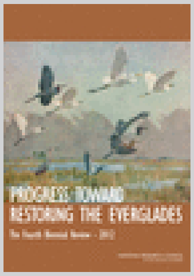


Progress Toward Restoring the Everglades: The Fourth Biennial Review, 2012

ISBN
978-0-309-25922-4

260 pages
7 x 10
PAPERBACK (2012)

Committee on Independent Scientific Review of Everglades Restoration Progress; Water Science and Technology Board; Board on Environmental Studies and Toxicology; National Research Council

PROGRESS TOWARD RESTORING THE EVERGLADES

The Fourth Biennial Review - 2012

Committee on Independent Scientific Review of Everglades Restoration Progress

Water Science and Technology Board

Board on Environmental Studies and Toxicology

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS   500 Fifth Street, NW   Washington, D.C. 20001

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competences and with regard for appropriate balance.

Support for this study was provided by the Department of the Army under Cooperative Agreement No. W912EP-04-2-0001. Support for this project was also provided by the U.S. Department of the Interior and the South Florida Water Management District. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

International Standard Book Number-13: 978-0-309-25922-4
International Standard Book Number-10: 0-309-25922-3

Cover credit: “Florida bird life.” Cover image courtesy of the University of Florida Digital Collections George A. Smathers Libraries, http://ufdc.ufl.edu.

Additional copies of this report are available for sale from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu/.

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

COMMITTEE ON INDEPENDENT SCIENTIFIC REVIEW OF EVERGLADES RESTORATION PROGRESS[1]

WILLIAM G. BOGGESS, *Chair*, Oregon State University, Corvallis
MARY JANE ANGELO, University of Florida, Gainesville
DAVID B. ASHLEY, University of Nevada, Las Vegas
CHARLES T. DRISCOLL, Syracuse University, New York
WILLIAM L. GRAF, University of South Carolina, Columbia
WENDY D. GRAHAM, University of Florida, Gainesville
SAMUEL N. LUOMA, University of California, Davis
DAVID R. MAIDMENT, University of Texas, Austin
DAVID H. MOREAU, University of North Carolina, Chapel Hill
SCOTT W. NIXON, University of Rhode Island, Kingston (through May 2012)
K. RAMESH REDDY, University of Florida, Gainesville
HELEN REGAN, University of California, Riverside
ELISKA REJMANKOVA, University of California, Davis
JEFFREY R. WALTERS, Virginia Polytechnic Institute and State University, Blacksburg

NRC Staff

STEPHANIE E. JOHNSON, Study Director, Water Science and Technology Board
DAVID J. POLICANSKY, Scholar, Board on Environmental Studies and Toxicology
MICHAEL J. STOEVER, Research Associate, Water Science and Technology Board
SARAH E. BRENNAN, Senior Program Assistant, Water Science and Technology Board

---

[1] The activities of this committee were overseen and supported by the National Research Council's Water Science and Technology Board and Board on Environmental Studies and Toxicology (see Appendix F for listing). Biographical information on committee members and staff is contained in Appendix G.

Acknowledgments

Many individuals assisted the committee and the National Research Council staff in their task to create this report. We would like to express our appreciation to the following people who have provided presentations to the committee and served as guides during the field trips:

Carlos Adorisio, South Florida Water Management District
John Anderson, U.S. House Water Resources and the Environment Subcommittee
Stu Appelbaum, U.S. Army Corps of Engineers
Nick Aumen, National Park Service
Ernie Barnett, South Florida Water Management District
Ronnie Best, U.S. Geological Survey
Samira Daroub, University of Florida Institute of Food and Agricultural Sciences
Stephen Davis, Everglades Foundation
Coby Dolan, Office of Rep. Debbie Wasserman-Shultz
Gretchen Ehlinger, U.S. Army Corps of Engineers
Shannon Estenoz, U.S. Department of the Interior
Evelyn Gaiser, Florida International University
Lawrence Gerry, South Florida Water Management District
Lawrence Glenn, South Florida Water Management District
Sara Gonzalez-Rothi, Office of Sen. Bill Nelson
Susan Gray, South Florida Water Management District
Matt Harwell, U.S. Fish and Wildlife Service (formerly)
Todd Hopkins, U.S. Fish and Wildlife Service
Don Jodrey, U.S. Department of the Interior
Robert Johnson, National Park Service
Bob Kadlec, Independent Consultant
Kelly Keefe, U.S. Army Corps of Engineers
Chris Kelble, National Oceanic and Atmospheric Administration
Dan Kimball, National Park Service

Greg Knecht, Florida Department of Environmental Protection
Steve Kopecky, U.S. Army Corps of Engineers
Kevin Kotun, National Park Service
Tom MacVicar, MacVicar, Federico, and Lamb
Philip Mancusi-Ungaro, U.S. Environmental Protection Agency
Cherise Maples, Seminole Tribe of Florida
Susan Markley, Miami-Dade County
Jeremy McBryan, South Florida Water Management District
Chris McVoy, South Florida Water Management District (formerly)
Melissa Meeker, South Florida Water Management District
Carol Mitchell, National Park Service
Gail Mitchell, U.S. Environmental Protection Agency
Temperince Morgan, South Florida Water Management District
Matt Morrison, South Florida Water Management District
Frank Nearhoof, Florida Department of Environmental Protection
Cal Neidrauer, South Florida Water Management District
Peter Ortner, University of Miami
Jon Pawlow, U.S. House Water Resources and the Environment Subcommittee
Gina Ralph, U.S. Army Corps of Engineers
Garth Redfield, South Florida Water Management District
Terrence “Rock” Salt, U.S. Department of the Interior (formerly)
Dan Scheidt, U.S. Environmental Protection Agency
Fred Sklar, South Florida Water Management District
Donato Surratt, National Park Service
Tom Teets, South Florida Water Management District
Karen Tippett, U.S. Army Corps of Engineers
David Tipple, U.S. Army Corps of Engineers
Joel Trexler, Florida International University
Bill Walker, Independent Consultant
David Wegner, U.S. House Water Resources and the Environment Subcommittee
Carol Wehle, South Florida Water Management District (formerly)
Paul Wetzel, Smith College
Walter Wilcox, South Florida Water Management District

Dedication

This report is dedicated to Dr. Scott W. Nixon (1943-2012), who served on the committee that authored this report until May 21, 2012, when he passed away suddenly. He was a valuable member of the committee. In particular, the committee and staff members will miss his good humor, patience, inquisitiveness, skepticism, perspective, and knowledge.

Dr. Nixon was professor of oceanography and UNESCO/Cousteau Chair in Coastal Ecology and Global Assessment at the University of Rhode Island, where he had been since he arrived as a post-doctoral research associate in 1969. He also had served as the director of Rhode Island Sea Grant. In addition to this committee, Dr. Nixon served on six other National Research Council (NRC) committees and on the NRC's Ocean Studies Board.

Held in high esteem by his colleagues, Dr. Nixon contributed not only his expertise but also brought a spirit of camaraderie to his service on NRC committees. However frustrated he might become with impenetrable documents and seemingly intractable problems, he never lost his humor and willingness to learn. His spirit and memory will continue as a model for NRC volunteers.

Preface

The South Florida ecosystem encompasses some of the world's largest, most diverse and distinctive wetland ecosystems, stretching more than 200 miles from Orlando to Florida Bay. The historical ecosystem consisted of a mosaic of sloughs and small lakes in the north that were linked by the meandering Kissimmee River floodplain to Lake Okeechobee, the Everglades headwaters. Lake Okeechobee fed the River of Grass as water flowed south through the pond apple forest, sawgrass plains, ridge-and-slough wetlands, tree islands, and marl prairies into the bays and estuaries. However, nearly 150 years of drainage, channelization, and flood control in support of agriculture, industry, and urban development have reduced the historical Everglades by more than half. Today, water historically destined for Everglades National Park must negotiate a maze of canals, levees, stormwater treatment areas, pump stations, and hydraulic control structures—approximately 40 percent (see NRC, 2010) never gets there because it is diverted via canals to the ocean or for other uses. Contaminants from agriculture, industry, and urban development have polluted the historically pristine waters with phosphorus, nitrogen, and mercury. Additionally, invasion by exotic species further compromises the system's ecological integrity.

In 1999, the state of Florida and the federal government agreed to a multi-decadal, multi-billion dollar Comprehensive Everglades Restoration Plan (CERP) to protect and restore the remaining Everglades while meeting the growing demands for water supply and flood control. The CERP is jointly managed by the U.S. Army Corps of Engineers (USACE) and the South Florida Water Management District (SFWMD). In authorizing the CERP, the U.S. Congress mandated periodic independent reviews of progress toward restoration of the Everglades natural system. The National Research Council's (NRC's) Committee on Independent Scientific Review of Everglades Restoration Progress, or CISRERP, was formed for this purpose in 2004.

This report, which is the fourth in a series of biennial evaluations that are expected to continue for the duration of the CERP, reflects the concerted efforts of 14 committee members and 4 NRC staff representing a wide range of scientific and engineering expertise. The committee met six times over an 18-month period, including four times in Florida and once in Washington, D.C. We reviewed a large volume of written material and heard oral presentations from state and federal agency personnel, academic researchers, interest groups, and members of the public. The committee's task is a daunting one, given the size and complexity of the Everglades ecosystem and corresponding scope of the CERP. I greatly appreciate the time, attention, and thought each committee member invested in understanding this complex system. I also appreciate their careful, rigorous analyses, expert judgment, constructive comments and reviews, and good humor with which they conducted their business. The report presents our consensus view of restoration accomplishments and emerging challenges primarily during the past 2 years but also over the 12 years since the project was authorized.

The committee is indebted to many individuals for their contributions of information and resources. Specifically, we appreciate the efforts of the committee's technical liaisons—David Tipple (USACE), Glenn Landers (USACE), Larry Gerry (SFWMD), and Robert Johnson (National Park Service)—who responded to numerous information requests and helped the committee utilize the vast resources of agency expertise when needed. Many others educated the committee on the complexities of Everglades restoration through their presentations, field trips, and public comments (see Acknowledgements).

The committee had the good fortune to be assisted by a dedicated and talented NRC staff including: Stephanie Johnson, David Policansky, Michael Stoever, and Sarah Brennan. Senior project officer, Stephanie Johnson, orchestrated the study for the NRC; her understanding of the science, engineering, and administrative aspects of the CERP, deft management skills, and ability to synthesize complex interrelationships are unparalleled. Scholar David Policansky's sage observations and illuminating questions were instrumental to the committee's deliberations and understanding of the complex Everglades ecosystem. Michael Stoever provided superb support during and between meetings and was instrumental in producing the final report. Sarah Brennan shared meeting support with Michael and attended to the complex logistical needs of the committee. Simply put, this report would not have been possible without the NRC staff's exceptional support and good humor. I know I speak for the entire committee in expressing our profound respect and appreciation.

This report was reviewed in draft form by individuals chosen for their breadth of perspectives and technical expertise in accordance with the procedures approved by the National Academies' Report Review Committee. The purpose of this independent review was to provide candid and critical comments to assist the institution in ensuring that its published report is scientifically credible and that it meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The reviewer comments and draft manuscript remain confidential to protect the deliberative process. We thank the following reviewers for their helpful suggestions, all of which were considered and many of which were wholly or partly incorporated in the final report: M. Siobhan Fennessy, Kenyon College; Elsa Garmire, Dartmouth College; Paul H. Glaser, University of Minnesota; Matthew C. Harwell, U.S. Environmental Protection Agency; Chris T. Hendrickson, Carnegie Mellon University; Wayne C. Huber, Oregon State University; Paul V. McCormick, Joseph W. Jones Ecological Research Center at Ichauway; Christopher McVoy, Independent Consultant; and Paul R. Wetzel, Smith College.

Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Kenneth W. Potter, University of Wisconsin. Appointed by the NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments received full consideration. Responsibility for the final content of this report rests entirely with the authoring committee and the NRC.

At the time of this writing, economic data suggest that economic recovery from the Great Recession of 2008 may finally be under way. However, state and federal budgets remain strained, and restoration has yet to begin in the core of the remnant Everglades 12 years after the CERP's initiation. The cost of restoration in both time and money continues to increase disproportionately as the ecosystem further degrades. There are signs of hope. Despite their financial difficulties the state and federal governments remain committed to the CERP, and even more promising, the recently announced Central Everglades Planning Project proposes to focus restoration on the core of the remnant Everglades and to pilot a new way of doing business that will expedite the planning process and get restoration projects implemented. The fate of this national treasure rests on their success. We offer this report in support of that grand endeavor.

William G. Boggess, *Chair*
Committee on Independent Scientific Review
of Everglades Restoration Progress (CISRERP)

Contents

APPENDIXES

Summary

The Florida Everglades, a large and diverse aquatic ecosystem, has been greatly altered over the past century by an extensive water control infrastructure, designed to increase regional economic productivity through improved flood control, urban water supply, and agricultural production. The remnants of the original Everglades now compete for vital water with urban and agricultural interests and are impaired by contaminated runoff from these two activities. The Comprehensive Everglades Restoration Plan (CERP), a joint effort led by the state and the federal government launched in 2000, seeks to reverse the decline of the ecosystem. This $13.5 billion project was originally envisioned as a 30- to 40-year effort to achieve ecological restoration by restoring the hydrologic characteristics of the Everglades, where feasible, and to create a water system that serves the needs of both the natural and the human systems of South Florida (Figure S-1).

The National Research Council (NRC) established the Committee on Independent Scientific Review of Everglades Restoration Progress (CISRERP) in 2004 in response to a request from the U.S. Army Corps of Engineers (USACE), with support from the South Florida Water Management District (SFWMD) and the U.S. Department of the Interior (DOI), based on Congress's mandate in the Water Resources Development Act of 2000 (WRDA 2000). The committee is charged to submit biennial reports that review the CERP's progress in restoring the natural system (see Box S-1). This is the committee's fourth report in a series of biennial evaluations.

The committee concludes that, 12 years into the CERP, little progress has been made on restoring the hydrology of the historical Everglades ecosystem; instead most of the recent progress has focused on the periphery. To reverse ongoing declines in the central Everglades, it will be necessary to expedite restoration planning and implementation in this area while integrating water quality and hydrologic improvements. The newly launched Central Everglades Planning Project offers an innovative approach to expedite restoration progress, although

FIGURE S-1 The South Florida ecosystem, which shares the same boundaries as the South Florida Water Management District.

SOURCE: © International Mapping Associates

BOX S-1
Statement of Task

This congressionally mandated activity will review the progress toward achieving the restoration goals of the Comprehensive Everglades Restoration Plan (CERP). The committee meets approximately four times annually to receive briefings on the current status of the CERP and on scientific issues involved in implementing the restoration plan, and it publishes biennial reports providing:

1. assessment of progress in restoring the natural system, which is defined by section 601(a) of WRDA 2000 as all the land and water managed by the federal government and state within the South Florida ecosystem;
2. discussion of significant accomplishments of the restoration;
3. discussion and evaluation of specific scientific and engineering issues that may impact progress in achieving the natural system restoration goals of the plan; and
4. independent review of monitoring and assessment protocols to be used for evaluation of CERP progress (e.g., CERP performance measures, annual assessment reports, assessment strategies, etc.).

additional rigorous analyses at the interface of water quality and quantity will be essential to maximize restoration benefits.

RESTORATION PROGRESS

The CERP, led by the USACE and the SFWMD, consists primarily of projects to increase storage capacity (e.g., conventional surface-water reservoirs, aquifer storage and recovery, in-ground reservoirs), improve water quality (e.g., stormwater treatment areas [STAs]), reduce loss of water from the system (e.g., seepage management, water reuse), and reestablish pre-drainage hydrologic patterns wherever possible (e.g., removing barriers to sheet flow, rainfall-driven water management). The CERP builds upon other activities of the state and the federal government aimed at restoration (hereafter, non-CERP activities), many of which are essential to the success of the CERP in achieving its restoration goals.

During the past two years, notable progress has been made in the construction of Everglades restoration projects, with eight CERP projects now under construction. These projects include all of the first-generation projects authorized by Congress (Picayune Strand, Site 1 Impoundment, Indian River Lagoon-South, and Melaleuca Eradication) as well as two second-generation projects (C-111 Spreader Canal, Biscayne Bay Coastal Wetlands) and two third-generation projects (Loxahatchee River Watershed Restoration, Lakeside Ranch STA) being constructed solely with state funding. This level of construction, and the associated program funding for 2010-2011, reflect significant implementation progress since the committee's previous review. Several major project phases are nearing completion in 2012, including the C-111 Spreader Canal Western Project and the Picayune Strand Merritt Canal components, which are expected to deliver significant increments of restoration benefits upon completion. Progress is also being made on important non-CERP projects, including the Kissimmee River, Modified Water Deliveries to Everglades National Park, and the state's Long Term Plan for Achieving Water Quality Goals.

Nevertheless, as noted in previous committee reports, production of natural system restoration benefits within the Water Conservation Areas and Everglades National Park continues to lag behind restoration progress in other portions of the South Florida ecosystem. Early CERP implementation has largely focused on the periphery of the remnant Everglades, and in the most recent CERP project schedule, the projects with the greatest potential benefits to the remnant Everglades (e.g., decompartmentalization, seepage management, central Everglades storage) have been significantly delayed or remain uncertain.

For project components that have been implemented, the committee was generally unable to obtain rigorous analysis of incremental restoration benefits. In some cases, the only descriptions of progress are anecdotal accounts of vegetation changes or field observations of new water flows. **Effective assessment of restoration progress will depend on monitoring data that cover periods long enough to establish pre-project trends, followed by similar data after the project (or project component) is complete to determine the ecological changes that can be ascribed to the project.** Such a scientifically derived assessment of ecosystem response to project implementation is important to enhance the understanding of ecosystem recovery processes and may be useful to build public support for ongoing restoration efforts.

The Central Everglades Planning Project provides a means to expedite the realization of restoration benefits to the remnant Everglades while addressing major impediments inherent in the USACE project planning and approval process. The Central Everglades Planning Project is one of five USACE pilot projects nationwide that will test a new accelerated project planning process, with the goal of delivering an approved project implementation report to Congress within two years. The focus on the central Everglades (Water Conservation Area 3 and Everglades National Park) is appropriate for this pilot, given the urgent need to address ongoing ecosystem decline, as noted in NRC (2008). The Central Everglades Planning Project process allows for the combination of increments of multiple CERP projects (e.g., storage, seepage management, decompartmentalization) within a new planning framework to more easily identify their interdependence and system benefits. The pilot also intends to test new approaches for project planning, including clear, early scoping of analyses and decision-making criteria, early coordination with decision makers at all levels of USACE leadership, and reduced reliance on detailed analyses within a framework of risk-based decision making. The Central Everglades Planning Project appears to be an important step forward, responsive to earlier concerns of this committee (NRC, 2007, 2008, 2010), and consistent with the concept of incremental adaptive restoration (NRC, 2007). However, at completion of this report, the process remained at an early stage, and no specific project plans were available for the committee to review.

State-proposed projects to improve water quality represent an important step forward, with critical implications for restoration of attributes in the central Everglades impacted by high levels of phosphorus. Additional progress toward meeting water quality criteria appears likely, because the state and the federal partners have recently agreed upon additional water quality improvements for the Everglades Protection Area. These proposed features, however, address only current inflows to the Everglades, and do not provide water quality treatment for increased water volumes anticipated under the CERP.

If the pace of restoration progress is to be maintained, then an increased level of federal funding will be necessary for two reasons. First, large cuts to the SFWMD budget have already led to deferral of several large projects, and relatively modest outlays are projected over the next five years, mostly for water quality improvements to attain compliance with water quality criteria. Projected funding relies heavily on a drawdown of reserve funds to levels that, without other changes, will leave the SFWMD with little flexibility and limited capability to fund new CERP projects. Second, overall state CERP spending (including land purchases and expedited construction efforts) has vastly exceeded federal spending. Thus, even if the state could sustain prior levels of spending, the SFWMD might be reluctant to do so until the overall spending gap is reduced between the two partners. Nevertheless, the capacity for increased federal spending could be impacted by CERP cost-sharing requirements, because calculations of the cost-share balance do not include extensive state expenditures from land purchases and construction for projects that are not yet authorized.

Without congressional action, project authorization could soon become a major impediment to restoration progress. To receive federal funding, individual CERP projects must be authorized by Congress. To date, only three projects have been congressionally authorized under WRDA 2007, and one additional project is under construction with programmatic authorization from WRDA 2000. Four additional projects await authorization. Without a new WRDA, the federal government will be unable to maintain progress on several second-generation, state-expedited projects now under way (e.g., C-111 Spreader Canal, Biscayne Bay Coastal Wetlands). Also, authorizations affect the projects that are eligible for cost-share crediting. With no additional authorized projects and at current rates of federal spending, the federal creditable expenditures could exceed the state's in approximately three years, bringing the CERP to a standstill because federal cost-share creditable obligations may not exceed those of the state. If Congress does not authorize additional projects and the state does not increase spending, federal funding and project implementation would need to be sharply curtailed. Additional project authorizations (with accompanying project partnership agreements) could allow for more than $500 million of state CERP-related expenditures being credited as cost-shared funds.

Innovative, multi-species approaches have been applied to resolve local conflicts between species management and restoration management, but such conflicts are likely to continue, requiring flexible and innovative multi-species approaches applied at even larger spatial scales to avoid restoration delays and optimize restoration benefits. Examples of innovative multi-species approaches include the Everglades Restoration Transition Plan (ERTP) to address a conflict between the water management needs of endangered snail kites and Cape Sable seaside sparrows in Water Conservation Area (WCA)-3A and an approach to address a conflict between stormwater treatment area (STA) operations and protection of the nests of black-necked stilts and other migratory birds. Additional conflicts between the needs of endangered species and what is required to restore the ecosystem restoration are inevitable in the transition to a fully implemented CERP. A recent conflict between efforts to protect snail kite nests and STA operations illustrates how single species management could potentially compromise water management required for system restoration.

Trajectories

An assessment of the status and trajectories of 10 ecosystem attributes reveals that conditions for tree islands, ridge-and-slough landscape, snail kites, and peat continue to degrade and that cattail coverage continues to expand 12 years after the initiation of the CERP. These declines can be attributed to altered hydrology and/or the elevated supply of phosphorus in the remnant Everglades. Despite its ability to search throughout the Everglades ecosystem for suitable conditions, the Everglade snail kite has experienced a precipitous decline in numbers over the past 15 years and is in danger of extirpation.

The state's extensive phosphorus control efforts over the past two decades appear to be stabilizing or improving the current trends for several ecosystem components driven by phosphorus (e.g., periphyton, soil P). Cattail expansion, however, is continuing but at a decreasing rate in some areas (e.g., WCA-2). Implementation of STAs and best management practices has markedly decreased phosphorus loads to the WCAs, and interior phosphorus concentrations have decreased in WCA-2 and -3 in response to decreases in the concentrations of inflowing waters. Despite this progress, impacted areas of the WCAs consistently fail the four-part test for compliance with Florida's water quality standards. Thus, it is widely recognized that additional water quality improvements are needed to prevent further degradation and reverse ongoing adverse impacts to the ecosystem caused by elevated phosphorus.

In contrast, the restoration of flows in the central Everglades has been limited, and the ecosystem attributes most directly influenced by hydrologic factors continue to decline. In many cases, these ongoing losses can only be recovered over long time scales. The velocity, depth, and duration of water in the Everglades are important controlling factors for the distinctive terrain of the Everglades: tree islands, ridge-and-slough topography, and peat accumulations. These landscape components have been severely degraded by flow alterations during past decades. Recovering additional losses will require decades if not centuries. Of the many projects under construction, only Mod Waters (a non-CERP project) and the C-111 Spreader Canal (a CERP project) offer promise of direct, significant effects in the central Everglades.

Substantial *near-term* progress to address both water quality and hydrology in the central Everglades is needed to prevent further declines. Near-term progress that addresses only water quality *or* water quantity leads to continued system declines of many components. Additionally, many improvements in water quality are linked with improvements in water quantity. Thus, decisions on restoration project design and scheduling should not be viewed as simple tradeoffs between water quantity and water quality. Instead, this qualitative analysis points to the need for a more critical and comprehensive quantitative analysis using models and field data to evaluate management alternatives in an integrated manner (see Chapter 5). Also, it highlights the importance of stabilizing and ultimately reversing declines of attributes that would take a long time to recover, particularly if other aspects of the restoration depend on them. Because of its focus on the remnant Everglades and accelerated planning, the Central Everglades Planning Project conceptually provides promise for rehabilitating the remnant Everglades.

Science and Decision Making

Recent science synthesis efforts represent an impressive accomplishment, although clearer acknowledgment of conflicts and tradeoffs will be essential to maximize restoration success. Science synthesis is important to advance understanding among the scientific community, inform policy decisions for managers, and translate important findings for the interested public. Collectively, the recent science synthesis efforts, including the 2009 System Status Report, the Scientific and Technical Knowledge Gained report, and the Synthesis of

Everglades Research and Ecosystem Services (SERES) project, among others, successfully address all three of these audiences. Together, they present a relatively consistent view of the scientific principles relevant to the Everglades restoration. If the best aspects of these synthesis efforts can be combined and continued in an efficient, ongoing manner, then the effort can help policy makers coalesce around a common vision of scientific principles, key uncertainties, and challenges. In the future, the effectiveness of the synthesis effort could be improved by explicitly addressing tradeoffs, conflicts, and commonalities among water quality, water quantity, and ecosystem responses.

A comprehensive assessment of monitoring efforts is necessary to ensure that fundamental short- and long-term needs of the CERP are met and critical gaps are addressed in the most cost-effective manner. The recent large and sudden cuts to the RECOVER Monitoring and Assessment Program pose a risk to system-wide assessment, which is important to the success of Everglades restoration. However, previous NRC committees have raised questions about the ambitious list of indicators for monitoring relative to the likelihood of sustained funding. Recurring evaluations of all monitoring (not just RECOVER-funded monitoring) in support of the CERP should assess the usefulness of existing datasets and performance measures, consider emerging priorities, and explore opportunities for improved efficiency.

Progress has been made in the development of linked hydrologic and ecological models, but they remain largely unavailable to project planning, limiting the ability to evaluate differential benefits and impacts of restoration alternatives. No ecological models have been approved for use in benefits analysis for CERP, even though integrated ecological models provide an important tool to assist with project planning, particularly to assess the responses of critical performance measures to project design alternatives and to understand the restoration tradeoffs implicit in alternative plan approaches. If ecological models are to be available to support restoration planning and assessment, the CERP model development, testing, and review process should be accelerated so that models can move more quickly from development and testing in the research domain to application in support of restoration.

Integrated, or linked, water quality and ecological models are essential tools for exploring the benefits and impacts of project alternatives that affect water quality, water quantity, and habitat. **To identify project designs and implementation sequences that maximize restoration benefits and assess potential impacts, project-planning teams need to analyze a range of inflow water quality conditions, including those that exceed targeted levels.** The legal requirement that water quality constraints be met should not limit the modeling analyses of restoration alternatives under a range of conditions. Being overly cautious with respect to water quality *modeling* could prevent a thorough exploration of restoration options and limit the understanding of water quality constraints in hydrologic restoration projects.

Transparent and systematic mechanisms to build trust and incorporate a range of stakeholder preferences relevant to CERP implementation into decision support frameworks would help to clarify and reduce conflict and enhance transparency. The committee acknowledges recent steps toward establishing formal structured decision support tools for components of the CERP with an emphasis on weighing multiple objectives. Decision support frameworks that build trust and provide opportunities for deliberation and negotiation can also assist in identifying and reducing sources of conflict, although they cannot, on their own, eliminate persistent conflict. Hence, additional mechanisms may be needed to resolve conflict, or at the very least, a strategy should be set in place for moving forward in the face of conflict while considering conflicting values, preferences, and objectives.

OVERALL EVALUATION OF PROGRESS AND CHALLENGES

Over the past two years, the pace of restoration implementation has improved, although restoration remains focused along the periphery of the remnant Everglades. Degradation of the Water Conservation Areas and Everglades National Park continues because of the altered hydrology and poor water quality in the system. Substantial progress has been made over the past two decades to reduce phosphorus in the inflows. Moreover, state and federal governments have reached agreement on the additional steps necessary to meet the phosphorus criterion for existing flows. However, minimal progress has been made on restoring the water flows essential to restoring the remnant Everglades ecosystem. The altered flow regimes have plagued the Everglade snail kite, whose trajectory to near extirpation is tied to that of the overall system. Degradation of key hydrology-dependent ecosystem components, such as the ridge and slough and tree islands, continues relatively unabated, and further losses can only be recovered over long timeframes, if at all.

Saving the historical Everglades at this critical juncture requires a new approach. Key components of a new strategy include: 1) focusing on restoring the central core of the historical Everglades to reverse the ongoing degradation before it is too late; 2) ending the segregation of water quantity and quality and integrating water quantity and quality analyses that explore opportunities to accelerate restoration in the remnant Everglades; and 3) finding a new way to do business that avoids costly and unproductive delays in the project planning and authorization processes. The Central Everglades Planning Project is a promising new initiative focused on the remnant Everglades with the goal of greatly expediting the project planning process.

Impressive science synthesis efforts over the past few years have advanced scientific understanding and provided a solid scientific foundation for decision making. Investments in continued cutting-edge research, consolidated and timely synthesis, and effective monitoring are critical to supporting sound decisions for a restored Everglades. However, key challenges remain—in particular, conflicts at the interface of water quality and quantity that have been exacerbated by the continuing challenges in meeting the 10 ppb water quality criterion and the resulting delays in implementing hydrologic restoration. Additional use of integrated ecosystem modeling and decision support tools could facilitate restoration progress by clarifying these conflicts, identifying interim strategies for limiting further degradation of critical ecosystem components, and enhancing the capacity to address these conflicts in a more timely and integrated way.

1

Introduction

The Florida Everglades, formerly a large and diverse aquatic ecosystem, has been dramatically altered over the past century by an extensive water control infrastructure designed to increase regional economic productivity through improved flood control, urban water supply, and agricultural production (Davis and Ogden, 1994; NRC, 2005). Shaped by the slow flow of water, its vast terrain of sawgrass plains, ridges, sloughs, and tree islands used to support a high diversity of plant and animal life. This natural landscape also served as a sanctuary for Native Americans. However, large-scale changes to the landscape have diminished the natural resources, and by the mid- to late-20th century, many of the area's defining natural characteristics had been lost. The remnants of the original Everglades (see Figure 1-1 and Box 1-1) now compete for vital water with urban and agricultural interests, and contaminated runoff from these two activities impairs the South Florida ecosystem.

Recognition of past declines in environmental quality, combined with continuing threats to the natural character of the remaining Everglades, led to initiation of the Comprehensive Everglades Restoration Plan (CERP) in the late 1990s. This unprecedented project envisioned the expenditure of billions of dollars in a multi-decadal effort to achieve ecological restoration by reestablishing the hydrologic characteristics of the Everglades, where feasible, and to create a water system that simultaneously serves the needs of both the natural and the human systems of South Florida. Within the social, economic, and political latticework of the 21st century, restoration of the South Florida ecosystem is now under way and represents one of the most ambitious ecosystem renewal projects ever conceived. This report represents the fourth independent assessment of the CERP's progress by the Committee on Independent Scientific Review of Everglades Restoration Progress (CISRERP) of the National Research Council (NRC).

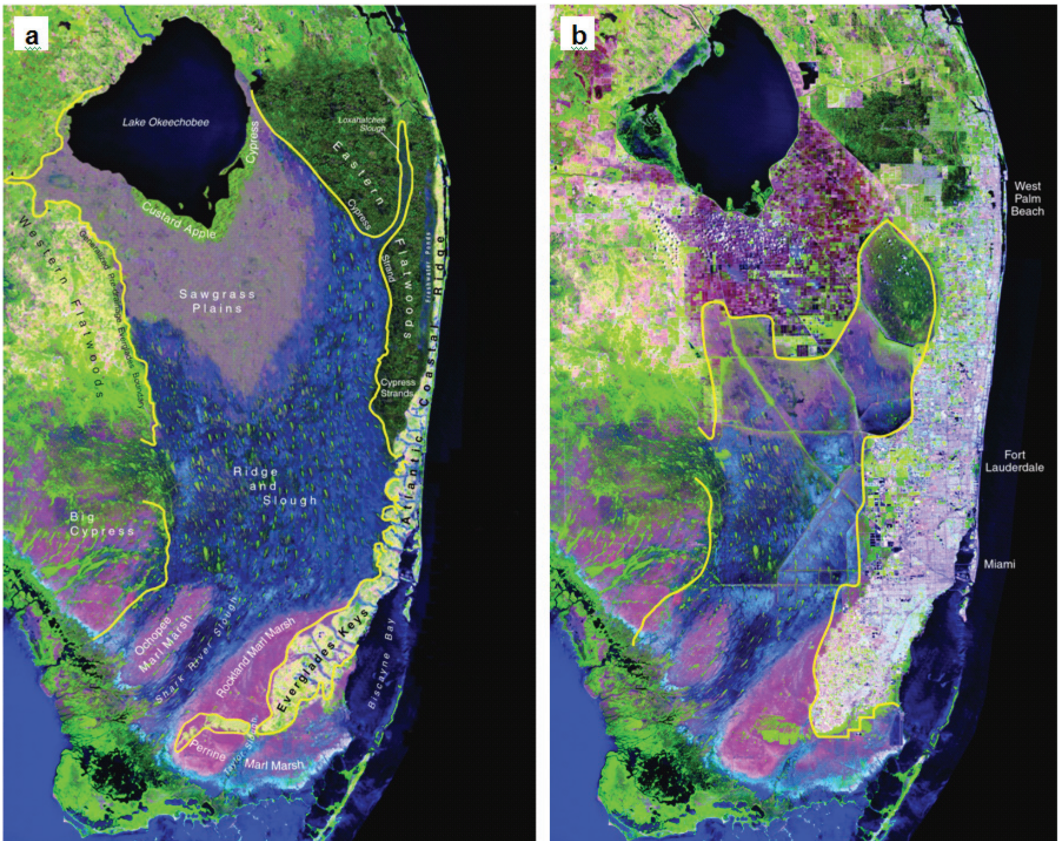


FIGURE 1-1 Reconstructed (a) pre-drainage (circa 1850) and (b) current (1994) satellite images of the Everglades ecosystem.

NOTE: The yellow line in (a) outlines the historical Everglades ecosystem, and the yellow line in (b) outlines the remnant Everglades ecosystem as of 1994.

SOURCE: Courtesy of C. McVoy, J. Obeysekera, and W. Said, South Florida Water Management District. © International Mapping Associates

THE NATIONAL RESEARCH COUNCIL AND EVERGLADES RESTORATION

The NRC has been providing scientific and technical advice related to the Everglades restoration since 1999. The NRC's Committee on the Restoration of the Greater Everglades Ecosystem (CROGEE), which operated from 1999 until 2004, was formed at the request of the South Florida Ecosystem Restoration

BOX 1-1
Geographic Terms

This box defines some key geographic terms used throughout this report.

- The **Everglades,** the **Everglades ecosystem,** or the **remnant Everglades ecosystem** refers to the present areas of sawgrass, marl prairie, and other wetlands and estuaries south of Lake Okeechobee (Figure 1-1b).
- The **original, historical, or pre-drainage Everglades** refers to the areas of sawgrass, marl prairie, and other wetlands and estuaries south of Lake Okeechobee that existed prior to the construction of drainage canals beginning in the late 1800s (Figure 1-1a).
- The **Everglades watershed** is the drainage that encompasses the Everglades ecosystem but also includes the Kissimmee River watershed and other smaller watersheds north of Lake Okeechobee that ultimately supply water to the Everglades ecosystem.
- The **South Florida ecosystem** (also known as the Greater Everglades Ecosystem; see Figure 1-2) extends from the headwaters of the Kissimmee River near Orlando through Lake Okeechobee and the Everglades into Florida Bay and ultimately the Florida Keys. The boundaries of the South Florida ecosystem are determined by the boundaries of the South Florida Water Management District, the southernmost of the state's five water management districts, although they approximately delineate the boundaries of the South Florida watershed. This designation is important and helpful to the restoration effort because, as many publications have made clear, taking a watershed approach to ecosystem restoration is likely to improve the results, especially when the ecosystem under consideration is as water dependent as the Everglades (NRC, 1999, 2004a).
- The **Water Conservation Areas** (WCAs) include WCA-1 (the Arthur R. Marshall Loxahatchee National Wildlife Refuge), -2A, -2B, -3A, and -3B (see Figure 1-2).

The following represent legally defined geographic terms used in this report:

- The **Everglades Protection Area** is defined in the Everglades Forever Act as comprising WCAs -1, -2A, -2B, -3A, and -3B and Everglades National Park.
- The **natural system** is legally defined in the Water Resources Development Act of 2000 (WRDA 2000) as all land and water managed by the federal government or the state within the South Florida ecosystem (see Figure 1-3). "The term 'natural system' includes (i) water conservation areas; (ii) sovereign submerged land; (iii) Everglades National Park; (iv) Biscayne National Park; (v) Big Cypress National Preserve; (vi) other Federal or State (including a political subdivision of a State) land that is designated and managed for conservation purposes; and (vii) any tribal land that is designated and managed for conservation purposes, as approved by the tribe" (WRDA 2000).

Many maps in this report include shorthand designations that use letters and numbers for man-made additions to the South Florida ecosystem. For example, canals are labeled C-#; levees and associated borrow canals as L-#; and structures, such as culverts, locks, pumps, spillways, control gates, and weirs, as S-# or G-#.

FIGURE 1-2 The South Florida ecosystem.

SOURCE: © International Mapping Associates

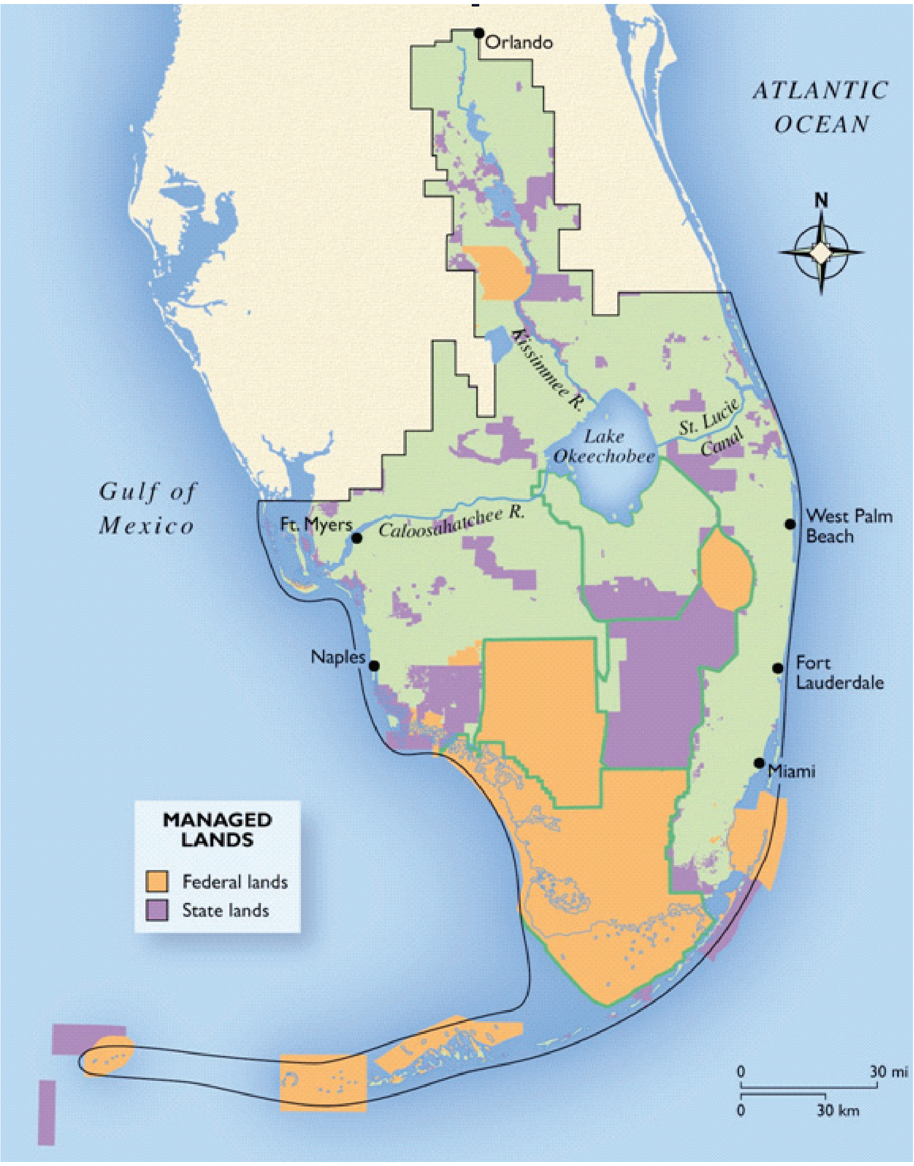


FIGURE 1-3 Land and waters managed by the state of Florida and the federal government as of December 2005 for conservation purposes within the South Florida ecosystem.

SOURCE: Based on data compiled by Florida State University's Florida Natural Areas Inventory (http://www.fnai.org/gisdata.cfm). © International Mapping Associates

Task Force (Task Force), an intergovernmental body established to facilitate coordination in the restoration effort, and the committee produced six reports (NRC, 2001, 2002a,b, 2003a,b, 2005). The NRC's Panel to Review the Critical Ecosystem Studies Initiative produced an additional report in 2003 (NRC, 2003c; see Appendix A). The Water Resources Development Act of 2000 (WRDA 2000) mandated that the U.S. Department of the Army, the Department of the Interior (DOI), and the state of Florida, in consultation with the Task Force, establish an independent scientific review panel to evaluate progress toward achieving the natural system restoration goals of the CERP. The NRC's Committee on Independent Scientific Review of Everglades Restoration Progress was therefore established in 2004 under contract with the U.S. Army Corps of Engineers (USACE). After publication of each of the first three biennial reviews (NRC, 2007, 2008, 2010; see Appendix A for the report summaries), some members rotated off the committee and some new members were added.

The committee is charged to submit biennial reports that address the following items:

1. An assessment of progress in restoring the natural system, which is defined by section 601(a) of WRDA 2000 as all of the land and water managed by the federal government and state within the South Florida ecosystem (see Figure 1-3 and Box 1-1);
2. A discussion of significant accomplishments of the restoration;
3. A discussion and evaluation of specific scientific and engineering issues that may impact progress in achieving the natural system restoration goals of the plan; and
4. An independent review of monitoring and assessment protocols to be used for evaluation of CERP progress (e.g., CERP performance measures, annual assessment reports, assessment strategies, etc.).

Given the broad charge, the complexity of the restoration, and the continually evolving circumstances, the committee did not presume it could cover all issues that affect restoration progress in any single report. This report builds on the past reports by this committee (NRC, 2007, 2008, 2010) and emphasizes restoration progress since 2010, high-priority scientific and engineering issues that the committee judged to be relevant to this timeframe, and other issues that have impacted the pace of progress. The committee focused particularly on issues for which the "timing was right"—that is, where the committee's advice could be useful relative to the decision-making timeframes—and on topics that had not been fully addressed in past NRC Everglades reports. Interested readers should look to past reports by this committee (NRC, 2007, 2008, 2010) to find detailed discussions of important topics, such as the human context for the CERP, climate change, water quality and quantity challenges, Lake Okeechobee, Modified Water Deliveries to Everglades National Park, and incremental adaptive restoration, which are not repeated here. Other issues, such as the impacts of pythons on Everglades mammals (Dorcas et al., 2012), emerged too late for in-depth analysis by the committee and may be considered in future reports.

The committee met six times during the course of this review; received briefings at its public meetings from agencies, organizations, and individuals involved in the restoration, as well as from the public; and took several field trips to sites with restoration activities (see Acknowledgments) to help it evaluate restoration progress. In addition to information received at the meetings, the committee based its assessment of progress on information in relevant CERP and non-CERP restoration documents. The committee's conclusions and recommendations also were informed by a review of relevant scientific literature and the experience and knowledge of the committee members in their fields of expertise. The committee was unable to consider in any detail new materials received after March 2012.

REPORT ORGANIZATION

In Chapter 2, the committee provides an overview of the CERP in the context of other ongoing restoration activities and discusses the restoration goals that guide the overall effort. An overview of the legal context for the CERP is also provided.

In Chapter 3 the committee analyzes the progress of CERP implementation, including recent developments at Picayune Strand, Biscayne Bay Coastal Wetlands, the C-111 Spreader Canal, Indian River Lagoon-South, and the Loxahatchee River Watershed and several pilot projects that are under way. Also discussed in the chapter are programmatic progress and issues.

In Chapter 4, the committee discusses the current trajectories for 10 ecosystem attributes in the remnant Everglades ecosystem. The chapter also considers the potential impacts on those trajectories of three hypothetical scenarios for future restoration and the timescales of reversibility associated with further declines, to illuminate priorities for future restoration efforts.

In Chapter 5, the committee discusses the contributions and use of science for CERP decision making. The chapter includes analyses of recent science synthesis efforts, project-level adaptive management, monitoring, modeling, and science and values in decision making.

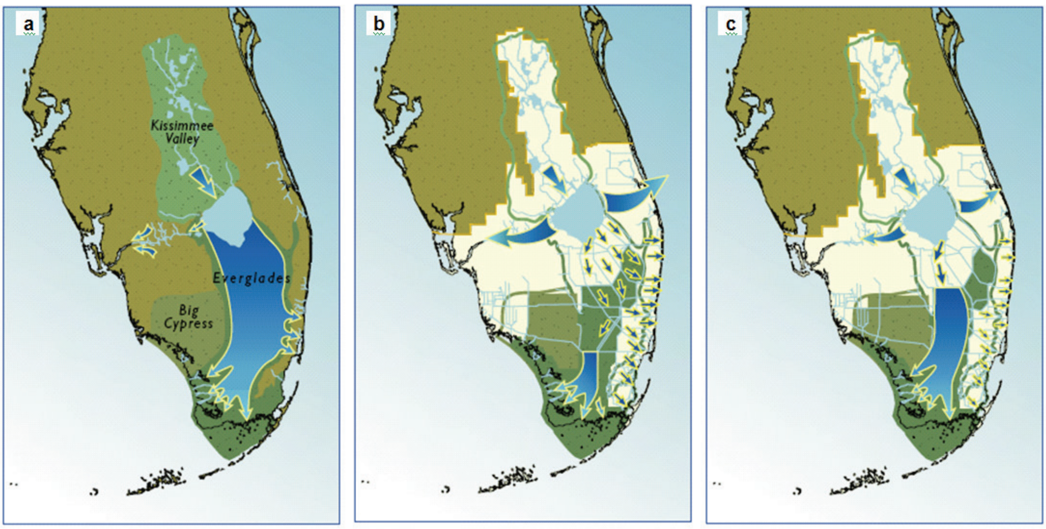
2

The Restoration Plan in Context

This chapter sets the stage for the fourth of this committee's biennial assessments of restoration progress in the South Florida ecosystem. Background for understanding the project is provided through descriptions of the ecosystem decline, restoration goals, the needs of a restored ecosystem, and the specific activities of the restoration project. An overview of the legal context is also included.

BACKGROUND

The Everglades once encompassed about 3 million acres of slow-moving water and associated biota that stretched from Lake Okeechobee in the north to Florida Bay in the south (Figures 1-1a and 2-1a). The conversion of the uninhabited Everglades wilderness into an area of high agricultural productivity and cities was a dream of 19th-century investors, and projects begun between 1881 and 1894 affected the flow of water in the watershed north of Lake Okeechobee. By the late 1800s, more than 50,000 acres north and west of the lake had been drained and cleared for agriculture (Grunwald, 2006). These early projects included straightening the channel of the Kissimmee River and constructing a channel directly connecting Lake Okeechobee to the Caloosahatchee River and, ultimately, the Gulf of Mexico. In 1907 Governor Napoleon Bonaparte Broward created the Everglades Drainage District to construct a vast array of ditches, canals, dikes, and "improved" channels. By the 1930s, Lake Okeechobee had a second outlet, through the St. Lucie Canal, leading to the Atlantic Ocean, and 440 miles of other canals altered the hydrology of the Everglades (Blake, 1980). After hurricanes in 1926 and 1928 resulted in disastrous flooding from Lake Okeechobee, the U.S. Army Corps of Engineers (USACE) replaced the small berm that bordered the southern edge of the lake with the massive Herbert Hoover Dike that now encircles the lake. The hydrologic end product of these drainage activities was the drastic reduction of water storage within the system and an



Pre-drainage Flow

Current Flow

Restored Flow

FIGURE 2-1 Water flow in the Everglades under (a) historical conditions, (b) current conditions, and (c) conditions envisioned upon completion of the Comprehensive Everglades Restoration Plan (CERP).

SOURCE: Graphics provided by USACE, Jacksonville District.

increased susceptibility to drought and desiccation in the southern reaches of the Everglades (NRC, 2005).

After further flooding in 1947 and increasing demands for improved agricultural production and flood control for the expanding population centers on the southeast Florida coast, the U.S. Congress authorized the Central and Southern Florida (C&SF) Project. This USACE project provided flood control with the construction of a levee along the eastern boundary of the Everglades to prevent flows into the southeastern urban areas, established the 700,000-acre Everglades Agricultural Area (EAA) south of Lake Okeechobee, and created a series of Water Conservation Areas (WCAs) in the remaining space between the lake and Everglades National Park (Light and Dineen, 1994). The eastern levee isolated about 100,000 acres of the Everglades ecosystem, making it available for development (Lord, 1993). In total, urban and agricultural development have reduced the Everglades to about one-half its pre-drainage size (see Figure 1-1b; Davis and Ogden, 1994) and have contaminated its waters with chemicals such as phosphorus, nitrogen, sulfur, mercury, and pesticides. Associated drainage and flood-control structures, including the C&SF Project, have diverted large quantities of water to the coastal areas, thereby reducing the freshwater inflows and natural water storage that defined the ecosystem (see Figure 2-1b).

The profound hydrologic alterations were accompanied by many changes in the biotic communities in the ecosystem, including reductions and changes in the composition, distribution, and abundance of the populations of wading birds. Today, the federal government has listed 67 plant and animal species in South Florida as threatened or endangered, with many more included on state lists. Some distinctive Everglades habitats, such as custard-apple forests and peripheral wet prairie, have disappeared altogether, while other habitats are severely reduced in area (Davis and Ogden, 1994; Marshall et al., 2004). Approximately 1 million acres are contaminated with mercury (McPherson and Halley, 1996). Phosphorus from agricultural runoff has impacted water quality in large portions of the Everglades and has been particularly problematic in Lake Okeechobee (Flaig and Reddy, 1995) (see Chapter 4 for a more detailed discussion of phosphorus enrichment in the Everglades). The Caloosahatchee and St. Lucie estuaries, including parts of the Indian River Lagoon, have been greatly altered by high and extremely variable freshwater discharges that bring nutrients and contaminants (Doering, 1996; Doering and Chamberlain, 1999).

At least as early as the 1920s, private citizens were calling attention to the degradation of the Florida Everglades (Blake, 1980). However, by the time Marjory Stoneman Douglas's classic book *The Everglades: River of Grass* was published in 1947 (the same year that Everglades National Park was dedicated), the South Florida ecosystem had already been altered extensively. Prompted by concerns about deteriorating conditions in Everglades National Park and other parts of the South Florida ecosystem, the public, as well as the federal and state governments, directed increased attention to the adverse ecological effects of the flood-control and irrigation projects beginning in the 1970s (Kiker et al., 2001; Perry, 2004). By the late 1980s it was clear that various minor corrective measures undertaken to remedy the situation were insufficient. As a result, a powerful political consensus developed among federal agencies, state agencies and commissions, Native American tribes, county governments, and conservation organizations that a large restoration effort was needed in the Everglades (Kiker et al., 2001). This recognition culminated in the Comprehensive Everglades Restoration Plan (CERP), which builds on other ongoing restoration activities of the state and federal governments to create one of the most ambitious and extensive restoration efforts in the nation's history.

RESTORATION GOALS FOR THE EVERGLADES

Several goals have been articulated for the restoration of the South Florida ecosystem, reflecting the various restoration programs. The South Florida

Ecosystem Restoration Task Force (hereafter, simply the Task Force), an intergovernmental body established to facilitate coordination in the restoration effort, has three broad strategic goals: (1) "get the water right," (2) "restore, preserve, and protect natural habitats and species," and (3) "foster compatibility of the built and natural systems" (SFERTF, 2000). These goals encompass, but are not limited to, the CERP. The Task Force works to coordinate and build consensus among the many non-CERP restoration initiatives that support these broad goals.

The goal of the CERP, as stated in the Water Resources Development Act of 2000 (WRDA 2000), is "restoration, preservation, and protection of the South Florida Ecosystem while providing for other water-related needs of the region, including water supply and flood protection." The Programmatic Regulations (33 CFR 385.3) that guide implementation of the CERP further clarify this goal by defining restoration as "the recovery and protection of the South Florida ecosystem so that it once again achieves and sustains the essential hydrological and biological characteristics that defined the undisturbed South Florida ecosystem." These defining characteristics include a large areal extent of interconnected wetlands, extremely low concentrations of nutrients in freshwater wetlands, sheet flow, healthy and productive estuaries, resilient plant communities, and an abundance of native wetland animals (DOI and USACE, 2005). Although development has permanently reduced the areal extent of the Everglades ecosystem, the CERP hopes to recover many of the Everglades' original characteristics and natural ecosystem processes. At the same time, the CERP is charged to maintain levels of flood protection (as of 2000) and provide for other water-related needs, including water supply, for a rapidly growing human population in South Florida (DOI and USACE, 2005).

Although the CERP contributes to each of the Task Force's three goals, it focuses primarily on restoring the hydrologic features of the undeveloped wetlands remaining in the South Florida ecosystem, on the assumption that improvements in ecological conditions will follow. Originally, "getting the water right" had four components—quality, quantity, timing, and distribution. However, the hydrologic properties of flow, encompassing the concepts of direction, velocity, and discharge, have been recognized as an important component of getting the water right that had previously been overlooked (NRC, 2003c; SCT, 2003). Numerous studies have supported the general approach to getting the water right (Davis and Ogden, 1994; NRC, 2005; SSG, 1993), although it is widely recognized that recovery of the native habitats and species in South Florida may require restoration efforts in addition to getting the water right, such as controlling exotic species and reversing the decline in the spatial extent and compartmentalization of the natural landscape (SFERTF, 2000; SSG, 1993).

The goal of ecosystem restoration can seldom be the exact re-creation of some historical or preexisting state because physical conditions, driving forces, and boundary conditions usually have changed and are not fully recoverable. Rather, restoration is better viewed as the process of assisting the recovery of a degraded ecosystem to the point where it contains sufficient biotic and abiotic resources to continue its functions without further assistance in the form of energy or other resources from humans (NRC, 1996; Society for Ecological Restoration International Science & Policy Working Group, 2004). The term *ecosystem rehabilitation* may be more appropriate when the objective is to improve conditions in a part of the South Florida ecosystem to at least some minimally acceptable level to allow the restoration of the larger ecosystem to advance. However, flood control remains a critical aspect of the CERP design, and artificial storage will be required to replace the lost natural storage in the system (NRC, 2005). For these and other reasons, even when the CERP is complete it will require large inputs of energy and human effort to operate and maintain pumps, stormwater treatment areas, canals and levees, and reservoirs, and to continue to manage exotic species. Thus, for the foreseeable future, the CERP does not envision ecosystem restoration or rehabilitation that returns the ecosystem to a state where it can "manage itself."

Implicit in the understanding of ecosystem restoration is the recognition that natural systems are self-designing and dynamic, and, therefore, it is not possible to know in advance exactly what can or will be achieved. Thus, ecosystem restoration is an enterprise with some scientific uncertainty in methods or outcomes that requires continual testing of assumptions and monitoring and assessment of progress (Box 2-1). Additional challenges in defining and implementing restoration goals are discussed in the initial National Research Council (NRC) biennial review (NRC, 2007).

What Natural System Restoration Requires

Restoring the South Florida ecosystem to a desired ecological landscape requires reestablishment of the critical processes that sustained its historical functions. Although getting the water right is the oft-stated and immediate goal, the restoration will be considered successful if it restores the distinctive characteristics of the historical ecosystem to the remnant Everglades (DOI and USACE, 2005). Getting the water right is a means to an end, not the end in itself. The hydrologic and ecologic characteristics of the historical Everglades serve as restoration goals for a functional (albeit reduced in size) Everglades ecosystem. The first Committee on Independent Scientific Review of Everglades Restoration Progress (CISRERP) review identified five critical components of Everglades restoration (NRC, 2007):

1. Enough water storage capacity combined with operations that allow for appropriate volumes of water to support healthy estuaries and the return of

BOX 2-1
The Dynamic Reference Concept

Defining ecological restoration targets and measuring progress toward those targets in a dynamic system suffering from many forms of degradation is a daunting task, particularly when some of the degradation may be irreversible and the ecosystem is inhabited by a plethora of non-native species and is profoundly impacted by climate change. New tools and approaches may prove useful in meeting this challenge. Instead of relying on historical precedence, the dynamic reference concept (Hiers et al., 2012) focuses on the best available sites (called reference sites) to define restoration goals and measure restoration progress. Use of reference sites to define restoration goals is a well-developed tradition in aquatic systems (Stoddard et al., 2006). What is new about the dynamic reference approach is the quantitative method used to define reference sites and track restoration progress and system change.

The dynamic reference approach has been applied to restoration of the longleaf pine (*Pinus palustris*) ecosystem on Eglin Air Force Base, Florida (Hiers et al., 2012), where the primary drivers of this ecosystem are fire, wind (most notably hurricanes), and soil-moisture (Hiers et al., 2007; Kirkman et al., 2001; Platt and Rathbun, 1993). Four different methods were used to identify proposed reference sites, which were plotted in ecological space along with non-reference sites of various types based on sampling of the vegetation community using non-metric multidimensional scaling (NMDS) ordination. By this process, a portion of the ecological space was identified as being reference; as a result, some sites previously designated as reference were reclassified as non-reference and vice versa. Resampling of individual reference sites revealed that although they remained within the reference space, their location within that space in some cases changed dramatically in response to fire and wind events. Resampling of non-reference sites revealed trajectories toward the reference space in response to restoration activities, chiefly restoration of historical fire regimes. At Eglin, the reference space represents the restoration target for the longleaf ecosystem, and this movement of non-reference sites toward reference space constitutes a quantitative measure of restoration progress. Over longer time intervals, the mean location of reference sites appears to be moving systematically in a particular direction in ordination space in response to climate change (K. Hiers, Eglin AFB, personal communication, 2012). In the dynamic reference approach, as the climate changes, so does the restoration goal.

The dynamic reference approach requires a sufficient number of reference sites to capture the variation in the community across key ecological gradients and in response to other drivers. This will limit its applicability in Everglades restoration because sufficient numbers of sites that are not significantly degraded may not exist for some community types. However, the approach might have some utility for features such as tree islands where some remain in good condition and there is a history of monitoring.

sheet flow through the Everglades ecosystem while meeting other demands for water;

2. Mechanisms for delivering and distributing the water to the natural system in a way that resembles historical flow patterns, affecting volume, depth, velocity, direction, distribution, and timing of flows;

3. Barriers to eastward seepage of water so that higher water levels can be maintained in parts of the Everglades ecosystem without compromising the current levels of flood protection of developed areas as required by the CERP;
4. Methods for securing water quality conditions compatible with restoration goals for a natural system that was inherently extremely nutrient poor, particularly with respect to phosphorus; and
5. Retention, improvement, and expansion of the full range of habitats by preventing further losses of critical wetland and estuarine habitats and by protecting lands that could usefully be part of the restored ecosystem.

If these five critical components of restoration are achieved and the difficult problem of invasive species can be managed (Box 2-2), then the basic physical, chemical, and biological processes that created the historical Everglades can once again work to create a functional mosaic of biotic communities that resemble what was distinctive about the historical Everglades.

The history of the Everglades likely will make replication of the historical system impossible. Because of the historical changes that have occurred through engineered structures, urban development, introduced species, and other factors, the paths taken by the ecosystem and its components in response to restoration efforts will not retrace the paths taken to reach current conditions. This means that the paths toward restoration will pass through different intermediate conditions from the ones they passed through on their way to the current status. This phenomenon often is referred to as *hysteresis* (e.g., NRC, 2012; Scheffer et al., 2001; Tett et al., 2007) and is a complicating factor in any estimates of how long restoration efforts are likely to take to achieve their goals (Chapter 4).

Even if the restored system does not exactly replicate the historical system, or reach all of the biological, chemical, and physical targets, the reestablishment of natural processes and dynamics should result in a viable and valuable Everglades ecosystem. The central principle of ecosystem management is to provide for the natural processes that historically shaped an ecosystem, because ecosystems are characterized by the processes that regulate them. If the conditions necessary for those processes to operate are met, then recovery of species and communities is far more likely than if humans attempt to specify and manage every individual constituent and element of the ecological system (NRC, 2007).

RESTORATION ACTIVITIES

Several restoration programs, including the largest of the initiatives, the CERP, are now under way. The CERP often builds upon non-CERP activities (also called "foundation projects"), many of which are essential to the effectiveness of the CERP. The following section provides a brief overview of the CERP and

BOX 2-2
Burmese Pythons in the Everglades

Invasive, non-native species are a major problem in the Everglades (NRC, 2008). Although there has been considerable success in controlling some non-native species (e.g., Melaleuca [*Melaleuca quinquenervia*]), new threats continue to emerge. The most alarming of the recent invaders is the Burmese python (*Python molurus bivittatus*), a native of southern Asia that can grow to more than 5.5 m in length (see Figure 2-2-1).

Burmese pythons were observed intermittently in Everglades National Park for about 20 years before being recognized as established there in 2000 (Meshaka et al., 2000). Pythons have increased dramatically in abundance and range since 2000 and are now found throughout Everglades National Park and much of South Florida (Figure 2-2-2). The presence of a generalist apex predator (i.e., with no predator of its own) in the ecosystem is of particular concern because it can have a number of direct and indirect effects on the community through competition and predation, resulting in considerable alteration of trophic structure (Dorcas et al., 2012). Additionally, snakes can persist at high densities and therefore have particularly large impacts as invasive species (Dorcas et al., 2012; Rodda and Savidge, 2007).

A recent paper by Dorcas et al. (2012) provides compelling evidence that Burmese pythons are indeed having such strong impacts on the Everglades ecosystem. Compari-

FIGURE 2-2-1 A Burmese python captured in Everglades National Park.

SOURCE: Photo by M. Rochford, provided by J. D. Willson, Virginia Tech.

sons of road surveys conducted in 1996-1997 and 2003-2011 revealed severe declines in mammal populations, especially for medium-sized predators, that coincide temporally and spatially with the proliferation of pythons in Everglades National Park. The authors documented population declines of 99 percent in both raccoons (*Procyon lotor*) and opossums (*Didelphis virginiana*), 87.5 percent in bobcats (*Lynx rufus*), and 94 percent in white-tailed deer (*Odocoileus virginianus*). In more than 35,000 miles of nocturnal road surveys in 2003-2011, not a single rabbit (*Sylvilagus* spp.) or fox (*Urocyon cinereoargenteus* and *Vulpes vulpes*) was seen in Everglades National Park. With the exception of deer, which declined throughout the study area, these mammal species are most abundant outside the python's current range, largely absent from areas in which pythons have been established for some time (i.e., Everglades National Park), and intermediately abundant in areas pythons invaded relatively recently. Anecdotal observations support the results of the road surveys: Everglades National Park personnel have had no reports of nuisance raccoons, which once required a removal program, since 2005 (Dorcas et al., 2012).

The declines of species such as rabbits, raccoons, and opossums are no doubt due to the direct effects of predation by pythons. Declines of bobcats and foxes could

continued

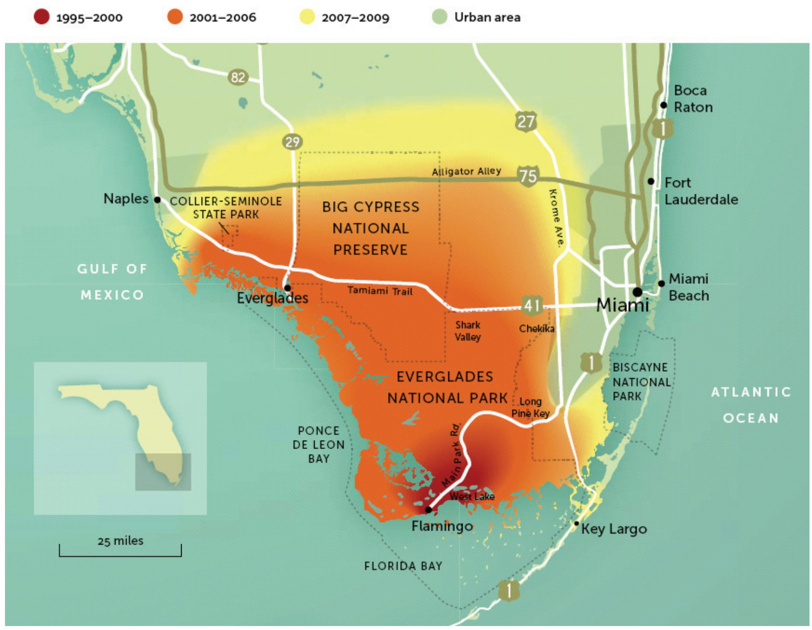


FIGURE 2-2-2 Approximate distribution of the Burmese python in South Florida from the 1990s to 2009.

SOURCE: Dorcas and Willson (2011).

BOX 2-2 Continued

be due to predation or, alternatively, might represent the indirect effect of reduced prey availability (i.e., competition). By eliminating mid-level predators, the python likely is having a myriad of as yet undocumented indirect effects on the ecosystem, both positive and negative. There may be additional undocumented direct effects as well, because more than 40 different species have been documented as python prey, including endangered wood storks (*Mycteria americana*), limpkins (*Aramus guarauna*), and several species of herons and egrets (Dorcas et al., 2012; Dove et al., 2011). The eventual impact on Florida panthers (*Puma concolor coryi*), a species of great conservation interest, remains a concern.

Can Burmese pythons be eradicated? Their current population is estimated to be 10,000 to 100,000 individuals and is probably closer to the upper end of this range, which would make them more numerous in the Everglades than in Asia (Dorcas and Willson, 2011). Preliminary modeling indicates that removing 2,000 to 10,000 per year (depending on current population size) is required to induce decline in the population (J. Willson, Virginia Tech, personal communication, 2012), whereas currently roughly 350 are being removed per year from Everglades National Park (Dorcas et al., 2012). Clearly the task is daunting, and likely impossible with current control methods. The problem is growing as the python increases in population and expands in range. How far will it spread? Its range in Asia includes temperate regions, and its physiology is such that it could survive throughout the Southeast (Rodda et al., 2009), although its range likely will be constrained by its niche, perhaps to only southern Florida (Pyron et al., 2008). However far it spreads, the Burmese python is a significant new challenge to restoration of the Everglades ecosystem.

some of the major non-CERP activities, as well as an update on the legal context for water quality.

Comprehensive Everglades Restoration Plan

WRDA 2000 authorized the CERP as the framework for modifying the C&SF Project. Considered a blueprint for the restoration of the South Florida ecosystem, the CERP is led by two organizations with considerable expertise managing the water resources of South Florida— the USACE, which built most of the canals and levees throughout the region, and the South Florida Water Management District (SFWMD), the state agency with primary responsibility for operating and maintaining this complicated water collection and distribution system.

The CERP conceptual plan (USACE and SFWMD, 1999; also called the Yellow Book) proposes major alterations to the C&SF Project in an effort to reverse decades of ecosystem decline. The Yellow Book includes approximately 50 major projects consisting of 68 project components to be constructed at a cost of approximately $13.5 billion (estimated in 2009 dollars; DOI and USACE, 2011; Figure 2-2). Major components of the restoration plan focus on restoring the quantity, quality, timing, and distribution of water for the natural system. The Yellow Book outlines the major CERP components, including the following:

- **Conventional surface-water storage reservoirs.** The Yellow Book includes plans for approximately 1.5 million acre-feet of storage, located north of Lake Okeechobee, in the St. Lucie and Caloosahatchee basins, in the EAA, and in Palm Beach, Broward, and Miami-Dade counties.
- **Aquifer storage and recovery (ASR).** The Yellow Book proposes to provide substantial water storage through ASR, a highly engineered approach that would use a large number of wells built around Lake Okeechobee, in Palm Beach County, and in the Caloosahatchee Basin to store water approximately 1,000 feet below ground; the feasibility of this approach is currently being examined through pilot tests.
- **In-ground reservoirs.** The Yellow Book proposes additional water storage in quarries created by rock mining.
- **Stormwater treatment areas (STAs).** The CERP contains plans for additional constructed wetlands that will treat agricultural and urban runoff water before it enters natural wetlands.[1]
- **Seepage management.** The Yellow Book outlines seepage management projects to prevent unwanted loss of water from the natural system through levees and groundwater flow. The approaches include adding impermeable barriers to the levees, installing pumps near levees to redirect lost water back into the Everglades, and holding water levels higher in undeveloped areas between the Everglades and the developed lands to the east.
- **Removing barriers to sheet flow.** The CERP includes plans for removing 240 miles of levees and canals, to reestablish shallow sheet flow of water through the Everglades ecosystem.

