Sustainable Water Resources Roundtable
Preliminary Report

September 30, 2005

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EXECUTIVE SUMMARY

The Sustainable Water Resources Roundtable (SWRR) brings together participants from diverse sectors – federal, state, corporate, non-profit, and academic – to advance knowledge and support the decision-making needed to sustain the quality and availability of the nation's water resources. In the large context of sustainability, water plays a central role and many government and private organizations have responsibility for or interest in water resources. All aspects of our society, economy and ecosystem are highly dependent on these resources. No organization addresses the full spectrum of water resource topics and it was this fragmentation of responsibility as well as the commonality of interest that led to the formation of the SWRR.

Just as the participants in the SWRR represent a wide range of interests and responsibilities related to water resources, we hope that this report is useful to a wide audience including organizations responsible for management of water resources, organizations that depend on them and individuals and organizations that are researching the field. The report is not designed to be highly technical but some of the relationships in the systems in which water is a part are indeed complex.

The SWRR is one of four natural resource roundtables advising the efforts of the White House Council on Environmental Quality to develop a comprehensive set of national environmental indicators. The other roundtables address critical issues and indicators for the management of forests, rangelands, and minerals and energy. The SWRR is also a subgroup of the Advisory Committee on Water Information (ACWI), which advises federal agencies responsible for managing water resources.

The SWRR has hosted multi-stakeholder meetings on research needs and indicators from December 2002 through June 2005 in California, Maryland, Michigan, Minnesota, Virginia, and Washington, D.C. The SWRR receives funding from public agencies and the private sector.

Contents of this Report

This report includes chapters on the role of indicators, conceptual foundations for the work of the roundtable, and criteria and indicators on the sustainability of water resources. The report also covers the research needs for sustainable water resources management that were discussed at the SWRR meetings and covered in depth at a workshop held at the University of Michigan in April 2005. The final chapter discusses conclusions, recommendations and future work, as well as how the federal and state governments, the private sector and non-profit organizations can help to achieve the sustainability of water resources. The appendices present a discussion of the water budget approach to management, a full list of candidate indicators and the terms of reference (bylaws) of the SWRR.

Defining Sustainability

The most widely known definition of sustainable development was put forth by the Brundtland Commission in 1987 as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainability is a complex subject and clear definitions of key terms such as sustainability, stability, equilibrium, limits, thresholds, and needs can enable a common understanding. Rather than choosing a strict definition of sustainability all the multiple SWRR partners could agree on, whether the Brundtland definition or developing an alternative, the SWRR agreed to propose a set of four sustainability principles for water resources management:

1. ***The value and limits of water***. Water resources are the basis of life and provide great value. While water is abundant, people need to understand and appreciate the limits of water resources in many regions, the environmental and economic costs of damaging water resources, and the risks to people and ecosystems of unbounded water and land use.

2. ***Shared responsibility***. Because water does not respect political boundaries, its management requires shared consideration of the needs of people and ecosystems up- and downstream and throughout the hydrologic cycle.

3. ***Equitable access***. Sustainability suggests fair and equitable access to water, water dependent resources and related infrastructure.

4. ***Stewardship***. Managing water to achieve sustainability challenges us, while meeting today's needs to address the implications of our decisions on future generations and the ecosystems upon which they will rely.

The discussion of the sustainability of water resources occurs within the context of the major driving issues of population, income, land use, climate change, and energy use. All of these key drivers affect water allocation through the demands for various uses. In some cases, the water resources themselves may be changed by major shifts in these drivers. For example, with climate change, we could see increased salt water intrusion into freshwater resources because of more frequent storms and possible sea level rise.

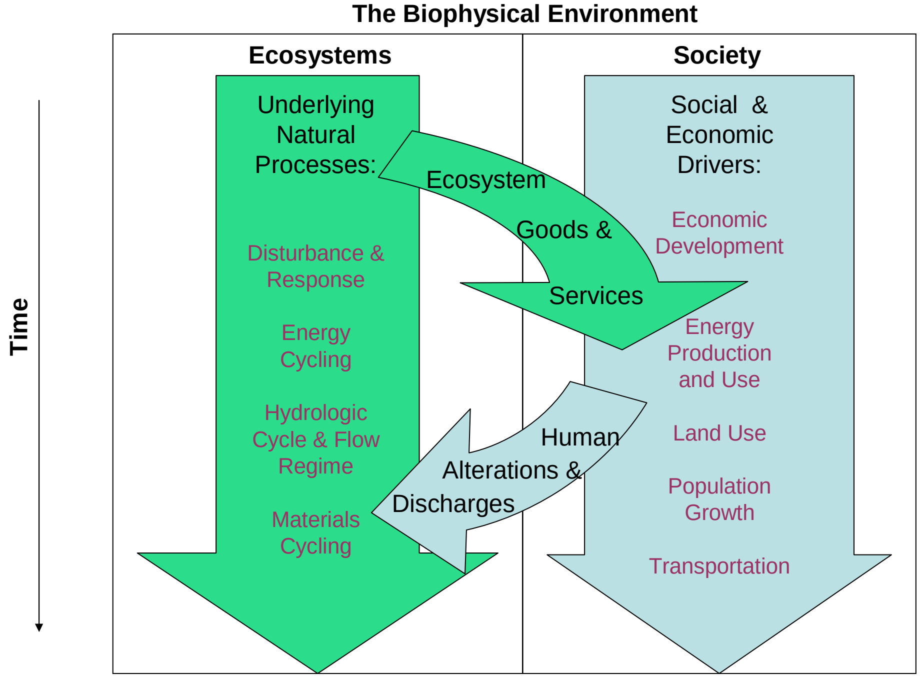
Representing Sustainability with Systems Concepts and Indicators

The sustainable development of water resources is a multi-dimensional way of thinking about the interdependencies among natural, social and economic systems in the use of water. The SWRR used systems concepts to represent our understanding of "how the world works." In the case of water resources, systems concepts represent those components and processes in our world by which water moves from place to place, interacts with other components of the ecosystem, and is used by humans. Understanding these components and processes is essential to identifying key indicators. We define indicators as measures that present relevant information on trends in a readily understandable way. Indicators can be presented in the form of numbers, charts, graphs, or maps. A good indicator sends society an important signal.

Figure ES.1 displays the overall relationships among ecosystem and society encompassed by the concept of sustainability. The view that sustainability is a property of the biophysical environment that emerges from interactions between the ecosystem and society is attractive to experts and managers in many fields. Ecosystems include all living things on Earth and the non-living systems with which they interact and on which they depend. Society includes all the human elements of the biosphere. Humans are a part of nature, not apart from it. The economic system is a part of the social system.

Figure ES.1

General Framework for Driving Forces and Underlying Processes



By offering a framework or system for organizing and communicating data, we can bring to light useful knowledge at whatever scale is needed by decision-makers. The framework itself provides a simple way to communicate complex interrelationships.

One way to apply the systems concepts of sustainability to identify effective indicators is to recognize that sustainability can be achieved by maintaining capital or capacities of all forms to meet various human and ecosystem needs within the biosphere. Economists regard capital as the capacity to produce a flow of value over an extended time – value that is produced by satisfying human needs. Although capital is a term most often identified with economics, it is also used for other types of analysis. All three systems – natural, social and economic – produce flows of services, experiences or goods that meet various needs over time. In this sense, all three systems contain capital. As a result, good indicators measure this capital as well as the direct and indirect impacts caused by changes in capital over time.

Summary

The goal of the sustainability indicators in this report is to tell us "where we are" in the quest for meeting short- and long-term social, economic and ecological needs with respect to water resources in the midst of a constantly changing ecosystem and the dynamics of human society. Indicators highlight important trends and help us begin to evaluate their causes and effects. They educate people and build awareness about the challenges we face. They give us a common language that allows us to share a deeper understanding of issues and forge the collective responses that every level of society must take.

The roundtable believes effective indicators will enable people in every watershed and community to gain new understanding and tools to make good decisions. And an informed citizenry may give the nation the best chance to ensure that its management of water resources is sustainable.

CHAPTER 1 INTRODUCTION

The Sustainable Water Resources Roundtable (SWRR) brings together participants from diverse sectors – federal, state, corporate, non-profit, and academic – to advance knowledge and support the decision-making needed to sustain the quality and availability of the nation's water resources.

Just as the participants in the SWRR represent a wide range of interests and responsibilities related to water resources, we hope that this report is useful to a wide audience including organizations responsible for management of water resources, organizations that depend on them and individuals and organizations that are researching the field. The report is not designed to be highly technical but some of the relationships in the systems in which water is a part are indeed complex.

The SWRR is one of four natural resource roundtables advising the efforts of the White House Council on Environmental Quality to develop a comprehensive set of national environmental indicators. The other roundtables address critical issues and indicators for the management of forests, rangelands, and minerals and energy. The SWRR is also a subgroup of the Advisory Committee on Water Information (ACWI), which advises federal agencies responsible for managing water resources.

The SWRR has hosted multi-stakeholder meetings on research and indicators from December 2002 through June 2005. SWRR receives funding from public agencies and the private sector.

Water Resources Management for Achieving Sustainability

The most widely known definition of sustainable development was put forth by the Brundtland Commission in 1987 as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainability is a complex subject and clear definitions of key terms such as sustainability, stability, equilibrium, limits, thresholds, and needs can enable a common understanding. Rather than choosing a strict definition of sustainability all the multiple SWRR partners could agree on, whether the Brundtland definition or developing an alternative, the SWRR proposed a set of four sustainability principles for water resources management:

1. ***The value and limits of water***. Water resources are the basis of life and provide great value. While water is abundant, people need to understand and appreciate the limits of water resources in many regions, the environmental and economic costs of damaging water resources, and the risks to people and ecosystems of unbounded water and land use.
2. ***Shared responsibility***. Because water does not respect political boundaries, its management requires shared consideration of the needs of people and ecosystems up- and downstream and throughout the hydrologic cycle.
3. ***Equitable access***. Sustainability suggests fair and equitable access to water, water dependent resources and related infrastructure.
4. ***Stewardship***. Managing water to achieve sustainability challenges us, while meeting today's needs to address the implications of our decisions on future generations and the ecosystems upon which they will rely.

As part of its mission, the SWRR also developed a framework for tracking and understanding changes to the health of its fresh and coastal waters, surface and ground water, wetlands and watersheds. We also worked on a methodology to understand the implications of long-term changes for ecosystems, communities, and industry.

In developing its framework, the SWRR asked its members two key questions: How can we define the most important water issues, and how can we determine indicators suitable for tracking these issues over time?

Water issues are broad and diverse. Water quality and availability issues can include water budgets for very large regions as well as surface and ground water supplies at the local level. Water quality issues include physical, chemical and biological concerns that are interconnected and complex. This complexity is compounded by extreme hydrologic events represented by floods and droughts. Water use issues also illuminate the competition between human needs (such as agriculture and public water supply), and the needs of fish, wildlife and flora.

Water sustainability is characterized by the capacity of water resources to meet human and ecosystem needs both in the present and over the long-term. Only by monitoring and understanding changes in the system can we tell if we are on the right track; if not, we must be able to take action to maintain capacities and reduce risk. A water budget may provide a useful model that focuses on the water itself. A water budget provides an accounting of the amount of water that flows into a given watershed and is taken out for various purposes. It may also account for the extent to which allocation of water meets or exceeds availability. A sophisticated water budget would illustrate how factors critical to water quality and quantity, such as climate change, impact natural resources and social systems. Appendix A contains a theoretical water budget.

What Are Indicators of Sustainability?

> *Indicators are natural, everywhere, part of everyone's life. Intuitively we all use indicators to monitor complex systems we care about or need to control. Indicators are a necessary part of the stream of information we use to understand the world, make decisions, and plan our actions.*
>
> *What do you keep an eye on, to be sure your home or workplace or community is in good shape? What would you ask about a place you might move to, to find out if you would like to live there? What would you want to know about your society fifty years from now, to be sure your grandchildren are living good lives?*
>
> *Indicators and Information Systems for Sustainable Development* by Donella Meadows, September 1998

As Donella Meadows eloquently describes, indicators are a natural part of life. They help us think about the long-term implications of our actions. By identifying key factors of complex phenomena, they help us understand complex systems and system interconnections. They help us realize what outcomes are likely to be sustainable, and where mid-course corrections are needed. Finally, indicators help people develop a common language about the issues that concern them, and to reach out to others about those issues.

At first glance, identifying indicators to achieve the sustainability of water resources might seem a reasonably straightforward task. But consider that water is the universal solvent, that it pervades nearly every place and everything on Earth, and that it is one of life's most essential ingredients. Consider also that sustainability involves the Earth's natural, social and economic systems, and that nothing is sustainable unless it respects the limits of each of these systems and nurtures them.

Contents of this Report

This report describes the preliminary results of the SWRR's efforts to date, which include:

- Development of principles, criteria and indicators to support decision-making;
- Identification of opportunities for collaboration on research needs; and
- Strategies to expand SWRR participation to states, non-profits, academia and corporations.

In addition, the appendices present a discussion of the water budget approach to management, a full list of candidate indicators, and the terms of reference (bylaws) of the SWRR.

The participants in SWRR intend that this report serves as a platform to continue our efforts to identify good information and effective indicators; promote collaboration on research; and increase public awareness about trends in water resources. Collectively, these efforts can support informed water management decisions that lead toward sustainability.

Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land.

Luna Leopold

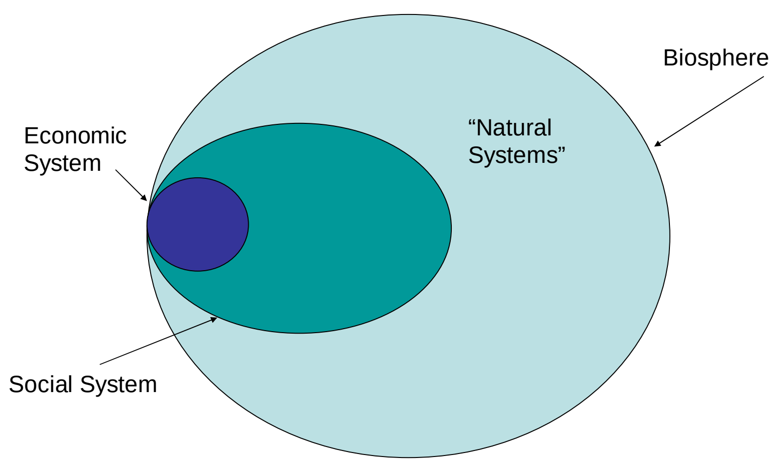
CHAPTER 2 CONCEPTUAL FOUNDATIONS FOR THE SUSTAINABLE WATER RESOURCES ROUNDTABLE

A General Framework for Understanding Sustainability

A set of underlying concepts was developed to guide the work of the Roundtable.[1] This conceptual framework includes two types of concepts: systems concepts and information concepts. Systems concepts are used to represent our understanding of "how the world works." In the case of water resources, systems concepts represent those components and processes in our world by which water moves from place to place, interacts with other components of the biosphere and is used by humans. Information concepts are used to describe ways to organize, communicate and apply information: their importance in identifying criteria and indicators is described in Chapter 3.

Figure 2.1 displays the overall relationships among three major systems (natural, social and economic) encompassed by the concept of sustainability. The Biosphere includes all living things on Earth and the non-living systems with which they interact and on which they depend. In our early work we used the term "Natural Systems" for the ecosystem. The Social System includes all the human elements of the Biosphere. The Economic System is embedded within the Social System. The concept of sustainability as a property of the biophysical system that emerges from interactions between the ecosystem and society is attractive to experts and managers in many fields.

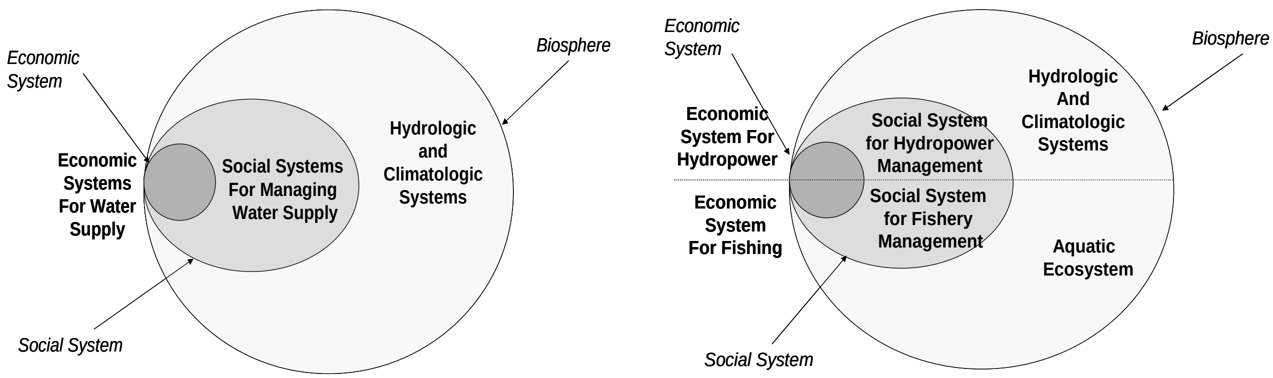
Figure 2.1
General Systems Perspective



One way to use systems concepts to identify effective indicators is to recognize that sustainability can be achieved by maintaining capital or capacities to meet various human and non-human needs within the biosphere. Economists regard capital as the capacity to produce a flow of value over an extended time – value produced by satisfying human needs. Although capital is most often identified with economics, it is also used for other types of analysis. All three systems – natural, social, and economic – produce flows of services, experiences, or goods that meet various needs over time. Thus, all three contain capital. Indicators measure this capital and the direct and indirect impacts caused by changes in capital over time.

Ultimately, our indicator framework should enable characterization of the relations between system processes and impacts on natural and human conditions over time. Figure 2.2 provides examples of the use of the general concepts in Figure 2.1 to describe relationships among the systems involved in producing hydropower and fish.

Figure 2.2
General Systems Perspective
Examples of Hydro and Fish



Major Categories of Indicators

Based on our understanding of the larger context of sustainability, the SWRR held a series of meetings to identify major categories in which to group indicators. Figure 2.3 shows the results.

Figure 2.3
Major Categories of Indicators

I. System Capacities and Their Allocation

2. Consequences of Water Allocation

3. Effects on People

4. Underlying Processes and Driving Forces

These four categories organize indicators logically in accordance with the most generally accepted concepts of sustainability. They include:

1. ***System capacities and their allocation***: Water resources capacities and their allocation to different uses and functions;

2. ***Consequences of water allocation***: The consequences of water allocation, including environmental conditions, and human uses of withdrawn water and water dependent resources;

3. ***Effects on people***: The effects of those consequences on human conditions; and

4. ***Underlying processes and driving forces***: Key processes and driving forces underlying these capacities, allocations, consequences and effects.

A key focus of SWRR's framework is the allocation of water between withdrawals for human use and the water in the environment as it is affected by withdrawals and return flows. The quality of water in the environment is affected by environmental processes, return flows from human uses of water, and the wastes and residuals from human activities. Water resources management determines this allocation which draws upon the capacity of the environmental system to make water available (gross availability) and the capacity of the infrastructure to withdraw and deliver water for various uses

The framework is also based on the concept that many different approaches to sustainability embrace the long-term maintenance of capacities, such as the capacities to meet human needs and the capacities to support life in the ecosystem. They also reflect that water resources management focuses on both human and environmental conditions.

Collectively, the categories resemble an accounting system covering both environmental and human components of water resources systems. They are designed to track important stocks and flows, or, in economic terms, assets and income. Capacities are stocks of water, flow capacities, or assets related to water, whereas water usage and its effects on people and the environment are flows, just as income is a flow. The categories can account for stocks and flows of water and for the human assets and benefits associated with the use of water or water dependent resources. The categories also provide a consistent way of accounting for environmental conditions that result from the interactions of hydrologic and biologic processes and human activities.

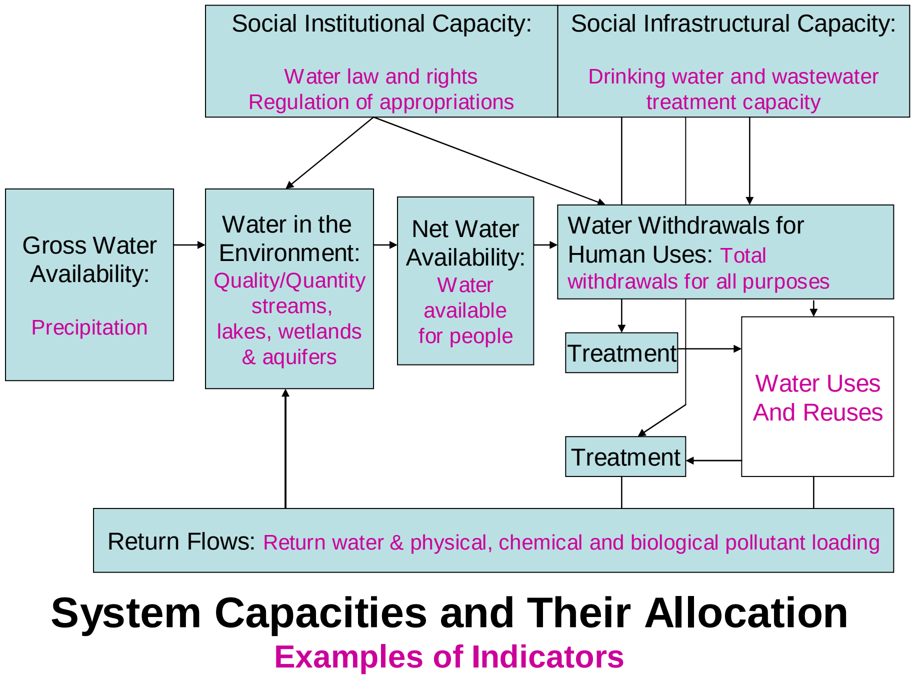
The SWRR's conceptual framework of indicators is not a complete systems model. Instead the framework represents the primary relationships among the four categories of key indicators and is a good way to organize complex information. It is consistent with discussions that have taken place among all four resource roundtables in their respective Integration and Synthesis Groups (ISG). The ISG Framework was developed to provide a basis for integration of indicators from other roundtables and indicator projects.[1]

Each of the four categories and example indicators are discussed below.

Systems Capacities and Their Allocations

Category 1 focuses on the capacities of the hydrologic cycle and human-built infrastructure, as well as social and economic capacities for managing and using water. The capacities and examples of indicators are shown in Figure 2.4

Figure 2.4
System Capacities and Their Allocation, Examples of Indicators

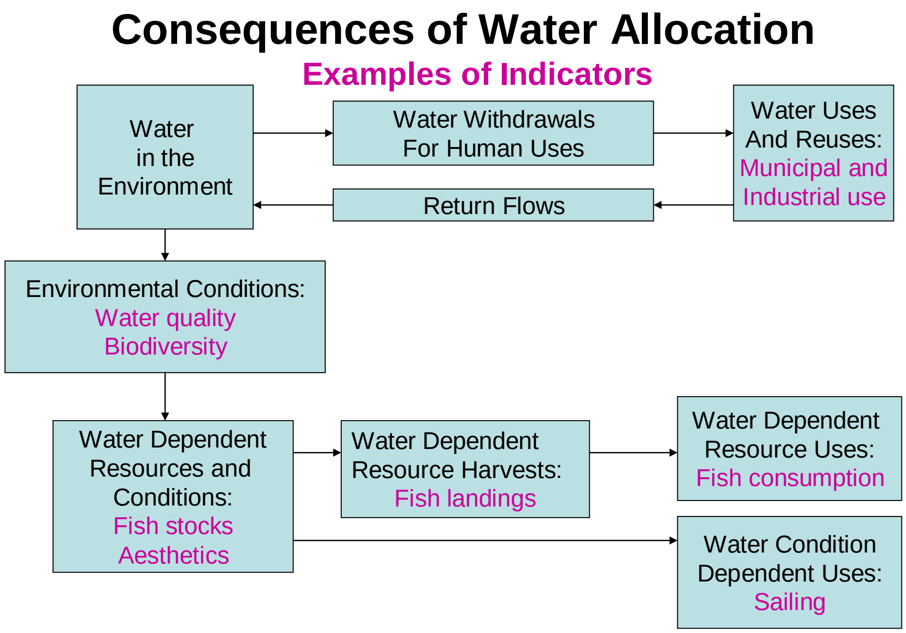


The availability of water for various uses depends on the types of flows that are a part of the hydrologic cycle and on the stocks of water from which humans can draw. In short, this is a water budget approach. A key feature of this category of indicators is the focus on allocation of water to different uses. Human-built capacities to withdraw, treat, transport, distribute and use water and to use it for transportation and recreation would also be addressed in this category.

Consequences of Water Allocation

The second category focuses on the consequences of water allocation for both human uses and the environment. Figure 2.5 shows major components and example indicators.

