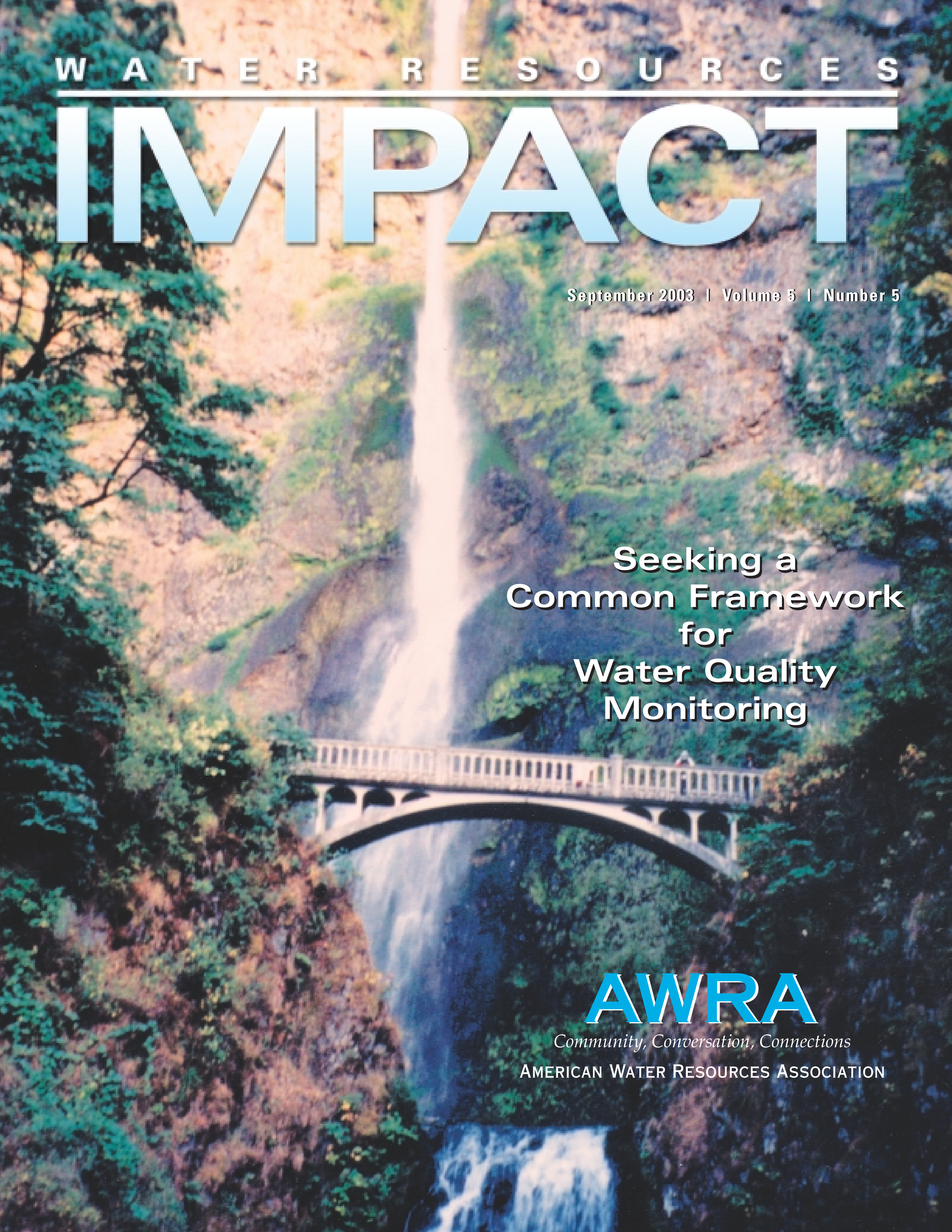


WATER RESOURCES

IMPACT

September 2003 | Volume 5 | Number 5

Seeking a Common Framework for Water Quality Monitoring

AWRA

Community, Conversation, Connections

AMERICAN WATER RESOURCES ASSOCIATION

NWQMC

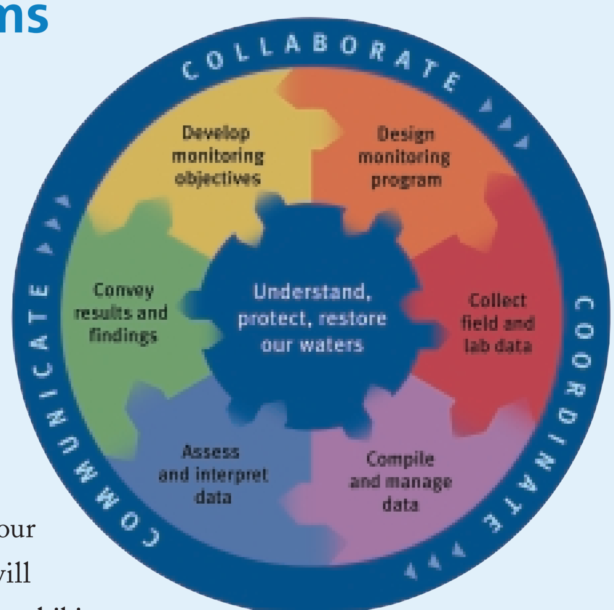
NATIONAL WATER QUALITY MONITORING COUNCIL

Working Together for Clean Water

2004 National Monitoring Conference

Building and Sustaining Successful Monitoring Programs

Chattanooga, Tennessee • May 17–20, 2004



Join us as we explore and share the experiences, expertise, lessons learned, innovations, and strategies that strengthen and sustain both the technical and institutional elements of our monitoring programs. The Chattanooga meeting will be the fourth National Monitoring Conference hosted by the National Water Quality Monitoring Council (NWQMC). Like its predecessors, the 2004 Conference will provide an outstanding opportunity to participate in technical programs and training, share successes, discuss issues, and network with our colleagues in the water monitoring community. The program will include plenary sessions, workshops, oral presentations, posters, exhibits, facilitated discussions, field trips, and informal networking opportunities.

The Council, chartered in 1997, promotes partnerships to foster collaboration, advance the science, and improve management within all elements of the water monitoring community, as well as to heighten public awareness, public involvement, and stewardship of our water resources. The Council has developed a monitoring and assessment framework that describes a process to produce and convey the information necessary to understand, protect, and restore our water resources. The 2004 conference will weave together five overall themes related to each element of the framework and critical to building and sustaining successful programs:

- Promoting collaborative efforts
- Exploring new and emerging methods and technologies
- Addressing changing expectations of monitoring
- Ensuring data and information comparability
- Sharing results and successes

Abstracts are currently being accepted!

For more information visit www.nwqmc.org.

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WATER RESOURCES
IMPACT
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SEEKING A COMMON FRAMEWORK FOR WATER QUALITY MONITORING

Associate Editor – ROBERT C. WARD (Robert.Ward@Colostate.edu)
Guest Associate Editor – CHARLES A. PETERS (capeters@usgs.gov)

The National Water Quality Monitoring Council (NWQMC) presents its proposed water quality 'monitoring framework' in this issue of *IMPACT*. The graphic representation of the framework (presented on pg. 3), is explained in a series of papers. The purpose of the framework is to support production of consistent and comparable water quality data and information in support of fair and equitable management decisionmaking. Additional information and detail regarding the framework is available on the NWQMC Website: http://water.usgs.gov/wicp/acwi/monitoring/. For example, terms marked with bold type in this issue are included in a glossary on the NWQMC website.

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3 A Framework for "Constructing" Water Quality Monitoring Programs
Charles A. Peters (capeters@usgs.gov)
Robert C. Ward (Robert.Ward@Colostate.edu)
The concept of a monitoring framework is presented along with a brief review of past efforts to establish a more common view of water quality monitoring. Reasons to hope this framework may improve water quality monitoring are enumerated.

FEATURE ARTICLES

8 The 3 C's: Communicate, Coordinate, Collaborate – Doing Together What We Can't Do Alone
Abby Markowitz (Abby.Markowitz@tetratech.com)
Linda T. Green (lgreen@uri.edu)
James Laine (jlaine@mail.dep.state.wv.us)
The outer ring of the monitoring framework graphic represents efforts to enhance communication among monitoring professionals. Producing consistent and comparable water quality data and information, across agencies and organizations, requires much more interaction among water quality monitoring professionals than has occurred in the past.

11 Identify Monitoring Objectives
Charles S. Spooner (spooner.charles@epa.gov)
Gail E. Mallard (gmallard@usgs.gov)
The first 'cog' of the monitoring framework highlights the importance of defining and documenting clear and precise information goals prior to initiation of a water quality monitoring program. Many of the details of a monitoring program's design are greatly influenced by the information purpose.

14 Monitoring Design
Anthony R. Olsen (Olsen.Tony@epamail.epa.gov)
Dale M. Robertson (dzrobert@usgs.gov)
The second 'cog' of the monitoring framework underscores the need to carefully establish and document the location of sampling sites, the frequency of sampling, the measurements to be made, and a plan to implement the design that recognizes the application difficulties the 'field' uncertainties present to the best laid plans of monitoring professionals.

17 Data Collection: Field and Laboratory Methods
Franceska Wilde (fwilde@usgs.gov)
Herbert J. Brass (Brass.Herb@epamail.epa.gov)
Jerry Diamond (jerryd@tetratech.com)
The third 'cog' of the framework speaks to the complexity involved in obtaining field samples and measuring chemical, biological and physical characteristics. Considerable 'tool' development has taken place within the subject of this cog over the past few years, thus helping monitoring professionals document the details required to produce consistent and comparable data.

22 Water Quality Data Management
Karen S. Klima (kklima@usgs.gov)
Kenneth J. Lanfear (lanfear@usgs.gov)
Ellen McCarron (ellen.mccarron@dep.state.fl.us)
The fourth 'cog' of the framework emphasizes the critical role of data storage and retrieval. While strings of numbers come from the laboratory, it is well configured and documented data records that are needed for accurate data analysis and interpretation. The factors that effect this transformation are discussed.

25 Assess and Interpret Data
Dennis R. Helsel (dhelsel@usgs.gov)
Lindsay M. Griffith (LGriffith@brwncald.com)
The fifth 'cog' in the framework encompasses the wide array of methods available for analyzing and interpreting water quality data. It is at this point in the monitoring system where considerable judgment on the part of the monitoring professional is required. With such individual judgment required, lack of consistency and comparability in choosing and applying data analysis methods results in a lack of consistency and comparability in the resulting information. Developments in the science behind water quality data analysis are pointing toward increased consistency in the future.

30 Conveying Results and Findings
Mary Ambrose (MAMBROSE@tceq.state.tx.us)
Abby Markowitz (Abby.Markowitz@tetratech.com)
Charles Job (job.charles@epa.gov)
The sixth 'cog' addresses the part of the monitoring framework with, perhaps, the least focus historically. There is little consistency in the way water quality information is reported/presented, thus leading this paper to discuss factors needed to effectively communicate with an array of audiences.

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[Cover Photo: Multnomah Falls, Oregon]

WATER RESOURCES IMPACT

A FRAMEWORK FOR 'CONSTRUCTING' WATER QUALITY MONITORING PROGRAMS

Charles A. Peters and Robert C. Ward

NWQMC Proposed Framework for Water Quality Monitoring Programs

INTRODUCTION

In ancient times the monitor was a person sitting in a crow's nest of the sailing ship watching and warning of land, reefs, whales, friends, and foes. In the present day, water monitoring is used to help water resource managers understand and avert potential negative impacts of anthropogenic or natural factors on our water resources. Consistent and comparable long term water quality, and quantity monitoring data are needed in order to, for example: (1) describe the status and trends of a water resource, (2) identify existing and emerging water quality issues, and (3) determine compliance with regulations. The data must lead to information that is provided in a manner that adds value and relevance to the water management community and the public. As Naisbitt stated in his 1982 book Megatrends (Naisbitt, 1982):

> "... uncontrolled and unorganized information is no longer a resource in an information society. Instead it becomes the enemy of the information worker ... information technology brings order ... and therefore gives value to data that would otherwise be useless."