---

[1] Although some STAs are included among CERP projects, the USACE has clarified its policy on federal cost-sharing for water quality features. A memo from the Assistant Secretary of the Army (Civil Works) (USACE, 2007) states: "Before there can be a Federal interest to cost share a WQ [water quality] improvement feature, the State must be in compliance with WQ standards for the current use of the water to be affected and the work proposed must be deemed essential to the Everglades restoration effort…This determination must be based on some finding other than the project is a part of CERP and generally will aid the restoration effort." The memo goes on to state, "the Yellow Book specifically envisioned that the State would be responsible for meeting water quality standards." Therefore, it appears that until the water flowing into the project features meets existing water quality requirements or unless a special exemption is granted for projects deemed "essential to Everglades restoration," the state is responsible for 100 percent of the costs of CERP water quality project features.

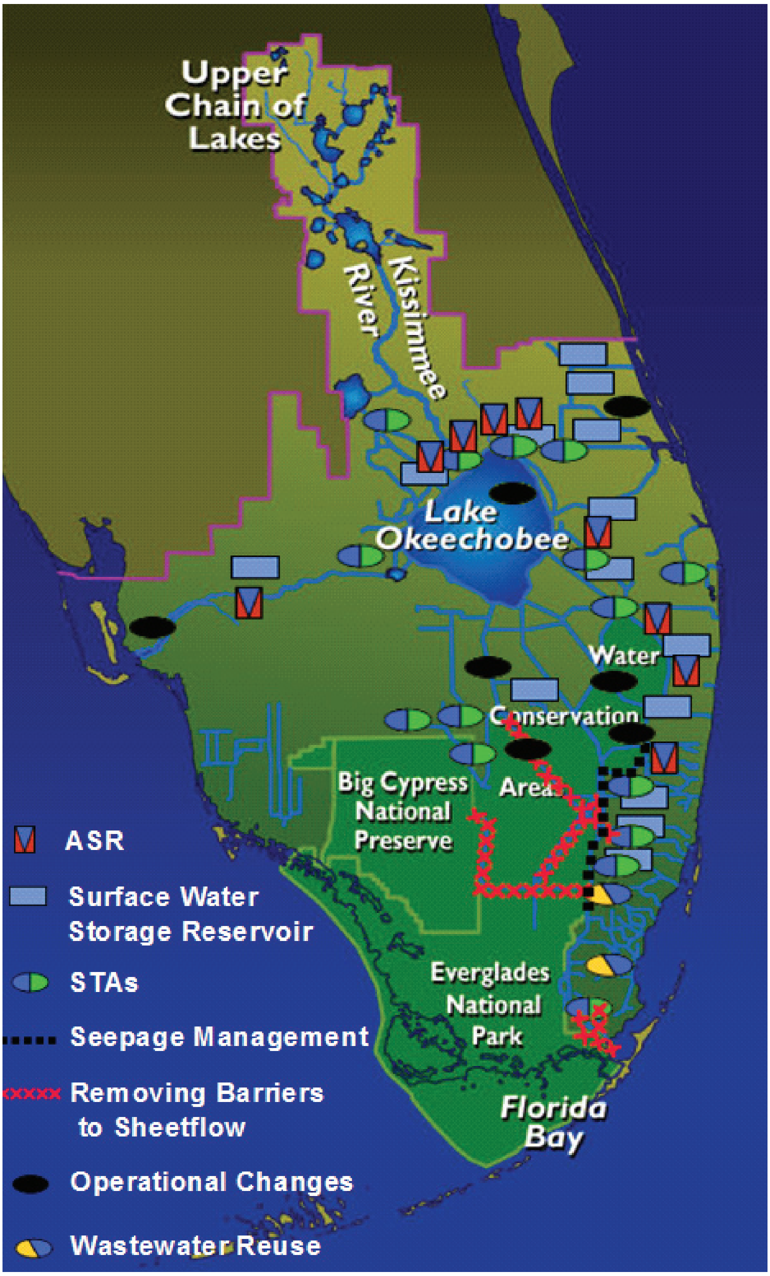


FIGURE 2-2 Major project components of the CERP.

SOURCE: Courtesy of Laura Mahoney, USACE.

- **Rainfall-driven water management.** The Yellow Book includes operational changes in the water delivery schedules to the WCAs and Everglades National Park to mimic more natural patterns of water delivery and flow through the system.
- **Water reuse and conservation.** To address shortfalls in water supply, the Yellow Book proposes two advanced wastewater treatment plants so that the reclaimed water could be discharged to wetlands along Biscayne Bay or used to recharge the Biscayne aquifer.

The largest portion of the budget is devoted to storage and water conservation projects and to acquiring the lands needed for them (see NRC, 2005).

The modifications to the C&SF Project embodied in the CERP are expected to take more than three decades to complete, and to be effective, they require a clear strategy for managing and coordinating restoration efforts. The Everglades Programmatic Regulations state that decisions on CERP implementation are made by the USACE and the SFWMD (or any other local project sponsors), in consultation with the Department of the Interior, the Environmental Protection Agency, the Department of Commerce, the Miccosukee Tribe of Indians of Florida, the Seminole Tribe of Florida, the Florida Department of Environmental Protection, and other federal, state, and local agencies (33 CFR Part 385).

WRDA 2000 endorses the use of an adaptive management framework for the restoration process, and the Programmatic Regulations formally establish an adaptive management program that will "assess responses of the South Florida ecosystem to implementation of the Plan; …[and] seek continuous improvement of the Plan based upon new information resulting from changed or unforeseen circumstances, new scientific and technical information, new or updated modeling; information developed through the assessment principles contained in the Plan; and future authorized changes to the Plan." An interagency body called Restoration, Coordination, and Verification (RECOVER) has been established to ensure that sound science is used in the restoration. The RECOVER leadership group oversees the monitoring and assessment program that will evaluate the progress of the CERP toward restoring the natural system and will assess the need for changes to the plan through the adaptive management process.

Major Program-level CERP-related Developments Since 2000

Several major program-level developments have occurred since the CERP was launched that have affected the pace and focus of CERP efforts. In 2004, Florida launched Acceler8, a plan to hasten the pace of project implementation that was bogged down by the slow federal planning process (for further discussion of Acceler8, see NRC, 2007). Acceler8 originally included 11 CERP project components and 1 non-CERP project, and although the state was unable to complete all of the original tasks, the program led to increased state investment and expedited project construction timelines for several CERP projects (see Chapter 3).

In 2008, Governor Charlie Crist announced the planned acquisition of 187,000 acres of agricultural land from the U.S. Sugar Corporation to maximize restoration opportunities for the South Florida ecosystem. The SFWMD subsequently launched the River of Grass public planning process to facilitate agency and stakeholder input on future uses of the new lands for restoration. In October 2010, the SFWMD closed on the purchase of 26,800 acres of land for approximately $197 million in cash and retained the option to acquire more than 153,000 additional acres over the next 10 years. Plans for use of the acquired lands have not been finalized at this time.

In 2011, the USACE initiated a pilot program to improve the pace of its project planning. As one of five pilot projects nationwide, the Central Everglades Planning Project was launched in November 2011, with the objective of developing a plan for restoration of the central Everglades that could be delivered for congressional authorization within two years. This effort has focused attention on central Everglades planning at all levels of the CERP partnering agencies and involves extensive stakeholder engagement facilitated by the Task Force. These initiatives are described in more detail in Chapter 3.

Non-CERP Restoration Activities

When Congress authorized the CERP in WRDA 2000, the SFWMD, the USACE, the National Park Service (NPS), and the U.S. Fish and Wildlife Service (FWS) were already implementing several activities intended to restore key aspects of the Everglades ecosystem. These non-CERP initiatives are critical to the overall restoration progress. In fact, the CERP's effectiveness was predicated upon the completion of many of these projects, which include Modified Water Deliveries to Everglades National Park (Mod Waters), C-111 (South Dade), and the Everglades Construction Project (see Box 2-3). Several additional projects are also under way to meet the broad restoration goals for the South Florida ecosystem and associated legislative mandates. They include extensive water quality initiatives, such as the Everglades Construction Project, and programs to establish best management practices (BMPs) to reduce nutrient loading.

Developments in the Legal Context for Water Quality

Although an evaluation of the scientific issues associated with Everglades restoration is not constrained by the legal and policy decisions currently being made by the state and federal governments or the courts, the committee recog-

BOX 2-3
Non-CERP Restoration Activities in South Florida

The following represent the major non-CERP initiatives currently under way in support of the South Florida ecosystem restoration (Figure 2-3-1). Progress on these non-CERP projects is discussed in Appendix B.

Kissimmee River Restoration Project

This project, authorized by Congress in 1992, aims to reestablish the historical river-floodplain system at the headwaters of the Everglades watershed and, thereby, restore biological diversity and functionality. The project plans to backfill 22 miles of the 56-mile C-38 Canal and carve new sections of the river channel to connect channel remnants, thereby restoring over 40 miles of meandering river channel in the Kissimmee River.

continued

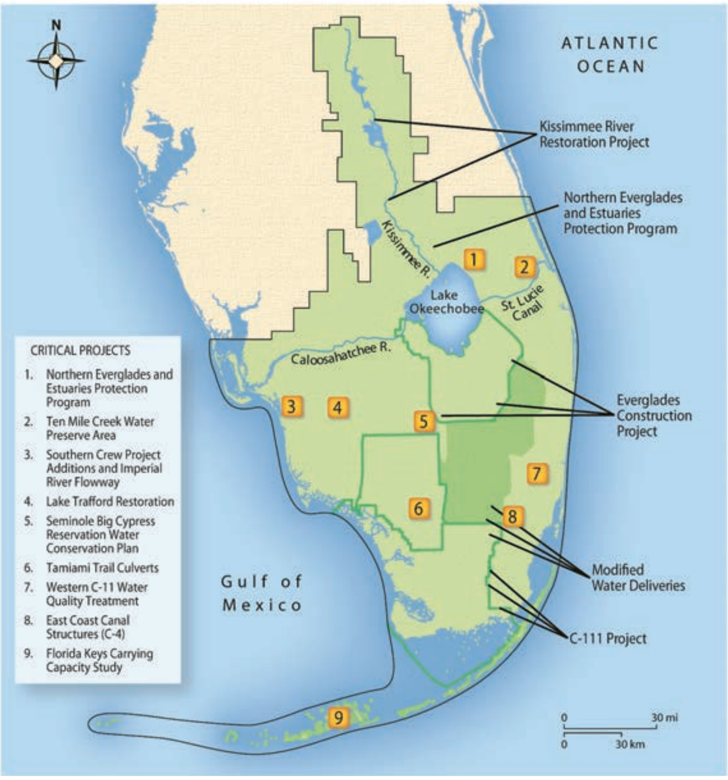


FIGURE 2-3-1 Locations of major non-CERP initiatives.

SOURCE: © International Mapping Associates

BOX 2-3 Continued

The project includes a comprehensive evaluation program to track ecological responses to restoration (Jones et al., 2010).

Everglades Construction Project and the Long-Term Plan

The Everglades Forever Act (F.S. 373.4592; see Appendix C) required the state of Florida to construct stormwater treatment areas (STAs) to reduce the loading of phosphorus into the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR), the WCAs, and Everglades National Park. These STAs are part of the state's Long-Term Plan for Achieving Water Quality Goals, including the total phosphorus criterion for the Everglades Protection Area of 10 parts per billion (ppb).[a]

Modifications to the C&SF: C-111 (South Dade) Project

This project is designed to improve hydrologic conditions in Taylor Slough and the Rocky Glades of the eastern panhandle of Everglades National Park and to increase freshwater flows to northeast Florida Bay, while maintaining flood protection for urban and agricultural development in south Miami-Dade County. The project plan includes a tieback levee with pumps to capture groundwater seepage to the east, detention areas to increase groundwater levels and thereby enhance flow into Everglades National Park, and backfilling or plugging several canals in the area. A combined operational plan (COP) will integrate the goals of the Mod Waters and C-111 projects and protect the quality of water entering Everglades National Park (DOI and USACE, 2005).

Modified Water Deliveries to Everglades National Park Project (Mod Waters)

This federally funded project, authorized in 1989, is designed to restore more natural hydrologic conditions in Everglades National Park. The project includes levee modifications and installation of a seepage control pump to increase water flow into WCA-3B and northeastern portions of Everglades National Park. It also includes providing flood mitigation to the 8.5-square-mile area (a low-lying but partially developed area on the northeast corner of Everglades National Park) and raising portions of Tamiami Trail.

nizes that it should be cognizant of the realities of the legal context in which Everglades restoration must take place. Accordingly, a review of the most significant recent legal actions is warranted.[2]

Currently, most of the legal issues related to restoration focus on water quality. Although the primary goal of the CERP is to "get the water right" by restoring the hydrology of the system, water quantity and water quality are inextricably

---

[2] A discussion of certain legal issues related to water quality is included solely to provide a context and the legal backdrop against which many Everglades restoration decisions are being made. Any discussion of legal issues included in this report or its appendices is not intended in any way to take a position on any legal issue, to provide any legal advice, or to comment on the merit of any particular court ruling or other legal decision.

Mod Waters is a prerequisite for the first phase of decompartmentalization (i.e., removing some barriers to sheet flow), which is part of the CERP[b] (DOI and USACE, 2005; NRC, 2008).

Northern Everglades and Estuaries Protection Program

In 2007, the Florida legislature expanded the Lake Okeechobee Protection Act (LOPA) to include protection and restoration of the Lake Okeechobee watershed and the Caloosahatchee and St. Lucie estuaries. The legislation, being implemented as the Northern Everglades and Estuaries Protection Program, will focus resources on restoration efforts for Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries. The Lake Okeechobee Watershed Construction Project Phase II Technical Plan, issued in February 2008 in accordance with LOPA, consolidated the numerous initiatives already under way through Florida's Lake Okeechobee Protection Plan (LOPP) and Lake Okeechobee and Estuary Recovery (LOER) Plan.

Critical Projects

Congress gave programmatic authority for the Everglades and South Florida Ecosystem Restoration Critical Projects in Water Resources Development Act (WRDA) 1996, with modification in WRDA 1999 and WRDA 2007. These were small projects that could be quickly implemented to provide immediate and substantial restoration benefits such as improved quality of water discharged into WCA-3A and Lake Okeechobee and more natural water flows to estuaries. Examples of the Critical Projects include the Florida Keys Carrying Capacity Study, Lake Okeechobee Water Retention and Phosphorus Removal, Seminole Big Cypress Reservation Water Conservation Plan, Tamiami Trail Culverts, Ten Mile Creek Water Preserve Area, and the Lake Trafford Restoration (DOI and USACE, 2011).[c] See also Appendix B.

---

[a] See http://www.sfwmd.gov/org/erd/longtermplan/index.shtml.

[b] See http://www.saj.usace.army.mil/dp/mwdenp-c111/index.htm for more information on Mod Waters and the C-111 Project.

[c] See http://www.saj.usace.army.mil/projects for more information on and the status of the Critical Projects.

intertwined (NRC, 2010), and any effort to address water quantity concerns must also consider water quality concerns. One of the most significant challenges to Everglades restoration is the inability to distribute treated water from the STAs into the Everglades Protection Area if that water leads to violations of legally mandated water quality standards. The history of Everglades water quality standards and associated issues are discussed in Chapter 4 of NRC (2010) and will not be repeated here. Issues related to compliance with water quality standards have been the subject of two significant and ongoing lawsuits. Both of these cases make it clear that discharging water into the Everglades Protection Area in a way that does not comply with U.S. Environmental Protection Agency (EPA)-approved water quality standards is considered to be a violation of federal law.

Appendix D provides a complete timeline of the significant legal actions related to water quality that affect progress toward meeting the CERP restoration goals. The EPA's Amended Determination and EPA's adoption of numerical nutrient water quality criteria for the state of Florida are two of the most important legal actions that have taken place since this committee's previous report.

The Amended Determination

On September 3, 2010, EPA issued its Amended Determination as directed by Judge Gold in an April 14, 2010, order, in which he found that EPA's 2009 "Determination" that Florida's water quality standards for the Everglades complied with the requirements of the Clean Water Act failed to comply with a previous court ruling and directed EPA and the Florida Department of Environmental Protection (FDEP) to take certain steps to comply with their mandatory duties under the Clean Water Act (CWA). In the Amended Determination, EPA directs FDEP to correct deficiencies in its water quality standards and articulates that "the narrative and numeric nutrient criteria in the State's water quality standards are not being met for the Everglades Protection Area." The Amended Determination was intended to provide an enforceable plan for ensuring that the water entering the Everglades Protection Area from the EAA and the C-139 Basin complies with the narrative and numeric phosphorus criteria, which are already in place for the Everglades Protection Area.

The Amended Determination specifically speaks to each of the directives ordered by Judge Gold. These actions include: (1) revisions to EPA's 2009 Determination; (2) directions to Florida for correcting deficiencies in Florida's Phosphorous Rule and the Amended Everglades Forever Act (EFA); (3) provisions for the "manner and method for obtaining enforceable [water quality based effluent limit or] WQBEL within time certain"; (4) requirements to measure and submit annual reports on cumulative impacts until Water Quality Standards are attained; (5) directions to Florida to conform all National Pollutant Discharge Elimination System (NPDES) and EFA permits pursuant to court orders by eliminating all nonconforming language and by including the WQBEL presented in the Amended Determination; and (6) establishment of an "enforceable framework for ensuring compliance with the CWA and Applicable Regulations" (EPA, 2010).

Of particular significance is the Amended Determination's establishment of a WQBEL that must be included in all permits for discharges from STAs. The WQBEL is intended to ensure that water leaving the STAs is of high enough quality to ensure compliance with narrative and numeric nutrient criteria. To meet the WQBEL, the Amended Determination states that total phosphorus concentrations in the discharge from the STAs may not exceed either: 10 ppb as an annual geometric mean in more than two consecutive years or 18 ppb as an annual flow-weighted mean. EPA maintains that "[c]ompliance with both parts of the WQBEL is necessary to assure that the STA discharges will not cause an exceedance of the long-term criterion of 10 ppb." The Amended Determination also instructs the state of Florida on how to meet the WQBEL and identifies specific milestones that must be met.

The Amended Determination states that to meet the WQBEL with existing flows, it will be necessary to establish approximately 42,000 additional acres of STAs. This could be accomplished by using land originally intended for the EAA reservoir (Phases A1 and A2) and U.S Sugar lands purchased by the state. EPA also asserts that the state should pursue additional source controls through additional or improved BMPs on farms in the EAA and/or subbasin treatment approaches as required by the Amended EFA as necessary to reduce the phosphorus load entering the STAs and to further optimize the performance of the STAs. The Amended Determination provided a 60-day opportunity for the state to propose an alternative for achieving water quality standards in the Everglades Protection Area. In November 2010, the Executive Director of the SFWMD notified EPA of the SFWMD's decision to decline the opportunity to provide an alternative proposal for achieving water quality standards created by the federal government for the Everglades. While referencing its history of good faith efforts to improve water quality in the Everglades, the SFWMD declined to comply with EPA's Amended Determination because of the high financial burden (estimated to be $1.5 to $2.0 billion) it would place on the state.

Since November 2011, the state of Florida has been actively working to reach agreement with EPA and other federal agencies on an alternative plan to meet the water quality criteria. The state believes that this alternative plan will achieve the same water quality goals as would the Amended Determination plan but at a lower cost and in a shorter timeframe. On June 13, 2012, EPA announced that the alternative plan addresses its previous objections and "provides an enforceable framework for ensuring compliance with the Clean Water Act" (Fleming, 2012). Presumably, EPA will submit the plan to the court that previously approved the Amended Determination. Additional detail on this plan is provided in Chapter 3.

EPA's Numerical Nutrient Water Quality Criteria for the State of Florida

The other major legal development regarding water quality since the committee's previous report involves the establishment of numeric nutrient criteria for water bodies in the state of Florida. At the time of this writing, EPA and FDEP each have promulgated different numeric nutrient criteria for phosphorus and nitrogen in certain water bodies in Florida, and it is expected that numeric nutrient criteria will be established for additional Florida water bodies in the future. Numerous environmental and business interests have challenged both the federal and state rules, and as a result, the issue of what numeric nutrient criteria ultimately will apply remains unresolved. In early 2012, a federal court upheld the majority of EPA's rule and remanded a portion of the rule to EPA for additional consideration. EPA has proposed an extension of the effective date of the portions of the rule that were found to be valid until October 2012. However, EPA has indicated that if it determines that the FDEP rule complies with the requirements of the Clean Water Act, then it will approve the Florida rule and withdraw the EPA rule. In June 2012, the FDEP rule was upheld by the state's administrative law judge, but EPA has not yet made any official determination regarding the adequacy of the Florida rule. A detailed description of both the federal and state rules and the various legal challenges involved in this issue is provided in Appendix E.

At this time, it does not appear that either of the pending rules for interior water bodies will have significant implications for Everglades restoration because numeric water quality standards for the Everglades have been in place for some time and there is no indication that either EPA or FDEP plans to extend its respective numeric nutrient criteria to replace the existing standard for the Everglades. In addition, neither rule addresses the ditches and canals in the Everglades and the EPA rule does not address estuaries. Nevertheless, EPA has indicated that it intends to promulgate a rule that establishes numeric nutrient criteria for estuaries and for South Florida ditches and canals in the future (see Appendix E). Depending on the specific numeric nutrient criteria EPA or FDEP chooses to apply to these water bodies, these future rules could have significant implications for Everglades restoration. If the criteria are set at levels currently not being met, then additional treatment or altered water management schedules may be required to comply with the law.

SUMMARY

The Everglades ecosystem is one of the world's ecological treasures, but for more than a century the installation of an extensive water control infrastructure has changed the geography of South Florida and facilitated extensive agricultural and urban development. These changes have had profound ancillary effects on regional hydrology, vegetation, and wildlife populations. The CERP, a joint effort led by the state and federal governments and launched in 2000, seeks to reverse the general decline of the ecosystem. Since 2000, the CERP and other major Everglades restoration efforts have adapted to changing budgets, refinements in scientific understanding, and an evolving legal context, particularly as it relates to water quality. The implications on implementation progress are discussed in more detail in Chapters 3 and 4.

3

Implementation Progress

This committee is charged with the task of discussing significant accomplishments of the restoration and assessing "the progress toward achieving the natural system restoration goals of the Comprehensive Everglades Restoration Plan [CERP]" (see Chapter 1). In this chapter, the committee updates the National Research Council's (NRC's) previous assessments of CERP and related non-CERP restoration projects (NRC, 2007, 2008, 2010). This chapter addresses programmatic and implementation progress as well as analyzes any natural system benefits resulting from the progress to date. This chapter ends with a short series of conclusions that encapsulate the committee's general assessment of restoration progress.

PROGRAMMATIC PROGRESS

To assess programmatic progress the committee reviewed a set of primary issues that strongly influence the progress of the CERP toward its overall goals of ecosystem restoration. These issues, described in the following sections, relate to scheduling, planning, funding, cost-sharing, land acquisition, and endangered species. The following review represents the next iteration of a series of similar reviews by previous committees (Box 3-1).

Project Scheduling and Prioritization

The CERP project construction schedule through 2020 is outlined in the Integrated Delivery Schedule (IDS; Figure 3-1), which was developed in consultation with the South Florida Ecosystem Restoration Task Force (hereafter, simply the Task Force) and reflects the priorities of the CERP partners as well as sequencing constraints and other project implementation issues. The IDS is revised several times per year to reflect changing budgets and other developments that affect project schedules. A review of recent changes to the IDS reveals

BOX 3-1
Key Prior NRC Conclusions on CERP Programmatic Issues

NRC (2007):

“. . . **there have been significant delays in the expected completion dates of several construction projects that contribute to natural system restoration**. . . . The delays seem to be the result of a number of factors, including budgetary and manpower restrictions, the need to negotiate resolutions to major concerns or agency disagreements in the planning process, and a project planning process that can be stalled by unresolved scientific uncertainties, especially for complex or contentious projects.”

NRC (2008):

“The complex project planning and approval process has been a major cause of delays for CERP projects to date. The greatest challenge in the project planning process has been developing technically sound project plans that are acceptable to the many agencies and stakeholders involved. . . . The infrequent and unpredictable federal authorization mechanism for CERP projects has caused some additional problems and attendant delays.”

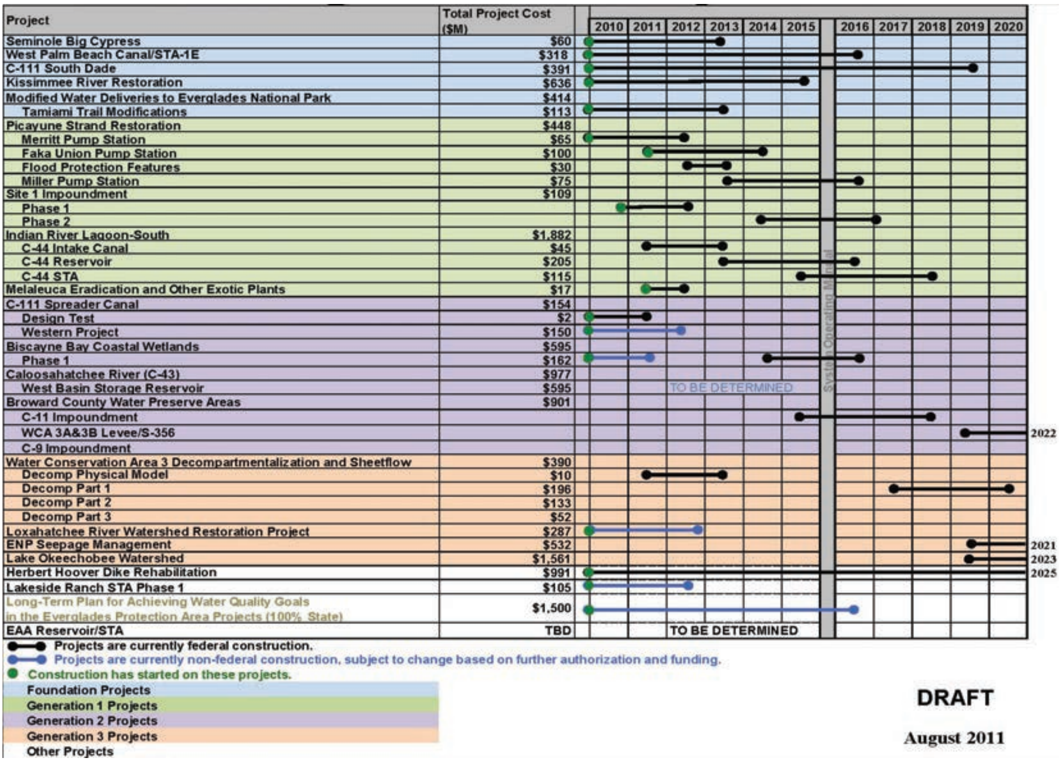
“**Deficiencies in CERP system-wide planning are affecting the delivery of natural system restoration benefits.** The CERP lacks a systematic approach to analyze the costs and benefits across multiple projects in support of project planning. Fundamentally, the CERP is designed as a system of related projects (i.e., components) that work together in the aggregate to produce overall restoration benefits. Without a system-wide planning process, it is not clear how system benefits can be optimized for any one project without any systematic consideration of other projects.”

“To reduce restoration delays, CERP planners should develop a stronger conceptual basis for multi-species recovery planning and management.”

NRC (2010):

“Given the slower than anticipated pace of implementation and unreliable funding schedule, projects should be scheduled with the aim of achieving substantial restoration benefits as soon as possible.”

that the anticipated pace of project construction has slowed significantly since the committee’s previous report (NRC, 2010). Of the 24 CERP and non-CERP project components in the most recent version of the IDS (August 2011) for which the scheduled construction can be directly compared to the March 2010 IDS, 14 were delayed (by an average of 3.4 years), 3 were accelerated (by an average of 1.3 years), and 7 had no change. In particular, NRC (2010) praised the acceleration of the Water Conservation Area (WCA)-3 Decompartmentalization and Sheetflow Enhancement (Decomp) project reflected in the March 2010 IDS, which showed all three phases of Decomp being completed by 2019.



Project	Total Project Cost ($M)
Seminole Big Cypress	$60
West Palm Beach Canal/STA-1E	$318
C-111 South Dade	$391
Kissimmee River Restoration	$636
Modified Water Deliveries to Everglades National Park	$414
Tamiami Trail Modifications	$113
Picayune Strand Restoration	$448
Merritt Pump Station	$65
Faka Union Pump Station	$100
Flood Protection Features	$30
Miller Pump Station	$75
Site 1 Impoundment	$109
Phase 1	
Phase 2	
Indian River Lagoon-South	$1,882
C-44 Intake Canal	$45
C-44 Reservoir	$205
C-44 STA	$115
Melaleuca Eradication and Other Exotic Plants	$17
C-111 Spreader Canal	$154
Design Test	$2
Western Project	$150
Biscayne Bay Coastal Wetlands	$595
Phase 1	$162
Caloosahatchee River (C-43)	$977
West Basin Storage Reservoir	$595
Broward County Water Preserve Areas	$901
C-11 Impoundment	
WCA 3A&3B Levee/S-356	
C-9 Impoundment	
Water Conservation Area 3 Decompartmentalization and Sheetflow	$390
Decomp Physical Model	$10
Decomp Part 1	$196
Decomp Part 2	$133
Decomp Part 3	$52
Loxahatchee River Watershed Restoration Project	$287
ENP Seepage Management	$532
Lake Okeechobee Watershed	$1,561
Herbert Hoover Dike Rehabilitation	$991
Lakeside Ranch STA Phase 1	$105
Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area Projects (100% State)	$1,500
EAA Reservoir/STA	TBD

●—● Projects are currently federal construction.

●—● Projects are currently non-federal construction, subject to change based on further authorization and funding.

● Construction has started on these projects.

Foundation Projects
Generation 1 Projects
Generation 2 Projects
Generation 3 Projects
Other Projects

FIGURE 3-1 Integrated Delivery Schedule, August 2011 draft.
NOTE: Project costs cited represent October 2008 price levels and have been adjusted for inflation based on construction start and finish dates for each contract.

SOURCE: K. Tippett, USACE, personal communication, 2011.

By accelerating the Decomp project, which has been identified as the highest priority project for reversing ecosystem decline and advancing restoration (Ad Hoc Senior Scientists, 2007), the committee concluded that the March 2010 IDS was consistent with the goal of achieving substantial restoration benefits as soon as possible. Unfortunately, in the August 2011 IDS, the completion of Decomp Part 1 had been pushed back until 2020, and construction of the other two Decomp phases are to begin after 2020 (see Figure 3-1).

The August 2011 IDS separates the projects into groups largely defined by the timing of their authorization. The foundation projects represent non-CERP (and largely pre-CERP) projects, such as Modified Water Deliveries to Everglades National Park (Mod Waters), C-111 South Dade, and the Kissimmee River Restoration. Generation 1 projects include those authorized in the 2007 Water Resources Development Act (WRDA; Picayune Strand, Site 1 Impoundment, Indian River Lagoon-South [IRL-S]) and the Melaleuca Eradication project, which was authorized within program authority. The construction of these projects is well under way (more detail on project-level progress is provided later in the chapter). Generation 2 projects include those projects that are anticipated to be included in the next WRDA bill, that is, projects with final or near-final project implementation reports (PIRs)—C-43, C-111 Spreader Canal, Biscayne Bay Coastal Wetlands, and Broward County Water Preserve Areas (WPAs). Two of the Generation 2 projects—C-111 Spreader Canal and Biscayne Bay Coastal Wetlands—have been the focus of expedited construction initiatives by the state of Florida. However, no federal funding can be provided to support continued construction progress until the projects are authorized. The Generation 3 projects reflect near-term priority projects for which project planning and development of a project implementation report (PIR) is far from complete. Note that the August 2011 IDS was published prior to the launch of the Central Everglades Planning Project (discussed later in this chapter).

Previous reports by this committee have noted that early authorizations have focused on more peripheral projects that have either strong local support or little opposition that would delay project planning. As a result, NRC (2007) concluded that "production of natural system restoration benefits within the Water Conservation Areas and Everglades National Park is lagging behind production of natural system restoration benefits in other portions of the South Florida ecosystem." Although the C-111 Spreader Canal and Broward County WPAs would enhance seepage management in the central Everglades, the remaining Generation 2 projects largely target restoration benefits outside of the remnant Everglades. Projects such as Decomp and Everglades National Park (ENP) Seepage Management (both Generation 3) combined with Modified Water Deliveries to Everglades National Park (Mod Waters) and additional water storage for central Everglades restoration offer the most promise for restoration of the "core" Everglades. However, the August 2011 IDS shows completion of many of these projects beyond 2020.

In response to past NRC criticisms and recognizing the need to stem ecosystem declines in the remnant Everglades, the CERP agencies launched the Central Everglades Planning Project in October 2011 (described in more detail in the next section). This project aims to deliver an increment of restoration to the central Everglades as soon as possible within certain constraints, such as using only publicly owned land. The prioritization of restoration in the central Everglades and the proposal to advance increments of restoration as a means of accelerating restoration is consistent with past committee recommendations (NRC, 2007, 2008, 2010). Meanwhile, the South Florida Water Management District (SFWMD) also appears to be prioritizing its investments toward further improvements to water quality to ensure compliance with the 1992 Consent Decree (discussed later in this chapter). As discussed in detail in Chapter 4, refocused efforts on the central Everglades and integrated water quality and quantity improvements are keys to reversing the declines in the historical Everglades.

Project Planning, Approval, and Authorization

A complex project planning, approval, and authorization process is in place for CERP projects (as described in NRC, 2007) that significantly affects the pace of project implementation. Past NRC reports have concluded that the federal planning process contributes to substantial restoration delays and does not effectively support system-wide planning (see Box 3-1). Senior CERP managers admit that the current U.S. Army Corps of Engineers (USACE) project planning and approval process frustrates local sponsors, Congress, and the USACE staff because it is time consuming, overly detailed, and expensive (S. Kopecky, USACE, personal communication, 2012). This section discusses a major initiative to address some of these planning and approval challenges, as well as continued delays in project authorization.

USACE Planning Transformation Pilots

In 2011, the USACE launched a nationwide pilot program to test a revised project planning and approval process to reduce the typical 6-year preauthorization timeframe to 18-24 months, while still addressing all current legal and programmatic requirements (such as National Environmental Policy Act [NEPA] and independent external peer review). The process requires a cultural shift toward less-detailed analyses and risk-based project planning. The process utilizes planning teams that consider what information is really needed to compare alternatives and reduce overall risk and includes early involvement by senior leadership and decision making at key project phases (or decision points).

At the heart of the revised process is a more aggressive and comprehensive early project scoping process. In the scoping phase, federal interest in the project is assessed, problems and opportunities are identified, and key assumptions and analysis plans are agreed upon (e.g., assessment measures, modeling tools, “future without project” conditions). The process compresses the scoping phase from three years into three months (Figure 3-2), which requires planners to balance and manage the level of detail in their considerations of benefits and

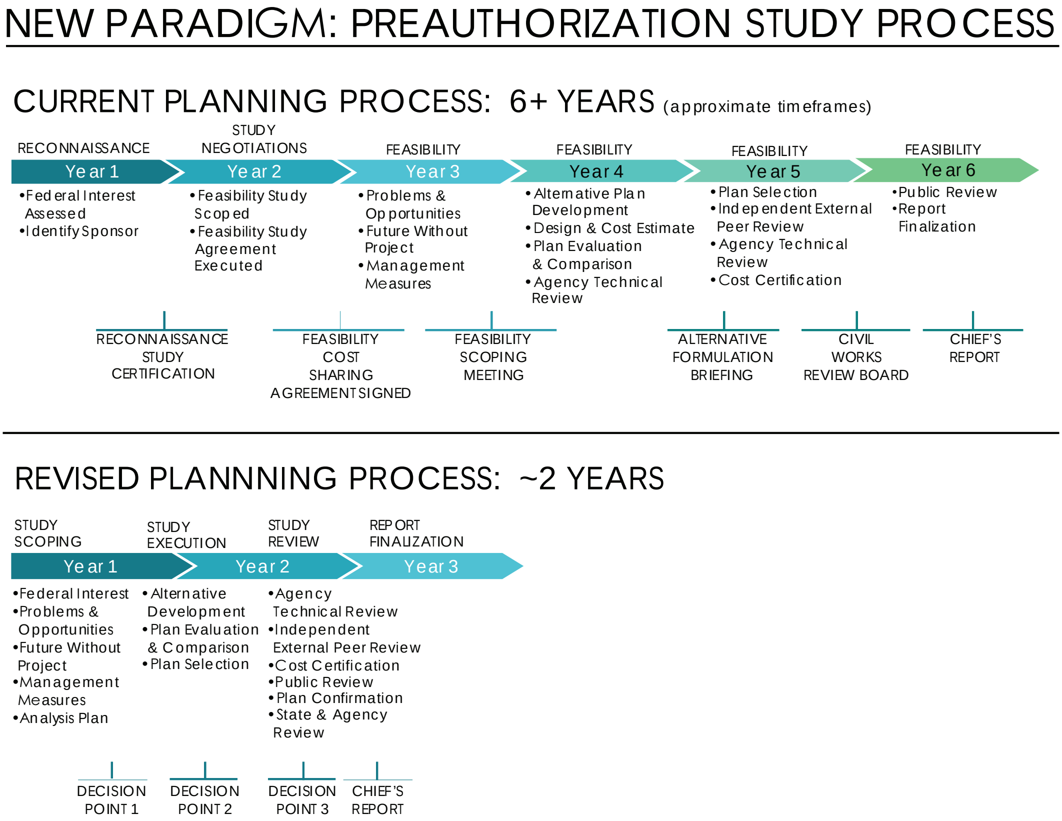


FIGURE 3-2 Comparison of the timeframes of the traditional USACE project planning and approval process against the revised planning pilot process.

SOURCE: Modified from S. Kopecky, USACE, personal communication, 2012.

uncertainty. Additionally, the process requires techniques to support extensive stakeholder involvement and public communication.

The USACE is testing its revised planning process with a nationwide pilot program focused on five projects—two navigation, one flood control, and two environmental restoration projects. The intent of the pilot program is three-fold: 1) demonstrate effectiveness and efficiencies of the new civil works planning paradigm, 2) inform future planning guidance, and 3) develop sustainable, replicable processes (S. Kopecky, USACE, personal communication, 2012). The

Central Everglades Planning Project was launched in October 2011 as one of the five pilots.

Central Everglades Planning Project

The purpose of the Central Everglades Planning Project is to substantially reduce the project planning and approval time for a suite of CERP project components to "improve the quantity, quality, timing, and distribution of water flows to the central Everglades (WCA-3 and [Everglades National Park] ENP)" (Box 3-2; USACE and SFWMD, 2012). Although the project focuses on the central Everglades, the redistribution of flows also could notably benefit the northern estuaries and Lake Okeechobee, and these benefits are included among the project objectives (Box 3-2; Figure 3-3). The scope of the project includes *increments*

BOX 3-2
Central Everglades Planning Project Purpose, Goal, and Objectives

Project purpose:

"The purpose of the CEPP [Central Everglades Planning Project] is to improve the quantity, quality, timing and distribution of water flows to the central Everglades (WCA 3 and ENP)."

Project goal:

"The goal of the CEPP is to improve the quantity, quality, timing, and distribution of water in the Northern Estuaries, Water Conservation Area 3, and Everglades National Park in order to restore the hydrology, habitat, and functions of the natural system."

Project objectives:

- "Restore seasonal hydroperiods and freshwater distribution to support a natural mosaic of wetland and upland habitat in the Everglades system
- Improve sheetflow patterns and surface water depths and durations in the Everglades system in order to reduce soil subsidence, the frequency of damaging peat fires, the decline of tree islands, and saltwater intrusion
- Reduce water loss out of the natural system to promote appropriate dry season recession rates for wildlife utilization
- Restore more natural water level responses to rainfall to promote plant and animal diversity and habitat function
- Reduce high volume discharges from Lake Okeechobee to improve the quality of oyster and submerged aquatic vegetation (SAV) habitat in the northern estuaries"

SOURCE: USACE and SFWMD, 2012.

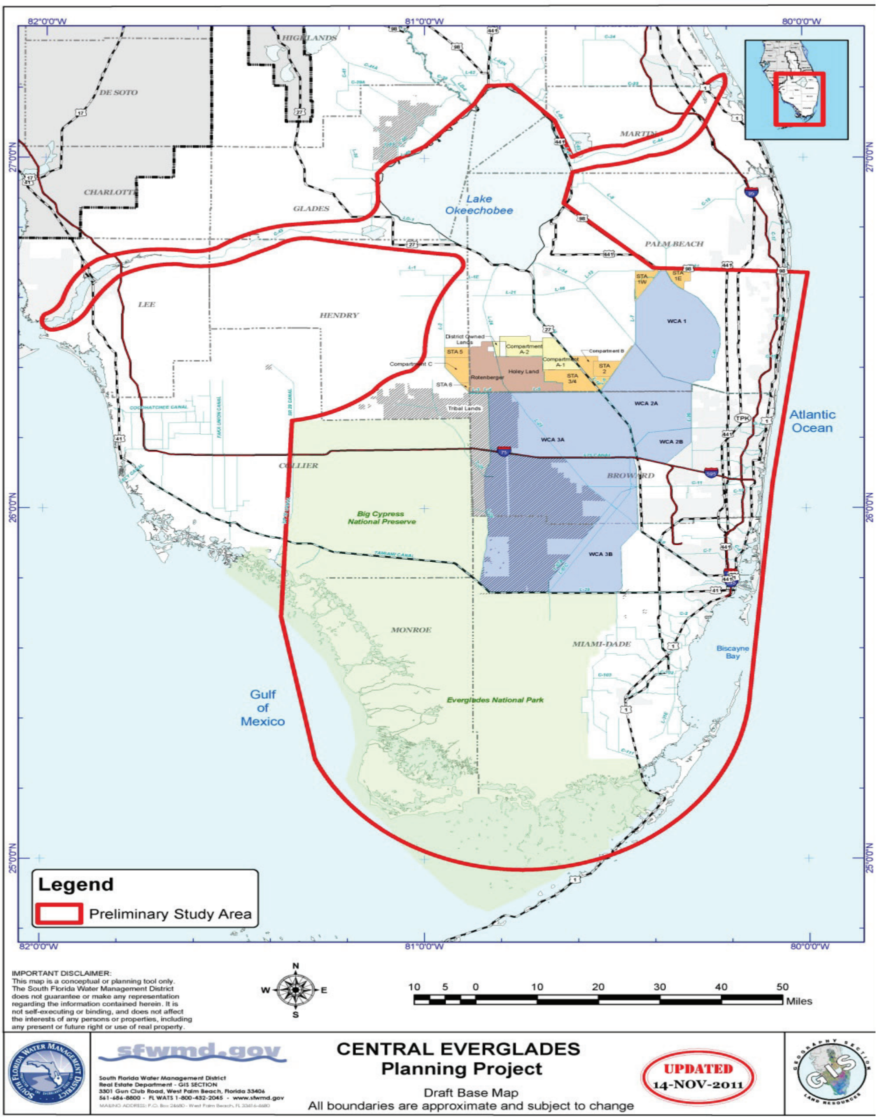


FIGURE 3-3 The Central Everglades Planning Project study region, including areas potentially impacted the project.

SOURCE: USACE and SFWMD (2012).

of a number of CERP project components described in the original restoration plan (the Yellow Book; USACE and SFWMD, 1999), such as the Everglades Agricultural Area Storage Reservoir, Decomp, seepage management, and rain-driven operations. The Central Everglades Planning Project shifts the planning emphasis from multiple independent project PIRs (each normally taking 6 or more years to complete) to a regional integrated PIR for the first increment of restoration on an expedited schedule of approximately 18 months. The central Everglades is an ideal pilot candidate for the USACE revised planning process and offers the ability to move toward a more integrated planning process where benefits can be aggregated both spatially and across project components, thereby addressing criticisms of previous NRC committees (Box 3-1). The project also incorporates the incremental adaptive restoration approach (NRC, 2007) as a means of moving forward with increments of restoration as quickly as possible, while learning in ways that enhance subsequent project designs. The process is early in its 18-month timeframe, and as of May 2012, there were no publicly available decision documents for the committee to evaluate.

Assessment

The proposed USACE planning transformation is clearly not business as usual. It is a striking change to a process and culture that have existed for some time, and it directly addresses several concerns raised by earlier reports of this Committee (see Box 3-1; NRC, 2007, 2008, 2010). The inclusion of the Central Everglades Planning Project as one of five nationwide pilots is both responsive to a recognized need for planning acceleration and a true test of the revised process. The USACE is to be commended for undertaking this much needed and ambitious effort.

The Central Everglades Planning Project team has identified several concerns and limitations in the Draft Project Management Plan (USACE and SFWMD, 2012). The timeframe of the Central Everglades Planning Project does not allow for the development of new planning tools or approaches that could help to facilitate the process. One of the most substantive concerns is the time available for formal approval of critical models, including the "local" model used to evaluate and compare project alternatives. The time required for USACE model approval may hamper the completion of the Central Everglades Planning Project within the 18-month target period. Another concern centers on the fact that data and design will be limited compared to those available during conventional project scope definition and PIR development. The prospect of greater uncertainty during the scoping phase is well recognized by the transformation process itself, although the formal methods for managing it have not been fully articulated and vetted. By recognizing and addressing these issues, the Project

Delivery Team can help to advance the Central Everglades Planning Project toward a timely, successful conclusion.

Project Authorization

Once project planning is complete and the USACE Chief of Engineers approves the PIR (also called the Chief's Report; see Figure 3-2), the project is submitted to Congress for authorization. Water Resources Development Acts have served as the mechanism to congressionally authorize Everglades restoration efforts and specific CERP projects (see Appendix C). The CERP was formally launched by WRDA 2000 and included authorizations for 4 pilot projects, 10 initial Everglades restoration projects (pending congressional approval of the PIRs), and an adaptive management and monitoring program. All other projects with costs exceeding \$25 million[1] must be individually authorized by Congress. WDRA 2000 stipulated that the initial project authorizations are subject to Section 902 of WRDA 1986, thereby requiring reauthorization if project costs increase by more than 20 percent of the original authorized cost (exclusive of inflation). As a result of the Section 902 limits or other major project changes, all 10 conditionally authorized projects now require reauthorization (S. Appelbaum, USACE, personal communication, 2012).

The CERP planning process was developed with the assumption that WRDAs would be passed every two years, but this has not occurred. Since WRDA 2000, Congress has passed only one WRDA; WRDA 2007 authorized Indian River Lagoon-South, Picayune Strand Restoration, and the Site 1 Impoundment Projects (Figure 3-4). Federal funding has been appropriated for construction of all three of these projects plus the Melaleuca Eradication, which was authorized under programmatic authority (see Table 3-1). Without additional congressional authorizations, no new CERP projects can receive federal appropriations to support construction. Since 2007, Chief's reports have been issued for four additional projects (C-43 Reservoir, C-111 Spreader Canal, Biscayne Bay Coastal Wetlands, Broward County Water Preserve Areas. These four projects represent the Generation 2 CERP projects (Table 3-1). Without passage of a new WRDA (or some other mechanism) to authorize these additional restoration projects, the federal government will be unable to maintain progress on several state-expedited projects now under way (e.g., C-111 Spreader Canal, Biscayne Bay Coastal Wetlands). The uncertain and sporadic occurrence of WRDA legislation has the potential to severely impede CERP progress, particularly for the four projects with completed Chief's Reports. Alternatives to using WRDA for project authorization may be

---

[1] Programmatic authority for smaller projects (less than \$25 million each) was subject to a total limit of \$206 million (WRDA 2000).

FIGURE 3-4 Locations of CERP and CERP-related projects and pilots listed in Table 3-1. Projects actively under construction are noted with a dark circle.

SOURCE: © International Mapping Associates

TABLE 3-1 CERP or CERP-related Project Implementation Status as of March 2012.

Project or Component Name	Yellow Book (1999) Estimated Completion Date	2010 Estimated Completion Date (NRC, 2010)	IDS (Aug. 2011) Estimated Completion Date
PILOT PROJECTS			
Hillsboro ASR Pilot (Fig. 3-4, No. 2)	2002	2009	Not specified
Kissimmee ASR Pilot (Fig. 3-4, No. 4)	2001	2012	Not specified
Regional ASR Study	NA	NA	Not specified
L-31N (L-30) **Seepage Management Pilot** (Fig. 3-4, No. 3)	2002	2010	On hold
LPA Seepage Management Pilot (Fig. 3-4, No. 13)	NA	NA	Not specified
C-111 Spreader Canal Design Test (Fig. 3-4, No. 10)	NA	2011	2011
Decomp Physical Model (Fig. 3-4, No. 12)	NA	2014	2014
RESTORATION PROJECTS—Generation 1			
Picayune Strand Restoration (Fig. 3-4, No. 6)	2005	2015	Merritt: 2012 Flood Prot: 2013 Faka-Union: 2014 Miller: 2016
Site 1 Impoundment* (Fig. 3-4, No. 2)	2007	2013	Phase One: 2013 Phase Two: TBD
Indian River Lagoon-South (Fig. 3-4, No. 7)		2023	Not specified
- C-44 Reservoir/STA*	2007	2014	2018
Melaleuca Eradication and Other Exotic Plants	2011	2026	2012
RESTORATION PROJECTS—Generation 2			
C-111 Spreader Canal*	2008		
- Western Project (PIR#1) (Fig. 3-4, No. 10)		2011	2012
Biscayne Bay Coastal Wetlands (Phase 1) (Fig. 3-4, No. 5)	2018	2011	2016
C-43 Basin Storage: West Basin Storage Reservoir (Fig. 3-4, No. 1)	2012	2013	TBD
Broward County WPAs			
- C-9 Impoundment* (Fig. 3-4, No. 8)	2007	2014	Not specified
- Western C-11 Diversion Impoundment* (Fig. 3-4, No. 9)	2008	2014	2018
- WCA-3A & -3B Levee Seepage Management* (Fig. 3-4, No. 8,9)	2008	2017	2022

PIR (or PPDR) Status	Authorization Status	Planning/ Design	Construction Status; Installation and Testing Status for Pilots
PPDR Final Oct. 2004	Authorized in WRDA 1999	Completed	Installed 2008; Testing ongoing
PPDR Final Oct. 2004	Authorized in WRDA 1999	Completed	Installed 2008; Testing ongoing
NA	NA	Completed	Ongoing
PPDR Final May 2009	Authorized in WRDA 2000	Completed	On hold
NA	NA	Completed	Ongoing
NA	Programmatic Authority WRDA 2000	Completed	Testing completed
NA	Programmatic Authority WRDA 2000	Completed	Ongoing
Submitted to Congress in 2005	Construction Authorized in WRDA 2007	Completed	Prairie Canal completed in 2007 (expedited by FL); Merritt, Faka Union ongoing
Submitted to Congress in 2006	Construction Authorized in WRDA 2007	Ongoing	Ongoing
Submitted to Congress in 2004	Construction Authorized in WRDA 2007		
		Completed	Ongoing
Final June 2010	Programmatic Authority WRDA 2000	Completed	Ongoing
Approved by USACE Chief of Eng. in Jan. 2012	Not authorized	Completed	Ongoing; expedited by FL
Approved by USACE Chief of Eng. in May 2012	Not authorized	Completed	Ongoing; expedited by FL
Approved by USACE Chief of Eng. in Jan. 2011	Not authorized	Completed	Not begun
Approved by USACE Chief of Eng. in May 2012	Not authorized		
		Ongoing	Not Begun
		Ongoing	Not Begun
		Ongoing	Not Begun

continued

TABLE 3-1 Continued

Project or Component Name	Yellow Book (1999) Estimated Completion Date	2010 Estimated Completion Date (NRC, 2010)	IDS (Aug. 2011) Estimated Completion Date
RESTORATION PROJECTS—Generation 3			
WCA-3 Decompartmentalization and Sheet flow (Decomp)[a] (Fig. 3-4, No. 12)			
- Decomp Part 1	2010	2012	2020
- Decomp Part 2	2010	2019	Not specified
- Decomp Part 3	2019	Beyond 2020	Not specified
Loxahatchee River Watershed	Not specified		Not specified
- C-51 and Loxahatchee (L-8 Basin) Reservoir (Fig. 3-4, No. 11)	2011	2008	2012
ENP Seepage Management (Fig. 3-4, No. 13)	2010	2016	2021
Lake Okeechobee Watershed (Fig. 3-4, No. 14)	2015	2015	2023
-Lakeside Ranch STA (Fig. 3-4, No. 15	2010	2011	Phase One: 2012 Phase Two: TBD

[a] Projects that were conditionally authorized in WRDA 2000, subject to approval of the PIR.

NOTES: Projects in Table 3-1 reflect those CERP projects or pilot projects that are now identified in the IDS (April 2011 version) for construction start prior to 2020, and other projects deemed by the committee to be relevant to CERP progress. This table does not include non-CERP foundation projects or "other projects" as classified by the IDS. Gray shading of project names reflects projects being expedited and/or carried out entirely with state funding as of 2012. Gray shading of construction cells indicates past or present aspects of projects that were expedited with state funding. In most cases, design and/or construction of these projects was moving forward prior to the finalization of the project implementation report (PIR). NA = not applicable; TBD = to be determined.

SOURCES: DOI and USACE (2011); SFERTF (2011); L. Gerry, SFWMD, personal communication (2012); G. Landers, USACE, personal communication (2012); USACE and SFWMD (1999).

feasible, although the committee is not aware that such mechanisms are being contemplated at this time.

Funding for South Florida Ecosystem Restoration

Once projects are authorized, the pace of restoration progress largely depends on the flow of funding to support their construction. Funding for Everglades restoration comes from two primary sources: the federal government and the state of Florida (largely via the SFWMD and the Florida legislature). For reporting purposes, funding is divided in two broad categories, one for CERP implementation and

PIR (or PPDR) Status	Authorization Status	Planning/ Design	Construction Status; Installation and Testing Status for Pilots
	Not authorized		
In development as part of CEPP		Ongoing	Not begun
Not begun		Not begun	Not begun
Not begun		Not begun	Not begun
In development	Not authorized	Ongoing	Expedited by FL
			On hold pending funding
On hold (pending pilot)	Not authorized	On hold	Not begun
In development	Not authorized	Ongoing	Not begun
			Ongoing; expedited by FL

the other for non-CERP restoration efforts. In the following section the committee reviews state and federal funding for restoration projects in the Everglades.

Financial History of Non-CERP and CERP Restoration Projects

Appropriations for non-CERP restoration projects, such as the Kissimmee River Restoration Project and Mod Waters, have been much greater than on CERP projects: $2.53 on non-CERP projects for every $1.00 on CERP projects. Non-federal partners have budgeted $3.28 for non-CERP projects for every $1.00 by the federal government (Table 3-2).

TABLE 3-2 Total Funding (in Millions) for CERP and Non-CERP South Florida Restoration Projects, FY 2002 to FY 2011 for Federal and Non-Federal Partners

	Federal (in million $)	State (in million $)
CERP	854	3,066
Non-CERP	2,150	7,045
Total	3,004	10,111

NOTE: This table includes appropriations, not precise expenditures, and cannot be used to calculate cost-sharing credits.

SOURCE: SFERTF (2012).

The CERP is a 50-50 cost-share program, but to date non-federal funding has been far greater than federal funding (Figure 3-5). Between fiscal year (FY) 2002 and 2011, the federal government appropriated a reported $854.0 million for the CERP, while the state of Florida budgeted nearly $3.1 billion (Table 3-2; SFERTF, 2012). It remains to be determined how much of that excess state funding is creditable to CERP cost-sharing, because cost-sharing credits are dependent on project partnership agreements that are signed for each project only after federal authorization and appropriation of federal funding. Federal funding for the CERP has increased in the past few years, while state funding has generally declined after a peak in 2007 associated with the launch of the Acceler8 program. Funding streams of the federal and state CERP partners are discussed in more detail in the following sections.

Recent Federal Funding for Restoration

Table 3-3 shows federal budgeted expenditures as reported in the Task Force cross-cut budget for FY 2009 through FY 2012. Funding in FY 2010 and FY 2011 was notably higher than in prior years, partially because of American Recovery and Reinvestment Act (ARRA) funding in FY 2010. More than 90 percent of CERP monies went to the USACE for major construction projects, pilot projects, and project planning and design, with some funding to the Department of Interior for CERP planning support.

A large portion of federal CERP funds have been directed toward planning and design, but increasingly federal funds are being directed toward construction. Of $561 million in federal CERP funding through FY 2010, $420 million was spent on design (75 percent), $101 million on construction of three authorized Generation 1 projects (Site 1 Impoundment, Picayune Strand, Melaleuca Eradication; 18 percent), and $41 million on land acquisition (7 percent). In

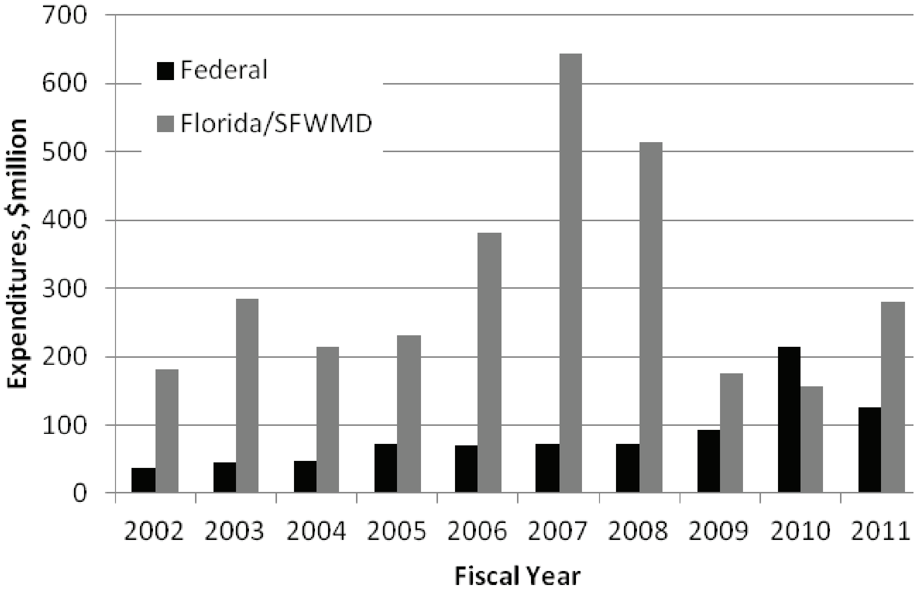


FIGURE 3-5 CERP-related expenditures by federal and non-federal partners.
NOTE: This figure includes all reported costs, including some that are not cost-shareable.

SOURCE: Data from SFERTF (2012).

FY 2011, nearly 70 percent of federal CERP funds were directed to project construction (K. Tippett, USACE, personal communication, 2011). Non-CERP projects continued to receive a large share of South Florida ecosystem restoration funds, and this funding has been relatively steady over the past four years. These funds are dispersed among a large number of projects and agencies; the major projects (>$5 million) are listed in Table 3-3.

Recent State Funding for Restoration

During the past three years several factors have stressed the SFWMD's financial position, raising questions about its ability to continue funding Everglades restoration. Probably the most severe impact has been the decline of housing values in the service area, which has led to sharp declines in property (ad valorem) taxes. Florida had the third most foreclosures in the nation, leading to legislative mandates in 2008 to reduce property taxes. The current governor, who campaigned on a platform of tax reductions and government downsizing,

TABLE 3-3 Federal Budgets for CERP and Non-CERP Projects for FY 2009 to FY 2012 ($ millions)

	FY 2009 (enacted)	FY 2010 (enacted)	FY 2011 (enacted)	FY 2012 (requested)
CERP Total	93	215	126	88
USACE (incl. ARRA)	85	207	118	80
• Planning and design				
• Construction at authorized projects (Site 1 Impoundment; Picayune Strand)				
• Pilot projects				
DOI	8.4	8.5	8.4	8.4
Non-CERP Total	241	289	229	248
Major projects (>$5 million):				
C&SF Project (incl. ARRA)	9.0	18	35	36
• C-111 S. Dade County				
• West Palm Beach Canal				
• Canal-51/STA-1E				
Critical Projects	3.5	2.7	5.2	1.0
USDA NRCS	61	154	111	63[a]
Kissimmee River Restoration	28	45	7.0	46
Mod Waters	60	8.4	8.0	8.0
Everglades National Park management	30	31	30	31
DOI land acquisition	0	0	0	31
USGS research, planning, and coordination	6.9	6.9	6.9	6.9

[a] Wetlands Reserve Program funding amounts for FY 2012 are not included.

SOURCE: SFERTF (2012).

ordered a further 25 percent reduction in ad valorem taxes for FY 2012.[2] A directive by a federal judge to address water quality in the Everglades Protection Area has compounded the agency's fiscal challenges.

Florida relies on several sources of revenue to fund restoration, including (1) a portion of SFWMD's ad valorem tax revenue; (2) an allocation from the Save Our Everglades Trust Fund (SOETF) administered by the Florida Department of Environmental Protection (FDEP) for the design, construction, and associated land costs for CERP projects; (3) the Florida Forever Trust Fund (FFTF), a state program for acquiring conservation and recreation lands, also administered by FDEP; and (4) $546 million in proceeds from Certificates of Participation issued by the SFWMD in November 2006 to fund Acceler8 projects. The time stream of revenues and expenditures for the SFWMD is shown in Figure 3-6. In six of the eight years shown (FY 2004-FY 2011), expenditures exceeded revenues. Deficits

---

[2] The state legislature ultimately implemented a 30 percent reduction in ad valorem taxes.

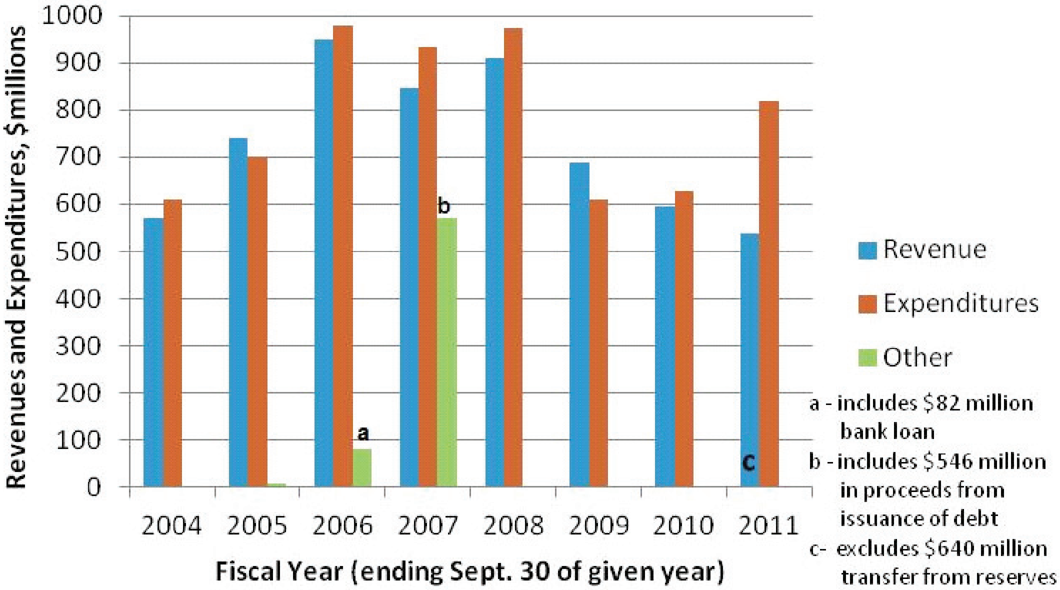


FIGURE 3-6 SFWMD revenues and expenditures, FY 2007 to FY 2011.
NOTE: To make revenues for FY 2011 consistent with earlier years, the budgeted $640 million transfer from fund balance was excluded from the revenue column.

SOURCE: Data from Statements of Revenues, Expenditures and Fund Balances, Comprehensive Annual Financial Reports FY2004-2010 and Updated Monthly Financial Statement for September 2011 (SFWMD, 2004, 2005, 2006, 2007, 2008a, 2009a, 2010, 2011a).

were covered either by bank loans, debt, or transfers from fund balances. Sharp declines in two parts of the revenue stream have affected the financial capacity of the SFWMD. Income from ad valorem taxes peaked in 2007 at $550 million when they accounted for two-thirds of revenue. In 2011 that source was $401 million, 27 percent less than in 2007. The FY 2012 budget includes only a projected $271 million from ad valorem taxes (SFWMD, 2012; L. Gerry, SFWMD, personal communication, 2012). Income from intergovernmental sources, particularly the state of Florida, also declined sharply. However, the SFWMD's ability to continue funding restoration initiatives is buffered to some extent by large fund balances that have accrued over prior years (Box 3-3).

SFWMD Expenditures. District expenditures on individual projects from FY 2007 to FY 2012 (see Table 3-4) show that the SFWMD has spent substantial sums

BOX 3-3
Role of Reserve Funds

Large reserve fund balances play an important role in tempering the short-term effects of recent budget declines. These funds are held in numerous separate accounts, the totals for which are shown in Figure 3-3-1. A large boost in SFWMD reserves occurred in FY 2007 with the issuance of $546 million of debt. As of September 30, 2010, the total was $856 million (SFWMD, 2012), but a substantial transfer from those sources was made in FY 2011 to cover shortfalls in the budget and the $194 million cost of acquiring the U.S. Sugar lands. The SFWMD's Monthly Financial Statement for September 2011 covering all expenditures for FY 2011 shows revenue from fund balances of $640 million, but only a portion of that was actually spent. When the tentative FY 2012 budget was submitted for approval in August 2011, it included a five-year $358 million plan to spend down fund balances, starting with an end-of-year projection of $417 million and leaving $59 million at the end of FY 2016 for contingencies and operations and maintenance of the capital reserve (SFWMD, 2011b). The actual end-of-year fund balance net of encumbrances was $475.5 million, considerably higher than the August projection (SFWMD, 2012).

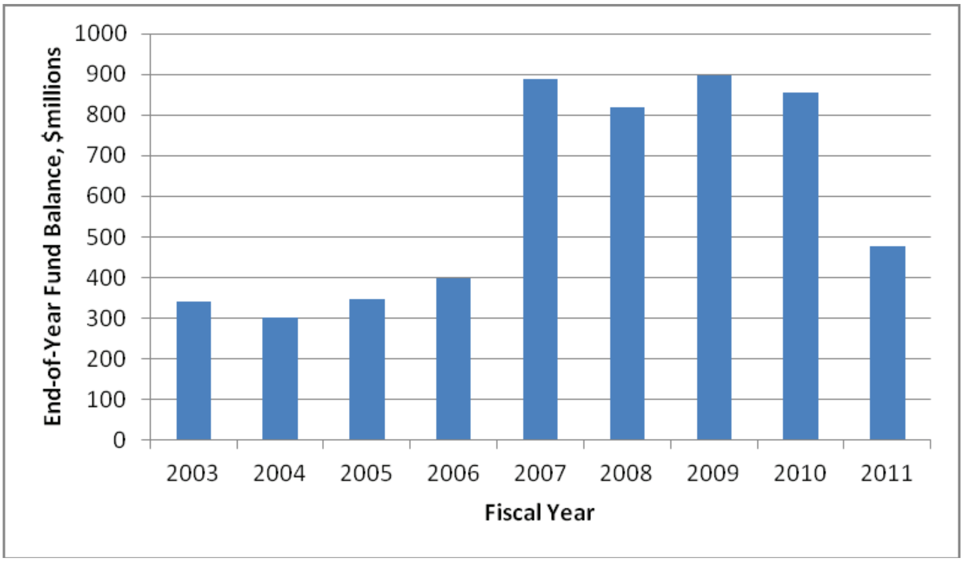


FIGURE 3-3-1 SFWMD total governmental fund balances, FY 2003-FY 2011.

SOURCES: Data from Comprehensive Annual Financial Reports FY 2004-FY 2010 and FY 2012 Budget Amendment passed February 9, 2012 (SFWMD, 2004; 2005; 2006; 2007; 2008a; 2009a; 2010; 2012).

TABLE 3-4 SFWMD Five-Year Expenditures (FY 2007-FY 2011) on CERP and CERP-related Projects and Programs

PROJECT	FY 2007-FY 2011 Total Expenditures, $million
PILOT PROJECTS	
ASR Regional Study	6.02
GENERATION 1 PROJECTS	
Indian River Lagoon-South/C-44 Reservoir and STA	107.07
Picayune Strand	33.01
GENERATION 2 PROJECTS	
Biscayne Bay Coastal Wetlands	35.64
C-111 Spreader Canal	19.61
Caloosahatchee River Region C-43 Basin Storage Reservoir—Part 1	15.11
Broward County Water Preserve Area (incl. C-11 Impoundment)	14.70
GENERATION 3 PROJECTS	
Loxahatchee River Watershed (North Palm Beach County—Part 1)	196.62
Lake Okeechobee Watershed	56.41
Everglades National Park Seepage Management	11.22
OTHER PROJECTS	
EAA Storage Reservoirs—Phase 1	242.95
River of Grass	225.54
Southern Crew/Imperial River Flow-way	13.56
Lake Trafford Restoration	9.17
PROGRAM SUPPORT	
Acceler8 Program Support	141.90
Adaptive Assessment and Monitoring	21.17
Interagency Modeling Center	11.13
Data Management	6.86

NOTE: Only projects with at least $5 million in total expenditures are included.

