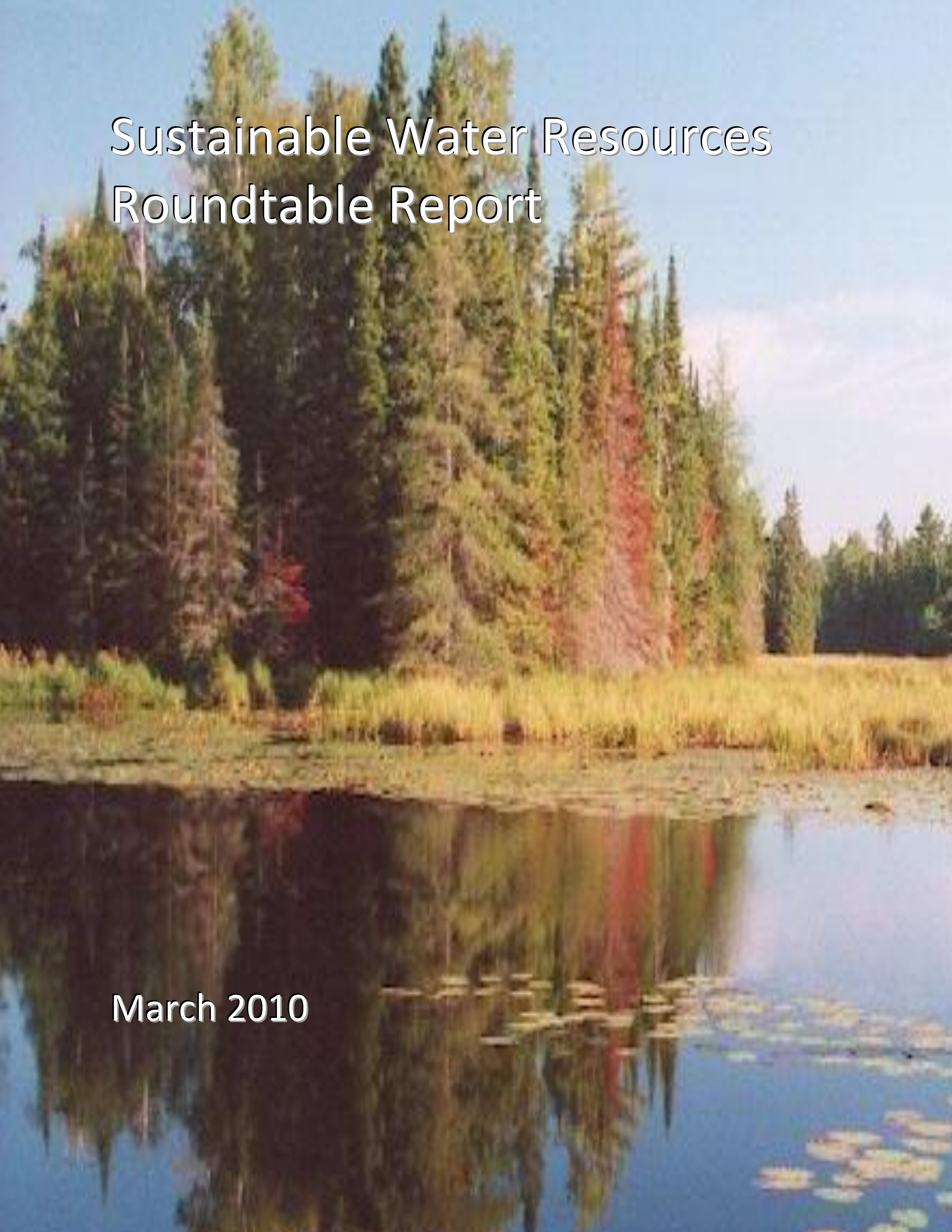


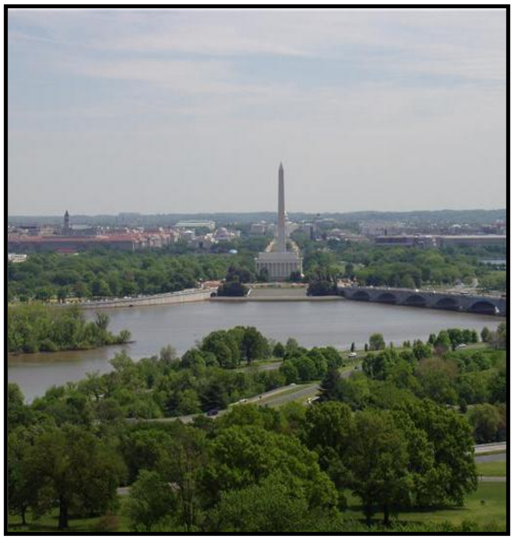
Sustainable Water Resources Roundtable Report

March 2010

Table of Contents

Foreword

The Sustainable Water Resources Roundtable provides a forum for the exchange of ideas and information to promote better decision making regarding the sustainable management of our nation's water resources. SWRR was established as the fourth multi-stakeholder resource roundtable, bringing together a wide range of participants representing a diverse range of interests from academia, state and federal government, non-profit organizations, corporations, and regional partnerships. SWRR is a subgroup to the Advisory Committee on Water Information, a Federal Advisory Committee under Office of Management and Budget Memorandum 92-01.



The roundtable encourages cross-sector collaboration and partnerships that foster greater understanding of our social, economic, and ecological systems. It supports development of sustainable management policies that contribute to the health and vitality of our economic, social, and environmental systems both now and in the future.

This report outlines the formation of SWRR, provides insight into its mission and goals, and highlights activities in 2008 and 2009. We also hope it effectively communicates the roundtable's contributions to the field of water resources and suggests how the work of the roundtable can be applied to water resource sustainability topics and activities throughout the nation.

This report consists of five main chapters. The first chapter provides an introduction to the history of SWRR and its relation to the other natural resource roundtables; the second discusses the roundtable's guiding principles and conceptual framework; the third provides a review of recent roundtable activities, and presentations and papers by SWRR participants and others who have contributed to the field of water resources.

The fourth chapter provides case studies that apply principles of sustainable management. These case studies demonstrate the value of applying a sustainable approach to water management that is consistent with the mission, vision, and goals of the roundtable. Featured topics in this chapter include the innovative use of key indicators by citizens and stakeholders in the Chesapeake Bay region, Minnesota's and Michigan's efforts to develop frameworks for sustainable allocation of water, and opportunities to use a system of indicators and integrated stakeholder involvement in the Missouri River Basin.

Chapter five provides insight into national initiatives on water resources and includes reports on the Council on Environmental Quality's National Environmental Status and Trends initiative, an interagency process led by the United States Forest Service; the United States Geological Survey National Water Census; The Heinz Center's work on ecosystem indicators; the Environmental Protection Agency Report on the Environment, water chapter, and collaborations between the roundtable and the Water Environment Federation. The roundtable anticipates that this report will be a resource for water resource managers, policymakers, and stakeholders who seek to inform policy decisions with principles of sustainable water management. In keeping with SWRR's focus to provide a forum for the exchange of ideas and information, we look forward to enhancing dialogue and meaningful partnerships with organizations, institutions, government, and citizens alike.

In 2010, SWRR will continue to be a forum for the exchange of information and ideas related to the sustainability of water resources. We have elected two new co-chairs, John Wells of the Minnesota Environmental Quality Board and Bob Wilkinson of the Bren School at UC Santa Barbara. The roundtable's 2010 meetings will take place in the San Francisco Bay area, the Midwest, and the Washington DC area. In 2010, the roundtable will work in support of: a) an ad hoc USGS working group to help design the national Water Census; b) efforts to build interest in and collaborate with the National Environmental Status and Trends project, which will establish a national set of environmental indicators; and c) the continuing national collaboration for a sustainable water resources future. In addition, we will continue efforts to further refine and populate the roundtable's framework of indicators for determining if the nation is managing its water resources on a sustainable basis. We welcome participation and input from all those with an interest in the sustainability of water resources.

Finally, we recognize the efforts of all of those that have contributed to the work of SWRR over the years, and those that have contributed to this report. Special thanks to Douglas J. Wade, who proposed regular SWRR reports to the roundtable develop as a means to engage partners, and to this report's contributors, including Douglas, David Berry, Warren Flint, Rhonda Kranz, Robin O'Malley, Ethan Smith, Alan Steinman, Stacy Tellinghuisen, John Wells, Harry Zhang, and the other SWRR participants and contributing organizations. .

Rick Swanson, US Forest Service
Robert Goldstein, Electric Power Research Institute
Co-Chairs Sustainable Water Resources Roundtable
February 2010

Supporting Organizations

University, Non-Profit, Companies & State

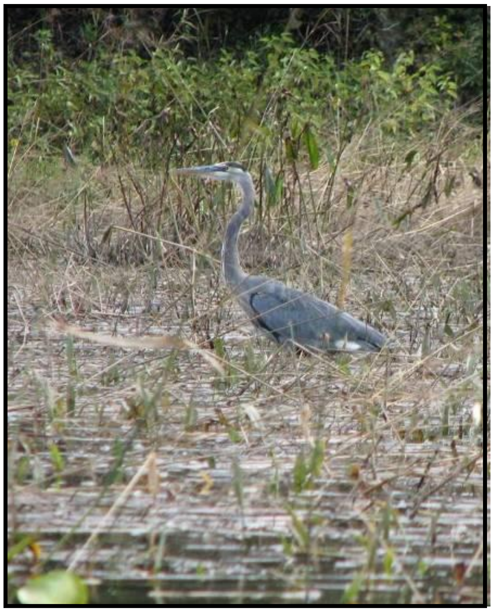
Alice Ferguson Foundation
American Water Resources Association
Annis Water Resources Institute
California Department of Water Resources
Ecological Society of America
Electric Power Research Institute
Five E's Unlimited
Illinois State Water Survey
Metropolitan Washington Council of Governments
Minnesota Environmental Quality Board
Rural Community Assistance Partnership
Universities Council on Water Resources
University of California, Santa Barbara
University of Illinois
University of Michigan, Ann Arbor
Water Environment Federation
Western Pennsylvania Watershed Program

Federal

Advisory Committee on Water Information
President's Council on Environmental Quality
U.S. Department of Agriculture
  Natural Resources Conservation Service
  Forest Service
U.S. Department of Commerce
  National Oceanic and Atmospheric Administration
U.S. Department of Energy
  National Energy Technology Lab
  National Renewable Energy Lab
U.S. Department of the Interior
  Bureau of Land Management
  Bureau of Reclamation
  Fish and Wildlife Service
  U.S. Geological Survey
U.S. Environmental Protection Agency

Chapter 1: *SWRR History*

The idea for a national water roundtable originated at a March 2001 meeting of the Interagency Working Group on Sustainable Development Indicators at which the work of three multi-stakeholder roundtables covering forests, rangelands, and minerals was presented. These roundtables focus, in part, on developing criteria and indicators to help report status and trends for more effective decision-making. It was proposed at this meeting to establish a water roundtable following the approach of the other roundtables.



The inaugural meeting of the Sustainable Water Resources Roundtable was held on December 10 and 11, 2002, in Alexandria, Virginia. Sixty people participated, representing federal agencies, state organizations, the corporate sector, and environmental organizations. The group developed a clear consensus that decision-making from the national level to the individual level would be aided by better information on water in the form of indicators that summarize information and make it readily understandable to the general public.

Several federal agencies had expressed enthusiasm in participating and actively supporting the roundtable. The United States Forest Service, The Bureau of Land Management, the Department of Energy, and the United States Geological Survey have been particularly active in their support. The USGS, which operates the Water Information Coordination Program under which the Advisory Committee on Water Information is established, agreed to provide the web pages for the roundtable and placed them online in February 2002.

Authority

The Sustainable Water Resources Roundtable is a subgroup of the Advisory Committee on Water Information and is part of the Water Information Coordination Program mandated by Office of Management and Budget Memorandum No. M-92-01, dated December 10, 1991. The roundtable reports to the Advisory Council on Water Information and operates under the Federal Advisory Committee Act.

Mission

The roundtable mission to promote sustainability of the nation's water resources is achieved through:

- Evaluation of information
- Development and use of indicators
- Targeting of research
- Engagement of people and partners

Vision

A future in which our nation's water resources support the integrity of economic, social, and ecological systems and enhance the capacity of these systems to benefit people and nature

Primary Goals and Objectives

- **Goal 1**: Provide an ongoing open forum for the exchange of ideas, data, and policy information among all stakeholders on relevant concepts, principles, criteria, indicators, management practices, and research.

- **Goal 2:** Facilitate collaborative, interdisciplinary scientific research on parameters related to the quality and availability of water and related resources, including research to fill gaps in data needed for the use of criteria and indicators, as well as research testing the application of sustainability principles and developing best management practices.

- **Goal 3:** Develop criteria and indicators - based on concepts of sustainability and principles of sustainable resource management - that characterize the quality and availability of water and related resources; promote the widespread use of the criteria and indicators.

- **Goal 4:** Engage in and support outreach to raise awareness of the need for sustainable water resource management and to promote policies and activities, informed by science, that should result in or improve the sustainable management of water resources.

Chapter 2: *Principles of Water Sustainability*

No organization addresses the full spectrum of water resource topics. Recognition of this fragmentation of responsibility as well as the commonality of interest across related disciplines led to the formation of the roundtable. In large part because its participants represent a wide range of interests and responsibilities related to water resources, the roundtable provides a productive forum for the exchange of ideas and information regarding the sustainability of the nation's water resources.

The roundtable supports the notion that water resources can be managed for human benefit and the benefit of the ecosystems. We recognize, for example, that measures to improve water quality cannot be achieved for the long term unless society values good quality water and is willing to change the behaviors that put water quality at risk. Likewise, our economic system is only sustainable if its growth does not exploit our natural resources beyond their capacity to be replenished or society's capacity to replace them without harm. .

Although our institutions have served us well, we now face progressively stronger and increasingly complex problems, which require a multi-dimensional approach to problem solving. The roundtable identified a set of principles to guide the nation as its institutions evolve to embrace this new approach and address water sustainability. Efforts to manage water resources provide the most benefit when they are viewed within the context of driving factors such as population, income, land use, climate change, and energy use. The below principles are envisioned to help water resource managers navigate within this ever-changing and dynamic context.

- **The value and limits of water:** Water supports all life and provides great value. While water is abundant, people need to understand and appreciate that it is limited in many regions, that there are environmental and economic costs of depleting or damaging water resources, and that unsustainable water and land use practices pose serious risks to people and ecosystems. The consumption of renewable natural resources is sustainable if it does not exceed the rate of long term renewal and does not impair the health and productivity of ecosystems, communities or the economy.

- **Shared responsibility:** Water does not respect political boundaries. Sustainable management of water requires consideration of the needs of people and ecosystems up- and down-stream and throughout the hydrologic cycle, and avoiding extreme situations that may deplete water in some regions to provide supplies elsewhere.

- **Equitable access:** Sustainability suggests fair and equitable access to water, water dependent resources, and related infrastructure. Equitable access requires continuous monitoring to detect and address problems as they occur, and means to correct the problems.

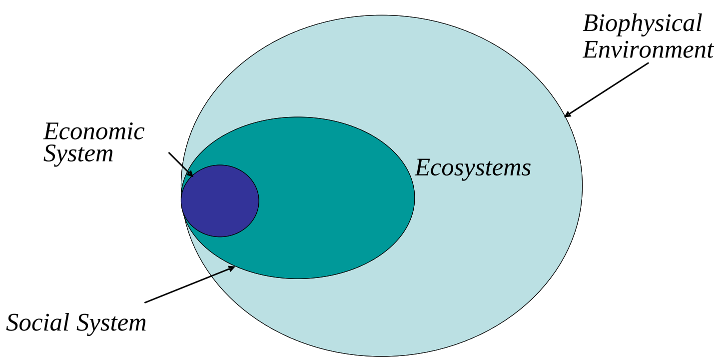
- **Stewardship:** Meeting today's water needs sustainably challenges us to continually address the implications of our water resources decisions on future generations and the ecosystems upon which they will rely. We must be prepared to correct policies and decisions if they create adverse unintended consequences.

Representing Sustainable Management with Systems Concepts and Indicators

The roundtable applies systems concepts as a way to represent its understanding of how the world works. These concepts are useful in the development of a framework for indicators to measure sustainability of water resources and to determine what research is needed. In the case of water resources, systems concepts represent those components and processes in our world by which water moves throughout the biosphere, how water interacts with humans, and how the ecosystem processes and stores water. Knowledge of our ecological, social, and economic systems and interactions between them is of critical importance in making informed policy decisions about how to manage water resources for current and future generations. The indicators the roundtable developed are derived from this knowledge and are defined generally as measures that present relevant information on trends in a readily understandable way.

The figure below displays the relationship between ecosystems, which include all living things and their physical environment, and society, which represents all the human elements of the biosphere, including the economic system.

General Systems Perspective: Essential Relationships of Sustainability



Source: Sustainable Water Resources Roundtable

General Systems Perspective: Essential Relationships of Sustainability. See the following documents for further detail:
Sustainable Water Resources Preliminary Report, September 2005 http://acwi.gov/swrr/Rpt_Pubs/prelim_rpt/index.html
Kranz, R., S. Gasteyer, H.R. Heintz Jr., R. Shafer, and A. Steinman 2004. Conceptual Foundations for the Sustainable Water Resources Roundtable, Water Resources Update. 127:11-19. http://www.ucowr.siu.edu/updates/127/Kranz.pdf

Indicators of water resource sustainability tell us ‘where we are’ in meeting short and long-term ecological, social, and economic needs and allow people to measure whether societal goals are being met. Indicators highlight trends, help evaluate causes and effects, and give us a common language and understanding of issues.

Effective indicators convey an important signal to society as they mirror society’s long term values. The paper on the energy-water nexus in Chapter 3 describes how water availability and energy use are critically important to society and have long term ramifications for future generations. The case studies in Chapter 4 illustrate how indicators can support the understanding of society’s long term needs, consistent with people’s culture and values. The roundtable believes that effective indicators represent tools from which we can make informed decisions and provide the opportunity to achieve sustainable and adaptive management of water resources. We also recognize that indicators of water resource sustainability should be relevant, measurable, understandable, and able to be scaled temporally and geographically.

Developing the Indicator Framework

Using its conceptual understanding of the relationships between system processes and natural and human conditions, the roundtable initially identified a list of nearly 400 candidate indicators (Appendix A). The roundtable developed a framework for organizing water sustainability indicators after several years of discussion. The five-part framework represents the inherent interdependency of our nation's water resources: a) water availability, b) water quality, c) human uses and health, d) environmental health, and e) infrastructure and institutions. Fourteen key indicator categories fall within this framework. In 2005, SWRR issued a Preliminary Report (available at http://acwi.gov/swrr/Rpt_Pubs/prelim_rpt/index.html) which details the development of the SWRR candidate indicators and various other roundtable activities. The roundtable periodically populates the framework with sample "candidate" indicators, which are posted on the SWRR web site. The roundtable has not developed a final set of indicators although it actively supports the National Environmental Status and Trends effort and other initiatives to build a foundation for an official set of environmental indicators for the nation.

A. Water availability

People and ecosystems need sufficient quantities of water to support the benefits, services and functions they provide. These indicator categories refer to the total amount of water available to be allocated for human and ecosystem uses.

1. Renewable water resources: Measures of the amount of water provided over time by precipitation in a region and surface and ground water flowing into the region from precipitation elsewhere. USGS considers renewable water resources to be the upper limit of water consumption that can occur in a region on a sustained basis.

2. Water in the environment: Measures of the amount of water remaining in the environment after withdrawals for human use.

3. Water use sustainability: Measures of the degree to which water use meets current needs while protecting ecosystems and the interests of future generations. This could include the ratio of water withdrawn to renewable supply.

B. Water quality

People and ecosystems need water of sufficient quality to support the benefits, services and functions they provide. This indicator category is for composite measures of the suitability of water quality for human and ecosystem uses.

4. Quality of water for human uses: Measures of the quality of water used for drinking, recreation, industry and agriculture.

5. Quality of water in the environment: Measures of the quality of water supporting flora and fauna and related ecosystem processes.

6. Water quality sustainability: Composite measures of the degree to which water quality satisfies human and ecosystem needs.

C. Human uses and health

People benefit from the use of water and water-dependent resources, and their health may be affected by environmental conditions.

7. Withdrawal and use of water: Measures of the amount of water withdrawn from the environment and the uses to which it is put.

8. Human uses of water in the environment: Measures of the extent to which people use water resources for waste assimilation, transportation and recreation.

9. Water-dependent resource use: Measures of the extent to which people use resources like fish and shellfish that depend on water resources.

10. Human health: Measures of the extent to which human health may be affected by the use of water and related resources.

D. Environmental health

People use land, water, and water-dependent resources in ways that affect the conditions of ecosystems.

11. Indices of biological condition: Measures of the health of ecosystems.

12. Amounts and quality of living resources: Measures of the productivity of ecosystems.

E. Infrastructure and institutions

The infrastructure and institutions communities build enable the sustainable use of land, water, and water-dependent resources.

13. Capacity and reliability of infrastructure: Measures of the capacity and reliability of infrastructure to meet human and ecosystem needs.

14. Efficacy of institutions: Measures of the efficacy of legal and institutional frameworks in managing water and related resources in a sustainable manner.

Chapter 3: *Outreach Activities, Presentations, and Contributions*

Because water resources have such a great influence on the vitality of our ecosystems, society and economy, there is great interest throughout the nation both in understanding trends in water quality and use and in learning what can be done to manage water resources in a sustainable manner. The roundtable has hosted multi-stakeholder meetings on indicators, innovative initiatives, and research needs from December 2002 through June 2009 in California, Colorado, Maryland, Michigan, Minnesota, Virginia, and Washington, D.C. In addition, the roundtable has helped to organize other meetings and provide panels and speakers on water sustainability with the National Environmental Status and Trends effort, National Council on Science and the Environment, the Water Environment Federation, the Ecological Society of America, and the Sustainable Forestry Roundtable, among others. It has also participated in meetings of the other roundtables to lend its water expertise to their discussions.

Roundtable Activities

SWRR Meeting: June 26, 27, 2008

At its June 2008 meeting, the roundtable continued its tradition of engaging leaders of programs of national interest and providing them a forum for the exchange of ideas and information. It also began initial discussions of how the roundtable might renew its efforts to help shape a sustainable future for the nation's water resources by adopting new approaches and initiatives.

The roundtable received thought provoking presentations on:

- National Water Program Strategy: Response to Climate Change, Jeff Peterson, EPA
- Water for America Initiative, from Eric Evenson, USGS
- Integrated Water Resource Services, from Jawed Hameedi, NOAA
- National Environmental Status and Trends Project, Rich Guldin, USFS
- State of the Nation's Ecosystems: 2008, Anne Marsh, The H. John Heinz III Center for Science, Economics and the Environment

The latter two are summarized below and the others are available via www.acwi.gov/swrr.

National Environmental Status and Trends Project

Rich Guldin, Director of Science, Policy, Planning, Inventory and Information, US Forest Service, briefed the roundtable on a new White House interagency indicator effort. Mr. Guldin reviewed the history of efforts to create a national set of environmental indicators over the last fifteen years. Describing a suitable framework within which the indicators can be nested proved difficult but doable. More difficult was institutional collaboration among federal agencies responsible for monitoring. Rich summarized the National Academy of Public Administration report: *A Green Compass: Institutional Options for Developing a National System of Environmental Indicators* (November 2007). Highlights from the NAPA report include:

- *America needs a comprehensive nationwide system of environmental indicators.*
- *While federal and state agencies collect a vast amount of environmental and natural resource data, our ability to produce actionable information is limited because data collected are inconsistent, incomplete and not adequate for decision-making.*
- *Undertake an intensive pilot to develop crosscutting indicators for an environmental issue that is nationally significant, high profile, multi agency in scope, and of immediate interest to state and local governments and the private sector. The panel suggests water quantity as a candidate issue.*
- *Think big, start small and ramp up fast.*

A joint Council on Environmental Quality, Office of Science and Technology Policy, Office of Management and Budget policy memo establishes that the initial phase of the NEST project be designed to help develop the vision for potential indicators, demonstrate the interagency collaboration that will select and implement these indicators, and provide a basis for improving the consistency and interoperability of data. A national forum will be convened to identify topics and questions that should be addressed by the indicators of water availability. Four agencies are involved: Agriculture (USFS and Natural Resources Conservation Service), Department of Commerce, National Oceanic and Atmospheric Administration, Department of the Interior, and the Environmental Protection Agency.

State of the Nation's Ecosystems: 2008

Anne Marsh, The H. John Heinz III Center for Science, Economics and the Environment, presented findings of the Center's *Report on the State of the Nation's Ecosystems: 2008*. The report describes 108 indicators of the condition and use of U.S. ecosystems. It is the second state of the nation's ecosystems report and like the first was developed through a multi-stakeholder collaboration. Forty-two indicators have data related to water resources. Four of the new indicators in the report relate to water: *change in stream flows* (a core national indicator), *freshwater acidity* (a fresh water indicator), *in-stream connectivity* (a fresh water indicator), and *coastal pattern* (a coasts and oceans indicator). Many of the water indicators in the report have also been refined (e.g. *at-risk native freshwater species, stream habitat quality, established non-native species*, and *areas with depleted oxygen*).

The presentations were followed by an open discussion on how the roundtable could best collaborate with these and other initiatives. Participants discussed what the roundtable might contribute to a new Administration in January 2009. Participants considered the roundtable well positioned to provide interagency cooperation through its variety of members and their missions.

Beginning a Discussion of Future Roundtable Activities

Paul Freedman, president of Limnotech and 2008-2009 president-elect of the Water Environment Federation, requested that the roundtable to begin dialogue on future roundtable endeavors. Mr. Freedman stated that the roundtable should be commended for its work with outreach, conducting workshops, raising awareness, exchanging technical information, and providing a forum for discussion of sustainability. Additionally, Mr. Freedman suggested that the roundtable reassess its objectives and posed questions for the group to consider. Should the roundtable:

- Continue its current focus as a forum?

- Reassess indicator activities?
- Strengthen its role in advancing knowledge?
- Play a bigger role in promoting research?
- Expand its role in public awareness?
- More actively advise government agencies and support their collaboration?
- Have a more topical focus (e.g., climate change, low impact development, policy)?
- Pursue grants to fund its operations?

In response, the roundtable discussed how it might better serve the public and policymakers, including the various national environmental indicator efforts and initiatives. The list of potential action items members identified included:

Outreach
1. Develop a core SWRR message based on the existing mission and goals.
2. Continue to support outreach about the roundtable at meetings of other organizations.
3. Encourage the sharing of member expertise through presentations and papers.
4. Continue and expand outreach to federal agencies and other user and potential partners.