Water monitoring, as a critical support activity for water quality management, unfortunately, has not identified a way to organize its larger self to give maximum 'value' to data and the information produced by individual organization monitoring efforts.

THE NEED FOR A COORDINATED APPROACH TO WATER QUALITY MONITORING

To design a water monitoring system that is organized and information goal oriented, as well as accountable for the information produced, the activities involved in monitoring must first be organized and coordinated.

What are the activities involved in monitoring? Why is it so difficult to organize and coordinate monitoring activities?

With all the various types and purposes of monitoring that exist today (e.g., **ambient**, process, **trend**, biological, **compliance**, and ground water), the difficulty in developing a common vision of what constitutes an organized water information (monitoring) system becomes obvious. Where is the common terminology for all types of monitoring? Where is the common framework for approaching the task of producing consistent and comparable water data and information?

Past definitions of water monitoring tend to focus on the actual means for collecting data, the science involved, or the location of water in the hydrological cycle, and not on the information purpose for monitoring (ITFM, 1995b). Recent 'credible data' laws reflect a need for legislatures to define the nature of data employed in water quality management decision making (e.g. http://data.opi.state.mt.us/bills/billhtml/HB0392.htm). In some ways, the need for credible data laws implies that the monitoring community has not established a common, well accepted, monitoring framework for producing information for management decision making.

The water information (monitoring) system needs to be defined to permit the organization of data and information that Naisbitt (1982) indicated was necessary to give value to data and information. A monitoring framework needs to be established, accepted, and employed to guide its design and operation and help reduce the chance that information loses connection with the original information objective.

The purpose of this paper is to propose a water monitoring framework that permits a general, and common, comprehension of the diverse array of activities involved in monitoring. Such an understanding is critical to the production of scientifically sound, consistent, and comparable water quality information required to support fair and equitable water quality decision making.

PAST EFFORTS TO ESTABLISH A 'MONITORING FRAMEWORK'

The need for a monitoring framework was recognized shortly after Congress passed the Federal Water Quality Act of 1965, which required states to establish monitoring programs. These programs were started with very little guidance and there were questions as to whether the monitoring programs were producing the information needed to comply with the law. In response to these concerns, a number of efforts set forth to define a common monitoring framework.

Snider and Shapiro (1976) developed a set of procedures to evaluate the operations of a water quality monitoring network. Such an evaluation, however, required that the operations be categorized and defined. The framework employed by Snider and Shapiro (1976) contained the following operations: (1) network plan and design, (2) personnel, (3) facilities and equipment, (4) sampling, 5) quality assurance, (6) data distribution and utilization, and (7) agency interactions.

The U.S. Environmental Protection Agency (1977) described a 'Basic Water Monitoring Program' designed to provide 'a basic structure which, when realized, will contribute to a more effective use of our water monitoring resources.' The report addressed the following topics, one per chapter of the report: (1) quality assurance, (2) intensive survey program, (3) ambient monitoring, (4) effluent monitoring, (5) proposed biological monitoring, and (6) data interpretation and reporting.

Rickert and Hines (1975), described a framework for assessing water quality that included eight elements: (1) delineation of river quality problems; (2) analysis of river hydrology; (3) selection of assessment methods; (4) identification, collection, and collation of required data; (5) data analysis, method formulation, and the testing of predictive capability; (6) forecasting impacts on planning alternatives; (7) communication of results; and (8) program evaluation.

Ward (1978), after reviewing the various purposes of monitoring associated with routine and special survey monitoring, proposed the concept of a 'water-quality information system' as a means of organizing the activities of monitoring around a clearly defined information goal. The activities included: (1) network design, (2) sample collection, (3) laboratory analysis, (4) data handling, (5) data analysis, and (6) information utilization.

The Intergovernmental Task Force on Monitoring Water Quality (ITFM) (1995a), identified five general purposes of monitoring and proposed a framework for water-quality monitoring consisting of the following components: (1) purpose, (2) coordinate/collaborate, (3) design, (4) implementation, (5) interpretation, (6) evaluate monitoring program, and (7) communication. Lack of agreement on the generality of the proposed ITFM monitoring framework seems to be reflected in an ITFM (1997) report that defined a conceptual framework for ground water quality monitoring.

Thus, the development of a monitoring framework has been an elusive goal of the monitoring community for a long time. The need for a well defined and widely agreed upon monitoring framework has been reinforced by much of the "information revolution" thinking that was initially articulated by Naisbitt (1982) and has experienced rapid development since.

A PROPOSED WATER QUALITY MONITORING FRAMEWORK

The current National Water Quality Monitoring Council (Council) evolved from the ITFM and continues its efforts to develop a widely accepted monitoring framework from which consistent and comparable water quality information can be produced. The framework will be used to:

- Guide the activities of the National Water Quality Monitoring Council and Methods and Data Comparability Board (Board) by identifying, connecting and prioritizing critical elements of a water quality monitoring program.

- Facilitate communication among professionals and volunteers working on different elements of monitoring programs (e.g., laboratory analysis and data analysis/interpretation).
- Guide the design of water quality monitoring programs to insure that all components are included, balanced, connected, and collectively focused on producing information.
- Respond to the need for a warehouse of consistent information on water monitoring design methodologies (e.g. provide "one-stop shopping" for the water monitoring community charged to produce consistent and comparable information for fair and equitable management decision-making).

To facilitate ease of communication of the concept of a 'monitoring framework,' the Council developed a graphic (see pg. 3) to rapidly convey the extent and interconnectivity of the major components (or 'cogs') involved in a larger systems view of water quality monitoring.

The Council defines a 'monitoring system,' or framework, by the flow of "information" through a series of sequential activities, each of which carefully builds upon the earlier steps to ultimately produce and convey water information. Before the flow of information can begin (on an operational level) the information goals must be defined along with a monitoring strategy designed to meet the goals. A monitoring design must be completed to guide operations involved in obtaining the desired information.

The collection of an environmental sample starts the flow of water information at the interface between the water and the monitoring personnel. Measurements are made, either in the field or on the sample in a laboratory, to convert the water's properties into numbers. The measurements can be physical, chemical, or biological in nature. Thus, collecting data in the field and laboratory is a major (i.e., costly and time consuming) activity involved in a monitoring framework.

Data are stored in an electronic data storage and retrieval system. Such a component, within an information system, acknowledges that data records require careful organization, in a timely fashion, for data analysis and interpretation. It is important that the data in the data storage system include sufficient descriptive information, about the data (i.e., "meta data"), for the data to be shared and compared among managers and the public, thus managing data represents a major 'cog' in a monitoring framework.

Data analysis and interpretation, via graphical presentation, statistics, modeling, or some combination of these, takes place at the point when sufficient data are available to support analysis for an identified information goal. The choice of data analysis methodology depends upon the information sought; however, there are no widely accepted 'standard' data analysis or interpretation methods that result in consistent and comparable information for management purposes. Ideally, the data analysis methods have been identified prior to sampling and were peer reviewed so that the data are collected in direct support of the data analysis methodology, and recognizing the assumptions inherent in data analysis methodologies. Thus, interpreting the data for the purposes intended represents a 'cog' in the monitoring framework.

The results of the data analysis are disseminated by various means, for use by water quality managers and/or the public. Conveying information and results to information users may take many forms, depending upon the information need, timeliness sought, and the management style of the decision maker. Again, there are no 'standard' methods for reporting and conveying water quality information from monitoring programs.

The graphical representation of the framework not only includes the six interconnected primary elements (or 'cogs'), but also reflects the need of the cogs to be held together by the three C's (collaboration, communication, coordination). The Council is currently developing the information infrastructure (Information Technology) to permit data, and information about data, to move seamlessly around the framework.

ADDITIONAL FEATURES SOUGHT FOR THE MONITORING FRAMEWORK

During the 3rd National Monitoring Conference in 2002, and afterwards, the exact organization and content of the monitoring framework has been debated. Suggestions included adding cogs to cover key topics deemed absent, or not emphasized sufficiently, in the current 'six-cog' framework. These recommendations can, in general, be classified in four categories:

1. Identify data users.
2. Engage monitoring partners.
3. Evaluate Monitoring program.
4. Use of information technology to connect framework cogs.

The tension between simplicity and completeness was discussed at length by the Council, and in the end, simplicity won out. The points raised by those suggesting adding the above cogs have been, in many ways, incorporated into the papers that follow. Also, more detailed descriptions of the recommended elements can be found on the Council's website: http://water.usgs.gov/wicp/acwi/monitoring

HOW WILL THE FRAMEWORK BE CONSTRUCTED AND PUT TO USE?

The reasons previous efforts to develop a conceptual framework for monitoring have not taken root in the monitoring community are many and include: (1) lack of follow up implementation efforts, (2) absence of wide spread acceptance of the framework, and (3) lack of a meaningful connection between the conceptual framework and products (tools) that can be usefully employed by those who conduct monitoring on a day-to-day basis.

The Council provides the mechanism to address all three of the above limitations. First, the Council has developed a track record of fostering cooperation and collaboration on water quality monitoring – from its 35 members representing a wide array of monitoring entities in the United States, to its biannually sponsored National Monitoring Conferences, to its encouragement of state/ regional monitoring Councils.

The Council, through its Methods Board in particular, is developing and distributing information and tools to assist the monitoring community in using more common methods to acquire and share water quality data. The Council intends to use the framework as a guide for development of an enhanced and more coordinated product (tool development) approach, implemented through the Council, State, and regional councils, regional and national monitoring conferences, and individuals and agencies. The Council's products and tools are made available on its website: http://water.usgs.gov/wicp/acwi/monitoring. Progress and new products are periodically announced on the Council's webpage. For example, the Council is now preparing a monitoring glossary, a draft of which can be found on the Council's webpage.

CONCLUDING REMARKS

To meet the data and information challenges facing water quality management today, across agencies and disciplines, requires a common view of water quality monitoring and a common vocabulary to facilitate collaboration and communication. The following papers initiate the effort to place flesh on the bones of the monitoring framework (see pg. 3). Thus, each of the following papers provides the insight and agreement that further defines a monitoring framework useful to everyone involved in water quality monitoring. There is also a discussion regarding a common monitoring vocabulary (i.e., a monitoring glossary, located on the Council website). The Council welcomes your input regarding the terms and definitions included in the framework and draft glossary.

While considerable dialogue, debate, and, yes, argument, has gone into the preparation of the following papers, it is realized that the monitoring framework is just beginning to serve the intended goal of the Council. The process that led to the Council proposing a water quality monitoring framework, including preparation of this issue of *Water Resources IMPACT*, has forced all of the participants (i.e., Council members, lead authors, and collaborators) to carefully examine exactly what we mean when we discuss water quality monitoring with other colleagues and the public. The monitoring framework enhances the dialogue that leads to consistency and comparability in water quality monitoring data and information that, in turn, supports fair and equitable water quality management decisions based on sound science.

NATIONAL WATER QUALITY MONITORING COUNCIL

What is the National Water Quality Monitoring Council?