SOURCES: Caffie-Simpson et al. (2011); Carney et al. (2012); Williams et al. (2008, 2009, 2010).

on program support and on projects in Generations 1, 2, and 3, as well as the Everglades Agricultural Area (EAA) Reservoir, which is currently on hold. Many of the projects in Table 3-4 were originally part of the state's Acceler8 program.

Projected expenditures in annual five-year capital budgets have been subject to considerable change over the past three years with deferral of some projects and reassignment of responsibility for construction of others from the SFWMD to the USACE. For example, the capital budget reported $228 million for the C-44 reservoir (part of IRL-S) in FY 2009-FY 2010, but the SFWMD spent less than $200,000 on the project during that time period (Caffie-Simpson et al., 2011; Williams et al., 2010), and the FY 2011 five-year budget shows less than $15 million for the project. A similar fate befell the C-43 reservoir, a Generation 2 project whose five-year budget projections went from $171 million (FY 2009) to $2.8 million (FY 2010) to $14.2 million (FY 2011). SFWMD staff report that capital construction responsibilities for these projects are being transferred to the USACE (L. Gerry, SFWMD, personal communication, 2012). Five-year funding of the C-111 Spreader Canal, another Generation 2 project, was projected to be $77.9 million starting in FY 2009, with most of that scheduled for FY 2009, but the SFWMD spent only $19.6 million in FY 2009-FY 2011. While some large construction projects were deferred, funding for other projects increased in the FY 2010 five-year budget, including a new flow equalization basin, budgeted at $70 million, to enhance the performance of the stormwater treatment areas (STAs).

Comparisons of the SFWMD's capital improvement plans (CIPs) from FY 2009 through FY 2012 reveal a dramatic reduction in projected spending for restoration—particularly for Generation 1 and 2 CERP projects—as well as for overall spending. The FY 2009 five-year CIP included $1.63 billion for Everglades restoration in FY 2010 through FY 2013, including CERP and non-CERP Everglades Restoration (SFWMD, 2008b).[3] The FY 2012 five-year capital budget for Everglades restoration is $544 million, one-third of the FY 2009 figure (Smykowski, 2012). Selected projects in the FY 2012 plan and contributions from the five-year reserves spend-down plan are shown in Table 3-5. Of special note is the $229 million projected five-year expenditure for the CERP, 48 percent of which is allocated to the Generation 3 project Loxahatchee River Watershed and another 34 percent to debt service. The only other CERP project with significant funding over the next five years is the C-44 Reservoir/STA (a Generation 2 project).

Cost-Sharing Challenges

The CERP is a partnership between the federal government and the state of Florida, with shared, equal financial responsibilities to support implementation of the project. However, according to USACE policy, the federal government is not permitted to outspend the non-federal sponsor at any point in the project. Although state funding for the CERP has far exceeded federal funding so far, the 50-50 cost-sharing requirements may hinder CERP progress in the years ahead because of reduced spending by the SFWMD on authorized projects.

---

[3] The $1.3 billion included construction of the C-43 and C-44 reservoirs, which have now been transferred to the USACE. Additionally, the total included service on the debt for the acquisition of 180,000 acres of U.S. Sugar land, although ultimately only 26,000 acres were acquired without any additional debt.

TABLE 3-5 Selected Projects in Five-Year Capital Improvement Plan and Five-Year Reserves Spend-Down Plan (FY 2012-FY 2016)

SFWMD Budget Category/Project	FY 2012-FY 2016 Five-Year Capital Improvement Plan ($millions)[a]	Contribution from FY 2012-FY 2016 Five-Year Reserves Spend Down ($millions)[b]
CERP TOTAL	229	
Loxahatchee River Watershed (L-8)	110	69
C-44 Reservoir/STA	36	30
C-111 Spreader Canal	1	
Debt Service	79	
DISTRICT EVERGLADES RESTORATION TOTAL	315	
Water Quality Enhancement Projects	164	100
Rotenberger Pump Station Design & Construction	5	
Compartment B Build-out	5	5
Compartment C Build-out	6	6
Debt Service and Debt Service Reserves	128	
COASTAL WETLANDS TOTAL	34	
Caloosahatchee Basin (C-43) Storage/Treatment and Facility	21	19
Local Projects	12	
Lakes Park Restoration	2	
LAKE OKEECHOBEE TOTAL	60	
Dispersed Storage (existing and new commitments)	46	46
Lakeside Ranch STA Phase I	4	6
Local Projects	8	

NOTE: Projects only shown with five-year expenditures equal to or greater than $1 million.

SOURCES: [a] Smykowski, 2012; [b] SFWMD, 2011b.

Cost-sharing credits can only be tapped as matching funds for projects that have been authorized by Congress, have received federal appropriations, and have a signed formal project partnership agreement between the USACE and the SFWMD. As of early 2012, these include only the four Generation 1 projects: IRL-S (reservoir and STA components only[4]), Picayune Strand, Site 1 Impoundment—Phase 1, and Melaleuca Eradication. As of September, 2011, the USACE calculated that the state had outspent the federal government on these four Generation 1 projects by $270 million (see Table 3-6). Total estimated costs for the Genera-

---

[4] The natural storage component of IRL-S does not yet have a signed PPA because only approximately one-third of the land for this component has been purchased. Water reservations—a prerequisite to the PPA—cannot be determined until the land is in public ownership.

TABLE 3-6 Calculated and Estimated Cost-sharing CERP Credits

	Federal (in million $)	Non-federal (State/SFWMD) (in million $)	Cost-Share Imbalance
Creditable expenditures as of September 30, 2011 associated with existing PPAs (i.e., Generation 1 projects)[a]	749	1,020	270
Estimated creditable expenditures associated with Generation 2 projects[b]	76	584	508

[a] These creditable expenditures include costs associated with feasibility study cost-share agreements, all project design costs eligible for cost-sharing (includes Generation 2 and later projects), and land acquisition and construction expenditures for authorized projects (or project components) for which federal funding has been appropriated and a project partnership agreement has been signed. These include the Generation 1 projects, with the exception of Phase 2 of the Site 1 Impoundment and the natural storage feature of the IRL-S project.

[b] Actual creditable expenditures related to land acquisition and construction expenditures are determined once the project has been authorized, federal funding has been appropriated, and a project partnership agreement has been signed.

SOURCE: K. Tippett, USACE, personal communication, 2012.

tion 1 and 2 projects are listed in Figure 3-1. The agencies estimate that the cost share imbalance associated with Generation 2 projects exceeds $500 million. The extensive "creditable expenditures" associated with land acquisition and construction costs that the state has amassed related to other CERP projects (e.g., some components of the Generation 1 projects and all later projects) are essentially locked up until those projects are authorized, federal funding is appropriated, and a project partnership agreement is signed.

According to the five-year projected CERP expenditures reported in the 2012 South Florida Environmental Report, the SFWMD expects to invest only approximately $37 million over five years in Generation 1 CERP projects (Smykowski, 2012). Thus, if this budget plan were followed with no additional authorized projects and federal expenditures of $100 million/year (consistent with recent year budgets; see Table 3-3), total federal cost-share credits could exceed state credits in approximately three years, bringing the CERP to a standstill. To avoid the situation where federal government cost-share credits might exceed state credits, the SFWMD and the USACE are evaluating the cost-share balance on a regular basis. In the absence of new CERP congressional authorizations, two basic alternatives are feasible: 1) reduce federal CERP spending (on either design or construction), thus further delaying restoration progress, or 2) increase state spending, either through cash payments from the SFWMD to the USACE or by transferring construction of Generation 1 CERP projects (with project partnership agreements) from the USACE to the SFWMD. Given the SFWMD's current budget outlook, accrued state cost-share credits associated with Generation 2 projects are critical to the future CERP implementation progress, and utilization of those credits is dependent on congressional authorization.

Land Acquisition for Restoration of the Everglades

Land acquisitions for restoration projects include lands to implement CERP and non-CERP projects and additional lands to protect and enhance wildlife habitat. As project plans are modified, the estimates of land requirements shift, and the Task Force annually estimates land acquisition progress relative to restoration needs. The Yellow Book (USACE and SFWMD, 1999) estimated that 402,479 acres would be needed to implement the CERP, of which 182,338 acres (45 percent) were already in public ownership. The most recent *Land Conservation Strategy* report (SFERTF, 2010a) estimates the total land acquisition needs for the CERP to be 390,929 acres, with 234,853 acres (or 60 percent) already acquired at a cost of $1.7 billion. Approximately $1.8 billion is needed to complete the remaining CERP land acquisition. The vast majority of the remaining land acquisition needs are associated with surface water storage projects (SFERTF, 2010a). These totals do not include the SFWMD's purchase of 26,800 acres from the U.S. Sugar Corporation, which closed in August 2010. Although the state retains an option on approximately 160,000 acres of U.S. Sugar land, future purchases are quite uncertain under prevailing economic conditions.

In September 2011, the Department of Interior announced a proposal to establish the Everglades Headwaters National Wildlife Refuge and Conservation Area, located northwest of Lake Okeechobee. If fully realized, the area would include up to 150,000 acres protected by conservation easements and land purchases to conserve habitats and protect the Kissimmee River watershed from development that could negatively impact Lake Okeechobee and Everglades water quality.

Endangered Species Issues

Past reports of this committee have highlighted concerns over the potential impacts of endangered species issues on restoration progress and emphasized the importance of multi-species management (NRC, 2008, 2010). In this section, the committee reviews the programmatic progress to address these issues and updates the outlook for potential concerns.

Multi-species Management in WCA-3A

For the past 15 years, issues involving endangered species have centered in WCA-3A, where flows through the S-12 gates have been regulated to protect a population (population A) of endangered Cape Sable seaside sparrows (CSSS; *Ammodramus maritimus mirabilis*) in Everglades National Park to the south, resulting in most years in water impoundment at the southern end of WCA-3A. High water levels in southern WCA-3A produce several adverse ecological effects, and the overall water management regime in WCA-3A has negative impacts specifically on endangered snail kites, which are now on the brink of extirpation (NRC, 2010). In addition to wet season high water levels that have been too high and last too long, kites have been adversely affected by dry season flows that have been too low and rates of recession that have been too fast (FWS, 2010).

Since 2002 the water management policy for WCA-3A has been codified in an Interim Operation Plan (IOP) that is a result of consultation between the USACE, the SFWMD, and the U.S. Fish and Wildlife Service (FWS) about the CSSS issue. The IOP expired in November 2010 and is being replaced by the Everglades Restoration Transition Plan (ERTP). The FWS applied its recent Multispecies Transition Strategy for WCA-3A (FWS, 2010) when producing its Biological Opinion for the ERTP. ERTP features include new, lower thresholds for high water levels in the wet season and the addition of recession rate and minimum stage criteria for WCA-3A designed to provide appropriate hydrology to support kite nesting, foraging by wood storks and other wading birds, tree islands, and wet meadow vegetation. Regulations are more flexible, and increased flow to the south is made possible by the removal of closure dates for the S-12C gate in force during the IOP. The CSSS is as well protected under the ERTP (i.e., no changes in hydroperiods at the NP-205 gauge) as under the IOP because of the eastern location of S-12C relative to CSSS population A and the use of stoppers in the Tram Road to prevent water flowing through S-12C to the west. The ERTP provides for suitable hydrological periods for a suite of endangered species and other community components and thus represents multi-species management (FWS, 2010). It further represents precisely the management approach for which the NRC (2010) and others (SEI, 2007) have advocated, successfully applied to operations at what is perhaps the most volatile flashpoint in the degraded natural system.

The ERTP is in the final stages of authorization and likely will be implemented for the first time some time in 2012. It is not a panacea: its effectiveness will be constrained by the continuing problems that the CERP is designed to correct. Specifically its focus is on improving hydrology in southern WCA-3A without causing increased deterioration of conditions in Everglades National Park to the south, given the existing water management infrastructure and availability of water in the central Everglades. The cost of this approach is likely to be increased drying out of northern and even central WCA-3A, increasing the rate of degradation in those areas. The next hydrologic alteration will come with the completion of the C-111 South Dade and Mod Waters projects (anticipated in 2013), when the ERTP will transition to a new water management plan known as the Combined Operational Plan (COP). However, the FWS has authorized the ERTP under the Endangered Species Act through 2016 to accommodate possible delays.

Some advocates for the CSSS view the ERTP as creating unacceptable risk to population A. Nevertheless, the ERTP represents a move by the FWS away from single-species, case-by-case management toward management that is broader in space and time and is better suited to handle the unexpected impacts on endangered species, both negative and positive, that certainly will arise during the transitional phase of CERP implementation.

Species Protection and STAs

The ongoing issues with endangered species in WCA-3A are a manifestation of continuing degradation of the natural system (see Chapter 4). In contrast, issues with endangered species and other birds in the STAs are new and representative of the sort of issues that are likely to arise repeatedly as the restoration proceeds. The STAs are new wetlands, and once operational they attracted droves of water birds, including nesting black-necked stilts (*Himantopus mexicanus*), which build nests at the end of the dry season (May-June) on the substrate in STA cells containing little or no water. In normal operations these cells would refill at the onset of the rainy season, which would destroy the stilt nests. Black-necked stilts are not endangered, but they are protected by the Migratory Bird Treaty Act. This elderly piece of legislation is less detailed than the Endangered Species Act and includes no provision for the FWS to authorize take. One approach to enforcing this legislation is use of an Avian Protection Plan, which was originally developed by the electric utility industry to address mortality from power line collisions. These plans, representing agreements between the FWS and the utility, are designed to reduce risk of avian mortality. Avian Protection Plans, by virtue of their existence, also reduce risk to the utility of enforcement (by the FWS) under the Migratory Bird Treaty Act, because the FWS considers willingness to negotiate an Avian Protection Plan sufficient evidence of concern for migratory birds. The SFWMD prepared an Avian Protection Plan for the original Everglades Construction Project STAs in cooperation with the FWS in September 2008, thus addressing the issue for these STAs. An Avian Protection Plan for a human-created and -managed wetland is unprecedented and viewed by the FWS as an important achievement.

The Avian Protection Plan includes a provision that managers should try to keep the water level in STA cells above 0.5 feet to prevent stilts from nesting. This same 0.5 feet criterion is found in the operating guidelines for the STAs.

Thus, managers can reduce stilt nesting by achieving their operating goals. When stilt nesting does occur, the Avian Protection Plan states that water must be diverted to other cells or STAs to avoid flooding of nests. The Avian Protection Plan appears to be working well thus far in that rerouting water to avoid flooding nests has had no significant impact on the operation of the STAs as a whole. Nesting occurs each year, more so in dry years such as 2009 when there were 873 stilt nests in the STAs, and there have been restrictions on individual STA cells each year (SFWMD and FDEP, 2012). However, no STA flow-ways have been restricted or taken off line to protect nesting birds, not even in 2009 (SFWMD and FDEP, 2010). The addition of flow equalization basins to the system (see Long-Term Plan later in the chapter) would reduce the frequency with which water levels in STA cells decline to levels that promote stilt nesting. The committee is not aware of any analysis that indicates that diverting water from individual cells to protect nesting birds has affected overall STA performance. In the absence of any such evidence, the Avian Protection Plan appears to provide a reasonable resolution to the issue.

The endangered species issue in the STAs involves the snail kite and appears to present more significant challenges than does the Migratory Bird Treaty Act. It is an unanticipated issue: in 2005 the FWS issued a non-jeopardy opinion as a result of its consultation on the original Environmental Impact Statement authorizing the construction of the STAs, concluding that the construction, operation, and maintenance of the STAs would have no adverse impact on snail kites (FWS, 2005). The SFWMD was given no authorization to "take" kites because the possibility of take was deemed unlikely. But in 2010 snail kites nested in significant numbers in STA 5 (Bearzotti et al., 2011). Managing for kites involves maintaining sufficiently high water prior to breeding, creating a suitable rate of recession thereafter, and maintaining a sufficient minimum stage during the dry season (FWS, 2010). In the STAs, normal operations maintain dry season low water levels suitable for kites, but nests can fail because of flooding from inflows, loss of food supply, or collapse of nest-supporting vegetation caused by rapid dry-down following outflows. Thus, nesting kites can affect STA operations in several ways over much of the year, and indeed kite nesting restricted operation of STA 5 for five months, and individual cells for an additional three months in 2010 (SFWMD and FDEP, 2012).

Currently, the SFWMD is consulting with the FWS about the effects of its STA operations on kites. Because Florida snail kites are considered to be near extirpation, loss of even a single kite or kite nest is a serious matter, and kite nests in STAs are being monitored and managed on a case-by-case basis to prevent any loss. Thus the approach to managing endangered species in the STAs is a single-species approach, in contrast to the multi-species approach applied in WCA-3A. Whether or not kites nest in STAs will depend on water levels and is unlikely in relatively dry years—indeed there was only one kite nest in an STA in 2011, when wet season high water levels were lower than in 2010 (SFWMD and FDEP, 2012)—but there is no obvious way to prevent kites from nesting in STAs in a year when water levels are favorable without compromising the operation of the STAs. Thus, the issue will recur in wet years.

Managing Endangered Species in a Changing System

The Endangered Species Act is a powerful litigation tool (Ruhl, 2004) that can and has been used to prevent or modify water management necessary for system restoration but possibly detrimental to endangered species (NRC, 1995, 2004a,b). Several assessments have noted that although a fully implemented CERP should provide for the needs of all endangered species within the Everglades, detrimental effects are likely at particular locations in the transition between the future restored system and the current one (NRC, 2005; SEI, 2003, 2007). Recent developments in WCA-3A and the STAs exemplify such conflicts and suggest ways they might be resolved and/or avoided. Resolution of the conflict between kites and sparrows in WCA-3A through the ERTP illustrates the potential of a multi-species approach to endangered species management that is more compatible with system restoration than the typical single-species approach (NRC, 2005, 2010; SEI, 2007). Resolution of the stilt issue in the STAs illustrates flexibility and creativity of water managers and regulators in addressing unanticipated impacts of changes to the system resulting from a restoration action. The ongoing issue with kites in the STAs illustrates the reality of local conflicts with the needs of endangered species that can significantly compromise water management required for system restoration.

The flexibility, creativity, and multi-species approach applied in these recent cases represents important progress in the evolution of a strategy for handling such conflicts, but the kite issue in the STAs shows that more work remains to be done. The next step is to develop ways to apply the flexibility, creativity, and multi-species approach evident in these examples to larger spatial scales to reduce the frequency and significance of local conflicts. This will be essential for the CERP; otherwise it is likely there will be repeated delays as local endangered species issues arise and are resolved. Additionally, multi-species approaches can be used to lend weight to system-wide endangered species benefits that counter local costs. In the case of kites, for example, such an approach might involve assigning more weight to population performance and less to the fate of individual nests, and incorporating criteria that result in high and low water levels and recession rates favorable to kites into operational specifications for CERP projects.

CERP IMPLEMENTATION PROGRESS

The following analysis of implementation progress focuses on CERP restoration projects and pilot projects. Many of the restoration projects build upon benefits provided by non-CERP projects, which are discussed in the next section. Additional information on implementation progress can be found in the 2010 CERP Report to Congress (USACE and DOI, 2011) and the 2011 Integrated Financial Plan (SFERTF, 2011). Past reports of this committee have relied heavily on the South Florida Environmental Reports for updates on restoration progress, although the level of detail reported has diminished greatly in recent years, associated with agency budget cuts. Thus, much of the information on implementation progress is derived from personal communications with agency staff.

The Yellow Book (USACE and SFWMD, 1999) outlined a conceptual plan for 68 project components and identified a schedule for implementation. The originally ambitious time table was impacted by delays in project planning and lower than expected program funding. As a result, the implementation schedule has been extended and revised several times since the CERP was launched. (See NRC [2008] for additional discussion of major causes of CERP delays.) The committee's efforts to track CERP project implementation is shown in Table 3-1, which includes CERP and CERP-related pilot projects and CERP projects included in the most recent Integrated Delivery Schedule (Figure 3-1). Figure 3-4 identifies most of the projects listed in Table 3-1 on a map of the South Florida ecosystem. The task of tracking project progress and assessing delays over time is complex because some projects have been reorganized, transferred out of the CERP, or split into phases to achieve incremental restoration where feasible.

As of March 2012, eight CERP restoration projects, including all four Generation 1 projects, two Generation 2 projects, and two Generation 3 projects, were actively under construction, and five pilot projects were in an installation and testing phase. Many more projects are in planning and design phases (see Table 3-1). Increased levels of federal funding since 2009 have supported continued construction progress on congressionally authorized (i.e., Generation 1) projects, and the state continues to fund expedited restoration projects not yet authorized, albeit at rates reduced from prior years. In the following sections the committee highlights CERP implementation progress with a focus on progress in achieving natural system restoration benefits through incremental implementation and learning achieved through CERP pilot projects. The committee reviews all projects under construction and assesses progress in pilot projects from which new data are available.

CERP Projects

Progress restoring the South Florida ecosystem will come about through implementation of restoration projects. One Generation 2 CERP project (C-111 Spreader Canal, Western Phase) is anticipated to be fully constructed by the middle of 2012, and a few additional project subcomponents have been completed or are nearing completion. These projects and their documented and/or anticipated benefits are discussed in this section, with emphasis on new information since the committee's last report (NRC, 2010).

Generation 1 Projects

The Generation 1 projects represent those projects authorized by Congress in WRDA 2007 (Picayune Strand Restoration, Site 1 Impoundment, and Indian River Lagoon-South) or via program authority (Melaleuca Eradication). These projects remain the only projects eligible for federal construction funding as of March 2012.

Picayune Strand. The Picayune Strand is a restoration project on a failed real estate development named Southern Golden Gate Estates in southwest Florida (see Figure 3-4, No.6 and Figure 3-7) that included more than 55,000 acres of drained wetlands with canals and 260 miles of roadway that blocked regional water flows. These development features impaired sheet flows into the Ten Thousand Islands National Wildlife Refuge, disrupted regional groundwater flows to adjacent natural areas, and altered habitat conditions by drastically reducing areas of freshwater wetlands. These changes particularly degraded habitat for the endangered Florida panther (USACE, 2011a). Picayune Strand is geographically important because it is contiguous with extensive protected state and federal lands.

The Picayune Strand Restoration is a $455 million project (in 2010 dollars) to remove roads to restore natural habitats, plug canals that disrupt surface and groundwater systems, and construct culverts under the Tamiami Trail south of the project to permit the return of sheet-flow conditions. The project also includes the construction of three pump stations and spreader systems, along with flood protection levees to maintain flood control to neighboring developed areas (Figure 3-7; SFWMD and USACE, 2011).

Progress is under way on several phases of the Picayune Strand Project as of early 2012 (see Table 3-7). The first phase of the project, which involved removal of roads, plugging of the Prairie Canal, and construction of culverts under US-41 Tamiami Trail, was expedited with funding from the SFWMD. Since authorization in 2007, the federal government has funded construction

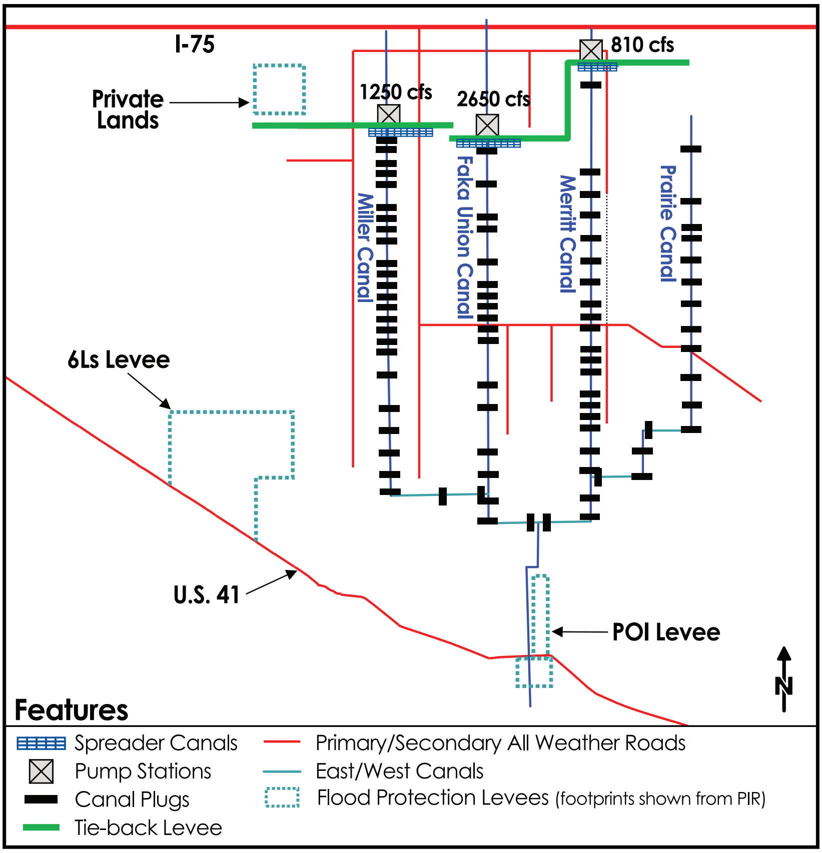


FIGURE 3-7 Simplified map showing Picayune Strand Restoration features.

SOURCE: USACE (2009a).

of the remaining project phases. Installation of 17 culverts (completed in 2006) beneath the Tamiami Trail has restored freshwater flows to coastal systems that had been cut off from their source areas by the highway and its associated canal, but the benefits of the culverts have not been quantified. Within parts of Picayune Strand, the landscape configuration has been returned to more natural configurations by road removal and canal plugs (Figure 3-8), resulting in increased habitat and prey for the Florida panther. SFWMD personnel report that plugging the Prairie Canal has resulted in increased water depths and longer inundation of the terrain extending 1 to 3 miles into neighboring Fakahatchee Strand Preserve

TABLE 3-7 Phases and Progress of the Picayune Strand Project

	Lead Agency	Road Removal	Canals to Be Plugged	Other	Project Phase Status
Prairie Canal	State-expedited project	65 miles	7 miles	Remove invasive vegetation, 17 culverts constructed, >13,000 acres of enhanced habitat	Completed in 2007
Merritt Canal	Federal	95 miles	13.5 miles	Remove invasive vegetation; construct Merritt pump station and spreader canal, ~14,000 acres of enhanced habitat	Construction began in 2010; anticipated completion in September 2012
Faka Union Canal	Federal	100 miles	12 miles	Remove invasive vegetation; construct Faka Union pump station and spreader canal	Construction began in 2011; anticipated completion in 2014
Miller Canal	Federal	65 miles	13 miles	Remove invasive vegetation; construct Miller Canal pump station and spreader canal	Anticipated to begin in 2013; to be completed in 2016
Protection Features	Federal	—	—	Flood protection for neighboring developed areas	Anticipated to begin in 2013; to be completed in 2016

NOTE: This table contains completion dates that have been updated since the August 2011 IDS was released.

SOURCE: L. Gerry, SFWMD, personal communication, 2011; G. Landers, USACE, personal communication, 2012; USACE (2011a).

State Park (L. Gerry, SFWMD, personal communication, 2011). However, no additional hydrologic analyses or assessments of restoration benefits have been published since the committee's last report. Ecological monitoring of project-related benefits was initiated after completion of the Prairie Canal Phase and will be expanded as each construction phase is completed (L. Gerry, SFWMD, personal communication, 2012).

Site 1 Impoundment. The Site 1 Impoundment project (also called Fran Reich Preserve; Figure 3-4, No. 2) is located in Palm Beach County south of the Loxahatchee National Wildlife Refuge (LNWR). With an anticipated total cost of $126 million (in 2010 dollars; SFERTF, 2011), the project is designed to reduce seepage and provide water storage to reduce water demands on Lake Okeechobee and LNWR. To accomplish these objectives, the project includes constructing a reservoir with a capacity of 13,300 acre-feet, along with supporting spillways, seepage management features, and a pump station. Phase 1 of the Site 1 Impoundment project (Figure 3-9), which began in October 2010, includes modifications to the existing levee on the northern edge of the impoundment, which are anticipated to reduce seepage from the southern end of LNWR.

FIGURE 3-8 Prairie Canal restoration in the Picayune Strand Project. Above, view in 2007 before restoration; Below, view in 2010 after restoration.

SOURCE: L. Gerry, SFWMD, personal communication, 2011.

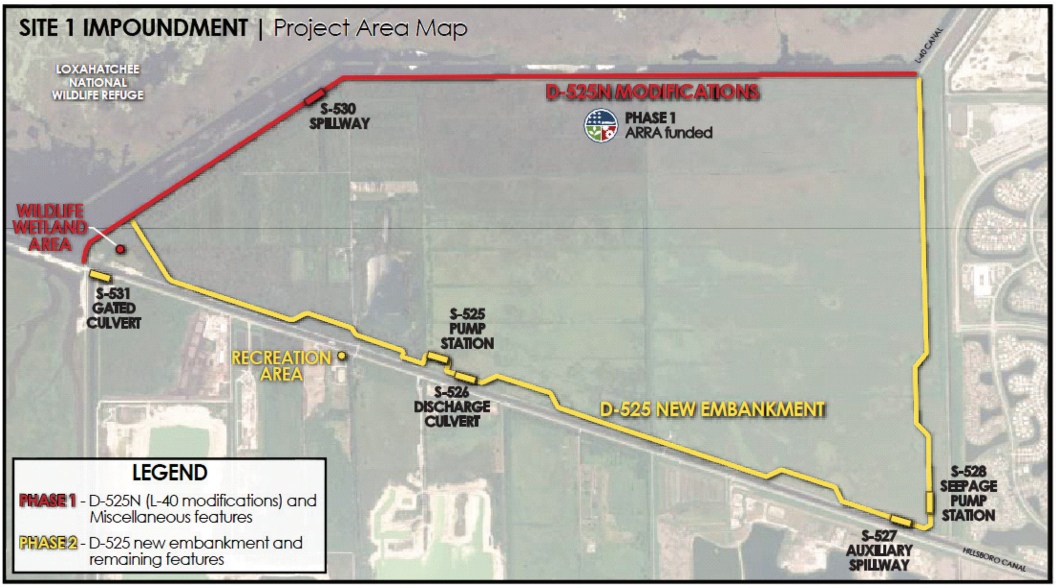


FIGURE 3-9 Phase 1 and 2 project elements of the Site 1 Impoundment.

SOURCE: USACE (2011c).

Phase 1, supported by $44 million in funding from the 2009 American Recovery and Reinvestment Act (ARRA), is anticipated to be completed in FY 2014, and the completion of the impoundment is on hold pending congressional reauthorization of the project necessitated by increased costs and sponsor support (USACE, 2011b; G. Landers, USACE, personal communication, 2012).

Indian River Lagoon-South. The Indian River Lagoon is a diverse biological estuary that includes the mouth of the St. Lucie River where it empties into the Atlantic Ocean on the east side of the Florida Peninsula. Water flows from urban and agricultural areas along with discharge releases from Lake Okeechobee have resulted in declining water quality in the lagoon and its associated habitats. Water managers have experienced difficulty controlling water quantity in the coastal drainages, and some lands have been drained for agricultural purposes, resulting in the loss of freshwater marsh areas. To reverse these trends, the Indian River Lagoon-South restoration project (Figure 3-4, No. 7) includes constructing reservoirs for 130,000 acre-feet of water storage, building four new STAs, and dredging 7.9 million cubic yards of muck to provide a clean channel bed for the St. Lucie River. These plans are substantially different from those published in the Yellow Book (USACE and SFWMD, 1999), but they represent a broadly based effort to restore water quality to the St. Lucie estuary, along with restored wetland and upland habitats and more natural flow patterns.

As part of the Indian River Lagoon-South project, the SFWMD acquired 20,000 acres of former marsh land in Martin County that had been drained as part of the Allapattah Ranch. The land was purchased to serve as a natural freshwater storage area in the basin. As of early 2012, the SFWMD has filled approximately 17 miles of drainage ditches on about 1,800 acres, and the modifications have resulted in new inundation regimes that have restored more natural hydrologic conditions on about 400 acres of wetlands. To date, vegetative response is limited because rainfall has been less than average in recent years. Additionally, the SFWMD has treated about 15,000 acres to control exotic species such as Brazilian pepper (*Schinus terebinthifolius*) and Old World climbing fern (*Lygodium microphyllum*). Overall, the restoration of this wetland area will improve wildlife habitat and provide more natural flows of fresh water to the estuary (L. Gerry, SFWMD, personal communication, 2011).

In November 2011, the USACE began construction on the C-44 reservoir and STA, which are major components of the Indian River Lagoon-South project. The reservoir will provide nearly 51,000 acre-feet of storage to improve the timing of deliveries of basin stormwater to the St. Lucie estuary. The discharged water will be treated by a 6,300-acre STA. The reservoir and STA are anticipated to be completed in 2016 and 2018, respectively (K. Tippett, USACE, personal communication, 2011).

Melaleuca Eradication and Other Exotic Plants. Fifteen invasive plant species pose serious threats to at least some portion of the South Florida ecosystem (Rodgers et al., 2010). Although invasive species management is not a major emphasis of the CERP, the Melaleuca Eradication and Other Exotic Plants CERP project provides support for the battle against invasive and exotic species. The U.S. Department of Agriculture built and operates the Invasive Plant Research Laboratory in Davie, Florida, to rear biological controls specifically to manage the spread of melaleuca, Brazilian pepper, Australian pine (*Casuarina equisetifolia*), and Old World climbing fern. The CERP provides for the construction of a 2,700 ft^2 mass rearing annex "to increase the number of biological control agents needed to effectively manage the four invasive exotic plant species" (USACE and SFWMD, 2010b). With ARRA funding and authorization under programmatic authority for projects totaling less than $25 million, the $2 million construction effort is anticipated to be completed by the end of 2012 (SFERTF, 2011; L. Gerry, SFWMD, personal communication, 2012).

Generation 2 Projects

Generation 2 projects include those that are anticipated to be included in the next WRDA. Because these projects are not yet authorized, they are not eligible to receive federal funding for construction, although in some cases projects have been expedited by the state of Florida. In the past two years, the state has continued construction of two Generation 2 projects: Biscayne Bay Coastal Wetlands and the C-111 Spreader Canal.

Biscayne Bay Coastal Wetlands. The Biscayne Bay Coastal Wetlands are located along the southeastern edge of the Florida Peninsula in the Miami-Dade County area (Figure 3-4, No. 5 and Figure 3-10) where confinement of flows to canals has resulted in loss of freshwater sheet flow in the coastal wetlands and altered salinity in the bay (USGS, 2005). Saltwater wetlands extend over 22,500 acres bordering Biscayne Bay, a unit of the national park system. The project is focused on returning as much as 40 percent of the canal flow in the area to rehydrate up to 11,300 acres of the wetlands with fresh water and to reduce salinity in the near-shore environment of the bay (USACE and SFWMD, 2010a). The total project envisions 13 pump stations, about 20 culverts reconnecting the wetlands, 7 miles of spreader canals, a 1-mile conveyance canal, and plugs for 8,000 feet of ditches at an estimated cost of $185 million (in 2010 dollars; SFERTF, 2011). To expedite project planning and construction, the project was split into two phases, and Phase 1 of the project includes installation of 7 pump stations, 10 culverts, 3 miles of spreader canals, and plugs for 2,500 feet of ditches (Figure 3-4), with the objective of restoring 3,700 acres of wetlands.

Phase 1 has been subdivided into regional project components—the Cutler Wetlands, the L-31 East Flow-way, and the Deering Estates (see Figure 3-10). By 2012, the SFWMD will have completed construction of four new culverts in the L-31 East Flow-way and all of the features in the Deering Estates area (spur canal extension, spreader canal, and pump station) at a construction cost of $5.2 million (excluding planning, engineering, and design costs). The SFWMD has also completed the design for the Cutler Flow-way component of the project and awaits the associated $20.5 million in funding (L. Gerry, SFWMD, personal communication, 2012). The remainder of the project features (including 5 pump stations, an inverted siphon, 6 culverts, 1 mile of spreader canal, and plugs in approximately 1.5 miles of ditches) will be constructed by the federal government at an estimated cost of $25.7 million pending congressional authorization of the project and funding appropriations (A. Saar, USACE, personal communication, 2012). The SFWMD reports, "Although freshwater has flowed into target areas since May 2010, and monitoring is underway, restoration responses have not been measured to date because the past two years have been relatively

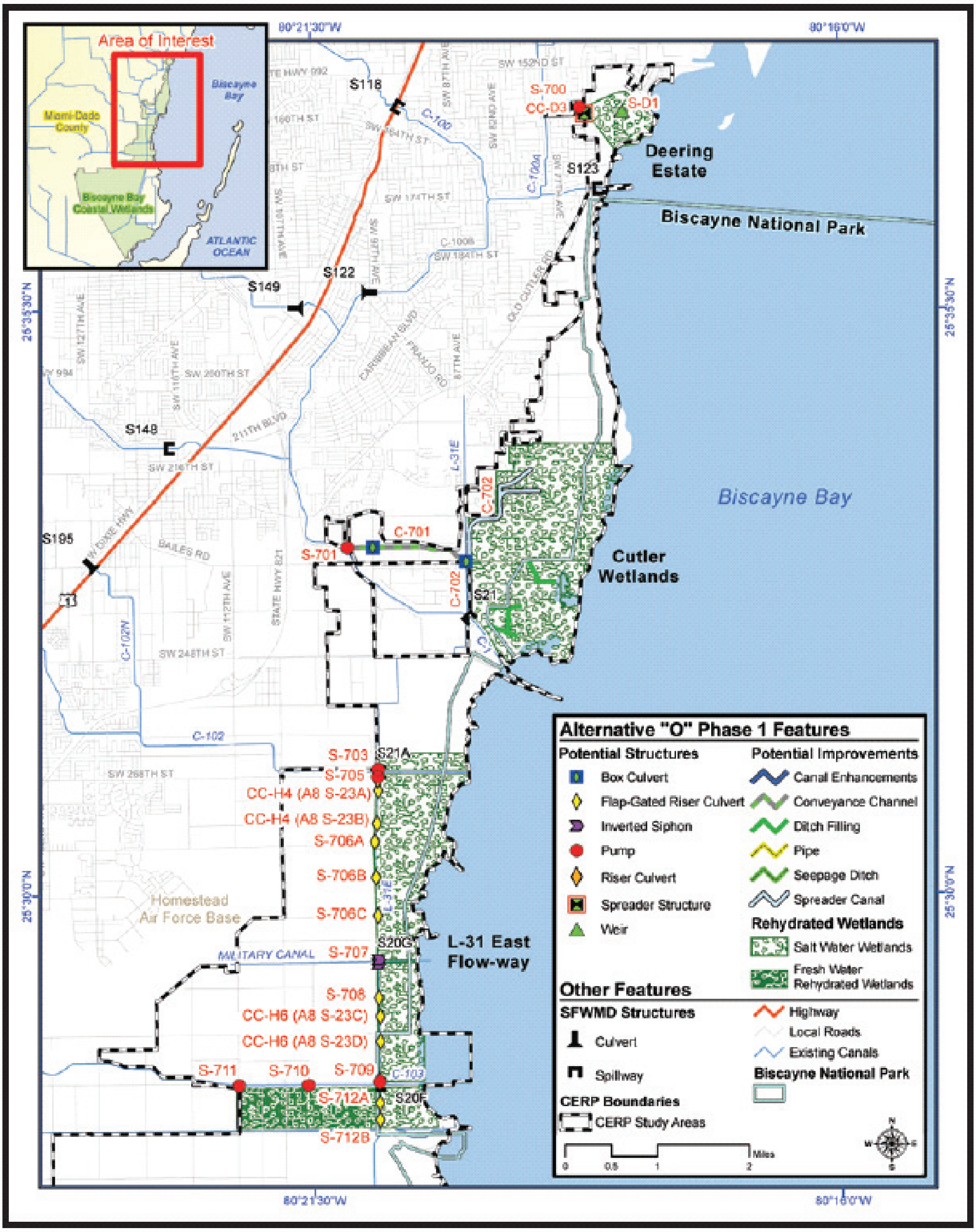


FIGURE 3-10 Biscayne Bay Coastal Wetlands project area in southeast Florida.

SOURCE: SFWMD and USACE (2010).

dry and discharges to coastal wetlands have been limited" (L. Gerry, SFWMD, personal communication, 2011).

Phase 1 of the Biscayne Bay Coastal Wetlands is a stand-alone project that is a first step toward achieving the ultimate objectives; other phases will follow but are not yet defined in detail. Phase 1 offers the opportunity for substantial, recognizable progress as well as for learning to improve the design and implementation of subsequent project phases. This approach represents an example of the concept of incremental adaptive restoration (NRC, 2007), and an adaptive management (AM) plan has been developed for the project that ranks the most pressing uncertainties and describes how they can be addressed in the project monitoring plan (USACE and SFWMD, 2010a). Additionally, the AM plan identifies management decision alternatives based on the outcomes of the monitoring.

C-111 Spreader Canal. The C-111 Canal (Figure 3-4, No. 10; Figure 3-11) is the southernmost canal of the entire Central and Southern Florida Project located south of Homestead, and thus it is the "end of the line" in the controlled hydrology of South Florida (USACE and SFWMD, 2011). The C-111 Spreader Canal project seeks to restore sheet flow to area wetlands and restore the quality, quantity, and timing of water flow to estuarine areas. The project has been divided into two phases accompanied by separate PIRs (USACE and SFWMD, 2011) and includes a pilot-scale test project. This approach allows for progress on the western features of the project (PIR 1), while uncertainties about certain design features in the spreader canal features (PIR 2) are being resolved. The western project includes:

- two pump stations (S-199 and S-200);
- a 590-acre detention pond at an agricultural area known as the Frog Pond, which serves to reduce seepage from Taylor Slough;
- extension and modification to the Aerojet Canal, which also serves as a seepage barrier;
- a plug in the L-31E Canal (at S-20A);
- the installation of 10 plugs in the C-110 canal; and
- operational changes at S-18C (Figure 3-5).

By preventing eastward seepage of water from Everglades National Park, the Western Project aims to increase flow volumes in Taylor Slough, thereby restoring coastal salinities in western Florida Bay.

By 2012, the SFWMD will have completed construction of all of the above features in the western project at a cost of $30 million, expediting the project in advance of congressional authorization. If the incremental operational changes

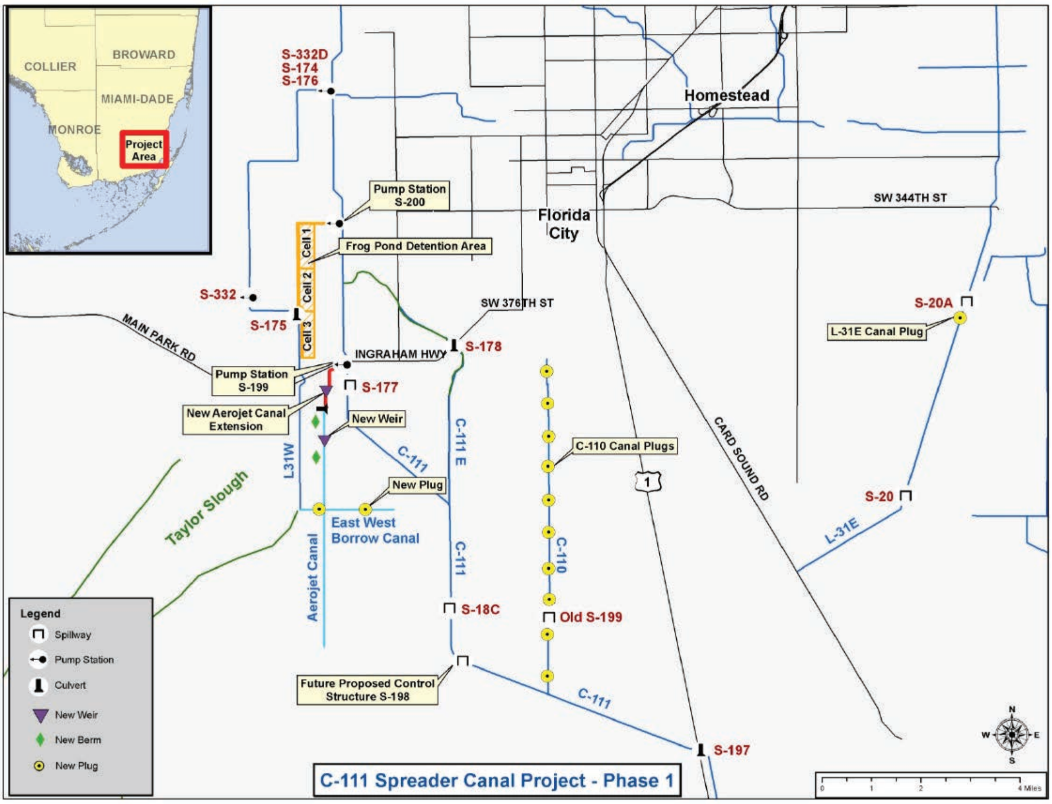


FIGURE 3-11 Project design features for the C-111 Spreader Canal Project.

SOURCE: SFWMD (2012).

at the S-18C structure do not produce the desired increases in Taylor Creek flows, then the federal government may construct an operable structure in the lower C-111 Canal (S-198) at an estimated cost of $5.3 million (2012 estimate) to produce the desired effect. SFWMD personnel expect to see increased amounts of fresh water appearing in Taylor Slough in 2012 as a result of the project, and the Frog Pond detention area should be fully operational by the end of 2012 (L. Gerry, SFWMD, personal communication, 2011; M. Collis, USACE, personal communication, 2012).

Generation 3 Projects

Generation 3 Projects are near-term priorities, but substantial work remains in planning and development of the PIRs. Some of these projects are being expedited with state funding. Of the Generation 3 projects listed in Table 3-1, only the Loxahatchee River Watershed Restoration and Lakeside Ranch STA projects have made substantial construction progress over the past two years.

Loxahatchee River Watershed Restoration. Although the USACE and the SFWMD are still finalizing plans for the Loxahatchee River Watershed Restoration project (formerly the North Palm Beach County project; Figure 3-4, No. 11) and no PIR has yet been drafted, the SFWMD has expedited several components, including the L-8 reservoir, which was intended to reduce high discharges to the Lake Worth Lagoon and enhance hydroperiods in an area known as the Loxahatchee Slough (see NRC, 2008). Currently, the water in the L-8 reservoir contains concentrations of chloride that exceed the Class I 250 mg/L discharge standard, limiting its release into the Grassy Water Preserve (unless diluted). The SFWMD intends to flush the reservoir several times once the full-size pumps are installed (by 2017) to reduce the elevated chloride concentrations, which are suspected to be related to prior mining and rock crushing processes. However, based on the state's new proposed plan to improve water quality control (described later in this chapter), the state is looking for an alternative storage feature for this project to replace the L-8 reservoir (Meeker, 2012).

One objective of the project is the restoration of the southern headwaters of the Loxahatchee River that begin north of LNWR (WCA-1) and flow north and east to the coast near Jupiter. Area canals have drained several thousand acres of wetland habitat, resulting in saltwater intrusion and periodic desiccation, particularly in Loxahatchee Slough. The SFWMD has installed culverts leading into the slough and established a control structure in the C-18 canal to raise water levels and extend periods of inundation. A more natural hydroperiod has been returned to 5,000 acres of the slough, and SFWMD personnel have observed that on the 5,000 acre tract, invading upland vegetation such as upland pine trees are now receding, replaced with wetland vegetation more similar to predrainage conditions (Figure 3-12; L. Gerry, SFWMD, personal communication, 2011, 2012).

Lakeside Ranch STA. The enactment of Florida's Northern Everglades Initiative in 2007 expanded the Lake Okeechobee Protection Act to the entire northern Everglades system, and identified the Lakeside Ranch STA as an expedited project. The Lakeside Ranch STA involves the construction of a 2,700-acre STA at Lakeside Ranch that will provide approximately 9 to 19 metric tons of

FIGURE 3-12 Upland pine trees on the east side of Loxahatchee Slough that are now stressed, according to SFWMD staff, because of increased water levels after the construction of the G-160 control structure.

SOURCE: L. Gerry, SFWMD, personal communication, 2012.

phosphorus reduction. The STA will be constructed in two phases (STA North and STA South). Phase I includes 925 acres of effective treatment area at a $31M construction cost and was completed in April 2012; Phase II includes 790 acres of effective treatment area at a $42M construction cost (L. Gerry, SFWMD, personal communication, 2012).

Pilot Projects

Pilot projects are important components of the CERP, enabling scientists and engineers to test the capacity of new technologies or approaches and to refine future project design. Although the pilot projects themselves are not expected to lead directly to natural system restoration, the learning that they generate has great value and can be used to improve the design of the full-scale projects. Ultimately, the objective of the pilot projects is to improve the likelihood that the full-scale projects meet their restoration objectives while possibly also making them more cost-effective. Three of the four projects discussed in this section have direct bearing on the planning for Generation 2 or 3 CERP projects.

Aquifer Storage and Recovery Pilot Studies and Regional Study

Aquifer storage and recovery (ASR) was originally conceived as a major water storage component of the CERP, intended to store 1.7 billion gallons per day in the subsurface during wet periods for use during dry periods. However, concerns existed about high operations and maintenance costs (particularly energy costs), feasible rates of water recovery, and the quality of recovered water and its impact on biota in receiving waters (NRC, 2001, 2010). Out of five original pilot sites to explore these technical and scientific concerns, two 5-million gallons per day (MGD) ASR systems were successfully constructed at the Kissimmee River and Hillsboro Canal.[5]

The Kissimmee River site has been the most successful to date, where cycle testing[6] has been conducted from January 2009 to present. Three cycle tests had been completed as of January 2012, with increasing storage volume and duration for each successive test, and a fourth is under way. Each of the tests achieved 100 percent recovery by volume. Arsenic concentrations in recovered water declined during each cycle test, and during Cycle 4 arsenic concentrations in the recovered water samples were found to comply with the Safe Drinking Water Act (<10 parts per billion (ppb) arsenic). Phosphorus concentrations at the Kissimmee River site also declined during each cycle test from 50 to 120 ppb in surface water to <10 ppb in recovered water samples. However, the UV-disinfection of recharge water has been found to be ineffective during the wet season because of turbidity, suggesting the need for alternative methods of disinfection to meet injection requirements. Cycle testing will end at this site in July 2013.

CERP project staff report that the pilot tests at the Hillsboro Canal site have not been as successful as those at the Kissimmee River site. Cycle testing at this site has been conducted from June 2010 to present, with two tests completed as of January 2012, and the third and final cycle test scheduled for 2012. Saline conditions at the Hillsboro Canal site have resulted in recoveries of only approximately 35 percent in the two cycle tests. Water quality monitoring data at this pilot site are limited, but available data indicate that arsenic is mostly below 10 ppb in the aquifer and recovered water (J. Mireki, USACE, personal communication, 2012).

In addition to the pilot studies described above, a regional groundwater modeling study is being conducted to reduce uncertainties related to regional-scale implementation of ASR in the CERP, a pilot implemented in response to recommendations in NRC (2001, 2002a). A regional groundwater flow and transport model has been developed, calibrated, reviewed, and approved by the Interagency Modeling Center. Preliminary results indicate that the original plan for 333 5-MGD ASR wells in the Upper Floridan aquifer is not feasible

---

[5] The Floridan aquifer proved to be too sandy for ASR at the Caloosahatchee site, and funding limitations prevented ASR pilot construction at the Port Mayaca and Moore Haven sites.

[6] Cycle testing involves freshwater injection followed by a rest period and subsequent withdrawal to examine feasible injection and recovery rates, impacts on local groundwater levels, and effects on water quality.

because excessive rise in aquifer heads north of Lake Okeechobee is predicted. Scenarios with 155 wells are currently being simulated. Modeling simulations and analysis will continue through 2012.

Both pilot test and groundwater modeling results suggest that the originally envisioned large-scale application of ASR will not be possible because of anticipated regional effects in the Upper Floridan aquifer and variable site-specific performance affecting the quantity and quality of recovered water. The pilot projects will continue to examine these effects under different implementation scenarios, and a technical data report analyzing the findings of all the ASR pilots and their implications for the CERP is anticipated in late 2013 (J. Mireki, USACE, personal communication, 2012). Considering these preliminary findings, the committee anticipates that ASR could be an effective water storage mechanism at some sites, but in general, CERP planners will need to substantially increase plans for other means of water storage (e.g., dispersed storage, lake storage, reservoirs) to achieve the original water storage objectives of the CERP.

Seepage Management

The CERP contains plans for seepage management projects east of WCA-3 and Everglades National Park to reduce eastward groundwater seepage and flooding of urban and agricultural lands. The CERP L-31N Seepage Management Pilot project (USACE and SFWMD, 2009b) was intended to inform the design of large-scale seepage management solutions for the L-31N levee, on the eastern edge of Everglades National Park. However the pilot project design, which involved bentonite slurry walls at depths of 77-82 ft below ground surface, was estimated to cost more than $16 million, which exceeded the Section 902 limit for the total project cost. As a result the L-31N Seepage Management pilot project has been put on hold.

Meanwhile, the Miami-Dade Limestone Products Association (LPA) independently funded a small-scale seepage study along the L-31N levee during 2009-2011 (MacVicar, Federico & Lamb, 2011a, b). The purpose of this study was to test the feasibility of constructing a larger-scale groundwater seepage control project adjacent to Everglades National Park to mitigate the effects of limestone mining in the Lake Belt region. A 1,000-foot long, 18-foot deep slurry wall was constructed in 2009. Although the slurry wall was found to have an impact on groundwater flow velocities and direction, it did not perform as well as expected in preventing eastward seepage. Tracer studies later showed that the wall leaked, and subsequent analyses identified problems with its installation and design. After additional field and modeling investigations, the LPA determined that these problems could be rectified by changing the cement-bentonite mixture, modifying the construction techniques, enhancing on-site testing of the integrity of the slurry wall during construction, and deepening the slurry wall to 35 feet to intersect a low-permeability layer (MacVicar, personal communication, 2012). The LPA proposed to conduct an additional pilot 2 miles in length, using these modified techniques, in exchange for wetland-mitigation credits. The Lake Belt mitigation committee approved this proposal in November 2011. Construction of the project began in February 2012 (Figure 3-13), and the project is expected to be completed by July 2012. The system will be monitored to assess its performance.[7]

The committee applauds the LPA project because it provides a good example of incremental adaptive restoration, by providing tangible increments of restoration while actively working to resolve questions that prevent implementation of the full-scale project (NRC, 2007). The project also offers the potential for substantial seepage management at little to no public cost. If this privately funded 2-mile seepage project is successful, then it could serve as a model for future publicly or privately funded CERP seepage control efforts.

Decomp Physical Model

The Decomp Physical Model (DPM) is a large-scale field experiment intended to inform project planning decisions by reducing uncertainty about the ecological effects of various options for restoring sheet flow to the ridge-and-slough landscape. In NRC (2010), the committee stated that the primary utility of the DPM will be to help to resolve the debate over the need for complete, partial, or no canal backfilling, and secondarily to add new data at an unprecedented level of detail to the existing, substantial body of work on the hydroecological impacts of restoring sheet flow. However, the report questioned whether the before-after-control-impact (BACI) design of the DPM would result in sufficient power to definitively differentiate the canal backfilling alternatives, and whether a clear mechanism existed by which the results of the project will affect decision making with respect to this issue (NRC, 2010).

The DPM study design has been altered very little since the committee's previous report and remains on schedule. The design includes 10 gated, 60-inch pipe culverts on the L-67A levee, a 3,000-foot gap in the L-67C levee, and three 1,000-foot sections in the adjacent L-67A canal with complete, partial, and no backfilling (USACE and SFWMD, 2010c). The culverts will be managed to create two annual pulse flow events, scheduled for 2012 and 2013, with monitoring from 2010 to 2015. The only change in the project design has been to restrict the pulse-flow events to a narrow November-December window rather than the wider October-January window originally planned to address concerns about

---

[7] See http://www.l31nseepage.org/index.html for additional information.

FIGURE 3-13 Trenching begins on the Limestone Products Association's 2-mile seepage barrier pilot, February 2012.

SOURCE: http://www.l31nseepage.org.

water quality, so that potential impacts are at their minimum (F. Sklar, SFWMD, personal communication, 2011). FDEP subjected the USACE's application for a permit to construct and operate the DPM to a high level of scrutiny and several requests for additional information but finally granted the permit in January 2012. The extensive permitting process appears to reflect not so much the actual impact of the DPM on water quality but rather the precedent that its permitting sets with respect to water management policy and procedures integrating water quality and water quantity.

C-111 Spreader Canal Design Test

The C-111 Spreader Canal design test was designed to inform future planning of the C-111 Spreader Canal "eastern project," which will replace existing portions of the lower C-111 Canal with a spreader canal that enhances sheet flow to Florida Bay and restoration efforts within the Southern Glades and Model Lands. The design test was developed to address the following questions (NRC, 2010; USACE, 2012a):

- How would a spreader canal affect surface- and groundwater levels to the north and south of its alignment?
- How much of the source water introduced into the spreader canal will return to C-111 and C-111E via groundwater?

The features of this design test include a 0.5-mile spreader canal, a 0.5-mile pipe to convey water to the spreader canal while keeping the test area separate from groundwater drawdown influences in neighboring canals, and a 50-cfs water discharge rate into the spreader canal (NRC, 2010). The USACE began testing in June 2010, with seven pump tests of increasing pumping duration (ranging from 12 hours to 10 days) and associated surface- and groundwater monitoring at each pumping intake site. The test was completed in August 2011, but the hydrologic data collected for this project have not been analyzed, and no additional progress is expected in the near future because of limited funding. The USACE anticipates that the data will be analyzed once the C-111 Spreader Canal Western Features project is completed and planning of the eastern project gets under way (USACE, 2012a).

NON-CERP RESTORATION IMPLEMENTATION

The aforementioned CERP restoration projects do not stand alone, but rather work in harmony with other non-CERP projects. The progress of the CERP depends upon the successful implementation and effective operation of these non-CERP projects, and three that are particularly important are the Mod Waters project, the restoration of the Kissimmee River, and the state's Long-term Plan for Achieving Water Quality Goals. This committee has followed the implementation of these projects in its past reports (NRC, 2007, 2008, 2010). Because these projects directly affect the CERP, a brief review of their progress is provided here. Additional details on the progress of these and other non-CERP projects are provided in Appendix B.

Modified Water Deliveries and Tamiami Trail

The Modified Water Deliveries to Everglades National Park project, authorized in 1989, is designed to restore flows into Northeast Shark River Slough that were diminished by the construction of the Tamiami Trail (U.S. Highway Route 41) and the L-29 canal and levee that parallel the highway. The restoration of these flows on a more natural annual schedule will feed much-needed water into Northeast Shark River Slough and return much of its natural function as a central flow-way in the park (SFNRC, 2010; USACE, 2009b). Additionally, the project was intended to improve hydrologic connectivity in WCA-3 by routing more water through WCA-3B. Improved flows were anticipated to offer habitat support for endangered species such as the wood stork, snail kite, Cape Sable seaside sparrow, and Florida panther.

After years of debate over the Mod Waters design, Congress, through the 2009 Omnibus Appropriations Act (P.L. 111-008), directed the USACE to construct a 1-mile bridge in the eastern end of the Tamiami Trail and raise the road to accommodate a canal stage of 8.5 ft—a project increment that is recognized as only a first step toward the originally intended restoration (NRC, 2008). The Act also directed the National Park Service (NPS) to evaluate the science of flows along the Tamiami Trail and to suggest how to improve the flows from a minimum of 1,400 cfs to 4,000 cfs. In its response to this directive, the NPS completed an environmental impact statement (NPS, 2010) and recommended a project alternative that would add 5.5 miles of bridges and raise the roadbed to accommodate a design high-water stage of 9.7 feet. This initiative would restore sheet flow across much of Northeast Shark River Slough, allow substantially higher flow volumes and velocities during wet weather conditions, and improve ecological connectivity between Everglades National Park and WCA-3 when implemented in conjunction with other planned restoration projects. Congress authorized the Next Steps Plan in the Consolidated Appropriations Act of 2012 (December 2011), but the associated $330 million (2010 cost estimate) has not been appropriated. The project would provide the conveyance capacity for flows of up to 4,000 cfs to Everglades National Park and create more natural geomorphology in the slough (NPS, 2010).

At the time of this NRC report, construction is progressing on the 1-mile bridge (Figure 3-14), with completion expected in December 2013. Because the Mod Waters project features are not yet completed, there are insufficient data to assess the restoration benefits of this project. Nevertheless, the project offers an important opportunity for learning about the ecological benefits of flow restoration. Plans allow for a small amount of water to move through WCA-3B, but the full usage of this route for large flows to Northeast Shark River Slough as part of the Mod Waters project are still under review (R. Johnson, NPS, personal communication, 2012).

FIGURE 3-14 Construction of the Tamiami Trail 1-mile bridge, December 2011. From left to right, the image shows the north edge of Everglades National Park, the new bridge under construction, the Tamiami Trail (U.S. Highway 41), the L-29 Canal, its levee, and the surface of WCA-3B.

SOURCE: B. Gamble, NPS, personal communication, 2012.

Kissimmee River Restoration

Under the Central and Southern Florida Project, the USACE replaced a sinuous 103-mile stretch of the Kissimmee River with a straight canal about half that length. The installation of control gates created an artificial flow regime, and the project resulted in the drainage of two-thirds of the flood plain (Jackson, 2011), with severe impacts to the wetland vegetation communities that hosted waterfowl, wading birds, and a variety of fishes (USACE and SFWMD, 2009a). Begun in 1999, the joint federal and state project on the Kissimmee River represents an effort to restore the original river and flood plain ecosystem (USACE and SFWMD, 2009a). Both the Kissimmee Headwaters Revitalization Project and the Kissimmee River Restoration Project are anticipated to be completed by 2014 (see Appendix B for more details).

Even though the project is not yet completed, there have been significant gains in measures related to the general goals of the project, such as flood plain inundation, channel flow, organic matter, and dissolved oxygen (Jackson, 2011; see Appendix B). Total phosphorus (TP) in the Kissimmee River remains at elevated levels, however. The partially restored landscape of the Kissimmee River (Figure 3-15) is already hosting increased numbers and densities of important species. Aquatic wading birds have increased in numbers, although their populations are still not large. Long-legged wading birds such as white ibis (*Eudocimus albus*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), and little blue heron (*Egretta caerulea*) have, in some years, been observed in numbers greater than twice that expected in the restoration (USACE and SFWMD, 2009a). In 2010, investigators found record numbers of wood storks (*Mycteria americana*) in the restoration area, and bass and sunfish make up an increasing percentage of the fish population (Jackson, 2011). In summary, the Kissimmee River Restoration Project is on track to restore one of the key components of the South Florida ecosystem. This achievement will increase the value of restoration downstream, providing a northern anchor to system-wide restoration.

Long-Term Plan for Achieving Water Quality Goals

As part of its Long-Term Plan for Achieving Water Quality Goals, the state has completed construction of STA Compartments B and C, which have expanded the areas of STA-2 and STA-5/6, adding approximately 11,500 acres of treatment area (Figure 3-16). Both areas were "flow capable" as of December 2010, and vegetation start-up is under way as of 2012. Four of the five planned pump stations are anticipated to be completed by May 2012. Meanwhile, enhancements to maintain or improve the performance of existing STAs continue, such as

FIGURE 3-15 A restored portion of the Kissimmee River, with the filled C-38 canal in the upper left and the newly re-carved channel of the restored river with an active flood plain on either side.

SOURCE: Jackson (2011), photo by Mark Bias, at http://www.saj.usace.army.mil/Divisions/Everglades/Branches/ProjectExe/Sections/UECKLO/KRR.htm.

addressing hydraulic short-circuiting and converting or reestablishing vegetation as needed (Ivanoff et al., 2012).

In early 2012, the state of Florida announced its plans to develop a water quality treatment plan intended to serve as a means of achieving the state's water quality legal obligations as an alternative to the approach set forth by the U.S. Environmental Protection Agency (EPA) in its 2010 Amended Determination. On June 4, 2012, the SFWMD outlined the general contours of its alternative plan. In particular, the state has articulated its intent and commitment to construct additional water storage and treatment projects to meet water quality goals. The plan is intended to provide sufficient treatment for the approximately 1.4 million acre-feet/year currently flowing out of the STAs to ensure that water in the Everglades Protection Area meets the legally required water quality standard.

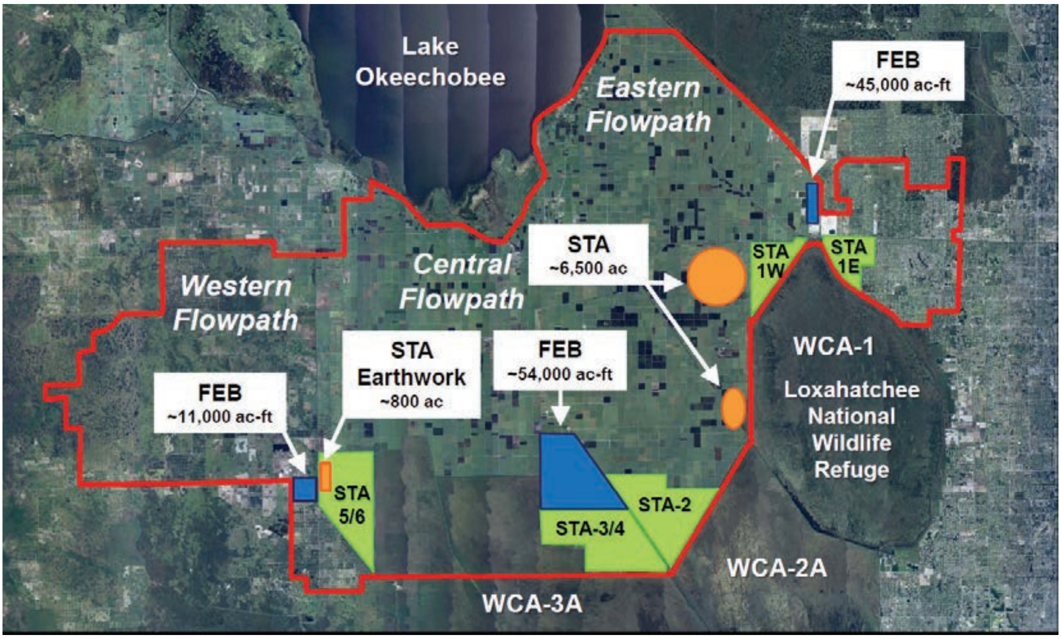


FIGURE 3-16 Location of the Everglades stormwater treatment areas (STAs): STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6 and the proposed locations for additional STAs, STA earthwork, and flow equalization basins (FEBs) announced on June 4, 2012.

SOURCE: Meeker, 2012.

The state anticipates that it will take approximately 12 years to construct and fully implement its proposed plan, although some features could come online in as soon as four years.

The proposed plan includes enhanced water quality treatment in each of the three flow paths into the Everglades Protection Area: the eastern flow path, the central flow path, and the western flow path (see Figure 3-16). In the eastern flow path, the state-proposed plan calls for the construction of a ~45,000 acre-foot capacity flow equalization basin to moderate inflows into existing STA-1E and STA-1W in addition to 6,500 acres of new STAs west of LNWR. The plan for the central flow path includes converting the Everglades Agricultural Area A-1 Reservoir footprint (north of existing STA-3/4) into a 54,000 acre-foot capacity flow equalization basin to moderate inflows into STA-3/4 and STA-2. In the western flow path, the proposed plan calls for construction of an ~11,000 acre-foot capacity flow equalization basin and an additional 800 acres of earthwork within existing STA-5/6 to maximize the efficacy of this treatment area. The state's plan also includes subregional source control measures (including enhanced best management practices) in the EAA, restoration of 15,000 acres of former citrus groves to wetland and upland habitat to reduce the loads on STA-5/6, and construction of a replacement storage feature in the Loxahatchee River Watershed (Meeker, 2012). As noted in Chapter 2, the EPA announced on June 13, 2012 that the state's plan provides an enforceable framework for ensuring compliance with Everglades water quality standards. The SFWMD Governing Board must still approve the plan.

Although the committee has not been provided with sufficient information to determine whether the plan's components will achieve a sufficient level of phosphorus reduction to meet legal obligations or restoration goals, the plan appears to be a significant step in the right direction. The plan's focus on providing significant additional flow equalization and water quality treatment is a significant development with important implications for restoration of both water quality and flow in the central Everglades.

CONCLUSIONS

During the past two years, notable progress has been made in the construction of Everglades restoration projects, with eight CERP projects now under construction. These projects include all of the Generation 1 projects authorized by Congress (Picayune Strand, Site 1 Impoundment, Indian River Lagoon-South, and Melaleuca Eradication) as well as two Generation 2 projects (C-111 Spreader Canal, Biscayne Bay Coastal Wetlands) and two Generation 3 projects (Loxahatchee River Watershed Restoration, Lakeside Ranch STA) constructed solely with state funding. This level of construction, and the associated program funding for 2010-2011, reflect significant implementation progress since the committee's previous review. Several major project phases are nearing completion in 2012, including the C-111 Spreader Canal Western Project and the Picayune Strand Merritt Canal components, which are expected to deliver significant increments of restoration benefits upon completion. Progress is also being made on important non-CERP projects, including the Kissimmee River Restoration and Mod Waters.

