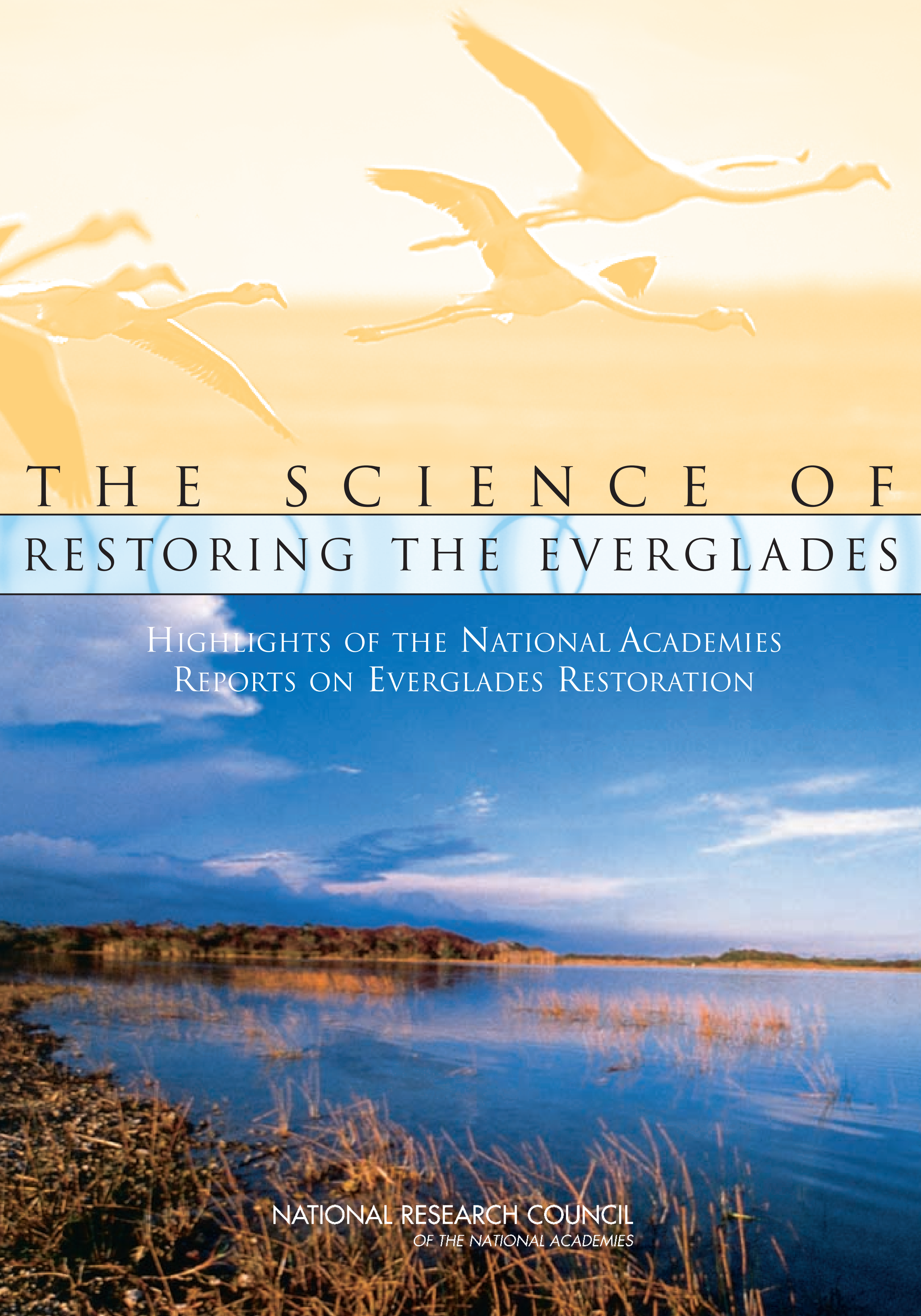
THE SCIENCE OF RESTORING THE EVERGLADES

Highlights of the National Academies Reports on Everglades Restoration



NATIONAL RESEARCH COUNCIL
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Florida's Everglades, the splendid River of Grass, is like no other place on Earth. Shaped by the flow of slow-moving water, its rich landscape of sawgrass ridges, sloughs and tree islands is home to alligators, many kinds of wading birds, and other plant and animal life. By the mid-twentieth century, a vast network of canals and levees, built to drain water for flood control, water supply, agriculture, and urban development, had profoundly altered the region's wetlands and reduced the Everglades to half its original size. Today, the wading bird population has sharply declined, and 68 plant and animal species are threatened or endangered.

