SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Executive Summary

Kissimmee River Restoration Studies

Volume I
Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River

Volume II
Defining Success: Expectations for Restoration of the Kissimmee River

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South Florida Water Management District
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Introduction

The Kissimmee River is a shallow, low-gradient river in south-central Florida. Before it was channelized for flood control, the river meandered for approximately 103 miles (166 kilometers) between Lakes Kissimmee and Okeechobee (**Figure 1**) through the 750 square mile (1942 hectare) Lower Kissimmee Basin. In most years the river overflowed its banks, inundating much of its up to two-mile (three kilometer) wide floodplain from four to eleven months. These extended periods of flooding sustained a diverse mosaic of floodplain wetlands, which provided habitat for abundant waterfowl, wading birds, fish, and amphibians.

Hurricanes in the 1920s and 1940s caused extensive flooding in southern Florida, which in some instances resulted in great losses of life and property. For example, back-to-back hurricanes on September 17 and October 12 1947 flooded 246,847 acres (99,973 hectares) in the Kissimmee Basin for an extended period of time and caused over $1 million in damage. These events prompted Congress to authorize the Kissimmee portion of the Central and Southern Florida Flood Control Project in 1954 to provide flood protection for surrounding communities and agricultural interests. Between 1962 and 1971, a number of modifications were made to the Kissimmee River, including excavation of a central canal and installation of six water control structures that subdivided the canal into five impoundments, also known as pools.

These changes converted the meandering river into the 56-mile (90 kilometer) long, 30-foot (9 meter) deep, and 90-300 foot (27-91 meters) wide canal called **C-38** (**Figure 2**). The canal cut through the natural meanders of the original river channel, intercepting virtually all flow from the river and floodplain, leaving the disconnected remnant channels on both sides of the canal without flow, and the floodplain without natural seasonal inundation. The water control structures were designed to regulate flow of water through the canal and to keep water levels constant within each pool. Collectively, these modifications to the river are referred to in this document as channelization. The resulting floodplain, remnant river channels, and the C-38 canal are collectively referred to as the channelized system.

OVERVIEW: Kissimmee River Restoration Studies

Scientists at the South Florida Water Management District have completed two important milestones in the monitoring program associated with the Kissimmee River Restoration Project. These two volumes are the first in a new series of publications on the Kissimmee River Restoration Project.

Volume I. Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River. *Summarizes the results of pre-restoration studies that set a baseline for evaluating future changes associated with the restoration project.*

Volume II. Defining Success: Expectations for Restoration of the Kissimmee River. *Compiles performance measures that were developed to evaluate the success of the project at reaching its goal of reestablishing ecological integrity.*

The success of the flood control project was shadowed by the dramatic impacts of channelization on the wetland ecosystem. While the project successfully controlled flooding, it had a devastating impact on the ecology of the river and its surrounding floodplain by eliminating continuous flow in the river and seasonal inundation of the floodplain. The project resulted in the loss of over 19,500 acres (7,951 hectares) of wetlands; dramatic declines in bird, fish, and other animal populations that depended on the wetlands; and substantial degradation of water quality.

The impacts of the channelization project on the river's natural ecosystem and resources were so pronounced that they elicited a grassroots effort to restore the river even before the Kissimmee portion of the Central and Southern Florida Flood Control Project was completed. In 1972, just one year after construction was completed, the Central and Southern Florida Flood Control District (now known as South Florida Water Management District) held the first public hearing on the potential for restoration of the Kissimmee River. Later in the 1970s, the Governor's office, state legislature, and federal government agencies endorsed the concept of restoration.

The U.S. Congress passed the Water Resources Development Act of 1992, which authorized ecosystem restoration of the Kissimmee River (Kissimmee River Restoration Project) and changes to several lakes in the upper basin of the watershed to support the river restoration (Headwaters Revitalization Project). The Kissimmee River Restoration Project dealt with modifications to canal C-38 and to the water control structures in the lower basin. The Headwaters Revitalization Project authorized modifications to Lakes Kissimmee, Hatchineha, Cypress, and Tiger in the Upper Kissimmee Basin to provide increased seasonal water storage so that releases to the Kissimmee River could be made more gradually and follow a more natural seasonal distribution. Recreating the natural seasonality of flow, especially to allow floodplain inundation for long periods that extend into the dry season, is essential to meeting the goals of the Kissimmee River Restoration Project. Headwaters Revitalization will have the additional benefit of increasing the quality and quantity of wetland habitat around the four upper basin lakes mentioned above.

A 1994 cost-sharing Project Cooperative Agreement (PCA) between the U.S. Army Corps of Engineers and the South Florida Water Management District combined the Kissimmee River Restoration Project and the Headwaters Revitalization Project into a single entity called the Kissimmee River Restoration Project. The agreement split the cost of the project evenly between the two agencies, assigning responsibility to the U.S. Army Corps of Engineers for design and construction; and to the South Florida Water Management District for real estate acquisition and restoration evaluation.

Land acquisition to acquire properties that could be flooded by the project, construction to restore the historic form of restored sections of river, and modifications in water operation schedules are the primary strategies to achieve the goals of the project. Plans to restore the Kissimmee River were developed based on several federal and state-sponsored studies. These studies examined approaches to meet the system's ecological needs while maintaining the same level of flood control as the channelized system.

