for conservation include native prairie and grassland habitats that occur throughout Texas north of the Arroyo Colorado watershed, and riparian habitats, recognized for their value as wildlife corridors in areas such as the Lower Rio Grande Valley. The plan recognizes reduced water quality, navigational dredging and disposal, and noxious brush and invasive plant species as a few of the priority threats affecting water resources in Texas. The Lower Laguna Madre Bay System is identified in the plan as a priority bay system for TPWD efforts, and dredging and excess nutrient concentrations from municipal and industrial discharges, agricultural runoff and discharged wastewaters from shrimp farms are listed as the primary threats to this bay system.

The Nature Conservancy of Texas (the Conservancy) has ongoing conservation assessments and planning efforts in Texas regarding regional biodiversity. The Conservancy’s planning efforts identify networks of places referred to as “portfolios” that, taken together, fully represent the characteristic biological diversity of an area (Comer et al. 2003). The Nature Conservancy uses an element-based approach to conservation assessment whereby a suite of species, communities, and ecological systems provide the focus for representing biodiversity (Comer et al. 2003). The Nature Conservancy of Texas has identified seven priority conservation elements in Texas: Tamaulipan Thornscrub System, Coastal Sandplain System, Ocelot, Barrier Islands, Hypersaline Laguna and Seagrasses, Colonial Waterbird Guild, and Shorebird Guild (The Nature Conservancy of Texas 2001).

The Nature Conservancy developed a conservation plan, in partnership with federal and state agencies in Texas, as well as Pronatura Noreste in Mexico, for the Laguna Madre region. The conservation area boundary includes coastal and inland ecosystems from just south of Corpus Christi in Nueces County, Texas to the Rio Soto la Marina near Las Pesca, Mexico. The Laguna Madre Conservation Area falls within the Conservancy’s Gulf Coast Prairies and Marshes and Tamaulipan Thornscrub Ecoregions (The Nature Conservancy 2001). An ecoregional plan is still in development for the Tamaulipan Thornscrub Ecoregion (Map 6 in Appendix B) but the Gulf Coast Prairies and Marshes Ecoregional Plan (The Nature Conservancy 2002) has been completed. Because of its near pristine condition and pending threats, the Laguna Madre Conservation Area was identified in the Gulf Coast Prairies and Marshes Ecoregional Plan as a Phase I action site, the highest priority level for conservation action (The Nature Conservancy 2002), a designation that places the Laguna Madre at the forefront of the Conservancy’s conservation efforts (The Nature Conservancy 2001).

The Laguna Madre Conservation Area of the Conservation Plan for the Texas Portion of the Laguna Madre (The Nature Conservancy of Texas 2001) includes portions of the Arroyo
The Arroyo Colorado is recognized as a critical portion of the Lower Laguna Madre Subdivision of the Gulf Coast Prairies and Marshes Ecoregion since it is the primary source of freshwater to the Lower Laguna Madre. Two of The Nature Conservancy’s conservation elements for Texas are relevant to the Arroyo Colorado and they are the Ocelot and Tamaulipan Thornscrub elements. Several conservation strategies are identified in the Conservation Plan for the Texas Portion of the Laguna Madre (The Nature Conservancy of Texas 2001) that effect either or both of the Ocelot and Tamaulipan Thornscrub elements.

Texas Parks and Wildlife Department developed the Texas Comprehensive Wildlife Strategy (TPWD 2005b) to assist TPWD and its conservation partners with the development of nongame initiatives and goals that will address the needs of animal species and habitats; and to meet eight required elements of the State Wildlife Grant program outlined by the U.S. Fish and Wildlife Service. The South Texas Plains is a Tier 1 – high priority ecoregion identified by TPWD in the Texas Comprehensive Wildlife Conservation Strategy, meaning that TPWD will focus its efforts to conserve, restore or enhance habitats in the South Texas Plains and other Tier 1 ecoregions over the next 10 years through acquisitions, partnerships with other entities, wildlife management plans, resource management plans, education and other programs (TPWD 2005b). Protecting remaining fragments of Tamaulipan thornscrub habitat in the Lower Rio Grande Valley and protecting and restoring corridors between these remnant tracts is the priority conservation action identified in the Texas Comprehensive Wildlife Conservation Strategy for the South Texas Plains. Riparian habitats are one of two high priority habitats identified in the Texas Comprehensive Wildlife Conservation Strategy.

In the Texas Comprehensive Wildlife Conservation Strategy (TPWD 2005b), TPWD recognized that the most significant conservation challenges to both freshwater and saltwater systems in Texas are reduced water quality and decreased water quantity. One strategy for protecting Texas springs and wetlands outlined in the Texas Comprehensive Wildlife Conservation Strategy is the implementation of the Texas Wetlands Conservation Plan (TPWD 1997). The goal of the Texas Wetlands Conservation Plan is to enhance the wetland resources of Texas with respect to function and value through voluntary conservation and restoration of the quality, quantity and diversity of Texas wetlands (TPWD 1997). The plan recognizes the importance of freshwater or brackish wetlands, such as potholes and resacas, as valuable fish and wildlife habitat along with the diversity of salt, brackish, and freshwater wetlands associated with the Gulf Coast Prairies and Marshes Region.

A few of the recommended actions in the Texas Wetlands Conservation Plan (TPWD 1997) pertaining to conservation are:

1. Support riparian and buffer protection, restoration and enhancement projects in urban areas to enhance wildlife habitat, demonstrate the benefits of wetlands, and reduce property losses from flooding.
2. Identify and implement wetland restoration and enhancement needs and opportunities on state-owned property.
3. Incorporate wetlands into collaborative, watershed-based resource management plans.
4. Improve water quality in Texas.
Specific recommended actions for wetland conservation on the Texas coast include encouraging additional protection for the Lower Laguna Madre and restoring degraded wetlands using measures such as restoring hydrology and others as appropriate (TPWD 1997).

So important are wetlands and riparian areas to protecting the water quality of rivers and streams and reducing the impacts of non-point source pollution that the Environmental Protection Agency (EPA) developed national management measures to promote the protection and restoration of wetlands and riparian areas and the use of vegetated treatment systems, and reported them in the National Management Measures to Protect and Restore Wetlands and Riparian Areas for the Abatement of Nonpoint Source Pollution (EPA 2005). The three national measures developed by EPA to protect and restore wetlands and riparian areas for the abatement of non-point source pollution include the following (EPA 2005).

1. Protect wetlands and riparian areas that are serving significant non-point source abatement function from adverse effects and maintain this function while protecting the other existing functions of these wetlands and riparian areas as measured by characteristics such as vegetative composition and cover, hydrology of surface water and ground water, geochemistry of the substrate, and species composition.
2. Promote the restoration of preexisting functions in damaged and destroyed wetlands and riparian systems, especially in areas where the systems will serve a significant non-point source abatement function.
3. Promote the use of engineered vegetated treatment systems such as constructed wetlands or vegetated filter strips where these systems will serve a significant non-point source pollution abatement function.

The U.S. Fish and Wildlife Service (USFWS) developed the Coastal Program to focus the USFWS' efforts in bays, estuaries and watersheds around the United States coastline. The purpose of the Coastal Program is to conserve fish and wildlife and their habitats to support healthy coastal ecosystems. The USFWS Coastal Program is guided by four goals:

1. Serve coastal communities by providing assessment and planning tools to identify priority habitats that should be protected and restored.
2. Conserve pristine coastal habitats through support of locally-initiated conservation efforts.
3. Restore degraded coastal wetland, upland, and stream habitats by working with partners to implement on-the-ground projects.
4. Focus resources through conservation alliances that leverage the financial and technical resources of project partners and multiply the impact of the taxpayers’ dollar.

A national strategic plan to focus the USFWS Coastal Program's conservation efforts is under development. The Texas Coastal Program was established in 1992 and focuses on restoring and protecting economically, recreationally and ecologically important coastal fish and wildlife habitats through partnerships. The Texas Coastal Program cooperates with resource management agencies, other government and non-governmental entities, industries, private landowners, and other citizenry by providing funding and technical support for habitat restoration and protection projects. The Texas Coastal Program work area includes all of the coastal counties of Texas.

The Canadian and U.S. governments signed the *North American Waterfowl Management Plan* (NAWMP) in 1986 to protect and restore North America’s waterfowl populations and their habitats (Esslinger and Wilson 2002). Updates to the plan in 1994 and 1998 include Mexico as a signatory. The purpose of the NAWMP is to achieve waterfowl conservation while maintaining or enhancing associated ecological values in harmony with human needs. The western U.S. Gulf Coast of Mexico (Gulf Coast) is one of six priority waterfowl habitat ranges to begin implementation of the NAWMP with the U.S. Fish and Wildlife Service as the lead agency. The Gulf Coast Joint Venture was formed to bring about a cooperative approach to conservation in the Gulf Coast and is composed of individuals, corporations, small businesses, sport enthusiast groups, conservation organizations, and local, state, and federal agencies. The Gulf Coast Joint Venture pursues actions to achieve and maintain healthy wetland ecosystems that are essential to waterfowl and supports wetland conservation actions that will provide benefits to species of fish and wildlife, in addition to waterfowl. The counties of Willacy, Cameron and Hidalgo are included within the conservation area of the Laguna Madre Initiative of the Gulf Coast Joint Venture.

Ducks Unlimited is a leader in conservation of wetlands and associated habitats that are essential to North America’s waterfowl (Ducks Unlimited 2001). Ducks Unlimited is a nongovernmental organization that works with public and private partners in the United States, Canada and Mexico to find cooperative solutions to problems regarding habitat conservation for North America’s migratory species including 36 species of ducks, 10 species of geese, and two species of swans. By conserving a broad array of wetland and upland habitats required for each phase of the species’ annual cycles, Ducks Unlimited conserves habitat that benefits other wildlife as well. Ducks Unlimited’s Conservation Plan (Ducks Unlimited 2001) is guided by seven principles and recognizes 33 important habitat priority areas. Tamaulipan Brushlands and West Gulf Coastal Plain are two habitat priority areas found in the watershed of the Arroyo Colorado.

A bi-national conservation plan involving the Lower Rio Grande Valley is the *Lower Rio Grande/Rio Bravo Binational Ecosystem Group Management Plan* (USFWS 2002) produced by a working group made up of personnel from the USFWS, TPWD, The Nature Conservancy, La Secretaria de Medio Ambiente y Recursos Naturales, La Secretaria de Desarrollo Urbano y Ecologia of the Tamualipas state government, and Pronatura Noreste (USFWS 2002). This document establishes a vision, objectives, strategies and specific activities for the protection...
and restoration of native plants and animals. This bi-national effort focuses on three elements: water conservation, species and habitat, and education for conservation.

In addition to conservation planning efforts, federal, state, and local governments, as well as nongovernmental organizations, have already placed numerous tracts of land in the Lower Rio Grande Valley into conservation. Tracts owned or managed by U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department are shown in Map 8 in Appendix B. While the overall percent of land in conservation in the South Texas Plains ecoregion is low (0.51%) (TPWD 2005b), protected sites in the Lower Rio Grande Valley contain remnant tracts of Tamaulipan thornscrub and wetland habitats that serve as models for restoration efforts on other lands under conservation. Significant sites conserving valuable habitats in the Lower Rio Grande Valley within the boundaries of the Arroyo Colorado watershed are described below. There are many other sites along the Rio Grande that are also in conservation but are out of the watershed boundaries, just as there are valuable habitats conserved in the region of the South Texas Plains north of the Arroyo Colorado watershed.

The Lower Rio Grande Valley National Wildlife Refuge was established in 1979 and currently contains over 100 tracts of land totaling more than 36,423 hectares (90,000 acres) and is considered a top priority acquisition area by the U.S. Fish and Wildlife Service. The refuge was established to implement a conservation effort to connect the natural existing tracts of brushlands located in the lower four counties of Texas that follow the last 442 river kilometers (275 river miles) of the Rio Grande. The headquarters of the refuge is located at Santa Ana National Wildlife Refuge, south of Alamo in Hidalgo County, Texas. Through continued acquisition efforts from willing sellers, the refuge will eventually encompass 53,622 hectares (132,500 acres). The Land Protection Plan: Lower Rio Grande Valley National Wildlife Refuge (USFWS 1983) and the Lower Rio Grande Valley and Santa Ana National Wildlife Refuges Interim Comprehensive Management Plan (USFWS 1997) recommend cooperative joint preservation efforts with Texas Parks and Wildlife Department and others to purchase easements along the Rio Grande corridor; acquisition of conservation easements to establish a wildlife corridor along the Rio Grande (approximately 96 kilometers wide on the U.S. and Mexican sides); and to complete the purchase of fee management units from willing sellers in the program area to conserve biotic communities in the Lower Rio Grande Valley.

The Laguna Atascosa National Wildlife Refuge contains over 34,920 hectares (86,000 acres) in Cameron and Willacy counties and consists of three main units: Laguna Atascosa Unit that comprises over 18,212 hectares (45,000 acres) that border 7.2 kilometers (4.5 miles) of the tidal segment of the Arroyo Colorado; Bahia Grande Unit that contains 8,057 hectares (19,909 acres); and South Padre Island Unit that includes 8,651 hectares (21,378 acres). Included within the Laguna Atascosa Unit is the Cayo Atascosa, which drains a large portion of Cameron County into the Arroyo Colorado. The refuge headquarters is located east of Harlingen in Cameron County. The first refuge tract was acquired in 1946 and land acquisition continues in accordance with the Laguna Atascosa National Wildlife Refuge Proposed Expansion Plan and Final Environmental Assessment and Conceptual Management Plan (USFWS 1999). The proposed refuge expansion plan includes an area along the shores of the Arroyo Colorado from the current refuge to the Port of Harlingen as described below.