Nevertheless, as noted in previous committee reports, production of natural system restoration benefits within the Water Conservation Areas and Everglades National Park continues to lag behind restoration progress in other portions of the South Florida ecosystem. Early CERP implementation has largely focused on the periphery of the remnant Everglades, and in the most recent CERP project schedule, the projects with the greatest potential benefits to the remnant Everglades (e.g., decompartmentalization, seepage management, central Everglades storage) have been significantly delayed or remain uncertain.

For project components that have been implemented, the committee was generally unable to obtain rigorous analysis of incremental restoration benefits. In some cases, the only descriptions of progress are anecdotal accounts of vegetation changes or field observations of new water flows. **Effective assessment of restoration progress will depend on monitoring data that cover periods long enough to establish pre-project trends, followed by similar data after the project (or project component) is complete to determine the ecological changes that can be ascribed to the project.** Such a scientifically derived assessment of ecosystem response to project implementation is important to enhance the understanding of ecosystem recovery processes and may be useful to build public support for ongoing restoration efforts.

The Central Everglades Planning Project provides a means to expedite the realization of restoration benefits to the remnant Everglades while addressing major impediments inherent in the USACE project planning and approval process. The Central Everglades Planning Project is one of five USACE pilot projects nationwide that will test a new accelerated project planning process, with the goal of delivering an approved project implementation report to Congress within two years. The focus on the central Everglades (Water Conservation Area 3 and Everglades National Park) is appropriate for this pilot, given the urgent need to address ongoing ecosystem decline, as noted in NRC (2008). The Central Everglades Planning Project process allows for the combination of increments of multiple CERP projects (e.g., storage, seepage management, decompartmentalization) within a new planning framework to more easily identify their interdependence and system benefits. The pilot also intends to test new approaches for project planning, including clear, early scoping of analyses and decision-making criteria, early coordination with decision makers at all levels of USACE leadership, and reduced reliance on detailed analyses within a framework of risk-based decision making. The Central Everglades Planning Project appears to be an important step forward, responsive to earlier concerns of this committee (NRC, 2007, 2008, 2010), and consistent with the concept of incremental adaptive restoration (NRC, 2007). However, at completion of this report, the process remained at an early stage, and no specific project plans were available for the committee to review.

State-proposed projects to improve water quality represent an important step forward, with critical implications for restoration of attributes in the central Everglades impacted by high levels of phosphorus. Additional progress toward meeting water quality criteria appears likely, because the state and the federal partners have recently agreed upon additional water quality improvements for the Everglades Protection Area. These proposed features, however, address only current inflows to the Everglades, and do not provide water quality treatment for increased water volumes anticipated under the CERP.

If the pace of restoration progress is to be maintained, then an increased level of federal funding will be necessary for two reasons. First, large cuts to the SFWMD budget have already led to deferral of several large projects, and relatively modest outlays are projected over the next five years, mostly for water quality improvements to attain compliance with water quality criteria. Projected funding relies heavily on a drawdown of reserve funds to levels that, without other changes, will leave the SFWMD with little flexibility and limited capability to fund new CERP projects. Second, overall state CERP spending (including land purchases and expedited construction efforts) has vastly exceeded federal spending. Thus, even if the state could sustain prior levels of spending, the SFWMD might be reluctant to do so until the overall spending gap is reduced between the two partners. Nevertheless, the capacity for increased federal spending could be impacted by CERP cost-sharing requirements, because calculations of the cost-share balance do not include extensive state expenditures from land purchases and construction for projects that are not yet authorized.

Without congressional action, project authorization could soon become a major impediment to restoration progress. To receive federal funding, individual CERP projects must be authorized by Congress. To date, only three projects have been congressionally authorized under WRDA 2007, and one additional project is under construction with programmatic authorization from WRDA 2000. Four additional projects await authorization. Without a new WRDA, the federal government will be unable to maintain progress on several second-generation, state-expedited projects now under way (e.g., C-111 Spreader Canal, Biscayne Bay Coastal Wetlands). Also, authorizations affect the projects that are eligible for cost-share crediting. With no additional authorized projects and at current rates of federal spending, the federal creditable expenditures could exceed the state's in approximately three years, bringing the CERP to a standstill because federal cost-share creditable obligations may not exceed those of the state. If Congress does not authorize additional projects and the state does not increase spending, federal funding and project implementation would need to be sharply curtailed. Additional project authorizations (with accompanying project partnership agreements) could allow for more than $500 million of state CERP-related expenditures being credited as cost-shared funds.

Innovative, multi-species approaches have been applied to resolve local conflicts between species management and restoration management, but such conflicts are likely to continue, requiring flexible and innovative multi-species approaches applied at even larger spatial scales to avoid restoration delays and optimize restoration benefits. Examples of innovative multi-species approaches include the Everglades Restoration Transition Plan (ERTP) to address a conflict between the water management needs of endangered snail kites and Cape Sable seaside sparrows in Water Conservation Area (WCA)-3A and an approach to address a conflict between stormwater treatment area (STA) operations and protection of the nests of black-necked stilts and other migratory birds. Additional conflicts between the needs of endangered species and what is required to restore the ecosystem restoration are inevitable in the transition to a fully implemented CERP. A recent conflict between efforts to protect snail kite nests and STA operations illustrates how single species management could potentially compromise water management required for system restoration.

4

Ecosystem Trajectories Affected by Water Quality and Quantity

Previous National Research Council (NRC) reports on Everglades restoration noted that progress had not yet occurred (NRC, 2007) or that it was slow (NRC, 2008, 2010) and emphasized that tangible restoration progress is needed to prevent irreversible ecosystem declines. Such declines result from disruptions in hydrologic and water quality conditions that have been so altered from their natural states that the ecological conditions in the remnant Everglades have departed ever further from the target conditions envisioned in the restoration plan. As noted in Chapter 3, restoration initiatives have focused mainly on the perimeter of the Everglades with little benefit to the remnant Everglades. The latest (August 2011) Integrated Delivery Schedule (IDS; see Figure 3-1) gives little cause for optimism, because the bulk of the Water Conservation Area (WCA)-3 Decompartmentalization and Sheet Flow Enhancement (Decomp) project has been delayed beyond 2020. Recent state budget cuts threaten to slow restoration progress even further. In light of the ongoing declines and the slow pace of restoration progress, NRC (2010) recommended "a rigorous scientific analysis of the short- and long-term tradeoffs between water quality and quantity for the Everglades ecosystem."

In this chapter, the committee explores recent trends, possible future trajectories, and timescales for recovery of 10 ecosystem attributes of the remnant Everglades to better understand the implications of the current slow pace of progress and the potential consequences of focusing on water quality at the expense of water quantity, or vice versa. The chapter is organized in four main sections. First, the committee examines the context for water quality and quantity issues and discusses instances when water quality concerns have delayed restoration progress or have the potential to impact the future pace of implementation. Second, the committee synthesizes its analysis of current conditions and trajectories for 10 ecosystem attributes under three generic restoration scenarios to provide insights on how ecosystem attributes might respond differentially to management efforts. Furthermore, the committee explains the tradeoffs involved when restoration efforts focus on only water quality or water quantity. Third, the committee discusses each of the 10 attributes considered in the condition and trajectory analysis, including supporting evidence for the synthesis section. Finally, the committee identifies key conclusions.

CONTEXT FOR WATER QUALITY AND QUANTITY ISSUES

The problems in the central Everglades result from hydrological conditions that make some areas often too dry, while other areas are often too wet. The sheet flow that characterized the original ecosystem occurs only in some areas when sufficient water is available. Moreover, compartmentalization has limited areas that can sustain flow velocities necessary to support the historic landscape features, such as the ridge and slough. As a result, topography and interconnected biological communities have changed.

Issues with water quality present additional challenges to future restoration progress. Additional stormwater treatment areas (STAs) and/or source controls (e.g., best management practices) are needed to address elevated concentrations and loads of nutrients, most notably phosphorus, in *current* sources of inflow to the central Everglades (EPA, 2010). Thus, hydrologic restoration involving additional flow volumes or even redistribution of existing flows cannot proceed as planned without introducing levels of contaminants that would substantially affect the ecosystem and likely lead to potential violations of the 1992 Consent Decree. This difficulty was discussed in detail in the committee's previous report (NRC, 2010). Restoration challenges are exacerbated because the original Comprehensive Everglades Restoration Plan (CERP) assumed that water quality would be largely addressed outside of the CERP by the state's Everglades Construction Project. Additionally, the natural system was likely sustained by large pulses of wet season flows, but STA performance depends upon dampening such flows (e.g., through the construction of flow equalization basins) to maximize phosphorus removal. Thus, new planning is essential to determine how to support substantive flow restoration while simultaneously protecting the ecosystem from adverse water quality impacts.

Attempts to restore flows in WCA-3 provide a clear example of the challenges stemming from the interplay between water quality and quantity. The hydropattern restoration project component in WCA-3 has been delayed by water quality concerns, and there are additional concerns about the ability to operate Decomp Part 1 under anticipated water quality conditions. The hydropattern restoration component, designed to spread treated water from the STAs along the northern boundary of WCA-3A to better replicate pre-drainage flows, was originally part of the Everglades Construction Project, begun in the 1990s (FDEP, 1999). However, concerns about distributing water with high phosphorus concentrations into unimpacted areas have delayed this effort, which has now been moved into Decomp Part 1 (Baisden et al., 2010). The project implementation report for Decomp Part 1, which includes plugging or filling the Miami Canal and hydropattern restoration in northern WCA-3A, has been delayed, largely because of concerns that the project (currently scheduled in the IDS to be completed by 2020) would not be operational because of water quality issues (USACE, 2012b).

One of the key features of Decomp is sheet flow through WCA-3. The Modified Water Deliveries to Everglades National Park (Mod Waters) project included preliminary steps toward that goal via plans for conveyance features in the L-67 levees that would enable water to flow from WCA-3A into WCA-3B and into Northeast Shark River Slough. The Florida Department of Environmental Protection (FDEP) has raised concerns that this restoration component could compromise water quality in WCA-3B, which is currently a rainfall-driven system (E. Marks, FDEP, personal communication, 2012). Additionally, during wet periods, stage constraints in WCA-3B and in the L-29 canal limit the flow of water through WCA-3B and into Northeast Shark River Slough. Instead, water will continue to flow from WCA-3A into the L-67 and L-29 canals, bypassing WCA-3B, and then under the new 1-mile bridge into Northeast Shark River Slough. This flow pattern, which likely will remain the only option until water quality and stage issues are resolved, is hardly the vision of restoration. Even the small adjustments in flow of existing water from WCA-3A to the south represented by the switch from the Interim Operational Plan (IOP) to the Everglades Restoration Transition Plan (ERTP; see Chapter 3) has raised concerns about a decrease in the quality of the water delivered to Everglades National Park (Surratt, 2010). With anticipated new water to increase flows, these concerns about where and when water can flow will be further magnified.

SYNTHESIS OF THE CURRENT STATUS AND TRAJECTORIES OF ECOSYSTEM ATTRIBUTES UNDER VARIOUS SCENARIOS

The following sections discuss the current state, trajectories, and timeframes of recovering ecosystem declines for 10 ecosystem attributes of the remnant Everglades. These ecosystem attributes include total phosphorus (TP) loads, interior TP concentrations, soil phosphorus, cattail (*Typha domingensis*), periphyton, fish mercury concentrations, peat depth, ridge-and-slough topography, tree islands, and snail kites. These attributes are thought to be good measures of changes in structure and functioning that have occurred because of disruptions in the quantity, distribution, and quality of water inflows. The committee also selected these attributes because they reflect important and valued system characteristics and because there is considerable information on their status from past monitoring and research. The spread of nonnative species, most notably Burmese pythons, reflects a significant change in the Everglades ecosystem (Dorcas et al., 2012), but abundance, effects, and potential for control of these species are not obviously related to water quality or flow, and so they are not included in this analysis. The attributes selected for this committee's evaluation are both similar to and different from those selected for other assessment reports. For example, except for periphyton these attributes do not overlap with the stoplight indicators of the South Florida Ecosystem Restoration Task Force (SFERTF, 2010b), which largely focus on organism response. In contrast, there is considerable overlap with the System Status Report (RECOVER, 2010) and CERP performance measures (RECOVER, 2007).

Table 4-1 summarizes the committee's assessment of status, current trends, and trajectories of all 10 ecosystem attributes under three generic restoration scenarios involving water quality and hydrology. More detailed discussions of each attribute that support the committee's assessment appear later in the chapter. By necessity, the table simplifies the complex ecosystem responses to management actions (much like a doctor's health checkup), but the chapter sections attempt to capture some sense of the underlying dynamics and complex interactions among the various ecosystem attributes. This analysis provides a realistic qualitative assessment that underscores the increasingly degraded condition of the remnant Everglades and illuminates the consequences of various restoration scenarios.

The current conditions of the 10 ecosystem attributes in varying states of decline are highlighted in Table 4-1. These conditions are driven by decades of diminished flow volumes and velocities, compartmentalization with associated distortions of water depths, altered hydroperiods,[1] and poor water quality. The committee summarizes the condition of each attribute by providing "grades" of the current state *relative to the pre-drainage system*: "A" no significant degradation, "B" evidence of degradation, "C" degraded, "D" seriously degraded, and "F" near irreversible[2] degradation. For most attributes, these grades range from B to C (evidence of degradation to degraded; e.g., interior TP concentrations, TP load, soil P, cattails, periphyton) to D (seriously degraded; e.g., peat, tree islands, ridge and slough, fish mercury). For the snail kite, whose population has declined to near extirpation, the conditions are dire (grade of F or near irreversible damage). The overall grade (or condition) for the 10 attributes is seriously degraded. Clearly the Everglades is in need of an aggressive and sustained restoration effort, beyond what is currently under construction (see Chapter 3), if

---

[1] "Hydroperiod describes the depth, duration and timing of inundation," (Sklar and van der Valk, 2002). The term is sometimes also defined as the length of time (usually within a year) that a feature or an area is flooded (Bedford et al., 2012).

[2] The committee considers irreversible degradation to represent ecosystem loss that cannot be restored over many centuries. Extinction is one example of irreversible degradation.

its structure and functioning are to improve. The grades are not intended to be used to prioritize restoration of a single attribute to the detriment of others, but to highlight the urgency for ecosystem restoration actions that could benefit a wide range of attributes, as well as the cost of inaction.

Table 4-1 also summarizes the current trajectories of the attributes (improving, stabilizing, or degrading), which are discussed in more detail in the following sections. The current trajectories in Table 4-1 can be characterized as those largely driven by hydrology (i.e., peat, tree islands, ridge and slough, snail kite); those largely affected by phosphorus concentrations (i.e., interior TP concentrations, periphyton) or load (i.e., TP load, soil phosphorus, cattail); and those largely responding to other mechanisms, although with linkages to hydrology (i.e., fish mercury). As shown in Table 4-1, the attributes most affected by hydrology, in general, are described as degrading, while those affected by phosphorus concentrations show a range of responses. Phosphorus-related stressors are stabilizing or stable to improving, because of the construction of STAs and implementation of source controls since the mid-1990s. Ecosystem conditions affected by phosphorus concentration are stable (periphyton), and those affected by loads are degrading but at slowing rates in some areas (cattails).

Using available science, monitoring, and modeling, the committee also considered how the current trajectories of the 10 attributes might change in response to three hypothetical scenarios of management actions: 1) improved water quality (with no increase in flow), 2) improved hydrology (with no additional water quality treatment), and 3) the combination of improved water quality and hydrology (see Box 4-1 for details on each scenario). Scenario 3 is the preferred scenario because it reflects the original CERP objective, but when it is achieved depends on the implementation schedule of restoration projects addressing water quality and quantity. These scenarios are simplifications of management alternatives. In Table 4-1, the effects of the three restoration scenarios on each ecosystem attribute are evaluated *relative to the attribute's current trend*. Thus, a 0 rating for an attribute that is currently degrading means it will continue to degrade under that scenario.

Estimates of the timescales for recovery are also described. These timescales reflect the committee's qualitative estimates of the time required after substantial degradation has occurred to recover the losses in that ecosystem attribute (i.e., snail kites, tree islands, ridge-and-slough topography, periphyton, peat, cattail) or to attain established restoration criteria (i.e., phosphorus concentrations and loads in the water and soil, fish mercury concentrations). The importance of providing estimates of the timescales for recovery is to emphasize that some attributes will take longer to recover than others. The outcome of this analysis is an understanding that near-term progress that addresses only water quality *or* water quantity leads to continued system declines of many components. The

TABLE 4-1 Summary of Trajectories of Different Ecosystem Attributes in the Current System and under Three Restoration Scenarios

Attribute	Current "Grade" of System (A to F)	Current System Trend	Effects of Restoration Scenarios on Current Trends			Timescales of Recovery[3]
			(1) Effect of Improved Water Quality[1]	(2) Effect of Improved Hydrology[1,2]	(3) Effect of Improvements in BOTH Water Quality and Hydrology[1]	
Stressors						
TP load	C	Stable to Improving	++	– –	+	Years
Interior TP conc.	B to C[4]	Stable to Improving	++	–	+	Decades
Soil P	C	Stabilizing	+	– –	+	Decades to centuries
Ecosystem condition						
Cattail	C	Degrading, but degradation slowing in some areas	+	– –	+	Decades to centuries (years if actively managed)
Periphyton	C	Stable	++	– –	+	Years. Recovered communities may not be the same as prior to disturbance
Peat	D	Degrading in dry areas	0	+ +	+ +	Centuries
Tree islands	D	Degrading	0	+[5]	+[5]	Decades to centuries; may require active restoration
Ridge and slough	D	Degrading	0	+	+ +	Centuries; could involve adaptive management
Snail kite	F	Degrading	0	+	+	Years to irreversible
Fish mercury	D	Stable	–	+	+	Years to decades

continued

analysis also helps to prioritize the focus: stabilizing and ultimately reversing declines of attributes that would take a long time to recover merit higher priority than attributes that would recover more quickly, all other things being equal, especially if other aspects of the restoration depend on them.

Observations

The committee's qualitative analysis (explained in more detail in the attribute-specific sections later in the chapter) led to several overarching observations. If only system hydrology were to be addressed in restoration projects over

TABLE 4-1 Continued

[1] The three scenarios considered are detailed in Box 4-1.
[2] Hydrologic improvements are assumed to address flow volumes, flow velocity and direction, flow variability and frequency, and water depths and their spatial distribution, timing, and duration.
[3] Timescales of recovery reflect the committee's qualitative estimates of the time required after substantial degradation has occurred to recover the losses in that ecosystem attribute (i.e., snail kites, tree islands, ridge-and-slough topography, periphyton, peat, and cattail) or to attain established restoration criteria (i.e., phosphorus concentrations and loads in the water and soil, fish mercury concentrations).
[4] The grade of B applies to Everglades National Park and WCA-2, while a grade of C applies to WCA-3 and LNWR.
[5] The "+" for scenario 2 for tree islands reflects minor improvement given the potential negative impacts of increased phosphorus on low elevation islands, whereas "+" for scenario 3 reflects moderate improvement (see the tree island section later in this chapter for more detail).

NOTES:
The following reflect responses to the three scenarios *relative to the current system trend*:
++ Major improvement in trend
\+ Minor to moderate improvement in trend
0 No change
\- Minor to moderate decline in trend
\- - Major degradation in decline in trend

"Grades" are based on an assessment of the current level of impairment of that ecosystem attribute *relative to a pre-drainage state*:
A No significant degradation
B Evidence of degradation
C Degraded
D Seriously degraded
F Near irreversible degradation

The trajectories presented in this table do not consider climate change and sea level rise effects, because the analysis was intended to highlight implications of decision-making alternatives over the next 1-2 decades. Climate change and sea level rise could certainly impact long-term trajectories of recovery and timescales of recovery, but these effects were not analyzed for this report.

the next decade, then minor to moderate improvements could be expected for the trajectories of ridge and slough, tree islands, fish mercury, and snail kites, and major improvements for peat. However, these improvements would be accompanied by major expansion of cattails and continued accumulation of soil phosphorus. Soil phosphorus and dense cattail stands, if not actively managed, may persist for decades to centuries because soil phosphorus will continue to impact vegetation—even as phosphorus concentrations in inflow waters improve—until the soils are buried by less contaminated organic matter. However, the timescale for recovery for periphyton is anticipated to be relatively short.

In contrast, if restoration priorities in the central Everglades focus only on

BOX 4-1
Three Scenarios of Management Action Used in the Committee's Analysis of Ecosystem Attribute Trajectories

The committee developed the following three scenarios for its analysis of likely changes to current ecosystem trajectories under different management actions:

1. **Improved water quality (with no increase in flow).** For this scenario the committee assumed a decrease in TP concentrations supplied to the Everglades Protection Areas from the STAs to meet the 18 parts per billion (ppb) TP annual flow-weighted mean, which was identified in the Amended Determination as one of two parts of an enforceable framework necessary to meet the 10 ppb geometric mean water quality criterion in the Everglades Protection Area. The second part was a requirement that STA discharge concentrations not exceed 10 ppb as an annual geometric mean (equal to approximately 12 ppb TP as a flow-weighted mean) in more than two consecutive years (EPA, 2010). An STA discharge of 18 ppb TP represents a 28 percent decrease in current flow-weighted mean TP concentrations and loads without any change in flow (compared to the flow-weighted mean of 25 ppb TP across all STAs; Pietro et al., 2010). Meeting both parts of the Amended Determination framework would require lower long-term TP averages than the short-term 18 ppb annual limit considered in this scenario.
2. **Improved hydrology (with no additional water quality features).** The committee considered improved hydrology to address flow volumes, flow velocity and direction, flow variability and frequency, and water depths and their spatial distribution, timing, and duration. For this scenario, the committee assumed an increase in flow volumes into the northern end of the Everglades Protection Area from the current annual average of 1.4 million acre-feet (MAF) to the CERP-proposed discharge of 1.7 MAF. Nevertheless, based on recent science suggesting a wetter pre-drainage system (~2.1 MAF; Wilcox, 2012), higher total flow volumes could be considered, as was done in the River of Grass planning process. An average annual discharge of 1.7 MAF represents a 21 percent increase in flow. Given that the current extent of STAs do not have capacity to accommodate this additional flow, such a scenario would involve 0.3 MAF of untreated water from Lake Okeechobee (at an assumed concentration of 100 ppb, see Figure 4-2) reflecting an additional 37 metric tons (mt) TP/year load. This represents an approximate 30 to 50 percent increase in the total TP load to WCAs -1, -2, and -3 (considering the five-year moving averages for 2009-2011; see Figure 4-3). The actual load increase could be even greater if the Lake Okeechobee water were distributed to only a single WCA. Additionally, the scenario assumes restoration features, including decompartmentalization, to address the currently altered water distribution and depths in the central Everglades, and releases that generate a flow velocity in the ridge and slough of at least 2.5 cm/s for a few weeks per year.
3. **Improvements in both hydrology and water quality.** The third scenario assumes the same hydrologic improvements of scenario 2, but it also assumes additional water quality features to reach the water quality objectives outlined in scenario 1. The combination of a 28 percent decrease in phosphorus concentration and a 21 percent increase in flow results in an assumed 13 percent decrease in phosphorus load to the Everglades Protection Area.

As noted previously, these are hypothetical scenarios with postulated endpoints, primarily to illuminate the different trajectories that ecosystem attributes could take under different scenarios. The committee has not analyzed what (or whether) specific project features could create these results.

the water quality of existing flows, then the ecosystem should see some recovery in periphyton and slow improvement in soil phosphorus and cattails. However, peat loss would continue in over-drained areas (e.g., northern WCA-3), and trajectories of deteriorating condition would continue for characteristic landscape features such as tree islands and ridge and slough. Most of these losses would require decades to centuries to recover under ideal conditions. The reality is that these optimal conditions might never occur, and opportunities for restoration could be lost. Meanwhile, the Everglade snail kite faces a serious threat of extirpation. Attributes most directly influenced by hydrology are continuing to decline and are the most difficult to recover (e.g., peat, tree islands, ridge and slough), making addressing them a high priority. The areas of the Everglades where these hydrology-driven attributes are relatively intact and functioning therefore merit priority for protection and management.

The benefits of restoration are not as simple and clear-cut as a tradeoff between water quantity and water quality. In many ways, improvements in water quality are linked with improvements in water quantity, and vice versa. For example, increases in water depth and duration will decrease the decomposition rates of peat and the associated release and transport of phosphorus, sulfur, and other nutrients associated with soil organic matter and therefore improve water quality. Likewise decreases in TP loads will likely encourage the development of native vegetation and the peat, landforms, and hydrology associated with that vegetation. Thus, benefits associated with management actions that improve water quality and water quantity are interconnected. Therefore, this qualitative analysis should be viewed only as a first step toward an integrated analysis of water quantity and water quality management actions. It points to the need for a more critical and comprehensive quantitative analysis using models to evaluate management issues in an integrated manner (see Chapter 5).

Nevertheless, based on this qualitative assessment of the central Everglades system components' status and trajectories, the committee concludes that *near-term* progress is needed in the central Everglades to address both water quality and quantity to prevent continued degradation that will take decades or longer to recover under optimal conditions. The committee is encouraged by the Central Everglades Planning Project, which intends to expedite the planning of the next increment of projects focused on the "core" rather than the periphery of the Everglades. This effort represents a significant step forward, although many details remain unresolved. The committee has not reviewed specific project plans, because the planning process was only in the early stages when this report was being finalized. But the Central Everglades Planning Project conceptually offers an opportunity to make significant steps toward reversing the declines in the remnant Everglades.

ANALYSIS OF ECOSYSTEM ATTRIBUTE TRAJECTORIES

The following sections summarize the current state of the science of key ecosystem attributes of the remnant Everglades and provide the basis for the committee's analysis of current status and trajectories under various restoration scenarios, as summarized in Table 4-1. These ecosystem attributes include: phosphorus loads and concentrations, soil phosphorus, cattails (*Typha*), periphyton, fish mercury concentrations, peat, tree islands, ridge-and-slough topography, and snail kites.

Phosphorus

The wetlands of the historical Everglades were primarily low-nutrient, phosphorus-limited systems. These biotic communities, including microbes, algae, and aquatic plants, are efficient in utilizing and conserving nutrients through reallocation and uptake of nutrients at very low concentrations. However, phosphorus loading from agricultural and urban lands has converted some of these areas from low-nutrient to high-nutrient systems, particularly near the source areas and along canals. The phosphorus inputs have led to substantial alterations to the indigenous system, including large incursions of cattail and disappearance of periphyton (discussed later in the chapter; McCormick et al., 2002; Noe et al., 2001, 2002; Richardson, 2008; Scheidt and Kalla, 2007).

Phosphorus Concentrations and Loads

This section describes trends in phosphorus loads and concentrations in Lake Okeechobee and in the Everglades Protection Area. Because a substantial quantity of "new water" for the CERP will be delivered from Lake Okeechobee, water quality trends in the lake have important implications for Everglades restoration plans. Five-year trailing moving averages (5YrTMA) of total phosphorus (TP) loads to Lake Okeechobee increased from 1994 until about 2006 to a maximum of about 700 metric tons (mt) per year, peaking after two consecutive years of heavy hurricane activity, and since 2006 the trend has been downward after several dry years (Figure 4-1). Even at the level of 500 mt in 2010, the average TP load is still far above the annual target of 140 mt. Phosphorus concentrations in the lake have seemingly returned to pre-hurricane levels following the sharp increases starting in 2005, although the current values (~100 parts per billion [ppb]) remain far above the target concentration of 40 ppb TP (Figure 4-2). It is too early to discern from the data whether the long-term increasing trends in loads and concentrations are, in fact, beginning to level off. Nevertheless, if increased amounts of Lake Okeechobee water are to be conveyed in the near term to the

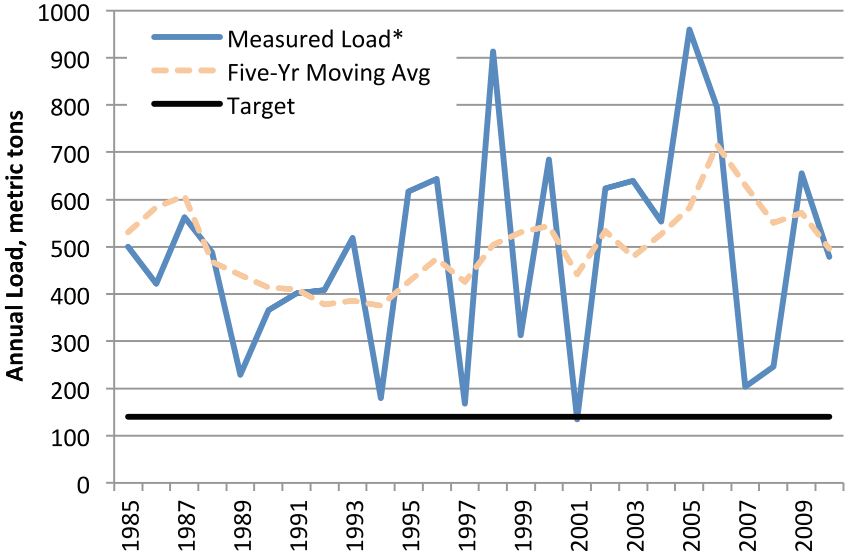


FIGURE 4-1 Annual total phosphorus loads and five-year trailing moving average loads to Lake Okeechobee. Reported loads include atmospheric deposition.

SOURCE: Data from Zhang and Sharfstein (2012).

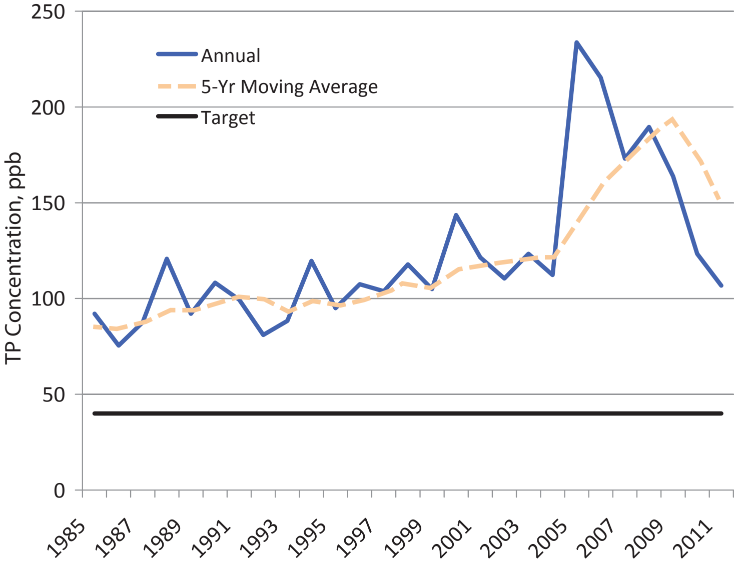


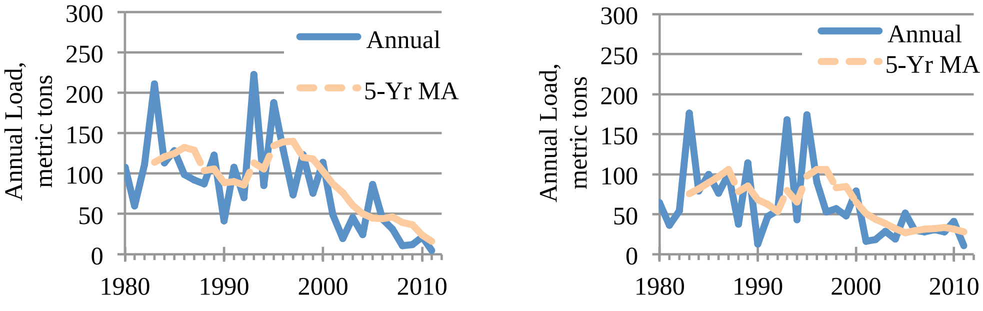
FIGURE 4-2 Annual average concentrations of phosphorus in Lake Okeechobee.

SOURCE: Adapted from Zhang and Sharfstein (2012), Figure 8-12.

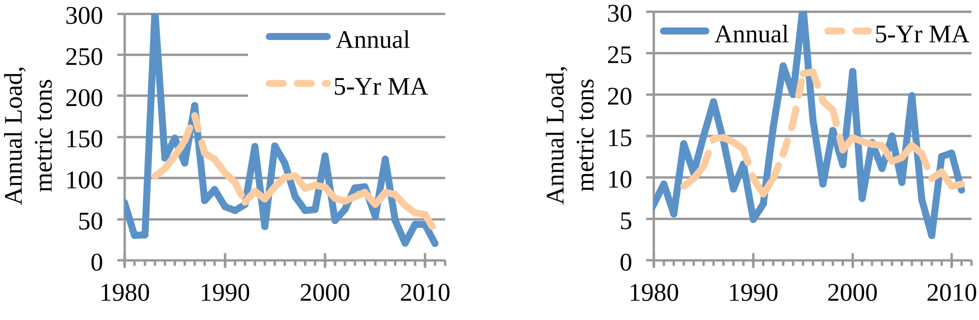
remnant Everglades through the CERP, significant additional water quality treatment will be needed.

Trends in TP loads in the Everglades Protection Area are far more encouraging. Annual and 5YrTMA loads for the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR, also called WCA-1), WCA-3, and Everglades National Park have declined sharply since the mid-1990s. In WCA-2 loading rates have been relatively stable since 2005 (Figure 4-3).

Inflow concentrations to LNWR have varied over a wide range (30 to 90 ppb) since 1994, while those for WCA-2 and -3 have steadily declined (Figure 4-4). Concentrations entering Everglades National Park (ENP) have fluctuated in a narrow range around the 10 ppb level since 2000.



WCA 1 WCA 2



WCA 3 ENP

FIGURE 4-3 Annual total phosphorus loads and five-year trailing moving averages of annual loads on individual components of the Everglades Protection Area.
NOTE: Please note the different scale used for Everglades National Park.

SOURCE: Payne et al. (2011).

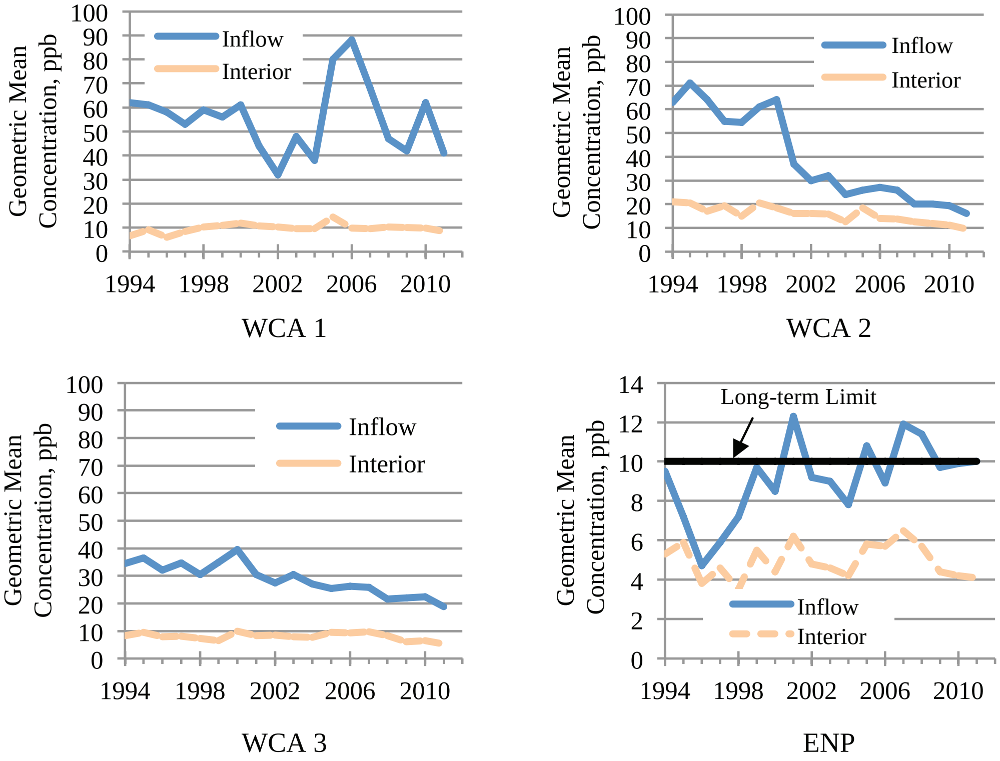


FIGURE 4-4 Annual geometric mean TP concentrations in the Everglades Protection Area. Concentrations at interior locations are geometric means over all monitoring locations within each component of the Everglades Protection Area for which sufficient samples were collected in an annual period.
NOTE: Please note the different scale used for Everglades National Park.

SOURCE: Payne et al. (2011).

Since 2000, trends in geometric mean TP concentrations of all interior locations have been relatively steady (in LNWR and ENP) or declining (in WCA-2 and -3). However, temporary increases in interior concentrations have been observed when intense rainy periods are followed drought years (see 2005 data in Figure 4-4).

The concentrations shown in Figure 4-4 are averaged over all interior sites. LNWR, WCA-2, WCA-3, and Everglades National Park (ENP) are protected by the water quality standards established in Florida's Administrative Code Chapter 62-302.540, but compliance with the phosphorus limits in the Everglades Protection Area is determined by two complex rules:

- In LNWR, WCA-2, and WCA-3, compliance with these standards is determined by a four-part test[3] applied separately to impacted areas (soil phosphorus greater than 500 mg P/kg) and unimpacted areas;
- In Everglades National Park, compliance with the standards is determined using the methods as set forth in Appendices A and B of the Settlement Agreement of 1991 entered as a Consent Decree in 1992 and modified in 1995. Appendices A and B of the Settlement Agreement provide an additional level of water quality protection for LNWR and Everglades National Park (Mo et al., 2012).

Unimpacted areas in the WCAs have consistently passed all parts of the four-part test since 2007. Impacted areas have consistently failed the annual all-site geometric mean limit of 11 ppb and the five-year annual geometric mean limit of 10 ppb. Annual geometric means for many individual stations have been below the 15 ppb limit (Payne and Xue, 2012). LNWR has been in compliance with the Consent Decree since June 2009, although "exceedances" occurred in November 2008 and June 2009 (SFWMD, 2009b). Compliance tests for Everglades National Park are based on flow-weighted mean concentrations in inflows to Shark River and to Taylor Slough and Coastal Basins. Shark River inflows just satisfied applicable criteria in 2008-2010. Concentrations in inflows to Taylor Slough and coastal basins have been well below applicable criteria in each of the past three years (Mo et al., 2012).

Given these past trends, the committee anticipates that a hypothetical future scenario of improved phosphorus treatment with no change in flow (scenario 1, Table 4-1) would lead to a 28 percent decrease in the phosphorus load to the Everglades Protection Area (see Box 4-1 for assumptions) and continued decrease in interior concentrations of total phosphorus particularly in LNWR and WCAs-2 and -3, which are most impacted by STA inflows (Table 4-1). Under the scenario of increases in discharge with no additional phosphorus treatment, it is anticipated that there would be a major increase in total phosphorus load to the Everglades Protection Area and, as a result, deterioration in interior phosphorus concentrations (although a lesser effect than what would be observed at inflow locations).[4] Finally under the scenario of both increases in flow and additional phosphorus treatment (scenario 3), the committee expects an overall decrease in phosphorus load (13 percent decrease), a lesser improvement than scenario 1

---

[3] The four-part test is used to assess compliance according to the following four provisions: (1) five-year geometric mean is less than or equal to 10 ppb, (2) annual geometric mean averaged across all stations is less than or equal to 11 ppb, (3) annual geometric mean averaged across all stations is less than or equal to 10 ppb for three of five years, and (4) annual geometric mean at individual stations is less than or equal to 15 ppb (FAC §§ 62.302.540).

[4] The committee has neither evaluated nor is providing any opinion on whether violations of the four-part test or the Consent Decree Appendices A or B will increase.

(see Box 4-1). Because the rates of response of phosphorus loads and interior TP concentrations have been relatively rapid, a reasonable timescale for recovery of total phosphorus loads and associated interior TP concentrations is anticipated to be years to decades (Table 4-1).

Soil Phosphorus

The primary cause of soil phosphorus enrichment in the Everglades is external loading from surface water inflows, although peat oxidation during prolonged drought or fire can contribute to phosphorus enrichment (Bruland et al., 2007; Scheidt and Kalla, 2007). Phosphorus from surface-water inflows is readily retained by sorption to soil or taken up by periphyton and vegetation; thus, soils are integrators of the long-term nutrient supply and indicators of surface-water quality. Soil phosphorus concentrations are generally highest in areas near inflow structures and lowest in interior areas (Figure 4-5). Between these two conditions there is a gradient in quality and quantity of organic matter, nutrient accumulation, and biogeochemical cycles. Cattail encroachment (described in more detail in the next section) is closely linked with increasing levels of soil phosphorus, and restoration goals aim to decrease or maintain long-term average soil phosphorus concentrations below 400 mg/kg to inhibit cattail expansion (Newman et al., 1996; Osborne et al., 2011b; Payne et al., 2003). The state considers soils in the Everglades to be phosphorus-enriched if the soil phosphorus exceeds 500 mg/kg.

Results from the U.S. Environmental Protection Agency (EPA) Regional Environmental Monitoring and Assessment Program (R-EMAP; Scheidt and Kalla, 2007) and the University of Florida Everglades Soil Mapping (ESM) project (Reddy et al., 2005) showed similar spatial patterns in soil phosphorus concentrations in surface (0-10 cm) soils (e.g., Figure 4-5). However, the ESM data suggest that the area of phosphorus enrichment may be smaller than that shown by the R-EMAP data. Scheidt and Kalla (2007) reported that in 2005 the soil phosphorus content exceeded 500 mg/kg in 25 ± 6 percent of the Everglades and 400 mg/kg in 49 ± 7 percent. These values are greater than those observed by EPA in 1995-1996 (16 ± 4 percent and 34 ± 5 percent, respectively). Bruland et al. (2007) also assessed rates of changes in soil phosphorus, focusing on WCA-3A between 1992 and 2003. In 2003, 30 percent of the surface soils were considered enriched (>500 mg/kg) in contrast to 21 percent in 1992.

The majority of phosphorus entering the Everglades is retained in various components of wetlands—either as plant or periphyton biomass or sorbed to peat or particulate matter (Figure 4-6). A lesser amount exists as dissolved phosphorus in the water column, because soluble phosphorus is usually quickly taken

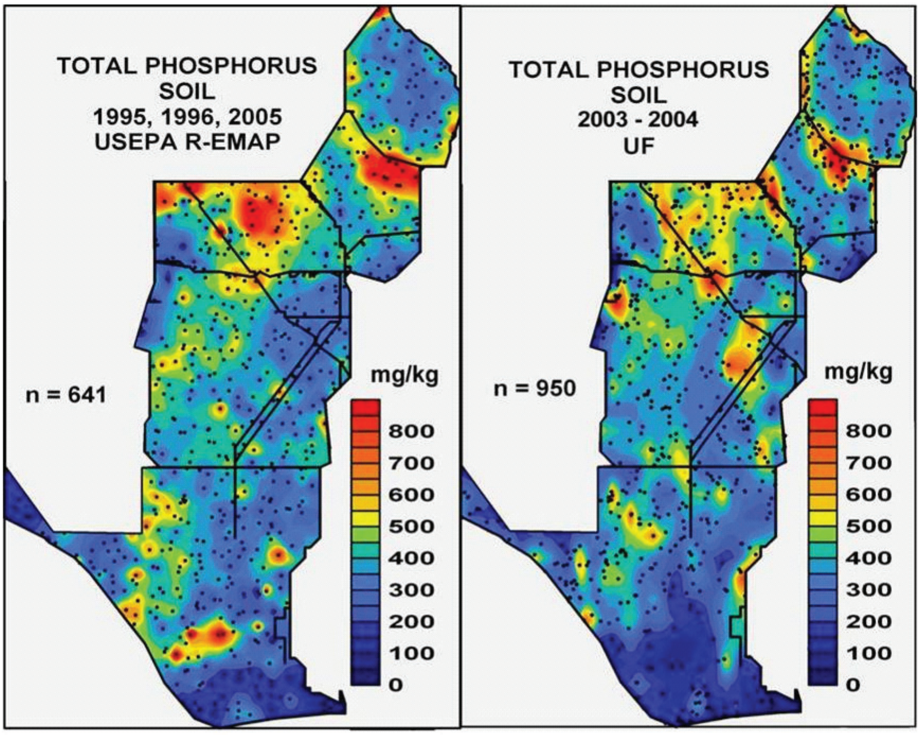


FIGURE 4-5 Spatial distribution of soil total phosphorus for the 0-10 cm soil profile for both R-EMAP (Scheidt and Kalla, 2007) and ESM/UF (Reddy et al., 2005) datasets. Maps by D.J. Scheidt.

SOURCE: Osborne et al. (2011a).

up by biotic communities. Storage of phosphorus in wetland vegetation and other biotic communities is generally small and short-term. When the vegetation dies and decomposes, through the processes of peat accretion, the detrital material accumulates and the plant phosphorus is cycled back into the soil. Soil porewater phosphorus concentrations in the nutrient-enriched areas are approximately 10 times higher than water column phosphorus, creating steep concentration gradients (Koch and Reddy, 1992). Long-term phosphorus storage occurs through burial of stable organic and mineral matter into soils (Craft and Richardson, 1993; Reddy et al., 1993). Vertical soil profiles from WCA-2A show nutrient-enriched material in surface soils (<15 cm depth) but not below 15 cm depth, suggesting minimal redistribution of buried soil phosphorus

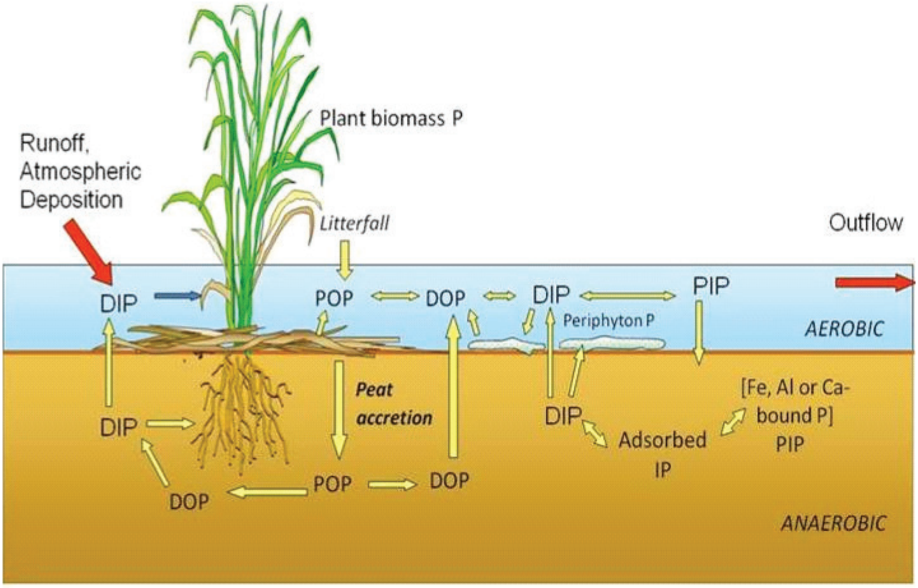


FIGURE 4-6 Phosphorus cycle in Everglades wetlands.
NOTE: Dissolved organic phosphorus (DOP), dissolved inorganic phosphorus (DIP), particulate organic phosphorus (POP), particulate inorganic phosphorus (PIP), and inorganic phosphorus (IP).

SOURCE: Reddy and DeLaune (2008).

(Figure 4-7). Dating techniques (Cs-137 and Pb-210) confirm that the accumulation of phosphorus-enriched soil occurred over the past 20 to 50 years (Craft and Richardson, 1993; Reddy et al., 1993).

Implementation of best management practices (BMPs) in the Everglades Agricultural Area (EAA) and establishment and optimization of STAs, however, have helped to significantly reduce phosphorus loads to the WCAs, particularly during the past decade (Figure 4-3). Based on this information, the committee judges that soil phosphorus may now be stabilizing, although more recent soil phosphorus analyses across a broad spatial scale would be needed to confirm this trend. When enriched soils are exposed to water with low phosphorus concentrations, they release phosphorus until a new equilibrium is reached. Fisher and Reddy (2001) showed high phosphorus flux (after external loads are curtailed) from nutrient-enriched soils that were exposed to surface water with total phosphorus concentration of <10 ppb. If it is assumed that approximately

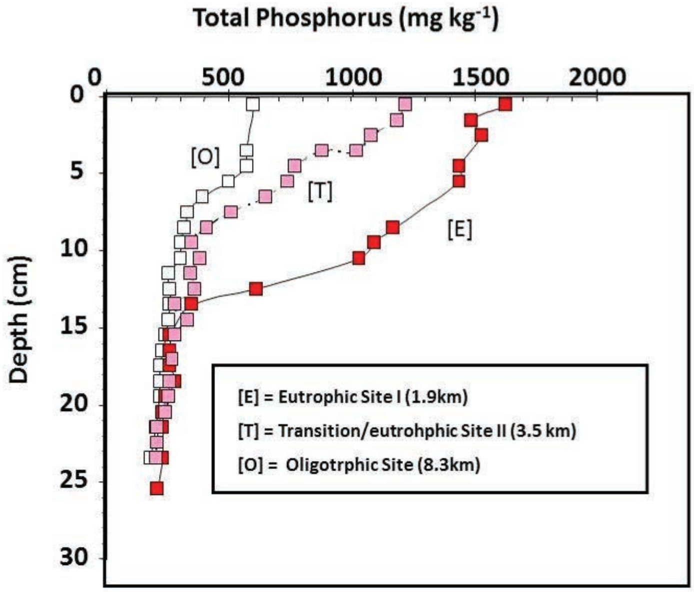


FIGURE 4-7 Vertical distribution of soil phosphorus in WCA-2A. The distance noted in the legend refers to the location of the site samples from the inflow point where agricultural drainage waters are discharged into WCA-2A.

SOURCE: Reddy et al. (1993).

25 percent of the total phosphorus in the top 30 cm of soil (Reddy et al., 1998) is potentially mobile and can diffuse at a rate of approximately 2 mg P m^{-2} day^{-1} into the overlying water column, this release of phosphorus from sediments would be sustained for a period of approximately five years. However, because the demand for soluble phosphorus is high among biotic communities, this release of phosphorus from soil will have minimal effect on the overlying water column phosphorus concentrations.

Further reduction of phosphorus concentrations in the inflow water (scenarios 1 and 3, Table 4-1) will help to reduce soil phosphorus enrichment in soils. However, cattails are extremely efficient at recycling phosphorus from aging and dying plant materials, inhibiting the export of phosphorus from dense cattail stands, even under conditions of reduced phosphorus loads. Thus, the recovery of soil phosphorus-enriched areas may take several decades to centuries (Walker and Kadlec, 2011), particularly in cattail-enriched areas. Reducing the impact of soil phosphorus on the Everglades landscape will more likely be driven by the rate of burial of soil phosphorus than by leaching the phosphorus out of the ecosystem.

Cattail

Species of cattails are among the most widespread and competitive emergent plants in freshwater wetland ecosystems. Their rapid expansion into wetlands that historically were not dominated by cattail has occurred across the globe, mostly in response to various natural and anthropogenic disturbances (Osland et al., 2011; Richardson, 2008). Prior to human impact, cattail had been a part of the Everglades ecosystem, although its extent was minor as evidenced by pollen records from peat cores (Willard and Weimer, 1997). However, since the 1970s, cattail has been spreading in phosphorus-enriched areas of the oligotrophic Everglades at the expense of sawgrass and other less competitive species (Richardson, 2008). This spread is associated with elevated phosphorus loads and altered hydroperiods (Newman et al., 1996). In areas that have been overdrained, oxidation of soil organic matter can release phosphorus, resulting in enhanced cattail growth in absence of external loads. Cattail expansion, resulting from years to decades of sediment phosphorus enrichment, is generally preceded by changes in more sensitive components of the ecosystem such as periphyton (Surratt et al., 2012; see next section). The spread of cattail greatly impacts ecosystem processes, including an increase in primary production, replacement of water column autotrophy with heterotrophy,[5] and sediment accretion (Hagerthey et al., 2010; Miao et al., 2000; Richardson, 2008). Other ecological implications of cattail expansion include decreases in dissolved oxygen concentration, degradation of fish and wading bird habitat, accelerated biogeochemical cycling of nutrients and metals, such as mercury (Osborne et al., 2011b), and marked changes to the calcareous periphyton and microbial communities (Gaiser et al., 2005; Ogram et al., 2011; Reddy et al., 1999).

Recent Trends in Cattail Expansion

Temporal changes in the extent of cattail in WCA-2A and WCA-3 have been well documented in nutrient gradient research, transect sampling, and remote sensing. In the 1940s, WCA-2A included nearly monospecific sawgrass plains in addition to sawgrass mosaics, wet prairies, and sloughs, but by 1991, cattail monocultures and larger areas of sparse cattails appeared in the eastern portion of the impoundment and along the southwestern boundary, with continued

---

[5] Autotrophs use energy from sunlight or inorganic chemicals, whereas heterotrophs derive energy from organic carbon.

expansion through 2003 (Figure 4-8). The average rate of cattail expansion, however, has decreased from 961 hectares/year (between 1991-1995) to 312 hectares/year (between 1995- 2003; Rutchey et al., 2008), likely because of the decrease in phosphorus loads into WCA-2A after 1995 (Figure 4-3b). The southward expansion of cattail could also have been decreased by the presence of dense sawgrass in the central parts of WCA-2A, which is more resistant to cattail invasion than open water sloughs (Richardson, 2008). Recent data and analysis indicating that the spread of cattail in central Everglades marshes has slowed somewhat in the past 5-10 years also have been reported by RECOVER (2010). However, considerable evidence (reviewed in Osborne et al. [2011b]) shows that existing high phosphorus concentrations in the soils of cattail marshes represent a source of phosphorus that will continue to impact downstream marshes even if canal phosphorus loading decreases substantially (see also previous section on soil phosphorus).

Vegetation mapping of WCA-3 shows a 63 percent increase in cattail acreage (nearly 12,500 ha) between 1995 and 2004 (Figure 4-9; Sklar et al., 2011). The emergent cattail mapped in the 2004 survey occurred both near canals and in interior locations. This rapid cattail expansion has been explained by hydrologic alterations of WCA-3 combined with large inflows of phosphorus, although the relative importance of these factors in cattail establishment has not been determined.

The emergence of cattail has also been recently observed in Upper Taylor Slough, where vegetation transects have been monitored since 1979.

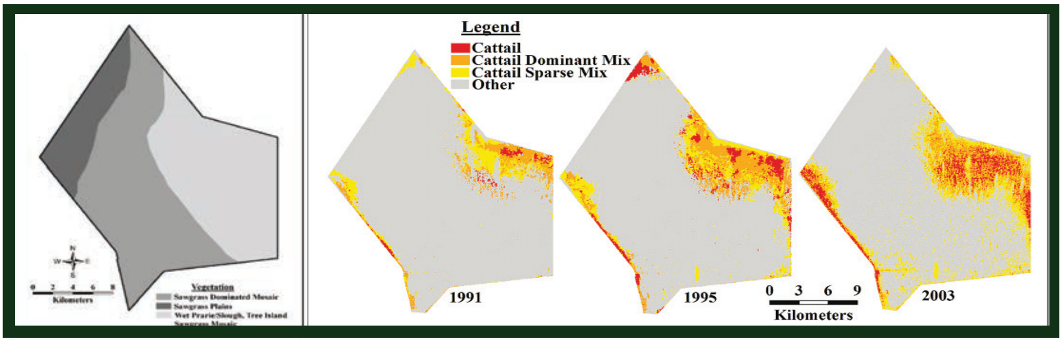
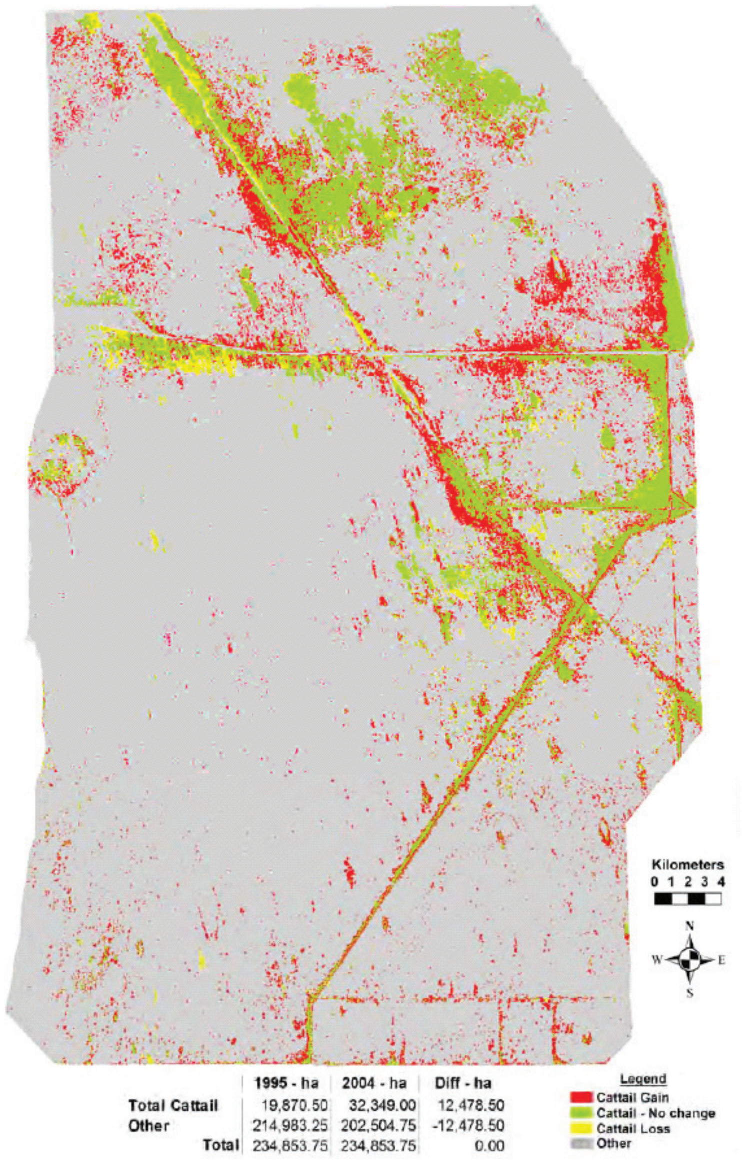


FIGURE 4-8 WCA-2A: (A) Map of three physiographic landscape categories within the WCA-2A impoundment based on 1940's aerial photography; (B) cattail spread 1991-2003.

SOURCE: Rutchey et al. (2008).



	1995 - ha	2004 - ha	Diff - ha
Total Cattail	19,870.50	32,349.00	12,478.50
Other	214,983.25	202,504.75	-12,478.50
Total	234,853.75	234,853.75	0.00

FIGURE 4-9 Change in cattail cover between 1995 and 2004 in WCA-3.

SOURCE: Sklar et al. (2011).

Between 2003 and 2007, sawgrass along one transect was replaced by cattail (Figure 4-10). The combination of increased hydroperiods associated with the operation of detention areas constructed for the C-111 South Dade project and increased nutrient loading likely allowed cattail to outcompete other species acclimated to shorter hydroperiods and oligotrophic conditions (e.g., muhly grass [*Muhlenbergia capillaris*]). This resulted in cattail spread of more than 0.2 km^2 in Taylor Slough. Although the cattail stand there is not as dense as tall monocultures that can be seen in WCA-2A, it is still denser than natural coverage of cattail in unimpacted areas, which is typically well below 5 percent with the exception of naturally enriched spots such as bird rookeries and alligator holes. According to Surratt et al. (2012), upstream surface water quality monitoring showed concentrations that were below phosphorus targets established for Taylor Slough. The recent discovery of cattail stands suggests that Taylor Slough "has been experiencing impacts for years to decades and that surface-water quality alone did not serve as an early warning indicator" (Surratt et al., 2012).

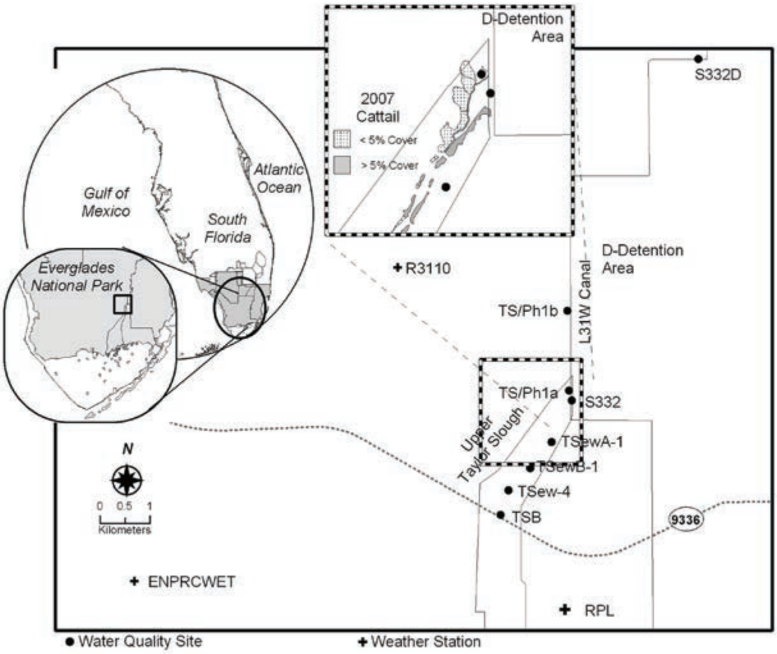


FIGURE 4-10 Upper Taylor Slough surface water quality and weather monitoring sites. Upper inset shows the cattail expansion in 2007. Stage gages are located at the TSB and S332.

SOURCE: Surratt et al. (2012).

To prevent dense cattail expansion, areas with newly emerging cattails should be treated before they become well established (Sklar et al., 2012).[6]

Predictions under Various Scenarios

Cattail expansion after the 1970s has resulted from increased phosphorus input combined with changed hydrology. Based on the trend data in WCA-2 and -3, cattail expansion is likely to continue in the future if the status quo is maintained. Improvement in water quality (scenario 1; Table 4-1) should slow cattail expansion overall, although altered hydrology would continue to foster cattail growth in overdrained areas. If no attempt is made to remove the cattail, then existing areas of cattail-dominated marshes are likely to persist for a long time—probably decades—even if the input of phosphorus-enriched water stops. This condition is due to the existing phosphorus-enriched soil in cattail-dominated areas and to an efficient internal recycling of nutrients from older to newer plant parts (see Soil Phosphorus section). Aggressive cost-effective cattail management strategies tested in small field-scale plots have been successful in removing dense cattail stands and rehabilitating the nutrient-enriched marsh using a combination of fire and herbicides (see Box 4-2). If hydrology is improved without additional water quality treatment (scenario 2; Table 4-1), then significant cattail expansion would be expected because of the substantial increase in phosphorus loads.

If both water quality and hydrology are improved according to the assumptions of scenario 3 (see Box 4-1), then the net phosphorus loads should decrease by 13 percent. Thus, the overall improvements to both water quality and hydrology should reduce the spread of cattail. However, the committee estimated that the large internal reservoirs of soil phosphorus would lead to minor to moderate (rather than major) improvements in current trends. In specific areas where much more water is being delivered than the 21 percent increase assumed in scenario 3, an expansion of cattail would be expected if overall phosphorus loads to those area increase. As noted previously for Taylor Slough, higher phosphorus loads and longer hydroperiods are suitable conditions for cattail expansion (Newman et al., 1996).

Periphyton

A complex entity called periphyton has been recognized as a suitable indicator of water quality deterioration in the Everglades, as well as a performance

---

[6] Recent results from a SFWMD study indicate that a single aerial application of imazamox at a rate of 0.28 kg/ha provided excellent control of cattails in marginally invaded marsh ridge-and-slough habitat with only minimal damage to desirable emergent macrophytes.

BOX 4-2
Aggressive Cattail Management Strategies

Two large ecosystem-scale experimental manipulations of cattail have been conducted in WCA-2 to test the efficacy of cattail removal strategies (Sklar et al., 2010, 2011) with promising results, and there are records on cattail suppression from other ecosystems such as Palo Verde National Park in Costa Rica or the upper St. Lawrence River wetlands (Farrell et al., 2010; Osland et al., 2011). Of the two Everglades experiments focused on removing cattail as a restoration method, the Fire Project aims to assess whether repeated fire can be used as an effective tool to manage cattail expansion. The project has been conducted in WCA-2A and has considered water levels, fuel loads, and fire intensity to maximize phosphorus loss from highly enriched habitats. Project results have been summarized in a process-based biogeochemical model that simulates plant growth and phosphorus dynamics in water to evaluate the effects of prescribed fire (Tian et al., 2010). The objectives of the Cattail Habitat Improvement Project (CHIP) are to accelerate the ecological rehabilitation of the phosphorus-enriched, emergent macrophyte Everglades marsh. Using a combination of herbicides and fire, open areas were created in enriched and moderately enriched areas of WCA-2A in July 2006. The most recent aerial photographs clearly show that for more than 925 days since the last herbicide application, and 1,406 days since the burn, an alternative regime of submerged aquatic vegetation (SAV) has been sustained in an otherwise cattail-dominated region of the Everglades. With minimal further active management, these plots could be sustained and dramatic shifts in phosphorus storage would likely be observed (Sklar et al., 2011).

Either fire alone or a herbicide-fire combination is a very cost-effective management approach. The cost estimate of removal ranges from approximately $40/acre using burning to $125/acre using herbicide (S. Newman, SFWMD, personal communication). Given the spatial extent of cattail, this type of management can be readily conducted. At the same time, the risk of burning or otherwise trying to eliminate most of the cattail still needs to be evaluated. It has been assumed that a large burn or herbicide treatment could cause a large downstream release of soil phosphorus. This effect must be considered as active marsh improvement is scaled up. Sufficient buffer zones will be needed to prevent any downstream nutrient transport (S. Newman and F. Sklar, SFWMD, personal communication, 2012).

measure of restoration success. Periphyton is defined as diverse communities of microorganisms, including cyanobacteria and algae, attached to the bottom sediments or stems of aquatic plants, or freely floating on the water surface (Figure 4-11; McCormick and Stevenson, 1998; Gaiser et al., 2011). Periphyton provides important functions in the Everglades: it contributes significantly to primary production and influences soil quality, nutrients, and dissolved gases (Gaiser, 2009; Liao and Inglett, 2012; Ogram et al., 2011). Periphyton was once found abundantly in the Everglades ecosystem, with the largest expanses in WCA-3 and Everglades National Park (Gleason and Spackman, 1974). However, throughout much of the Everglades, periphyton communities have been either

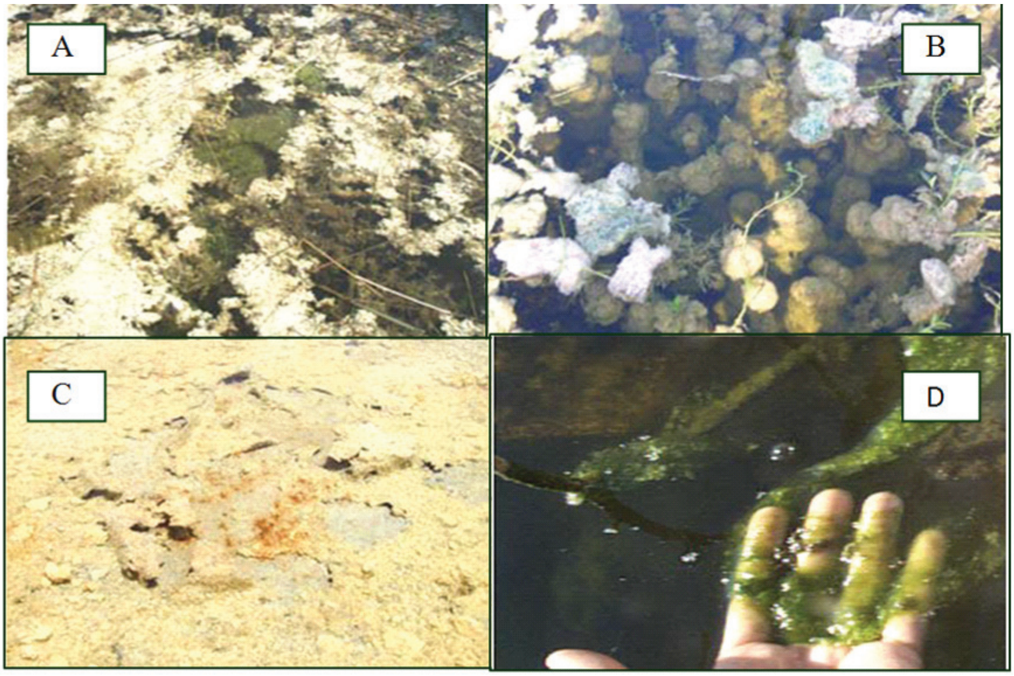


FIGURE 4-11 Photographs showing different types of periphyton-substrate associations: (A) calcareous floating (metaphyton), (B) calcareous epiphytic (attached to stems of aquatic plants), (C) calcareous epipelic (attached to bottom sediments), and (D) green filamentous periphyton

SOURCE: Gaiser et al. (2011).

reduced or even completely eliminated because of exposure to high phosphorus loads and, in some areas, replacement by dense cattails (McCormick and O'Dell, 1996; McCormick et al., 1996).