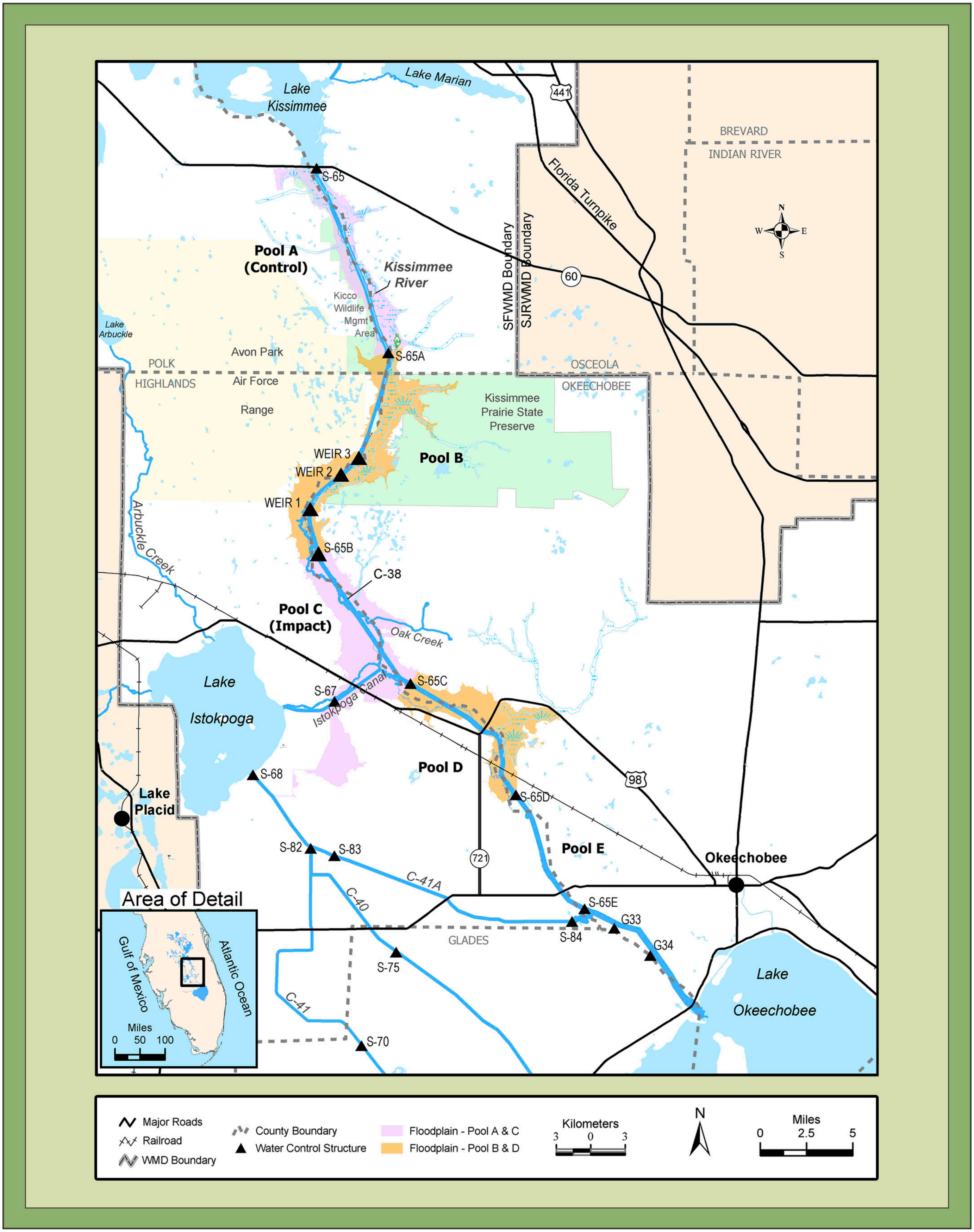


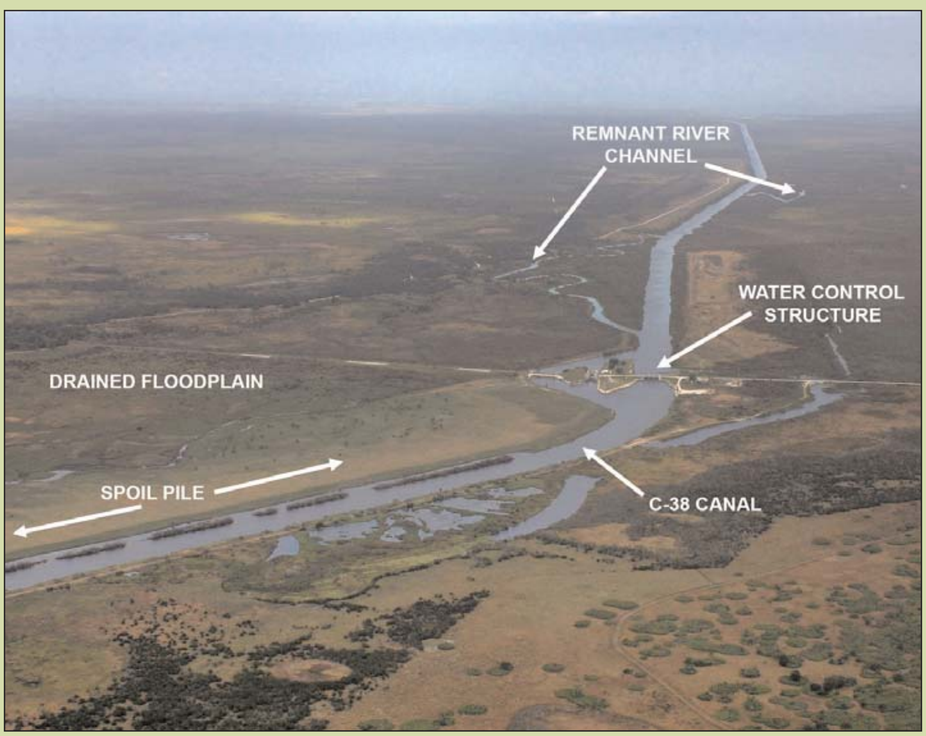
***Figure 1.** Location of the Kissimmee River in Florida. The C-38 canal cuts through the floodplain and intercepts the meandering river channel. The channelized system includes the floodplain, remnant river channels and the C-38 canal. The canal is divided into a series of five impounded pools (Pools A-E) by six water control structures (S-65 to S-65E). The Upper Chain of Lakes through Lake Kissimmee provides water to the Kissimmee River, which discharges into Lake Okeechobee.*

Figure 2. *Photographs of the Kissimmee River prior to channelization and after channelization.*

Prior to Channelization

- *Prior to channelization, the Kissimmee River seasonally overflowed its banks, flooding its broad floodplain.*
- *This "flood pulse" supported a diverse wetland ecosystem that provided habitat for abundant populations of invertebrates, fish, birds, and other animals.*
- *Water was conveyed downstream by both the river channel, and, when inundated, the floodplain.*

After Channelization



- *Channelization of the Kissimmee River involved the excavation of canal C-38 and installation of water control structures that divided the canal into five pools.*
- *The canal cut through the natural meanders of the original river channel, intercepting all flow from the river and floodplain, and leaving the remnant channels on both sides of the canal without flow and the floodplain without seasonal flooding.*
- *Although these remnant channels contained water, they were stagnant.*
- *Drier conditions over much of the floodplain resulted in former wetland plant communities converting to upland communities within a few years.*

Timeline of Significant Events Related to the Kissimmee River

1920s-1940s	*Hurricanes and flooding in the upper basin*
1954	*Congress authorizes Kissimmee portion of the Central and Southern Florida Flood Control Project*
1962-1971	*Central and Southern Florida Flood Control Project channelizes the Kissimmee River*
1971	*Governor's Conference on Water Management recommends restoration of the river*
1976	*Kissimmee River Restoration Act creates Kissimmee River Coordinating Council*
1978-1985	*First Federal Feasibility Study*
1983	*Coordinating Council recommends the backfilling plan*
1984-1990	*Kissimmee River Demonstration Project*
1986	*Water Resources Act mandates that enhancements to environmental quality in the public interest should be calculated as equal to other costs*
1988	*Kissimmee River Restoration Symposium adopts the ecological integrity goal*
1991	*Second Federal Feasibility Study recommends the level II backfilling plan*
1992	*Water Resources Act authorizes the Kissimmee River Restoration Project*
1994	*The District and the US Army Corps of Engineers sign Project Cooperative Agreement*
1994	*Construct test backfill and conduct high flow tests on backfill stability*
1996	*Headwaters Revitalization feasibility study completed*
1995-1999	*The District conducts baseline sampling*
1999-2001	*Phase I of backfilling*
2006-2012	*Phase II/III backfilling and Phase IV of backfilling*
2012	*Implementation of new headwaters stage regulation schedule*
2017	*Restoration monitoring concludes*

Construction for the Kissimmee River Restoration Project is divided into four major phases, which involve backfilling sections of the canal and removal of two water control structures. Phase I was initiated in 1999 and completed in February 2001. The final phase of project construction is expected to be completed by 2012. The new headwaters revitalization stage regulation schedule is scheduled for implementation in 2012 following completion of construction for the Kissimmee River Restoration Project (**see "Timeline" text box**). The PCA also requires the South Florida Water Management District to continue restoration evaluation monitoring for five years following completion of construction.

Among the expected benefits of the Kissimmee River Restoration Project are:

- maintenance of the same level of flood control as the channelized system;
- reconnection of 43 miles (69 kilometers) of continuous, meandering river channel;
- reestablishment of 40 square miles (104 square kilometers) of floodplain wetlands.

These habitat improvements are expected to benefit over 300 species of fish and wildlife.

THE RESTORATION EVALUATION PROGRAM

The Kissimmee River Restoration Project is one of the largest river restorations in the world. The project will restore approximately 40 square miles (104 square kilometers) of floodplain wetlands and will reconnect over 43 miles (69 kilometers) of meandering river channel. Construction components of the project will be completed over a projected 13 year period and will cost an estimated $578 million (in Fiscal Year 2004 dollars). Over 102,000 acres (40,500 hectares) of land have been acquired.

The project is noteworthy not only for its size and scope, but for its uncommon goal of reestablishing the ecology of the river and floodplain. While many restoration projects attempt to reconstruct critical habitat features for individual species, the Kissimmee River Restoration Project is one of the few in the world to attempt reestablishment of the integrity of an entire ecosystem. Reestablishment of ecological integrity means that the river and floodplain ecosystem's restored physical and chemical components will help drive recovery of the plant and animal communities associated with the river and floodplain before the Central and Southern Florida Flood Control Project.

Figure 3. *Projected timeline for major components of the Kissimmee River Restoration Project, including real estate acquisition, headwaters revitalization, Phases I through IV of backfilling and construction, restoration evaluation, and operational modeling.*

***Ecological Integrity** — The capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to natural habitat of the region.*

Because of its scope and significance, the Kissimmee River Restoration Project requires a comprehensive monitoring and evaluation program to assess the restoration project's success, as called for in the 1991 U.S. Army Corps of Engineers document, *Final Integrated Feasibility Report and Environmental Impact Statement: Environmental Restoration of the Kissimmee River, Florida* described later in this section. The studies presented in Volume I of the Kissimmee River Restoration Studies series, *Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River*, represent the basis of the South Florida Water Management District's Kissimmee River Restoration Evaluation Program, documenting studies of the channelized system before restoration began. These baseline studies will provide data for evaluating future changes that result from the Kissimmee River Restoration Project.

In addition to collecting data and reporting results, the studies contained in Volume I provide the data for the restoration expectations presented in Volume II, *Defining Success: Expectations for Restoration of the Kissimmee River*. Expectations are formal statements predicting responses of specific ecological attributes, such as fish and bird populations, or water quality, to restoration.

As a vital component of the restoration project, the evaluation program is designed to:

- determine if the project goals are being met;
- aid in the understanding of unexpected responses;
- guide management, both in later phases of the project and in future management of the restored ecosystem.

To accommodate these three objectives and the Kissimmee River Restoration Project's overall goal of reestablishing ecological integrity, the evaluation program includes many components focusing on four major categories of monitoring, as called for in the *Final Integrated Feasibility Report and Environmental Impact Statement*:

(1) **Ecological:** Ecological monitoring is intended to measure changes in attributes that would indicate the attainment of the ecological integrity goal. These attributes include water quality, vegetation, habitat, fish and wildlife, endangered species, and ecosystem functions such as energy flow and nutrient cycling.

(2) **Hydraulics:** Monitoring of water levels, velocities, and flows is needed to evaluate five specific hydrologic criteria for the restoration project, to support modeling for finalizing plans for the last phase of the project, to guide operations, and to aid in the interpretation of the results of other monitoring studies.

(3) **Sedimentation:** The restored river channel will consist of segments of remnant river channel reconnected across the backfilled canal. Monitoring is needed to determine if the managed flow regime results in erosion and deposition in the reconstructed river channel, leading to excessive sedimentation.

(4) **Stability of the restored river channel:** Similar to sedimentation, monitoring of cross-sections is needed to determine if the reconstructed river channel remains stable under the managed flow regime.

KEY ELEMENTS FOR RESTORATION EVALUATION

Selection of Metrics

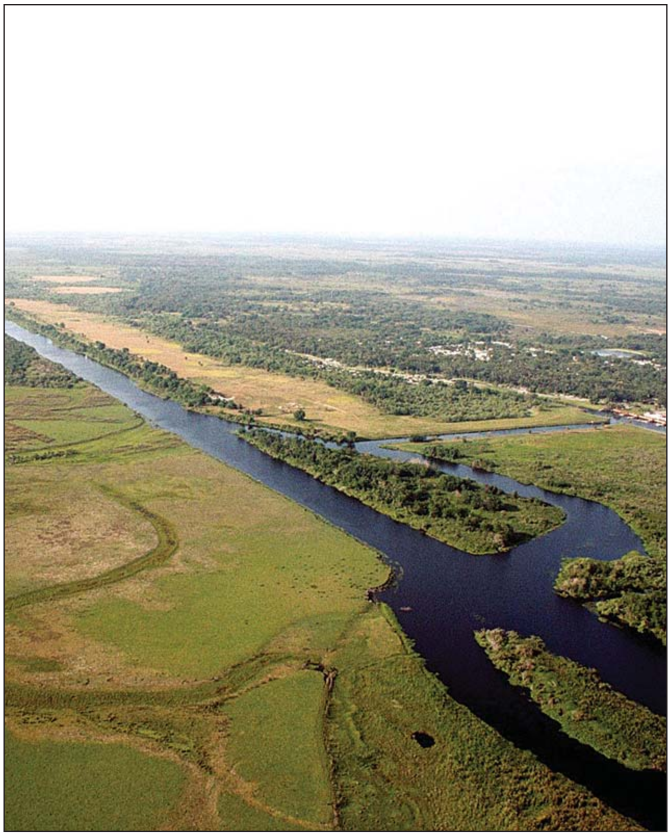
An important step in developing the evaluation program was to select metrics that could be used to measure attributes of the river and floodplain. For example, an attribute such as vegetation can be quantified with various metrics. The evaluation program is quantifying vegetation with metrics that describe the area of coverage (e.g., width of littoral (edge) vegetation beds in the river channel, area of wetlands on the floodplain) and metrics that describe changes in the species composition of plant communities (e.g., relative percent cover of emergent species in littoral plant communities; relative percent cover of plant species found in certain types of marsh). The metrics used in the evaluation program are indicators of progress towards reestablishment of ecological integrity. They were selected based on their ability to show measurable responses to channelization and restoration efforts.