Figure 2.5
Consequences of Water Allocations, Examples of Indicators

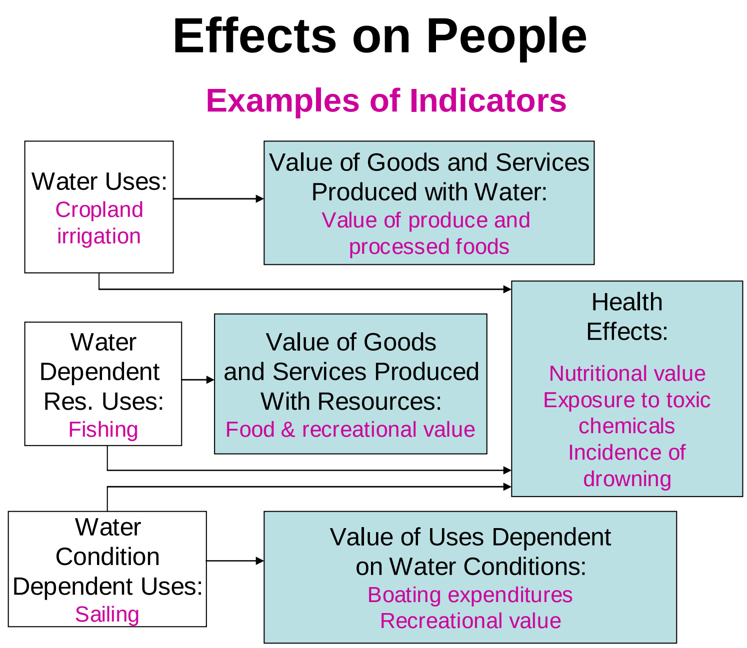


Note that this category includes elements from the first category, such as "Water in the Environment" since it is affected by withdrawals and return flows. Water in the environment is also affected by flows over land surfaces managed or altered by humans. As a result, this category includes both water quality and other environment conditions that are affected by withdrawals, return flows, and discharges of wastes and residuals from human activities. This major category also includes indicators of Water Dependent Resources and Conditions, of Harvests of such resources and their uses, and of the uses that are dependent on in situ water conditions.

Effects on People

While the second category involves measuring the consequences of water allocation in environmental or physical terms, the third category focuses on accounting for the effects on people. These are shown in Figure 2.6 Elements from Figure 2.5 are carried forward into Figure 2.6.

Figure 2.6
Effects on People



Incidence People are affected by their direct use of water for drinking, cooking, and sanitation. They are also affected by their use of a wide range of goods and services produced using water. These include irrigated crops, food products, thermo-electric and hydro-electric power, and a wide variety of manufactured goods. People are also affected by use of water dependent resources that are extracted, such as fish and cranberries. And finally, people are affected by uses of water that depend on its in situ conditions such as recreation and transportation. The indicators in this category focus on the value people experience from uses of water, water dependent resources, and water conditions. They also focus on water-related health effects on people.

Underlying Processes and Driving Forces

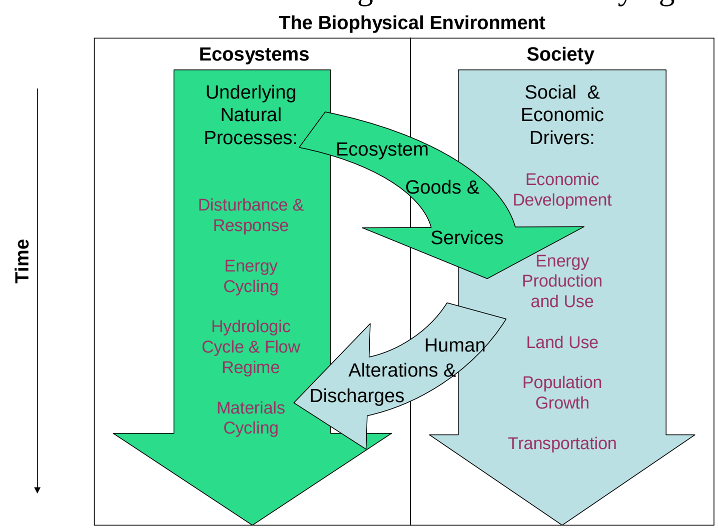
The fourth category recognizes that there are important underlying or driving forces that affect the capacities of water resource systems and the environmental and human conditions that result from those capacities. These include human population and economic growth, land use patterns, residual flows and waste discharges, and climate. It derives from an understanding of systems interrelationships shown in Figure 2.1.

Summary

In summary, the extent to which water resources, as currently managed and used by humans, contribute to sustainability can be assessed by considering trends in the ecological, economic and social capacities and conditions that are related to water resources as well as trends in their short-term contributions to meeting human needs and wants.

The indicators in the major categories outlined by the SWRR can provide the information for good assessments. In general, if important ecological, economic and social capacities that are dependent on, or closely related to, water resources are declining substantially over extended periods of time, it would be important to analyze the causes of the trends to evaluate whether they are driven by the natural variability of the system or by management that does not contribute to sustainability.

Figure 2.7
General Framework for Driving Forces and Underlying Processes



In making such an assessment, it is important to consider that sustainable systems are dynamic and enduring. Therefore, the assessment should identify long-term trends and should consider the extent to which trends of possible concern are being offset, or adapted to, by other elements of the systems. Figure 2.7 is a simplified summary of the Driving Forces and Underlying Processes that make up some of the dynamics of society’s interaction with the biophysical environment that includes some of the main variables such as population growth and land use.

It is also worth noting that care should be taken when good measures of capacity are not available and attention is shifted to measuring either current performance or processes that cause changes in capacity. Because such measures are indirect indicators of capacity, they may not give a realistic picture of capacity trends. For example, some processes on which capacity depends are able to continue at a fairly constant level of performance until a tipping point is reached, after which performance and capacity decline sharply.

As the above models illustrate, relationships among elements of the ecosystem, economic and social system are complex. Population, income, land use, climate change, and energy use are key conditions that affect water allocation. They are major drivers of trends in water supply, demand, quality and therefore sustainability and are so broad that they may be overlooked when the focus is narrowed to a particular indicator related to water. Given our conceptual understanding of the relationships between system processes and impacts on natural and human complex interrelationships, the SWRR developed a list of nearly 400 candidate indicators, which are shown in Appendix C. As a result, the SWRR identified specific criteria to identify a sample of the most effective indicators. These selection criteria are presented in the following chapter.

End Notes

1. 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

2. http://www.sustainableforests.net/docs/ISG%20Progress%20Report%20041101.pdf

> *Water is a vital commodity, common value, and shared responsibility. What continues to change over time, is not the drive to sustainably meet human needs to ensure respective definitions of well-being, but the way we characterize our needs, wants, and desires, and the way we approach our 'work'…sustainable development. Members of the SWRR have served the nation well in developing shared Criteria and Indicators to characterize and frame key conditions and trends of sustainable water resources.*

Albert Abee
National Coordinator Sustainable Development,
USDA Forest Service

CHAPTER 3 SELECTING SUSTAINABILITY INDICATORS

We define indicators as measures that present relevant information on trends in a readily understandable way. Indicators can be presented in the form of numbers, charts, graphs, or maps. Based on the four major categories of indicators, the SWRR initially identified over 400 indicators. These indicators are provided in Appendix C. A critical task of the roundtable was to reduce this to a reasonable number of the most essential indicators. The SWRR settled on 17 indicators using a rigorous selection process.

The SWRR began to identify indicators for achieving sustainable water resources with a systematic set of principles. Fortunately, a group of world-renowned experts had gathered at the Rockefeller Foundation's Study and Conference Center in Bellagio, Italy in 1996 to assess progress in the art and science of sustainability indicators. They met in response to a call by the World Commission on Environment and Development and others for development of new ways to assess progress toward sustainable development. The result was the Bellagio Principles, a set of ten purpose and process factors that guide the development and use of sustainability indicators, which the SWRR adopted at its June 2003 meeting.

The Bellagio Principles

The principles encompass the whole process of community planning and assessment. They cover how indicators fit within a community's planning process, how to choose and design them, and how they can best be interpreted and communicated. The authors specified that the principles are interrelated and should be applied as a complete set. They also intended for the principles to apply to organizations at all levels, from the neighborhood to the nation. Table 3.1 shows the ten Bellagio Principles. These ten principles encompass four elements of assessing progress. The first element (principle 1) is the starting point of any assessment – a vision of sustainable development and clear goals for achieving that vision. The second element (principles 2 through 5) concerns indicator content. The third element (principles 6 though 8) deals with process issues. The fourth element (principles 9 and 10) addresses the need to establish a continuing capacity for assessment.

Table 3.1
The Bellagio Principles

1. GUIDING VISION AND GOALS
Assessment of progress toward sustainable development should:
- Be guided by a clear vision of sustainable development and goals that define that vision

2. HOLISTIC PERSPECTIVE
Assessment of progress toward sustainable development should:
- Include review of the whole system as well as its parts
- Consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of that state, of their component parts, and the interaction between parts
- Consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms

3. ESSENTIAL ELEMENTS

Assessment of progress toward sustainable development should:

- Consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over-consumption and poverty, human rights, and access to services, as appropriate
- Consider the ecological conditions on which life depends
- Consider economic development and other, non-market activities that contribute to human/social well-being

4. ADEQUATE SCOPE

Assessment of progress toward sustainable development should:

- Adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short term decision-making
- Define the space of study large enough to include not only local but also long distance impacts on people and ecosystems
- Build on historic and current conditions to anticipate future conditions - where we want to go, where we could go

5. PRACTICAL FOCUS

Assessment of progress toward sustainable development should be based on:

- An explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria
- A limited number of key issues for analysis
- A limited number of indicators or indicator combinations to provide a clearer signal of progress
- Standardizing measurement wherever possible to permit comparison
- Comparing indicator values to targets, reference values, ranges, thresholds, or direction of trends, as appropriate

6. OPENNESS

Assessment of progress toward sustainable development should:

- Make the methods and data that are used accessible to all
- Make explicit all judgments, assumptions, and uncertainties in data and interpretations

7. EFFECTIVE COMMUNICATION

Assessment of progress toward sustainable development should:

- Be designed to address the needs of the audience and set of users
- Draw from indicators and other tools that are stimulating and serve to engage decision-makers
- Aim from the outset for simplicity in structure and use of clear and plain language

8. BROAD PARTICIPATION

Assessment of progress toward sustainable development should:

- Obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women, and indigenous people - to ensure recognition of diverse and changing values
- Ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action

9. ONGOING ASSESSMENT

Assessment of progress toward sustainable development should:

- Develop a capacity for repeated measurement to determine trends
- Be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently
- Adjust goals, frameworks, and indicators as new insights are gained
- Promote development of collective learning and feedback to decision-making

10. INSTITUTIONAL CAPACITY

Continuity of assessing progress toward sustainable development should be assured by:

- Clearly assigning responsibility and providing ongoing support in the decision-making process

- Providing institutional capacity for data collection, maintenance and documentation
- Supporting development of local assessment capacity

The SWRR Criteria

The roundtable adapted and condensed the Bellagio Principles to establish five criteria for identifying, organizing, evaluating and choosing appropriate indicators. Because the Bellagio Principles encompass the whole process of community planning and assessment, and because the SWRR required selection criteria for a much narrower purpose, the roundtable decided to establish its own, smaller set of guiding principles. The roundtable adapted and condensed the Bellagio Principles to establish five criteria. These criteria provided guidance on: 1) what indicators should describe; 2) what makes them relevant; 3) how they should address time horizon and scale; 4) what's needed to make them realistic and defensible; and 5) the importance of their being easily understood. Table 3.2 lists the five criteria.

Table 3.2
SWRR Criteria for Selecting Indicators

Criteria for identifying, organizing, evaluating and choosing appropriate indicators

1. DEFINING THE STATE OF THINGS
Indicators must consider the condition and capacity of social, ecological and economic systems, including:
- System condition and capacity
- Direction and rate of change
- Interactions across systems and system parts

2. RELEVANCE
Indicators must focus on what's most relevant to sustainability (things of both current and long-term consequence to the well-being of ecological, social, and economic systems).

3. APPROPRIATE TIME HORIZON AND SCALE
Criteria and indicators must adopt a time horizon long enough to capture both human and ecosystem time scales, thus responding to the needs of future generations as well as those of short-term decision-making. They also must define a space of study large enough to include local- and long-distance impacts on people and ecosystems.

4. INDICATOR INTEGRITY
Indicators must be measurable, unbiased, and scientifically defensible; geographically located and differentiated; and at some point, supported by available data. They also should possess a short lag time between the state of affairs referred to and the ability to measure the indicator.

5. UNDERSTANDABILITY
People must be able to "get it" or the indicator will have little value.

Defining the State of Things

The SWRR criteria ask that sustainability indicators define the condition and capacity of water-related social, ecological and economic systems, and that they address not only system condition and capacity, but direction and rate of change of these systems and interactions across system parts.

Each recommended indicator, whether it's the total amount of water available in a watershed or the amount of water needed to sustain biological systems, should allow people to track its direction and rate of change over time. The indicator should also illuminate cause-and-effect relationships. In other words, the system of indicators the SWRR recommends must look at condition and capacity as it evolves over time, and must gather the information necessary to understand not only what's happening, but why.

Relevance

It is easy to get trapped into thinking that what we measure is important *because* we can measure it. This SWRR criterion asserts that we must focus on those factors that are relevant to both the current and long-term well-being of social, ecological and economic systems. This isn't an easy task, since we may not always know what's really of long-term consequence. But it's useful to pause and ask whether a measure has much chance of being important 25, 50 or 150 years from today. Asking this question helps distinguish the noise from the music.

Time Horizon and Scale

Time and geographic scale pose complicated issues for indicator design. Because sustainable development means meeting today's needs as well as those of the indefinite future, indicators must record information that is, or is likely to be, important both today and well into the future.

But this factor also recognizes that some variables change slowly over decades or centuries. One example is the succession of a disturbed forest ecosystem, which may take hundreds of years to evolve from pasture and pine forest to its ultimate climax state of a hardwood forest. In this example, potential indicators tracking changes in that plot of land should measure parameters that might indicate important changes in the future, as well as what seems important today.

The geographic side of scale imposes similar considerations. In particular, people need to look at a large enough picture to fully understand what's going on. For example, a community might get a false sense of the sustainability of its actions if it didn't consider the effects of importing water on the basin of origin, as well as the receiving watershed.

Geographic scale brings another set of issues that affect indicator design and selection: how society organizes itself to meet needs. People have generally organized governments along political boundaries with only a passing connection to natural systems. And yet sustainable development requires the understanding and thoughtful interplay between natural and political systems. As a result, indicators need to present information in both formats.

Indicator Integrity

For an indicator to be effective, its quality, source and reliability – in short, its integrity – must be scientifically defensible. Otherwise, people won't trust it. The integrity of an indicator must be perceived as being "above the fray" to insulate it from criticisms of special interests who may deny the trend it suggests and oppose the decisions it implies.

In addition to being scientifically defensible, a good indicator tells people in various regions (i.e., at various scales) information of importance to them. This suggests that, where possible, information should be geographically located or mapped. It also suggests that people be able to assemble the indicator with sufficient speed that its message to those who can do something about it arrives in a timely manner.

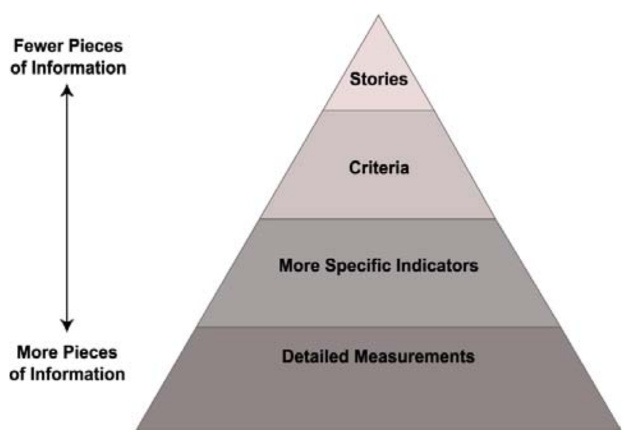
Finally, the SWRR argued that, at some point, sufficient data be available to support the indicator. It goes without saying that sound data is essential to a good indicator. But it's also important that the best indicator not be ignored because supporting data is not yet available. There are many gaps in availability of data on water. In some cases data is proprietary to private land owners and not available. Given all of this, the SWRR wanted to present the indicators it believes should be adopted, even when the data to support them has yet to be collected.

Understandability

A good indicator sends society an important signal. It tells the story that needs telling. Further, to become part of a story and to have informative value, people must be able to "get it." That's a challenge as often in presentation and packaging as in the collection and management of data.

The Information Pyramid in Figure 3.1 shows a general concept that has become well accepted as a basis for developing environmental indicator systems.[1] It shows a hierarchical arrangement with relatively general and simple stories that most people can absorb at the top and increasing detail, specificity and complexity at successively lower levels in the pyramid. The pyramid metaphor is based on the idea that there are more building blocks, more pieces of information, in the lower tiers of the pyramid.

Figure 3.1
Information Pyramid



At the top of the Information Pyramid is the most widely communicated form of information, relatively simple stories that are told in various media. Such stories can be developed by interpreting more detailed criteria and indicators that are produced using data from measurements. Data from measurements is the most detailed form of information and tends to be used mostly by experts.

Criteria are more general and less detailed than indicators. The SWRR identified three types of criteria:

- A specific target that is accepted as a threshold of success for an objective.
- A generally desirable direction of change for a category of phenomena.
- A general category of phenomena for which society may later specify the desirable direction of change or a specific target.

Three concrete examples illustrate these three types of criteria:

- Criteria as target: 10% increase in water for irrigation.
- Criteria as direction of change: Increase water for irrigation.
- Criteria as category for potential directional goal or target: water for irrigation.

At this juncture, the third approach might be best suited to the SWRR's goal. The second approach was used in the Forest Roundtable's identification of the "Criteria and Indicators for Conservation and Sustainable Management of Temperate and Boreal Forests." The second, directional or targeted approach, often encounters controversy because of peoples' different values and desired outcomes. However, consensus on specific targets may emerge from ongoing discussions within our roundtable.

Given the hierarchy of information, the SWRR also identified three views of the roles and uses of indicators:

- Assessment, Diagnosis, Prognosis, Prescription, Treatment, Reassessment
- Policy-Making, Forecasting and Evaluation, and Management
- Research and Education

The first view distinguishes between information on conditions (assessment), information that can explain the causes of observed conditions (diagnosis) and information that forecasts future conditions (prognosis). As we know from our experience with the health care system, different types of information are used to perform these different functions. In particular, health assessment uses a relatively small number of indicators of overall health, while diagnosis uses more detailed and specific information about the causes of illness. These differences reflect both the costs of acquiring and using various types of information and the effectiveness of different measures.

The second view takes a management perspective. Here too, different types of information are useful in performing different functions. High-level policy and resource allocation decisions tend to be based on more general information, while operational management uses more detailed, often spatially specific, information.

Research and education produce and communicate knowledge of how systems work. Such information is often very detailed and specialized, although in education it is often simplified. The knowledge developed by research often includes improved understanding of the causal relationships among the components and subsystems of a system. The interpretation of indicators to assess and diagnose water resources sustainability can be improved by such research.

One common aspect of all three views is the role of information as feedback in a cyclical process of decisions, actions, observation of consequences, decisions, etc. In health care, treatment is accompanied by feedback from monitoring and continued assessment of the patient's condition. In policy and management, feedback is used in performance measurement, program and policy evaluation, and monitoring of management practices. In research, observation provides feedback on the validity of hypotheses. In all these contexts, continual improvement occurs as feedback promotes learning and evolution. Indicators for sustainable water resource management can also facilitate feedback in order to promote more effective learning and evolution of policies and management practices.

Conclusions about Sustainability Indicators

Sustainability indicators tell us "where we are" in the quest for short- and long-term equilibrium between social, economic and ecological needs. They highlight important trends and help us begin to evaluate their causes and effects. They educate people and build awareness about the challenges we face. They give us a common language that allows us to share a deeper understanding of issues and forge the collective responses that every level of society must take.

The roundtable believes that effective indicators will enable people in every watershed and every community to gain new understanding and tools to make good decisions. And perhaps more than anything else, an informed citizenry will give the nation the best chance to ensure that its management of water-related resources is sustainable. As Donella Meadows emphasizes in her work on indicators for sustainable development:

> *It's easy enough to list the characteristics of ideal indicators. It's not so easy to find indicators that actually meet these ideal characteristics…. (But) despite their difficulties and uncertainties, we can't manage without indicators.*

The next chapter presents the 17 indicators identified by the SWRR for the four major categories of indicators discussed in the previous chapter.

End Notes

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CHAPTER 4 THE SWRR INDICATORS

The SWRR framework of indicators encompasses the following set of categories/subcategories for key indicators. For each of the 17 candidate indicators, we provide the following information:

- What is the indicator?
- Why is the indicator important?
- What does the indicator show?

A. **System capacities, quality and allocation:** Capacities are the amounts (e.g., flow rates) and quality of water available in nature and the related ability to allocate water among various human uses through social and economic processes.

1. **Gross water availability**. An estimate of the total amount of renewable water supply in the natural system

2. **Total withdrawals for human uses.** A measure of the total water withdrawn for use by people

3. **Water in the environment**. A measure of the water remaining in the environment after withdrawals and consumption

4. **Water quality**. A representation of the quality of water in the environment

5. **Total capacity to store, deliver, and treat the water supply over unit of time** (i.e., infrastructure capacity). By basin, watershed or aquifer, estimations of:
   - Public supply, private supply
   - Irrigation
   - Industrial/commercial
   - Thermo-electric
   - Capacity for treatment of return flows in municipal waste streams

6. **Social and organizational capacity**. Measures of the capacity of society and its organizations to manage water sustainably, including:
   - Number of organizations dedicated to water and water-related education
   - Number of states active in statewide comprehensive water planning
   - Numbers of states with regulations providing equal protection and access by all sectors to water resources
   - Numbers of states with emergency rules in place that address human preparedness, resistance and resilience to/from/with water problems and disasters

B. **Consequences of the way we allocate water capacity:** Allocations result in the flow of water to various human uses and water remaining in the environment.

7. **Environmental conditions.** Indices of the biological, chemical and physical conditions of the environment, including:

- Index of biological integrity
- Extent of eutrophication (chlorophyll a, organic carbon)
- Contaminant body burdens in biota (or contaminant burdens in excess of health advisory triggers)
- Water quality impacts (need composite index or method) (plankton biodiversity index by water body type, since plankton=base of food chain)
- Extent of altered wetlands (acres or % wetlands converted)
- Extent of altered river flow (e.g. due to impoundment or levee constraints)

8. **Resources and conditions**. Characterization of the amounts and quality of resources supported by water, including:

- Total availability of waters of suitable quality to maintain recreational uses
- Toxics body burdens and population changes in fish and birds

9. **The quality and quantity of water for human uses.** Measuring the quality and quantity of water used in different sectors, including:

- Quantity of water used for public supply: per capita use of water (would need total population)
- Quantity of water used for irrigation: per acre use of water for irrigation (by major crop type)
- Quantity of water used for industrial & commercial purposes: usage per day per employee (or per ton of finished product; or per unit produced)
- Quantity of water used for thermo-electric power generation: per unit of power generated, or consumptive use per unit of power generated
- Populations served by community water systems (drinking water measure) that meet all health-based standards
- Hydro-electric output per unit flow

10. **Resources withdrawals and use.** Uses of resources that depend upon water in the ecosystem, including:

- Uses of harvested resources (e.g. consumption of fish, oysters, crabs, cranberries or other resources); numbers of sport fishing, water fowl hunting licenses sold annually
- Uses of non-harvested water dependent resources (e.g. water-based recreation days); boat, water craft sales/licenses sold; marine fuel sales, non-sport birding surveys)

C. **Effects on people of the conditions and uses of water resources:** Flows of water in the environment affect water dependent resources and the environmental conditions for humans.

11. **Human conditions**. Measures of the value people receive from the uses of water and the costs they incur, including:

- Value of goods and services related to uses of water withdrawn (e.g. public supply, etc.)

- Value of use of non-harvested water dependent resources (e.g. recreation days)
- Value of uses of harvested resources (e.g. fish value or cranberry value)
- Human health conditions related to water resource use/exposure

D. **Important factors affecting water resources:** People use land, water and water dependent resources in ways that affect the conditions of ecosystems and human life.

12. **Land use.** Measures of the important elements of land use that affect water quality and quantity, including:
    - A GIS-based presentation of land cover elements, including information on impervious surfaces, stream crossings, point and non-point sources, etc.

13. **Residual flows.** An accounting of the flow of water and wastes back into the water system, including:
    - Loading from point sources (chemical and biological pollutants)
    - Loading from non-point sources (chemical and biological pollutants)

14. **Social and economic processes.** Measures of the systems people and organizations develop to influence water resources and sustainability, including:
    - Water pricing (e.g., full-cost basis for pricing)

15. **Ecosystem (environmental) processes.** Measures of ecosystem system processes that govern water resources and sustainability, including:
    - Net Ecosystem Productivity – carbon flux over time per unit area

E. **Composite sustainability assessment:** These indicators combine or otherwise integrate some of the above indicators. Although more thought needs to be given here, we suggest two indicators. Each should be GIS based and designed for presentation at watershed, regional, state or national levels.