Currently, periphyton is most abundant in oligotrophic sloughs and wet prairie habitats (Richardson, 2008). Periphyton is known to respond quickly (days to weeks) across large spatial scales (meters to tens of kilometers) to changes in environmental conditions (Gaiser et al., 2004). Several metrics serve as reliable measures of the response of periphyton to water quality changes— abundance (total biomass), quality (TP concentration in periphyton tissue), and species composition—which can be used collectively to assess periphyton's condition. Of these metrics, the TP concentration in periphyton tissue has been identified as one of the best measures of phosphorus load history (Gaiser, 2009; Gaiser et al., 2006; McCormick and Stevenson, 1998). Although increases in water and soil phosphorus are only detectable after years of enhanced phosphorus loading, effects upon periphyton TP concentration are immediate (Gaiser et al., 2004).

Recent Trends

Large areas of periphyton mat have been lost in WCA-2 and WCA-3 because of nutrient impacts, and species composition and metabolism have been altered (Gaiser et al., 2004; McCormick and O'Dell, 1996). Analysis of periphyton metrics in 2005 and 2006 demonstrated a general north to south trend of increasing periphyton biomass and decreasing periphyton TP concentration over the Everglades Protection Area (Figure 4-12a). WCA-2 and WCA-3 showed a slight improvement in periphyton TP concentration between 2005 and 2006 followed by some increases in 2007 (Figures 4-12b and Figure 4-13; RECOVER, 2010).

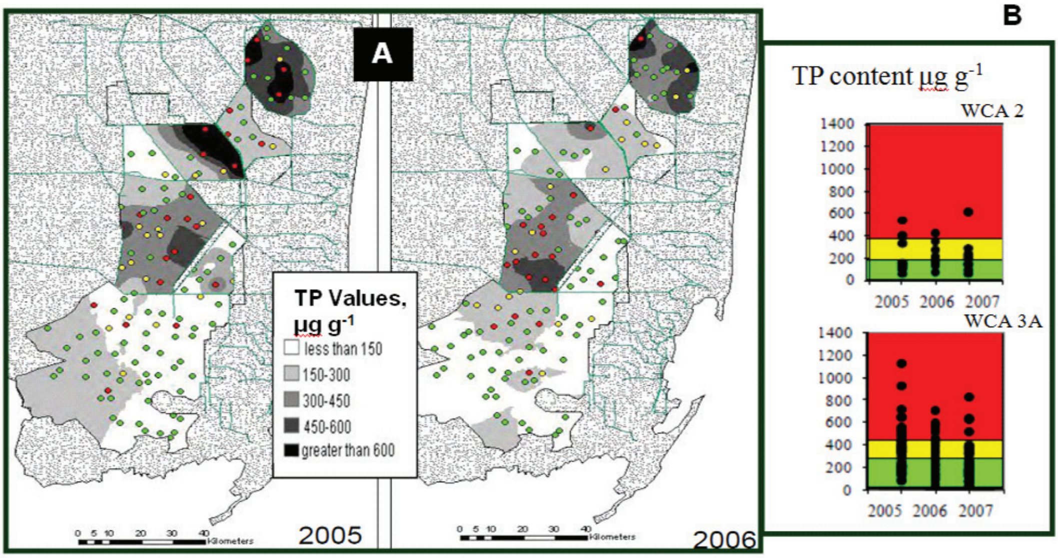
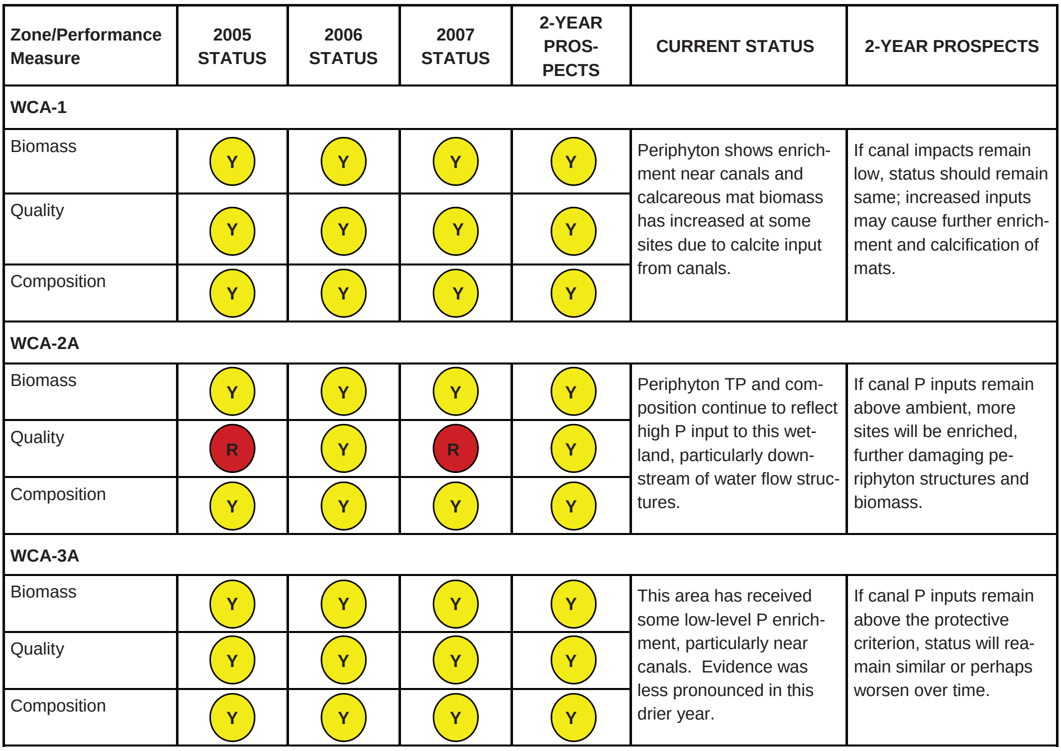


FIGURE 4-12 Examples of system assessment based on periphyton. (A) Pattern of distribution of TP concentration in periphyton across the Greater Everglades in fall 2005 and 2006. (B) Distribution of values for periphyton phosphorus, TP, for surveys in 2005 and 2006 in WCA 3A.
NOTE: Sites are coded as: green = within 1 standard error [SE] of mean in natural system, yellow = > 1 SE of natural system mean, and red = >2 SE of natural system mean.

SOURCES: Gaiser (2009) and RECOVER (2010).



Zone/Performance Measure	2005 STATUS	2006 STATUS	2007 STATUS	2-YEAR PROSPECTS	CURRENT STATUS	2-YEAR PROSPECTS
WCA-1						
Biomass	Y	Y	Y	Y	Periphyton shows enrichment near canals and calcareous mat biomass has increased at some sites due to calcite input from canals.	If canal impacts remain low, status should remain same; increased inputs may cause further enrichment and calcification of mats.
Quality	Y	Y	Y	Y		
Composition	Y	Y	Y	Y		
WCA-2A						
Biomass	Y	Y	Y	Y	Periphyton TP and composition continue to reflect high P input to this wetland, particularly downstream of water flow structures.	If canal P inputs remain above ambient, more sites will be enriched, further damaging periphyton structures and biomass.
Quality	R	Y	R	Y		
Composition	Y	Y	Y	Y		
WCA-3A						
Biomass	Y	Y	Y	Y	This area has received some low-level P enrichment, particularly near canals. Evidence was less pronounced in this drier year.	If canal P inputs remain above the protective criterion, status will remain similar or perhaps worsen over time.
Quality	Y	Y	Y	Y		
Composition	Y	Y	Y	Y		

FIGURE 4-13 Stoplight indicator assessment of each WCA. The data are scored based on the proportion of sites falling within each categories. Red indicates failure, yellow indicates caution and green indicates success.

SOURCES: SFERTF (2010b); Gaiser, (2009).

However, it is difficult to discern temporal trends with only three years of data, particularly in the context of natural hydrologic variation.

Predictions under Various Scenarios

Continued or increased input of above-ambient phosphorus concentrations will both increase severity of enrichment effects near canals and cause periphyton deterioration effects to cascade downstream. In contrast, enhanced water treatment will promote periphyton recovery. Periphyton can recover in areas recently dominated by cattails only if the cattails are first eliminated (see

Box 4-2). Increased input of water treated for phosphorus removal (i.e., scenario 3 in Box 4-1) will likely increase periphyton development, particularly in areas that have been overly dry. However, because the overall load reductions are greatest in scenario 1 (see Box 4-1), the committee estimates larger improvement for this scenario.

No long-term observations exist to provide reliable predictions for timeframes for recovery of periphyton once it is degraded or eliminated from an area. However, there is anecdotal support for a relatively rapid recovery of periphyton calcareous mats after the completion of the phosphorus dosing experiment in Everglades National Park (Gaiser, FIU, personal communication, 2011). After a complete collapse of the calcareous mats following dosing of phosphorus above-ambient levels for five years, the periphyton seemingly recovered about a year after dosing was terminated. Periphyton re-appeared quickly where cattails were not present, but the periphyton recovery was never fully documented. A second example comes from the CHIP project (Box 4-2; Sklar et al., 2011), for which higher periphyton productivity was observed in the plots after cattails were removed compared to the cattail-dominated control. However, the taxonomic composition of this re-emergent periphyton is not known (S. Newman, SFWMD, personal communication, 2011). The establishment of periphyton in STAs could also provide information on the potential for recovery of this important ecosystem component, although little data are available on STA periphyton. Because periphyton is such a diverse and complex community, better characterization is needed. To obtain a better understanding of under what conditions and how quickly periphyton can be restored, performance measures such as biomass, species composition, and nutrient content, as measured in the Everglades Protection Area by Restoration, Coordination, and Verification (RECOVER), should be monitored in STAs, CHIP, and other manipulated settings.

Fish Mercury

Mercury contamination is a chronic environmental problem in the South Florida ecosystem. Elevated concentrations of mercury have been observed in fish and other animals such as the American alligator, softshell turtles, and the Florida panther (Gu et al., 2012). The source of ionic mercury inputs to South Florida is overwhelmingly from atmospheric deposition, and these inputs have remained relatively constant to the Everglades since the early 2000s. However, the formation of methyl mercury—which strongly bioaccumulates up the aquatic food chain and results in high concentrations in fish—varies across the Everglades landscape based on hydrology and the supply of sulfate, phosphorus and other contaminants. Elevated concentrations of sulfate, primarily derived from agricultural lands, are processed in downstream wetlands by sulfate-reducing bacteria, which also convert ionic mercury to methyl mercury. Human exposures to mercury are largely from consumption of fish. Methyl mercury is a neurotoxin, and to limit human exposure to mercury, Florida has issued fish consumption advisories.

The spatial pattern of sulfate across the Everglades Protection Area reflects the source of sulfate largely from the Everglades Agricultural Area (Figure 4-14). The highest sulfate concentrations generally occur in WCA-2 and decrease southward. High sulfate concentrations are also noted along canals because of preferential flow along these conduits. Sulfate concentrations have generally held steady or declined between 1979 and 2010 in inflows to and outflows from the major regions of the Everglades Protection Area (Payne et al., 2011). These long-term declines in sulfate are linked to long-term declines in fish mercury concentrations.

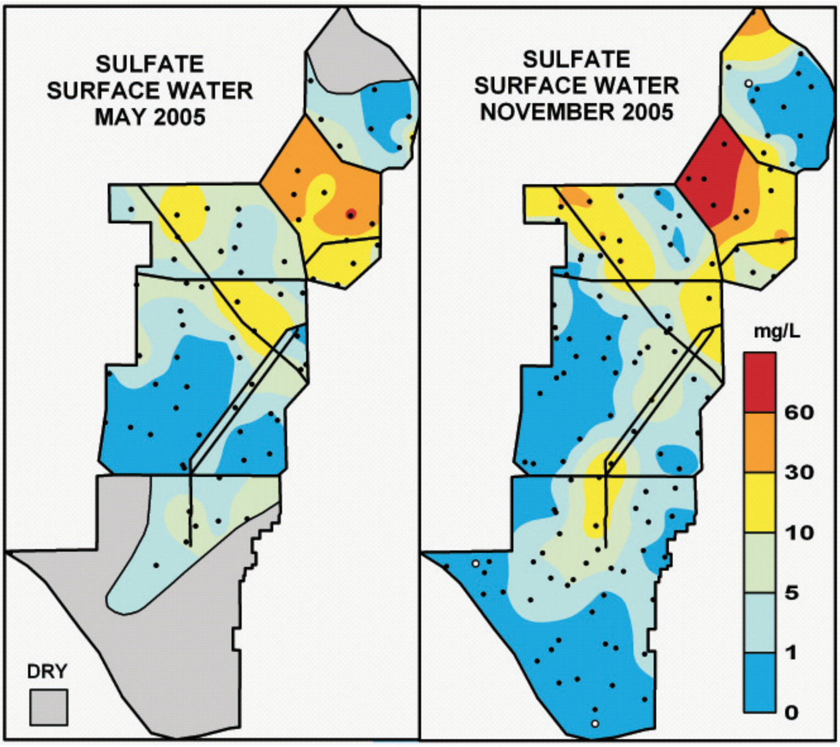


FIGURE 4-14 Spatial pattern of concentrations of sulfate in the Everglades Protection Area.

SOURCE: Scheidt and Kalla (2007).

A complex relationship exists between sulfate concentrations and the formation of methyl mercury. Maximum formation of methyl mercury appears to occur around sulfate concentrations of 10-20 mg/L. At sulfate concentrations below this range, increases in sulfate will result in increases in methyl mercury formation. At sulfate concentrations above this value, increases in sulfate will result in decreases in methyl mercury formation. This response results in a "hotspot" of elevated methyl mercury concentrations and fish mercury concentrations in the Everglades (see NRC, 2010). The location of this hotspot would likely shift with variations in water discharge and transport of sulfate.

Monitoring data show clear spatial patterns of fish mercury that are linked to the spatial patterns of sulfate (Figure 4-14) and nutrients (Figure 4-4) in the Everglades. Recent monitoring data (2009-2010) for largemouth bass show low methyl mercury concentrations in the STAs (~0.1 μg/g), high concentrations in the WCAs (~0.5 μg/g), and very high concentrations in Shark River Slough in the Everglades National Park (~1.2 μg/g; much higher than in other portions of the Park) (Gu et al., 2012). For reference the EPA-recommended criterion for fish mercury is 0.3 μg/g. This spatial pattern reflects variations in the processes controlling fish mercury concentrations. Under high sulfate concentrations in waters adjacent to the EAA, as in the STAs, microbes produce high sulfide concentrations that inhibit the production and bioavailability of methyl mercury (Benoit et al., 2003). As EAA drainage moves south into the WCAs and ultimately into Everglades National Park, sulfate concentrations and the production of sulfide generally decrease, thereby allowing for more formation of methyl mercury by reducing inhibition effects from sulfide. Nutrients potentially also play an important role. High inputs of nutrients from the EAA support high biomass production, which decreases the mercury concentration in biota via a process known as biodilution.[7] With decreases in phosphorus concentrations with distance from the EAA, decreases in net aquatic production decrease the biodilution phenomenon and concentrations of mercury in fish and other biota increase.

Long-term observations show that concentrations of mercury in largemouth bass have significantly declined in the WCAs since measurements were initiated in the late 1980s (Figure 4-15). Mercury concentrations in largemouth bass were very high in the early to mid-1990s in the WCAs. Indeed the "hotspot" of fish mercury at that time was located in WCA-3A. However, the decreases in fish mercury concentrations ceased by 1998, and concentrations have remained relatively constant since that time. These decreases in mercury concentrations in largemouth bass are thought to result from declines in sulfate inputs (Kalla et

---

[7] Biodilution is a phenomenon through which concentrations of a contaminant (e.g., mercury) in organisms decrease because of increases in nutrient supply and associated increases in biomass (Chen and Folt, 2005; Pickhardt et al., 2002).

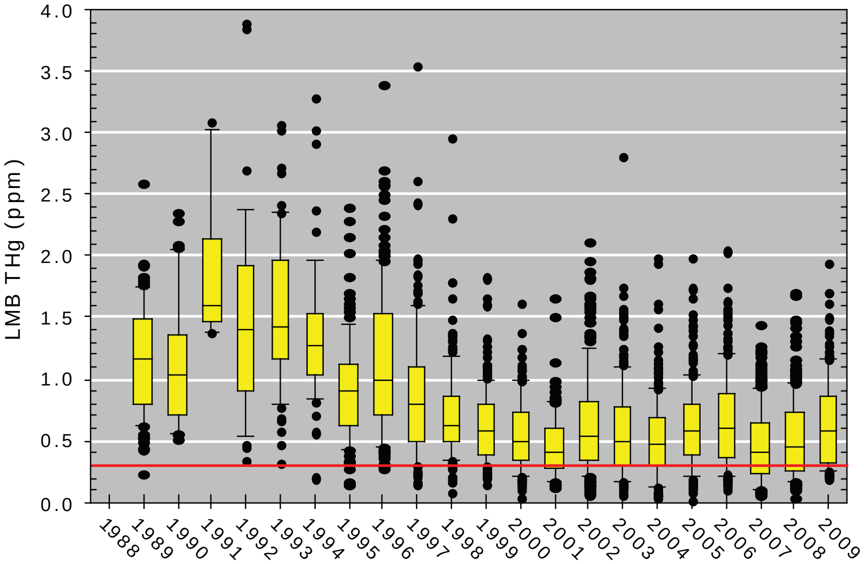


FIGURE 4-15 Annual summaries of mercury concentrations in largemouth bass collected from canal and marsh sites in WCAs -1, -2, and -3 from 1989 to 2010. Note that mercury concentrations are normalized to a standard fish length of 356 mm. The red line indicates the EPA methyl mercury criterion of 0.3 ppm.

SOURCE: Axelrad et al. (2011).

al., 2010). At Shark River Slough, long-term measurements of mercury concentrations in largemouth bass show considerable year-to-year variability, with no significant trends (Gu et al., 2012).

Using the current understanding of the patterns and mechanisms driving fish mercury concentrations in the Everglades, one can speculate on the trajectories that fish mercury concentrations might take under various future management strategies. The two major drivers of fish mercury concentrations that might be affected by restoration management changes are: (1) agricultural sulfate inputs that control the production of methyl mercury and (2) phosphorus inputs that control fish mercury concentrations. Based on the available monitoring data, it appears that fish mercury concentrations are in quasi steady-state with respect to these drivers and that they respond relatively quickly to environmental change (~ years to a decade). If water and phosphorus inputs to the Everglades remain steady, then fish mercury concentrations should remain relatively constant through time. With improved hydrology (i.e., increased water discharge, decompartmentalization) but no additional water quality features (i.e., scenario 2 in Box 4-1), it is anticipated that fish mercury concentrations would decrease. With the restoration of sheet flow the interaction of water with wetlands will likely facilitate the removal of sulfate, thereby reducing methyl mercury formation and fish mercury concentrations. Additionally, increased phosphorus concentrations associated with scenario 2 lead to greater biodilution of mercury.

This projected outcome of hydrologic change is based on considerable speculation about the driver of system response (i.e., biodilution). Other outcomes may occur. Alternating drying and wetting cycles can facilitate mineralization of organic sulfur in peat deposition, releasing sulfate followed by the methylation associated with the subsequent sulfate reduction. Restoration of a more normal hydroperiod to the Everglades would likely diminish this phenomenon and could decrease fish mercury concentrations. Also the committee has assumed that elimination of channelized flow with decompartmentalization would decrease sulfate transport southward and decrease fish mercury concentrations. However, a more distributed transport of sulfate, which would be a by-product of decompartmentalization, would likely spread out mercury contamination in fish. The committee believes this action would result in an overall decrease in fish mercury concentrations, but this management action could increase fish mercury concentrations in areas of the Everglades that previously have not experienced high concentrations.

If improved controls on phosphorus supply decrease phosphorus loading to the Everglades, fish mercury concentrations could increase. This response would be due to decreases in biomass production associated with decreases in nutrient loading and a resulting decrease in the biodilution of fish mercury. Finally, management measures that involve simultaneous increases in discharge and decreases in phosphorus would likely decrease fish mercury because of the effectiveness of decompartmentalization in the immobilization of sulfate (but see above discussion). These effects are summarized in Table 4-1.

Peat

Most of the historical Everglades was underlain by organic-rich peat soils (Figure 4-16), approximately 2 to 10 feet thick. The peat soil's thickness decreased toward the southern Everglades, where it formed a thin, sometimes patchy layer over marl soils (McVoy et al., 2011).[8] In addition to providing the substrate for the sawgrass plains and ridge-and-slough landscapes, peat soils in the Everglades provided the critical elevation differences that hydrologically dif-

---

[8] Marl soils are comprised of calcitic mud deposited from calcareous periphyton and have lower organic content.

FIGURE 4-16 Peat and marl soils of the Everglades.

SOURCE: Scheidt and Kalla (2007).

ferentiated ridges from sloughs, and, in many cases, tree islands from sloughs. In the pre-drainage system, the decreasing thickness of the peat soils with distance downstream from Lake Okeechobee was responsible for much of the regional land slope that drove sheet flow.

Peat accumulates when detrital plant biomass partially decomposes under anaerobic conditions and is buried and compacted, creating a soil with approximately 90 percent organic matter content (Figure 4-17). Rates of peat accumulation in the Everglades are a function of the balance between net primary productivity—the transformation of inorganic carbon (CO_2) into organic carbon through photosynthesis—and abiotic and biotic decomposition processes. In areas unimpacted by phosphorus, peat accretion rates are extremely low, in the range of 0.2 to 2 mm per year (see Table 4-2; Box 4-3). Phosphorus-enriched areas have been shown to accrete organic matter at higher rates (approximately 5 to 12 mm per year), although peat produced in cattail-dominated areas is of poor quality and easily decomposed, which releases nutrients into the water column.

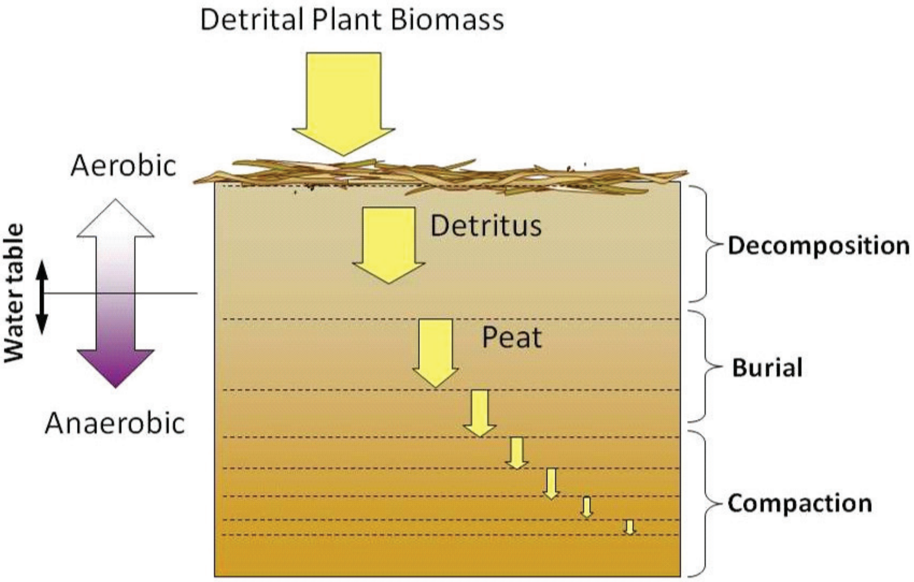


FIGURE 4-17 Decomposition and burial of organic matter and genesis of organic soil.

SOURCE: Reddy and DeLaune (2008).

Altered hydrologic regimes have led to significant losses of peat, particularly in overdrained areas. Rates of peat loss (i.e., loss of peat soil mass and the associated critical loss of peat-based elevation or subsidence) are directly related to the position of the water surface relative to the ground (peat) surface. As long as surface water covers the peat, anaerobic conditions prevail within the soil profile, and peat accumulation outpaces peat oxidation. If the water table drops below the surface, air enters the portion of the profile above the water table and allows aerobic microbial oxidation of the organic matter to occur. Peat decomposition also releases phosphorus, sulfur, and other nutrients, impacting water quality once the area is rehydrated. Peat decomposition rates under aerobic (drained) soil conditions have been shown to be approximately 3 to 5 times higher than under anaerobic (flooded) soil conditions (DeBusk and Reddy, 1998; McLatchey and Reddy, 1998; Wright and Reddy, 2001). Additionally, as the water table drops, a larger fraction of the profile is subject to oxidation, and the overall rate of subsidence increases. In a field study using controlled water tables, Stephens and Johnson (1951) found a linear relationship between subsidence rate and depth of the water table. Similarly, Volk (1973) found that the decomposition

TABLE 4-2 Peat Accretion Rates in Select Hydrologic Units of South Florida Wetlands

Location	Method Used	Peat Accretion Rates (mm yr^{-1})	Reference
Loxahatchee NWR	^{137}Cs	0.8	Craft and Richardson (1993)
	^{137}Cs	1.1 – 4.2	Robbins et al. (1999)
	^{210}Pb	1.1	Craft and Richardson (1993)
	^{14}C	0.9	Craft and Richardson (1993)
WCA-2A	^{137}Cs	1 – 12	Reddy et al. (1993)
WCA-2A enriched	^{137}Cs	5.3 ± 0.9	Craft and Richardson (1993)
	^{137}Cs	2.6-5,1	Robbins et al. (1999)
	^{210}Pb	5.8 ± 1.4	Craft and Richardson (1993)
WCA-2A unenriched	^{137}Cs	2.0 ± 0.6	Craft and Richardson (1993)
	^{137}Cs	1.1 – 1.2	Robbins et al. (1999)
	^{210}Pb	2.0 ± 0.1	Craft and Richardson (1993)
	^{14}C	0.6	Craft and Richardson (1993)
WCA-2B	^{137}Cs	2.4 ± 0.4	Craft and Richardson (1993)
WCA-3A	^{137}Cs	1.7 ± 0.3	Craft and Richardson (1993)
WCA-3A north	^{137}Cs	0.7-2.8	Robbins et al. (1999)
WCA-3A north	^{137}Cs	0.4-1.4	Robbins et al. (1999)
	^{210}Pb	1.4	Craft and Richardson (1993)
	^{14}C	0.2	Craft and Richardson (1993)
Shark River Slough-Ridge	^{137}Cs	2.0-3,5	Clark and Reddy (2007)
Shark River Slough-Slough	^{137}Cs	1.3-5.4	Clark and Reddy (2007)
Taylor Slough	^{210}Pb	3.0	Meeder et al. (1996)
Mangroves	^{210}Pb	1.0	Meeder et al. (1996)
STA-1W	Soil properties-bulk density, TP, δ^{15}N, and δ^{13}C	10 ± 3	Bhomia et al. (2012)
STA-1W (Cell 5)	Soil properties-bulk density, TP, δ^{15}N, and δ^{13}C	12 ± 6	Bhomia et al. (2012)
STA-2	Soil properties-bulk density, TP, δ^{15}N, and δ^{13}C	11 ± 3	Bhomia et al. (2012)
STA-3/4	Soil properties-bulk density, TP, δ^{15}N, and δ^{13}C	17 ± 8	Bhomia et al. (2012)

NOTES: Accretion rates measured using the Cs-137 technique represent < 40 years and using Pb-210 techniques represent <100 years. Values shown (at limited sites) show peat accretion in inundated areas.

rates of Everglades peat soils were significantly lower when the water table was raised from 25 cm to 5 cm below the soil surface.

Other factors can also impact rates of peat loss. Nutrient loading can increase peat decomposition rates (DeBusk and Reddy, 1998). If the peat soil actually dries, then it becomes at risk for fires that can cause substantial losses, as in the May 1981 muck fires in northern WCA-3A when 9 to 29 cm of peat were lost (Wetzel, 2002).

One of the most well-known cases of drainage of peatlands occurred in the EAA, which was drained for agricultural production beginning in the early

BOX 4-3
Estimated Historic Rates of Peat Accretion

Based upon ^{14}C dating, McDowell et al. (1969) estimated that peat soil in the EAA first formed about 4,400 years ago. From these studies it was estimated that it took approximately from 500 to 1,000 years to form the first 7.6 cm of a marl/organic soil on top of the bedrock, while peat developed at about 7.3 cm per century from about 3,500 to 1,200 years before present. By 1914, approximate peat depth was 3.65 m, which represents an average accretion rate of about 8.4 cm/century (0.84 mm/yr). Scholl et al. (1969) estimated soil accretion using ^{14}C dating in sediment cores obtained from several locations in the freshwater Everglades, coastal mangroves, Florida Bay, and Rodriquez key (Atlantic Ocean). During the past 4,000 years, coastal sedimentation has occurred at a rate of 3 cm/100 years (0.3 mm/yr). Calcitic mud formation in nearby coastal freshwater swamps has averaged 1.6 cm/100 years (0.16 mm/yr). Soil accretion rates in these ecosystems were approximately equal to the rate of sea-level rise.

1900s. These soils subsided at a rate of approximately 2.5 cm/year, which then declined to a current average rate of about 1.5 cm/yr (Shih et al., 1998; Snyder, 2005). Over the course of less than 100 years in the EAA, a significant portion of the peat, which took more than 5,000 years to form, was lost to biological oxidation and fire (Stephens et al., 1984) (Figure 4-18).

A substantial fraction of Everglades peat soils have already been lost, leaving about 25 percent of the remnant Everglades with a peat thickness of less than 1 foot (Scheidt and Kalla, 2007). Sklar et al. (2010) estimated that 7 billion cubic meters of peat have been lost in the remnant Everglades since drainage began. Scheidt et al. (2000) estimated that between 1946 and 1996, water depths lowered by drainage and reduced inflows have caused the Everglades Protection Area to lose up to 28 percent of its organic soil volume (Figure 4-19), with soil oxidation, subsidence, and peat fires as the causes. Upper and lower limits of peat loss between 1946 and 1996 show significant loss in northern WCA-3A, -3B, -2A and Northeast Shark River Slough in Everglades National Park (Figure 4-20; Scheidt et al., 2000). McVoy et al. (2011) state that the historical record suggests that peat soil has also been lost in Shark River Slough and from what are now called the marl prairies flanking Shark River Slough to the east and west. This loss likely occurred before 1946 and therefore would not be reflected in the Scheidt et al. (2000) study.

Equally important as the overall loss of peat is the spatial distribution of that loss. The spatially uneven rates of peat accretion and loss within the impounded system hinder the slope-generating role for peat, thereby affecting the capacity to support the water flow and depths that ecological attributes such as ridge and

FIGURE 4-18 Peat loss as a result of soil subsidence in the Everglades Agricultural Area. The concrete post was buried in 1927 at the Everglades Research and Education Center, University of Florida, Belle Glade, Florida. In 1927, the top of the post was flush with the soil surface, and more than 6 feet of soil subsidence has occurred since that time.

SOURCE: K. R. Reddy, University of Florida.

slough and tree islands depend upon. Within the impounded WCAs, a portion of the original peat-based land surface slope remains, yet the water surface, rather than paralleling the ground surface as it did originally under sheet flow, now tends toward level. As a result, the higher upstream areas (e.g., northern WCA-3a) have shorter hydroperiods and endure aerobic conditions for longer

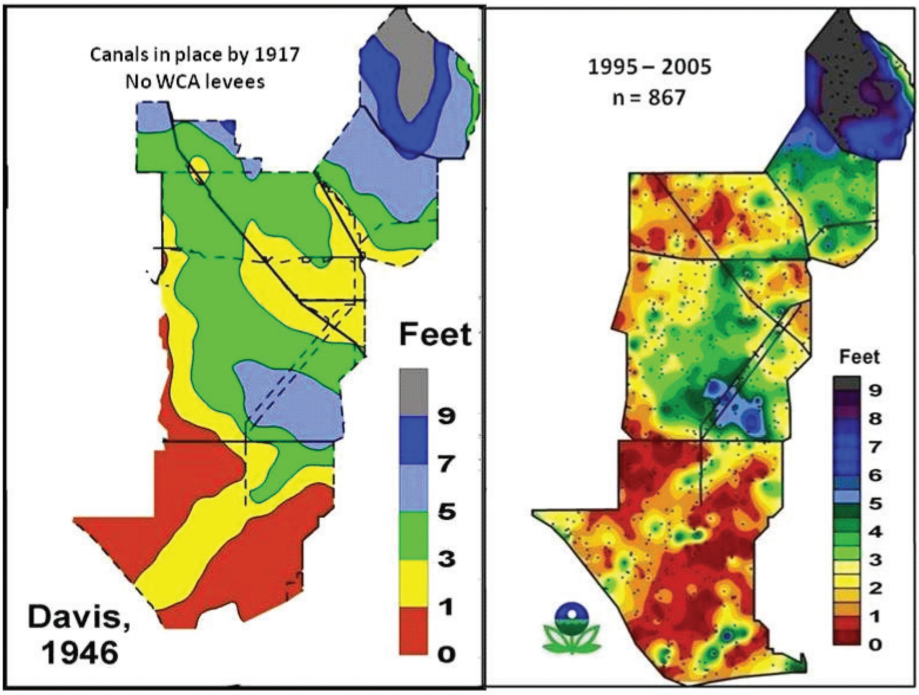


FIGURE 4-19 Maps of peat thickness in the Everglades in 1946 (left) and 1995-2005 (right).

SOURCES: Davis (1946); Scheidt and Kalla (2007).

durations, accelerating peat decomposition. The net effect is to undo the original downward slope of the ground surface, driving the peat surface within the impoundment area toward becoming level, that is, parallel to the water surface.

Predictions under Various Scenarios

Overall, accretion of organic matter in the central Everglades is very slow, and it takes centuries to accumulate significant amounts of organic matter under oligotrophic conditions (Table 4-2). Because decomposition exceeds primary productivity when water level is below the soil surface for extended periods, overly dry areas of the Everglades continue to lose peat. Water quality improvement alone will not alter the trend of peat loss in dry areas. Hydrologic restoration to increase hydroperiods in the Everglades, particularly in currently overly drained areas, is key to reversing ongoing peat loss.

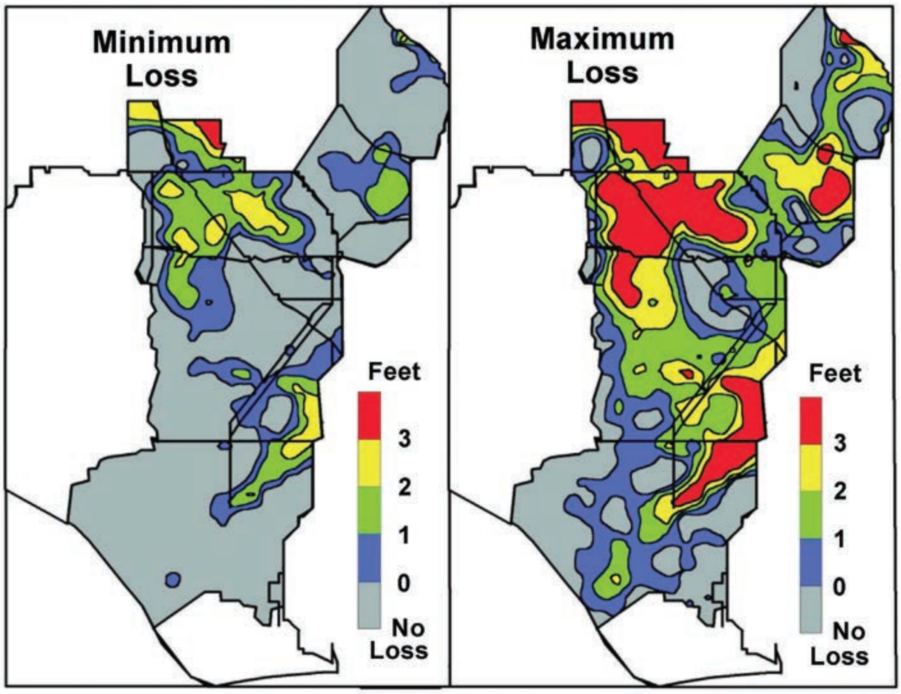


FIGURE 4-20 Difference in peat thickness between 1946 and the R-EMAP studies.

SOURCE: Scheidt et al. (2000).

The unusual nature of the Everglades as a "hillslope wetland" makes protection even more challenging. If impoundments are not removed, and if a sloped water surface parallel to the sloped ground surface is not restored (i.e., sheet flow), then the impounded portions of the remnant Everglades will remain on a trajectory to become a series of disjointed flat steps, without the slope necessary to sustain the ridge-and-slough landscape. Protection of peat soils in the remnant Everglades would require removal of impounding impediments to flow as well as simultaneous restoration of upstream inflows.

Ridge and Slough

The ridge-and-slough landscape in the historical Everglades consisted of patterned peatland surfaces with hundreds of alternating ridges and linear sloughs, aligned parallel to the direction of regional water flow. In its original form, the ridge-and-slough landscape was the essence of the Everglades—half land and half water. Tree islands were scattered irregularly throughout the landscape, slightly higher and drier than the ridges. The ridges were covered by sawgrass, while the sloughs, typically 1 to 2 feet lower in elevation under pre-drainage conditions, were populated by aquatic species such as water lilies. In the pre-drainage system, both ridges and sloughs were inundated annually, with the ridges submerged for as much as 10 months per year, while the sloughs were nearly always below the water table (McVoy et al., 2011). The ridge-and-slough terrain extended hundreds of miles from the sawgrass plains south of Lake Okeechobee to the end of Shark River Slough, covering about 1.5 million acres (McVoy et al., 2011). Because of its unusual geometry, the landscape sustained long-lived fish, alligators, and otters, and the landscape represented "a principle center for primary and secondary production and interannual survival of aquatic organisms" in South Florida's freshwater wetlands (Ogden, 2005).

Beginning in the late 1800s, construction of canals and the lowering of Lake Okeechobee stages lowered water depths within the Everglades. Later, in the 1950s and 1960s, construction of the WCAs partially reversed some of the lowering of water depths, but at the same time distorted the spatial distribution of water depths and greatly reduced, if not eliminated, sheet flow. These water management activities disrupted important controls on ridge-and-slough landscape processes, and by the late twentieth century the degradation of ridge-and-slough patterning became widely recognized. Throughout the system, the elevation differences between ridges and sloughs are now significantly reduced relative to the pre-drainage system; the maximum elevation difference currently measured is about 0.7 feet, and the minimum is zero (McVoy et al., 2011). Sawgrass or wet prairie vegetation has expanded into some aquatic sloughs, and in some areas, the ridges and sloughs have lost their linear geometry (Figure 4-21). As of 2005, 28 percent of the original ridge-and-slough landscape was considered degraded, and another 27 percent had been drained and lost to urban or agricultural land uses (McVoy et al., 2011). Harvey et al. (2012) identified a smaller surviving percentage—about 22 percent—in those areas bounded by WCA-2, WCA-3, and Everglades National Park.

Recent scientific investigations have improved understanding of the dynamics of this complex system. Research reported by Harvey et al. (2011; summarized by Harvey et al., 2012), Larsen et al. (2009), Larsen and Harvey (2010), and McVoy et al. (2011) leads to a general model for ridge-and-slough processes, which highlights the system requirements to avert further declines and improve the condition of the remnant ridge and slough. A series of drivers are thought to contribute to the maintenance of the Everglades ridge-and-slough landscape. First, the prevailing type of water flow must be a broad, shallow distribution of water (many miles wide; i.e., sheet flow) that does not include a

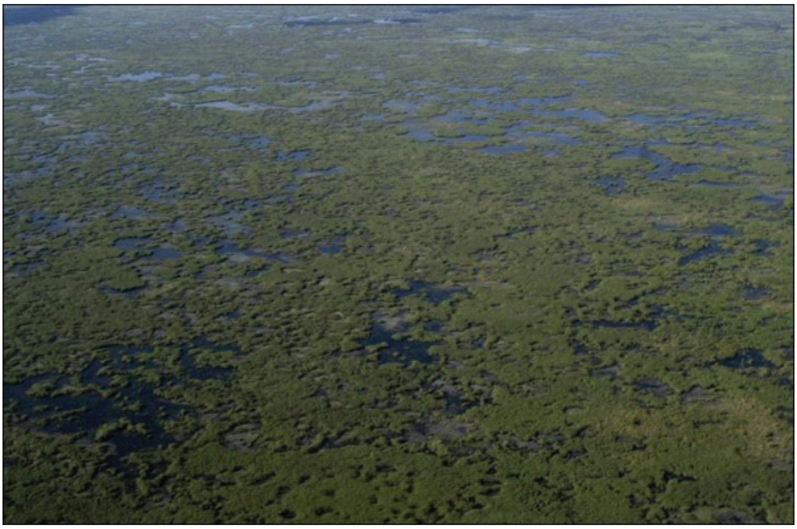


FIGURE 4-21 Two aerial views of ridge-and-slough topography in WCA-3A. Above, an example of a functional ridge-and-slough system from the central part of WCA-3A showing features with distinctive linear orientation reflecting flows. Below, an example from the northern portion of WCA-3A with severely degraded ridge-and-slough topography showing lack of elongated and oriented forms and with extensive sawgrass cover.

SOURCES: Images by Christopher McVoy and SFWMD; Fling et al. (2009).

centralized and confined conveyance channel. Second, this sheet flow generally needs to be from a definable and little-changing direction. This directionality of flow is critical in creating and maintaining the linear characteristics of the ridges and sloughs so that directional flows control the system's horizontal geometry. Third, flow velocity must be at least greater than 2.5 cm/s in order to entrain fine organic particles, or floc, from the sloughs and to redeposit them on the ridges. The ridge height then becomes limited by the depth of these relatively fast-moving sheet flows. Fourth, the depth of flow needs to fluctuate annually so that the ridges are not continuously inundated with the concomitant loss of sawgrass.

Additionally, the form of the vegetation in the sloughs exerts control over these physical processes. In pre-drainage sloughs, water depths were great enough to permit aquatic species such as water lilies to survive but not other intrusive species that have dense stem networks (McVoy et al., 2011). If the vegetation in the sloughs is too dense, then the flows are not able to entrain and redistribute the floc to the ridges, which disrupts the system dynamics. The growth of sawgrass or wet prairie vegetation in the sloughs as a result of consistently shallow water depths thus disrupts the entire ridge-and-slough process. Woody vegetation may invade ridges that are subject to long-term dry conditions. High levels of phosphorus may also stimulate the growth of invasive vegetation in sloughs, creating greater stem density and influencing the mobility of floc from sloughs to ridges. Thus, hydrologic restoration combined with water quality restoration offers the greatest prospects to improve conditions of the ridge and slough. Yet water quality restoration alone has little effect on the current downward trajectory.

Disruption of these drivers leads to continuing degradation of the ridge-and-slough landscape in the remnant Everglades (Figure 4-22). Although the difference in elevation between ridge and slough is significantly degraded throughout the system, the present condition of the characteristic ridge-and-slough patterning (plan view) within the remnant Everglades ranges from quite similar to pre-drainage patterning (e.g., south of I-75 and west of the Miami Canal), to partial disintegration of the pattern (e.g., east of Miami Canal), to complete loss of pattern (i.e., conversion to uniform stands of sawgrass, as in northern WCA-2A) (McVoy et al., 2011). Also, recent trends in the ridge-and-slough landscape are variable according to location, and the characteristic patterning can undergo significant degradation or enhancement on decadal timescales as a result of flow modifications (NRC, 2010; Sklar et al., 2009). In those cases where ridge-and-slough terrain has lost its directional alignment, resulting in irregularly shaped ridges rising above surrounding pools, the change from aligned to unaligned forms took only a few decades, essentially since the completion of the WCAs (McVoy et al., 2011).

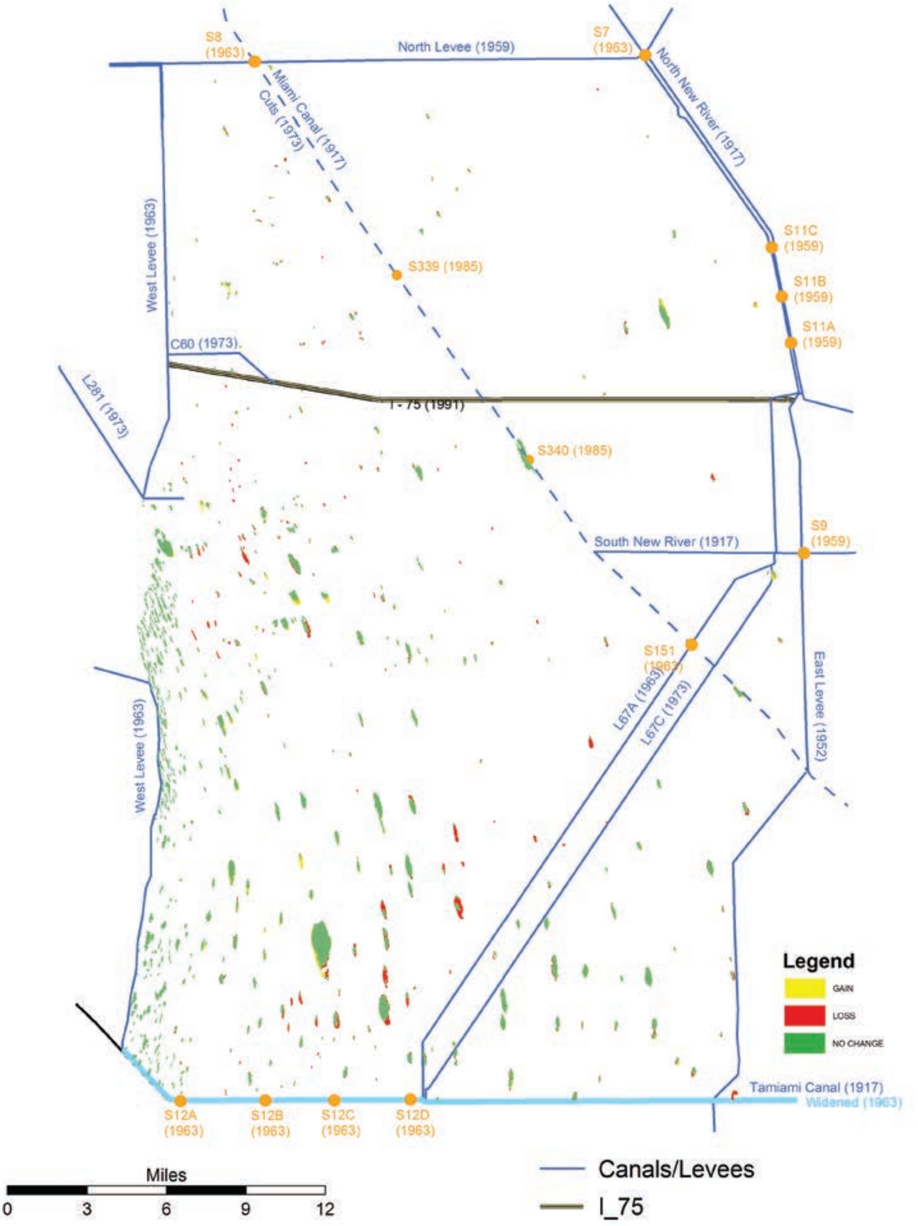


FIGURE 4-22 Changes in the areal extent of tree islands between 1995 and 2004 in WCA-3. Yellow areas show where the islands have expanded, red areas show where they have lost their vegetation, and green areas are unchanged.

SOURCE: F. Sklar, SFWMD, personal communication, 2010.

The length of time required to restore areas of ridge and slough that are presently disappearing is unclear although losses are likely to occur more quickly than restoration. Researchers do not completely agree on how long restoration of ridge and slough might require, but computer simulation models that account for some of the system drivers suggest that many centuries would be needed (Harvey et al., 2012). Other researchers, however, including some at the public session where Harvey et al. (2012) presented their results, have indicated that more rapid restoration may be possible. In some instances where dense wet prairie vegetation now clogs the sloughs in extremely degraded areas, additional efforts, such as vegetation removal, could be required to facilitate restoration.

Tree Islands

Tree islands are "small, slightly elevated forested wetlands within a ridge-slough matrix" (Sklar et al., in review). Two major types of tree islands occur in the Everglades. Pop-up tree islands (also known as floating or barrier tree islands) originate when a large portion of peat detaches from the substrate and are colonized with shrubs and trees; these occupy Loxahatchee National Wildlife Refuge and WCA-2A. Fixed teardrop-shaped tree islands are associated with topographical variations in the mineral substrate and extend from WCA-3 to Shark River Slough in Everglades National Park (van der Valk and Sklar, 2002). Tree islands play a crucial ecological role in the Everglades, providing habitat for a range of fauna, sequestering and cycling nutrients, and contributing to the spatial heterogeneity and landscape complexity of the ecosystem (Sklar et al., 2011; van der Valk and Sklar, 2002; Wetzel et al., 2005, 2011). Tree islands also have long-established and deep-rooted cultural heritage and societal importance. Hence, maintenance and restoration of tree islands are key components of Everglades restoration.

Drainage, compartmentalization, and subsequent changes in hydrology resulted in a loss of 67 percent of tree island area from 1940 to 1995 (Figure 4-22; Sklar et al., 2005). Further declines of 6 percent in total acreage of tree islands continued between 1995 and 2004 (Figure 4-23) (Sklar et al., 2011). Although some tree islands have experienced gains in acreage, many more have declined (Figure 4-23). The conditions causing tree island degradation and decline have not abated and therefore continued declines can be expected. The greatest ongoing threats to tree islands are altered hydrological regime and altered fire regime.

Four components of hydrology—depth, hydroperiod, flow, and quality—can impact tree islands if extreme conditions outside the normal historic range are experienced for extended periods (van der Valk and Sklar, 2002). Because tree islands are nutrient hotspots and serve as nutrient sinks, water quality is regarded as the least important stressor among these components. However, water quality

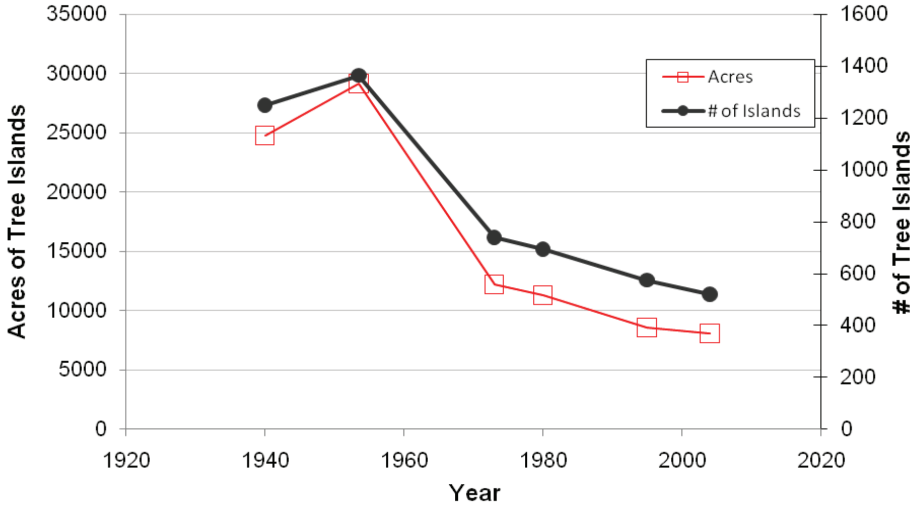


FIGURE 4-23 Tree island trends between 1940 and 2004 in WCA-3. The apparent increase in acreage and number of islands between 1940 and the mid-1950s is likely a combination of differences in mapping techniques and increases in areas covered by trees and shrubs (e.g., colonization of ridges) after extensive drydowns and shortened hydroperiods.

SOURCE: F. Sklar, SFWMD, personal communication, 2010, 2012.

is an important factor in the accumulation and distribution of phosphorus on tree islands (Wetzel et al., 2005, 2011).

High water depths and long periods of inundation or flooding cause plant stress, failure of seed germination, and diminished wading bird nest habitat (Sklar and van der Valk, 2002). Simulations with the Everglades Landscape Vegetation Model (ELVM; a simulation model that links fire, nutrient dynamics, hydrological regimes, and vegetation succession on tree islands to analyze management alternatives) suggested that in WCA-2A tree island water depths of 30 cm for longer than 150 days result in loss of tree island species, and these results align well with historical records (Wu et al., 2002). Nevertheless, for Shark River Slough tree islands, water levels deep enough to protect the thin peat covering from both microbial oxidation and fires were critical to the elevated areas' ability to support woody species.

Shallow water depths and reduced hydroperiods result in peat oxidation and muck fires, which lower the elevations of peat-based tree islands. The overall effect and legacy of the 1915 to 1950s period of uncontrolled Everglades drainage was a flattening of the landscape: lowering the tree islands and the ridges relative to the sloughs and moving the elevations of tree islands closer to those of ridges (McVoy et al., 2011). Subsided tree islands with reduced peat become more vulnerable to flooding even under normal water depths and particularly under restored conditions. Peat oxidation and loss of up to 1 cm per year can occur under extended periods of shallow water depth (F. Sklar, SFWMD, personal communication, 2011), with greater rates in a muck fire. The May 1981 muck fires in the northern portion of WCA-3A resulted in 9 to 28 cm of peat loss (Wetzel, 2002). In Shark River Slough 55 percent of islands and 58 percent of tree island hectares have been lost because of peat oxidation caused by fires and lack of water (Sklar, 2012). Fire frequency in the Everglades is estimated to be approximately 10-14 years (Gunderson and Snyder, 1994), but drier conditions increase the frequency, size, and intensity of fires. Under wetter conditions fire is a natural part of the disturbance regime and does not have the devastating effects evident with the large, frequent, and high-intensity fires under drier conditions.

WCA-3A currently experiences hydrologic extremes to differing degrees. In general, the northern part of WCA-3A has become drier, whereas tree islands in the southern areas experience higher water depths, ponding, and longer hydroperiods. Wetzel (2002) reported that tree island peat depths are generally shallower in northern WCA-3A (0.62-1.08 m) compared to southern WCA-3A (1.08- 1.22m) as a result of peat oxidization. The northern tree islands in WCA-3A have also become more vulnerable to fires than their southern counterparts.

If water depths are substantially reduced for extended periods of time, then peat will oxidize, lowering the elevation of the island. The island then becomes more susceptible to inundation and drowns, reducing the diversity of floral species on the islands to those that are flood tolerant (Wetzel, 2002). However, even woody species that are flood tolerant can perish under sustained extreme flooding events, resulting in "ghost islands" that are lacking in floral diversity; it is estimated that the drowning process can take 20 years (Sklar, SFWMD, personal communication, 2011). Eventually, if tree islands subside to the extent that they lose their elevation above the surrounding ridges, then they can no longer support woody vegetation, and the vegetation is replaced by sawgrass and cattails.

If existing conditions are maintained, then the decline of tree islands will continue. Unless decompartmentalization occurs, tree islands in the southern portions of WCA-3A will continue to experience inundation and ponding and to lose species diversity (shifting to more flood-tolerant species). Hydrologic restoration (e.g., increased flow volumes, more natural hydroperiods and water depths) offers opportunities for recovery of tree islands, particularly in the southern and central portions of WCA-3A, where the greatest number of higher elevation tree islands remains. Much of the tree island acreage in northern WCA-3A has already been lost because of peat subsidence, and some remaining subsided islands may experience greater inundation, reduction in floral diversity, and ultimate loss with hydrologic restoration. Nevertheless, there is substantial variability in the current elevations of tree islands, which will result in different responses to restored water depths. With hydrologic restoration, many tree islands that are currently on a trajectory of drowning can recover, particularly if their elevation differences remain, although active restoration in the form of tree planting may be needed in some cases (van der Valk and Sklar, 2002). Natural recolonization of degraded islands can occur through seed dispersal if there are nearby islands with sufficient diversity and abundance of species (van der Valk and Sklar, 2002; Wetzel et al., 2005; Wu et al., 2002). Nevertheless, with long-term flooding and associated declines in plant diversity, opportunities for natural recovery through natural seed dispersal and recolonization will be lost over time. It may be possible to restore severely subsided tree islands by raising the elevation of their heads, although such efforts would be expensive and labor intensive (van der Valk and Sklar, 2002).

The restoration of hydrologic flow, water depths, and duration will benefit many tree islands, but high phosphorous levels may promote cattail and willow encroachment on islands with elevations that are low relative to the surrounding marshes. However, as phosphorus increases, vegetation and peat increase on tree islands that sequester and redistribute phosphorus (Wetzel et al., 2011). Hence, the detrimental effects of altered water depths and duration are expected to exceed the effects of water quality on tree islands. Improved hydrology and water quality offer the best opportunity for tree island restoration across the landscape (Bedford et al., 2012), although some subsided islands may become inundated and lose floral diversity because of variations in tree island elevation across the landscape. When considering restoration alternatives, the choice does not appear to be one of causing harm versus not, but instead one of causing the least overall harm while promoting the most improvement.

ELVM simulations suggest that restoration of 60 percent of tree islands known to be lost could occur within 50 years (Wu et al., 2002). However, there are reasons to believe that the time to recover tree islands in WCA-3A is substantially underestimated. The predictions were based on flows that had been increased to pre-drainage levels and not the lower flows proposed under the CERP. Furthermore, the model was designed for, and calibrated well with, tree island dynamics in WCA-2A, but it did not calibrate well with islands in WCA-3, in part because WCA-3 has experienced substantial fire-induced peat losses that were not explicitly modeled.

Snail Kite

Snail kites in the Everglades are part of a subspecies (*Rostrhamus sociabilis plumbeus*) that includes other populations in Cuba and northwestern Honduras

(Sykes et al., 1995). The two other subspecies of snail kite extend through Mexico, Central America, and all of South America. The Everglade kites are the only snail kites in the United States, and the population has been designated as endangered because of its limited distribution and declining numbers.

The decline of the snail kite in South Florida reflects the degradation of the ecosystem on which it depends. The committee's previous report (NRC, 2010) discussed the decline of the snail kite over the past decade, which has reduced the population to an extremely low level (Figure 4-24). Kite populations have fluctuated historically in response to drought cycles, with prior low points in the 1960s (Takekawa and Beissinger, 1989) and late 1980s (Beissinger, 1995), but the current decline differs in being driven by degradation of habitat in previously productive areas (e.g., Lake Okeechobee, WCA-3A) as well as by climate (Reichert et al., 2011). Kites are highly mobile, and they move throughout the system to find conditions favorable for foraging and breeding (Bennetts and Kitchens, 1997; Takekawa and Beissinger, 1989). However, in recent years con-

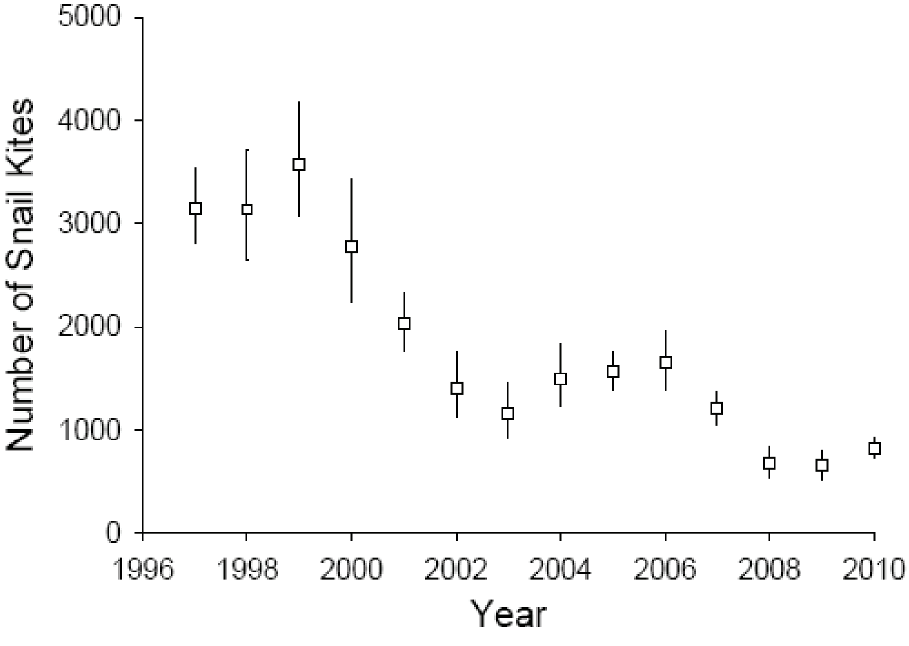


FIGURE 4-24 Population size and associated 95 percent confidence intervals of snail kites, 1997-2010.

SOURCE: Reichert et al. (2011).

ditions have generally been unfavorable everywhere, and the kite population in the Everglades has declined precipitously. One can argue that the current trajectory of the kite population, which has brought it to the brink of extirpation, mirrors the current trajectory of the ecosystem and reflects the fact that every part of the Everglades has been altered, such that the kites have increasing difficulty finding suitable conditions anywhere (Kitchens et al., 2002).

The most recent decline of the snail kite has been specifically linked to unfavorable conditions in southwestern WCA-3A, their primary nesting area during the past decade (see Endangered Species Issues in Chapter 3). Prolonged high water levels in southern WCA-3A have well-documented, adverse effects on kites (NRC, 2010). However, the problem is more complicated than wet season water levels that are too high and last too long. These conditions and the accompanying loss of tree islands that serve as nesting sites might explain the lack of kite nesting in some former nesting areas, such as eastern WCA-3A (Figure 4-25). However, kites also suffer from dry season lows that are too low and rates of recession that are too fast (FWS, 2010). Kites are highly specialized feeders, relying on apple snails (*Pomacea paludosa*) to feed themselves and their young. Not coincidentally, these snails are also adversely impacted by these same hydrological problems, that is, prolonged wet season high water, prolonged dry downs in the dry season, and rates of recession that are too fast (FWS, 2010).

It is actually rapid rates of recession and low water levels in the dry season, not prolonged high water during the wet season that explain poor nesting success in southwestern WCA-3A over the past decade (NRC, 2010). It is the minimum stage, not the wet season high water maximum, that is most highly (and positively) correlated with kite nesting success (Cattau et al., 2008; FWS, 2010). Historically kite numbers have decreased during droughts and increased during wet periods (Takekawa and Beissinger, 1989). This explains the seemingly paradoxical pattern that kite nesting, which is adversely affected by prolonged high water, is concentrated in southern WCA-3A, where water levels are the highest, rather than in central or northern WCA-3A. When the kites shifted away from the ponded areas in eastern WCA-3A in the 1980s, they initially moved to central WCA-3A (Figure 4-25). However, these areas now dry out too much and too fast to support kite nesting. Thus the kites have shifted to the seemingly unsuitable southwestern portion of WCA-3A, not because conditions there are ideal, but because conditions everywhere else in WCA-3A are even worse. In some places prolonged high water has converted the wet prairies and emergent marshes that the kites use for foraging to other habitat types (Holling et al., 1994; Sklar et al., 2001; Zweig and Kitchens, 2008). These habitat types still occur in abundance; however, the more pervasive problem is that the historical wet season/dry season water cycles that support kite nesting and large apple snail populations (SEI, 2007) no longer reliably occur in these habitats.

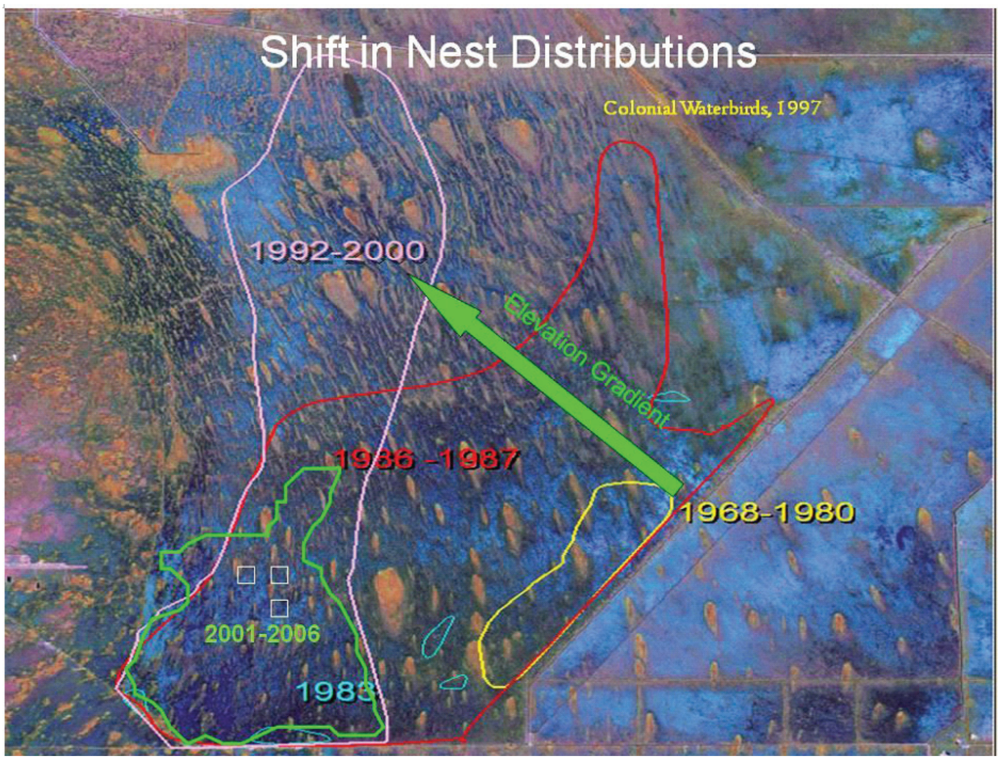


FIGURE 4-25 Shifts in the distribution of nesting snail kites in WCA-3A, 1968-2006.

SOURCE: FWS (2010).

Looking beyond WCA-3A, the picture is much the same. The kites formerly nested in large numbers in the Kissimmee Chain of Lakes, Lake Okeechobee (Cattau et al., 2009), and WCA-3B and WCA-2 (Bennetts et al., 1994; Sykes, 1983). Thus, the dependence of kite reproduction on WCA-3A is a relatively recent phenomenon (Figure 4-26), and the dependence on the southwestern portion of WCA-3A is even more recent (Figure 4-25). In most of these former nesting areas, hydrology or habitat (or both) are altered in ways that make it unlikely that kites will return in significant numbers without restoration. Lake Okeechobee continues to be unproductive under current water management, although there were a few nests there in 2010 following three years with no nests (Figure 4-26). WCA-2 has experienced extensive loss of the tree islands (Sklar et al., 2009), which kites use as nesting sites, and no nesting has occurred there

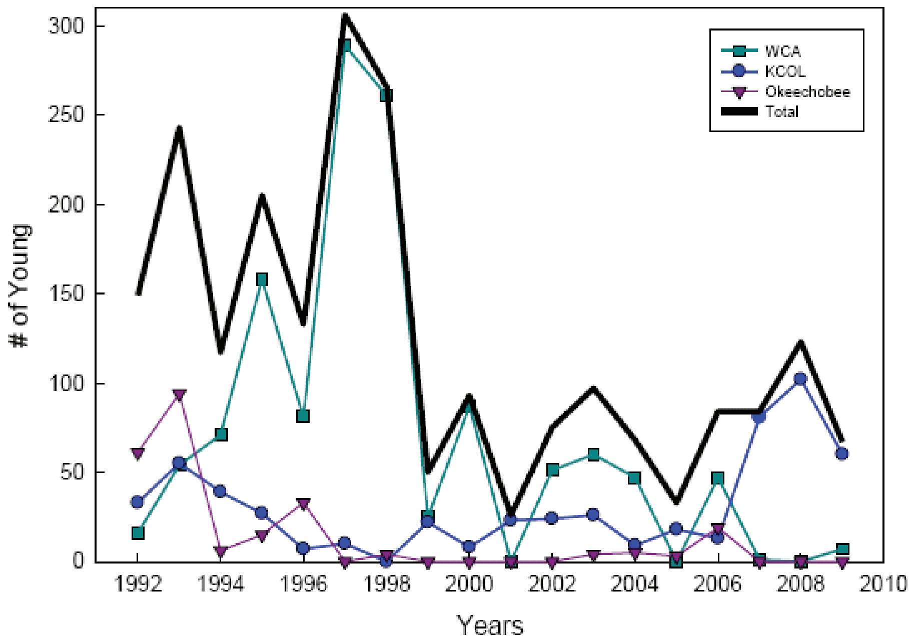


FIGURE 4-26 Number of young fledged from kite nests in the Water Conservation Areas (WCA), Kissimmee Chain of Lakes (KCOL), and Lake Okeechobee (Okeechobee), 1992-2009.

SOURCE: Cattau et al. (2009).

in recent years. The ridge-and-slough landscape of WCA-3B is highly degraded (SCT, 2003), and there have been a few nests there in some years and none in others. Some nesting has occurred in Everglades National Park, but the dry season water levels there tend to be too low. Interestingly, kites have resumed nesting in the Kissimmee Chain of Lakes, coincident with their increasing ability to forage on an invasive apple snail species (*Pomacea insularum*) found in abundance there (see below). This area has been the primary nesting area during the past few years because productivity in WCA-3A has declined to near zero (Figure 4-26).

