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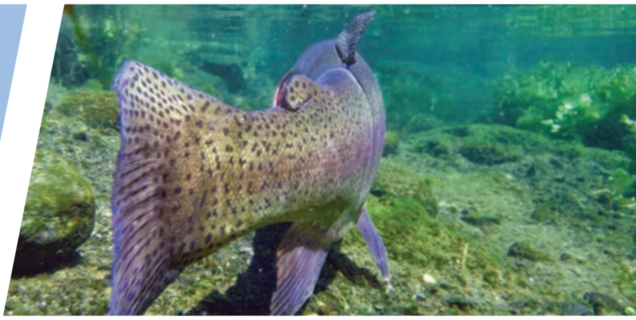
United States
Environmental Protection
Agency

# Safe and Sustainable Water Resources

## STRATEGIC RESEARCH ACTION PLAN 2016–2019



**Office of Research and Development**
Safe and Sustainable Water Resources

EPA 601/K-15/004

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## Strategic Research Action Plan 2016–2019

U.S. Environmental Protection Agency
November 2015

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# List of Acronyms

| | |
|---|---|
| ACE | Air, Climate, and Energy |
| AOPs | Adverse Outcome Pathways |
| AWQC | Ambient Water Quality Criteria |
| BMP | Best Management Practices |
| CCL | Contaminant Candidate List |
| CECs | Contaminants of Emerging Concern |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CSO | Combined Sewer Overflow |
| CSS | Chemical Safety for Sustainability |
| CWA | Clean Water Act |
| DoD | Department of Defense |
| EPA | U.S. Environmental Protection Agency |
| GI | Green Infrastructure |
| HABs | Harmful Algal Blooms |
| HAWQS | Hydrologic and Water Quality System |
| HHRA | Human Health Risk Assessment |
| HSPF | Hydrologic Simulation Program FORTRAN |
| HSRP | Homeland Security Research Program |
| NEPA | National Environmental Policy Act |
| ORD | Office of Research and Development |
| PIPs | Pathfinder Innovation Projects |
| RARE | Regional Applied Research Effort |
| RCRA | Resource Conservation and Recovery Act |
| SBIR | Small Business Innovation Research |
| SDWA | Safe Drinking Water Act |
| SHC | Sustainable and Healthy Communities |
| SSWR | Safe and Sustainable Water Resources |
| STAR | Science To Achieve Results |
| SWAT | Soil Water Assessment Tool |
| SWMM | EPA's Stormwater Management Model |
| UCMR | Unregulated Contaminants Monitoring Rule |
| UST | Underground Storage Tanks |
| VELMA | Visualizing Ecosystems for Land Management Assessments |
| WMOST | Watershed Management Optimization and Support Tool |

# Executive Summary

Water is one of our Nation's most precious resources—we depend upon it for our lives and our livelihoods, for healthy ecosystems, and for a robust economy. About 400 billion gallons of water are used each day in the United States. Yet a host of challenges threaten the safety and sustainability of our water resources, including biological and chemical contaminants; aging water-system infrastructure; demands from the energy, agriculture, and manufacturing sectors; population change; climate change; extreme weather events (e.g., hurricanes, tornadoes, heat waves, drought, wildfire); and homeland security events. The U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD) has a dedicated research program focused on addressing these challenges.

ORD's Safe and Sustainable Water Resources (SSWR) research program is using an integrated systems approach to develop scientific and technological solutions to protect human health, and to protect and restore watersheds and aquatic ecosystems. This work is being done in partnership with other EPA programs, federal and state agencies, academia, nongovernmental agencies, public and private stakeholders, and the global scientific community. This cross-cutting approach maximizes efficiency, interdisciplinary insights, and integration of results. The SSWR research program's activities are guided by four objectives:

- **Address current and long-term water resource challenges for complex chemical and microbial pollutants.** This objective involves strengthening the science for drinking water and water quality standards and guidance for new and emerging contaminants that threaten human health and aquatic ecosystems. It also covers developing new methods for detecting, quantifying, monitoring, and treating those contaminants.

- **Transform the concept of 'waste' to 'resource.'** Through innovative water treatment technologies, green infrastructure, and improved management approaches, stormwater, municipal wastewater, and other 'post-use' waters will be valued as a resource for fit-for-purpose water reuse, energy, nutrients, metals, and other valuable substances.

- **Quantify benefits of water quality.** Clean water and healthy ecosystems provide many services that are currently undervalued. By developing models and tools to estimate the economic benefits of water quality improvements, this research will aid in the protection or restoration of water quality.

- **Translate research into real-world solutions.** SSWR aims to move its results out of the lab and into the hands of end users, who can use these data and tools to manage water resources and infrastructure sustainably.

To achieve these overarching objectives and address their respective scientific challenges, SSWR research projects are organized into four interrelated topics: Watershed Sustainability, Nutrients, Green Infrastructure, and Water Systems. Each topic carries specific near- and long-term goals designed to yield practical tools and solutions for ensuring sustainable water resources. This *SSWR Strategic Research Action Plan 2016–2019* outlines these topics and the overall structure and purpose of the SSWR research program. SSWR's scientific results and innovative technologies will support EPA's mandate to protect the chemical, physical, and biological integrity of the Nation's waters and to ensure safe drinking water and water systems.

# Introduction

Water is essential for human health and well-being, all types of ecosystems, and a robust economy. The production of many goods and services, such as agriculture, energy, manufacturing, transportation, fishing, and tourism, depends on the availability and quality of water. Humans and many animals and plants depend on available sources of freshwater, which are surprisingly miniscule—0.007 percent—compared with the total amount of Earth's water. These sources are continually in flux, changing biologically, chemically, and geologically. As the movement of water through the hydrologic cycle is continually dynamic, so too are the changing spatial and temporal demands on water quantity and quality for various uses.

U.S. Environmental Protection Agency (EPA) scientists and engineers and their partners are addressing 21st century water resource challenges by integrating research on environmental, economic, and social factors to provide lasting, sustainable solutions that advance the goals and cross-Agency priorities identified in the *FY2014–2018 EPA Strategic Plan* (EPA Strategic Plan) in support of the EPA's mission to protect human health and the environment.

To assist EPA in meeting its mission and priorities, the Safe and Sustainable Water Resources (SSWR) research program within EPA's Office of Research and Development (ORD), the science arm of the Agency, developed this *Strategic Research Action Plan, 2016–2019* (StRAP 2016–2019).

The SSWR StRAP is one of six research plans, one for each of EPA's national research programs in ORD. The six research programs are:

- Air, Climate, and Energy (ACE)
- Chemical Safety for Sustainability (CSS)
- Homeland Security Research Program (HSRP)
- Human Health Risk Assessment (HHRA)
- Safe and Sustainable Water Resources (SSWR)
- Sustainable and Healthy Communities (SHC)

EPA's six strategic research action plans are designed to guide a comprehensive research portfolio that delivers the science and engineering solutions the Agency needs to meet its goals and objectives, while also cultivating a new paradigm for efficient, innovative, and responsive environmental and human health research.

The SSWR StRAP 2016–2019 outlines the approach designed to achieve EPA's goal to protect America's waters. It highlights how the SSWR research program integrates efforts with other research programs across ORD to provide a seamless and efficient overall research portfolio aligned around the central and unifying concept of sustainability. No other research organization in the world matches the diversity and breadth represented by the collective scientific and engineering staff of ORD, their grantees, and other partners. They are called upon to conduct research to meet the most pressing environmental and related human health challenges facing the Nation and the world.

# Environmental Problems and Program Purpose

Impairment of water quality and diminished water availability are concerns for human and ecosystem health, economic prosperity, and social well-being. Some of the pressing challenges facing our water resources are described below.

**Watersheds**

Across the Nation's watersheds, excess levels of nutrients and sediment remain the largest impediment to water quality. The rate at which water bodies are added to the water quality impairment list exceeds the pace that restored waters are removed from this list. Harmful cyanobacteria and other harmful algal blooms that pose health risks to humans, animals, and ecosystems are largely driven by excess nutrients. EPA and the states do not have the capacity or the tools to assess each water body individually for chemicals and pathogens.

**Wetlands**

The Nation's wetlands provide numerous ecosystem benefits, such as water quality improvement, groundwater recharge, erosion and flooding protection, and habitats for commercially and recreationally valuable or imperiled species. Wetlands are continuing to decline, and the rate may accelerate as acreage, even in conservation, is converted to serve evolving trends in energy and food production.

**Groundwater**

Increasingly, groundwater is becoming an important water source. Sustainability of groundwater with regard to drawdown, recharge, and increasing potential of contamination is a growing concern.

**Undervalued water resources**

Inadequate knowledge of the value of water underlies the daunting challenge to fund the repair and replacement of existing infrastructure with new and innovative technologies that are more resilient and energy efficient, while also ensuring protection of underground sources of drinking water. People tend not to fund or conserve what they do not sufficiently value. Although estimates exist for the cost to deliver safe drinking water to taps—less than $3.75 for every 1,000 gallons (AWWA, 2012)—we lack a more comprehensive evaluation of the benefits of water quality that includes human and environmental health and ecosystem services.

**Stormwater**

For many cities, stormwater management remains one of the greatest challenges to meet water quality standards. When surges in stormwater overwhelm combined sewer systems (systems that convey both sewage and stormwater together), untreated human, commercial, and industrial waste often is discharged directly into surface waters.

**Aging infrastructure**

The Nation's water treatment and delivery systems pose increasingly greater challenges for delivering adequate supplies of safe drinking water. Leaking pipes and water main breaks are responsible for a loss of up to 40 percent of treated drinking water. Additionally, compromised infrastructure can contaminate treated drinking water, surface water, and groundwater. To restore and expand the Nation's deteriorating, buried drinking water pipe system to accommodate a changing population will cost more than $1.7 trillion by 2050 (AWWA, 2012). This estimate does not include other critical infrastructure investment needs, including water treatment plants and storage tanks, nor investments in post-use water and stormwater management. Small systems that serve fewer than 3,300 persons and account for 95 percent of the Nation's 156,000 public water systems face even greater technical, financial, and operational challenges to develop and maintain the capacity to comply with new and existing standards.

**Climate**

In addition to the challenges described above, other water-resource stressors, such as climate change and variability, must be taken into account. Climate models project that distinctive regional differences in climate impacts will occur, affecting the hydrologic cycle. Examples of hydrologic impacts include warmer water temperatures, changes in precipitation patterns and intensity, more frequent and intense flooding and droughts, increased evaporation, changes in soil moisture, and earlier snowpack melt with lower flows in late summer (Melillo et al. 2014). These changes may affect human health, especially vulnerable and sensitive sub populations, for example by increased incidence of waterborne disease related to heavy rain events. These changes may also affect ecosystems, for example by resulting in lower stream flows, warmer temperatures, and lower dissolved oxygen. Human, animal, and ecosystem health may also be affected by varying sensitivities of algal and cyanobacteria species to the interaction between warmer temperatures and nutrients.