16. **Water use sustainability.** In each watershed, show the ratio of water withdrawn to renewable supply.

17. **Water quality sustainability**. In each watershed, indicators of the suitability of water quality for the uses desired, including ecosystem uses.

Indicator #1: Gross Water Availability

What is This Indicator?

This indicator reports the total amount of renewable water supply in the natural system. Different approaches have been used to quantify gross water availability, but all approaches require measurements (or estimates) of one or more of the water-budget components illustrated in Appendix A.

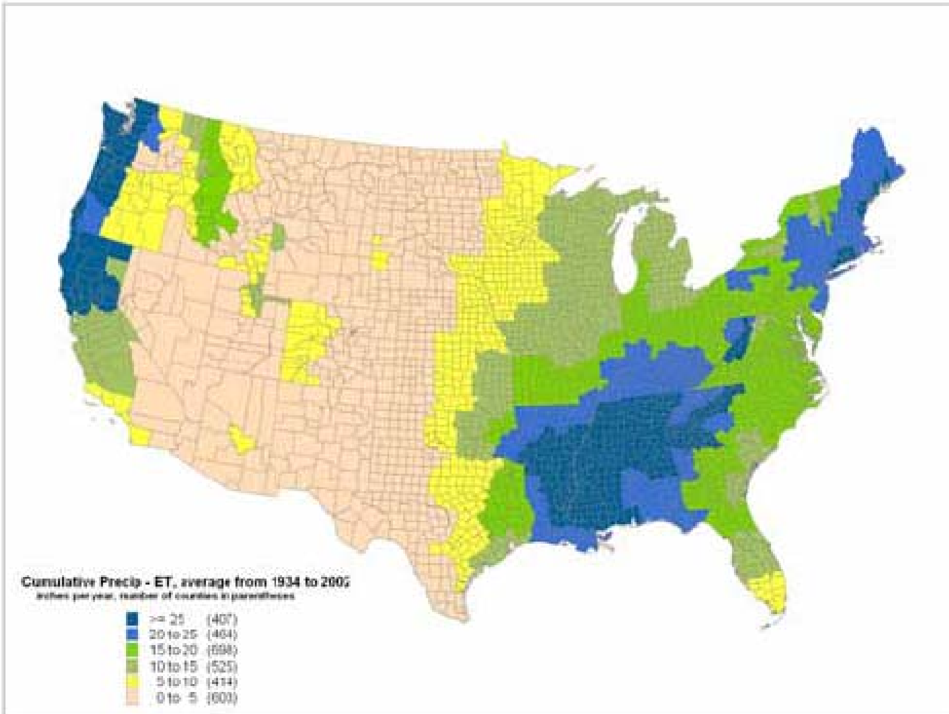
One of the simplest approaches is to quantify the mean annual surface and sub-surface (shallow aquifer) runoff, accumulated as river discharge.[1] Another approach defined the *renewable supply* in a region as the amount of available precipitation, which is shown in Figure 4.1.1.[2] Available precipitation is defined as the difference between precipitation and potential evapotranspiration totaled for all months in a year when precipitation exceeds potential evapotranspiration.

The U.S. Geological Survey defined the renewable supply of water within a watershed as the sum of precipitation and imports, minus natural evapotranspiration and exports.[3] They also showed that renewable supply could, alternatively, be determined as the sum of surface-water outflow and consumptive use minus the long-term depletion of ground-water storage in a watershed. The USGS noted that although renewable supply represents the flow that is theoretically available for use in a watershed on a permanent basis, it is actually a “simplified” upper limit to the amount of water consumption that could occur in a region on a sustained basis. It is simplified in the sense that the variables involved—precipitation, imports, natural evapotranspiration, and exports—are subject to change due to natural causes and human intervention. Moreover, where there are legal and institutional requirements to maintain minimum flows in streams to enable uses such as navigation, hydroelectric power generation, fish propagation and habitat, the actual amount of available water is reduced to an amount that might be defined as *net water availability*.

An important yet unresolved issue concerns how to measure and report the variability of gross water availability over both short and long periods of time. Although the amounts of water that are available for average hydrologic and climate conditions are important, many additional issues in water sustainability are concerned with the availability of water over a wide range of hydrologic conditions extending from very low-flow conditions to very high-flow conditions. As a result, an indicator (or indicators) of gross water availability should reflect how the variability of water availability changes with time. Work remains to determine statistical measures of the variability of gross water availability that provide meaningful information to decision-makers and the public.

Water, water, everywhere, Nor any drop to drink.
The Ancient Mariner. Part ii. Samuel Taylor Coleridge (1772–1834)

Figure 4.1.1
Available Precipitation (difference between monthly precipitation and potential evapotranspiration) across the United States based on 1934-2002 average data at the climate division level.



(Source: Figure from S. Roy, K. Summers and R. Goldstein, using USGS data, paper presented at SWRR meeting at EPRI, Palo Alto, March 2004)

Why is it Important?

Gross water availability is important because it is the foundation for understanding the quantities of water that are available for human and ecosystem uses and how those quantities vary over time.

What Do the Data Show?

Nationwide, the renewable supply of water (precipitation less evapotranspiration) is much larger than the rate of consumptive use.[4] From a national perspective, therefore, water resources appear ample. Locally, however, the situation varies widely. Much of the western U.S., except some coastal areas, has far lower water availability than the eastern U.S. In the eastern states, water availability is lower in regions with higher potential evapotranspiration, such as south Florida.[5] Overall, these results are consistent with those of the USGS using 1980 data and updated by Alley using 1995 data. Alley notes, however, that these maps can suggest a relative abundance of water in regions that actually face challenging water-availability issues. He cites as an example the South Atlantic-Gulf region, an area with so-called "water wars" among competing in the courts for allocations of water from sources that cross boundaries.

End Notes

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2. Roy, S.B., Ricci, P.F., Summers, K.V., Chung, C.F., and Goldstein, R.A., 2005, Evaluation of the sustainability of water withdrawals in the United States, 1995-2025: submitted for publication.

3. U.S. Geological Survey, 1984, National water summary 1983—Hydrologic events and issues: U.S. Geological Survey Water-Supply Paper 2250.

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5. Roy et al, *op. cit*.

The life in us is like the water in the river. It may rise this year higher than man has ever known it, and flood the parched uplands; even this may be the eventful year, which will drown out all our muskrats. It was not always dry land where we dwell. I see far inland the banks which the stream anciently washed, before science began to record it freshets.

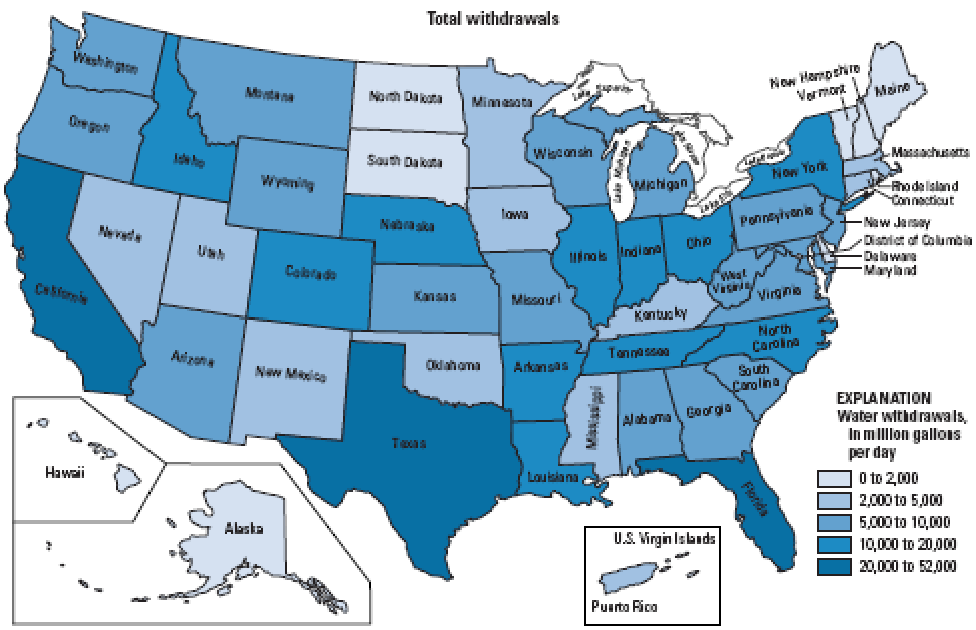
— *Henry David Thoreau, 1854, from "Walden*

Indicator #2: Total Water Withdrawals for Human Uses

What Is This Indicator?

This indicator reports the total amounts of surface water and ground water that are withdrawn from the natural system for human uses. The indicator includes both fresh water and saline-water withdrawals. The U.S. Geological Survey (USGS) has collected withdrawal data at five-year intervals since 1950 (Figure 4.2.1). The USGS data show how total amounts as well as the relative amounts withdrawn from surface water and ground water change over time for a given location. The USGS collects data at the county level, but reports the totals for each state. The data could also be aggregated to estimate withdrawals by river basin or sub-basin.[1]

Figure 4.2.1
Total water withdrawals for the United States, 2000[2]



Why Is This Indicator Important?

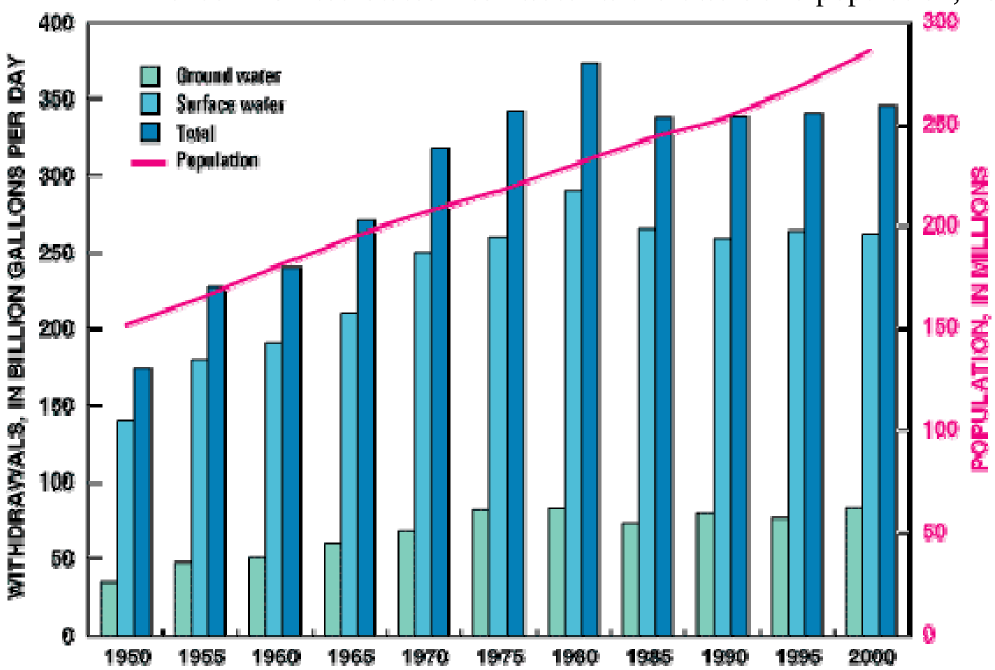
This indicator shows how human needs and uses impact total water availability as well as other measures of water resource sustainability (see also Indicator 16 on water use sustainability).

What Do the Data Show?

Total surface water and ground water withdrawals in the United States were about 408 billion gallons per day (Bgal/d) in 2000. Approximately 85 percent came from fresh water sources; fresh surface water withdrawals were 262 Bgal/d and fresh ground water withdrawals were 83 Bgal/d. California had the largest total withdrawals (51.2 Bgal/d).

Total withdrawals of water in the United States increased steadily from 1950 to 1980, and then declined more than 9 percent from 1980 to 1985. Withdrawal totals have varied by less than 3 percent between the 5-year intervals since 1985 (Figure 4.2.2). Although the population of the United States has steadily increased over the past 50 years, withdrawals have remained relatively stable since 1985 because withdrawals for the two largest uses of water—thermoelectric power and irrigation—have stabilized (see also Indicator 9 on the quality and quantity of water for human uses).

Figure 4.2.2
Trends in United States fresh water withdrawals and population, 1950-2000[3]



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2. Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated Use of Water in the United States in 2000: U.S. Geological Survey Circular 1268, 46 p.

3. Ibid.

Indicator #3: Water in the Environment

What is This Indicator?

This indicator reports the flows and storage volumes of water in the environment. The data needed to support these indicators are partially available at this time. Streamflow data are collected as part of the National Streamflow Information Program of the USGS.[1] The USGS currently operates about 7,000 streamflow gauges, which would provide a substantial database. Data networks to support ground-water level indicators are not as well established. Although there are approximately 42,000 long-term observation wells in the United States that have five or more years of water-level records, there is no nationwide, systematic ground-water level monitoring program to support a water-resources indicator program.[2] The USGS does maintain a smaller network of about 140 wells to monitor the effects of droughts and other climate variability on ground-water levels.[3] Additional sources of hydrologic data that would be useful for monitoring water in the environment include data on the storage content of many of the nation's largest reservoirs reported by the U.S. Bureau of Reclamation,[4] and the data for approximately 76,000 dams maintained by the U.S. Army Corps of Engineers.[5]

As with several of the other indicators related to water flow, an important yet currently unresolved issue concerns how to measure and report the variability of hydrologic conditions over both short-term and long-term periods. Many SWRR participants have recommended that streamflow conditions should be reported for a range of flows that extend from very low-flow to very high-flow conditions, and not simply reported for the annual mean flow. Work remains to determine the most appropriate range of flow and storage conditions to monitor and report.

Why is This Indicator Important?

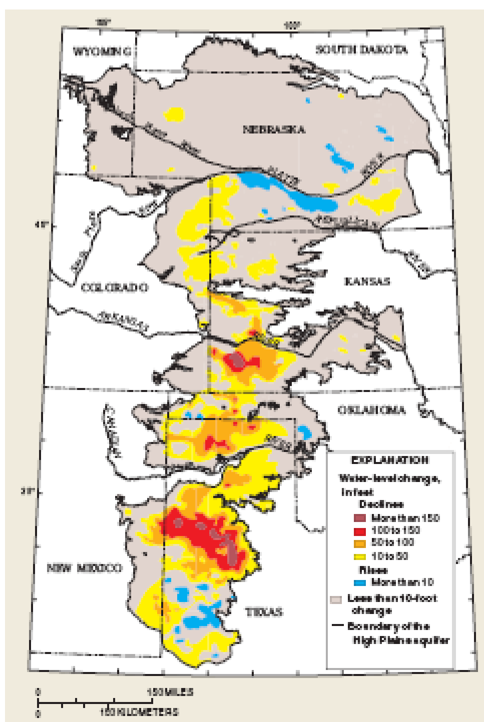
This indicator is important for determining how much water is currently available in our rivers, lakes, reservoirs, and aquifers, and how these flow rates and storage volumes are changing in response to natural variation and human intervention. This water supports the needs of all forms of life living in the ecosystem and is a resource for future human uses.

What Do the Data Show?

Changes in the hydrologic regime of a watershed result from natural causes and human actions. One of the primary benefits of information networks that collect hydrologic data over long periods of time is that they provide the data to document these changes and inform management decisions. Recently, several studies have used the Hydro-Climatic Data Network streamflow dataset to evaluate changes in streamflow across the nation. This dataset, developed by the USGS, consists of streamflow data collected at more than 1,500 gauging stations at sites that are relatively free of human influences. These studies indicate an upward trend in the lower and moderate streamflows in parts of the U.S. since the late 1930s, yet do not show statistically significant increases in higher streamflows.[6,7,8]

Withdrawing groundwater from wells creates a cone of depression and a reduction in water pressure and water levels. If recharge is enhanced by pumping, there may be no long-term reduction in the amount of water stored in an aquifer, and water-levels can rebound when pumpage is reduced or terminated. On the other hand, if groundwater is removed from an aquifer at a rate greater than it can be recharged, resulting in ever-lowering groundwater levels, then groundwater is mined and the amount of water stored in the aquifer is reduced permanently. In addition to reducing the amount of water that is stored in an aquifer, ground-water depletion can reduce surface-water flows, cause land subsidence, or lead to a deterioration of ground-water quality, particularly in coastal aquifers that are susceptible to saltwater intrusion.[9] Ground-water depletion occurs at scales ranging from a single well to regional aquifer systems underlying several states. One of the best documented examples of regional ground-water depletion occurs in the High Plains aquifer, where ground-water withdrawals, primarily for irrigation, have caused large-scale declines of the water table and accompanying reductions in ground-water storage (see Figure 4.3.1). In response to these declines, in 1988, Federal, state, and local water-resource agencies collaborated to implement a monitoring program to assess annual changes in ground-water levels.

Figure 4.3.1
Changes in ground-water levels in the High Plains aquifer from before ground-water development to 1997[10]



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3. U.S. Geological Survey, 2005b, Ground-water climate response network: information and data available online at http://groundwaterwatch.usgs.gov/

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9. Bartolino, J.R., and Cunningham, W.L., 2003, Ground-water depletion across the Nation: U.S. Geological Survey Fact Sheet 103-03, 4 p.

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Indicator #4. Water Quality in the Environment

What is This Indicator?

This indicator provides a representation of the quality of water in the environment. Because of the myriad chemical constituents that can potentially impair water quality, it is clear that this indicator would need to address a large number of constituent types. Therefore, the indicator likely would be a composite indicator that could take one of a number of forms. For example, the indicator might consist of a single value, or index, that synthesizes all of the data into an overall measure of the quality of the water environment, such as "the percentage of streams within a basin that meet all water-quality standards." Alternatively, the indicator might consist of several water-quality measures shown together in a single summary graphic (such as a star diagram, or two- or three-dimensional bar charts; see Lane and others, 1999, for examples)[1] or shown separately in a series of maps, graphs, or tables.

Several suggestions were made during the SWRR discussions concerning the specific types of data that should contribute to a composite water-quality indicator. To a large extent, these suggestions were consistent with the data types identified in other environmental indicator initiatives, such as the Heinz Center's *State of the Nation's Ecosystems*[2] and U.S. EPA's *State of the Environment*.[3] These data types include nutrients (such as nitrogen and phosphorus concentrations); dissolved oxygen levels; bacterial measures; and pesticides, volatile organic compounds, and other chemical contaminants.

Why is This Indicator Important?

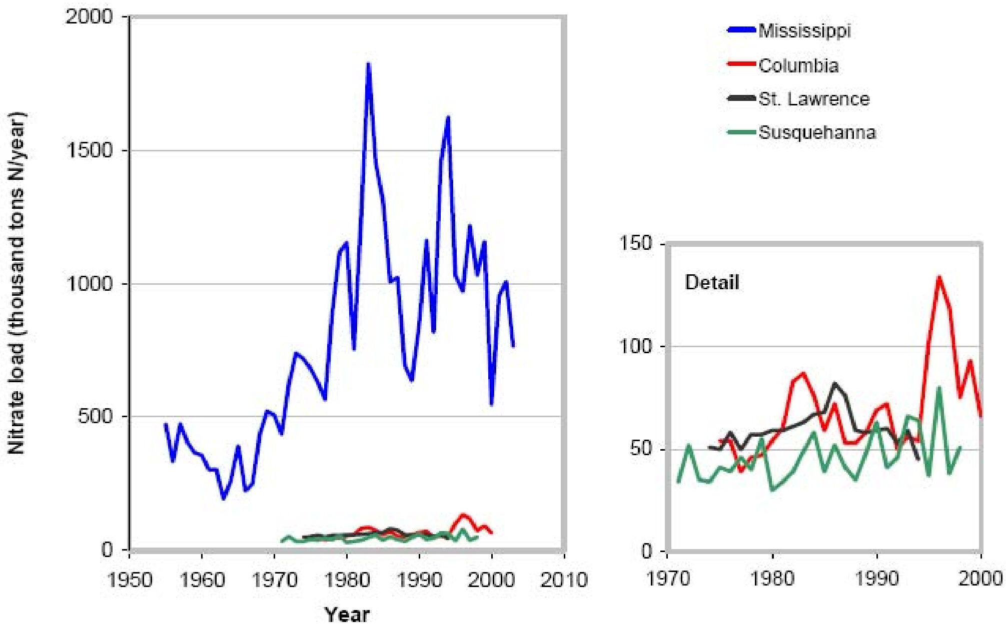
Water quality is critical to the health of human beings and ecosystems.

What Do the Data Show?

One of the most important measures of the water quality conditions of a stream or lake is the concentration of nitrogen. Nitrogen is a critical nutrient for plants and animals and a key indicator of ecosystem function. Excess nitrogen concentrations may indicate a decline in the ability of watersheds to assimilate point and non-point and atmospheric sources of nitrogen pollutants. The resulting nitrogen may have harmful effects as it moves downstream to coastal ecosystems. An indicator of nitrogen in the water environment has been prepared for the Heinz Center and EPA indicator initiatives using stream flow and water quality data collected by the USGS. The indicator tracks trends in the discharges of nitrate from the four largest rivers in the United States: the Mississippi, Columbia, St. Lawrence, and Susquehanna. While not inclusive of the entire nation, these four rivers account for approximately 55 percent of all fresh water flow entering the ocean from the lower 48 States.

The amount of nitrate carried by two of the four rivers covered in this indicator increased for several decades peaking in the early 1980s or 1990s. (see Figure 4.4.1). The Mississippi River had the most striking increase in nitrate discharge but has declined in recent years. The Mississippi, which drains more than 40 percent of the area of the lower 48 states, carries roughly 15 times more nitrate than any other U.S. river. The nitrate load in the Columbia River increased to almost twice its historical loads during the later half of the 1990s, but returned to levels similar to those seen in the 1980s during 2000, the last year of record. Nitrate loads in the Susquehanna and St. Lawrence Rivers do not appear to have shown upward or downward trends during their periods of record.

Figure 4.4.1
Nitrate Load Carried by Major Rivers.[4]



(Source: Figure prepared for the U.S. Environmental Protection Agency State of the Environment 2006 report using data from U.S. Geological Survey.)

End Notes

1. Lane, M.E., Kirshen, P.H., and Vogel, R.M., 1999, Indicators of impacts of global climate change on U.S. water resources: Journal of Water Resources Planning and Management, v. 125, no. 4, p. 194-204.
2. Heinz Report
3. U.S. EPA Report, State of the Environment, 2006.
4. *Ibid.*

Indicator #5: Total Capacity to Store, Deliver, and Treat Water

What is This Indicator?

This indicator reports the ability of the nation's infrastructure to store, deliver, and treat water for human use. The United States has invested enormous resources to build capacity to ensure adequate water supplies despite geographic and seasonal variations in the natural hydrologic cycle. Human water use requires infrastructure that can meet specific needs. These needs include drinking water, irrigation, industry and commerce, navigation, and thermo-electric generation, among others.

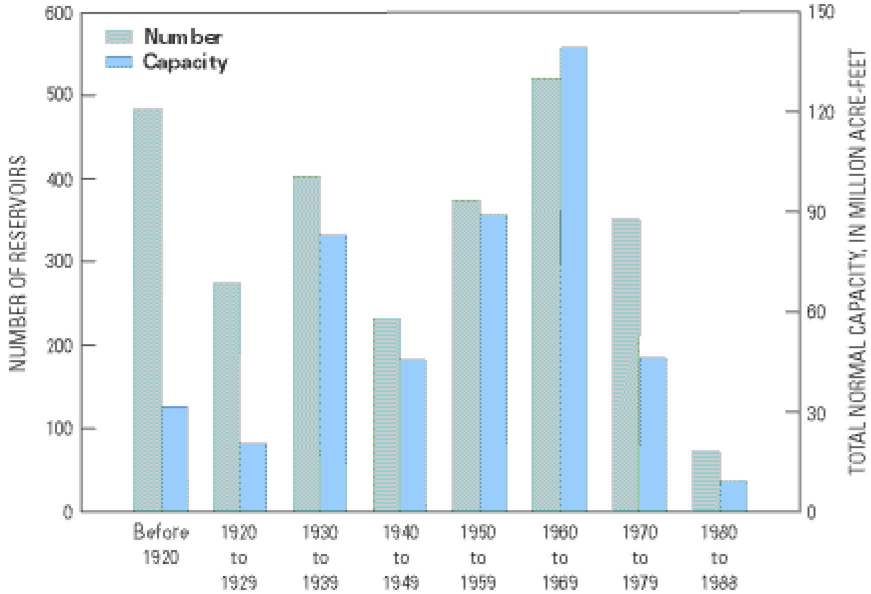
It is important to quantify the available infrastructure in a watershed to withdraw, store, deliver, and treat water for various human needs. These quantities could be reported in units that are consistent with other water budget components of the hydrologic cycle (such as million gallons per day or cubic feet per second). As an example, it's critical that communities know that they have the capacity to withdraw so many Mgal/day from surface-water and ground-water sources, and that they withdraw 50 percent of that capacity on an average day, but 90 percent of that capacity on a peak-demand day. State and local water-resource agencies would likely need to compile this type of data.