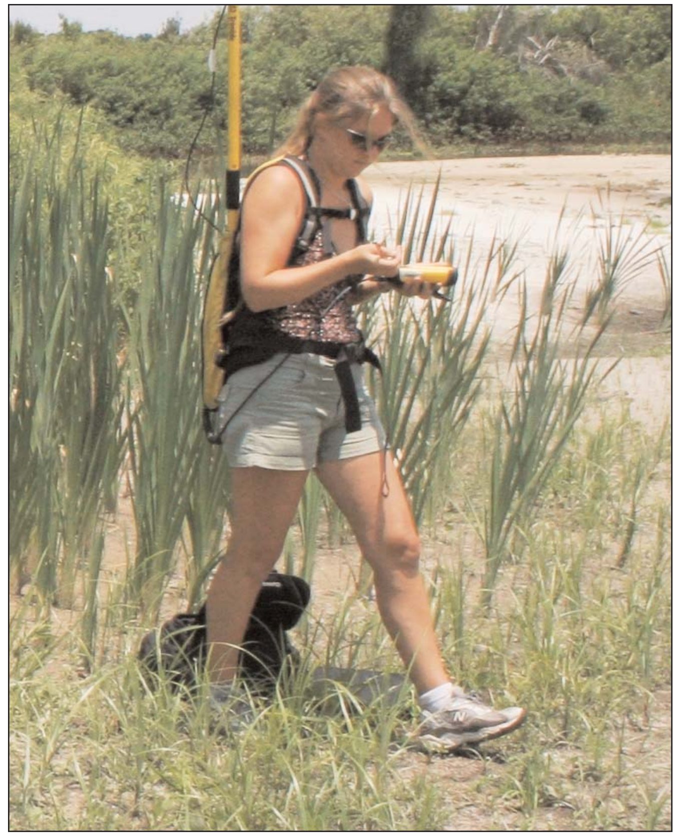
***Metric** — An environmental characteristic that can be measured over time to monitor, assess, manage, and communicate information about a project.*

Estimation of Baseline Conditions

Many restoration projects involve dramatic changes over time. However, being able to demonstrate that change has occurred necessitates collection of data before the restoration begins. Such pre-restoration data are used to establish baseline conditions for evaluating changes in the ecosystem that result from restoration. Most of the chapters in Volume I describe studies of the channelized system that were conducted during a baseline period between 1995 and 1999, immediately prior to Phase I of the restoration project, but some baseline conditions (used in the hydrology and water quality chapters) were determined from a longer record of channelized system data that began as early as 1972.

***Baseline Condition** — The state of the channelized system prior to the restoration project.*





Reference Conditions for Restoration Expectations

Monitoring of a metric over time can be used to detect changes in the ecosystem. To determine whether these changes represent improvements in the ecosystem, do not make a difference, or lead to further degradation, the current state of the system prior to restoration (baseline) must be compared to a reference condition (an estimate of pre-channelization conditions) that represents the ecosystem with ecological integrity. Ideally, the reference condition would be based on information about the Kissimmee River ecosystem prior to channelization. However, direct pre-channelization information was not available for many metrics. Therefore, in many cases reference conditions were based on information from other rivers or wetlands with similar characteristics that were relatively unimpacted, or data from an area of the Kissimmee River ecosystem where flow was experimentally reintroduced into a small section of river channel in the 1984-1990 Demonstration Project (see *Timeline of Significant Events* text box).

> ***Reference Condition*** *— The state of attributes with ecological integrity. This can be based on information from the pre-channelization river and floodplain, from other rivers and wetlands that are similar to the pre-channelization Kissimmee River, or from experimental data.*

Specific examples of methods used to estimate pre-channelization reference conditions include:

- pre-channelization aerial photography, used to determine the distribution of wetland plant communities on the floodplain and the distribution of sand bars in the river channel;
- data on oxygen concentrations from seven other rivers in the same watershed as the Kissimmee River;
- data on river channel sediments and littoral vegetation from sections of river to which flow had been reintroduced during the Demonstration Project.

Reference conditions were used both to interpret the impacts of channelization and also to develop specific expectations (predictions) for the restored ecosystem. These restoration expectations will be used to determine how successful the restoration of the Kissimmee River is within five years following completion of construction and implementation of the Headwaters Revitalization Project.

Distinguishing Restoration Effects from Other Causes of Change

Natural ecosystems change constantly, so it is important to distinguish between changes due to the restoration project and those due to other causes, such as shifts in climate or flood events. An approach employed in many of the baseline studies involved sampling a given metric in both the area selected for restoration and in a control area that will not be affected by the restoration project. Pool A of the Kissimmee River has been chosen as the control area because it is upstream of the restoration and C-38 will not be backfilled there. Remnant channels and floodplain in Pool A will therefore be minimally affected by the restoration project. Monitoring for several studies continues on a regular basis to provide data for making comparisons of the area of the restoration project relative to those in the control area before and after the restoration. This comparison process greatly assists in determining the most likely causes of change.

VOLUME I

ESTABLISHING A BASELINE: PRE-RESTORATION STUDIES OF THE CHANNELIZED KISSIMMEE RIVER

Volume I summarizes a group of studies of the channelized Kissimmee River and floodplain. These studies were conducted to establish a baseline for evaluating changes resulting from the restoration project. There are a total of 14 chapters in Volume I. The first chapter provides an overview of the restoration project and the evaluation program. The remaining 13 chapters present original baseline data collected in the channelized Kissimmee River ecosystem. Most of these chapters also present reference conditions for one or more metrics that were used to estimate the impacts of channelization on the natural river channel and floodplain.

Summary of Volume I

- *Baseline studies showed that channelization of the Kissimmee River altered hydrologic conditions in the natural river channel and on the floodplain.*
- *Hydrologic alterations resulted in the loss of flow in river channels and drastically reduced inundation of the floodplain.*
- *In remnant river channels, plant and animal communities became more similar to those of lakes and ponds than to those of free-flowing rivers.*
- *On much of the floodplain, wetland plant and animal communities were replaced by terrestrial communities.*

The ecological impacts of channelization resulted primarily from the loss of flow in remnant river channels and drainage of most of the floodplain. Baseline sampling was thus focused in remnant river channels and the floodplain, the two major habitats that had supported native communities of plants and animals prior to channelization. This sampling strategy allowed inferences to be made about changes in these habitats due to channelization by comparing baseline results with reference conditions. This strategy also established a baseline for evaluating future changes that will result from restored flow in the reconnected river channel and from restored inundation patterns on the floodplain.

Sampling Strategy

- *Ecological impacts of channelization resulted from loss of flow in remnant river channels and drainage of the floodplain.*
- *For this reason, baseline sampling was focused in remnant river channels and the floodplain.*

Highlights of each of the 13 baseline chapters are summarized below.

HYDROLOGY (Chapter 2)

The Central and Southern Florida Flood Control Project substantially altered the hydrology of the Kissimmee River. In Chapter 2, changes in rainfall, water level (stage), and flow were examined by comparing data collected at permanent stations in the river channel for up to 35 years before 1962, when excavation of the C-38 canal began, with data collected for up to 27 years after 1971, when channelization was completed. In general, these comparisons showed that channelization narrowed the range of stage variation in the river channel and floodplain, and resulted in flow being carried by the C-38 canal rather than the remnant river channels. Before channelization, flow in the river channel had a distinct seasonality with peak monthly discharges occurring in September-October. After channelization, flow in the C-38 canal was characterized by a decrease in wet season flows so that monthly discharge was more uniform throughout the year. Flow patterns in the C-38 canal were more erratic (especially by increasing the number of days with no flow) than in the river prior to channelization. This chapter also summarizes data collected during the baseline period by an enhanced hydrologic monitoring network, expanded to include floodplain stations, which was established for restoration evaluation.

Impacts of Channelization on the Hydrology of the River and Floodplain

- *Flow was carried by the C-38 canal rather than the remnant river channel, which was approximately only one-third the width and depth of the canal.*
- *Narrowed the range of water level (stage) variation in the remnant river channel.*
- *Caused more erratic flow patterns, especially by increasing the number of days with no flow.*
- *Decreased seasonality of flow, especially loss of peak monthly discharges in September-October.*
- *Greatly reduced the seasonality of water level fluctuation and extent of floodplain inundation.*

RIVER CHANNEL GEOMORPHOLOGY (Chapter 3)

The geomorphology study focuses on attributes of the river channel that are likely to respond directly to reestablishment of flow and that influence habitat quality for plants and animals using the river channel. These attributes include point bars, a type of sand bar associated with the inner edge of a bend in the river channel, and the accumulation of organic matter on the river bottom. Pre-channelization aerial photography revealed active formation of point bars on almost every meander bend, while aerial photography of the channelized system showed that none of the meanders in the study area had active point bars and that relict point bars were overgrown with vegetation. Sediment samples from remnant river channels showed that organic deposits were thicker and covered a larger portion of the channel than in the reference condition based on remnant channels with partially restored flow. These organic deposits altered the river channel by reducing average channel depth, increasing the width/depth ratio, and reducing channel cross-sectional area.