Communications through Data Dissemination
1. Explore web based forums for data and information sharing on water and water sustainability. Since the meeting, Brand Niemann created a 'Wiki' submittal for SWRR available at http://waterwiki.wik.is/.
2. Work with the Water Environment Federation to develop a clearinghouse for information on water sustainability activities (e.g. references and literature). The federation could provide technology and staff. SWRR would provide intellectual input and resources from its broad network. This could include putting SWRR meeting notes on the federation Web site.

Case Study/Pilot Study Development
1. Explore ideas for case studies or pilot studies.
2. Review and evaluate already existing case studies for lessons learned. Since the meeting some case reviews were written for the SWRR report.

SWRR Role in Other Activities
1. National Environmental Status and Trends Forum. The question was asked if the roundtable should have a role in NEST activities, and if so, what those roles may involve. Since the meeting, SWRR has become very active in supporting this effort..
2. USGS Water for America program. SWRR should explore the potential for providing input to the program, which has evolved into the U.S. Water Census initiative.

SWRR Meeting: June 16, 17, 2009
Presentations on the Roundtables

A panel of representatives from the three active resources roundtables presented their accomplishments, their work on indicators and what they saw as their next steps. Peter Gaulke, Strategic Planning & Sustainability Office, U.S. Forest Service, spoke on the Roundtable on Sustainable Forests; Clifford Duke of the ESA spoke on the Sustainable Rangelands Roundtable; and

John Wells, Minnesota Environmental Quality Board, gave a presentation on the Sustainable Water Resources Roundtable. The session concluded with Douglas J. Wade, contractor with U.S. Army Corps of Engineers, providing a presentation and discussion of the SWRR report, after which the presenters led a panel discussion and answered questions concerning the role of the roundtables moving forward and cooperation among them on 'The Year of the Forest,' the National Environmental Status and Trends effort, and other projects.

White House Council on Environmental Quality

Jeff Peterson, Deputy Associate Director for Water Policy, White House Council on Environmental Quality, reminded the roundtable that he had previously presented to the roundtable and recognized the importance of the work done by SWRR to support the sustainability of water resources. Mr. Peterson stated that a key role of the roundtable is to work with a range of stakeholders to improve management of water resources. The council also brings together people with diverse views and works to strengthen the protection of the environment. Its charter charges it to:

> "…encourage productive and enjoyable harmony between man and his environment…to eliminate damage to the environment and the biosphere…and to enrich understanding of ecological systems…"

To accomplish this, the council coordinates federal environmental efforts, working closely with agencies and other White House offices in development of environmental policies and initiatives. The current areas of focus on water resources are large aquatic ecosystems such as the Great Lakes and the Chesapeake Bay, restoring the broad jurisdiction of the Clean Water Act, and the design criteria that might apply to efforts to improve management of water data, including indicators and a working model presented by the National Environmental Status and Trends effort. The roundtable found these topics to be highly relevant to its work and included them in the meeting proceedings posted on its Web site.

National Environmental Status and Trends

Rich Guldin, U.S. Forest Service, gave a presentation on the NEST water pilot and developing water indicators. The National Environmental Status and Trends project proposes using indicators to answer five main questions about water resources:

1. How much water do we have?
2. How much water do we use?
3. What is the condition of aquatic ecological communities?
4. What is the physical and chemical quality of our water?
5. Is the water we have suitable for human use and contact?

The presentation was followed by working breakout sessions to give feedback on the approach and indicators NEST proposed to post on its Web site at http://www.fs.fed.us/NEST/. Based upon this discussion and the roundtable's longstanding work on indicators, the roundtable provided written comments to the project. See Appendix B of this report for more information.

Federal Initiatives in the new Administration

A series of presentations were given on federal agency programs of the new Administration related to water sustainability:

- USFS Rick Swanson, Watershed Condition Framework
- NOAA Jawed Hameedi, NOAA Programs Related to Water Sustainability
- BLM Nancy Dean, Bureau of Land Management Work in Water Resources
- USGS Eric Evenson, National Water Census
- EPA Ellen Tarquinio National Aquatic Resources Survey
- NRCS Jan Surface, NRCS water related programs

The presentations were followed by a panel discussion, which raised several points:

- Opportunities exist for collaboration among agencies, particularly if funds are made available by Congress.
- There is overlap between programs and much information could be shared.
- It is difficult to demonstrate the effectiveness of programs to OMB.
- A handbook on indicators of program effectiveness would help all those assessing their programs by enabling work from a common base.
- BLM, USFS and EPA will meet to explore how indicators might be better applied in program design and evaluation.

It was noted that collaboration is not limited to federal agencies. There are also advantages of working, for example, with private industry. The National Oceanic and Atmospheric Administration shares information on navigation and weather with companies and the information exchange can work both ways. Participants mentioned that regional and local collaboration is also important: the overall data on water and environment are so vast that it makes sense to clip it down to the state and local level while also working with data across boundaries, since watersheds and natural features do not follow state lines.

There was a discussion of moving toward the ideal of a central data warehouse that would be accessible via the internet. The data gateways of each agency or organization represent small pieces of the total picture. Such a central data base would need to be updated regularly (e.g., listings and status of impaired streams changes frequently). This would require a concerted effort to establish, but well worth the effort, since better decision-making would result if all organizations had access to the same data sets.

Future Meetings

Suggestions for future roundtable meetings included:

- Presentations on effective public education and outreach efforts and briefing by decision makers

- A session on the Alliance for Water Stewardship's plan for development of global certification of water professionals and water authorities
- Invite the participation of the Army Corps of Engineers. It was pointed out that the Corps was a founding member of SWRR, but has not participated in the last few years.
- Broadcast meetings over the Internet
- Include local groups and county planning offices that need better information on watersheds when planning where to put schools and commercial facilities

Other SWRR Activities

The roundtable was represented at the February 26-28, 2008 meeting of the Roundtable on Sustainable Forests as part of a panel addressing climate change and the role of the water, forest, and rangeland roundtables.

The *SWRR Draft Compendium of February 5, 2008* was presented at the February 2008 Advisory Council on Water Information meeting as the current compilation of indicators in map and graph form that could be used to support the roundtable's indicator framework. The content mostly originates from federal agencies as part of their data collection programs. During the council meeting, representatives suggested topics that might be added to the compendium, e.g., runoff, floods and droughts, soil loss, and additional aspects of the hydrologic cycle. See http://acwi.gov/acwi2008/slide.lib/SWRR-Indicators-Feb05Draft-Part1and2combined_new.pdf.

In June 2008, the Water Environment Federation held the specialty conference Sustainability 2008, *Green Practices for the Water Environment*, at the National Harbor in Maryland. Roundtable members Tim Smith and Harry Zhang, served on the program committee. The large number of papers presented in the conference proceedings enhances the pool of studies available for technology transfer to federal agencies, providing external information to the federal government as envisioned by the Federal Advisory Committee Act. The papers are listed with links in Appendix C of this report. Appendix D of this report presents papers from the federation's 2008 annual conference, which focused on sustainable water resources management.

The federation conducted committee meetings of its Community of Practice Task Forces and, as part of the Sustainable Watersheds Task Force, Smith and Zhang presented their draft study: *Methodology for Rating Watershed Sustainability as a Basis for Certification*. This study was published by the federation as a Technical Practice Update in September 2009, and is available as an electronic download at www.wef.org/ScienceTechnologyResources/TPUs/.

The Community of Practice also initiated a Sustainability Metrics Work Group, with the objective of defining ways to measure aspects of water sustainability. This work group would operate across all the task forces in the committee, but is just beginning. In the future, topics like climate change may be addressed. The metrics concept is very close to that of indicators and, to date, the examples under discussion include biofuels, marine fisheries, and energy/water interactions.

At the request of the Environmental Protection Agency, Office of Research and Development, the roundtable identified members willing to author a paper to illustrate the use of water sustainability indicators when applied to a current problem having major water impacts. *Water Sustainability Indicators and Biofuels Production* (Smith and Zhang) was presented at the Oct. 2009 WEFTEC conference in Orlando Florida as part of the Sustainable Water Resources Management track. It will be available in the conference proceedings. WEFTEC proceedings can be found at http://www.ingentaconnect.com/content/wef/wefproc. The work was stimulated in part by the passage of the 2007 Energy and Independence Security Act.

The Energy and Water Nexus

By Stacy Tellinghuisen

Supported by U.S. Department of Energy, National Energy Technology Lab and National Renewable Energy Lab, the roundtable hosted two meetings on the relationships between water and energy. The National Energy Technology Lab contributed resources for this paper based on the presentations at those meetings.

Introduction

Water and energy are inextricably linked: electricity generation requires substantial volumes of water, and providing water supplies requires significant volumes of energy. The U.S. Geological Survey estimated that in 2000, thermoelectric power plants accounted for 39 percent of all water withdrawals in the U.S. Likewise, energy is used to pump, convey, treat, and heat or cool potable water supplies, and to treat and discharge wastewater. In 2001, California's water sector used 19 percent of the state's electricity, and 30 percent of natural gas used outside of power plants. Similar links between energy and water are evident throughout the United States.

The impacts of climate change will compound the challenges of the energy-water nexus. Reduced snow packs in the Western U.S. and earlier spring runoff may decrease hydroelectric generation and water supplies available for power plants' cooling needs. The impacts of a changing climate on the energy-water nexus abound, even in the popular press. In 2006, a heat wave in Europe led to the temporary shut down of several nuclear plants and relaxed environmental constraints on operating plants; and recent droughts in the Colorado River basin and the Southeastern U.S. have highlighted conflicts between power plants, municipal and agricultural needs. Higher summer temperatures are likely to drive demand for air conditioning, further increasing summer peak electrical loads and exacerbating power plants' summertime cooling needs.

Fortunately, awareness of the energy-water nexus is growing; numerous agencies and organizations have generated research on the emerging challenges and solutions. In 2007, the Sustainable Water Resources Roundtable conducted two meetings that focused on the energy-water nexus. As part of its January meeting, an energy-water panel presented the overarching issues associated with the energy-water nexus. Much of the two-day meeting in May 2007 focused on different facets of the energy-water nexus, including challenges, on-going research, technical, and policy solutions. Meeting participants represented a range of sectors impacted by the energy-water nexus: government agencies, the electricity sector, universities, and non-governmental organizations. The following chapters present important background information and summarize participants' presentations.

Background

Historically, the energy and water sectors have operated independently of each other. Power plants were constructed with little concern over the future reliability of water supplies, and water conveyance systems were built without considering power requirements. For example, California's State Water Project conveys water from Northern to Southern California, and is the single largest user of electricity in the state. Around the time of its construction, Lewis Strauss famously predicted that in the future, electrical energy would be "too cheap to meter." Today, with concerns mounting over greenhouse gas emissions and the availability of affordable future electricity supplies, energy-intensive water supplies will likely face much greater opposition. Likewise, new power plants reliant on fresh or sea water supplies also face greater opposition, from both the environmental community and local municipal or agricultural communities whose water needs compete directly with those of power plants.

Water for Energy

Almost all forms of electricity generation require water. Thermoelectric power plants that rely on fossil and nuclear fuels have historically used water to cool and condense steam. Three types of cooling systems dominate: in the eastern U.S. and on the West coast, many plants are located along rivers or the ocean and use water in once through cooling systems. While rates of withdrawal are extremely high in these systems, only a small portion of water is evaporated, or consumed. In inland areas of the western U.S., most thermoelectric plants employ wet-recirculating cooling systems, which withdraw exponentially less water than once-through systems, but consume substantially more. Dry cooling systems use air to cool and condense steam from a power plant's turbines. These systems require minimal amounts of water, offering significant water savings compared to once through or wet-recirculating systems.

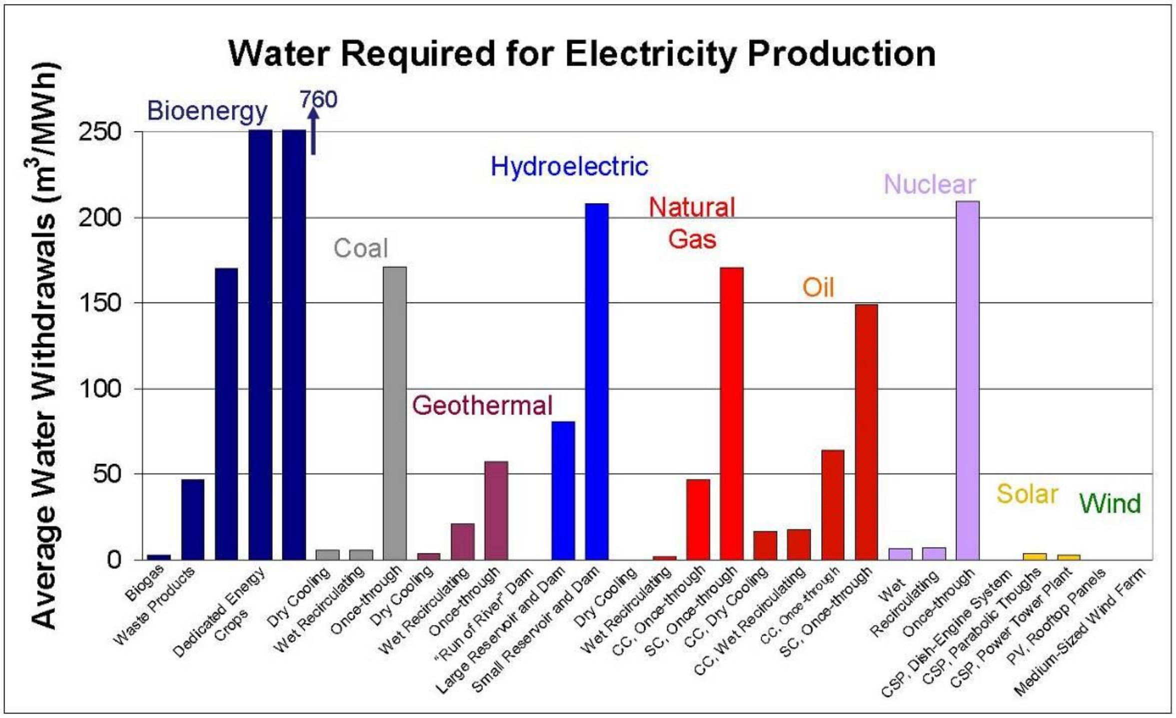


Figure 1: Water requirements for different forms of electricity generation vary substantially, depending on the primary fuel source and the technology employed. Source: Presentation by Stacy Tellinghuisen, May 2007 (research authors include others)

Although the cooling systems account for the majority of water used in power generation, water is also used in other parts of the process: water may be used to mine, process, or transport fuels (i.e., a coal slurry line). These processes may have important local impacts on water resources. Emerging fuel sources such as oil shale, tar sands, and marginal petroleum reserves may have additional water needs and significant local impacts on water quality and quantity.

Water use for renewable forms of energy varies substantially. Solar photovoltaics, wind turbines, and landfill gas-to-energy projects require very little water, if any. Geothermal and concentrating solar power systems that employ dry cooling also have minimal water requirements. In contrast, irrigated bioenergy crops could potentially consume exponentially more water per unit of electricity generated than even the most thirsty, once-through cooled thermoelectric plants. Geothermal plants may also have high water requirements, depending on the geothermal resource and the conversion technology employed. Many geothermal plants, however, rely on geothermal fluids (often high in salts or other minerals) to meet their cooling needs. Finally, although reservoirs often have multiple purposes (e.g. flood control, water storage, and recreation); evaporative (consumptive) losses from hydroelectric facilities per unit of electricity are higher than many other forms of generation (see figure 1).

Energy for Water

The water and wastewater sectors require energy in numerous processes: Water is needed to pump, convey, treat, and distribute potable water; end users demand energy for heating, cooling, and pressurizing water supplies; and energy is used to treat wastewater before it is discharged. The energy intensity of water varies, and is highly dependent on local conditions. Southern California, with its myriad of supplies, serves as an apt example: water conveyed through the Los Angeles Aqueduct is a net producer of hydroelectric power, while the State Water Project and the Colorado River Aqueduct use energy to lift water over mountain ranges. Seawater desalination requires more energy per unit of water provided than most existing imported water supplies. Local ground water and recycled water, in contrast, have much lower energy requirements (see figure 2).

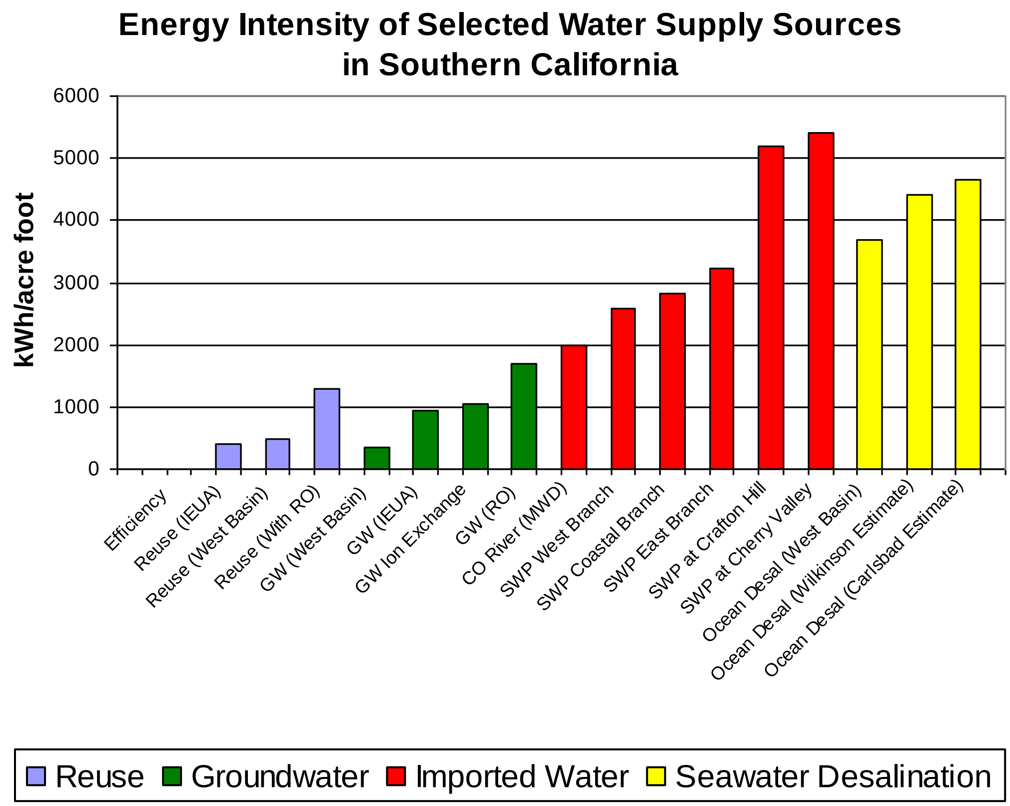


Figure 2: Energy intensity of water supplies in Southern California. Source: Professor Bob Wilkinson, UCSB.

As many regions' easily accessible water supplies reach full allocation, water providers will be forced to look towards more energy intensive supplies such as deeper ground water aquifers, seawater desalination, or desalination of brackish ground water or surface supplies. More stringent water quality standards and emerging contaminant issues may further increase the energy demands of providing water.

Context: Population Growth and Climate Change

Many of the challenges presented by the energy-water nexus are created – and compounded – by existing issues. Population has grown most rapidly in the arid Southwestern U.S., increasing water demands in both the municipal and thermoelectric generating sectors. Energy needs are projected to skyrocket between now and 2030; the electricity industry anticipates investing more than $275 billion in 292 GW of new generating capacity. Compounding this, the costs of complying with existing environmental regulations increase each year. The potential costs associated with climate change and greenhouse gas mitigation would further add to industry costs.

The impacts of climate change on the energy-water nexus will be many and varied. Research indicates that the average temperature of the U.S. has increased 0.5 to 1.0 degrees over the past century, comparable to global trends (see figure 3); recent reports have suggested an even more substantial warming in the Western U.S., where existing water supplies are already constrained. Climate change is expected to shift patterns of precipitation and shorten the winter season. In the Western U.S., this may result in diminished snowpacks and earlier spring runoffs, turning a valuable water supply into a flood hazard. Climate change may directly impact hydroelectric power production and water supplies for thermoelectric generation. System feedbacks and interactions, however, make local or regional climate change predictions challenging. As the knowledge base of climate change shifts, a “learn as we go” management strategy will be important. Furthermore, collaboration, cooperation, and communication between water managers and scientists will be essential.

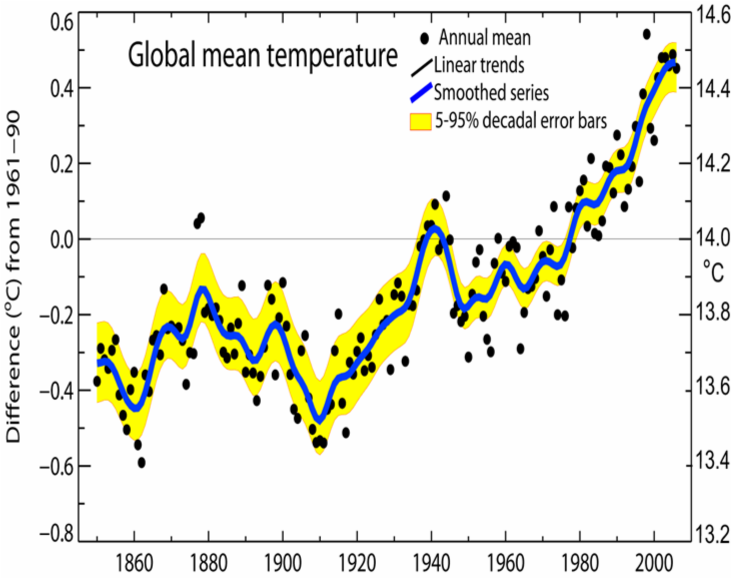


Figure 3: Global mean temperature, 1850 – 2005. Source: Presentation by Kelly Elder, USFS, May 2007.

Political Initiatives

Awareness of the energy-water nexus – and the need for integrated planning – has increased in recent years. Federal initiatives, led primarily by the national labs and university teams, have worked to identify major challenges, develop tools for long-range planning, and offer potential solutions. Legislative bills were proposed in both 2004 (H.R. 4835 and S. 2658) and 2005 (H.R. 3182 and S. 1860). The Energy Policy Act of 2005 provided new authorization to the Department of Energy for energy-water related research and development. Finally, the energy-water roadmap process identified a series of specific needs, described in greater detail in the chapter addressing future challenges.

Existing Challenges and Solutions

Constituents affected by the energy-water nexus face both technical and political challenges. Several of these challenges are being addressed by national labs, research institutions, and non-governmental organizations. Their research and findings are outlined below.

Thermoelectric Power plants: Cooling Needs

As older power plants are retired and newer plants are constructed, the electricity sector will have opportunities to reduce its water requirements; ongoing research at both the National Energy Technology Lab and Electric Power Research Institute is investigating the potential to reduce the electricity sector’s water needs. Nationwide, the magnitude of future withdrawals and consumption by power plants will depend greatly on the cooling configurations of new power plants, which are heavily influenced by regulation. NETL analyses have assessed water needs under several future scenarios, ranging from a "status quo" scenario to one that retrofits existing facilities with wet recirculating cooling systems. These analyses underscore the need for improved water use efficiencies at thermoelectric power plants. In support of this need, NETL is working to develop technologies for commercial demonstration by 2020 that can reduce freshwater withdrawal and consumption by 70 percent or greater at a levelized cost of less than $1.60 per 1000 gallons freshwater conserved.

Thermoelectric power plants can reduce their water demands in several ways. Researchers at EPRI have investigated several opportunities for reducing water demand. The principal reductions in water use can be obtained by cooling and condensing steam using a dry cooling system. Dry cooling has several drawbacks, however, which hinder its widespread implementation. Dry cooling may increase a project's capital costs by 5 – 15 percent, and requires more land than a wet-cooled power plant. During hot summer months, when electricity is most valuable, dry cooled systems suffer energy penalties on the order of 9 – 16 percent. On the hottest days, plants may be forced to reduce their output (load shedding) in order to meet acceptable operating conditions. EPRI continues to investigate ways to improve dry cooling technology. In addition, their research addresses the following opportunities:

- Improving the thermal conversion efficiency of a plant, so that more electricity is produced per unit of water used for cooling
- Recycling water within a generating facility
- Using degraded water supplies for cooling

Strategies for reducing the impact of thermoelectric power plants vary, depending on local conditions. Creating a tool box of technologies and practices that reduce water demands, therefore, has great value for the thermoelectric power sector (see figure 4).

Figure 4. Strategies for increasing fresh water use efficiency. Source: Presentation by Bob Goldstein, EPRI, May 2007.

Many renewable forms of energy use less water than conventional, thermoelectric power plants; investing in water-efficient forms of renewable energy can have substantial benefits for the water sector. Wind has emerged as one of the most cost-competitive renewable sources of energy. Integrating wind (and other renewables) into the existing generation and transmission system, however, faces hurdles (see figure 5): Often, wind resources are not located near transmission lines and are intermittent in nature. Furthermore, although costs for all forms of renewable generation have fallen in recent years, the *capital* costs often are higher than those of coal or other fossil fuels. Two tactics for addressing these challenges and integrating wind power were presented at the SWRR meeting: one, a technical strategy and the other, a policy-based strategy. In addition, a vision of the future role of wind power and potential markets was presented.

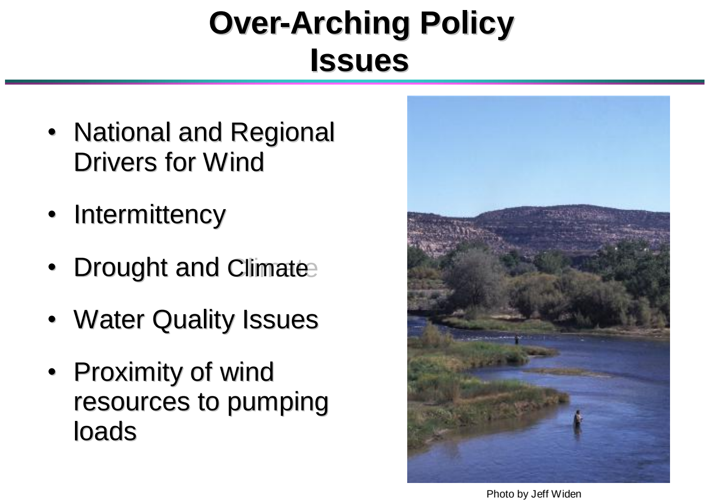


Figure 5: Over-arching technical and policy issues act as challenges and drivers to integrating wind energy. (Source: Bart Miller, Western Resource Advocates)

Integrating wind power and other intermittent renewables into the existing electrical grid system creates several technical challenges. Hydroelectric resources represent one solution, by helping utilities integrate and balance the intermittency of wind power. Hydropower generators can respond quickly to imbalances in the electricity grid, making them effective in serving load and balancing uncertain or intermittent resources. A utility's ability to integrate wind and hydropower depends to a great extent, however, on local conditions, such as:

- The amount of hydroelectric generating capacity available to balance large amounts of wind power (potentially thousands of megawatts in some regions of the country)
- The operational flexibility of hydroelectric facilities (due to environmental or other issues)
- The economic value of existing hydropower operations (i.e. it may be more profitable to use hydropower facilities to generate power at peak periods of demand, rather than reserve it for use when wind is intermittent)
- Historic water rights
- Crop-specific water requirements by time of year

Although hydropower has the potential to balance intermittent generation from other renewables, the degree to which wind and hydropower resources are integrated in a larger electric system depends largely on these system-specific characteristics.

