U.S. Geological Survey
New Hampshire-Vermont Water Science Center
Strategic Science Plan, 2007-2012

Figure 1. USGS New Hampshire-Vermont Water Science Center offices.

This Strategic Science Plan (henceforth the Science Plan) identifies water-resource related management problems, needs, and issues important to the States of New Hampshire and Vermont, to the New England region, and to the Nation. The Science Plan will provide direction for the U.S. Geological Survey (USGS) New Hampshire-Vermont Water Science Center (the WSC) and also will help guide future training, hiring decisions, and other resource allocations. Collectively, the WSC Science Plan and other USGS planning documents outline steps needed to successfully accomplish USGS vision and mission goals for the next 5 years and beyond.

The Science Plan was prepared by the management staff of the WSC and was based on the mission of the USGS, science planning by the USGS, the vision of the WSC, and several guiding principles considered essential to the success of the USGS program. These principles are (1) know the needs of USGS programs and cooperators and other customers; (2) promote a high level of science in the WSC; (3) hire and maintain a highly qualified staff; and (4) communicate information that is timely, accessible, and easily understood. Input from 20 representatives of cooperating agencies, as well as WSC staff, factored into the development of the Science Plan. Input from cooperators was gathered by questionnaires and discussions during April—June 2007; staff input was gathered during reviews of draft Science Plan documents.

The Mission of the USGS is to serve the Nation by providing reliable scientific information to

- describe and understand the Earth;
- minimize loss of life and property from natural disasters;
- manage water, biological, energy, and mineral resources; and
- enhance and protect our quality of life.

New USGS Science Strategies were announced in 2007 that define 6 science directions for the agency for the decade from 2007-2012.

The Vision of the New Hampshire-Vermont WSC is to expand its role as a principal provider of hydrologic data and information essential to protecting and managing the water resources of the two states, the New England region, and the Nation as a whole. The information the USGS provides is policy relevant but impartial. The data and information are important to a range of Federal, State, regional, and local government policymakers, resource managers, scientists, and the public. The WSC will maintain a leadership role in the scientific and water-resources community by

- providing high quality and timely reports, data, and information that are accessible (both easy to obtain and easy to understand) to cooperators and the public;
- staying current on technological and scientific advances and hydrologic, environmental, and natural-resources issues;
- being the first choice of cooperators, water-resource managers, science educators, and the public for water-resource-related science, information, and data;
- providing data and results that meet cooperator needs and exceed their expectations; and
- providing a healthy, safe, and pleasant work environment for its employees and providing opportunities for professional development and career advancement.

Diversity of Geography, Development, and Programs

USGS water programs in New Hampshire and Vermont are varied and reflect the diverse physical and cultural geography of the two States and the region. They also reflect the scientific, technical, and management needs of numerous local, county, State, regional, and Federal agencies. Brief overviews of the physical geography, population, and development of New Hampshire and Vermont, particularly as related to water resources, are presented below.

Physical Geography

New Hampshire and Vermont are northern New England States that are primarily located in the New England physiographic region. Only areas of western Vermont are outside this province; these areas are part of the St. Lawrence Valley and the Valley Ridge provinces. The regions differ in topography, hydrology, and geology. Overall, the States are hilly and mountainous and are known for their scenic beauty and high-quality natural resources that attract visitors from across the globe.

Important water bodies serve as the borders of the two States. They include the Atlantic Ocean in eastern New Hampshire, the Connecticut River between New Hampshire and Vermont, and Lake Champlain in western Vermont. New England region's largest river—the Connecticut River—originates in New Hampshire and Vermont. The Androscoggin, Nashua, and Memphremagog Rivers flow into the two States.

The principal aquifers in New Hampshire and Vermont that supply water for public and domestic supplies consist of (1) discontinuous, unconsolidated, glacial stratified-drift deposits composed of sand and gravel; (2) crystalline bedrock; and (3) carbonate bedrock (Vermont only). Glacial till and other types of bedrock cover large areas of the State but typically are low yielding and serve small public water-supply systems and rural residents relying on private wells.

Annual precipitation amounts in New Hampshire and Vermont vary primarily based on elevation. The minimum precipitation is about 34 inches in the lowlands of central and southern New Hampshire, and the maximum is greater than 60 inches in the higher terrain of the Green and White Mountains. Much of this precipitation falls as snow in the winter months. Precipitation is evenly distributed throughout the year, and about half of the annual precipitation becomes runoff to streams and rivers. Historically, the greatest flooding in the two States has been caused by rain on a melting snow pack or by hurricanes.

Population, Development, and Water Resources

New Hampshire and Vermont historically have been rural States with localized cities or population centers. The 2000 census population was 1,240,000 in New Hampshire and 609,000 in Vermont. Population growth has been greater in New Hampshire than in Vermont, with the State experiencing a 25 percent growth from 1980 to 2000. Population growth in New Hampshire has been especially pronounced in the southern third of the State as residential and commercial growth from the Boston metropolitan area expands northward. The greatest population and commercial growth in Vermont has been in the Burlington area. This recent population growth has begun to change the physical and social landscape of the two States. Parts of both States are losing their historic rural character as these areas become more suburbanized.

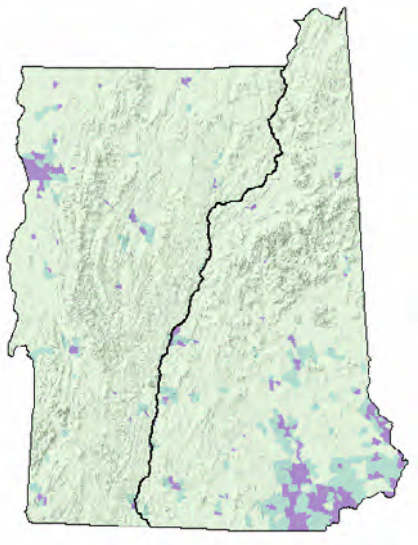

Figure 2. Population density in New Hampshire and Vermont based on the 2000 census.

New Hampshire's population is primarily in the southern third of the State along the Interstate 93 and Route 3 corridors and includes the cities and towns of Nashua, Salem, Manchester, Concord, and Portsmouth. Other major population centers are located in the Lakes Region and along the Connecticut River. Much of the northern half of the State's land area is part of the White Mountain National Forest—a major scenic, recreational, and timber-producing region. New Hampshire's agricultural industry is scattered across the State, generally located along rivers and in valleys.

Vermont, like New Hampshire, has population centers and extensive rural and forested areas. Major population centers include Burlington and surrounding communities, Montpelier, Rutland, and Bennington. Green Mountain National Forest occurs along the Appalachian Mountains in the State. Vermont has a large dairy industry that is present in the Lake Champlain Valley and other areas of the State.

Figure 3. Impounded rivers are common and provide storage for hydropower, flood control, drinking water supplies, and recreational uses.