Impacts of Channelization on River Geomorphology

- *Absence of flow in remnant river channels due to channelization allowed organic matter to accumulate on the river channel bottom.*
- *Absence of flow in remnant river channels due to channelization ended active point bar formation in the river.*

DISSOLVED OXYGEN (Chapter 4)

Dissolved oxygen is essential to the metabolism of most aquatic organisms and in rivers is related to flow. Because oxygen needs vary by species, low dissolved oxygen levels can limit the species that occur in an aquatic system. Chronically low dissolved oxygen concentrations have been observed in the Kissimmee River system since channelization. In this study, the concentration of dissolved oxygen was measured in remnant river channels to establish a baseline for evaluating changes resulting from the restoration project. The baseline data showed very low concentrations of dissolved oxygen, averaging less than 2 mg/L. The baseline data were compared with reference data from seven streams located in or near the Kissimmee Basin that were less impacted than the Kissimmee River. These comparisons showed that the concentration of dissolved oxygen during the baseline period was lower than in the reference streams, which suggests that channelization and loss of flow substantially decreased the concentration of dissolved oxygen in remnant river channels.

Impacts of Channelization on Dissolved Oxygen

- *Loss of flow decreased the concentration of dissolved oxygen in remnant river channels to levels that adversely affected aquatic invertebrates and fish.*

WATER QUALITY (Chapter 5)

Water quality in the Kissimmee River and floodplain is influenced by activities and processes throughout its watershed, including the upper basin. This study characterized the baseline status of several key measures of water quality, including turbidity, total suspended solids (TSS), nutrient concentrations, and chlorophyll-a concentrations in remnant river channels and the C-38 canal. C-38 was sampled because it contained the only significant volume of water that flowed downstream.

Based on reference data from eight free-flowing streams in or near the Kissimmee Basin and knowledge of the Kissimmee River's pre-channelized characteristics, turbidity and TSS were estimated to be low prior to channelization. Turbidity and TSS have continued to be low after channelization and are expected to remain low after restoration.

Impacts of Channelization on Water Quality

- *Turbidity and suspended solids remained low after channelization.*
- *Loss of flow permitted occasional increases in chlorophyll-a concentrations (indicating algal blooms) in the remnant river channel.*
- *Channelization is believed to have facilitated nutrient transport from agricultural watersheds downstream to Lake Okeechobee.*
- *The nutrient evaluation is a "monitoring only" study. It includes no expectations because of the lack of suitable data on pre-channelization conditions. However, this monitoring will provide data to detect important changes in nutrient concentrations following restoration.*

Although data prior to canal construction are unavailable, C-38 is believed to have facilitated nutrient transport to Lake Okeechobee by improving drainage and allowing more intensive agriculture, especially in the lower part of the basin where agricultural lands draining to Pools D and E are the most concentrated sources of phosphorus. Because reference data for phosphorus and other water

quality parameters are unavailable, evaluation of these parameters was confined to description of baseline conditions. In remnant river channels and in C-38 (Pools A and C), median concentrations of chlorophyll-a, total phosphorus, total nitrogen, specific conductance, and pH were moderate during the 1996-1999 baseline period. Occasional increases in chlorophyll-a concentrations indicated the presence of algal blooms, which likely resulted from loss of flow. Variation in color, organic carbon, specific conductance, chloride, alkalinity, and pH reflected seasonality in headwater and tributary discharges. Higher ionic content and phosphorus concentrations in some river runs may have been indicative of agricultural inflows.

Total phosphorus concentrations at the upper four C-38 (gated) structures followed the trend of concentrations in Lake Kissimmee. Increased concentrations of phosphorus at S-65, coupled with high discharges from a succession of storms, resulted in disproportionately large phosphorus loading from S-65 in 1998. Phosphorus monitoring should continue for the next several years to determine if restoration is beneficial in reducing phosphorus loads downstream to Lake Okeechobee.

ALGAE (Chapter 6)

As primary producers, algae are key components of aquatic food webs. Algae also can play an important role in nutrient cycling and oxygen dynamics within river/floodplain systems. The species composition and biomass of algae in aquatic systems are affected by numerous factors, including nutrient availability and flow conditions. The baseline algal studies examined periphyton and phytoplankton communities in remnant river channels. Periphyton are algae attached to surfaces such as submerged aquatic vegetation; phytoplankton are algae suspended in the water column. Periphyton and phytoplankton communities in remnant channels were described using richness (the number of algal species present) and biovolume (a measure of the quantity of each species of algae present). Periphyton communities also were described by the percentage of algal cells that were rheophilic (thriving in flowing water environments). Data from baseline sampling, along with information from the scientific literature and best professional judgment, were used to characterize the impacts of channelization on the algal community. Channelization and loss of flow may have caused the dominant species of algae present in the river channel to shift from species normally found in flowing water environments (i.e., rivers and streams) to species that are commonly found in lakes and ponds.

Algae in the Channelized River

- *The algal community is dominated by species not typical of flowing water.*
- *The algae study is a "monitoring only" study. It includes no expectations because of the lack of suitable data on pre-channelization conditions.*
- *However, the study will provide monitoring data to detect important changes in the algae community following restoration.*

LITTORAL VEGETATION (Chapter 7)

Comparison of baseline and reference data sets for littoral (edge) vegetation suggests that the elimination of flow to remnant river channels brought about by channelization led to increases in the widths of littoral vegetation beds and changes in the composition of littoral plant communities. The cover of emergent species (plants rooted in the river bed with leaves reaching above the water surface) decreased relative to cover of floating and surface mat-forming plant species. This is because emergent species are able to resist dislocation by flowing water, while floating species are not. Loss of flow in remnant river channels likely precipitated a string of further effects associated with these changes in littoral vegetation, including interrelated effects on channel morphology,

Impacts of Channelization on Littoral Vegetation

- *Vegetation beds were much narrower on average (4 meters) under flowing conditions than in the remnant river channels after channelization (9 meters).*
- *After channelization, vegetation mats in some cases expanded to span the remnant river channel.*
- *Percent relative cover of floating and mat-forming species was on average substantially lower under flowing conditions (5%) than in the no-flow baseline period (50%).*

water quality, and wildlife habitat. Reestablishment of flow in remnant channels is expected to restore littoral vegetation to conditions more typical of flowing, pre-channelization conditions, in which littoral vegetation was limited to narrow zones near the edges of channels, and was dominated by emergent species.

FLOODPLAIN VEGETATION (Chapter 8)

The major components of pre-channelization floodplain wetlands were Broadleaf Marshes, Wet Prairie, and Wetland Shrub communities. This study describes the composition of these important plant communities, explains the methods used to collect baseline-period species data for future comparison with post-restoration data, and provides estimates of plant community changes that occurred as a result of loss of inundation of the floodplain following channelization. Detailed information on the species composition of pre-channelization plant communities was not available; therefore this study is a "monitoring-only" study; it will track changes in the species composition of floodplain communities that result from restoration of floodplain inundation.

> ***Species Composition of Floodplain Plant Communities***
>
> - *Following loss of floodplain inundation, many sampled locations known to have been wetlands prior to channelization converted to uplands.*
> - *The floodplain vegetation study is a "monitoring-only" study. It includes no expectations because of the lack of suitable data on pre-channelization conditions.*
> - *However, the study will provide monitoring data to detect important changes in the species composition of plant communities following restoration of floodplain inundation.*

VEGETATION CLASSIFICATION (Chapter 9)

A vegetation classification system specific to the Kissimmee River area was developed to ensure that plant communities of the Kissimmee River, its floodplain, and uplands are accurately and consistently described throughout the course of the Kissimmee River Restoration Project. The classification was developed using photointerpretation of 1996 aerial photography, associated field data, and two previous classifications of the Kissimmee River area that were developed prior to and immediately following channelization. The classification is hierarchical, including general categories (for example, "Shrublands") that encompass numerous plant communities within the category (for example "Wetland Shrub" communities), which in turn contains very specific types of plant communities that can be described and identified based on their dominant species (for example, "Carolina willow communities").

> ***Vegetation Classification***
>
> - *The Kissimmee River Vegetation Classification System provides a standard "vocabulary" for use in the vegetation mapping and other studies to describe the river, floodplain, and upland vegetation that is characteristic of the Kissimmee River.*
> - *The chapter describes:*
>   - *the background of the classification;*
>   - *vegetation categories;*
>   - *linkages with previous classifications of the Kissimmee River area;*
>   - *methods and decision rules used to apply the categories to vegetation data.*

FLOODPLAIN VEGETATION MAPPING (Chapter 10)

Vegetation maps were developed from aerial photographs of the river and floodplain taken before and after channelization. These maps were compared to evaluate changes in the distribution of plant communities on the floodplain. The maps describe floodplain vegetation prior to channelization (1954), three years after channelization, and 17 years after channelization (1996), which was immediately prior to Phase I of the Kissimmee River Restoration Project. Prior to channelization, the floodplain was dominated by wetland plant communities, primarily Broadleaf Marsh, Wet Prairie, and Wetland Shrub communities. Construction of the C-38 canal and diversion of channel and overbank flow to the canal resulted in loss of seasonal inundation of the floodplain and precipitated dramatic reductions in the area of wetland vegetation within a few years of completion of C-38 (**Figure** 4).