Throughout the twentieth century, the Everglades epitomized the American conflict between economic development and environmental conservation. In recent years, the region has embraced the challenge of protecting and restoring native species and ecosystems while still meeting human needs for space and natural resources.

LIKE MANY LARGE ENGINEERING PROJECTS, the restoration of the Everglades is a daunting task. It is extremely complex for several reasons: first, the Everglades ecosystem is huge, stretching over 18,000 square miles from the Kissimmee River watershed to Florida Bay and the coral reefs (see Figure 1); second, the restoration plan must attempt to balance the interests of many stakeholders; third, restoration goals must consider the complex and often competing needs of different plant and animal species; fourth, the plan must take into account unknown factors such as future climate change and urban population growth; finally, and maybe most importantly, there are competing visions of what will constitute successful restoration.

Figure 1. Much bigger than just Everglades National Park, the greater Everglades ecosystem (or South Florida ecosystem*) extends south from the Kissimmee River watershed to Lake Okeechobee, through the remaining Everglades, and on to the waters of Florida Bay and the coral reefs.

**The South Florida ecosystem as legally defined in the Water Resources Development Act of 2000.*

Since 1993, an unusual coalition of local, state, and federal agencies, as well as non-government organizations, local tribes, and citizens, has been working to reverse the damage to the Everglades. The effort is led by two organizations that know where the water goes in South Florida—the U.S. Army Corps of Engineers (the Corps), which built most of the canals and levees in the Everglades, and the South Florida Water Management District. In 1999, the Corps issued its blueprint for the restoration effort, the Comprehensive Everglades Restoration Plan (the Restoration Plan). The plan's primary goal is to "get the water right"—that is, to deliver the right amount and quality of water to the right places at the right times. The plan proposes more than 50 major projects to be constructed over an estimated 36 years at a cost of approximately $7.8 billion.

SIDEBAR 1

Everglades-Related Reports from the National Academies

Does Water Flow Influence Everglades Landscape Patterns? (2003)

Science and the Greater Everglades Ecosystem Restoration: An Assessment of the Critical Ecosystem Studies Initiative (2003)

Adaptive Monitoring and Assessment for the Comprehensive Everglades Restoration Plan (2003)

Regional Issues in Aquifer Storage and Recovery for Everglades Restoration (2002)

Florida Bay Research Programs and their relation to the Comprehensive Everglades Restoration Plan (2002)

Aquifer Storage and Recovery in the Greater Everglades Restoration Plan: A Critique of the Pilot Projects and Related Plans for ASR in the Lake Okeechobee and Western Hillsboro Areas (2001)

While not all parties agree on the details of the restoration, there is near universal agreement that the best possible science should support planning, implementation, and, ultimately, operation of restoration projects. Good science can increase the reliability of the restoration outcome, help provide solutions for unanticipated problems, and potentially reduce long-term costs.

Responding to a request from the U.S. Department of the Interior (on behalf of the South Florida Ecosystem Restoration Task Force) to provide advice on scientific aspects of restoration activities, the National Academies established the Committee on Restoration of the Greater Everglades Ecosystem (CROGEE) in September 1999. A second National Academies' committee, the Panel to Review the Critical Ecosystems Studies Initiative, in 2002 reviewed the Department of the Interior's Critical Ecosystems Studies Initiative, a major engine of science and research related to the restoration.

This brochure highlights some important themes that have emerged from the reports to date from these committees (see Sidebar 1). In producing these reports, committee members have worked collegially with restoration project leaders, scientists from many agencies, and representatives from environmental and agricultural organizations. They have spent considerable time in Florida on site visits and in regular meetings with representatives from the Corps, the South Florida Water Management District, and other involved agencies including the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, the U.S. Environmental Protection Agency, and the National Park Service.

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The Certainty of Uncertainty

A FUNDAMENTAL QUESTION of Everglades restoration is how to capture and store water and then distribute it to replenish water in the ecosystems during dry periods (see Sidebar 2, p.4). Restoration planners are evaluating several possible technologies for doing this, perhaps the most ambitious of which is a system of aquifer storage and recovery (ASR). Conceived as the linchpin for "getting the water right," the aquifer storage and recovery plan proposes drilling more than 300 wells in South Florida that would funnel up to 1.7 billion gallons of water a day into underground aquifers to be stored and pumped out as needed.