The water supplies of the larger cities in the two States are from reservoirs, lakes, and rivers. For example, Massabesic Lake serves Manchester, New Hampshire, and surrounding towns; Pennichuck Reservoir serves Nashua and surrounding towns; and Lake Champlain provides water to the Burlington area. Outside these population centers, most of the residents and industries rely on ground-water wells as their water source. About 60 percent of the residents in the two States get their water from wells, and about 50 percent of the homes rely on private wells. There is an estimated 200,000 public and private water supply wells in New Hampshire alone. Increased usage of surface- and ground-water supplies will be necessary to meet projected future demands as population and commercial growth continues in the States.

In addition to supplying water for public supplies, the rivers and lakes in New Hampshire and Vermont serve many other uses. Since colonial times, the rivers of the region have been dammed to provide power for mills and other emerging industries. This usage continues today and may increase as energy needs continue to rise. The damming of rivers and lakes to increase water storage has had significant impacts on aquatic life and streamflow.

Major Water-Resources Issues

The Science Plan categorizes New Hampshire's and Vermont's important water-resources issues and needs into several broad programmatic areas that reflect important societal needs. In many cases, the program areas are interrelated and overlap. More detail about each of these major programmatic areas is presented in separate program-specific plans, which document program opportunities, goals, and actions. A brief description of all projects currently (2007) being conducted by the WSC can be found on the Internet at http://nh.water.usgs.gov or http://vt.water.usgs.gov

Hydrologic Systems, Surveillance, and Hazards

The USGS has the principal responsibility within the Federal Government to provide the hydrologic information and understanding needed by others to achieve the best use and management of the Nation's water resources. Part of this mission includes the responsibility of minimizing the loss of life and property from natural disasters such as floods and droughts.

The USGS has a nationwide network of ground-water and surface-water monitoring sites. In 2007,

the USGS operated 100 surface-water gaging sites and 38 ground-water level monitoring wells in New Hampshire and Vermont. These monitoring wells provide the basis for the State's flood warning system, drought monitoring system, and flood way mapping. These networks are the foundation for water-resource management throughout the States and the Nation.

The WSC will work to maintain its leadership in providing ground- and surface-water resource information for the States and the Nation. The quality of the hydrologic information provided by the USGS will be the standard to which others are compared. The USGS and the WSC will strive to be on the forefront of hydrologic research and related technical advances.

Environmental Quality and Human Health

Environmental quality and human health are closely intertwined and are grouped for purposes of this plan. Some environmental causes of human disease are naturally occurring, such as arsenic and radon, and other environmental causes are linked to contamination. Water and air contamination are the most generally recognized adverse effects of humans on the environment, and both can adversely affect human health.

The water-related issues falling under this broad category include such things as (1) surface- and ground-water contamination associated with human activities such as both older and newer urban development including roadways, wastewater disposal, and agriculture; (2) atmospheric deposition, including mercury contamination; (3) natural sources of contamination and their effects on ground and surface waters; and (4) aquatic-habitat degradation. Contaminants include a variety of microorganisms and chemical compounds, such as nutrients, metals, pesticides, and volatile organic compounds and newly recognized "emerging contaminants," which include pharmaceuticals, hormones, personal care and household products, and many other synthetic organic compounds.

The WSC will maintain a high level of expertise in water-quality sampling and data analysis and work with our cooperators to remain a primary source of information on the quality of the waters of New Hampshire and Vermont.

Water Availability and Sustainability

New Hampshire and Vermont are water-rich States, and historically, their water-resources have been considered adequate to meet societal needs. Locally, however, increasing water use may be exceeding the sustainable yield of supplies. Drought also can lead to short-term water shortages, both locally and statewide, as was last experienced in 2001— 2002. New questions are being raised about competing water needs as population and development increases, contamination restricts the use of some water supplies, competing human and ecological uses are identified, and water needs for waste assimilation continue to increase. To properly manage and ensure a safe and sustainable water supply that meets all the needs of New Hampshire and Vermont, reliable and accurate information on water availability and sustainability is required.

The WSC will strive to provide the information needed to understand water use and availability, to identify areas at risk from contamination or over use, and to assist managers in assessing opportunities or limitations to expansion

Communication, Information Management, and Science Support

The USGS Mission is to "provide reliable scientific information." Our ability to manage and communicate that information is critical to accomplishing our mission and will be focus of the WSC for the next 5 years. The New Hampshire-Vermont WSC must continually evaluate and improve how information is presented and conveyed. This evaluation requires asking our cooperators and stakeholders on a regular basis how we are doing and how we can do better.

For More Information

If you would like additional information or would like to provide suggestions for improvement of the New Hampshire-Vermont WSC's science program or operations, please contact

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The USGS New Hampshire-Vermont Water Science Center (WSC) will work to maintain its leadership in providing water-resource information for the States and the Nation. The quality of the hydrologic information provided by the WSC will be among the finest in the Nation. The WSC will strive to be on the forefront of hydrologic applications and related technical capabilities.

A foundation of USGS water-resource information is the long-term hydrologic data-collection and surveillance networks. Currently (2007), the USGS operates a network of 100 surface-water-monitoring sites in New Hampshire and Vermont, 96 of which have their data transmitted in real-time to be available on the Internet (fig. 1). A small subset of these sites includes some form of water-quality measurements, from simple water temperature to in-situ measurement of other physical parameters such as specific conductance and turbidity. The USGS operates a ground-water-monitoring network of 38 sites, 2 of which have their data transmitted in real-time (fig. 2). About two-thirds of the ground-water network is based in New Hampshire.

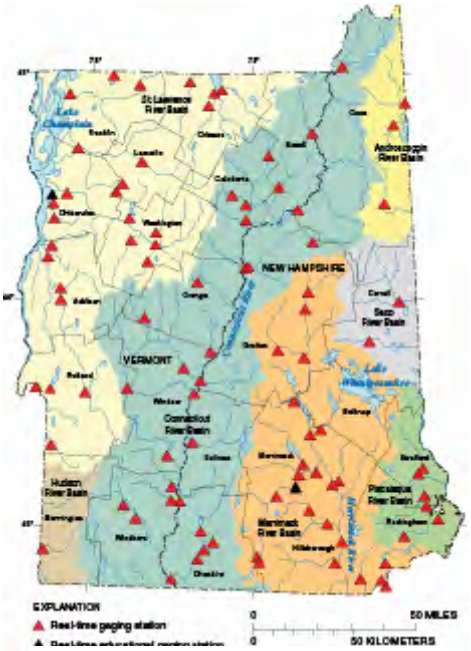

Figure 1. USGS streamflow gages in New Hampshire and Vermont, 2007.

Figure 2. USGS ground-water monitoring wells in New Hampshire and Vermont, 2007.

Floods are the single most costly and life threatening natural disaster in New Hampshire, Vermont, and the Nation. Data from these surveillance networks are used to monitor and assess flood conditions. The National Weather Service uses streamflow data from this network in their forecast models to provide flood warnings and alerts. The U.S. Army Corp of Engineers uses these data to manage operations of 12 flood-control projects throughout the two-state area. In addition, data from these networks are used to monitor other hydrologic conditions such as droughts and ice jams. These long-term data are critical to State, local, and Federal officials in order to understand and manage water availability and use. Other uses of the data include management of lakes and ponds, power generation, habitat and wildlife protection, navigation, and recreation.