Local, state, and national policies have played – and will continue to play – an influential role in the development of renewables. To assess the impact of different political, technical, and environmental factors, Western Resource Advocates surveyed 21 cities. Specifically, WRA's analysis identified which factors influenced municipalities' procurement of wind power. Through their surveys and independent research, WRA found that fast-paced growth in energy demands, water scarcity, the cost of traditional energy sources, and proximity to wind resources all play a role. The single most important factor in whether a city has or is likely to have wind power, however, is local community support. Community support is evidenced by voluntary wind power purchase programs, state- or municipal-level renewable portfolio standards, city council resolutions, and other measures. Building community support will serve as an important step in expanding the role of wind power in meeting local electricity demands.

In addition to technical and political barriers, cost represents a primary challenge to greater implementation of renewables. Wind power has emerged as one of the most cost-competitive forms of renewables, with prices comparable to electricity generated from natural gas. In many regions of the country, however, coal power remains the cheapest source of new electricity. Greater development of renewables hinges in part on the continued existence of the production tax credit. If transmission, regulatory, and economic barriers are addressed, future generation is likely to be much more competitive and will have the potential to provide significantly greater volumes of electricity. The National Renewable Energy Lab continues to address these issues and to develop, test and improve technology options. Figure 6 illustrates characteristics of existing wind power generation, barriers, and a vision of future generation.

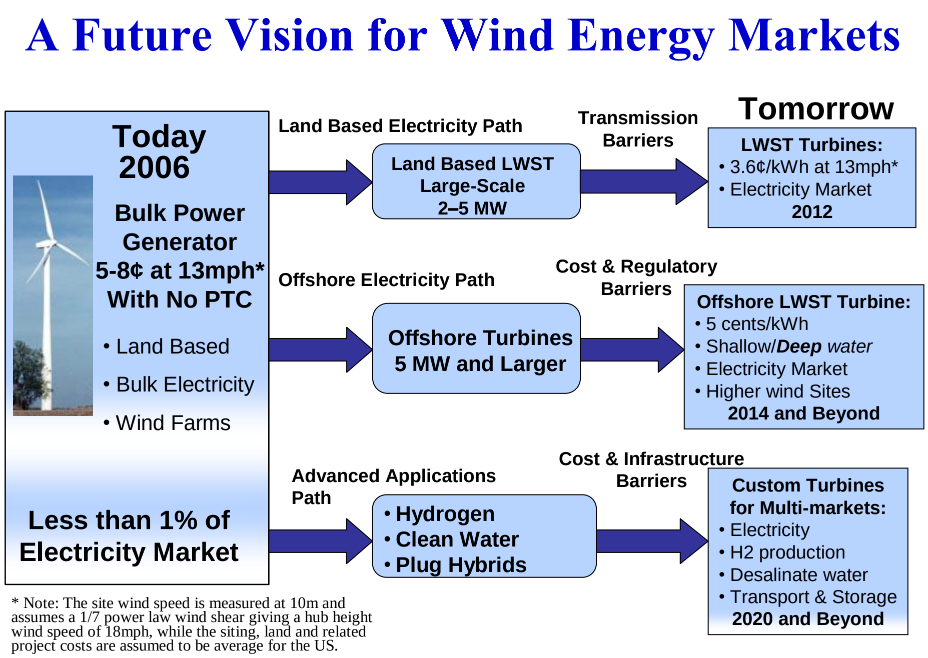


Figure 6: The wind energy market in 2006, existing barriers, and future wind energy markets.

As figure 6 illustrates, future markets for wind power will likely differ from today's markets. Desalination of brackish ground water or seawater represents a viable market for wind power - both now and in the future. Growing municipalities, particularly in the arid Southwest, will increasingly have to look toward energy-intensive water supplies such as brackish ground water. Many of these regions have significant wind resources, which could be used to power desalination facilities. In particular, agriculture in the Great Plains region once relied heavily on wind power. Now, as agricultural economies shift to municipal and industrial economies wind can play an important and cost-effective role in meeting local water and power needs. Furthermore, because water can be stored, daily fluctuations of wind has limited negative implications for water supplies.

The barriers and opportunities presented here represent a subset of those facing all renewable sources of energy. Other sources of renewable energy encounter a different set of issues – solar thermal plants, for example, may require large tracts of land; geothermal plants may incur substantial energy penalties during summer months. Addressing these barriers and integrating renewable sources of energy may provide significant benefits to the water sector.

Future Challenges

Many of the challenges and solutions outlined above will continue to face the energy and water sectors in coming years. Emerging issues may intensify these challenges. For example, stricter environmental regulations on fossil fuel-based power plants will increase water required for scrubbing to reduce NOx and SOx emissions, and pressure to capture and store carbon emissions will further increase plants' water demands and degrade water quality used in these processes.

The ethanol boom may present the greatest emerging challenge in the energy-water nexus. In January, 2007, 112 biorefineries were in production in the U.S., and an additional 76 biorefineries were under construction, according to the Renewable Fuels Association. Ethanol plants use, on average, five gallons of water for every gallon of ethanol produced. In addition to water used in processing, ethanol may lead farmers to grow crops on marginal lands, increasing water demands for irrigation.

Providing policy-makers, members of industry, and regulators with analyses to inform decision making is an essential step toward integrated planning. Researchers at the University of California developed a broad analysis to assess the impact of different energy portfolios on California's future water resources. Their research demonstrates that in 2020, under the state's renewable portfolio standard, statewide water withdrawals for electricity generation are likely to increase by 35 percent, relative to 2005. Using the same fuel mix but converting a portion of the state's power plants to dry cooling systems and other water-efficient technologies may reduce statewide freshwater withdrawals by 66 percent, relative to projected demand in 2020. Relying on a water-efficient portfolio of renewable resources provides even more substantial freshwater savings, reducing overall freshwater needs by 90 percent. These scenarios do not necessarily provide a likely picture of California's electricity sector in 2020, but demonstrate "bookend scenarios" and illustrate the benefits – and impacts – of energy choices.

Meeting future water and energy needs will require integrated planning on behalf of both the energy and water sectors. Both technological and policy-oriented solutions will play a role in meeting future energy and water needs. Additional research will also play a role in helping to develop more water-efficient forms of energy, and energy-efficient ways to acquire and provide water. The roadmap process identified, among others, the following national research and policy needs:

- Improved data on regional water availability and sustainability, including improved data collection, frequency, sensors and data management systems

- Coordinated regional natural resources planning, including modeling and decision support tools, an assessment of ecological water needs, and modeling of climate, hydrology, meteorology variability and uncertainty
- Improved materials, processes, and technologies to enhance water use efficiency and energy use efficiency, including applied research and more joint industry-government field demonstrations of emerging technologies
- System-level consideration of energy-water solutions, such as energy and water transmission infrastructure improvements, and co-location of energy and water production facilities

Conclusion

Choices about future energy and water supplies have long-term ramifications. Utilities typically design power plants to last at least fifty years; water conveyance systems often are designed to supply water for an even longer time horizon. Therefore, considering the long term impacts of energy and water choices is essential when making large capital investments, as the consequences of each choice of technology, both positive and negative, will be experienced for two or three generations. Many factors influence energy and water planning - cost, environmental concerns, and regulatory constraints, to name a few. To reliably meet future energy and water demands, however, energy systems must consider future water availability and trends in technology that influence competing demands. Likewise, the development of new water supplies must consider the availability – and affordability – of future energy supplies and trends in energy use.

Technological and policy-based measures can help relieve strains on energy and water supplies. Researchers at national labs, universities, non-governmental organizations, and industry organizations have identified opportunities in the energy-water nexus and tactics for reducing the impact of our energy and water systems. Additional barriers and research needs remain. Reducing the water use of thermoelectric plants and integrating water-efficient renewables into the existing electric grid present ongoing challenges to the electricity sector. Similarly, as existing water supplies become more constrained, future supplies are likely to be more energy-intensive. The rising pressures of climate change, population growth, and fuel costs may compound these challenges, underscoring the importance of integrated planning for future water and energy supplies.

Acknowledgements

We are grateful to the National Energy Technology Laboratory of the Department of Energy for providing financial support to the Sustainable Water Resources Roundtable some of which enabled the preparation of this paper. Some of the funds also supported the two meetings at which the main SWRR discussion on water and energy occurred. Other support for those meetings was provided by the National Renewable Energy Laboratory of the Department of Energy and the second of the two meetings was hosted by NREL.

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Presentation by John Gasper, Argonne National Lab, January 2007.

Selected Abstracts by Roundtable Participants

Finley, T., Leathers, G., and Zhang, H. X., Managing Water Risks in Water Scarce World: Use of WBCSD Global Water Tool for Sustainable Water Management, Proceedings, WEFTEC.08, Water Environment Federation, October 2008. Water availability and the ability to discharge are growing issues for businesses around the world. Access to water of sufficient quality and quantity has emerged as a critical issue affecting economic activity, development, and business on every continent. There is a growing need for a practical tool that can map water use and effectively assess water risks for industries, especially global companies and organizations with operations and suppliers in numerous countries. Such a tool has been developed by the Global Business Council for Sustainable Development, and can be used by global companies to identify, prioritize, and manage water risks. This is a public-domain and easy to use tool that allows companies or organizations to map their water uses and risks relative to water availability in their global operation and supply chains.

Smith, Ethan T., *Water Resources Sustainability*. On-line essay in July 2008 AWRA Water Resources Impact, available via the AWRA Water Blog at http://awramedia.org/mainblog/ Click on the category Water Resources in the Next Decade.

> The essay includes the essential elements of water sustainability, and what must be done to mitigate problems in the future.

Smith, Ethan T., Zhang, Harry T. *Sustainability of Marine Resources: Fisheries Utilization*, presented at the 2008 WEFTEC conference in Chicago, IL.

The paper addresses the problem of sustainable marine fisheries, as exemplified by the work of the National Marine Fisheries Service and the Marine Stewardship Council. Indicators for commercial fisheries resources are developed from available data. See Reports and Publications, WEF Papers, www.acwi.gov/swrr

Wells, John. *'Managing for Water Sustainability'*. Presented at AWRA Annual Conference, New Orleans on Nov. 17-21, 2008. The report by the Minnesota Environmental Quality Board is available at http://www.eqb.state.mn.us/project.html?Id=19502

Selected Abstracts by Water Resource Professionals

Finley, T., Leathers, G., and Zhang, H. X., Managing Water Risks in Water Scarce World: Use of WBCSD Global Water Tool for Sustainable Water Management, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Water availability and the ability to discharge are growing issues for businesses around the world. Access to water of sufficient quality and quantity has emerged as a critical issue affecting economic activity, development, and business on every continent. There is a growing need for a practical tool that can map water use and effectively assess water risks for industries, especially global companies and organizations with operations and suppliers in numerous countries. Such a tool has been developed by the Global Business Council for Sustainable Development, and can be used by global companies to identify, prioritize, and manage water risks. This is a public-domain and easy to use tool that allows companies or organizations to map their water uses and risks relative to water availability in their global operation and supply chains.

Hudson, Joyce, and Robert J. Freeman *Encouraging Green Development with Decentralized Wastewater Approaches*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

The population of the United States is projected to increase 40 percent from 2006 to 2050, approximately 120 million people. That growth will bring a substantial increase in demand for infrastructure: housing, transportation, water and wastewater, and all the support structure for modern civilization. The resulting demand on existing natural resources will be seen in areas such as energy consumption, water use, and land use. The pressure on the existing environment from this development will manifest itself in the health of our watersheds, surface and ground water quantity and quality, health of plant and animal ecosystems, air quality, and the overall quality of life. To mitigate this situation, EPA national strategy development in the Southeast U.S. emphasizes decentralized/cluster wastewater approaches.

Rehring, John, et al, *Practical and Sustainable Water Supply: Making the Most of What You Have*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Water providers throughout the country are seeking reliable, sustainable water supplies to meet current and future demands. However, capital costs of water acquisition and delivery infrastructure can be enormous, and renewable supplies can be vulnerable to drought and climate change induced changes in hydrology. Utilities in the Rocky Mountain region have identified practical approaches for renewable supplies through reuse of effluent return flows, use of off-peak capacity in existing major pipelines, and conjunctive use of surface water and ground water supplies. Together, these measures will help address increasing demands while enhancing drought-year reliability.

Roll, Bruce and Bobby Cochran. '*Leveraging Ecosystem Markets for Sustainability',* Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

In 2007 there were 48 water quality trading programs around the globe. Similar growth in market-based environmental policies has occurred to meet climate change goals, mitigate wetland loss, and promote recovery of endangered species. Advocates of market-based approaches to environmental policies have espoused the economic and environmental benefits of tradable emission permits, credits, taxes, and other tools for more than 30 years. Market tools have demonstrated successes, but they have also raised concerns and some have not achieved their goals. Of the 48 water quality trading programs around the world, only 21 are active, and even fewer have actually delivered a trade. Many of these challenges do not stem from problems inherent to markets, but instead point to design problems in both current environmental policies and market structures. This paper presents a framework for an ecosystem services marketplace that attempts to address these problems.

Chapter 4: Applications and Case Studies

This chapter highlights four case studies that demonstrate the use of indicators to understand sustainable water management. As an evolving record of what works, the roundtable will report on lessons learned by other organizations to advance sustainable management of the nation's water resources, emphasize the formulation of local and regional policy considerations, and help to guide future initiatives. Highlighting these case studies also will, we hope, serve to stimulate future roundtable collaborations.

Sustaining the world's water resources is an urgent environmental and socio-economic challenge. The combination of rising demand for water, inefficient water use, and contamination of water supplies is producing dire consequences for ecosystems and the health and hygiene of the world's populations. Constraints on water availability also represent a serious obstacle to economic development. Sustainable development is the key to water quantity and quality management, as well as national security, economic health, and societal well-being (Flint, 2004). The Chesapeake Bay case study illustrates an indicator strategy for engaging the regional community in restoring water quality. The Missouri River Basin case study outlines opportunities for using water sustainability indicators to promote sound decision making at a major river basin scale.

Chesapeake Bay – The Opportunity for Integrated Solutions

By R. Warren Flint, Ph.D., Five E's Unlimited (rwflint@eeeee.net)

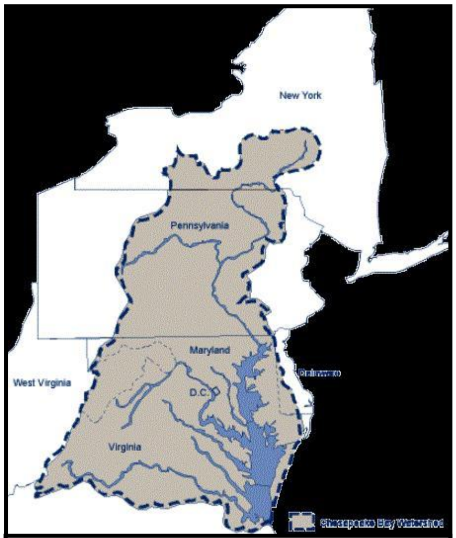


Figure 1. Map of the Chesapeake Bay watershed.

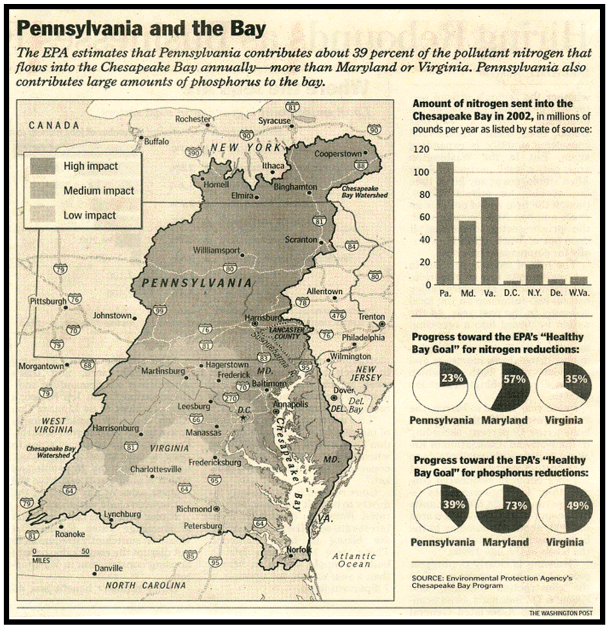
The Chesapeake Bay is one of the better-studied ecosystems in the world. Yet in 2008, Chesapeake Bay water quality was rated very poor, with only 21 percent of established goals met for restoring this declining ecosystem. The Bay remains in a degraded state due to a variety of stressors, including point and non-point sources of polluted runoff, eutrophication, hypoxia, land development, disease, over-fishing, invasive species, toxic contaminants, and climate change. Where there is crisis with regards to the present state of the Chesapeake Bay, an opportunity also exists for the Bay ecosystem to become a focus for improvement strategies built upon a foundation of environmental decision making supported by learning-based management, and guided by the iterative and constructive process of "thinking like a watershed" (Flint, 2006). But to succeed in achieving a system that is both resilient and sustainable in the face of its many different stressors, stakeholders must embrace a management approach that is participatory, adaptive, and ecosystem-based. This ecosystem-based management approach is challenged by a mind-set of (1) piecemeal, disconnected inquiry regarding how to best manage the Bay in a way that will show measurable improvements and (2) an isolated grassroots effort that emphasizes all-inclusive engagement of stakeholders for better awareness and more informed decision-making.

The Bay watershed (see figure 1) supports significant agricultural, forest, fishery, and tourism sectors that provide valuable goods and services to the 17 million residents in the watershed. For example, in

2004 the economic value of the Chesapeake Bay was thought to be more than $1 trillion per year. In addition to its monetary worth, the Bay includes treasured landscapes, cultural, historical, and recreational assets that are priceless.

The overall health of the Bay and its watershed remains degraded despite the restoration efforts of the past 25 years, which have only resulted in some limited successes in specific geographic areas and certain parts of the ecosystem. Several of the Bay's living resources, including crabs, fish and oysters, are stressed by pollution and over-harvest. Vital habitats such as wetlands and forests are lost to growth and development at significant rates. Water quality remains severely degraded from a variety of land-based activities. Some conditions are the legacy of decades of human activities. Others are magnified as the region continues to experience rapid population growth.

Federal, state, and local resource managers have been setting goals and collecting various kinds of data, including nutrient inputs, for more than four decades. These numerous management systems have had limited success in improving the Bay's ecologically degraded status since before the 1970s. Following a large U.S. Environmental Protection Agency study in the early 1970s, formation of a multi-state compact to address the Bay's problems, and considerable discussion and deliberation (U.S. Environmental Protection Agency, 1987), the goal was set to reduce the flow of nutrients into the Bay by 40 percent, a goal that was reaffirmed at the turn of the century (U.S. Environmental Protection Agency, 2000).



More recent data indicates that to meet water quality goals for the Bay, nitrogen and phosphorus pollution must be reduced by 44 percent and 27 percent respectively in all parts of the watershed, despite expected population increases of 30 percent between 2000 and 2030 (Federal Leadership Committee for the Chesapeake Bay, 2009). This will require significant reductions in pollution from urban, suburban and agricultural lands; municipal and industrial discharges; leaching to surface waters from septic systems; and atmospheric deposition of nitrogen to the Bay and its watershed. Existing tools, programs, authorities and resources have been insufficient. Strategies that engage the general public are imperative because only through attitude and behavior shifts of a critical mass of the population living in the Chesapeake watershed will system-wide improvement activities begin to make a real difference in the health of the ecosystem.

Serious management problems potentially serving as road blocks to genuine, integrated ecosystem-wide improvement for the Chesapeake Bay with regard to effects of nutrient runoff can be attributed to the "blame game," capriciously pointing the finger at those parts (states) within the watershed that are thought to be causing the most harm from inputs. For example, as suggested by a U.S. Environmental Protection Agency report (2003) and Washington Post news article (Washington Post, Sunday, May 16, 2004 entitled "Pennsylvania Pollution Muddies Bay Cleanup" by David Fahrenthold), the State of

Pennsylvania was singled out as one of the primary contributors of nutrients (nitrogen) to the Bay ecosystem. If, however, a more real view of the data were developed that did not focus upon total nutrient loading by each state over an annual cycle, but instead calculated loadings of nitrogen based upon total land area of each state's contribution to the overall watershed, then a different picture is observed. The results for nitrogen loading by jurisdiction on a per acre basis of the overall watershed, using the Environmental Protection Agency's own data, indicated that Pennsylvania contributed 7.53 lb/acre/yr, Maryland contributed 7.58 lb/acre/yr and Virginia contributed 7.61 lb/acre/yr. This is certainly not the same interpretation as cited by the Washington Post news article where the most blame was placed on Pennsylvania even though it showed the lowest nutrient input per acre of the three major contributing states (see adjacent portion of news article). These kinds of management decisions are an example of why decades have passed without major improvement to the Chesapeake and why new collaborative, integrated approaches are now needed from watershed-focused managers.

Population growth, land development, and increasing technology demands are outpacing our ability to protect ecologically and culturally significant landscapes. The loss of forests, wetlands and healthy streams damages the ecosystem. Working farms and forests, significant to rural economies, have been fragmented and reduced. Historic landscapes are threatened by encroaching development. For example, about 25 percent of the Chesapeake Bay watershed is used for agriculture, which delivers a diverse array of products, anchors rural communities, and provides open space, wildlife habitat, and other amenities. While agriculture is an important component of the landscape and economy, it also is a major source of nutrients and sediment that adversely affect water quality in the Bay and its tributaries. When one is "thinking like a watershed," however, it can quickly be recognized that agricultural best management practices present a real opportunity for advancing major improvements to water quality, as New York City learned in its efforts to improve the quality of its domestic water supply (Flint, 2006). Although agriculture has reached nearly 50 percent of agriculture's goals for nitrogen, phosphorus, and sediment reduction in the Chesapeake, much more can be done to achieve the broader goals for protecting and restoring the Bay and its tributary waters. In short, the Bay's most sensitive and important landscapes are those that reflect and promote the on-going exchange between people and place. Therefore, some of the more immediate solutions might best be found in the engagement and behavioral change of people.

The Chesapeake Bay and its watershed encompass a large geographic area, including different landscapes and an increasingly diverse society. The choices made by individuals, communities and governments drive ecosystem changes measured in the health of fish and wildlife, the quality of water, and condition of habitats and lands. Thus, there is a real need to empower local efforts because local governments, watershed organizations, and residents have a great interest and ability to restore the environment. In order to better inform these choices and bring more awareness to the people who ultimately will most affect change, there is a growing need to improve collection, dissemination, and relevance of scientific information such that decisions are made with the best available knowledge. Such information needs to include not only measures of ecological health, but also the economic and social ramifications of available options toward improving the Bay ecosystem.

Recognition for the importance of public participation over the history of Chesapeake Bay resource management has evolved through a relatively isolated (from governance and environmental management actions) citizen and stakeholder belief in a strategy for improving the overall state of the Chesapeake. Stakeholders concerned about this ecosystem began to develop an indicator strategy that was much more successful at engaging region-wide community approaches toward improvement in water resource quality than any of the traditional management-designed nutrient abatement efforts toward improving ecosystem health. The discussion of indicators of Bay health came very early in the attempts to save the Bay from degradation in the face of rapidly escalating impacts of regional urbanization and agricultural intensification in its watershed. This public discourse led to an important re-conceptualization of the problem of Chesapeake Bay pollution (Horton, 1987). Old maps of the Bay were discarded, not because of changes in erosion or political boundary shifts, but because a new perception of the Bay “system” was emerging. The public discussion eventually worked; through the contributions of scientists, politicians, and many others, the public developed a new spatial model that related values placed on the Bay to a new, watershed-scale dynamic. People gradually learned that to think like a bay, one has to first learn to think like a watershed (Norton, 2005, pg. 435). This process exemplified social learning at its best, because communities that once related to the Bay locally were able to add another scale to their understanding and to their sense of responsibility.

The process did not succeed by trying to achieve widespread agreement with a single value or a single way of measuring value; rather it proceeded as participants proposed, discussed, and deliberated about what trends and features of their environment should be monitored and which of these could be treated as indicators that correspond to various management goals and community objectives. This was an excellent way to ensure that all residents understood their connection to local streams and rivers to foster stewardship and achieve the overall goals for a healthy Bay. In this way the principles of community members were extremely important in public discourse and deliberation because people appealed to their core values as they argued for the importance of particular trends, features, and indicators. They said that, given the values they hold dear, given their aspirations for their place, they think certain goals should be set, as tentative starting points for management actions. They recommended these goals be stated explicitly in terms of a physical, measurable indicator that allows assessment of the management process over time.

A process developed — suffused with values and love for the Bay and for the many distinct communities that exist there — generated by a public discourse concerning turbidity in the Bay. The urgency of this discourse drove scientists to do basic research that led to the conclusion that the main continuing threat to the Bay was widespread sources of nutrients: from sewage outflows, and from runoff from farmers' fields, suburban lawns, highways, and parking lots. Through public discourse over a period of a decade or so that included ongoing involvement of scientists and managers, Bay residents evolved a broad "mental model" of Bay pollution based on the hypothesis that the decline of submerged aquatic vegetation was a result of explosions in planktonic populations that were living on excess nutrients and threatening to turn the waters anoxic when they died and decomposed.