Storage

The number and size of reservoirs are important sub-indicators of water infrastructure capacity, particularly surface-water storage. Figure 4.5.1. shows the number and total normal capacity of large reservoirs in the United States and Puerto Rico completed before 1920, during each decade from 1920 to 1979, and from 1980 to 1988. Normal capacity is the total volume in a reservoir below the normal retention level.[1]

Total reservoir storage conditions change in response to variability in the hydrologic cycle, water use, reservoir sedimentation, and reservoir construction and removal. In a 2002 Report to Congress, the USGS recommended that an appropriate assessment of surface-water storage would regularly update reservoir storage conditions and account for construction of new reservoirs, decreases in reservoir storage capacity due to sedimentation, and any removal of dams.[2]

Figure 4.5.1
Number and Capacity of Reservoirs Built Since Before 1920 to 1988



(Source: U.S. Geological Survey, Report to Congress, *Concepts for National Assessment of Water Availability and Use*, U.S. Geological Survey Circular 1223, August 2002)

Treatment

Local water utilities must make significant investments to install, upgrade, or replace equipment in order to deliver safe drinking water and protect public health. Every four years, EPA conducts a survey of the states for anticipated costs of these investments and reports the results to Congress. The results are also used to help determine the amount of funding each state receives for its Drinking Water State Revolving Fund program, which funds the types of projects identified in the survey. Table 4.5.1 shows the total national need by system size and project type as well as by current and future need over the next 20 years.[3] The need includes installation of new infrastructure as well as rehabilitation or replacement of deteriorated or undersized infrastructure. It also includes the need to address aging infrastructure that is adequate now, but will require replacement or significant rehabilitation over the next 20 years.

Table 4.5.1
Total Need by Project Type
(in millions of January 2003 dollars)

System Size and Type	Distribution and Transmission	Treatment	Storage	Source	Other	Total Need	Number of Systems[6]
Large Community Water Systems (serving over 50,000 people)	$89,779.9	$20,091.3	$6,994.5	$4,715.8	$1,270.2	$122,851.7	1,041
Medium Community Water Systems (serving 3,301 to 50,000 people)[1]	$73,454.4	$14,906.2	$9,473.3	$4,392.8	$790.9	$103,017.4	7,638
Small Community Water Systems (serving 3,300 and fewer people)[1,2]	$18,624.3	$6,164.1	$6,263.8	$2,871.0	$248.3	$34,171.5	43,039
Costs Associated with the Recently Promulgated Arsenic Rule[3]		$947.4				$947.4	
Not-for-profit Noncommunity Water Systems[4]	$425.3	$670.2	$1,620.3	$681.0	$0.8	$3,397.5	21,400
American Indian and Alaska Native Village Water Systems[4,5]	$1,347.3	$462.2	$490.3	$135.1	$13.6	$2,448.5	974
Subtotal National Need	$183,631.1	$43,241.4	$24,842.2	$12,795.6	$2,323.7	$266,834.1	
Costs Associated with Proposed and Recently Promulgated Regulations (Taken from EPA Economic Analyses)		$9,927.4				$9,927.4	
Total National Need	$183,631.1	$53,168.8	$24,842.2	$12,795.6	$2,323.7	$276,761.5	

System Size and Type	Distribu-tion and Trans-mission	Treat-ment	Storage	Source	Other	Total Need	Number of Systems[6]

Note: Numbers may not total due to rounding.

[1]Does not include the costs associated with the recently promulgated Arsenic Rule and proposed or recently promulgated SDWA regulation; these costs are included on a separate line in this table.
[2]1999 Needs Assessment findings adjusted to January 2003 dollars and reallocated based on 2003 inventory of small systems.
[3]Does not include costs for American Indian and Alaska native village water systems to comply with the recently promulgated Arsenic Rule; these costs are incorporated in the estimate for American Indian and Alaska native village water systems.
[4]1999 Needs Assessment findings adjusted to January 2003 dollars.
[5]Includes cost for compliance with the recently promulgated Arsenic Rule
[6]Number of large, medium, and small systems is determined from the 2003 Needs Assessment sample frame. Number of not-for-profit, American Indian, and Alaska native village systems is determined from the 1999 Needs Assessment sample frame. The numbers in the 2003 Needs Assessment may differ from the Safe Drinking Water Information System (SDWIS) due to changes in system inventories and the way the 2003 Needs Assessment classifies some systems (i.e., systems that serve Alaska native villages are classified in SDWIS as small systems, but are classified in the 2003 Needs Assessment as Alaska native village water systems).

Other Indicators

The American Society of Civil Engineers (ASCE) periodically issues a progress report on the condition of the nation’s infrastructure, including drinking water, wastewater, dams, and navigable water ways (see Table 4.5.2).[4] In 2003, with the guidance of a 20-member advisory council, ASCE evaluated existing data reports for each category. ASCE determined progress and trends since 2001 by evaluating the infrastructure's condition, performance, capacity, and funding relative to actions taken by policy makers to address issues and problems.

Table 4.5.2
ASCE Progress Report on the Nation’s Infrastucture, 2003

Area	2001 Grade	2003 Trend	Comment
Drinking Water	D	Down	“While drinking water quality remains good, the infrastructure of the nation's 54,000 drinking water systems is aging rapidly. Federal funding remains flat, while the infrastructure needs continue to increase. There is an annual shortfall of $11 billion needed to replace or rehabilitate facilities that are nearing the end of their useful life and to comply with federal water regulations.”
Wastewater	D	Down	“The nation's 16,000 wastewater systems face enormous needs. Some sewer systems are 100 years old and many treatment facilities are past their recommended life expectancy. Currently, there is a $12 billion annual shortfall in funding for

Area	2001 Grade	2003 Trend	Comment
			infrastructure needs; however, federal funding has remained flat for a decade. Because of this continuing shortfall, more than one-third of U.S. surface waters do not meet water quality standards."
Dams	D	Down	"The number of unsafe dams has risen by 23 percent to nearly 2,600. Because of downstream development, the number of "high-hazard potential dams" - those whose failure would cause loss of life - has increased from 9,921 in 2001 to 10,049 in 2003." "Some progress is being made through the repair of small watershed dams constructed with assistance from the USDA since 1948. This is only a small portion of the total number of non-federal dams. On the federal side, the federally-owned dams are in good condition; however, continuing budget restrictions are placing pressure on and limiting many agency dam safety programs."
Navigable Waterways	D+	Down	"Despite the significance of the waterway link to the global economy, national investment in water resources projects has not kept pace with U.S. economic and social expansion." "Half of the navigation locks on inland waterways exceed their 50-year design life. System capacity has been impacted by deferred maintenance, which has led to a doubling of out-of-service times at navigation locks over the last 10 years. Funding shortfalls have delayed completion of many ongoing capital improvement projects by 5 to 10 years, resulting in construction cost increases of $300 million and lost benefits of over $2 billion. The unexpended balance in the Inland Waterway Trust Fund has grown to $360 million."

(Source: American Society of Civil Engineers)

Why is This Indicator Important?

An abundance of water in the aggregate belies increasingly limited water supplies in many regions, reflecting uneven distribution of the nation's water resources. Dam construction, groundwater pumping, and interbasin conveyance provides the water to meet growing human needs. However, future opportunities for large-scale expansion of seasonally reliable water supplies are limited due to lack of project sites, reduced funding, and other social and economic factors. Future water needs will increasingly be met by reallocation of existing supplies.[5]

What Do the Data Show?

Storage

According to the U.S. Army Corps of Engineers, in 2001, there were 77,000 dams higher than 6 feet in the United States and Puerto Rico. Because some reservoirs have multiple dams, this corresponds to about 68,000 reservoirs nationwide. Omitting dams that are control structures on large natural lakes, such as Lake Superior, the total volume of water stored in these reservoirs under typical conditions is about 422 million acre-feet (520 cubic kilometers).

In 1995, the U.S. Global Change Research Information Office found that the developed capacity of reservoirs represented only about 70 percent of the potential capacity.[6] They also reported that sedimentation was reducing existing reservoir capacity by about 1.5 million acre-feet (maf) per year. They also concluded that sizable investments were needed to rehabilitate, maintain, and, in some cases, remove dams.

Treatment

There are approximately 160,000 public drinking water systems in the United States. The U.S. Environmental Protection Agency classifies public supply systems into various categories. In 2004, most people in the U.S. (268 million) received their water from a community water system. There are approximately 54,000 community water systems, but just 7percent of those systems serve 81 percent of the people.[7]

The EPA's 2003 Needs Assessment indicates that community water systems and non-for-profit non-community water systems need $276.8 billion over the next 20 years to install, upgrade, and replace infrastructure. The nation's 1,041 largest community water systems (serving more than 50,000 people) accounted for 44 percent of the total need. Most of the infrastructure needs represent projects that would fund preventive measures to ensure the continued provision of safe drinking water rather than as corrective actions to address an existing violation of a drinking water standard. In addition, transmission and distribution projects represented about two-thirds of the total needs.

End Notes

1. Ruddy, B.C., and Hitt, K.J., 1990, *Summary of Selected Characteristics of Large Reservoirs in the United States and Puerto Rico*, U.S. Geological Survey Open-File Report 90–163, p. 295.

2. U.S. Geological Survey, Report to Congress, *Concepts for National Assessment of Water Availability and Use*, U.S. Geological Survey Circular 1223, August 2002, http://water.usgs.gov/pubs/circ/circ1223/html/cover.html.

3. U.S. EPA, *Drinking Water Infrastructure Needs Survey and Assessment: Third Report to Congress*, June 2005, p. 24 and 27.

4. American Society of Civil Engineers, "2003 Progress Report," http://www.asce.org/reportcard/index.cfm?reaction=full&page=6.

5. U.S. Department of Agriculture, *Agricultural Resources and Environmental Indicators*, Agricultural Handbook No. (AH722), February 2003, Chapter 2.1, page 1, http://www.ers.usda.gov/publications/arei/ah722/.

6. Kenneth D. Frederick, "America's Water Supply: Status and Prospects for the Future," *Consequences*, Vol. 1., No. 1, Spring 1995.

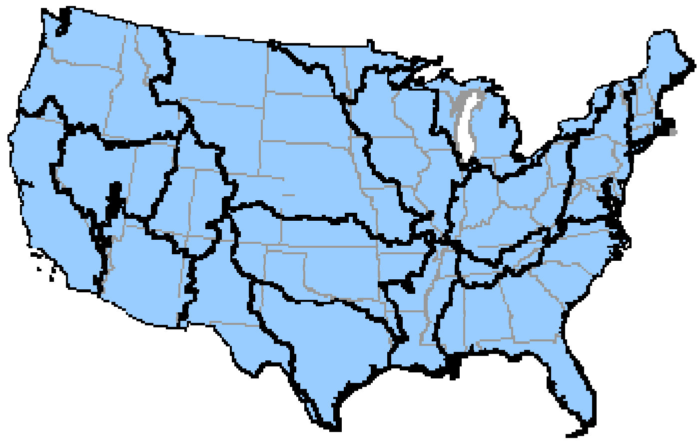
7. U.S. EPA, FACTOIDS: Drinking Water and Ground Water Statistics for 2004.

As water spilt on the ground, which cannot be gathered up again.

The Bible: 2 Samuel xiv. 14.

Indicator 6: Social and Organizational Capacity

Figure 4.6.1
Organizations by Watershed



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Source: EPA/CTIC Know Your Watershed: http://www.ctic.purdue.edu/KYW/NWN/US_Watersheds_8digit.html, accessed October 18, 2005.

What is this Indicator?

This indicator measures the capacity of society and its organizations to manage water sustainably. Social capacity is demonstrated by the existence of organizations dedicated to engaging civil society and government in water quality protection—whether at the regional, state, watershed, sub-watershed, or community level. This indicator will provide a count of these organizations per capita as a way of assessing the social and organizational capacity. Since numbers in and of themselves tell only part of the story, the indicator will build on work by Moote and Koontz (2003) in classifying watershed organizations as citizen-based, agency-based, and mixed. This will indicate the not only the number of watershed organizations, but also the type of organizations. Social scientists who study watershed management have increasingly argued that the membership composition is extremely important in the kinds of activities these organizations are willing to undertake, their level of community support, and their ability to sustain activity over time (Moote and Koontz 2003; Bloomquist and Schlager 2005).

Why is this Indicator Important?

Water resources sustainability is ultimately dependent on social action. Watershed organizations are widely viewed as the expressions of civic interest in water quality protection (NAS 1999). Their durability over time should indicate social and organizational capacity for management of water resources. Watershed organizations and water stewardship organizations potentially provide an oversight organization that can support or encourage regulation and management decisions by federal or local government, on the one hand, and create resistance for decisions that may harm water quality over time. Even if water quality, measured biophysically, does not improve in the short term, the existence of watershed organizations or other water activist organizations indicates civic engagement in water issues, and thus capacity to manage water resources on the basis of goals of water resources sustainability.

What do the current data show?
While databases have been identified, analysis of the number and type of watershed organizations has not yet been completed. The web sites listed below are compilations of watershed organizations by region and nationally. They need to be analyzed and tabulated to complete this indicator.

End Notes

1. National Academy of Sciences. 1999. *New Strategies for America's Watersheds*. Washington, DC: National Academy Press.

2. Moote, Elizabeth and Thomas Koontz. 2003. A Typology of Collaborative Watershed Groups: Citizen-Based, Agency-Based, and Mixed Partnerships. *Society and Natural Resources*. 16:451–460, 2003.

3. Bloomquist, W and R. Schlager. 2005. Political pitfalls of integrated watershed management. Society and Natural Resources 18 (2): 101-117 2005.

3. http://www.chesapeakebay.net/wshed_directory.htm

4. http://www.ctic.purdue.edu/kyw

5. http://www.dep.state.pa.us/dep/deputate/watermgt/WC/Subjects/WSNoteBks/shedtable.htm

6. http://www.rivernetwork.org/library/index.cfm?doc_id=116

Indicator #7: Environmental Conditions

What is This Indicator?

This indicator addresses consequences of water allocations on the physical, biological, and chemical conditions of the environment. There are no good summaries of water quality currently accepted in the US partly because of widely different standards and methods among the many agencies that take measurements. A rating system developed for the second National Coastal Condition Report (NCCR II) can serve as a good example.

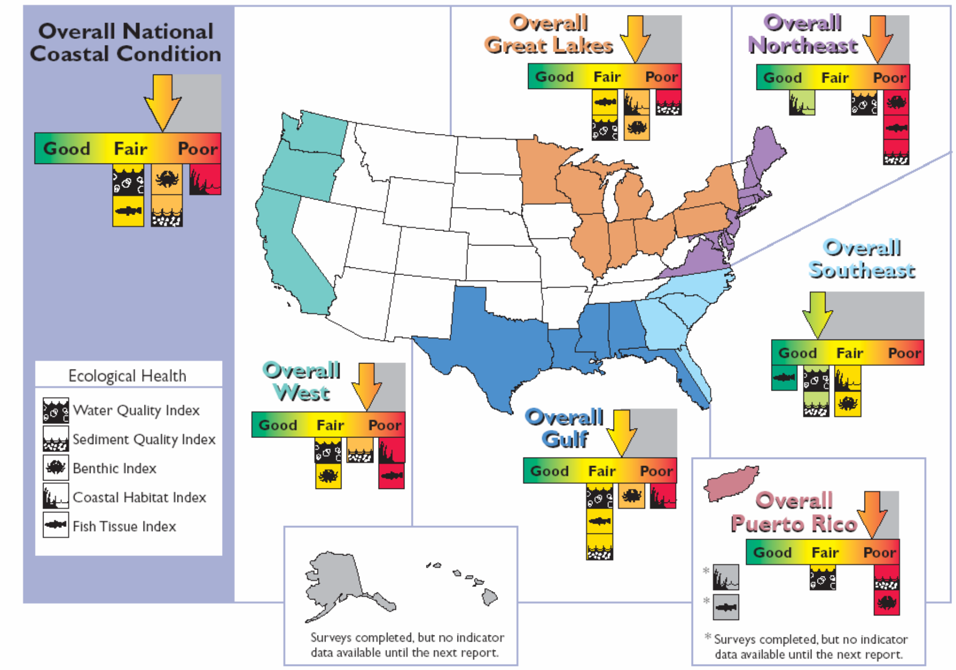
Other reports attempt to address environmental conditions. The U.S. EPA's Draft Report on the Environment (ROE) (2003) has two indicators for the condition of surface waters and watersheds in the U.S. Altered fresh water ecosystems, reports the percentage of each of the major fresh water ecosystems that are altered. The definition of "altered" varies for each water type. The data are incomplete, vary in consistency from state to state, and are not aggregated. The conceptual approach has merit, despite problems in development and implementation of the index The second index in the ROE is the lake trophic state index, which classified lakes into eutrophic, mesotrophic, or oligotrophic states. No national data were available, and the one report was based on phosphorus concentrations in northeast lakes. The limitations to this index include: the lack of national data; no accounting for non-lentic water bodies; and the fact that biota respond to variables besides phosphorus.

The second National Coastal Condition Report (NCCR II) is the result of collaboration among the U.S. EPA, NOAA, U.S. Fish and Wildlife Service, and USGS. The NCRR II is concerned with the condition of coastal regions of the United States. The NCRR II characterizes coastal water bodies based on measures related to aquatic and human uses. The ecological condition of individual sites is scored and assigned to one of three categories: 'good,' 'fair,' or 'poor.' Each region is then assigned a rating based on the overall condition of individual sites (Figure 4.7.1). For the NCRR II, coastal condition was characterized using data from EPA's National Coastal Assessment (NCA), NOAA's Status and Trends Program (NS&T), and FWS's National Wetlands Inventory (NWI). Table 4.7.2 shows the indices used to measure aquatic and human uses.

Table 4.7.1
Indices Used for the National Coastal Condition Report II map

Aquatic Use Indices	**Index components**
1. Water Quality Index	dissolved oxygen, chlorophyll a, nitrogen, phosphorus, water clarity
2. Sediment Quality Index	sediment toxicity, sediment contaminants, sediment TOC
3. Benthic Index	benthic community diversity, pollution-tolerant species, pollution-sensitive species
4. Coastal Habitat Index	long-term decadal wetland loss rate (1780-1990); present decadal wetland loss rate (1990-2000)
Human Use Indices	
5. Fish Tissue Contaminants Index	composite concentrations in relation to EPA Guidance range
All indices calculated based on 1997-2000 data.	

Figure 4.7.1
Overall national and regional coastal condition between 1997 and 2000



(Source: U.S. EPA, December 2004. National Coastal Condition Report II. Office of Research and Development/Office of Water. EPA-620/R-03/002. (http://www.epa.gov/owow/oceans/nccr2/)

Why is This Indicator Important?

The information provided by the NCCR II can help focus the attention of water quality managers and decision-makers on three critical challenges: 1) areas with problems in need of restoration; 2) areas with good water quality in need of protection; and 3) areas where additional data are needed.

What Do the Data Show?

The NCRR II rated the overall quality of national coastal waters as 'fair.' Specifically, 21 percent of the estuarine area of the country is unimpaired and 44 percent is threatened for human and/or aquatic life uses. The remaining 35 percent are considered impaired: 15 percent of the coastal waters are impaired for both human and aquatic life use; 13 percent for aquatic life use only; and 7 percent for human use only.

To reflect the natural geographic differences in aquatic ecosystem characteristics, the NCRR II identified indices specific to six major regions in the U.S. The scale of each indicator was unique to the site within each region. The whole region was then ranked based on the percentage of sites that were categorized good, fair, or poor. A system of this type is important for characterization at regional and national scales; however, an obvious drawback of NCRR II is the limited geographic focus on coastal waters

The NCRR II is a product of the data that comprises it. Debate is inevitable regarding the relative importance of certain data as well as the presence or absence of certain data. Although the data elements included in these indices are broad, there are no elements that explicitly deal with impacts of ground water withdrawal or threatened/endangered species. There is no perfect index and different data elements may be needed at finer geographic scales. The NCRR II report relies heavily on data collected through EPA's National Coastal Assessment (NCA) from 1999 - 2000 and the coastal portion of the 1997-1998 Mid-Atlantic integrated Assessment (U.S. EPA/EMAP and NCA). In summary, it is difficult to find a single set of water indicators useful at all scales and for all regions. A challenge of future work in developing indicators to assess environmental condition will be to find commonalities that can work at the national level, but have sufficient detail to be helpful to regions and specific sites.

End Notes

1. Gerritsen, J. 1995. Additive biological indices for resource management. J. No. Am. Benthol. Soc.14L 451-457.

2. U.S. EPA. 2001. National Coastal Condition Report. United States Environmental Protection Agency. Office of Research and Development and Office of Water. EPA 620/R-01/005. Washington, D.C.

3. Draft Report on the Environment. Technical Document. US EPA Office of Research and Development and the Office of Environmental Regulation. EPA 600-R-03-050, U.S. EPA. 2003, Washington, D.C. and Science Advisory Board comments on ROE: http://www.epa.gov/sab/pdf/sab_05_004.pdf)

4. U.S. EPA. 2004. National Coastal Condition Report II. United States Environmental Protection Agency. Office of Research and Development and Office of Water. EPA 620/R-03/002. Washington, D.C.

Greater familiarity with marshes on the part of more people could give man a truer and more wholesome view of himself in relation to Nature. In marshes, Life's undercurrents and unknowns and evolutionary changes are exemplified with a high degree of independence from human dominance as long as the marshes remain in marshy condition. They have their own life-rich genuineness and reflect forces that are much older, much more permanent, and much mightier than man.

— *Paul L. Errington "Of Men and Marshes*

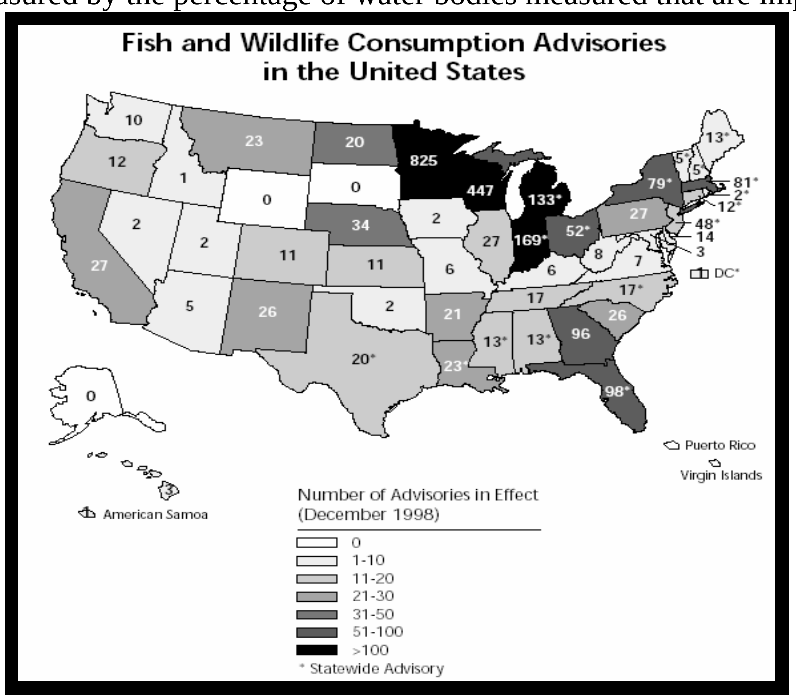
Indicator #8: Resources and Conditions

What is This Indicator?

This indicator characterizes the amount and quality of resources that are directly or indirectly dependent on water quality and/or quantity. It includes measures that can indicate whether resources in the environment associated with water are impacted by changes in the biogeochemical integrity of aquatic ecosystems. Such measures include fish contamination and the percentage of impaired water bodies.

Indicator 8 is designed to be a measure of the condition of the resource in the natural environment rather than when consumed by people. Fish consumption advisories, while based on safety of the fish for human consumption are also a measure of the condition of a watershed itself because they are issued when the concentration of toxic substances in fish and shellfish in a water body exceed safe levels. Contamination of edible organisms like oysters, indicate pollution problems in a water body such as persistent toxic chemicals contaminating the sediments or pathogens contaminating the water.