> ***Impacts of Channelization on Area of Major Floodplain Vegetation Types***
>
> - *Prior to channelization, wetland vegetation occupied over 80% of the floodplain area of Pools A, B, C, and D.*
> - *By 1974, three years after channelization was completed, over 60% of pre-channelization wetlands had disappeared and upland vegetation covered more than half of the original floodplain's area.*

AQUATIC INVERTEBRATES (Chapter 11)

Aquatic invertebrates play an integral role in aquatic ecosystem food webs and processes, including nutrient cycling and decomposition of detritus. Aquatic invertebrate communities were sampled in seven remnant river channel habitats and three floodplain habitats (woody shrub, broadleaf marsh, and floodplain woody debris). These habitats were selected because they were hypothesized to have been negatively impacted by channelization, and because aquatic invertebrate communities within these habitats were expected to show positive responses following restoration. This study indicates that channelization likely altered aquatic invertebrate community structure and functional characteristics in river channel and

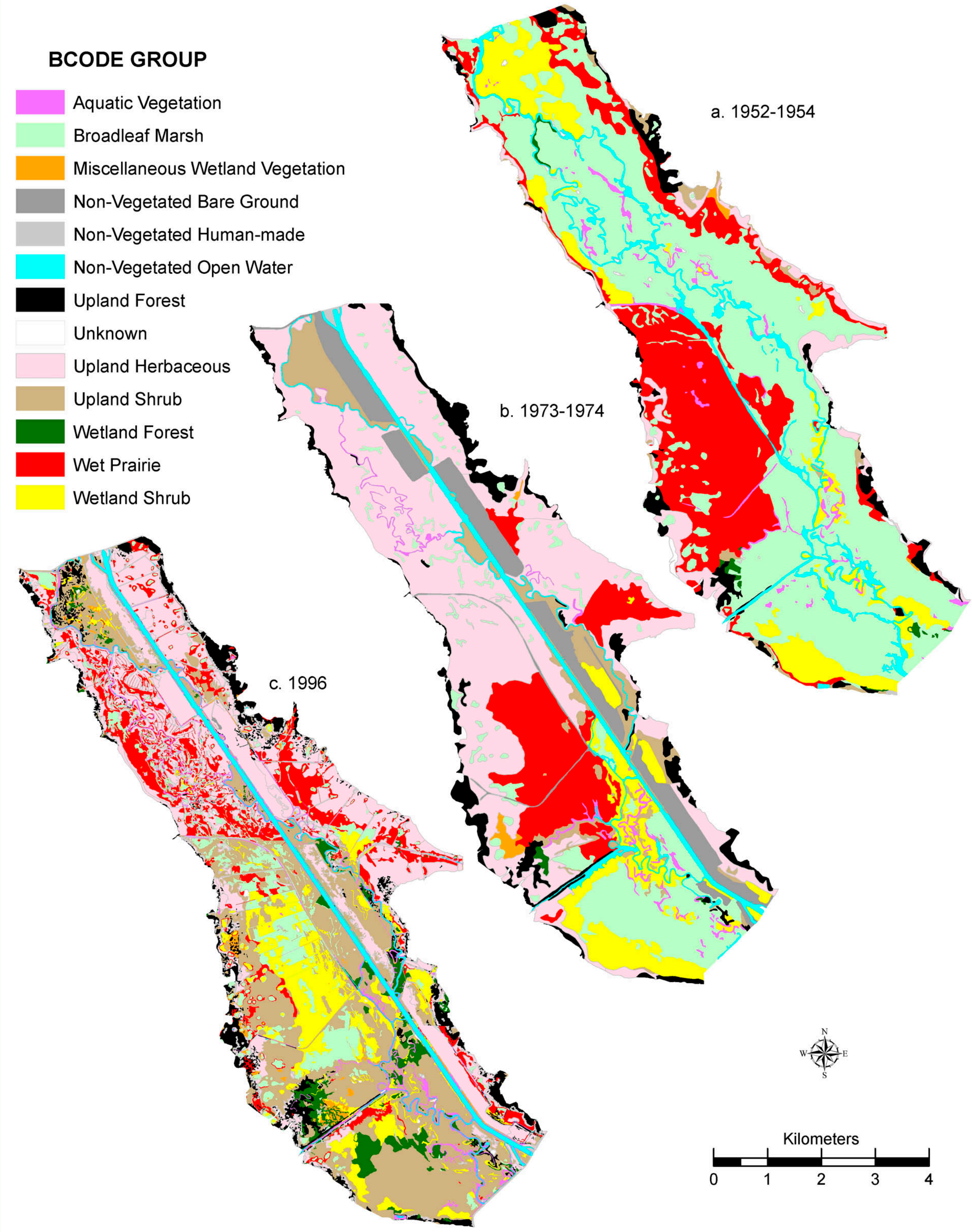


Figure 4. *Vegetation maps of Pool C: (a) 1952-1954 (pre-channelization, reference period) (data from Pierce et al. 1982); (b) 1973-1974 (early post-channelization) (data from Milleson et al. 1980); and (c) 1996 (post-channelization, baseline period).*

> ***Impacts of Channelization on Aquatic Invertebrates***
>
> - *Lack of flow resulted in a filter-feeding guild of invertebrates dominated by active-filtering microcrustaceans instead of passive-filtering macroinvertebrates, which are characteristic of free-flowing rivers.*
> - *Lack of flow resulted in invertebrate communities dominated by individuals belonging to taxa with broad ranges of ecological tolerances, and containing few individuals belonging to species typical of flowing water.*
> - *Shortened hydroperiods decreased invertebrate diversity and secondary production in floodplain wetlands.*

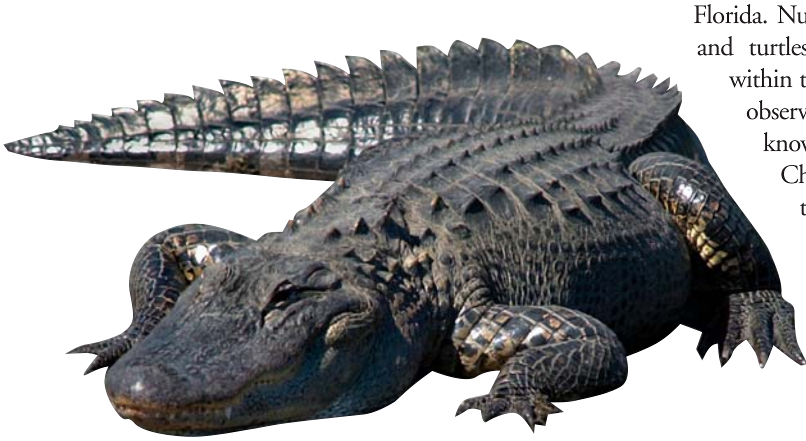
floodplain habitats. During the baseline period, aquatic invertebrates of remnant river channel habitats were representative of low-flow and depositional habitats rather than flowing water habitats. For instance, filtering-collector invertebrates that can account for up to 75% of mean annual density, biomass, and production on woody debris in free-flowing rivers accounted for less than 2% of mean annual density, biomass, and production in remnant river channels. Floodplain habitats (most of which were marshes prior to channelization) were dry during much of the baseline period. When compared to other marsh systems of Florida (e.g., water conservation areas and flatwoods marshes), these habitats were characterized by very low species richness and diversity.

AMPHIBIANS AND REPTILES (Chapter 12)

Amphibian and reptile (herpetofauna) communities can serve as indicators of the health of aquatic ecosystems, especially wetlands. Adult and larval herpetofauna are major consumers of invertebrates

> ***Impacts of Channelization on Amphibians and Reptiles***
>
> - *Amphibian and reptile community structure was severely altered in floodplain habitats, with many common and characteristic taxa absent from baseline surveys.*
> - *Channelization severely altered floodplain hydrology and patterns of amphibian reproduction in floodplain habitats.*
> - *Common and highly visible species typical of upland habitats in central Florida were absent from baseline surveys.*

and algae and, in turn, are prey for many invertebrates, fishes, and birds, as well as other amphibians and reptiles. Thus, they play an integral role in food web dynamics and energy flow through aquatic and terrestrial ecosystems. This study examined baseline characteristics of amphibians and reptiles in several altered floodplain habitats of the channelized Kissimmee River ecosystem. These habitats were selected because they were hypothesized to have been negatively impacted following channelization, and because they were expected to show significant positive responses following restoration. The 14 taxa observed in remnant wetland habitats account for less than 50% of all taxa likely to occur in natural wetlands of central Florida. Numerous species of treefrog, most water snakes, alligator, and turtles were conspicuously absent from remnant wetlands within the channelized system. Similarly, the 18 taxa captured or observed in upland habitats represent only 33% of species known to occur in upland hammocks of central Florida. Characteristic taxa such as box turtle, glass lizard, spadefoot toad, and several species of treefrog and rat snake were not observed during baseline studies. Comparisons between the distribution of amphibians and reptiles in the altered floodplain habitats with their distribution in undisturbed wetlands and upland habitats suggest that channelization severely impacted amphibian and reptile community structure and patterns of amphibian reproduction in floodplain habitats.



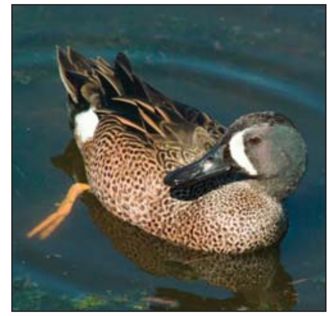
FISH COMMUNITIES (Chapter 13)

Fish communities are ecologically important components of river-floodplain ecosystems, and the species of game fish are highly valued by fishermen. This chapter compiles the results of several studies of varied attributes of fish communities in remnant river channels, the C-38 canal, and the floodplain, as well as diet analyses and larval fish sampling. Fish surveys were used to evaluate multiple metrics in habitats severely altered by channelization. Comparisons of baseline fish communities to pre-channelization communities indicate that floodplain and river channel fish community structure has shifted so that post-channelization communities in remnant river channels are dominated by fishes characteristic of still water systems, such as lakes, or of degraded conditions. One of the studies also found that sunfishes and bass comprised 38% of the fish community in the remnant river channels, while this group typically comprises 70% of the fish community in other peninsular Florida rivers. Additionally, fishing effort for largemouth bass as a percentage of the total effort by recreational fisherman has decreased by approximately 30%. Channelization impacts on floodplain fish communities include a decrease in the number of species occurring in floodplain marshes from 24 to 10 species and dominance by species that thrive in temporarily inundated or degraded wetland habitats.