**Food-Energy-Water Nexus**

Drinking water treatment and transport and post-use water collection and treatment consume approximately 4 percent of the Nation's electricity (EPRI, 2002). Electricity costs represent roughly 25–40 percent of a municipal wastewater treatment plant's total operating budget. Electricity can account for 80 percent of a drinking water treatment plant's treatment and distribution costs (EPA, 2013a). The SSWR research program plans to provide results for assessing transformative system approaches for lowering energy consumption for water treatment systems. For drinking water treatment, we will continue to seek approaches for lowering energy consumption through innovative treatment methods and approaches for plants of all scales, but particularly for small systems. For post-use water treatment and water reuse systems, the initial goal focuses on systems and approaches to achieve neutral energy consumption and ultimately to become net energy producers. In some cases, green infrastructure may play a role in decreasing the overall volume of post-use water and, therefore, the energy needed for treatment.

Research on water reuse systems emphasizes the treatment and water quality standards for fit-for-purpose potable and non-potable end uses. This may allow reduced energy consumption by minimizing treatment steps depending on the targeted end-use water quality, for example agriculture that benefits from nutrient-rich water. The reuse of various, and in some cases nontraditional, sources of water (e.g., treated post-use municipal water, saline or brackish waters, produced waters from energy production, agricultural return flows) will help mitigate the critical need for available freshwater that is expected to intensify over time. Recovering biogas from post-use water may achieve energy neutral or positive goals, while recovering and recycling other valuable commodities (e.g., nutrients, metals) may reduce the energy needed to generate novel sources. Research is described in detail in the Water Systems topic's Integration and Collaboration section.

**Amplifying stressors**

Water quality and quantity challenges will be amplified by other stressors, such as extreme weather events (e.g., hurricanes, tornadoes, heat waves, drought, wildfire). Some of these extreme weather events may be exacerbated by climate change, land-use change, energy and food production, accidental or purposeful contamination, and population change. Many of these stressors will be more pronounced in areas that are least resilient to climate impacts. For example, population growth is projected to continue increasing in U.S. shoreline counties that are vulnerable to sea level rise and more frequent and extreme storms, and where 39 percent of the U.S. population is already concentrated and another 52 percent live in counties that drain to coastal watersheds (NOAA State of Coast Report 2013). In the southwestern United States, increased temperatures and changes to precipitation and snowpack are expected to impact the region's critical agriculture sector, affecting one of the Nation's fastest growing populations—now at 56 million and expected to increase 68 percent to 94 million by 2050 (Hoerling et al., 2013). Water resources in many areas are already strained and will be further stressed by severe and sustained drought and over-utilization, resulting in increasing competition among domestic water supplies, agriculture, energy production, and ecosystems (Garfin et al., 2014).

These water resource challenges also offer opportunities for innovation, economic development, and improvements in watershed sustainability and human health. For example, post-use water treatment innovations can transform the concept of 'waste' to 'resource' by recapturing and reusing commercially valuable post-use constituents (e.g., nutrients, energy, metals). Additional benefits of these newer technologies include improved energy efficiency from both treatment operations and reduced de novo production of resources from their original sources in the environment. Green infrastructure can help mitigate stormwater runoff and potentially reduce gray infrastructure investment costs and energy use, improve property values, create wildlife habitat, and recharge groundwater.

## SSWR Research Program

The SSWR StRAP 2016–2019 outlines the approach designed to achieve EPA's goal to protect America's waters. It highlights how the SSWR research program integrates efforts with the other five national research programs, other Agency partners, and external partners to provide a seamless and efficient overall research portfolio aligned around the central and unifying concept of sustainability.

The SSWR research program uses an integrated, systems approach to mission-driven, state-of-the-art research. The goal is to support innovative scientific and technological solutions that ensure clean, adequate, and equitable supplies of water to protect human health and to protect and restore watersheds and aquatic ecosystems. Future SSWR research will focus on high-priority, current and long-term water resource challenges identified in partnership with EPA programs and regional offices and others to inform the Agency's decisions, implementation needs, and translation of research findings to support communities, states, and tribal partners. The overarching watershed approach to SSWR drinking water, post-use water, stormwater, and ecosystems research recognizes the dynamic 'one water' hydrologic cycle. Integrated throughout the program are the goals of a sustainable environment, economy, and society and the overarching drivers of a changing climate, extreme weather events, population change, and evolving trends in land use, energy, agriculture, and manufacturing.

The following Problem Statement and Program Vision guide the research program:

### Problem Statement

**Together, the interrelated challenges of impaired water quality, diminished water availability, the Nation's aging water infrastructure, and inadequate knowledge of the value of water quality benefits threaten safe and sustainable water resources. These challenges are further amplified by a host of current and emerging environmental stressors, including climate change and variability, extreme weather events, population change, and evolving trends in land use energy, agriculture, and manufacturing.**

### Program Vision

**The Safe and Sustainable Water Resources research program uses an integrated, systems approach to support innovative scientific and technological solutions that ensure clean, adequate, and equitable supplies of water to protect human health and to protect and restore watersheds and aquatic ecosystems.**

# Program Design

The SSWR StRAP 2016–2019 provides both a vision and an actionable blueprint for advancing water research in ways that meet the priorities and legislative mandates of EPA, while addressing the most critical needs of Agency partners and stakeholders.

## Building on the 2012–2016 Research Program

This StRAP builds on the successful research outlined in the previously developed SSWR StRAP 2012–2016 and like that work, it will continue advancing science and technology solutions for the Nation's high- priority, current, and emerging water resource and human health challenges. The SSWR StRAP 2016–2019 now places more emphasis on harmful cyanobacteria and algal blooms, groundwater quality, water quality improvement from green infrastructure, resilience to climate change and extreme weather events, quantifying the benefits of water quality, and community support tools. In addition, SSWR is partnering with other federal and state agencies, private and public organizations, and communities to contribute EPA's unique expertise in water quality, water reuse, and green infrastructure to the rapidly growing area of the 'Food-Energy-Water' nexus.

The updated plan presented here consolidates research into four interrelated research topics:

1. Watershed Sustainability
2. Nutrients
3. Green Infrastructure
4. Water Systems (drinking water and post-use water systems)

The four topics and their related research challenges and priorities are described in detail in the Research Topics section.

Various ORD programs and grants continue to be integrated into SSWR by the topic(s) each supports. Extramural research examples include the Water Technology Innovation Center, EPA Science to Achieve Results (STAR) grants, and the Small Business Innovation Research (SBIR) program. ORD research programs also include opportunities to compete for funding within EPA such as the Regional Applied Research Effort (RARE) program, which funds partnerships between regional and ORD scientists to conduct research, and the Pathfinder Innovation Projects (PIPs), which provide seed funding for potentially high-risk, high-reward research concepts.

## EPA Partner and Stakeholder Involvement

The SSWR StRAP 2016–2019 guides ORD research to address the high-priority needs of the Agency and its partners and stakeholders. Accordingly, it was developed with considerable input and support from EPA's ORD labs and centers; Office of Water, Office of Policy, and other program offices; regional offices; and external advisory committees. Research priorities were identified through numerous sources, including two meetings with the EPA Science Advisory Board and the Board of Scientific Counselors during the 2012–2015 planning period, the annual SSWR research conference, annual SSWR program update, annual meeting of the ORD and Office of Water Assistant Administrators and Regional Administrators, quarterly meetings with Office of Water senior staff, visits to regional offices, in-person 'Chautauquas' with researchers and policy staff and regular communications with the ORD lab and centers, Office of Water, and regional offices. These efforts produced a prioritized list of research needs for the Office of Water and regional offices that has served as the foundation for the SSWR StRAP 2016–2019 research goals.

Research planned for the SSWR StRAP 2016–2019 also was informed by external partners. The SSWR staff and researchers serve on several task groups and are actively engaged on projects with numerous U.S. federal agencies and other domestic and international organizations (see Appendix 1). The SSWR National Program Director is the co-chair for the Subcommittee on Water Availability and Quality that advises and assists the White House National Science and Technology Council and the Committee on Environment, Natural Resources, and Sustainability on matters related to the availability and quality of water resources. The Subcommittee on Water Availability and Quality comprises over a dozen federal agencies that meet monthly, facilitating effective outcomes of coordinated multi-agency water-related activities. The SSWR National Program Director also serves on the Global Water Research Coalition, which meets biannually to leverage expertise among the participating international research organizations, coordinate research strategies, and actively manage a centralized approach to global issues. SSWR interacts with academia through scientific conferences, informal professional relationships, and formal grants and cooperative agreements. These venues afford the opportunity to not only leverage expertise and funding, but also the ability to identify unique niche areas to which SSWR can make the greatest scientific contributions.

## Integration across Research Programs

EPA's six research programs work together to address science challenges that are important for more than one program. Coordination efforts can range from formal integration actions across the programs at a high level to collaborative research among EPA scientists working on related issues.

To integrate research on significant cross-cutting issues, EPA developed several 'Research Roadmaps' that identify both ongoing relevant research and important science gaps that need to be filled. These Roadmaps serve to coordinate research efforts and to provide input that helps shape the future research in each of the six programs. Roadmaps have been developed for the following areas:

- Nitrogen and Co-Pollutants
- Children's Environmental Health
- Climate Change
- Environmental Justice

SSWR is the lead national program for EPA's *Nitrogen and Co-pollutants Roadmap*, and SSWR provides the foundation for research on nutrients (see Nutrients topic section). Overarching research on impacts of climate variability and change will be integrated with the Air, Climate, and Energy (ACE) research program through the Climate Change Roadmap. SSWR is also identifying opportunities to integrate with the Children's Environmental Health Roadmap and the Environmental Justice Roadmap. The SSWR program also informs critical research areas identified in the ORD cross-cutting Research Roadmaps, as illustrated in Table 1. Efforts to ensure integration across the research programs are described in more detail in each of the Research Topic sections.

**Table 1. SSWR Research Program Contributions to Critical Needs Identified by ORD Roadmaps**

Multiple checkmarks indicate a larger contribution of SSWR activities and interest in the identified science gaps of the Roadmaps than a single checkmark; a blank indicates no substantive role.

| ORD Roadmap | SSWR Topic Area | | | |
|---|---|---|---|---|
| | Watershed Sustainability | Nutrients | Green Infrastructure | Water Systems |
| Climate Change | ✓ | ✓✓ | ✓ | ✓ |
| Environmental Justice | | ✓ | ✓✓ | ✓✓ |
| Children's Health | | ✓ | | ✓ |
| Nitrogen & Co-Pollutants | ✓✓ | ✓✓✓ | ✓ | ✓✓ |

## SSWR Research Supports EPA Strategic Plan

EPA's Strategic Plan[1] identifies five goals and four cross-Agency strategies to support its mission to protect human health and the environment. The SSWR research program supports the Strategic Plan's second goal, 'Protecting America's Waters,' and its aims to protect and restore waters to ensure that drinking water is safe and sustainably managed; and that aquatic ecosystems sustain fish, plants, wildlife and other biota, as well as economic, recreational, and subsistence activities. EPA's objectives for Protecting America's Waters are twofold:

1. **Protect Human Health**
   Achieve and maintan standards and guidelines protective of human health in drinking water supplies, fish, shellfish, and recreational waters, and protect and sustainably manage drinking water resources.

2. **Protect and Restore Watersheds and Aquatic Ecosystems**
   Protect, restore, and sustain the quality of rivers, lakes, streams, and wetlands on a watershed basis and sustainably manage and protect coastal and ocean resources and ecosystems.