The National Water Quality Monitoring Council (the Council) was created in 1997. It has 35 members – a balanced representation of federal, state, interstate, tribal, local, and municipal governments; watershed and environmental groups; the volunteer monitoring community; universities; and the private sector (including the regulated community). The Council is co-chaired by the U.S. Geological Survey and the U.S. Environmental Protection Agency. The Council is chartered as a subgroup of the Advisory Committee on Water Information under the Federal Advisory Committee Act. It meets regularly at locations throughout the country.

Purpose?

The purpose of the Council is to provide a national forum for coordination of consistent and scientifically defensible methods and strategies to improve water quality monitoring, assessment, and reporting. The Council promotes partnerships to foster collaboration, advance the science, and improve management within all elements of the water quality monitoring community, as well as to heighten public awareness, public involvement, and stewardship of our water resources.

The Challenge?

Each year government agencies, industry, academia, and private organizations devote enormous amounts of time, energy, and money to monitor, protect, manage, and restore water resources and watersheds. Differences in monitoring system design strategies, sampling and laboratory methods, data analysis procedures, and data management technology have often made it difficult for monitoring information and results to be shared and used by all. The restoration and protection of water quality is dependent upon detailed, understandable, easily accessible, consistent, and comparable data and information.

For Additional information, see http://water.usgs.gov/wicp/acwi/monitoring

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WATER RESOURCES IMPACT

THE 3C's: COMMUNICATE, COORDINATE, COLLABORATE DOING TOGETHER WHAT WE CAN'T DO ALONE

Abby Markowitz, Linda T. Green, and James Laine

Sustainable protection and restoration of our water resources require the participation of all stakeholders in designing and applying strategies that recognize diverse interests and integrate sound science with social, economic, and cultural factors. Monitoring is a key component of environmental protection. Monitoring frameworks (as discussed in the *Overview/Introduction*) seek to organize a series of sequential activities to produce and convey water information. A unique, and deliberate feature of the National Council's monitoring framework is the inclusion of an "outer ring," containing the "3C's," – communicate, collaborate and coordinate – describing processes which are integral to each of the elements of this monitoring framework.

Communication, coordination, and collaboration within and among monitoring entities (agencies, organizations, universities) is necessary to effectively and accurately address our fundamental questions: *What is the condition of our surface, ground, estuarine, and coastal waters? Where, how, and why are water quality conditions changing over time? Where are the problems and what is causing them? Are programs to prevent or remediate problems working effectively? Are water quality goals and standards being met?* No single entity can effectively assess all the water within its jurisdiction. Yet, to truly meet our water quality goals, it is imperative to ask, answer, and act on these questions – through communication, coordination, and collaboration.

The short term benefits of the 3C's in monitoring are many. They include resource and information sharing; enhanced, and more widely applicable, assessment tools; increased quality and quantity of data and information, with potentially, less cost; and reporting consistency, which fosters confidence in information. In the longer term, the 3C's move us closer to a time when monitoring is consistent, comparable, scientifically defensible, and the resulting information is accessible and facilitates sound decision making by all stakeholders. Without applying this longer term vision, we will not be able to answer those fundamental questions and, without answers, we will not be able to protect and restore our waters. At first glance, the 3C's seem synonymous; and they are often used interchangeably. However, they are also steps along a continuum – communication can lead to coordination, which can lead to collaboration. The 3C's are also nested concepts – certainly, communication and coordination are encased within collaboration. Within the monitoring framework, the Council defines them as follows:

- ***Communication*** is the process of conveying information; can be one way or an exchange of thoughts, messages, or ideas.

- ***Coordination*** is a process in which two or more participants link, harmonize or synchronize interaction and activities.

- ***Collaboration*** is a process in which two or more participants work collectively to deal with issues that they cannot solve individually; partnerships, alliances, teams.

COMMUNICATION

Within the monitoring framework, the first step in the continuum is almost always communication, which starts when someone decides to share some information with – or seek information from – someone else. With the growth of the internet, the ease with which information can be exchanged has increased dramatically. For example, EPA supports numerous libraries, hot lines, clearinghouses, newsletters, listservs and other paper and online communication vehicles on a myriad of environmental topics. Most monitoring entities also have websites to facilitate communication with various audiences. Newsletters are another commonly used communication vehicle. An excellent example is the national *Volunteer Monitor* newsletter, published twice yearly, which facilitates the exchange of ideas, monitoring methods, and practical advice among volunteer monitoring groups.

... collaboration is a partnership, among equal participants, to develop and implement a joint project or plan ... a collaborative project has shared goals developed by all members of the collaboration

COORDINATION

Coordination usually begins with an overall effort or process – such as assessing a state's water resources – that would benefit from the coordinated (linked, synchronized, harmonized, etc.) efforts of several participants. Each participant group decides what type of role in the process best fits their abilities and goals. In essence, each participant identifies which piece of the framework they feel comfortable providing to the overall effort. State and regional **Monitoring Councils** have become critical forums for communication and coordination among monitoring groups. Monitoring Councils exist in several states, such as Maryland, Colorado, Kentucky, Texas, Virginia, and Montana; as well as in several large basins, such as the Connecticut River, Lake Michigan, and Upper Mississippi Basin. Interstate basin commissions (e.g., Delaware River Basin Commission, Ohio River Valley Water Sanitation Commission) and multiagency major basin programs (e.g., Chesapeake Bay Program and the Great Lakes Commission) are also institutional vehicles for the 3C's. Each of these entities seeks to provide a forum for effective communication, coordination, and collaboration among individuals and organizations involved in water monitoring. In a very real way, they provide a formal arena – including an actual table around which people can gather – for exploring monitoring, and assessment issues of interest.

In 2000 and 2001, the National Water Quality Monitoring Council (NWQMC) conducted an assessment of these organizations, gathering information on goals, objectives, activities, structure, and membership. Several common themes for state and regional councils emerged:

- Provide opportunities for communication and coordination among members.
- Promote collaborative watershed based monitoring.
- Improve documentation of monitoring activities.
- Use precious monitoring resources more efficiently.
- Raise public awareness.
- Foster inclusiveness in monitoring.

The various activities of these councils and commissions are often specifically designed to communicate what various monitoring entities are doing – minimizing redundancy and maximizing opportunities for coordination and collaboration. The following examples, from Virginia and Maryland, illustrate how Councils are developing tools to establish and maximize coordination among monitoring groups.

Virginia Water Monitoring Council

In 2001, the Virginia Water Monitoring Council (VWMC) (http://www.vwrrc.vt.edu/vwmc/) developed a Water Monitoring and Needs Assessment Survey, part of which is ongoing. The survey asked for input on the needs of water monitors to evaluate possible services and activities the VWMC can offer to Virginia's water monitoring community. In June of 2002, the VWMC Steering Committee used the results of the survey as an analysis tool in their strategic planning process. The two greatest needs identified were development of

1. Communication and partnership building activities – such as a directory of monitoring efforts, citizen education, calendar of monitoring events, networking and partnership building opportunities including training workshops and conference.
2. Guidance documents – such as data reporting protocols and data analysis tools.

The ongoing component of the survey seeks to document all current and historic water monitoring activities in Virginia. The survey, which can be completed online, identifies public and private groups and individuals generating water quality and quantity data. One result of the survey is a user-friendly searchable online database. Users can search on location, matrices monitored, parameters assessed, and type of organization collecting the data. The inventory facilitates information exchange and interest in water monitoring throughout Virginia and can be used as a planning and assessment tool for issues surrounding water resources.

Maryland Water Monitoring Council

The Maryland Water Monitoring Council's (MWMC) (http://www.mgs.md.gov/mwmc/) "Program Coordination Committee" (PCC) promotes collaborative and comparable watershed monitoring strategies that leverage limited monitoring resources and reduce duplication of effort. MWMC identified four initial elements required to build and sustain statewide programmatic coordination:

1. A clearinghouse containing program metadata.
2. A comprehensive statement of water monitoring goals for Maryland agencies, including approaches to address the goals, and the programs currently in place.
3. A process for routine information exchange among monitoring groups to encourage collaboration when locations, program goals, and approaches are compatible.
4. A collaborative effort in the development of a statewide monitoring strategy.

One result of their coordination was the review of locally collected storm water data and the realization that actual loads were different than those used in the Chesapeake Bay Program's storm water models. As a result, the Bay Program applied an adjustment factor to the urban storm water loadings predicted by the model so the results would conform to that data. The PCC has also begun holding informal roundtable meetings designed for person-to-person exchange of information about the kinds of monitoring being planned. The result of the 2002 roundtable was a geographically referenced online database of monitoring sites to ensure that everyone knows where everyone else will be monitoring.

COLLABORATION

Collaboration is a partnership, among equal participants, to develop and implement a joint project or plan. Whereas in a coordinated effort participants pursue their own goals but link or synchronize those goals with the goals of others. A collaborative project has shared goals developed by all members of the collaboration. A collaborative project is often the result of answering the question, what can we accomplish together that we can't do well on our own, or more simply, what can we do together that none of us can do alone?

2002 National Monitoring Conference

A capacity building workshop for state and regional councils was held at the 2002 National Monitoring Conference in Madison, Wisconsin. Workshop participants explored the issues, obstacles, and challenges involved in building and maintaining council type organizations and discussed how to successfully increase communication, coordination, and collaboration among monitoring entities. Participants considered a series of three steps that build toward collaboration: (1) getting to the table, (2) defining objectives, and (3) making it happen. During the workshop, participants brainstormed issues and challenges and developed broad recommendations for addressing the three steps above. All agreed that planting the seeds for collaborative monitoring requires:

- Identifying common ground among and a common language for all potential collaborators.
- Articulating the "what's in it for me?" for all members of the monitoring community.
- Answering the question "what can we do together that none of us can do alone?"

Workshop participants also acknowledged the role of the National Council in facilitating and fostering successful collaborative monitoring efforts at the state and regional level. Participants recommended that that NWQMC focus on identifying success stories illustrating the economic, political, scientific, educational, and environmental benefits of collaboration, demonstrating that collaboration leads to reduction in effort, duplication, and cost through combining expertise and resources; and identifying the tools and strategies needed to create an atmosphere for WIN-WIN collaboration.

At the end of an effective collaborative project each participant can examine the results and see the short and long term value gained in creating a product that benefits not only each participant but ultimately improves the health of our waters (a true WIN-WIN situation). In a very true sense, the proof of effective collaboration will be the products resulting from these efforts and whether, through collaboration, we are able to overcome the political, technical, and financial obstacles of the past – and future. Working together, whether communicating information, coordinating activities, or collaborating on a project is not easy. Even coordinating the schedules of busy people for a meeting can be a daunting task. Despite all the difficulties, the sum total of perspective, knowledge, skills, and resources that each participant brings to the table is certainly much more than any of the parts alone, and is an essential piece of the monitoring framework for understanding, protecting, and restoring our waters.

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HAVE SOME COMMENTS ABOUT THIS ISSUE?

SEND US YOUR FEEDBACK

(COMMENTS ON PREVIOUS ISSUES ARE ALSO WELCOME)

Water Resources IMPACT is in its fifth year of publication and we have explored a lot of ideas. We hope we've raised some questions for you to contemplate. "Feedback" is your opportunity to reflect and respond. We want to give you an opportunity to let your colleagues know your opinions . . . we want to moderate a debate . . . we want to know how we are doing.

Send your letters by land-mail or e-mail to Robert Ward or Charles Peters (for this issue), or to Earl Spangenberg (Editor-In-Chief). Either way, please share your opinions and ideas. Please limit your comments to approximately 350 to 400 words. Your comments may be edited for length or space requirements.