The emergence of this mental model of bay degradation resulted in the identification of an important, but simple indicator – bay water clarity – which was, in turn, related to a landscape-scaled dynamic, the rate of nutrient and sediment loading from various sources. Water clarity, as an indicator of success regarding efforts to save the Bay, was then related in many different ways by many different people to their own values and feelings about what was important to them. The choice of water clarity as a key indicator solidified collaborative action and resolve on the part of the public, the states, and the agencies not often observed with traditional water quality control programs; it also expressed concretely the many ways the communities around the Bay valued it. Taking aggressive action to reduce nutrient-loading and sediment erosion, hypothesized to be driving the increase in turbidity (Newcomb and Jensen,1996), was a positive expression of values placed on a variety of bay-dependent options, including fishing, boating, and maintaining tourism-related businesses. The indicator of water clarity, as was pointed out by scientists during the public deliberations, could track reductions in nutrients and sediments entering the estuary. The variable of water clarity singles out possible nutrient and sediment problems from a number of sources in the watershed, including:

- forest practices
- nutrient loading
- agriculture practices
- impermeable surfaces
- transportation
- recreation
- solid waste
- erosion
- spills
- stormwater
- urbanization/land development
- wastewater systems mining

The variable of water clarity “touches” many of the important dynamics of the Bay ecosystem and thus, is important in many ways. For example, submerged underwater grasses, which depend on the penetration of sunlight and thus affected by water clarity, are the foundation of the complex bay food web, which supports populations of fish and shellfish. Water clarity is essential to the widespread practice of "crab dipping," and of course it affects the quality of boating and swimming experiences. People's evaluations, in other words, were summarized and expressed in the choice of the key indicator of water clarity that could be scientifically or otherwise related to many important social values. It is, like percentage of pervious surfaces, a pretty good measure of broad processes that affect many ecosystem services from the Bay important to society. Rather than measuring the economic value of all of the different resources important to the public from the Bay and then aggregating their collective ecosystem service measures into something that might be meaningful and instructive, the process involved choosing a measurable physical-ecological indicator (water clarity) and setting a specific goal regarding reduction of nutrients by a specific date that promoted a uniquely efficient or welfare-maximizing outcome. In this setting ecological, lexicological (linguistic), biological, economic, anthropological, and sociological evidence was relevant and could be brought to bear upon the public discourse in which indicators and goals were proposed, advocated, criticized, and reformulated.

In this way, proposed indicators and goals are evaluated from many different perspectives and allowed to be assessed based on many value systems. If we can find an indicator that is consensually accepted as expressive of many of the shared values of the community, as in the case of water quality in the Chesapeake, and if we can identify physical dynamics that drive the problem, then we can begin to set goals associated with the indicator and begin to act collectively and experimentally. As we so act, it becomes possible to test both scientific hypotheses about how things work and hypotheses about what goals and objectives truly support our values. Starting from wherever they are, through an inclusive, transparent process of public participation communities can begin a course of cooperative action and experimental management, focusing their attention on reducing uncertainty and on the ongoing articulation and development of goals and objectives. This kind of collaborative, integrated effort will encourage a focus on sustainability and adopting an ecosystem-based, adaptive management approach to improve and sustain the Bay and its watershed.

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Missouri River Basin: The Need for Sustainable Management

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Socio-economic and political trends, community structures, and the very texture of our daily lives are increasingly shaped by advances in science and technology in more dynamic ways than most people may realize. The application of these advances has substantially aided economic development in the United States and increased people's quality of life. However, economic expansion and its benefits have been coupled with the depletion of natural resources on which our continued economic development and quality of life depend. Continued economic development that comes at the expense of the long-term health of ecosystems, combined with the inability to fully incorporate community and cultural values in decision making processes has led to community atrophy that reflects the need for sustainable water resource management. There are practical ways to enable people from all walks of life to contribute to science, thereby improving people's well being and the well being of their communities and environment. The increasing importance of science in today's world calls for far greater interaction among all stakeholders. This recognition is prominently demonstrated in the case of the long-term management efforts occurring in the Missouri River basin. It is imperative to restore community perspectives, commit to the use of sound science and integrated water resource management, and to identify the uses and value provided by natural resources that are relevant and provide enduring value to the public and stakeholders.

Figure 1: Image featured in USFWS 2003 Amendment to the Biological Opinion on the Operation of the Missouri Bank Stabilization and Navigation Project and Operation of the Kansas Reservoir System', dated December 16, 2003

During recent decades, the Missouri River has become the subject of controversies involving how to support the needs of the Missouri River's complex ecological system while simultaneously accounting for the region's varied cultural, social, and economic needs. The scale and scope of these challenges in the Missouri River Basin provides insight into the myriad of challenges confronting local, state and federal agencies, stakeholders, and the public alike. Since the enactment of the Flood Control Act of 1944, the needs of the people and ecosystems that rely on a healthy Missouri River Basin have changed and have thus necessitated the enactment of new federal statutes (e.g., Water Resources Development Act), institutional arrangements, and new ways of thinking. Accordingly, recent federal frameworks, committees, and interagency dialogue efforts have formed to resolve conflict, address public core values, protect riverine ecosystems and listed threatened or endangered species, and seek socio-economic benefits for current and future generations. The history of the management efforts with the Missouri River suggests that integrated water resource management strategies have not been pursued in a full, transparent, all-inclusive public engagement process that considered and applied the core values of citizens who live in the basin. Implementing these measures in a collaborative, science based framework supports synergy among our environmental, social, and economic systems.

The Missouri River is the nation's largest river system and travels through seven states, representing a critical ecosystem that has provided abundant water resource benefits to people for hundreds of years. The flow of the Missouri has been augmented over the past several decades through a series of civil engineering projects conducted by the Army Corps of Engineers in an effort to provide hydro-electric power, water reservoirs, flood protection, and others. Approximately 67 percent of the Missouri River is impounded by dams or chanelized for commercial navigation, resulting in significant alterations to flow regimes, average channel width, and sediment loadings (Missouri Department of Natural Resources, 2006). While people have undoubtedly benefited from the Missouri River's resources, these benefits have come at the expense of detrimental environmental impacts to critical flora and fauna species, including the endangered interior least tern (*Sterna antillarum*), threatened Northern Great Plains piping plover (*Charadrius melodus*), the pallid sturgeon (*Scaphirhynchus albus*), and the cottonwood tree (*Populus* spp.) (USFWS, 2003). Over the past several decades, more than 3 million acres of natural riverine habitat have been degraded; populations of aquatic insects which serve a prominent role in the aquatic food web have been reduced by nearly 70 percent from historical levels; 51 of 67 key native species are now considered threatened or are experiencing declines in population, and the viability of Missouri River Basin cottonwood tree species has declined significantly throughout the Missouri basin (MRRP, 2007). Development within the Missouri floodway has also resulted in impacts to cultural resources of Native American tribes living along the river; efforts have been underway to protect remains and artifacts believed to be buried within the floodway.

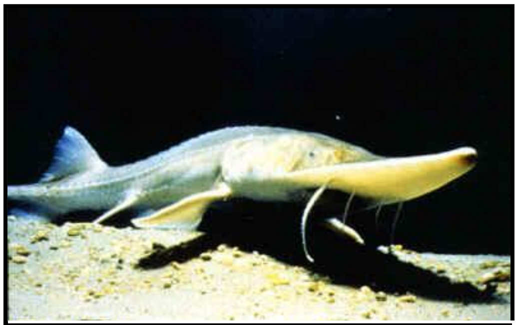


Image courtesy USFWS

A journey upstream from the base of the Missouri River underscores the rich diversity of cultures, communities, climate, habitats, and flora and fauna species present throughout the Missouri basin. In recognizing the unique value the Missouri River provides, an important question becomes evident: how can communities and stakeholders create adaptive management strategies that acknowledge this diversity and value in a manner that everyone can support?

Continuing piecemeal and consumption-oriented approaches to water policy coupled with a limited selection process for key stakeholder involvement cannot solve the critical problems confronting the Missouri River. Traditionally, scientific disciplines apply a sectorial approach to the evaluation of water management policy as evidenced by a general lack of coordination among needs such as power generation, riverine navigation and commerce, recreational needs and others. However, such challenges also present an opportunity to explore paradigm shifts in how the Missouri basin is managed comprehensively for both current and future generations. An enduring, equitable solution to these problems must involve the integration of a systems based approach to decision making that accounts for the needs of flora and fauna species, their habitat needs, as well as the needs of people, industries, tribal communities, and others.

Systems based approaches embrace principles of sustainability which anchors a system of scientific information, ecosystem, and social communities that are evaluated on multiple temporal scales (Norton, 2005). Sustaining water resources over the long-term requires a multi-dimensional way of thinking about the inter-dependencies among natural, social, and economic systems in a manner which ensures continued economic vitality while enhancing and preserving ecological integrity, social well-being, and security for all.

Over the last three decades, state and federal efforts to enhance riverine flood control measures, navigation, and electric power generation have been hampered by several extensive droughts throughout the Missouri watershed. Most notably, droughts in upper basin states in late 1987 and throughout 1988 led to droughts that impacted lower basin states until approximately 1992 (MELPR, 2008). Upper Basin governors lobbied the Corps to change its Missouri River management plan, calling for the release of less water, thereby keeping lake levels higher to support infrastructure and recreational interests. Lower Basin states voiced great opposition citing adverse flood control, inland drainage, and navigation consequences that were unacceptable. These droughts, along with newly proposed projects that prompted section 7 Endangered Species Act consultation measured led the Corps to update its Master Water Control Manual, a comprehensive guide used by the Corps to operate a system of six dams along the Missouri River. Following initiation of consultation by the Corps with the United States Fish and Wildlife Service in 1989, the Corps conducted nearly eleven years of consultation with the United States Fish and Wildlife Service, studying the potential impacts of Corps water resource projects on threatened or endangered species under the Endangered Species Act.

In December 2000, a jeopardy Biological Opinion released by the United States Fish and Wildlife Service in cooperation with the Corps stated that management strategies to date have been "detrimental to the survival and recovery of the endangered pallid sturgeon and least tern and the threatened piping plover (USFWS, 2000)." In 2003, the Corps re-initiated formal section 7 Endangered Species Act consultations with United States Fish and Wildlife Service given new scientific information concerning mortality rates and critical habitat protections of several threatened and endangered species (USFWS, 2003). To account for these newly discovered impacts under the Endangered Species Act, the Corps proposed comprehensive drought conservation plans, a commitment to adaptive management, increased efforts to support population growth of the pallid sturgeon and others. The Corps proposal did not however account for alterations to spring flow rise and low summer flow as provided under the terms of the 2000 Biological Opinion. Consequently, the 2003 Biological Opinion was amended by the Corps to provide "bimodal spring pulse releases from Gavins Point Dam for the benefit of the endangered pallid sturgeon (USACE, 2003)".

As the Biological Opinion consultation process continued, and updates to the Corps Water Control Manual were underway, the Corps announced in 2002 its 'Environmental Operating Principles' for the Missouri River and included the following:

- Strive to achieve environmental sustainability. An environment maintained in a healthy, diverse, and sustainable condition is necessary to support life.

- Seek ways and means to assess and mitigate cumulative impacts to the environment; bring systems approaches to the full life cycle of our processes and work.
- Recognize the interdependence of life and the physical environment. Proactively consider environmental consequences of Corps programs and act accordingly in all appropriate circumstances.
- Build and share an integrated scientific, economic, and social knowledge base that supports a greater understanding of the environment and impacts of our work.
- Respect the views of individuals and groups interested in Corps activities. Listen to them actively and learn from their perspective in the search to find innovative win-win solutions to the nation's problems that also protect and enhance the environment (Barton, 2008).

This began a new process of inquiry for the governing entities responsible for Missouri River management. Chief among these efforts was the Corps creation of the Missouri River Recovery Program, which has been funded by the Corps over the past five years. The Missouri River Recovery Program provides a framework for the Missouri River Ecosystem Restoration Plan and the Missouri River Recovery Implementation Committee, both of which were funded through the Water Resources Development Act of 2007 as omnibus appropriation bills in the United States Congress.

An understanding of the history of the interaction among the Corps and United States Fish and Wildlife Service including the joint efforts to initiate ecological restoration programs throughout the Missouri basin, and updates to longstanding federal management frameworks are critical in understanding how current efforts to redefine the nature in which tribal groups, citizens, federal agencies and stakeholders interact. The Missouri River Recovery Program, which is managed in part by the Corps, has focused upon restoring critical habitat features, providing real-time system monitoring and analysis of flow conditions, implementing a research and science program, and focusing on public involvement (MRRP, 2007). The program includes a consultation process that involves the Corps working with other federal agencies, states, tribes and non-governmental stakeholders, largely through the Missouri River Recovery Implementation Committee. The ultimate goal of the recovery program is the design of a long term Missouri River Ecological Restoration Program that will guide a system-wide recovery program for many years and lead to a self-sustaining, naturalized Missouri River ecosystem. And as the last principle listed above suggests, the Corps shows a willingness to respect and listen to the views of individuals and groups with specific interests in the basin.

In support of ecosystem-based management for the Missouri River, indicators of sustainability can link sectors of our economy, environment and society, and signal where improvements may be needed in order to achieve long-term management goals. Effective indicators can serve as a metric for determining progress in achieving sustainable, integrated water resource policy. For example, an economic indicator that does not include long-term environmental and social considerations will not likely move water resource protection in a sustainable direction (e.g., the Missouri River conflict). Likewise, an environmental indicator that does not take into account economic and social impacts will likely not provide adequate insight into the best way to improve watershed health and vitality. The development of indicators that account for the needs of social, economic, and environmental interests should reflect the core values of the communities impacted by resource management decisions (Flint, 2006). The organization of indicators can be aided by the use of indicators sets which group categories of indicators and can provide greater value and information for resource managers.

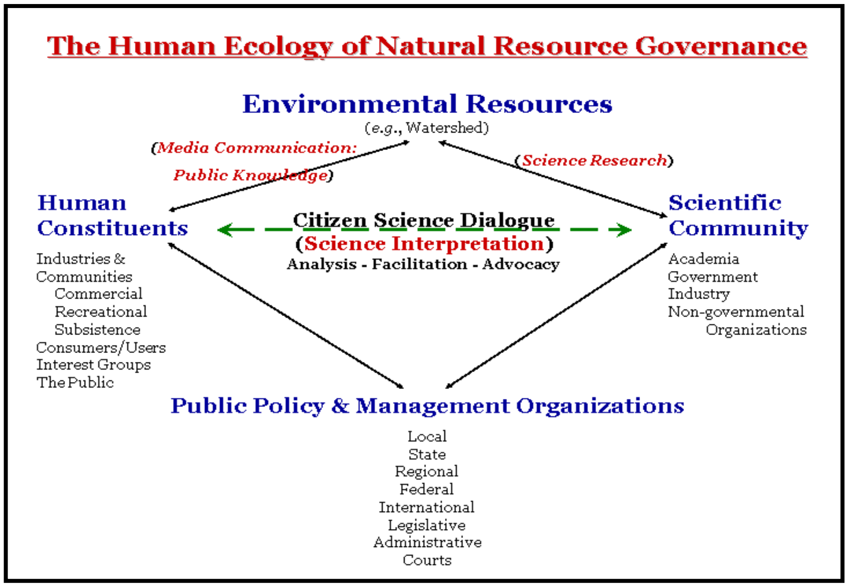
Water resource indicator sets are intended to reflect inclusive public participation on a basin-wide scale, recognizing that such a process can discover the core values of all stakeholders that promote social values people cherish. The Corps and United States Fish and Wildlife Service management efforts have employed similar iterative and collaborative planning frameworks under the National Environmental Policy Act. For instance, the Corps developed an Environmental Assessment and subsequently a final Environmental Impact Statement for the revision to the Missouri River Master Water Control Manual, and in so doing, engaged in public scoping meetings and tribal consultations that sought views from citizens and stakeholders across multiple states. The emergence of transformative facilitation efforts in would suggest that all parties need to be together at some early stage in the core value identification aspects of any public participation effort. Transformative facilitation implies that there are no ‘right’ or ‘wrong’ answers to the issue of natural resources and public welfare, but instead a ‘continuum of right.’ By facilitating a collaborative framework by which stakeholders can interact and share varied points of view throughout the decision making process, the conditions for sustained dialogue and integrated water resource planning can support paradigm shifts that jointly benefit the needs of people and the environment.

Failure to employ dialogue that helps stakeholders from civil society make connections between science and technology trends and social values can come at great cost, as history has shown for the Missouri River (Norton, 2005). Experts have created a conceptual gulf between the information they gather and the relationship between ecological and socio-economic science and public values. Policy discourse currently suffers because, whereas economic data is easily associated with the well-being of citizens in our democracy, ecological data has no such resonance. And yet, in the overall dialogue about community values the two are very much interrelated. Scientific discourse has to meet the real needs of real people, respecting individual rights and empowering communities to win public and political support. A model demonstrating how this can happen is shown in the adjacent diagram. The model illustrates the central, cross-cutting role for science so that capacity-building and the transfer of knowledge enable communities to address, for example their conservation-based development needs. By building models for engaging science in a more interactive and publicly inclusive way, we can make active partners of all the parties involved and ensure the full participation of all potential stakeholders.

Sustaining water resources requires a multi-dimensional way of thinking about the connections or inter-dependencies among natural, social, and economic systems in the use of water to achieve economic vitality while enhancing/ preserving ecological integrity, social well-being, and security for all. The ecologically sound, sustainable development of water resources:

- Involves policies, plans, and activities that improve equality of access and quality of life for all

- Identifies the multi-dimensional impacts (broadly categorized as environmental, social and economic) of any decision
- Promotes the need for balance among the different dimensions, across sectors, themes, and time scales
- Recognizes the limits and boundaries beyond which ecosystem behavior might change in unanticipated ways
- Advocates consideration of spatial scales, recognizing that interactions occur among different geographical ranges - globally, nationally, regionally and locally
- Challenges us to look to the future and to fully assess and understand the implications of the decisions made today on the lives and livelihoods of people in the future and the natural ecosystems upon which they will rely



When one shifts from viewing science exclusively as an academic activity and begins to see science as a part of a larger social dialogue and deliberation, relevance to real social values becomes one important determinant of what counts as sound science. Sustainability practitioners should believe in sharing scientific and technology information as a part of the public process, as demonstrated by the following diagram that shows experts sharing information with civil society to develop 'public ways of knowing,' rather than as an input into the process from the 'outside' or as an 'add-on'. Successful use of science in a public, democratic policy formation process requires a free flow of information in multiple directions. What appears to be missing in the study and application of sustainability is a multidisciplinary, integrative language capable of supporting multidisciplinary public discourse and deliberations. Indeed, the relationship between science and society has experienced significant stress. Science and its products are intersecting more frequently with certain human beliefs and values; public disaffection and shift in attitudes predict a more difficult and intrusive relationship between science and society in times to come if we don't find another way of doing business.

As science encroaches more closely on heavily value-laden issues, the public is increasingly adopting a stronger role in both the regulation of science and the shaping of the research agenda. Therefore, we can and should adopt a much more inclusive approach that engages many different sectors (communities) assertively in discussing the meaning and usefulness of science. We must try to find common ground through open, rational discourse. A theory of effective community capacity building with regards to economic and environmental management must be a theory of action. The actions can be motivated only by social values, and all actions, including scientific study, are suffused with values (Norton, 2005). No system for managing the environment or a community's economy can be understood in purely physical terms. Understanding the physical systems involved is of course important. But since we seek a system of active, adaptive management, our scientific models must be understood as embedded in a larger process of social discourse and political institutions. Our processes of management must therefore include a means of identifying, justifying, and/or legitimating science by reference to some social value whose measure is evaluated by relevant indicators of sustainability. This exemplifies how the application of citizen science can make a real difference in Missouri River strategic planning for sustainability.

The extent to which citizen-based scientific collaboration can be applied to long-term management of the Missouri River will depend on the commitment by key federal agencies, stakeholders, and community members. Their ability to foster new collaboration and new ways of thinking about how we value resources will largely determine the fate of endangered species and the myriad of water resource value that the Missouri River offers. The Association of the Missouri River Association of States and Tribes has supported the development of new studies that would comprehensively examine the current uses and needs derived from the Missouri basin and determine if policy changes are warranted in order to best meet the current and future needs in the basin, recognizing the major changes that have occurred in the basin's environmental, cultural, and economic conditions since the passage of the 1944 Flood Control Act and subsequent water resource laws. Initiated in October 2009, the proposed study by the association was authorized by Congress and funding was appropriated in the FY2009 Omnibus Appropriations Act (MoRAST, 2009). The evaluation of the current needs of people and nature within the Missouri basin may serve as an ideal opportunity to utilize indicators as a way to chart a new course in water resource management, accounting for the long-term needs of people and nature.

"There are not many rivers, one for each of us, but only this one river, and if we all want to stay here, in some kind of relation to the river, then we have to learn, somehow, to live together (Kemmis, 1990)."

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Sustainability in the Land of 10,000 Lakes

By John R. Wells, Minnesota Environmental Quality Board

Introduction

The concept of *water sustainability* goes to the heart of Minnesota's goals for managing water yet remains unclear to many. *Minnesota Statutes*, section 4A.07, defines *sustainable development* as "development that maintains or enhances economic opportunity and community well-being while protecting and restoring the natural environment upon which people and economies depend. Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs." In short, the concept suggests that people need the opportunity to live well while respecting the environment and the needs of future generations.

The Minnesota Department of Natural Resources developed a definition in 2005 that adapts the concept of sustainability to water use: "*Sustainable water use* is the use of water to provide for the needs of society, now and in the future, without unacceptable social, economic or environmental consequences." Of course, the meaning of "without unacceptable environmental consequences" must be consistent with "protecting and restoring the natural environment upon which people and economies depend."

The 2009 session of the Minnesota Legislature weighed in on the question by defining when water use is sustainable:

> *"…water use is sustainable when the use does not harm ecosystems, degrade water quality, or compromise the ability of future generations to meet their own needs.* [H.F. 1231, section 30, *Laws of Minnesota 2009*, Chapter 172]

While none of these definitions provides direct operational guidance, they point the way to it. An operational water quantity sustainability definition should include at least two factors:

- Water use that meets today's needs of people and ecosystems; that is, that does not cause conflicts between human uses nor harm ecosystem functions or degrade water quality
- Water use that reserves sufficient water of the quality necessary to meet the long term future needs of people and ecosystems

Sustainable water use also can be understood as use that does not cause a long term mining of the water resource. This, the future component of the definition, requires us to understand how much of the renewable water resource we use today and are expected to use in the future, after that which we must leave for ecosystems. Developing the information and measures to construct a useful indicator of water sustainability has been a state focus for several years.

Assessing Water Sustainability Statewide

The 2007 Environmental Quality Board report, *Use of Minnesota's Renewable Water Resources: Moving toward Sustainability*, describes results of a reconnaissance level evaluation of water sustainability. The report compared present levels of water use, as well as demand projected to the year 2030, with estimates of supply.

The purpose was to evaluate how much of a county's renewable water resource was already in use or likely to be so in the future. But to make a fair comparison, the analysis adjusted appropriations from surface waters coming into a county, since resource estimates on the supply side of the equation did not include such waters. The analysis also removed non-consumptive water uses from the tally, since such waters remain available for people and ecosystems.

The 2005 water use values were calculated by averaging each county's per capita demand for the years 1995 to 2005 in order to provide a baseline not artificially affected by a single year's weather. These same use rates were applied in estimating demand in 2030.

Managing water among competing demands "without unacceptable consequences" while "protecting and restoring the environment" is a challenge. The need to maintain instream flows – those flow levels necessary for the protection of aquatic communities – demonstrates this. Water availability and use are unevenly distributed across the landscape and time, and the life history of many aquatic organisms depends on this variability. In contrast, people and business often demand certainty.

The assessment worked with published methods describing recharge to the water table system and, in the case of the Watershed Characteristics method, discharge from the system. It used these as surrogates for generating sustainable supply values, developing five sets of renewable resource estimates. For this report, the USGS Regional Regression Recharge method determined the upper and lower limits of recharge based on the premise that an entire county is quantified by either the lowest or highest rate of recharge demonstrated within its land area. For this reason, these values serve as the high and low bars of supply estimates. The remaining three methods produced results that generally fall within these county ranges and are presumably closer to the amounts that might be sustainably tapped in a given area. The analysis used the median volume of remaining three renewable water estimates for each county in making comparisons with demand for that county.

If the water used in a given county is greater than the project's supply estimates, this means *only* that more water is demanded from a county's "home grown" supply than may be available over the long term. This might mean that water users are depleting a county's waters (i.e., pumping reserves faster than they can be replaced) or drawing upon reserves that are imported from another county. It might also mean that ground water appropriations are, or will be, inducing recharge from surface waters at a greater pace than usual, potentially drawing down base stream flows, lake levels or wetlands.

Another point to note is that previous work has shown that analysis on an annual basis underestimates the frequency of demand outstripping supply. The uncertainties and assumptions of the assessment notwithstanding, if a county in this position had to rely only on water within its boundaries, it might be well advised to manage its water carefully.

Figure 1.

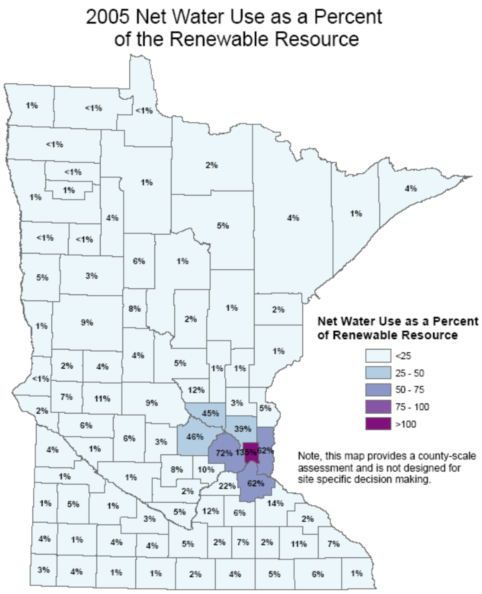

Figure 2

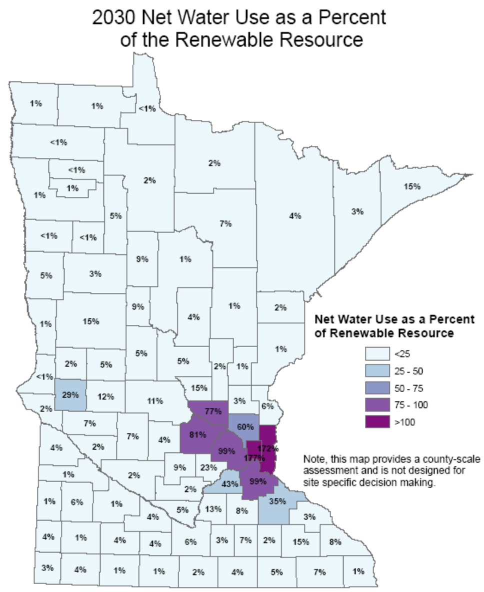

Figure 1 reports the 2005 results and is entitled "net" because it reports the results after accounting for imported waters and non-consumptive uses. In 2005, only one county – Ramsey – appeared to use more than 100 percent of its homegrown renewable water resource – reporting 135 percent. This may suggest that Ramsey, a small county with a large population base, draws on the water resources of adjoining counties.

In the seven-county metropolitan area, the net water use of renewable resources ranged from 10 percent in Carver County to 135 percent in Ramsey County. In Greater Minnesota, the range was from less than 1 percent in seven counties to 46 percent in Wright County. Three counties were between 50 and 75 percent and another three were between 25 and 50 percent. The same counties showing higher percents of use in 2005 also showed higher percents in 2030.

