taking the long view

The journey toward sustainable water resources management begins by determining the most important water issues and indicators

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As water quality professionals work toward sustainable management of water resources, we are constrained by institutional arrangements designed for past conditions. While our institutions have served us well, they are limited to physical, chemical, engineering, and other traditional water concerns. For the future, we must take a holistic view of wetlands, watersheds, and habitats — simultaneously considering water quality and availability; freshwater and coastal waters; surface water and groundwater; water and land use; and physical, chemical, and ecological characteristics. Furthermore, we must consider this great variety of water resources in relation to other environmental and natural resources, as well as our national economy and culture.

Table 1. Ten Criteria Used to Select Indicators Most Frequently Cited by GAO Survey Respondents

Measurable	Data quality
Relevant	Importance
Appropriate geographic scale	Appropriate temporal scale
Understandable	Data comparability
Data available	Trend data available

Source: U.S. General Accounting Office (2004). *Environmental Indicators: Better Coordination Is Needed to Develop Environmental Indicator Sets That Inform Decisions.*

In an effort to address these issues, the Sustainable Water Resources Roundtable (SWRR) was created in 2001. This subgroup of the U.S. Advisory Committee on Water Information was formed to promote information exchange among representatives of government, industry, and environmental, professional, public interest, and academic groups. The roundtable is intended to provide an open venue for examining water resource interrelationships and their future implications.

To date, SWRR has focused on defining the most important water issues and determining indicators for tracking these issues over time.

Selecting Indicators

History has shown that the long-term survival of a civilization depends greatly on its ability to manage land and water resources in conjunction with economy and culture. Sustainable solutions to water resource problems can be found if people thoroughly understand the issues and how each aspect of the society contributes to them.

Solutions to water sustainability problems are characterized by properties that may indicate the overall stability of the system. Selecting the right indicators is a complicated process. Some indicators are quantitative, but others are qualitative and not readily measured. Choosing the number of indicators to track is a delicate balance; too many will overwhelm the policy-making process, while too few will fail to describe issues sufficiently. Although there is no single set of criteria for what makes a good indicator, Table 1 (above) provides a basic checklist to follow.

If we can observe the behavior of an entire system, then we have a better chance of knowing whether the system is stable. Figure 1 (below) depicts at least some major interrelationships that involve water and the rest of the physical–economic–cultural system. This figure conveys the complexity of the system, how difficult it will be to maintain sustainable conditions over time, and why it will take many years to really understand the system.

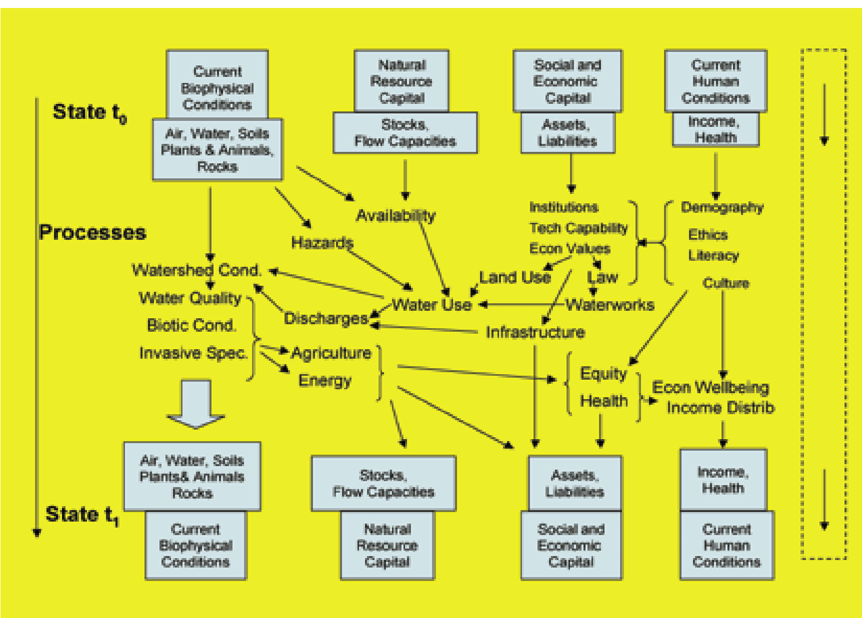
In September 2005, SWRR published a report with chapters on the role of indicators, conceptual foundations for the work of the roundtable, and criteria and indicators on the sustainability of water resources. The report includes a comprehensive review of 17 indicators, available online (see sidebar, p. 67). The following are some of the indicators we feel are the most important.