WATER RESOURCES IMPACT

IDENTIFY MONITORING OBJECTIVES

Charles S. Spooner and Gail E. Mallard

There are many reasons to monitor water quality. Questions that can be answered, but require monitoring data include:

- Is the water acceptable for drinking or swimming or irrigation or aquatic habitat or other uses?
- Is water quality getting better or worse?
- If water quality issues or problems exist in the water body, what are the causes of those problems?
- Is water quality changing because of changes in land use or management practices?
- Are regulatory requirements being met?
- How does the quality of a specific water body compare with those nearby or across the country?

None of these questions has an easy answer. Each requires a specific set of measurements, taken in appropriate places using appropriate techniques, and interpreted in view of existing standards and other information. To achieve success, the question should determine the monitoring objectives and the objectives should determine the monitoring design. The more specific the objectives are, the more likely it is that the monitoring design will be appropriate and the original question will be answered.

The water quality monitoring framework described in the *Overview/Introduction* to this series of papers is designed to make sure that all of the necessary steps are followed in constructing a monitoring program so that questions such as those posed above can be answered with confidence. A first and extremely important step in this process is to identify monitoring objectives. If the monitoring objectives are not clearly defined or are not clearly understood by both those conducting the monitoring and those receiving the final results, the entire effort may be unsuccessful. Thus, at each step there is a need to pause and look back to confirm adherence to the reasons for monitoring in the first place. When the monitoring design and all other steps (cogs) of the monitoring framework address the monitoring objectives, the overall design is likely to be successful. Broken links in this sequence may mean that the original question(s) will not be answered.

In this paper, we use selected general monitoring objectives to illustrate the use of a recognized process for converting study goals into monitoring plans. The data quality objectives process (DQO process) (U.S. EPA, 2000) is widely regarded as the basic process of defining monitoring objectives and deriving data needs from them, and then converting those needs into statistical specifications for studies.

Understanding and documenting management and stakeholder needs requires one to:

1. Define the problem or issue. Identify the planning team members and the decision makers, develop a conceptual model of the environmental issue to be investigated, and identify the project's budget, personnel, and timing.
2. State the decisions that must be made. Define the principal study question(s), and alternative actions, and develop a set of decision rules for addressing both simple and complex decisions to be based on the data.
3. Identify the data needed to make the decision. Identify the information needed and determine the sources of that information. This may include specifying the tolerable limits of error that can be accepted in the study.

WATER QUALITY MONITORING OBJECTIVES

Four general objectives for water quality monitoring are listed and discussed in order from the simplest to the most complex. It should be clearly understood that each of these objectives is important, and meeting them requires considerable environmental knowledge and technical skill. Even though more measurements are required for trend analysis than for water quality assessment and more still for pollution source identification and model verification, all four of the objectives have an important place in the discipline of water quality monitoring. Collectively, the results obtained by meeting these monitoring objectives can be used to answer most of the questions listed above.

... one of the strengths of the monitoring framework is that it emphasizes the need for feedback at every step of the process

Water Quality Status

At its simplest and most straightforward, water quality assessment is a description of the current status of a water body – measurement of physical characteristics, measures of concentrations of selected chemicals, and/or an assessment of the status of aquatic biota. It can also include comparisons to conditions at a reference site or to a standard or other benchmark. An example of monitoring that would meet this goal would be to know that the concentration of nitrate in a ground water monitoring well is 0.5 milligrams per liter of nitrate and that this is consistent with ground water in undeveloped watersheds (Nolan and Hitt, 2002).

Trend Analysis

Trend analysis requires a series of measurements taken over time. An important monitoring requirement for trend detection and determination is that monitoring procedures use the same approaches and methods over time. Otherwise, a change in analytical method, for example, could cause an apparent change in measured chemical concentration and an apparent trend even though, in reality, there is none. Because natural factors such as flow characteristics of a river, can cause changes in water quality, it is usually important to correct for natural variability when monitoring objectives include trend detection

Contaminant Source Assessments

Understanding the sources of contaminants requires knowledge not only of water quality characteristics but also of land use or other factors that can influence water quality. An example of this monitoring objective would be to identify the relation between water quality and land use. Approaches to this sort of monitoring effort could include a bracketed approach in which, for example, water quality at an upstream site that is mostly forested is compared to water quality downstream after the influence of tributaries draining more diverse land uses are included. It is especially important to include seasonal or flow related fluctuations in water quality in this sort of analysis and possibly additional studies to identify the source of increased loads. Of course, this analysis can become extremely complex when there are multiple land uses and possible multiple sources of contaminants. Elements of trend analyses may need to be incorporated among the objectives. This is one reason why studies of nonpoint source contamination are so complex and why it is difficult to quantify the benefits derived from changes in management practices.

Model Calibration and Verification

Water quality modeling attempts to take some of the questions about relations between land use and chemical characteristics a step further. At its most complex, there is an attempt to quantitatively understand the relations between water quality and the natural and human variables that affect water quality. To accomplish this, detailed monitoring and special studies may be needed. Calculation of total maximum daily loads is an example of an objective in which monitoring provides data used to calculate water quality at times or places outside the range of observed conditions.

FACTORS TO CONSIDER IN ESTABLISHING OBJECTIVES

There are a number of important factors that must be considered in establishing monitoring objectives that can reasonably be met with available resources and time. It is possible to design a monitoring effort that can compensate for most complications, but they will need to be anticipated and accommodated so that the results from the monitoring effort address the original objectives.

Resources and Time

In developing monitoring objectives, available financial and human resources and available time will constrain the objectives that can be practically pursued. While monitoring is needed more than ever, and local decisions provide incentives to undertake it, monitoring still faces hurdles of cost, logistics, and overlapping expectations. It is important that these constraints are factored in when monitoring objectives are being developed because a mismatch between objectives and resources can lead to truncated projects and to dissatisfaction with the monitoring process.

Variability

Water is a resource of many dimensions. Water conditions vary over both time and space. For example, dissolved oxygen concentrations in a stream will change throughout the day in response to photosynthesis and respiration. Further, dissolved oxygen concentrations at any point in time are likely to be different at different places in the stream. Thus, important aspects of the streams quality can only be understood adequately with detailed observations that take into consideration temporal and spatial variability and other natural factors as well as changes in human influences such as land use. Consideration of all sources of variability must be part of the process of developing monitoring objectives. Costs are an issue. An effort to increase the precision of an estimate may lead to the need for a greater number of samples and increased monitoring costs.

Natural water quality or background conditions may also need to be taken into consideration in developing monitoring objectives. For example, water may be naturally high in arsenic or other metals because of geological factors rather than human activities. If the objective is to determine whether water is suitable for human consumption, the knowledge that arsenic concentrations are above a regulatory threshold may be all that is needed. When water is unsuitable for human use, however, the question of why it is unsuitable usually arises. Answering this question can require additional samples or more study. The implication of this sort of situation in developing a monitoring strategy is that if one anticipates that follow up efforts may be needed, then resources can be reserved for this purpose or the two aspects of the study can possibly be combined.

In some cases, it is a matter if time. Often one of the objectives of monitoring is to evaluate the effects of some change in human activity, such as a change in agricultural practices designed to improve water quality. If State or local agencies, or the people who have implemented the change, or the general public are interested in this objective, patience will be needed and monitoring may need to continue for some time in order to demonstrate a positive effect. For example, studies of shallow ground water conducted in Maryland have shown that it may take several years to see changes in nitrate concentrations resulting from reductions in fertilizer use (Speiran *et al.*, 1998)

Regulatory Requirements

The importance of monitoring objectives to monitoring programs is seen in legislation such as the Clean Water Act, Safe Drinking Water Act, etc. In most instances, monitoring is not specified, but decisions that are expected to be based on monitoring are specified. For example, Section 305(b) of the Clean water Act requires states to prepare a report, which is based on information from monitoring. Section 303(d) of the Act requires a judgment and a set of actions that also require monitoring. In these cases the details of monitoring are not provided, and require that local objectives be established as guides. Monitoring of effluents to ensure compliance with permit limits has as its objective a simple assessment of discharge concentrations or loads below those allowed in permits.

Shared Monitoring Efforts

Shared monitoring data can reduce the need for new monitoring and can reduce costs. Access to comparable data is essential to shared efforts. The National Water Quality Monitoring Council has examined ways to facilitate data sharing by identifying how standardized data analysis tools, and well documented field and laboratory methods and robust monitoring data records can promote the collection of comparable data that can be productively shared between monitoring organizations. State and regional monitoring councils can provide the mechanisms for efficiently addressing overlapping objectives. Monitoring consortia can be used to share costs of monitoring (U.S. EPA, 1997).

FEEDBACK NEEDED EARLY AND OFTEN

One of the strengths of the monitoring framework is that it emphasizes the need for feedback at every step of the process. Thus the monitoring design must be compared to the monitoring objectives to see if the design will realistically allow those objectives to be met. After data are collected, and during the interpretation stage, another review of the monitoring objectives is needed. At this stage, it may be possible to answer some or all of the questions posed when the monitoring objectives were developed. But often this is not the case and another round of sampling and analysis may be required to address unexpected findings or just to compensate for natural variability. It is also possible that the results of monitoring may trigger new questions that lead to development of another effort. Again, this is a strength of the monitoring framework because it encourages frequent analysis of the data and helps to assure that the objectives are modified if need be.

In conclusion, the statement of monitoring objectives is essential to directing and focusing the monitoring process. This is inevitable because the reliance on technology based permits to control pollution and restore water quality has given way to management procedures and conservation programs that must meet local water quality goals. The process grows more important as monitoring grows more rigorous and complex. Monitoring is critical to "Information-based Environmental Protection" (Mehan, 2002) – a principle that will guide monitoring in the foreseeable future.

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MONITORING DESIGN

Anthony R. Olsen and Dale M. Robertson

The monitoring design component of the overall Monitoring Framework provides answers to the questions: What site or environment will be monitored? What will be measured at the site? Where will the measurements be taken? What methods will be used to collect the data? When and how frequently will the measurements be made? Since answers to these questions encompass most of the activities people think about in a monitoring program, some consider monitoring design as the entire process of implementing a monitoring program (i.e., the entire Monitoring Framework). Here, we take a more limited view for monitoring design activities. A natural tension exists between monitoring design, the monitoring objectives, scientific capabilities, and institutional capabilities (e.g., budgets, personnel). Monitoring objectives guide the development of the monitoring design, as was discussed in the previous paper. At the same time, the development of the monitoring design, almost always, requires clarification and prioritization. The available budget or personnel capabilities may limit options for a design to meet the objectives and, therefore, might require elimination of one or more of the monitoring objectives. In addition, the monitoring design must be sufficient to enable the planned data analysis component of the study.

WHAT WILL BE MONITORED?

The development of a monitoring design typically requires that the initial monitoring objective be refined to clarify exactly what will be monitored. The statistical survey design literature uses the phrase "target population" to identify explicitly what is to be included in the study such as a specific waterbody or location, while other monitoring programs may focus on a general class of aquatic resource for a region, state, or the entire nation. General classes may include streams and rivers, lakes and reservoirs, estuaries and coastal waters, recreational beach waters, ground water, drinking water sources, and drinking water intakes.

WHAT WILL BE MEASURED?

The monitoring objectives are the basis for determining what exactly will be measured. Many times this is straightforward. For example, the objectives may specify that a specific chemical (e.g., dioxin), or may specify that a specific bacteria, such as Escherichia (*E-coli*), must be monitored at a beach.