Operation and maintenance of the networks includes measuring streamflow during a variety of conditions and locations. These include floods, wintertime ice measurements on rivers, using cableways where no other structures are available, and working along roadways that include lane closures and traffic control. Safety is our top priority—for the public and for our employees. The WSC will look for opportunities to reduce the hazards associated with data-collection activities such as advancements in acoustic technologies (fig. 3), that keep our personnel out of the water, off the ice, and out of roadways will be adopted where feasible and appropriate.

Figure 3. Using an Acoustic Doppler Collection Platform to measure streamflow in a river.

Providing the kinds of information our customers and stakeholders need, when and how they need it, is nearly as important as safety. The results of a strategic questionnaire indicated that adding or reactivation of gaging stations and displaying this data in real-time on USGS web sites is of extreme importance; therefore, the WSC will use the automated tools available to monitor the real-time data on the Internet and make sure it is accessible and accurate. The WSC will continue to use the redundant system of national servers and the NWISweb software to assure that computer or Internet problems do not or rarely affect availability of the data. The WSC will maintain contingency operations at backup sites if the WSC National Water Information System (NWIS) server fails for an extended period of time. Additionally, the WSC will explore new ways to enhance the accessibility and presentation of the data on the Internet by adding customer specific thresholds that are especially useful to local emergency management officials and the general public during flood events (fig. 4).

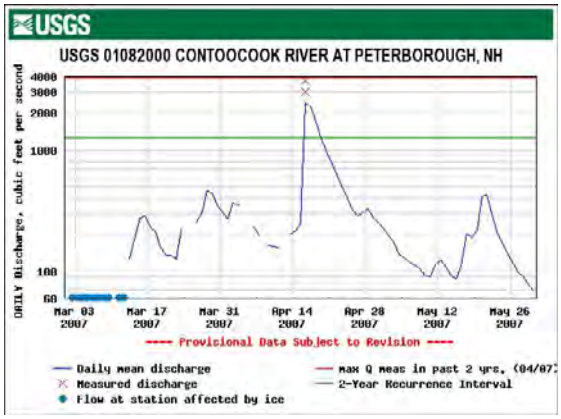

Figure 4. Real-time streamflow data displayed on the USGS web page.

Both Federal and State funds are not expected to meet the demand for real-time streamflow, water quality, and ground-water level data. Many of the strategic planning questionnaire responses pointed to the high cost of network operations and the cooperator's inability to continue to cover annual increases in these costs. A major focus of the WSC must be to reduce the cost of operation by evaluating how we currently (2007) collect and process the data; by evaluating workforce, supplies, and support needs; and by identifying and implementing efficiencies. This is a critical need

and must be considered as a part of all strategic actions.

In 2006, the USGS worked with the New Hampshire Rivers Management Advisory Committee to help craft a long-term streamgaging network needs report for the New Hampshire State Legislature. This report identified the need for more than 20 new gages in the State to fill existing data gaps. In 2007, the USGS began working with the State of New Hampshire to expand the statewide streamflow gaging network during 2007-09. In this 2-year period, 15 new or reactivated streamflow gages are planned statewide. Long-term funding mechanisms for the State's gaging needs, including appropriate levels of USGS federal-state cooperative funds, must still be identified. Additional funds for streamflow gages in the 2 states may also come from future increases in funding for the USGS National Streamflow Information Program.

The value of the WSC streamgaging network has been exemplified during recent flooding and ice-jam events in New Hampshire and Vermont. Extreme rainfall events resulting in flooding in New Hampshire occurred in October 2005, May 2006, and April 2007. These flood events have caused millions of dollars in damage in the State, especially in the southern areas, and have each resulted in Presidential disaster declarations. The May 2006 flood resulted in 12 streamgages having peak-of-record flows, and 7 of these streams had 100+ year recurrence intervals. Working with other Federal and State agencies, such as the Federal Emergency Management Agency, staff from the WSC made numerous flood-discharge measurements, flagged high-water marks at many locations in the State, and documented the magnitude of the floods. During the winter 2007 ice jam on the Winooski River in Montpelier, Vermont, USGS staff installed a temporary gage to monitor river conditions in the city to supplement nearby gages. These data were crucial for emergency-management decision making by city and State officials.

In 2007, the WSC began meeting with the National Weather Service and the US Army Corps of Engineers to discuss mechanisms to increase information exchange between the agencies regarding stream-flow and ice-cover conditions for improved flood forecasting. Improved communication and collaboration is a logical extension of the mission of all three agencies.

Understanding the long-term water-level conditions of surficial and bedrock aquifers in the two States is critical for ensuring the availability of sufficient ground-water supplies when demands for this resource is increasing. The WSC will work with the States of New Hampshire and Vermont to determine ways to expand existing ground-water-level monitoring networks and to have these data increasingly available on a real-time basis.

These are only some of the goals necessary to improve the availability of hydrologic information to address resource-management needs while helping to reduce the economic and human cost of natural disasters. A brief description of all projects currently (2007) being conducted by the WSC can be found on the Internet at http://nh.water.usgs.gov or http://vt.water.usgs.gov. If you would like to provide additional suggestions for improvement, please contact

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Environmental Quality and Human Health

There are many environmental concerns in the States of New Hampshire and Vermont relating to how land-use activities, point- and nonpoint discharges, waste-disposal practices, and naturally occurring and atmospherically transported contaminants affect the quality of aquatic resources. Water issues related to environmental quality and human health are closely intertwined and, for purposes of this science plan, are treated collectively. They include (1) surface- and ground-water contamination associated with urban development, agriculture, mining activities, wastewater disposal, and other sources; (2) atmospheric deposition, including nitrogen and mercury; (3) the presence of naturally occurring trace metals and radionuclides; and (4) aquatic invasive species.

Understanding the source and fate of nutrients in the surface waters of New Hampshire and Vermont are important water-quality issues. Controlling the delivery of nitrogen and phosphorus to prominent water bodies in the two States is an active regulatory program area. Examples include reducing amounts of phosphorus entering Lake Champlain in Vermont, New York, and Canada; and managing nitrogen inputs to Long Island Sound from the Connecticut River Basin. These waters are enriched with nutrients resulting in degraded water quality and excessive aquatic-plant growth. Similar issues are found in numerous other smaller lakes, rivers, and coastal estuaries. Major nutrient sources include nonpoint-source runoff from agricultural and urban areas, atmospheric deposition of nitrogen, and direct and indirect discharges of wastewater. An active area of scientific research has emerged for these topics and nationwide strategies to assess water-quality conditions and management options are under consideration because of the significance and complexity of the nutrient-enrichment problems within coastal waters and lakes. These include developing effective and efficient nutrient monitoring and modeling studies.

Figure 1. Connecticut River near the New Hampshire, Vermont, and Massachusetts borders.