Figure 4.8.1
Contamination of Fish and Wildlife
(as measured by the percentage of water bodies measured that are impaired)



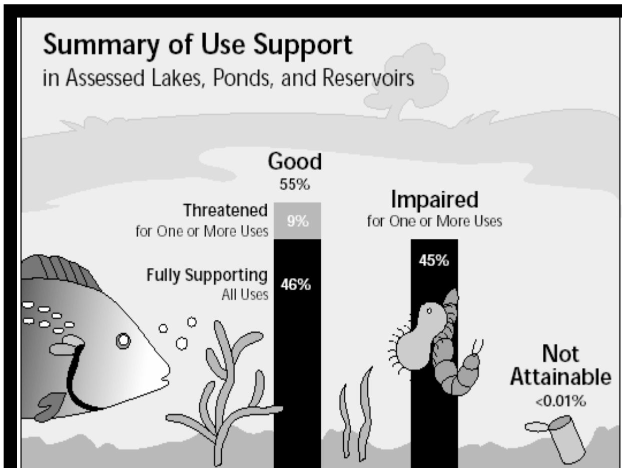
(Source: U.S. Environmental Protection Agency, National Water Quality Inventory 1998 Report (http://www.epa.gov/305b/98report/index.html)

Measures of the toxicity levels in the bodies of fish and other aquatic species represent a pinnacle indicator in aquatic ecosystems because of the bio-accumulation of chemicals that can occur in aquatic food chains where fish harvested for human use are the top predators in the system

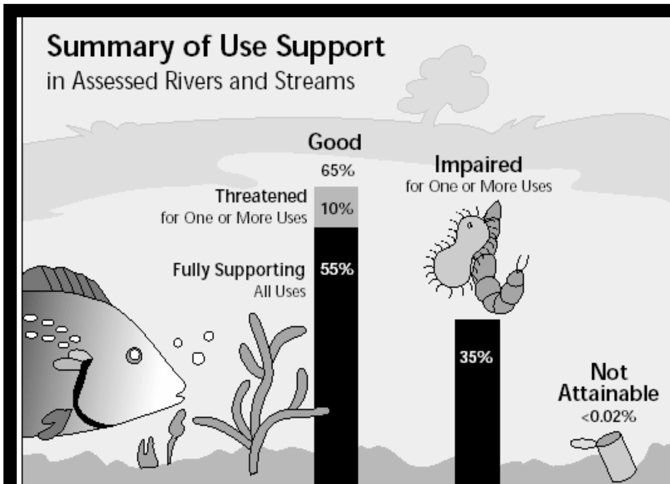
Synthetic chemicals, trace elements, and other contaminants can, in sufficient quantities, harm people as well as fish and other wildlife. As a result, it is important for the public and decision-makers to understand both the frequency of chemical contamination and the degree to which these contaminants exceed regulatory standards and guidelines. The number of contaminants found in fresh water fish offer information about how widespread these compounds are in the environment. Although the presence of chemical contamination does not necessarily mean that the levels are high enough to cause problems, comparison to standards and guidelines offer a useful reference to help judge the significance of contamination.

The two figures (Figures 4.8.2 and 4.8.3) below illustrate the percent of impaired waters based on the 1998 U.S. Environmental Protection Agency State and Tribal Section 305(b) Reports for rivers and streams and lakes, ponds, and reservoirs, respectively. While based on standards for use of the resources by people, the data say something about the condition of the water and the life within it. The data supporting these measures are based upon the assessment of 23 percent of all known rivers and streams in the U.S. and 42 percent of all known lakes, ponds, and reservoirs in the U.S.

Figure 4.8.2 and Figure 4.8.3
Summary of Use Support



This figure presents the status of the assessed acres of lakes, reservoirs, and ponds. Of the more than 17 million acres of lakes, reservoirs, and ponds assessed, 55% fully support their designated uses and 45% are impaired for one or more uses. Nine percent of the assessed waters are fully supporting uses but threatened.

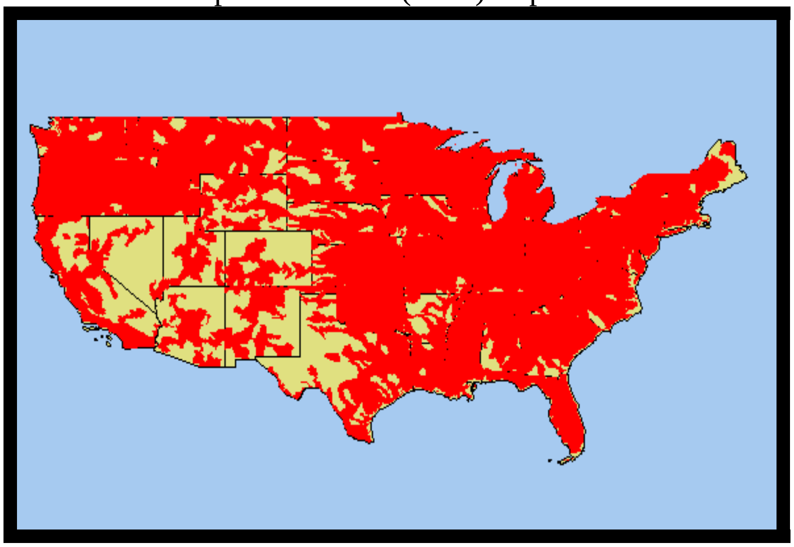


This figure presents the status of the assessed miles of rivers and streams. Of the more than 800,000 miles of rivers and streams assessed, 65% fully support their designated uses and 35% are impaired for one or more uses. Ten percent of the assessed waters are fully supporting uses but threatened.

(Source: 1998 U.S. EPA State and Tribal Section 305b Report)

Another sub-indicator compares the number of water bodies (streams, rivers, lakes, reservoirs, etc.) that are safe from any kind of harm in recreational use by the public with the total number of measured water bodies available for public use. Harm includes public health reasons or other physical public risk issues. The U.S. Clean Water Act Section 303(d) requires states to report a prioritized list of waters not meeting water quality standards and to establish Total Maximum Daily Loads (TMDLs) to correct the impairments. The “Impaired Waters” map for the U.S. shown below is from the 2002 National Water Quality Assessment Database, which summarizes water quality information provided by the states in the 2002 305(b)/303(d) Integrated Reporting cycle. In the SWRR criteria for indicators Indicator 8 is an indicator of the condition of resources in the environment and Indicator 10 is a measure of resources withdrawn by people for their use. The impaired waters map is not purely a map of resource condition since the criteria for whether waters are impaired is based on suitability for various human uses but it does give a general idea of the condition of water resources.

Figure 4.8.4
U.S. EPA, Watershed Tracking and Environmental Results, EnvrioMapper for Water to show National Trends for Impaired Waters (2002) Impaired water shaded in red.



Source: U.S. EPA, http://www.epa.gov/waters/enviromapper/index.html)

What Do the Data Show?

The consumption advisory map for 1998 illustrated in Figure 4.8.1 shows that only 2 of the 48 contiguous states did not report the need for issuing consumption advisories. For the other 46 states, the Great Lake's states had the highest number of fish consumption advisories, followed by the states in the extreme southeast of the U.S. The Sustainable Water Resources Roundtable only found data for 1998 so no trends can be reported for consumption advisories across the U.S. Although no continuous records on an annual basis were discovered for the reporting of consumption advisories, the importance of this measure as a potential health risk indicator to humans from the use of water related resources suggests the need to keep continuous and consistent annual reporting records on this measure.

In 2002, the U.S. EPA estimated that 300,000 miles (482,790 km) of impaired rivers and shorelines existed in the U.S. (Cech, 2003; pg. 334). Contamination was caused primarily by sediments, excess nutrients, and micro-organisms. The EPA also estimated that most of the U.S. population lives within ten miles of these impaired waters.

#9: The Quantity and Quality of Water for Human Uses

What is This Indicator?

The first part of this indicator reports how the water that is withdrawn within (or imported to) a watershed is actually used by the different water use sectors within the watershed. The USGS has collected national data at five-year intervals on amounts of water used in homes, businesses, industries, and agriculture.[1,2] The data are collected at the county level, but are totaled and reported for each state. SWRR recommends that water uses be reported periodically for at least the following four water use categories: public supply, irrigation, industrial and commercial purposes, and thermo-electric power generation. These data might also be used to derive related indicators, such as per capita use of water, per acre use of water (by major crop type), water usage per day per employee (or per ton of finished product or per unit produced), and per unit of power generated (or consumptive use of water per unit of power generated).

Several people involved in SWRR have recommended that the amount of water withdrawn for human uses that is reused be reported. This could include the total quantity of water that is used in multiple cycles in industrial or thermo-electric power generation processes. The quantity of water reused in a watershed is important to sustainability because it demonstrates the extent to which communities and industries within a watershed are conserving (or efficiently using) their water supplies. The quantity that is actually reported would need to be considered carefully. For example, one could report the quantity of water that is delivered to a facility without regard to how many cycles the water is used once it arrives at the facility (for example, one million gallons per day delivered). Alternatively, one could report the total amount of water that is delivered to a facility and multiply it by the number of cycles in which it is used before being consumed or discarded (for example, one million gallons per day delivered multiplied by five cycles of use while at the facility, for a total of five million gallons per day). Work remains to be done on this aspect of this indicator.

The second part of this indicator reports on the quality of water delivered for human uses. One possible measure of this could be the percentage of the population served by community water systems that meet all health-based standards.

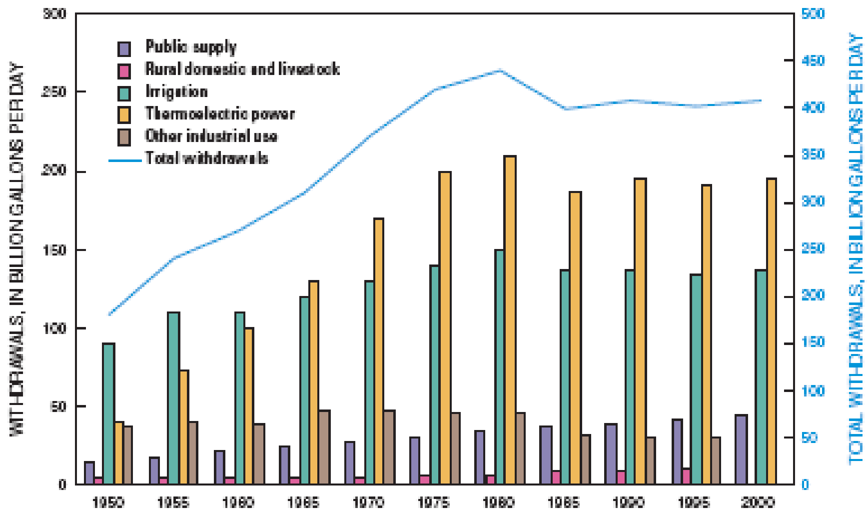
Why is This Indicator Important?

This information is important for understanding the types of uses to which the water is being supplied and how those uses change with time in response to demographic changes, economic trends, and other factors.

What Do the Data Show?

Trends in the allocation of water withdrawals to the major water use categories for the 50-year period 1950-2000 are shown in Figure 4.9.1. The largest uses of water have consistently been for irrigation and thermo-electric power generation, although the amounts of water used for these purposes have stabilized since 1985. With respect to water use for thermo-electric power generation, since the 1970s, power plants increasingly were built with (or converted to) closed-loop cooling systems or air-cooled systems, instead of using once-through cooling systems. The use of re-circulated water for cooling in a closed-loop system reduces the water requirement of a power plant, resulting in reduced water withdrawals.[3] Estimated withdrawals for public supply have increased continually since 1950, as has the population served by public suppliers. The percentage of population served by public suppliers increased from 62 percent for 1950 to 85 percent for 2000.[4]

Figure 4.9.1
Trends in total water withdrawals by water-use category, 1950-2000.[5]



End Notes

1. Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: U.S. Geological Survey Circular 1268, 46 p.
2. U.S. Geological Survey, 2004, Estimated use of water in the United States county-level data for 2000: data available at: http://water.usgs.gov/watuse/data/2000/index.html.
3. Hutson et al, op. cit.
4. Ibid.
5. Ibid.

Indicator 10: Resources withdrawals and use

What is This Indicator?

Indicator 8 is a measure that assesses the condition of water related resources in their natural state. This indicator, by contrast, measures resources directly or indirectly dependent on water that are withdrawn from the environment and used by people. Such measures include public participation in fresh water recreation.

Americans enjoy recreation in and around water, from bird watching and fishing to sailing and swimming. The sub-indicator measures the number of fresh water anglers and total fishing licenses sold annually to illustrate trends in the public activity of fresh water fishing in the U.S. These measures of public participation in fresh water recreation imply the value and importance that people place on this form of recreation. Information on trends in participation in fishing document the demand for recreation opportunities and can be useful in assessing people's perceptions regarding the value and safe use of these resources. If the demands change over time, this can be a factor indicating changing public perception of the risks associated with using water resources.

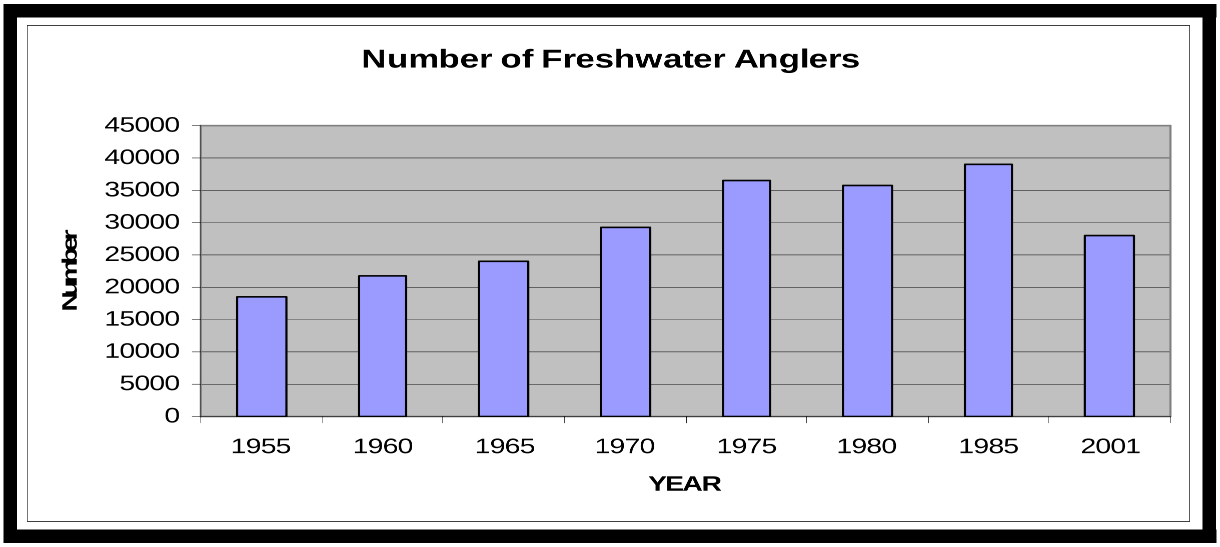
What do the Data Show?

The U.S. Fish and Wildlife Service sponsors a National Survey of Fishing, Hunting, and Wildlife-Associated Recreation every five years. The questions are developed in concert with technical committee members from every state and with representatives of non-governmental organizations such as the Wildlife Management Institute and the American Sportfishing Association. The most-recent survey was conducted in 2001. The 2001 survey indicated that:

- over 34 million people went fishing;
- they fished an average of 16 days per participant and spent an average $1,046 each;
- 28.4 million anglers went fresh water fishing, while 9.1 million went saltwater fishing; and
- overall, anglers spent $14.7 billion in 2001 for fishing trips, $17 billion on equipment, and $4 billion for licenses, stamps, tags, land leasing and ownership, membership dues and contributions, and magazines.

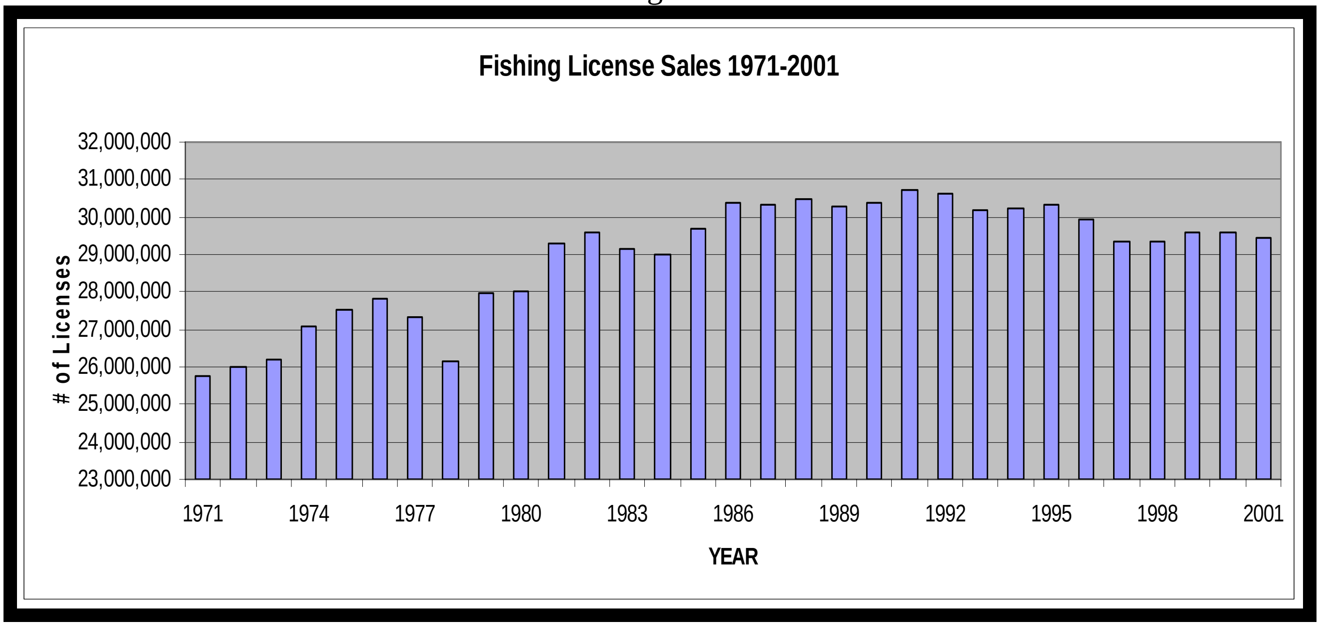
If the two graphs below, Figures 4.10.1 and 4.10.2 for number of fresh water anglers and fishing license sales over a 45 and 30 year period respectively are examined for trends, it appears that both measures suggest a decline in fresh water fishing in recent years. Peaks in human fishing participation occurred in the late 1980s and early 1990s. Present measures for fresh water anglers have dropped to levels observed in the early 1970s, even though the U.S. population has significantly increased over this period of time. This drop in fresh water participation could potentially be linked to either a decline in amount of fish being caught in more recent years, and thus less desire on the part of the angler, or to the perception that fresh water fishing resources are not as safe and free of human health risk as they use to be.

Figure 4.10.1
Public Participation in Fresh water Recreation
(as measured by the number of fishing licenses, number of anglers - change per year)



(Source: U.S. Fish and Wildlife Service – National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (http://www.fws.gov/fishing)

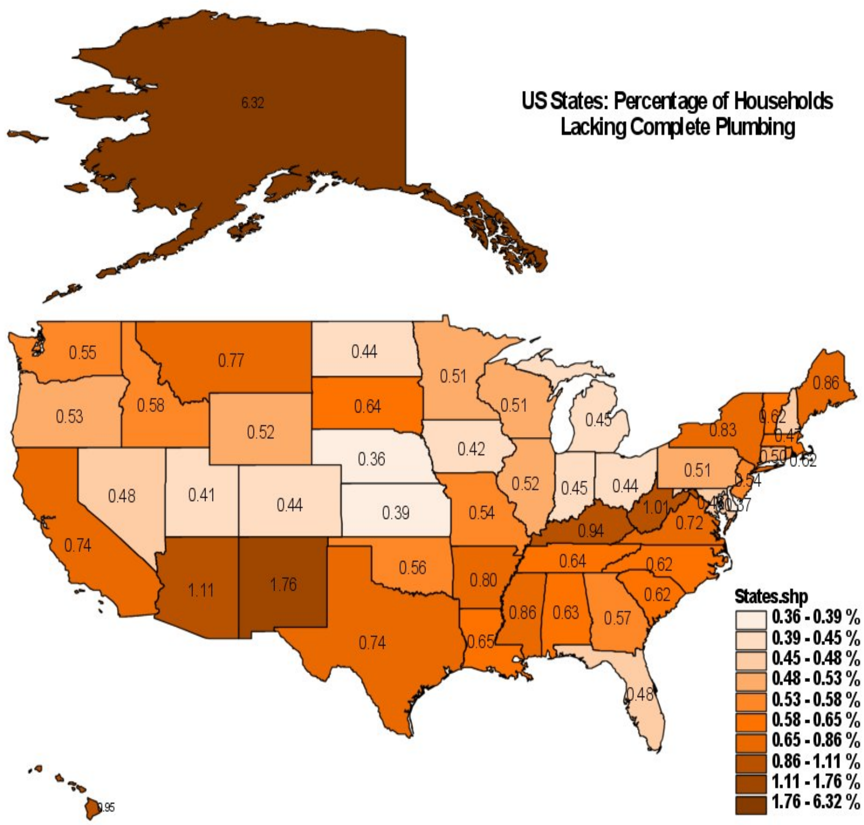
Figure 4.10.2
Fresh water Fishing License Sales



(Source: American Sport Fishing Association - http://www.asafishing.org/asa/statistics/participation/fishlicense_30yr.html)

Indicator 11: Human Conditions.

Figure 4.11.1
Percent of the Population Lacking Complete Plumbing by State



Source: Rural Community Assistance Partnership. 2004. *Still Living without the Basics in the 21st Century*. http://www.rcap.org/resources/basics.html, accessed 10/03/05.

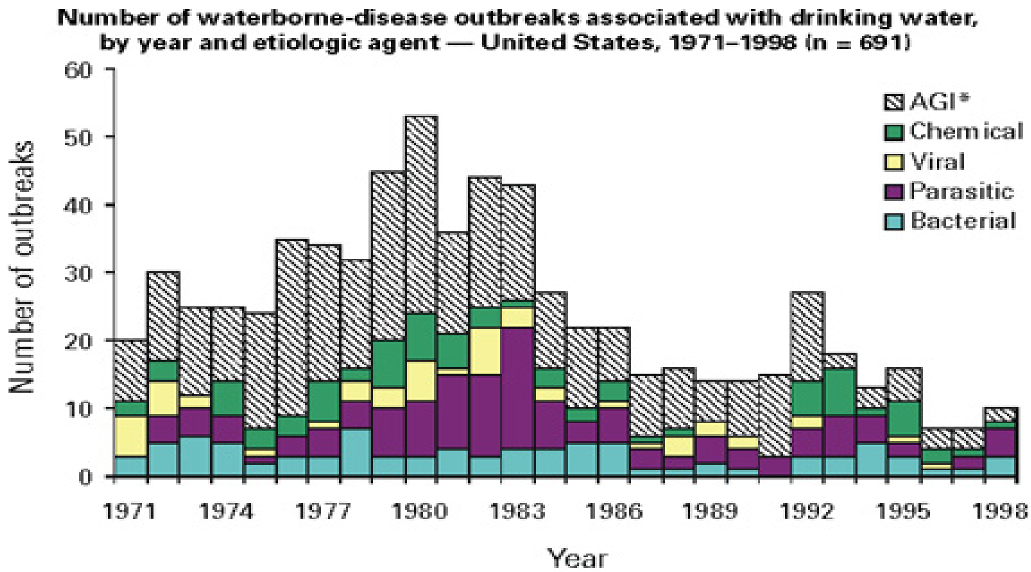
What is this Indicator?

This indicator measures the value people receive from the uses of water and the cost they incur from not having these resources. One of the critical measures of value is the access of people to potable water and sanitation. A measure of that is the availability of plumbing and sanitation for the population. This tells us the population living with access to the basic resources of potable water and sanitation. There is a well established link between potable water and public health.

A second measure of the quality of the water coming through the infrastructure system is the number of reported cases of waterborne disease from 1972 through 1998. Waterborne disease outbreaks provide a good measure of the quality of the water that is delivered to people in the U.S. While this may be seen as an indicator of the quality of water treatment facilities, it is notable that many of the most serious recent outbreak in North America, at Walkerton, Canada, was as much about poor source water protection as about poor facilities management.[1] Seven people lost their lives when the water system in Walkerton, Ontario was contaminated with *E. coli* O157 bacteria and many more became ill.

These two measures together make up part of the indicator of the human well being as related to water.

Figure 4.11.2
Reported Incidence of Waterborne Disease: Number of outbreaks, etiologic agent, and source of waterborne exposure—1971-1998



*Acute gastrointestinal illness of unknown etiology.
Adapted From: Surveillance for Waterborne Disease Outbreaks - US, 1997-1998 (2)
Accessible at: http://www.cdc.gov/mmwr/preview/mmwrhtml/ss4904a1.htm

Why is this Indicator Important?

The percent of the population living without access to potable water and sanitation is an accepted international indicator of quality of life. Indeed, the United Nations Children's Fund (UNICEF) has correlated the percentage of the population with potable water and sanitation with deaths per 1,000 for children under five years old in 20 nations[2]. Their research shows that the greater the access to potable water and sanitation the lower the incidence of early child mortality. Even if people have access to piped water, the question still remains whether the water that is coming out of the tap is potable. This can be measured by the trend in outbreaks in of waterborne disease. This information is collected periodically by the Center for Disease Control (CDC).

What Do The Data Show?