Section 305(b) of the Clean Water Act requires biennial reports to Congress on the status and trends of navigable waters that meet water quality standards. The **water quality standards** in a state enable a specific set of parameters to be identified as necessary to be measured. In other situations, the objectives may only say that the condition of the aquatic resource be determined. Aquatic resources are complex ecosystems and can be viewed from many alternative perspectives. Assessing condition can depend on measurement of chemical contaminants, water temperature, instream physical habitat, riparian habitat, sediment contamination, benthic macroinvertebrate community, fish community, periphyton community, as well as other factors. Certainly, agreement will be needed on which measurements will constitute the monitoring program's concept of "the condition of the aquatic resource."

Simply defining what parameters or constituents are to be measured is not sufficient for developing a monitoring program because most parameters can be monitored using many different techniques. Therefore, we must also know how the data will be used or in other words know the objectives for the data. Data quality objectives (DQOs) define how accurate we must be when collecting the data and therefore, what methods can be used to collect the data in the field, and what laboratory procedures may be required. These topics are covered in the 'Collect Field' and 'Lab Data' cog.

... the monitoring objectives of many programs may require overall quantitative estimates, such as the percent of all streams within a state that meet their designated uses

WHEN AND HOW FREQUENTLY WILL THE MEASUREMENTS BE TAKEN?

Another important question is "When and how frequently should and will the measurements be taken?" When to sample is often determined by the objectives of the monitoring program. The frequency of data collection should depend on the specific question to be answered and several factors specific to what is being monitored, such as the expected variability of the parameter, response time of the parameter and the system, and how the parameter fluctuates with season and flow (if we are monitoring streams).

States are required by the U.S. Environmental Protection Agency (USEPA) to report on the waters of their state that meet designated uses, such as supporting aquatic life use. A state standard may specify that pollutant concentrations may not exceed a limit during an entire monitoring period or more than 10 percent of the time. In practice, states typically monitor monthly or quarterly for pollutants. When biological measurements are used, it is common to monitor only once during a year. If only a single measurement is made during a year, when should it be measured? One approach is to define an index period, for example, during summer lowflow in streams or after fall overturn in lakes. The index period is not intended to represent annual average conditions but instead result in a measurement that provides an index on the quality of the aquatic resource.

Various temporal strategies have been used to collect samples to describe changes in water quality. These strategies range from basic fixed period sampling strategies – such as monthly – to extensive automated sampling techniques. The USGS' national stream quality accounting network (NASQAN) used basic monthly sampling of streams across the nation for more than 20 years to monitor the water quality at a fixed set of locations. In some cases, even less frequent sampling such as quarterly or annual sampling has been used by many state agencies to describe annual conditions. The USGS' National Water Quality Assessment (NAWQA) Program typically collects fixed period monthly samples supplemented by a few manually collected high flow samples each year.

The frequency of data collection is often determined by the variability in the constituent being measured. With this information the USEPA (1997) has defined statistical approaches to determine the sampling frequency required to measure a mean concentration to within a specified range. A few studies have been conducted to determine how various temporal sampling strategies affect the estimated summary concentrations and loads in streams. Results from these studies can be used to define the appropriate frequency for a monitoring program.

The frequency of monitoring of some studies is based on evaluating compliance with an issued permit. Some facilities are required to obtain a state point source discharge permit. The permit may include requirements on the frequency of monitoring.

A typical long term monitoring program continues taking measurements at the same frequency each year; therefore, it is important to consider the variability in water quality and how long it will take to detect a change in water quality of a specified magnitude prior to defining the sampling frequency. An alternative is to conduct monitoring every several years. Data from the two different periods are then statistically compared or when sufficient data become available annual summaries from specified periods are compared. When collecting data every several years, it is important to consider possible factors that are periodic and may bias data collected every several years, such as periodic El Niño events.

WHERE WILL MEASUREMENTS BE TAKEN?

Site selection is a critical part of the monitoring design. Seldom is it possible to measure at all locations in a study area (i.e., the entire target population). What options are available for selecting sites and what governs which option should be used? The latter depends on a quantitative statement of the monitoring objectives.

In general, a goal in site selection is to obtain a "representative" sample. If the sample is not representative, then the information produced will not address the monitoring objectives. The difficulty is that representative means different things to different groups. Consequently, it is necessary to be very specific about what is meant by a **representative sample** before one can determine whether the site selection process is consistent with the objectives.

Sites are often selected to represent large geographic areas. Various approaches have been used to classify large areas into smaller regions of similar water quality. These approaches can be subdivided into geographically dependent and geographically independent approaches. In geographically dependent classification schemes, broad areas or regions are defined that reflect the geographic distribution of various explanatory characteristics, such as ecoregions. Geographically independent frameworks are usually determined by watershed attributes that can be defined independently of a geographic region. Whichever method is used, it is important that the regionalization scheme be based on the distribution of the most strongly related environmental factors and important to know how well the data collected at the selected sites represent the water quality of the larger areas they were chosen to represent.

There are two ways to determine where to select a site within a defined stratum of a regionalization scheme: **professional judgment** and **probability survey** design. In professional judgment, sites are selected to represent specific conditions. In a probability survey design, such as a simple random sampling, sites are randomly chosen in specific stratum of the regionalization scheme. A version of professional judgment is a gradient study that investigates the relationship between a response indicator and one or more stressor indicators. For example, a study may investigate the influence of agriculture and urban development on pesticide concentrations in streams in headwater areas. Particular watersheds could be selected using existing knowledge on their environmental characteristics computed using GIS data. The USGS' NAWQA Program incorporates local knowledge about streams in selecting sites to meet an objective of understanding relationships between stressors and water quality. **Reference conditions** of specific environmental characteristics may be required to aid in the interpretation of data collected within a study region. Reference conditions may be defined as conditions at sites that are not subject to disturbance, or are minimally impacted sites. In other cases, reference conditions are conditions that are typical for sites that represent a certain type of impact, such as water quality in areas with agriculture on clay soils. Reference sites are often selected using professional judgment.

The monitoring objectives of many programs may require overall quantitative estimates, such as the percent of all streams within a state that meet their designated uses. For example, section 305(b) of the Clean Water Act requires states to estimate the stream length (or number of lakes or estuarine area) in their state that is impaired. Incorporating some form of "random selection" to locate sites is necessary to obtain a representative sample. A probability sample, or survey design, is the only site selection approach available that will produce quantitative estimates with an accompanying statement of precision (e.g., 95 percent confidence intervals). Simple random sample, stratified random sample, and systematic sample are common survey designs that have been used in monitoring programs. A simple random sample of all lakes in a state can be achieved by: creating a list of all the lakes and using a random sampling algorithm to select a sample of lakes. States are increasing their use of probability survey designs as integral components of their monitoring programs, particularly for streams and rivers. Further information on probability sampling applied to aquatic resources is available at http://www.epa.gov/nheerl/arm/.

IMPLEMENTING A MONITORING DESIGN

Knowing what will be monitored, what will be measured, when and how frequently it will be measured, and where it will be measured, are all essential elements of a monitoring design. However, knowing this information may not be adequate for others to implement the monitoring program. Documenting the design, including rationale for decisions, is also critical when the design is implemented and when the data that are collected are used by others.

Once sites are selected, a plan must be developed to visit the sites and collect the agreed upon measurements. A typical situation is that all that is known about a selected site is its geographic location and environmental characteristics. To access the site and enable sampling to be conducted may require that land ownership be determined and permission granted before a visit to the site. A well thought out protocol for how to contact landowners, what information to provide them, and how to followup with landowners can significantly increase the likelihood of a landowner granting access. A logistical plan may be necessary to increase the efficiency of visiting sites.

Before fieldwork begins, some type of **quality assurance project plan** (QAPP) should be developed. The content of the plan will reflect all components of the Monitoring Framework. Details on field crew training, field measurement protocols, shipping and sample handling, laboratory analysis protocols, and data management are essential topics to be covered in the plans. Most important is that the quality assurance plan become an active, living document that is a routine part of the monitoring program. Many projects funded by the USEPA require an approved QAPP prior to starting the project. Guidelines for such plans are available from U.S. EPA's Quality System web site (http://www.epa.gov/quality/index.html). The content of the plans will reflect all components of the Monitoring Framework.

SUMMARY

The monitoring design cog cannot be considered in isolation of the other cogs in the monitoring framework. For example, the objectives of a monitoring program govern the monitoring design and at the same time the monitoring design forces clarification of the monitoring objectives. Assessing and interpreting the resulting data must be matched to the monitoring design. Designing a monitoring program is a team and an iterative process that involves all the cogs of the monitoring framework.

[An expanded version of this paper is available on the NWQMC website: http://water.usgs.gov/wicp/acwi/monitoring/]

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WATER RESOURCES IMPACT

DATA COLLECTION: FIELD AND LABORATORY METHODS

Franceska Wilde, Herbert J. Brass, and Jerry Diamond

INTRODUCTION

Sound water resource management depends on the availability of reliable scientific data on which to base management decisions. To serve this purpose, data collection and analysis activities should be governed by a clearly articulated monitoring design based on project objectives. Thus, any scientifically valid water quality investigation requires: data that accurately represent the water medium sampled under the intended spatial and temporal conditions; use of appropriate methods that yield impartial and reproducible results; and data of the type and quality to satisfy the purpose for which the data are collected.

Documenting data quality is fundamental to data collection processes in the field and laboratory.

Documenting the quality of environmental data in monitoring programs is essential and integral to the entire data collection process, and relates to how methods are selected, implemented, and quality assured for field activities and laboratory analyses. Placing an emphasis on the quality of data, rather than on a particular collection method, furthers comparability and fosters opportunities for collaboration among the scientific, regulatory, and land management sectors of Federal, state, and private monitoring communities (NWQMC, Methods and Data Comparability Board, 2001). This is of particular concern for long term monitoring programs that seek to discern environmental patterns over time and across sampling locations, and for data sharing and synthesis over local, regional, and national scales. Costly duplication of efforts often can be avoided when data collection organizations use a standard practice for determining **data comparability** that is based on data quality. Emphasis on data quality also results in greater flexibility in methods selection and greater latitude in using and comparing new data collection technologies as they become validated and available.

Data comparability is the determination that water quality monitoring data can be validly applied by other than the data originators, even if project objectives differ

Recently, new tools and guidance have become available to help organizations determine the appropriate level of data quality needed for a given objective, to quantify or otherwise measure and document the quality of the data collected, and to select appropriate and compatible field and laboratory methods that will produce data of known and acceptable quality. The Methods and Data Comparability Board, under the auspices of the National Water Quality Monitoring Council (NWQMC), is engaged in interagency collaboration to identify, examine, and develop data collection approaches and tools that improve collecting data of known quality, facilitate data transferability, and allow collaboration among data gathering organizations (see http://wi.water.usgs.gov/pmethods/index.html and http://water.usgs.gov/wicp/ acwi/monitoring). This paper incorporates examples of these tools, as it summarizes the major elements of data collection as applied to water quality monitoring projects.