1. Approximately 3,020 hectares (7,464 acres) along both sides of the Arroyo Colorado upstream from the Arroyo Colorado Unit of the TPWD Los Palomas Wildlife
Management Area to the Port of Harlingen. This area includes an approximate 0.8-kilometer (1/2-mile) zone on either side of the Arroyo Colorado. This corridor excludes land within the city limits of Rio Hondo, Texas, and lands where the city may plan to expand in the future.

2. Approximately 4,209 hectares (10,400 acres) on the north side of the Arroyo Colorado downstream from the Arroyo Colorado Unit of the TPWD Los Palomas Wildlife Management Area to the west boundary of Laguna Atascosa NWR and north to the North Floodway. This area excludes land within the boundary of Arroyo City, Texas, and lands where the city may plan to expand in the future.

The U.S. Fish and Wildlife Service leases 23.75 hectares (58.65 acres) of Laguna Atascosa National Wildlife Refuge to Cameron County and it is operated as Adolph Thomae, Jr. County Park. The park is along 2.7 kilometers (1.7 miles) of the south side of the tidal segment of the Arroyo Colorado just east of the Arroyo City boundary. The park provides public access to the Arroyo Colorado through fishing piers, public boat launch, and overnight tent and RV camping.

The Estero Llano Grande State Park/World Birding Center is a 69-hectare (170-acre) tract within the City of Weslaco, Hidalgo County, Texas, that is operated by the Texas Parks and Wildlife Department. It is one of nine sites of the World Birding Center, a partnership project of federal, state, and municipal entities that works to significantly increase the appreciation, understanding, and conservation of birds and other wildlife and their habitat through education, community involvement, and sustainable nature tourism. Estero Llano Grande State Park contains approximately 16 hectares (40 acres) of land between Llano Grande Lake and a floodway levee managed by the International Boundary and Water Commission. Approximately 8 hectares (20 acres) of this area (along the eastern lake frontage) is an exotic-grass dominated mesquite savannah owned by TPWD. The remaining 8 hectares (20 acres), under a 20-year lease begun in 2002, consists of early successional woodland and a remnant mature ebony forest.

The remainder of Estero Llano Grande State Park is north/northwest of the IBWC levee, outside of the floodway. It consists of a 19-hectare (46-acre) former agricultural field containing the park headquarters and 8 hectares (20 acres) of created wetlands built in 2002 through a partnership with Ducks Unlimited. Additionally, the park contains approximately 24 hectares (60 acres) of early successional woodland, a 1.2-hectare (3-acre) permanently flooded lake, a 0.4-hectare (1-acre) temporary wetland (also created by Ducks Unlimited), a 366-meter (1,200-foot) long permanently flooded return-flow drainage ditch, and a 914-meter (3,000-foot) long emergency-drainage canal. The state park is adjacent along its eastern border to the 25-hectare (60-acre) Mercedes Tract of the Lower Rio Grande Valley National Wildlife Refuge, managed by the USFWS. Also under the management of Texas Parks and Wildlife Department, as part of Estero Llano Grande State Park is the 14-hectare (35-acre) MacWhorter Unit, located along Llano Grande Lake, within the floodway, approximately 6 kilometers (4 miles) west of the park. Mature ebony woodland borders the Arroyo Colorado on this tract, with the remainder of the tract ranging from savannah to sparse woodland maintained by IBWC.

Texas Parks and Wildlife Department owns and manages other properties within and near the Arroyo Colorado watershed as wildlife management areas. The Las Palomas Wildlife Management Area was established in the late 1950’s with the purchase of two properties in the
Lower Rio Grande Valley. The primary purpose of the land acquisitions was to preserve habitat for the declining white-winged dove population in Texas. The initial acquisitions were not in the Arroyo Colorado watershed, per se; however, subsequent land purchases include properties along the Arroyo Colorado and within the watershed. These later properties are the Arroyo Colorado (307 hectares/760 acres), Baird (49 hectares/122 acres), Chapote (89 hectares/220 acres), and Taormina (243 hectares/600 acres) units. In addition, TPWD Wildlife Division staff provides technical assistance to landowners who wish to protect, enhance, or create wildlife habitats on their properties.

Local municipalities own properties along the Arroyo Colorado, some of which are managed in partnership with nongovernmental organizations for wildlife habitat. Example properties are the City of Harlingen’s Hugh Ramsey Nature Park and Harlingen Thicket properties. The Arroyo Colorado Audubon Society of South Texas has helped restore wetland, grasslands, and thornscrub habitats at Hugh Ramsey Nature Park. In addition, nongovernmental organizations own properties for conservation. The Nature Conservancy of Texas manages two sites: the Lennox Foundation Southmost Preserve (418 hectares/1,034 acres) and Chihuahua Woods Preserve (141 hectares/349 acres) that are outside of the boundaries of the Arroyo Colorado watershed but contain valuable Tamaulipan thornscrub habitat. The Frontera Audubon is a non-profit organization dedicated to the conservation of the environment of the Lower Rio Grande Valley. The organization manages a 6-hectare (15-acre) nature preserve in Weslaco featuring mature native woodlands, trails, wetlands, Sabal Palm grove and butterfly gardens. Water, from a nearby drainage canal, flows through the wetlands at the Frontera Audubon Nature Preserve before it reaches the Arroyo Colorado.

The Valley Land Fund strives to preserve, enhance and expand the native wildlife habitat of the Rio Grande Valley through education, land ownership and the creation of economic incentives for preservation. One of the priorities of the Lone Star Chapter of the Sierra Club is the establishment of a sufficient level of public funds at the state and federal levels for the next ten years to enhance, manage, and conserve the natural and cultural resources of Texas (through parkland acquisition, wildlife habitat protection, purchase of development rights, conservation easements, and other mechanisms) for the use and enjoyment of present and future generations. The Lower Rio Grande Valley Group of the Lone Star Chapter supports habitat conservation in the Lower Rio Grande Valley as well as water quality improvement in the Rio Grande, the Arroyo Colorado and the Lower Laguna Madre.

Smaller nongovernmental organizations in the Lower Rio Grande Valley are involved in habitat conservation and educational outreach. The Native Plant Project began in 1982 for the purpose of surveying, recording and documenting native plant species of the Lower Rio Grande Valley. The group produces a monthly publication and provides monthly programs to educate the citizens about the qualities and value of native plants. The Native Plant Project has also produced five handbooks on native plants useful for landscaping. Other nongovernmental organizations involved in habitat conservation through education, public awareness, planning and other volunteer efforts include Valley Proud Environmental Council, Valley Sportsmen Club, Lower Laguna Madre Foundation, Coalition to Save the Arroyo Colorado, Texas Master Naturalist Rio Grande Valley Chapter and Valley Nature Center.
Institutional Framework
Contributors: Chris Anzaldua, David Buzan, Rob Hauch, Gary Jones, Kay Jenkins, Butch Palmer, Jamie Schubert, Andy Tirpak

Before developing and implementing habitat restoration strategies in the watershed of the Arroyo Colorado, it is important for project sponsors to be aware of the boundaries, regulations and policies of the managing entities of the Arroyo Colorado. Construction of large projects, especially those that involve federal funds, often require federal, state and local permits and environmental clearances. Finally, there are nonregulatory programs that may be able to assist in the development and implementation of habitat restoration projects by providing funds acquired as restitution for environmental disturbances or impacts to fish and wildlife resources.

Managing Entities and Policies of the Arroyo Colorado

The Arroyo Colorado serves as a floodway; a conveyance for wastewater effluent, irrigation return flows and stormwater runoff; an inland transportation route and a recreational area in the Lower Rio Grande Valley. The United States International Boundary and Water Commission (IBWC) maintains perpetual levee and floodway easements or rights of way along the Arroyo Colorado to manage the stream for flood control and flood conveyance. The Lower Rio Grande Flood Control Project was authorized by an Act of Congress of the United States approved August 19, 1935 (49 Stat. 660) and by Acts 1934, Forty-third Legislature of Texas, Fourth Called Session, Page 71, Chapter 29. In Acts 1937, Forty-fifth Legislature of Texas, Page 402, Chapter 202, the State of Texas granted and conveyed to the United States of America, the perpetual right and easement to enter and reenter in and upon the beds and banks of the Rio Grande in Cameron County and Hidalgo County and the perpetual right and easement to enter and reenter in and upon the beds and banks of the Arroyo Colorado in Cameron County, Willacy County and Hidalgo County to facilitate the acquisition, operation and maintenance of the Lower Rio Grande Flood Control Project.

The legislative act specifically provides the United States with the perpetual right and easement, in regards to the Arroyo Colorado (beginning at FM 1015 near Mercedes and downstream), for handling, flowing, carrying, diverting, confining, and controlling flood and drainage water or waters, together with the right to clear and grub said land, and maintain the same free of trees and brush and the right to construct, operate and maintain suitable channels, drainage ditches and structures, flood control and irrigation structures, or any other type or kind of structure, or excavation of any nature whatsoever, as may from time to time be deemed necessary by the engineers for the proper and efficient maintenance and operation of the Lower Rio Grande Flood Control Project. The State of Texas retains concurrent jurisdiction with the United States of America over the lands included in the granted easement and did not relinquish any rights that the State of Texas or its citizens or owners of property had to the waters of the Rio Grande or the Arroyo Colorado and in the use of or access to those waters.

Structures or projects built on the levees or within the Arroyo Colorado floodway require a license or permit from the IBWC. Obtaining a license from the IBWC requires initial coordination with the Mercedes Field Office and obtaining clearances from federal and state resource agencies. All license applications are reviewed for potential impacts to flood conveyance and
flood control functions of the floodway and levees. Much of the Arroyo Colorado floodway is
under license for agricultural production in the non-tidal segment and the vegetation is not
permitted to grow over 0.9 meters (3 feet) tall. General conditions and construction conditions,
when applicable, are attached to granted licenses. The IBWC levee easements end
downstream of FM 800 near Palm Valley, although the IBWC still manages the stream channel
downstream to the Laguna Madre. Maintenance of the channel banks through Harlingen
involves annual mowing of the banks from the water level to the high water mark indicated with
red painted pipes located on the banks.

The U.S. Army Corps of Engineers and its local sponsor maintain the dredged navigation
channel known as the Gulf Intracoastal Waterway – Tributary Channel to Harlingen, Texas in
the tidal segment of the Arroyo Colorado. The maintenance dredging cycle of the Tributary
Channel varies with location. The channel’s intersection with the Gulf Intracoastal Waterway
has a historical dredging cycle of about 3 years, the turning basin has a historical dredging cycle
of about 2.5 years and the middle reach of the channel has a historical dredging cycle of 5 to 8
years. The Arroyo Colorado Navigation District of Cameron and Willacy Counties, created in
1927, was dissolved in 1983. The Port Of Harlingen Authority is currently the local sponsor of
the Tributary Channel.

In addition to the IBWC and the U.S. Army Corps of Engineers who maintain the Arroyo
Colorado, several drainage and/or irrigation districts manage stormwater runoff and irrigation
return flow within the watershed of the Arroyo Colorado. The districts manage the drainage
easements that convey stormwater runoff and irrigation return flow through ditches, pipes and
channels to the Arroyo Colorado.

Regulatory Programs Pertaining to Fish and Wildlife Resources

Habitat restoration activities within the watershed boundaries of the Arroyo Colorado may be
subject to various federal regulations that are described below.

Rivers and Harbors Act (1899) - Under section 10 of the Act, the building of any wharfs,
piers, jetties, and other structures, as well as excavating or filling within navigable waters,
requires authorization from the United States Army Corps of Engineers.

Clean Water Act - The Federal Water Pollution Control Act Amendments (1972) (as
amended, the Clean Water Act) stipulate broad national objectives to restore and maintain the
chemical, physical, and biological integrity of the Nation’s waters. In addition, the amendments
significantly expand provisions related to pollutant discharges. These include requirements that
limitations be determined for point sources which are consistent with State water quality
standards, procedures for State issuance of water quality standards, development of guidelines
to identify and evaluate the extent of non-point source pollution, water quality inventory
requirements, as well as development of toxic and pretreatment effluent standards.

Section 402 of the 1972 amendments established the National Pollutant Discharge Elimination
System (NPDES) to authorize EPA issuance of discharge permits. Important provisions are
contained in Section 404 of the amendments. This section authorizes the U.S. Army Corps of
Engineers to issue permits for the discharge of dredged or fill material into navigable waters at
specified disposal sites. The Environmental Protection Agency is given oversight authority that includes the ability to prohibit the use of a site as a disposal site based on a determination that discharges would have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas, wildlife, or recreational uses.

The Endangered Species Act (1973) - The Endangered Species Act provides for the conservation of ecosystems upon which threatened and endangered species of fish, wildlife, and plants depend. The U.S. Fish and Wildlife Service is charged with administering the Act for non-marine species. The National Marine Fisheries Service administers the act for marine species. The Act authorizes the determination and listing of species as endangered and threatened; prohibits unauthorized taking, possession, sale, and transport of endangered species; provides authority to acquire land for the conservation of listed species, authorizes establishment of cooperative agreements and grants-in-aid to States that establish and maintain active and adequate programs for endangered and threatened wildlife and plants. Section 7 of the Endangered Species Act requires Federal agencies to insure that any action authorized, funded or carried out by them is not likely to jeopardize the continued existence of listed species or modify their critical habitat.

Fish and Wildlife Coordination Act (1934) - The amendments of the Fish and Wildlife Coordination Act enacted in 1946 require consultation with the U.S. Fish and Wildlife Service and the fish and wildlife agencies of States where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted . . . or otherwise controlled or modified" by any agency under a Federal permit or license. Consultation is to be undertaken for the purpose of "preventing loss of and damage to wildlife resources."

401 Water Quality Certification - Applicants for Federal permits or licenses for activities involving discharges into navigable waters (under Section 404 of the Clean Water Act) are required to provide a State certification that the proposed activity will not violate applicable water quality standards. In Texas, the Texas Commission on Environmental Quality administers the 401 water certification program for most permit actions. The Texas Railroad Commission administers the program for discharges related to oil and gas exploration and development activities.