Atmospheric deposition has been a major water-quality issue in New Hamsphire and Vermont for many years. In the late 1970s and the 1980s, the emphasis was on lake acidification and associated mortality of fish and other aquatic organisms. The issue faded from widespread public attention in the late 1980s following national Clean Air Act amendments. Recently, atmospheric deposition has received renewed attention, and concerns have broadened to include atmospheric mercury deposition. Acid rain itself also has received renewed interest relating to stream acidification, the effects on soil-calcium depletion, reduced forest growth and health, nitrate saturation of watersheds, and the slower-than-anticipated recovery of streams and lakes caused by reduced rates of nitrate deposition. The effects of climate change and resultant increases in air temperature also are related to the atmospheric deposition debate. Furthering our understanding of trends in

atmospheric deposition, its effects on aquatic and terrestrial ecosystems, and how management actions relate to changing environmental conditions are important research areas.

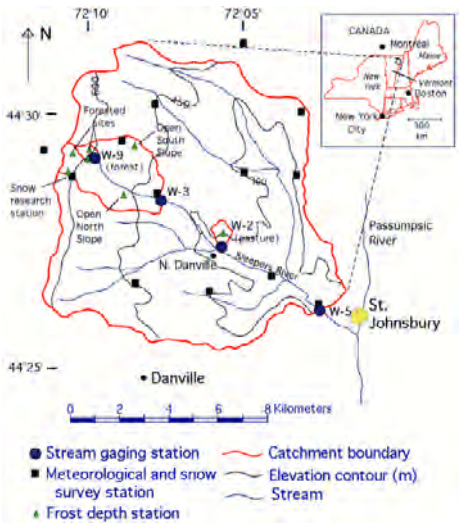

Figure 2. The Sleepers River watershed in Vermont has been the site of USGS research since 1990 in the area of small catchment hydrology and biogeochemical budgets.

The spread of invasive species in the Nation's lands and waterways is one of the most serious environmental problems facing the United States in the 21st century. In New Hampshire, the most problematic invasive species of aquatic plant is known as variable leaf water-milfoil. In Vermont, water chestnut, Eurasian milfoil, zebra mussel, and sea lamprey are important aquatic invasive species. These "invasives" alter the ecosystem and threaten ecosystem biodiversity. The lakes and ponds of the two States are important economic resources and are highly regarded for their inherent beauty and recreational uses. Invasive aquatic species can negatively affect swimming, boating, fishing, and property values. Research on the occurrence, environmental factors that promote their presence, and effective control strategies can be useful in minimizing the spread of these unwanted aquatic plants and animals.

A broad list of compounds, commonly referred to as "emerging contaminants," is receiving growing attention from scientists, water and environmental managers, and the general public. These contaminants typically are present in the environment at very low concentrations, and their effect on human health is not well understood. There is evidence to suggest, however, that some emerging contaminants, by virtue of their ability to interact with the endocrine system, are causing a variety of adverse health effects in humans and wildlife. These contaminants are expected to receive increased attention over the next several years.

Figure 3. Variable leaf water-milfoil infestation in a New Hampshire lake.

Numerous other environmental-quality concerns exist in the region. The sanitary quality of public bathing beaches in the many lakes of the region and coastal waters has been a focus of State public-health and environmental-monitoring agencies. A major issue is developing in-stream flow requirements in a scientifically defensible manner, to ensure that the multiple and often competing demands for water resources have minimal effects on aquatic ecosystems. In Vermont, managing stormwater from development so that the hydrologic characteristics of streams are not changed is a cornerstone of their water-resource protection efforts. The effects of road salting and other deicing activities on water quality have recently taken on more importance in the two States.

Understanding the effects of contaminated Superfund and Resource Conservation and Recovery Act (RCRA) sites on local and regional surface and ground waters is often needed so that remedial operations can be targeted and effective. Within New Hampshire and Vermont, abandoned landfills, former industrial operations and mills, accidental spills, and old metal-mining sites are commonly found contaminated sites.

Ground waters in New Hampshire and Vermont are important sources of drinking water for households, businesses, and industry not served by public water-supply systems. In addition, numerous

community water systems use ground water from both surficial and bedrock aquifers. The States are underlain by fractured crystalline and carbonate bedrock. This Precambrian to Cretaceous bedrock is somewhat impermeable, has low porosity, and is dominantly igneous and metamorphic. Interconnected fractures transmit water to wells drilled into the bedrock. Surficial aquifers, by contrast, are discontinuous glacial deposits that overlie the bedrock; these transmit water through primary porosity and are a major source of water for some areas of both States. Our knowledge of sustainable yields from these aquifers and the extent of anthropogenic and natural contaminants in the water are limited despite the importance of ground water. Over the past decade, the U.S. Geological Survey (USGS), in cooperation with other agencies, has made noteworthy progress in understanding arsenic in ground waters of the New England region and Methyl tert-Butyl Ether (MTBE) in New Hampshire.

Figure 4. USGS hydrologist collecting ground-water samples.

A large part of the USGS program in New Hampshire and Vermont focuses on environmental quality and human-health issues. The projects range from routine water-quality assessments to advanced research and are too numerous to describe here. A brief description of all projects currently (2007) being conducted by the New Hampshire-Vermont Water Science Center (WSC) can be found on the Internet at http://nh.water.usgs.gov

Program Plans, Goals, and Actions

In 2007, the WSC conducted a planning exercise to gather information and ideas from within and outside the USGS to help formulate a strategic science plan for the period 2007–2012. The following paragraphs incorporate key ideas from that exercise and relate to future USGS science strategies.

- The WSC will continue to measure nitrogen loads in the Connecticut River in New Hampshire, Vermont, and Massachusetts, which is important to the management of Long Island Sound, and will continue to pursue projects to quantify the nutrient loads in other watersheds.

- The WSC will continue to take a lead role in regional surface- and ground-water modeling of contaminants and water availability. The WSC will pursue opportunities to build upon current (2007) and recent models and continue to develop additional models.

- The WSC will continue to play a role in researching the effects of atmospheric deposition. It will continue to investigate biogeochemical stream processes in northeast Vermont and their relations to atmospheric deposition. It will pursue new opportunities to develop integrated monitoring and assessment programs, such as a program to conduct long-term monitoring of atmospheric deposition and forest health and mercury in the environment.

Figure 5. USGS hydrologist collecting a depth-integrated water-quality sample.

- The WSC will continue to collaborate with other agencies in multidiscipline investigations on the effects of Superfund and RCRA contamination sites on local surface and ground waters. Expansion of this work into risk assessments and feasibility plans will be pursued.

- The WSC will remain actively involved in ground-water-quality assessments for both natural and anthropogenic contaminants. This includes further refinement of recent work on arsenic and MTBE and new work for other contaminants such as manganese, uranium, methane, and ethanol. Relating the occurrence of these contaminants to water-supply usage also will be pursued.