The SSWR research program supports EPA Goal 2 and its objectives, and the cross-Agency strategies, by efficiently integrating and translating environmental, economic, and social research into visible and sustainable solutions for local, state, and tribal communities. Innovative solutions will be key to meeting the Agency's strategic goal of protecting America's waters. EPA has committed to innovation for solving sustainability challenges in two recent documents: *Technology Innovation for Environmental and Economic Progress: An EPA Roadmap* (2012)[2] and *Promoting Technology Innovation for Clean and Safe Water: Water Technology Innovation Blueprint – Version 2* (2014).[3]

### EPA Strategic Plan (FY2014–2018)
### *Goals and Cross-Agency Strategies*

***EPA Strategic Goals***

**Goal 1: Addressing Climate Change and Improving Air Quality**

**Goal 2: Protecting America's Waters**

**Goal 3: Cleaning Up Communities and Advancing Sustainable Development**

**Goal 4: Ensuring the Safety of Chemicals and Preventing Pollution**

**Goal 5: Protecting Human Health and the Environment by Enforcing Laws and Assuring Compliance**

***Cross-Agency Strategies***

- **Working Toward a Sustainable Future**
- **Making a Visible Difference in Communities**
- **Launching a New Era of State, Tribal, Local, and International Partnerships**
- **Embracing EPA as a High-Performing Organization**

[1]Fiscal Year 2014–2018 EPA Strategic Plan http://www2.epa.gov/planandbudget/strategicplan
[2]http://www2.epa.gov/envirofinance/innovation
[3]http://www2.epa.gov/innovation/water-innovation-and-technology

## Statutory and Policy Context

EPA is responsible for protecting the Nation's water resources under the Clean Water Act (CWA), which establishes the basic structure for (1) restoring and maintaining the chemical, physical, and biological integrity of the Nation's waters by preventing point and nonpoint pollution sources; (2) providing assistance to publicly owned treatment works for the improvement of post-use water treatment; and (3) maintaining the integrity of wetlands (U.S. EPA, 2013b). The CWA provides for the protection of above-ground sources of drinking water as determined by each state. Groundwater protection provisions are included in the Safe Drinking Water Act (SDWA), Resource Conservation and Recovery Act, and the Comprehensive Environmental Response, Compensation, and Liability Act ('Superfund').

The SDWA directs EPA to set national safety standards for drinking water delivered to consumers by public water systems. It also authorizes other regulatory programs (e.g., Underground Injection Control, Wellhead Protection), as well as funding, training, public information, and source water assessment programs, to foster the protection of many sources of drinking water.

EPA created the Office of Underground Storage Tanks (UST) to carry out a congressional mandate to develop and implement a regulatory program for underground storage tank systems. The greatest potential threat from a leaking UST is contamination of groundwater. EPA, states, and tribes work together to protect the environment and human health from potential UST releases.

EPA's Office of Water, which has primary responsibility for implementing the provisions of the CWA and the SDWA, is a key partner for the SSWR research program. For more information on EPA responsibilities under these statutes, see the links provided in Table 2.

**Table 2. Statutory and policy drivers for SSWR research**

| Legislation | Acronym | Website |
|---|---|---|
| Clean Water Act | CWA | http://www2.epa.gov/laws-regulations/summary-clean-water-act |
| Safe Drinking Water Act | SDWA | http://water.epa.gov/lawsregs/rulesregs/sdwa/index.cfm |
| Resource Conservation and Recovery Act | RCRA | http://www2.epa.gov/laws-regulations/summary-resource-conservation-and-recovery-act |
| Comprehensive Environmental Response, Compensation and Liability Act ("Superfund") | CERCLA | http://www.epa.gov/superfund/policy/cercla.htm |
| Federal Underground Storage Tank Regulations (Revised 2015) | USTs | http://www.epa.gov/oust/fedlaws/ |
| National Environmental Policy Act | NEPA | http://www2.epa.gov/nepa |

# Research Program Objectives

The SSWR program addresses four broad research objectives that support EPA's goals and cross-Agency strategies noted above and are critical to meeting the needs of the Agency, its partners, and other stakeholders. Together, these research objectives provide a platform for protecting the quality and supply of America's waters from headwaters to streams, rivers and lakes, coastal waters, and groundwater.

### Objective 1: Address Current and Long-Term Water Resource Challenges for Complex Chemical and Microbial Pollutants

Water resources in the United States face many challenges from known and emerging chemical and microbial pollutants. SSWR research on chemical and microbial contaminants, including nutrients, aims to strengthen water systems' resiliency and compliance with drinking water and water quality standards. In addition, SSWR research helps protect America's source waters and supports new or revised drinking water standards to address known and emerging contaminants that endanger human health and aquatic ecosystems. Through partnerships with program and regional offices, states, tribes, and local communities, SSWR will work toward a more sustainable future, while making a visible difference in local communities.

ORD researchers will continue to provide timely support for regulatory and guidance decisions for water resources. Additionally, water systems researchers will strive to develop new and innovative methods for detecting, quantifying, monitoring, and treating microbial and chemical contaminants. The SSWR StRAP 2016–2019 emphasizes addressing contaminants as groups, as well as individually, when developing novel methods for quantifying human exposure and assessing human health risks. Water systems researchers will also explore ways to treat water and post-use water effectively for chemicals and pathogens with technologies and approaches that reduce energy consumption and provide the ability to reuse and recover resources, as described below. SSWR will continue its focus on affordable, simple, and effective water treatment solutions for small systems.

### Objective 2: Transform the Concept of 'Waste' to 'Resource'

Combined sewer overflow (CSO) events continue to vex many U.S. communities, particularly in the Northeast, Midwest, and Pacific Northwest. Combined sewer systems that collect stormwater and municipal post-use water are often overwhelmed during storm events, resulting in the direct discharge of overflow into waterways. Although SSWR research will continue to address CSO events by implementing green infrastructure (GI) to capture stormwater flow, new research efforts will investigate the use of GI to recharge groundwater and the capture and storage of stormwater to augment water supplies in arid and semi-arid parts of the United States.

SSWR's drinking water and post-use water systems research will focus on transformative approaches for water reuse and resource recovery. Communities in dry climates need guidance at the federal level on water reuse treatment for fit-for-purpose end uses, such as direct potable, indirect potable, and non-potable reuse. Fit-for-purpose treatment can reduce energy costs by tailoring treatment schemes and approaches for a targeted end-use water quality. In addition to water reuse, SSWR researchers will partner with others within and outside of the Agency on recovering and reusing energy, nutrients, and possibly metals and other valuable substances to advance the transformation of 'waste' to 'resource.' Increased energy recovery in post-use water systems can potentially lead to net-zero energy consumption for the systems and, in some cases, make the post-use water system a net producer of energy. Life-cycle analyses of water systems for small communities will lead to new approaches for transforming water systems. This research strives to develop a framework for local communities to make informed decisions on treatment and conveyance systems that include water reuse and resource recovery for a more sustainable future.

### Objective 3: Quantify Benefits of Water Quality

Degradation of water quality due to chemical and microbial contaminants, including nutrients that drive harmful cyanobacteria and algal blooms, continues to outpace water quality improvements from regulatory and non-regulatory, incentive-based actions. The challenges of protecting good water quality or restoring impaired water quality are hampered by inadequate knowledge of the value of improved water quality and its wide-ranging benefits, which span human and environmental health and ecosystem services.

Through partnerships with EPA's Office of Policy and Office of Water, and external grants funded by SSWR, successful efforts will develop the models and tools needed to estimate the economic benefits of water quality improvements. The research aims to advance national water quality cost-benefit analysis and modeling tools for surface waters, from headwater streams to downstream estuarine and coastal waters. The modeling tools will build the capacity for estimating economic benefits of water quality improvements through revealed preference (i.e., human use) studies that identify market and non-market values associated with water quality, and stated preference (i.e., non-use) studies that will capture the broader ranges of non-market values. The research will identify the optimal choice of water quality indicators—those metrics most useful for linking water quality models to economic valuation.

### Objective 4: Translate Research into Real-World Solutions

The translation and application of research results through practical tools has historically challenged scientists and engineers. ORD aims to move our research results out of the lab and into the hands of end users who depend on these data and tools.

Watershed sustainability research builds the capacity to assess and map the integrity and resiliency of water resources and watersheds at national and regional scales, and provides modeling tools and applications for integrated watershed management. Research on chemical and microbial contaminants will strengthen methods to prioritize, derive, and implement Ambient Water Quality Criteria to protect human health and aquatic life from the expanding numbers, combinations, and novel features of contaminants in groundwater, drinking water, and surface water. Research tools that assess and predict effects and cumulative impacts of energy and mineral extraction processes on groundwater and surface water quality and aquatic life will inform and empower communities to protect water, while developing the Nation's future energy and mineral resource portfolio. Translating and communicating the results of the economic benefits of CWA regulations will strengthen efforts and support for developing and implementing regulatory actions to improve water quality across the Nation.

Nutrient enrichment of the Nation's water bodies continues to be a significant risk to human health and ecosystems. Research in this area will advance the science needed to inform decisions to prioritize watersheds and nutrient sources for nutrient management and define appropriate nutrient levels for the Nation's waters. Novel field and laboratory-based studies, state-of-the-art modeling, and other research syntheses will make significant progress toward important and challenging areas of scientific uncertainty related to nutrient management.

Multimedia approaches will reduce the unintended consequences and capture the cumulative benefits of actions, which can be equally as important as direct benefits. New scientific information, analytical approaches, and science communication that advance the science and increase the accessibility of this science will become available to decision makers.

The SSWR program plans to implement place-based GI studies and water system pilot projects in communities throughout the Nation. Results from these projects can be translated to communities for informed decisions on the placement and effectiveness of resource recovery technologies. GI place-based studies will help make a visible difference in underserved communities by helping capture stormwater runoff for mitigating CSO events and, in some communities, augment existing water supplies. SSWR researchers will continue to develop user-friendly models and tools for GI placement and implementation to help communities solve water management challenges. SSWR will also partner with other EPA program offices and the external research community to develop tools that address life-cycle costs (i.e., including planning, design, installation, operation and maintenance, and replacement), performance, and resiliency of gray and green infrastructure and hybrid systems to provide a more complete basis for decision making at the local and watershed levels.

Communication plays a large role in our plans for real world solutions. The SSWR communications team conducts several monthly public webinars on its research and will explore other opportunities to have an open dialogue with state and community stakeholders. SSWR hosts, in collaboration with the Association of State Drinking Water Administrators, an annual workshop for small systems professionals for the release of cutting-edge research results. A monthly small systems webinar, which offers continuing education credits to water managers, is also co-hosted by SSWR and EPA's Office of Water.

# Research Topics

In SSWR, research is organized by four interrelated topics (Figure 1). Each topic has near-term and long-term goals designed to help SSWR accomplish its overarching objectives (Table 3). These projects involve significant integration and collaboration with other EPA research programs, federal agencies, and external partners, as described below.

1. **Watershed Sustainability**
   Gathering, synthesizing, and mapping the necessary environmental, economic, and social (human health and well-being) information on watersheds, from local to national scales, to determine the condition and integrity, future prospects, and recovery potential of the Nation's watersheds.

2. **Nutrients**
   Conducting EPA nitrogen and co-pollutants research efforts for multiple types of water bodies and coordinating across media (water, land and air) and various temporal and spatial scales, including support for developing numeric nutrient criteria, decision support tools, and cost-effective approaches to nutrient reduction.

