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Everglades Restoration Science and Decision-Making in the Face of Climate Change: A Management Perspective

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Abstract Managers were invited to attend the two-day "Predicting Ecological Changes in the Florida Everglades in a Future Climate Scenario" workshop and to participate in discussion and panel sessions. This paper provides a management perspective on the technical presentations presented at the workshop, identifying information of particular interest to Everglades restoration decision-making. In addition, the paper highlights the points related to science and decision-making that emerged from the discussion sessions and provides thoughts for future discussion in a follow-up forum. Particular focus is dedicated to the importance of and challenges associated with integrating science and decision-making. In addition, the paper offers a management perspective on the uncertainties of climate science and the implications they have for influencing Everglades restoration decision-making. The authors propose that on the one hand, even given uncertainties associated with predicting the ecological response to climate change, there remains a scientific consensus that Everglades restoration is generally on the right track. On the other hand, uncertainty can be a significant barrier to climate science influencing the implementation of restoration and adaptive management programs.

Keywords Everglades · Everglades restoration · Climate change · Science and decision-making · Large-scale ecosystem restoration

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Introduction

In the vast wetland and estuarine ecosystems of south Florida, management of water and other natural resources and ecosystem restoration are bound together in a complex web of overlapping regulatory and management jurisdictions, segregated budget control, and competing goals established by decades of layered policy and legal frameworks. Because land and water use is so often a zero sum game where benefits for some come at costs to others, this web exists in a political environment frequently characterized by direct competition. The politics and management of water in south Florida have evolved over approximately 20 years since 1990 to incorporate concepts of ecological sustainability and ecosystem restoration and today the greater Everglades is the subject of the world's largest ecosystem restoration effort.

The Everglades restoration program is built on a foundation of retrospective science that predicts ecological response to restoration activities by understanding historic ecological and hydrologic conditions. Phenomena associated with climate change, including for example sea-level rise, temperature change, and changing weather patterns, however, may produce conditions in the future unlike the historical conditions that form the basis of the restoration program. This uncertainty poses challenges to decision-makers faced with investment and management decisions to commit resources and construct infrastructure over a time period that coincides with unpredictable and potentially dramatic ecological change.[1] Having

[1] For the purposes of this paper, the terms "manager" and "decision-maker" are determined to mean essentially the same thing, namely a person whose role in the Everglades restoration program comes with decision-making authority or influence or the responsibility to provide recommendations to decision-makers. People falling into this group include project and program managers, political appointees, elected officials and policy officials.

said that, the uncertainties associated with climate change do not dramatically affect the basic restoration approach being pursued by the government. Uncertainties may matter more at the implementation phase of restoration where trade-offs between competing objectives are managed directly.

In the context of Everglades restoration, climate change seems to inspire consideration at the extremes. In the formal water resources planning process for Everglades restoration projects planned to date, consideration of climate change effects is limited to evaluations of sea-level rise scenarios as a check on performance of the selected plan. Although a formal planning framework exists for Everglades restoration projects, this framework does not require evaluation of alternative plans in the context of climate change at a landscape scale nor does it incorporate consideration of extreme climate change scenarios (USACE 2003). Presently, planning efforts do not incorporate assumptions about potential future changes in rainfall patterns, evapotranspiration effects, salinity, or changes in the extent and distribution of peat soils, because there is no agreement on such assumptions or how to apply those in an ecosystem restoration and public infrastructure planning framework. For the most part, this approach is driven by agency policy and program implementation guidance for making public works investment recommendations. At the other end of the reaction spectrum, the potential impacts of climate change are considered so calamitous for south Florida that Everglades restoration seems a futile enterprise aimed at restoring resources doomed to being engulfed by the sea in the near (enough) future (Goodell 2013). Such opposite conclusions are understandable and perhaps inevitable in the vacuum of certainty that surrounds regional climate change science.

The exercise at the center of the "Predicting Ecological Changes in the Florida Everglades in a Future Climate Scenario" workshops and described in this series of papers attempted to test the limits of our ability to predict regional ecological response to various climate change scenarios both for specific ecological attributes such as water quality and wetland health and at the landscape scale. Workshop participants included scientists, resource managers, and senior program managers with responsibilities for advising decision-makers. Not surprisingly, uncertainty was a theme touched upon by almost all participants. What was surprising, however, is that despite high levels of scientific uncertainty, general conclusions probably can be reached with an adequate level of confidence for decision-makers about the soundness and wisdom of Everglades restoration as an infrastructure program, an approach to regional sustainability, and a policy and budget priority for both the state of Florida and the United States. The unanimous conclusion of participating scientists was that Everglades restoration is not only worthwhile, but also that even more aggressive restoration action and timeframes may be the region's best hope for mitigating the ecological impacts of climate change in south Florida.