Non-Regulatory Programs Beneficial to Fish and Wildlife Resources

Natural Resource Damage Assessment Program - The National Contingency Plan (NCP), 40 CFR §300.615 (d)(2), Oil Pollution Act (OPA) §1006(c)(1)-(3) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), provide that the parties responsible for the release, or threatened release, of hazardous substances, pollutants, or contaminants that could endanger human health and/or the environment are liable for any resulting damages. The Natural Resource Damage Assessment Program (NRDA) provides its Trustees and a responsible party the opportunity to reach negotiated agreements pertaining to natural resource damage assessment claims. Under authorization of these Acts, the Trustees assess natural resource damages under their trusteeship and “develop and implement a plan for the restoration, rehabilitation, replacement, or acquisition of the equivalent,” of the injured natural resources.
Typically these cases are resolved in a cooperative fashion that allows the responsible party and the Trustees to negotiate a Settlement Agreement. Through these agreements, the responsible party is required to undertake a habitat restoration project or pay the Trustees an amount that would allow them to undertake a project that will compensate the public for the restoration, replacement, rehabilitation or acquisition of natural resources and natural resource services injured, destroyed or lost as a result of the Incident. Trustees participating in the Natural Resource Damage Assessment Program represent federal agencies including the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration and state agencies including, in Texas, the Texas Commission on Environmental Quality, Texas Parks and Wildlife Department and the Texas General Land Office. Trustees representing other federal and state agencies may also be involved depending on the nature and location of the incident.

**Texas Parks and Wildlife Department's Kills and Spills Team (KAST)** – Response to dieoffs of fish and wildlife as well as to pollution incidents that threaten fish, wildlife, and their habitat is provided by the Texas Parks and Wildlife Department's Kills and Spills Team. The goals of the team are to work with other organizations to identify the cause of the dieoff or pollution incident and to do whatever is necessary and possible to stop the dieoff and pollution. Kills and Spills team members are pollution biologists that work closely with game wardens and scientists from other agencies to achieve those goals. Whenever the dieoff is caused by human actions, KAST members evaluate the numbers of fish and wildlife killed and their economic value. This information may be used to seek monetary civil restitution from the party responsible for causing the dieoff. Funds received from civil restitution cases are frequently used to help create or restore habitat.
Toolkit of Strategies for Improving Water Quality and Fish and Wildlife Habitat in the Arroyo Colorado

Contributors: Loretta E. Mokry and Tim Noack

Habitat Feasibility Study

To assist the Arroyo Colorado Habitat Restoration Workgroup with the development of this habitat restoration plan, Texas Parks and Wildlife Department developed a project scope of work with the input of workgroup members and published a request for qualifications and expressions of interest for engineering/consulting firms and universities to conduct a feasibility study for habitat restoration/modification to improve water quality in the Arroyo Colorado. Five firms responded by the June 16, 2005 deadline. Specific criteria pertaining to the responding firms’ organization, staffing and relevant work experience were scored by the selection committee, made up of Habitat Restoration Workgroup members. Alan Plummer Associates, Inc. (APAI) was selected by the committee as the most qualified to provide the services requested in the project scope of work. A contract was negotiated with Alan Plummer Associates, Inc. on August 12, 2005 and a Notice to Proceed was issued on dated August 15, 2005. The scope of work for the feasibility study required the following deliverables.

- Summary of Relevant Literature and Data
- Set of Preliminary Modification and Habitat Restoration Alternatives (Toolkit)
- Technical Engineering Report

Compilation and Summary of Relevant Literature and Data

Alan Plummer and Associates, Inc. conducted a literature review and provided a summary of the compiled data, information and studies pertaining to the Arroyo Colorado and to water quality improvement strategies in general. The summary was provided to the Habitat Workgroup in draft form in September 2005. The Arroyo Colorado Feasibility Study Reference List and Summaries is included in Appendix C of APAI’s final technical report (APAI 2006) to assist the stakeholders and the workgroups in finding information that they may need to implement recommended water quality and habitat improvement strategies and projects.

Development of the Preliminary Habitat Alternatives

Alan Plummer Associates Inc. was asked to investigate and develop preliminary designs for habitat-oriented water quality improvement strategies feasible for implementation in the non-tidal and tidal portions of the Arroyo Colorado including, but not limited to, wastewater treatment wetlands, stormwater detention and treatment strategies, off channel wetlands, on channel habitat enhancements, and stream bank stabilization. The APAI project team attended the Habitat Workgroup meeting held at Texas A&M – Kingsville Citrus Center on August 4, 2005 and described the process that APAI would use to conduct the feasibility study. The APAI project team met with staff from TPWD serving on the Habitat Restoration Workgroup and the Watershed Coordinator at a project kickoff meeting on August 5, 2005 in Brownsville to further refine the feasibility study scope of work.
The APAI project team presented a discussion document containing brief descriptions, schematics, photographs and additional information from reference sources for 50 potential habitat strategies for improving water quality in the Arroyo Colorado at the Habitat Restoration Workgroup meeting on October 18, 2005. The 50 strategies were grouped into four major categories; the first three categories correlate to the source of the water being treated (non-point source, point source, or collective [both]) while the fourth category contained management strategies. At the suggestion of a workgroup member and with consensus of the rest of the workgroup members, Arroyo Colorado channel weirs were added to the comprehensive list as a potential strategy for consideration. To assist the workgroup members in selecting ten strategies for further evaluation by APAI, the APAI project managers grouped together the strategies that were similar so that the revised comprehensive list contained 36 strategies.

Selection of Ten Strategies for Further Evaluation

At the October 18, 2005 Habitat Restoration Workgroup meeting, members chose strategies that are supported by documented studies to reduce pollutant loads and that had the possibility of increasing fish and wildlife habitat in the Arroyo Colorado watershed. The ten strategies receiving the highest number of votes by the workgroup members and selected for further evaluation by the APAI project team are provided in Table 3 below, grouped according to the source of pollutants for which they are best suited to treat.

Table 3. Ten water quality improvement strategies selected by the Arroyo Colorado Habitat Restoration Workgroup for further evaluation by Alan Plummer Associates, Inc.

<table>
<thead>
<tr>
<th>Major Treatment Category</th>
<th>Strategy</th>
</tr>
</thead>
</table>
| Non-point Source Pollutants | 1. Ponds (micropool extended detention ponds, multiple pond systems, wet extended detention ponds).  
2. Stormwater wetland systems using a series of wetland cells within small drainages and wetland swales.  
3. Stormwater wetland systems using extended detention shallow wetlands, pocket wetlands and pond/wetland systems.  
5. Filtration using vegetated filter strips.  
6. Channels with wet swales or wetlands. |
| Point Source Pollutants | 7. Constructed wetlands for tertiary treatment following an individual wastewater treatment plant (mechanical or lagoon).  
8. Regional constructed wetlands polishing flows from multiple wastewater treatment plants in close proximity. |
| Collective | 9. Large scale on-channel wetland systems.  
10. Large scale off-channel wetland system. |
Six of the ten strategies selected by the Habitat Restoration Workgroup members for further evaluation by APAI, involve strategies to reduce non-point source pollutant loads, two involve treatment systems for reducing point source pollutant loads, and two involve treatment systems for collective (non-point and point source) loads. The ten strategies are further described in the following paragraphs and in the final technical report (APAI 2006). At the suggestion of the workgroup, the original strategies that APAI provided the workgroup along with the accompanying descriptions, schematics and photographs were included as an appendix of the final technical engineering report produced by Alan Plummer Associates, Inc. in association with Crespo Consulting Services, Inc., named Feasibility Study for Habitat Restoration/Modification to Improve Water Quality in the Arroyo Colorado, Strategies to Enhance Both Water Quality and Habitat (APAI 2006).

Ponds (Strategy 1) – Ponds are constructed stormwater retention basins that have a permanent pool of water throughout the year (APAI 2006). Runoff from each rain event is detained and treated in the pool through settling and biological activity until it is replaced by runoff from the next storm event. Stormwater ponds are among the most cost-effective and commonly used stormwater management techniques and when designed properly, they can provide multiple benefits including wildlife habitat and aesthetics. There are a variety of pond designs to accommodate specific circumstances and multiple stormwater ponds can be placed in series or in parallel trains to increase performance or meet site design constraints (APAI 2006). The most common stormwater pond designs include wet ponds that have a permanent wet pool equal to the water quality volume, wet extended detention ponds that split the water quality volume equally between the permanent pool and extended detention, micropool extended detention pond that incorporates only a small micropool at the outlet of the pond, and multiple pond systems that provide water quality and quantity volume storage in two or more cells.

Stormwater ponds are generally applicable within a variety of landscapes including within new development and redevelopment, residential and nonresidential areas, and urban and agricultural areas (APAI 2006). The main constraints for determining suitability of this strategy are the land requirements and sufficient drainage area to sustain a permanent pool of water. Typically a minimum of 10 hectares (25 acres) of drainage area is needed for a wet pond and wet extended detention pond to maintain a permanent pool while at least 4 hectares (10 acres) is needed to maintain a permanent pool in a micropool extended detention pond. Smaller drainage areas are acceptable when flows into the ponds come from sources other than just rainfall. Size of stormwater ponds should be approximately 2 to 3 percent of the drainage area being treated. Additional details regarding site requirements, effectiveness, costs and conceptual designs for stormwater ponds are provided in the final technical report (APAI 2006).

Stormwater wetland systems using a series of wetland cells within small drainages and wetland swales (Strategy 2) - Stormwater runoff can also be treated through the use of wetland treatment systems. Wetland treatment systems differ from stormwater ponds in that they have large areas of shallow water and emergent vegetation. Wetland plants affect the hydraulic characteristics of the wetland, act as sources and sinks of certain water quality constituents, and support microbial species on their surfaces that perform many of the biochemical transformations that occur in treatment wetlands. Stormwater wetlands are among the most effective of the non-point source treatment strategies for pollutant removal. The main constraint for employing stormwater wetland treatment systems is that they
require either sufficient base flow or a water table that is high enough to support aquatic vegetation in the wetland. The wetland treatment systems described for Strategy 2 in the final technical report developed by APAI are generally applicable to linear drainages, such as channels and swales. These include series of wetland cells created by the construction of small weirs across drainage channels and wetland swales that do not involve the construction of weirs. Additional details regarding site requirements, effectiveness, costs and conceptual designs for wetland treatment systems within a small drainage or swale are provided in the final technical report (APAI 2006).

**Stormwater wetland treatment systems using extended detention shallow wetlands, pocket wetlands and pond/wetland systems (Strategy 3)** - Stormwater runoff wetland treatment systems included in this strategy are similar to those in Strategy 2 except that they are not necessarily limited to linear drainages and they generally include some sort of a pond or pool. Extended detention shallow wetland designs incorporate a forebay in front of the wetland, a wetland with both shallow water and deep water marsh components, and a micropool at the outflow. Pocket wetlands are intended for small drainage areas of two to four hectares (five to 10 acres) and typically require supplemental water sources or excavation to the water table to maintain sufficient hydrology to support the wetland plants. The pond/wetland system consists of a forebay followed by a wet pond and a shallow marsh. Stormwater wetlands included in Strategies 2 and 3 are widely applicable, have relatively low maintenance costs associated with them, are good at nutrient removal and can be used to create wildlife habitat. Additional details regarding site requirements, effectiveness, costs and conceptual designs for wetland treatment systems using extended detention shallow wetlands, pocket wetlands and pond/wetland systems are provided in the final technical report (APAI 2006).

**Bank/slope stabilization using bioengineering with vegetation for erosion control (Strategy 4)** - Stream bank erosion is a natural process in streams, but the rate of erosion can significantly increase in stream channels that are altered or that drain watersheds with large amounts of impervious surfaces. Strategy 4 focuses on erosion control techniques that employ vegetation in bioengineering applications to provide structural integrity and stability to eroding slopes and stream banks. Bioengineering utilizes appropriate plants and other locally available materials but can also be used in combination with traditional engineering techniques such as rock or concrete structures, especially in more urban watersheds. Bioengineering designs are generally suitable for stream slopes where velocities are less than 3 meters/second (10 feet/second).

Bank and slope stabilization primarily address instream loadings of sediment by controlling erosion in the multiple zones along the stream bank including the toe zone, splash zone, bank zone and terrace zone. Successful designs will employ the appropriate plant selection for each zone so that the plants will thrive and most adequately restore riparian buffers. The riparian area of a stream is the land adjacent to that body of water that is, at least periodically, influenced by flooding. Preserving and restoring the riparian buffer of a stream is a very effective method for trapping sediment and nutrients in surface runoff from the drainage basin. Wider riparian zones with shallow slopes are more effective at removing pollutants than narrow, steep sloped stream banks. Conceptual designs, removal efficiencies, regulatory requirements and costs of several types of bioengineering techniques are provided in the feasibility study engineering report (APAI 2006).
Filtration using vegetated filter strips (Strategy 5) - Vegetated filter strips are zones of vegetation through which sediment and pollutant-laden flows are directed before being discharged to a concentrated flow channel. Both naturally occurring and preserved vegetation zones, as well as constructed vegetation zones, typically mowed turf grass, are considered filter strips. Dense vegetation in filter strips removes pollutants through detention, filtration, sediment deposition, infiltration and adsorption in the soil, and uptake by the vegetation and associated microbes. This strategy is often used in conjunction with other strategies to reduce the sediment and pollutant loading to the downstream treatment strategies. Vegetated filter strips also reduce maintenance costs of downstream strategies and enhance overall pollutant removal capabilities. Recently, vegetated filter strips have also been used to address issues involving groundwater recharge and reducing the impacts of development on the hydrologic regime of an area including stream channel erosion and peak storm discharges.