[1] Hrudy, Steven. 2004. Safe Drinking Water – Lessons from Recent Outbreaks in Affluent Nations. London: International Water Association Press.
[2] UNICEF, ***State of the World's Children 2000***

In the United States, the U.S. Census long form survey has the number of people who say they have water and sanitation in the home since 1950. The percentage of the population lacking either plumbing has diminished steadily from 27 percent in1950 to .64 percent of the population in 2000. As is clear from the map above, however, the distribution of those lacking plumbing services is not even across the United States. Alaska, Arizona and New Mexico carry disproportionate percentage of those lacking plumbing services. Viewed by ethnicity, Native Americans and Hispanic-Latino/as are disproportionately likely to be living without water and sanitation.[3]

The numbers additionally show that there has been a steady decrease in the population impacted by waterborne disease, although Figure 11.2, above, shows a slight spike in 1998. It is notable that CDC itself believes that there are methodological problems with the way that they currently count the incidences of waterborne disease, as they only track emergency room visits that are diagnosed as such.[4]

Conservation is a positive exercise of skill and insight, not merely a negative exercise of abstinence or caution...."

Aldo Leopold, 1949.

[3] http://www.rcap.org/resources/basics.html, accessed October 4, 2005.
[4] http://www.cdc.gov/ncidod/eid/vol7no3_supp/hunter.htm, accessed October 4, 2005.

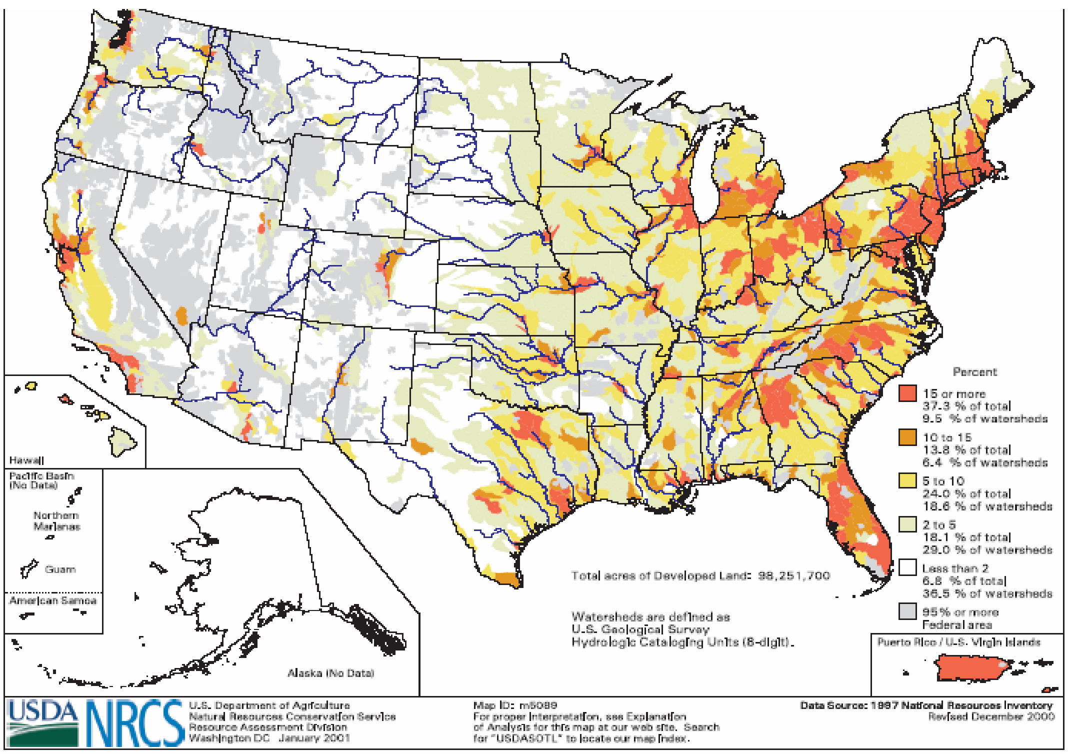
Indicator #12: Land use

What is This Indicator?

This indicator addresses the important elements of land use – developed land and cropland – that affect water quality and quantity. The developed land measure includes small-urban, large-urban, and built-up areas, as well as highways, roads, railroads, and associated right-of-ways in rural areas. The cropland measure shows the watersheds that have the highest potential for sediment, pesticide, and nutrient runoff, as well as pesticide and nitrogen leaching to groundwater. The data for both measures is presented on a watershed basis using the U.S. Geological Survey's 8-digit hydrologic cataloging unit.

Other indicators of land use warrant consideration, including measures of general distribution of land cover and of specific hydrologic or ecological functions, such as the extent of watershed impervious surface or tree canopy. The National Land Cover Database, under development by a consortium of agencies, is expected to make of such indicators possible in the near future.

Figure 4.12.1
Percent of Hydrologic Unit in Developed Land, 1997



The developed land map is posted at: http://www.nrcs.usda.gov/technical/land/meta/m5089.html The maps for both measures were developed by the Natural Resources Conservation Service and partners based upon the NRCS 1997 National Resources Inventory, a statistical sampling of various data sets. The cropland maps are posted at: http://www.nrcs.usda.gov/technical/land/lgif/m1737l.gif

Figure 4.12.2
Watersheds with a High Potential for Soil, Pesticide, and Nitrogen Runoff

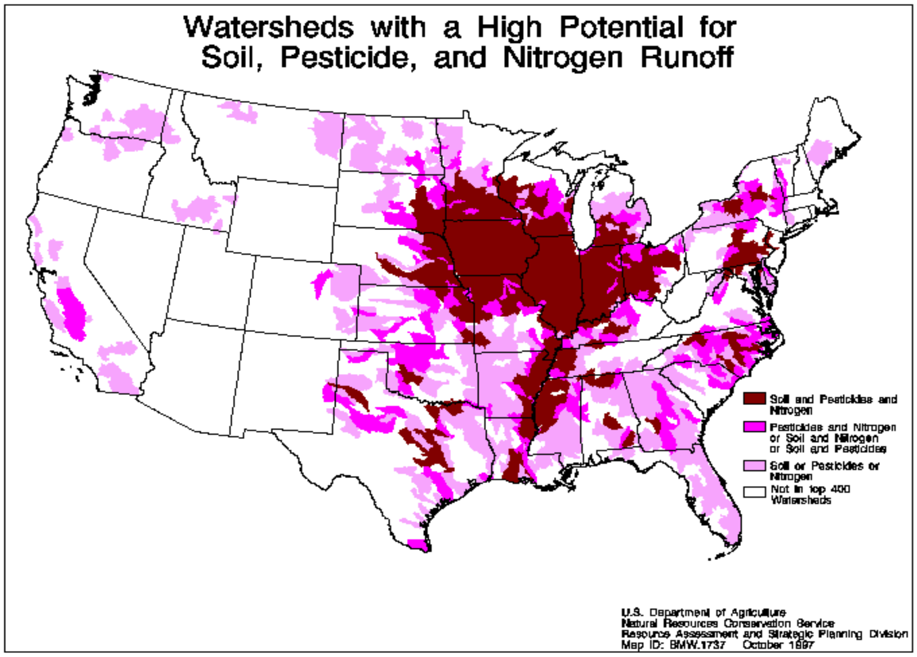
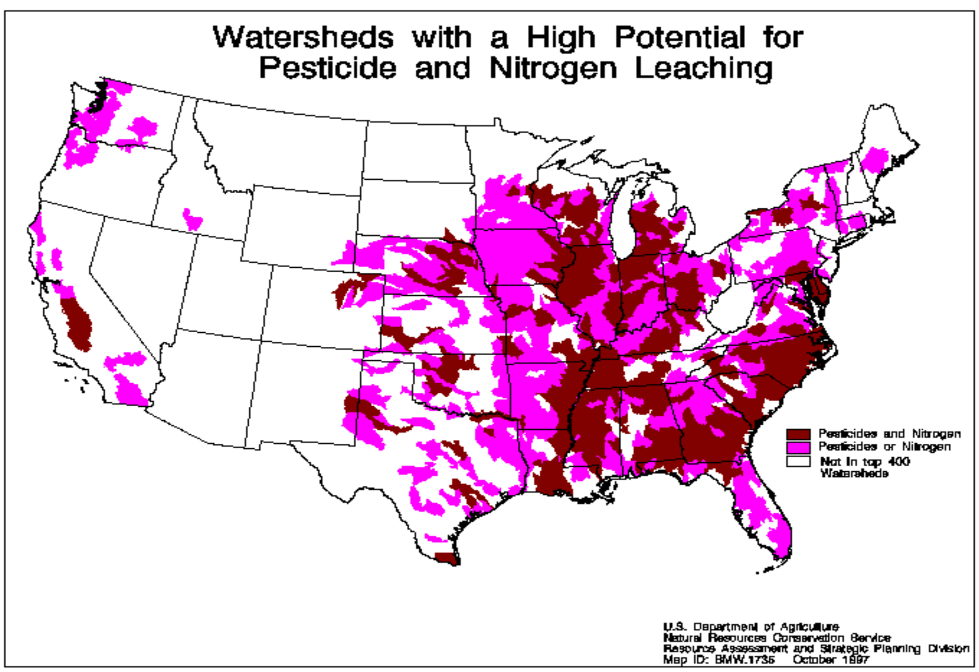


Figure 4.12.3
Watersheds with a High Potential for Pesticide and Nitrogen Leaching



Why is This Indicator Important?

The way people, business, and government use land profoundly affects water resources. It affects the timing and magnitude of surface water flows, the recharge of ground water, the demand for water and the resultant discharge of wastewater. Further, the chemicals put on the land end up in the water thus affecting water quality. Land use also directly and indirectly affects wildlife habitat and other valued, water dependent ecosystem features.

What Do the Data Show?

As shown in Figure 4.12.1, in 1997, over 98 million acres of land in the 48 contiguous states are considered developed. Nearly 10 percent of the nation's watersheds have at least 15 percent of their land in a developed state. The extent of development is greatest in the Northeast, the Southeast Piedmont, Florida, the Industrial Midwest, including the Great Lakes states, and parts of the West Coast. While the measure is useful with implications for a broad range of water-related concerns – from timing of flows to water quality, quantity, use and habitat destruction – it does not directly measure these factors.

As shown in Figures 4.12.2 and 4.12.3, from one-third to one-half of the watersheds in the 48 contiguous states show high potential for pollutant runoff and infiltration from cropland. This assessment is based on a determination of the top 400 watersheds for each factor. The greatest concerns were evident in the Midwest and Southeast.

Example of Land Use Impact on Water: Abandoned Mine Drainage (AMD)

The Abandon Mine Lands (AML) fund distributes funds to states impacted by mining. Figure 4.12.4 outlines how many people are impacted by abandoned mine lands per state and the per capita benefit each state receives. Reclamation funds are granted to states based on their current production, not historic production numbers. It is estimated that high priority restoration projects throughout the country would cost over $3 Billion to complete. Additional measures such as Clean Water Act Compliance documents such as the 303(d) and 305 (b) lists of streams not meeting their intended use and reasons why streams don't attain their designated uses illustrates problems created by AMD.

The Office of Surface Mining (OSM) estimates that 3.5 million Americans live within one mile of a health and safety concern associated with abandoned coal mines. OSM cites the following health dangers associated with abandoned mines: underground fire potential, highwalls and steep inclines, subsidence from underground mining, open mineshafts, and polluted water. OSM reports, though a countrywide system isn't available for quantifying human risk, Pennsylvania has reported 45 deaths and 19 injuries in its anthracite region in the past 30 years. In addition to the human risk potential, AMD impacts aquatic life, human health, recreation and tourism revenues, as well as reducing property values. Growing evidence links metals contamination of water by AMD with health problems such as colorectal cancer and renal failure. Numerous health institutes are now quantifying the health impacts correlating to this metals exposure.

Figure 4.12.4
Impact of Acid Mine Drainage Lands

Available data shows that AMD is a complex occurrence resulting from iron sulfide (pyrite) interacting with air and water. This chemical process creates an acidic condition that further breaks down pyrite, exacerbating the situation. There are numerous passive and active methods for treating AMD. Dominant metals such as iron, aluminum, and manganese can be precipitated out of these discharges by pH adjustment. Scientific research conducted by Chuck Cravotta of the USGS indicated there are over 27 difference elements present in AMD.

Although AMD has occurred since the dawn of the Industrial Revolution, great strides have been made to understand the phenomena and its treatment. Resource Recovery, extracting mineral assets from the water, has gained popularity and with proper market development could assist in offsetting treatment costs. New technology and better understanding of chemistry and kinetics also helps engineers design smaller and more efficient treatment systems. Underground mining has created vast underground storage for water and new initiatives revolve around the concept of beneficial use of this stored water for municipal supplies and for generation of electricity.

End Notes

Summary Report: 1997 National Resources Inventory (Revised December 2000), U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, D.C.

Potential Priority Watersheds for Protection of Water Quality from Nonpoint Sources Related to Agriculture. Poster Presentation at the 52nd Annual SWCS Conference. Toronto, Ontario, Canada, July 22-25, 1997 (Revised October 7, 1997) Robert L. Kellogg, Susan Wallace, and Klaus Alt (retired), Natural Resources Conservation Service and Don W. Goss, Texas Agricultural Experiment Station, Temple, Texas.

Indicator #13: Residual Flows

What is This Indicator?

This indicator reports the flow of water and wastes back into the water environment after human use and, possibly, treatment. These flows can originate from either point or non-point sources.

Why is This Indicator Important?

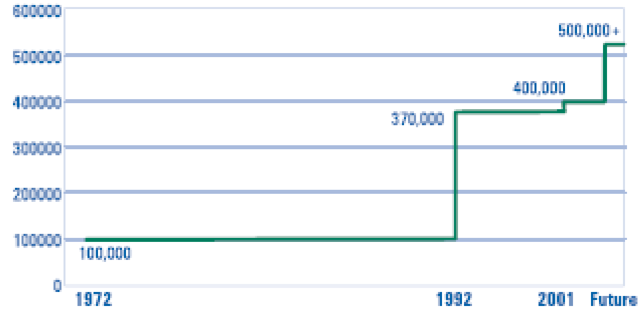
Residual flows are important because they may contain chemical and biological constituents detrimental to the environment, or have physical properties (such as temperature) that impair the environment.

What Do the Data Show?

An important source of data on wastewater discharges to the water environment is provided by the National Pollutant Discharge Elimination System (NPDES), which is administered by the U.S. EPA. NPDES is a national system for permitting of wastewater discharges that was created under the Federal Water Pollution Control Act (FWPCA) Amendments of 1972 (further amended in 1977 as part of the Clean Water Act). Under NPDES, all facilities that discharge pollutants from any point source into waters of the United States are required to obtain a permit. Pollutants are defined broadly by the NPDES regulations and litigation and include any types of industrial, municipal, and agricultural waste discharge into water. Municipal sources are publicly owned treatment works that receive primarily domestic sewage from residential and commercial customers. While provisions of the NPDES Program do address certain types of agricultural activities (such as concentrated animal feeding operations), the majority of agricultural facilities are define as non-point sources and are exempt from NPDES regulation [1] As shown in Figure 4.13.1, as of 2001, more than 50 categories of industry (including several hundred thousand businesses) and the nation's network of more than 16,000 municipal sewage treatment systems comply with standards implemented in NPDES permits.[2]

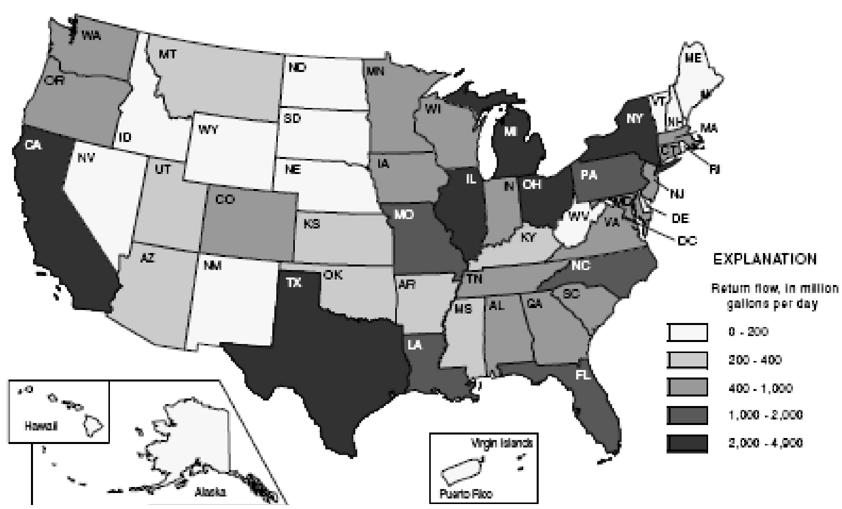
As shown in Figure 4.13.2, the USGS reported total releases of some 41,000 million gallons per day of treated wastewater from about 16,400 publicly-owned treatment facilities nationwide during 1995.[3] The return of treated water generally is to surface waters, although over two percent of the treated wastewater that was released was reclaimed for beneficial uses such as irrigation of golf courses and public parks. Illinois and Ohio, which have large public supply withdrawals, reported the largest releases of treated wastewater; Florida, California, and Arizona reported large uses of reclaimed wastewater.[4]

Figure 4.13.1
Growth of the NPDES Program
(number of facilities or sources)



(Source: USEPA, 2001)

Figure 4.13.2
Wastewater treatment return flow by State, 1995



(Source: Solley and others, 1998)

End Notes

1. U.S. Environmental Protection Agency, Office of Wastewater Management, 2005, Water permitting 101: http://www.epa.gov/npdes/pubs/101pape.pdf, Sept. 22, 2005.

2. U.S. Environmental Protection Agency, Office of Water, 2001, Protecting the Nation's waters through effective NPDES permits—A strategic plan, FY 2001 and beyond: http://www.epa.gov/npdes/pubs/strategicplan.pdf, Sept. 22, 2005.

3. Solley, W.B., Pierce, R.R., and Perlman, H.A., 1998, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 71 p.

4. Ibid

Indicator #14: Social and Economic Processes

What is this Indicator?

This indicator measures the systems people and organizations develop to influence water resources and sustainability. One of several measures to assess the extent to which systems have been developed to influence water resources sustainability is the extent to which water resources planning institutions have been developed at the state level.

One of the critical asymmetries of water planning in the United States is that political jurisdictions have rarely followed hydrologic boundaries. As a result, planning, policies and regulations that impact water quality are decided by institutions with responsibility for geographic areas that either cut across or are contained within hydrologic areas. Water resource sustainability is potentially threatened because decisions are made and systems put into place that make sense at the county or township level, but would not have if thought through at the watershed level.

We are able to count the number of states that have developed water planning entities that are designed to harmonize water resources issues with the other planning goals of the planning authorities. This count can be disaggregated by type (watershed planning, conservation planning) and the models for management tested for impacts on water resources sustainability. We do not necessarily assume that a greater number of water planning entities represents social and economic processes that are more sustainable. It does indicate processes that tie water resources to economic and social decision making.

Why is this Indicator Important?

While the Federal Government has a significant role in management of interstate waterways, much of the management and regulation of water quality is still left to states[1]. One of the critical asymmetries of water planning in the United States is that political jurisdictions have rarely followed hydrologic boundaries. As a result, planning, policies and regulations that impact water quality are decided by institutions with responsibility for geographic areas that either cut across or are contained within hydrologic areas. Water resource sustainability is potentially threatened because decisions are made and systems put into place that make sense at the county or township level, but would not have if thought through at the watershed level.[2]

What Do the Data Show?

To different degrees, some states attempt to develop planning and regulatory authorities that operate on a watershed basis. Examples include Massachusetts, Maryland, and California. Others empower regional planning authorities to implement water quality and quantity planning and management guidelines. No list currently exists of water planning and management institutions at the state level and such data needs to be developed to complete this indicator.

End Notes

1. Kemmis, Daniel. 2000. "Learning to think like a region." *High Country News*, April 10, 2000.

2. Rogers, Peter. 1996. *America's Water: Federal Roles and Responsibilities*. Boston: MIT Press.

Indicator #15: Health of Ecosystem Processes

What is this Indicator?

This indicator measures ecosystem processes that govern water resources and sustainability.

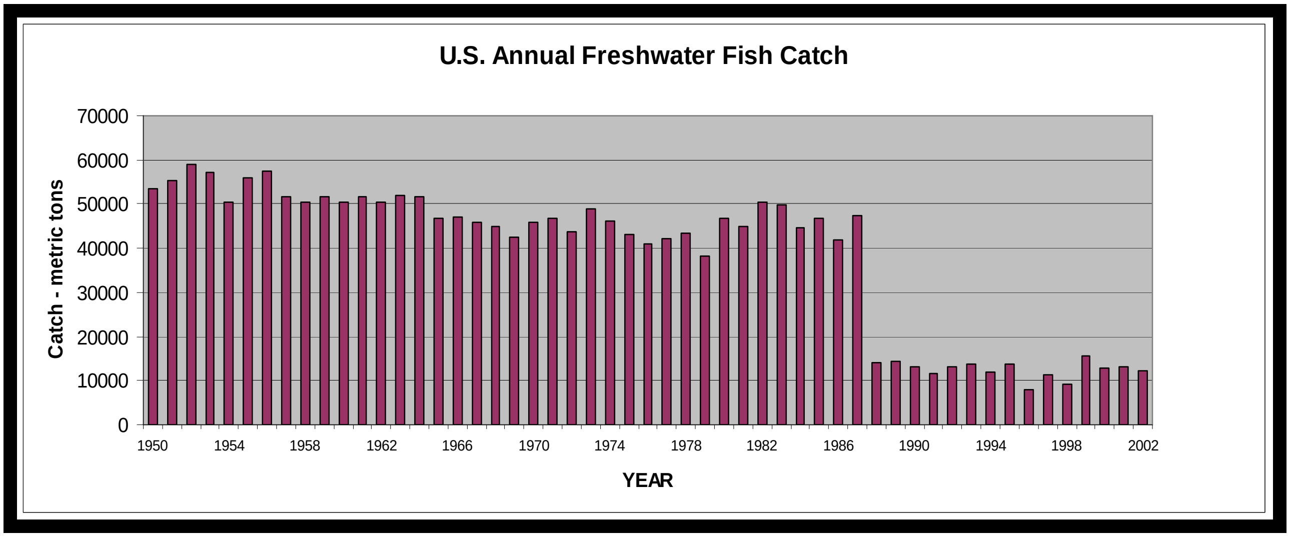
Fresh water Fish Catch (as measured in fish catch amount per year)

The integration of biological productivity in an aquatic ecosystem through a measure like fish production, can demonstrate the health of that ecosystem's different interrelated processes. If there are no fish to catch in a particular body of water, one could assume that this system is much less productive (less healthy) than a body of water that allowed fisherman to catch 10 lbs of fish per man-hour of fishing. The measurement of fish productivity in ecosystems from the measurement of fish catch is a good indicator of aquatic ecosystem health because:

- Fish populations and individuals generally remain in the same area during summer seasons.
- Communities are persistent and recover rapidly from natural disturbances.
- Comparable results can be expected from an unperturbed site at various times.
- Fish have large ranges and are less affected by natural microhabitat differences than smaller organisms. This makes fish extremely useful for assessing regional and macro-habitat differences.
- Most fish species have long life spans (2-10+ years) and can reflect both, long-term and current water resource quality.
- Fish continually inhabit the receiving water and integrate the chemical, physical, and biological histories of the waters.

Fish represent a broad spectrum of community tolerances from very sensitive to highly tolerant and respond to chemical, physical, and biological degradation in characteristic response patterns.

Figure 4.15.1
U.S. Annual Freshwater Fish Catch



(Source: The World Resources Institute Earth Trends Report, *Capture by Species: Fresh water Fish* (http://earthtrends.wri.org/searchable_db) as reported by the Food and Agricultural Organization of the United Nations, 2004 (http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp)

What Do the Data Show?

As shown in the U.S. annual fresh water fish catch graph illustrated above, 53 years of annual fish catch data show a major decline in catch after 1987. This decline is so sharp and large that one might conclude the data before and after 1987 might have been collected or reported in different ways. Since the data was all collected by the same organization (FAO of the UN) it could reasonable be presumed that there were no major shifts in collection or reporting method. If so, then the steep decline for fish catch after 1987 might suggest an indication of less fish production in fresh water ecosystems in the U.S. related to declining health of these ecosystems. But alternative interpretations of the data can also be made, especially because the decline in annual fish catch also somewhat mirrors the decline in fishing participation by humans as illustrated in Indicator #8 of this report that addresses resources and conditions.