3. **Green Infrastructure**
   Creating innovative tools, technologies, and strategies for managing water resources (including stormwater) today and for the long-term.
4. **Water Systems**
   Developing tools and technologies for the sustainable treatment of water and post-use water and promoting the economic recovery of water, energy and nutrient, and other resources through innovative municipal water services and whole system assessment tools. This area focuses on small water systems and can be scaled up to larger systems.

The four research topics of the SSWR StRAP 2016–2019 align with EPA's Strategic Plan to help ensure that natural and engineered water systems have the capacity and resiliency to meet current and future water needs for the wide range of human and ecological requirements. Research aims, in turn, are advanced by research projects to meet articulated science challenges. Examples of research projects are provided for each research topic and are described in more detail later in this section. Research outputs synthesize and translate scientific and technological accomplishments, and will be communicated to a broad audience who rely on EPA research for knowledge and decision making. Examples of possible outputs are provided in Appendix 2.

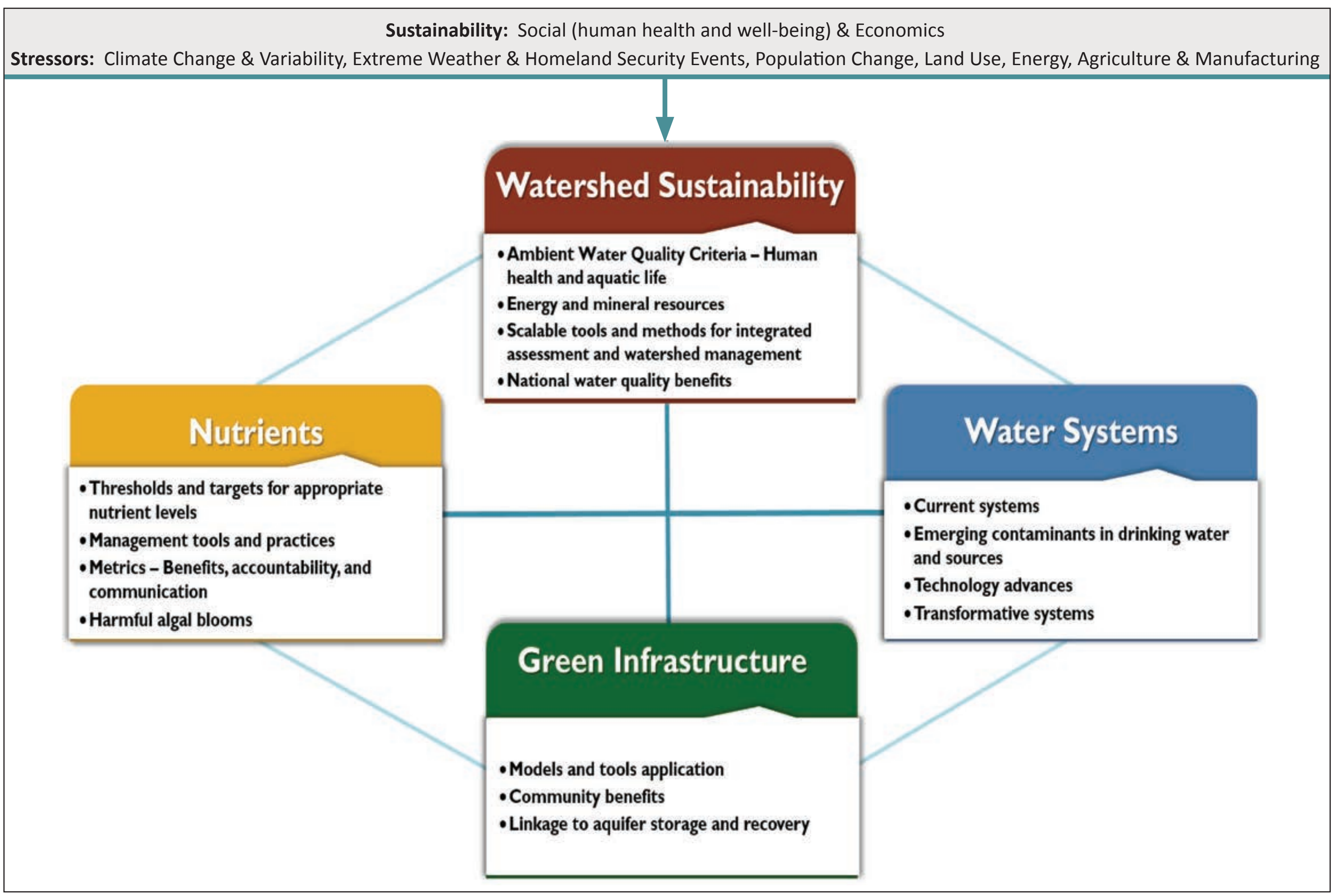


**Figure 1. SSWR Research Topics and Projects.**

**Table 3. SSWR Research Topics: Near- and Long-Term Aims**

| Research Topic | What We Do | Near-Term Aim | Long-Term Aim |
|---|---|---|---|
| **Watershed Sustainability** | Gather, synthesize, and provide the necessary environmental, economic, and social information on watersheds—from local to national scales—to determine condition, future prospects, and recovery potential of the Nation's watersheds. | Develop methods to assess watershed integrity nationally and the tools necessary to maintain the sustainability and resilience of watersheds; develop understanding and tools to address energy and mineral resources; identify causes of watershed impairment and attributes that promote integrity and resilience; and develop approaches to watershed sustainability that integrate ecological condition, economic benefits, and human well-being. | Conduct national and scalable mapping assessments of watershed sustainability using indicators of ecological condition, economic benefits, and human well-being; and develop and demonstrate the tools for achieving sustainable and resilient watersheds and water resources. |
| **Nutrients** | Conduct nutrient research for multiple water-body types with coordination across media (water, land, and air) and various temporal spatial scales, including support for developing numeric nutrient criteria, decision support tools, and cost-effective approaches to nutrient reduction. | Improve the science needed to define appropriate nutrient levels and develop technologies and management practices to monitor and attain appropriate nutrient loadings, and examine the occurrence and effects of harmful algal blooms. | Assess ecosystem and human health and the societal benefits resulting from management actions to achieve appropriate and sustainable nutrient levels in the Nation's waters. |

**Table 3. (continued) SSWR Research Topics: Near- and Long-Term Aims**

| Research Topic | What We Do | Near-Term Aim | Long-Term Aim |
|---|---|---|---|
| **Green Infrastructure** | Develop innovative tools, information, and guidance for communities to manage water resources, including stormwater, with green infrastructure to move toward more natural hydrology and increased resilience to future changes, such as climate and extreme weather events. | Assist decision makers, planners, and developers in understanding how to incorporate effective green infrastructure opportunities into their stormwater management plans at the property level and community scales. | Develop and demonstrate tools and provide information and guidance for communities to assess the effectiveness and benefits of green infrastructure as part of their approach for managing water volume and improving water quality. |
| **Water Systems** | Develop, test, and evaluate innovative tools, technologies, and strategies for managing water resources and protecting human health and the environment as climate and other conditions change; and support the economic recovery of resources through innovative water services and whole-system assessment tools. Particular attention will be given to small systems because of their limited resources. | Support drinking water and wastewater regulations, guidance, and implementation of programs at all levels. Develop, test, and promote the adoption of drinking water, stormwater, and wastewater technologies that will protect human health and the environment, while maximizing resource conservation and recovery. Closely align contaminant research with other topics to ensure that common tools and models are effectively employed across the water cycle. | Conduct integrated sustainability assessments, develop novel approaches, and prioritize risks to provide a framework for decision making related to alternative approaches to existing water systems to meet the goals of public health protection and resource recovery. |

Natural and engineered water systems are inextricably linked through the hydrologic cycle; therefore, the four research topics are also interrelated. Current water services are mostly achieved through separate engineering systems to provide distinct functions, including safe drinking water, sewage treatment, stormwater control, and watershed management. Multiple stressors and more stringent water quality goals threaten the future effectiveness and affordability of this 'siloed' approach to water resource management. A systems-level view of integrated water services is necessary to develop optimal solutions. Focusing on one part of the system, even when using system analysis tools, such as life-cycle assessment, may shift problems to other sectors. Although this document defines four separate topic areas for clarity of presentation, the program emphasizes this systems-level view.

Overarching goals for all four topics are environmental, economic, and social sustainability. All four topics also include multiple stressors affecting water quality and quantity, including climate change and variability, extreme weather events (e.g., flooding, hurricanes, tornadoes, earthquakes, heat waves, drought, wildfire—many of which may be amplified by climate), land-use change, energy, agriculture, manufacturing, accidental or purposeful contamination, aging infrastructure, and population change. Broad linkages among topic areas (e.g., the interaction of complex chemical and microbial contaminants between the built infrastructure and watersheds) are identified as specific projects are planned and implemented. Relationships among the other five research programs are illustrated in Figure 2. For example, Figure 2 illustrates that, although the Watershed Sustainability and Water Systems topic areas have direct and implied linkages with all five ORD research programs, the Nutrients and Green Infrastructure topic areas currently link to three and two of the programs, respectively. These linkages are briefly described in the 'Integration and Collaboration' sections included in each of the project discussions under the Topic headings.

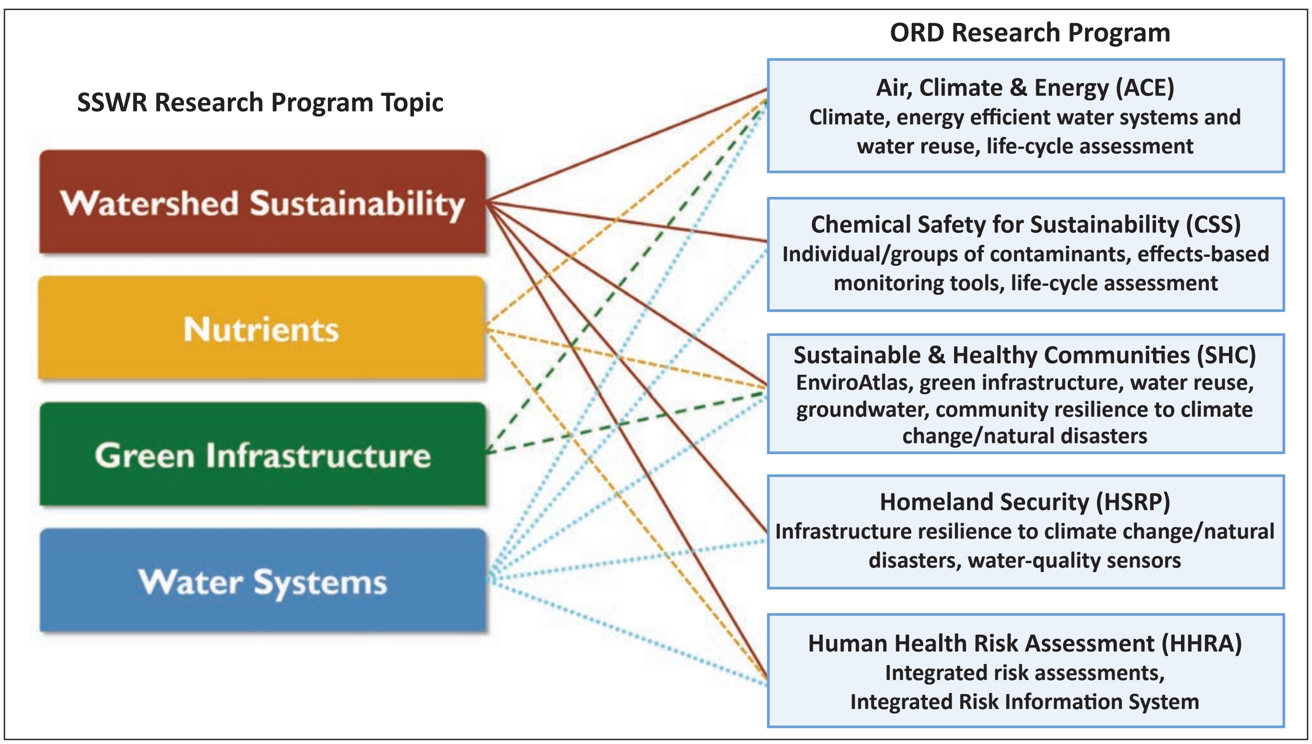


**Figure 2. SSWR Cross-Research Program Integration.**

## Topic 1: Watershed Sustainability

Advancing the sustainable management of the Nation's water resources to ensure sufficient water quality and quantity to support current and future environmental, socio-economic, and public health requirements is a national priority. To achieve the National Environmental Policy Act goal of sustainability, conditions of adequate and accessible supplies of clean water for health (human and ecological), economic and social requirements need to be created and maintained from headwater catchments to great river basins to coastal systems. Adverse impacts on watersheds and water resources associated with the overarching stressors already described, however, continue to be major drivers of changes in aquatic ecosystems and the global hydrologic cycle.

