Coordinated national water-quality monitoring and reporting— a framework to support decision making

Protecting, improving and maintaining the quality of the Nation's rivers, lakes, and estuaries is critical for safe drinking water and recreation; fish, shellfish, and wildlife health; and crop irrigation. Water quality and quantity are critical for healthy people, thriving communities, and resilient ecosystems which sustain people and communities. Tracking our effectiveness at maintaining water quality and understanding the investments needed to achieve water quality goals require monitoring. Faced with the responsibility of wisely using limited funding for environmental monitoring, it is increasingly important to leverage existing monitoring activities among Federal, State, Tribal, and other monitoring organizations to assess current water-quality conditions in the Nation's rivers, lakes, and estuaries and track long-term changes in response to population growth, land-use changes, and climatic changes in the United States.

Monitoring conducted throughout the Nation can support not only the objectives of the original monitoring organization collecting the data, but also secondary use of the data for other objectives. For example, Stets et al. (2018) used data from numerous Federal, State, and local water-quality databases to link increases in chloride concentrations in U.S. rivers between 1992 and 2012 to the increased potential for corrosion in drinking water in urban areas. Dodds et al. (2009) used nitrogen and phosphorus data from multiple Federal, State, and local organizations to document US$2.2 billion annual value losses in recreational water usage, waterfront real estate, spending on recovery of threatened and endangered species, and drinking water treatment as a result of anthropogenic eutrophication of freshwater systems throughout the United States. Vidic et al. (2013) used water-quality data from five Federal, State, and non-governmental databases to show that concentrations of barium, strontium, and bromide were elevated in Pennsylvania rivers in areas of known brine effluents from centralized waste treatment plants that may have been receiving flowback and produced water from Marcellus Shale gas development. And Oelsner et al. (2017) used data from over 600 monitoring organizations to determine long-term trends in water quality at over 1,000 river sites in the United States, providing information to support local, regional, and Federal efforts to track the effectiveness of investments in pollution control. Such secondary use of water-quality data adds value to the data beyond the original expense by increasing our collective ability to address environmental issues at multiple scales.

Past progress to promote coordination

In 2006, the Heinz Center recommended increased integration of the Nation's monitoring and reporting efforts to enable improved decision making and lower the costs of monitoring overall. In particular, they note:

> *The benefits of increased integration are clear and substantial. Key among these benefits is that data can be more usable, across more regions and types of land ownership, if*

common or consistent methods are employed. Such consistency can allow, for example, one state (or federal agency) to compare its data to another's, allow data from all states and agencies to be aggregated upward to produce national or regional perspectives on issues that cross state or agency boundaries, and allow extraction of subsets of data to "drill down" on particular places of interest. Longer term savings (or cost avoidance) are possible and likely benefits of a more integrated system.

Numerous other efforts have identified the need for coordination of reporting and monitoring activities in the United States. In 2000, the Government Accountability Office (then General Accounting Office; 2000) reported that U.S. Environmental Protection Agency and states could not make statistically representative statements of the condition of the Nation's waters nor did they have enough monitoring data to support the full range of Clean Water Act decision needs. In 2001, the National Research Council determined that limited budgets were preventing states from monitoring adequate for assessing the conditions of their waters and advocated for the development of a uniform, consistent approach to ambient monitoring and data collection. In 2002, the National Academy of Public Administration recommended that monitoring agencies should work to reduce duplication of efforts, promote resource sharing, and enhance collaboration to improve the effectiveness of water programs to protect water quality. In 2004, the U.S. Commission on Ocean Policy found that the nation needs a coordinated, comprehensive monitoring network that can provide the information necessary for managers to make informed decisions, adapt their actions as needed, and assure effective stewardship of water resources. More recently, Duriancik et al (2018), noted that coordination of monitoring with similar objectives can support better documentation of conservation outcomes and watershed changes at a range of scales, an important goal of many monitoring programs.

Two past efforts have formally recommended specific broad changes to monitoring in the United States. First, in 1995, the Intergovernmental Task Force on Monitoring Water Quality comprised of 19 Federal and state agencies developed a strategy for national scale water-quality monitoring to support decision making in all levels of government and the private sector. The strategy was designed to collaboratively expand the base monitoring already being conducted to support users at multiple scales and achieve a better return on public and private investments in monitoring. Specific recommendations were made for sampling frequency, constituent coverage, reporting requirements, and logistical coordination. Some elements of this strategy – such as the establishment of the National Water Quality Monitoring Council (NWQMC), development of the National Environmental Methods Index, implementation of the National Aquatic Resource Surveys, deployment of the National Water Quality Portal, and the creation of a reference site network – have been realized, but full implementation has not been achieved. All of these accomplishments aim to use monitoring resources efficiently and protect investments in monitoring data through method documentation, increased consistency, and data sharing.