Water Quality in the Environment

Because of the myriad chemical constituents that potentially can impair water quality, this indicator clearly would have to address a large number of constituent types. Therefore, the indicator likely would be a composite that could take any number of forms, ranging from a single value or index to several water quality measures.

Nitrogen concentration is one of the most important water quality measures for streams and lakes. An indicator of nitrogen in the water environment has been prepared for the Heinz Center (Washington, D.C.) and U.S. Environmental Protection Agency (EPA) indicator initiatives, using streamflow and water quality data collected by the U.S. Geological Survey (USGS). The indicator tracks trends in nitrate discharges from the four largest rivers in the United States: the Mississippi, Columbia, St. Lawrence, and Susquehanna. While

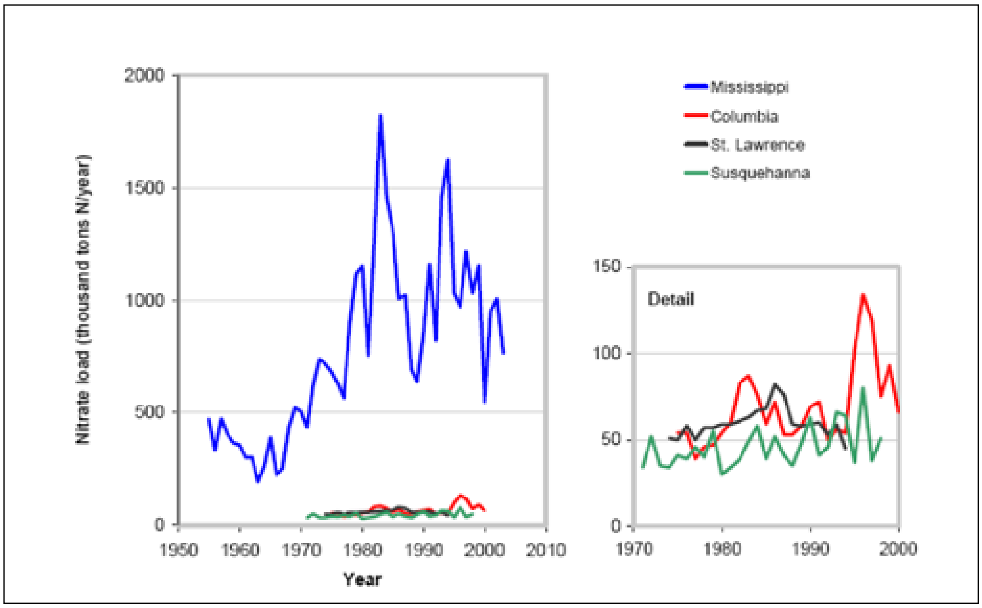
Figure 1. Water Resources in the Physical–Economic–Cultural System



not inclusive of the entire nation, these four rivers account for approximately 55% of all freshwater 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 2, right). The Mississippi River had the most striking increase in nitrate discharge, but this has declined in recent years. The Mississippi, which drains more than 40% 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 2. Nitrate Load Carried by Major Rivers



Source: U.S. Environmental Protection Agency (2003). *Draft Report on the Environment* (EPA 600-R-03-050).

Environmental Conditions

This indicator addresses consequences of water allocations on the physical, biological, and chemical conditions of the environment. Although several efforts have been made to summarize water quality conditions in the United States, no commonly accepted summaries exist. The widely different standards and methods used by the many agencies that take measurements are partly responsible for this deficiency.

EPA's 2003 *Draft Report on the Environment* has two indicators for the condition of surface waters and watersheds in the United States. The first index, *altered fresh water ecosystems,* reports the percentage of each of the major freshwater ecosystems that are altered. The second index, *lake trophic state index*, which classifies lakes into eutrophic, mesotrophic, or oligotrophic states, is based on phosphorus concentrations in northeast lakes. The limitations to this index include the lack of national data, failure to account for nonlentic waterbodies, and the fact that biota respond to variables other than phosphorus.