SSWR's watershed sustainability research aims to advance integrated water resource and watershed management approaches, models, and decision making tools to ensure sustainable water resources. Project areas described below focus on national-scale assessments of aquatic resource conditions; watershed integrity and resilience; new or revised Ambient Water Quality Criteria to protect human health and aquatic life from chemical and microbial contaminants, including nutrients and pathogens and chemicals of emerging concern; protection of water resources while developing energy and mineral resources; and creation of a national water quality benefits model framework.

**Topic Highlights**

**Tools for systems approach to watershed management under variable climate regimes.**

**Economic benefits of improved water quality for national regulatory actions.**

### Project 1: Assess, Map and Predict the Integrity, Resilience, and Recovery Potential of the Nation's Water Resources

Advancing EPA's ability to estimate and map the ecological condition and integrity of water resources in freshwater, estuarine, and nearshore coastal ecosystems is the focus of this project research area. The project research will improve capabilities for determining the integrity of watersheds and aquatic systems therein and their future sustainability (i.e., the sustained provision of ecosystem services and beneficial uses). Ultimately, the research will enhance EPA's ability to set sound water policy for the protection of aquatic life and human health applicable to the Nation's flowing waters, lakes and reservoirs, wetlands, estuaries, coastal waters, and groundwater, and provide tools to estimate the expected improvement in aquatic condition, integrity, and resiliency resulting from any proposed policy or management decision.

The primary legislative driver for this project area is the CWA requirement to assess and report on the condition and integrity of the Nation's water resources. The scale of the research creates the greatest scientific challenge—providing the scientific basis and tools for integrated assessment of watersheds and water bodies, from headwaters to coastal systems, at local, regional, and national scales, and at yearly and decadal time scales. The project will include research to:

- Support and advance national and regional monitoring and assessment needs, includ ing direct technical support for EPA Office of Water's National Aquatic Resource Survey program on survey design and analyses, indi cator development, and the technical trans fer of tools.

- Explore, synthesize, and advance the modification or application of existing models and diagnostic systems for integrated watershed management at multiple scales for multiple waterbody types.

- Assess and evaluate ecological factors that underpin watershed resiliency and recovery potential.

- Advance the science reinforcing watershed-waterbody connectivity, including developing connectivity indicators, quantifying temporal-spatial variations in connectivity, relating connectivity to ecosystem functions and processes, and integrating connectivity approaches into watershed integrity.

The project research will strengthen EPA's ability to estimate and map the condition and integrity of the Nation's water resources, and develop improved capabilities to determine the integrity of any watershed in the Nation. Additionally, ORD research will evaluate and strengthen the watershed integrity approach and quantify the attributes of watershed resiliency and connectivity at multiple spatial and temporal scales. Understanding the resiliency and recovery potential of water resources and watersheds to stressors, including climate change, will be important to future policy and management decisions by stakeholders at national, regional, state, and local scales.

The project research will advance diagnostic bioassessment capabilities for the early detection of invasive species through development and application of metagenomic technologies. These tools will assist the Great Lakes National Program Office and support the Great Lakes Water Quality Agreement. New areas of SSWR research will investigate the potential impacts of extreme weather events, such as drought and flooding, and wildfires on water quality. Lastly, project research will enable EPA's Office of Water and regional offices to estimate the expected improvement in aquatic condition, integrity, and resiliency resulting from any proposed policy and management actions.

*Integration and Collaboration*

The project continues the long-standing collaborative partnership with EPA's Office of Water, regional offices, and states, and with the National Oceanic and Atmospheric Administration, U.S. Geological Survey, and Fish and Wildlife Service, on the assessment and mapping of the condition of aquatic resources across the Nation. Watershed integrity, resiliency, and connectivity research involves collaborative partnerships across research conducted under the Watershed Sustainability, Nutrients, and Green Infrastructure topics; with ORD's Air, Climate, and Energy (ACE) research topic on Climate Impacts, Vulnerability, and Adaptation in developing information, methods, and tools to improve understanding of the location, extent, and type of vulnerabilities to populations, ecosystems, and the built environment; and ORD's Sustainable and Healthy Communities (SHC) research program, in particular the EnviroAtlas. The collaboration with SHC will support integrated modeling for local, state, and regional partners that links watershed sustainability to the provision of ecosystem goods and services.

### Project 2: Science to Support New or Revised Water Quality Criteria to Protect Human Health and Aquatic Life

Research in this project area focuses on the scientific information and tools to strengthen existing Ambient Water Quality Criteria or advance new methods for prioritizing, deriving, and implementing these criteria. The aim is to address the challenges presented by the expanding numbers, combinations, and novel features of chemical and biological contaminants, including microbial pathogens in drinking water, groundwater, and surface water. The primary legislative drivers for this project are the CWA and SDWA. This project addresses several science challenges. One such challenge is presented by the rapidly expanding range and characteristics of contaminants considered contaminants of emerging concern (CECs). These include chemicals that were not previously regarded as environmental pollutants (e.g., pharmaceuticals), chemicals for which the presence in the environment was largely unnoticed but has been 'discovered' more recently (e.g., through advancing analytical capabilities), and chemicals that may not necessarily be new, but for which the potential for risk to human health or the environment was not widely recognized. Project 2 research will provide EPA's Office of Water, regional offices, states, tribes, and other stakeholders with the science and tools to support the implementation of Ambient Water Quality Criteria to protect human health and aquatic life. This research includes the following:

- Addressing human health risks associated with chemical and microbial Ambient Water Quality Criteria (AWQC).

- Advancing research methods for identifying chemical contaminant exposure routes and chemical family models, in addition to bioactivity-based criteria as an alternative to chemical detection, and screening tools to determine when multi route exposures should be considered for chemical contaminants in water. This research supports source water and drinking water exposure needs.

- Addressing human health risks associated with microbial contaminants. Microbial research advances methods to identify and quantify levels of microbial contaminants and includes fecal source tracking approaches, evaluation of viral indicators, statistical and process models for predicting levels of microbial contamination, and assessment of human health exposure and effects from pathogens.

- Advancing AWQC to protect aquatic life. This area focuses on toxicity testing, data analysis, and method development to support improvements in AWQC derivation procedures. Likely issues include chemical group-based extrapolations to address limited data, changes in data requirements appropriate to chemicals of emerging concern, improved descriptors of effects on assemblages of species, consideration of multiple routes of exposures, and uncertainty characterization.

- Advancing tools and technology applications. Research in this area will support developing methods and techniques for measuring the concentrations and distributions of select, high-priority CECs in water; understanding ecotoxicity of selected CECs; linking aquatic life and human health adverse outcome pathways (AOPs) that are sensitive to CECs via targeted, functional genomic, and molecular endpoints; supporting EPA's Office of Water in identifying a list of candidate CECs for future human health and aquatic life criteria development and derivation; and supporting the Contaminant Candidate List (CCL) and Unregulated Contaminants Monitoring Rule (UCMR) programs.

Project research on the occurrence, exposure, and health effects of waterborne pathogens and relationships to microbial indicators will serve to inform regulatory and policy decisions that will improve microbial water quality in watersheds and reduce health impacts. Project results will also lead to new or revised human health and aquatic life criteria for chemicals. The research will assist EPA's Office of Water's efforts to identify and quantify drinking water contaminants (including precursors for contaminants potentially formed during water treatment) along with other monitoring requirements under the SDWA for the protection of source water.

*Integration and Collaboration*

Research on AWQC for human health will integrate with and benefit from linkages to other projects in the Watershed Sustainability topic and research in the Water Systems topic to improve post-use water treatment and develop new indicators of treatment effectiveness; research in the Nutrients topic on development of methods to detect cyanotoxins in surface waters; and ORD's Chemical Safety and Sustainability (CSS) research on rapid screening tools for chemical contaminants or groups of contaminants. Project 2 research on AWQC for aquatic life will integrate with and benefit from CSS research regarding chemical screening methods, AOP identification, and population modeling. Effects of exposure will be addressed through aquatic toxicity tests conducted in coordination with the CSS Toxicity Translators research. Other linkages include methods used for measuring the concentrations and distributions of CECs in freshwater and marine environments, which may include similar approaches as those used in the Green Infrastructure and Water Systems topics, and the passive sampling procedures used in SHC. Further, this research will be linked to CSS, as functional, genomic, and molecular endpoints are similar in both research programs.

### Project 3: Protecting Water while Developing Energy and Mineral Resources

Increasing demands for energy and mineral resources, the desire to supply a greater fraction of energy and mineral resources domestically, increasing competition for clean freshwater, and the need to mitigate the production and release of greenhouse gases all point to the necessity for greater diversification of both energy and mineral production. The Nation's current and future energy portfolio may span such diverse activities as enhanced recovery of conventional and unconventional fossil fuels; geothermal, wind, wave, and solar energy; biofuels; and possibly nuclear energy, all of which exert differing pressures on water resources. In addition, mineral mining in the United States may increase with green energy technology development, which requires a variety of metals, including rare earth elements used for wind turbines, solar panels, batteries, and other products.

The primary legislative drivers for this project are the provisions for groundwater protection within the SDWA, Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund), and sections 402 and 404 permitting provisions of the CWA. Energy and mineral production impacts surface and subsurface water resources directly through discharges of post-use waters and indirectly through accelerated rates of geochemical weathering that alters the ionic composition and conductivity of receiving waters. These processes are likely to exacerbate impacts in the future. Research to understand impacts on aquatic resources over the entire life cycle (e.g., from extraction, production, transportation, use, storage, disposal, residuals) of conventional and unconventional energy sources, metals, and minerals is the focus of this project area. Project research includes the following:

- Assessing and predicting the toxicological, biological, and ecological effects of post-use waters (e.g., altered ionic composition) associated with energy and mineral extraction activities.

- Assessing challenges to sustainable water resource management from underground injection practices, including assessment of the benefits and risks of using aquifers to store water for future use and to sequester polluted waters.

- Evaluating cumulative impacts of energy and mineral extraction activities on aquatic life from changes in land use, water quantity and quality, and habitat availability.