Figure 2 reports the 2030 results. In 2030, Ramsey County continued to be above 100 percent, with Washington County's growth also pushing its estimated use above renewable resource levels (177 and 172 percent, respectively). Dakota and Hennepin counties were estimated at 99 percent.

In the seven-county metropolitan area, the 2030 projections, as a percent of renewable resources, ranged from 23 percent in Carver County to 177 percent in Ramsey County, while in Greater Minnesota the range was from less than 1 percent in six counties to 81 percent in Wright County. Four counties ranged between 75 and 100 percent, one county between 50 and 75 percent, and another four between 25 and 50 percent.

Because the assessment investigated supply and demand at a county scale, it is important to consider how to interpret and use the results. The project's principal conclusion is that the results cannot be used for actual site-specific decisions. Nevertheless, the results have helped stimulate important conversations. How can a county possibly be using more water today than the system might tolerate long term? How can several other counties already be using a high percentage of their renewable supplies? On the other hand, how can so many counties in which water seems in short supply show up as comfortably within their capacity?

The answers to these questions are complicated, and highlight many issues that still remain in pursuit of a reliable water sustainability indicator. For example, while the assessment and conclusions do not account for surface water entering a county – or even for ground water that may, in effect, be drawn from a neighboring county – they signal an early caution for those concerned about the ability of water resources to sustain development and support ecosystems.

This uncertainty makes prudent the call for careful and cautious allocation of water from the state's confined aquifers. It makes better understanding of where ground water can be found, and how much can be sustainably and safely consumed, an obvious state priority. It also makes better knowledge of the connection between ground water and surface water important for a number of reasons. These include:

- The contribution ground water makes to surface flows – low flows are, in fact, ground water discharges
- How these contributions may be put at risk by ground water use
- The need to consider combined use of surface and ground waters
- The influence ground water may have on the quality of surface waters, and vice versa

As the Minnesota DNR concluded in a 2005 assessment, "working toward sustainability requires us to monitor and analyze more; to address demands collectively; to use water efficiently; and above all to recognize water's value to our neighborhoods, communities, economy, environment, and continued existence on this planet."

Water Sustainability 2008: The Policy Implications

Minnesota law governing the allocation of water resources is comprehensive and thorough. And in practice, the state applies this body of law effectively in response to applications for water use. However, with the 2007 study, among other efforts, the state has only recently begun to consider whether its water supplies are sufficient to meet the long range seasonal requirements of communities, businesses and ecosystems.

To understand the policy implications of the picture presented by its 2007 report, the Environmental Quality Board resolved at its February 2008 meeting to:

1. *Consider how the state might establish (and/or has established) protective and achievable standards to quantify and address the environmental impacts of proposed water uses*
2. *Take a broad look at water availability and appropriations, including but not limited to issues specific to the ethanol industry, finding a way to put consideration of proposed water uses into a broader framework and perspective*
3. *Summarize need and options for collecting additional data important to comprehensive and timely analysis of proposed water uses*

In addressing these charges, the Environmental Quality Board convened over a dozen meetings involving over four dozen managers and technical experts. Participants discussed the issues and identified Minnesota's needs both today and long term, and reached a set of 14 inter-related conclusions and 15 recommendations for action or further consideration. These are summarized below under each of the above charges.

Charge One – Achieving protective standards

While Minnesota employs commendable water management methods in response to permit requests, it could strengthen these efforts by accelerating the strategic acquisition of hydrologic, hydrogeologic and ecological information and improving the tools it uses to apply this information.

The state should:

1. Establish a long-term strategy for generating and managing the information needed to integrate water sustainability assessment results into regulatory programs on a statewide basis. This strategy must address the legal, financial and security issues that influence public access to this information. Strategy elements also should include:

- Allocation plans by aquifer and watershed
- Continuing efforts to build, maintain and use existing models, such as the Metropolitan Council ground water model
- New efforts to assess regional water availability and sustainability using a variety of methods, models and mapping

2. Maintain and enhance the ambient water quality monitoring network and other monitoring activities to enable more systematic water quality assessment when evaluating water availability and the potential significance for water use, especially for potable water supply.

3. Refine the aquifer protection threshold concept to work in more complicated situations both to protect aquifers and to provide an indication of water sustainability. This should include the development of thresholds for regional systems.

4. Identify defensible criteria for assessing the critical water levels or flow conditions required to support ecosystems. The criteria should consider ecosystem-sensitive practices that protect critical components of the hydrograph, including:

- A habitat- and population-based minimum flow
- A high flow protection standard that protects critical habitat-forming and silt-flushing high flows
- Protections for downstream needs
- Protections for the natural variability of flows over time (hydrograph shape)

Charge Two – Planning for water sustainability

Minnesota is characterized by dramatic spatial and temporal variability of its water resources; the demands people place and will place on these resources; the extent to and manner in which ecosystems depend on water; the interplay between water availability, water quality and land use; and chronic shortages of information, staff and financial resources. Minnesota should consider a number of steps to strengthen planning for water sustainability and increase the likelihood that water will be managed sustainably over the long-term.

The state should:

1. Work with local governments, regional development staff and others to plan and manage water systematically at an area-wide scale through designated *water appropriation and use management areas*. It should identify priority areas and priorities for their implementation based upon a system of criteria that includes an assessment of an area's water sustainability limits, the competition for water, water quality concerns, future growth prospects and local interest.

2. Understand how state and local activities and incentives to encourage economic development may affect water availability and sustainability in the areas of interest prior to release of funds or approval of plans.

3. Develop a system of incentives to reward local units of government that incorporate water availability and sustainability considerations into their water and land use plans and decisions.

4. Continue efforts to develop and apply water sustainability models and planning tools, integrating new information and research results, as well as additional social, economic and environmental data. As part of these efforts, the state should establish a water sustainability information system steering committee to consider:

- System users and the questions they need addressed
- Scale and scope implications of user needs
- Available information and database management issues
- Design for easy and continuous information updates
- A long term business management plan

5. Develop Minnesota's resource system planning capability, including efforts to define water sustainability limits; link water management to land use decision-making; seek opportunities for conjunctive surface and ground water management; and consider the use of economic mechanisms in water management.

6. Continue to track and assess the implications of population, economic, climate and land use changes on management practice, sustainability planning and priority setting.

7. Examine opportunities to employ economic policies and incentives in support of sustainable water management. These should include:

- Requiring water users to conduct more aquifer and watershed monitoring and to help support information systems development and analysis
- Providing additional incentives for water conservation and wise management
- Encouraging consideration of alternative water supplies, gray water reuse, conjunctive use and other water saving measures when siting high water uses or designing infrastructure
- Developing methods for making credible estimates of the value of ecosystem services, as well as the economic implications for communities and individuals of water use policies and prospects

Charge Three – Defining water information needs

Although Minnesota's water management program has a strong data collection component, more information is needed to answer today's critical questions. The state does not collect or process sufficient water-related information to know with certainty overall whether it is managing water resources sustainably. State and local governments should work together to address this by: a) developing the information necessary to plan for sustainable resource use, and b) better linking their resource planning efforts. This would help them understand resource limits and vulnerabilities, and plan accordingly.

The state should:

1. Establish a long-term strategy for generating and managing the information needed to integrate water sustainability assessment results into regulatory programs on a statewide basis (see recommendation one under charge one).

2. Develop a water sustainability data acquisition plan for inclusion in the 2010 state water plan that: a) sets priorities and standards for the next decade of data collection and funding; b) identifies the lead agency for collecting specific data types; c) provides for a routine appraisal of data collection efforts; and d) sets timelines for lead agencies to collect high priority data.

3. Define a strategy for integrating the information needed to assess water sustainability at statewide, regional or county scales. The strategy should: a) define the format for electronic data transfer between state and local agencies; b) set standards for documenting the source and quality of datasets, transferring data to be used in a state geographic information system, and uniquely identifying features such as wells, springs, lakes and rivers to which data are related; c) identify how the state will provide technical support to local governments accessing state data and providing data that is generated through state funding back to the state; and d) provide adequate funding for collecting and maintaining the data and developing applications for sharing the data.

4. Adopt a hydrologic cycle systems approach to monitoring water resources, since an understanding of each aspect of the hydrologic cycle is necessary to managing water sustainably. Priority needs include:

Surface water

- Improved stream gauging coverage to provide better low flow statistics and enhance understanding of ecosystems and ground water
- Collection of water chemistry

Ground and surface water interaction

- Linked monitoring of ground water levels and surface waters
- Compilation of water level and pumping histories for priority aquifers and linkage to relevant surface water resources
- Identification of aquifer and surface water body connections
- Inventory of springs

Ground water

- Statewide coverage of county geologic atlases with improved hydrologic property data
- Accurate information on well locations and real-time monitoring in select locations
- Work to remove backlog of water well logs that have not been scanned or whose location has not been verified and automate verified information
- Collection of water chemistry and age data
- Incorporation of ground water quality and aquifer property information into the County Well Index

Climate

- Temperature
- Precipitation
- Evapotranspiration
- Snow pack

5. Establish technical and stakeholder advisory committees to help Minnesota develop and adopt social, economic and environmental indicators to assess management choices and measure progress toward water sustainability.

In summary, information is the key ingredient in building an indicator of water sustainability to inform the management of Minnesota's water. In one sense, the state's water resources have all been allocated and every use has its purpose, whether for people or the environment. So the manager's task is to understand how much water may be available, the quality of that water, how the water is currently being used, what or who is depending on that source, and what will happen to public interests if a change is made. To complicate the matter, water in the natural environment is anything but constant. In fact, ecosystems depend upon this natural variability for their survival. For people depending on a reliable supply of water or worried about drought or flood flows, variability can be a great concern.

These factors illustrate the challenges involved in constructing a meaningful water sustainability indicator. The indicator must be built upon solid base of information and a proper understanding of the resource. It must aid in answering the questions decision makers and citizens ask. It must be able to indicate whether water of sufficient quality can be reliably tapped in a location or a region and whether the use can be sustained over the long run without harming the natural environment, other users, or the prospects of future generations. The hope is that the Environmental Quality Board's conclusions and recommendations will set a course for collecting and applying the information essential to understanding whether Minnesota's management of water resources is sustainable.

Michigan Innovations in Water Management

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Introduction

The availability and use of freshwater is a growing concern in the United States and around the globe. Despite apparently abundant water resources, several conflicts over water use have emerged in the Great Lakes region and the State of Michigan. These conflicts resulted in legislation that both addresses water withdrawal from the Great Lakes basin and requires the state of Michigan to begin a process to address the sustainability of water resources. The former resulted in Michigan's support of the St. Lawrence River—Great Lakes Water Resources Compact, whereas the latter resulted in the formation of a ground water conservation advisory council (newly renamed the Water Resources Conservation Advisory Council). This case study addresses the development of indicators of sustainable use of water, the creation of a Water Withdrawal Assessment Process to determine if a proposed withdrawal will create an Adverse Resource Impact in Michigan, and how the lessons learned in Michigan may be applied to other units of government addressing similar issues.

Michigan and the Great Lakes Compact

Michigan is a state that, overall, has an abundant quantity of fresh water. In addition to bordering four of the five Laurentian Great Lakes (over 5150 km of Great Lakes shoreline), Michigan has more than 35,000 mapped lakes and ponds and over 58,500 km of streams. This surface water is sustained both by precipitation, which averages about 81 cm/yr, and by ground water. In 2000, the pumpage of fresh ground water in Michigan was estimated to be approximately 2,763 x 10^6 L/d, which is about 2.6 percent of the estimated 102 x 10^9 L/d of natural recharge to Michigan's ground water systems. Based on these data, there is an understandable perception that Michigan's ground water is abundant and its uses can be sustainable.

Despite the large volume of fresh water in Michigan, there are significant concerns over diversion (i.e., the physical removal and transport of water out of the basin). There is a strong public view that the water (both surface water and ground water) in the Great Lakes basin should not be diverted outside the basin. On December 13, 2005, the governors and premiers of the Great Lakes states and provinces signed the Annex 2001 Implementing Agreements ("Annex 2001"), which included a ban on new diversions of water outside the Great Lakes Basin (with limited exceptions). The Agreements consisted of two elements: the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement, which is a good-faith agreement among the eight Great Lakes states, Ontario, and Quebec; and the Great Lakes-St. Lawrence River Basin Water Resources Compact, which is a binding agreement among just the states.

Among the principles on which a new decision-making standard would be based, Annex 2001 includes two integral to understanding the work of Michigan's Groundwater Conservation Advisory Council:

- No significant adverse individual or cumulative impacts on the quantity and quality of the waters and water-dependent natural resources of the Great Lakes Basin
- Compliance with applicable state, provincial, federal, and international laws and treaties
  Annex 2001 also includes the following commitments:

- Establishing programs to manage and regulate new or increased withdrawals
- Implementing effective mechanisms for decision making and dispute resolution
- Developing a mechanism by which individual and cumulative impacts of water withdrawals can be assessed
- Improving the sources and applications of scientific information regarding the waters of the Great Lakes Basin and the impacts of the withdrawals from various locations and water sources on the ecosystems

Michigan Groundwater Conservation Advisory Council (Phase I)

Relative to surface water, less attention has been paid to the withdrawal of ground water in the Great Lakes Basin, despite the fact that ground water supplies up to 67 percent of the water in tributaries feeding the Great Lakes (Holtschlag & Nicholas, 1998). This oversight is perhaps not surprising given the volume of surface water in the region, but it does reflect a lack of understanding of system hydrology. Because surface water and ground water are one connected hydrologic system (Winter *et al.*, 1998), ground water withdrawal can strongly influence stream flows and alter temperature regimes for cold water and cool water streams in the basin (Grannemann *et al.,* 2000; Baker *et al.;* 2003, Wehrly *et al.*, 2006). This has implications for both water quantity and quality; ground water withdrawals can result in reduced flows to streams and alter wetland hydrology, potentially impacting biotic resources and ecological processes (Poff *et al.*, 1997; Richter *et al.*, 2003; Cott *et al.*, 2008). Alternatively, ground water quality can be affected if withdrawals induce water of poorer quality into an aquifer (Grannemann *et al.*, 2000; Polizzotto *et al.*, 2008).

The combination of an apparently abundant overall supply of ground water and the absence of regulatory control of this resource in Michigan, as well as regional involvement in development of the Great Lakes Compact, catalyzed the Michigan legislature to pass legislation in 2003. Public Act 148 mandated the formation of the Groundwater Conservation Advisory Council (hereafter, the "Council"), and explicitly denoted that its membership would consist of 10 voting members and three non-voting (state agency) members. Council members were selected and appointed to provide a broad representation of perspectives with respect to the uses and social values of water in Michigan.

The Council was charged to do the following: 1) study sustainability of the state's ground water use and whether the state should provide additional oversight of ground water withdrawals; 2) monitor Annex 2001 implementation efforts and make recommendations on Michigan's statutory conformance with Annex 2001, including a) whether ground water withdrawals should be subject to best management practices or certification requirements and b) whether ground water withdrawals impact water-dependent natural features; and 3) study the implementation of and the results from the ground water dispute resolution program. Concurrent with the work of the Council, a ground water inventory and mapping project was initiated, as mandated by Public Act 148, section 32802. A multi-agency team comprised of scientists from Michigan Department of Environmental Quality, United States Geological Survey, and Michigan State University finished this project in August 2005; the results from this project are available on-line (http://gwmap.rsgis.msu.edu/).

Reauthorization of the Council (Phase II)

In February 2006, the Michigan legislature enacted legislation, which for the first time established regulation of water withdrawals in the state, and consistent with the language of the Great Lakes Compact, explicitly noted that science should be used as the basis for decision making. The legislation reauthorized Council and required it to address three major tasks. The first was to develop criteria and indicators to evaluate the sustainability of the state's ground water use. The importance of sustainable ground water use was implicitly recognized as part of the Council's final report (GWCAC, 2006), but the report did not include specific recommendations on how sustainable use could be evaluated. The second major task was to design and make recommendations regarding a water withdrawal assessment tool; the purpose of the tool was to assist in determining whether a withdrawal would create an adverse resource impact. The final major task was to study and make recommendations as to whether the state should consider, as part of its ground water conservation programs, proposals to mitigate adverse impacts to the Waters of the State or to the Water-dependent Natural Resources of the State that may result from ground water withdrawals.

Table 1: Recommended ground water sustainability indicators and their associated measurements and criteria for the environmental, economic, and social sectors

Indicator	Measurement	Criteria
Environmental Sector		
1. Ground water contribution to stream baseflow	1-1. Change in ground water contribution over time	1-1. Adequate ground water discharge to maintain natural flow and temperatu regimes
2. Ground water withdrawals	2-1. Volume of water use by secto	2-1. Efficient use to maintain adequate supply for public and private needs
3. Land use/land cover	3-1. % natural land use/land cover 3-2. % impervious surface	3-1. Increase 3-2. Decrease below reference impairment thresholds
4. Ground water contamination	4-1. Number of at-risk sites	4-1. Decrease
5. Ground water-dependent natu communities	*Not developed*	*Not developed*
Economic Sector		
6. Cost of ground water by releva economic sector	*Not developed*	*Not developed*
7. Ground water Dependent Commerce	7-1. Product-revenue per unit grou water per sector 7-2. Efficiency of ground water us per sector	7-1. Increase 7-2. Increase
8. Water usage from alternative sources	8-1. Gallons of water recycled 8-2. Gallons of water used from collection of stormwater	8-1. Increase 8-2. Increase
Social Sector		
9. Public education	9-1. Public knowledge of ground water resources 9-2. Water resource education	9-1. Increase 9-2. Increase

	9-3. Local government training	9-3. Increase
10. Conservation	10-1. Public water systems using ground water	10-1. Efficient use to maintain adequate supply for public and private need
	10-2. Water utilization by sector	10-2. Unspecified
11. Restricted ground water acce	11-1. Use restrictions due to contamination	11-1. Decrease
	11-2. Adverse resource impacts (ARIs)	11-2. Decrease
	11-3. Water Use conflicts	11-3. Decrease

Criteria and indicators for sustainable use of ground water. A day long workshop was held in March 2007 that brought together recognized experts in the sectors of environmental science, economic development, and social equity. A summary report is available at: http://www.michigan.gov/documents/dnr/GW_Sustainability_Workshop_report5_ads_196985_7.pdf. The workshop identified a short (3-5) working list of indicators and criteria for each sector. Criteria and indicators can be useful tools to evaluate and measure the sustainability of natural resources (Kranz *et al.*, 2004; Steinman *et al.*, 2004). Indicators were defined as measures that present relevant information on trends in a readily understandable way. Good indicators should adequately represent the societal concern, be measurable, consistent, based on available or obtainable information, and comparable among various geographic regions. Based on their expertise, workshop participants were divided into environmental, social, and economic work groups, and instructed to identify indicators they believed most appropriate, irrespective of whether or not data were currently available.

Eleven indicators were identified (see table 1). Five environmental indicators were developed that focused on both water quantity and quality. An indicator addressing the impacts of water withdrawal on ground water-dependent biota was not developed. Although workshop participants agreed that this indicator is very important, there were concerns that withdrawal-related impacts on biota could not be clearly or empirically associated with a change in ground water resources, given the state of the science. Consensus was reached on three general economic indicators (table 1), but there was considerable debate within this group. Areas not originally identified by the economic breakout group, but specified later in the group discussion, included the tourist economy reliant upon Michigan's renowned ground water-fed rivers and lakes and the sustainable use of Michigan's abundant ground water resources as a focal point in the vision for Michigan's future economic health. In addition, three social sector indicators were identified (see table 2) that focused on public education, conservation, and restricted ground water access.

The workshop report includes six recommendations (GWCAC, 2007):

- Adopt the set of sustainability indicators described in the workshop report in conjunction with an implementation program to determine the current status of these indicators.
- Create/appoint a ground water sustainability indicators working group to refine the indicators and measures identified in the workshop report and to consider additional indicators not identified in the report.
- Require the working group to meet annually to review the indicators, assess data trends, and modify or add indicators, as needed, based on sound science, research and knowledge.

- Refine the criteria for ground water sustainability indicators, where appropriate.
- Aggregate the key indicators from the environmental, social, economic sectors into a set of comparative metrics to determine the overall status of ground water sustainability.
- Collect, generate, and analyze relevant data to assist the evaluation and effective management of state ground water resources for use by future generations.

Water withdrawal assessment tool: The purpose of the water withdrawal assessment tool is to assist a large quantity user (defined as greater than 100,000 gal/d in any 30-day period), or the state, in determining if a withdrawal is likely to cause an Adverse Resource Impact. In this case, the ARI is characterized in terms of an ecological functional impairment and defined as whether or not a water withdrawal impairs the ability of a surface water body to support "characteristic fish populations" (see below for definition). Thus, characteristic fish populations were used as a biological proxy for overall stream functional integrity.

The Council developed a water withdrawal assessment *process*, with two levels: 1) a screening tool, that is designed to allow those proposed withdrawals that are highly certain not to cause an ARI; and 2) for those withdrawals not initially allowed, the applicant may either change the characteristics (e.g., size, location, or depth) of the proposed withdrawal in the hope this will result in a different decision or they may choose to pursue the withdrawal and request the MDEQ to undertake a site-specific review. The applicant may provide site-specific measurements to assist with this review, but it is anticipated that in most cases the MDEQ will use readily available information to conduct the site-specific review.

The water withdrawal assessment tool includes three models that are linked through a GIS to associate information about streamflow, ground water withdrawal, and extant fish communities with specific stream segments across Michigan (see figure 1). In aggregate, these linked models help determine the impact potential of the proposed withdrawal on fish populations.

The streamflow model is a regression model that describes how much flow is in Michigan streams, and is based on data from 147 gages in Michigan or adjacent states (Hamilton *et al.*, 2008). An index flow was calculated for each gage; index flow is defined as the median flow for the summer month with lowest flow at a site. Summer months (usually August or September) were used in this analysis because this is when the lowest flows and warmest temperatures result in the greatest stress to fish.

The withdrawal model describes how much a ground water withdrawal will reduce streamflow in nearby streams. This model takes into account the amount and continuity of withdrawal, plus depth of well, distance of well from stream and aquifer properties (Reeves *et al.*, 2009). The water withdrawal assessment tool accounts for direct surface water withdrawal by subtracting it from the amount of available water.

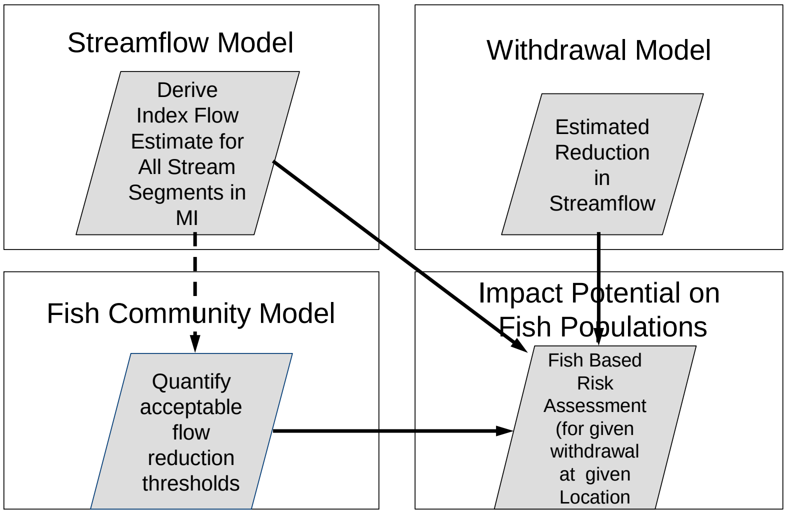

Figure 1. Schematic showing the 3 linked models (streamflow, water withdrawal, and fish community) that together determine potential impacts to fish populations in Michigan streams. See text for details of each model and how they interface.

The fish community model is a statistical model that describes how reduced streamflow will affect characteristic fish populations. This model takes advantage of Michigan Department of Natural Resource's long-term dataset of fish abundance at about 1700 stream locations in Michigan. It relates fish abundance to 11 river classes in Michigan based on temperature type (cold, cold-transitional, cool, and warm; Lyons *et al.,* in press) and size (large rivers, small rivers, and streams). This model describes, for each of the 11 stream classes, the change in characteristic fish populations caused by reducing streamflow (see figure 2).

Based on available data from the MDNR, two curves were generated for each of the 11 stream classes in Michigan; these curves show how fish population responds as flow is incrementally reduced (see figure 3). Curve A shows the response of *thriving* species (i.e., those fish whose needs are best-matched to the temperature and flows of the given stream class). Curve B indicates the impact on abundance of *characteristic* species (i.e., those fish whose needs are still matched to the temperature and flows of the given stream class, but not as well-matched as *thriving* species). More details on the explicit definitions of thriving and characteristic fish species can be found in Zorn *et al.* (2008).

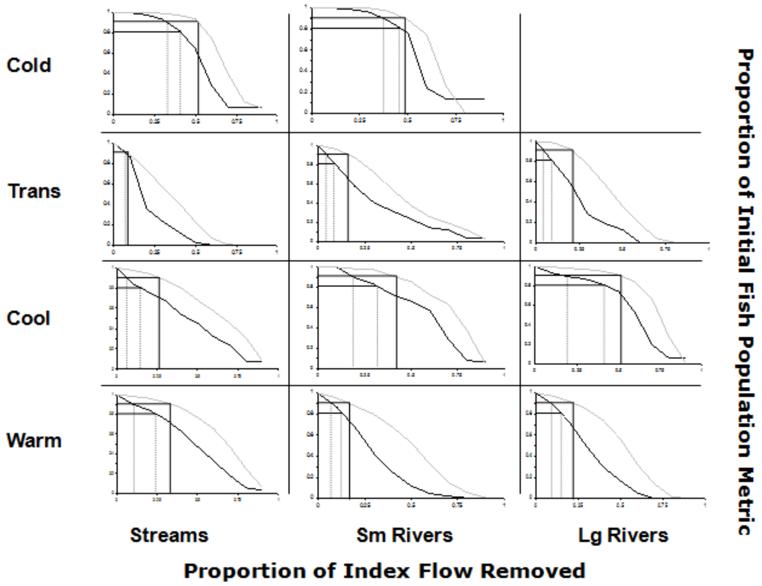

Figure 2. The eleven stream types found in Michigan, showing the unique Impact Assessment Model developed for each type. Note the fairly strong patterns seen across the size categories for each temperature category. Cold Trans. = Cold Transitional.

Both the *thriving* and *characteristic* fish curves show a decline as flow is removed, although the thriving species clearly decline more quickly (see figure 3). As flow continues to decline with continued extraction, tolerant species will become dominant, and then finally there will be severe alteration of ecological structure and function. The points at which these changes take place vary depending on the stream class. For example, fish associated with cold water streams can withstand a significant amount of water withdrawal, as in many areas of Michigan abundant ground water inflow provides a buffering capacity to withdrawal (Zorn *et al.*, 2008). In contrast, fish associated with cold/transitional rivers and streams, which are very near the thermal tolerance of thriving species, are far more sensitive to water withdrawals.