Second, in response to the U.S. Commission on Ocean Policy, the Council on Environmental Quality charged the NWQMC to develop a framework for monitoring coastal waters. In 2006, the NWQMC and more than 80 stakeholders developed a framework for establishing a network of networks that supplemented existing Federal monitoring with monitoring conducted by state and local organizations to track current conditions and long-term trends in U.S. coastal waters and inland tributaries. The framework included specific recommendations for site locations,

sampling frequency, and constituent coverage. This framework, which was refined in 2008, has resulted in several regional pilot efforts, but full implementation has not been achieved. It suffered in part from being too ambitious and too narrow -- ambitious in its recommendations for numbers of sampling sites, pollutants and frequency; and narrow in its focus on coastal waters and pollutant loads delivered from inland waters, overlooking the monitoring needs of lakes, streams and inland wetlands.

The 2006 Heinz Center report identified several important barriers to the full implementation of coordinated monitoring and reporting:

- *Integration of monitoring programs is hard work and is often not visibly supported by agency management over the lengthy time periods involved in such efforts.*
- *Integration can be viewed as a risk to continued attainment of an agency's statutory mandates or its commitments to key client constituent groups or to maintaining the continuity of data series.*
- *Agencies may fear loss of resources or autonomy through participation in cross-cutting strategic alignment efforts.*
- *There are often significant fiscal costs to undertaking integration activities. Support and funding for such efforts may be becoming harder to obtain, in part because of strong fiscal pressures on agencies.*
- *It is difficult, if not impossible, to mandate integration if the relevant user communities and agencies are resistant.*

and recommended several considerations for successful integration, given these barriers:

- *Integration must go beyond federal programs. States, industry, nongovernmental organizations (NGOs), and the research community should be involved as priorities are set.*
- *Design and control/oversight of an integrated system need not imply detailed control over the decisions of each element within that system.*
- *Proceed slowly and incrementally—attempting a grand synthesis that addresses all monitoring needs and programs is likely to fail. Some level of strategic overview is useful and important.*
- *Discussions of the importance or benefits of integration should not be interpreted as negating the need for increased resources for monitoring overall.*
- *Successful integration requires high-level agency and organization commitment, involvement, and support.*

The new effort described below aims to increase coordination for national water-quality monitoring and reporting in a way that builds on previous efforts, taking into consideration lessons learned about barriers and recommendations for success.

Small steps can advance coordination of national water-quality monitoring and reporting

Building on previous efforts, this white paper recommends small changes that organizations can make without extensive modification to their current monitoring approach and without securing large new sources of funding. In this way, monitoring organizations could continue to address their own priorities while realizing additional benefits from being part of a larger coordinated effort. The recommendations herein do not cover every need for coordinated water-quality

monitoring and reporting in the United States; broader needs have been well described by numerous past efforts and these still stand as long-term goals. Rather, these recommendations represent small steps that can be taken now to help move that broader effort forward. As advocated for by the Heinz Center in 2006, these recommendations are intended to proceed slowly and incrementally. Success with these small steps could lead to further coordination efforts in the future.

1. Consistency in data discoverability

Water-quality data has been collected by hundreds of monitoring organizations in the United States since 1899, resulting in hundreds of millions of data records. Currently, these records are stored in different formats in hundreds of different data bases. While the originating monitoring organizations can successfully use these data for the original goals of data collection, secondary users often aren't aware of the existence of these data and(or) require large investments of time and money to locate, combine, and harmonize the data (Sprague et al., 2017).

The Water Quality Portal (WQP; www.waterqualitydata.us) was deployed in 2012 by the U.S. Geological Survey, the U.S. Environmental Protection Agency, and the National Water Quality Monitoring Council to combine and serve water-quality data from numerous sources in a standardized format. It is currently the largest single point of access for water-quality data in the United States and delivers over 300 million data records from over 400 monitoring organizations (though it does not include all data from all monitoring organizations in the United States). The common denominator is that all participating organizations map their data holdings to a common data structure or template, the Water Quality Exchange (WQX). As described by Read et al. (2017):

> *Key technological features of the WQP include a community-developed water quality data model, robust web services, and geospatial referencing to the NHDPlus catchments, all of which enable large volumes of water quality data to be integrated with other national-scale data sets relevant to natural resources. These features make discoverable and accessible high-value data from Federal, State, Tribal, and nongovernmental sources, dating back more than a century. Any data provider, including individuals, who meets minimum metadata requirements, may incorporate their data into the system through the USEPA STOrage and RETrieval Water Quality eXchange (WQX), to be used in context with hundreds of millions of water data records. There is a positive feedback loop to community adoption of common data models and data repositories: continued community engagement will further improve the data model, data quantity will increase, and the tools available to users will grow.*

Goal 1: Water-quality data collected in the United States are available in a format consistent with WQX and from a single unified database.