To assist in identifying methods that fulfill project objectives, the Methods Board has developed the National Environmental Methods Index (NEMI) (www.nemi.gov), a web based compendium that summarizes available laboratory and field methods performance information

SELECTION AND QUALITY ASSURANCE OF FIELD AND LABORATORY METHODS

One tool to help organizations establish appropriate sampling designs and to select appropriate data collection methods is the **Data Quality Objective** (**DQO**) process (USEPA, 2000). The DQO process is a systematic, iterative, planning framework through which project goals and objectives are articulated, appropriate types of environmental and quality control data are determined, and tolerable levels of uncertainty are established, often resulting in specified "DQOs." This planning process facilitates critical sampling and analysis decisions, such as the type of samples required (e.g., temporal or spatial composite; grab or isokinetic) and the detection level at which selected constituents should be measured. Thus, the objectives that follow from this decision process involve implementing the monitoring design under specific site conditions, which bear directly on the representativeness of the data to be collected. For example, an emergency response project may place emphasis on rapidity of data collection by using on-site field analyses, and have less need for precise laboratory methods (Table 1). A compliance monitoring program, on the other hand, will generally require precise, accurate laboratory methods to support compliance activities and enforcement actions and to reduce the potential for **false positive** or **false negative** data (a false signal that a contaminant has been detected in the sample, or no signal, when in fact, a contaminant is present).

Example of a DQO: Determine, to a 95% degree of statistical certainty, if there is a significant (50%) change in average nitrate concentration over time at given sampling locations

The collection of scientifically defensible water quality data depends not only on consistent implementation of

TABLE 1. Relationships Among Common Data Collection Elements and Various Types of Monitoring Projects.

Data Collection Elements	Compliance Evaluations	Ambient Investigations	Emergency Investigations
In situ (field) Measurement	Not necessary unless specified	Usually necessary	Preferred
Sampling Design	Targeted	Statistical or targeted	Targeted
Definitive/Confirmatory Laboratory Method	Routinely Required	Routinely required	Often required
Rapidity of Analysis	Determined by regulatory holding times	Determined by analyte or project requirements	Important factor
Use of New, Innovative, or Advanced Technologies (e.g., remote sensing)	As appropriate (slowly being incorporated)	Determined by project, purpose, approach objectives	Often encouraged
Quality Assurance (QA) Procedures; Quality Control (QC) Samples and Metrics	Defined by regulatory programs, criteria, and measurement method	Fundamental requirements defined by organization; additional QA/QC determined by the project or program systematic planning process	QA/QC provisions mandatory
Comparability	Uniform or comparable methods important	Currently, varies among programs and projects	Currently, comparability often unknown
Documentation	Defined by regulatory programs and criteria	Essential	Defined by program requirements

appropriate methods based on project objectives, but also on clear instructions to the data collectors, documentation of the methods used, and data verification. Table 2 shows the general flow of specific tasks for developing an appropriate environmental monitoring effort, and illustrates the interdependence of field and laboratory activities. Carefully prepared and peer reviewed project plans provide a blueprint for implementing field and laboratory activities, and often include a **sampling and analysis project plan** (**SAPP**) and **quality assurance project plan** (**QAPP**). These plans incorporate information and decisions from the systematic planning process, and stipulate the appropriate field and laboratory methods to be used (USEPA, 2000). Use of these project plans throughout the data collection effort provides a barrier to loss of data integrity. Ensuring data integrity is critical for judging environmental compliance with applicable laws and for supporting the foundation of scientific knowledge used in policy and management decisions nationwide.

Although commonly treated as separate and independent operations, the field and laboratory components of the data collection process actually form a continuum in which the field and laboratory methods must be compatible with each other as well as with project objectives. The evaluation of routine sampling and quality control methods, or development of new methods, is as important as the choice of analytical methods in terms of minimizing sample bias or interferences. For example, as laboratory method detection levels decrease, sample vulnerability to contamination tends to increase exponentially, and consequently, field sampling methods must be able to maintain sample integrity to accommodate the heightened analytical sensitivity.

Field Methods

A fundamental requirement for data collection activities is to implementing good field practices; for example, using standard or customized procedures to prevent sample contamination, ensuring that onsite measurements accurately reflect site and sample characteristics, and integrating of quality control measures into all field activities.

In order to define data collection tasks for field personnel, SAPPs and QAPPs are best developed iteratively and as a team. Such plans should specify: (a) a list of required minimum data elements (preferably, the

TABLE 2. Generalized Sequence of Typical Environmental Monitoring Project Activities (DQOs, Data Quality Objectives; QA/QC, quality assurance and quality control; NEMI, National Environmental Methods Index; lab, laboratory; QAPP, quality assurance project plan; SAPP, sampling and analysis project plan).

(a) Review project purpose, scope, and environmental framework in conjunction with the proposed project design (project design developed from DQOs, including QA/QC requirements and data use). Identify sample matrices, sample analytes, and field measurements.

(b) Review field site information, including historical data; consider preliminary site assessment to refine sampling design and sample collection methods.

(c) Review and identify appropriate available field data collection methods and quality control measures: e.g., using DQOs, through NEMI, other recommended references, or guidance sources, evaluate need for methods development to meet objectives.

(d) Identify appropriate lab methods based on DQOs and associated field requirements (e.g., through NEMI). Evaluate need for methods development to meet objectives in consultation with the laboratory.

(e) Select, order, and test appropriate field and lab equipment and supplies.

(f) Document project protocols for field and laboratory activities, data entry, technical audits and peer review in planning documents, such as a SAPP or QAPP.

SAPP Basic Elements:
- Purpose of study, study design, DQOs, sampling locations, timeframe
- Sampling schedule; sampling/QC methods, equipment, handling; safety plans
- Laboratory methods, QC measures, accreditation/certification, rapidity of results to client

QAPP Basic Elements:
- Project management, problem definition, DQOs and QA protocols, training, accreditation/certification requirements
- Overall design of measurement/data acquisition approach
- Assessment and oversight procedures
- Data validation and usability metrics

(g) Identify ancillary data and collection methods.

(h) Develop sampling schedule, work plan, sample and data management plans/protocols, safety plan, training plan, and schedule for technical review of data and data collection. Identify any accreditation/certification required for field and lab personnel and incorporate into project plans, as appropriate.

(i) Communicate about field and lab methods to project personnel and provide each with project planning documents.

(j) Communicate with the lab to ensure that project QC protocols will be incorporated in laboratory data collection tasks. Review lab and field data with respect to accomplishment of project objectives.

recommended core data elements as set forth in NWQMC Methods and Data Comparability Board (2001, 2002a), and the protocols by which the data should be collected; (b) the types and minimum amount of quality-control samples to be collected; (c) the qualifications and training needed by data collectors and other project personnel; and (d) a safety plan that specifies site-specific known or anticipated hazards.

When samples are collected from the field for laboratory analysis, they should be handled, preserved, transported, and stored as indicated in the SAPP or QAPP and by the laboratory performing the analysis. Many monitoring and consensus based standards organizations have excellent references on sample handling procedures for most analytes and types of media (e.g., USGS, 1997; ASTM, 1997, 2000). Unambiguous, accurate, and complete documentation is necessary for all data collected or recorded in the field, including specific sampling locations and identifiers, site conditions, date and time of collection, instrument calibration, and other information as specified in the project plans.

Laboratory Methods

Laboratory methods should meet many of the same general quality-assurance attributes described above for field methods. In particular, laboratory methods should:

- Be conducted in an independently accredited laboratory (NWQMC Methods Board, 2002b).
- Meet the precision, accuracy, bias, sensitivity, and other data measurement and data quality requirements defined for the project.
- Be thoroughly documented and validated.
- Be consistently implemented by trained analysts using appropriately calibrated equipment.
- Ensure that sample holding times and preservation conditions are met.

The Methods Board and the NWQMC recommend the National Environmental Laboratory Accreditation Program (NELAP) as the preferred accreditation body for Federal laboratory accreditation (NWQMC, 2002b)

Accurate and complete documentation of records is necessary. Project plans should stipulate any nonroutine laboratory sample handling procedures, in addition to the analytical methods selected. Method performance in certain matrices (e.g., certain wastewater effluents or drinking waters high in dissolved solids) may be far different (poorer) than those same method characteristics based on laboratory reagent water or other relatively simple matrices (NWQMC Methods Board, 2001). Therefore, it is imperative that a laboratory archive permanent records of its ongoing performance of a method.

FUTURE DIRECTIONS

With the increasing awareness of potentially widespread health effects of various biological pathogens and manmade chemicals, there is a growing mandate for monitoring these analytes. The types of biological analytes that are being incorporated into mainstream monitoring programs have been increasing, requiring, for example, new methods to identify and enumerate newly recognized human pathogens. Application of microbial source-tracking techniques to monitoring programs also is an area of expanding research (http://water.usgs.gov/owq/microbial.html). To address emergency and homeland security issues, the public and private sectors are developing test kits (e.g., using immunoassay methods to detect pesticides or PCBs) and other rapid detection techniques for in situ determination of contaminants, rather than having to rely on traditional laboratory analyses in such instances. The increasing usefulness of remote sensing technologies to detect water quality patterns is another of the many areas that may change the way in which environmental data are collected in the future.

Many of these new directions in environmental monitoring require technological innovations, necessitating extensive method development and validation. Validation of laboratory methods for new analytes is difficult because appropriate reference methods are often lacking (NWQMC Methods Board, 2001). Another challenge is demonstrating method comparability and performance criteria that meet regulatory objectives. Moreover, existing field methods and quality assurance procedures for data collected for these emerging analytes need to be evaluated and adapted or new methods developed and tested.

In a systematic planning process, it is useful to document performance characteristics by which methods can be objectively compared and the resulting data realistically defined (NWQMC Methods Board, 2001). Instead of using a prescriptive approach for selection of field and laboratory methods, a **performance based system (PBS)** approach could allow for greater flexibility. Such flexibility can be important, for example, when a prescribed data collection method is impractical or unsuitable. A PBS approach could more easily allow use of new methods or new technologies (GAO, 2001). The PBS approach must be applied cautiously, however, because of inherent implementation issues that are yet to be resolved, such as legal liability of laboratories and regulatory agencies, technical expertise of laboratory auditors, and appropriate methods verification procedures. Attempts at using a PBS approach include NOAA's Status and Trends Program, EPA's streamlining procedures for water compliance methods, and EPA's Solid Waste methods program.

A PBS approach would require documenting the quality of data obtained from a method without specifying the method itself (NWQMC Methods Board, 2001)

With the advent of more affordable and usable technologies, data collection methods will become more refined, resource efficient, and perhaps more automated. Regardless of the methods used, however, the basic principles of data collection outlined in this paper remain the same. Consistent use of these principles will improve the quality and usability of environmental data, thereby enhancing the NWQMC's goal of improving the quality of information used in environmental decision making.

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WATER RESOURCES IMPACT

WATER QUALITY DATA MANAGEMENT

Karen S. Klima, Kenneth J. Lanfear, and Ellen McCarron

Data management covers a variety of activities associated with collecting, developing, maintaining, archiving, and operating data systems that support program or watershed management. Data management has evolved substantially in the past decade due to the rise of the Internet, increased emphasis on enterprise architecture, and world events demonstrating the need for better security.

Management of water data is essential to a successful monitoring program, and has been recognized by the U.S. Environmental Protection Agency (EPA) as one of the 10 basic elements of a State water monitoring program (USEPA, 2003). Managing water data also is one of the six cogs in the 'Framework for Monitoring' developed by the National Water Quality Monitoring Council (and the reason for this paper). Despite the growing importance of water quality data management systems, only 23 out of the 44 responding States reported adequate data management systems (Association of State and Interstate Water Pollution Control Administrators, 2002). The National Academy of Public Administration (Kirlin *et al.*, 2002) found that data management typically is a State's second greatest need, representing over 15 percent of water quality management resource needs.