Everglades Restoration in Brief

The National Research Council's Committee on Independent Scientific Review of Everglades Restoration Progress opened its Fourth Annual Biennial Review with the following description of the Everglades.

> The south Florida ecosystem encompasses some 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 (NRC 2012, p. xi).

Between the late nineteenth century and the 1960s, the Everglades was subject to large-scale public works projects designed to drain vast portions of the system, particularly along the lower east coast and approximately 700,000 acres immediately south of Lake Okeechobee, for urban and agricultural development (Godfrey and Catton 2011). The central and southern portions of the Everglades were set aside for water storage and environmental conservation including 1.5 million acres (2380 square miles) of Everglades National Park. The largest components of the south Florida drainage strategy included the construction of the Herbert Hoover Dike around Lake Okeechobee, the channelization of the Kissimmee River in the Everglades headwaters, and the construction of the Central and Southern Florida Flood Control Project, a vast infrastructure system consisting of 1600 miles of canals and levees and more than 60 major water control structures. These drainage efforts were extremely successful as evidenced by the fact that modern development patterns in south Florida are defined first and foremost by the limits of the drainage system (Godfrey and Catton 2011).

Although the region receives nearly 60 in. of rain annually, flooding of developed areas and agriculture is not common. During the 6 month wet season, billions of gallons of water are discharged to the east and west coasts every day. Despite this massive loss of water from the system annually, the region boasts high per capita water use rates (SFWMD 2008). The unintended ecological consequences of drainage on such a massive scale were equally far reaching and included a significant reduction of wading bird populations, large-scale reductions in the spatial extent of habitat, degraded water quality, and 71 threatened and endangered species (Davis and Ogden 1994; USACE 1999; USACE and SFWMD 2010). As the region's human population more than tripled the projections of those who designed the regional water management system, the ecological impacts of drainage and development grew over time. Today the Everglades, and the people who rely on it for water supply, economic prosperity and a high quality of life, fluctuate between extreme conditions of flood and drought as the system struggles to meet competing demands it was not designed to meet (Godfrey and Catton 2011). The hydrology of the massive wetland system has been altered dramatically, and nutrient enrichment from agriculture and urban development has contributed to the degradation of significant portions of the landscape (USACE 1999). Important shifts in philosophy and policy came in the 1980s and 1990s, paving the way for a number of large-scale programs designed to arrest and reverse the ecological degradation of the Everglades (Godfrey and Catton 2011). "Everglades restoration" is the shorthand term for a group of efforts including ecosystem scale land acquisition, infrastructure modification and operational revision aimed at restoring the greater Everglades ecosystem, while providing for other water-related needs of the region (WRDA 2000). The central hypothesis of the restoration effort is that once the hydrology of the Everglades is restored, the ecology will recover (SFERTF 2012).

A key assumption underlying the restoration effort is that the south Florida ecosystem receives adequate rainfall to meet most water needs including ecosystem demands and that what is missing is adequate infrastructure to capture, store, clean, and deliver that water to all uses at the right times and in the right places (USACE 1999). Restoration's key hypothesis and assumptions are already being applied in the restoration of the Kissimmee River, one of the first large projects to move into implementation mode, and are proving to be sound (Godfrey and Catton 2011). As reaches of the Kissimmee are dechannelized and as the flood plain is being brought into public ownership and allowed to absorb the seasonal flooding of the restored river, key ecological features of the historic river including native fish and water fowl populations and sand bar formation have begun to rebound (Glenn 2012; Jones et al. 2013). The strategies being pursued by Everglades restoration include building annual and interannual storage back into the water management system, reconfiguring water management features that are currently impeding the proper distribution of water through the system, and building features to remove excess nutrients from water before it flows into the Everglades (USACE 1999; SFERTF 2012). The program is being primarily implemented and funded by the state of Florida and the federal government.