The kites are not as directly impacted by deterioration of water quality as are many other fauna and flora of the Everglades, although they can be indirectly impacted by changes in habitat mediated by water quality, such as cattail invasion. Instead, the problems that have plagued the kites in various areas of the central Everglades result from altered flow regimes; that is, they are problems of water quantity and distribution, especially seasonal cycles, rather than water quality. Restoration of historical seasonal cycles of water levels and recession is necessary not only to create suitable nesting conditions for kites, but also to support the life cycle of their apple snail prey. Snail kites are very successful in other areas with extensive, shallow wetlands (e.g., the Llanos of Venezuela and the Pantanal of Brazil), and although little is known about where snail kites were most successful in the pre-drainage Everglades and to what extent their distribution changed during wet and dry cycles, the committee judges that conditions for the kite should improve in the Everglades with system-wide hydrologic restoration. Two independent panels of ornithologists and wetland experts have reached the same conclusion (SEI, 2003, 2007). The strength of the kites' response will be complicated by the fact that restoration might reduce the amount of preferred wet prairie habitat while increasing the quality (due to restored hydrological cycling) of remaining habitat.

Conservation increasingly focuses on those few areas that remain potentially suitable for the snail kite. Recent changes in water management in WCA-3A focus on improving conditions for kites and apple snails in the area on which kites have become most dependent, that is, southwestern WCA-3A (see Chapter 3). This likely will improve the kites' nesting success in the target area (southern WCA-3A) but at the expense of making conditions even worse for them (and other system components) in other areas (central and northern WCA-3A). Until more substantial progress is made with all that the CERP is designed to accomplish in the central Everglades—increased inputs of water, a shift in the distribution of water from west to east, restoration of sheet flow and historic seasonal cycles of water levels and recession—kite conservation likely will remain in crisis as the system continues to degrade. Local actions, such as in WCA-3A, may ward off extirpation, but having a viable population is likely contingent on system-wide restoration. Not until then will the kites' mobility and resiliency become the assets they once were.

The kites' adaptability may enable them to persist despite continuing system degradation. Specifically the kites appear to be increasingly able to sustain themselves on exotic apple snails: recent increases in nesting in the Kissimmee Chain of Lakes (Cattau et al., 2009) and in the STAs (see Chapter 3) involve use of this prey. The kites may be adapting to these large snails by foraging for juveniles (Cattau et al., 2009) and by adults feeding snails to nestlings (Williams, 2011), and even by behavioral changes in prey handling that enable the kites to extract the large exotic snails more efficiently (H. Tipton, FWS, personal communication, 2011).

CONCLUSIONS

An assessment of the status and trajectories of 10 ecosystem attributes reveals that conditions for tree islands, ridge-and-slough landscape, snail

kites, and peat continue to degrade and that cattail coverage continues to expand 12 years after the initiation of the CERP. These declines can be attributed to altered hydrology and/or the elevated supply of phosphorus in the remnant Everglades. Despite its ability to search throughout the Everglades ecosystem for suitable conditions, the Everglade snail kite has experienced a precipitous decline in numbers over the past 15 years and is in danger of extirpation.

The state's extensive phosphorus control efforts over the past two decades appear to be stabilizing or improving the current trends for several ecosystem components driven by phosphorus (e.g., periphyton, soil P). Cattail expansion, however, is continuing but at a decreasing rate in some areas (e.g., WCA-2). Implementation of STAs and best management practices has markedly decreased phosphorus loads to the WCAs, and interior phosphorus concentrations have decreased in WCA-2 and -3 in response to decreases in the concentrations of inflowing waters. Despite this progress, impacted areas of the WCAs consistently fail the four-part test for compliance with Florida's water quality standards. Thus, it is widely recognized that additional water quality improvements are needed to prevent further degradation and reverse ongoing adverse impacts to the ecosystem caused by elevated phosphorus.

In contrast, the restoration of flows in the central Everglades has been limited, and the ecosystem attributes most directly influenced by hydrologic factors continue to decline. In many cases these ongoing losses can only be recovered over long time scales. The velocity, depth, and duration of water in the Everglades are important controlling factors for the distinctive terrain of the Everglades: tree islands, ridge-and-slough topography, and peat accumulations. These landscape components have been severely degraded by flow alterations during past decades. Recovering additional losses will require decades if not centuries. Of the many projects under construction, only Mod Waters (a non-CERP project) and the C-111 Spreader Canal (a CERP project) offer promise of direct, significant effects in the central Everglades.

Substantial *near-term* progress to address both water quality and hydrology in the central Everglades is needed to prevent further declines. Near-term progress that addresses only water quality *or* water quantity leads to continued system declines of many components. Additionally, many improvements in water quality are linked with improvements in water quantity. Thus, decisions on restoration project design and scheduling should not be viewed as simple tradeoffs between water quantity and water quality. Instead, this qualitative analysis points to the need for a more critical and comprehensive quantitative analysis using models and field data to evaluate management alternatives in an integrated manner (see Chapter 5). Also, it highlights the importance of stabilizing and ultimately reversing declines of attributes that would take a long time to recover, particularly if other aspects of the restoration depend on them. Because of its focus on the remnant Everglades and accelerated planning, the Central Everglades Planning Project conceptually provides promise for rehabilitating the remnant Everglades.

5

Science and Decision Making

The Comprehensive Everglades Restoration Plan (CERP) has a strong history of scientific accomplishment. More than 120 scientific papers related to the Everglades were published between 2001 and 2011, most of which were peer reviewed. About 50 of those papers were published in the past three years. This body of work provides a growing and impressive underpinning of knowledge from which to guide the restoration project; inform monitoring, assessment, and adaptive management; and ultimately support decision making. This committee judges that synthesis of this science is an essential step to making it accessible for effective decision making across all CERP components. In this chapter the committee focuses on the progress made in synthesizing science across a range of integrative activities, all of which are ultimately intended to support decision making for the CERP. First, the committee reviews various activities aimed at collating and synthesizing the information gained from research and monitoring activities related to the CERP. Progress in, and budgetary impacts to, the monitoring and assessment plan and related activities are then assessed. Modeling activities and the ways models have been used to inform restoration efforts are highlighted. Finally, the committee reviews ongoing progress in developing decision support tools and underscores the roles science and social values play in decision making under risk and uncertainty.

SCIENCE SYNTHESES

Although previous National Research Council (NRC) reviews commended the science that was done to support the CERP, there were questions about the science's effectiveness in influencing policy. One recommendation was to put greater emphasis on synthesis of the scientific findings. The 2010 NRC report defined research synthesis as "the process of accumulating, interpreting and articulating scientific results thereby converting them to knowledge and information." Two important outcomes of synthesis are to better understand fundamental system properties and to minimize the kind of scientific and technical disagreements that impede decision making. As the definition implies, part of the complexity (and the challenge) of synthesizing the science for a large ecosystem restoration effort is that there are multiple audiences. For the science community, synthesis should advance understanding. For the policy community, which includes science managers and their advisors as well as decision makers, synthesis can be a source of policy recommendations (outlining policy choices) and a tool for managing conflict. For the interested public, synthesis is a tool for translating what can otherwise be obscure observations about the ecosystem and recommendations for restoration.

Other restoration efforts of the CERP's scale usually have chosen to address one of these audiences at a time, to greater or lesser effect. For example, the CALFED Bay-Delta Science Program in California (now the Bay-Delta Stewardship Council's Science Program) chose to solicit thorough scientific reviews by a single or a few authors on about 12 key subjects. These were termed white papers and were aimed mostly at a scientific audience. The program later summarized a decade of research in a State of the Science Report (Healey et al., 2008), a single document that summarized science accomplishments for the policy community and the interested public. The science supported by the CALFED Bay-Delta Science Program proved most useful in the development of biological opinions used for policy purposes by the resource agencies; some white papers were important in those documents, and others were not. The influences on policy came from continuing exposure to the body of work through workshops and conferences more so than from any single synthesis document.

In contrast, since the last NRC review, the Everglades restoration effort has put together what can only be described as a plethora of synthesis efforts. These include special issues of scientific journals, the RECOVER 2009 System Status Report (2009 SSR; RECOVER, 2010); the RECOVER Scientific Knowledge Gained Document (RECOVER, 2011a); the Synthesis of Everglades Research and Ecosystem Services (SERES) Project, sponsored by the National Park Service; the New Science document produced by the South Florida's Everglades Restoration Task Force's (hereinafter, the Task Force) Working Group and Science Coordination Group (2010); the Marine and Estuarine Goal Setting for the South Florida Ecosystem (MARES) Project, sponsored by the National Oceanic and Atmospheric Administration (NOAA); and the Task Force's System-wide Indicators (stoplight) reports (SFERTF, 2010b). MARES remains in a formative stage and will not be considered here. The System-wide Indicators reports were reviewed in NRC (2010).

These products take different approaches and cover the full spectrum of detail and audiences. The 2009 SSR full report is a comprehensive synthesis narrative accompanied by a 20 page "Key Findings" document and a dedicated website. The Scientific and Technical Knowledge Gained in Everglades Restoration (1999-2009) report (STKG) is composed of 50 two-page reports. The SERES Project is a comprehensive synthesis effort involving literature reviews and original scenario analyses. The New Science summary is four pages (WG and SCG, 2010). Each of the above is organized differently, either around geography or around (often different) critical issues. Each claims to be unique, either in choice of audience or in what data are employed. Taken as a whole they might be seen as an experiment in how best to conduct science syntheses for multiple audiences.

Below the committee briefly discusses the strengths and weaknesses of several of these efforts. The purpose of this review, of course, is to constructively encourage an increasingly effective effort into the future. What should not be lost is that this array of products represents an admirable accomplishment and a serious response to the suggestion that syntheses are important communication tools for a restoration effort. Taken together these synthesis reports address all three major audiences. They include written narratives for scientists who want to see detailed justifications for conclusions; executive summaries with conclusions directed at managers and policy makers; and creative websites for the interested public. Viewed individually, each of these synthesis efforts is interesting and seems to add value (see discussion below). Taken together, they present a relatively consistent view of the broader principles governing the state of the various sciences relevant to the CERP. But they also seem to suggest at least something of a fractured management approach, wherein different governance groups (both among and within reports) each presents its independent perspective on the science and its separate set of recommendations for management.

Peer-Reviewed Literature Syntheses

Recent peer-reviewed publications aimed at synthesis for scientists include the 2009 special issue of the journal *Ecological Indicators* (Doren et al., 2009) that was discussed in the NRC 2010 report. In 2011 a set of 26 synthesis papers was published in a special issue of *Critical Reviews in Environmental Science and Technology* (Reddy et al., 2011). These papers were authored by some of the most active agency and academic researchers working on the Everglades ecosystem. They reviewed a broad array of the important technical issues and provided a useful, peer-reviewed scientific underpinning for the policy dialogue. The Everglades Annotated Research References document assembled for the committee by CERP staff (N. Aumen, NPS, personal communication, 2011) also provided an excellent overview of at least some of the influential science that has been published. Like previous NRC committees, this committee has seen evidence that the traditional science and monitoring supporting the CERP continue to make strong progress on developing understanding of the ecosystem and how it is changing.

2009 System Status Report

The RECOVER 2009 System Status Report (SSR; RECOVER, 2010) is a comprehensive synthesis that is built around scientific conclusions from MAP and some non-MAP monitoring and historical data. The SSR is organized by geographic region, in contrast to the SERES literature reviews (Borkhataria et al., 2011) and the STKG report (RECOVER, 2011a), which are organized by technical issue.

The full 2009 SSR is a narrative report (more than 500 pages) that is a useful but traditional scientific description of monitoring results. The full report is supplemented by a 20-page Key Findings report, a short, easy-to-read brochure that should be very useful for technically oriented staff, managers, and decision makers. The Key Findings succinctly tie together interim goals, hypothesis clusters, indicators, and conclusions from the monitoring and assessment program, and include bullets describing their management relevance. This type of integration across what were once separate efforts is rare and will pay off in the future. In addition, the Key Findings subjectively evaluate the question of whether RECOVER's scientific synthesis of the data yields the same message as do the trends in the stoplight indicators reported by the Task Force. In most, but not all cases, the answer is yes. Of course, critics might question the objectivity of the analysis, but it sets a good precedent (actually testing what indicators indicate) and is perhaps a desirable next step in the evolution of the performance measure concept.

The 2009 SSR also includes a creative website, which has the potential to be an effective and novel presentation of the report. The goal was to allow "managers, stakeholders and scientists with different degrees of technical expertise and interest to easily explore the SSR at the desired level of detail." Where complete, the website is indeed successful in allowing readers to "'drill down' from general information . . . to the very technical annual reports used to compile the SSR."[1] The reader can also easily navigate to summaries for each region and to key issues within regions. The website contains more details than the Key Findings and fewer than the full report.

Unfortunately, the website does not yet appear to be fully populated. Where done well, the more detailed assessment can be coupled with the Key Findings to tell a coherent story about a geographic location. For example, the Lake Okeechobee section of the website provides enough easy-to-access detail to satisfy a more scientific audience while the Key Findings provide the "bottom line" that the policy community desires. But, all the sections for all the geographic regions are not equally populated with metrics or well linked to the

---

[1] See http://www.evergladesplan.org/pm/recover/recover.aspx.

Key Findings. For example, the Key Findings for the Greater Everglades are coherently presented and mesh nicely with the management relevance, but the website is incomplete in its coverage, and therefore does not fully capitalize on the opportunity to support the Key Findings with more detail. The structure and concepts are there to use the Key Findings and the website in a complementary manner, but the two give the perception of having been developed by two separate groups that never fully integrated.

The website also allows for a tiered approach to the use of performance measures. The 2010 NRC report recommended that a small set of performance measures would be more effective in communicating with policy makers than a very large set. That is a valid comment if the performance measures are viewed as individual indicators of performance, outside the context of ecosystem complexities. Clearly the CERP has taken this to heart. At the same time, too few performance measures can understate integrative complexities in an ecosystem and have little explanatory power, which is especially important when the restoration effort involves a complex geography cross cut with equally complex physical, chemical, and ecological issues. While not necessarily calling them performance measures, the 2009 SSR uses multiple metrics to assess the status of different major ecosystem attributes across four different geographical areas (see Box 5-1 for one example).

The website approach will facilitate the wide dissemination of the outcomes of the monitoring and assessment program and other scientific efforts to a number of relevant audiences if continued. Unfortunately, most times series on the website end in 2008. Frequent updates would allow readers to follow environmental change in each geographic area. Continuing updates of the graphics alone could be a practical way to present real-time results and avoids the cumbersome process of writing a full report each year. Full assessments, of course, would still be important at some longer time intervals.

The substantial effort put into interpretation and synthesis of the monitoring and assessment data is clearly essential to the success of the restoration and is a notable accomplishment. However, the committee cautions both the managers and scientists involved in this endeavor that the 2004-2008 period of record is short and requires a context that only further data can provide. Perhaps more importantly, it was a period during which the ecosystem was strongly perturbed by three hurricanes and then a drought. Although older time series were available for interpretation of some data, other interpretations relied heavily on the 2004-2008 period. This is not to say that management decisions should wait for "all the data." After all, complete knowledge of the system is not an attainable goal, nor is it necessary from a policy perspective. But any decisions based upon a limited period alone should be considered contingent upon further evaluation. As a result, management decisions need to allow room for flexibility and

BOX 5-1
Lake Okeechobee Indicators and Metrics

Table 5-1-1 shows the implicit indicators and metrics used on the website to characterize Lake Okeechobee. Taken together, these implicit indicators and metrics provide a succinct but fairly comprehensive synopsis of trends in the various aspects that define the status of Lake Okeechobee. Other geographical areas (Greater Everglades, Northern Estuaries, Southern Coastal System, and ecosystem components that include some overarching indicators) are not as thoroughly populated with metrics. Nevertheless, the website makes it clear that these "indicators" target what the SSR authors consider important issues for each area. The set of formally chosen key indicators, underlain by this informal tracking system on the web, overcomes the lack of explanation that is characteristic of using only a few key indicators while retaining the advantage of being succinct and transparent.

SOURCE: Available at http://www.evergladesplan.org/pm/ssr_2009/mod_lo.aspx.

TABLE 5-1-1 Indicators and Metrics for Lake Okeechobee

Indicator	Metric
Lake stage	• Mean monthly lake stage
Macroinvertebrates	• Community health indices • Abundance and composition of numerically dominant taxa
Native fish	• Community composition for dominant species—Electrofishing • Community composition for dominant species—Trawl sampling • Black crappie catch rate • Chironomid (crappie prey) abundance
Periphyton	• Epipelic biomass • Epiphytic biomass on different plant species • Epipelic and epiphytic biovolumes • Phosphorus content of epiphytic periphyton
Phytoplankton	• Community composition • Total lake biovolume and chlorophyll a • Diatom/cyanobacteria ratio • Microcystin concentrations
Submerged aquatic vegetation (SAV)	• SAV biomass • SAV distribution • SAV acreage
Wading birds	• Prey—Wet season biomass • Prey—Dry season biomass • White ibis—Location and number of nests • Wood stork—Location and number of nests • Proportion of wading bird nests in the Everglades
Water quality	• TP load • Pelagic TP, total nitrogen (TN), dissolved inorganic nitrogen (DIN), soluble reactive phosphorus (SRP) • TN:TP ratio • SRP:DIN • Algal bloom frequency • Water clarity • Nearshore TP, TN:TP, SRP:DIN

use the tools of active and passive adaptive management. A comprehensive monitoring and assessment program (discussed later in this chapter) as well as continuing and timely interpretation and synthesis of monitoring data are vital to adaptive management.

The real challenge for any program of this sort is to support and embed the effort that is necessary to move the program forward and create the context for today's data for the decades to come. The 2009 SSR is a good beginning—not the end. The notable achievements of the RECOVER effort and its admirable translation onto a platform for many levels of understanding will be wasted unless the effort is perpetuated. On the other hand, the frequency of updates to the full SSR could be reduced (e.g., to once every three or four years) if the website were more consistently populated and the time series graphics and associated interpretations were updated annually.

Scientific and Technical Knowledge Gained in Everglades Restoration (1999-2008)

The STKG report (RECOVER, 2011a) is another scientific reference aimed at multiple audiences. It contains summaries of 50 topics—each limited to about two pages—organized around the five critical topics for Everglades restoration (as defined earlier by NRC [2007]). Authors of the two-page articles were asked to not provide recommendations or opinions. The result is an encyclopedia of Everglades restoration issues of greater (e.g., Lake Okeechobee) or lesser (copper in snails) importance. This compendium could be of value for readers looking for a snapshot of a particular issue, but for an integrated view of restoration issues it is insufficient. Differences in quality among the summaries exist. Many are scholarly and contain enough detail to give the reader a useful overview of the literature. Others, such as in the climate change section, are more general and do not adequately incorporate important studies. Also of concern are contradicting details between interpretations in these summaries and other syntheses of the same subject. For example, the STKG synthesis for Lake Okeechobee emphasizes the importance of rates of change in lake stage and shifting ecological zonation, whereas the 2009 SSR emphasizes submerged aquatic vegetation (one ecological zone) at different lake stages. All of these interpretations are of scientific interest, but even subtle differences among synthesis documents could create confusion for less-scientific audiences and could contribute to, rather than help manage, conflicts about appropriate actions. It is also notable that the Ecosystem Services summary paints a more optimistic picture of the usefulness of this tool than does the NRC (2010) report. In summary, there is no established formula for the most effective approach to developing synthesis documents. The approach of the STKG report has been used elsewhere and has its value. But in the future, it may be a less desirable approach because of the lack of integration and the challenges in negotiating areas of scientific disagreement. The summary on stormwater treatment areas, which appeared in an early draft, was deleted from the final document because legal sensitivities made it difficult to develop a rigorous consensus summary of the science.

SERES

The Synthesis of Everglades Research and Ecosystem Services Project, sponsored by the National Park Service's Critical Ecosystem Studies Initiative, is being conducted by a team of 15 scientists, largely from academia or the Everglades Foundation with a few agency participants. The SERES Project will not repeat the efforts of the other syntheses and indeed makes minimal references to the stoplight indicators, hypothesis clusters, the STKG report, or the 2009 SSR. In the end, however, much of the same science is reviewed.

An interesting aspect of the SERES Project was the effort to identify key questions raised by "managers, decision-makers, and key opinion leaders" that would define the direction of the synthesis effort (SERES Project Team, 2010). The resulting seven general questions were then framed to encourage development of scenarios about implications of different restoration strategies. Developing and analyzing different scenarios that would, for example, balance water quality and water quantity choices in different ways was an important recommendation of NRC (2010). This, of course, is an ambitious undertaking that requires more than just synthesis, if done at any depth. As of March 2012, the alternatives analysis remained under revision,[2] and therefore, will not be reviewed here. The alternatives analysis will also consider economic valuation of the ecosystem services of the different restoration scenarios (P. Wetzel, SERES principal investigator, personal communication, 2012). The committee's previous guidance on this topic (NRC, 2010, which was informed by NRC, 2004b) states that economic valuation of ecosystem services, while valuable, is a complex undertaking that needs to be done with proper rigor. Previous NRC committees were skeptical that enough resources and/or high quality data were available for a robust analysis of ecosystem services in an ecosystem with the scope and complexity of the Everglades.

Aside from the identification of key questions, the main publicly available SERES product to date has been a compilation of literature reviews focused on water quality, landscape patterns, soils, and food webs (Borkhataria et al., 2011). The SERES sub-groups differed in their approach to synthesis, the degree to

---

[2] When released, the report can be found at http://www.everglades-seres.org/Products.html.

which they addressed the questions posed, the degree to which scenarios were developed, and the recommendations or messages for management.

The water quality chapter is a comprehensive review of Everglades water quality, and the data and presentation are scholarly but not unique. The review did not construct scenarios, but it directly confronted the central conundrum of the restoration effort (i.e., water quality and quantity), despite the authors presenting somewhat contradictory views. First they state that there is no tradeoff between hydrologic flows and water quality and that "the only way to maintain a non-impacted Everglades wetland is for water entering the system to have total phosphorus (TP) concentrations at or below 10-12 μg/L." A more constructive statement suggested a direction that science can take to address the challenges related to water quality and quantity:

> Hydraulic restoration could further increase nutrient and contaminant loading if the new water is enriched relative to background levels. Balancing tradeoffs of hydraulic and water quality targets is dependent on understanding (1) the vulnerability of 'recipient' ecosystems, (2) expectations of 'source' water quality and loads, and (3) ecosystem responses to contaminant loading. (Borkhataria et al., 2011)

The next phase of synthesis reports might profit from directly addressing this type of understanding in different types of Everglades environments.

The food-web chapter was particularly well done. Its discussion of optimization approaches could be employed to address challenges like those stated in the water quality chapter. The conceptual models presented of succession in the various animal and plant communities following perturbation and recovery (e.g., drying, nutrient input) support their final conclusion: recovery of upper trophic levels and multi-species assemblages as well as reasonable control of invasive species is feasible, but multi-species tradeoffs must be quantified to find solutions. The chapter subgroup concluded: "If the trade-offs inherent within the Everglades system are not acknowledged, and management actions switch between the extremes of what is best for one group versus another, the outcome is likely to be more harmful than need be for all groups involved."

The soils and landscape chapters are also comprehensive, scholarly reviews of processes that drive the configuration of the greater Everglades. The integrative consideration of water quality and effects of hydrology provide a model for the kinds of scenarios and tradeoffs that should guide future syntheses. No synthesis of water quality should fail to consider influences of hydrology and vice versa. These chapters also make it clear that modeling of tradeoffs is essential to finding solutions and/or identifying next steps to address the grand challenges facing this restoration effort.

Overarching Assessment

The Everglades synthesis efforts, in total, reflect scientific progress, the influence of science on policy, and the cohesiveness of governance. In terms of science, the progress in understanding the diverse and complex environments that comprise the Everglades ecosystem is impressive. The growth of conventional knowledge underpinned by scholarly literature is the first step in building science-based policy. The redundancy from the various efforts makes it clear that there is a growing coalescence around the central scientific principles that govern the status of the various ecosystems and the needs, in the broadest sense, for a successful restoration. This consensus was evidenced by the Working Group and Science Coordination Group's New Science summary (WG and SCG, 2010).

The New Science summary also displayed a weakness that was evident in most of the syntheses, that is, failure to acknowledge conflicts among some of the most fundamental needs of a successful restoration. For example, the summary exhibits a "blind" spot where the silos of hydrology and water quality intersect. Despite universal agreement in the scientific community that the two issues are equally important, the summary seldom attempts to bridge the two issues. After presenting options for increasing flows, the summary provides the following caveat: "Yet, increased flows should be achieved without harmful water levels or impacts to water quality and will be evaluated by policy-makers." Such a weak statement does not address the often unstated skepticism about whether phosphorous limits can be achieved (and what to do if they cannot?) or the need for more understanding of how and where hydrology and eutrophication interact. Ultimately, finding restoration solutions will require an integrated understanding of the interplay between hydrology and water quality, quantification of the tradeoffs, and identification of opportunities to benefit food webs with less than absolute solutions for either issue.

The next generation of science and syntheses should start with the recognition that fundamental conflicts exist among the solutions being presented; recognize that science can contribute to these solutions; and be guided by scenario building and optimization approaches (e.g., multi-species) that look for opportunities to find optimal balances. As a guide for policy makers (and governance), this fractured approach to synthesis has disadvantages. If policy makers receive multiple recommendations (with sometimes differing details) from multiple directions, then they might conclude that there is confusion about the best path forward.

Continuing some sort of synthesis effort into the future is critical. However, it would not be cost-effective to repeat the entire large and, in some ways duplicative, effort. Furthermore, multiple reviews probably take more resources away from new science than can be justified. The best aspects of the effort, however, should be continued to push policy toward a common view of the major scientific principles, including explicit recognition of important uncertainties and grand challenges. The present set of documents represents a good start in that direction. Although improvements are needed, the synthesis efforts are a remarkable achievement not only in the scale of effort that was required but also in the depth, breadth, and relevance of what was produced.

MONITORING AND ASSESSMENT AND RECENT BUDGETARY IMPACTS

The importance of monitoring and assessment to the success of Everglades restoration has been recognized from the beginning by the CERP partners and by prior NRC committees. This committee was specifically charged to review monitoring and assessment strategies and protocols used to evaluate CERP progress (see Box S-1), and the following section discusses the recent impacts of budgetary cuts on the monitoring and assessment program.

Beginning with a dedicated NRC workshop in November 2001, a primary focus of the NRC's reviews has been on the development of an effective monitoring and assessment plan (MAP) and the selection of appropriate and practical performance measures by RECOVER (NRC, 2003b, 2007, 2008, 2010). Performance measures are defined as:

> indicators of conditions in the natural and human systems that have been determined to be characteristic of a healthy, restored ecosystem. Achieving the targets of a well-selected set of performance measures is expected to result in system-wide sustainable restoration. The performance measures . . . are used by RECOVER to predict system-wide performance of alternative plans and assess actual performance following implementation.[3]

As noted in NRC (2008), performance measures of ecosystem conditions and critical ecosystem stressors on the ecosystem (e.g., estuarine salinity, soil, and water phosphorus concentrations, hydropatterns) have been developed, which allows the evaluation and assessment processes to focus on the current perception of cause-and-effect relationships. This is a great strength of the performance measure system, because an understanding of ecosystem dynamics is crucial for implementing an adaptive management approach.

The criteria used in the selection of performance measures are described in detail in RECOVER (2007) and NRC (2008). The performance measures, in turn, drive the selection of specific parameters that are to be monitored. The CERP partners and contractors, especially the RECOVER Adaptive Assessment Team, have devoted a great deal of thoughtful effort to the design, modification, and

---

[3] See http://www.evergladesplan.org/pm/recover/eval_team_perf_measures.aspx.

implementation of the MAP over the past decade and more. The link between the selection of a manageable number of performance measures and the long-term sustainability of the monitoring program was clearly identified in the March 2001 draft of the MAP:

> The monitoring and assessment plan must be sustainable for perhaps five decades or longer if it is to be successful in guiding CERP throughout its implementation and subsequent operation. The high cost of monitoring a large number of parameters over a large area and a long period of time is a major reason that many monitoring plans in support of adaptive assessment and management have failed to be sustainable. Therefore, it is crucial to identify a minimum set of performance measures that will indicate whether CERP is achieving ecological recovery of the greater Everglades ecosystem and is meeting its water supply and flood protection objectives. (USACE and SFWMD, 2001)

More than 900 performance measures were originally identified for water quality alone, which provides perspective on the seriousness of efforts to make the MAP sustainable. By the time of the 2001 draft of the MAP (USACE and SFWMD, 2001), the Adaptive Assessment Team had reduced the number of performance measures to about 150 (of which about 70 were related to water quality, 20 to hydrology, and 60 to biology and soils). These were further reduced to a total of 83 (NRC, 2007) and then to 53 (NRC, 2008). The MAP and its performance measures were reviewed extensively in NRC (2008), which concluded that "[t]he number of performance measures is not inherently problematic" but noted presciently that "the set of performance measures should be reviewed regularly to determine whether . . . adequate data collection for each could be sustained over the course of the restoration."

Budget Pressures on Restoration Monitoring

RECOVER-funded monitoring through the MAP is an important part of a larger monitoring effort related to restoration. The RECOVER-funded monitoring is cost-shared (50-50) between the state and federal partners, is contracted, and fills gaps in existing agency monitoring programs. It is difficult to assess the full history and amount of funding that has been devoted to monitoring in the South Florida ecosystem because many entities collect a diverse mix of data in this large and geographically complex area. Moreover, monitoring data have been, and continue to be, collected for a variety of purposes, including regulatory compliance, baseline determinations, project impacts, trend analyses, and experimental results. Some measurements are intermittent; others are long-term and ongoing. No entity compiles all of the restoration-relevant monitoring conducted by agencies, universities, or other organizations, and no attempt

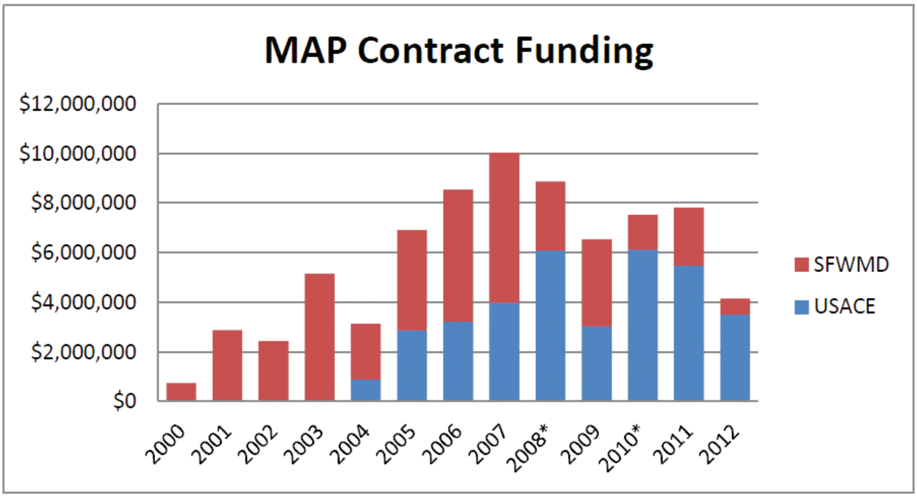


FIGURE 5-1 RECOVER-funded MAP monitoring contract expenditures, by agency from 2000 to 2012. Years marked with asterisks (2008 and 2010) include funds for subsequent years.

SOURCE: G. Ehlinger, USACE, personal communication, 2011.

has been made to track changes in the various monitoring budgets that have implications for the CERP.

The cost of the RECOVER-funded monitoring through the MAP increased from about $0.7 million in fiscal year (FY) 2000 to about $10 million in FY 2007, and MAP funding has declined roughly 60 percent since 2007, with a sharp cut of 48 percent in FY 2012 (Figure 5-1, G. Ehlinger, USACE, personal communication, 2012). About 60 percent of the MAP budget has been devoted to monitoring in the Greater Everglades module,[4] with 15-20 percent devoted to the southern coastal systems and, beginning in FY 2009, about 5 percent to the northern estuaries (RECOVER, 2012). Additional RECOVER funding is used to support staff responsibilities for evaluation and assessment, adaptive management, and providing a system-wide restoration view (not included in Figure 5-1).

The declining trend in MAP funding since FY 2007 is a serious concern for the CERP and for this committee. These cuts are amplified by cuts in many other agencies' monitoring budgets. For example, the South Florida Water Management District (SFWMD), which funds the largest regional monitoring program, reported a reduction of approximately 50 percent in its environmental

---

[4] The RECOVER Greater Everglades module includes the Everglades Protection Area and additional wetland and natural areas within and south of Lake Okeechobee.

monitoring expenditures from FY 2007 to FY 2012 (Figure 5-2). Other agencies, including the U.S. Geological Survey (USGS) and the National Park Service, also reported downward trends in their monitoring budgets (C. Mitchell, NPS, personal communication, 2011; B. Rosen, USGS, personal communication, 2011). The committee does not have sufficient information to fully evaluate the effects of these cuts on RECOVER's capacity to assess restoration progress and support adaptive management. However, agency participants in the committee's October 2011 meeting on the MAP noted that, overall, the monitoring cuts affect the capacity to understand system-wide ecosystem responses and reduce the amount of information available to explain why changes may have occurred.

2011 MAP Re-Optimization and Re-prioritization Process

In this section, the committee offers observations on the procedures that were designed and implemented under great pressure and haste during the summer of 2011 to obtain mandated reductions in the CERP MAP funding for FY 2012. In

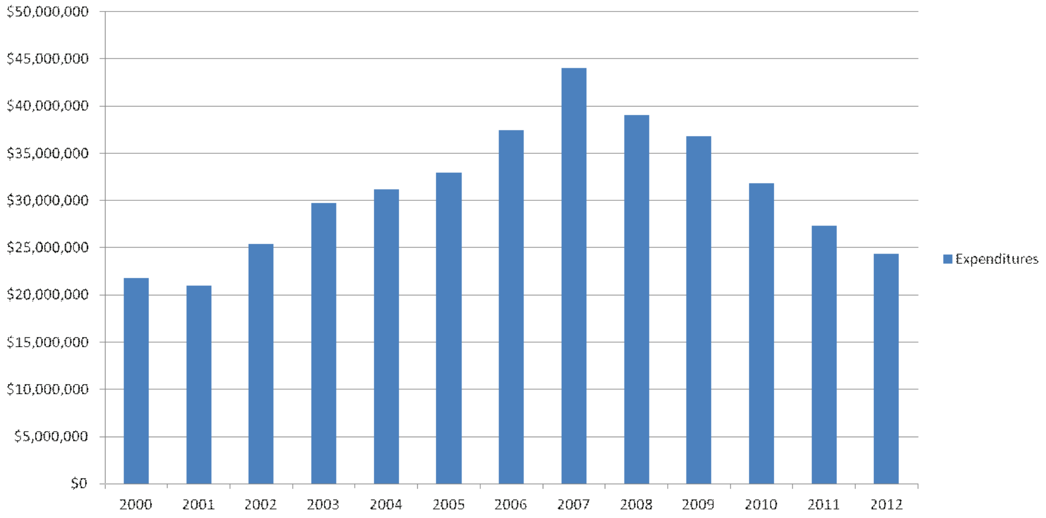


FIGURE 5-2 SFWMD monitoring expenditures, including expenditure for water quality, ecological, and hydrologic monitoring (including associated staff salaries), but excluding expenditures for RECOVER MAP monitoring. SFWMD reports that the cost reductions in monitoring from 2007 to 2012 are based on continual network optimization; improved efficiencies/process improvements; application of new technology in the field, lab, and data validation areas; and conversion of contracts to SFWMD staff.

SOURCE: S. Gray, SFWMD, personal communication, 2012.

March 2011, RECOVER staff developed directions for implementing a system-wide re-prioritization/re-optimization process to select which MAP system-wide monitoring components would be continued, reduced, or eliminated (RECOVER, 2011b). The directions describe in considerable detail a three-part process that was implemented in early June 2011. The first part was an initial optimization of each of the four MAP regions (Greater Everglades, Southern Coastal Systems, Northern Estuaries, and Lake Okeechobee) by the MAP regional coordinators in a workshop setting, with the goal of making existing monitoring as efficient and as optimized as possible. Because MAP monitoring was designed by scientific experts and was based on conceptual modeling, performance metrics, or restoration targets, detailed discussions about changes to sampling stations, methods, or parameters did not occur without a review of the scientific and data objectives and each monitoring component's relationship to restoration. Once monitoring had been optimized, workshop participants (including principal investigators contracted by RECOVER, scientists, agency science managers, appropriate project delivery team [PDT] members, universities, and environmental organizations) then conducted scenario analyses using hypothetical budget reduction levels. Principal investigators were asked how they would implement their monitoring component given a specific reduction in budget (i.e., 25, 50, 60, and 75 percent budget reductions). Additionally, principal investigators contracted by RECOVER were specifically asked how large a cut they could bear without compromising the value of the remaining monitoring program. The regional coordinators were also tasked with providing the system-wide team with 50 and 65 percent reduction scenarios. Results of the optimization (including discussion) and scenario analyses were documented for use during the prioritization process "to promote transparency and fairness as well as to document how decisions were made" (RECOVER, 2011b). Although "fairness" is an admirable goal, fairness may not be a useful criterion in a decision-making process that should be linked to the ongoing need (or lack of a need) for various performance measures that justify the specific monitoring activities.

In the second part of the process, the regional coordinators met with the regional teams (composed of principal investigators and other subject matter experts) and the Regional Prioritization Team (composed of RECOVER members, agency staff, and PDT members) in late August 2011 to prioritize monitoring in each MAP region. The prioritization process was guided by eight "decision-support guidelines" (see Box 5-2). Although the guidelines seem reasonable, they do not mention the performance measures that were used to design the MAP in the first place. Using these guidelines, the regional coordinators were instructed to "use the consolidated Monitoring Information Matrix and any other resources they deemed necessary to prioritize the monitoring in their region REGARDLESS of funding. The initial ranking was rooted in science and should

BOX 5-2
MAP Re-prioritization Decision-Support Guidelines

1. *Does this monitoring meet a CERP project need?* Monitoring should relate to one of the following projects that is already being constructed or slated for construction in the next five years:
    a. Immediate CERP Projects: C-44, Biscayne Bay Coastal Wetlands, C-111 Spreader Canal, Picayune Strand, Site 1 Impoundment, Long-term Plan, Systems Operations.
    b. Important Non-CERP Projects: Modified Water Deliveries, C-111 South Dade, Everglades Restoration Transition Plan (ERTP), Kissimmee River Restoration Project.
    c. Projects in the Planning Phase: Loxahatchee, Decomp.

2. *Is this regulatory monitoring?*

3. *Is this monitoring required for operations?* (i.e., is the information garnered from this monitoring used in weekly operations meeting, etc.?)

4. *Is this monitoring related to an Interim Goal (IG)?*

5. *Does this monitoring contribute to current ecological models?* Modeling can help verify restoration performance in the future and support near-term planning efforts.

6. *Does this monitoring contribute significantly to the RECOVER System Status Report?*

7. *Does this monitoring contribute significantly to other reports such as the South Florida Environmental Report (SFER), Stoplight Indicator Report, etc.?*

8. *Does this monitoring fill an information gap identified in the CERP Priority Program Uncertainties list?*

SOURCE: RECOVER (2011b).

represent how the monitoring would be prioritized if funding was unlimited" (RECOVER, 2011b). The purpose of this exercise is unclear because the experts who designed the MAP began from such a base and then struggled for more than a decade to reduce the number of performance measures and the cost of monitoring. The regional coordinators' priorities were documented and submitted to the MAP System-wide Prioritization Team, which prioritized the MAP monitoring components for FY 2012.

In the third and final step, the MAP System-Wide Prioritization Team (the team) met in September 2011 to make the final decision regarding what monitoring components would be funded in FY 2012. The team was selected on the basis of "scientific expertise, programmatic knowledge of CERP and related activities, and agency affiliation." The participants comprised 16 people (7 from the U.S. Army Corps of Engineers, 3 from the U.S. Fish and Wildlife Service, 3 from SFWMD, 2 from Everglades National Park, and 1 from USGS). No scientists from academic or nongovernmental organizations were included. The team separated the monitoring components into three tiers based on how well they met the Decision Support Guidelines (Box 5-1), utilizing the regional coordinators' input and making necessary revisions (in consultation with the regional coordinators). A component's assignment to a tier was also influenced by a desire to continue monitoring in all geographic regions (Greater Everglades, Lake Okeechobee, Southern Coastal Systems, and Northern Estuaries) to maintain a system-wide view. The monitoring components were entered into a spreadsheet by tier with each activity listed in random order within the assigned tier. The team allocated funds to each activity beginning with Tier 1, again drawing on the regional coordinator's recommendations (after the regional prioritization workshops and using the results of the scenario analyses developed during optimization). The committee has not reviewed in detail the final spreadsheet that summarizes the outcomes of the prioritization but is concerned that the outcomes of key parts of the decision-making process were strongly influenced by the three regional coordinators.

The initial allocation indicated that all Tier 1 monitoring would be funded. Given this outcome, the team decided it would be appropriate to anonymously rank the Tiers 2 and 3 monitoring components. There was substantial time for discussion of the resulting rankings, and the decision-making rationale, the discussion, and any ancillary information used in the process were recorded. With one exception,[5] all monitoring components were cut significantly, although all Tier 1 and Tier 2 activities received at least some funding. The team decided that if additional funds became available for FY 2012, then they would be allocated in rank order beginning with the first unfunded monitoring component in Tier 3 (G. Ehlinger, USACE, personal communication, 2012).

The committee appreciates that the MAP leaders had to respond to a very large mandated reduction in funding in a very short time. The impact on morale must have been severe, and there is a natural desire to respond to such a crisis with decisions that would be perceived as fair as well as thoughtful. Although parts of the process remain opaque and some CERP managers and scientists remain dissatisfied with parts of the end result, it is not practical or productive for the committee to find fault with the process or its immediate results. The committee has no forecasts of future MAP funding, but it seems prudent to assume

---

[5] Only funding for Florida Bay juvenile sportfish monitoring was not cut by this re-prioritization effort.

that the current level of funding will be maintained or decline further, at least in the next few years. Thus, the committee considered appropriate next steps, given that cuts and budgetary pressures are likely to continue.

Next Steps

As noted earlier, the CERP MAP was designed to fill critical gaps in other regional monitoring programs. Now the MAP is shrinking as the gaps are almost certainly growing and new gaps are almost certainly opening. Although the CERP is struggling with many budget uncertainties, the committee remains convinced of the importance of system-wide monitoring to the success of Everglades restoration. Therefore, to ensure that existing monitoring is cost-effective and provides sufficient support for CERP planning, adaptive management, and public communication, a comprehensive review of all monitoring programs that were considered in the original design of the MAP is needed, considering recent and projected reductions. The major MAP budget reductions for FY 2012 were implemented very quickly, and time was not available to reconsider the essential components of a monitoring program or to consider the shifting budgets of other agency monitoring programs. The Science Coordination Group of the Task Force may be well positioned to facilitate such a review. At the same time, to ensure that monitoring funding is being used most effectively, RECOVER and the Science Coordination Group should reexamine the performance measures and the stoplight indicators to see if they should be reduced or otherwise modified, in the context of reduced MAP funding.

When the results of these two efforts are brought together, they should lead to a thoughtful reconsideration of priorities for the MAP consistent with realistic projections of future funding levels. A return to fundamentals may lead to a reconsideration of some of the decisions made in haste last August and September. A revised and almost certainly reduced set of performance measures may necessitate revisions to the "Decision Support Guidelines" issued for last summer's emergency actions. These, in turn, may lead to different choices in monitoring parameters, locations, monitoring frequency, and levels of support. A coordinated analysis of fundamental monitoring needs in support of the CERP and a review of the full extent of restoration-related monitoring efforts in South Florida may also illuminate opportunities for cost-savings and efficiencies not previously recognized.

STATUS OF MODELING EFFORTS IN SUPPORT OF RESTORATION

The NRC committee has previously emphasized the need to develop and thoroughly test integrated or linked hydrologic, water quality, and ecological modeling tools to integrate available information and examine implications of alternative restoration designs and system operation in the Everglades ecosystem (NRC, 2007, 2008, 2010). These models could provide important tools to guide field research, foster the objective analysis of field data, evaluate restoration benefits and impacts to various ecological attributes and regions, and evaluate tradeoffs associated with restoration alternatives. In particular, NRC (2010) expressed strong criticism, stating that "little recent progress has been made in developing integrated hydrologic, ecological, and biogeochemical models to inform restoration decision making and to provide input for adaptive management." Meanwhile, budget cuts in both state and federal agencies over the past two years appear to have slowed model development and testing in support of the CERP. In this section, the committee revisits this issue to assess progress in addressing integrated modeling needs.

Linked Ecological Models

Development and refinement of ecological models for the CERP have continued over the past few years with the Joint Ecosystems Modeling group, a partnership of the USGS, National Park Service (NPS), U.S. Fish and Wildlife Service (FWS), USACE, SFWMD, and University of Florida. Table 5-1 shows that progress has been made in developing models that link hydrology with ecology. Twelve of the 19 ecological models listed can be driven by CERP hydrological models (i.e., the South Florida Water Management Model [SFWMM or the 2x2] and the Regional Simulation Model [RSM]) and/or observed hydrological data (i.e., Everglades Depth Estimation Network [EDEN]).

For a model to be utilized for CERP planning or project design, it must be explicitly used to simulate a CERP performance measure or incorporated into a project-specific CERP implementation report. Additionally, multiple levels of review (e.g., by the agency responsible for developing the model, by external experts, by the RECOVER team, and by the USACE) are required for use in CERP benefits analysis, considering new USACE rules for assuring the quality of planning models (USACE, 2011c). As Table 5-1 shows, no ecological models have successfully completed all four steps in the review process with respect to ecological outputs. The Everglades Landscape Model (ELM[6]), a transient integrated ecological-hydrologic-water quality model, has been approved by the USACE for project-specific use, but only for hydrologic and water quality applications. Two ecological models (Slough Vegetation Performance Measure; Prey-Based Freshwater Fish Density Performance Measure) have completed three of the four review steps, with the fourth currently under way. The fact that none of the

---

[6] See http://www.ecolandmod.ifas.ufl.edu.

19 ecological models developed has been reviewed and accepted for use for CERP projects and available to support benefits analysis is unfortunate. CERP staff report that eight ecological models, designated "ecological planning tools" (S. Romanach, USGS, personal communication), have been used by project teams (Table 5-1), even though none has cleared all levels of review.

Linked Water Quality Models

As discussed in Chapter 4 of this report (and summarized in Table 4-1), simultaneous improvement of both water quality and hydrology is ideally needed to reverse the decline of key ecosystem attributes. Developing regional coupled hydrologic-water quality modeling capability would provide an important tool for quantitative evaluation of a range of alternative restoration scenarios and their potential short- and long-term effects on biotic and abiotic attributes. Without such modeling tools to foster further examination of scenarios at the interface of water quality and quantity, decision makers are more likely to exercise an abundance of caution with respect to water quality, possibly to the detriment of key ecosystem components driven by the system's altered hydrology. Unfortunately, little progress has been made in the past two years regarding development and application of the RSMWQ (the water quality engine for the RSM).

The recent use of ELM in the Decomp planning process is a promising step forward. ELM has been used in the Decomp Part 1 project to evaluate hydrologic conditions, water column phosphorus concentrations, and phosphorus accumulation rates in marshes within the Water Conservation Areas (WCAs) with different project configurations to assess how the project will affect water quality within the WCAs. The Decomp project team, however, was constrained to run simulations that assumed all inflows from the STAs to the WCAs entered with a conservative phosphorus concentration of 10 parts per billion (ppb).[7] This constraint limits the potential to explore real-world scenarios and their resulting phosphorus distributions within the WCAs. The committee understands that the Consent Decree requires all areas of the WCAs and Everglades National Park to comply with the 10 ppb phosphorus criterion. However, unless a wider range of phosphorus inflows are considered in analyses of possible project scenarios,

---

[7] By comparison, the Amended Determination proposed a two-part enforceable framework to meet the geometric mean of 10 ppb in the Everglades Protection Area, with TP concentrations of the STA discharge not to exceed: 1) 18 ppb as an annual flow-weighted mean, and 2) 10 ppb as an annual geometric mean (equal to approximately 12 ppb flow-weighted mean) in more than two consecutive years (EPA, 2010). Under the recently released STA permits, "The discharge must not exceed: (1) 13 parts per billion (ppb) measured as an annual flow-weighted mean (FWM) in more than 3 years out of 5 on a rolling annual basis; and (2) 19 ppb measured as an annual flow-weighted mean in any year" (EPA, 2012).

TABLE 5-1 Status of Developing and Review of Ecological Models for CERP Planning

Model	Lead (Point of Contact)	Accepts 2X2 Input	Accepts RSM Input
Ecological Models			
Alligator Habitat Suitability Index Model	ENP-SFNRC w/Brandt-Mazzotti (D. Shinde)	Yes	Yes (converted RSM)
Amphibian Community Species Richness (v.2.0.0)	JEM-USGS (H. Waddle, S. Romanach)	Under way	Yes (converted RSM)
Biscayne Bay Nearshore SAV	UM (R. Santos, D. Lirman)	Yes	Yes
Cape Sable Seaside Sparrow Hydrologic Impact Evaluator (HIE)	USACE/ENP-SFNRC (D. Donalson)	Yes	Yes
Estuarine Prey Fish Biomass (v.1.0.0)	JEM-Audubon (J. Lorenz, S. Romanach)	No	No
Everglades Landscape Model (v.3.8.4)	UF (C. Fitz)	Yes	Yes
Everglades Vegetation Landscape Succession (v. 1.1)	ENP-SFNRC (L. Pearlstine)	Yes	Yes (converted RSM)
Florida Bay SAV	SFWMD	Yes	Yes
Juvenile Spotted Seatrout	NOAA-NMFS (C. Kelble)	Yes	Yes
Juvenile Spotted Seatrout	ENP-SFNRC based on Ault et al.	Yes	n/a
Mangrove Fish	NOAA-NMFS	Yes	Yes
Prey-Based Freshwater Fish Density Performance Measure	USACE/ENP-SFNRC (J. Trexler, D. Donalson)	Yes	Yes
Roseate Spoonbill Landscape Suitability Index (v.1.0.0)	JEM- Audubon (J. Lorenz, S. Romanach)	No	No
Slough Vegetation Performance Measure	ENP-SFNRC (M. Zimmerman, G. Reynolds)	Yes	Yes
Southwest Florida Feasibility Study Amphibian Community Habitat Suitability Index	UF (F. Mazzotti, L. Brandt)	No	No
Southwest Florida Feasibility Study Aquatic Fauna Communities Habitat Suitability Index	UF (F. Mazzotti, L. Brandt)	No	No
Southwest Florida Feasibility Study Large Mammal Connectivity	UF (F. Mazzotti, L. Brandt)	No	No
Southwest Florida Feasibility Study Wading Birds Landscape Suitability Index	UF (F. Mazzotti, L. Brandt)	No	No
Wood Stork Foraging Suitability	ENP-SFNRC (L. Pearlstine, A.Lo Galbo, S. Romanach)	Yes	Planned

[a] ELM has been approved for water quality and hydrology applications at a project-level for Decomp. This model has not gone through the USACE ecosystem outputs model approval process with regard to ecological parameters, even though the model has been positively reviewed by an independent panel (Mitsch et al., 2007).

NOTE: This table is intended to provide information about ecological models linked with hydrologic models, and whether they have been used in CERP projects. Information is from

Accepts EDEN Input	Internal (Agency) Review	External Review	**RECOVER review**	**USACE Review**	**Used By Project**
Yes	No	No	No	No	Yes
Yes	Yes	No	No	No	Yes
No	Yes	Yes	FY 13	No	No
Yes	Yes	Yes	No	No	Yes
No	Yes	Yes	No	No	No
No	Yes	Yes	Yes	**Yes** for hydro and WQ, **No** for eco[a]	Yes
Yes	Yes	Yes	No	No	No
No	Yes	Yes	Yes	No	Yes
No	Yes	No	Prelim	Prelim	No
n/a	No	No	No	No	No
No	Yes	No	FY 13	No	No
Yes	Yes	Yes	Yes	Under way	Yes
No	Yes	Yes	No	No	No
No	Yes	Yes	Yes	Under way	Yes
No	Yes	Yes	No	No	No
No	Yes	Yes	No	No	No
No	Yes	Yes	No	No	No
No	Yes	Yes	No	No	No
Yes	No	No	No	No	Yes

federal sources (USACE, NPS, USGS, FWS) and reflects progress as of November 2011. The table was subsequently shared with the SFWMD for review. Models listed here were developed and used after the USACE model review process (USACE, 2011c) went into effect.

SOURCE: A. LoShiavo, USACE, personal communication, 2012; S. Romanach, USGS, personal communication, 2011; K. Taplin, USACE, personal communication, 2012.

including those currently being achieved by the STAs, viable project alternatives may be overlooked. Additionally, project planners and decision makers will lack a full understanding of the implications of delaying hydrologic restoration until the ultimate water quality objectives are met versus proceeding sooner with slightly elevated phosphorus levels.

ELM appears to be the only water quality model that has been approved for use by the USACE and that is actually used in CERP project planning (although not widely so). However, it is not listed among the modeling tools for use in the Central Everglades Planning Project (USACE and SFWMD, 2012). Other water quality models that seem essential to an ongoing Central Everglades Planning Project, such as the Dynamic Model for Stormwater Treatment Areas (DMSTA), have not undergone a formal, external peer review. External peer review is important, particularly for models that are used extensively in the planning process, and peer review of the DMSTA is a high priority.

SCIENCE AND VALUES IN DECISION MAKING

Decision support tools provide an important link between science and decision making and also offer a mechanism to incorporate stakeholder preferences in a formal way to inform decision making. NRC (2010) urged development and use of multi-criteria decision support tools to provide more rigorous scientific support for decision making. In this section the committee discusses the importance of considering stakeholder preferences in addition to science synthesis in decision making and reviews the progress made thus far in developing structured decision support tools to assist CERP decision making.

Decision Making under Risk and Uncertainty

Restoration and management of the Everglades is a major endeavor in decision making under risk and uncertainty. The Everglades is temporally and spatially complex, and meeting CERP goals relies on the successful application of available scientific knowledge to multi-faceted goals for restoration and the integration of the values and priorities of a broad range of stakeholders. Despite the huge body of knowledge acquired on the biotic and abiotic processes underpinning the Everglades, uncertainties about which actions will best promote the goals of the CERP and the effects of such actions on components of the Everglades will always persist. While much is known about the past and current states of the Everglades and the processes that drive change (McVoy et al., 2011; SFWMD, 2011c), uncertainties remain in forecasting the likely consequences of management actions or inaction. For instance, the timescales over which the landscape responds to changes in flow and the difference between degradation and restoration timescales are still highly uncertain (Larsen et al., 2011) and yet important pieces of information for scheduling management actions and restoration efforts. It may require many decades of experiments and field observations to have all the information in hand to make management decisions with confidence. Meanwhile, conditions within the Everglades may continue to deteriorate, and opportunities for restoration could be lost if the system crosses a threshold from which recovery is impossible with the available resources (Polasky et al., 2011; Suding and Hobbs, 2009). Indeed, both financial and natural resources may disappear.

Effective decision making under risk and uncertainty requires careful consideration of scientific information (or knowledge or evidence) and values (or preferences or utilities). While scientific information is based on objective data or evidence (which may be highly uncertain), values are subjective and will usually differ across stakeholders (Borsuk et al., 2001). This distinction between knowledge and values is important because disagreements and conflicts between stakeholders usually arise because of differently held values, but they are often characterized as disagreements because of uncertainty in knowledge. For example, much of the global debate over climate change was attributed to uncertainty in data when preferences over mitigation strategies were largely at play (Opotow and Weiss, 2000; Stoll-Kleemann et al., 2001). It is only when stakeholder values are explicit that negotiation to resolve conflict can be effective. When conflict is inappropriately or wholly attributed to uncertainty in knowledge, the only course of action to resolve the conflict is to keep the "status quo" while more data is collected (Peterson et al., 2005). Stakeholders who prefer the status quo have an incentive to conceal their values by arguing that more time is needed to reduce uncertainty. Stakeholder values are a critically important part of the decision equation (Keeney, 1996), and yet this aspect of decision making is often given short shrift.

Multicriteria Decision Analysis

The CERP requires input and support from multiple stakeholders, who bring different perspectives and values, opinions on desirable outcomes, suggested alternatives, and views about the attributes that the most desirable alternative should have to satisfy a specified goal. Multicriteria Decision Analysis (MCDA) is a framework that aims to articulate these differences and organize them into a coherent framework for decision support. MCDA techniques are usually based on three main components: (1) a decision goal, (2) a list of criteria or objectives that are considered, at least in part, to be necessary to meet that goal, and (3) a list of alternatives from which the best option, or set of options, is selected to reach the decision goal. MCDA uses both scientific knowledge and individual and social values to inform decision making in a structured framework. It can also assist in weighing actions that need to satisfy multiple objectives and has been recommended for this purpose in previous NRC reports (NRC, 2010).

The CERP has made tentative positive steps toward developing MCDA for structured decision support as a response to the recommendations made in NRC (2010). An interagency working group (the Task Force's Working Group and Science Coordination Group) has considered a framework for MCDA and structured decision support based on established theory and successful practical examples with a view to weighing multiple objectives. Some components of the framework have been identified and are currently being explored in a limited and informal way. These include alternatives analysis, performance measures, and linked ecological/hydrological models to inform the outcomes of different management alternatives that address the issue of water quality and quantity. While stakeholder engagement to identify social values has not yet been incorporated, strategies have been tentatively explored to involve stakeholders in decision analysis in a meaningful way. However, the initial enthusiastic activity has lost momentum with staffing changes, budget cuts, and new agency priorities stalling this promising effort.

A collaborative effort is also under way with the USACE Engineer Research and Development Center, RECOVER team members, Everglades scientists, CERP managers, and University of Florida researchers to develop quantitative decision analysis tools to support evaluation and assessment of performance measures and indicators focusing on adaptive management in WCA-3. The case study will be based on regulation of water depth, duration, nutrients, and flow in relation to ridge and slough, tree islands, and aquatic fauna restoration indicators. It will use existing models to simulate the potential outcomes of management alternatives under different future conditions in a way that informs decision making under uncertainty; a related framework for Everglades restoration appears in Fitz et al. (2011). Water quality issues and stakeholder values are not included in the first prototype but could be included later, pending funding and stakeholder buy-in. Funding for this effort ends in 2012, and further funds to extend this work are not expected. This effort represents promising progress in developing structured decision support for weighing multiple objectives and criteria for CERP activities. Similar elements for structured decision support are proposed for the Central Everglades Planning Project, with notable stakeholder participation emulating the River of Grass participatory process.

Important steps have been made toward establishing structured decision support tools for components of the CERP with an emphasis on weighing multiple objectives, and a wide range of stakeholders are now engaged in the Central Everglades Planning Project. However, transparency in the ways in which stakeholder preferences and values will inform decision making has been lacking, resulting in a degree of opacity in how decisions are actually made. Even though the River of Grass participatory process is considered a model of stakeholder participation, it is unclear how that process, if allowed to come to completion, would have translated stakeholder values to inform decisions in a transparent and systematic way. Stakeholder engagement appears to be a prominent and promising feature of the Central Everglades Planning Project, but it remains unclear how stakeholder values will be systematically incorporated into the decision support framework. Current directions in the development of MCDA in the CERP to support decision making acknowledge the importance of stakeholder values and preferences but do not make the important step of highlighting mechanisms for their formal inclusion in structured decision support. Failure to incorporate stakeholder preferences and values in a meaningful and transparent way can (and does) result in conflict, dissent, and, in the extreme case, legal action. The values across the range of stakeholders under risk and uncertainty are as complex and multi-faceted as the science that informs the CERP and should be addressed as such (i.e., they need to be made transparent and systematic and be explicitly incorporated into decision processes). MCDA is one of many frameworks that can be used, in conjunction with mechanisms for building trust and opportunities for deliberation and negotiation, to weigh the effects of different stakeholder values and preferences on CERP outcomes.

CONCLUSIONS AND RECOMMENDATIONS

Recent science synthesis efforts represent an impressive accomplishment, although clearer acknowledgment of conflicts and tradeoffs will be essential to maximize restoration success. Science synthesis is important to advance understanding among the scientific community, inform policy decisions for managers, and translate important findings for the interested public. Collectively, the recent science synthesis efforts, including the 2009 SSR, the STKG report, and the SERES project, among others, successfully address all three of these audiences. Together, they present a relatively consistent view of the scientific principles relevant to the Everglades restoration. If the best aspects of these synthesis efforts can be combined and continued in an efficient, ongoing manner, then the effort can help policy makers coalesce around a common vision of scientific principles, key uncertainties, and challenges. In the future, the effectiveness of the synthesis effort could be improved by explicitly addressing tradeoffs, conflicts, and commonalities among water quality, water quantity, and ecosystem responses.

A comprehensive assessment of monitoring efforts is necessary to ensure that fundamental short- and long-term needs of the CERP are met and critical gaps are addressed in the most cost-effective manner. The recent large and sudden cuts to the RECOVER MAP pose a risk to system-wide assessment, which is important to the success of Everglades restoration. However, NRC committees have previous voiced concern about the ambitious list of indicators for monitoring relative to the likelihood of sustained funding. Recurring evaluations of all monitoring (not just RECOVER-funded monitoring) in support of the CERP should also assess the usefulness of existing datasets and performance measures, consider emerging priorities, and explore opportunities for improved efficiency.

Progress has been made in the development of linked hydrologic and ecological modeling tools, but they remain largely unavailable to project planning, limiting the ability to evaluate differential benefits and impacts of restoration alternatives. No ecological models have been approved for use in benefits analysis for CERP, even though integrated ecological models provide an important tool to assist with project planning, particularly to assess the responses of critical performance measures to project design alternatives and to understand the restoration tradeoffs implicit in alternative plan approaches. If ecological models are to be available to support restoration planning and assessment, then the CERP model development, testing, and review process should be accelerated so that models can move more quickly from development and testing in the research domain to application in support of restoration.

Integrated, or linked, water quality and ecological models are useful tools for exploring the benefits and impacts of project alternatives that affect water quality, water quantity, and habitat. **To identify project designs and implementation sequences that maximize restoration benefits and assess potential impacts, project-planning teams need to analyze a range of inflow water quality conditions, including those that exceed targeted levels.** The legal requirement that water quality constraints be met should not limit the modeling analyses of restoration alternatives under a range of conditions. Being overly cautious with respect to water quality *modeling* could prevent a thorough exploration of restoration options and limit the understanding of water quality constraints in hydrologic restoration projects.

Transparent and systematic mechanisms to build trust and incorporate a range of stakeholder preferences relevant to CERP implementation into decision support frameworks would help to clarify and reduce conflict and enhance transparency. The committee acknowledges recent steps toward establishing formal structured decision support tools for components of the CERP with an emphasis on weighing multiple objectives. Decision support frameworks that build trust and provide opportunities for deliberation and negotiation can also assist in identifying and reducing sources of conflict, although they cannot, on their own, eliminate persistent conflict. Hence, additional mechanisms may be needed to resolve conflict or at the very least, a strategy should be set in place for moving forward in the face of conflict while considering conflicting values, preferences, and objectives.

References

Ad Hoc Senior Scientists. 2007. Draft Recommendations and Conclusions from an Ad-hoc Senior Scientist Workshop on Comprehensive Everglades Restoration Plan (CERP) "Restoration Priorities." September 14, 2007. Miami, FL: Florida Atlantic University.

Axelrad, D. M., T. Lange, and M. C. Gabriel. 2011. Mercury and sulfur monitoring, research and environmental assessment. Chapter 3B in South Florida in 2011 South Florida Environmental Report. West Palm Beach: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2011_sfer/v1/chapters/v1_ch3b.pdf. Accessed April 2, 2012.

Baisden, S., D. Gentry, and A. Watson. 2010. Decompartmentalization of Water Conservation Area 3. Poster presented at the Greater Everglades Ecosystem Restoration Conference, July 2010. Available at http://conference.ifas.ufl.edu/GEER2010/Poster%20PDFs/Watson_Decomp_GEER_SC.pdf.

Balci, P., and L. Bertolotti. 2012. Appendix 10-2: Caloosahatchee River Watershed Protection Plan Update in 2012 South Florida Environmental Report. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/appendices/v1_app10-2.pdf. Accessed June 5, 2012.

Bearzotti, R., H. Chen, M. Chimney, S. Colon, T. DeBusk, M. C. Gabriel, B. Garrett, G. Goforth, N. Iricanin, D. Ivanoff, B. Kattel, C. King, M. Korvela, J. Krenz, J. Galloway, N. Larson, S. Miao, T. T. Piccone, L. Toth, S. K. Xue, and M. Zamorano. 2011. Performance and optimization of the Everglades stormwater treatment areas. Chapter 5 in 2011 South Florida Environmental Report. West Palm Beach: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2011_sfer/v1/chapters/v1_ch5.pdf. Accessed March 29, 2012.

Bedford, B., R. Labisky, A. van der Valk, and J. Volin. 2012. Ecological Effects of Extreme Hydrological Events on the Greater Everglades. Independent Scientific Review Panel Report to RECOVER. February 6, 2012.

Beissinger, S. R. 1995. Modeling extinction in periodic environments: Everglades water levels and Snail Kite population viability. Ecological Applications 5:618-631.

Bennetts, R. E., and W. M. Kitchens. 1997. Population dynamics and conservation of Snail Kites in Florida: the importance of spatial and temporal scale. Colonial Waterbirds 20:324-329.

Bennetts, R. E., M. W. Collopy, and J. A. Rodgers, Jr. 1994. The Snail Kite in the Florida Everglades: a food specialist in a changing environment. Pp. 507-532 in Everglades: The Ecosystem and Its Restoration, S. M. Davis and J. C. Ogden, eds. Delray Beach, FL: St. Lucie Press.

Benoit, J. M., C. Gilmour, A. Heyes, R. P. Mason, and C. Miller. 2003. Geochemical and biological controls over methylmercury production and degradation in aquatic ecosystems. Pp. 262-297 in Biogeochemistry of Environmentally Important Trace Elements, vol. ACS Symposium Series #835, Y. Chai and O. C. Braids, eds. Washington, DC: American Chemical Society.

Bertolotti, L., and P. Balci. 2012. Appendix 10-1: St. Lucie River Watershed Protection Plan Update in 2012 South Florida Environmental Report. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/appendices/v1_app10-1.pdf. Accessed June 5, 2012.

Bhomia, R., P. W. Inglett, D. B. Ivanoff, and K. R. Reddy. 2012. Soil accretion rates in the Stormwater Treatment Areas of the Everglades (in preparation).

Blake, N. 1980. Land into Water—Water into Land: A History of Water Management in Florida. Tallahassee, FL: University Presses of Florida.

Borkhataria, R., D. L. Childers, S. E. Davis, III, V. Engel, E. E. Gaiser, J. W. Harvey, T. E. Lodge, F. Miralles-Wilhelm, G. M. Naja, T. Z. Osborne, R. G. Rivero, M. S. Ross, J. Trexler, T. van Lent, and P. R. Wetzel. 2011. Review of Everglades Science, Tools and Needs Related to Key Science Management Questions. Available at http://www.everglades-seres.org/Products_files/SERES_Reviews_Merged%20copy.pdf. Accessed May 29, 2012.

Borsuk, M., R. Clemen, L. Maguire, and K. Reckhow. 2001. Stakeholder values and scientific modeling in the Neuse River watershed. Group Decision and Negotiation 10:355-373.

Bruland, G. L., T. Z. Osborne, K. R. Reddy, S. Grunwald, S. Newman, and W. F. DeBusk. 2007. Recent changes in soil total phosphorus in the Everglades: Water conservation area 3A. Environmental Monitoring and Assessment 129:379-395.

Caffie-Simpson, W., V. Lopez, M. Morrison, J. Outland, and G. Knecht. 2011. Comprehensive Everglades Restoration Plan Annual Report–470 Report, in Appendix 7-1: 2011 South Florida Environmental Report. Available at http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2011_sfer/v1/appendices/v1_app7-1.pdf. Accessed March 6, 2012.

Carney, A., S. Feken, S. Jones, B. Lawhon, and R. Linch. 2012. Comprehensive Everglades Restoration Plan Annual Report–470 Report, Appendix 1-4 in 2012 South Florida Environmental Report. Available at http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/appendices/v1_app1-4.pdf. Accessed March 29, 2012.

Cattau, C., W. M. Kitchens, B. Reichert, A. Bowling, A. Hotaling, C. Zweig, J. Olbert, K. Pias, and J. Martin. 2008. Snail Kite Demography Annual Report 2009. U. S. Geological Survey Florida Cooperative Fish and Wildlife Research Unit. University of Florida.

Cattau, C., W. M. Kitchens, B. Reichert, J. Olbert, K. Pias, J. Martin, and C. Zweig. 2009. Snail Kite Demography Annual Report 2009. Unpublished report for the U.S. Army Corps of Engineers. Jacksonville, FL: USACE.

Chen, C. Y., and C. L. Folt. 2005. High plankton biomass reduces mercury biomagnification. Environmental Science and Technology 39:115-121.

Clark, M. W., and K. R. Reddy. 2007. Spatial variability and modeling of soil accretion in the Shark River Slough of the Everglades. Final report submitted to the Department of Interior, Everglades National Park.