The following describes some of the elements that affect the design of a data management system, and two examples of major water data systems: the EPA Storage and Retrieval System (STORET) and the U.S. Geological Survey (USGS) National Water Information System (NWIS).

FACTORS TO CONSIDER IN DESIGNING A DATA MANAGEMENT SYSTEM

Water quality data management is driven by business, mission, and monitoring objectives. Many government agencies, and all Federal agencies, now require formal capital asset planning for long term investments in computing infrastructure. Systems typically are evaluated for return on investment, risk management, and total cost of ownership, which often leads to enterprise architectures that offer common services and consolidated purchases. Few modern systems are developed in an isolated environment.

Data Entry

Data input necessarily involves a limited number of recognized users whose identities must be validated through security procedures. Data entry procedures should be tailored to the collection process. Field crews need to enter relatively small amounts of data about stations visited on a trip; data may be entered via laptops, personal data assistants (PDAs), or cell phones, or may be transcribed from written field notes. Recording media retrieved from field instruments also must be matched appropriately to collection information. Event timing, buffering capability, and redundancy of the entire chain of transmission become critical issues in designing real-time systems, because real-time data must be captured when it arrives or it may be lost forever. Finally, incorporating data from laboratories and other partners frequently involves batch processing large amounts of data.

Data may need to be assigned provisional status until quality control checks are completed. This is important for real-time data, which usually come directly from a field sensor with only minimal checking. Periodic calibration of sensors in the laboratory or field may necessitate later adjustment of data after they have been reported. Therefore, the system should provide some means of flagging, correcting, or removing questionable data and documenting these changes.

... while data capture operations focus on the dimension of time, usually the present, data retrieval operations tend to focus on the spatial dimension, the station

Database Development

The data model serves as a bridge between those collecting the data and the information processing systems that support those using the data. The data model is a conceptual schema that maps data relations, and focuses on those relations that matter most to the business. Successful data modeling requires substantial interaction among managers, stakeholders, program staff, and technical experts, and should not be left to one group.

Metadata

The value of metadata (data about data) often becomes apparent only long after the data are collected. The Advisory Committee on Water Information (ACWI), through the National Water Quality Monitoring Council, has published *Data Elements for Reporting Water Quality Results of Chemical and Microbiological Analytes* (*available at* http://wi.water.usgs.gov/pmethods/elements/elements.html). The recommended data elements are grouped into seven major topics:

1. Contact
2. Results
3. Reason for Sampling

4. Date/Time
5. Location
6. Sample Collection
7. Sample Analysis

Although the ACWI data elements are not organized into a formal schema of a data set, the USGS and EPA are discussing the need for a standard interchange schema between STORET and NWIS.

Data Preservation

Failure to adequately protect systems can affect the integrity of data, privacy of data sources, availability of data for analysis, and even the very existence of the data. Maintaining a "chain of custody" for any data value may be important for legal and enforcement purposes. Modern database management systems record transactions. Whenever data are modified, some record is made of who made the changes and why.

Data must be replicated or archived to survive even the complete destruction of the primary physical site of the database. Although archiving has always been important, recent terrorist activities have demonstrated that this aspect of data management must not be neglected.

An important consideration when converting to a new data management system is whether to convert historical data or begin with all new data. Some data elements important to the new system may never have been recorded in the old system, thus negating updated quality assurance checks and other desired features. The EPA, facing this choice in modernizing STORET, made the decision to freeze the old STORET data in 1999 and send all subsequent data to the new STORET system. For the EPA, the quality assurance needs of the new STORET for monitoring and enforcement could not be compromised to accommodate the historical data. The USGS, in modernizing NWIS, made the *opposite* decision because USGS scientists often require historical data to analyze long term trends. The EPA and USGS are working on a portal to provide an integrated view of selected data in both systems.

Data Discovery and Retrieval

Larger databases, such as STORET and NWIS, are easy to find on the Internet because major search engines index the USGS and EPA websites and many popular web pages link to these sites. This may not be true for the databases of smaller agencies. It is important that at least the "home page" of a database be designed to interact with search engines. Sites such as "Search Engine Watch" (http://searchenginewatch.com/) offer help in this regard. (Mention of commercial names is for identification purposes only and does not constitute endorsement by the U.S. Government.)

While data capture operations focus on the dimension of time, usually the present, data retrieval operations tend to focus on the spatial dimension, the station. These opposing characteristics can create difficult demands on systems designed to serve both purposes. The USGS solved this problem by splitting NWIS into a collection side, called NWIS, and a distribution side, called NWISWeb. While this creates two copies of the data, which must be carefully synchronized, it greatly simplifies the distribution effort.

A water database must be able to serve data in a variety of standard formats. Protocols for exchanging water quality data are yet to be established. In the interim, delivery in a tab-delimited format (which is easily imported into spreadsheets) may be sufficient for many applications. Electronic data delivery upon request is equivalent to the "just in time" delivery systems used in many industries. "Just in time" delivery, besides being cheaper and more convenient for users, ensures that users have the most current and correct data.

EXAMPLES OF DATA SYSTEMS

STORET
(Storage and Retrieval System)

The EPA has established STORET as the national repository of water information to support State and Tribal monitoring programs, national water quality assessments, and Clean Water Act implementation. STORET contains water data from a variety of organizations across the country, from small volunteer watershed groups to State and Federal environmental agencies. States, Tribes, and Federal grantees are asked to directly or indirectly make their data available through the new STORET system.

STORET was modernized in 1999 to not only update its data model and database design, but also to link the data with metadata to ensure that the quality of the data is known. The modernized STORET system, version 2.0, was released in April of 2003. Those organizations that contribute data to STORET operate the system locally. The local STORET system is a data management system with data entry and reporting software modules that are installed using an EPA supplied CD-ROM. Once installed, the STORET system operates locally, allowing organizations to control access to the data and the rules for its internal use. Organizations can export copies of their entire STORET database to EPA for inclusion in EPA's national repository. Exportation to the EPA is encouraged but is not mandatory, and the frequency of submittal to EPA STORET is variable. STORET data in the national repository are extracted, transformed, and loaded into an Internet accessible data warehouse. Internet users can then browse and download monitoring data from the STORET data warehouse (http://www.epa.gov/STORET/).

The next version of STORET will operate within the National Environmental Information Exchange Network, where States and the EPA can exchange data using XML (Extensible Markup Language) format across EPA's node known as the "Central Data Exchange" (http://www. sso.org/ecos/eie/COMPLETE_BLUEPRINT_JUNE_01_FINAL.pdf).

The Florida Department of Environmental Protection (FDEP) STORET system (*accessed at* http://STORET.dep.state.fl.us) is an example of a distributed STORET system. Many local instances of STORET are uploaded into the FDEP system.

NWIS
(National Water Information System)

More than 800 Federal, State, and local agencies cooperate with the USGS in collecting data that are stored in NWIS. Water data come into NWIS from a variety of sources including real-time transmissions, field notes and field equipment, and from the USGS National Water Quality Laboratory. Access to NWIS data servers is limited to internal users and automated processes. In the NWIS data servers, the data are read, initially checked, and transformed as needed.

All public output from NWIS is through NWISWeb, which has replicating webservers at three dispersed locations. Much of the design of NWIS and NWISWeb satisfies the need to present real-time data from about 7,000 stations nationwide. Most of these stations report streamflow, but an increasing number of stations report real-time water quality data. NWIS contains 3.5 million discrete water quality data analyses for 1.5 million sites. Data initially entered into NWIS are assigned a "provisional" status, indicating that they have undergone essentially no review, except for threshold checking. At some point, usually within one year of collection, all data are reviewed, and may be adjusted based on equipment calibration and rating curves derived from field data. After review, data are given "approved" status.

The primary customers for NWIS data are USGS scientists and scientists from cooperating agencies. NWIS data form the basis for many USGS reports and papers. Although data have always been available to the public, the ease of retrieval through NWISWeb substantially increased accessibility of the data (NWISWeb served 172,000 distinct hosts in December of 2002). NWISWeb attracts a large following among recreational boaters and fishermen interested in streamflow, temperature, and other automatically sensed constituents. NWIS received the Grace Hopper Government Technology Leadership Award as one of the top 10 government technology achievements in 2002.

CONCLUSIONS

Data management serves a critical function in both preserving information and making that information available. Major water data systems such as STORET and NWIS were designed to serve agency missions. Although they are evolving towards common standards and practices, and the EPA and USGS are working on a portal to provide a more integrated view, much work remains to develop systems that can not only share data, but also meet the mission requirements of both agencies.

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ASSESS AND INTERPRET DATA

Dennis R. Helsel and Lindsay M. Griffith

Assessing and interpreting data is a challenge. It is a fundamental part of a "monitoring framework," especially if scientifically sound information is to be the basis for management decision making. In defining the 'assess and interpret data' cog in the monitoring framework, this article, due to limitations of length, focuses primarily on statistical methods – separating signals from noise

Statistical methods were first developed to interpret the results from designed experiments, but are now commonly applied to the "undesigned experiments" of environmental sciences. These observational studies measure the effects of variables such as climate or human interactions that are not under the control of the investigator. Conclusions from observational studies indicate associations but not necessarily causation. Trends are perhaps the clearest example. Detection of a trend does not prove that the change is caused by time, though time is used as the explanatory variable. The true causes are often unknown, and may not have been measured in the study. As a result, quantification of a past change is no guarantee that the trend will continue to occur, as future directions of the underlying causes are not known. Regardless, determination of an associative signal is still a vast improvement over qualitative opinions about observed data. One of the most unfortunate statements in scientific reports goes something like "water quality data were highly variable." They always are. It is our professional duty to see that data interpretation does not stop there.

DETERMINE WHETHER THE QUESTION IS "HOW OFTEN" OR "HOW MUCH"

It is crucial to specify whether questions are being asked about the frequency of occurrence, or about mass or volume. Defining the type of question leads directly to the type of statistical method to employ – **nonparametric** or **parametric** methods.

Questions of frequency are concerned with how often something occurs. The common question "Do two groups have similar values, or is one higher than the other?" is a question of frequency, more clearly seen if restated as "Are high values occurring more frequently in one group than the other?" Most questions asked of environmental data are questions of frequency. They are best answered using statistical methods that measure and test frequency distributions – nonparametric methods. Nonparametric methods are based on percentiles, represented by ranks, of the data. Measures of frequency (percentiles) and tests of frequency (nonparametric methods) best answer questions concerning frequency.