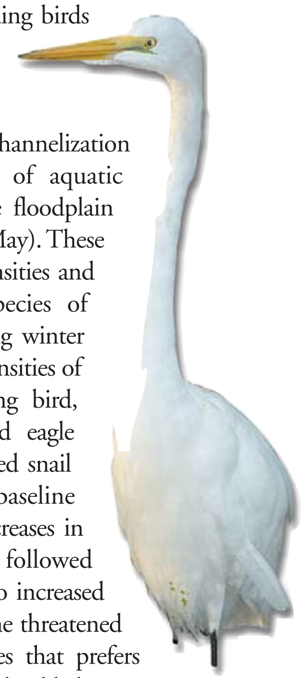
Impacts of Channelization on Fish

- *Riverine fish communities are dominated by species that are characteristic of non-flowing systems and/or degraded conditions.*
- *Sunfish and bass relative abundance declined by approximately 50%.*
- *Fishing effort for largemouth bass decreased by approximately 30%.*
- *The number of fish species occurring in floodplain marshes decreased from 24 to 10 species.*
- *Floodplain fish community shifted from a mix of species to dominance by species typical of temporarily inundated or degraded wetland habitats.*

BIRD COMMUNITIES (Chapter 14)



The avian community is an essential and often highly visible part of riverine/wetland ecosystems. Wetland birds are useful indicators of ecosystem change because they respond to many different environmental variables, including hydrology, vegetation structure, and food availability. This chapter reports the results of several studies related to wading birds and waterfowl, as well as investigations of protected species such as bald eagle, snail kite, Audubon's crested caracara, and wood stork. Aerial surveys were employed to estimate baseline and reference conditions for densities of wading birds and waterfowl using the floodplain. Comparisons were made between baseline and reference data to analyze the effects of channelization on wading birds and waterfowl; and to develop expectations for their responses to the restoration project. Baseline surveys (1996 – 1998) revealed that channelization substantially reduced the density of aquatic long-legged wading birds using the floodplain during the dry season (December – May). These surveys also showed much lower densities and that approximately nine fewer species of waterfowl used the floodplain during winter (November – March). In addition, densities of wood storks, an endangered wading bird, were uniformly low, and few bald eagle territories were found. No endangered snail kites were encountered during baseline airboat surveys, probably due to decreases in available foraging habitats that followed channelization. Channelization led to increased suitability of floodplain habitat for the threatened Audubon's crested caracara, a species that prefers a mixture of grassland/prairie and wetland habitats.



Impacts of Channelization on Birds

- *Dry season density of aquatic long-legged wading birds declined.*
- *Species richness and densities of overwintering waterfowl declined.*
- *Appropriate habitats for wood stork, bald eagle, and snail kites declined.*
- *Available habitat increased for Audubon's crested caracara, which prefers a mixture of terrestrial and wetland habitats.*

Summary of the Impacts of Channelization

Hydrology

- Flow was carried by the 30-foot deep C-38 canal rather than the original shallow river channel.
- Drastically narrowed the range of water level (stage) variation on the remnant river channel.
- Caused more erratic flow patterns, especially by increasing the number of days with no flow.
- Decreased seasonality of flow, especially loss of peak monthly discharges in September-October.
- Greatly reduced the seasonality of water level fluctuation and extent of floodplain inundation.

Geomorphology

- Absence of flow in remnant river channels due to channelization allowed organic matter to accumulate on the river channel bottom.
- Absence of flow in remnant river channels due to channelization ended active point bar formation in the river.

Water quality

- Turbidity and suspended solids remained low after channelization.
- Loss of flow permitted occasional increases in chlorophyll-a concentrations (indicating algal blooms) in the remnant river channel.
- Channelization is believed to have facilitated nutrient transport from agricultural watersheds downstream to Lake Okeechobee.
- The nutrient evaluation is a "monitoring only" study. It includes no expectations because of the lack of suitable data on pre-channelization conditions. However, this monitoring will provide data to detect important changes in nutrient concentrations following restoration.

Dissolved Oxygen

- Loss of flow decreased the concentration of dissolved oxygen in remnant river channels to levels that adversely affected aquatic invertebrates and fish.

Algae

- Algal community is dominated by species not typical of flowing water.
- The algae study was a "monitoring only" study. It included no expectations because of the lack of suitable data on pre-channelization conditions.
- However, the study will provide monitoring data to detect important changes in the algae community following restoration.

Littoral vegetation

- Vegetation beds were much narrower on average (4 meters) under flowing, pre-channelization conditions than in the no-flow baseline data (9 meters). During the baseline period, vegetation mats in some cases expanded to span the remnant river channel.
- Percent relative cover of floating and mat-forming species was on average substantially lower under flowing conditions (5%) than in the no-flow baseline period (50%).

Floodplain plant communities

- Following loss of floodplain inundation, many sampled locations known to have been wetlands prior to channelization had converted to uplands.

Mapping of floodplain wetlands

- Prior to channelization, wetland vegetation occupied over 80% of the floodplain area of Pools A, B, C, and D.
- By 1974, three years after channelization was completed, over 60% of pre-channelization wetlands had disappeared and upland vegetation covered more than half of the original floodplain's area.

Invertebrates

- Lack of flow resulted in a filter-feeding guild of invertebrates dominated by active-filtering microcrustaceans instead of passive-filtering macroinvertebrates which are, characteristic of free-flowing rivers.
- Lack of flow resulted in invertebrate communities dominated by individuals belonging to taxa with broad ranges of ecological tolerances, and containing few individuals belonging to species typical of flowing water.
- Shortened hydroperiods decreased invertebrate diversity and secondary production in floodplain wetlands.

Herpetofauna

- Amphibian and reptile community structure was severely altered in floodplain habitats, with many common and characteristic taxa absent from baseline surveys.
- Channelization severely altered floodplain hydrology and patterns of amphibian reproduction in floodplain habitats.
- Common and highly visible species typical of upland habitats in central Florida were absent from baseline.

Fish

- Riverine fish communities are dominated by species that are characteristic of non-flowing systems and/or degraded conditions.
- Sunfish and bass relative abundance declined by approximately 50%.
- Fishing effort for largemouth bass decreased by approximately 30%.
- The number of fish species occurring in floodplain marshes decreased from 24 to 10 species.
- Floodplain fish community shifted from a mix of species to dominance by species typical of temporarily inundated or degraded wetland habitats.

Birds

- Dry season density of aquatic long-legged wading birds declined
- Species richness and densities of overwintering waterfowl declined.
- Appropriate habitats for wood stork, bald eagle, and snail kites declined.
- Available habitat increased for Audubon's crested caracara, which prefers a mixture of terrestrial and wetland habitats.

VOLUME II

DEFINING SUCCESS: EXPECTATIONS FOR RESTORATION OF THE KISSIMMEE RIVER

Volume II is a compilation of 25 restoration expectations that were developed from reference and baseline data presented in Volume I. The expectations were developed to evaluate the Kissimmee River Restoration Project and guide future management of the restored river. This set of 25 expectations was derived from an initial set of 61 restoration expectations that were developed over an almost two-year period ending as the first phase of the restoration project was beginning in July 1999. This initial set of expectations was shortened to 25 expectations during several rounds of external and internal peer-review, primarily by combining related expectations and deleting those that lacked reference data. Volume II documents the development of each expectation and will serve as the definitive source of success criteria for the remainder of the restoration project. The restoration expectations can be used to evaluate restoration success and guide management because each expectation describes the anticipated response of an attribute of the ecosystem to the restoration project.

> ***Attribute*** *— Any of the non-living (abiotic) and living (biotic) components of an ecosystem.*

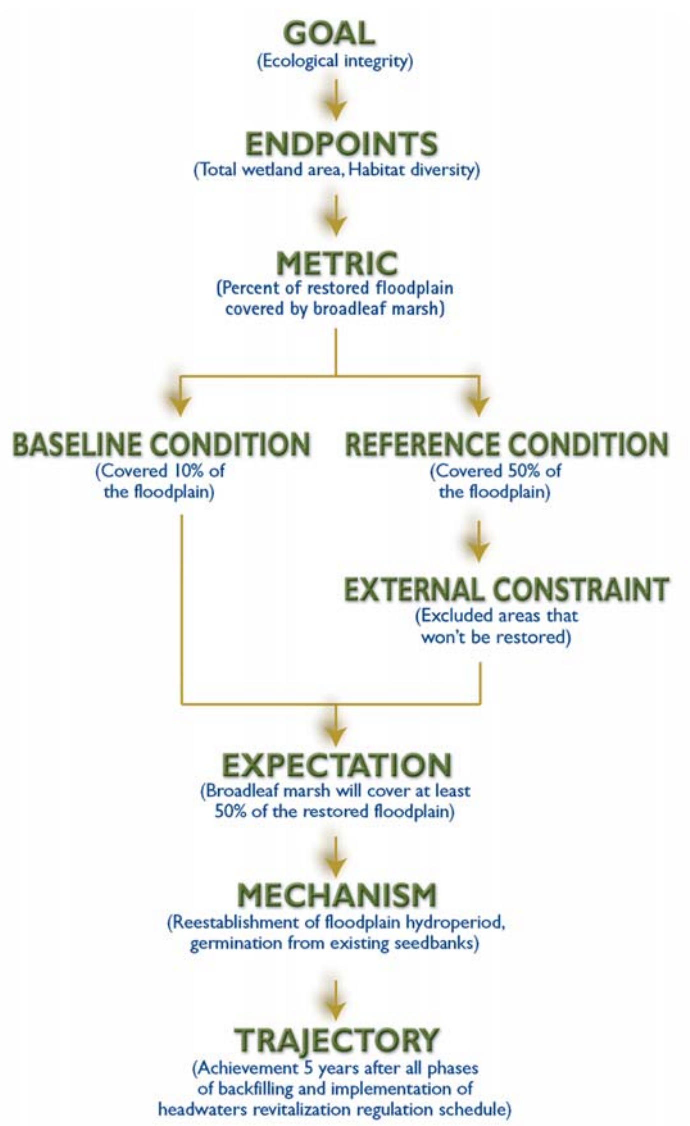


Figure 5. *Process or sequence of steps for developing a restoration expectation for Kissimmee River Restoration Project. Parentheses contain examples based on Expectation 13 for Areal Coverage of Broadleaf Marsh.*

Anticipated responses of individual attributes are based on the difference between the baseline condition of the channelized ecosystem and an estimate of the reference condition prior to channelization, before ecological integrity was lost. Abiotic attributes can include water, soils, and materials such as oxygen. Biotic attributes can include a population of a single species such as largemouth bass or a community of species such as the group of plant species that form a marsh wetland on the floodplain. Each attribute is described by at least one metric that indicates how the attribute is being quantified. The metric can be expressed in many different forms such as concentration, duration, flow, number of species, number of individuals, or area of coverage. It may also specify a location where the measurements will be made, such as on the floodplain; and a time period for making measurements, such as only during the wet season. Because the expectations specify predicted values for particular metrics, they can be tested with data collected in the future by the evaluation program.