- Assessing risks to groundwater and surface water from current, transitioning, and emerging technologies/practices for the life cycle of conventional and unconventional energy, minerals, metals, and other materials.

The research will advance the assessment and prediction of effects and cumulative impacts of energy and mineral extraction processes, including post-use water, on groundwater and surface water quality and aquatic life. The project aims to understand and describe the implications of different energy production and mineral extraction technologies relative to the short- and long-term availability and quality of groundwater and surface water to:

- Optimize environmental and public health safeguards for energy and mineral resources development, using approaches and technologies that provide long-term protection of groundwater and surface water resources;

- Identify technologies that increase water reuse or improve the quality of water discharged post-use, or both; and

- Inform stakeholders of evolving understanding and new technologies that might influence decisions regarding development of energy and mineral resources and their alternatives.

Project 3 research will enable better protection of the Nation's groundwater and surface water resources in the areas of energy and mineral resource development; empower communities to protect environmental and economic health; and support EPA program and regional offices in carrying out their immediate, intermediate-term, and longer-term needs with respect to water and resource extraction. The project will synthesize and integrate information on the role of water in energy production and mineral extraction to inform planning, evaluation, and decision making among community, private, and public stakeholders. This research will support aquifer exemption decisions and the review of coal mining proposals made by EPA's Office of Water and regional offices.

*<u>Integration and Collaboration</u>*

The research in this project will be integrated with other Watershed Sustainability projects evaluating water resource condition and integrity and Ambient Water Quality Criteria. Aquifer storage and recovery and aquifer exemption research will involve collaboration across EPA's Office of Water, regional offices, and other partners. Aquifer exemption research ties in with mining-related groundwater remediation efforts in ORD's SHC research program. Project 3 research will integrate with and benefit from Sustainable Energy and Mitigation research in ORD's ACE research program, which aims to examine how changes in resources, fuels, and technologies for energy production and use affect air emissions, air quality and water demand, and the risks or benefits to the environment and human health.

### Project 4: National Water Quality Benefits

EPA's ORD, Office of Policy, and Office of Water have formed a collaborative team of economists, ecologists, and water quality modelers to develop a national water quality benefits modeling framework to support greatly improved quantification and monetization of the economic benefits of EPA regulations (e.g., improvements to human health, recreation, other environmental services). This project area focuses on ORD's contribution to the three-office effort. Although EPA's Office of Air and Radiation has the modeling capability for quantifying air quality benefits to support most Clean Air Act regulatory programs (i.e., Environmental Benefits Mapping and Analysis Program-Community Edition, or BenMAP-CE), the Office of Water currently has no similar off-the-shelf modeling capability, which is reflected in its benefit analyses for CWA regulations to date. EPA aims to add to the body of existing valuation research and improve methodologies for translating regulatory decisions and the resulting estimates of water quality improvements into environmental services, and ultimately, monetized benefits. Such an effort may require economic valuation of changes in water quality, quantity, stream condition, and related ecosystem services.

This high-priority research aims to advance national water quality cost-benefit analysis and modeling tools for surface waters, from headwater streams to downstream estuarine and coastal waters. The modeling tools will build the capacity for estimating economic benefits of water quality improvements through revealed-preference (i.e., human-use) studies that identify market and non-market values associated with water quality and stated preference (i.e., non-use) studies that will capture the broader ranges of non-market values. The research will identify the optimal choice of water quality indicators—those metrics most useful for linking water quality models to economic valuation.

The three-office effort aims to develop a broad-based benefits estimation model framework that incorporates modules focusing on five main water body types (the Great Lakes, estuaries, freshwater lakes and rivers, coastal waters, and small streams) that may benefit from EPA regulatory actions. Additionally, the research will evaluate the potential causal relationships between metrics of watershed integrity and stream condition and measures of human health outcomes. The three offices are using extramural (EPA STAR grants) and intramural staff resources in parallel to complete necessary models and research to improve our ability to estimate benefits from national regulations.

*Integration and Collaboration*

In addition to collaborating with EPA's Office of Water and Office of Policy, this project will be integrated with several other Watershed Sustainability topic projects. It will also be integrated with research under the Nutrients topic on economic values associated with harmful algal blooms (HABs) or changes in water quality due to reductions in nutrients, and Green Infrastructure topic research focused on mechanistic techniques for simulating green infrastructure scenarios at multiple scales to evaluate water quality benefits. This project also will coordinate with ORD's ACE and SHC research programs to help address important cross-Agency Nitrogen and Co-pollutants Roadmap research recommendations and use existing collaborative research involving EPA, the U.S. Department of Agriculture, and academic partners in the development and application of the Hydrologic and Water Quality System [HAWQS] modeling platform, where appropriate.

## Topic 2: Nutrients

Nutrient pollution (i.e., nitrogen and phosphorus) remains one of the most significant environmental and human health issues in the United States, having a considerable impact on local and regional economies. Progress has been made to reduce the nitrogen and co-pollutant (e.g., phosphorus, sulfur, sediments) loadings that can cause adverse environmental impacts, such as acid rain, HABs, and degradation of waters serving as drinking water sources; however, nutrients are still released and discharged at concentrations that have significant adverse impacts on human health and ecosystems. A critical question is how to achieve the beneficial level of nutrients that provides multiple services, such as food production, while protecting human and ecosystem health (U.S. EPA Science Advisory Board, 2011). The pressures of climate change, extreme weather events, land-use change, and the resource needs of an expanding and shifting human population are likely to exacerbate the significant adverse impacts of excessive nutrients in coming years (Millennium Assessment, 2005).

## Topic Highlights

**Multimedia modeling to inform nutrient and hypoxia management in the Mississippi River Basin and the northern Gulf of Mexico.**

**Improved quantification and prediction of nutrient-enhanced coastal acidification and hypoxia.**

### Project 1: Reducing Impacts of Harmful Algal Blooms

Although HABs may occur naturally, ecosystem alterations from human activities appear to be increasing the frequency of some HABs, resulting in a variety of ecological, economic, and human health and animal impacts. The primary legislative driver for this project is the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014 (Pub. L. No. 113-124, 2014). This project will provide stakeholders and decision makers with improved scientific information and tools to assess, predict, and manage the risk of HABs, associated toxicity events and the ensuing ecological, economic, and health impacts. The project directly addresses legislative mandates, EPA's research needs, EPA's program office initiatives, and community and other stakeholder needs by doing the following:

- Improving the science of HAB and toxin detection by developing HAB-specific analytical methods and sampling strategies.
- Assisting EPA's Office of Water in developing new HAB indicators, sampling designs, and protocols for use in national-scale assessments.
- Developing improved approaches to understanding the interactive effects of increasing water temperatures, nutrient loads, and other drivers on HAB development and toxin production.
- Developing improved models to project risk of HABs under warming climate scenarios.
- Improving understanding of the human health and ecosystem effects resulting from toxin exposure.
- Providing drinking water treatment system operators with improved methods for detecting and treating toxins to limit or prevent human exposures.

*Integration and Collaboration*

This project will be focused on four interrelated research areas that span other Nutrients topic projects and other ORD research programs, including ACE, SHC, CSS, the modeling and sensor applications of ORD's Homeland Security Research Program, and ORD's Innovation program.

### Project 2: Science to Inform the Development of Nutrient Thresholds and Targeting Actions

Two key policy challenges associated with nutrient management are (1) prioritizing watersheds and nutrient sources for nutrient management actions and (2) setting quantitative thresholds for management, such as load reduction goals, secondary air quality standards, total maximum daily loads, nutrient or other water quality criteria, and quantitative goals for biological indicators of aquatic life use. This project will provide science that supports the efforts of the Office of Water and the National Ambient Air Quality Standards Program. It will address key research areas drawn from EPA's Nitrogen and Co-pollutants Roadmap, the Nancy K. Stoner memorandum (U.S. EPA, 2011b), and stakeholders. The research areas include the following:

- Identification of nutrient-sensitive human and aquatic life uses of water resources and useful quantitative indicators of status or condition.
- Quantitative relationships between nutrient loading and effects on water quality and nutrient-sensitive uses in aquatic ecosystems across a range of temporal and spatial scales.
- Quantification of sources, transport, and fate of nutrients in watersheds, groundwater, and airsheds.

Progress in these key research areas will address a variety of policy-related research needs and advance the state of the science using new tools, technologies, and models. Research will involve quantifying the status of aquatic life uses and overall condition of aquatic ecosystems, predicting downstream water quality impacts associated with nutrient management decisions in watersheds and airsheds, characterizing aquatic life responses to temporally varying nutrient loading and water quality, and understanding and predicting responses to nutrients in the context of other drivers (e.g., climate warming, coastal acidification, hydrologic changes).

*Integration and Collaboration*

The research in this project will be leveraged with other Nutrients topic projects and watershed-scale work and for developing criteria, threshold, and targeting outputs and approaches incorporated in the Watershed Sustainability topic.

### Project 3: Science to Improve Nutrient Management Practices, Metrics of Benefits, Accountability, and Communication

To increase the adoption rate of innovative management practices at larger scales, research is needed to support a broad selection of policy options (regulatory and voluntary), for example, market-based approaches, incentive programs, and watershed education and outreach. This project complements research underway with the U.S. Department of Agriculture, states, and other stakeholder groups that is designed to inform programs, policies, and management decisions to reduce nutrient loadings. The questions from the programs, regional offices, and states driving the scope of this research area are:

1) How do we use regulatory and voluntary approaches to promote more innovative and effective management practices to reduce nutrient pollution?
2) How do we verify, value, and communicate the effectiveness of nutrient reduction policy and management?

This project has four major areas of focus:

1) Tools for the application of innovative management practices.
2) Modeling approaches for consideration of market-based policy options, economic evaluations, and ecosystem services.
3) Monitoring and modeling approaches for verification of nutrient reductions associated with management practices,

including cost effectiveness, adoption rate, cumulative benefits, and unintended consequences.

4) Science for enabling effective communication.

This project produces the applied science that will allow for better management of nutrient loads to the Nation's waters, thereby making advancements toward the full restoration of designated uses and adequate protection and meeting future demands for sustainable clean sources of water.

*Integration and Collaboration*

This research builds on the collaboration already underway with other federal and state agencies. This work addresses two sections presented in EPA's Nitrogen and Co-pollutants Roadmap: Science Challenges Focused on Best Management Practices Effectiveness, and Assessing and Reporting on Effectiveness. Close collaboration with EPA's Office of Air and Radiation (on abatement of $NO_x$ and $NH_3$ atmospheric deposition) and Office of Water (on surface water, groundwater, and drinking water aspects) is fundamental. In addition, this project will link with SSWR projects in the Watershed Sustainability, Green Infrastructure, and Water Systems Topics. An example of a nitrogen topic that integrates contributions from ACE, SHC, and SSWR research programs is eutrophication stemming from nitrogen loading delivered from the Mississippi River Basin to the Gulf of Mexico. In this example, the one-environment model, nitrogen deposition, and model linkages are developed under ACE; nitrogen and phosphorus loadings to the edge of field, aggregation to the Mississippi River Basin (cross-scale), and response to climate change are developed under SSWR; and linkages to ecosystem health and services and broad nitrogen budget research are developed under SHC. Other integrative efforts include SHC's work on integrated nitrogen management, ecosystem goods and services, and EnviroAtlas.