EPA's second *National Coastal Condition Report* (*NCCR II*) has several positive features. The result of collaboration among EPA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Fish and Wildlife Service (FWS), and USGS, *NCRR II* focuses on the condition of U.S. coastal regions, and characterizes coastal waterbodies based on measures related to aquatic and human uses. The ecological condition of individual sites is rated as good, fair, or poor. Each region then is assigned a rating based on the overall condition of individual sites (see Figure 3, p. 67). For *NCRR II*, coastal condition is characterized using data from EPA's National Coastal Assessment, NOAA's Status and Trends Program, and the FWS National Wetlands Inventory. Table 2 (left) shows the indices used to measure aquatic and human uses.

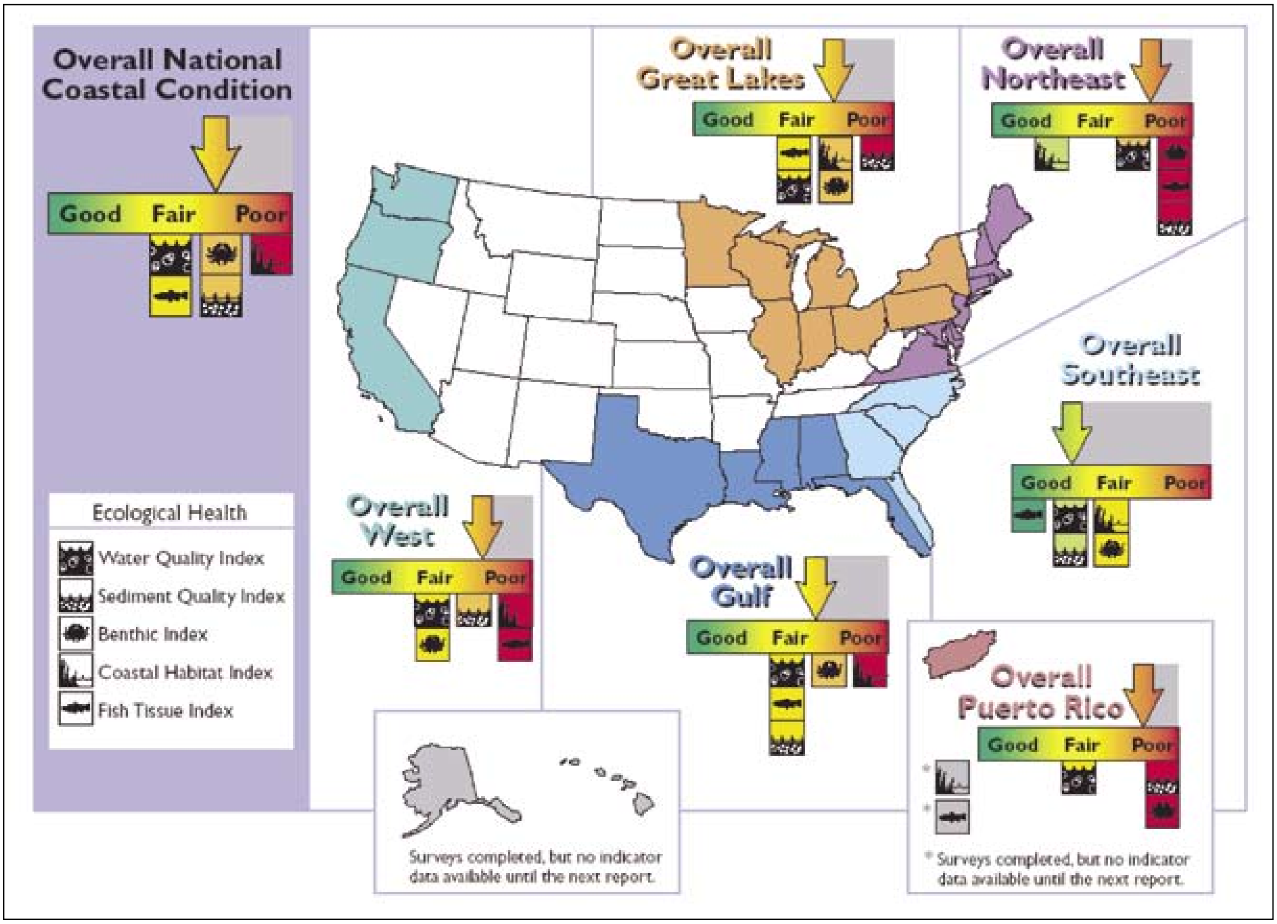
NCRR II rates the overall quality of national coastal waters as fair. Specifically, 21% of the estuarine area of the country is unimpaired, and 44% is threatened for human or aquatic