- The WSC will remain actively involved in the National Water Quality Assessment (NAWQA) program. It will play a major role in New England NAWQA studies and regional and national synthesis of surface-, ground-water, and ecological data. The WSC will explore opportunities for cooperative projects that build upon these efforts.

- The WSC will promote surface-water-quality monitoring programs in New Hampshire and Vermont, which focus on nutrients, trace elements, pharmaceutical and personal care products, and other emerging contaminants. It plans to participate in multidisciplinary projects investigating the effects, if any, of these contaminants on aquatic biota. The WSC also will continue environmental monitoring of trace-element contamination at abandoned copper mines in Vermont.

- The WSC will investigate opportunities to expand research and data-collection projects for lakes and other impounded or embayment waters. These activities will focus on developing tools for the management and allocation of resources to monitor and control aquatic invasive species and the sanitary quality of swimming areas and to protect lake ecosystems.

- The WSC will continue to be a major research and environmental data collection partner in the Lake Champlain Basin by working with the Lake Champlain Basin Program, other agencies, and academia.

- In recent years, the WSC has provided borehole logging and other geotechnical support for the State of New Hamsphire and other Federal agencies. The WSC will make other agencies aware of the full range of its capabilities, including such things as solute-transport modeling, and will pursue opportunities to expand its role in assisting state, regional and Federal agencies.

- The WSC will promote incorporating data collection and research on how climate changes may affect the availability and quality of the region's water resources.

The above summarizes some of the principal plans and goals of the New Hampshire-Vermont WSC in the programs areas of environmental quality and human health. If you would like to discuss any of the above plans or make additional suggestions, please contact

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Water Availability and Use

New Hampshire and Vermont are water-rich States, and historically, the supply of water resources has been considered adequate to meet needs. However, increasing water use in many communities has resulted in local water use advisories and restrictions during periods of high water demand and (or) drought. At the same time, there can be many competing demands for available water supplies—from public drinking water to in-stream fish protection. Balancing these competing demands is becoming a greater and greater water-resource management activity in New Hampshire, Vermont, and the Nation.

Population growth and accompanying development in areas of New Hampshire and Vermont in the past few decades has led to appreciable increases in the demand for water and concerns for protecting ground- and surface-water resources and its quality. New questions are being raised about competing water needs. These questions include: "What are the effects of population and development; how can we effectively assimilate our waste waters; what are effects of proposed new water withdrawals; and how will water bottling operations affect local water supplies?"

The U.S. Geological Survey (USGS) conducts data-collection and scientific studies that directly and indirectly address the issues of water availability and use. In particular, the USGS National Water-Use Information Program works in cooperation with local, State, and Federal environmental agencies to collect water-use information. The USGS also compiles the data from hundreds of thousands of sites to produce water-use information aggregated at the county, State, and national levels. Every 5 years, data at the State level is compiled into a national water-use data system and is published in a national circular. Figure 1 shows estimated water use in New Hampshire and Vermont for 2000 based on this compilation effort.

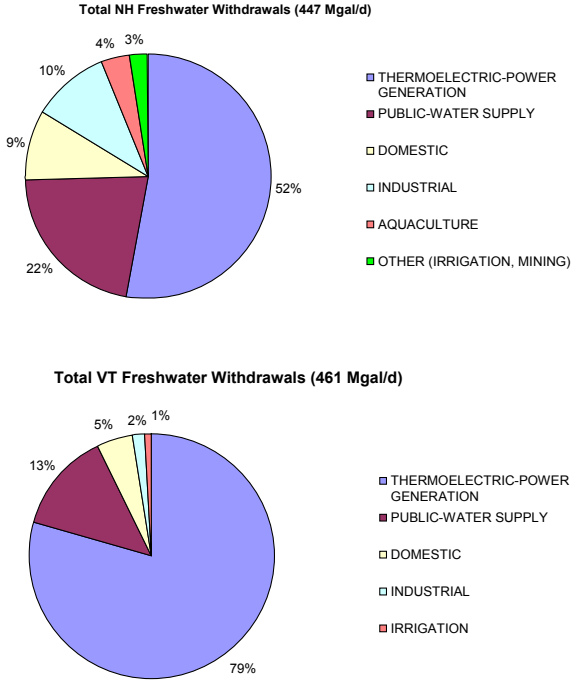

Figure 1. Freshwater use in New Hampshire and Vermont in 2000.

The USGS hydrologic monitoring program, commonly referred to as the data program, is critical to addressing questions concerning water availability and sustainability. The data program in New Hampshire and Vermont provides data on real-time hydrologic conditions as well as historical data; this program is discussed in the *Strategic Science Plan for Hydrologic Systems, Surveillance, and Hazards* section of this strategic plan. The sustainability of the water supplies of New Hampshire and Vermont will depend largely on the ability of each State to protect its water resources from contamination and over utilization from multiple users. Therefore, many USGS studies, which address environmental-quality issues and are discussed in the *Environmental Quality and Human Health* section of this plan, indirectly address the issue of water availability. In many urban areas, surface water and ground water have been subjected to anthropogenic contaminants, which increase the cost of using these resources for water supply or preclude their use entirely. Ground-water protection is a concern because of the time and money required to remediate contaminated aquifers.

Both stratified-drift aquifers and bedrock aquifers are important sources of ground water in New Hamsphire and Vermont. The extent and characteristics of many aquifers have not been fully evaluated in all areas; therefore, the potential of the aquifers as water supplies and their vulnerability to contamination is not fully understood. As suburban development spreads into rural areas and more people draw on the bedrock aquifer, the sustainable yield of this aquifer also is becoming a subject of increasing importance.

Southeastern New Hampshire is one area of the two States where concerns over water availability and use is prominent. The proximity of the seacoast region in Southeastern New Hampshire to metropolitan Boston has led to a 36 percent population increase over the past 20 years. This development has been accompanied by an appreciable increase in use of ground water from both domestic and public-supply wells, especially from the fractured-bedrock aquifer. During this same period, per capita usage also has increased to meet the needs of modern appliances and landscaping. Wells in New Hampshire are being drilled progressively deeper to supply domestic needs. Coincident with the increasing water demands have been new impervious surfaces from roads, parking lots, commercial buildings, homes, and other developments—these impervious surfaces decrease recharge to aquifers.

