WRITTEN TESTIMONY OF

DR. CRAIG STOW
PHYSICAL RESEARCH SCIENTIST
GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

FIELD HEARING ON
NUTRITENT POLLUTION IN THE GREAT LAKES

BEFORE THE
SUBCOMMITTEE ON WATER RESOURCES AND ENVIRONMENT
COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE
U.S. HOUSE OF REPRESENTATIVES

May 12, 2008

Madame Chair, and Members of the Subcommittee, good morning, and thank you for inviting me to discuss contributions made by the National Oceanic and Atmospheric Administration (NOAA) to water quality improvement in the Great Lakes. I am Dr. Craig Stow, a physical research scientist at NOAA's Great Lakes Environmental Research Laboratory (GLERL), headquartered in Ann Arbor, Michigan.

The Laurentian Great Lakes are a major resource to North America, containing 18 percent of the world's surface freshwater and 90 percent of the surface freshwater of the U.S. They serve as the focus for a multi-billion dollar tourism and recreation industry, supply 40 million people with drinking water, provide habitat for wildlife and fish, and support transportation and diverse agricultural production. The basin is home to about 15 percent of the U.S. population and 60 percent of the Canadian population.

The Great Lakes are one of the Earth's greatest treasures and one of the Nation's most important aquatic resources from an economic, geographic, international, ecological, and societal perspective. The Great Lakes continually face extremes in natural phenomena such as storms, erosion, high waves, high and low water levels, and climate variability, all of which influence water quality and efforts to restore habitat. Population growth and changes in land use in the region will continue to increase stresses on the Great Lakes, adding to the complexity of management issues. The one thing that we can predict with near certainty is that the Great Lakes ecosystem will continue to change, and adapting to those changes poses a challenge for effective use and management.

In regard to water quality, multiple stressors directly or indirectly affect the Great Lakes ecosystem. Harmful algal blooms and low bottom water oxygen (hypoxia) are stressors to the Great Lakes ecosystem. Invasive species are perhaps the greatest challenge to a healthy Great Lakes. Add to this mix the impacts of local land use and climate change

and the situation becomes very complex, making management, restoration and planning even more difficult.

In the early 1970s when Lake Erie was declared dead, the solution, based on best available science, was relatively clear: nutrient loading must be reduced. Our ecological understanding and technological know-how have significantly improved since the 1970s. The Great Lakes have a large, complex and economically important user base and are heavily impacted by human activities with resultant multiple stresses. Many parts of the lakes are highly eutrophic – the result of an enrichment in dissolved nutrients which has stimulated plant growth resulting in a depletion of dissolved oxygen when the plant life decays. Eutrophication and other stresses to the lakes have created the need for ecological prediction of oxygen deficiency, harmful algal blooms, recreational water quality, recreational and commercial fisheries production, invasive species and extreme natural events (high winds, storms, dramatic changes in water influx). Future successes will depend on a comprehensive and balanced ecosystem approach.

NOAA's ROLE IN THE GREAT LAKES

NOAA's mission is: "To understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social and environmental needs." That mission statement captures the essence of one of NOAA's four primary goals: "Protect, restore and manage the use of coastal and ocean resources through ecosystem-based management." NOAA has environmental stewardship, assessment, and prediction responsibilities in the Great Lakes. NOAA conducts physical, chemical, and biotic research and environmental monitoring and modeling, providing scientific expertise and services to manage and protect Great Lakes ecosystems. The preeminent research and monitoring that NOAA conducts helps improve the understanding and prediction of Great Lakes processes, including the connections among the atmosphere, water and sediments. All of NOAA's offices play a vital role in supporting the economy of the Great Lakes through NOAA's four strategic themes — ecosystems, weather and water, climate, and commerce and transportation.

The Great Lakes ecosystem is one of the most clearly definable regions under NOAA's purview and mission responsibilities, and the region holds a long history of interagency partnerships and collaborations among States, Tribes, and other Federal partners. The partnerships in the Great Lakes region have led the Nation in innovative management strategies for decades, with efforts that have spanned thousands of miles, and provide a large-scale testing ground for new science and management.