Table 2. Indices Used for the *National Coastal Condition Report II* Map

Index	Components
Aquatic Use	
Water Quality	Dissolved oxygen, chlorophyll a, nitrogen, phosphorus, water clarity
Sediment Quality	Sediment toxicity, sediment contaminants, sediment TOC
Benthic	Benthic community diversity, pollution-tolerant species, pollution-sensitive species
Coastal Habitat	Long-term decadal wetland loss rate (1780–1990), present decadal wetland loss rate (1990–2000)
Human Use	
Fish Tissue Contaminants	Composite concentrations in relation to U.S. EPA guidance range

All indices calculated based on 1997–2000 data.

Figure 3. Overall National and Regional Coastal Condition, 1997–2000



Source: U.S. Environmental Protection Agency (2004). *National Coastal Condition Report II* (EPA 620/R-03/002).

life uses. The remaining 35% is considered impaired.

To reflect the natural geographic differences in aquatic ecosystem characteristics, *NCRR II* identifies indices specific to six major regions in the United States. The scale of each indicator is unique to the site within each region. The whole region is ranked based on the percentage of sites categorized as 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 its limited geographic focus on coastal waters.

NCRR II is a product of the component data. Debate is inevitable regarding the relative importance, 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 address impacts of groundwater withdrawal or threatened and endangered species.

It is difficult to find a single set of water indicators useful at all scales and for all regions. The challenge in developing indicators to assess environmental condition is finding those that work at the national level while retaining sufficient detail to be helpful to regions and specific sites.

Gross Water Availability

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 require measuring the water-budget components of the hydrologic cycle within a watershed.

One of the simplest approaches is quantifying the mean annual surface and subsurface runoff, accumulated as river discharge. Another approach defines the *renewable supply* in a region as the amount of available precipitation. *Available precipitation*, in turn, is defined as the difference between precipitation and potential evapotranspiration totaled for all months in a

For More Information

The Sustainable Water Resources Roundtable Web site, acwi.gov/swrr, includes updates on activities, as well as its reports and publications to date. The *2005 Preliminary Report of the Sustainable Water Resources Roundtable* and all 17 indicators are included in their entirety.

year when precipitation exceeds potential evapotranspiration.

USGS defines the *renewable supply of water* within a watershed as the sum of precipitation and imports minus natural evapotranspiration and exports. USGS also has shown that renewable supply alternatively could be determined as the sum of surface water outflow and consumptive use minus the long-term depletion of groundwater storage in a watershed. USGS notes 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 requirements to maintain minimum flows in streams for 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.*

Nationwide, the renewable supply of water is much larger than the rate of consumptive use. However, while water resources appear ample from a national perspective, local situations vary widely. For example, much of the western United States, except some coastal areas, has far lower water availability than the East. And in the eastern states, water availability is lower in regions with higher potential evapotranspiration, such as south Florida.

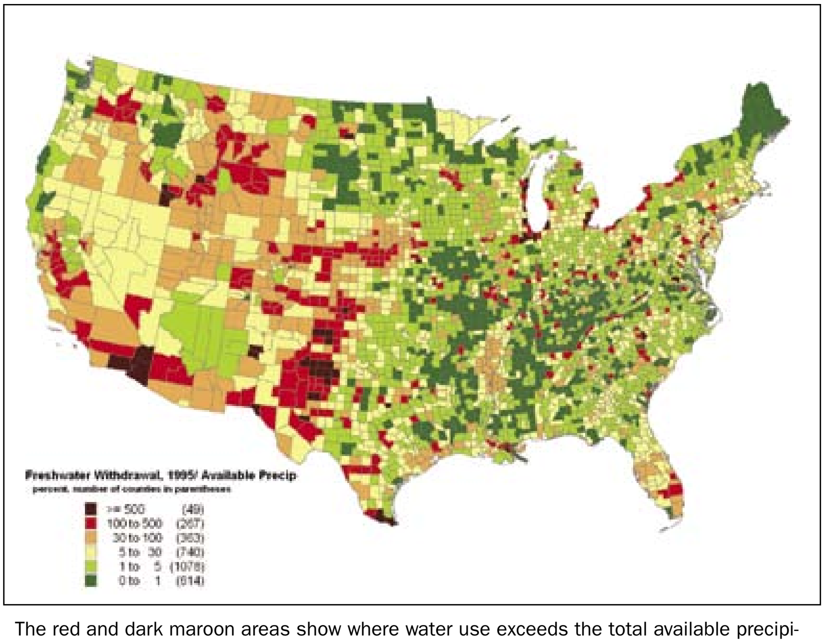
Water Use Sustainability

Water use sustainability requires meeting the needs of humans and nature for the long term on local, national, and global scales. 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. As a gross measure of long-term sustainability, people only can 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 groundwater, surface water, or built infrastructure, or alternatively, is mined from local groundwater.