It isn't yet known if the proposed system will accomplish what it's meant to do. Although aquifer storage and recovery has been successfully used on a much smaller scale in Florida since 1983, the scale of the new proposal is unprecedented and has raised several concerns. For example, how much of the surface water stored in aquifers can actually be recovered? What if fresh surface water mixes with salt water underground or dissolves undesirable chemicals from the rocks in which it is stored? Will too many closely spaced wells fracture rock formations and allow salt water to move into shallow fresh water aquifers?

Dealing with these uncertainties is the main thrust of the first report in this series, *Aquifer Storage and Recovery in the Greater Everglades Restoration Plan*, which reviewed the Corps pilot project to drill several test wells. The report urges the Corps to apply the principles of adaptive management to the project—that is, to design it in such a way that enables engineers to answer important questions as the project is implemented, and thus to design better project components as they proceed, or to reverse course if necessary. For a first-of-its-kind engineering project like aquifer storage and recovery, adaptive management can help to both avoid negative consequences and ensure that project goals are being met.

The report identifies three key areas of uncertainty—regional issues, water quality, and local performance—for which an improved understanding requires actions well beyond the scope of the pilot project that was originally proposed. It recommends that the Corps develop a more complete picture of the region by developing a regional-scale groundwater flow model and conducting exploratory drilling to characterize underlying rock formations, water quality, and other physical features. It also advises a number of field and laboratory studies to ensure the water is safe for all its intended uses.

Overall, the Corps was very responsive to these suggestions as affirmed in the review of the revised pilot plan, *Regional Issues in Aquifer Storage and Recovery for Everglades Restoration* (2002). The report concludes that the revised plan could have been even more consistent with the principles of adaptive management. It also recommends that those monitoring ecologic effects of water from aquifer storage and recovery systems pay more attention to impacts on the ecosystem as a whole, rather than just toxicity to individual organisms.

SIDEBAR 2

The Challenges of Water Storage

Historically, much of the water in the Everglades came from overflows from Lake Okeechobee's southern banks that continued as uninterrupted sheet flow to the Gulf of Mexico and Florida Bay. Now when it rains north of Lake Okeechobee, canals built to protect Floridians from flooding channel precious freshwater out to sea—water that is bad for estuarine ecosystems, but needed in the Everglades. Roads, levees, and agricultural areas south of the Lake further interrupt the flow of water.

Today, Lake Okeechobee is relied on to meet many demands for fishing, water supply for neighboring towns, and bird habitats including the endangered Everglades snail kite. In its present state of use, the lake by itself cannot serve as the water storage system for replenishing the Everglades.

In looking for alternative means to capture and store water, the Task Force has proposed Aquifer Storage and Recovery (ASR) and some other technologies that are yet unproven. The full-scale aquifer storage and recovery plan for Lake Okeechobee is designed to, among other things, provide regional storage, reduce harmful discharges to close-by estuaries, and enhance flood protection.

The Search for Evidence in Florida Bay

FLORIDA BAY, a large shallow estuary just south of the Everglades, was once a fisher's paradise. For decades until the late 1980s, its crystal-clear waters yielded rich fish and shrimp harvests; dense meadows of seagrasses provided a habitat for many kinds of animal life and helped clear the water by reducing the amount of suspended sediment. Since then, its seagrass meadows and animal populations have sharply declined and its waters have become increasingly cloudy.

An important assumption made by scientists and managers associated with the Restoration Plan, and by the public, is that the increased freshwater flows deemed beneficial to the Everglades ecosystems would also benefit Florida Bay; they believe that hypersalinity (too much salt) has caused the seagrass die-off. One of the competing hypotheses that has emerged in the Florida Bay research community suggests that current conditions are instead the result of algal blooms that proliferate as nitrogen-rich waters mix with phosphorus-rich waters. Under this hypothesis, more freshwater might actually do harm by ferrying more nitrogen into the bay, mostly from fertilizers in soil.

The issues of Florida Bay illustrate some of the complexities of the restoration. What is good for one part of the system may or may not be good for another, necessitating careful research on the unique needs of distinct ecosystems. The issues also illustrate the difficulty in defining success; historical accounts suggest that the bay was a murky body of water in the early 1900s. Does success mean restoring the historical bay, or the gin-clear waters of recent memory?

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In the report, *Florida Bay Research Programs and their relation to the Comprehensive Everglades Restoration Plan* (2002), the study committee urges more specific research to pinpoint the exact cause of the seagrass die-off. The report also advises researching uncertainties regarding the potential long-term effects of the Restoration Plan on Florida Bay to allow time for alternative strategies to be developed if needed. More precise characterization of the bay's earlier history would help clarify how the plan might affect the bay.