- Identify steps to promote incorporation of more data into the WQP, including from groups not currently contributing, such as universities, citizen monitoring groups, drinking water and wastewater utilities, and additional state and Federal agencies. Getting data into the WQP is achieved through publishing in WQX.
- Develop recommendations for how monitoring organizations could develop public-facing customized entry points into the WQP, to promote public access to their data and increase the visibility of their contributions to the WQP. Suggest funding sources that could be

targeted to fund these efforts, and identify a pilot state effort to use for marketing this idea.

2. Consistency in data reporting quality

Another critical challenge for secondary use of water data is understanding the quality of data collected by other organizations. This not only includes accurate and consistent metadata elements such as parameter names and units of measurement (Sprague et al., 2017), but also estimated uncertainty associated with the laboratory methods and field data collection.

Approaches to address data quality in a network vary from voluntary guidelines for data reporting to quantified or qualified uncertainty based on a variety of indicators. Current examples may include tiers of data quality based on the metadata availability, validation samples for quality assurance and the adherence to standard protocols.

Goal 2: Water-quality data collected in the United States are presented with consistent qualifying information on data completeness and quality.

- Develop tiered system to categorize data based on metadata completeness, availability of QAPP and(or) QA/QC data, sampling frequency, documented laboratory method, or other characteristics.
- Develop plans for an on-line application (possibly linked with the WQP) to show the initial tier status of data in the WQP to promote coordination and improvements to data reporting. This could build off of work already being done to document incomplete metadata in the WQP through the USEPA "Water Quality Indicators Data Usability Improvement Project" at https://echo.epa.gov/maps/wqimap/dataquality.

3. Consistency in data collection

Monitoring organizations face many common water-quality challenges across the United States, ranging from protecting drinking water supplies to combating nutrient enrichment. As a result, there are already many unintentional commonalities in the monitoring approaches used by different organizations. By making small changes that build upon the commonalities already in place, a greater amount of consistent water-quality information would be available for future secondary uses. Some of these future secondary uses can already be anticipated, including the on-going need to document current water-quality conditions at a local, regional, and National scale; identify new and emerging threats to water quality; and track the effectiveness of money spent to clean up water pollution. Increased consistency can also position the United States to better answer future questions that can't yet be anticipated.

In addition, small increases in consistency among monitoring organizations can ensure a nominal level of monitoring within a State or watershed even with fluctuating funding levels within individual organizations. This can help preserve the ability of monitoring organizations to meet their own needs. It can also help address water-quality issues that cross jurisdictional boundaries.

Goal 3: The United States has a core set of sites that are sampled over the long term by multiple monitoring organizations using a minimum set of common design elements. These common

design elements can be built upon as needed by the originating monitoring organizations to meet additional local needs.

- Identify a set of broad objectives to be served by a network(s) of core sites.
- Identify a minimum set of common design elements (to include considerations such as spatial and temporal representativeness, parameters, and methods) that would optimally be included at sites in a core network. Pilot this effort for nutrients.
    - Identify sites that already incorporate these elements and designate them as a core network.
    - Identify sites that could incorporate these elements with only small changes to the current design.
    - Identify any remaining large spatial gaps.
- Develop plans for an on-line mapping application (possibly linked with the WQP) to show these sites, publicize the core network, and highlight gaps in order to promote future coordination and additions to the network.

Next steps

For each of the three goals, a small workgroup will be formed. Each workgroup will have a dedicated lead who will convene meetings and facilitate decision making. The workgroup leads will solicit input and workgroup participation from the contributors to the current effort (listed below), the National Water Quality Monitoring Council, the Association of Clean Water Administrators, and other stakeholder groups as appropriate. Each workgroup will ideally provide their final decisions and implementation steps in writing by March 31, 2019. The workgroup leads will be Dwane Young, USEPA (goal #1), Brian Pellerin, USGS (goal #2), and Lori Sprague, USGS (goal #3).

The outcome from each of these three goals is intended to help monitoring organizations assess their current status with respect to coordinated monitoring and reporting goals and provide a specific set of criteria for them to use to engage in further coordination.

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