The Council recognized that the determination of ARI might be improved with more scientific information, given broad variability of streams within each stream classification, but also realized that the determination of ARI thresholds is based on societal values, as well as science. To that end, it was suggested to use both 10 percent and 20 percent reductions on the two fish response curves as the starting point for setting thresholds for ecological risk. Horizontal lines were extended from the y-axis, at the 90 percent (i.e., 10 percent reduction) and 80 percent (i.e., 20 percent reduction) values, to the points where they intersected the fish response curves (see figure 4). At those two points, vertical lines were extended down to the x-axis, which indicated the proportional flow removals associated with each threshold risk. This process ensured that ecological risks were kept relatively low and stayed clear of the portions of the curves that corresponded to notable replacements of sensitive species.

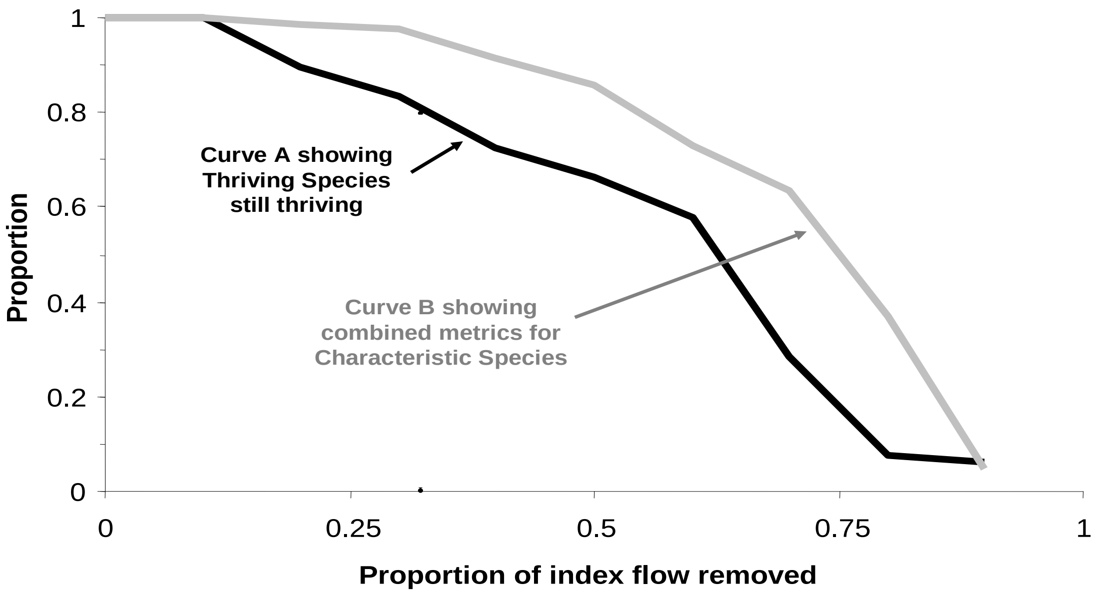

Figure 3. The two curves showing different aspects of the functional responses of fish populations to increasing water withdrawals from Michigan streams. Curve A refers to *thriving* fish species; curve B refers to *characteristic* fish species.

The Council's approach resulted in three vertical lines and four corresponding zones (A-D): the far left vertical line (demarcating zones A and B) showed the theoretical edge of minor impact, whereas the far right vertical line showed the theoretical start of an ARI (see figure 4). Hence, Zone A represents minimal measurable impact on fish populations, but as more flow is removed, there is a gradient of increasing risk to the point where notable replacement of fish species occurs, thereby constituting an ARI (figure 4).

The Council recognized that applying the water withdrawal assessment tool in the natural world would not be without difficulty (cf. Steinman et al. submitted). Effective water resources management involves a number of critical elements: 1) use of science to help frame management decisions; 2) broad stakeholder participation to find social balance points and to encourage public buy-in and eventual implementation; 3) development of a process by which the science can be applied effectively and transparently; and 4) establishment of structures or processes that allow for a continued evaluation or adaptation of the model and science over time.

The Council developed a decision-making process that addressed both the science and enabling legislation behind the Council (see figure 5). According to 2006 Public Act 33, a person considering a new or increased large quantity withdrawal is not allowed to cause an ARI. A proposed user may either start the application process on-line by using the screening tool or they may work directly with MDEQ staff to conduct a site-specific analysis (figure 5). The screening tool calculates the amount of flow reduction for the appropriate stream segment and makes one of two determinations for the proposed withdrawal: 1) is not likely to cause an ARI and is authorized; or 2) there is too much uncertainty in the outcome to determine whether or not the withdrawal would be likely to cause an ARI, and therefore the withdrawal may not proceed without a site-specific review.

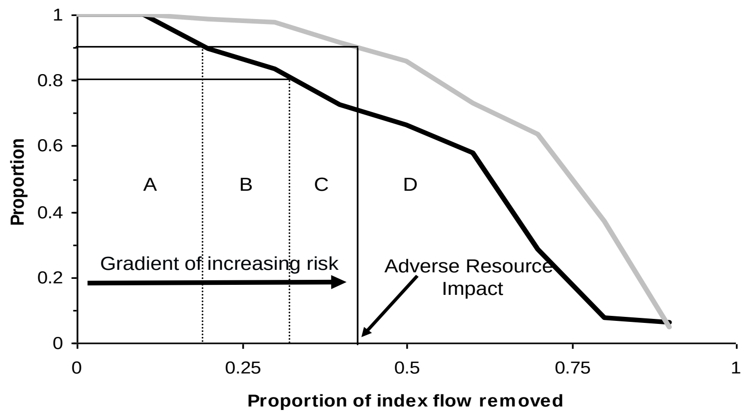

Figure 4. Hypothetical example showing the four policy zones (A-D), demarcated by increasing levels of index flow removal. Curves for thriving (dark line) and characteristic (light line) fish species correspond to figure 3.

For a Zone A determination (ARI not likely; see figures 4 and 5), the user would simply register the proposed withdrawal with MDEQ and receive authorization to proceed. For Zones C and D determination (ARI possible; figures 4 and 5), the applicant can modify the proposal and try the screening tool again or they can request the MDEQ to conduct a site-specific analysis of the withdrawal. Retrying the screening tool may include reconfiguring the withdrawal (e.g., from a different depth or location). A site-specific analysis will have less uncertainty associated with the withdrawal estimate than the screening tool. As of July 9, 2009, use of the screening tool is required by individuals proposing a large quantity withdrawal from the waters of Michigan.
As new users establish themselves in a watershed, the cumulative impact from all users may bring the watershed to the brink of an ARI. Hence, collective actions may be needed, involving both the proposed new user and existing users; this approach is consistent with riparian rights (reasonable-use doctrine). It is critical that water use programs not favor one user over another based on the temporal sequence of authorization of withdrawals.

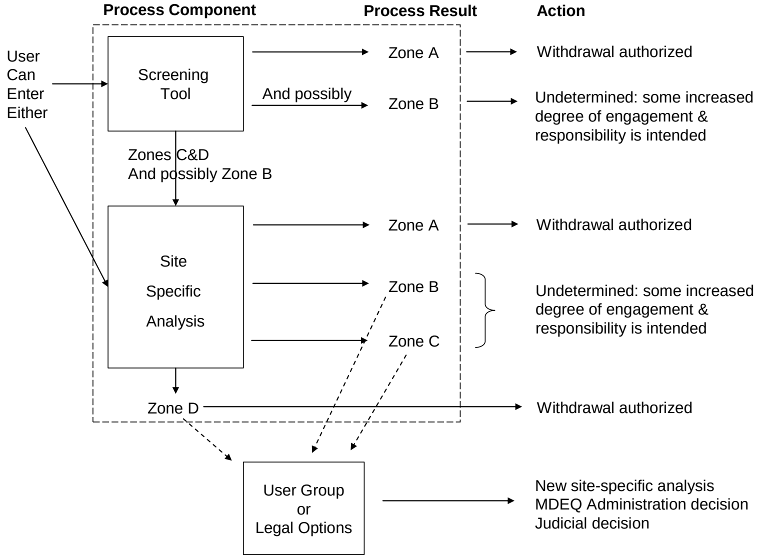

Figure 5. Decision making system associated with the water withdrawal assessment process. Zones listed under Process Result correspond to figure 4.

Michigan Water Resources Conservation Advisory Council

The Council was dissolved by Executive Order in 2007 and reformed as the Michigan Water Resources Conservation Advisory Council through Public Act 189 (2008) to serve as a representative, collaborative forum for study and evaluation of the state's water management programs. The Council will periodically provide recommendations regarding current and future state programs and legislation to state leadership. Immediate Council tasks of the include: 1) evaluation of the Water Withdrawal Assessment Tool; 2) evaluation of the overall Water Withdrawal Assessment Process; 3) recommendations for inclusion of Great Lakes, inland lakes, and other waters in the process; 4) examining any potential legal conflicts within the process; and 5) recommendations for a new state water conservation and efficiency program.

Acknowledgements

Michigan's Groundwater Conservation Advisory Council contributed their time, energy, and knowledge to the developments described in this case study. Special appreciation is extended to Jim Nicholas (USGS), Paul Seelbach (MDNR), Jon Allan (Consumers Energy), and Frank Ruswick (MDEQ). In addition, the Michigan Departments of Environmental Quality and Natural Resources provided funding to develop the water withdrawal assessment tool, the Michigan Environmental Council and Great Lakes Fishery Trust provided funding to support the Sustainability Workshop, and input by Mary Ogdahl (AWRI), Dave Hamilton (MDEQ), Howard Reeves (USGS), and Randy Hunt (USGS) on prior summaries is greatly appreciated.

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Chapter 5: *Highlights of National Initiatives on Sustainable Water Management*

Recent Heinz Center Work on Water Indicators

In October 2008, the Heinz Center published *State of the Nation's Ecosystems 2008*, a report which includes 108 indicators of the condition and use of U.S. ecosystems, including 55 indicators that relate wholly or partially to water resources (see list below). The report has the same overall reporting framework as the 2002 *State of the Nation's Ecosystems*, but has more data and improved indicators.

Four of the six new indicators in the 2008 report are related to water resources. To capture changes in water across all ecosystems, the report includes a new core national indicator, *change in stream flows*. This indicator measures changes in high flows, low flows and the variability of flows compared to a baseline in the 1940s and 1950s. The indicator also compares streams to reference streams (in the USGS Hydro Climatic Data Network) that have been relatively unaffected by land use change or dams or diversion since monitoring began. To improve reporting on chemical characteristics of fresh waters, the report now includes the indicator, *freshwater acidity*. This indicator measures the amount of nitrogen and sulfate deposited from the atmosphere to watersheds each year as well as the percentage of stream miles and area of lakes and ponds with different levels of acid-neutralizing capacity (data are currently available only for streams). The report also includes two new indicators that focus on pattern of water resources in the landscape. *In-stream connectivity* reports on the proportion of watershed with different distances from their outlet (pour point) to the nearest dam or diversion. Some data for this indicator are available, but require substantial processing to merge stream-reach data with dam locations, and diversion data are a major gap. The indicator, *pattern in coastal areas*, is intended to focus on the intermingling of natural and non-natural features in the land and seascape, but requires additional development.

Many of the existing water resources indicators have been improved since the 2002 report. For example, the indicator, *established non-native freshwater species*, has been refined so that it only includes freshwater fish that are truly *established* in the watershed, not those that are just introduced but for which populations have not gained a foothold (finhold?). Thanks to data from EPA's Wadeable Streams Assessment, the *stream habitat quality* indicator is partially populated with data for the first time (data for lakes and larger rivers are still unavailable). The *at-risk native freshwater species* indicator includes new maps (showing risk by state) and a new metric that provides information on the percentage of at-risk species whose populations are declining, stable or increasing. The coastal indicator, *areas with depleted oxygen,* includes data for the first time, from Chesapeake Bay and the Gulf of Mexico; data on other estuaries would help round out this important picture. The report's chemical contamination indicators, which report on stream water, ground water, sediments and fish tissues, have all been updated to incorporate the most current detection limits and benchmarks, including the use of USGS's Health Based Screening Levels, which complement EPA regulatory limits. Indicators on *nitrate* and *phosphorus* concentrations in water now include maps which allow readers to locate sampling sites with high and low concentrations. Additional refinements are noted in the technical documentation of the report.

The report is available for sale through Island Press; federal agencies and partners have access to a web version of the report, and all data are available through the Heinz Center website (www.heinzcenter.org/ecosystems)

Water-Related Indicators: The State of the Nation's Ecosystems 2008

Core National Indicators

- Ecosystem extent (coastal wetlands, ponds, freshwater wetlands)
- Movement of nitrogen (major rivers)
- Carbon storage (wetlands, sediments)
- Chemical contamination (water, sediment, fish)
- Change in stream flows
- Production of food and fiber and water withdrawals
- Outdoor recreation

Fresh Waters

- Extent of freshwater ecosystems
- Altered freshwater ecosystems
- In-stream connectivity
- Phosphorus in lakes, reservoirs and large rivers
- Freshwater acidity
- Water clarity
- Stream habitat quality
- At-risk native freshwater species
- Established non-native freshwater species
- Animal deaths and deformities
- Status of freshwater animal communities
- At-risk freshwater plant communities
- Water withdrawals
- Ground water levels
- Waterborne human disease outbreaks
- Freshwater recreational activities

Coastal Waters

- Coastal living habitats
- Shoreline types
- Pattern in coastal areas
- Areas with depleted oxygen
- Contamination in bottom sediments
- Coastal erosion
- Sea surface temperature
- At-risk native marine species
- Established non-native species in major estuaries
- Unusual marine mortalities
- Harmful algal events
- Condition of bottom-dwelling animals
- Chlorophyll concentrations
- Commercial fish and shellfish landings
- Status of commercially important fish stocks
- Selected contaminants in fish and shellfish
- Recreational water quality

Other Ecosystems

- Nitrate in farmland streams and ground water
- Nitrate in forest streams
- Nitrate in grassland and shrubland ground water
- Nitrate in urban and suburban streams
- Phosphorus in farmland streams
- Phosphorus in urban and suburban streams
- Pesticides in farmland streams and ground water
- Streambank vegetation (urban and suburban areas)
- Chemical contamination in urban/suburban streams
- Potential soil erosion (farmlands)
- Stream habitat quality (farmlands)
- Number and duration of dry periods in grassland and shrubland streams
- Depth to shallow ground water (grasslands and shrublands)
- Riparian condition (grasslands and shrublands)
- Status of animal communities in urban and suburban streams

Planning for the Future

As the State of the Nation's Ecosystems 2008 was being published, the Heinz Center also released *Environmental Information: A Road Map to the Future*. This short policy report (available for download at www.heinzcenter.org/ecosystems) recommends Congressional authorization of a set of national environmental indicators, to be selected and overseen by a stakeholder-rich process. The report describes using the process of selecting national indicators to engage in dialogue with states and other key stakeholders at the regional level, both to design the national indicators and identify appropriate and helpful changes to monitoring to make data more comparable and consistent.

The report recommends that funding for monitoring and reporting at federal and state levels be increased, within a more integrated overall system. In broad outlines, these recommendations mirror those made to the executive branch in their formulation of the National Environmental Status and Trends program. This important initiative could have a crucial effect on the future of national indicator reporting and the continued evolution of the nation's valuable environmental monitoring infrastructure.

National Environmental Status and Trends

In June 2008, The Council on Environmental Quality, the Office of Management and Budget, and the Office of Science and Technology Policy announced the creation of a nationwide effort that directs Federal agencies to begin developing a national set of indicators. The program, known as National Environmental Status and Trends, presents scientifically based measures of conditions of our environment that are meant to spur greater collaboration, discussion, and dialogue and promote informed decision making on the sustainable management of the nation's water resources. The NEST project focuses on a set of indicators focusing on water quality and quantity. CEQ Chairman James L. Connaughton said "Our Nation will benefit from a consistent set of indicators for our environment and natural resources….most NEST indicators will be produced from data collected by ongoing federal and state programs. This action plan will improve the quality and uniformity of those data to provide nationally consistent, and more widely accessible, indicators."

Richard Guldin presented an overview of the NEST project at the June 2008 roundtable meeting held at the Top of the Town in Arlington Virginia. Guldin's presentation provided insight into the formation of policies and programs on environmental indicators over the years. The eventual creation of NEST was borne of a multitude of cross-cutting, collaborative efforts across a variety of disciplines and federal agencies that utilized indicators to measure the status of key conditions in our environment.

In 2002, Heinz Center issued its first State of the Nation's Ecosystems report that focused on the use of developing reliable metrics or indicators as a way to measure progress; EPA issued its draft *Report on the Environment* (discussed further below); Forest Service issued the *National Report on Sustainable Forests* in 2003. Around the same time, Ted Heintz, formerly of Interior, headed the CEQ collaboration on indicators with other agencies including EPA, USGS, NOAA, OMB and others in developing a *System of Indicators of the Nation's Environment*. In 2006, the Department of the Interior collaborated with the National Academy of Public Administration to review recent efforts with environmental indicators and to focus on how to navigate institutional collaboration challenges. That effort resulted in the report, *A Green Compass: Institutional Options for Developing a National System of Environmental Indicators*. Among its key findings was the conclusion: “It is clear America needs a comprehensive nationwide system of environmental indicators.” The report also concluded that future efforts should “undertake an intensive pilot to develop crosscutting indicators for an environmental issue that is nationally significant, high profile, multi-agency in scope, and of immediate interest to state and local governments and the private sector.” The report suggested that water quantity may be a prime candidate issue to begin exploring.

All of these reports provided the impetus for the creation of NEST as a nationwide pilot program on environmental indicators. As Guldin indicated in his presentation at the June 2008 SWRR meeting, defining indicators and the framework in which the indicators would be imbedded was difficult but certainly achievable. Further, the creation of a workable system of collaboration and discourse between federal agencies would also prove difficult, but that this collaboration is precisely what is required to progress the development of environmental indicators on a national scale. In short, SWRR remains actively engaged with this emerging sustainability initiative and hope others will participate in this meaningful and necessary dialogue.

USGS National Water Census

The 21st Century brings a new set of water resource challenges. Water shortage and use conflict have become more commonplace in many areas of the United States – even in normal water years – for irrigation of crops, for growing cities and communities, for energy production, and for the environment and species protected under the law. Much has changed since the last overall assessment of water resources for the Nation was published by the Water Resources Council in 1978.

It is time for a comprehensive examination of water availability in the United States using what we have learned during the past 30 years and with up-to-date capabilities. In response to a request from Congress, the USGS released a report in 2002 entitled, Concepts for National Assessment of Water Availability and Use, Circular 1223. The circular outlines a broad framework by which a national assessment could take place and advocates using 21 water resources regions for the study units.

In 2005, USGS embarked on a pilot study of water availability in the Great Lakes Basin. The pilot focuses on understanding the dynamics of the water resources in the basin in terms of the flows and yields of both ground and surface water and demonstrates the importance of water-use data to quantifying water availability.

In 2007, the USGS released its 10-year science strategy in Facing Tomorrow's Challenges -- U.S. Geological Survey Science in the Decade 2007-2017 Circular 1309. One of the seven major strategic directions identified in the circular is “A Water Census if the United States: Quantifying, Forecasting, and Securing Freshwater for America’s Future.” These are the initial steps to implementing a national water census and producing a water availability and use assessment for America.

What needs to be done

In the next decade, the nation will need new appraisal for water availability that links both water quality and quantity, tracks changing flow, use, and storage of water, as well as developing models and predictive tools to guide its decisions. In 2007, the National Science and Technology Council released a report entitled "A Strategy for Federal Science and Technology to Support Water Availability and Quality in the United States." That report stated, "The United States has a strong need for an ongoing census of water that describes the status of our Nation's water resource at any point in time and identifies trends over time." In its simplest terms the philosophy of the initiative is "You can't manage what you don't measure." Knowing our nation's water "assets" and rates of use on an ongoing basis is crucial to wise management. The USGS will release an implementation plan in the fall of 2009, demonstrating how it will put the National Water Census into operation. In this plan, the USGS will:

- Bring existing plans and legislative mandates together in one strategy
- Integrate existing science efforts across the USGS and the Department of the Interior to bring more resources to bear on water availability questions
- Design the plan to answer the questions:
    - Does the Nation have an adequate quantity of water with sufficient quality and timing characteristics to meet both human and ecological needs?
    - Will this water be present to meet both existing and future needs?

The USGS goal is to place technical information and tools into the hands of stakeholders that allow them to evaluate water availability for the questions that they are facing. The responsibility for management of water supplies rests at the state and local government level, but knowledge of the hydrologic system is needed across state lines. Therefore, we need to provide a seamless national database of water availability data across jurisdictional boundaries. The National Water Census will use and build on data and assessments accomplished through state and local initiatives, as well as information produced under programs such as the Cooperative Water Program. The National Water Census will also use the strength of other programs such as:

- The National Water Quality Assessment Program to demonstrate the linkages between water quality and quantity and the degree of water quality impairment that limits water availability
- Regional ground water availability studies to provide critical information that includes recharge, yields, changes in storage, trends in ground water indices, and ground water-surface water interactions
- The National Water Use Information Program to assess water withdrawals across the country
- The National Cooperative Geologic Mapping Program for information on the geohydrologic framework of aquifer systems

The products of the National Water Census will include:

1. A database of hydrologic indicators, addressing:
    - Precipitation
    - Evapotranspiration
    - Water in storage in snowpack, ice fields, and large lakes
    - Ground water level indices

- Rates of ground water recharge
- Changes in ground water storage
- Stream and river run-off characteristics
- Stream and river baseflow characteristics
- Total water withdrawals by source
- Interbasin transfers
- Consumptive uses
- Return flows
- Impaired surface and ground water supplies used for existing demands

2. A program for assessing flow needs for wildlife and habitat which will:

   - Classify the streams across the nation for their hydro-ecological type
   - Systematically examine the ecological affects of hydrologic alteration
   - Develop flow alteration – ecological response relationships for each type of river or stream

3. An application for delivering water availability information at scales relevant to the user

4. A series of studies focused on selected watersheds where there is significant competition over water resources. Here the USGS and stakeholders will work collaboratively to comprehensively assess the technical aspects of water availability.

"The USGS should focus on the scientific integration of water use, water flow, and water quality in order to expand knowledge and generate policy-relevant information about human impacts on both water and ecological resources." [*Estimating Water Use in the United States: A New Paradigm for the National Water-Use Information Program*.]

"The United States has a strong need for an ongoing census of water that describes the status of our Nation's water resource at any point in time and identifies trends over time." [*A Strategy for Federal Science and Technology to Support Water Availability and Quality in the United States.*]

Elements of the Plan

Water use science

Humans have had a profound effect on the hydrologic cycle throughout the post-development era. We change the run-off characteristics of the landscape, we affect how much water evaporates to the atmosphere, and we consume water and transfer it to other watersheds before it is returned to the environment. Understanding man's use of water and how man moves water on the landscape is the science of water use. This strategy will focus significant resources to better understanding and quantifying water use in the nation and to apply statistical rigor to the information that we use.

Water use will be estimated by 1) integrating national, state, and private databases of population, housing, climatological, agricultural, and economic information; 2) developing statistical relations between these data sets and metered withdrawal and delivery data for users across the region; and 3) using these relations to estimate water use (demand) across the region by small geographic areas. Many partners in all levels of government, industry, agriculture, water purveyors, and interest groups have much knowledge to share in this arena and the USGS will develop means to incorporate this information. Read more about water use in the United States.

Hydrologic indicators

Hydrologic indicators represent the basic building blocks of the water cycle. Understanding water availability is based on obtaining information about, and understanding the trends in, these indicators. The USGS will work to systematically produce information on:

- Precipitation
- Evapotranspiration
- Water in storage in snowpack, ice fields, large lakes and reservoirs
- Ground water level indices
- Rates of ground water recharge
- Changes in ground water storage
- Stream and river runoff characteristics
- Stream and river baseflow characteristics
- Total water withdrawals by source
- Interbasin transfers
- Consumptive uses
- Return flows
- Ecological flow characteristics
- Impaired surface and ground water supplies used for existing demands

The delivery of this information must be timely and in a form that can be easily used by resource managers. It will be the goal of the USGS to provide this information at scales defined by the end user. We will strive to provide much of this information in a "point and click" environment, where the user identifies the point in the watershed that they are interested in, has a basin boundary automatically delineated, and then gains access to the relevant hydrologic indicators and trends within that boundary.

Focused studies

Throughout our country, there are areas where competition for water resources has reached a level of national attention and concern. Sometimes the competing interests are multiple human needs – needs for potable water, irrigation, energy, industrial processes or other uses. In other circumstances, the competition is between human needs and aquatic ecosystems needs. The nation needs an assessment of these areas which comprehensively examines all of the hydrologic and biologic aspects of water availability. USGS is proposing a series of studies, focused on selected watersheds, where there is a desire on the part of watershed stakeholders to conduct a comprehensive technical assessment of water availability with the best available tools. The USGS would work collaboratively with watershed stakeholders and the various agencies involved to scope and conduct these studies.

Cooperation with other agencies and stakeholders

There are many opportunities to strengthen our understanding of water availability information through integration of national, regional and state datasets. The USGS will reach out to other federal, state and regional agencies to make those linkages. This is particularly true within agencies involved in environmental regulation, water allocation, water infrastructure, agriculture, energy, climatology and meteorology, as well as entities that maintain databases on commercial and industrial applications. The USGS will also be working over the coming months with stakeholders to further develop this implementation plan. The USGS wants to hear about information useful to the assessment process, the kinds of products most desired by resource management agencies, and what may help increase public understanding of water availability.

Suggested Further Reading

Barlow, Paul M., et al, Concepts for National Assessment of Water Availability and Use, Report to Congress, Circular 1223, U.S. Geological Survey, Reston, Virginia, 2002. See http://water.usgs.gov/wsi/.

National Science and Technology Council, A Strategy for Federal Science and Technology to Support Water Availability and Quality in the United States, Committee on Environment and Natural Resources, Subcommittee on Water Availability and Quality, Washington, DC, September 2007. See http://water.usgs.gov/wsi/.

Water Environment Federation 2008

Formed in 1928, the Water Environment Federation is a not-for-profit technical and educational organization with 35,000 individual members and 81 affiliated Member Associations representing an additional 50,000 water quality professionals throughout the world. WEF and its member associations proudly work to achieve their mission of preserving and enhancing the global water environment.

The roundtable is grateful for the opportunity to collaborate with the federation and welcomed its Managing Director of Technical and Educational Services, Mr. Matthew Ries, at the June 2008 SWRR meeting. Mr. Ries outlined the federation's mission and its ever-growing presence in the field of water resources.