Go with the Flow

THE HISTORIC FLOW of slow-moving water from Lake Okeechobee to Florida Bay probably fashioned the unique topography of the Everglades—a parallel arrangement of evenly spaced sawgrass ridges and open-water sloughs, dotted with higher tree islands (see Figure 2). These landforms provide the diverse habitats that support plant and animal life. Tree islands are nesting sites for alligators and roosting birds; the topography and vegetation of the ridges and sloughs is believed to contribute directly to the productivity and diversity of fish and wading birds.

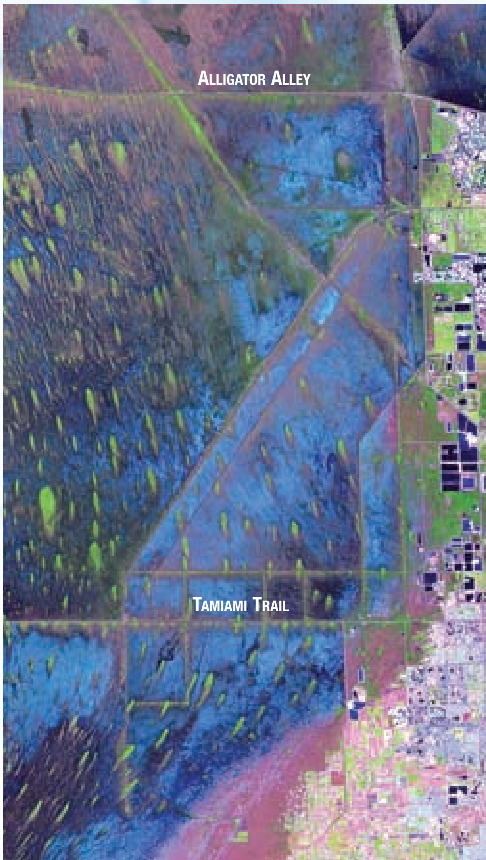

Figure 2. The light green teardrop shapes are the tree islands in this satellite image of the ridge and slough landscape. The degradation of the ridge and slough pattern south of the Tamiami Trail shows how barriers to flow may affect the landscape. Source: South Florida Water Management District.

Degradation of the ridges, sloughs, and tree islands is well documented, particularly in association with major barriers to flow—canals, levees, and roads such as the Tamiami Trail. In many places, the landscape is flattening and losing the diversity of habitat on which many species depend. Data are lacking on water flow either before or after flow was disturbed by development, but circumstantial evidence indicates that the direction, speed, and distribution of water flow are vitally important to maintaining ecologically important landforms. Due in part to the lack of data and in part to current model constraints, the Restoration Plan does not emphasize water flow despite its probable importance.

In *Does Water Flow Influence Everglades Landscape Patterns?*, the study committee concludes that ignoring flow introduces an important source of uncertainty in the Restoration Plan. Because the exact mechanisms for degradation are not known, the report urges focused research to gain a better scientific understanding of the processes that affect the maintenance of the ridges and sloughs and tree islands, including flows, yearly cycles of water depth, floods and droughts, fire, and their interactions. The report advises against establishing flow performance measures until ridge and slough maintenance processes are better understood.

Are We Making Progress?

THE BASIC PREMISE of the Restoration Plan is that restoring the historical water flow patterns to the remaining wetlands will reverse declines in many native species and biological communities. In order to measure changes in ecosystem conditions, extensive ecological research, monitoring, and adaptive management are planned during construction and after projects are completed. The proposed Monitoring and Assessment Plan (MAP) was reviewed in the report, *Adaptive Monitoring and Assessment for the Comprehensive Everglades Restoration Plan (2003).*

A big challenge for monitoring restoration progress is deciding what success means. At this point, no one knows what the restored Everglades will look like. It is certain that it won't look like the historic Everglades, because much of it has been permanently altered by roads and other development. Wading bird populations may not return to their previous locations even if restored because they've found new homes. Instead, progress must be measured by setting restoration targets.

Many restoration targets have focused on species restoration, for example, managing desired water levels for a specific endangered species. However, such performance measures may be at odds with overall restoration goals. Some targets that have been set—4,000 nesting pairs of wood storks in the Everglades and the Big Cypress Swamp, or 65-75% seagrass coverage of Florida Bay—may not be achievable, risking the credibility of restoration plans. Further, these performance measures do not reflect possible ecological tradeoffs that might have to be made to benefit one species at the expense of another.