## Topic 3: Green Infrastructure

Across the United States, more than 700 cities rely on combined sewer systems to collect and convey sanitary sewage and stormwater to post-use water treatment facilities. Most of these communities are older cities in the Northeast, Midwest, and Pacific Northwest. When wet weather flows exceed the capacity of the combined sewer systems and treatment facilities, stormwater, waste (untreated human, commercial, and industrial), toxic materials, and debris are diverted to combined sewer overflow (CSO) outfalls and discharged directly into surface waters. These CSOs carry microbial pathogens, suspended solids, floatables, and other pollutants and can lead to beach closures, shellfish bed closures, contamination of drinking water supplies, and other environmental and human health impacts. For many cities with combined sewer systems, CSOs remain one of the greatest challenges to meeting water quality standards. Changes in weather patterns could further amplify investments required to mitigate CSOs, as the frequency and severity of CSO events are largely determined by climatic factors, including the form, quantity, and intensity of precipitation.

Research on green infrastructure (GI) contains two projects focusing on (1) GI Models and Tools and (2) GI Information and Guidance Based on Community Partnerships. The GI projects aim to capture GI research at multiple scales; from local (e.g., permeable pavement in parking lots) to watershed (e.g., application of GI models to optimize best management practices) scales. The research will explore the use of GI to improve water quality and to control stormwater runoff to minimize impacts on leaking underground storage tanks through stormwater diversion and capture. GI research can be instrumental in the revitalization of brownfields and abandoned properties in U.S. cities facing urban blight.

**Topic Highlights**

**Report on the role of green infrastructure in sustainable stormwater management in a wide range of communities in varying geographic and climatic regions across the United States.**

**Addition of a cost benefits component to the National Stormwater Calculator.**

### Project 1: Green Infrastructure Models and Tools

The models and tools research strives to advance appropriate support for decision making, planning, and implementation of effective GI for

- stormwater control in urban settings and sewersheds,
- post-use water management,
- long-term control plans for CSOs,
- pollutant load reduction and total maximum daily loads studies,
- agricultural runoff management,
- climate change adaptation and hazards resilience, and
- enhancement of other ecosystem services.

Examples of specific research in GI modeling and tools include the incorporation of water quality issues (e.g., nutrients) in existing models such as in the GI module of EPA's Stormwater Management Model (SWMM). Other examples are increasing the interoperability of existing GI-related models, including, but not limited to: Visualizing Ecosystems for Land Management Assessments (VELMA), Hydrologic Simulation Program FORTRAN (HSPF), Watershed Management Optimization and Support Tool (WMOST), and the Soil Water Assessment Tool (SWAT). This project aims to optimize existing GI-related models and tools through information gap analyses and development and evaluation of improved models and tools for estimating life-cycle costs and benefits. Project researchers will also participate in model technical support, data management, and coding improvements. Through EPA's Science to Achieve Results extramural grants program, SSWR will support a center for sustainable water infrastructure modeling research that facilitates technology transfer of open-source water infrastructure models and GI tools. A crucial component of the project area includes technical outreach and training for stakeholders (e.g., states, municipalities, utilities).

Two broad outputs comprise the anticipated research accomplishments for the GI Models and Tools efforts: (1) performance information, guidance, and planning tools for program offices and community partners to facilitate increased adoption of GI (planned for FY2016), and (2) demonstrations of modeling tool approaches (for program offices and community partners) to assess GI effectiveness for managing both runoff volume and water quality at multiple watershed scales (planned for FY2019).

Results from the GI-modeling research will provide greater capacity for decision makers to (1) understand the benefits and tradeoffs of including GI in urban, suburban, and rural development; (2) access and apply the data, tools, and models they need to select and implement the most appropriate GI across landscape types in mixed-use systems; and (3) make significant advances toward maintaining ecological and human health and water quality protection, sustainability, and resiliency in the long term.

### Project 2: Support Increased Adoption of Green Infrastructure into Community Stormwater Management Plans and Watershed Sustainability Goals: Information and Guidance through Community Partnerships

Community GI research builds on existing place-based field studies that examine the efficacy of GI in stormwater control plans. A recent project in Kansas City quantified the sewershed response after the installation of GI practices for CSO control. Sewershed flow data were collected before and after GI installation, and ORD performed evaluations of land use, soil infiltration, drainage areas, and individual bioretention unit performance. Kansas City has used the results to adapt GI approaches in the service area. EPA is communicating the results and lessons learned to other municipalities. ORD plans to collaborate with the Camden County Metropolitan Utilities Authority in New Jersey to monitor cisterns and bioinfiltration/biofiltration practices to gain knowledge on GI placement and effectiveness.

Another current collaboration with the City of Birmingham (Alabama) will adapt ORD's Stormwater Calculator to include green and gray infrastructure costs for land development in the Birmingham area. Future GI community research plans include the application of GI models and tools to existing and future place-based research sites, implementation of GI in drought-prone areas for water collection and aquifer storage, and increased collaboration with underserved communities through the EPA Administrator's initiative on *making a visible difference in communities*. Research supporting the GI place-based project consists of providing classification frameworks for prioritizing selection of and extrapolating results from place-based studies, pre-implementation planning, GI implementation and monitoring, assessing groundwater impacts, and implementation of natural GI for improved water management.

The main GI place-based research project output will consist of guidance and examples demonstrating the effectiveness, costs, benefits, and risks/constraints on the use of GI to treat stormwater and post-use water and recharge aquifers at multiple scales.

Anticipated impacts from GI place-based research results include:

- a better understanding of socio-economic drivers for GI implementation,
- transferring results and conclusions from place-based studies to other communities challenged by CSO or water supply issues to inform their water management decisions,
- increasing the overall resiliency of water systems in the United States,
- augmenting the use of GI for water capture and aquifer recharge, and
- increasing our understanding of the role of natural GI in wastewater and stormwater management efforts.

*Integration and Collaboration*

The GI research will integrate with ORD's SHC research projects that involve community planning and development and groundwater research and with ORD's ACE research on resilience to climate change and extreme weather events. The proposed research links with EPA's Nitrogen and Co-pollutants Roadmap, particularly in the area of water quality modeling for GI installations. For example, systematic studies on the use of GI for nitrogen and co-pollutant removal from stormwater runoff can inform communities on specific GI practices that may supply the added benefit of pollutant removal. The place-based GI research strives toward helping underserved communities challenged by CSO or water-supply issues and aligns with EPA's Environmental Justice Cross-Cutting Roadmap and the EPA Administrator's initiative on *making a visible difference in communities*.

EPA researchers anticipate continued collaborations with other federal agencies such as the U.S. Geological Survey and the U.S. Army Corps of Engineers. Place-based GI projects currently work closely with local governments and utilities (e.g., the Greater Metropolitan Sewer District of Cincinnati) and will continue to do so.

## Topic 4: Water Systems

ORD provides critical support to EPA's Office of Water and regional offices and water utilities to help current water systems provide safe drinking water and properly treated post-use waters. ORD also contributes essential information to the Office of Water on human health risks posed by contaminants (including microbial, chemical, and radiological) associated with water systems. In addition to this critical support to program and regional offices, ORD recognizes the need for addressing near-term and long-term challenges to water systems. The Water Systems topic research aims to push forward the next generation of technological, engineering, and process advances to maintain safe and sustainable water resources for humans and the environment, while also augmenting and improving water resources.

Research in the Water Systems topic is intended to support future community projects funded through the Water Infrastructure Finance and Innovation Act and the Clean Water and Drinking Water State Revolving Funds by identifying and promoting treatment processes and technologies that enhance energy efficiency and, for drinking water, make use of alternative sources of water (e.g., post-use or brackish). The Water Systems topic research will also develop approaches and evaluate technologies to help water systems evolve toward a more sustainable future. The three project areas in the Water Systems research topic are complementary and focus on continuous, integrated research. The integrated themes for the projects include the following:

- Integrated assessment tool to define optimal resource recovery-based water systems, including recovering and treating water fit-for-purpose at various scales.
- Advanced monitoring and analytical tools (i.e., multiple parameters) for effective integrated water system management to minimize human and ecological risk.
- Development and demonstration of individual technologies and integrated systems to improve the collection, treat ment, and distribution of water (drinking water and post-use water) and the recovery of resources.
- Advancement of technologies for measuring health risks in current and future systems.

### Topic Highlights

**Updated analytical methods for contaminants of emerging concern in water, including improved analysis, detection, and treatment of HABs and algal toxins from watersheds to drinking water facilities.**

**Rapid toxicity screening of water contaminants of emerging concern and disinfection byproducts for effects on human health.**

### Project 1: Current Systems and Regulatory Support

Project 1 covers the development and evaluation of data, approaches, and technologies that will support the promulgation and implementation of federal water regulations and guidance while also addressing regional, state, and community concerns. The specific objectives of Project 1 are to (1) supply research results to support federal regulations and guidance; (2) provide strategies to regional offices, states, and communities for improved regulatory compliance; and (3) provide rapid and effective emergency response when appropriate (e.g., water system shut-down due to source water contamination). These objectives include research on contaminants that undergo periodic congressionally mandated regulatory cycles of review, such as the Microbial Disinfection By-Product Rules, and chemicals and pathogens on the Contaminant Candidate List and the Unregulated Contaminants Monitoring Rule List and other contaminants of concern (including groups of contaminants). Other objectives include optimizing treatment, monitoring, and analytical processes; exposure/risk assessments for compliance with post-use water treatment regulations; and improved pathogen control.

### Project 2: Next Steps — Technology Advances

Although the approaches in this project may support current and near-future regulatory processes, or may be transformative in nature, they are reasonably well developed. They are not, however, ready for routine or regulatory use. Project 2 will expedite the development of these approaches to promote wider acceptance and implementation by program offices, regional offices, states, communities, and others within the time frame of the current project period (2016–2019). The project includes advances in several areas, such as resource recovery, treatment, monitoring and analytical measurements, collection and distribution systems, methods and approaches to predict or monitor human health outcomes, and risk assessment. It will also focus on new ways of assessing risks from chemical and microbial contaminants, provide data on currently unregulated contaminants, and develop new analytical methods based on identified future needs.

### Project 3: Transformative Approaches and Technologies for Water Systems

This project will develop approaches and evaluate technologies that will help transform water systems toward a more sustainable future. Water systems challenged by issues such as shrinking resources, aging infrastructure, shifting demographics, climate change, and extreme weather events need transformative approaches that meet public health and environmental goals, while optimizing water treatment and maximizing resource recovery and system resiliency.

Project 3 involves four main efforts corresponding to the integrated themes described above. The first effort develops an integrated sustainability assessment framework based on linkages among drinking water, post-use water, stormwater, and natural infrastructure contained within a watershed. The framework will integrate various complementary system-based tools, such as life-cycle assessments and life-cycle costs; advanced water footprinting approaches; energy analyses; and resiliency to climate-induced events to evaluate alternative, innovative water system approaches quantitatively. The second effort focuses on the development of real-time (or near real-time) measurements for monitoring potential chemical and microbiological risks from recycled water and other alternative sources. The third focus area emphasizes the demonstration and evaluation of alternative systems to generate performance data. Market adoption factors will be considered, including public acceptance, regulatory and policy drivers/barriers, and business and economic development potential. The final area involves the development of transformative approaches to waterborne human health risk measurements, including high-throughput sequencing to identify novel indicators and surrogates to assess the efficacy of water reuse systems.