Craft, C. B., and C. J. Richardson. 1993. Peat accretion and N, P, and organic C accumulation in nutrient-enriched and unenriched Everglades Peatlands. Ecological Applications 3:446-458.

Davis, J. H., Jr. 1946. The peat deposits of Florida: their occurrence, development and uses. Florida Department of Conservation, Geological Bulletin No. 30. Florida Geological Survey. Tallahassee, Florida. Available at http://ufdc.ufl.edu/UF00000489/00001/130j. Accessed May 29, 2012.

Davis, S. M., and J. C. Ogden, eds. 1994. Everglades: The Ecosystem and Its Restoration. Delray Beach, FL: St. Lucie Press.

DeBusk, W. F., and K. R. Reddy. 1998. Turnover of detrital organic carbon in a nutrient-impacted Everglades marsh. Soil Science Society of American Journal 62:1460-1468.

Doering, P. H. 1996. Temporal variability of water quality in the St. Lucie Estuary, South Flordia. Journal of the American Water Resources Association 32:1293-1306.

Doering, P. H., and R. H. Chamberlain. 1999. Water quality and source of freshwater discharge to the Caloosahatchee Estuary, Florida. Journal of the American Water Resource Association 35:793-806.

DOI (Department of the Interior) and USACE (U.S. Army Corps of Engineers). 2005. Central and Southern Florida Project Comprehensive Everglades Restoration Plan: 2005 Report to Congress. Available at http://www.evergladesplan.org/pm/program_docscerp_report_congress_ 2005.cfm.

DOI and USACE. 2011. Comprehensive Everglades Restoration Plan Central and Southern Florida Project: 2010 Report to Congress. Available at http://www.evergladesplan.org/pm/program_docs/cerp_reports_congress.aspx. Accessed January 13, 2012.

Dorcas, M. E., and J. D. Willson. 2011. Invasive pythons in the United States: Ecology of an introduced predator. Athens, GA: University of Georgia Press.

Dorcas, M. E., J. D. Willson, R. N. Reed, R. W. Snow, M. R. Rochford, M. A. Miller, W. E. Meshaka, Jr., P. T. Andreadis, F. J. Mazzotti, C. M. Romagosa, and K. M. Hart. 2012. Severe mammal declines coincide with python proliferation in Everglades National Park. Proceedings of the National Academy of Sciences 109:2418-2422.

Doren, R. F., J. C. Trexler, M. Harwell, and G. R. Best. 2009. Indicators for Everglades Restoration. Ecological Indicators 9(Supp. 1).

Dove, C. J., R. W. Snow, M. R. Rochford, and F. J. Mazzoti. 2011. Birds consumed by the invasive Burmese python (*Python colurus bivittatus*) in Everglades National Park, Florida. The Wilson Journal of Ornithology 123:126-131.

EPA (Environmental Protection Agency). 2010. United States Environmental Protection Agency Amended Determination. Available at http://peer.org/docs/fl/9_22_10_EPA_Amended_Determination.pdf. Accessed March 29, 2012.

EPA. 2012. Fact Sheet – Restoring Everglades Water Quality. Available at http://epa.gov/region4/water/documents/everglades/everglwater-restoration-06132012.pdf. Accessed June 15, 2012.

Farrell, J. M., B. A. Murry, D. J. Leopold, A. Halpern, M. B. Rippke, K. S. Godwin, and S. D. Hafner. 2010. Water-level regulation and coastal wetland vegetation in the upper St. Lawrence River: inferences from historical aerial imagery, seed banks, and *Typha* dynamics. Hydrobiologia 647:127-144

FDEP (Florida Department of Environmental Protection). 1999. Everglades Restoration: Accelerating Implementation of Phase 2 of the Everglades Forever Act. Available at http://www2.fiu.edu/~serp/jrpp/evrgrept.pdf. Accessed May 29, 2012.

Fisher, M. M., and K. R. Reddy. 2001. Phosphorus flux from wetland soils affected by long-term nutrient loading. Journal of Environmental Quality 30:261-271.

Fitz, H. C., G. A. Kiker, and J. B. Kim. 2011. Integrated ecological modeling and decision analysis within the Everglades landscape. Critical Reviews in Environmental Science and Technology 41:517-547.

Flaig, E. G., and K. R. Reddy. 1995. Fate of phosphorus in the Lake Okeechobee watershed, Florida, USA: Overview and recommendations. Ecological Engineering 5:127-142.

Fleming. G. K. 2012. Letter to Mr. H. T. Vinyard, Jr. Florida Department of Environmental Protection. Atlanta, Georgia. U. S. Environmental Protection Agency. June 13.

Fling, H., N. Auman, T. Armentano, and F. Mazzotti. 2009. The role of flow in the Everglades Landscape. University of Florida IFAS Extension Circular DIR 1452. Available at http://edis.ifas.ufl.edu/uw199. Accessed on February 22, 2011.

FWS (U.S. Fish and Wildlife Service). 2005. Biological Opinion on STA 2 Cell 4 and STA 5 Flowway 3. Vero Beach, FL: South Florida Field Office.

FWS. 2010. USFWS Multi-Species Transition Strategy for Water Conservation Area 3A. Vero Beach, FL: U.S. Fish and Wildlife Service South Florida Ecosystems Services Office.

Gaiser, E. 2009. Periphyton as an indicator of restoration in the Florida Everglades. Ecological Indicators 9:37-45.

Gaiser, E. E., L. J. Scinto, J. H. Richards, K. Jayachandran, D. L. Childers, J. C. Trexler, and R. D. Jones. 2004. Phosphorus in periphyton mats provides the best metric for detecting low-level P enrichment in an oligotrophic wetland. Water Research 38:507-516.

Gaiser, E. E., J. C. Trexler, J. H. Richards, D. L. Childers, D. Lee, A. L. Edwards, L. J. Scinto, K. Jayachandran, G. B. Noe, and R. D. Jones. 2005. Cascading ecological effects of low-level phosphorus enrichment in the Florida Everglades. Journal of Environmental Quality 34:717-723.

Gaiser, E. E., J. H. Richards, J. C. Trexler, R. D. Jones, and D. L. Childers. 2006. Periphyton responses to eutrophication in the Florida Everglades: Cross-system patterns of structural and compositional change. Limnology and Oceanography 51:617-630.

Gaiser, E., P. V. McCormick, S. E. Hagerthey, and A. D. Gottlieb. 2011. Landscape patterns of periphyton in the Florida Everglades. Critical Review in Environmental Science and Technology 41(S1):92-120.

Gleason, P. J., and W. Spackman, Jr. 1974. Calcareous periphyton and water chemistry in the Everglades. Pp. 146-181 in Environments of South Florida: Present and past memoir (Second Edition), P. J. Gleason, ed. Coral Gables, FL: Miami Geological Society.

Grunwald, M. 2006. The Swamp: The Everglades, Florida, and the Politics of Paradise. New York: Simon and Schuster, Inc.

Gu, B., D. M. Axelrad, and T. Lange. 2012. Regional mercury and sulfur monitoring and environmental assessment, Chapter 3B in the South Florida Environmental Report. West Palm Beach: South Florida Water Management District. Available at http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/chapters/v1_ch3b.pdf. Accessed on May 14, 2012.

Gunderson, L. H., and J. R. Snyder. 1994. Fire patterns in the southern Everglades. Pp. 291-306 in Everglades: The Ecosystem and its Restoration, S. M. Davis and J. C. Ogden, eds. Delray Beach, FL: St. Lucie Press.

Hagerthey, S. E., J. J. Cole, and D. Kilbane. 2010. Aquatic metabolism in the Everglades: Dominance of water column heterotrophy. Limnology and Oceanography 55:653-666.

Harvey, J. W., G. B. Noe, L. G. Larsen, D. J. Nowacki, and L. E. McPhillips. 2011. Field flume reveals aquatic vegetation's role in sediment and particulate phosphorus transport in a shallow aquatic ecosystem. Geomorphology 126(3-4):297-313.

Harvey, J., L. L. Larsen, K. Skalak, and J. Choi. 2012. Greater Everglades: Five Reasons Why Flow is Important, in Science Workshop for CERP, February 13, 2012, West Palm Beach, Florida, SFWMD. Available at http://sfwmd.iqm2.com/Citizens/VideoMain.aspx?MeetingID=1122. Accessed on February 21, 2012.

Healey, M. C., M. D. Dettinger, and R. B. Norgaard, eds. 2008. The State of Bay-Delta Science, 2008. Sacramento, CA: CALFED Science Program. Available at http://www.science.calwater.ca.gov/publications/sbds.html. Accessed May 14, 2012.

Hiers, J. K., J. J. O'Brien, R. E. Will, and R. J. Mitchell. 2007. Forest floor depth mediates understory vigor in xeric *Pinus palustris* ecosystems. Ecological Applications 17:806-814.

Hiers, J. K., R. J. Mitchell, A. Barnett, J. R. Walters, M. Mack, B. Williams and R. Sutter. 2012. The dynamic reference concept: measuring restoration success in a rapidly changing no-analogue future. Ecological Restoration 30:27-36.

Holling, C. S., L. H. Gunderson, and C. J. Walters. 1994. The structure and dynamics of the Everglades system: guidelines for ecosystem restoration. Pp.741-756 in Everglades: The Ecosystem and Its Restoration, S. M. Davis and J. C. Ogden, eds. Delray Beach, Florida: St. Lucie Press.

Ivanoff, D., S. Colon, and H. Chen. 2012. STA vegetation survey results. Appendix 5-3 in 2012 South Florida Environmental Report. West Palm Beach: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/appendices/v1_app5-3.pdf. Accessed March 29, 2012.

Jackson, S. 2011. Kissimmee River Restoration Everglades Division, Upper East Coast and Kissimmee/Lake Okeechobee Section. Jacksonville, FL: U.S. Army Corps of Engineers. Available at http://www.saj.usace.army.mil/Divisions/Everglades/Branches/ProjectExe/Sections/UECKLO/KRR.htm. Accessed July 21, 2011.

Jones, B. L., S. G. Bousquin, D. H. Anderson, D. J. Colangelo, L. Spencer, J. W. Koebel Jr., M. D. Cheek, J. Valdes, B. Anderson, and C. Carlson. Chapter 11: Kissimmee Basin in 2011 South Florida Environmental Report. Available at http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2011_sfer/v1/chapters/v1_ch11.pdf. Accessed June 6, 2012.

Kalla, P., C. Pollman, D. Scheidt, and X. Yin. 2010. Mercury in the Greater Everglades: Changes in Bio-magnification over Time, and Relationships to Other Contaminants; Across the Landscape-R-EMAP 1995-2005. Greater Everglades Ecosystem Restoration (GEER) Meeting, July 2010. Program and Abstracts. Naples, Florida.

Keeney, R. L. 1996. Value-Focused Thinking: A Path to Creative Decision Making. Cambridge, MA: Harvard University Press.

Kiker, C. F., J. W. Milon, and A. W. Hodges. 2001. Adaptive learning for science based policy: The Everglades Restoration. Ecological Economics 37:403-416.

Kirkman, L. K., R. J. Mitchell, R. C. Helton, and M. B. Drew. 2001. Productivity and species richness across an environmental gradient in a fire-dependent ecosystem. American Journal of Botany 88:2119-2128.

Kitchens, W. M., R. E. Bennetts, and D. L. DeAngelis. 2002. Linkages between the snail kite population and wetland dynamics in a highly fragmented south Florida hydroscape. Pp. 183-203 in Linkages Between Ecosystems: The South Florida Hydroscape, J. W. Porter and K. G. Porter, eds. Delray Beach, FL: CRC/St. Lucie Press.

Koch, M. S., and K. R. Reddy. 1992. Distribution of soil and plant nutrients along a trophic gradient in the Florida Everglades. Soil Science Society of American Journal 56:1492-1499.

Larsen, L. G., and J. W. Harvey. 2010. How vegetation and sediment transport feedbacks drive landscape change in the Everglades and wetlands worldwide. The American Naturalist. Available at http://www.jstor.org/stable/10.1086/655215?ai=sa&ui=9uzh&af=H&. Accessed February 22, 2012.

Larsen, L. G., J. Harvey, and J. P. Crimaldi. 2009. Predicting bed shear stress and its role in sediment dynamics and restoration potential of the Everglades and other vegetated flow systems. Ecological Engineering 35(12):1773-1785.

Larsen, L., N. Aumen, C. Bernhardt, V. Engel, and T. Givnish. 2011. Recent and historic drivers of landscape change in the everglades ridge, slough, and tree island mosaic. Critical Reviews in Environmental Science and Technology 41:344-381.

Liao, X., and P. W. Inglett. 2012. Biological nitrogen fixation in periphyton of native and restored Everglades marl prairies. Wetlands 32:137-148.

Light, S. S., and J. W. Dineen. 1994. Water control in the Everglades: A historical perspective. Pp. 47-84 in Everglades: The Ecosystem and Its Restoration, S. M. Davis and J. C. Ogden, eds. Boca Raton, FL: St. Lucie Press.

Lord, L. A. 1993. Guide to Florida Environmental Issues and Information. Winter Park, FL: Florida Conservation Foundation.

MacVicar, Federico & Lamb, Inc. 2011a. Evaluating the Performance of a Partially Penetrating Seepage Barrier between Everglades National Park and the L-31N Canal: A Report to the Miami-Dade Limestone Products Association. Available at http://www.l31nseepage.org/DOCUMENTS/L-31N%20Seepage%20Management%20Post-Construction%20Report%207-2011.pdf. Accessed June 7, 2012

MacVicar, Federico & Lamb, Inc. 2011b. Evaluating the Performance of a Partially Penetrating Seepage Barrier between Everglades National Park and the L-31N Canal: A Report to the Miami-Dade Limestone Products Association. Available at http://www.l31nseepage.org/DOCUMENTS/Summary%20of%20Model%20Results%20for%20the%20L-31N%20Seepage%20Barrier%208-2011.pdf. Accessed June 7, 2012.

Marshall, C., Jr., R. Pielke Sr., L. Steyaert, and D. Willard. 2004. The impact of anthropogenic land cover change on the Florida peninsula sea breezes and warm season sensible weather. Monthly Weather Review 132:28-52.

McCormick, P. V., and M. B. O'Dell. 1996. Quantifying periphyton responses to phosphorus in the Florida Everglades: a synoptic-experimental approach. Journal of North American Benthological Society 15:450-468.

McCormick, P. A., and R. J. Stevenson. 1998. Periphyton as a tool for ecological assessment and management in the Florida Everglades. Journal of Phycology 4:726-733.

McCormick, P. V., R. S. Rawlick, K. Lurding, E. P. Smith, and F. H. Sklar. 1996. Periphyton-water quality relationships along a nutrient gradient in the northern Florida Everglades. Journal of North American Benthological Society 15:433-449.

McCormick, P. V., S. Newman, S. Miao, D. E. Gawlik, D. Marley, K. R. Reddy, and T. D. Fontaine. 2002. Effects of anthropogenic phosphorus inputs on the Everglades. Pp. 123-146 in The Everglades, Florida Bay and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook, J. W. Porter and K. G. Porter, eds. Boca Raton, Florida: CRC Press.

McDowell, L. L., J. C. Stephens, and E. H. Stewart. 1969. Radiocarbon chronology of the Florida Everglades Peat. Soil Science Society of America Proceedings 33:743-745.

McLatchey, G. P., and K. R. Reddy. 1998. Regulation of organic matter decomposition and nutrient release in a wetland soil. Journal of Environmental Quality 27:1268-1274.

McPherson, B. F., and R. Halley. 1996. The South Florida Environment: A Region Under Stress. USGS Circular 1134.Washington, DC: U.S. Printing Office.

McVoy, C. W., W. P. Said, J. Obeysekare, J. A. Van Arman, and T. W. Dreschel. 2011. Landscapes and Hydrology of the Predrainage Everglades. Gainesville, FL: University Press of Florida.

Meeder, J. F., M. S. Ross, G. Telesnicki, P. L. Ruiz, and J. P. Sah. 1996. Vegetation analysis in the C-111/Taylor Slough basin. Document 1: The southeast saline Everglades revisited: a half-century of coastal vegetation change. Document 2: Marine transgression in southeast saline Everglades, Florida: rates, causes, and plant sediment responses. Final Report. Contract C-4244. Southeast Environmental Research Program. Miami, FL: Florida International University.

Meeker, M. 2012. Everglades Restoration Strategies. Presentation to the SFWMD Governing Board, June 4, 2012. Available at http://static-lobbytools.s3.amazonaws.com/press/20120604_everglades_restoration_strategies_presentation_to_the_sfwmd_governing_board.pdf. Accessed June 6, 2012.

Meshaka, W. E., Jr., W. F. Lotus, and T. Steiner. 2000. The herpetofauna of Everglades National Park. Florida Scientist 63:84-103.

Miao, S. L., S. Newman, and F. H. Sklar. 2000. Effects of habitat nutrients and sources on growth and expansion of *Typha domingensis*. Aquatic Botany 68:297-311.

Mitsch, W. J., L. E. Band, and C. F. Cerco. 2007. Everglades Landscape Model (ELM), Version 2.5: Peer Review Panel Report. Submitted January 3, 2007 to the South Florida Water Management District, West Palm Beach, FL. Available at http://my.sfwmd.gov/elm (Peer Review: Comments tab). Accessed June 7, 2012.

Mo, C., V. Ciuca, and S. Van Horn. 2012. Settlement Agreement Report: Fourth Quarter, October-December 2011. South Florida Water Management District. Available at www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/sa_rpt_oct-dec2011.pdf. Accessed March 11, 2012.

Newman, S., J. B. Grace, and J. W. Koebel. 1996. Effects of nutrients and hydroperiod on *Typha*, *Cladium*, and *Eleocharis*: implications for Everglades restoration. Ecological Applications 6:774-783.

Noe, G. B., D. L. Childers, and R. D. Jones. 2001. Phosphorus biogeochemistry and the impact of phosphorus enrichment: Why is the Everglades so unique? Ecosystems 4:603-624.

Noe, G. B., D. L. Childers, A. L. Edwards, E. Gaiser, K. Jayachandran, D. Lee, J. Meeder, J. Richards, L. J. Scinto, J. C. Trexler, and R. D. Jones. 2002. Short-term changes in phosphorus storage in an oligotrophic Everglades wetland ecosystem receiving experimental nutrient enrichment. Biogeochemistry 59:239-267.

NPS (National Park Service). 2010. EVER Tamiami Trail Modifications: Next Steps, Final Environmental Impact Statement - November 2010. Available at http://parkplanning.nps.gov/document.cfm?parkID=374&projectID=26159&documentID=37956. Accessed June 15, 2012.

NPS (National Park Service). 2011. Tamiami Trail Modifications: Next Steps Website. Available at http://www.nps.gov/ever/naturescience/nessrestoration.htm. Accessed July 14, 2011.

NRC (National Research Council). 1995. Science and the Endangered Species Act. Washington, DC: National Academy Press.

NRC. 1996. Upstream: Salmon and Society in the Pacific Northwest. Washington, DC: National Academy Press.

NRC. 1999. New Directions for Water Resources Planning for the U.S. Army Corps of Engineers. Washington, DC: National Academy Press.

NRC. 2001. Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan: A Critique of the Pilot Projects and Related Plans for ASR in the Lake Okeechobee and Western Hillsboro Areas. Washington, DC: National Academy Press.

NRC. 2002a. Regional Issues in Aquifer Storage and Recovery for Everglades Restoration. Washington, DC: National Academy Press.

NRC. 2002b. Florida Bay Research Programs and Their Relation to the Comprehensive Everglades Restoration Plan. Washington, DC: National Academy Press.

NRC. 2003a. Does Water Flow Influence Everglades Landscape Patterns? Washington, DC: National Academies Press.

NRC. 2003b. Adaptive Monitoring and Assessment for the Comprehensive Everglades Restoration Plan. Washington, DC: National Academies Press.

NRC. 2003c. Science and the Greater Everglades Ecosystem Restoration: An Assessment of the Critical Ecosystems Initiative. Washington, DC: National Academies Press.

NRC. 2004a. River Basins and Coastal Systems Planning Within the U.S. Army Corps of Engineers. Washington, DC: National Academies Press.

NRC. 2004b. Valuing Ecosystem Services: Towards Better Environmental Decision-Making. Washington, DC: National Academies Press.

NRC. 2005. Re-Engineering Water Storage in the Everglades: Risks and Opportunities. Washington, DC: National Academies Press.

NRC. 2007. Progress Toward Restoring the Everglades: The First Biennial Review—2006. Washington, DC: National Academies Press.

NRC. 2008. Progress Toward Restoring the Everglades: The Second Biennial Review—2008. Washington, DC: The National Academies Press.

NRC. 2010. Progress Toward Restoring the Everglades: The Third Biennial Review—2010. Washington, DC: National Academies Press.

NRC. 2012. Sustainable Water and Environmental Management in the California Bay-Delta. Washington, DC: National Academies Press.

Ogden, J. 2005. Everglades Ridge and Slough Conceptual Ecological Model. Wetlands 25: 810-820.

Ogram, A., A. Chauhan, K. Sharma Inglett, K. Jayachandran, and S. Newman. 2011. Microbial ecology and Everglades restoration. Critical Review in Environmental Science and Technology 41(S1): 289-308.

Opotow, S., and L. Weiss. 2000. New ways of thinking about environmentalism: Denial and the process of moral exclusion in environmental conflict. Journal of Social Issues 56:475-490.

Osborne, T. Z., G. L. Bruland, S. Newman, K. R. Reddy, and S. Grunwald. 2011a. Spatial distributions and eco-partitioning of soil biogeochemical properties in Everglades National Park. Environmental Monitoring and Assessment.

Osborne, T. Z., S. Newman, D. J. Scheidt, P. I. Kalla, G. L. Bruland, M. J. Cohen, L. J. Scinto, and L. R. Ellis. 2011b. Landscape patterns of significant soil nutrients and contaminants in the greater Everglades ecosystem: Past, present, and future. Critical Reviews in Environmental Science and Technology 41:121-148.

Osland, M., J. E. Gonzalez, and C. J. Richardson. 2011. Restoring diversity after cattail expansion: disturbance, resilience, and seasonality in a tropical dry wetland. Ecological Applications 21:715-728.

Payne, G. G., and S. K. Xue. 2012. Water quality in the Everglades Protection Area. Chapter 3A in 2012 South Florida Environmental Report. West Palm Beach: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/chapters/v1_ch3a.pdf. Accessed April 2, 2012.

Payne, G., K. Weaver, and T. Bennett. 2003. Development of a numeric phosphorus criterion for the Everglades Protection Area. Chapter 5 in 2003 Everglades Consolidated Report, West Palm Beach: South Florida Water Management District.

Payne, G. G., K. Hallas, and S. K. Xue. 2011. Status of water quality in the Everglades Protection Area. Chapter 3A in 2011 South Florida Environmental Report. West Palm Beach: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2011_sfer/v1/chapters/v1_ch3a.pdf. Accessed April 1, 2012.

Perry, W. 2004. Elements of South Florida's Comprehensive Everglades Restoration Plan. Ecotoxicology 13:185-193.

Peterson, M. N., M. J. Peterson, and T. R. Peterson. 2005. Conservation and the myth of consensus. Conservation Biology 19:762-767.

Pickhardt, P. C., C. L. Folt, C. Y. Chen, B. Klaue, and J. D. Blum. 2002. Algal blooms reduce the uptake of toxic methylmercury in freshwater food webs. Proceedings of the National Academy of Sciences 99:4419-4423.

Pietro, K., G. Germain, R. Bearzotti, and N. Iricanin. 2010. STA performance, compliance and optimization. Chapter 5 in South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District.

Platt, W. J., and S. L. Rathbun. 1993. Dynamics of an old-growth longleaf pine population. Proceedings of the Tall Timbers Fire Ecology Conference 18:275-297.

Polasky, S., S. R. Carpenter, C. Folke, and B. Keeler. 2011. Decision-making under great uncertainty: environmental management in an era of global change. Trends in Ecology & Evolution 26:398-404.

Pyron, R. A., F. T. Burbrink, and T. J. Guiher. 2008. Claims of potential expansion throughout the U.S. by invasive python species are contradicted by ecological niche models. PLoS ONE 3:e2931.

RECOVER. 2007. Development and Application of Comprehensive Everglades Restoration Plan System-wide Performance Measures. Available at http://www.evergladesplan.org/pm/recover/perf_systemwide.aspx. Accessed June 15, 2008.

RECOVER. 2010. Comprehensive Everglades Restoration Plan: 2009 System Status Report. Available at http://www.evergladesplan.org/pm/ssr_2009/cerp_ssr_2009.aspx. Accessed May 29, 2012.

RECOVER. 2011a. Scientific and Technical Knowledge Gained in Everglades Restoration (1999-2009). Restoration Coordination and Verification, U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. Available at http://www.evergladesplan.org/shared-definition/sd_2010.aspx. Accessed May 29, 2012.

RECOVER. 2011b. Monitoring and Assessment Plan (MAP) Regional and System-wide Prioritization Process: Instructions. August 2011.

RECOVER. 2012. MAP Implementation Summary Report. January 2012.

Reddy, K. R., G. R. Best, and F. Sklar. 2011. Biogeochemistry and water quality of the Everglades: Symposium interview. Critical Reviews in Environmental Science and Technology 41(S1):1-3.

Reddy, K. R., R. D. DeLaune, W. F. DeBusk, and M. Koch. 1993. Long-term nutrient accumulation rates in the Everglades wetlands. Soil Science Society of America Journal 57: 1145-1155.

Reddy, K. R., Y. Wang, W. F. DeBusk, M. M. Fisher, and S. Newman. 1998. Forms of soil phosphorus in selected hydrologic units of the Florida Everglades. Soil Science Society of America Journal 62:1134-1147.

Reddy, K. R., J. R. White, A. Wright, and T. Chua. 1999. Influence of phosphorus loading on microbial processes in soil and water column of wetlands. Pp. 249–273 in Phosphorus Biogeochemistry in Subtropical Ecosystems: Florida as a Case Example, K. R. Reddy, G. A. O'Connor, and C. L. Schelske, eds. Boca Raton, FL: CRC Press/Lewis Publishers.

Reddy, K. R., S. Newman, S. Grunwald, T. Z. Osborne, R. Corstanje, G. Bruland, and R. Rivero. 2005. Spatial distribution of soil nutrients in the Greater Everglades Ecosystem, Final Report. West Palm Beach, FL: South Florida Water Management District.

Reddy, K. R., and R. D. DeLaune. 2008. Biogeochemistry of Wetlands: Science and Applications. Boca Raton, FL: CRC Press Taylor and Francis Group.

Reichert, B., C. Cattau, W. Kitchens, R. Fletcher, J. Olbert, K. Pias, C. Zweig and J. Wood. 2011. Snail kite demography annual report 2010. U.S. Geological Survey Florida Cooperative Fish and Wildlife Research Unit, University of Florida.

Richardson, C. J. 2008. The Everglades experiments: Lessons for ecosystem restoration. New York: Springer-Verlag.

Robbins, J. A., K. R. Reddy, C. W. Holmes, N. R. Moorhead, M. Marot, and R. W. Rood. 1999. Sediment core dating with ^{137}Cs. Final Report submitted to the South Florida Water Management District. Contract No. C-5324.

Rodda, G. H., and J. A. Savidge. 2007. Biology and impacts of Pacific island invasive species. 2. *Boiga irregularis,* the Brown Tree Snake (Reptilia: Colubridae). Pacific Science 61:307-324.

Rodda, G. H., C. S. Jarnevich, and R. N. Reed. 2009. What parts of the US mainland are climatically suitable for invasive alien pythons spreading from Everglades National Park? Biological Invasions 11:241-252.

Rodgers, L., M. Bodle, and F. Laroche. 2010. Chapter 9: Status of nonindigenous species in the South Florida environment in 2010 South Florida Environmental Report. Available online at http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_sfer/tab2236037/2010%20report/v1/chapters/v1_ch9.pdf. Accessed June 7, 2012.

Rodgers, L., M. Bodle, D. Black, and F. Laroche. 2012. Chapter 7: Status of Nonindigenous Species in 2012 South Florida Environmental Report. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/chapters/v1_ch7.pdf. Accessed June 5, 2012.

Ruhl, J. B. 2004. The battle over Endangered Species Act methodology. Environmental Law 34:555-603.

Rutchey, K., T. Schall, and F. Sklar. 2008. Development of vegetation maps for assessing Everglades restoration progress. Wetlands 28:806-816.

Scheffer, M., S. Carpenter, J. A. Foley, C. Folke, and B. Walker. 2001. Catastrophic shifts in ecosystems. Nature 413:591–596.

Scheidt, D. J., and P. I. Kalla. 2007. Everglades ecosystem assessment: Water management and quality, eutrophication, mercury contamination, soils and habitat: Monitoring for adaptive management: A REMAP status report. EPA 904-R-07-001. Athens, GA: USEPA Region 4. Available at http://www.epa.gov/region4/sesd/reports/epa904r07001.html. Accessed May 29, 2012.

Scheidt, D., J. Stobier, R. Jones, and K. Thornton. 2000. South Florida ecosystem assessment: Everglades water management, soil loss, eutrophication and habitat. Available at http://www.epa.gov/region4/sesd/reports/epa904r00003.html. Accessed March 11, 2012

Scholl, D. W., F. C. Craighead, and M. Stuiver. 1969. Florida submergence curve revisited: Its relation to coastal sedimentation rates. Science 163:562-564.

SCT (Science Coordination Team). 2003. The Role of Flow in the Everglades Ridge and Slough Landscape. Available at http://www.sfrestore.org/sct/docs/. Accessed November 12, 2009.

SEI (Sustainable Ecosystems Institute). 2003. South Florida Ecosystem Restoration Multi-Species Avian Workshop: Scientific Panel Report. Portland, OR: SEI.

SEI. 2007. Everglades Multi-Species Avian Ecology and Restoration Review Final Report. November 2007. Portland, OR: SEI.

SERES Project Team. 2010. Key Questions at the Interface of Science and Management. Available at http://www.everglades-seres.org/Products_files/SERESKeyScienceManagementQuestions_1.pdf. Accessed May 29, 2012.

SFERTF (South Florida Ecosystem Restoration Task Force). 2000. Coordinating Success: Strategy for Restoration of the South Florida Ecosystem (July 2000). Available at http://www.sfrestore.org/documents/work_products/coordinating_success_2000.pdf. Accessed August 20, 2010.

SFERTF. 2006. Coordinating Success: Strategy for Restoration of the South Florida Ecosystem and Tracking Success, Biennial Report for FY 2004–2006 of the South Florida Ecosystem Restoration Task Force. Available at http://www.sfrestore.org/ documents/2004_2006_strategic_plan_volume%20I.pdf. Accessed March 11, 2012.

SFERTF. 2007. Tracking Success: 2007 Integrated Financial Plan for the South Florida Ecosystem Restoration Task Force. Available at http://www.sfrestore.org/documents/2007_ifp.pdf. Accessed on March 11, 2012

SFERTF. 2009. Tracking Success: 2009 Integrated Financial Plan for the South Florida Ecosystem Restoration Task Force. Available at http://www.sfrestore.org/documents/Integrated_Financial_Plan_09.pdf. Accessed March 11, 2012.

SFERTF. 2010a. South Florida Ecosystem Restoration Land Conservation Strategy. Available at http://www.sfrestore.org/issueteams/latt/documents/LCS_final_accepted_October_2010.pdf. Accessed March 6, 2012.

SFERTF. 2010b. System-wide Ecological Indicators for Everglades Restoration. Available at http://www.sfrestore.org/documents/Final_System-wide_Ecological_Indicators.pdf. Accessed March 29, 2012.

SFERTF. 2011. 2011 Integrated Financial Plan for the South Florida Ecosystem Restoration Task Force. Available at http://www.sfrestore.org/documents/2011_Integrated_Financial_Plan_Final.pdf. Accessed May 29, 2012.

SFERTF. 2012. South Florida Ecosystem Restoration Task Force and Working Group, "Cross-Cut Budget". Available at http://www.sfrestore.org/documents/index.html. Accessed January 30, 2012.

SFNRC (South Florida Natural Resources Center, Everglades National Park). 2010. Tamiami Trail Modifications: Next Steps Project, Project Evaluation Report. SFNRC Technical Series 2010:1. Available at http://www.nps.gov/ever/naturescience/loader.cfm?csModule=security/getfile&PageID=309168. Accessed July 13, 2011.

SFWMD (South Florida Water Management District). 2004. Comprehensive Annual Financial Report (CAFR)—2004. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2004_sfwmd_cafr.pdf. Accessed March 29, 2012.

SFWMD. 2005. Comprehensive Annual Financial Report (CAFR)—2005. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2005_sfwmd_cafr.pdf. Accessed March 29, 2012.

SFWMD. 2006. Comprehensive Annual Financial Report (CAFR)—2006. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2006_sfwmd_cafr.pdf. Accessed March 29, 2012.

SFWMD. 2007. Comprehensive Annual Financial Report (CAFR)—2007. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2007_sfwmd_cafr.pdf. Accessed March 29, 2012.

SFWMD. 2008a. Comprehensive Annual Financial Report (CAFR)—2008. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2008_sfwmd_cafr.pdf. Accessed March 29, 2012.

SFWMD. 2008b. FY 2009 Budget Document. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2009_budget.pdf. Accessed March 29, 2012.

SFWMD. 2009a. Comprehensive Annual Financial Report (CAFR)—2009. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2009_sfwmd_cafr.pdf. Accessed March 29, 2012.

SFWMD. 2009b. 2010 SFWMD Budget Reflects Continued Commitment to Ecosystem Restoration. West Palm Beach, FL: South Florida Water Management District. Available at http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/nr_2009_0922_fy2010_budget.pdf. Accessed April 2, 2012.

SFWMD. 2010. Comprehensive Annual Financial Report (CAFR)—2010. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2010_sfwmd_cafr.pdf. Accessed March 29, 2012.

SFWMD. 2011a. Monthly Financial Statement—September 2011. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/monthly_financial_statement_2011_september_updated.pdf. Accessed March 29, 2012.

SFWMD. 2011b. Standard Format Tentative FY 2012 Budget Submission. Available at http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/fy2012_budget_submission_august_1_report.pdf. Accessed March 29, 2012.

SFWMD. 2011c. 2011 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District.

SFWMD. 2012. A Resolution of the Governing Board of the South Florida Water Management District Amending The Fiscal Year 2011 - 2012 Budget—Resolution Number 2011-201. Passed and adopted February 9, 2012. Available at http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/fy12_ba_no_1_res_2012_201.pdf. Accessed March 29, 2012.

SFWMD and FDEP. 2010. South Florida Environmental Report: Volume 1. The South Florida Environment. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_sfer/tab2236037/2010_report/v1/vol1_table_of_contents.html. Accessed March 24, 2012.

SFWMD and FDEP. 2012. South Florida Environmental Report: Volume 1. The South Florida Environment. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/vol1_table_of_contents.html. Accessed March 24, 2012.

SFWMD and USACE. 2010. CERP Project: Biscayne Bay Fact Sheet. Available at http://www.evergladesplan.org/docs/fs_bbcw_june_2010.pdf. Accessed June 15, 2011.

SFWMD and USACE. 2011. CERP Project: Picayune Strand. Available at http://www.evergladesplan.org/pm/projects/proj_30_sgge.aspx. Accessed June 14, 2011.

SFWMD, FDEP, and FDACS (Florida Department of Agriculture and Consumer Services). 2008. Lake Okeechobee Watershed Construction Project: Phase II Technical Plan. Available online at https://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_koe/portlet_northerneverglades/tab2302093/lakeo_watershed_construction%20proj_phase_ii_tech_plan.pdf. Accessed June 5, 2012.

SFWMD, FDEP, and FDACS. 2011. 2011 Lake Okeechobee Protection Plan Update. Available at http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/lopp_update_2011.pdf. Accessed June 5, 2012.

Shih, S. F., B. Glaz, and R. E. Barnes, Jr. 1998. Subsidence of organic soils in the Everglades Agricultural Area during the past 19 years. Soil and Crop Science Society of Florida Proceedings 57:20-29.

Sklar, F. 2012. How Has Our Understanding of the Greater Everglades Ecosystem Changed Since 2001. In South Florida Ecosystem Restoration Task Force SCG Sponsored Public Workshop on Science. February 14, 2012. Available at http://www.sfrestore.org/cepp/meetings/021312/GE_Science_for_CEPP.pdf. Accessed May 25, 2012.

Sklar, F. H., and A. V. D. Valk. 2002. Tree Islands of the Everglades: An Overview. Pp. 1-18 in Tree Islands of the Everglades, F. H. Sklar and A. V. D. Valk, eds. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Sklar, F., C. McVoy, R. Van Zee, D. E. Gawlik, K. Tarboton, D. Rudnick, S. Miao, and T. Armentano. 2001. The effects of altered hydrology on the ecology of the Everglades. Pp. 39-82 in The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook, J. W. Porter and K. G. Porter, eds. Boca Raton, Florida: CRC Press.

Sklar, F. H., M. J. Chimney, S. Newman, P. McCormick, D. Gawlik, S. L. Miao, C. W. McVoy, W. P. Said, J. Newman, C. A. Coronado, G. Crozier, M. Korvela, and K. Rutchey. 2005. The ecological-societal underpinnings of Everglades restoration. Frontiers in Ecology and the Environment 3:161-169.

Sklar, F., T. Dreschel, and K. Warren. 2009. Ecology of the Everglades Protection Area. Chapter 6 in 2009 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at https://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_sfer/tab2236041/2009report/report/v /vol1_table_of_contents.html.

Sklar, F., T. Dreschel, and K. Warren. 2010. Ecology of the Everglades Protection Area. Chapter 6 in 2010 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_sfer/tab2236037/2010%20report/v1/chapters/v1_ch6.pdf. Accessed April 2, 2012.

Sklar, F., T. Dreschel, and K. Warren. 2011. Ecology of the Everglades Protection Area. Chapter 6 in 2011 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2011_sfer/v1/chapters/v1_ch6.pdf. Accessed May 29, 2012.

Sklar, F., T. Dreschel, and R. Stanek. 2012. Everglades research and evaluation. Chapter 6 in 2012 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v1/chapters/v1_ch6.pdf. Accessed April 2, 2012.

Sklar, F., L. Heisler, A. McLean, C. Coronado-Molina, C. Saunders, G. Kiker, and P. Fletcher. In review. The Conceptual Ecological Model for Everglades Tree Islands.

Smykowski, M. 2012. Five-Year Capital Improvements Plan. Chapter 4 in 2012 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2012_sfer/v2/chapters/v2_ch4.pdf. Accessed March 29, 2012.

Snyder, G. H. 2005. Everglades Agricultural Area soil subsidence and land use projections. Proceedings of the Soil and Crop Science Society of Florida 64:44-51.

Society for Ecological Restoration International Science & Policy Working Group. 2004. The SER International Primer on Ecological Restoration. Available at http://www.ser.org/content/ecological_restoration_primer.asp. Accessed April 3, 2012.

SSG (Science Sub-Group). 1993. Federal Objectives for the South Florida Restoration by the Science Sub-Group of the South Florida Management and Coordination Working Group. Miami, FL.

Stephens, J. C., C. H. Allen, Jr., and E. Chen. 1984. Organic soil subsidence. Reviews in Engineering Geology 16:107-122

Stevens, J. C. and L. Johnson. 1951. Subsidence of organic soils in the upper Everglades region of Florida. Soil Science Society of Florida Proceedings 11:191-237.

Stoddard, J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. H. Norris. 2006. Setting exceptions for the ecological condition of streams: the concept of reference condition. Ecological Applications 16:1267-1276.

Stoll-Kleemann, S., T. O'Riordan, and C. C. Jaeger. 2001. The psychology of denial concerning climate mitigation measures: Evidence from Swiss focus groups. Global Environmental Change 11:107-117.

Suding, K. N., and R. J. Hobbs. 2009. Threshold models in restoration and conservation: a developing framework. Trends in Ecology and Evolution 24:9.

Surratt, D. 2010. Water Quality Analyses of ERTP Alternatives. Presentation to the Technical Oversight Committee, October 19, 2010.

Surratt, D., D. Shinde, and N. Aumen. 2012. Recent Cattail Expansion and Possible Relationships to Water Management: Changes in Upper Taylor Slough (Everglades National Park, Florida, USA). Environmental Management 49(3):720-733.

Sykes, P. W. 1983. Snail Kite use of the freshwater marshes of south Florida. Florida Field Naturalist 11:73-88.

Sykes, Jr., P. W., J. A. Rodgers, Jr., and R. E. Bennetts. 1995. Snail Kite (*Rostrhamus sociabilis*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America. Available at http://bna.birds.cornell.edu/bna/species/171. Accessed June 13, 2012.

Takekawa, J. E., and S. R. Beissinger. 1989. Cyclic drought, dispersal, and the conservation of the Snail Kite in Florida: Lessons in critical habitat. Conservation Biology 3:302-311.

Tett, P., R. Gowen, D. Mills, T. Fernandes, L. Gilpin, M. Huxham, K. Kennington, P. Read, M. Service, M. Wilkinson, and S. Malcolm. 2007. Defining and detecting Undesirable Disturbance in the context of Eutrophication. Marine Pollution Bulletin 53: 282-297.

Tian, H., X. Xu, S. Miao, E. Sindhoj, B. J. Beltran, and Z. Pana. 2010. Modeling ecosystem responses to prescribed fires in a phosphorus-enriched Everglades wetland: I. Phosphorus dynamics and cattail recovery. Ecological Modelling 221:1252-1266.

USACE. 2007. Memorandum for Director of Civil Works on Comprehensive Everglades Restoration Plan, Water Quality Improvements. Washington, DC: USACE.

USACE. 2009a. Picayune Strand Restoration Project: Facts and Information. Available at http://www.evergladesplan.org/docs/fs_picayune_oct_2009.pdf. Accessed June 19, 2011.

USACE. 2009b. Modified Water Deliveries to Everglades National Park and Tamiami Trail. Available at http://www.evergladesplan.org/docs/fs_tamiami_trail_120409.pdf. Accessed July 13, 2011.

USACE. 2011a. Picayune Strand Restoration Project: Facts and Information, March 2011. Available at http://www.evergladesplan.org/docs/fs_picayune_mar_2011.pdf. Accessed May 29, 2012.

USACE. 2011b. Site 1 Impoundment, August 2011. Available at http://www.evergladesplan.org/docs/fs_site_1_aug_2011.pdf. Accessed May 29, 2012.

USACE. 2011c. Assuring Quality of Planning Models. Circular No. 1105-2-412. March 31, 2011. Available at http://publications.usace.army.mil/publications/eng-circulars/EC_1105-2-412.pdf.

USACE. 2012a. C-11 Spreader Canal Design Test. Water Quality Summary Report for CERPRA Permit: 294662-001. February 2012.

USACE. 2012b. Status Report For Decomparmentalization and Sheetflow Enhancement Project Implementation Report 1. February, 2012.

USACE and DOI. 2011. 2010 Report to Congress for CERP. Available at http://www.evergladesplan.org/pm/program_docs/cerp_reports_congress.aspx#rtc. Accessed March 5, 2012.

USACE and SFWMD. 1999. Central and Southern Florida Project Comprehensive Review Study, Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. Available at http://www.evergladesplan.org/pub/restudy_eis.cfm#mainreport. Accessed March 5, 2012.

USACE and SFWMD. 2001. Draft Monitoring and Assessment Plan of the Comprehensive Everglades Restoration Plan. March 29, 2001. Jacksonville, FL.

USACE and SFWMD. 2009a. Kissimmee River Restoration Progress: Facts and Information. Available at http://www.saj.usace.army.mil/Divisions/Everglades/Branches/ProjectExe/Sections/UECKLO/DOCS/KRR/Kissimmee_FS_Nov2009.pdf. Accessed July 21, 2011.

USACE and SFWMD. 2009b. L-31N (L-30) Seepage Management Pilot Project Final Integrated Pilot Project Design Report Environmental Assessment. Volume 1. June 2009 Revision

USACE and SFWMD. 2010a. Central and Southern Florida Project, Comprehensive Everglades Restoration Plan, Biscayne Bay Coastal Wetlands Phase 1 Draft Integrated Project Implementation Report and Environmental Impact Statement. Available at http://www.evergladesplan.org/pm/projects/project_docs/pdp_28_biscayne/031910_dpir/031910_bbcw_dpir_vol_1_main_report.pdf. Accessed July 15, 2011

USACE and SFWMD. 2010b. Central and Southern Florida Project, Comprehensive Everglades Restoration Plan: Melaleuca Eradication and Other Exotic Plants, Implement Biological Controls, Final Integrated Project Implementation Report and Environmental Impact Statement. Available at http://www.evergladesplan.org/pm/projects/docs_95_melaleuca_pir.aspx. Accessed February 27, 2012.

USACE and SFWMD. 2010c. Installation, Testing and Monitoring of a Physical Model for the Water Conservation Area 3 Decompartmentalization and Sheet Flow Enhancement Project: Final Environmental Assessment and Design Test Documentation Report. April 2010. Available at http://www.evergladesplan.org/pm/projects/docs_12_wca3_dpm_ea.aspx. Accessed June 14, 2010.

USACE and SFWMD. 2011. Annex E, Part 4: Adaptive Management Plan in Biscayne Bay Coastal Wetlands Integrated Project Implementation Report and Environmental Impact Statement, January 2012—Final. Available at http://www.evergladesplan.org/pm/projects/project_docs/pdp_28_biscayne/010612_fpir/010612_vol_3_annex_e.pdf.

USACE and SFWMD. 2012. Central and Southern Florida Project Comprehensive Everglades Restoration Plan: Central Everglades Planning Project, Draft Project Management Plan, February 2012.

U.S. Geological Survey. 2005. The Challenge of Water Management, The Kissimmee-Okeechobee-Everglades System, Development and Drainage in the Lower East Coast. Poster, Images, and Text. Available at http://sofia.usgs.gov/publications/posters/challenge. Accessed June 17, 2011.

van der Valk, A., and F. Sklar. 2002. What we know and should know about tree islands. Pp. 499-522 in Tree Islands of the Everglades, F. H. Sklar and A. V. D. Valk, eds. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Volk, B. G. 1973. Everglades histosol subsidence: 1. CO_2 evolution as affected by soil type, temperature, and moisture. Soil and Crop Science Society of Florida Proceedings 32:132-135.

Walker, W. W., and R. H. Kadlec. 2011. Modeling phosphorus dynamics in Everglades wetlands and stormwater treatment areas. Critical Reviews in Environmental Science and Technology 41(S1):430-446. Available at http://www.wwwalker.net/pdf/crest_531225_www_rhk_2011.pdf. Accessed April 3, 2012.

Wetzel, P. R. 2002. Analysis of tree island vegetation communities. Pp. 357-389 in Tree Islands of the Everglades, F. H. Sklar and A. v. d. Valk, eds. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Wetzel, P. R., A. G. van der Valk, S. Newman, G. E. Gawlik, T. Troxler Gann, C. A. Coronado-Molina, D. L. Childers, and F. H. Sklar. 2005. Maintaining tree islands in the Florida Everglades: Nutrient redistribution is the key. Frontiers in Ecology and the Environment 3:370-376.

Wetzel, P. R., F. H. Sklar, C. A. Coronado, T. G. Troxler, S. L. Krupa, P. L. Sullivan, S. Ewe, R. M. Price, S. Newman, and W. H. Orem. 2011. Biogeochemical processes on tree islands in the greater Everglades: Initiating a new paradigm. Critical Reviews in Environmental Science and Technology 41:670-701.

WG (Working Group) and SCG (Science Coordination Group). 2010. New Science: Advancing Understanding of the South Florida Ecosystem. Available at http://www.sfrestore.org/information_brief/New_Science_May_20_2010.pdf. Accessed May 25, 2012.

Wilcox, W. 2012. Regional System Perspectives. In South Florida Ecosystem Restoration Science Coordination Group Sponsored Public Workshop On Science. February 14, 2012. Available at http://www.sfrestore.org/cepp/meetings/021312/6_c_Big_Picture_Synthesis.pdf. Accessed May 29, 2012.

Willard, D. A., and L. M. Weimer. 1997. Palynological Census Data from Surface Samples in South Florida. Reston, VA: U.S. Geological Survey.

Williams, T. 2011. Incite life support. Audubon 113(6):58-67.

Williams, B., V. Lopez, J. Outland, and G. Knecht. 2008. Comprehensive Everglades Restoration Plan Annual Report—470 Report. Appendix 7A-1in 2010 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_sfer/tab2236041/volume1/appendices/v1_app_7a-1.pdf. Accessed March 29, 2012.

Williams, B., V. Lopez, J. Outland, and G. Knecht. 2009. Comprehensive Everglades Restoration Plan Annual Report—470 Report. Appendix 7A-1 in 2010 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at https://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_sfer/tab2236041/2009report/report/v1/appendices/v1_app7A-1.pdf. Accessed March 29, 2012.

Williams, B., V. Lopez, J. Outland, and G. Knecht. 2010. Comprehensive Everglades Restoration Plan Annual Report—470 Report. Appendix 7A-1 in 2010 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_sfer/tab2236037/2010%20report/v1/appendices/v1_app7A-1.pdf. Accessed March 29, 2012.

Wright, A. L., and K. R. Reddy. 2001. Heterotrophic microbial activity in Northern Everglades wetland soils. Soil Science Society of America Journal 65(6):1856-1864.

Wu, Y., K. Rutchey, W. Guan, L. Vilchek, and F. Sklar. 2002. Spatial simulation of tree islands for Everglades restoration. Pp. 469-498 in Tree Islands of the Everglades, F. H. Sklar and A. v. d. Valk, eds. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Zhang, H., and B. Sharfstein. 2012. Lake Okeechobee Protection Program. Chapter 8 in 2012 South Florida Environmental Report. West Palm Beach, FL: South Florida Water Management District. Available at http://www.sfwmd.gov/sfer. Accessed May 29, 2012.

Zweig, C. L., and W. M. Kitchens. 2008. Effects of landscape gradients on wetland vegetation communities: Information for large-scale restoration. Wetlands 28(4): 1086-1096.

Acronyms

ARRA	American Recovery and Reinvestment Act
ASR	aquifer storage and recovery
BACI	before-after-control-impact
BMP	best management practice
CEPP	Central Everglades Planning Project
CERP	Comprehensive Everglades Restoration Plan
CESI	Critical Ecosystem Studies Initiative
CHIP	Cattail Habitat Improvement Project
CIPs	capital improvement plans
CISRERP	Committee on Independent Scientific Review of Everglades Restoration Progress
COP	combined operational plan
CREW	Corkscrew Regional Ecosystem Watershed
CROGEE	Committee on the Restoration of the Greater Everglades Ecosystem
C&SF	Central and Southern Florida
CSSS	Cape Sable seaside sparrows
CWA	Clean Water Act
DMSTA	Dynamic Model for Stormwater Treatment Areas
DO	dissolved oxygen
DOI	U.S. Department of the Interior
DPM	Decomp Physical Model
EAA	Everglades Agricultural Area
EDEN	Everglades Depth Estimation Network
EFA	Everglades Forever Act

ELM	Everglades Landscape Model
ELVM	Elevated Landscape Vegetation Model
ENP	Everglades National Park
EPA	U.S. Environmental Protection Agency
ERTP	Everglades Restoration Transition Plan
ESM	Everglades Soil Mapping
FAC	Florida Administrative Code
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FFTF	Florida Forever Trust Fund
FWS	U.S. Fish and Wildlife Service
FY	fiscal year
GEER	Greater Everglades Ecosystem Restoration
IDS	Integrated Delivery Schedule
IGs	Interim Goals
IOP	Interim Operational Plan
IRL-S	Indian River Lagoon-South
LNWR	Loxahatchee National Wildlife Refuge
LOER	Lake Okeechobee and Estuary Recovery
LOPA	Lake Okeechobee Protection Act
LOPP	Lake Okeechobee Protection Plan
LPA	Limestone Products Association
MAF	million acre-feet
MAP	monitoring and assessment plan
MARES	Marine and Estuarine Goal Setting for the South Florida Ecosystem
MCDA	Multicriteria Decision Analysis
MGD	million gallons per day
mt	metric tons
NEEPP	Northern Everglades and Estuaries Protection Program
NEPA	National Environmental Policy Act
NOAA	National Oceanic Atmospheric Administration
NPS	National Park Service
NRC	National Research Council

PDT	project delivery team
PIRs	project implementation reports
ppb	parts per billion
RECOVER	Restoration, Coordination, and Verification
R-EMAP	Regional Environmental Monitoring and Assessment Program
RSM	Regional Simulation Model
SAV	submerged aquatic vegetation
SERES	Synthesis of Everglades Research and Ecosystem Services
SFER	South Florida Environmental Report
SFERTF	South Florida Ecosystem Restoration Task Force
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
SOETF	Save Our Everglades Trust Fund
SR	State Road
SSAC	site specific alternative criteria
SSR	System Status Report
STA	stormwater treatment area
STKG	Scientific and Technical Knowledge Gained
SWIM	Surface Water Improvement and Management
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WCA	Water Conservation Area
WPA	Water Preserve Area
WQ	water quality
WQS	water quality standards
WQBEL	water quality based effluent limit
WRDA	Water Resources Development Act
WY	water year
5YrTMA	Five-year trailing moving averages

Appendix A

National Research Council Everglades Reports

Progress Toward Restoring the Everglades: The Third Biennial Review, 2010 (2010)

This report is the third biennial evaluation of progress being made in the Comprehensive Everglades Restoration Plan (CERP), a multi-billion dollar effort to restore historical water flows to the Everglades and return the ecosystem closer to its natural state. The report finds that while natural system restoration progress from the CERP remains slow, in the past two years, there have been noteworthy improvements in the pace of implementation and in the relationship between the federal and state partners. Continued public support and political commitment to long-term funding will be needed for the restoration plan to be completed. The science program continues to address important issues, but more transparent mechanisms for integrating science into decision making are needed. Despite such progress, several important challenges related to water quality and water quantity have become increasingly clear, highlighting the difficulty of achieving restoration goals simultaneously for all ecosystem components. Achieving these goals will be enormously costly and will take decades at least. Rigorous scientific analyses of potential conflicts among the hydrologic requirements of Everglades landscape features and species, and the tradeoffs between water quality and quantity, considering timescales of reversibility, are needed to inform future prioritization and funding decisions. Understanding and communicating these tradeoffs to stakeholders are critical.

Progress Toward Restoring the Everglades: The Second Biennial Review, 2008 (2008)

This report is the second biennial evaluation of progress being made in the Comprehensive Everglades Restoration Plan (CERP), a multi-billion dollar effort to restore historical water flows to the Everglades and return the ecosystem closer to its natural state. Launched in 2000 by the U.S. Army Corps of Engineers and the South Florida Water Management District, the CERP is a multi-organization planning process that includes approximately 50 major projects to be completed over the next several decades. The report concludes that budgeting, planning, and procedural matters are hindering a federal and state effort to restore the Florida Everglades ecosystem, which is making only scant progress toward achieving its goals. Good science has been developed to support restoration efforts, but future progress is likely to be limited by the availability of funding and current authorization mechanisms. Despite the accomplishments that lay the foundation for CERP construction, no CERP projects have been completed to date. To begin reversing decades of decline, managers should address complex planning issues and move forward with projects that have the most potential to restore the natural ecosystem.

Progress Toward Restoring the Everglades: The First Biennial Review, 2006 *(2007)*

This report is the first in a congressionally mandated series of biennial evaluations of the progress being made by the CERP, a multi-billion dollar effort to restore historical water flows to the Everglades and return the ecosystem closer to its natural state, before it was transformed by drainage and by urban and agricultural development. The report finds that progress has been made in developing the scientific basis and management structures needed to support a massive effort to restore the Florida Everglades ecosystem. However, some important projects have been delayed because of several factors including budgetary restrictions and a project planning process that can be stalled by unresolved scientific uncertainties. The report outlines an alternative approach that can help the initiative move forward even as it resolves remaining scientific uncertainties. The report calls for a boost in the rate of federal spending if the restoration of Everglades National Park and other projects are to be completed on schedule.

Re-engineering Water Storage in the Everglades: Risks and Opportunities *(2005)*

This report reviews and evaluates not only storage options included in the plan, but also other options not considered in the plan. Along with providing hydrologic and ecological analyses of the size, location, and functioning of water storage components, the report also discusses and makes recommendations on related critical factors, such as timing of land acquisition, intermediate states of restoration, and tradeoffs among competing goals and ecosystem objectives.

There is a considerable range in the degree to which various proposed storage components involve complex design and construction measures, rely on active controls and frequent equipment maintenance, and require fossil fuels or other energy sources for operation. The report recommends that, to the extent possible, the CERP should develop storage components that have fewer of those requirements, and are thus less vulnerable to failure and more likely to be sustainable in the long term.

The CERP imposes some constraints on sequencing of its components. The report concludes that two criteria are most important in deciding how to sequence components of such a restoration project: (1) protecting against additional habitat loss by acquiring or protecting critical lands in and around the Everglades and (2) providing ecological benefits as early as possible. The report recommends that methods be developed to allow tradeoffs to be assessed over broad spatial and long temporal scales, especially for the entire ecosystem, and gives an example of what an overall performance indicator for the Everglades system might look like.

Adaptive Monitoring and Assessment for the Comprehensive Everglades Restoration Plan *(2003)*

A key premise of the CERP is that restoring the historical hydrologic regime in the remaining wetlands will reverse declines in many native species and biological communities. Given the uncertainties that will attend future responses of Everglades ecosystems to restored water regimes, a research, monitoring, and adaptive management program is planned. This report assesses the extent to which the restoration effort's "monitoring and assessment plan" included the following elements crucial to any adaptive management scheme: (1) clear restoration goals and targets, (2) a sound baseline description and conceptualization of the system, (3) an effective process for learning from management actions, and (4) feedback mechanisms for improving management based on the learning process.

The report concludes that monitoring needs must be prioritized, because many goals and targets that have been agreed to may not be achievable or internally consistent. Priorities could be established based on the degree of flexibility or reversibility of a component and its potential impact on future management decisions. Monitoring that meets multiple objectives (e.g., adaptive management, regulatory compliance, and a "report card") should be given priority. Ecosystem-level, systemwide indicators should be developed, such as land-cover and land-use measures, an index of biotic integrity, and diversity measures. Region-wide monitoring of human and environmental drivers of the ecosystem, especially population growth, land-use change, water demand, and sea level rise are recommended.

Does Water Flow Influence Everglades Landscape Patterns? *(2003)*

A commonly stated goal of the CERP is to "get the water right." This has largely meant restoring the timing and duration of water levels and the water quality in the Everglades. Water flow (speed, discharge, direction) has been considered mainly in the coastal and estuarine system, but not elsewhere. Should the restoration plan be setting targets for flows in other parts of the Everglades as well?

There are legitimate reasons why flow velocities and discharges have thus far not received greater emphasis in the plan. These include a relative lack of field information and poor resolution of numerical models for flows. There are, however, compelling reasons to believe that flow has important influences in the central Everglades ecosystem. The most important reason is the existence of major, ecologically important landforms—parallel ridges, sloughs, and "tree islands"—are aligned with present and inferred past flow directions. There are difficulties in interpreting this evidence, however, as it is essentially circumstantial and not quantitative.

Alternative mechanisms by which flow may influence this landscape can to some extent be evaluated from short-term research on underlying bedrock topography, detailed surface topographic mapping, and accumulation rates of suspended organic matter. Nonetheless, more extensive and long-term research will also be necessary, beginning with the development of alternative conceptual models of the formation and maintenance of the landscape to guide a research program. Research on maintenance rather than evolution of the landscape should have higher priority because of its direct impact on restoration. Monitoring should be designed for the full range of flow conditions, including extreme events.

Overall, flows approximating historical discharges, velocities, timing, and distribution should be considered in restoration design, but quantitative flow-related performance measures are not appropriate until there is a better scientific understanding of the underlying science. At present, neither a minimum nor a maximum flow to preserve the landscape can be established.

Florida Bay Research Programs and Their Relation to the Comprehensive Everglades Restoration Plan *(2002)*

This report of the Committee on Restoration of the Greater Everglades Ecosystem (CROGEE) evaluated Florida Bay studies and restoration activities that potentially affect the success of the CERP. Florida Bay is a large, shallow marine system immediately south of the Everglades, bounded by the Florida Keys and the Gulf of Mexico. Some of the water draining from the Everglades flows directly into northeast Florida Bay. Other freshwater drainage reaches the bay indirectly from the northwest.

For several decades until the late 1980s, clear water and dense seagrass meadows characterized most of Florida Bay. However, beginning around 1987, the seagrass beds began dying in the western and central bay. It is often assumed that increased flows to restore freshwater Everglades habitats will also help restoration of Florida Bay. However, the CERP may actually result in higher salinities in central Florida Bay than exist presently, and thus exacerbate the ecological problems. Further, some percentage of the proposed increase in fresh surface-water flow discharging northwest of the bay will eventually reach the central bay, where its dissolved organic nitrogen may lead to algal blooms. Complicating the analysis of such issues is the lack of an operational bay circulation model.

The report notes the importance of additional research in the following areas: estimates of groundwater discharge to the bay; full characterization and quantification of surface runoff in major basins; transport and total loads of nitrogen and phosphorous from freshwater sources, especially in their organic forms; effects on nutrient fluxes of decreasing freshwater flows into the northeastern bay, and of increasing flows northwest of the bay; and the development of an operational Florida Bay circulation model to support a bay water quality model and facilitate analysis of CERP effects on the bay.

Science and the Greater Everglades Ecosystem Restoration: An Assessment of the Critical Ecosystems Study Initiative *(2003)*

The Everglades represents a unique ecological treasure, and a diverse group of organizations is currently working to reverse the effects of nearly a century of wetland drainage and impoundment. The path to restoration will not be easy, but sound scientific information will increase the reliability of the restoration, help enable solutions for unanticipated problems, and potentially reduce long-term costs. The investment in scientific research relevant to restoration, however, decreased substantially within some agencies, including one major Department of the Interior (DOI) science program, the Critical Ecosystem Studies Initiative (CESI). In response to concerns regarding declining levels of funding for scientific research and the adequacy of science-based support for restoration decision making, the U.S. Congress instructed the DOI to commission the National Academy of Sciences to review the scientific component of the CESI and provide recommendations for program management, strategic planning, and information dissemination.

Although improvements should be made, this report notes that the CESI has contributed useful science in support of the DOI's resource stewardship interests and restoration responsibilities in South Florida. It recommends that the fundamental objectives of the CESI research program remain intact, with continued commitment to ecosystem research. Several improvements in CESI management are suggested, including broadening the distribution of requests for proposals and improving review standards for proposals and research products. The report asserts that funding for CESI science has been inconsistent and as of 2002 was less than that needed to support the DOI's interests in and responsibilities for restoration. The development of a mechanism for comprehensive restoration-wide science coordination and synthesis is recommended to enable improved integration of scientific findings into restoration planning.

Regional Issues in Aquifer Storage and Recovery for Everglades Restoration: A Review of the ASR Regional Study Project Management Plan of the Comprehensive Everglades Restoration Plan *(2002)*

The report reviews a comprehensive research plan on Everglades restoration drafted by federal and Florida officials that assesses a central feature of the restoration: a proposal to drill more than 300 wells funneling up to 1.7 billion gallons of water a day into underground aquifers, where it would be stored and then pumped back to the surface to replenish the Everglades during dry periods. The report says that the research plan goes a long way to providing information needed to settle remaining technical questions and clearly responds to suggestions offered by scientists in Florida and in a previous report by the NRC.

Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan: A Critique of the Pilot Projects and Related Plans for ASR in the Lake Okeechobee and Western Hillsboro Areas *(2001)*

Aquifer storage and recovery (ASR) is a major component in the CERP, which was developed by the U.S. Army Corps of Engineers (USACE) and the South Florida Water Management District (SFWMD). The plan would use the upper Floridian aquifer to store large quantities of surface water and shallow groundwater during wet periods for recovery during droughts.

ASR may limit evaporation losses and permit recovery of large volumes of water during multi-year droughts. However, the proposed scale is unprecedented and little subsurface information has been compiled. Key unknowns include impacts on existing aquifer uses, suitability of source waters for recharge, and environmental and/or human health impacts due to water quality changes during subsurface storage.

To address these issues, the USACE and SFWMD proposed aquifer storage recharge pilot projects in two key areas. The CROGEE charge was to examine a draft of their plans from a perspective of adaptive management. The report concludes that regional hydrogeologic assessment should include development of a regional-scale groundwater flow model, extensive well drilling and water quality sampling, and a multi-objective approach to ASR facility siting. It also recommends that water quality studies include laboratory and field bioassays and ecotoxicological studies, studies to characterize organic carbon of the source water and anticipate its effects on subsurface biogeochemical processes, and laboratory studies. Finally, it recommends that pilot projects be part of adaptive assessment.

Appendix B

Status of Key Non-CERP Projects

KISSIMMEE RIVER RESTORATION

Overview: The project has two parts. First, the Kissimmee Headwaters Revitalization Project focuses on the upper Kissimmee River Basin to improve three canals, construct supplemental levees, and change the operating schedules for Kissimmee, Hatchineha, Cypress, and Tiger lakes. The more ambitious Kissimmee River Restoration Project focuses on the lower portion of the river's watershed, by replacing the designed channel with a more natural geomorphology, backfilling 22 miles of the C-38 Canal, re-carving 10 miles of the historical river channel, reestablishing approximately 40 miles of meandering river channel, removing control structures S-65B and S-65C, and redefining the operations of S-65 that controls flows through the Kissimmee River (Figure B-1).

Status: Three of the four phases (reaches) of the Kissimmee River Restoration Project to backfill the C-38 Canal have been completed, which resulted in backfilling 14 miles of C-38 Canal and restoring a 24-mile section of the original river channel. Phase 4B backfilling began in 2009 and was completed in 2010. The last remaining construction phases, which are anticipated to be finished by 2015, will backfill the final 9 miles of C-38 Canal and recarve 4 miles of the historical river channel. Most of the 102,061 acres of land needed for the restoration have been acquired. In the upstream areas, the headwaters revitalization is expected to be complete in 2014, providing important upstream integrity to the entire river system and supporting downstream restoration (SFWMD, 2010). By 2015, operating rules are to be in place for control structures, and the entire project will be finished. Table B-1 details restoration progress made on this project.

Observed Benefits: About 7,700 acres of formerly drained portions of the river's floodplain are now experiencing enhanced inundation and are reverting back to wetland habitat (Figure B-2). A comprehensive evaluation program for tracking

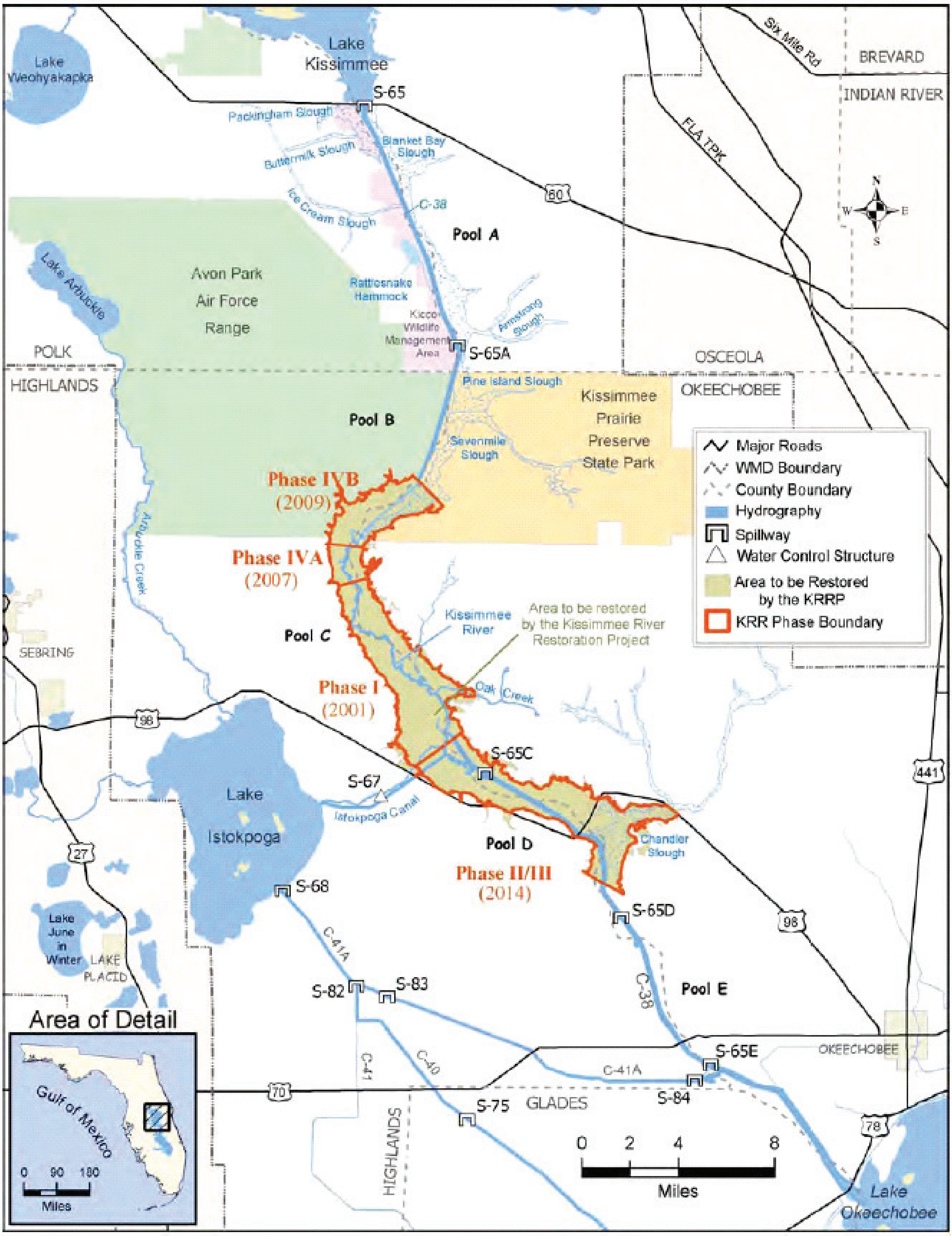


FIGURE B-1 Kissimmee River Restoration Project area on the lower Kissimmee River.