SIDEBAR 3

Active vs. Passive Adaptive Management

Restoration planners' current management approach has been described as a "passive" adaptive management approach; science is used to develop best-guess predictive models, make policies according to these models, and revise them as data become available. The National Academies advise that every effort be made to take a more "active" adaptive management approach by developing alternative hypotheses for the expected consequences of a particular project and then design the project so the hypotheses can be experimentally tested. The use of more active adaptive management has been hindered in part by a concern over experimenting with complex ecosystems, but in some cases, the long-term payoff of what can be learned may be worth the short-term risks.

To complement the more than 100 individual hydrologic and ecological performance measures identified so far, the report advises developing some ecosystem-level, systemwide indicators of ecosystem health such as overall patterns of native species diversity. Measurements of nutrient runoff and the amount of organic material in soil are also good indicators of ecosystem condition. When possible, monitoring should be supplemented with active research designed to answer a specific scientific question (see Sidebar 3).

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It is also vital to measure the external drivers, such as sea-level rise, that could have a profound impact on ecosystem restoration. The report concludes that too little attention is paid to monitoring external drivers. Trends in climate change, sea-level rise, and extreme weather should be monitored and modeled on a regionwide basis, as should trends in population change, urban growth, agriculture, economic activity, and tourism.

Figure 3. CESI funding helped support research groups from Florida International University that are studying ecosystem response to different concentrations of phosphorus at flume sites in the Everglades. Source: FIU, 2003

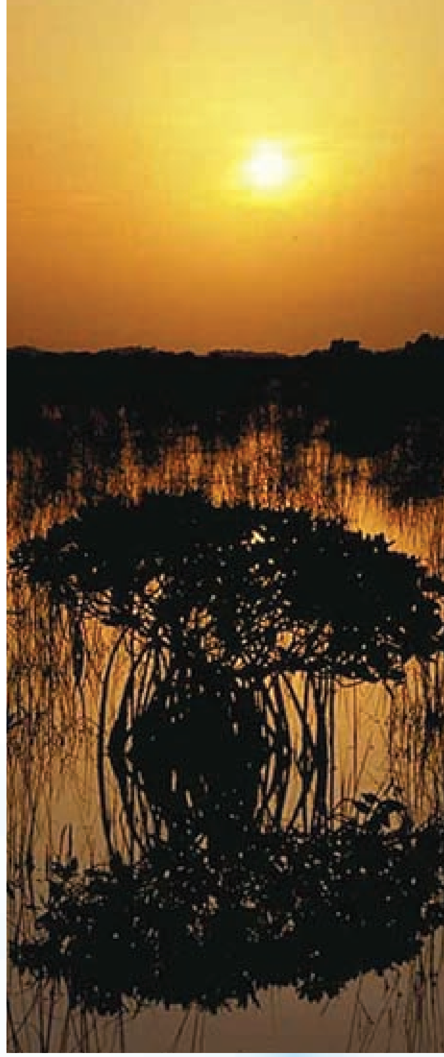
Making Use of the Science

IN A PERFECT WORLD, planners and managers under pressure to meet restoration project deadlines would have timely access to relevant scientific research results. Since restoration efforts began, the region has been rich with many agencies conducting scientific and engineering research; however, limited funding, divergent agency missions, insufficient coordination, and compressed timetables have left critical voids in the restoration science.

In 1997, the U.S. Department of the Interior established the Critical Ecosystem Studies Initiative (CESI) program, intended to meet the most important science information needs to support restoration project planning, design and implementation. The program is reviewed in the report, *Science and the Greater Everglades Ecosystem Restoration: An Assessment of the Critical Ecosystem Studies Initiative* (2003).

One of the program's challenges is to identify and fund the research to answer critical questions that would improve the likelihood of meeting restoration goals. For example, research on how plant communities respond to various phosphorus concentrations (see Figure 3) is designed to help Florida set maximum allowable phosphorus concentrations to protect downstream ecosystems.

Despite extensive research, the restoration effort risks being data rich and information poor in the absence of ecosystem-wide "synthesis" and "integration." Synthesis is the complex process of accumulating, interpreting, and articulating scientific results. It requires an ability to mesh research findings across many spatial scales, for example, understanding how a study of microbial processes in soil applies to ecosystem-wide conditions. Synthesis must also account for many variables from tidal changes to decadal changes in sea-level rise to the impact of restoration projects as they are implemented. Integration is the process of applying the resultant scientific information to project planning.