Discussion of Technical Presentations: Key Messages of Interest to Everglades Restoration Decision-Makers

Resource managers and policy officials were invited to attend a two-day technical meeting entitled "Predicting Ecological Changes in the Florida Everglades in a Future Climate Scenario" and co-hosted by Florida Atlantic University Center for Environmental Studies (FAU-CES), the U.S. Geological Survey (USGS), and Florida Sea Grant. The workshop brought together experts in Everglades ecosystems to predict how ecological systems might respond under a number of potential climate change scenarios. Scenarios included changes in rainfall, evapotranspiration rates, sea-level rise, and temperature. The details of the analyses are documented in other papers in this series (Obeysekera et al. 2014). Managers and policy officials, including the authors, were asked to attend the entire two-day meeting, which consisted of presentations of the scenarios and the predictive work, followed by breakout groups and wrap up panel discussions. The workshop produced the following broad scientific "take-away" messages useful to Everglades restoration decision-makers and outlined areas where the nexus between science and decision-making might be improved.

- Drier conditions may cause more significant ecological impacts than wetter conditions.

With the exception of some water quality parameters, which are predicted to respond negatively to both increased and decreased rainfall conditions, and which will be discussed briefly in a moment, most scientists predicted more significant negative ecological response to scenarios that produce conditions drier than the base condition than to those that produce conditions wetter than the base condition. In particular, drier conditions pose a significant threat to the peat soils that underlie the Everglades. Peat lands all over the world form when precipitation exceeds ET, and therefore the worst-case scenario for peat soils in the Everglades is reduced rainfall and increased evapotranspiration (Nungesser et al. 2014). Peat oxidation, mineralization, and the release of CO_2 occur when peat soils are exposed to certain dry conditions (Nungesser et al. 2014). In fact, peat loss is a significant contributor of CO_2 in the region. For the purposes of comparison, peat loss in the Everglades ecosystem contributes 27 million tons of CO_2 per year to the atmosphere compared to 30 million tons per year contributed by the regional transportation sector (Nungesser et al. 2014). The driest conditions occur in the scenario that combines decreased rainfall and increased ET, and are predicted to be catastrophic for peat accumulation (Orem et al. 2014). Peat loss and decreased accumulation rates will lead to a loss in dynamic storage and disrupt elevation gradients contributing to surface water flows, key attributes of the Everglades ecosystem. The take home message regarding this worst-case scenario for peat soils is that increased peat loss combined with decreased accumulation poses a compounded and potentially devastating threat to the Everglades. Drier conditions also pose an increased fire risk to both vegetation and dried out peat soils. While quantifying this risk is an acknowledged area of uncertainty, we know from experience that increases in the duration, frequency, and/or intensity of dry downs in the Everglades result in increased incidences of fire, and those events have significant economic costs.

With respect to aquatic and marine species and systems, decreased rainfall alone results in decreases in small freshwater fish density, reductions that increase when combined with increased ET (Catano et al. 2014). Further evidence that drier conditions pose a significant ecological threat is the fact that the delivery of freshwater from the Everglades is the single largest factor affecting ecosystem states and services in Florida Bay and the Florida Keys, while the next four highest factors are phenomena related to climate change including ocean acidification, temperature change, sea-level rise, and weather pattern changes (Keamey et al. 2014).

Drier conditions are not the only changes with negative ecological ramifications.

While most participating scientists seemed more concerned about scenarios that produce drier conditions, some ecological parameters are predicted to respond negatively to wetter conditions as well. For example, climate change scenarios that include increased rainfall are likely to cause increased water quality degradation including increased phosphorus and sulfur enrichment as well as increased methyl mercury contamination (Orem et al. 2014).

With the current water management system, it also seems reasonable to predict that wetter conditions will cause ecological impacts similar to those produced by wet years today, particularly in the absence or under-design[2] of Everglades restoration features aimed at alleviating high water conditions. These impacts include inundation of Lake Okeechobee littoral habitats, damaging discharges of fresh water to coastal estuaries, and inundation of tree islands in the central Everglades.

A Management Perspective on Climate Science Uncertainty

Although participating scientists emphasized significant uncertainties associated with predicting the response of specific ecological parameters to climate change-induced conditions, we should not assume that such uncertainty prevents restoration managers from factoring climate change into certain management and investment decisions even when those decisions commit significant resources and have longer implementation timeframes. What is the basis of this statement? While most people acknowledge that climate change may offer up conditions unlike any recorded in the region, none of the predicted conditions, aside from the most dire inundation predictions, are significantly different from those we have previously experienced. Climate change is not expected, at least in the next century, to cause snowy winters, or desert conditions, or rain forest conditions in south Florida. Scientists predict further compression of the inter-annual hydrologic cycle, saltwater intrusion, fire, and continued threat of tropical weather events—all conditions we live with today. Scenarios that have the southern part of Florida underwater by the year 2100 are arguably outside the spectrum of certainty that is relevant or useful to current restoration managers. After all, if south Florida is underwater a century from now, any and all infrastructure investments, from water management features to airport runways, and all policies that do not promote divestment and evacuation of the region will seem unwise in retrospect. On the other end of this decision-making spectrum, climate change may produce increases in ecosystem goods and services that would be of interest to the public and decision-makers (e.g., increase in the extent or change in the distribution of estuarine/marine species).