Major federation initiatives of 2008 included a collaborative focus on infrastructure, microconstituents, service to utilities, collaboration with the water community, and sustainability. The federation continues to be involved in the major sustainability initiatives nationwide including their role in the National Summits for a Sustainable America, their participation in the Effective Utility Management Project, formation of a Sustainability Community of Practice, and first Sustainability Conference: Green Practices in the Water Environment. For more information, please visit www.wef.org.

EPA Report on Environment, Water Chapter

EPA's mission to protect human health and the environment involves studying trends in the condition of our nation's air, water, and land, as well as trends in ecological systems and human health. In 2001, EPA embarked on an initiative to incorporate the use of indicators for national environmental and health conditions and other important trends. The following excerpt is a description from the EPA website on this initiative. For more information, please visit http://www.epa.gov/roe/

EPA initially presented these indicators in its Draft Report on the Environment Technical Document), and its publicly oriented companion document the Draft Report on the Environment), both released in 2003. Since 2003, EPA has revised, updated, and refined the 2003 report in response to scientific developments, as well as feedback from its Scientific Advisory Board and stakeholders. As a result, the latest edition - featured throughout this site - provides both an update and an improvement over the 2003 draft editions.

EPA anticipates that the indicators comprising the main content of the report will be updated with new data points annually on the web if the data are available. Depending on availability, new indicators may also be added to the report's website. Full paper versions of the report and technical appendix are planned for release every four years, with the next release scheduled for 2012.

In the water chapter of report, EPA seeks to assess national trends in the extent and condition of water, stressors that influence water, and associated exposures and effects among humans and ecological systems. The indicators in this chapter address seven fundamental questions about the state of the nation's waters:

- What are the trends in the extent and condition of fresh surface waters and their effects on human health and the environment? This question focuses on the nation's rivers, streams, lakes, ponds, and reservoirs.
- What are the trends in the extent and condition of ground water and their effects on human health and the environment? This question addresses subsurface water that occurs beneath the water table in fully saturated soils and geological formations.
- What are the trends in the extent and condition of wetlands and their effects on human health and the environment? Wetlands—including swamps, bogs, marshes, and similar areas—are areas inundated or saturated by surface or ground water often and long enough to support a prevalence of vegetation typically adapted for life in saturated soil conditions.
- What are the trends in the extent and condition of coastal waters and their effects on human health and the environment? Indicators in this report present data for waters that are generally within 3 miles of the coastline (except the Hypoxia in Gulf of Mexico and Long Island Sound indicator).
- What are the trends in the quality of drinking water and their effects on human health? People drink tap water, which comes from both public and private sources, and bottled water. Sources of drinking water can include both surface water (rivers, lakes, and reservoirs) and ground water.
- What are the trends in the condition of recreational waters and their effects on human health and the environment? This question addresses water used for a wide variety of purposes, such as swimming, fishing, and boating.
- What are the trends in the condition of consumable fish and shellfish and their effects on human health? This question focuses on the suitability of fish and shellfish for human consumption."

Appendix A: *Matrix of Candidate SWRR Criteria & Indicators*

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
	Social Criteria			**Related Social Indicators**
1	Social well being resulting from the use of water and water-related ecological resources	Human health	Waterborne Disease Outbreaks	Annual violations of health-based standards (EPA)
2			Chronic morbidity/ mortality by population and age group	Waterborne human disease outbreaks – drinking/ recreation/lake vs. pool
3			Cancer outbreaks	Coliform violations of treated water
4			Recreational exposures	Vector-borne diseases
5				Organochlorine pesticides and PCBs in bed sediment and whole fish from U.S. rivers and streams
6				Living in high risk areas – acid mine drainage, radon, fish consumption (subsistence or others with fish-dependent diets)
7		Water use	Domestic water use by type and region/scale	Percent of households served by private wells
8				Rates of withdrawal vs. long-term renewable rates sustainable over long term, including resilience to droughts
9				Interior vs. exterior water use per capita
10				Energy to water use ratio
11				Water supply per capita
12				Water use per capita
13			Community capacity and opportunity to grow	
14		Recreation	Number of visitors to major water sites	Number of boats (motorized/non-motorized)
15				Number of boating days available
16				Number of public access sites
17				Value in dollars per year represented by visitors to major water sites
18			Lost recreational opportunities (or “access lost”)	Number of days closed due to water quality problems

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
19				Number of beach closings (EPA)
20			Swimming pool/water park usage	Consumptive use and loss of water from pools/water parks
21			Value of recreational activities related to water	Percentage of economy from water recreational activities
22			Recreational activities from surfing to fly fishing, bird watching/hiking	Fishing/hunting licenses obtained
23			Fishing and hunting activities	Number of beach closings
24				Percentage of population engaged in fishing or hunting
25			Festivals held around water ways	
26			Value of riparian business development (e.g. riverside restaurants, etc.)	Percentage of economy from riparian business
27		Human water infrastructure	Population served with water that meets drinking water standards and wastewater that meets effluent limits and in-stream water quality standards	Percent of utilized water supply capacity
28			Adequacy of community water and sanitation systems	Percent of communities nearly maxing out their water and wastewater treatment systems capacity
29				Percent of population served safe drinking water (also percent by income and ethnicity)
30				Percent of population served by adequate wastewater treatment facilities
31			Affordability of water and sanitation	Water and wastewater treatment costs (as a percentage of household income?)
32			Gap between estimated water infrastructure need (future) and supply	
33			Efficiency/measured losses of water	Amount of wastewater reused
34				Assimilative capacity (used?)
35				Percent of water and wastewater treatment plants needing major investments or recently having undergone such improvement
36				Number of new state or federal road

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
				projects or major upgrade projects within an 8-digit HUC within the last 15 years
37				Percent of population served by small drinking-water systems (systems that serve less than 3,200 people)
38				Percent of WWT plants needing major investments or recently having undergone such improvements
39				Percent of water treatment plants needing major investment
40				Proportion of wastewater receiving secondary treatment
41				Number of desalination or reverse osmosis plants built
42				Percent of desalination plants with feed water from the ocean versus mineralized ground water
43				Number of aquifer storage and recovery (ASR) projects approved and/or in operation
44		Cultural	Culturally distinct connections to the environment (traditional use areas)	Non-white population cultural values
45				Capacity to support subsistence fisheries and other aquatic resources
46				Change in critical local fish, seafood, wildlife or plants stocks
47				Existence value to individuals of high quality ecological water resources
48				Community pride/celebrations (e.g., walleye, shad, shrimp fests, catfish fry's)
49				Consumption of fish and seafood
50				Percent of population that feels water has a spiritual value
51				Aesthetic aspect of drinking water: taste and odor
52				Aesthetic aspect of water bodies (bank and water): trash, foam, smell, look, oil, scum, color
53				Amount of personal contributions in watershed and water quality organizations
54				Publications about the importance of water quality, water system integrity
55				Significance communities place on the aesthetic value of water

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
56			Understanding of water conservation as an ethical value by sector	Percents of population using conservation techniques by sector (including individual/municipal/business)
57				Municipal regulations that encourage domestic water conservation
58				Cost of water (relative to true full cost)
59				Willingness to modify water use based on understanding of full cost (percent of population)
60				Incentives for water conservation measures
61			Ecological literacy Societal attitude toward waste and/or degradation of water resources	Knowledge level of citizenry: Percentage of the population that views clean water, under some circumstances, as a non-renewable resource
62				Activities by individuals
63				Educational activity by governments and institutions
64				Sustainability research
65				Activities of landowners and businesses (including farms)
66				Number of volunteer monitors in a watershed
67				Number of high school students trained in the hydrologic cycle, watershed, and geographic elements of water issues
68				Percentage of population that knows what watershed they live in
69				Number of publications dedicated to education about ecological literacy
70				Organizations dedicated to water and ecological education
71				Number of watershed organizations in a state/region promoting water stewardship
72				Percent of population using conservation techniques for yard care
73				Municipal regulations that encourage domestic water conservation
74			Intergenerational equity	Changes in water use by type over time
75				Change in water quality/flow over time
76				Water use versus (projected) water sustainability

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
77				Adequacy of time horizon of governmental planning efforts
78		External dependence	Interbasin transfers of water	
79			Other "out of area" resource transfers	Extent of state and federal subsidies of resource transfers
80				Interbasin transfers
81				Discharge/withdrawals/use across boundaries
82		Commercial		Commercial fishery receipts
83				Native American whaling
84				Percent of households dependent on commercial fishing
85		Domestic		
86	The social capacity for the management of water and related land resources for sustainability, including human health and well-being	Legal	Water rights	Number of states going to a permit system
87			Water markets	Between sector water trades
88			Environmental justice	
89			Comprehensive water resources planning	Number of states active in statewide comprehensive water planning
90			Extent that legal structures reflect inter-connectedness of water resources	
91		Institutional	The capacity and performance of government and agencies	
92			The capacity and performance of NGOs	
93			The inter-relationships between government and NGOs	Extent of cooperation and leveraging of resources
94			Political commitment to water resources sustainability	
95		Socio-technical capacities	Education and human capital	
96			Research	
97			Physical infrastructure	
98		Political commitment		Number of moratoria on development
99		Disaster	Preparedness	

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
		readiness and hazard mitigation	(readiness prior to threat)	
100			Resistance (defense during onslaught)	
101			Resilience (ability to recover)	
102		External dependence		
	Economic Criteria			**Related Economic Indicators**
103	Capacity to make water of appropriate quality and quantity available for human uses	Water availability	Precipitation	Daily, monthly, and annual rates
104				Quality of atmospheric deposition
105			Snow pack	Storage in perennial snowfields and glaciers
106				Quality indicators?
107			Evaporation	Daily, monthly, and annual rates
108				Quality indicators?
109			Transpiration (agriculture and natural vegetation)	Daily, monthly, and annual rates
110				Quality indicators?
111			Streamflow	Annual and periodic (5- to 10-year) summaries by the 352 river-basin hydrologic accounting units
112				Assessments of long-term trends, including changes in low flows, high flows, and timing of flows; number and duration of dry periods in streams and rivers; deviations from average conditions of the volume and timing of streamflow
113				Bacteriological contaminants
114				Total dissolved solids
115				Nitrogen concentrations, including nitrate
116				Phosphorus concentrations
117				Chemical contaminants
118				Temperature for intended use
119			Lakes	Total storage in large lakes (and trends over time)
120				Bacteriological contaminants
121				Total dissolved solids

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
122				Nitrogen concentrations
123				Phosphorus concentrations
124				Chemical contaminants
125				Harmful algal blooms
126				Temperature for intended use
127			Wetlands	Total acreage, by location (Nation, State, County)
128				Bacteriological contaminants
129				Total dissolved solids
130				Nitrogen concentrations
131				Phosphorus concentrations
132				Chemical contaminants
133			Reservoirs	Total available storage
134				Construction and removal activity
135				Sedimentation rates
136				Bacteriological contaminants
137				Total dissolved solids
138				Nitrogen concentrations
139				Phosphorus concentrations
140				Chemical contaminants
141				Harmful algal blooms
142			Ground water (fresh and saline)	Ground-water-level indices for a range of hydro-geologic environments and land-use settings
143				Changes in ground-water storage due to withdrawals, saltwater intrusion, mine dewatering, and land drainage for major aquifer system
144				Availability and quantity of saline ground water
145				Bacteriological contaminants
146				Total dissolved solids
147				Nitrogen concentrations
148				Phosphorus concentrations
149				Chemical contaminants
150			Ocean desalinated water	Quantity of available desalinated ocean water
151				Quality indicators?
152			Wastewater reuse	Quantity of (1) available wastewater for reuse and (2) amount that is actively used
153				Bacteriological contaminants
154				Total dissolved solids
155				Nitrogen concentrations
156				Phosphorus concentrations
157				Chemical contaminants

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
158			Imported/transferred water	Quantity of (1) available imported water and (2) amount that is actively used
159				Bacteriological contaminants
160				Total dissolved solids
161				Nitrogen concentrations
162				Phosphorus concentrations
163				Chemical contaminants
164			Gross availability	Total available sources of water (by spatial and temporal measurement units)
165		Watershed condition	Land cover: vegetation type, human structures (including impervious surfaces), rangeland, and so forth	Percentage of land surface (in a given area) that is impervious
166				Percentage of land surface overlying (prime) aquifer-recharge areas covered by development
167			Land uses and practices, including water-quality indicators	Identifying specific pollution sources, which could include: (1) the number of permitted withdrawal sites where ground water is contaminated, (2) the number of Superfund sites, (3) number of water bodies listed as impaired under section 303(d) of the Clean Water Act; (4) water bodies that do not meet State WQS listed in State 305(b) reports under the Clean Water Act
168				Alteration of timing and flows
169				Chemical constituents in highway runoff
170				Impact of mine waste and contamination
171			Land form and alterations (topographic, including drainage networks, channelization, wetland areas, soil losses, and so forth)	Number of reported cases of subsidence or sinkhole development
172			Human population, including transient populations such as tourists and migrant workers	
173		Water withdrawals, use, and consumption		Total withdrawals for all uses, in gallons per day
174				Withdrawals by source (surface

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
				water or ground water), in gallons per day
175				Withdrawals by type (freshwater or saline water), in gallons per day
176			Offstream uses of water	Public supply, in gallons per day
177				Non-public supply, in gallons per day
178				Domestic, in gallons per day
179				Irrigation, in gallons per day
180				Livestock, in gallons per day
181				Aquaculture, in gallons per day
182				Industrial, in gallons per day
183				Commercial, in gallons per day
184				Mining, in gallons per day
185				Thermoelectric power, in gallons per day per kWh generated for each generation technology, cooling technology, fuel source and pollution mitigation technology.
186			Instream uses of water	Hydroelectric power, in gallons per day
187				Transportation, in gallons per day
188				Recreation, in gallons per day
189				Wastewater assimilation, in gallons per day
190				Consumptive uses, in gallons per day, by offstream use (includes water incorporated into products that are exported from a basin)
191				Applied use, in gallons per day
192				Conveyance loss, in gallons per day
193				Reclaimed wastewater (is this the same as water reuse?), in gallons per day
194			Use/benefit ratios	Population size (number of people)
195				Per capita use of water (gallons per day per person)
196				Industrial employment (number of employees)
197				Per employee water use (gallons per day/ per employee)
198				Number of irrigated acres
199				Per acre irrigation application rates (acre-feet per acre)
200				Amount of thermoelectric or hydroelectric power generated (kilowatt hours)
201				Withdrawals per power generated (kilowatt-hour of generation per gallon used)

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
202				Water-use in relation to measures of water availability (renewable rates)
203				Net availability: Total available sources of water less total uses, which include withdrawals for human uses, ecosystem uses, uses to meet legal requirements, and so forth
204				Water withdrawals by unit area
205		Human infrastructure	Potable water systems	Total withdrawal (gallons per day), storage (gallons), and delivery (gallons per day) capacity of each system
206				Number and percentage of population served by public-water systems
207				Number and capacity of ground-water supply wells and artificial recharge facilities (including aquifer storage and recovery systems)
208				Number of water-supply systems needing major investments or recently having undergone such improvement
209				Population served by small drinking-water systems (less than 3,200 people)
210			Water-treatment facilities	Acre-feet of water treated
211				Percentage of total wastewater treated
212				Number of water-treatment facilities needing major investments or recently having undergone such improvement
213			Wastewater Reuse	Acre-feet of water treated for reuse
214				Percentage of total wastewater treated and reused
215			Irrigation systems	Acre-feet of irrigation capacity
216			Energy production systems	Number and generation capacity (kilowatts) of thermal and hydroelectric power plants
217				Acre-feet of applied water per kWh electricity generated
218			Transportation systems	
219			Wastewater-treatment facilities	Number and capacity (gallons per day) of wastewater treatment plants
220				Capacity of wastewater treatment facilities as percentage of total wastewater generated
221				Number of wastewater-treatment facilities needing major investments

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
				or recently having undergone such improvement
222				Proportion of wastewater receiving secondary treatment
223			Desalination systems	Number and capacity (gallons per day) of surface-water and ground-water desalination systems
224				Acre-feet of surface-water and ground-water desalinated
225			Inter-basin transfers	Acre-feet conveyed
226			Energy use	Kilowatt-hour per acre-foot for conveyance, distribution, end-use pumping and thermal (heating and cooling), and wastewater treatment
227			Flood Prevention	Number of dams, canals, levees, and pumping stations constructed to divert water or manage flooding
228		Water conservation	Supply infrastructure (by category, i.e. municipal, irrigation, and so forth)	Acre-feet saved through conveyance system improvements (such as canal lining)
229				Miles of lined canals
230				Miles of unlined canals
231				Water use by type of irrigation technology (such as flood irrigation or drip irritation)
232				Investment in agricultural water-conservation measures
233			End-user equipment	Number of ULF toilets installed
234				Percentage of water conserving appliances and fixtures e.g., 1.5 gpf (gallons per flush) toilets, low flow sink and shower heads, energy and water efficient clothes washing and dishwashing machines, drought-resistant landscaping, drip irrigation, etc.
235				Metering
236		Water-use policies and practices	Policies to support efficient end-user practices	Incentives for efficient water use
237				Voluntary versus mandatory measures
238				Monthly water billing (versus quarterly)
239			Water price	Tiered rate structures
240				Full-cost basis for pricing (such as include environmental externalities)
241				Life-cycle cost basis for pricing
242				Pricing by season and water

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
				availability
243	Economic well being resulting from use of water and affected land resources	Economic-value indicators: for each economic use of water (municipal, industrial, agricultural, energy production, transportation, recreation and tourism, mining) the following indicator sub-categories will be needed:		Value of goods and services produced by use of water; or, value of goods and services produced per gallon of water used; or, value of goods and services produced by use of water relative to cost of water used
244				Total employment and wages (payrolls) derived from water use in each economic sector/activity
245				Tax revenues (including fees such as at recreational facilities) generated from water use in each economic sector/activity
246				Trade balance?
247		Recreational revenue	Bodies of water available for recreational use	Lakes of appropriate quality – summer
248				Rivers of appropriate quality – summer
249				Lakes of appropriate quality – winter
250				Rivers of appropriate quality – winter
251				Coastal water of appropriate quality
252			Facilities available for recreation on the watershed	Restaurants on water bodies
253				Outfitters on water bodies (such as for rafting, boating, fishing, and so forth)
254				Hiking/biking trails on water ways
255		Economic costs of water-related hazards	Floods	
256			Droughts and other water shortages	
257	Capacity to gain economic value from use of water-related ecological resources	Capacity to support aquatic species of economic value	Commercial	Value of commercial harvest of given species, or aggregate value, measured by sales

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
258				Value of investment in fleets, gear, and supplies
259				Employment/income within commercial fishing sector
260			Sport	Value of sport harvest of given species, or aggregate value, measured by expenditures
261				Recreation revenue data
262				Employment/income within sport fishing sector
263		Capacity to support non-aquatic species of economic value	Commercial	Population trends, harvest data
264				Value of commercial harvest of given species, or aggregate value, measured by expenditures
265				Value of investment in gear and supplies
266				Employment/income within sector
267			Sport	Value of sport harvest of given species, or aggregate value, measured by expenditures
268				Recreation revenue data
269				Employment/income within sector
270	Value of investments to maintain or enhance the quality and quantity of water	Agriculture	Investment in reduction of non point pollution sources	Governmental research and grant investment
271				Non-governmental research and grant investment
272				Agricultural producer pollution abatement investment
273		Energy Production	Value of investments in improvements in efficiency of water	Governmental research and grant investment
274				Non-governmental research and grant investment
275				Energy producer retrofit or replacement investment
276			Value of investments in improvements in quality of water	Governmental research and grant investment
277				Non-governmental research and grant investment
278				Energy producer retrofit or replacement investment
279		Industrial land use (current and	Investment in reduction of point sources of	Governmental research and grant investment

#	*CRITERION*	*CATEGORY*	*Sub-CATEGORY*	*Indicators*
		past; includes retail)	pollution	
280				Non-governmental research and grant investment
281				Water-treatment investment
282				Pollution abatement investment
283			Capacity to manage drainage and impermeable surfaces	Public investment
284				Private (industry) investment
285		Municipal land use (current and past)	Investment in reduction of point sources of pollution	Governmental research and grant investment
286				Non-governmental research and grant investment
287				Water-treatment investment
288				Pollution abatement investment
289			Capacity to manage drainage and impermeable surfaces	Public investment
290		Transportation	Value of investments in reduction of pollution sources	Governmental research and grant investment
291				Non-governmental research and grant investment
292				Private investment
293		Recreational (including parks, forests, water-fun parks, lakes)	Value of investments in improvements in quality of water	Governmental research and grant investment
294				Non-governmental research and grant investment
295				Private investment
296		Water-Resources Planning		
297		Agriculture		Water requirements by crop by type of irrigation system currently installed
298				Water conservation potential savings by crop
299				Capital requirements by type of water conservation measure
300				Water conservation potential by change from crop X to crop Y
	Environme			**Related Environmental**

#	*CRITERION*	*CATEGORY*	*Sub-CATEGORY*	*Indicators*
	ntal Criteria			**Indicators**
301	Capacity to make water of appropriate quality and quantity available to support ecosystems at multiple spatial and temporal scales	Measurements of water quality	Measurements that describe the physical properties of the water	Temperature
302				water clarity
303				TSS
304			Measurements that describe chemical composition of water	dissolved oxygen DO
305				total nitrogen TN
306				total phosphorus TP
307				Salinity
308				Cl chlorine
309				BOD biological oxygen demand
310				Toxicity - total; water; sediment (by toxin- PCBs, pesticides, metals)
311				Ammonia, Oxides of Nitrogen NH3/NO2/NO3
312				pH
313				Conductivity
314			Measurements of specific organisms inferring water quality conditions required to thrive	Algae
315				Invertebrates
316				Vertebrates
317				fecal coliform/pathogens
318		Measurements of water that show the amount that is in storage and is available for use	Measurements of the water available from aquifers	Availability = amount withdrawn (discharge rates); renewing ground water (recharge rate); sustainable yield (discharge/recharge ratio)
319				Storage = volume (aquifer capacity); level
320				total gaining & loosing reaches over time (between surface water and the aquifer)
321				hyporrbeic storage

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
322				Ground water (base flow contributes to minimum stream flow)
323			Lakes and reservoirs - Measurements of water available in lakes and impoundments	Storage = volume; level; timing of release
324				areal extent
325				interbasin transfers
326			Coasts	change in volume that reaches the ocean
327				change in sea level
328			Streams and Rivers	Flow: minimum instream flow to support fish and wildlife habitat; flood stages
329				hyporheic storage
330			Estuaries	areal extent (natural vs. managed)
331				Volume
332				temporal dynamics
333			Wetlands	Storage
334				areal extent (natural vs. managed)
335			Precipitation and snow pack	Volume
336				areal extent
337				permanence of snowpack and glaciers
338		Potential human causal factors	Land use	extent in length and width of riparian vegetation
339				percent of impervious surface
340				composition and configuration of land use
341				structure & relationship of land use, e.g. storm water placement of impervious surfaces
342				NPDES (location, load) number & location of permitted discharges
343				non-point sources surface area (animal, mining)
344				population density
345				number of stream crossings
346				area of NPS (agric, animal feedlots, industry, residential, parks, golf courses)
347			Discharge and withdrawals	number & location of dams, wells, water and wastewater treatment plants, stormwater outfalls, surface water intakes
348				percent of separated stormwater/sewer systems
349				number & location & efficiency of OWS (such as private septic

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
				systems)
350				number & location of superfund sites, LUST, etc
351				toxic release inventory – releases to water bodies (land, SW, GW)
352				landfills (#, loc, size, condition)
353			Structural modifications of hydrological systems	number of stream miles that are ditched and/or channelized
354				percentage of stream miles that are ditched and/or channelized
355				number of dams, canals, and pumping stations constructed to divert water or manage flooding
356				dredging for navigation (extent – miles, volume)
357				BMPs (#, loc, size, conditions)
358				constructed ditches
359			Water conservation measures	percent of total water
360				industrial, agricultural and domestic water use in conservation practice
361				Xeroscaping
362	Integrity of water-dependent ecosystems at multiple scales	Material and energy-flow	Productivity & Energy Flow	Primary productivity
363				Secondary Productivity
364				Net Ecosystem Productivity
365			Material fluxes & cycles	Nitrogen and Phosphorus
366				Trace elements (e.g. Si, Hg)
367				Sulfur
368				Atmospheric influence
369				Pollutant loading
370		Biotic Integrity	Organism Condition	Disease
371				Metabolic state
372			Species/Population Condition	Population size
373				Population demographics (population structure and dynamics)
374				Generic diversity
375			Community/Ecosystem Condition	Indices of Biotic Integrity for various assemblages
376				Community size and composition
377				Physical habitat (change) (state + change)
378				Non-native species
379				Threatened/endangered species
380		Landscape Condition	Extent & Condition of Habitat Types	extent of habitat (wetlands, reservoirs, and aquifers)

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
381				spatial connectivity
382				diversity of w-d habitats: patch; biological
383			Landscape Structure	Extent of terrestrial & aquatic landscapes (connectivity, composition)
384				Presence and amount of each part (or patch) within the landscape
385				Physical distribution or spatial arrangement of patches within the landscape
386		Disturbance Regime	Disturbance	Frequency
387				Magnitude
388				Extent
388			Eco-Stability	Resilience
390				Resistance

Appendix B: SWRR Letter to the National Environmental Status and Trends Project

The Sustainable Water Resources Roundtable

SWRR

September 29, 2009

Richard W. Guldin
Director, Quantitative Sciences
USDA Forest Service, Research & Development
1400 Independence Ave., S.W.
Washington, DC 20250-1120

Dear Rich:

The Sustainable Water Resources Roundtable, a national collaboration of federal, state, local, corporate, non-profit and academic interests, applauds the work done to date to develop a National Environmental Status and Trends Indicators database. The roundtable has greatly appreciated its conversations with you over the last two years and we believe that the prototype you have put together within the water arena demonstrates a great deal of thought and hard work. In fact, we believe it demonstrates the great promise of a national environmental indicators system.

Because the roundtable has spent a number of years thinking about how to devise a national set of water-related indicators – as you know, this is a fundamental element of our mission to promote sustainability of the nation's water resources – we hope our experience may be helpful to the NEST project.

In addition to its laudable commitment to make NEST relevant to policy makers and science based, the project identifies several important goals, among them to regularly report on current environmental conditions and recent trends, and to facilitate public discourse and decision making over the long term at the national level regarding environmental goals and priorities. The project also recognizes the importance of using NEST to understand the effects of changes in environmental processes and economic activities.

Without a doubt, a national indicator package that sheds light on current environmental conditions while informing public decision making about the economy and the environment over the long term will be a remarkable accomplishment.