Vegetated filter strips are most effective for sheet flows and provide little treatment for concentrated flows. The contributing drainage area to a vegetated filter strip should be kept below two hectares (five acres). They have proven successful on agricultural lands or in urban areas where they are used to treat runoff from isolated impervious areas such as rooftops and small parking lots. They are sometimes incorporated into buffer zones along drainages and serve to physically protect the drainage. A three lateral zone system including a stormwater depression, grass filter strip and forested filter strip is effective in providing water quality improvement and a buffer zone for receiving streams. More details regarding conceptual designs, limitations, effectiveness and costs associated with vegetated filter strips are provided in the final technical report (APAI 2006).

Channels with wet swales or wetlands (Strategy 6) – This strategy involves making modifications to a drainage channel to create a wet swale. Wet swales or wetland channels consist of broad open vegetated channels capable of temporarily storing water. The wet swale is similar to the series of wetland cells within small drainage described above in Strategy 2 and has similar water quality treatment mechanisms including settling of suspended solids, adsorption, and uptake of pollutants by vegetative root systems. This strategy differs from Strategy 2 in that the channels are widened to create swales and wetlands and are thus less linear than those in Strategy 2. More details regarding conceptual designs, limitations, and effectiveness associated with wet swales are provided in the final technical report (APAI 2006).

Constructed wetlands for tertiary treatment following an individual wastewater treatment plant (Strategy 7) - Constructed wetland treatment systems, such as free water surface wetlands, are composed of one or more treatment cells designed and constructed to provide treatment of waste streams. Well designed constructed wetlands closely resemble natural wetlands in appearance and function. They incorporate open water areas, emergent marshes, sometimes submerged aquatic vegetation, and varying water depths, all of which are typical wetland features. Wastewater polishing wetland systems using rooted, water-tolerant plant species and shallow, flooded, or saturated soil conditions have proven to be very reliable. They must be operated so that the normal operating water depths will support the growth of emergent vegetation.

Wetland treatment systems are effective in removing biochemical oxygen demand, suspended solids, nitrogen, and phosphorus, as well as for reducing metals, organics, and pathogens. However, wetland treatment systems are land intensive. They are typically constructed outside
of the 100-year floodplain or are protected from floods by levees or berms. Although it is often desirable to develop wetland treatment systems in the immediate vicinity of a wastewater treatment plant, larger wastewater flows may require pumping the effluent to a larger, offsite wetland. A general rule of thumb is that it takes approximately 10 hectares (25 acres) of constructed wetlands to treat 3.79 million liters (one million gallons) of effluent. Often free surface water wetlands used as treatment systems are designed with wildlife habitat creation as a secondary or primary goal. More details regarding conceptual designs, limitations, effectiveness and costs associated with constructed wetlands for treatment of wastewater effluent are provided in the final technical report (APAI 2006).

Regional constructed wetlands polishing flows from multiple wastewater treatment plants in close proximity (Strategy 8) – Regional constructed wetlands for tertiary treatment following multiple wastewater treatment plants are free water surface wetlands that are constructed to treat the waste stream from more than one wastewater treatment plant. These wetlands can also be used to provide for treatment of industrial and agricultural wastewaters.

Large scale on-channel constructed wetland systems (Strategy 9) – This strategy involves the construction of a wetland treatment system within the stream channel for the purpose of treating flow from both point and non-point source discharges. Construction of on-channel wetlands is typically not considered feasible due to a number of factors including inappropriate water depths for establishment of emergent vegetation, very high potential for short-circuiting of flows through the system resulting in ineffective contaminant removals, substantial deposition of sediments, impedance of storm flows within the channel and floodway, and frequent damage to the wetland plant communities from high velocity flows during storm events (APAI 2006). The on-channel constructed wetland systems strategy was included in the comprehensive list of strategies and the ten selected strategies for further consideration at the request of the Habitat Restoration Workgroup. Habitat Restoration Workgroup members were interested in determining if a constructed wetland was feasible in the Llano Grande area for treatment of collective flows in the Arroyo Colorado.

Large scale off-channel constructed wetland systems (Strategy 10) – Off-channel constructed wetland systems are located such that they could receive flow from collective drainages conveying both point and non-point source discharges. Potentially, an off-channel regional wetland could either receive collective flows prior to their reaching the Arroyo Colorado or water could be diverted from the Arroyo Colorado to a large-scale wetland polishing system, either within or outside of the floodway levees (Fig and Fig ). Although it is feasible that some locations may be able to receive diverted flows from drainage channels or the Arroyo Colorado, diversion flows would most probably require pumping. Although pumping water to the wetlands adds more cost to the wetland system, it does enable more control of inflows to the system. Potential sites for an off-channel collective wetland treatment system within the Arroyo Colorado watershed would be wherever there are drainage ditches or channels that convey multiple flows from municipal discharges, agricultural irrigation return flows and/or stormwater runoff from agricultural fields or urban areas to the Arroyo Colorado and these flows can be rerouted to an appropriate site for development of a wetland system. Large-scale wetland treatment systems can easily incorporate habitat restoration and enhancement, education and outreach, and ecotourism components. Examples of existing large scale wetland treatment systems in Texas,
along with limitations, effectiveness and costs are included in the final technical report (APAI 2006) prepared by Alan Plummer Associates Inc.

Conceptual drawings of potential large-scale wetland systems for the Arroyo Colorado prepared by APAI (2006) are provided in Figure 16 and Figure 17 below.

Figure 16. Conceptual design of a regional or large-scale off-channel constructed wetland within the floodway levees for treatment of collective flows containing point source and non-point source discharges (APAI 2006).
Figure 17. Conceptual design of a regional or large-scale off-channel constructed wetland outside the floodway levees for treatment of collective flows containing point source and non-point source discharges (APAI 2006).

Final Technical Report (Toolkit)

The final technical report, *Feasibility Study for Habitat Restoration/Modification to Improve Water Quality in the Arroyo Colorado* (APAI 2006), prepared by Alan Plummer Associates, Inc. is a valuable resource to anyone desiring to implement a strategy to improve the water quality and/or to restore and enhance aquatic and riparian habitats associated with the Arroyo Colorado. Relevant data provided by the TCEQ and other agencies about the water quality problems, flow volumes and flow velocities and sources of pollutant loadings has been compiled and presented to help stakeholders determine appropriate strategies for their area or concern. There are many variables and factors involved in selecting the right strategies for improving water quality and the right sites for implementing strategies and these are explained in the final report. The report contains brief descriptions of the comprehensive list of strategies initially considered and provides additional information about the ten strategies selected by the Habitat Restoration Workgroup for further evaluation. Site selection considerations for non-point source, point source and collective strategies are summarized in easy to read tables. Some of these strategies will require site specific feasibility analyses, final engineering studies and/or
permitting to implement. Finally, a reference list and summaries of the relevant information contained in the references is provided in the report.

The recommendations for habitat restoration presented in the following section of the plan include strategies for protecting and restoring terrestrial and aquatic habitats that are valuable to fish and wildlife resources in the Lower Rio Grande Valley and the watershed of the Arroyo Colorado. The final technical report of the Feasibility Study for Habitat Restoration/Modification to Improve Water Quality in the Arroyo Colorado (APAI 2006) is the "toolkit" recommended by the Habitat Restoration Workgroup for implementing specific projects designed with the primary objective of improving water quality in the Arroyo Colorado. The Workgroup's recommendations include some actions pertaining to habitat preservation, restoration and enhancement that may not be included in the final technical report. However, all of the 51 strategies presented in the toolkit are feasible and their implementation in appropriate sites would reduce pollutant loadings or increase assimilative capacity of the Arroyo Colorado and thus improve habitat for fish and wildlife that depend on the fresh and brackish waters of the Arroyo Colorado.
Arroyo Colorado Habitat Restoration Plan

Recommended Habitat Restoration Implementation Plan for the Arroyo Colorado

Contributors: Randy Blankinship, David Buzan, Chris Hathcock, Loretta Mokry, Tim Noack, Jarrett “Woody” Woodrow and all of the participating members of the Arroyo Colorado Habitat Restoration Workgroup

Four main threats to the habitats associated with the Arroyo Colorado, and important for maintaining water quality, are recognized by the Arroyo Colorado Habitat Workgroup in this habitat restoration plan. Continued loss of wetlands, riparian areas and other valuable terrestrial habitats in the Arroyo Colorado watershed from land use conversion further exacerbates the poor water quality problems in the Arroyo Colorado as well as threatens the fish and wildlife resources that depend upon the habitats. Continued channel and streambank erosion contributes to non-point source pollutant loadings in the Arroyo Colorado and to the loss of riparian areas. Invasive plant species are degrading terrestrial and aquatic habitats throughout the Arroyo Colorado watershed by decreasing plant diversity and excluding species having more value to wildlife and improved water quality. Finally, continued dissolved oxygen problems in the tidal segment of the Arroyo Colorado, caused by point source and non-point source pollutant loadings and modified channel configurations that support excessive algal populations, threatens the ability of the Arroyo Colorado to maintain its role of providing nursery habitat for commercially and recreationally important fisheries species.

Several federal, state, local and binational efforts are underway to address these threats to the terrestrial and aquatic habitats in the Lower Rio Grande Valley. These conservation efforts and plans call for the protection and restoration of riparian habitats, wetlands, thornscrub habitat, wildlife corridors and grasslands; the protection, enhancement and restoration of biodiversity; and the provision of water in sufficient quantity and quality to support fish and wildlife resource needs. Many of the existing conservation efforts and plans encompass parts of or the whole Arroyo Colorado watershed and these efforts are supported by Arroyo Colorado Habitat Restoration Workgroup.

The Arroyo Colorado Habitat Restoration Plan presents recommendations developed by the Arroyo Colorado Habitat Workgroup that address the identified threats to the habitats in the Arroyo Colorado watershed and water quality in the Arroyo Colorado. Many of the recommendations are based on the results of a habitat restoration feasibility study conducted by Alan Plummer Associates, Inc. (APAI) in association with Crespo Consulting Services, Inc. to assist the Habitat Restoration Workgroup’s efforts. The final technical report from the study is named Feasibility Study for Habitat Restoration/Modification to Improve Water Quality in the Arroyo Colorado, Strategies to Enhance Both Water Quality and Habitat (APAI 2006) and it contains valuable information about 51 strategies that were evaluated for potential implementation in the Arroyo Colorado watershed. This technical engineering report is an excellent toolkit of project ideas and references for use by the Arroyo Colorado Watershed Partnership.

Specific actions in this habitat restoration plan developed by the Arroyo Colorado Habitat Restoration Workgroup fall under three main objectives: 1) conserve existing riparian and wetland habitats, 2) reduce channel and streambank erosion, and 3) construct wetlands to
Arroyo Colorado Habitat Restoration Plan

improve the water quality in the Arroyo Colorado. Under the first objective, Action 1 encourages the Arroyo Colorado Watershed Partnership collaboration with ongoing federal, state, and nongovernmental organizations’ efforts to conserve terrestrial habitats in the watershed of the Arroyo Colorado. Action 2 recommends additional conservation of wetlands, resacas and riparian areas. Actions 3-7 call for participation in advisory groups and the development and implementation of projects to meet the second objective of reducing channel and streambank erosion. Lastly, Actions 8-10 recommend the construction of wetlands for treating point source, non-point source and collective waste streams before they reach the Arroyo Colorado, after they reach it, or both, to improve the water quality in the Arroyo Colorado. Potential sites for implementing the recommended actions are based on information compiled by APAI from the Hydrologic Simulations Program-Fortran (HSPF) model runs by the Texas Commission on Environmental Quality (TCEQ) on data for an 11-year period from January 1, 1989 through December 31, 1999 (APAI 2006). The TCEQ divided the Arroyo Colorado watershed into 14 sub-basins (Map 4 in Appendix B) for modeling purposes and these sub-basins are used below when potential sites for implementing actions are suggested.

Conserve Existing Riparian and Wetland Habitats

Almost all of the federal, state, nongovernmental and local conservation efforts and plans that include the Lower Rio Grande Valley call for the acquisition of the remnant tracts of Tamaulipan thornscrub habitat, the conservation of riparian areas along the Rio Grande, Arroyo Colorado, and drainages, and the protection and restoration of resacas and other freshwater wetlands. Many of the plans recognize the importance of conserving and restoring drainages and riparian habitats that connect remnant tracts of Tamaulipan thornscrub habitat for use as corridors by wildlife in the region. Two of the three national management measures developed by the EPA for protecting the water quality of rivers and streams and reducing the impacts of non-point source pollution involve the protection and restoration of existing wetlands and riparian areas that abate non-point source pollution (EPA 2005).

Conservation of habitats and abating threats to biodiversity do not necessarily involve acquisition of properties. Tools such as conservation easements, private landowner assistance, and partnerships can meet the objective of conserving habitat while allowing additional uses of the property in some cases. Protecting undeveloped wetlands and riparian areas and restoring damaged habitats could be expected to cost less than creating new habitats, although additional constructed wetlands are needed and recommended to reduce non-point source pollutant loadings to the Arroyo Colorado. Recommendations of the Arroyo Colorado Habitat Workgroup for conservation of riparian and wetland habitats in the Arroyo Colorado watershed are provided below.

Action 1 - Support the ongoing efforts of the federal, state and local agencies and organizations to implement terrestrial habitat conservation objectives in the Arroyo Colorado watershed through partnerships and funding.

- Laguna Atascosa National Wildlife Refuge Proposed Refuge Expansion Plan, including acquisition of land along the shores of the Arroyo Colorado from the current refuge boundaries to the Port of Harlingen (USFWS 1999).

- U.S. Fish and Wildlife Service Wildlife Corridor Project.
Texas Parks and Wildlife Department’s Private Lands Enhancement and Landowner Incentive Program.

The Consolidated Farm Service Agency’s Conservation Reserve Program and Agricultural Conservation Program.

The Nature Conservancy of Texas conservation and restoration of native terrestrial vegetation through cooperative projects and private lands initiatives (The Nature Conservancy 2001).