During the panel discussions at the conclusion of the climate scenario workshop, scientists unanimously agreed that, even given the uncertainty associated with predicting ecological response to climate change, they would not recommend an alternative to restoring the Everglades or abandoning the effort because of the anticipated adaptation response the restoration program will provide. It seems clear, however, that beyond such broad "stay the course" decisions, uncertainty may be inhibiting climate science from adequately informing restoration program implementation activities, including project design, sequencing, and monitoring and research programs. Uncertainty about climate science may also be inhibiting adaptive resource and restoration management decisions. There are always challenges associated with adaptively managing resources to reduce future risk, and these challenges can be compounded by the existence of scientific uncertainty.

The Potential for Climate Change Science to Inform Restoration Decision-Making

One stated objective of the climate scenario workshop was to "[c]onsider options for future resource management and scientific needs and capabilities to support management adaptations (FCES 2013, p. 1)." This objective reflects the

[2] Design efforts typically do not include features required to manage the most extreme hydrologic conditions due to the high cost and low frequency of occurrence of those conditions.

on-going sense by many in the Everglades that climate science and management can and should be better integrated.[3] The integration of science and decision-making generally in the Everglades has been a discussion topic for the National Research Council's Committee on the Independent Scientific Review of Everglades Restoration Progress (Committee) (NRC 2008, 2010, 2012) and the South Florida Ecosystem Restoration Task Force (2013). The NRC reminds us that the statutory and regulatory underpinnings of the Comprehensive Everglades Restoration Plan include the expectation that science, new information, technology and circumstances will inform the restoration process, as well as the recognition that factors other than these influence the outcomes of engineering and management decisions (NRC 2010). In its 2010 report, the Committee pointed out that the extent to which science influences policy depends, in part, on the extent to which the accumulation, interpretation and articulation of scientific results are converted into knowledge and information in a process the Committee terms "science synthesis" or "research synthesis" (NRC 2010). In 2012, the Committee reviewed the numerous Everglades science synthesis efforts conducted to date and concluded that while these are impressive in both scope and scale, more work needs to be done to synthesize a common view of "major scientific principles, including explicit recognition of important uncertainties and grand challenges" (NRC 2012, p. 160). The Committee's analysis and recommendations seem to us to be relevant and helpful when considering the extent to which climate science (a "grand challenge") can or is likely to inform restoration management and decision-making. During the discussion sessions of the climate scenarios workshop, a number of areas of general agreement emerged on the topic of the intersection of climate science and management.

Workshop Discussion and Panel Sessions: Areas of General Agreement on the Intersection of Climate Science and Management

The workshop included breakout and panel discussions on the topics of research gaps and the intersection of climate science and management. Six areas of general agreement emerged relative to climate science and management. From a management perspective, these points of agreement represent concepts and ideas that in our estimation requires varying degrees of additional scientific evaluation and dialog between scientists and managers. Such dialog would be aided greatly if it is framed by a broader perspective on the topic, such as that of the NRC discussed earlier. Absent a broader framework that reflects what we have learned generally about the role science plays in the restoration effort, the areas of agreement identified in the climate scenarios workshop may be difficult to act upon due to the long standing lack of synthesis of major scientific principles that NRC identified in 2012.

The areas of agreement below are excerpted from the official workshop summary, which organizes them as "A Path to More Effective Ecosystem-Based Management" (FCES 2013). The points below represent three categories of issues. First, there are recommendations related to specific research areas that should inform management actions in the near term, such as critical tipping points to be avoided, the value of environmental variability and ecological resilience, and the impacts of sea-level rise. Second, there is a recommendation for open and honest communication between scientists, managers and the general public. Finally, there is a recommendation for expanding ecosystem research to include societal needs and dynamics. We offer a management perspective on these points, and offer some additional thoughts for consideration as they are fleshed out in future discussions.