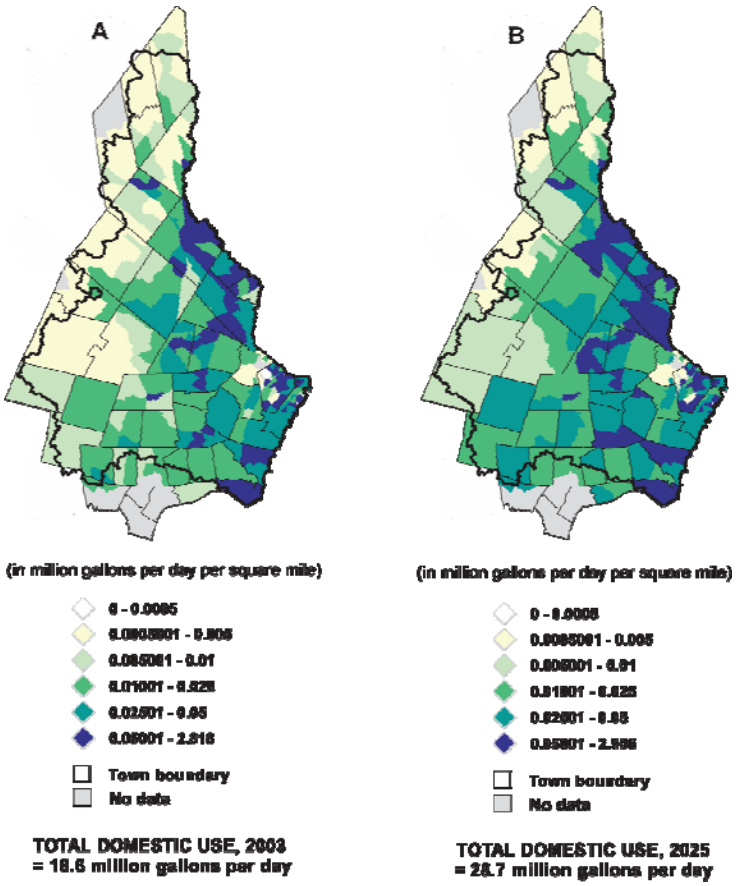

Figure 2. Projected domestic water use in the Seacoast region of New Hampshire for (**A**) 2003 and (**B**) 2025.

The combined effects of recharge losses and increased withdrawals on ground-water resources in the seacoast region have not been fully quantified. The USGS, in cooperation with the New Hampshire Department of Environmental Services, has conducted a study of current and future water demands (fig. 2) and how these increased demands could affect

the bedrock aquifer and long-term availability. Included in the study are a number of new and innovative analytical methods to estimate per capita water use and how much water various commercial operations use.

In the near future, expanded analysis of water availability and use will occur throughout New Hampshire with the development of a State Water Master Plan. This Plan will identify current and future water demands and how these demands relate to available water resources. In Vermont, there is interest in conducting detailed aquifer mapping and water availability studies so the State can plan for future water supplies.

In 2007, the New Hampshire-Vermont Water Science Center (WSC) conducted a planning exercise to gather information and ideas from within and outside the USGS to help formulate a Strategic Science Plan for the next 5 years. The following paragraphs incorporate key ideas from that exercise.

- Continued growth in the demand for ground water from small-scale or domestic ground-water systems. This growth will be dependent upon ensuring the long-term availability of adequate and clean water supplies from surficial and bedrock aquifers. The WSC will work to expand our knowledge and understanding of the quantity and quality of water in these aquifers.

- The WSC will work to relate the needs expressed by communities, regional planning commissions, and State agencies for a greater understanding of current demand, how well our resources meet the demand, and how availability compares to the projected demands in the future. In addition, it will be necessary to understand hydrologic variability in rivers and ground waters by seasons, years, and changing watershed and climatic conditions.

- The WSC, with participation of cooperating agencies, will regularly review and analyze the surface-water and ground water monitoring networks to ensure that the network is continuing to address cooperator needs and at the same time is fulfilling the USGS mission with regard to water availability and use.

Figure 3. Domestic wells supply nearly one-half of the population of New Hampshire and Vermont.

- Similarly, the WSC, with the participation of cooperating agencies, will work toward expanding the ground-water-level monitoring network in New Hampshire and Vermont and add real-time telemetry to more wells. The WSC also will regularly published water-level maps and maintain long-term storage of water-level data.

- The WSC will maintain a strong water-use program with the goal of providing water-use data in formats and categories most needed by cooperators and water managers.
- The WSC will pursue opportunities to build on the national USGS science strategies regarding water-availability and use initiative to develop new studies that focus on where this information is most critical, such as the development of the New Hampshire Water Master Plan, Vermont ground-water assessments, and other regional studies.

- The USGS will conduct data-collection and hydrologic studies in New Hamsphire and Vermont that provide for the evaluation of various water-management alternatives through new and innovative techniques. Linking surface- and ground-water models to address water availability, such as has been proposed in the Lower Merrimack River Watershed, is an example of this work.

- The WSC will continue to advance the science of water use by pursuing new studies that create robust empirical relations between societal behaviors and water demand. Improving our understanding of current water demands will aid in the prediction of future water needs.

- Water managers need to better understand and define competing ecological and human water needs if water resources are to be properly managed. The WSC will work with cooperators to fill this need by conducting studies to evaluate, for example, how effectively water releases and regulated streamflow mimic natural processes and affect ecosystems and how ground-water withdrawals affect streamflow and wetlands. On a larger scale, there is a need to evaluate the possible effects of climate change on water quantity.

The above are some of the principal plans and goals of the New Hampshire-Vermont WSC in the program area of water availability and use. A brief description of all projects currently (2007) being conducted by the WSC can be found on the Internet at http://nh.water.usgs.gov or http://vt.water.usgs.gov. If you would like to discuss any of the topics listed above, make additional suggestions, or learn more about the USGS in New Hampshire and Vermont, please contact

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Water-use data, combined with other USGS information, have facilitated a unique understanding of the effects of human activity on the Nation's water resources. As water availability continues to emerge as an important issue in the 21st century, the need for consistent, long-term water-use data will increase to support wise use of this essential natural resource.

Robert M. Hirsch
USGS Associate Director for Water

U.S. Geological Survey
New Hampshire-Vermont Water Science Center
Strategic Science Plan, 2007-2012

Communication, Information Management, and Science Support

The U.S. Geological Survey (USGS) Mission is to "provide reliable scientific information." Our ability to manage and communicate that information is critical to our success; we must continually evaluate and improve how we convey information and our scientific understanding. This evaluation requires asking our cooperators and stakeholders on a regular basis how we are doing and how we can do better.

In 2007, the New Hampshire-Vermont Water Science Center (WSC) used a questionnaire and meetings with many of our cooperators, as well as USGS employees, to get feedback on how the USGS can improve the way we communicate and the way we provide information and project results. This plan incorporates these suggestions.

Communication

The WSC will hold regular, project-specific meetings with cooperators to help keep everyone attuned to project methodologies, what we are learning, problems we encounter, and overall status of the project.

The WSC will distribute periodic newsletters to provide cooperators, stakeholders, and the public with regular reminders of the work the USGS is doing in New Hampshire and Vermont. These newsletters will highlight selected projects, provide a forum for discussion of changes in our monitoring networks, and advertise the availability of new reports.

The WSC will increase USGS participation in scientific and resource-management workgroups, committees, and professional societies. Through this participation, the USGS will become a partner in helping to address New Hampshire and Vermont's environmental and water-resource management issues.

One of the major recommendations to the WSC during the strategic planning process was for the WSC to become a more active partner in facilitating what we do and do not know about particular water resource issues. As a result of this feedback, the WSC will enhance USGS participation in various seminar series' (brown-bag seminars, symposiums, New Hampshire and Vermont university seminars) to provide opportunities for technology transfer as well as discussions on further needs for water data collection and research in the region.