**Action 2 - Protect and restore existing riparian areas, resacas, and freshwater wetlands.**

- Acquire updated land use and land cover data to help stakeholders identify existing or former riparian areas, resacas and freshwater wetlands.
- Conserve riparian areas through acquisition, conservation easements and other conservation actions such as the Natural Resources Conservation Service’s Wetland Reserve Program.
- Restore riparian areas by partnering with public and private landowners to reduce habitat clearing or overgrazing on lands adjacent to drainages and the Arroyo Colorado, control invasive plant species, restore hydrology (occasional flooding), and re-vegetate with native riparian plant species.
- Protect and restore resacas and freshwater wetlands through acquisition and restoration of hydrology.
- Support the use of native plants in vegetated filter strips (Strategy 5 in APAI 2006) employed near riparian areas, resacas and other freshwater wetlands.

**Reduce Channel and Streambank Erosion**

Reducing channel and streambank erosion along the drainage ditches leading to the Arroyo Colorado and within the channel of the Arroyo Colorado would reduce non-point source pollutant loadings to the Arroyo Colorado, reduce the frequency of channel maintenance activities, and help preserve riparian habitats. The Arroyo Colorado Habitat Workgroup makes the following recommendations for reducing channel and streambank erosion on the drainages within the Arroyo Colorado watershed and on the Arroyo Colorado pilot channel.

**Action 3 - Work with drainage districts to modify drainage ditches and maintenance practices to reduce channel and streambank erosion**

- Support the acquisition of wider easements for drainages to allow for the modification of drainage ditches and for implementation of Strategies 2, 4, 5 and 6 in the final technical report (APAI 2006).
- Participate with drainage districts to develop channel configurations that do not require as much vegetation removal through mechanical means or the use of herbicides.
- Develop partnerships with drainage districts and adjacent landowners to allow for improved channel configuration designs that support wetlands within the channels and riparian areas along the banks (Strategies 2, 4 and 6 in the final technical report by APAI 2006).
Action 4 - Participate with IBWC during development of maintenance or new work projects for the Arroyo Colorado.

- Serve in advisory capacities to assist in the development of pilot channel configurations with banks that are less steep and that can support vegetation such as riparian woodland plants or native prairie grasses.
- Assist the IBWC in developing license conditions that seek to reduce channel and streambank erosion such as requiring the implementation of vegetated filter strips (Strategy 5 in the final technical report by APAI 2006) between row crop fields and the pilot channel.
- Assist the IBWC and landowners in identifying hot spots of channel and streambank erosion.

Action 5 - Develop partnerships with the IBWC, drainage districts, and private landowners to implement bank/slope stabilization projects (Strategy 4 in the final technical report APAI 2006) in hot spots along the Arroyo Colorado or in drainages within the watershed.

Action 6 - Implement projects that would detain stormwater runoff, reduce sediment load and reduce the volume and velocity of the flow of the runoff in drainage ditches and the Arroyo Colorado (Strategies 1, 2, 3 and 6 in the final technical report APAI 2006).

Action 7 - Support ongoing and increased use of vegetated filter strips (Strategy 5 in the final technical report APAI 2006) around agricultural production and urban development areas to slow stormwater runoff from these areas.

Construct Wetlands to Improve the Water Quality in the Arroyo Colorado

Implementation of any or all of the recommendations made in the two sections above dealing with conservation of riparian and wetland habitats and controlling channel and streambank erosion would improve the quality of the water in the Arroyo Colorado. Reducing erosion also reduces the amount of non-point source pollutants in the water. In addition, to removing sediments, the implementation of vegetated filter strips (Strategy 5 in the final technical report APAI 2006) and bank/slope stabilization using bioengineering (Strategy 4 in the final technical report APAI 2006) reduces nutrients from stormwater runoff. Nutrients contribute to algal growth which in turn leads to low dissolved oxygen conditions in the water column. Conserving riparian areas and wetlands also helps reduce erosion, sediment loads and non-point source pollutants from reaching the Arroyo Colorado.

Strategies with the primary purpose of removing either point source or non-point source pollutants from water draining into or flowing in the Arroyo Colorado are feasible for implementation in the watershed of the Arroyo Colorado. The third national management measure developed by the EPA for protecting the water quality of rivers and streams and reducing the impacts of non-point source pollution is the construction of treatment wetlands that abate non-point source pollution (EPA 2005). The Arroyo Colorado Habitat Restoration Workgroup recommends the following actions involving constructed wetlands to improve water quality in the Arroyo Colorado.
Action 8 - Implement stormwater wetland systems (Strategies 2, 3, and 6 in the final technical report APAI 2006) in urban developments, redevelopments and in areas under agricultural production to reduce non-point source pollutant loading to the Arroyo Colorado.

Action 9 - Build constructed wetlands for tertiary treatment of waste streams from individual wastewater treatment plants (Strategy 7 in the final technical report APAI 2006) and/or for polishing flows from multiple wastewater treatment plants in close proximity (Strategy 8 in the final technical report APAI 2006) with habitat features when feasible.

Action 10 - Construct large off-channel treatment wetlands that treat flows from both point and non-point discharges and provide habitat (Strategy 10 in the final technical report APAI 2006).

Factors Affecting the Selection of Recommended Actions

There are many variables to consider when evaluating which of the recommended actions presented in this plan by the Arroyo Colorado Habitat Restoration Workgroup to implement and they are discussed in the final technical report produced by APAI (2006). The recommended actions in this plan should be implemented in combinations that provide the optimum pollutant reduction to the critical reach of the Arroyo Colorado. Final selection of recommended actions and locations for their implementation will be influenced by several factors including the variables described below, as well as the availability of funding for identified actions and the support of local governments.

**Constructed wetlands for tertiary treatment of waste streams** - Recommended actions involving polishing of wastewater discharges using constructed wetlands (Actions 9 and 10 above and Strategies 7, 8 and 10 in final technical report APAI 2006) tend to provide the greatest benefit since wastewater treatment plants provide a relatively consistent flow and water quality. Furthermore, low dissolved oxygen conditions in the Arroyo Colorado are associated with low (dry weather) conditions. Constructed wetlands that are properly maintained have been shown to effectively reduce oxygen-demanding wastes, suspended solids, nitrogen and phosphorus in treated wastewater discharges. Constructed wetlands may enhance ecological services associated with increased availability of habitat particularly for birds, reptiles and amphibians. In a region like the lower Rio Grande Valley where bird watching is a growing industry and contributor to the economy, constructed wetlands may offer increased economic benefits to local communities. Constructed wetlands are being used for tertiary treatment of waste streams in a number of states including Texas, California and Florida.

APAI (2006) provides conceptual designs, estimated load reductions and estimated costs associated with strategies involving the treatment of wastewater streams. Final feasibility analyses and engineering designs are required before implementing these actions and strategies on any site. Several factors should be considered for implementation of strategies to reduce loading of nutrients and oxygen-demanding wastes from wastewater treatment plant discharges. Some of these factors are provided below.
Constructing wetlands for wastewater treatment plants should be considered when current and anticipated future performance is expected to be in compliance with wastewater discharge permit requirements. Constructed wetlands “polish” or enhance the quality of wastewater that has already been treated to secondary or advanced secondary levels of treatment. Constructed wetlands should not be used to compensate for earlier treatments that are not working properly.

Sites with adequate land area, appropriate site topography and suitable soils should be selected for the construction of wetlands. When land is limited adjacent to the wastewater treatment plant, consideration may be given to pumping wastes to other areas with sufficient land area, and suitable topography and soils.

Constructed wetlands for the treatment of wastewater streams should be built to treat flows from facilities in the sub-basins nearest the zone of impairment in the tidal segment of the Arroyo Colorado (Sub-Basins 8 and 9). Wastewater discharges from these facilities have the least amount of time for the assimilation of oxygen-demanding components and nutrients in the Arroyo Colorado before reaching the zone of impairment.

Sub-basins with facilities contributing the greatest loadings of oxygen-demanding and nutrient wastes to the Arroyo Colorado (Sub-Basins 3 and 8) should be considered a high priority for constructed wetland polishing systems. The seasonal variation in waste loading and subsequent wastewater discharge loading should also be considered. Some facilities may experience increased volumes of wastes or loading of particular oxygen-demanding or nutrient waste streams during certain seasons of the year, for example during periods where agricultural products are being harvested and washed. Areas of expected population and/or industrial growth where there is anticipated to be significant increases in waste loading within the next decade should also be considered.

Potential sites for implementing strategies to treat wastewater streams from individual wastewater treatment plants include the Weslaco, Rio Hondo, La Feria, San Benito, Mission, Pharr, McAllen and Hidalgo plants. Currently, there are efforts by Arroyo Colorado Partners to construct wetlands to treat waste streams from wastewater treatment plants. The City of La Feria is applying for grants to help convert their old lagoons into constructed treatment wetlands. The City of Weslaco and Texas Parks and Wildlife Department are in early discussions about a joint effort to construct treatment wetlands on 8 hectares (20 acres) of the Taormina Unit of the Las Palomas Wildlife Management Area for partial treatment of Weslaco’s municipal discharge. Potential sites for treating the combined waste streams from multiple wastewater treatment plants in close proximity include: Pharr and San Juan plants, Donna and Weslaco plants, and the two Harlingen and the San Benito plants.

Constructing an adequate amount of well-designed wetlands required to treat all of the waste streams from the San Benito and Harlingen plants individually or in combination would provide the greatest improvement to water quality in the Arroyo Colorado from implementing Actions 9 or 10. Due to the location of the San Benito and Harlingen wastewater treatment plants in Sub-Basin 8, effluent from these facilities has the least amount of time for natural treatment before reaching the impaired zone of the Arroyo Colorado. Treating the effluent from these plants in constructed wetlands prior to it reaching the impaired zone would reduce the amount of pollutant loadings in this stream segment and would improve dissolved oxygen conditions in the tidal segment.
Ponds, bioengineering, vegetated filter strips and constructed wetlands for treatment of non-point source discharges - Recommended actions involving the use of non-point source strategies (Actions 2, 3, 4, 5, 6, 7, 8 and 10 above and Strategies 1-6 and 10 in the final technical report by APAI 2006) to treat non-point source pollutants have been described in detail in APAI (2006). These strategies have gained wide acceptance and are being used in large number of communities and situations across country. Effective implementation of strategies to reduce non-point source waste loading involves consideration of many of the same factors as are involved in considering suitable sites for using constructed wetlands to treat point sources of waste. Final feasibility analyses and engineering is required for implementing these actions and strategies on most sites. Some of the factors to consider for implementing the non-point source actions and strategies are described below.

- Communities that are actively implementing effective stormwater control measures and are meeting stormwater treatment regulations should be considered for implementation of these actions. Since these strategies require long-term commitment of the community to ensure the treatment facilities are properly operated and maintained, those communities and districts that have demonstrated commitment to effective stormwater control measures should be given future project support.
- Sites with adequate land area, appropriate site topography and suitable soils should be selected for the construction of treatment facilities that function as designed and provide significant reduction of wastes.
- Priority areas for implementation are those that are close to the zone of impairment and that contribute substantial non-point wastes to the Arroyo Colorado (Sub-Basins 8 and 9). Non-point pollutant loads from these areas will have the least amount of time to be assimilated in the Arroyo Colorado before reaching the zone of impairment.
- Priority areas for implementation are also those that contribute non-point source pollutants to dry weather flows and include Sub-Basins 3-9.
- Areas where expected population and/or industrial growth are likely to occur within the next decade should also be considered for implementation of these strategies.
- Economic benefits may be associated with the construction of certain types of non-point source control strategies. For example, projects that are in close proximity to natural areas or that include habitat components should attract birds and other wildlife. Land value on properties near these types of projects may also increase due to the wildlife viewing opportunities. As mentioned earlier, bird watching is currently a viable component of the local economy and some habitats constructed for non-point source control will improve bird watching opportunities.

Potential areas for implementation of recommended actions and strategies to reduce non-point source pollutant loadings to the Arroyo Colorado include: 1) the Progreso area (Sub-Basin 5) to treat runoff from colonias, irrigation return flow and agricultural runoff; 2) the reach between Mercedes and La Feria (Sub-Basin 6) to treat agricultural runoff and irrigation return flows; 3) the area draining to the zone of impairment and just upstream of it to treat urban, industrial and agricultural runoff (Sub-Basins 9 and 10); and 4) the San Benito area (Sub-Basin 8) to treat runoff from colonias.

Potential areas for bank/slope stabilization projects to reduce channel and streambank erosion include banks along the tidal portion of the Arroyo Colorado (Sub-Basin 9) and where drainages
converge with the Arroyo Colorado. Vegetative filter strips and wet swales may be appropriate treatment systems for the reach in the non-tidal segment between the cities of Pharr and Las Milpas (Sub-Basin 3) to treat agricultural runoff and irrigation return flows. The area along the north side of the non-tidal segment of the Arroyo Colorado between the cities of Mercedes to La Feria (Sub-Basin 6) may be appropriate for the application of wet swales and bank/slope stabilization projects.

Large off-channel constructed wetlands for treatment of point source and non-point source pollutants – The factors to consider for implementing the actions and strategies for point source and non-point source are also applicable for collective strategies (Action 10 above and Strategies 9 and 10 in the final technical report APAI 2006).

Potential sites for implementing collective strategies include combining the wastewater discharge from the Weslaco wastewater treatment plant with stormwater runoff from surrounding urban areas (Sub-Basin 5) and treating the combined flow with a constructed wetland; combining the Progreso wastewater treatment plant flows with runoff from colonias, irrigation return flows and agricultural runoff (Sub-Basin 5) and treating the combined flows with a constructed wetland; and combining flows from the San Benito wastewater treatment plant with runoff from colonias and urban areas (Sub-Basin 8) and treating the combined flow through constructed wetlands. As stated previously, constructed wetlands for treatment of waste streams from wastewater treatment facilities located in Sub-Basin 8 either individually (Action 9) or in combination with non-point source discharges (Action 10) within the sub-basin would provide the greatest improvement to water quality in the Arroyo Colorado tidal segment from these actions since loadings from these sources have the least amount of time to be assimilated in the Arroyo Colorado before reaching the impaired zone.