RESTORATION EXPECTATIONS DEVELOPMENT

A major goal of Volume II was to document the development of each expectation in a standardized format. This format reflects the actual process used to guide the development of the expectations (**Figure 5**) and ensures that critical pieces of information are specified for each expectation. The common format also allows them to be reviewed and readily compared.

> ***Restoration Expectation*** *— A description of the condition of ecological integrity for one or more specific metrics that describe an attribute within the Kissimmee River ecosystem.*

As shown in **Figure 5**, the process of developing expectations begins with the goal of reestablishing ecological integrity. For purposes of developing restoration expectations, the time period before the Central and Southern Florida Flood Control Project represents ecological integrity in the Kissimmee Basin. The next step involved expressing the ecological integrity goal as a set of key characteristics of the system called endpoints. Each endpoint was represented by one or more metrics. For each metric, studies were conducted to collect data on remnant river channels or on the floodplain to establish the baseline condition. Reference conditions used to estimate pre-channelization conditions were identified from pre-existing data for each metric, and reference condition estimates were adjusted to account for constraints that are outside the influence of the restoration project. For example, the use of the restored ecosystem by highly mobile animals such as birds may be influenced by habitat conditions outside of the project area. The summary statement of an expectation is expressed as the difference between the baseline condition and the reference condition, adjusted for anticipated external constraints. For each expectation, a mechanism is proposed that outlines conceptually how the restoration project will cause the expectation to be achieved. Finally, a trajectory or appropriate time frame is identified for achieving the responses.

Expectations and Reference Conditions

- *Expectations were developed only when suitable reference data were available to estimate pre-channelization conditions.*
- *A number of attributes for which reference conditions were not available will be monitored because of their importance to the system, although expectations were not developed.*

OVERVIEW OF THE RESTORATION EXPECTATIONS FOR THE KISSIMMEE RIVER AND FLOODPLAIN

Expectations were developed for metrics for which reference conditions were found. Despite extensive efforts, adequate reference conditions were not found for some important attributes, such as phosphorus, algal communities, and the species composition of floodplain plant communities. Although these attributes lack expectations, they are and will continue to be monitored. The 25 expectations (see the inset boxes below) are written in a highly technical style to facilitate formal statistical testing. The following paragraphs provide more general descriptions of the expectations.

Hydrology, Geomorphology and Water Quality Restoration Expectations

The first nine expectations describe responses by non-living or abiotic attributes of the ecosystem, including hydrology (depth and flow of water), geomorphology (river channel characteristics), and water quality (dissolved oxygen and turbidity). These abiotic responses are important because they describe habitat conditions that will lead to responses by plants and animals. Of these nine, five are especially important because they describe the reestablishment of the hydrologic attributes (water level, velocity, and discharge) that will drive other responses to the restoration project. These hydrologic

expectations emphasize the maintenance of flow in the river channel throughout the year, with a seasonal pattern of increasing and decreasing flow as in the pre-channelization river. The hydrologic expectations also emphasize a natural pattern of water level fluctuation in the river and floodplain and a slow rate of water level recession after high-water events, allowing the floodplain to be inundated for long periods of time.

Two expectations describe geomorphic responses to changes in the transport and deposition of river channel sediments that reflect the reestablishment of pre-channelization flow. These changes will result in exposure of the natural sand sediments and active formation of point sand bars. These geomorphic responses are critical for reestablishing habitat for plants and animals in the river channel.

The last two abiotic expectations describe changes in two general indicators of water quality — concentration of oxygen dissolved in water, and water turbidity. Maintaining desirable concentrations of

Expectations for Hydrology

1) *The number of days that discharge is equal to 0 cfs in a water year will be zero for the restored channel of the Kissimmee River.*
2) *Intraannual monthly mean flows will reflect historic seasonal patterns and have interannual variability (coefficient of variation) 1.0.*
3) *River channel stage will exceed the average ground elevation for 180 d per water year and stages will fluctuate by 3.75 feet.*
4) *An annual prolonged recession event will be reestablished with an average duration 173 days and with peak stages in the wet season receding to a low stage in the dry season at a rate that will not exceed 1.0 ft (30 cm) per 30 days.*
5) *Mean velocities within the main river channel will range from 0.8 to 1.8 ft/s (0.2 to 0.6 m/s) a minimum of 85% of the year.*

Expectations for Geomorphology

6) *In restored river channels, mean thickness of substrate-overlying river bed deposits will decrease by 65%, percent of samples without substrate-overlying river bed deposits will increase by 165%, and the thickness of substrate-overlying river bed deposits at the thalweg (deepest point in the channel) will decrease by 70%.*
7) *Point bars will form on the inside bends of river channel meanders with an arc angle 70°.*

dissolved oxygen is important because it is essential to most aquatic organisms. The expectation for dissolved oxygen predicts increased concentrations of dissolved oxygen. In remnant river channels, the concentration of dissolved oxygen is chronically low because the lack of flow reduced the rate at which oxygen in the air dissolved into river water, and because dead plant material accumulated in the stagnant remnant channels.

Expectations for Water Quality

8) *Mean daytime concentration of dissolved oxygen in the Kissimmee River channel at 0.5–1.0 m depth will increase from 1–2 mg/L to 3–6 mg/L during the wet season (June–November) and from 2–4 mg/L to 5–7 mg/L during the dry season (December–May). Mean daily concentrations will be greater than 2 mg/L more than 90% of the time. Dissolved oxygen concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50% of the time.*
9) *Mean turbidity in the restored river channel will not differ significantly from mean turbidity in similar south Florida streams (3.9 NTU), and the median Total Suspended Solids concentration will not exceed 3 mg/L.*

The turbidity of water (an inverse measure of water clarity) is important because higher turbidity levels may indicate increases in sediment transport, limit light for submerged vegetation and attached algae, and decrease the efficiency with which some animals filter food from the water.

Vegetation Restoration Expectations

The remaining expectations focus on biological aspects of the Kissimmee River's restored channel and floodplain. All of the biotic expectations are valuable as biological indicators of restoration success, but many also serve as indicators of habitat conditions for other organisms. For example, vegetation is an important component of the habitat of many animals because it can serve as a food source and provide shelter. Invertebrates, amphibians, reptiles, and small fish are important food sources for larger animals such as largemouth bass and wading birds that occupy positions at the top of the food web.

Expectations for Vegetation

10) *Littoral vegetation beds will persist in restored river channels, but their mean widths will decrease to: (a) Five meters or less from the bank on inner channel bends. (b) Four meters or less from the bank on straight channel reaches.*
11) *Littoral plant community structure will undergo the following changes in restored river channels: (a) Combined mean relative cover of emergent species will increase to ≥80%. (b) Combined mean relative cover of floating and mat-forming species will decrease to ≤ 10%.*
12) *Wetland plant communities will cover ≥80% of the area of the restored floodplain in Phases I-IV.*
13) *Broadleaf marsh will cover at least 50% of the floodplain restored in Phases I-IV.*
14) *Wet prairie communities will cover at least 17% of the floodplain restored by Phases I-IV of the restoration project.*

Changes in plant communities in the restored river channel and floodplain are described by five expectations. In the restored river channel, vegetation cover is expected to decrease as a result of reestablishing continuous flow. The relative cover of emergent plant species should increase, and the relative cover of floating and mat-forming species should decrease. Expectations for plant communities on the floodplain predict increases in the total area of wetland plant communities, particularly broadleaf marsh and wet prairie, the two most common types of wetland found in this ecosystem.

Aquatic Invertebrates, Amphibians, and Reptiles Restoration Expectations

Aquatic invertebrates, amphibians, and reptiles will play many roles in the restored river floodplain ecosystem, especially because individual taxa will tend to occupy positions near the middle of the food web. Expectations for aquatic invertebrates describe changes in communities or guilds (i.e., a group of organisms using the same resources, such as consuming the same types of food) using measures of abundance and community structure in the restored river channel and on the floodplain.

The two expectations for amphibians and reptiles describe the richness (number of species) of the community in the restored ecosystem and the number of months out of the year that larval amphibians will be present in restored floodplain wetlands.

Expectations for Aquatic Macroinvertebrates

15) Macroinvertebrate drift composition will be dominated by Coleoptera, Diptera, Ephemeroptera, and Trichoptera.

16) The passive filtering-collector guild will account for the greatest proportion of mean annual density, mean annual biomass, and mean annual snag-dwelling macroinvertebrate production.

17) Aquatic macroinvertebrate species richness and species diversity will be ≥ 65 and ≥ 2.37 respectively, in restored broadleaf marsh (currently pasture in the channelized system).

18) The macroinvertebrate fauna of river channel benthic (bottom associated) habitats will primarily consist of taxa that are common and characteristic of sandy substrates.

Expectations for Amphibians and Reptiles

19) At least 24 wetland amphibian and reptile taxa will be found in broadleaf marsh habitats that have been restored from pasture.

20) Larval amphibians will be present for at least seven months each year in broadleaf marsh habitats that have been restored from pasture.

Fish and Bird Restoration Expectations

Fish and birds will also play diverse roles in the restored ecosystem, and some species belonging to these groups tend to occupy the highest positions in the food web. Fish and birds are especially important groups of animals because they include taxa that are significant to the local economy as recreational resources (game fish and waterfowl) and some, such as most wading birds, that are highly visible and valued by the public. Three expectations describe anticipated changes in the fish communities in the river channel and floodplain. These fish expectations describe increases in the abundance of small fish in restored marshes, a shift in the structure of the fish community in the river channel towards one more typical of a flowing water system, and an increase in the number of species and proportion of individuals occurring in restored marshes that are off-channel dependents (i.e., at least one stage in the life cycle is restricted to non-flowing, vegetated areas that are usually found in habitats off the main channel).