The WSC will hold internal meetings to provide an opportunity for USGS staff in our two offices to interact regarding particular subject areas and issues. In addition to sharing technology and expertise, these meetings will build better working relationships and facilitate more open communication.

Information Management

The WSC will continue to put all reports on the Internet with permission from the cooperators. Occasionally, traditional USGS reports do not meet the cooperators' needs -- cooperators are requesting reports that are succinct, timely, visually appealing, and directed toward non-technical audiences. The USGS will strive to provide these types of report products in addition to the more technical reports and peer-reviewed journal articles.

Increasingly, the information the WSC collects must be disseminated rapidly to meet the needs of cooperators, other government agencies, and the general public. The WSC will continue to make improvements to our web interfaces and to evaluate and improve how cooperators and the public can access our information. One tool the

WSC is using to make our information available to the user is ArcGIS viewers (fig. 1).

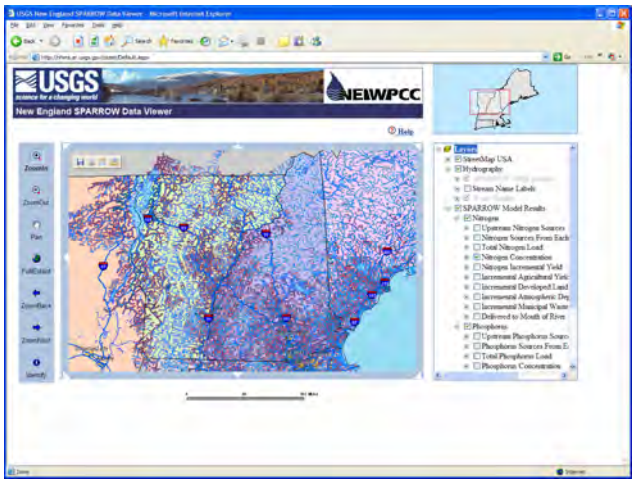

Figure 1. Image of the New England SPARROW ArcGIS viewer displaying model results in an interactive mode.

The National Water Information System (NWIS) provides an outstanding tool to manage and present water-monitoring data. The magnitude of information stored in NWIS sometimes makes it difficult to pinpoint the answer to a particular query. NWIS is a national application, and enhancements are somewhat out of our control. The WSC will continue to work with the NWIS development team to effect changes that it will better address our customers' needs.

Science Support

Science support comes in many forms, such as computer hardware and software, geospatial interpretive support, financial support, human resource/employee development, and technology transfer. The WSC has an outstanding team of scientists, technicians, and support personnel. It will strive to support all aspects of their jobs so that they can continue to provide advanced, technically correct, and impartial science information to address our customers' needs.

The WSC will keep abreast of advances in information technology and provide the tools needed by our scientists and cooperators. As advances in technology occur, we must evaluate their affect on our ability to serve our customers' information-management needs and to support upgrades where appropriate. The WSC will continue to provide employee-development opportunities including USGS training programs, college classes, on-the-job opportunities, mentoring, conferences, and symposiums. As science advances, it is critical to maintain a workforce that is at the cutting edge of these advances. Employee development is one key to successfully achieving our vision.

The geographic representation of information is an important component of all USGS programs. The WSC will continue to integrate the use of geographic information systems (GIS) into all areas of our science. The WSC also will maintain a core group of GIS experts to provide support to projects in the interpretation and presentation of results.

Safety is the number one priority for the WSC. Many jobs our employees perform have related hazards and safety concerns. The WSC will continue to support a strong safety-awareness program through safety training, job-hazard analyses, strong safety-communication programs, and sponsoring a collateral-duty safety officer.

Presentation of the science results is almost as important as the science itself; without the presentation, the science would never be seen. The time it takes to write, review, and produce a publication has improved in recent years, but it still remains an issue. The WSC will strive to improve production times without affecting report quality.

These and other goals will help the USGS fulfill its vision. A brief description of all projects currently (2007) being conducted by the WSC can be found on the Internet at http://nh.water.usgs.gov or http://vt.water.usgs.gov . If you would like to provide additional suggestions for improvement, please contact

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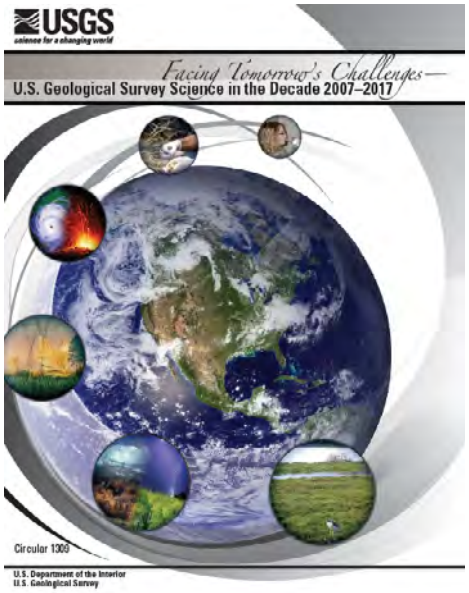
Executive Summary - Facing Tomorrow's Challenges – U.S. Geological Survey Science in the Next Decade 2007-2017, USGS Circular 1309

In 2007, the U.S. Geological Survey published *Facing Tomorrow's Challenges --U.S. Geological Survey Science in the Next Decade 2007-2017*. This report describes new science directions for the agency in the next 10 years. The executive summary of the report is presented below. The full report is available at the USGS web site: http://pubs.usgs.gov/circ/2007/1309/



In order for the U.S. Geological Survey (USGS) to respond to evolving national and global priorities, it must periodically reflect on, and optimize, its strategic directions. This report is the first comprehensive science strategy since the early 1990s to examine critically major USGS science goals and priorities. The development of this science strategy comes at a time of global trends and rapidly evolving societal needs that pose important natural-science challenges. The emergence of a global economy affects the demand for all resources. The last decade has witnessed the emergence of a new model for managing Federal lands—ecosystem-based management. The U.S. Climate Change Science Program predicts that the next few decades will see rapid changes in the Nation's and the Earth's environment. Finally, the natural environment continues to pose risks to society in the form of volcanoes, earthquakes, wildland fires, floods, droughts, invasive species, variable and changing climate, and natural and anthropogenic toxins, as well as animal-borne diseases that affect humans. The use of, and competition for, natural resources on the global scale, and natural threats to those resources, has the potential to impact the Nation's ability to sustain its economy, national security, quality of life, and natural environment. Responding to these national priorities and global trends requires a science strategy that not only builds on existing USGS strengths and partnerships but also demands the innovation made possible by integrating the full breadth and depth of USGS capabilities. The USGS chooses to go forward in the science directions proposed here because the societal issues addressed by these science directions represent major challenges for the Nation's future and for the stewards of Federal lands, both onshore and offshore. The six science directions proposed in this science strategy are summarized in the following paragraphs. The ecosystems strategy is listed first because it has a dual nature. It is itself an essential direction for the USGS to pursue to meet a pressing national and global need, but ecosystem-based approaches are also an underpinning of the other five directions, which all require ecosystem perspectives and tools for their execution. The remaining strategic directions are listed in alphabetical order.