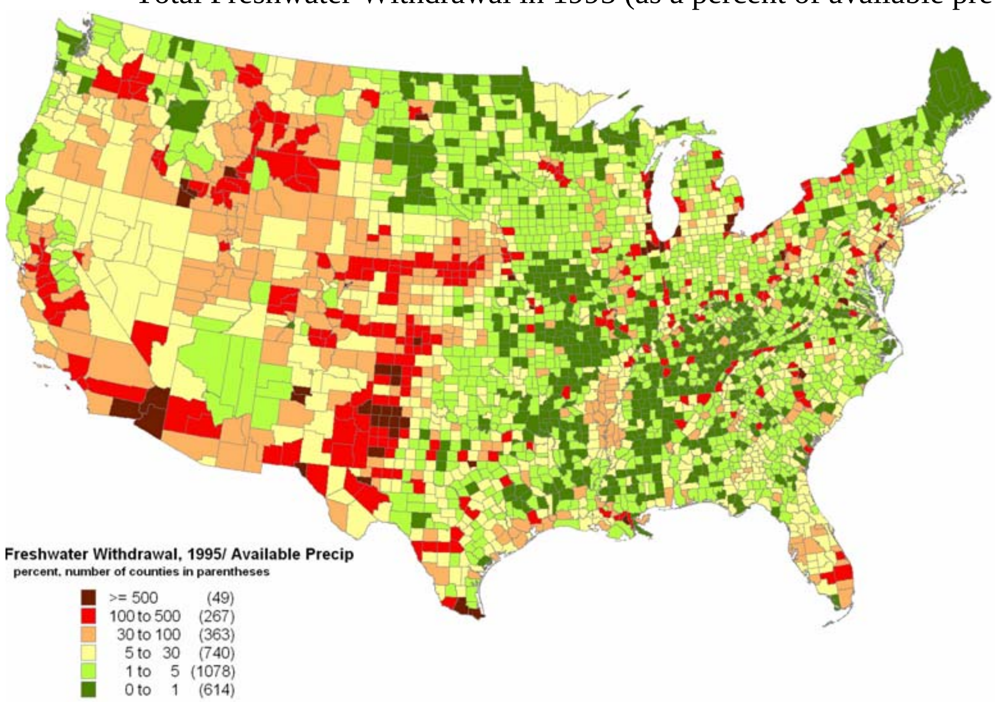
Indicators #16: Water Use Sustainability

What Is This Indicator?

Water use sustainability requires meeting the needs of humans and nature over the long term at a variety of scales, from local to national to global. This indicator reports the total amount of fresh water withdrawn for human uses as a percent of available precipitation (shown as gross water availability, or (total precipitation minus potential evapotranspiration, in Indicator 1). As a gross measure of long term sustainability, people can only withdraw as much fresh water overall as is eventually renewed by net precipitation and is not required to support ecosystems.

This measure does not account for flows of water from one area to another. In many populated areas and dry agricultural counties, more water is withdrawn than falls as precipitation. That water is either drawn from other areas conveyed by ground water, surface water or built infrastructure, or alternatively, is mined from local ground water.

Figure 4.16.1
Total Freshwater Withdrawal in 1995 (as a percent of available precipitation)



Source: Paper presented at SWRR meeting at EPRI, Palo Alto, 2004, S. Roy, K. Summers and R. Goldstein, using USGS data,) Roy, S.B., Ricci, P.F., Summers, K.V., Chung, C.-F., and Goldstein, R.A., 2005,Published as Evaluation of the Sustainability of Water Withdrawals in the United States, 1995-2025; Journal of the American Water Resources Association, 41(5):1091-1108, October 2005

An indicator of water use sustainability should ideally be map based at a fine enough resolution to be useful at the different scales needed for water supply planning. But in neither of the example indicators shown have we reached the ideal. That will require a, mapable quantification of the extent of renewable water supplies across the nation, the variable and fluctuating needs of ecosystems, and the needs of people for water today and for the long term future.

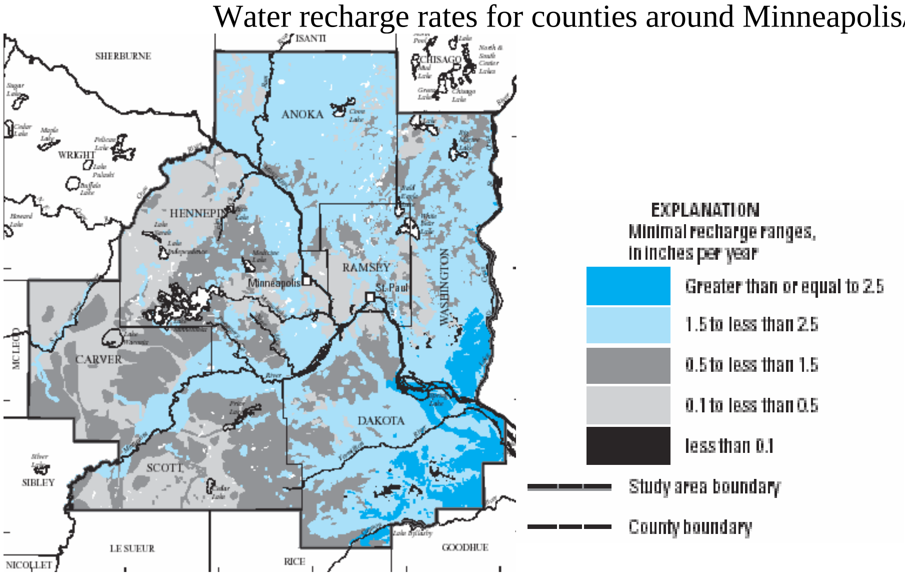
Why is This Indicator Important?

Water use sustainability is a key indicator because it helps us understand when and where water needed for human and ecosystem uses may exceed available supplies. In many regions of the US and the world, water is used at rates that cannot be maintained. Being aware of where these trends exist will support development of the information, programs and policies required to avoid critical water shortages in the near and long term.

Kanivetsky and Shmagin have looked at how the recharge/discharge rates of ground water and surface water flows vary with the bedrock and quaternary (surface and soil) geology. From such analyses, they define recharge and discharge parameters that can help quantify the limits of sustainable water use. Figure 4.16.1 presents results of such an analysis for the Twin Cities, Minnesota.

Figure 4.16.2

Water recharge rates for counties around Minneapolis/Saint Paul



(Source: Roman Kanivetsky, Minnesota Geological Survey, 2001)

What Do the Data Show?

The United States has renewable supplies of water larger than the rate of use, but it is not evenly distributed. Many areas use more water than can be considered sustainable. Nationally, water resources appear ample but this is an indicator for which the nationwide average is not meaningful. Locally, the situation varies widely. In all the red and dark maroon areas on Figure 4.16.1, water use exceeds the total available precipitation. This excess is made up by drawing water from other areas or drawing down water supplies. This may not be ecologically, economically or politically viable for the long term.

End Notes

Shmagin, B. and Kanivetsky, R., 2002, System analysis to estimate subsurface flow: from global level to State of Minnesota: Environmental Geology, v.42, no. 2-3, p. 259-269.

Indicator #17: Water Quality Sustainability

Responsibility for monitoring of water quality is held by many diverse government agencies at the federal and state level. Each state submits 305b reports on water quality to the Environmental Protection Agency but they are not useful as a source of national-level water quality information because states have different standards, different mechanisms of interpreting those standards, and inconsistent commitments to reporting the results of their assessments. The scale used for the reports is the 8 digit HUC watersheds which are convenient for mapping the country but too large to reflect the scale of most of the projects that an agency would implement to improve water quality.

In addition to the problems with measures of surface fresh water, to get an overall indicator of water quality we would need to integrate or include data on groundwater, wetlands, estuaries and coasts that based on compatible methodologies and comparable assessments.

The National Water Quality Monitoring Council, like the SWRR a subgroup of the Advisory Committee on Water Infromation is working with many agencies to identify, examine, and recommend monitoring approaches that facilitate collaboration and yield comparable data and assessment results.

In a time of tight budget constraints the funds to expand monitoring and analysis of water quality may not be readily available. The SWRR will support efforts to make good data available so that in the future good indicators of water quality can be developed.

Alaska Salmon Stream
David Berry

4.18 Applications of Indicators at Regional and Local Scale

The leaders of nations can't keep track of every family, species, business or lake. But actors down the line, in the family, near the lake, need detailed information to keep their part of the system functioning well.

Indicators and information Systems for Sustainable Development by Donella Meadows, September 1998

The Issue of Geographic Scale

The struggle for sustainable management of water-related resources takes place at every scale, from the neighborhood to the nation and from the smallest watershed to the largest basin. While Minnehaha Creek in Minnesota has a lot in common with the Mississippi River, the differences in their size mean different numbers and levels of interested governments, different social, economic and ecological issues and perspectives about what's important and, therefore, different types and ways of presenting the indicators people need.

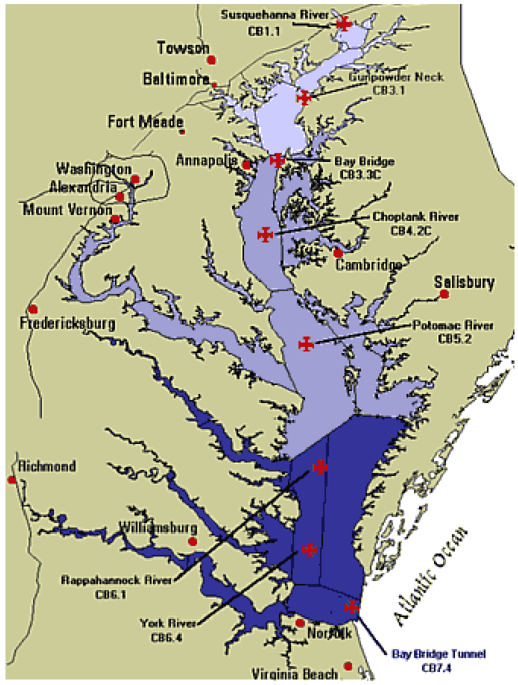
The citizens and managers of Minnehaha Creek, an urban-suburban stream, want to understand how urban storm water runoff affects dissolved oxygen and the stream's bass fishery. People focused on the Mississippi River may have an interest in dissolved oxygen and fish, but the scale of their interests dictates that they begin their review with a different screen. They'll need information that helps place concern with dissolved oxygen and fisheries in perspective, both geographically (i.e., where the problems exist) and topically (what other problems compete for their attention). In addition, the state, interstate and national levels of government that might have interest in the Mississippi's management needs, are more likely to focus on broader policy and funding questions than they are contacting riparian landowners to solve a specific runoff problem. That might lead a Mississippi interest to look for indicators that sum up the problem and rank it in comparison to others, like systems degraded by agricultural practices.

Depending on its location on the Mississippi and its connection to the river, each state along the way from Lake Itasca to the Gulf of Mexico is likely to have its own unique perspective about the river. A trip up the Mississippi's largest tributary, the Missouri, would take one through states of still greater distinction, with different climates, habitats, economies and water law. Scale determines focus; the people and resources at a given scale determine the issues that gain prominence and the indicators they require.

Local and Regional Scale: An Example of the Chesapeake Bay

The Chesapeake Bay Program combines characteristics of local geographic scale in a unique water resources region of the nation. (See http://www.chesapeakebay.net/.) Figure 4.18.1 depicts the bay.

Figure 4.18.1
Chesapeake Bay with Main Tidal Rivers



(Water Quality is Collected at Representative Stations Shown.)

Table 4.18.1 summarizes the most important water indicators developed for the bay, organized along the lines of the major categories used in the program: *Animals & Plants, Habitat, Water Quality, and Pollutants*. Additional categories are not described here.

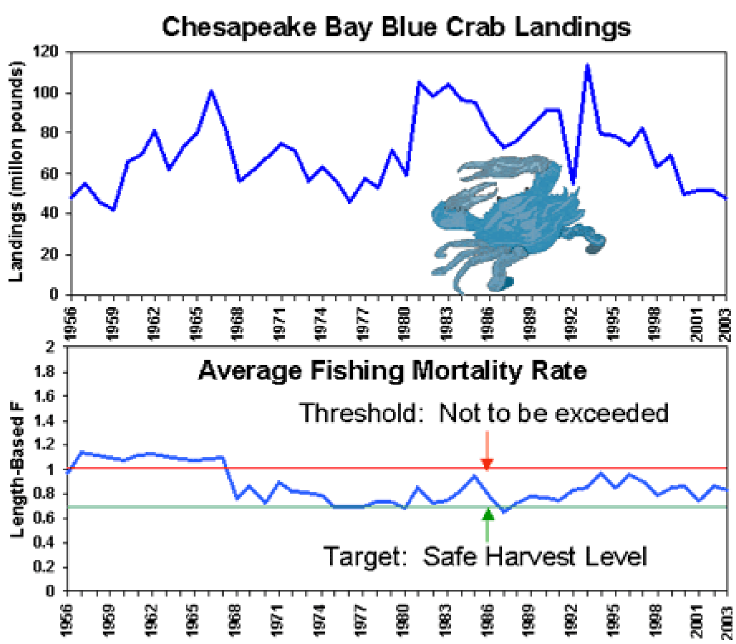
Table 4.18.1
Selected Generalized Water Indicators Used in the Chesapeake Bay Program, by category

Animals & Plants	Dissolved Oxygen
Bay Grasses	Nitrogen
Birds	Phosphorus
Crabs & Shellfish	Sediment
Fish	Suspended Solids
Benthos	Submerged Aquatic Vegetation Area
Habitats	Temperature
Stream Miles for Migratory Fish	SalinityChemical Contaminants
Wetlands Protection	Pollutants
Oyster Bed Restoration	Air Pollution
Water Quality	Nutrient & Sediment Loads
River Flow	Wastewater Flows
Chlorophyll *a*	Population
Secchi Depth	

The 64,000 square mile Chesapeake Bay watershed extends from New York to Virginia, and from West Virginia to Delaware. Many of the issues throughout this watershed are related to water quality and for that reason the indicators chosen as important tend to reflect this concern. For example, the Chesapeake Bay Program conducts analyses from provisional data collected by Maryland's Department of Natural Resources and Old Dominion University for surface temperature, bottom dissolved oxygen, water clarity and surface salinity. The program also tracks average monthly river flow data provided by the United States Geological Survey.

While Table 4.18.1 shows only a list of indicators, a deeper understanding of how measures can contribute to understanding real-world conditions is provided by Figure 4.18.2. The Chesapeake Bay is the largest producer of crabs in the country; it's estimated that more than a third of the nation's catch of blue crabs comes from Bay waters. Commercial harvests in a good year can yield close to 100 million pounds annually. There is concern about the blue crab fishery due to increased harvest pressure. The 2003 harvest of approximately 48 million pounds is below the long-term average and near historic lows. The 2003 fishing mortality rate did not exceed the "over fishing" threshold, but is above the desired target. The indicator tells a story about the Chesapeake Bay blue crab fishery and raises important questions that water managers and policy makers need to answer.

Figure 4.18.2
Blue Crab Commercial Harvest Statistics



Sources: Landings - National Marine Fisheries Service, NOAA
Mortality - Chesapeake Bay Stock Assessment Committee

Geographic scale has a great influence on the kind of water indicators people need and expect. Some indicators, like water use and dissolved oxygen, tend to appear in some form at many scales. But others appear at the level of a locality or region. Indicators developed for specific regions like the Chesapeake Bay, Everglades, Great Lakes and the arid Southwest might be particular to a region and might not recur elsewhere (for example, Blue Crab statistics for the Chesapeake Bay). The SWRR recognizes the importance of such regional efforts to painting the national picture of water sustainability.

CHAPTER 5 RESEARCH NEEDS FOR SUSTAINABLE WATER RESOURCES MANAGEMENT: THE SWRR ANN ARBOR MEETING ON RESEARCH

At every meeting of the Sustainable Water Resource Roundtable, water resource experts shared information as well as perspectives on how to promote better decision making in the U.S. on sustainability of water resources. Discussions of research needs and opportunities for collaboration among public and private organizations have been central to our work from the outset. To further this objective, a workshop of experts was convened in April 2005 to explore research priorities with an emphasis on sustainability in the Great Lakes Region. While the meeting focused on the Great Lakes Region, the discussion and conclusions are broadly relevant to sustainability of water resources.

Hosted by SWRR and the University of Michigan, 75 experts convened for a two-day workshop April 5 and 6, 2005 in Ann Arbor Michigan. The workshop consisted of over 25 technical presentations on sustainability research by leading experts from six perspectives:

- Power Generation
- Agriculture and Forestry
- Urban Issues (water supply, storm water, wastewater, land use, etc)
- Manufacturing/Industry
- Ecological Protection and In-stream Uses
- Ethics, Law and Policy

The workshop also included breakout discussion groups on the above topical categories, with the exception of Ethics, Law & Policy, which was merged into discussions of the other five. Each group was charged with examining research needs from its special perspective and reporting back to the entire group. In plenary session, participants examined the differences, similarities and commonalities of the small group conclusions.

Several key observations emerged in the conversation, including the need to:

- Improve understanding of the critical water resource processes that impact sustainability
- Develop decision support models and tools
- Conduct a better inventory of critical data
- Adopt new monitoring technologies
- Develop a conceptual approach to quantify the value of water
- Establish new policies and law to manage water on a regional basis
- Solve the forecast drain in central human resources and knowledge

Each is very briefly described below based on discussion in the separate and plenary sessions.

Process Research: All groups recommended that a better understanding was needed of the cause and effect processes impacting sustainability, although the specifics often differed. However, one common issue was the need to better understand the link between land uses and water quantity, quality and ecological health.

Decision Support Tools: Although often using different terminology, all of the groups recognized a priority need for analytical tools and models that can support better decision making on sustainability relevant to policy decisions. Each of the groups highlighted a priority to develop, improve, and more widely use decision support tools/models. Specifically the groups saw a need to increase the use scientific knowledge and insights in policy decision making in a quantitative fashion; quantitative with respect to quality, quantity, uses and valuation.

Data Inventory: Each group recognized that predicting the future and making important policy decision was predicated on the need to have a more comprehensive understanding of current conditions. Each group emphasized the need to build a better inventory of current and baseline conditions, but here again they each focused on different elements of it ranging from better database management, to better inventory of land uses and water data, to better understanding of natural baseline variability and existing conditions, as well as better information in new pollutants

Technologies: There was broad agreement on the need for new monitoring technologies both for water quantity and quality, not only for traditional contaminants such as nutrients and bacteria, but exotics such as pharmaceuticals and viruses. Additional examples of new technologies could include wireless and remote sensing. Individual groups suggested the need for advanced treatment and water use efficiency technologies.

Value of Water in Policy Decisions: All the groups recognized that as a society and an economy we have poor quantitative understanding of the "value" of water. Here again, there was a consensus opinion that developing approaches that recognize the value of water in its various uses by different stakeholders was a key to guiding decision making for sustainability, protecting all uses. The value of water must be incorporated into policy decisions.

Better Law & Policies: All of the groups recognized that new regional and national policy was needed to better promote sustainability. How those policies would be created or implemented was not an area of consensus and in fact was an area of disagreement. However, the group did express two strong areas of agreement. First, policy was needed to promote sustainability and research through integration and better use of existing the operations of individual government agencies and creation of new approaches. Second, managing water resource sustainability must have a regional focus and needs to come from an understanding of regional hydrology and regional uses.

Human Resources: A surprising area of consensus discussion by the group of experts was the recognition that sustainability is threatened by a current forecast indicating a shortage of knowledgeable and experienced water professionals. The experts recognized that universities were producing fewer environmental scientists and engineers with relevant specialization than in the past and that over the next ten years a major segment of professionals with key knowledge would be retiring. This is true both in academia and in large agencies such as USGS and EPA. Research is needed as to how these critical human resources and knowledge base can be sustained.

Collaboration: One final area of commonality in all of the group discussions was the need to encourage more collaboration among agencies, with industry, among governments, NCOs, and research institutions. The group strongly felt there were many shared interests and that our overall effectiveness would be greatly enhanced by more collaboration, whether by voluntary encouragement, economic incentives or policy/law changes.

The above were the overarching and consensus research recommendations of the experts at the SWRR Ann Arbor meeting. The detailed and specific recommendations provided by the individual sector groups are found in the SWRR report on the meeting titled Great Lakes Region Research Priorities Workshop (available on the SWRR web page). It is interesting to note that although the five groups were organized to evaluate research needs in the context of separate stakeholder perspectives needs that in the end there was considerable commonality to their separately conceived priorities. These underscore the realization that sustainability is a common interest, and vehicle for collaboration *not confrontation* among different users. Researching and promoting sustainability can best be realized by collaborative efforts.

The research recommendations are summarized in Table 1 below, which provides a matrix of research areas (Process Understanding, Inventory, Tools, Technology, Policy, and Law) mapped against the relevant sectors.

Table 5.1
Abstracted Summary of Sector Discussions on Research Needs for Sustainability

Urban	Power	Industry	Agri/Forestry	Ecology
Process				
• Tolerable loss of water • Population & land use impacts on quantity and quality	• Regional hydrology	• Factors that determine lake levels	• Soil loss • Economic links to sustainability • Effects of land use changes	• Quantification of stressors & receptors • Definition of baseline conditions • Resistance & resilience • Resistance & resilience • Effectiveness of BMPs
Tools				
• Metrics to determine "value" of water	• Decision support tools • Better methods for TMDL analysis • Watershed, hydrology & biogeochemical models	• Predictive models • Tools to understand and predict lake levels	• Decision support tools	• Decision support tools • Improved criteria
Inventory				
• Comprehensive data base of all uses • Inventory of available water	• Aquifer data base • Regional hydrology • Technologies for water treatment and efficiency	• Inventory of baseline conditions • Data base of emerging pollutants	• Database of land use • Data base of emerging pollutants	• Comprehensive data base of all uses • Inventory of baseline conditions
Technology				

Urban	Power	Industry	Agri/Forestry	Ecology
• New monitoring technologies (quantity and quality)	• Water treatment technologies • Fresh water conservation	• New monitoring technologies (quantity and quality) • Conservation and reuse technologies	• Riparian management effectiveness & approaches	• New monitoring technologies (quantity and quality) • Effectiveness of BMPs
Policy				
• Value of water • Shortage of appropriate engineers and scientists • Stakeholder involvement • Management structure • Social landscapes • Use allocation	• Value of water • Shortage of appropriate scientists and engineers	• Lake level management • Promote collaboration	• Science based policy • Relation between economic factors and sustainability • Public perceptions • Valuation	• Criteria for social valuation • Better defined goals • Better collaboration
Law				
• Land use taxation	• Water rights • Integrated planning among overlapping agencies	• Regulatory incentives	• Policy tools	• Water withdrawal laws (indicator based)

There is new evidence that water scarcity will be the world's leading resource issue as we enter the new century.

— *Lester Brown "State of the World, 1999*

CHAPTER 6 FUTURE WORK AND THE ROLE OF ORGANIZATIONS

This chapter discusses the future work of the SWRR, which includes broadening and deepening the participation of the many organizations who share interest and responsibility for managing water resources.

Different organizations have different jobs in society's pursuit of sustainable development. This dictates the scale and focus of the indicators in which they will have an interest, and for which a system of indicators can be designed.

Roles of Various Organizations

The roles of the federal, state, local and tribal governments in helping society become sustainable are complex and multi-faceted. Each can be advocates and integrators of social, economic and environmental goals. They work to protect and allocate resources. They levy taxes and set fees, fund research, educate, regulate, subsidize, invest and act as product consumers. They also collaborate extensively with other levels of government, regional organizations, non-governmental organizations and the private sector. Organizations in the private and non-profit sectors also have a variety of roles. How organizations perform each of these jobs is important but understanding how to do a job in a sustainable manner is not always easy. All organizations can benefit from clear definitions of key terms and guidance on translating indicators into actions. The scale and focus of each organization dictates the indicators in which it will have an interest, and for which a system of indicators can be designed. At the same time, the roles and responsibilities sometimes overlap or work together as the following sections illustrate.

State Governments

The states have the lead responsibility for managing water quantity but serve as implementing arms of EPA in water quality management even when they have their own state water quality regulations.

In working to manage water sustainably, states will benefit from understanding how water affects and is affected by social, economic and environmental systems, today and long term. This is a daunting task, and it makes opportunities for collective action beyond a single state's borders important to seize. Examples of these opportunities include:

- Understanding sustainable development
- Understanding systems, system change and drivers
- Understanding out-of-bounds inputs and sinks (such as mercury or acid deposition from sources outside a state's boundaries)
- Collaboration in monitoring, research, assessment, regulation, education, fund raising, consuming

These state opportunities also show the work of the Sustainable Water Resources Roundtable to be timely and on target. In particular, the SWRR can help by developing a uniform framework for understanding water sustainability, including a vision, principles, criteria and indicators. It also can help by identifying the key water connections within and among social, economic and environmental systems.

States will benefit greatly from a commonly accepted definition and conceptual model for understanding and measuring progress toward water sustainability. The model should include examples of how the concept of water sustainability includes, pervades and affects social, economic and environmental elements. Just like you cannot "take water out of the environment," one cannot divorce water from its uses and benefits when analyzing its "sustainability." In other words, the concept of state "water sustainability" has little meaning in a vacuum – without the tie to how water management may or may not meet existing and long-term future needs of people and ecosystems.