NOAA has over 15 Congressional mandates that guide its specific responsibilities in the Great Lakes. NOAA is mandated to provide research, monitoring and coordination throughout the Great Lakes Basin on ecosystem issues such as water resources, invasive species, foodweb dynamics, pollutants, hydrology, hydrodynamics, ice, water quantity and quality and so forth. NOAA's programs in the Great Lakes work in partnership with one another, and with other federal and state agencies to provide comprehensive science, management, and technical assistance tools to foster comprehensive environmental

stewardship of the area. NOAA's research, monitoring and operational services contribute to the protection and restoration of the Great Lakes ecosystem and the socio-economic health and safety of the public; most of these activities are connected to water quality.

Water quality is affected by multiple factors, and therefore improvements in water quality are dependent on a number of programs coordinated to work in an efficient way to improve overall ecosystem health. NOAA is working to address environmental issues in the Great Lakes through a regional ecosystem approach. By using an ecosystem approach, NOAA strives to use a science and policy framework that recognizes the fundamental interconnections of all ecosystem components, and emphasizes the maintenance of biological diversity, natural relationships among all species including humans, and dynamic processes that ensure ecosystem sustainability.

NOAA promotes a science-based approach to water quality improvements and restoration and NOAA's research provides critical information toward this end. Highlighted below are some of NOAA's efforts that contribute to improvement of water quality through interagency coordination, state partnerships, forecasts for Great Lakes conditions such as hypoxia, restoration planning, research and response for harmful algal blooms and aquatic nuisance species, monitoring activities, and hazardous materials response. Several of NOAA's activities in the Great Lakes specifically relate to water quality improvement and restoration. For example, NOAA:

- Predicts impacts of pollution and coastal development on sensitive habitats and resources, including the use of contaminant-monitoring sites in Green Bay, and Lakes Michigan, Huron, St. Clair, Erie and Ontario to determine contaminant trends;
- Works with states to analyze changes in coastal land cover and plan habitat restoration and conservation;
- Acts on behalf of the Secretary of Commerce as a natural resource trustee for the public to protect and restore aquatic species and their habitats, and associated services such as safe navigation and transportation, recreation, commercial fishing, shoreline stabilization, and flood control;
- Collects, analyzes and distributes historical and real-time observations, and predictions of water levels, coastal currents and other meteorological and oceanographic data;
- Leverages other assets such as the CoastWatch node in Ann Arbor to utilize NOAA environmental satellite and in-situ data to monitor the health of the ecosystem;
- Provides scientifically sound information on ecosystem processes and is developing ecosystem forecasting tools to improve management decisions, mitigate human impacts, and reduce the risks to human health;
- Develops and implements techniques and products to improve severe storm forecasting, and provides the weather and flood warnings, forecasts, and meteorological and hydrologic data used by research, environmental management, transportation, and community interests in the Great Lakes;
- Provides surveying, nautical charts, and other navigation services for safe shipping and boating;

- Monitors ice hazards to maritime shipping industry, which is the lifeblood of the industry and commerce on the Great Lakes and St. Lawrence Seaway;
- Partners with universities through the National Sea Grant College Program and GLERL to encourage stewardship of Great Lakes coastal natural resources by providing funding to, and conducting joint projects with area universities for research, education, outreach and technology transfer;
- Partners with state Coastal Zone Management Programs to work with local communities and state agencies to preserve, protect, develop, restore, and enhance coastal zone resources, providing research, education, and protection of coastal and estuarine areas by balancing state and national interests to promote conservation and responsible development; and
- Protects and provides interpretive information on approximately 160 historic shipwrecks at the 448-square mile Thunder Bay National Marine Sanctuary and Underwater Preserve, located off the coast of Alpena, Michigan in Lake Huron.

REGIONAL PARTNERSHIPS

In 2006, NOAA created eight regional teams in recognition of the unique needs of the various geographic regions of the U.S. The Great Lakes is one of these regions and I lead this effort. NOAA is well represented in the Great Lakes by over 65 physical offices and 140 programs. Applying a regional approach means that NOAA will draw upon the expertise of its regional offices and partners to champion the improved development, implementation, and delivery of products and services in the Great Lakes region. NOAA's strength and capacity derive from strong collaborative ties among its programs and with its partners and customers. Through the regional approach NOAA is improving outreach and communications to increase awareness and delivery of our services and also develop them from the bottom up to ensure they best serve the needs of the public. It is at the regional scale that NOAA can blend the place-based needs of customers and partners with its priorities and responsibilities as a federal agency. Ensuring consistent, high-value services to NOAA customers is more important than ever, especially given recent public attention to the state of the oceans, the effects of climate change, and impacts of natural disasters. Strengthening these relationships also is essential to the "one NOAA" principles of improved internal communications and efficiency.