Although the program has had some success in using research findings to inform restoration planning, there is a substantial gap in both synthesis and integration. To address this gap, the report advises developing a multi-disciplinary restoration-wide mechanism for science synthesis.

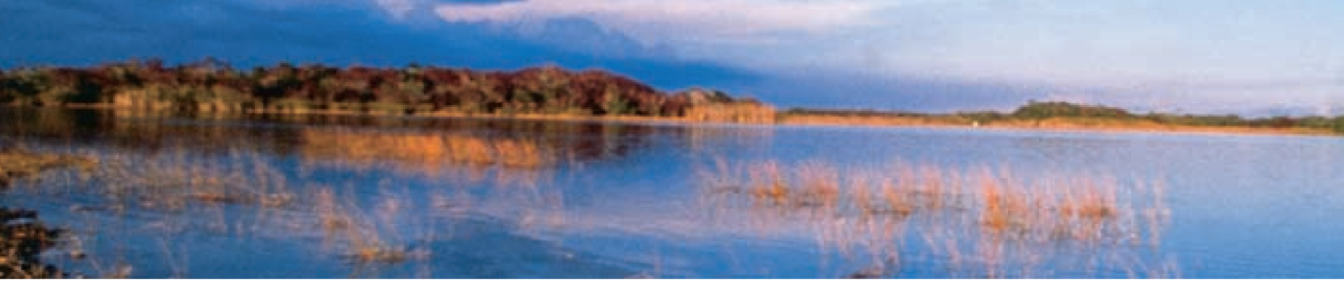
Where Do We Go From Here?

Congress increasingly requires independent scientific review to ensure both neutrality and scientific accuracy in federal agency projects. The National Academies will likely continue in its role of providing science advisory services to those agencies working on restoration plans, both through committees overseen by the Committee on Restoration of the Greater Everglades Ecosystem and other advisory bodies that may be formed.

Total costs for the Everglades restoration, including money spent on water quality and other projects, are expected to exceed the $7.8 billion price tag for the Restoration Plan. Still, the cost is comparable to other complex engineering projects, such as Boston's Big Dig, which is currently estimated at about $12 billion, or the cost of a large city's water or wastewater treatment facilities.

What most people want to know is if the money is being spent wisely and if the proposed technologies will work. Implementers must assess not only the technical aspects of a technology, but more fundamentally, whether it makes sense. For example, one of the most important considerations for aquifer storage recovery technology is whether the ecological benefits are worth the high energy costs of pumping water into and out of the aquifers over the anticipated life of the project. This consideration is among the hard policy decisions to be made.

World-class scientists and engineers are working on Everglades restoration plans. Their efforts could go a long way to revitalizing the Everglades, but it is not yet known if they will. Because of this uncertainty, it is vitally important to keep sight of some of the most important principles of sound science: true adaptive management that is not just an adjust-as-you go approach, but rather an informed process towards good design; research that seeks not only to ascertain trends but also to answer specific scientific questions; and careful monitoring and assessment that is communicated effectively to decision makers.



The National Academies provide a unique public service by engaging scientists, academics and practitioners in meaningful dialogue on the most challenging issues in science, engineering, and medicine. The institution—with its first organization, the National Academy of Sciences, chartered in 1863—has gained a reputation for providing insightful and balanced advice to the government and nation.

From the nation's wetlands to the Missouri River to restoring the Everglades, no important water-related controversy has escaped the attention of the National Academies. Committees organized by the Water Science and Technology Board or the Board on Environmental Studies and Toxicology have produced many reports on these and other topics. Committee members are selected for the individual expertise, and the committee is balanced to represent various points of view. At a time when water resources management is one of the nation's most complex endeavors, these reports provide thoughtful analysis and helpful direction to policymakers and stakeholders.

This brochure highlights some of the most important scientific themes that have emerged from the reports to date on the restoration of the Everglades. With support from sponsors, the National Academies will likely continue in its science advisory role to the agencies working on restoration plans.

For more information, contact the Water Science and Technology Board at 202-334-3422 or visit www.national-academies.org/wstb. This brochure was prepared by the National Research Council based on National Academies' reports. It was written by Nancy Huddleston and designed by Michele de la Menardiere. Photos are courtesy of the South Florida Water Management District, the South Florida Wetland Ecosystems Lab of Florida International University, Patricia Jones Kershaw, and Ralph W. Scott