> "There is a need for improved communication, outreach and education, which engages both managers and the general public. Scientific understanding of the impacts of climate change must be communicated openly and honestly" (FCES et al. 2013).

Communication between scientists and the various audiences who will benefit from their work is challenging on a number of levels. At times, miscommunication or missed opportunities for effective communication are the result of not only a lack of understanding at the level of knowledge but also at the level of perspective. A scientist's quest for certainty or confidence, for example, may overshoot a manager's need for certainty or confidence. Alternatively, a manager may misinterpret the existence of scientific uncertainty as the "insufficiency" of certainty for decision-making. Good communication is a two-way street and is most effective when there is understanding at the levels of language, knowledge, and culture. In this context, "culture" refers to the respective customs, norms, and beliefs of the scientific and decision-making communities. There is an important role for individuals in both the scientific and management communities who can cross the communication divide to frame science questions in ways that are useful to managers, and to interpret findings in ways that correctly represent the science involved (Policansky 1998). Effective managers incorporate scientists into the decision-

[3] The primary obstacles to integration of emerging climate science into decision-making involve organizational jurisdictions, budgeting priorities, and funding. It might be worth making a general statement here recognizing that it can be difficult to accurately assess to what extent science is influencing management when one considers all of the non-scientific factors that are weighed in management decisions.

making process and encourage integrity in the framing of questions and the applications of findings. Effective scientists understand the decision-making process enough to know when and how science might be brought most effectively to bear on it, and are able to communicate with multiple audiences. Finally, the most recent recommendations from the NRC (2012) on science synthesis touch on the importance of identifying areas of common understanding as well as areas of disagreement and uncertainty. This open and honest approach to building consensus around uncertainties, challenges and trade-offs is the "other side of the coin" of helping managers make decisions (NRC 2012).

> "We need to expand the scope of ecosystem analysis to encompass societal needs and dynamics, including economics and water demands. For South Florida, integrated ecosystem-human system planning and analysis should include consideration of the entire Kissimmee-Okeechobee-Everglades system and the adjacent marine system."

This insight is of particular importance to the Everglades restoration and broader water management decision-making process. The exercise conducted for this workshop did not take into account the universe of deliberate choices that might be made relative to human demands on the ecosystem that could mitigate some of the potential ecological impacts of climate change. For example, under the projected 10 % decrease in rainfall scenario considered at the workshop, it is very likely that the agricultural and development sectors of the region will make their own investment and management decisions that will alter conditions on the ground. In other words, agriculture in south Florida may adapt radically to such a dramatic reduction in rainfall. It would be useful to consider what those changes might be. In addition, water managers might change the way water is allocated to human use in the face of impending reductions in rainfall. The increased frequency of drought conditions in the past decade, for example, induced policy changes such as restricted irrigation policies (SFWMD 2008).

Similarly, salinity levels in south Florida's estuaries would significantly increase in such a scenario, requiring re-setting of ecological targets, revisions to water management practices, and re-evaluation of restoration plans based on historical salinity regimes. Furthermore, a shift toward more marine conditions may result in different economic uses and activities, especially those involving commercial and recreational fisheries.

> "Adaptive management is a recommended approach to build resilience needed to deal with climate change. A better understanding of the ecosystem resilience to change is also necessary."

South Florida water managers adaptively operate the water management system on a daily basis to meet various management objectives. In the early decades of regional water management, water supply and flood protection were dominant operational objectives. In recent decades, however, as understanding and values have changed, environmental protection and ecosystem restoration have become important water management objectives as well. Ecological processes such as the loss and accumulation of peat soils or healthy ranges of estuarine salinity, for example, are understood as ecological values worthy of protection and restoration. If predictions could be made regarding the potential impacts of climate change on peat processes or salinity levels, these would better inform today's management choices in ways that could build ecological resilience. As logical and reasonable as this sounds, however, it is important not to underestimate the challenges associated with adaptively managing water resources operations and prioritizing restoration activities. If managers or restoration planners consider prioritizing peat resilience or estuary adaptation, doing so will necessarily come at the expense of some other value or demand. Under current conditions, for example, areas in the central Everglades regularly dry down unnaturally and experience peat loss. To reduce these dry downs, water managers can either redirect water that is currently being delivered elsewhere, and/or restoration planners can prioritize and accelerate the implementation of features designed to alleviate dry downs. Both of these approaches require redistribution of benefits and/or resources, the perennial problem for managers and decision-makers. Uncertainties associated with climate change need not take Everglades restoration in a dramatically different direction; nonetheless, uncertainty about effects and appropriate responses can be a significant obstacle to adaptively managing resources to build resilience against a predicted future impact, if doing so comes at a cost today.