Regional Collaboration will improve our value to customers by identifying and applying NOAA's full range of capabilities, within and across regions. It will also allow us to design the best solutions to address geographically specific problems. This effort will use existing authority and accountability structures and does not entail changes to NOAA's organizational structure. NOAA's leadership is committed to Regional Collaboration as an approach to engaging partners and customers, and delivering NOAA services. A senior leadership team has been established to guide the efforts of regional and priority area teams as they engage with external partners to develop and implement strategies that address the following priorities in the regions: hazard resilient coastal communities, integrated ecosystem assessments, and integrated water resource services.

INTERAGENCY COORDINATION

Interagency partnerships and collaborations have played a historic role in efforts to protect the Great Lakes ecosystem and improve water quality. Underpinning the foundation for collaboration in the Great Lakes is the President's U.S. Ocean Action Plan of December 17, 2004, which calls on federal agencies to work together with their partners in state, local and tribal authorities, as well as with the private sector, our international partners and other interests, to make our oceans, coasts, and Great Lakes cleaner, healthier, and more productive.

Also in 2004, President Bush established the Great Lakes Interagency Task Force through the Great Lakes Executive Order, which promotes partnership among federal agencies to help protect and restore the Great Lakes.

Currently, NOAA is also appointed as the U.S. chair to the International Joint Commission's Council of Great Lakes Research Managers. The International Joint Commission has overall water quality responsibilities for the Great Lakes. The Council of Great Lakes Research Managers has responsibilities to coordinate Great Lakes Research related to water quality.

THE ROLE OF RESEARCH IN SERVING THE PUBLIC

Research underpins NOAA's science-based mission of understanding and predicting changes in the Earth's environment and conserving and managing coastal and marine resources to meet our Nation's economic, social, and environmental needs. Robust environmental observation, assessment, and prediction capabilities provide the foundation for performing NOAA's mission. Research is the cornerstone on which to build and improve environmental forecasts that can enable ecosystem-based management and provide critical weather, climate, and water quality information for decision makers and the public. We ensure NOAA research and services meet the needs of our stakeholders by seeking regular feedback from the research community, operational users, and stakeholders. NOAA scientists and our external partners work together to improve the quality of people's lives and to meet our Nation's economic, social, and environmental needs.

Ecosystem Forecasting

NOAA conducts scientific research directed towards creating new tools and approaches for management and protection of coastal ecosystems that can also lead to improvements in water quality. To anticipate and minimize how stresses from human and natural causes will affect ecological processes, NOAA is developing ecological forecasting tools that predict the effects of biological, chemical, physical, and human-induced changes on ecosystems and their components. These tools include research on understanding ecological processes, conceptual models of ecosystem function, and statistical and process-driven prediction models. As these tools are developed in the research environment, NOAA scientists identify, consult, and collaborate with user groups representing the ultimate operators and beneficiaries to determine the most useful

operational parameters, products, and delivery methods. This often requires the involvement of the operational branches of NOAA to plan for routine application and dissemination of ecological forecasts. Public workshops are conducted to identify user needs and services are developed accordingly. This model has been successfully applied by GLERL for forecasts of Great Lakes ice conditions, water levels, circulation and thermal structure, and waves, and is in the process of being applied for beach closures, harmful algal blooms, hypoxia/anoxia, and fish recruitment.

Lake Erie "Dead Zone"

An important research project is addressing the Lake Erie hypoxic or "dead" zone that has grown worse in recent years. Hypoxia has been responsible for the contamination of drinking water supplies and death of wildlife. NOAA's Center for Sponsored Coastal Ocean Research (CSCOR) in the National Ocean Service's National Centers for Coastal Ocean Science is funding a project to create, test and apply models to forecast how anthropogenic (land use, invasive species) and natural stresses (climatic variability) influence hypoxia formation and ecology in Lake Erie, with an emphasis on fish production. Currently funded projects are mapping the extent of hypoxia across Lake Erie, investigating the causes and consequences of hypoxia and forecasting alternatives for the management of nutrient loading to minimize harmful phytoplankton problems in zebra mussel-invaded habitats.