The Federal Government

The Federal Government is the largest land owner in the United States. These lands are managed the National Park Service, Bureau of Land Management and Fish and Wildlife Service of the Department of the Interior, the US Forest Service of the Department of Agriculture and the Defense Department with its large military bases and reserves. As a landowner, the Federal government shares responsibility with the states for the management of the quality and quantity of much of the nation's surface and ground water and whether or not those resources are managed on a sustainable basis. There are many other roles and responsibilities in federal water management and these, at times, can be overlapping, and in apparent conflict among the federal agencies and bureaus.

The Environmental Protection Agency monitors water quality as do Bureaus of the Department of Interior and the Department of Agriculture. The US Geological Survey in the Department of Interior for example, maintains approximately 7000 stream gauges measuring flow. The National Oceanic and Atmospheric Administration monitors and works with marine coastal and estuarine resources.

The Environmental Protection Agency, Fish and Wildlife Service and the Natural Resources Conservation Service have Congressional mandates to regulate and enforce environmental laws related to water often in relationship with state governments.

The US Army Corps of Engineers and the Bureau of Reclamation in the Interior Department have responsibilities for management of dams, levees and rivers and the Tennessee Valley Authority is responsible for river basin management in its jurisdiction.

Research related to water resources availability, demand, quality and sustainability is carried out by all of the agencies named with the addition of the Department of Energy.

In all of this work the responsibility for water resources is shared in various ways with state, tribal and local governments and with private property owners. The great diversity of issues, jurisdictions, ad responsibilities among so many organizations makes coordination and collaboration challenging. This makes the work of the Sustainable Water Resources Roundtable, its sponsoring organization the Advisory Committee on Water Information (ACWI) and other ACWI sub groups such as the National Water Quality Monitoring Council particularly important.

The Private Sector

As global demands for water increase and access and availability become more unpredictable, the business community is seeing the need to move forward in developing innovative ways to manage water in a sustainable manner. Not only is this good for business, but for the communities in which businesses work and the environmental resources on which they depend. Clean freshwater is essential environmentally, socially, and economically.

The business community is facing many water-related challenges that can constrain activities. Water costs are increasing as a result of competition, supplier disruptions from water shortages, and governmental regulations that are becoming more stringent as they move from technology to watershed health-based approaches. Allocations, water supply reliability, consistent quality, and rights for water use and discharge of pollutants are not assured into the future. Sustainability of water and other natural resources are becoming of increasing concern to customers, shareholders, and the communities in which business operate and in which their employees live. Balancing these and other competing water needs requires innovative ideas and forward thinking, planning, and management.

Sustainable use of water will keep costs of running a business down in the long run and those companies that move beyond efficiency to holistic sustainability approaches can benefit by identifying new market opportunities, creating shareholder value, and increasing public and community support for their companies' practices. Partnerships and collaborations are important. Many businesses are working with communities and non governmental organizations on mutually important water issues. There are increasing examples of businesses collaborating with environmental organizations on protection and restoration of wetlands, or coordinating with community groups on investments and source water protection. Business often takes a back seat to government and they, along with other stakeholders, will need to find ways to increase their opportunity to participate in policy decisions. In addition, better coordination within their own supply and marketing structure can help to assure that corporate policy and standards are maintained.

The business community needs a range of information to better understand water resources in an integrated economic, social and environmental context. This includes the following types of information:

- Analytic tools and predictive models that can support better decision making.
- Science based indicators that can provide an inventory of baseline conditions, changes in water sources, soil loss, and impacts of business practices
- Databases of emerging pollutants and land use changes
- Regional hydrology
- Economic links to sustainability

- Opportunities to work collaboratively with other sectors
- Innovative educational programs and learning tools for business and community leaders

The Sustainable Water Resources Roundtable efforts to date address many of these needs. In addition to the development of criteria and indicators, the Roundtable is directing efforts to identify research needs critical for business, social, and ecological decision making.

Non-Governmental Organizations

Non Governmental Organizations (NGOs) play significant roles in the use and understanding of natural resources at the local, national and international levels. Those with interest in sustainable use of natural resources include scientific and business institutions and associations, environmental organizations, humanitarian and community development groups, foundations, and charitable and religious organizations.

NGOs address water resource issues through social, economic, and environmental lenses. Research oriented NGOs provide scientific or conceptual information on these issues to the public, industry, government or other sectors. Some NGOs play an advocacy role in policy or actions that impact sustainable water resource use decisions, and support the goals of their particular constituencies. Others may mitigate perceived negative impacts of resource decisions including issues of social and environmental equity or they may initiate actions themselves. They can also act as watchdogs of public, private, and governmental activities and resource use decisions.

SWRR products have the potential to strengthen the effectiveness of a range of NGO activities. Common concepts and language can play a judicatory role in forming alliances among groups with diverse goals, and can facilitate dialogue on potentially contentious issues. A set of criteria and indicators in a framework that shows the relationships among ecological, social, and economic components of resource use can provide useful tools to identify trends, causes, and outcomes and help design approaches to enhance or mitigate impacts of human activities and natural processes on water resources. Such a framework can help address perceived conflicts between ecosystem and human needs, communities and industry, or land conversion and the provision of ecosystem services. NGOs range from small volunteer groups working in their local watershed to large professional groups at the international level. To be useful to organizations working at all scales, criteria and indicators must provide a range of choices and possible measurement options to enable groups to gather and interpret the type of information they need for their particular objectives.

NGOs often form around an issue that affects a local region or a particular issue impacting a citizens group. Foundations, scientific institutions, and policy makers are encouraging many NGOs to couch their issue in larger contexts such as climate change and integrated sustainable food systems. These larger concepts are seldom the driver for their on-the-ground work but good indicators can help couch their concern within larger conceptual models.

The NGO community could benefit greatly from the cross sector collaboration of the SWRR process. If successful, this model will support the provision and sharing of ideas, access to information on the functioning of aquatic systems and water resource allocation and use, and results and interpretation of indicator data. NGOs can also benefit from open discussions with multiple parties about research needs that can support NGO work.

Conclusions and Future Work

The circulation of this Preliminary Report marks the completion of the first round of SWRR work on criteria and indicators. To highlight our work on research, Chapter 5 of this report is derived from the executive summary of a report on a major meeting on research on sustainability of water resources held by the SWRR at the University of Michigan at Ann Arbor. (The full report is posted on the SWRR web site.)

The first useful outcomes of this work are that the participating federal, state and private organizations and others who discover the work will have an opportunity to:

- Select and use whichever indicators are useful for their work;
- Continue to explore opportunities to pool resources and otherwise collaborate on research; and
- To build relationships and expand the sharing of information and viewpoints about the sustainability of water resources.

We hope that over the next few months, SWRR will receive feedback and better yet, participation on the roundtable by a widening circle of people.

The tasks ahead of the SWRR and its participants include the following:

- Continue to revise and refine the indicators for sustainability of water resources. We plan to develop indicators at various scales that will allow for tracking national, state and local trends related to water sustainability.

- Assist agencies by describing the need for programs to collect the information necessary for generating indicators. Some of the recommended indicators from our long process of distilling ideas from many sectors have not been completed and in some cases this is because no organization is yet gathering the needed data. We will support government agencies in maintaining and increasing the resources they need to gather and analyze this data.

- We will work to increase representation from regional water management programs to benefit from the alternate points of view and experience, and to offer the benefits of the networking and interactions among SWRR participants to those organizations and programs.

- Expand relationships with the scientific community, to draw on the best ideas in water disciplines and encourage research into sustainability as it relates to water resources.

- Consult with the National Research Council Key National Indicator Initiative, the Council on Environmental Quality, the Heinz Foundation and others on water-related indicators.

- Explore, in partnership with other water resource related organizations and forums, a National Forum on Sustainable Water Resources.

It's but little good you'll do watering last year's crops.
Adam Bede. Chap. xviii.

George (Marian Evans Cross) Eliot (1819-1880)

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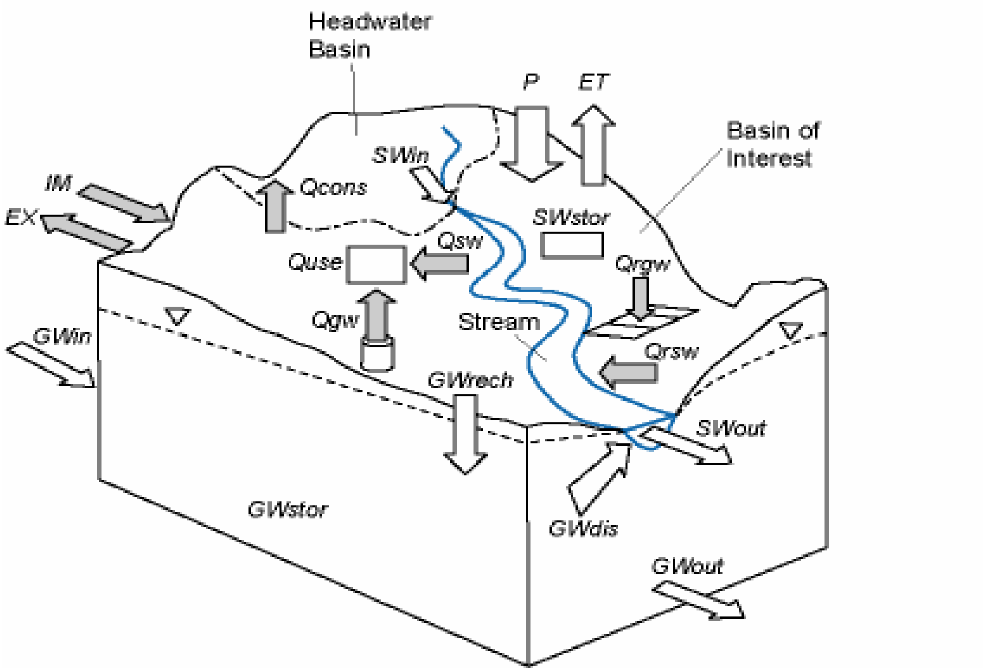
APPENDIX A: THE HYDROLOGICAL CYCLE

In many places in the text of the SWRR report, there are references to the hydrological cycle and to a water budget approach to sustainable management of water resources. Figure A.1 illustrates components of the hydrologic cycle in a representative watershed (basin). The hydrologic components serve as a basis for several of the indicators described in Chapter 4. The level of detail given of components of the hydrologic cycle varies with the purpose and scope of the particular analysis. For example, the ground-water discharge term (GWdisch) shown in the figure could be further divided to include discharges to streams, discharges to wetlands, or evapotranspiration losses directly from the water table. For this analysis, we group all ground-water discharge processes into a single total discharge rate.

Figure A.1
Water-budget components of a hypothetical watershed



Source: Paul Barlow, US Geological Survey, 2005

Definitions
P: precipitation; ET: evapotranspiration; SWin: streamflow into the basin; SWout: streamflow out of the basin; GWin: ground-water flow into the basin; GWout: ground-water flow out of the basin; IM: imported water (anthropogenic transfers); EX: exported water (anthropogenic transfers); SWstor: storage in surface-water reservoirs, including human-built reservoirs, lakes, snowpack, etc.; GWstor: storage in ground-water reservoirs; GWrech: ground-water recharge other than from human sources; GWdis: ground-water discharge other than to human withdrawal points; Qsw: human withdrawals from surface-water sources; Qgw: human withdrawals from ground-water sources; Quse: human uses of water; Qreuse: human re-uses of water; Qrsw: return of water to the surface-water hydrologic environment after human use; Qrgw: return of water to the ground-water hydrologic environment after human use; Qcons: consumptive uses of water.

Appendix B: Terms of Reference

The Sustainable Water Resources Roundtable has this Terms of Reference, which was approved by the members of ACWI at the 2003 Annual Meeting June 2, 2003

I. **Official designation and authority.**

The Sustainable Water Resources Roundtable (SWRR) is a subgroup of the Advisory Committee on Water Information (ACWI) Hence, the Roundtable is part of the Water Information Coordination Program mandated by OMB Memorandum No. M-92-01, dated December 10, 1991. The Roundtable reports to the ACWI and operates under the Federal Advisory Committee Act (FACA), as outlined in this Terms of Reference.

II. **Purpose, background, scope, and functions.**

A: Purpose: The purpose of the Roundtable is to provide an open forum for exchanging ideas and information to foster collaboration on ways to manage water resources in such a way that the resource and its uses may be sustained over the long term. The Roundtable has adopted the Brundtland Commission (1987) definition of sustainable development as a starting point for discussions, with the full expectation that the many different dimensions of water sustainability will be a focal point of the Roundtable's activities:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Roundtable participants are committed to interdisciplinary, inter-jurisdictional, and cross-ownership collaboration that identifies and supports national, state, and field-level activities to sustain water resources. Roundtable discussions and activities will focus in part on criteria, indicators, and methods for assessing the sustainability of water resources, as well as exploring, promoting, and improving how this information is used to promote sustainable water resource management.

B: Background: The Sustainable Water Resources Roundtable is one of a number of on-going efforts to develop ways of collecting, organizing, and using information on conditions and trends to promote sustainable development. The Roundtable grew from the Interagency Working Group on Sustainable Development Indicators, which published the report *Sustainable Development in the United States; an Experimental Set of Indicators*. The Roundtable has also benefited from the experience of similar Roundtables on forests, rangelands, and minerals and energy.

State governments, communities, corporations and nongovernmental organizations (NGOs) have also independently undertaken studies on the development of sustainability indicators. This Roundtable will discuss ways to coordinate and integrate the results of these various efforts so that the indicators and related data can be made accessible and useful to people in a wide range of contexts.

C: Scope: In practice, the scope of the Roundtable's activities and accomplishments will depend on the initiatives and priorities of the participants, as well as the availability of resources. Issues the Roundtable will likely explore include:

- Contributing to the development of a list of national-level ecological, social, and economic criteria and indicators along with measurement protocols that characterize water resources and their uses;
- Identifying existing data sets and measurement protocols that can be used to conduct assessments using the criteria and indicators;

- Contributing to the development of a national data inventory framework from which governmental and non-governmental agencies, tribes, other organizations, and universities collaboratively access and evaluate water-resources indicator data from across the United States;
- Identifying data-collection and research needs to characterize and improve the sustainability of the Nation's water resources; and
- Contributing to the development of a collaborative 2005 report on the sustainability of water resources and uses in the United States, utilizing the criteria and indicators.

However, the Roundtable is specifically charged with reporting to the Advisory Committee on Water Information and other interests by October 2005 on conditions and trends of the Nation's water resources that affect the long-term sustainability of these resources. The Roundtable may suggest research studies, policies, strategic objectives, and priorities considered potentially useful in inventorying or monitoring water-resource sustainability. The Roundtable also may issue periodic reports before and after October 2005 related to water-resource sustainability.

D: Functions: The functions and tasks of the Roundtable include the following:

- To serve as a national forum for sharing information and promoting responsibility and research for sustaining the Nation's water and related land resources. The Roundtable is not a decision-making body, but rather an opportunity to engage individuals representing diverse groups, organizations, interests, and backgrounds.
- To identify and describe criteria, indicators, and methods that characterize the sustainability of the Nation's water resources; to share information about data availability and quality, data gaps, and how best to acquire desired information; and to share perspectives about trends affecting the Nation's water and related land resources that have policy or other coordination implications.
- To produce products that will disseminate the work of the Roundtable (such as white papers, web listings, newsletter articles), as specified in a Work Plan, and accomplished depending on the availability of resources.
- To consult regularly with the forestry, rangelands, and minerals Roundtables about common considerations and programs.
- To conduct outreach activities to inform others about the findings, recommendations, and activities of the Roundtable and to provide an opportunity for interested groups to participate in the Roundtable.
- To report annually the progress of the Roundtable to the ACWI.

III. **Implementation.**

A: Roundtable Participation: The Roundtable recognizes the importance of having a broad range of interests represented among its particpates and will seek to achieve and maintain the diversity.

The Roundtable will consist of representatives of federal, tribal, and state agencies, as well as diverse national organizations, companies, and individuals committed to sustaining the Nation's water and related resources.

Participation in the Roundtable and any of its workgroups and functions is open to all interested parties and is intended to be inclusive of a wide range of interests.

B: Roundtable Work Groups: The Roundtable will accomplish most of its work through work groups that seek to assess existing information, define concepts in water-resources sustainability, research topics in water-resources sustainability, develop reports, and conduct outreach to key constituencies.

Work groups are established according to the interests of individuals who wish to undertake specific actions or activities; formation of work groups occurs either during regularly scheduled Roundtable meetings or by approval of the Steering Committee between meetings.

Roundtable participants may want to be part of specific work groups that develop as part of the Roundtable process. Participation in work groups would require ongoing, consistent involvement and representation.

Participation in a Roundtable work group is voluntary and provides opportunities for participants to focus on high priority tasks important to the Roundtable, individual participants, or participating organizations.

C: Guiding principles: The Roundtable is a self-directed body that strives to conform to principles of operation rather than rigid rules of governance. However, in the course of conducting its activities, decisions will be governed by the following guiding principles:

Consensus: The Roundtable actions in general will be governed by consensus decision-making, indicating the general acceptance and/or support of participants.

Diversity: Fundamental to the Roundtable is the participation of individuals representing diverse interests and organizations. Hence, the Roundtable actions should reflect diverse participation to the extent feasible and consistent with the overall Roundtable composition.

Consistency: Actions, findings, and recommendations by the Roundtable should strive to build a web of consistency in thought and action.

Scientific and Technical Accuracy: The Roundtable will strive to incorporate the most current and scientifically accurate information and data on water-resource availability, use, and sustainability in its reports and other products.

Feasibility: Sustainable water resource plans require scientifically sound theory as well as realistic expectations for implementation. Hence, the Roundtable will focus on data-collection methods, scientific approaches, or actions that are considered feasible.

D: Role of Co-chairs and Steering Committee: The Steering Committee provides principal leadership for the Roundtable, insuring that the activities and accomplishments of the Roundtable progress adequately and conform to the Roundtable objectives, principles, and scope. The Co-chairs act as agents of the Steering Committee but in this regard must also provide additional leadership. The steering Committee and Co-chairs do not set the agenda of the Roundtable, but rather facilitate a process for the Roundtable to establish its own agenda and then facilitate and monitor the accomplishment of that agenda. Some of the overall roles and responsibilities include:

- Take an active role in leadership of the Roundtable, including personal initiative and encouraging involvement from the organizations that the individual represents.
- Act as advocate and spokesperson for the Roundtable promoting its agenda, accomplishments, and findings.
- Seek to broaden the participation in the Roundtable by active recruitment among those in government, business, environmental, public interest, academic, professional association, and other organizations.
- Develop and manage a budget, including solicitation of funding, to provide resources for the Roundtable operations. Identify services in kind that organizations may be able to contribute to Roundtable operations.

- Identify and work with organizations that can be local conveners of Roundtable meetings, in various parts of the nation.
- Develop an ongoing work program for the Roundtable, with support of the general roundtable participants and the supporting organizations. Monitor the progress of this program.
- Charter work groups of the Roundtable in response to Roundtable initiatives.
- Work to develop relationships with ongoing programs in other organizations that relate to sustainable water resources. Take an active role in creating positive and complementary actions that minimize duplication among programs.
- Participate in administrative decisions of the Steering Committee.

Co-Chairs of the Roundtable are normally drawn from the Steering Committee. Ideally, there should be chairs from the public and private sectors. They serve for one year, and this term may be renewed

IV. Participation, Duties, and Guidelines:

Roundtable participants are expected to contribute to the workings of the Roundtable by contributing in at least one of many different roles:

- Attend meetings where participants will have the opportunity to share information, ideas, and views with other Roundtable participants and to assist in documenting the discussions.
- Participate in conference calls to plan or discuss Roundtable and/or work group activities.
- Share information internally with the participating organization and externally with appropriate constituency groups.
- Carry out activities and report results, prepare presentations, and otherwise disseminate information.
- Help prepare, edit, or review written reports by the Roundtable and workgroups.
- Contribute resources in staff, money, or materials in support of the Roundtable.
- Actively recruit new members and supporters for the Roundtable.
- Participants may serve on the Steering Committee or as a Co-chair.
- Participants of the Roundtable will receive no pay, allowances, or benefits by reason of their service on the Roundtable

Appendix C: Matrix of candidate SWRR Criteria & Indicators

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
	SOCIAL CRITERIA			**SOCIAL RELATED 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
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

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
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 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

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
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
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	Knowledge level of citizenry
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
77				Adequacy of time horizon of governmental planning efforts
78		External	Interbasin transfers of	

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
		dependence	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 readiness and hazard mitigation	Preparedness (readiness prior to threat)	
100			Resistance (defense during onslaught)	
101			Resilience (ability to recover)	
102		External		

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
		dependence		
	ECONOMIC CRITERIA			**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
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

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
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
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

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
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 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
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)
202				Water-use in relation to measures of water

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
				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 (kilowatt-hours) of thermal and hydroelectric power plants
217				Acre-feet of applied water required
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 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)

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
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 ULF toilets installed relative to total
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 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

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
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
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

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
279		Industrial land use (current and past; includes retail)	Investment in reduction of point sources of pollution	Governmental research and grant investment
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		
	ENVIRON MENTAL CRITERIA			**ENVIRONMENTAL INDICATORS**
297	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
298				water clarity
299				TSS
300			Measurements that describe chemical composition of water	dissolved oxygen DO

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
301				total nitrogen TN
302				total phosphorus TP
303				salinity
304				Cl chlorine
305				BOD biological oxygen demand
306				Toxicity - total; water; sediment (by toxin- PCBs, pesticides, metals)
307				Ammonia, Oxides of Nitrogen NH3/NO2/NO3
308				pH
309				conductivity
310			Measurements of specific organisms inferring water quality conditions required to thrive	algae
311				invertebrates
312				vertebrates
313				fecal coliform/pathogens
314		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 groundwater (recharge rate); sustainable yield (discharge/recharge ratio)
315				Storage = volume (aquifer capacity); level
316				total gaining & loosing reaches over time (between surface water and the aquifer)
317				hyporrbeic storage
318				Groundwater (base flow contributes to minimum stream flow)
319			Lakes and reservoirs - Measurements of water available in lakes and impoundments	Storage = volume; level; timing of release
320				areal extent
321				interbasin transfers
322			Coasts	change in volume that reaches the ocean
323				change in sea level
324			Streams and Rivers	Flow: minimum instream flow to support fish and wildlife habitat; flood stages
325				hyporheic storage
326			Estuaries	areal extent (natural vs. managed)
327				volume
328				temporal dynamics
329			Wetlands	storage
330				areal extent (natural vs. managed)
331			Precipitation and snow pack	volume
332				areal extent
333				permanence of snowpack and glaciers
334		Potential human causal factors	Land use	extent in length and width of riparian vegetation
335				percent of impervious surface

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
336				composition and configuration of land use
337				structure & relationship of land use, e.g. storm water placement of impervious surfaces
338				NPDES (location, load) number & location of permitted discharges
339				non-point sources surface area (animal, mining)
340				population density
341				number of stream crossings
342				area of NPS (agric, animal feedlots, industry, residential, parks, golf courses)
343			Discharge and withdrawals	number & location of dams, wells, water and wastewater treatment plants, stormwater outfalls, surface water intakes
344				percent of separated stormwater/sewer systems
345				number & location & efficiency of OWS (such as private septic systems)
346				number & location of superfund sites, LUST, etc
347				toxic release inventory – releases to water bodies (land, SW, GW)
348				landfills (#, loc, size, condition)
349			Structural modifications of hydrological systems	number of stream miles that are ditched and/or channelized
350				percentage of stream miles that are ditched and/or channelized
351				number of dams, canals, and pumping stations constructed to divert water or manage flooding
352				dredging for navigation (extent – miles, volume)
353				BMPs (#, loc, size, conditions)
354				constructed ditches
355			Water conservation measures	percent of total water
356				industrial, agricultural and domestic water use in conservation practice
357				xeroscaping
358	Integrity of water-dependent ecosystems at multiple scales	Material and energy-flow	Productivity & Energy Flow	Primary productivity
359				Secondary Productivity
360				Net Ecosystem Productivity
361			Material fluxes & cycles	Nitrogen and Phosphorus
362				Trace elements (e.g. Si, Hg)
363				Sulfur
364				Atmospheric influence
365				Pollutant loading
366		Biotic Integrity	Organism Condition	Disease
367				Metabolic state
368			Species/Population Condition	Population size
369				Population demographics (population structure and dynamics)
370				Generic diversity
371			Community/Ecosystem Condition	Indices of Biotic Integrity for various assemblages

#	CRITERION	CATEGORY	Sub-CATEGORY	Indicators
372				Community size and composition
373				Physical habitat (change) (state + change)
374				Non-native species
375				Threatened/endangered species
376		Landscape Condition	Extent & Condition of Habitat Types	extent of habitat (wetlands, reservoirs, and aquifers)
377				spatial connectivity
378				diversity of w-d habitats: patch; biological
379			Landscape Structure	Extent of terrestrial & aquatic landscapes (connectivity, composition)
380				Presence and amount of each part (or patch) within the landscape
381				Physical distribution or spatial arrangement of patches within the landscape
382		Disturbance Regime	Disturbance	Frequency
383				Magnitude
384				Extent
385			Eco-Stability	Resilience
386				Resistance