Understanding Ecosystems and Predicting Ecosystem Change: Ensuring the Nation's Economic and Environmental Future

In collaboration with others, the USGS reports on the state of the Nation's terrestrial, freshwater, and coastal/marine ecosystems and studies the causes and consequences of ecological change, monitors and provides methods for protecting and managing the biological and physical components and processes of eco-systems, and interprets for policymakers how current and future rates of change will affect natural resources and society. The USGS works in collaboration with others to understand the distribution, interactions, condition, and conservation requirements of organisms in an ecosystem context, and predicts changes to biodiversity resulting from land-cover change, climate change, and other impacts to ecosystems. The USGS and its partners will advance understanding, through research, of ecosystem structure, function, patterns and processes, and will develop new products, including standardized national maps of ecosystems in the United States. They will also provide regularly updated reports on the status of ecosystems and assessment of trends that will help communities and managers make informed decisions that take into account ecosystem health and sustainability.

Climate Variability and Change: Clarifying the Record and Assessing Consequences

The USGS scientists will meet the pressing needs of the U.S. Department of the Interior, policy-makers, and resource managers for scientifically valid state-of-the-science information and predictive understanding of climate change and its effects. Studies of the interactions among climate, earth surface processes, and ecosystems across space and time will contribute directly to the strategic goals of the U.S. Climate Change Science Program. To answer questions about how the world is changing, the USGS will expand its already strong research and monitoring initiatives in the science of carbon, nitrogen, and water cycles, hydroclimatic and ecosystem effects of climate change, and land-cover and land-use change. The USGS will continue studies of paleoclimate and past interactions of climate with landscapes and ecosystems, and apply the knowledge gained to understanding potential future states and processes. Expanded and modernized USGS observing networks of land, water, and biological resources will be crucial to rigorous analyses of future responses to climate change. The USGS will provide robust predictive and empirical tools for managers to test adaptive strategies, reduce risk, and increase the potential for hydrologic and ecological systems to be self-sustaining, resilient, or adaptable to climate change and related disturbances.

Energy and Minerals for America's Future: Providing a Scientific Foundation for Resource Security, Environmental Health, Economic Vitality, and Land Management

The USGS energy and minerals resource research will be broadened to contribute more comprehensively to discourse and decisions about future natural resource security, environmental effects of resource use, the economic vitality of the Nation, and management of natural resources on U.S. Department of the Interior, Federal and other lands. A wide-ranging, multidisciplinary approach is used to understand and evaluate how the complex life cycle of occurrence, formation processes, extraction methods, use, and waste products of energy and mineral resources influence, or are influenced by, landscape, hydrology, climate, ecosystems, and human health. Cumulative knowledge, long-term data, and new understanding of resource origin and assessment methodologies will improve the reliability and accuracy of national and global assessments and information products, especially as the energy mix evolves and new requirements for rare and scarce materials used by the Nation emerge. Information from the USGS resource cycle increasingly will be put in economic terms so that policymakers can more clearly weigh competing alternatives. Through partnerships and collaborations, USGS natural resource knowledge and expertise helps advance the Nation's economy and improve its competitiveness.

A National Hazards, Risk, and Resilience Assessment Program: Ensuring the Long-Term Health and Wealth of the Nation

The USGS collects accurate and timely information from modern earth observation networks, assesses areas at risk from natural hazards, and conducts focused research to improve hazard predictions. In addition, the USGS works actively with the Nation's communities to assess the vulnerability of cities and ecosystems and to ensure that science is effectively applied to reduce losses. The USGS will develop a national risk-monitoring program, built on a robust underpinning of hazard assessment and research, to visualize and provide perspectives at multiple scales of vulnerability and resilience to adverse land change and hazards. Accurate observations, focused

research, and timely communications will safeguard people and property and keep natural hazards from becoming natural disasters.

The Role of Environment and Wildlife in Human Health: A System that Identifies Environmental Risk to Public Health in America

The USGS can contribute substantially to public health decisionmaking. The USGS monitors wildlife, is at the forefront of identifying wild animal disease reservoirs, and maintains critical knowledge about wild animal disease transmission to humans, drinking-water contaminants, air-dust-soil-sediment-rock contaminants, pathogens in recreational water, and the use of wild animals as sentinels of human health. To employ this expertise in support of the Nation's health needs, the USGS will fully integrate its massive data holdings and environmental science expertise to produce a national database and atlas of geology, and ecology-sourced diseases and toxicants. Once this atlas is in place, the USGS will partner with allied health science agencies to support spatially related health research.

A Water Census of the United States: Quantifying, Forecasting, and Securing Freshwater for America's Future

The USGS will develop a Water Census of the United States to inform the public and decisionmakers about (1) the status of its freshwater resources and how they are changing; (2) a more precise determination of water use for meeting future human, environmental, and wildlife needs; (3) how freshwater availability is related to natural storage and movement of water, as well as engineered systems, water use, and related transfers; (4) how to identify water sources, not commonly thought to be a resource, that might provide freshwater for human and environmental needs; and (5) forecasts of likely outcomes for water availability, water quality, and aquatic ecosystem health caused by changes in land use and land cover, natural and engineered infrastructure, water use, and climate.

The six strategic science directions outlined here are themselves interrelated. Their interaction, correlation, and interplay reveal the complexity of the Earth's natural, physical, and life systems. Developing new understanding, therefore, requires a "systems" approach that calls upon the full range of USGS capabilities. The USGS, with its breadth of scientific expertise, can provide an important perspective on the entire web of interrelated natural processes that affect national and global well-being. Understanding the implications of these intricate linkages requires that data and information be readily shared among USGS scientists and collaborators, and with our partners and customers in forms suited to their needs, interests, and responsibilities. Thus, expansion of information technology to allow for seamless data and information sharing is an important component of the USGS science strategy. However, information technology is only one of the technological areas that will require continual updating. The USGS must keep abreast of advances in areas, such as environmental sensors, microbiology, nanotechnology, and many others that are now, or will become, critical to the mission. Therefore, the SST has identified two critical crosscutting science directions that are essential for the success of the science strategy:

Data Integration and Beyond

The USGS will use its information resources to create a more integrated and accessible environment for its vast resources of past and future data. It will invest in cyberinfrastructure, nurture and cultivate programs in natural-science informatics, and participate in efforts to build a global integrated science and computing platform.

Leveraging Evolving Technologies

The USGS will foster a culture and resource base that encourages innovation, thereby advancing scientific discovery through the development and application of state-of-the-art technologies. The next decade poses formidable challenges, but it also holds unprecedented opportunities for USGS science to improve the economic and environmental health and prosperity of people and communities across the Nation and around the world. The USGS looks forward to applying the full breadth and depth of its scientific capabilities to meet the challenges of the 21st century.