In 2005, GLERL, in collaboration with researchers from the U.S. and Canada, initiated one of the largest, most comprehensive Lake Erie research field programs ever conducted. The project, the International Field Years on Lake Erie (IFYLE), is focused on hypoxia and harmful algal blooms. Lake Erie's harmful algal blooms in the west basin, recurring low oxygen episodes ("dead zones") in the central basin, and invasive species have the potential to disrupt normal food web and ecosystem processes, and in turn, jeopardize the ability of Lake Erie to provide valued ecosystem services (e.g., recreational and commercial fish production, safe drinking water, and clean, bacteria-free beaches). The primary objectives of the IFYLE program are to evaluate the causes and impacts of hypoxia and harmful algal blooms in Lake Erie.

The IFYLE program involves approximately 40 scientists from NOAA, 17 different universities, and private institutions spread across 7 states and 4 countries. This program is integrative with involvement by numerous U.S. and Canadian universities and federal, state, and provincial agencies.

NOAA Center of Excellence for Great Lakes and Human Health

The NOAA Center of Excellence for Great Lakes and Human Health began in 2004 and focuses on understanding the inter-relationships between the Great Lakes ecosystem, water quality and human health. The Center employs a multidisciplinary approach to understand and forecast coastal-related human health impacts for natural resource and public policy decision-making, and develop forecasting tools to reduce human health risks associated with three research priority areas: beach closures, harmful algal blooms, and drinking water quality.

One example of the need for forecasting coastal-related human health impacts deals with drinking water quality. The Cleveland Water District provides drinking water to approximately 1.5 million people in 72 communities in Northeast Ohio. The water system gets its source water from the Lake Erie Central Basin through four water intakes covering approximately 27 miles of shoreline in the greater Cleveland area. In August 2006, three of the four Cleveland Water District water treatment plants were exposed to hypoxic water from Lake Erie, compromising water quality in the system. Hypoxic waters are low in pH and temperature and have a high manganese content that negatively impacts water processing. In an effort to investigate, research, and limit future water quality impacts to Cleveland's drinking water, GLERL, in collaboration with the Ohio Sea Grant Program, deployed Real-Time Coastal Observation Network (ReCON) buoys during the 2007 field year to develop mitigating solutions to the problem of hypoxic water intake. The ability to observe the onset of hypoxic waters in real-time by ReCON buoys has resulted in an early warning system allowing the Cleveland Water District the advance notice required to place alternate processing and storage techniques on standby during hypoxia events. In addition, real-time observations of Lake Erie temperature profiles provide the ability to detect deep water movement that can result in sudden changes in oxygen, pH, and temperature levels at water intakes. Future forecast plans include the prediction of these deep water movements using local wind forecasts.

The Center uses a multidisciplinary approach to translate scientific information and research into materials to aid health officials, local governments, and communities in making sound environmental decisions. Working with the end users is critical for this process to be effective. As one example, during 2006 and 2007 the Center held user needs workshops in Toledo, Bay City, and Green Bay to discuss how harmful algal blooms can affect drinking water quality. The purpose of these workshops was to bring together public health and natural resource managers and decision makers interested in harmful algal blooms to determine the extent of the harmful algal bloom issue in the region, create a venue to understand and assess existing knowledge of harmful algal blooms, and identify methods in which these blooms are monitored for and reported to the public. Stakeholders from the public health, drinking water, and beach management sectors, as well as academia, U.S. and Canadian federal, state, county and city governments, and community members participated. This type of outreach is critical to identify community needs and translate scientific information into a concise, easily understood format.

Managing Impacts of Multiple Stressors in Coastal Ecosystems

A new 5-year project was initiated in 2007 to examine the way in which multiple stressors, including watershed nutrient inputs, declining water levels, and invasive species, affect management goals and activities and economics in Saginaw Bay on Lake Huron. Project participants include GLERL, universities, state management agencies and the private sector. The state management participants will help to clarify the primary endpoints of public concern such as nuisance algae, harmful algal blooms, and sport-fish growth rates. Project participants will develop several parallel ecosystem-scale models that will describe our current understanding of the relationship between the important

ecosystem stressors and the endpoints of concern, and lead to a new way to fully integrate research and management.