Appendix D contains a list of selected marsh plants indigenous to Hidalgo and/or Cameron counties that are recommended for planting in created or restored freshwater and salt water wetlands.

Funding Sources

There are a variety of grants available that can assist the Arroyo Colorado Partnership and its stakeholders in implementing the recommended actions in this plan to improve habitat and water quality in the Arroyo Colorado. Information regarding available federal grants can be found online at [www.grants.gov](http://www.grants.gov) while information regarding available state grants in Texas can be found online at [www.governor.state.tx.us/divisions/stategrants](http://www.governor.state.tx.us/divisions/stategrants). Appendix E contains a table of common sources of funding used to support water quality and habitat conservation. The Lower Rio Grande Valley Development Council may also be a source of information regarding grants to support local government efforts to implement the recommended actions of this plan. The most efficient mechanism for disseminating information regarding grant opportunities as they arise is via a watershed partnership list serve.

Measuring Success

The best way to measure the success of implementing the recommended habitat actions in this plan is to measure the impact on water quality conditions and aquatic organisms in the Arroyo
The Arroyo Colorado Habitat Restoration Workgroup recommends conducting the two studies proposed below so that the results of these studies can be compared to the results of earlier completed studies to measure the success of all of the actions implemented by the workgroups.

**Arroyo Colorado Non-Tidal Biodiversity Assessment** - The objective of this study is to measure the biodiversity in species richness, relative abundance and distribution of aquatic organisms (nektonic and benthic) as an assessment of 1) stream community health and 2) success of efforts to improve water quality in the non-tidal portion of the Arroyo Colorado. Base line studies of the Arroyo Colorado non-tidal aquatic communities were conducted by Texas Commission on Environmental Quality and Texas Parks & Wildlife Department and are available for comparison. These studies showed reduced biodiversity of organisms with species present being more tolerant of heavily polluted waters. Efforts to reduce nutrient loading and other pollutants in the basin may be measurable through increased species diversity and improved aquatic habitat function in the Arroyo Colorado non-tidal portion. Such indicators are an ultimate measure of watershed protection plan success.

**Arroyo Colorado Tidal Dissolved Oxygen Assessment** – The objective of this activity is to measure dissolved oxygen levels in the Arroyo Colorado tidal portion as an assessment of habitat function. Base line studies of the Arroyo Colorado tidal dissolved oxygen profiles were conducted by Texas Commission on Environmental Quality and Texas Parks & Wildlife Department and are available for comparison. Low dissolved oxygen levels affect utilization of the stream by aquatic organisms and changes in productivity associated with this problem have been documented in the Arroyo Colorado tidal portion. Efforts to reduce nutrient loading in the basin may be measurable through improved dissolved oxygen levels and reduction in the size and period of hypoxic zones in the Arroyo Colorado tidal portion. Such an indicator is an ultimate measure of watershed protection plan success.

**Arroyo Colorado Tidal Biodiversity Assessment** - The objective of this study is to measure the biodiversity in species richness, relative abundance and distribution of aquatic organisms (nektonic and benthic) as an assessment of 1) estuarine community health and 2) success of efforts to improve dissolved oxygen levels in the tidal portion of the Arroyo Colorado. Base line studies of the Arroyo Colorado tidal aquatic community were conducted by Texas Parks & Wildlife Department in 1966-69 and 2001-03 and are available for comparison. Low dissolved oxygen levels affect utilization by and production of aquatic organisms and have been documented in the Arroyo Colorado tidal portion. Efforts to reduce nutrient loading in the basin and improve dissolved oxygen levels may be measurable through improved aquatic community utilization and production as an ultimate measure of watershed protection plan success.
Acknowledgements

The Arroyo Colorado Habitat Restoration Plan was prepared from the literature listed in the Literature Cited section on the following page and from information provided by the contributors listed for each section of the plan. Loretta Mokry and Tim Noack with Alan Plummer Associates, Inc. continued to provide their expertise to the Workgroup after their contractual requirements were met, for which the Workgroup is grateful. Lisa Williams (The Nature Conservancy of Texas), Kim Jones (Texas A&M University-Kingsville), Chris Hathcock (Texas Parks and Wildlife, State Parks), David Buzan (Texas Parks and Wildlife Department, Coastal Fisheries), Chris Anzaldua (International Boundary and Water Commission, U.S. Section), John Jacob (Texas Sea Grant) and Clare Lee (U.S. Fish and Wildlife Service) reviewed chapters of the draft plan and provided valuable suggestions.

Laura de la Garza, Arroyo Colorado Watershed Coordinator, reviewed the entire draft plan and provided welcome comments and support. Roger Miranda, geochemist with the Texas Commission on Environmental Quality, Border Assessment Team, also reviewed and made corrections throughout the entire text of the draft plan. Roger Miranda and the Texas Commission on Environmental Quality supported the efforts of Texas Parks and Wildlife Department and Alan Plummer Associates, Inc. by providing data from their modeling runs, for use in completing the feasibility study and developing the habitat restoration plan.

This is a report of the Coastal Coordination Council pursuant to National Oceanic and Atmospheric Administration Award No. NA04NOS4190058.

This report is funded in part by grants/cooperative agreements from the National Oceanic and Atmospheric Administration and the Environmental Protection Agency. The views expressed herein are those of the authors’ and do not necessarily reflect the views of NOAA and EPA or any of their sub-agencies.
Literature Cited


Jacobs, J.L. 1981. *Soil Survey of Hidalgo County, Texas.* United States Department of Agriculture, Soil Conservation Service in cooperation with the Texas Agricultural Experiment Station.


Williams, D., C.M. Thompson, and J.L. Jacobs. 1977. *Soil Survey of Cameron County, Texas.* United States Department of Agriculture, Soil Conservation Service in cooperation with the Texas Agricultural Experiment Station.
Appendix A. Members of the Arroyo Colorado Habitat Workgroup

Chris Anzaldua  
*International Boundary and Water Commission, U.S. Section*

Steve Benn  
*Texas Parks and Wildlife Department*

Paul Bergh  
*Coalition to Save the Arroyo Colorado*

Randy Blankinship  
*Texas Parks and Wildlife Department*

Mary Lou Campbell  
*Lower Rio Grande Valley Sierra Club*

Jim Chapman  
*Lower Rio Grande Valley Sierra Club*

Laura de la Garza  
*Texas Sea Grant  
Arroyo Colorado Watershed Coordinator*

Olivia Gomez  
*Texas Parks and Wildlife Department*

Neil Haman  
*Texas Water Development Board*

Chris Hathcock  
*Texas Parks and Wildlife Department  
State Parks Division*

Tom Heger  
*Texas Parks and Wildlife Department*

Kay Jenkins  
*Texas Parks and Wildlife Department  
Habitat Restoration Workgroup Coordinator*

Gary Jones (retired)  
*International Boundary and Water Commission, U.S. Section*

Kim D. Jones, Ph.D.  
*Texas A&M-Kingsville*

Earlene Lambeth  
*Texas Commission on Environmental Quality*

Roger Miranda  
*Texas Commission on Environmental Quality*

Alan Moore  
*Cameron County Drainage Dist. # 5*

Wilson Palmer, Jr.  
*Port of Harlingen*

Sam Patten  
*Texas Parks and Wildlife Department*

Christine Rakestraw  
*Coalition to Save the Arroyo Colorado*

Tony Reisinger, Jr.  
*Marine Advisory Service*

Ernesto Reyes  
*U.S. Fish and Wildlife Service  
Ecological Services Division*

John Wallace  
*Laguna Atascosa Wildlife Refuge*

Lisa Williams  
*The Nature Conservancy of Texas*
Appendix B. Maps

Map 1. The location of the Arroyo Colorado watershed in Hidalgo, Willacy and Cameron counties of South Texas.
Map 3. The Texas Commission on Environmental Quality classified reaches (Segment 2202 and Segment 2201) and the zone of impairment in the Arroyo Colorado in the Lower Rio Grande Valley, Texas.
Map 4. Pollutant loading by sub-basins (delineated for modeling purposes) of the Arroyo Colorado watershed in South Texas, based on data from Hydrologic Simulations Program-Fortran model runs by the Texas Commission on Environmental Quality for an 11-year period from January 1, 1989 through December 31, 1999, compiled by Alan Plummer Associates, Inc. and Crespo Consulting, Inc.
Map 5. The ten ecoregions of Texas adapted from Gould (1975) used in conservation planning by Texas Parks and Wildlife Department.
Map 6. The Tamaulipan Thornscrub Ecoregion recognized by The Nature Conservancy in its conservation efforts.
Map 7. The Nature Conservancy’s identified conservation areas within the Gulf Coast Prairies and Marshes Ecoregion of Texas.
Map 8. Federal and state properties in conservation as national wildlife refuges, state wildlife management areas and state parks within the Lower Rio Grande Valley region of Texas.
Appendix C. Rare plants and animals potentially occurring within the watershed of the Arroyo Colorado in South Texas.
Compiled by Chris Hathcock, January 2006.

Table heading abbreviations: TOES - Texas Organization for Endangered Species; TPWD - Texas Parks and Wildlife Department; and USFWS - United States Fish and Wildlife Service.

Conservation Status Key: E – Endangered; T – Threatened; PE – Proposed Endangered; PT – Proposed Threatened; C1 – Candidate for listing for which substantial supporting information exists; C2 – Candidate for listing for which substantial supporting information does not exist; C3 – Once candidate for listing, but is no longer; WL – Watch List; DL – De-listed; EX – Extirpated; “Blank” – rare, but no regulatory listing status.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>TOES</th>
<th>TPWD</th>
<th>USFWS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Birds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown Pelican</td>
<td>Pelecanus occidentalis</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Reddish Egret</td>
<td>Egretta rufescens</td>
<td></td>
<td>T</td>
<td>C2</td>
</tr>
<tr>
<td>Wood Stork</td>
<td>Mycteria americana</td>
<td>T</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>White-faced Ibis</td>
<td>Plegadis chihi</td>
<td>T</td>
<td>T</td>
<td>C2</td>
</tr>
<tr>
<td>Muscovy Duck</td>
<td>Cairina moschata</td>
<td></td>
<td></td>
<td>WL</td>
</tr>
<tr>
<td>Fulvous Whistling-Duck</td>
<td>Dendrocygna bicolor</td>
<td>T</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harlequin Duck</td>
<td>Histrionicus histrionicus</td>
<td></td>
<td></td>
<td>C2</td>
</tr>
<tr>
<td>Masked Duck</td>
<td>Oxyura dominica</td>
<td></td>
<td></td>
<td>WL</td>
</tr>
<tr>
<td>Golden Eagle</td>
<td>Aquila chrysaetos</td>
<td></td>
<td></td>
<td>WL</td>
</tr>
<tr>
<td>White-tailed Hawk</td>
<td>Buteo albicaudatus</td>
<td>T</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Zone-tailed Hawk</td>
<td>Buteo albonotatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gray Hawk</td>
<td>Buteo nitidus</td>
<td>T</td>
<td>T</td>
<td>C2</td>
</tr>
<tr>
<td>Northern Gray Hawk</td>
<td>Buteo nitidus maximus</td>
<td>T</td>
<td>T</td>
<td>C2</td>
</tr>
<tr>
<td>Common Black-Hawk</td>
<td>Buteogallus anthracinus</td>
<td>T</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Hook-billed Kite</td>
<td>Chondrohierax uncinatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Swallow-tailed Kite</td>
<td>Elanoides forficatus</td>
<td>T</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Merlin</td>
<td>Falco columbarius</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aplomado Falcon</td>
<td>Falco femoralis</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>American Peregrine Falcon</td>
<td>Falco peregrinus anatum</td>
<td>E</td>
<td>E</td>
<td>DL</td>
</tr>
<tr>
<td>Arctic Peregrine Falcon</td>
<td>Falco peregrinus tundrius</td>
<td>T</td>
<td>T</td>
<td>DL</td>
</tr>
<tr>
<td>Bald Eagle</td>
<td>Haliaeetus leucocephalus</td>
<td>E</td>
<td>E</td>
<td>E/PT</td>
</tr>
<tr>
<td>Attwater’s Greater Prairie-Chicken</td>
<td>Tympananchus cupido attwateri</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Snowy Plover</td>
<td>Charadrius alexandrinus</td>
<td></td>
<td></td>
<td>C3</td>
</tr>
<tr>
<td>Piping Plover</td>
<td>Charadrius melodus</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>Northern Jacana</td>
<td>Jacana spinosa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eskimo Curlew</td>
<td>Numenius borealis</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Black Skimmer</td>
<td>Rynchops niger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal Least Tern</td>
<td>Sterna antillarum antillarum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