An indicator of water use sustainability ideally should be a mappable quantification of the extent of renewable water supplies across the nation, the variable and fluctuating needs of ecosystems, and the human needs for water today and in the future.

Figure 4. Total Freshwater Withdrawal in 1995



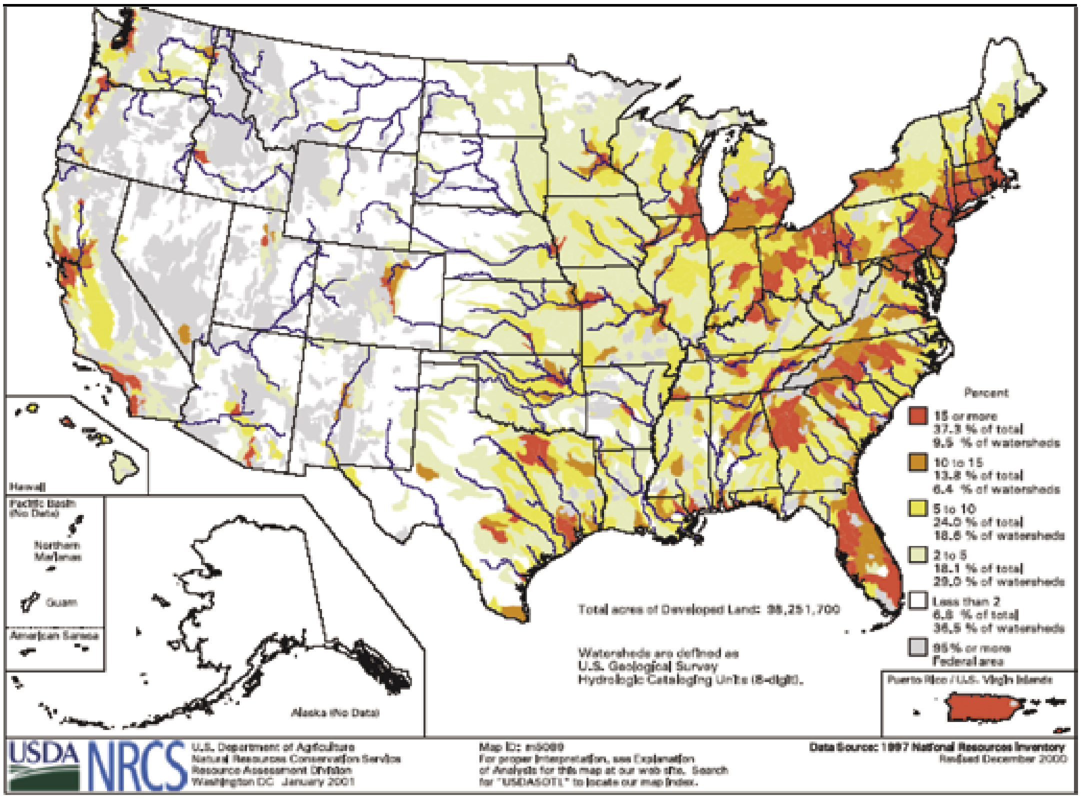
The red and dark maroon areas show where water use exceeds the total available precipitation.

Source: S. B. Roy et al (2005). "Evaluation of the Sustainability of Water Withdrawals in the United States, 1995–2025," *Journal of the American Water Resources Association*, 41(5):1091-1108.

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 United States and the world, water is used at rates that cannot be sustained. 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.

The United States has renewable supplies of water larger than the rate of use, but they are not evenly distributed. While national water resources appear ample, this is an indicator for which the nationwide average is not meaningful. Many areas use more water than can be considered sustainable. Figure 4 (left) shows areas of the United States where water use exceeds total available precipitation. This excess is made up by

Figure 5: Percent of Hydrologic Unit in Developed Land



Source: U.S. Department of Agriculture.