Harmful Algal Bloom Research and Response

A stressor that leads to reductions in water quality is the rapid proliferation of toxic or nuisance algae, called a harmful algal bloom. Harmful algal blooms include cyanobacteria, especially *Microcystis*, which can produce potent toxins; and macro algae, such as *Cladophora*, that build up on beaches, impacting tourism and recreation. In the Great Lakes, NOAA scientists have documented harmful algal bloom toxin levels that were 10 times higher than the World Health Organization recreational standards. NOAA is working with its federal partners to organize harmful algal bloom research around a suite of complementary and interconnected programs and activities that involve a mix of extramural and intramural research, long-term regional ecosystem-scale studies supported by short-term targeted studies, collaborations between academic and federal scientists, and multiple partnerships with Federal, state and tribal managers. EPA, a key partner, is working to determine whether cyanotoxins should be regulated under the Safe Drinking Water Act, but does not yet have sufficient information to make this determination.

Great Lakes Coastal Forecasting System

In April, 2006, NOAA announced the completion of the Great Lakes Operational Forecast System (GLOFS) for lakes Superior, Huron, and Ontario. This system is a NOAA automated model-based prediction system aimed at providing improved predictions (guidance) of water levels, water currents and water temperatures in the 5 Great Lakes (Erie, Michigan, Superior, Huron and Ontario) for the commercial, recreation, and emergency response communities. This system is an excellent example of how NOAA is meeting its mission responsibility through research projects that were developed in NOAA laboratories and are now being transferred to operational use. This forecast system, which is built on 15 years of solid research and testing, benefits all who use the Great Lakes – be it for recreational or commercial purposes. In addition to supporting critical economic uses, the GLOFS also enhances efforts to promote public safety by providing better navigational and coastal information to civil authorities and coastal managers involved in search and rescue missions and other emergency response operations.

NOAA's Center for Operational Oceanographic Products and Services maintains the GLOFS in an operational environment 24 hours a day, seven days a week to provide accurate information needed by the diverse user population in their day-to-day use of the lakes. GLOFS generates hourly "nowcast" guidance (analyses) for present conditions and four times daily forecast guidance (out to 30 hours) of total water level, current speed and direction, and water temperature for each of the Great Lakes. The GLOFS predictions enable users to increase the margin of safety and maximize the efficiency of commerce throughout the Great Lakes. Both the nowcasts and the forecasts use information generated by a three-dimensional hydrodynamic model that includes real-time data and forecast guidance for winds, water levels, and other meteorological parameters to predict water levels, currents, and temperatures at thousands of locations throughout the five lakes. Key products include data and animated map plots of water

levels, water currents, and water temperatures; these products are available at http://tidesandcurrents.noaa.gov/ofs/glofs.html.

RESTORATION

NOAA's restoration activities in the Great Lakes region are important for the improvement of water quality because they restore habitat and clean contaminated sites. In support of the President's Great Lakes Executive Order, NOAA's FY 2008 budget request includes $1.5 million to establish a Great Lakes Habitat Restoration Program that will mobilize NOAA's restoration assets to restore Great Lakes aquatic resources and serve as a focal point for NOAA's broader restoration efforts in the region. The program will also support major restoration projects in Great Lakes Areas of Concern that achieve significant improvement in habitat function and provide community-wide human use benefits, while ensuring appropriate monitoring and feedback. Working with our partners, results will be used to apply lessons learned to other science-based restoration efforts throughout the Great Lakes basin.

NOAA's restoration role includes coordinating with remedial agencies on cleanup of contaminated sites, restoring injured resources and lost services, natural resource damage assessments and restoration in conjunction with other trustee agencies, working with states, tribes, and other partners to fund habitat restoration projects, and conducting research and monitoring activities. NOAA, through the Damage Assessment, Remediation, and Restoration Program, works with our partner agencies including states, tribes, and the U.S. Fish and Wildlife Service, to promote assessments and cleanup activities that will protect the aquatic environment, integrate restoration into clean up actions, and reduce overall injury to natural resources. By working cooperatively at sites with remedial and trustee agencies, local groups, and potentially responsible parties, NOAA decreases contaminant loads, reduces risks to protect sensitive species, and improves and restores habitat function. This can be accomplished through NOAA's trustee authority to cooperatively address liability, to assess natural resource damages, and to restore natural resources. NOAA is currently addressing cleanup and restoration at 16 hazardous waste sites in the Great Lakes region.