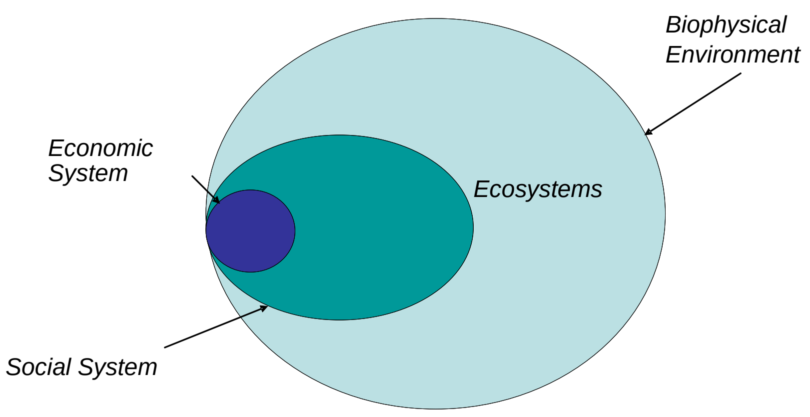
In the spirit of supporting the NEST's pursuit of this goal, we would like to offer a few suggestions based upon our experience wrestling with three questions that we suspect NEST also has had to, or will need to, confront. The questions are:

- What are the important issues that people need to understand?
- Are there fundamental, underlying relationships that people must recognize in order to gain this understanding?
- What is the key to making data something people can call "information"?

First, we believe that the roundtable made its most important decision at the outset, which was to define the basic relationships between economic, social and environmental interests. The roundtable embraced a systems concept that views economic activity as nested within society and society within ecosystems. (See figure 1.) This picture of the world was an important and significant departure from earlier models. Yet, it became a critical and oft-used source in our subsequent discussions about indicators and the criteria with which they should be selected.

Figure 1.

General Systems Perspective: Essential Relationships of Sustainability



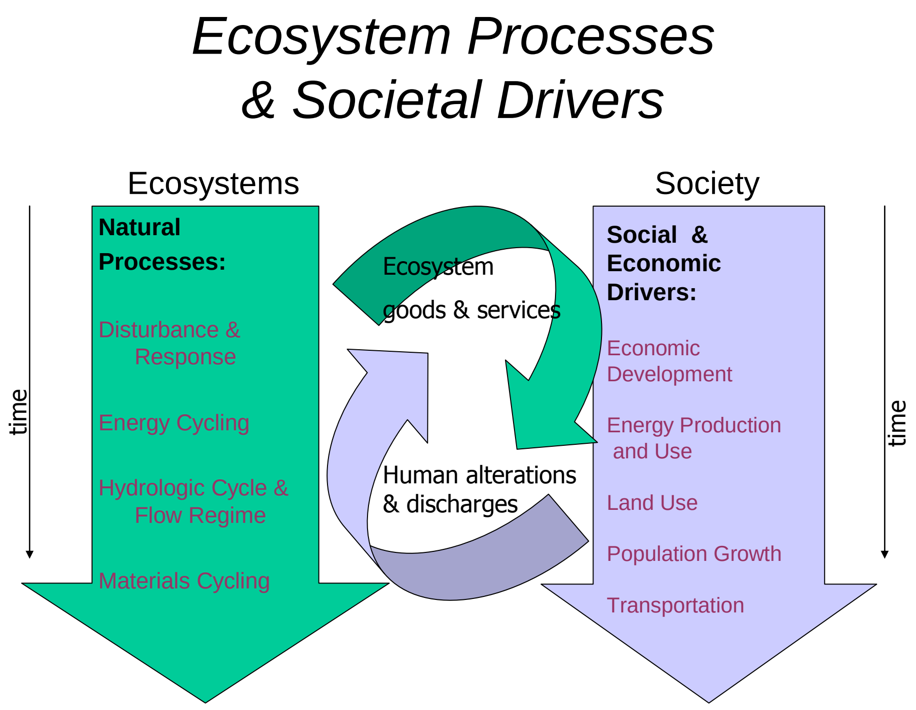
Source: Sustainable Water Resources Roundtable

This systems perspective is significant because it illustrates that people and economies depend on the environment for their well being. While the idea is simple, it provides a foundation for understanding how things fit together, which is important in the choices people make in selecting and interpreting indicators.

The three concentric ovals represent what economists call "capital," the capacity to produce value over time. Environmental, social and economic systems produce value through flows of services, experiences or goods that meet human and ecosystem needs over time. We achieve sustainability by maintaining this capital to meet needs.

With this understanding, the three dimensions of capital became the logical basis for the roundtable's criteria for the selection of indicators. And because the flow of goods and services within any one dimension depends on the capacity and condition of the resource, the drivers that affect it, and the processes by which the resource responds to these drivers, a roundtable framework of indicator categories emerged. See figure 2.

Figure 2.



Source: Sustainable Water Resources Roundtable

The framework provides the organization and rationale for the factors and relationships necessary to track the health and wealth of the nation's economic, social and ecological capital. Without its systems concept, the roundtable's system of indicators would have lacked context and, therefore, rigor.

It would be fair to ask whether and how this construct might actually affect the important questions NEST poses and the indicators it presents in response. Besides providing an intellectual foundation, would there be tangible benefit? We would argue "yes" because data without context provides only limited information, and given the NEST project's focus on providing the information that decision makers need, context becomes fundamental.

The NEST water use indicators provide a good illustration. Water use data presented alone lacks the context that would give it meaning. That context, which is defined by the basic relationships of figure 1, is to understand water use in relation to the supply from which it is secured. Given the need for policy makers to understand long term implications, people need to know, not only how much we use, but the proportion we now use of the total we might safely take on a long term basis.[1]

While there may be a fair argument about whether NEST or its users should provide the context, we would suggest that NEST must, at least, present its information in a way that decision makers might see the need for that context and understand how to develop it. In the water use example, the goal would be to present use data in concert with data on the sources of supply. If this were not possible on a national scale, NEST could alternatively describe the steps its users would need to follow to construct their own supply—demand understanding for a given source of water.

In short, we believe the NEST project would be strengthened by incorporation of the roundtable's general systems perspective and linking it to the criteria for indicator selection.

We hope you find these comments helpful. Thank you for the opportunity to put them forward. As we said earlier, we believe the NEST project holds great promise for the nation and we look forward to a continuing dialog with you as the project moves forward.

Sincerely,

John R. Wells
Steering Committee
Sustainable Water Resources Roundtable

and

Strategic Planning Director
Minnesota Environmental Quality Board
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cc: Rick Swanson, Co-Chair
Robert Goldstein, Co-Chair
David Berry, Manager

[1] Sticking with the roundtable's understanding of capital, we would define "safely" to mean without harming the ability of either the economy, society or the ecosystem to provide its goods and services.

Appendix C: *Water Environment Federation Sustainability 2008, Green Practices for the Water Environment June 22-25, 2008, The Gaylord National on the Potomac, National Harbor, MD*

Session 1: Municipal Green Infrastructure Programs
Green Infrastructure at the Campus and Watershed Scale at the University of North Carolina at Chapel Hill
Carolyn Elfland, Sharon Myers, *the University of North Carolina at Chapel Hill;* Ted Brown, Sally Hoyt, *Biohabitats, Inc.*

Lansing, Michigan's Downtown Rain Gardens: Design and Community Involvement Anne M. Thomas, Daniel P. Christian, *Tetra Tech*; Chad A. Gamble, *City of Lansing*; John T. Killips, *Tetra Tech*

A Natural Drainage Approach for the City of Seattle's Right-of-Way Tracy Tackett, *Seattle Public Utilities*

Turning Toward Green Practices: The Kansas City Model Ginevera Moore, *Mid-America Regional Council*

Rooftops to Rivers: Aurora, Illinois' Use of Green Infrastructure in Riverfront Cleanup and Urban Redevelopment Bill Abolt, *Shaw Environmental, Inc.;* Bob Newport, *U.S. EPA Region 5*

Capturing Stormwater for Water Supply Needs in Charlotte County, Florida James E. Scholl, *Malcolm Pirnie, Inc.;* Jeff Pearson, *Charlotte County Utilities*

Session 2: The Big Picture: National & International Watershed Perspectives
Developing a Watershed Sustainability Index and Incentives for Integrated Water and Resource Management
S.D. Struck, L.L. Shoemaker, *Tetra Tech, Inc.*

EPA's New Technical Guidance for National Pollutant Discharge Elimination System (NPDES) Watershed-Based Permitting Danielle Stephan, *U.S. Environmental Protection Agency;* Kellie DuBay, Greg Currey, *TetraTech, Inc.;* Trish Rider, Marcus Zobrist, Patrick Bradley, *U.S. Environmental Protection Agency*

Reforming for Water Sustainability in Australia - The Drought with the Silver Lining John W. Norton, Jr., Russell Beatty, John Summers, *MWH Australia, Inc.;* Charles Ainger, *MWH UK, Inc.*

Practical Progress in the New Zealand Journey towards More Sustainable Water and Wastewater Management
James (Jim) W Bradley, Paula M Hunter, *MWH New Zealand Ltd*

River Basin Management System: A Dynamic Environmental Management Tool for Developing Long-Term Water Quality Improvement Plans Michael Waddell, *CDM (Camp Dresser McKee)*

Session 3: Assessing Sustainability for Treatment Plants
Evaluation of Alternatives for a Greenfield Water Reclamation Facility, Incorporating Carbon-Footprint and Sustainability Perspectives Robert Forbes, Keith Reeves, Bruce Johnson, Felicia Wyatt, *CH2MHILL*

Embodied Energy in Municipal Water and Wastewater Sharon M. deMonsabert, Ali Bakhshi, Jamie L. Headley, *George Mason University*

Renew and Reduce: Energy Solutions to Improve Plant Operations Steven R Hall Jr., *Metcalf & Eddy/AECOM*

Evaluating Sustainability Options for Wastewater Treatment Systems Jim Condon, *Olsson Associates*

The Production of Hydrogen and Electricity as New Energy in Anaerobic Wastewater Treatment Processes Baikun Li, *University of Connecticut;* Michael D. Curtis, *Fuss & O'Neill;* Yogesh Sharma, Daqian Jiang, *University of Connecticut*

Session 4: Climate Change Mitigation at WWTPs
The Importance of Selecting the Right Greenhouse Gas Model for Sustainable Design Decisions in Wastewater Treatment A.R. Shaw, *Black & Veatch;* K.A. Third, S. Cooper, *Sinclair Knight Merz*

Greenhouse Gas Inventories From WWTPs - The Trade-Off with Nutrient Removal David de Haas, Jeff Foley, *GHD;* Keith Barr, *Brisbane Water*

Comparative Energy- and Carbon- Footprints for Activated Sludge Layouts Diego Rosso, *University of California, Irvine;* Michael K. Stenstrom, *University of California, Los Angeles*

Carbon Footprinting for Biosolids Processing and Management Alternatives at DC WASA's Blue Plains AWTP Mohammad Abu-Orf, Jeffrey Reade, Laetitia Mulamula, Charles Pound, Robert G. Sobeck, Jr., Edward Locke, *Metcalf and Eddy/AECOM;* Chris Peot, Sudhir Murthy, Salil Kharkar, Walter Bailey, Leonard Benson, Martin Sultan, John Carr, Rouben Derminassian, George (Yi-Ming) Shih, *DC WASA*

GHG Emissions, Nitrous Oxide and Your Bioreactor – Things to Think About Dean M. Shiskowski, *Associated Engineering*

Session 5: Evaluating Green Infrastructure Practice: Beyond Water
The Effect of Low-Impact-Development on Property Values Bryce Ward, Ed MacMullan, Sarah Reich, *ECONorthwest*

Low Impact Development and Green Infrastructure Demonstration Study for the Cumberland Community Improvement District in Cobb County, Georgia Joel Tillery, Aditya Tyagi, Doug Baughman, Dan Medina, *CH2M HILL*

Mt. Airy Rain Catchers - Rain Barrels and Gardens in a Suburban Watershed Ward G. Wilson, *Tetra Tech, Inc.*

Seattle Public Utilities' Natural Drainage System Operation and Maintenance Drena Donofrio, Tracy Tackett, *Seattle Public Utilities*

Session 6: Planning and Modeling for the Water Environment
The 'G' Word: Sustainable Hydrology, Land Use, and Growth Juli Beth Hinds, *VHB Pioneer;* Nigel Pickering, *Charles River Watershed Association*

Green Infrastructure Planning in Highly Urbanized Watersheds: A New York City Example Dawn Henning, Sri Rangarajan, *HydroQual, Inc.*

Building a Sustainable Region, One Drop at a Time! Tim Bate, *Milwaukee Metropolitan Sewerage District;* Karen Sands, *Earth Tech;* Kevin Shafer, *Milwaukee Metropolitan Sewerage District*

Sustainable Integrated Watershed Management in the Tualatin Basin Bruce Roll, Bruce Cordon, Peter Guillozet, Kendra Petersen-Morgan, Brian Vaughn, Kendra Smith, *Clean Water Services*

HSPF Toolkit: A Tool for Stormwater Management at the Watershed Scale Y.M. Mohamoud, R. Parmar, K. Wolfe, J. Carleton, *U.S. Environmental Protection Agency*

Session 7: Treatment: Novel & Natural
Tarrant Regional Water District's Field-Scale Wetland Phase 1 Operations – Lessons Learned Loretta E. Mokry, *Alan Plummer Associates, Inc.;* Darrel Andrews, Woody Frossard, *Tarrant Regional Water District;* Alan H. Plummer, Jr., *Alan Plummer Associates, Inc.*

Evaluation of the Green Oxidant Ferrate for Wastewater Reuse for Wetland Restoration Brady K. Skaggs, Robert S. Reimers, Andrew J. Englande, Jr., Ponsawat Srisawat, *Tulane University;* Gordon C. Austin, *Sewerage and Water Board of New Orleans*

Saving the Planet with a Bar of Soap and a Truck That Smells Like French Fries: Building Sustainable Synergies between the Public and their Utilities Rob McElroy, *Daphne Utilities*

Integrating Demineralization with Wastewater Treatment to Generate Nutrient Rich Recycled Water for Sustainable Agricultural Use Graham J.G. Juby, Don W. Zylstra, Susanna, *Carollo Engineers;* Perry R. Louck, *Rancho California Water District;* Behrooz Mortazavi, *Eastern Municipal Water District*

Session 8: Achieving Energy Management and Efficiency
OWASA's Carbon Foot Print Analysis and Opportunities for Industry-Wide, Efficiency-Gain Tracking John Willis, *Brown and Caldwell;* Patrick Davis, *Orange Water and Sewer Authority (OWASA);* Ted Hull, *Brown and Caldwell;* Ed Kerwin, *Orange Water and Sewer Authority (OWASA)*

Balancing Treatment Process Requirements and Energy Management Harold Schmidt, Jr., *MWH Americas, Inc.*; Scott Kelly, *JEA*; Paul Deule, *City of Orlando*; Jerry Manning, *City of North Port*; David Peters, *City of Stuart*

Energy Savings and Air Quality Benefits from the Santa Clara Valley Water District's Water Use Efficiency Programs Jeannine Larabee, Hossein Ashktorab, *Santa Clara Valley Water District*

Wastewater Energy Efficiency Is Attainable Joseph Cantwell, *Science Applications International Corporation*

Energy Management Techniques and Outcomes at the Metropolitan Water Reclamation District of Greater Chicago Sanjay Patel, Osoth Jamjun, Susan O'Connell, *Metropolitan Water Reclamation District of Greater Chicago*

Session 9: Performance of Green Infrastructure Practice: Water Quantity & Quality
Water Quality and Flow Performance-Based Assessments of Stormwater Control Strategies During Cold Weather Months Robert M. Roseen, James J. Houle, Thomas P. Ballestero, Pedro Avelleneda, Joshua Briggs, George Fowler, Robert Wildey, *University of New Hampshire*

The Promise of Stormwater Phytotreatment Anne MacDonald, David Dods, Kathi Futornick, Ari M. Ferro, *URS Corporation*

Pervious Asphalt: A Case Study of Impacts on Storm Water Volume and Pollutant Load Amy Post, Willie Gonwa, *Symbiont*; Kimberly Kujoth, *City of Milwaukee*

Case Study: Enhanced Porous Concrete Pavement System Creates Advantages for All Stakeholders James B. Leedom, Kenneth E. Kaszubowski, *The Sigma Group*

Session 10: Green Infrastructure Tools and Approaches

Developing the Great Lakes Cities Permeability Index Steve Wise, Julia Kennedy, Bill Eyring, *Center for Neighborhood Technology*

Expanding the Green Build-Out Model to Quantify Stormwater Reduction Benefits in Washington, DC Michael Sullivan, Brian Busiek, *LimnoTech*; Heather Whitlow, Meredith Upchurch, *Casey Trees*; Jenny Molloy, *U.S. Environmental Protection Agency*

An Appraisal of Stormwater Reclamation and Reuse In Hawaii Woodie Muirhead, *Brown and Caldwell*

Greensteams: Milwaukee's Green Infrastructure Flood Reduction Program Margaret A. Kohring, *The Conservation Fund*

New Approaches to "Greening" Stormwater Karen Cappiella, Kelly Collins, David Hirschman, Mike Novotney, *Center for Watershed Protection*

Investigating Urban Growth Planning Impacts on Stormwater Control Measure Performance Brenna Enright, Barry J. Adams, *University of Toronto*

Session 11: Water Sustainability: Gray & Green

Managing Water Risks in a Water Scarce World: Use of WBCSD Global Water Tool for Sustainable Water Management Harry X. Zhang, Jan Dell, *CH2M HILL*

Distributed Wastewater Systems Meet Economic, Social, and Environmental Sustainability Goals: An Illustration from a Water and Wastewater Utility Todd A. Danielson, *Loudoun Water*

A Green Approach to Combined Sewer Overflow Control: Source Control Implementation on a Watershed Scale James T. Smullen, R. Dwayne Myer, Shannon K. Reynolds, *CDM*

Wastewater Reuse: South Florida's Answer to a Sustainable 21st Century E. Vadiveloo, R. Cisterna, *Hazen and Sawyer, P.C.*

Cost Effective, Low Maintenance System to Achieve Total Phosphorus < 0.5 mg/l Pio Lombardo, *Lombardo Associates, Inc.*

Countywide Onsite Sewage Disposal System Characterization and Selection of Appropriate Centralized or Distributed Treatment Options for Anne Arundel County, Maryland Laurens van der Tak, Brian G. Marengo, *CH2M HILL*; Blaine Weitzel, *Harms & Associates*; Thor Young, *Stearns & Wheler*; Chris Murphy, Chris Phipps, *Anne Arundel County*

Session 12: Climate Change Management, Mitigation, & Adaption
How Green Is Your Footprint? The Impact of Greenhouse Gas Emissions on Strategic Planning Patricia Scanlan, *Black & Veatch Corporation;* Holly Elmendorf, *Gwinnett County Department of Water Resources;* Hari Santha, James Rowan, *Black & Veatch Corporation*

Greenhouse Gas Releases From Treatment Wetlands versus Conventional Treatment: Defining Relative Impacts and Net Benefits J. Jordahl, P. Frank, M.J. Kealy, *CH2M HILL*

Program Design and Implementation to Reduce Arlington County Carbon Emissions and Improve Air and Water Quality William E. Roper, John Morrill, Joan Kelsch, *Arlington County, Virginia*

Wetland Assimilation: Climate Change Adaptation and Restoration in the Mississippi Delta Sarah K. Mack, *Tulane University School of Public Health and Tropical Medicine;* J. Day, *Louisiana State University;* A.J. Englande, Jr., R.S. Reimers, *Tulane University School of Public Health and Tropical Medicine;* G.C. Austin, *Sewerage and Water Board of New Orleans*

A Delivery Mechanism for Driving Sustainable Solution Development and Capital Investment to Meet UK Carbon Emission Targets Ajay K Nair, Stephen J Palmer, *MWH UK Ltd*

Session 13: Incorporation of Green Infrastructure into CSO Programs
Assessment of Low Impact Development on CSO Kaniz Siddiqui, *Metropolitan Sewer District of Greater Cincinnati;* Philip Gray, *XCG;* John Aldrich, *CDM*

Philadelphia's Storm Water and CSO Programs: Putting Green First Mark Maimone, *CDM*; Howard Neukrug, Amy Leib, *Philadelphia Water Department*

Incorporating Green Infrastructure and Future Land Use Demand in a CSO Long Term Control Plan James C. Schlaman, *Black & Veatch;* Bryce Lawrence, Scott Schulte, *Patti Banks Associates*

Glencoe Rain Garden: Successful Management of Combined Sewer Flows Timothy Kurtz, Henry Stevens, *City of Portland, Bureau of Environmental Services*

Session 14: Stormwater & LID for the Watershed
Watershed Approach to Integrating Green and Hard Infrastructure: New York City's Staten Island Bluebelt Dana Gumb, James Garin, *New York City Department of Environmental Protection;* Sandeep Mehrotra, Brian Henn, *Hazen and Sawyer, P.C.*

Restoring a Watershed through LID and Reduce Storm Water Neal Shapiro, *City of Santa Monica*

Justifying Sustainable Stormwater Facilities in Sewer Design Projects: Portland's Successes Bill Owen, Tim Kurtz, *City of Portland, Bureau of Environmental Services*

Customer-Based Stormwater Control – Seattle's Policies and Pilots Timothy Lowry, *Seattle Public Utilities*

Comprehensive Watershed Management Plan for a Sustainable Development of Lehigh Acres, Lee County, FL Robert S. Copp, *A.D.A. Engineering, Inc.;* Lee Flynn, *AIM Engineering, Inc.*

Session 15: Renewables: Developing an Energy Source
Producing Green Energy from Post-Consumer Solid Food Wastes at a Wastewater Treatment Plant Using an Innovative New Process Donald M.D. Gray (Gabb), Paul J. Suto, Mark H. Chien, *East Bay Municipal Utility District*

The City of San Jose Biomass Waste to Energy Evaluation Jay R. Surti, *CH2M HILL, Inc.*, Dave Tucker, *City of San Jose*

Digester Gas Powers Energy Conservation at Baltimore's Back River WWTP Ralph B. (Rusty) Schroedel, *Earth Tech, Inc.;* Peter V. Cavagnaro, *Johnson Controls, Inc.;* Nick Frankos, Duncan Mukira, *City of Baltimore*

Making Methane: Co-Digestion of Organic Waste with Wastewater Solids David L. Parry, Scott Vandenburgh, Michael Salerno, *Camp Dresser & McKee Inc.*

Posters – Monday, June 23, 2008
A Watershed Management Plan to Sustain a High Quality Lake Maumelle Water Supply and Resource J. Trevor Clements, Kimberly Brewer, *Tetra Tech*

On An Accounting System and Protocol to Measure, Verify, and Register Progress Toward Sustainable Ecosystem Improvements from Managing Stormwater to Restore Environmental Flows Mary Jo Kealy, Dan Medina, Mark Mittag, Brent Brown, *CH2MHILL*

The Millbrae Results of Simultaneously Mitigating Upward Spiraling Energy Costs and Modernizing Its Wastewater Treatment Facilities Richard V. York, *City of Millbrae, Retired;* Joseph Magner, *City of Millbrae;* Greg Chung, *Kennedy/Jenks Consultants*

Posters – Tuesday, June 24, 2008
District of Columbia Water and Sewer Authority Rain Garden Pilot Project Kenneth Eyre, Michael Thorstenson, *Greeley and Hansen LLC*

A Site Evaluation Tool for Assessing Water Quality Impacts from Conventional and Low Impact Development Scott Job, Heather Fisher, Bobby Tucker, *Tetra Tech, Inc.*

Sustainable Energy Management: Augmenting Anaerobic Digesters to Increase Biogas-Fueled Combined Heat and Power Production Drury D. Whitlock, Julian Sandino, Daniel L. Gall, Marialena Hatzigeorgiou, Tim Shea, Dimitri Katehis, *CH2M HILL*

Implementation of Sustainability Is a Grassroots Effort Karen Pallansch, *Alexandria Sanitation Authority*; Stephen Hayashi, Bruce Corning, Veronica O. Davis, *Malcolm Pirnie, Inc.*

Appendix D: *Water Environment Federation WEFTEC.08 Annual Conference, Sustainable Water Resources Management, Technical Sessions, October 18-22, 2008, Chicago, Illinois*

Reports and Publications

Arifian, Gregory, *Carbon Footprinting: Using Carbon Emissions Analysis to Achieve Energy Independence*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Finley, T., Leathers, G., and Zhang, H. X., *Use of the WBCSD Global Water Tool to Assess Global Water Supply Risk and Gain Valuable Strategic Perspective*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Garvey, Elisa, et al, *Supporting Implementation of Sustainability Concepts Using* a *System-Wide Modeling Approach* - - *Inland Empire Utilities Agency Case Study*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Gluck, Steven J., *Strategic Sustainable Solutions: What Works and What Doesn't*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Hudson, Joyce, and Robert J. Freeman, *Encouraging Green Development with Decentralized Wastewater Approaches*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Kenel, Pamela P., et al, *Sustainability Metrics: Applications for Utility Planning*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Li, Susanna, et al, *Pilot Testing of Zero-Liquid-Discharge Technologies Using Brackish Ground Water for Inland Desert Communities*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Orphan, Lynn H. and Douglas W. Karafa, *Adaptive Management—Beyond TMDL Compliance*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Rehring, John, et al, *Practical and Sustainable Water Supply: Making the Most of What You Have*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Roll, Bruce and Bobby Cochran, *Leveraging Ecosystem Markets for Sustainability*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Schreiber, Robert P., et al, *Toward Implementation of a National Ground Water Monitoring Network*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Whitlock, Drury and Glen Daigger, *Full Cost Accounting for Wastewater Utilities*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Case Studies

Bate, Timothy, et al, Milwaukee's *Next Step: Watershed Restoration Plans*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Conrads, Paul, et al, *Maximizing Data Collection Networks by Using Data-Mining Techniques—A Case Study in the Florida Everglades*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Fono, Lorien, et al, *Water Resources Protection as a Driver for Wastewater Project Selection*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Harper, Stephen, et al, *Analysis of Nutrient Removal Costs in the Chesapeake Bay Program and Implications for the Mississippi-Atchafalaya River Basin*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Kepke, Jacqueline, et al, *Developing an Integrated Water Servicing Strategy for Infill Development: Botany Case Study in Sydney, Australia*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Kulkarni, A.A., and S.P. Aggarwal, *Site Suitability Analysis of Water Conservation Structures for Sub-Watershed in Ujjani Catchment, India—A Geospatial Approach*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Minarik, Thomas, et al, *Dissolved Oxygen in the Chicago Area Waterway System* - *Using a CDOM Program to Support Water Quality Improvement Efforts*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.

Mosteller, Kevin, et al, *Balancing the Three Pillars of Sustainable Design for the Sugar Creek WWTP Expansion Project*, Proceedings, WEFTEC.08, Water Environment Federation, October 2008.