The expectations for bird communities call for increases in the number of long-legged wading birds during the dry season and for increases in the number of waterfowl species and total individuals during the winter.

Expectations for Fish

21) Mean annual density of small fishes (fishes ≤ 10 cm total length) within restored marsh habitats will be ≥ 18 fish/m^2.

22) Mean annual relative abundance of fishes in the restored river channel will consist of ≤ 1% Amia calva (bowfin), ≤ 3% Lepisosteus platyrhincus (Florida gar), ≥ 16% Lepomis auritus, redbreast sunfish, and ≥ 58% centrarchids (sunfishes).

23) Off-channel dependents will comprise ≥50% of fish assemblage composition in restored floodplain habitats and will be represented by ≥ 12 taxa. Young-of-the-year or juveniles will comprise ≥ 30% of the off-channel dependent guild.

Expectations for Birds

24) Mean annual dry season density of long-legged wading birds (excluding cattle egrets) on the restored floodplain will be ≥ 30.6 birds/km^2.

25) Winter densities of waterfowl within the restored area of floodplain will be ≥ 3.9 ducks/km^2. Species richness will be ≥ 13.

Expectations for the Kissimmee River Restoration Project

Hydrology

1) The number of days that discharge is equal to 0 cfs in a water year will be zero for the restored channel of the Kissimmee River.
2) Intraannual monthly mean flows will reflect historic seasonal patterns and have interannual variability (coefficient of variation) ≤1.0.
3) River channel stage will exceed the average ground elevation for 180 d per water year and stages will fluctuate by 3.75 feet.
4) An annual prolonged recession event will be reestablished with an average duration ≥173 days and with peak stages in the wet season receding to a low stage in the dry season at a rate that will not exceed 1.0 ft (30 cm) per 30 days.
5) Mean velocities within the main river channel will range from 0.8 to 1.8 ft/s (0.2 to 0.6 m/s) a minimum of 85% of the year.

Geomorphology

6) In restored river channels, mean thickness of substrate-overlying river bed deposits will decrease by ≥65%, percent of samples without substrate-overlying river bed deposits will increase by ≥165%, and the thickness of substrate-overlying river bed deposits at the thalweg (deepest point of the channel) will decrease by ≥70%.
7) Point bars will form on the inside bends of river channel meanders with an arc angle ≥70°.

Water Quality

8) Mean daytime concentration of dissolved oxygen in the Kissimmee River channel at 0.5–1.0 m depth will increase from ≤1–2 mg/L to 3–6 mg/L during the wet season (June–November) and from 2–4 mg/L to 5–7 mg/L during the dry season (December–May). Mean daily concentrations will be greater than 2 mg/L more than 90% of the time. Dissolved oxygen concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50% of the time.
9) Mean turbidity in the restored river channel will not differ significantly from mean turbidity in similar south Florida streams (3.9 NTU), and the median Total Suspended Solids concentration will not exceed 3 mg/L.

Vegetation

10) Littoral vegetation beds will persist in restored river channels, but their mean widths will decrease to: (a) Five meters or less from the bank on inner channel bends. (b) Four meters or less from the bank on straight channel reaches.
11) Littoral plant community structure will undergo the following changes in restored river channels: (a) Combined mean relative cover of emergent species will increase to ≥80%. (b) Combined mean relative cover of floating and mat-forming species will decrease to ≤10%.
12) Wetland plant communities will cover ≥80% of the area of the restored floodplain in Phases I-IV.
13) Broadleaf marsh will cover at least 50% of the restored floodplain in Phases I-IV.
14) Wet prairie communities will cover at least 17% of the floodplain restored in Phases I-IV of the restoration project.

Aquatic Macroinvertebrates

15) Macroinvertebrate drift composition will be dominated by Coleoptera, Diptera, Ephemeroptera, and Trichoptera.
16) The passive filtering-collector guild will account for the greatest proportion of mean annual density, mean annual biomass, and mean annual snag-dwelling macroinvertebrate production.
17) Aquatic macroinvertebrate species richness and species diversity will be ≥ 65 and ≥ 2.37 respectively, in restored broadleaf marsh (currently pasture in the channelized system).
18) The macroinvertebrate fauna of river channel benthic (bottom associated) habitats will primarily consist of taxa that are common and characteristic of sandy substrates.

Amphibians and Reptiles

19) At least 24 wetland amphibian and reptile taxa will be found in broadleaf marsh habitats that have been restored from pasture.
20) Larval amphibians will be present for at least seven months each year in broadleaf marsh habitats that have been restored from pasture.

Fish

21) Mean annual density of small fishes (fishes ≤10 cm total length) within restored marsh habitats will be ≥18 fish/m^2.
22) Mean annual relative abundance of fishes in the restored river channel will consist of ≤1% *Amia calva* (bowfin), ≤3% *Lepisosteus platyrhincus* (Florida gar), ≥16% *Lepomis auritus*, redbreast sunfish, and ≥58% centrarchids (sunfishes).
23) Off-channel dependents will comprise ≥50% of fish assemblage composition in restored floodplain habitats and will be represented by ≥12 taxa. Young-of-the-year or juveniles will comprise ≥30% of the off-channel dependent guild.

Birds

24) Mean annual dry season density of long-legged wading birds (excluding cattle egrets) on the restored floodplain will be ≥30.6 birds/km^2.
25) Winter densities of waterfowl within the restored area of floodplain will be ≥ 3.9 ducks/km^2. Species richness will be ≥13.

KISSIMMEE RIVER RESTORATION SUCCESS AND ADAPTIVE MANAGEMENT

The restoration expectations will be used to guide the evaluation of project success and modification or adaptation of management actions for the restored Kissimmee River and floodplain. Assessment of project success will consider all of the expectations, which collectively describe the state of a Kissimmee River and floodplain with ecological integrity. This assessment will also consider other information collected by the evaluation program, including monitoring information that may not be associated with specific restoration expectations.

Evaluation of the restoration expectations will provide feedback for adaptive management by indicating whether particular attributes are recovering to the predicted state within the specified appropriate time frame (**Figure 6**). Slower recovery of an attribute can serve as a trigger for analysis to determine why the response is occurring more slowly than anticipated and whether monitoring should be continued or modified. Such analyses would also consider if modifications to management actions, such as fine tuning of flow regimes, are necessary to facilitate recovery. Alternatively, these analyses may also lead to reevaluation of expectations.

> ***Adaptive Management** — An approach to the management of natural resources where management actions are monitored, evaluated, and used to adjust future management actions.*

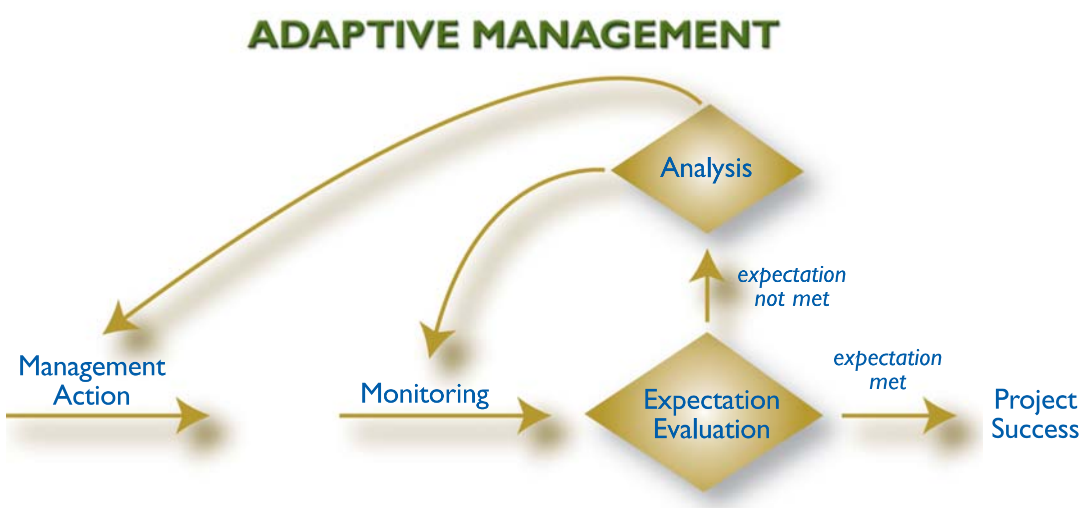


Figure 6. *Adaptive management is an iterative process that involves monitoring, evaluating expectations, and analysis to determine if monitoring should be continued, modified, or terminated; and whether management actions need to also be modified to achieve project success.*

KISSIMMEE RIVER RESTORATION:
L O O K I N G   F O R W A R D

This new series of publications on the Kissimmee River Restoration Program begins with two volumes that establish the foundations of the restoration evaluation program. Volume I, *Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River*, characterizes the condition of the channelized system and uses comparisons to reference conditions to identify metrics that indicate the impacts of channelization and that should be most useful for evaluating the restoration project. Volume II, *Defining Success: Expectations for Restoration of the Kissimmee River*, summarizes the 25 expectations that can be used to evaluate the restoration project. Completion of restoration project construction is projected for 2012, and monitoring for restoration evaluation is required by federal-state agreement to continue for an additional five years through 2017. As future project milestones are reached, additional publications or brochures will be added to this series.

The comprehensive analysis of data presented in these two volumes sets the stage for evaluation of the first phase of the restoration project by identifying specific metrics for measurement and time lines for evaluation. Coupling the understanding gained from the existing field monitoring program for restoration evaluation to the insights that will be gained from future hydrologic simulation analyses of basin operations will facilitate ongoing adaptive management and ultimately will result in greater integration of Kissimmee watershed management with the Kissimmee River Restoration Project. Integration of management practices will be essential for addressing the pressing and sometimes conflicting issues associated with flood control, water supply, water quality, and natural systems management in the Kissimmee watershed, which is predicted to increase in population size by approximately 90% over the next twenty years, making it the fastest growing region within the South Florida Water Management District boundaries.

For additional information on Kissimmee River Restoration please visit our website at: **www.sfwmd.gov**

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