AQUATIC NUISANCE SPECIES RESEARCH AND RESPONSE

Aquatic nuisance species have the potential to impact water quality. For example, recent declines in water quality (e.g., harmful algal blooms, *Cladophora* outbreaks) in the Great Lakes have been attributed to the establishment of zebra and quagga mussels, prolific invasive species which have fundamentally altered ecosystem food webs and nutrient cycling. The major pathways by which aquatic nuisance species reach U.S. ecosystems all involve human activities, especially commerce and trade. Solutions to problems related to aquatic nuisance species will undoubtedly affect both the costs and policies of commerce and trade. Congress (in the *Aquatic Nuisance Prevention and Control Act of 1990* (16 U.S.C. 4701 *et seq.*)) and the White House (in Executive Order 13112) identified aquatic species invasions as a growing national problem requiring federal action.

NOAA is one of several federal agencies given joint responsibility for developing and implementing a national aquatic nuisance species response and action plan. NOAA serves as co-chair of both the national Aquatic Nuisance Species Task Force and the Invasive Species Council. The NOAA Sea Grant program, GLERL, and CSCOR are three programs that invest in research towards understanding, preventing, responding to, and managing aquatic species invasions in U.S. coastal ecosystems.

In July 2003, NOAA established the NOAA National Center for Research on Aquatic Invasive Species, a virtual center for the coordination of existing research programs throughout NOAA. The Center, administratively housed at GLERL, fosters partnerships to address prevention, early detection, rapid response, and management of invasive species, a major restoration and water quality issue for Great Lakes ecosystems.

It is safe to say that the risks associated with ballast water introductions have been reduced by the regulatory requirements imposed on vessels entering U.S. ports from beyond the Exclusive Economic Zone. GLERL, in conjunction with the Smithsonian Environmental Research Center, recently completed a scientific assessment of the effectiveness of ballast water exchange and concluded that, in the absence of effective alternative treatment technologies, the use of ballast water exchange has reduced the risk of ballast associated invasions to our coastal estuaries. In addition, new policies and regulations by both the U.S. and Canada have been established for vessels entering the Great Lakes that officially have no ballast on board (NOBOB vessels). These new requirements were based on findings of the NOBOB Research Program led by GLERL that NOBOB vessels still presented a level of invasion risk. Finally, considerable work has been done on development of new technologies to treat ballast water.

We have made progress in documenting the occurrences and spread of invasive species. Some of the best documented areas are the Great Lakes, where both Canadian and U.S. entities have played a significant role in documenting nonindigenous species occurrences. GLERL is creating a specific Great Lakes database in partnership with the U.S. Geological Survey, which will be rolled-out by the end of this calendar year. Even with baselines, though, monitoring of new introductions and invasion rates will continue to be problematic. Survey work is expensive in terms of both human and financial resources, and we cannot monitor all areas all of the time. We will continue to be dependent on observant individuals (including the general public), as illustrated by the most recent discovery of a new species in the Great Lakes: bloody red shrimp. Even though GLERL does extensive survey work, the bloody red shrimp was not found by our scientists as part of a formal survey. Instead, it resulted from an independent observation by one of our scientists at our boat docking facility near Muskegon, Michigan. The identification of new species (and ascertaining whether they are new introductions) and determining if such species are potentially invasive will continue to be an issue.

Finally, the most extensive scientific work has documented an apparent connection between zebra mussels and several deleterious impacts to the Great Lakes including toxic blue-green algal blooms, major impacts in the trophic chain with the disappearance of the

benthic amphipod *Diporeia*, decreased growth of Great Lakes whitefish, and avian botulism in the Great Lakes causing thousands of water fowl deaths. Research is now being conducted to determine if there is a link between the mussels and expansion of the dead zone in Lake Erie.

SUMMARY

Water-quality improvements and restoration need to be based on the best available science and an ecosystem-based management approach is essential. NOAA's research in the Great Lakes takes a proactive approach and is focused on predicting ecosystem response to management decisions. By predicting the effects of biological, chemical, physical and human-induced changes on ecosystems and their components, decision makers will be better informed and have the tools to make economically and ecologically sound decisions.

Thank you again for inviting me to present this overview of NOAA's current contributions to water quality improvements in Great Lakes ecosystems.

I would be happy to answer any questions you might have.