SOURCE: Jones et al. (2011).

TABLE B-1 Restoration Progress on the Kissimmee River Restoration Project

Construction Sequence	Name of Construction Phase	Timeline	Backfilled Canal (miles)	River Channel Recarved (miles)	River Channel to Receive Reestablished Flow (miles)	Total area (acres)	Wetland Gained (acres)	Location and Other Notes
1	Phase I	June 1999 - February 2001 (complete)	8	1	14	9,506	5,792	Most of Pool C, small section of lower Pool B
2	Phase IVA	June 2006 - September 2007 (complete)	2	1	4	1,352	512	Upstream of Phase I in Pool B to Wier #1
3	Phase IVB	June 2008 - December 2009 (complete)	4	4	6	4,183	1,406	Upstream of Phase IVA in Pool B (upper limit approximately at location of Wier #3)
4	Phase II/III	April 2012 - October 2014 (projected)	9	4	16	9,921	4,688	Downstream of Phase I (lower Pool C and Pool D south to the CSX Railroad bridge)
		Restoration Project Totals	**22**	**10**	**40**	**24,963**	**12,398**	
						(40 sq mi)	**(20 sq mi)**	
NA	Headwaters lakes (Lakes Kissimmee, Cypress, Hatchineha, and Tiger)		NA	NA	NA	63,585	7,200	Total area includes entire area of the lakes; wetlands gained includes only the acres of improved littoral zone vegetation expected to be gained by increased high stage.
NA	Kissimmee River Pools A-D		NA	NA	NA	38,207	12,398	Total area includes all of pools A-D within 100-year floodline, including areas that will not be restored. Wetlands gained is the total area of wetlands that will be restored in KRR project area.
		Area totals				101,793	19,598	

SOURCE: http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/krr_krrep_factstour_sheet.pdf; dated August 2010.

FIGURE B-2 Images showing ecosystem restoration in the Phase I reach of the Kissimmee River. ABOVE: Prior to restoration this channel was clogged with aquatic vegetation resulting from the lack of high flows brought about by the drainage and channel works on the main stream. In the restored case, aquatic vegetation forms bands along the channel edges leaving the channel itself clear of aquatic vegetation. BELOW: Prior to restoration this flood plain was not hydrologically connected to the river, so its vegetation was mostly upland species for pasturage. In the restored case, the flood plain periodically receives water from the channel, and its marsh vegetation community now reflects pre-drainage conditions.

SOURCE: Jackson (2011)

environmental responses to the restoration is gauging the success of the project in meeting its goal of restoring ecological integrity for the river and the floodplain. Densities of long-legged wading birds on the restored floodplain have exceeded restoration expectations each year since 2002, with the exception of the drought year 2007.

In recent years the river has had continuous flows without periods of dry channel, and there have been periods of flood plain inundation (although not to pre-drainage depths). Organic material on the bed of the channel has declined 71 percent, returning the system to close to its original sandy condition. The concentrations of dissolved oxygen (DO) have generally improved: DO values near the surface of the river have met or exceeded the target value of 5-7 mg/l 97 percent of the time (much better than the 50 percent expected).

Integrated Financial Plan (IFP; SFERTF, 2009b) Start Date: 1994
Current Estimated Completion Date: 2015
Original Estimated Cost (WRDA 1992): $427M
2011 IFP Estimated Cost: $819.3M ($333.3M appropriated through fiscal year [FY] 2010)

EVERGLADES STORMWATER TREATMENT AREAS

Status: Construction of Compartments B and C build-outs and commissioning of associated pump stations are scheduled for completion in June 2012. When these new stormwater treatment areas (STAs) become operational, the total treatment wetland area will be approximately 57,000 acres. STA-5 Flow-way 3, which became flow-capable in 2006 and began limited operation in 2008, dried out during drought conditions in water year (WY) 2009. This flow-way was off-line for the latter half of WY 2010, all of 2011 and the first half of 2012 because of Compartment C construction activities. Large-scale bulrush planting was conducted in WY 2011-WY 2012. Planted areas included STA-5 Cells 1A and 1B; STA-1E Cells 5, 6, and 7; STA-1W Cells 5A and 5B; and STA 3/4 Cell 1A.

Observed Benefits: Since 1994, the Everglades STAs along with agricultural best management practices have retained more than 3,800 metric tons (mt) of phosphorus that would otherwise have entered the Everglades Protection Area.

Start Date: Authorized in 1994, Everglades Forever Act
Current Estimated Completion Date: Not available
Original Estimated Cost for Land, Design, and Construction: $825M
Current Estimated Cost for Land, Design, and Construction: $897M

MODIFICATIONS TO C-111 (SOUTH DADE)

Status: To date, two interim pump stations and one permanent pump station have been completed, along with construction of a retention/detention zone, replacement of the Taylor Slough Bridge, the backfilling of Canal 109, the removal of 4.75 miles of spoil mounds along lower C-111, and the construction and transfer to the sponsor of the S-331 Command and Control Center. Two features remain to be constructed: a detention area north of the existing retention/detention zone and the plugging of the L-31W Canal. A construction contract to extend the S-332B North detention area and contain discharges from the 8.5 square mile area STA component of the Mod Waters project is anticipated in 2012. Three project features have been deferred to the Comprehensive Everglades Restoration Program and are now components of the C-111 Spreader Canal - Western project: the pump station 332E, the spreader canal, and the C-110 backfill.

Observed Benefits: Not yet fully implemented. Distribution of flows has improved downstream of the Taylor Slough bridge replacement and C-111 Spoil Mounds Removal areas.

IFP Start Date: 1994
Current Estimated Completion Date: 2017
Original Estimated Cost: $121M (1994)
2011 IFP Estimated Cost: $391M ($118.7M appropriated through FY 2010)

MODIFIED WATER DELIVERIES TO EVERGLADES NATIONAL PARK

Status: Construction features completed:

1. Gated spillway structures S-355A and B in the L-29 Levee
2. Modifications to the S-333 and S-334 structures to accommodate higher water levels in the L-29 Canal
3. Raising the Tigertail Camp
4. Pump Station S-356 between L-31N Canal and L-29 Canal
5. Osceola Camp elevation evaluation
6. Degradation of the L-67 Extension Canal and Levee (4 of 9 miles degraded)
7. Levees and a seepage collector canal to provide flood mitigation for the east Everglades residential area (8.5 square mile area)
8. Pump Station S-357 constructed
9. S-331 Command and Control (cost shared with the C-111 [South Dade] Project)

Work is in progress on the Tamiami Trail Modifications feature with the ongoing construction of the 1-mile bridge and raising the road bed to accommodate a stage of 8.5 ft in the L-29 Canal. The project is currently estimated to be completed by December 2013.

The following project features were originally included in the Mod Waters project, but their completion is "affected by budget constraints" (SFERTF, 2011):

1. Structures S-345 A, B, and C through the L-67A and C Levees
2. Structures S-349 A, B, and C in the L-67A Borrow Canal
3. Degradation of remaining five miles of L-67 Extension Levee and Canal

Observed Benefits: Not yet implemented
IFP Start Date: 1990
Current Estimated Completion Date: 2013
Original Estimated Cost: $98M (1989)
2011 Estimated Cost: $417.2M ($398.9M appropriated through FY 2011)

NORTHERN EVERGLADES AND ESTUARIES PROTECTION PROGRAM

Status: In 2007, the Florida legislature expanded the Lake Okeechobee Protection Act to include protection and restoration of the interconnected Kissimmee, Lake Okeechobee, Caloosahatchee, and St. Lucie watersheds. This interagency initiative, known as the Northern Everglades and Estuaries Protection Program (NEEPP), focuses on the water storage and water treatment needed to help improve and restore the Northern Everglades and coastal estuaries. As part of this initiative, the South Florida Water Management District (SFWMD) and the state will expand water storage areas, construct treatment marshes, and expedite environmental management initiatives to enhance the ecological condition of the lake and downstream coastal estuaries. The NEEPP requires the SFWMD, in collaboration with the Florida Department of Environmental Protection (FDEP) and the Florida Department of Agriculture and Consumer Services (FDACS) as coordinating agencies and in cooperation with local governments, to develop (1) the Lake Okeechobee Watershed Construction Project Phase II Technical Plan, (2) the St. Lucie River Watershed Protection Plan, and (3) the Caloosahatchee River Watershed Protection Plan. The Phase II Technical Plan was submitted to the legislature in February 2008, and the St. Lucie River and Caloosahatchee River Watershed Protection Plans were submitted in January 2009. Although Northern Everglades projects have been conceptually identified in these plans, specific projects and activities will be included in the annual work plan for each fiscal year. The first updates to the River Watershed Protection Plans were submitted to the Florida legislature in 2012. The Lake Okeechobee Phase II Technical Plan was updated in 2011 by the coordinating agencies.

Observed Benefits: Coordinating agencies have been able to implement a large number of phosphorus reduction projects, including phosphorus source control grant programs for agricultural landowners, dairy best available technology pilot projects, soil amendment projects, isolated wetland restoration, remediation of former dairies, and regional public/private partnerships. Also, six Hybrid Wetland Treatment Technology projects have been constructed in a joint effort between the SFWMD and FDACS in the St. Lucie and Lake Okeechobee watersheds. A comprehensive monitoring program for water quality in the lake and watershed and ecological indicators in the lake has been implemented. The Phase II Technical Plan is currently being implemented.

Start Date: 2007
Current Estimated Completion Date: Not available
Original Estimated Cost (2008): $1.3 to 1.7 billion for the NEEPP, including CERP and non-CERP features
2011 Estimated Cost: Estimates for the near-term components of the Lake Okeechobee Protection Plan are $92.6 million. Near-term cost estimates for the St. Lucie and Caloosahatchee River Protection Plans are $196.3 million and 49.6 million. Cost estimates do not include long-term implementation measures.

INVASIVE SPECIES MANAGEMENT

Status: Progress is being made through several programmatic initiatives. Biocontrol agents have been successfully developed and introduced for Melaleuca with the plant being cleared and now under maintenance control in Water Conservation Areas 2 and 3 and Lake Okeechobee; efforts to develop agents for Lygodium are continuing; and conventional controls (physical removal, herbicide applications) and airborne surveys are carried out regularly. New management approaches for invasive plants have been developed through applied research and information exchange between cooperators. Funding comes from specific projects under the CERP (Melaleuca Eradication and Other Exotic Plants project, funded in 2002) and a variety of state-based non-CERP projects. Surveys of invasive species are conducted by a variety of agencies (FDEP, SFWMD, National Park Service [NPS]) and through interagency collaborations such as the Everglades Cooperative Invasive Species Management Area, Lake Okeechobee Interagency Aquatic Plant Management Team, and South Florida Ecosystem Restoration Task Force. Shortages of funds for monitoring and assessment of remote sections of Everglades National Park and the time intensive development process of biocontrol agents hampers further progress. Management of exotic animal species lags well behind efforts for invasive exotic plants. Intensified efforts have recently been underway to develop new control tools and management strategies for several priority invasive animal species.

Observed Benefits: Regional coordinated efforts have yielded an Everglades Protection Area with few significant melaleuca infestations and most of the remaining dense populations are now found on private lands. Biocontrol agents are being introduced for Lygodium and Schinus; Lygodium is considered a major threat to ecosystem integrity.

Start Date: 2007
Current Estimated Completion Date: TBD
Original Estimated Cost: Information not found
Current Estimated Cost: Information not found

EVERGLADES AND SOUTH FLORIDA (E&SF) RESTORATION: CRITICAL PROJECTS

East Coast Canal Structures (C-4)

Status: Construction of a gated water control structure (S-380) in the C-4 Basin in Dade County southeast of the Pennsuco wetlands is complete.

Observed Benefits: Raised surface and ground water levels to help preserve wetlands, increased aquifer recharge, and reduced seepage.

IFP Start Date: 1999
IFP Completion Date: 2003
2011 IFP Cost: $3.7M ($3.7M appropriated through FY 2010)

Tamiami Trail Culverts

Status: Original plans included Phase 1 placement of 77 culverts along the Tamiami Trail (62 culverts west of State Road (SR) 92 in the Picayune Strand area, plus 15 culverts east of SR92 near the Big Cypress Preserve area), and Phase 2 resurfacing of Tamiami Trail related to these efforts. Construction of 17 Western Phase 1 Tamiami Trail Culverts between SR92 and SR29 in Collier County was completed in May 2006. This portion of Phase 1 has been included as a component of the Picayune Strand Restoration Project (see Chapter 3) and will be cost-shared under that CERP program instead of the Critical Projects Authority. Since the initial planning, the scope of the project was modified because of budget and time constraints. The remainder of Phase 1 and Phase 2 work is on hold pending funding.

Observed Benefits: Installation of Phase 1 culverts under the Tamiami Trail established more natural hydropatterns north and south of the highway, which is expected to enhance biological restoration in the area.

IFP Start Date: 1998
Current Estimated Completion Date: TBD
2011 IFP Estimated Cost: $25.6M (for the original plan) ($3.6M appropriated through FY 2010)

Florida Keys Carrying Capacity Study

Status: This project has been completed. It included the development of a decision-making tool, which will provide a comprehensive basis for coordinating and strengthening water- and land-related planning efforts by local, state, and federal agencies.

Observed Benefits: The South Florida Regional Planning Council has agreed to steward and maintain the Carrying Capacity Impact Assessment Model as a decision-making tool. The Florida Marine Research Institute has also agreed to steward and maintain the databases.

IFP Start Date: 1997
IFP Completion Date: 2003
2011 IFP Estimated Cost: $4.5M ($4.5M appropriated through FY 2010)

Western C-11 Water Quality Treatment

Status: Construction is complete for this project to improve the quality and timing of stormwater discharges to the Everglades Protection Area from the Western C-11 Basin located in south central Broward County. The structures have been turned over from the U.S. Army Corps of Engineers (USACE) to the SFWMD for operation and maintenance.

Observed Benefits: The S-381 structure in the C-11 Canal separates clean seepage flows from untreated agricultural and urban stormwater runoff. The S-9A Pump Station pumps clean seepage water into Water Conservation Area (WCA)-3A.

IFP Start Date: 1997
IFP Completion Date: 2006
2011 IFP Estimated Cost: $18.5M ($18.5M appropriated through FY 2010)

Seminole Tribe Big Cypress Reservation Water Conservation Plan

Status: Construction of the Phase 1 conveyance canal system was completed in 2004. Construction is under way on water control and treatment facilities in the western portion of Big Cypress Reservation. Phase 2 of this project has been divided into four basins. The USACE completed construction of the largest basin, Basin 1, in August 2008 and was transferred for operations and maintenance in February 2010. Permeability rates necessitated design modifications for the other three basins. Construction of Basin 4 will begin in late 2012. The two remaining construction features, Basin 2 and Basin 3, are scheduled for construction completion in 2014.

Projected Benefits: Should improve the quality of agricultural water runoff within the reservation, restore storage capacity, and return native vegetation.

IFP Start Date: 1997
Current Estimated Completion Date: 2014 for all basins (Basin 1 is complete.)
Original Estimated Cost: $75.3M (1996)
2011 IFP Estimated Cost: $60M ($46.2M appropriated through FY 2010)

Southern CREW Project Additions and Imperial River Flow Way

Status: This project aims to reestablish more natural flow patterns to 4,100 acres in the Southern Corkscrew Regional Ecosystem Watershed (CREW) to improve and restore the hydrology and ecology of the project area. Land acquisition has been accomplished with state and federal cost sharing. Because of escalating land costs and the difficulty in restoring hydrology in the areas south of the Kehl Canal, the SFWMD governing board approved changes to the project footprint in March 2009, removing the southern half of Sections 32 and 33 that are south of the Kehl Canal. The SFWMD continues to acquire land for this smaller footprint and construct the project.

Observed Benefits: Removal of exotic species, primarily Melaleuca trees, on more than 2,560 acres has occurred. Two miles of canals have been plugged, associated berms have been breached, and 2 miles of dirt roads have been degraded to restore sheet flow in Section 25, restoring hydropatterns on approximately 640 acres of wetlands.

IFP Start Date: 1995
Current Estimated Completion Date: 2015
Yellow Book Original Estimated Cost: $33.5M ($3.4M Construction and $30.1M Real Estate)
2011 IFP Estimated Cost: $33.3M ($1.5M appropriated through FY 2010)

Lake Okeechobee Water Retention and Phosphorus Removal

Status: Construction of two new stormwater treatment areas within the Taylor Creek/Nubbin Slough Basin was physically completed in September 2006. The 120-acre Taylor Creek STA has been transferred to the SFWMD for operation and maintenance, repair, replacement, and rehabilitation. The interim construction and testing phase for the 810-acre Nubbin Slough STA identified a need for construction repairs and modifications. These repairs are currently under way; transfer of the Nubbin Slough STA is scheduled for late 2012.

Projected Benefits: To improve the quality of water flowing into Lake Okeechobee.

IFP Start Date: 1997
IFP Completion Date:
Construction complete: 2006
Testing complete; transfer to sponsor: 2012
2011 IFP Cost: $23.1M ($22.8M appropriated through FY 2010)

Ten Mile Creek Water Preserve Area

Status: Construction of an above-ground reservoir, stormwater treatment area, pump station, and gated water-level control structure was completed in 2006. Since that time, interim operations, testing, and monitoring have been under way by the SFWMD and the USACE in accordance with the water quality permit and Project Cooperation Agreement. During the process to transfer the project to the SFWMD for full operations, the USACE and the SFWMD identified operational concerns and a need for a course of action to remediate. The additional project needs that have been identified have significant associated costs. In June 2009 the SFWMD transferred responsibility for the Ten Mile Creek project to the USACE, which has placed the facility in a passive operating state. The 2009 Water and Energy Appropriations Act increased the federal spending authorization by $3.5 million; this funding was identified for the completion of a post-authorization change report and for facility maintenance until 2013.

Projected Benefits: Will provide 6,000 acre-feet of seasonal or temporary storage of stormwater from the Ten Mile Creek Basin on 526 acres of land, which will moderate high-volume freshwater flows and salinity fluctuations in the St. Lucie Estuary and reduce sediment and nutrient loads to benefit 2,740 acres of estuarine habitat.

IFP Start Date: 1997
IFP Completion Date: TBD
2011 IFP Cost: $50M ($49.3M appropriated through FY 2011)

Lake Trafford Restoration

Status: The in-lake portion of dredging was completed by spring of 2006. The second phase of construction and muck removal was completed in 2011.

Observed and Projected Benefits: Approximately 3 million cubic yards of organic sediments that blanketed the bottom of the lake were removed. Expectations include improving water quality, reestablishing native vegetation, and improving subsequent flows to Corkscrew Swamp Sanctuary and the Florida Panther National Wildlife Refuge. Lake monitoring by the local university has identified significant improvement in the quality of the lake from Phase I and Phase II dredging.

IFP Start Date: 1999
Completion Date: 2011
Yellow Book Original Estimated Cost: $15.4M
2011 IFP Estimated Cost: $26M ($13M appropriated through FY 2010)

SOURCES: Balci and Bertolotti (2012); Bertolotti and Balci (2012); Rodgers et al. (2012); SFERTF (2007; 2009; 2011); SFWMD (2007; 2008a; 2008b; 2011a; 2011b); USACE (2007); Williams et al. (2008); L. Gerry, SFWMD, personal communication, 2012; D. Tipple, USACE, personal communication, 2012.

Appendix C

Timeline of Significant Events in South Florida Ecosystem Management and Restoration

1934 Everglades National Park is authorized.

1948 Congress authorizes the Central and Southern Florida Flood Control Project to control the water flow in the Everglades. From 1949 to 1969, the U.S. Army Corps of Engineers (USACE) and the Central and Southern Florida (C&SF) Flood Control District built and operated the project works.

1968 Biscayne National Park is established as a national monument; expanded to a national park in 1980.

1972 The Florida Water Resources Act establishes fundamental water policy for Florida, attempting to meet human needs and sustain natural systems putting in place a comprehensive strategic program to preserve and restore the Everglades ecosystem.

1974 Big Cypress National Preserve is created.

1983 Florida Governor's Save Our Everglades Program outlines a six-point plan for restoring and protecting the South Florida ecosystem so that it functions more like it did in the early 1900s.

1987 The Florida Surface Water Improvement and Management Act requires the five Florida water management districts to develop plans to clean up and preserve Florida lakes, bays, estuaries, and rivers.

1989 The Modified Water Deliveries to Everglades National Park Project is authorized.

1990 The Florida Preservation 2000 Act establishes a coordinated land acquisition program at $300 million per year for 10 years to protect the integrity of ecological systems and to provide multiple benefits, including the preservation of fish and wildlife habitat, recreation space, and water recharge areas.

1992 Federal and state parties enter into a Consent Decree on Everglades water quality issues in federal court. Under the agreement, all parties commit themselves to achieving both the water quality and quantity necessary to protect and restore the unique ecological characteristics of the Arthur R. Marshall Loxahatchee National Wildlife Refuge and Everglades National Park.

The Water Resources Development Act (WRDA) of 1992 authorizes the Kissimmee River Restoration Project and the C&SF Project Restudy, a comprehensive review study for restoring the hydrology of South Florida.

1994 The Florida Everglades Forever Act enacts into state law the settlement provisions of federal-state water quality litigation and provides a financing mechanism for the state to advance water quality improvements in the Everglades by constructing more than 44,000 acres of stormwater treatment areas (STAs) for water entering the Everglades Protection Area. The act also requires the South Florida Water Management District to ensure that best management practices (BMPs) are used to reduce phosphorus in waters discharged into the STAs from the Everglades Agricultural Area (EAA) and other areas. The rule-making process by which the numeric total phosphorus criterion of 10 parts per billion (ppb) is proposed for the Everglades Protection Area also was established by this act.

1996 WRDA 1996 formally establishes the intergovernmental South Florida Ecosystem Restoration Task Force to coordinate the restoration effort among the state, federal, tribal, and local agencies. It authorizes the USACE to implement the critical restoration projects (see Box 2-3).

Section 390 of the Farm Bill grants $200 million to conduct restoration activities in the South Florida ecosystem.

1999 WRDA 1999 extends Critical Restoration Project authority until 2003 and authorizes two pilot infrastructure projects proposed in the Comprehensive Everglades Restoration Plan (CERP).

The Florida Forever Act improves and continues the coordinated land acquisition program initiated by the Florida Preservation 2000 Act of 1990 and commits $300 million per year for 10 years.

2000 WRDA 2000 authorizes the CERP as a framework for modifying the Central and Southern Florida Project to increase future water supplies, with the appropriate timing and distribution, for environmental purposes so as to achieve a restored Everglades ecosystem, while at the same time meeting other water-related needs of the ecosystem. WRDA 2000 includes $1.4 billion in authorizations for 10 initial Everglades infrastructure projects, 4 pilot projects, and an adaptive management and monitoring program. It also grants programmatic authority for projects with immediate and substantial restoration benefits at a total cost of $206 million and establishes a 50 percent federal cost-share for implementation of the CERP and for operation and maintenance.

The Florida legislature passes the Lake Okeechobee Protection Act, a phased, comprehensive program designed to restore and protect the lake.

2003 Programmatic Regulations are issued that establish a procedural framework and set specific requirements that guide implementation of the CERP to ensure that the goals and purposes of the CERP are achieved.

2004 The State of Florida unveils a plan to accelerate restoration of America's Everglades (Acceler8).

2005 The State of Florida announces the Lake Okeechobee Estuary Recovery Plan to help restore the ecological health of Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries.

2007 The Florida state legislature authorizes the Northern Everglades and Estuaries Protection Program, which expands the Lake Okeechobee Protection Act to strengthen protection for the northern Everglades by restoring and preserving the Lake Okeechobee, Caloosahatchee, and St. Lucie watersheds, including the estuaries.

WRDA 2007 authorizes three projects under the CERP: the Indian River Lagoon-South Project, Picayune Strand Restoration, and the Site 1 Impoundment Project. WRDA 2007 also increases funding limits for WRDA 1996 critical projects and for three WRDA 1999 authorized pilot projects.

2008 The state of Florida announces that it will begin negotiations to acquire 187,000 acres of farmland in the EAA from the U.S. Sugar Corporation for $1.75 billion for the purpose of restoration, and a negotiated proposal to acquire the land for $1.34 billion is approved by the South Florida Water Management District's governing board.

2009 Federal and state parties enter into a "master agreement" detailing how the costs and duties will be shared for 68 projects that Congress approved in 2000, beginning with the reclamation of 55,000 acres in the Picayune Strand.

2010 The South Florida Water Management District's governing board approves a revised plan to purchase 26,800 acres of land for approximately $197 million, while retaining the option to acquire more than 153,000 additional acres over the next 10 years.

SOURCES: SFERTF (2006); http://everglades.fiu.edu/reclaim/timeline/index.htm; http://www.washingtonpost.com/wp-dyn/content/article/2008/06/24/AR2008062401140.html.

Appendix D

Timeline of Significant Legal Actions Related to Water Quality

TIMELINE OF SIGNIFICANT LEGAL ACTIONS

1988	U.S. v. SFWMD filed (Moreno case)*
1991	Everglades Protection Act (EP Act) enacted in Florida**
1992	Consent Decree approved by Court in U.S. v. SFWMD*
1994	Everglades Forever Act enacted in Florida**
1999	EPA signed Consent Decree agreeing to establish TMDLs****
1999	Florida enacted Florida Watershed Protection Act**
2001	FDEP set TMDL for phosphorous in Lake Okeechobee**
2001	Modified Consent Decree approved and the court ruled to appoint a Special Master*
2003	“Conceptual Plan” approved by SFWMD*
2003	Everglades Forever Act amended**
2003	Court says change in Florida law will have no effect on federal enforcement*
2003	Florida adopted new water quality default criterion for P**
2004	Miccosukee v. U.S. case filed (Gold case)***
2005	Determination in Moreno case of violation of Consent Decree*
2006	Judge Gold ordered a hearing on EPA’s review of Florida’s WQS for P***
2008	Judge Gold issues judgment***
2009	EPA issues “Determination”***
2010	(January 4) Judge Gold holds evidentiary hearing
2010	(March 31) Judge Moreno adopts Special Master’s Report from 2006*
2010	(April 14) Judge Gold orders EPA to issue an “Amended Determination”***
2010	(September 3) EPA issues “Amended Determination”***
2010	(October 25) Moreno hearing*
2010	SFWMD sends letter to EPA declining to comply with Amended Determination***

2010 The Court, in a lawsuit involving a bond issue, rules SFWMD has legal authority to purchase U.S. Sugar property****
2011 Governor Rick Scott suspends rulemaking in Florida**
2011 (March 23) Judge Moreno orders construction previously allowed on Everglades reservoir to be stopped*
2011 (April 26) Judge Gold issues Omnibus Order***

Key
*U.S. v. SFWMD (Moreno case)
**State of Florida Legislation and Regulation
***Miccosukee v. U.S. (Gold case)
****Miscellaneous Related Legal Actions

DETAILS OF SIGNIFICANT LEGAL ACTIONS

***1988 U.S. v. SFWMD filed (Moreno case).** U.S. government sued the State of Florida and SFWMD arguing the state was threatening the water quality of Everglades National Park (ENP) and the Loxahatchee NWR due to the state's failure to enforce water quality laws. *United States v. South Florida Water Management District*, 847 F. Supp. 1567 (S.D. Fla. 1992).

****1991 Everglades Protection Act (EP Act) enacted in Florida.** The Marjorie Stoneman Douglas Everglades Protection Act (EP Act) required the state to develop a Surface Water Improvement and Management (SWIM) plan for the Everglades restoration. The SWIM plan was to provide a roadmap for compliance with water quality standards as well as restoration of hydroperiods. The EP Act also required Florida Department of Environmental Protection (FDEP) and SFWMD to develop permitting programs and required SFWMD to apply for interim permits for discharges to the Everglades Protection Area. The EP Act also authorized SFWMD to impose additional ad valorem taxes on properties within the EAA and to adopt stormwater utility fees.

***1992 Consent Decree approved by Court in U.S. v. SFWMD.** The Governor conceded liability in the Moreno case and the state entered into the Consent Decree, which was approved by the Court and upheld (in most respects) on appeal. *United States v. South Florida Water Management District*, 28 F.3d 1563 (11th Cir. 1994), *cert. den. Western Palm Beach Cty. Farm Bureau v. U.S.*, 524 U.S. 1107 (1995). The EP Act served as the basis for the terms of the Consent Decree. The Consent Decree required the State to take certain actions necessary to ensure discharges to the federal lands meet agreed upon interim P levels by 1997 and final P levels by 2002. Specifically, the Consent Decree required:

(1) the state to build and operate a minimum of 32,000 acres of STAs; (2) the state to implement a regulatory program to require farms to implement BMPs in the EAA; and (3) the state to adopt a SWIM plan. Once the Court approved the Consent Decree it became an Order of the Court. The state's SWIM plan, which was intended to be the basis of restoration under the EP Act and the Consent Decree, was challenged by agricultural interests. Agricultural interests also challenged proposed permits issued by FDEP.

****1994 Everglades Forever Act enacted in Florida.** Agricultural interest entered into settlement discussions with the federal and state governments. These discussions led to a 1993 "Statement of Principles," which formed the basis of new state legislation that substantially altered the 1991 EP Act. This legislation, the Everglades Forever Act (EFA), removed the requirement for adoption of a SWIM plan, modified timetables for achieving water quality standards, and required the state to adopt a numerical phosphorus standard. The EFA provided that if the state did not adopt a numerical standard by the end of 2003, a default standard of 10 parts per billion (ppb) would go into effect. The EFA mandated that FDEP and SFWMD ensure compliance with state water quality standards in the Everglades Protection Area (EP Area) by the end of 2006. The EFA adopted a schedule of constructing STAs. It also authorized an agricultural privilege tax and the use of Alligator Alley toll finds. These changes to state law made state law inconsistent with the 1992 Consent Decree, which had utilized the 1991 EP Act as its foundation. After many years of legal haggling a revised Consent Decree was approved in 2001 (see note 9).

******1999 EPA signed Consent Decree agreeing to establish TMDLs.** Florida did not make sufficient progress in establishing total maximum daily loads (TMDLs) for impaired waters in the state. Consequently, a U.S. District Court for the Northern District of Florida approved of a consent decree compelling U.S. Environmental Protection Agency (EPA) to establish TMDLs for 500 water bodies on Florida's §303(d) list. *Florida Wildlife Federation, Inc., et al. v. Browner, et al.*, Case No. 4:98cv356-WS, Order Approving Consent Decree (N.D. Fla. Aug. 7, 1999).

****1999 Florida enacted Florida Watershed Protection Act.** The Watershed Protection Act, §403.067 Fla. Stat., requires FDEP to evaluate the quality of water bodies and, for those with impaired quality, establish TMDLs. Under the Act, FDEP may implement Basin Management Action Plans to integrate the appropriate management strategies to achieve TMDLs. The Act also empowers FDEP to promulgate rules establishing best management practices and other interim measures.

****2001 FDEP set TMDL for Phosphorous in Lake Okeechobee.** The TMDL allows an annual load of 140 metric tons of phosphorous to Lake Okeechobee to achieve an in-lake target phosphorous concentration of 40 ppb in the pelagic zone of the lake. http://www.dep.state.fl.us/water/wqssp/everglades/lakeo-tmdl.htm

***2001 Modified Consent Decree approved and Special Master Appointed.** Due to the changes in state law resulting from the 1994 EFA, the 1992 Consent Decree was revised and approved by the Court in 2001. Among other things, the revised Consent Decree extended the deadline for compliance with the 10 ppb phosphorous water quality standards until the end of 2006. The Court also agreed to appoint a Special Master to oversee the details of compliance with the Consent Decree.

***2003 "Conceptual Plan" approved by SFWMD.** In 2003, the SFWMD governing board approved a document titled *Everglades Protection Area Tributary Basins Conceptual Plan for Achieving Long-Term Water Quality Goals Final Report (Conceptual Plan)*. The Conceptual Plan questioned the ability to meet water quality standards by the 2006 deadline and thus extended the final deadline for achieving the 10 ppb to 2026. The Conceptual Plan also established a 2016 deadline for meeting an interim standard of 15 ppb.

****2003 Everglades Forever Act amended.** In 2003 the Florida legislature amended the EFA to adopt the SFWMD Conceptual Plan, thereby extending the deadlines for compliance with water quality standards as provided in the Conceptual Plan. Once again, a Florida legislative change created inconsistencies between Florida state law and the federal court-approved Consent Decree. Most significantly, Florida law now had a 2016 deadline (with legislative authority to extend it to 2026) for meeting 10 ppb, whereas the federal court-approved deadline remained at 2006.

The judge who at the time was in charge of what is now referred to as the Moreno case, Judge Hoeveler, made it clear that the change to Florida law would "have no effect" on federal enforcement. Subsequently, the sugar industry had Judge Hoeveler removed from the case and replaced with Judge Moreno, who appointed a new Special Master to oversee compliance with the Consent Decree.

****2003 Florida adopted new water quality default criterion for P.** The Everglades Forever Act required the adoption of this criterion, 10 ppb of phosphorous, by the end of 2003.

*****2004 Miccosukee v. U.S. case filed (Gold case).** In *Miccosukee Tribe of Indians of Florida v. United States of America* (Case No. 04-21448; this case was later consolidated with *Friends of the Everglades v. United States of America*, Case No. 04-22072), the Tribe filed suit to compel the EPA to review and disapprove the amended Everglades Forever Act and to comply with the standards already set forth under the Clean Water Act.

***2005 Determination in Moreno case of violation of Consent Decree.** The Miccosukee Tribe made a motion to declare violations of the Consent Decree based on exceedances of phosphorous levels in the Loxahatchee National Wildlife Refuge. The Court found that these exceedances were not excusable errors and thus concluded that they constituted a violation of the Consent Decree.

*****2006 Judge Gold ordered a hearing on EPA's review of Florida's WQS for P.** In separate actions brought by the Miccosukee Tribe and by Friends of the Everglades, each sought review of EPA's determination that the amendments to the EFA were not new or revised water quality standard (WQS) subject to review under §303(c) of the Clean Water Act (CWA). Additionally, both parties sought to have the court decide that EPA's determination approving parts of the Phosphorous Rule as new or revised WQS was arbitrary and capricious, and that other parts EPA had found were not new or revised WQS were also ARB and CAPR.

*****2008 Judge Gold issues judgment.** Judge Gold, in a judgment order of the consolidated cases, determined that amendments to the EFA were new or revised water quality standards that EPA must approve or disapprove. With regards to the Phosphorous Rule, Judge Gold approved the numeric criterion for phosphorous but set aside EPA's approval of certain subsections of the Phosphorous Rule.

*****2009 EPA issues "Determination."** Responding to Judge Gold's language in his summary judgment order that required EPA "to comply with its duty under the Clean Water Act to approve or disapprove those changes consistent with the findings and conclusions" of the order, EPA issued its 2009 determination. EPA conducted a more thorough review of the effects of the amendments to the EFA on state WQS. EPA disapproved as new or revised WQS those amendments to the EFA that were moderating provisions. With regard to the Phosphorous Rule, EPA disapproved portions of the rule (subsections (1), (2), and 5(a-c)) and found that they were not in effect as WQS.

*****2010 (January 4) Judge Gold held evidentiary hearing.** Judge Gold held an evidentiary hearing on plaintiffs' motions to enforce the 2008 order, where they alleged that revised administrative orders for the STA permits did not comply with the court's 2008 order. This hearing resulted in the April 2010 order.

***2010 (March 31) Judge Moreno adopts Special Master's Report from 2006.** In this order, Judge Moreno compels construction of the Everglades Agricultural Area (EAA) A-1 Reservoir based on the recommendations of the Special Master.

*****2010 (April 14) Judge Gold orders EPA to issue an "Amended Determination."** On April 14, 2010, Judge Gold found that the "Determination" made by EPA in 2009 did not fully comply with his prior summary judgment order by continuing to find that the state of Florida and EPA had no need to take further action pursuant to CWA §303(c). Additionally, Judge Gold found that FDEP failed to comply with his summary judgment order by continuing to issue Administrative Orders that relied on disapproved language in the EFA and the Phosphorous Rule. Judge Gold ordered EPA to issue an Amended Determination (discussed below at note 19), prohibited FDEP from issuing further NPDES permits for STAs that discharge into, or within, the Everglades Protection Area until FDEP is in compliance with the CWA, and finally commanded EPA Administrator Lisa Jackson to personally appear before him to report on the status of the compliance with his Order (a decision later overturned by the 11th circuit).

*****2010 (September 3) EPA issues "Amended Determination.** On September 3, 2010, EPA issued its Amended Determination as directed by Judge Gold. This Amended Determination specifically speaks to each of the directives ordered by Judge Gold. These actions include: (1) revisions to EPA's 2009 Determination, previously discussed; (2) directions to Florida for correcting deficiencies in both Florida's Phosphorous Rule and the Amended Everglades Forever Act; (3) provisions for the "manner and method for obtaining enforceable WQBEL within time certain"; (4) requirements to measure and submit annual reports on cumulative impacts until Water Quality Standards are attained; (5) directions to Florida to conform all NPDES and EFA permits pursuant to both the Court's 2008 order and the 2010 order by eliminating all nonconforming language and by including the WQBEL presented in the Amended Determination; and (6) establishment of an "enforceable framework for ensuring compliance with the CWA and Applicable Regulations."

***2010 (October 25) Moreno hearing.** This hearing revolved around exceedances of phosphorous occurring in the Loxahatchee NWR during 2009.

*****2010 SFWMD sends letter to EPA declining to comply with Amended Determination.** On November 2, 2010, the Executive Director of the SFWMD sent a letter to EPA Regional Administrator for Region IV, Gwen Fleming, informing her of SFWMD's decision to decline the opportunity to provide an alternative proposal for achieving water quality standards created by the federal government for the Everglades. While referencing its history of good faith efforts in improving water quality in the Everglades, the SFWMD declined to follow EPA's Amended Determination plans because of the high financial burden it would place on the state.

******2010 The court, in a lawsuit involving a bond issue, rules SFWMD has legal authority to purchase U.S. Sugar property.** In *Miccosukee Tribe of Indians of Florida v. South Florida Water Management District*, 48 So. 3d 811 (Fla. 2010), the district sought validation of Certificates of Participation to purchase 73,000 acres of land from the U.S. Sugar Corporation for the purpose of Everglades restoration. The court found that the economic feasibility of the COPs were beyond the scope of judicial review; that the district has the authority to acquire land for the purpose of protecting water and water-related resources; that there was competent, substantial evidence in the record that the issuance of COPs was in the public purpose; that no voter referendum was required under Florida Constitution Article VII, Section 12; that the district is not a "state agency" for purposes of Florida Constitution Article VII, Section 11(f), and therefore does not need legislative approval for issuance of COPs; that the district could create a nonprofit leasing corporation for the sole purpose of facilitating COPs transactions; that the district has authority to purchase land with the express purpose of conveying it to a local governmental entity; that the purchase option expenses do not serve a public purpose and therefore cannot be financed by COPs; and other factual findings regarding the payment for purchase options.

****2011 Governor Rick Scott suspends rulemaking in Florida.** On January 5, 2011, Governor Scott signed an executive order directing all State agencies under the Governor's control to suspend rulemaking except at the direction of the newly created Office of Fiscal Accountability and Regulatory Reform.

***2011 (March 23) Judge Moreno issues order reversing previous order compelling construction of the EAA A-1 Reservoir.** Judge Moreno, in accepting the recommendation of his court-appointed advisor, found the water district's declining budget, the U.S. Sugar land purchase, and another judge's order had altered restoration plans. Accordingly, Judge Moreno reversed his previous order that had compelled the construction of the EAA A-1 Reservoir.

*****2011 (April 26) Judge Gold issues Omnibus Order.** According to Judge Gold this order attempts to give EPA the tools necessary to bring the full force of the

CWA to bear upon the restoration of the Everglades. Judge Gold recognizes EPA's "more committed effort" to comply with the April 14, 2010, order and granted EPA's motion to amend the order to eliminate the requirement that EPA withdraw FDEP's authority to issue NPDES permits, and also seeks to transfer permitting authority to EPA pursuant to the CWA. This will help achieve the goals presented in the EPA's Amended Determination.

Appendix E

Status of Numerical Nutrient Water Quality Criteria for the State of Florida

The federal Clean Water Act (CWA) requires all states to adopt water quality standards (WQS) for the water bodies within their states. The U.S. Environmental Protection Agency (EPA) is required to review and approve these water quality standards. Under the CWA, water quality standards consist of both *designated uses* (e.g., designated for drinking water, for shellfish harvesting, or to be fishable and swimmable) and the *water quality criteria* established to protect the designated use. If a state water quality standard is determined to be inadequate to comply with the requirements of the CWA, then EPA must disapprove the standard, and if the state fails to adopt a standard that is adequate for EPA to approve, then EPA must step in and adopt its own water quality standard for that water body in that state. Many, but not all, water quality criteria are expressed as numeric limitations on the concentration of particular pollutants that can be in a particular water body without interfering with the designated use of that water body. For many years the state of Florida has had a narrative water quality standard for nutrients in its water bodies. The narrative standard provides that "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of flora or fauna." However, because it is difficult to enforce such a vague standard and because Florida's waters continue to be degraded by nutrient inputs, the Florida Department of Environmental Protection (FDEP) has been under pressure for many years to develop more specific numeric nutrient criteria.

In 2008, the Florida Wildlife Federation and four other environmental organizations filed a lawsuit against EPA, asserting that because the state of Florida had not yet adopted numeric nutrient criteria, the CWA obligated EPA to establish them. The Florida Department of Agriculture and Consumer Services, the South Florida Water Management District (SFWMD), and 11 trade associations intervened in the case. In 2009, EPA determined that because of the large numbers of water bodies in Florida that are currently impaired by nutrients and because the numbers of nutrient-impaired waters in Florida continue to grow, Florida's existing narrative nutrient standards were not adequate and numeric nutrient criteria for nitrogen and phosphorus were necessary. Accordingly, EPA entered into a consent decree with the Florida Wildlife Federation and in December 2010 published its rule for a numeric nutrient standard for inland freshwater bodies in the state of Florida (excluding South Florida canals). EPA's rule established numeric criteria for chlorophyll a, total nitrogen (TN), and total phosphorus (TP) for three categories of lakes (colored lakes, clear lakes with high alkalinity, and clear lakes with low alkalinity) and TN and TP criteria for streams, depending on the watershed in which the streams are located. EPA has also indicated that it planned to propose a second rule in the future, which would establish a numeric nutrient standard for estuaries, coastal waters, and South Florida canals. Although EPA's numeric nutrient standards will not apply directly to the Everglades Protection Area, which already is subject to the numeric criterion of 10 parts per billion (ppb) total phosphorus (TP), the estuary and coastal waters numeric nutrient criteria may have significant implications for the Everglades because run-off and discharge from both Lake Okeechobee and the Everglades ultimately reach estuaries and coastal areas.

The state of Florida, the Florida Commissioner of Agriculture, the SFWMD, and 22 other organizations brought legal challenges to EPA's 2009 determination and numeric nutrient criteria rule. On February 18, 2012, the U.S. District Court for the Northern District of Florida issued an order on these consolidated cases, which "upholds the [EPA] Administrator's determination that 'numeric nutrient criteria are necessary for Florida waters to meet the Clean Water Act's requirements,' upholds the Administrator's lake and spring criteria, invalidates the stream criteria, upholds the decision to adopt downstream protection criteria, upholds some but not all of the downstream protection criteria, and upholds the Administrator's decision to allow—and the procedures for adopting—site-specific alternative criteria."[1] Pursuant to the court's order, most of EPA's rule has been determined to be valid and was to "take effect on March 6, 2012—or an extended date approved by the court under . . . the consent decree—unless by that date the provision has been superseded by a Florida rule that the [EPA] Administrator has approved." EPA has proposed an extension of the effective date of the rule until October 6, 2012.[2] With regard to the two aspects of the rule that the court found to be invalid—numeric nutrient criteria for Florida streams that are not in the South Florida Region, and downstream protection criteria for unimpaired lakes—the EPA plans to issue a revised rule by November 30, 2012.

---

[1] *Florida Wildlife Federation, Inc. et al., v. Lisa P. Jackson, etc., et al.*, Order on the Merits (Consolidated Case No. 4:08cv324-RH/WCS, February 18, 2012.

[2] See http://water.epa.gov/lawsregs/rulesregs/florida_inland.cfm.

On April 22, 2011, FDEP petitioned EPA to withdraw its January 2009 determination that numeric nutrient criteria are necessary in Florida and to repeal its November 2010 numeric nutrient criteria for lakes and streams. The FDEP asserted that because it is committed to developing its own numeric criteria for waters in Florida, the EPA criteria are not necessary. The petition stated that FDEP was committed to develop and formally adopt its rule by January 2012, followed by legislative ratification under Florida law. On June 13, 2011, EPA sent an "Initial Response" to FDEP's petition stating that "EPA is prepared to withdraw the federal inland standards if FDEP adopts, and EPA approves, their own protective and scientifically sound numeric standards." On October 24, 2011, FDEP submitted its draft numeric nutrient criteria rule to EPA, and EPA responded with support for FDEP's efforts, stating its preliminary conclusion that EPA would approve the October 2011 draft rule. EPA stated its belief "that the proposed regulatory numeric criteria developed by FDEP represent very significant progress in protecting the State's unique aquatic resources." EPA noted, however, that final approval or disapproval of FDEP's numeric nutrient criteria rule would follow normal review of the rule and record.

On December 8, 2011, the Florida Environmental Regulation Commission (ERC) modified and approved FDEP's final rule for adoption (Chapters 62-302 and 62-303, F.A.C.; see Box E-1). The final rule approved by ERC incorporated two rule provisions that were not included in the initial proposed rule submitted to EPA on October 24, 2011: one exempting certain types of water bodies and conveyances from the definition of "stream," and another affirming that the "rules shall be effective only if EPA approves these rules in their entirety, concludes rulemaking that removes federal numeric nutrient criteria in response to the approval, and determines, in accordance with 33 U.S.C. § 1313(c)(3), that these rules sufficiently address EPA's January 14, 2009 determination." Additional details on the amended rule are provided in Box E-1. Governor Scott signed the bills into law in February 2012, and the Florida numeric nutrient criteria were subsequently submitted to EPA for approval.

On December 1, 2012, the Florida Wildlife Federation and other environmental groups filed an administrative rule challenge seeking to invalidate FDEP's proposed numeric nutrient rules, asserting that certain provisions of the rules are invalid exercises of delegated legislative authority. The challenge asserted that, "contrary to FDEP's claims, the rules are not designed to protect state waters from the adverse impacts of nutrient overenrichment. Instead, these rules go so far as to prevent a finding of impairment due to nutrients until the waterbody is covered with nutrient-fueled toxic blue-green algae (cyanobacteria)." In June 2012, the administrative law judge hearing the rule challenge upheld FDEP's numeric nutrient criteria rule. On June 13, 2012, FDEP submitted a letter to EPA enclosing the administrative order upholding FDEP's rule, stating that FDEP intends to

BOX E-1
FDEP's Proposed Numeric Nutrient Criteria

The FDEP numeric nutrient criteria final rule (F.A.C. 62-302.531) sets forth a complex scheme of "numeric interpretations" of the existing narrative nutrient standard, which will continue to apply to all water bodies in the state. A numeric interpretation of the narrative standard and biological measurements are added for each water body using a hierarchical approach, depending on whether and what type of site-specific numeric thresholds have already been established for that water body. There are three main standards under this hierarchy. Under the first standard, "where a site specific numeric interpretation of the [narrative] criterion [. . .] has already been established by the Department, this numeric interpretation shall be the primary interpretation." Where there are multiple such interpretations for a water body, the rule dictates that FDEP's most recent interpretation shall apply. The rule identifies the following as the primary site-specific interpretations: total maximum daily loads (TMDLs) "that interpret the narrative water quality criterion for [. . .] one or more nutrients or nutrient response variables" listed in the rules; "site specific alternative criteria (SSAC) for one or more nutrients or nutrient response variables" established in the rules; "estuary-specific numeric interpretations of the narrative nutrient criterion established" in the rules; or "other site-specific interpretations for one or more nutrients or nutrient response variables that are formally established by rule or final order" by FDEP. If the first standard is not applicable for a specific water body, under the second standard the numeric interpretation of the narrative criteria would be based on "an established, quantifiable cause-and-effect relationship" between nutrient concentrations and impacts to the aquatic biology. The rule establishes no numeric nutrient threshold for streams in the South Florida region; the narrative criterion continues to apply to streams in this area. The FDEP rule excludes certain man-made ditches, canals, and other conveyances, as well as wetlands, certain non-perennial water segments, portions of streams that exhibit lake characteristics, and tidally influenced stream segments from the definition of "stream" within the rule; as such, the narrative standard continues to apply to these bodies until numeric interpretations can be scientifically established.

move forward to adopt numeric nutrient criteria for coastal and estuarine waters and urging EPA to favorably consider FDEP's petition requesting that EPA repeal its federally promulgated rule. As of May 2012, EPA had not yet responded to FDEP's request. If EPA finds FDEP's rule to be adequate and thus repeals the federal rule, the FDEP rules will be the governing numeric nutrient criteria rule. If EPA finds FDEP's Rule to be inadequate and declines to repeal the federal rule, the portions of the EPA Rule upheld by the court will go into effect. EPA has proposed an extension of the effective date of that rule until October 2012.

Appendix F

Water Science and Technology Board; Board on Environmental Studies and Toxicology

WATER SCIENCE AND TECHNOLOGY BOARD

DONALD I. SIEGEL, *Chair*, Syracuse University, New York
LISA ALVAREZ-COHEN, University of California, Berkeley
EDWARD J. BOUWER, Johns Hopkins University, Baltimore, Maryland
YU-PING CHIN, Ohio State University, Columbus
OTTO C. DOERING, Purdue University, West Lafayette, Indiana
M. SIOBHAN FENNESSY, Kenyon College, Gambier, Ohio
BEN GRUMBLES, Clean Water America Alliance, Washington, DC
GEORGE R. HALLBERG, The Cadmus Group, Watertown, Massachusetts
KENNETH R. HERD, Southwest Florida Water Management District, Brooksville, Florida
GEORGE M. HORNBERGER, Vanderbilt University, Nashville, Tennessee
KIMBERLY L. JONES, Howard University, Washington, DC
LARRY LARSON, Association of State Floodplain Managers, Madison, Wisconsin
DAVID H. MOREAU, University of North Carolina, Chapel Hill
DENNIS D. MURPHY, University of Nevada, Reno
MARYLYNN V. YATES, University of California, Riverside

Staff

JEFFREY W. JACOBS, Director
LAURA J. EHLERS, Senior Program Officer
LAURA E. HELSABECK, Senior Program Officer
STEPHANIE E. JOHNSON, Senior Program Officer
M. JEANNE AQUILINO, Financial and Administrative Associate
ANITA A. HALL, Senior Program Associate
MICHAEL J. STOEVER, Research Associate
SARAH E. BRENNAN, Senior Program Assistant

BOARD ON ENVIRONMENTAL STUDIES AND TOXICOLOGY

ROGENE F. HENDERSON, *Chair*, Lovelace Respiratory Research Institute, Albuquerque, New Mexico
PRAVEEM AMAR, Clean Air Task Force, Boston, Massachusetts
MICHAEL J. BRADLEY, M.J. Bradley & Associates, Concord, Massachusetts
JONATHAN Z. CANNON, University of Virginia, Charlottesville
GAIL CHARNLEY, HealthRisk Strategies, Washington, DC
FRANK W. DAVIS, University of California, Davis
RICHARD A. DENISON, Environmental Defense Fund, Washington, DC
CHARLES T. DRISCOLL, JR., Syracuse University, New York
RICHARD M. GOLD, Holland & Knight, LLP, Washington, DC
LYNN R. GOLDMAN, Johns Hopkins University, Baltimore, Maryland
LINDA E. GREER, National Resources Defense Council, Washington, DC
WILLIAM E. HALPERIN, University of Medicine and Dentistry, New Jersey, Newark
PHILIP K. HOPKE, Clarkson University, Potsdam, New York
HOWARD HU, University of Michigan, Ann Arbor
SAMUEL KACEW, University of Ottawa, Ontario, Canada
ROGER E. KASPERSON, Clark University, Worcester, Massachusetts
THOMAS E. MCKONE, University of California, Berkeley
TERRY L. MEDLEY, E. I. du Pont de Nemours & Company, Wilmington, Delaware
JANA MILFORD, University of Colorado at Boulder
FRANK O'DONNELL Clean Air Watch, Washington DC
RICHARD L. POIROT, Vermont Department of Environmental Conservation, Waitsfield
KATHRYN G. SESSIONS, Health and Environmental Funders Network, Bethesda, MD
JOYCE S. TSUJI, Exponent, Inc., Bellevue, WA

Senior Staff

JAMES J. REISA, Director
DAVID J. POLICANSKY, Scholar
ELLEN K. MANTUS, Senior Program Officer for Risk Analysis
SUSAN N. J. MARTEL, Senior Program Officer for Toxicology
RAYMOND A. WASSEL, Senior Program Officer for Environmental Studies
EILEEN N. ABT, Senior Program Officer
MISADA KARALIC-LONCAREVIC, Manager, Technical Information Center
RADIAH ROSE, Manager, Editorial Projects

Copyright © National Academy of Sciences. All rights reserved.

Appendix G

Biographical Sketches of Committee Members and Staff

William G. Boggess, *Chair,* is professor and executive associate dean of the College of Agricultural Sciences at Oregon State University (OSU). He previously served as the president of the OSU Faculty Senate. Prior to joining OSU, Dr. Boggess spent 16 years on the faculty at the University of Florida in the Food and Resource Economics Department where he was involved with Everglades work. His research interests include interactions between agriculture and the environment (e.g., water allocation, groundwater contamination, surface-water pollution, sustainable systems, water and environmental policy); economic dimensions and indicators of ecosystem health; and applications of real options to environmental and natural resources. Dr. Boggess previously served on the Oregon Governor's Council of Economic Advisors, the Board of Directors of the American Agricultural Economics Association, and the Food Alliance, and he currently serves on the Board of the Oregon Environmental Council. He served on the State of Oregon Environment Report Science Panel and has been active in the design and assessment of the Oregon Conservation Reserve Enhancement Program. Dr. Boggess served as a member of the NRC Committee on the Use of Treated Municipal Wastewater Effluents and Sludge in the Production of Crops for Human Consumption, and on the second and third Committees on Independent Scientific Review of Everglades Restoration Progress. He received his Ph.D. from Iowa State University in 1979.

Mary Jane Angelo is professor of law at the University of Florida's Levin College of Law and Director of the Environmental and Land Use Law Program. Her research areas focus on environmental law, water law, administrative law, biotechnology law, dispute resolution, pesticides law, law and science, and legal ethics. Prior to joining the faculty, Ms. Angelo served as an attorney in the U.S. Environmental Protection Agency's Office of General Counsel and as senior assistant general counsel for the St. Johns River Water Management District. She received her B.S. in biological sciences from Rutgers University and her M.S. and J.D. from the University of Florida.

David B. Ashley is professor of civil engineering at the University of Nevada, Las Vegas (UNLV). Dr. Ashley also served as the eighth president at the school from 2006 to 2009. Prior to joining UNLV, President Ashley served as executive vice chancellor and provost at the University of California, Merced and held the Shaffer-George Chair in Engineering. He has also served as dean of engineering at The Ohio State University and has held civil engineering faculty positions at the University of California, Berkeley, the University of Texas at Austin, and the Massachusetts Institute of Technology. Dr. Ashley's principal research and teaching activities are in the area of construction project planning, focusing primarily on risk analysis and management of large-scale, complex projects. His recent studies have addressed innovative project financing and new project procurement approaches. He has served on several NRC committees, including the Committee on Assessing the Results of External Independent Reviews for U.S. Department of Energy Projects. Dr. Ashley received a B.S. in civil engineering and an M.S. in civil engineering-project management from the Massachusetts Institute of Technology, and an M.S. in engineering-economic systems and a Ph.D. in civil engineering-constructing engineering and management from Stanford University.

Charles T. Driscoll (NAE) is university professor in the Department of Civil and Environmental Engineering at Syracuse University where he also serves as the director of the Center for Environmental Systems Engineering. His teaching and research interests are in the area of environmental chemistry, biogeochemistry, and environmental quality modeling. A principal research focus has been the response of forest, aquatic, and coastal ecosystems to disturbance, including air pollution, land use change, and elevated inputs of nutrients and mercury. Dr. Driscoll is currently a principal investigator of the National Science Foundation's Long Term Ecological Research Network's project at the Hubbard Brook Experimental Forest in New Hampshire. He is a member of the National Academy of Engineering and was a member of the NRC's Panel on Process of Lake Acidification, the Committees on Air Quality Management in the U.S. and the Collaborative Large-scale Engineering Analysis Network for Environmental Research (CLEANER), and the second and third Committees on Independent Scientific Review of Everglades Restoration Progress. Dr. Driscoll received his B.S. in civil engineering from the University of Maine and his M.S. and Ph.D. in environmental engineering from Cornell University.

William L. Graf is Foundation University Distinguished Professor, Emeritus, at the University of South Carolina. His expertise is in fluvial geomorphology and hydrology, as well as policy for public land and water. Dr. Graf's research and teaching have focused on river-channel change, human impacts on river processes, morphology, and ecology, along with contaminant transport and storage in river systems. His present work emphasizes the downstream effects of dams on rivers. In the arena of public policy, he has emphasized the interaction of science and decision making, and the resolution of conflicts among economic development, historical preservation, and environmental restoration for rivers. Dr. Graf has served as member of the NRC's Water Science and Technology Board and Board on Earth Sciences and Resources, the Panel to Review the Critical Ecosystem Studies Initiative, the Committee on Restoration of the Greater Everglades Ecosystem, and the first three Committees on Independent Scientific Review of Everglades Restoration Progress, serving as chair of the second committee. He is chair of the NRC's Geographical Sciences Committee. He is also a national associate of the National Academies and an American Association for the Advancement of Science fellow. Dr. Graf earned a certificate of water resources management and his Ph.D. from the University of Wisconsin, Madison, in 1974.

Wendy D. Graham is the Carl S. Swisher Eminent Scholar in Water Resources in the Department of Agricultural and Biological Engineering at the University of Florida and director of the University of Florida Water Institute. Her research is focused on coupled hydrologic-water quality-ecosystem modeling; water resources evaluation and remediation; evaluation of impacts of agricultural production on surface- and groundwater quality; and development of hydrologic indicators of ecosystem status. She has previous NRC committee experience, having served on the Committee on Seeing into the Earth: Non-Invasive Techniques for Characterization of the Shallow Subsurface for Environmental Engineering Applications, and as a member of the third Committee on Independent Scientific Review of Everglades Restoration Progress. Dr. Graham received her B.S.E. in environmental engineering from the University of Florida and her Ph.D. in civil engineering from the Massachusetts Institute of Technology.

Sam Luoma is an emeritus senior research hydrologist in the Water Resources Division of the U.S. Geological Survey, where he worked for 34 years. He also holds an appointment as a research professor at The John Muir Institute of the Environment, University of California, Davis. Dr. Luoma's research centers on fate and effects of chemical contaminants, including their interactions with sediments, particularly in the San Francisco Bay-Delta. He served as the first lead scientist on the CALFED Bay-delta program and is the editor-in-chief of *San Francisco Estuary & Watershed Science*. He has published extensively on the bioavailability and ecological effects of metals in aquatic environments as well as on environmental implications of nanotechnology and coordination between science and water policy. He has helped refine approaches to determine the toxicity of marine and estuarine sediments. In 2004 he was a Fulbright Distinguished Scholar at The Natural History Museum, London, and continues to be affiliated with that institution working on environmental contamination issues. He has served multiple times on the U.S. Environmental Protection Agency's Science Advisory Board Subcommittee on Sediment Quality Criteria and on several NRC committees, including the Committee on Sustainable Water and Environmental Management in the California Bay-Delta. Dr. Luoma received his B.S. and M.S. in zoology from Montana State University, Bozeman, and his Ph.D. in marine biology from the University of Hawaii, Honolulu.

David R. Maidment is the Hussein M. Alharthy Centennial Chair in Civil Engineering and director of the Center for Research in Water Resources at the University of Texas at Austin. His expertise is in surfacewater hydrology, and in particular in the application of geographic information systems to hydrology. Dr. Maidment has extensive previous NRC committee experience, having served as chair of four committees, including two concerned with Federal Emergency Management Agency floodplain mapping and two concerned with U.S. Geological Survey water resources research, and a member of three other committees, including the Committee on Review of Methods for Establishing Instream Flows for Texas Rivers. He received his B.E. in agricultural engineering from the University of Canterbury, Christchurch, New Zealand, and his M.S. and Ph.D. in civil engineering from the University of Illinois at Urbana-Champaign.

David H. Moreau is Research Professor, Department of City and Regional Planning, at the University of North Carolina at Chapel Hill. He recently completed a term as Chair of the Curriculum for the Environment and Ecology. His research interests include analysis, planning, financing, and evaluation of water resource, water quality, and related environmental programs. Dr. Moreau is engaged in water resources planning at the local, state, and national levels. He has served on several NRC committees, including the Committee on New Orleans Regional Hurricane Protection Projects Review, the Committee on the Mississippi River and Hypoxia in the Gulf of Mexico, and the second, third, and fourth Committees on Independent Scientific Review of Everglades Restoration Progress, and he is a current member of the Water Science and Technology Board. Dr. Moreau recently completed 19 years as a member and 16 years as

Chairman of the North Carolina Environmental Management Commission, the state's regulatory commission for water quality, air quality, and water allocation. For his service to North Carolina he was awarded the Order of the Long Leaf Pine, the highest civilian award offered by the State. He received his B.S. and M.S. from Mississippi State University and North Carolina State University, respectively, and his Ph.D. degree from Harvard University.

Scott Nixon was professor of oceanography and the URI UNESCO-Cousteau Chair in Coastal Ecology and Global Assessment at the University of Rhode Island. His research focused on productivity and biogeochemical cycling of coastal ecosystems, with emphasis on estuaries, lagoons, and wetlands. He was interested in comparative and historical ecology and conducted ecosystem-level experiments using mesocosms. Dr. Nixon previously served as a member of the NRC's Ocean Studies Board, chair of the Committee to Review the Florida Keys Carrying Capacity Study, vice-chair of the Committee on Restoration of the Greater Everglades Ecosystem, and a member of four other NRC committees. He was a past co-editor-in-chief of *Estuaries and Coasts* and a national associate of the National Academies. He also had served as the director of Rhode Island Sea Grant from 1984 to 2000. Dr. Nixon received a B.A. in biology from the University of Delaware and a Ph.D. in botany/ecology from the University of North Carolina-Chapel Hill.

K. Ramesh Reddy is graduate research professor and chair of the Department of Soil and Water Science at the University of Florida. His research areas include biogeochemistry, soil and water quality, ecological indicators, and restoration of wetlands, and aquatic systems. Dr. Reddy investigates biogeochemical cycling of macro-nutrients in natural ecosystems, including wetlands, shallow lakes, estuaries, and constructed wetlands, as related to soil and water quality, carbon sequestration, and greenhouse gas emissions. He served as a member of the U.S. National Committee for Soil Sciences in the National Academy's Policy and Global Affairs Division. He served on the U.S. Environmental Protection Agency's Science Advisory Board Panel. Dr. Reddy served as a member of the second and third Committees on Independent Scientific Review of Everglades Restoration Progress. Dr. Reddy earned his Ph.D. in agronomy and soil science from Louisiana State University in 1976.

Helen Regan is an associate professor of biology at the University of California, Riverside. Her research areas span quantitative conservation ecology and probabilistic risk assessment. Dr. Regan has applied population models, uncertainty analyses, and decision-making techniques to address a variety of conservation and wildlife management issues. She focuses on methodological issues of these techniques, the practicalities of their application and their interpretation for management. Projects include ecological risk assessment of chemical contaminants, population viability of species impacted by a range threats, monitoring of multiple species habitat conservation plans, population-level effects of habitat fragmentation, and fire and disease on plants in fire-prone ecosystems. Current research includes examination of the impact of uncertainty on potential adaptation strategies for threatened species impacted by climate change. She currently serves on the Standards and Petitions Subcommittee of the International Union for the Conservation of Nature Species Survival Commission and on the scientific advisory committee for the Australian Centre of Excellence for Risk Analysis. Dr. Regan received her B.S. from LaTrobe University and her Ph.D. from the University of New England in Armidale, both in Australia.

Eliska Rejmankova is a professor in the department of Environmental Science and Policy at University of California, Davis, where she has been a member of the community since 1987. Her current research encompasses wetland ecology at population, community, and ecosystem levels. At the ecosystem level she studies vegetation response to changes in nutrient inputs and salinity. At the population and community levels she focuses on life histories of several South/Central American species of malaria-transmitting mosquitoes. In addition to her current research, Dr. Rejmankova's interests include ecosystem and community ecology with particular attention to aquatic and wetland environments; wetland biogeochemistry; response of micro- and macrophytes to changes in nutrient limitation; nutrient resorption; life history strategies of malaria-transmitting mosquitoes habitat selection by ovipositing females; larval habitat characteristics; linking the changes of ecosystem structure to changes in malaria vector species with applications for malaria risk assessment; and wetland ecosystem management and conservation. She has been a member of the working group on tropical coastal research named "Caribbean Initiative" and has been on the advisory board for the ecology education at the University of South Bohemia, Czech Republic. Dr. Rejmankova received a B.S. and M.Sc. in Botany from Charles University in Prague and a Ph.D. in plant ecology from the Czech Academy of Sciences.

Jeff Walters is the Harold Bailey Professor of Biology at Virginia Polytechnic Institute and State University, a position he has held since 1994. His professional experience includes assistant, associate, and full professorships at North Carolina State University from 1980 until 1994. Dr. Walters has done extensive research and published many articles on the red-cockaded woodpeckers in North Carolina and Florida, and he chaired an American Ornithologists'

Union Conservation Committee Review that looked at the biology, status, and management of the Cape Sable seaside sparrow, a bird native to the Everglades. His research interests include cooperative breeding in birds, reproductive biology of precocial birds, primate intragroup social behavior, ecological basis of sensitivity to habitat fragmentation, kinship effects on behavior, and dispersal behavior. Dr. Walters served in two panels set up through the Sustainable Ecosystems Institute that addressed issues with endangered birds in the Everglades restoration in addition to previously serving as a member of the NRC's Committee on Restoration of the Greater Everglades Ecosystem and the first Committee on Independent Scientific Review of Everglades Restoration Progress. He holds a B.A. from West Virginia University and a Ph.D. from the University of Chicago.

Staff

Stephanie E. Johnson, study director, is a senior program officer with the Water Science and Technology Board. Since joining the NRC in 2002, she has served as study director for 12 committees on topics such as water reuse, desalination, Chesapeake Bay nutrient management, and Everglades science. She has also worked on NRC studies on contaminant source remediation, the disposal of coal combustion wastes, and water security. Dr. Johnson received her B.A. from Vanderbilt University in chemistry and geology, and her M.S. and Ph.D. in environmental sciences from the University of Virginia.

David J. Policansky is a scholar and director of the Program in Applied Ecology and Natural Resources in the Board on Environmental Studies and Toxicology. He earned a Ph.D. in biology from the University of Oregon. Dr. Policansky has directed approximately 35 NRC studies, and his areas of expertise include genetics, evolution, ecology, including fishery biology, natural resource management, and the use of science in policy making.

Michael J. Stoever is a research associate with the Water Science and Technology Board. He has worked on a number of studies including Desalination: A National Perspective, the Water Implications of Biofuels Production in the United States, and the Committee on Louisiana Coastal Protection and Restoration. He has also worked on NRC studies on the FEMA National Flood Insurance Program, the effect of water withdrawals on the St. Johns River, and Chesapeake Bay restoration. Mr. Stoever received his B.A. in political science from The Richard Stockton College of New Jersey in Pomona, New Jersey.

Sarah E. Brennan is a senior program assistant with the Water Science and Technology Board. Since joining the NRC in 2010, she has worked on five projects including Everglades restoration progress, U.S. Army Corps of Engineers' water resources, and water and environmental management in the California bay delta. Before joining WSTB, Ms. Brennan was a Peace Corps Volunteer in Ghana, West Africa. She received her B.S. in International Development from Susquehanna University.