*Integration and Collaboration*

The Water Systems research links with the other ORD research programs. For example, the energy footprint reduction connects with ORD's ACE. The work to increase resiliency and preparedness for extreme weather events links with ORD's Homeland Security research program. The monitoring protocols and health-risk assessment research relate to ORD's CSS. Data development for human health risk will also link with research in ORD's Human Health Risk Assessment research program. Finally, the demonstrations and acceptance at the community level, along with testbed research, will interact with ORD's SHC.

The Water Systems topic research will provide input to EPA's Nitrogen and Co-pollutants Roadmap, particularly in the area of water quality nutrient and co-pollutant removal from post-use water in reuse and post-use water treatment. Pilot-scale research on monitoring and treatment systems will help underserved communities challenged by water treatment issues and aligns with EPA's Environmental Justice Roadmap and the EPA Administrator's initiative on *making a visible difference in communities*. The research projects align with EPA's Children's Environmental Health Roadmap through research on health risks from exposure to contaminants in drinking water (e.g., cell-based bioassays). Additionally, this research links with EPA's Climate Change Roadmap through research on energy-reducing or energy-producing treatment processes and broad life-cycle assessments for maximizing water system efficiency.

ORD researchers enjoy a long history of collaboration with EPA's programs and regional offices. In addition to EPA partners, researchers working under the Water Systems topic expect to continue collaborations with municipalities, utilities, and state officials and organizations (e.g., the Association of State Drinking Water Administrators and the Environmental Research Institute of the States). Collaborations will also continue with the Water Research Foundation, Water Environment Research Foundation, Water Reuse Research Foundation, and academia on research involving water treatment and reuse.

# Anticipated Research Accomplishments and Projected Impacts

SSWR research is using an integrated, systems approach to develop scientific and technological solutions to protect human health and to protect and restore watersheds and aquatic ecosystems. This research will have the greatest impact when products are developed and delivered in ways most useful to SSWR partners and stakeholders. ORD products specifically designed to be useful in the hands of partners are termed 'outputs.' The proposed SSWR outputs for FY2016–FY2019 are listed in Appendix 2. Examples of anticipated accomplishments for each research topic are summarized below.

## Watershed Sustainability

Research on watershed sustainability will produce integrated water resource and watershed management approaches, models, and decision making tools to ensure sustainable water resources. The anticipated accomplishments include innovative tools for multiscale assessment, mapping, and prediction of multimedia effects on the condition, integrity, and sustainability of the Nation's waters, and cost-benefit analysis and modeling tools for estimating the economic benefits of water quality improvements for surface waters, from headwater streams to downstream lakes, estuaries, and coastal ecosystems. In addition, anticipated research accomplishments will advance the science and provide approaches and modeling tools to strengthen Ambient Water Quality Criteria for chemical and microbial contaminants to protect human health and aquatic life and for assessing risks to watershed integrity and sustainability over the entire life cycle of conventional and unconventional energy and mineral extraction technologies and practices. The research will advance the sustainable management of the Nation's water resources to ensure sufficient water quality and quantity to support environmental, socio-economic, and public health needs now and into the future.

## Nutrients

Anticipated accomplishments will improve our ability to analyze and detect harmful algal blooms, better understand the interactive effects of temperature and nutrient loadings on harmful algal bloom development, and provide drinking water treatment system operators with improved methods for detecting and treating toxins on site. Research will also target where the greatest improvements can be achieved by reducing point-source and nonpoint-source nutrient loading. Specifically, this work will support the development of numeric nutrient criteria and improved technologies. It will also support development of best management practices and inspection and maintenance practices to monitor and reduce nutrient loading cost effectively using current regulatory, voluntary, and green-infrastructure approaches. In addition, a multimedia approach to evaluate management practices from a multisector, multi-scale systems perspective will improve management of nutrient loadings in the Nation's water bodies toward the full restoration of designated uses, while meeting future demands for sustainable clean sources of water.

## Green Infrastructure

Anticipated accomplishments for this research include the development and implementation of innovative models, tools, technologies, and strategies for managing stormwater runoff and other flooding events, using natural and built green infrastructure in combination with gray infrastructure over the long term. This will be especially valuable when existing infrastructure will require repairs or replacement and improved resiliency is needed for climate change, extreme weather events, and security threats. Another accomplishment will be to verify reliability—and explore with partners the ability to quantify the comparative costs and benefits of—gray and green infrastructure for managing water volume and improving water quality and other benefits. Other benefits include groundwater recharge, rainwater harvesting for irrigation, improving human health by reducing ground-level ozone and particulate matter and providing opportunities for recreation, reducing urban heat islands, creating habitat, improving property values, creating new jobs, etc. This work also aims to anticipate any unintended consequences related to increased water permeation into soil and groundwater. We expect that research results from this topic will increase the ability for community planners to make well-informed decisions concerning implementation of green infrastructure.

## Water Systems

This research will continue providing the high level of public health protection and research support to the program and regional offices with a focus on sustainable treatment technologies to address existing and emerging chemical and microbial contaminants, both individually and in groups. Anticipated impacts include increasing water reuse (and public acceptance of its use). Water reuse research will include efforts to maximize the recovery of other resources embedded in post-use waters, such as nutrients, energy, and materials (e.g., metals, chemicals), using resilient and energy-efficient technologies. Our aim is for the resource recovery studies to increase energy efficiencies and reduce costs for post-use water treatment. Water Systems topic research will advance cost-effective treatment technologies, operations, and maintenance for small water systems by providing evaluations of novel treatment processes and assessing sustainable approaches, including effective decentralized systems. Using resilient approaches for all systems will make the systems more prepared for extreme weather events, climate change, and security threats, resulting in better protection of water quality and availability, human and environmental health, and capital investments.

# Conclusions

Water knows no borders. From the highest headwaters to the farthest oceans and back as water vapor, water flows in a highly interrelated cycle. Consequently, threats to our water resources, such as contaminants, increased use, aging infrastructure, climate change, and extreme weather events, do not affect just one river, reservoir, or estuary, but instead ripple through the whole system.

Our Nation’s response to these challenges must be equally dynamic. The SSWR research program takes an integrated approach that examines the entire cycle to develop long-term, real-world solutions. This Strategic Research Action Plan maps out the targeted steps that will be taken in the next 4 years. It was developed in collaboration with other EPA research programs, federal agencies, private and public stakeholders, and colleagues in the scientific community. Such cross-cutting communication and all-level partnerships are key to seamless, effective responses. Progress made in one area can cascade through different scales—local, state, regional, and national.

This research is guided by overarching objectives that change the water-management paradigm: 'wastewater' becomes a valuable commodity, undervalued water becomes a resource with quantified benefits, and isolated quick fixes become system-wide solutions. This work will yield the innovative tools and information needed to protect the quality, supply, and resiliency of America’s waters, sustaining them so that they, in turn, can sustain our Nation.

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# Appendix 1

Partners and Stakeholders for Safe and Sustainable Water Resources Research

*Note: SSWR works with many partner and stakeholder organizations, and new partnerships are continually forming; therefore, this list is not comprehensive.*

Federal Agencies

- Department of Agriculture
  - U.S. Forest Service
- Department of Commerce
  - National Oceanic and Atmospheric Administration
- Department of Defense
  - U.S. Army Corps of Engineers
- Department of Energy
- Department of Interior
  - U.S. Geological Survey
  - U.S. Fish and Wildlife Service
- National Aeronautics and Space Administration
- National Science Foundation

State/Local Organizations

- Environmental Council of the States/ Environmental Research Institute of the States
- National Association of Clean Water Agencies
- Association of State Drinking Water Administrators

Non-governmental Organizations

- Water Research Foundation
- Water Environment Research Foundation
- Water Reuse Foundation
- The Nature Conservancy

International Organizations

- Global Water Research Coalition
- Environment Canada
- United Nations Environment Programme
  - Project on International Nitrogen Management System

# Appendix 2

**Table of Proposed Outputs, Safe and Sustainable Water Resources research program FY 2016–2019**

*The following table lists the expected outputs from the Safe and Sustainable Water Resources research program, organized by topic. Note that outputs may change as new scientific findings emerge. Outputs are also contingent on budget appropriations.*

| Project Area | Area-Specific Outputs |
|---|---|
| **Watershed Sustainability** | |
| Sustainable Water | FY2018 – Guidance to characterize and predict the condition and integrity of aquatic systems and their watersheds at multiple scales.<br>FY2019 – Scientific tools for multi-scale assessments of multi-media effects on the condition, integrity, and sustainability of the Nation's waters. |
| Water Quality Criteria | FY2019 – Scientific basis and tools for expanded water quality criteria capability to protect human health and aquatic life. |
| Minerals and Energy | FY2017 – Synthesis of the science on groundwater quality impacts around uranium *in situ* recovery sites.<br>FY2019 – Proactive approaches to assessing risks to watershed integrity and sustainability associated with current, transitioning or emerging technologies and practices, including water use, for the life cycle of conventional and unconventional energy, minerals, and other materials. |
| Water Quality Benefits | FY2019 – Provide economic analyses, water quality models and knowledge to program offices, to support the economic valuation of changes in water quality, water availability and related ecosystem services, at appropriate scales for the Nation's main water body types. |
| **Nutrients** | |
| Harmful Algal Blooms | FY2019 – Science and tools that advance the ability of stakeholders to more effectively, and economically, characterize and manage (prevent, control and mitigate) risks posed by harmful algal blooms. |
| Nutrient Threshold Targets and Nutrient Management | FY2019 – Methods, tools, data and scientific analyses to inform prioritization of watersheds for management of nutrients and set nutrient specific water quality and aquatic life thresholds; and demonstrate and communicate new metrics, management approaches, and use of monitoring data to verify the expected benefits from applying nutrient reduction management practices. |

| Project Area | Area-Specific Outputs |
|---|---|
| **Green Infrastructure** | |
| GI Models and Tools | FY2016 – Provide performance information, guidance and planning tools for program offices and community partners to facilitate increased adoption of GI.<br>FY2019 – Demonstrate modeling tool approaches for program offices and community partners to assess green infrastructure (GI) effectiveness for managing both runoff volume and water quality at multiple watershed scales. |
| GI Community | FY2019 – Advance the ability of communities and watershed organizations to make informed decisions on whether and how to implement GI for stormwater and post-use water treatment, water capture, and aquifer recharge. |
| **Water Systems** | |
| Water Systems - Regulatory Support | FY2017 – Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk.<br>FY2019 – Develop and demonstrate individual technologies and integrated systems to optimize the collection, treatment, and distribution of water (drinking water and wastewater) and the recovery of resources.<br>FY2019 – Communication of technological advancements for measuring health risks in current and future systems. |
| Next Generation Water Systems | FY2018 – Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk.<br>FY2019 – Develop and demonstrate individual technologies and integrated systems to optimize the collection, treatment and distribution of water (drinking water and wastewater) and the recovery of resources.<br>FY2019 – Communication of technological advancements for measuring health risks in current and future systems. |
| Water System Approaches | FY2017 – Integrated assessment tool to define optimal resource recovery–based water systems including water fit for purpose at various scales.<br>FY2018 – Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk.<br>FY2019 – Develop and demonstrate individual technologies and integrated systems to optimize the collection, treatment, and distribution of water (drinking water and wastewater), and the recovery of resources.<br>FY2019 – Communication of technological advancements for measuring health risks in current and future systems. |

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