78
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Conservation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds (continued)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior Least Tern</td>
<td>Sterna antillarum athalassos</td>
<td>E</td>
</tr>
<tr>
<td>Sooty Tern</td>
<td>Sterna fuscata</td>
<td>E</td>
</tr>
<tr>
<td>Red-billed Pigeon</td>
<td>Columba flavirostris</td>
<td>E</td>
</tr>
<tr>
<td>Cactus Ferruginous Pygmy-Owl</td>
<td>Glaucidium brasilliananum cactorum</td>
<td>E</td>
</tr>
<tr>
<td>Western Burrowing Owl</td>
<td>Speotyto cunicularia hypugea</td>
<td>C2</td>
</tr>
<tr>
<td>Ringed Kingfisher</td>
<td>Ceryle torquata</td>
<td>C2</td>
</tr>
<tr>
<td>Botteri’s Sparrow</td>
<td>Aimophila botterii</td>
<td>T</td>
</tr>
<tr>
<td>Texas (=Sennett’s) Olive Sparrow</td>
<td>Arremonops rufivirgatus</td>
<td>C2</td>
</tr>
<tr>
<td>Northern Beardless-Tyrannulet</td>
<td>Camptostoma imberbe</td>
<td>C2</td>
</tr>
<tr>
<td>Brown Jay</td>
<td>Cyanocorax morio</td>
<td>C2</td>
</tr>
<tr>
<td>Brownsville Common Yellowthroat</td>
<td>Geothlypis trichas insperata</td>
<td>C2</td>
</tr>
<tr>
<td>Sennett’s Hooded Oriole</td>
<td>Icterus cucullatus sennettii</td>
<td>C2</td>
</tr>
<tr>
<td>Audubon’s Oriole</td>
<td>Icterus graduacauda audubonii</td>
<td>C2</td>
</tr>
<tr>
<td>Altamira Oriole</td>
<td>Icterus gularis</td>
<td>C2</td>
</tr>
<tr>
<td>Migrant Loggerhead Shrike</td>
<td>Lanius ludovicianus migrants</td>
<td>C2</td>
</tr>
<tr>
<td>Rose-throated Becard</td>
<td>Pachyramphus aqlaiæ</td>
<td>C2</td>
</tr>
<tr>
<td>Tropical Parula</td>
<td>Parula pitiayumi</td>
<td>C2</td>
</tr>
<tr>
<td>Mammals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mexican Long-tongued Bat</td>
<td>Choeronycteris mexicana</td>
<td>C2</td>
</tr>
<tr>
<td>Gulf Coast Hog-nosed Skunk</td>
<td>Conepatus leuconotus texensis</td>
<td>C1</td>
</tr>
<tr>
<td>Mountain Lion</td>
<td>Felis concolor</td>
<td>C2</td>
</tr>
<tr>
<td>Texas Margay</td>
<td>Felis wiedii cooperi</td>
<td>C1</td>
</tr>
<tr>
<td>Southern Yellow Bat</td>
<td>Lasiurus ega</td>
<td>E</td>
</tr>
<tr>
<td>Ocelot</td>
<td>Leopardus pardalis</td>
<td>E</td>
</tr>
<tr>
<td>Jaguarundi</td>
<td>Leopardus yaguarondi</td>
<td>E</td>
</tr>
<tr>
<td>Cave Myotis</td>
<td>Myotis velifer</td>
<td>E</td>
</tr>
<tr>
<td>White-nosed Coati</td>
<td>Nasua narica</td>
<td>E</td>
</tr>
<tr>
<td>Coue’s Rice Rat</td>
<td>Oryzomys couesi</td>
<td>C2</td>
</tr>
<tr>
<td>Jaguar</td>
<td>Panthera onca</td>
<td>E</td>
</tr>
<tr>
<td>West Indian Manatee</td>
<td>Trichechus manatus</td>
<td>E</td>
</tr>
<tr>
<td>Bottle-nosed Dolphin</td>
<td>Tursips truncates</td>
<td>T</td>
</tr>
<tr>
<td>Molluscs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas Hornshell</td>
<td>Popenaias popeii</td>
<td>C1</td>
</tr>
<tr>
<td>Insects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smyth’s Tiger Beetle</td>
<td>Cicindela chlorocephala smythi</td>
<td>C2</td>
</tr>
<tr>
<td>Sub-tropical Blue-black Tiger Beetle</td>
<td>Cicindela nigrocoerulea subtropica</td>
<td>E</td>
</tr>
<tr>
<td>Maculated Manfreda Skipper</td>
<td>Stallingsia maculosus</td>
<td>C2</td>
</tr>
<tr>
<td>Common Name</td>
<td>Scientific Name</td>
<td>Conservation Status</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>Fishes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>River Goby</td>
<td>Awaous banana</td>
<td></td>
</tr>
<tr>
<td>Fat Snook</td>
<td>Centropomus parallelus</td>
<td>WL</td>
</tr>
<tr>
<td>Rio Grande Darter</td>
<td>Etheostoma grahami</td>
<td></td>
</tr>
<tr>
<td>Rio Grande Darter</td>
<td>Etheostoma radiosum</td>
<td>T</td>
</tr>
<tr>
<td>Rio Grande Chub</td>
<td>Gila pandora</td>
<td>T</td>
</tr>
<tr>
<td>Blackfin Goby</td>
<td>Gobionellus atripinnis</td>
<td>E</td>
</tr>
<tr>
<td>Rio Grande Silvery Minnow</td>
<td>Hybognathus amarus</td>
<td>EX</td>
</tr>
<tr>
<td>Headwater Catfish</td>
<td>Ictalurus lupus</td>
<td>T</td>
</tr>
<tr>
<td>Chihuahua Catfish</td>
<td>Ictalurus sp.</td>
<td>C2</td>
</tr>
<tr>
<td>Opposum Pipefish</td>
<td>Microphis brachyurus</td>
<td>T</td>
</tr>
<tr>
<td>Rio Grande Shiner</td>
<td>Notropis jemezanus</td>
<td>T</td>
</tr>
<tr>
<td>Phantom Shiner</td>
<td>Notropis orca</td>
<td>X</td>
</tr>
<tr>
<td>Bluntnose Shiner</td>
<td>Notropis simus</td>
<td>T</td>
</tr>
<tr>
<td>Shovelnose Sturgeon</td>
<td>Scaphirhynchus platorynchus</td>
<td>T</td>
</tr>
<tr>
<td>Texas Pipefish</td>
<td>Syngnathus affinis</td>
<td>WL</td>
</tr>
<tr>
<td><strong>Turtles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loggerhead</td>
<td>Caretta caretta</td>
<td>T</td>
</tr>
<tr>
<td>Atlantic Green Turtle</td>
<td>Chelonia mydas</td>
<td>E</td>
</tr>
<tr>
<td>Leatherback</td>
<td>Dermochelys coriacea</td>
<td>E</td>
</tr>
<tr>
<td>Atlantic Hawksbill</td>
<td>Eretmochelys imbricata</td>
<td>E</td>
</tr>
<tr>
<td>Texas Tortoise</td>
<td>Gopherus berlandieri</td>
<td>T</td>
</tr>
<tr>
<td>Atlantic Ridley</td>
<td>Lepidochelys kempi</td>
<td>E</td>
</tr>
<tr>
<td><strong>Lizards</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reticulated Collared Lizard</td>
<td>Crotaphytus reticulatus</td>
<td>T</td>
</tr>
<tr>
<td>Keeled Earless Lizard</td>
<td>Holbrookia propinqua</td>
<td>T</td>
</tr>
<tr>
<td>Texas Horned Lizard</td>
<td>Phrynosoma cornutum</td>
<td>T</td>
</tr>
<tr>
<td><strong>Snakes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scarlet Snake</td>
<td>Cemophora coccinea</td>
<td>WL</td>
</tr>
<tr>
<td>Black-striped Snake</td>
<td>Coniophanes imperialis</td>
<td>T</td>
</tr>
<tr>
<td>Indigo Snake</td>
<td>Drymarchon corais</td>
<td>T</td>
</tr>
<tr>
<td>Speckled Racer</td>
<td>Drymobius margaritiferus</td>
<td>WL</td>
</tr>
<tr>
<td>Northern Cat-eyed Snake</td>
<td>Leptodeira septentrionalis</td>
<td>T</td>
</tr>
<tr>
<td><strong>Salamanders</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Spotted Newt</td>
<td>Notophthalmus meridionalis</td>
<td>E</td>
</tr>
<tr>
<td>Rio Grande Lesser Siren</td>
<td>Siren intermedia texana</td>
<td>E</td>
</tr>
<tr>
<td><strong>Frogs and Toads</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giant Toad</td>
<td>Bufo marinus</td>
<td>WL</td>
</tr>
<tr>
<td>Sheep Frog</td>
<td>Hypopachus variolosus</td>
<td>T</td>
</tr>
<tr>
<td>White-lipped Frog</td>
<td>Leptodactylus labialis</td>
<td>E</td>
</tr>
<tr>
<td>Mexican Burrowing Toad</td>
<td>Rhinophrynus dorsalis</td>
<td>T</td>
</tr>
<tr>
<td>Mexican Treefrog</td>
<td>Smilisca baudinii</td>
<td>T</td>
</tr>
<tr>
<td>Rio Grande Chirping Frog</td>
<td>Syrrhophus guttulatus</td>
<td>WL</td>
</tr>
<tr>
<td>Common Name</td>
<td>Scientific Name</td>
<td>Conservation Status</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>Plants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vasey’s Adelia</td>
<td>Adelia vaseyi</td>
<td>E</td>
</tr>
<tr>
<td>South Texas Ambrosia</td>
<td>Ambrosia cheiranthifolia</td>
<td>E</td>
</tr>
<tr>
<td>Yellowshow</td>
<td>Amoreuxia wrightii</td>
<td></td>
</tr>
<tr>
<td>Prostrate Milkweed</td>
<td>Asclepias prostrata</td>
<td>T</td>
</tr>
<tr>
<td>Star Cactus</td>
<td>Astrophytum asterias</td>
<td>E</td>
</tr>
<tr>
<td>Kleyber’s Saltbrush</td>
<td>Atriplex klebergorum</td>
<td>E</td>
</tr>
<tr>
<td>Texas Ayenia</td>
<td>Ayenia limitaris</td>
<td>E</td>
</tr>
<tr>
<td>Chihuahua Balloon-vine</td>
<td>Cardiospermum dissectum</td>
<td>WL</td>
</tr>
<tr>
<td>Texas Windmillgrass</td>
<td>Chloris texensis</td>
<td>WL</td>
</tr>
<tr>
<td>Mission Fiddlewood</td>
<td>Citharexylum spathulatum</td>
<td>WL</td>
</tr>
<tr>
<td>Runyon’s Corycactus</td>
<td>Coryphantha macromeris var. runyonii</td>
<td>T</td>
</tr>
<tr>
<td>Lila De Los Llanos</td>
<td>Echeandia chandleri</td>
<td>WL</td>
</tr>
<tr>
<td>Small Yellow Alichoche</td>
<td>Echinocereus berlandieri var. angusticeps</td>
<td>T</td>
</tr>
<tr>
<td>Gregg’s Wild-buckwheat</td>
<td>Eriogonum greggii</td>
<td>WL</td>
</tr>
<tr>
<td>Jopoy</td>
<td>Esenbeckia runyonii</td>
<td>WL</td>
</tr>
<tr>
<td>Johnston’s Frankenia</td>
<td>Frankenia johnstonii</td>
<td>E</td>
</tr>
<tr>
<td>Plains Gumweed</td>
<td>Grindelia oolepis</td>
<td>WL</td>
</tr>
<tr>
<td>Runyon’s Waterwillow</td>
<td>Justicia runyonii</td>
<td>WL</td>
</tr>
<tr>
<td>Zapata Bladderpod</td>
<td>Lesquerella thamnophila</td>
<td>T</td>
</tr>
<tr>
<td>Runyon’s Huaco</td>
<td>Manfreda longiflora</td>
<td>T</td>
</tr>
<tr>
<td>Walker’s Manioc</td>
<td>Manihot walkerae</td>
<td>E</td>
</tr>
<tr>
<td>Falfurrias Milkvine</td>
<td>Matelea radiara</td>
<td>E</td>
</tr>
<tr>
<td>Few-spine Prickly-pear</td>
<td>Opuntia engelmannii</td>
<td>T</td>
</tr>
<tr>
<td>Texas Palmetto</td>
<td>Sabal mexicana</td>
<td>T</td>
</tr>
<tr>
<td>Montezuma Baldcypress</td>
<td>Taxodium mucronatum</td>
<td>E</td>
</tr>
<tr>
<td>Straw-spine Glory of Texas</td>
<td>Thelocactus bicolor var. flavidispinus</td>
<td>T</td>
</tr>
<tr>
<td>Ashy Dogweed</td>
<td>Thymoophylla tephroleuca</td>
<td>E</td>
</tr>
<tr>
<td>Bailey’s Ballmoss</td>
<td>Tillandsia baileyi</td>
<td>WL</td>
</tr>
</tbody>
</table>
Appendix D. Selected marsh plants (freshwater and salt water) indigenous to Hidalgo and/or Cameron counties suitable for wetland creation and restoration projects.