> "In collaboration with managers and the public, we (restoration scientists) must build an understanding of the importance of environmental variability in natural ecosystems, including recognition of the importance of pulsed events."

The Everglades restoration process has illuminated the challenges scientists and managers face planning, evaluating, and managing at the ecosystem scale. The complexity of ecosystems also presents problems for stakeholder groups, who have first-hand or intergenerational knowledge of the Everglades but are not often well versed in ecosystem processes at a system-wide level. The Central Everglades Planning Project, the most recent phase of the Comprehensive Everglades Restoration Plan currently in the planning process, has illuminated this challenge very clearly. The project seeks to restore flows from Lake Okeechobee to the central and southern Everglades. This project is incorporating the latest science indicating that the original 1999 restoration plan underestimated historic flows through the Everglades, and recognizes the importance of peak flow even if, as an initial phase, it falls short of accommodating those flows. Stakeholders who recreate in the central Everglades met this new information with significant skepticism because the restored Everglades currently envisioned does not match the Everglades they know and the generation before them knew first hand. The fact is that most stakeholders have vested interests in the modern, compartmentalized, fragmented, highly managed, somewhat predictable Everglades—whether they fish in canals, farm on drained wetlands, or live in a suburb of the east coast. One of the great challenges of Everglades science is to illuminate how the system operated as a system, including natural variability, and why restoring natural ecosystem functions is important for creating adaptability and resiliency. It is then the job of decision-makers to balance vested interests in the current system and such restoration objectives.

> "Management decision support should incorporate indicators that minimize the risk of reaching critical tipping points."

The identification of critical tipping points is extremely important for decision-makers, particularly as they are faced with the trade-offs of prioritization and resource allocation. If climate change is poised to deal the Everglades a hand of rapid and dramatic change, it will be very important for scientists and decision-makers to understand the point beyond which change is irreversible or which represents the start of a chain reaction of impacts that may lead to new, and undesirable states of stability. The Everglades 10 ppb phosphorus standard is an example of a scientific tipping point analysis that has heavily influenced Everglades management, decision-making, and policy. It is also important to understand where we are at any given time on the tipping point continuum, which is an argument for adequate monitoring and data collection.

> "One recommended focus for management is the appropriate delivery of freshwater flows to coastal wetlands, which provide a critical defense of the Everglades landscape and water supplies in the face of sea-level rise. For South Florida, sea-level rise appears likely to be the element of climate change that will most strongly and quickly alter our environment and society" (FCES 2013).

Decision-makers are ironically aided in this area of focus because rising seas are already causing impacts along the coast and in low-lying areas in Miami-Dade County and the Florida Keys. Water managers have had to deal directly with the challenge by implementing infrastructure modifications of select coastal flood control structures to combat the effects of saltwater intrusion, while still providing flood protection to interior areas by moving water out of the system and into coastal estuaries. Maintaining a balance of saltwater intrusion protection versus inland flood protection will be very difficult in some parts of the region and ultimately very expensive infrastructure changes including relocating drinking wells or the installation of alternative water supplies may be necessary.

Looking Ahead

The climate scenario workshop was an interesting exercise that provided insights not only into the types of change Everglades might experience as the climate changes, but also into the challenges of producing climate science that can be influential in management and decision-making processes. We hope the dialog continues as it is not enough to say "science should influence decision making" or "adaptive management should be implemented to reduce future risk associated with climate change." If these good ideas are to become good practice, they have to be thought through carefully with consideration given to constraints. Topics that we as restoration program managers would like to see explored in greater detail in follow-up forums include

- Exploring new and innovative methods for breaking down barriers of communication between science and management;
- Developing a cadre of "translators" in the science and management communities, consisting of individuals skilled at crossing the communication divide to increase scientific understanding, to provide relevant, useful and timely analysis to decision-makers, and to build the capacity to effectively communicate with multiple audiences;
- Engaging scientists and managers in thinking about how to respond to the NRC's 2012 recommendations regarding the synthesis of science;
- Identifying ecological tipping points and connecting those to realistic management actions that might be taken to avoid them;
- Identifying relationships between ecological effects caused by climate change and social effects, including economic activity; and
- Identifying infrastructure tipping points and potential adaptation responses.

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