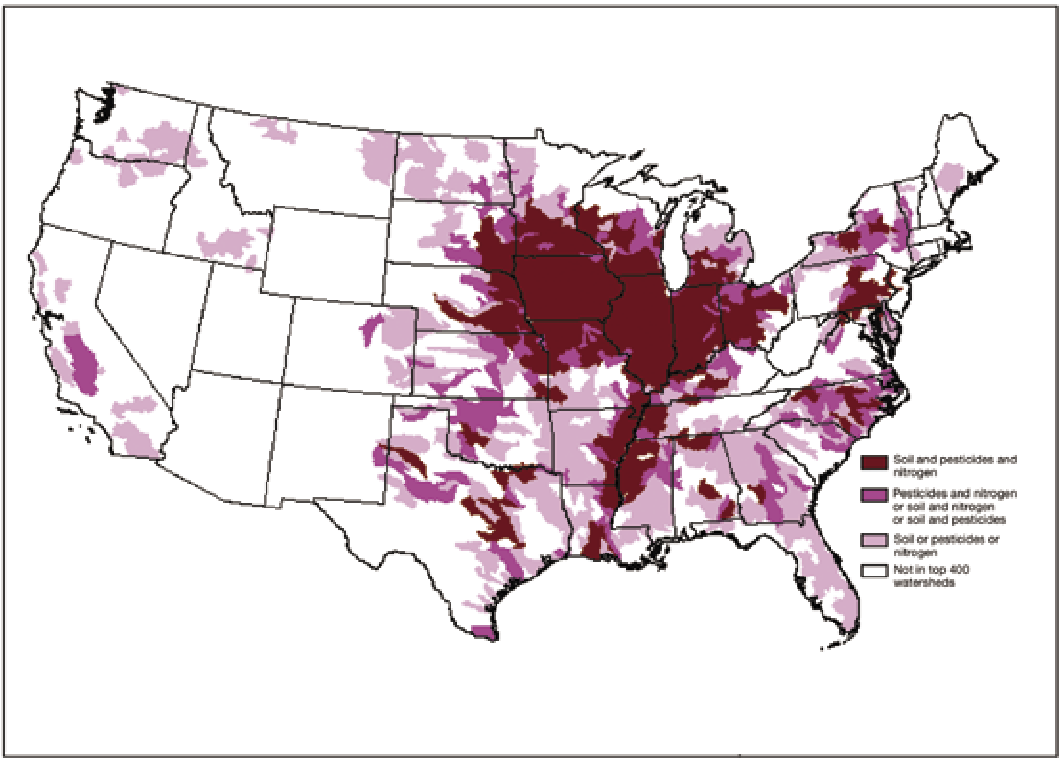
drawing water from other areas or drawing down water supplies — strategies that might may not be ecologically, economically, or politically viable for the long term.

Land Use

This indicator addresses the important elements of developed land and cropland that affect water quality and quantity. The developed land measure includes urban and built-up areas, as well as highways, roads, railroads, and associated rights of way 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 are presented on a watershed basis using USGS's 8-digit hydrologic cataloging unit.

The ways people, business, and government use land affect water resources profoundly. Land use can have an impact on the timing and magnitude of surface water flows, groundwater recharge, demand for water, and resultant discharge of wastewater. Further, the chemicals used on the

Figure 6. Watersheds With High Potential for Soil, Pesticide, and Nitrogen Runoff



Source: U.S. Department of Agriculture.

land affect water quality. Land use also directly and indirectly affects wildlife habitat and other valued, water-dependent ecosystem features.

As shown in Figure 5 (p. 69), more than 40 million ha (98 million ac) in the 48 contiguous states were considered developed in 1997. Nearly 10% of the nation's watersheds have at least 15% 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, and use, as well as habitat destruction — it does not directly measure these factors.

As shown in Figure 6 (above), 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.

Next Steps

SWWR participants are committed to interdisciplinary, interjurisdictional, and cross-ownership collaboration that identifies and supports national, state, and field-level activities to sustain water resources. In addition to investigating water indicators — particularly those that can support the efforts of other organizations doing related work — SWRR continues to recruit representatives from additional water interests, such as environmental groups, the business community, and Western water management agencies. The roundtable also is working to establish and maintain relationships with the scientific community to help build on the best ideas and practices in the water discipline and to encourage research in sustainable water resources.

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