Selected Freshwater (salinity <0.5 ppt) Marsh Plants Indigenous to Hidalgo and/or Cameron Counties (Categorized by Maximum Water-Depth Tolerances)

Transitional – seasonally flooded

GRASSES
Andropogon glomeratus (bushy bluestem)
Distichlis spicata (coastal saltgrass)
Echinochloa crus-pavonis (Gulf cockspur)
Echinochloa muricata
Echinochloa polystachya
Eragrostis reptans (creeping lovegrass)
Eriochloa punctata (Louisiana cupgrass)
Leersia hexandra (clubhead cutgrass)
Leptochloa fascicularis (bearded sprangletop)
Leptochloa nealleyi (Neally sprangletop)
Leptochloa panicoides (Amazon sprangletop)
Leptochloa uninervia (Mexican sprangletop)
Panicum hians (gaping panicum)
Panicum hirsutum (hairy panicum)
Panicum virgatum (switchgrass)
Paspalum hartwegianum (Hartweg paspalum)
Paspalum lividum (longtom)
Paspalum pubiflorum (hairyseed paspalum)
Paspalum virgatum (talquezal)
Phalaris caroliniana (Carolina canarygrass)
Setaria parvifolia (knotroot bristlegrass)
Sporobolus buckleyi (Buckley dropseed)

FORBS
Amaranthus australis (southern water hemp)
Amaranthus rudis (Nuttall’s water hemp)
Bidens laevis (beggarticks)
Bidens odorata (beggarticks)
Callitriche nuttallii (water starwort)
Callitriche terrestris (water starwort)
Echinodorus berteroii (= E. rostratus; burhead)
Echinodorus cordifolius (burhead)
Eustoma evaluatum (bluebell gentian)
Hydrocotyle bonariensis (water pennywort; sombrerillo)
Selected Freshwater Marsh Plants Indigenous to Hidalgo and/or Cameron Counties (continued)

Justicia runyonii (Runyon’s waterwillow)
Polygonum lapathifolium (pale smartweed)
Rumex chrysocarpus (= R. berlandieri; dock)
Rumex crispus (curly-leaf dock)
Rumex pulcher (dock)

SHRUBS
Cephalanthus salicifolius (Mexican buttonbush)
Hydrolea spinosa (spiny hydrolea)

Shallow – seasonally flooded to permanently flooded to 15 cm
Bacopa monnieri (water hyssop)
Bacopa rotundifolia (disc water hyssop)
Carex brittoniana (sedge)
Callitriche nuttallii (water starwort)
Callitriche terrestris (water starwort)
Cyperus articulatus (joint-stem umbrella sedge)
Cyperus digitatus (finger umbrellasedge)
Cyperus elegans (umbrellasedge)
Cyperus macrocephalus (largehead umbrellasedge)
Cyperus ochraceus (umbrellasedge)
Cyperus odoratus (umbrellasedge)
Cyperus oxylepis (umbrellasedge)
Cyperus virens (umbrellasedge)
Eleocharis minima (spikerush)
Eleocharis parvula (spikerush)
Eurystemon mexicanum
Heteranthera dubia (mud plantain)
Heteranthera Liebmannii (water stargrass)
Heteranthera limosa (mud plantain)
Heteranthera reniformis (mud plantain)
Ludwigia octovalvis (water primrose)
Ludwigia peploides (water primrose)
Ludwigia repens (water primrose)
Marsilea macropoda (water clover)
Marsilea vestita (water clover)
Pluchea purpurascens (salt marsh fleabane)
Polygonum densiflorum (stout smartweed)
Polygonum pennsylvanicum (pink smartweed)
Polygonum persicaria (smartweed)
Polygonum punctatum (smartweed)
Polygonum setaceum (smartweed)
Schoenoplectus saximontanus (= Scirpus supinus; bulrush)
Selected Freshwater Marsh Plants Indigenous to Hidalgo and/or Cameron Counties (continued)

Mid-Depths – 15 to 50 cm water depths

*Eleocharis acicularis* (spikerush)  
*Eleocharis albida* (spikerush)  
*Eleocharis austrotexana* (spikerush)  
*Eleocharis cellulose* (spikerush)  
*Eleocharis interstincta* (spikerush)  
*Eleocharis montevidensis* (spikerush)  
*Eleocharis palustris* (syn. *E. macrostachya*; large spikerush)  
*Phragmites australis* (common reed)  
*Sagittaria longiloba* (flecha de agua)  
*Schoenoplectus americanus* (=Scirpus olneyi; Olney bulrush)  
*Schoenoplectus californicus* (=Scirpus californicus; giant bulrush, tule)  
*Schoenoplectus pungens* (=Scirpus americanus; cronquist, American bulrush)  
*Schoenoplectus tabernaemontani* (=Scirpus validis; soft-stem bulrush)  
*Typha domingensis* (narrow-leaf cattail)

Deep – 50 to 100 cm water depths

ROOTED FLOATING  
*Eichornia crassipes* (water hyacinth)  
*Nelumbo lutea* (yellow lotus)  
*Nymphaea elegans* (blue water lilly)  
*Nymphaea mexicana* (yellow water lilly)

SUBMERGENT  
*Ceratophyllum demersum* (coontail)  
*Najas guadalupensis* (southern naiad)  
*Najas marina* (naiad)  
*Potamogeton nodosus* (pondweed)  
*Utricularia biflora* (bladderwort)

Free-Floating  
*Azolla caroliniana* (water fern)  
*Azolla mexicana* (water fern)  
*Lemna valdiviana* (small duckweed)  
*Spirodela polyrhiza* (giant duckweed)  
*Wolflia columbiana* (water meal)  
*Wolffiella floridana* (mud midget)  
*Wolffiella gladiata* (mud midget)
**Selected Salt and Brackish Marsh Plants Indigenous to Hidalgo and/or Cameron Counties (Categorized by Maximum Water-Depth Tolerance)**

Salinity key:  
- **S** – tolerates salinity > 17.0 ppt;  
- **B** – tolerates salinity between 0.5 and 17.0 ppt;  
- **E** – tolerates either saline or brackish waters

**Transitional – seasonally flooded**

**GRASSES**
- *Andropogon glomeratus* (bushy bluestem) **B**
- *Distichlis spicata* (coastal saltgrass) **E**
- *Eriochloa punctata* (Louisiana cupgrass) **E**
- *Leptochloa fusca* **B**
- *Leptochloa uninervia* (Mexican sprangletop) **S**
- *Monanthochloë littoralis* (shoregrass) **E**
- *Panicum hirsutum* (hairy panicum) **B**
- *Paspalum denticulatum* **B**
- *Paspalum vaginatum* (seashore paspalum) **E**
- *Setaria parvifolia* (knotroot bristlegrass) **S**
- *Spartina alterniflora* (smooth cordgrass) **E**
- *Spartina patens* (wiregrass) **S**
- *Spartina spartinae* (Gulf cordgrass) **E**
- *Sporobolus virginicus* (seashore dropseed) **E**
- *Sporobolus wrightii* **E**

**FORBS**
- *Amaranthus australis* (Gulf Coast water hemp) **B**
- *Aster subulatus* (saltmarsh aster) **B**
- *Echinodorus berteroi (= E. rostratus; burhead) **B**
- *Eclipta prostrata* (hierba de tago) **B**
- *Eustoma evallatum* (bluebell gentian) **B**
- *Hydrocotyle bonariensis* (water pennywort; sombreroillo) **E**
- *Rumex chrysocarpus (= R. berlandieri; dock) **B**

**Shallow – seasonally flooded to permanently flooded to 15 cm**

- *Bacopa monnieri* (water hyssop) **B**
- *Bacopa rotundifolia* (disc water hyssop) **B**
- *Cyperus articulatus* (joint-stem umbrella sedge) **E**
- *Cyperus ochraceus* (umbrellasedge) **B**
- *Heteranthera dubia* (mud plantain) **B**
- *Marsilea vestita* (water clover) **B**
- *Pluchea purpurascens* (salt marsh fleabane) **E**

**Mid-Depths – 15 to 50 cm water depths**

- *Eleocharis austrotexana* (spikerush) **B**
- *Eleocharis interstincta* (spikerush) **B**
- *Schoenoplectus californicus (=Scirpus californicus; giant bulrush, tule) **B**
- *Schoenoplectus pungens (=Scirpus americanus; cronquist, American bulrush) **B**
- *Schoenoplectus tabernaemontani (=Scirpus validis; soft-stem bulrush) **B**
Selected Salt and Brackish Marsh Plants Indigenous to Hidalgo and/or Cameron Counties (continued)

*Scirpus robustus* (= *S. maritimus*; saltmarsh bulrush) **B**
*Typha domingensis* (narrow-leaf cattail) **E**

Deep – 50 to 100 cm water depths
ROOTED FLOATING
*Nymphaea mexicana* (yellow water lilly) **B**

SUBMERGENT
*Ruppia maritime* (widgeon grass) **E**
Appendix E. Common sources of funding used to support water quality and habitat conservation.

<table>
<thead>
<tr>
<th>Source</th>
<th>Grant Information</th>
<th>Web Link – CTRL + click to enter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Federal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRANTS.GOV</td>
<td>Portal for all federal grant programs. Search options and useful assistance</td>
<td><a href="http://www.grants.gov/">http://www.grants.gov/</a></td>
</tr>
<tr>
<td>US Environmental Protection Agency</td>
<td>This funding link identifies funding opportunities for watershed protection</td>
<td><a href="http://www.epa.gov/ogd/grants/funding_opportunities.htm">http://www.epa.gov/ogd/grants/funding_opportunities.htm</a></td>
</tr>
<tr>
<td></td>
<td>Wetland related grant opportunities identified at this USEPA website</td>
<td><a href="http://www.epa.gov/owow/wetlands/initiative/#financial">http://www.epa.gov/owow/wetlands/initiative/#financial</a></td>
</tr>
<tr>
<td>US Fish and Wildlife Service</td>
<td>Portal site into grant opportunities with USFWS</td>
<td><a href="http://www.fws.gov/grants/">http://www.fws.gov/grants/</a></td>
</tr>
<tr>
<td></td>
<td>The Coastal Program provides small grants to support coastal habitat conservation initiatives</td>
<td><a href="http://www.fws.gov/texascoastalprogram/">http://www.fws.gov/texascoastalprogram/</a></td>
</tr>
<tr>
<td>Natural Resource Conservation Service</td>
<td>Portal site into NRCS programs including granting program</td>
<td><a href="http://www.nrcs.usda.gov/programs/">http://www.nrcs.usda.gov/programs/</a></td>
</tr>
</tbody>
</table>
## Sources of Funding Support* - Arroyo Colorado Watershed Partnership

<table>
<thead>
<tr>
<th>Sources of Funding Support</th>
<th>Description</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wetlands Reserve Program</td>
<td><a href="http://www.nrcs.usda.gov/programs/wrp/">http://www.nrcs.usda.gov/programs/wrp/</a></td>
</tr>
<tr>
<td></td>
<td>Conservation Reserve Program</td>
<td><a href="http://www.nrcs.usda.gov/programs/crp/">http://www.nrcs.usda.gov/programs/crp/</a></td>
</tr>
<tr>
<td>State</td>
<td>Governor’s Office Portal for grants. Search functions, toolkits, and other resources</td>
<td><a href="http://www.governor.state.tx.us/divisions/stategrants/">http://www.governor.state.tx.us/divisions/stategrants/</a></td>
</tr>
<tr>
<td></td>
<td>Portal for funding opportunities through TCEQ. Many regional programs like Clean Rivers are funded through TCEQ.</td>
<td><a href="http://www.tceq.state.tx.us/nav/funding/funding_opps.htm">http://www.tceq.state.tx.us/nav/funding/funding_opps.htm</a> l</td>
</tr>
<tr>
<td></td>
<td>The Section 309 funding allows for grants to be used by participating partners to implement</td>
<td><a href="http://www.glo.state.tx.us/coastal(cmp/309/309grants.htm)">http://www.glo.state.tx.us/coastal(cmp/309/309grants.htm)</a></td>
</tr>
<tr>
<td></td>
<td>Coastal Management Program funds are used to support various priorities identified in the Coastal Management Plan</td>
<td><a href="http://www.glo.state.tx.us/coastal/grants/index.html">http://www.glo.state.tx.us/coastal/grants/index.html</a></td>
</tr>
<tr>
<td></td>
<td>Provides information on upcoming grant cycle for FY2006</td>
<td><a href="http://www.glo.state.tx.us/coastal/grants/cycle11.html">http://www.glo.state.tx.us/coastal/grants/cycle11.html</a></td>
</tr>
<tr>
<td></td>
<td>Coastal Impact Assistance Program is a program that utilizes federal revenues from offshore resource extraction to be applied to participating states. Funding may become available in 2007</td>
<td><a href="http://www.glo.state.tx.us/coastal/ciap/index.html">http://www.glo.state.tx.us/coastal/ciap/index.html</a></td>
</tr>
</tbody>
</table>
## Sources of Funding Support* - Arroyo Colorado Watershed Partnership

<table>
<thead>
<tr>
<th>Sources</th>
<th>Details</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texas Water Development Board</td>
<td>Clean Water State Revolving Fund Program</td>
<td><a href="http://www.twdb.state.tx.us/publications/forms_manuals/PGM_forms_main.asp#CWSRF">http://www.twdb.state.tx.us/publications/forms_manuals/PGM_forms_main.asp#CWSRF</a></td>
</tr>
<tr>
<td>Texas Parks and Wildlife Department</td>
<td>Portal for grant information</td>
<td><a href="http://www.tpwd.state.tx.us/business/grants/">http://www.tpwd.state.tx.us/business/grants/</a></td>
</tr>
<tr>
<td></td>
<td>Texas Recreation and Parks Account provides funding to communities across the state through its grant, assistance, education, and outreach programs.</td>
<td><a href="http://www.tpwd.state.tx.us/business/grants/trpa/">http://www.tpwd.state.tx.us/business/grants/trpa/</a></td>
</tr>
<tr>
<td></td>
<td>Creates cooperative partnerships between private property owners and wildlife biologists. The TPWD Landowner Incentive Program helps to protect endangered species and habitats found on private property.</td>
<td><a href="http://www.tpwd.state.tx.us/landwater/land/private/lip/">http://www.tpwd.state.tx.us/landwater/land/private/lip/</a></td>
</tr>
<tr>
<td>Other</td>
<td>National Fish and Wildlife Foundation</td>
<td><a href="http://www.nfwf.org/guidelines.cfm">http://www.nfwf.org/guidelines.cfm</a></td>
</tr>
<tr>
<td></td>
<td>General Matching Grant Program for fish and wildlife resource priorities</td>
<td><a href="http://www.nfwf.org/grant_apply.cfm">http://www.nfwf.org/grant_apply.cfm</a></td>
</tr>
<tr>
<td></td>
<td>Special Grant Programs – List 45 special grant sources administered by NFWF. Several have application to wildlife resources within the Arroyo watershed.</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Funding sources may vary and are subject to change. It is recommended to check the websites for the most up-to-date information.
### Sources of Funding Support* - Arroyo Colorado Watershed Partnership

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Website Links</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate Wetland Restoration Partnership</td>
<td>A potential source of funding for coastal habitat restoration. CWRP has provided funding to the Bahia Grande Restoration Project in the Rio Grande Watershed</td>
<td><a href="http://www.coastalamerica.gov/text/cwrp.html">http://www.coastalamerica.gov/text/cwrp.html</a></td>
</tr>
<tr>
<td>Governor’s Office - Foundations</td>
<td>A list of and search function for Foundations</td>
<td><a href="http://www.governor.state.tx.us/divisions/stategrants/foundations/view">http://www.governor.state.tx.us/divisions/stategrants/foundations/view</a></td>
</tr>
</tbody>
</table>

* Funding sources change and new opportunities are always presenting themselves. This table is only valid as of February 24, 2006.