The distributions of two groups of data are presented as boxplots in Figure 1. Boxplots are based on percentiles, and are one of the most useful graphical methods for data analysis (Helsel and Hirsch, 2002). The answer to the question "Are concentrations generally higher in the first group than the second?" appears to be "yes." High concentrations are found more frequently in samples from the industrial areas than from the

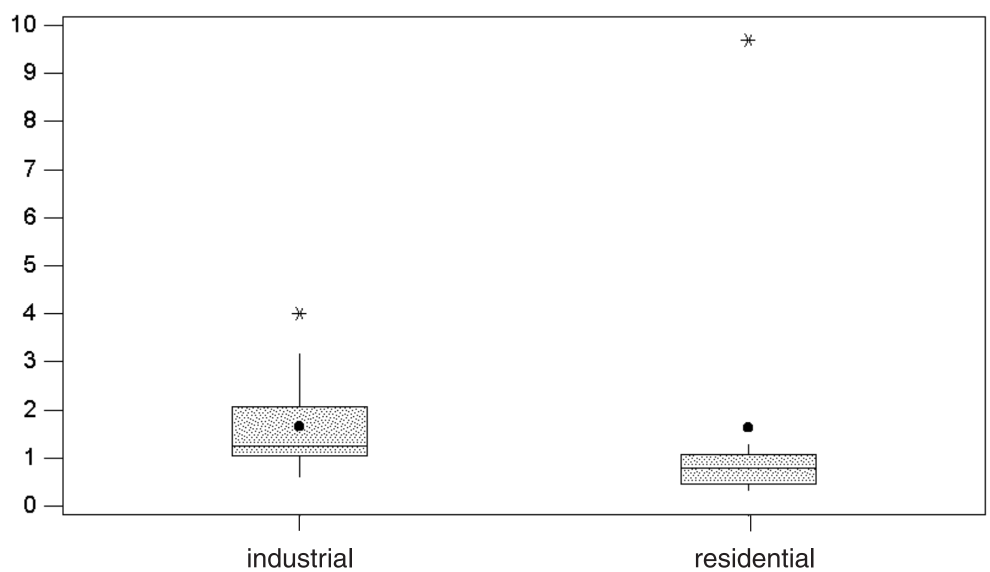

Figure 1. Boxplots of Nitrogen in Precipitation at Urban Sites. Means are shown as solid circles (from data cited in Helsel and Hirsch, 2002).

residential areas when tested by a (nonparametric) Mann-Whitney test.

The second type of question is concerned with how much has accumulated; these are questions of mass or volume. Of interest is the total sum, added together from many parts. Methods using the mean and standard deviation, called parametric methods, are the most appropriate type of statistical tests to answer questions of accumulated amounts.

The mean nitrogen concentration is shown as a solid circle for each group in Figure 1. Though frequencies differ, the mean concentration is nearly the same in each group. Samples from residential areas include one "outlier," an infrequent large value. This outlier contributes a large proportion of the nitrogen, and has a large influence on the mean for that group. If these data represented monthly values, and the amount of nitrogen falling in precipitation was of interest, the mean nitrogen concentration would be the appropriate measure to use in computing mass. Assuming similar rainfall amounts, the mass of nitrogen deposited would be roughly the same in these two areas, though occurring in differing patterns. The answer to the question "Is the mass of nitrogen deposition higher in industrial areas?" is "no." A (parametric) t-test finds no difference in the mean nitrogen concentrations for the two groups.

Therefore, it is very important to be clear on which question is being asked. Is it the frequency (pattern) of concentrations, or the accumulated amount? If it is frequency, use tests that measure frequency (nonparametric tests). If it is the amount, use tests that measure the amount (parametric tests). Using one type of test to answer a question about the other is flawed science, and may result in an answer that misses the mark.

It is sometimes suggested that data appearing to follow a normal distribution should be analyzed with parametric tests, while data that appear nonnormal be analyzed with nonparametric tests. This rule does not consider the question being asked, and is not necessary. Nonparametric tests are only about 4 percent less efficient than parametric tests when applied to data that exactly follow a normal distribution For data in the real world of monitoring, this rarely occurs. Nonparametric tests are either more powerful than parametric tests (for nonnormal data), or similar in power for approximately normal data (Helsel and Hirsch, 2002, Chap. 10). So there is little lost in using nonparametric tests on data that fail to be proven nonnormal. Parametric tests can also be applied to nonnormal data by first using power transformations such as the Box-Cox series, though issues with interpretation do result (tests on logarithms are testing the geometric mean, not the mean, for example). The most appropriate method is the one that best answers the question being asked – frequency or amount? This question is independent of and transcendent of the shape of any one particular data set.

MATCH OBJECTIVES TO METHODS

Objectives of the monitoring program should be the primary determinant of the statistical methods to be employed. In their review of data analysis methods for water quality monitoring, Griffith *et al.* (2001) demonstrate the great variety of methods currently being used. Often there was no supportive reasoning for why the methods used were chosen, even though method selection can dramatically affect the information produced. In order to produce transparent and comparable information from which to make decisions, the method should be chosen to match the stated objective. Listed below are five objectives covering most situations for which monitoring data are collected. For each objective, the types of statistical methods appropriate for use are briefly discussed.

... statistical methods were first developed to interpret the results from designed experiments, but are now commonly applied to the "undesigned experiments" of environmental sciences

Comparing Data to a Standard

Compliance is one of the primary reasons for which monitoring is conducted. Compliance determines whether a measured statistic falls above or below a defined standard.

Determine whether the regulation applies to measures of frequency or amount. For example, Section 303(d) of the Clean Water Act states that Total Maximum Daily Loads (TMDLs) are a measure of the allowed load or mass of some contaminant. TMDLs are in units of mass. Yet the legal standard states that no more than 10 percent of measured loads shall exceed the standard. This is in fact a question of frequency, with the 90th percentile the statistic that is compared to the standard. If the 90th percentile of samples is greater than the legal limit, and the samples were collected to represent the time period under regulation, then values exceeding the standard can be expected to occur more than 10 percent of the time, and the standard would be violated. Even though the mass of material is calculated as the "raw data," the statistic on which to judge compliance is a percentile. Quantile tests and associated confidence intervals on percentiles (also called tolerance intervals) may be used to determine whether significantly more than 10 percent of the measured loads exceed the standard.

Historically, water quality regulations in the United States have targeted the mean concentration. However, the use of a percentile to reflect a frequency goal is becoming more common. For example, Colorado's standard for acute ammonia toxicity states that the 85th percentile of unionized ammonia shall not exceed 0.02 mg/L as N.

The European Union has adopted a 95th-percentile standard for its rule on the Quality of Bathing Water (COM(2002)591) for both Intestinal Enterococci and Escherischia coli. High concentrations are allowed, but only infrequently.

Significance tests to compare data to a standard are known as "one-sample" tests, comparing one collection of data to a single number. The mean is compared to a standard using the one-sample t-test, the median using a one-sample Wilcoxon or sign test, and a percentile using the quantile test.

Comparing Data Under Differing Conditions

One of the most common situations in environmental monitoring is to compare concentrations at background sites to potentially contaminated areas, determining whether their levels are similar or different. A second common comparison is to detect differences among groups of data classified by some attribute, such as different land use types. For these comparisons, the most common objective is to answer "are data in one group generally higher than another?" This is a question of frequency. Classic nonparametric methods for comparing groups include the sign test, the rank-sum test, and the Kruskal-Wallis test.

Traditional statistical tests determine whether the true difference between group medians (or means) equals zero. As sample size increases, the precision in measuring this difference increases, perhaps so much so that measured differences can be smaller than those of practical concern. In reality, the difference is never expected to be exactly zero. It may not matter if the difference is small, as long as it doesn't exceed some limit large enough to be of concern. An alternative form of statistical test that determines whether differences are larger than an acceptable interval around zero, instead of whether differences are zero, is called an equivalence test. Used primarily in the health sciences, equivalence tests have been suggested for use in environmental science by McBride (1997). The cost of using these tests is that another parameter must be specified, the acceptable limit around zero within which groups are "equivalent." The benefit of using equivalence tests is that the limit determining similarity is set by the user, and is not a function of sample size.

Detecting Trends

The third monitoring objective is trend detection. "Is water quality getting better, or worse?" Restating the question as "are high concentrations getting more frequent, or less frequent?" shows this generic trend question to be one of frequency. The nonparametric test most often used for trend detection is the Seasonal Kendall test (Helsel and Hirsch, 2002). Often superimposed on the overall trend of natural systems is a regular seasonal variation, which can either be avoided if considered noise, or expressly modeled if considered part of the signal.

If mass or volume is to be tested for trend, parametric regression methods model the change in mean over time. Modern regression methods use diagnostics such as Mallow's Cp and PRESS to arrive at a good model, rather than more antiquated methods such as stepwise regression. Multiple regression models rival **deterministic models** in their ability to mimic and forecast changes in water quality.

Summarizing Spatial Patterns

A fourth monitoring objective is to collect data representing an area and then summarize results on a map. Colors define map categories, portraying either a classification ("meets objectives" versus "doesn't meet objectives"), a percentile (the 90th percentile; the median concentration) or a parameter (mean concentration). Data for mapping purposes could have been collected over a regular grid, or by a random sampling approach, or by using a stratified design with unequal weights representing a correlative variable such as population density.

When generating a spatial surface of the data, a variety of techniques may be used. The most common method is some variant of kriging, a least squares approach that generates a mean surface incorporating the spatial correlation between data. Ordinary kriging is appropriate if the mean is the appropriate statistic for display. Alternatives to ordinary kriging include spatial smooths, which produce a robust surface similar to a spatial median, and indicator and probability kriging, the latter of which maps percentiles for the data.

Forecasting to Unsampled Times or Places (Modeling)

Monitoring data are collected at a finite number of times and locations. It is often of interest to extend those results to other locations or times that are similar to the original data. Methods for forecasting include statistical models, often regression equations, and deterministic water quality models. Deterministic models are commonly used for research sites, where parameters such as soil permeability are known and conditions are more controlled. Statistical models are commonly used for larger areas, leveraging their ability to account for variations of unknown cause.

The simplest statistical model is to define an area considered similar in conditions to data collected in the monitoring program, and assign the attributes of the measured data to that entire area. The U.S. Environmental Protection Agency's Environmental Monitoring and Assessment (EMAP) Program collects data in a structured way so that the mean and standard deviation of the measurements within an area represents those for the entire area. This approach is most useful when the end product is a set of regional summary statistics, often displayed as a colored map.

A second statistical approach is to relate the variable being mapped through a regression equation to auxiliary variables measured at greater spatial detail. Regression models provide a way to introduce greater detail into map products than would be possible by interpolating a surface using only the mapped variable itself. For each location where the auxiliary variables are defined, the regression equation is used to predict a value for the mapped variable of interest. Probabilities of exceedance may also be estimated using logistic regression and interpreted as the probability that some threshold concentration is exceeded, or the probability that a specific condition is present.

Adding process understanding to regression models takes a step towards interpreting true cause, and can increase the spatial accuracy of patterns if the cause is correctly discerned. The SPARROW model (Smith *et al.*, 1997) adds instream parameter decay coefficients to regression relationships in order to produce a more accurate spatial picture of water quality within stream segments. Causes for changes in water quality concentrations once a chemical reaches the stream are explicitly modeled. SPARROW is one example of integrating deterministic and statistical modeling techniques, a direction likely to increase in the coming years.

Deterministic water quality models take the next step towards the goal of process understanding. These models attempt to quantitatively represent the transformation and transport processes occurring in natural systems. If deterministic models correctly reflect the understanding of how water quality changes, and if that understanding is sufficiently correct, these models provide an unsurpassed look at how water quality changes over space and time. However, the reality is that the complexity of changing quality is rarely capable of being summarized by the models existing today. Local scale variation can be modeled more adequately than variation at regional scales.

USE STATISTICAL METHODS WHEN DETERMINING COMPLIANCE

Compliance is usually judged by directly comparing a computed mean or percentile to the numeric standard. This approach ignores the inherent noise in the process that would be evaluated by a test of significance. As highlighted by Smith *et al.* (2001), failure to consider the inherent noise when judging compliance results in potentially frequent errors. Standard practice for TMDL legislation is to compute the percentage of observed loads that exceed the numeric standard. If more than 10 percent of the load measurements exceed the standard, the stream segment is considered in violation. Smith *et al.* (2001) demonstrate that if streams actually in compliance are sampled nine times, the probability that at least one sample will exceed the standard, and therefore cause the stream to be declared out of compliance, is 61 percent. It is very easy to have more than one of nine observations exceed a standard simply by chance, resulting in a high rate of false noncompliance. As an alternative method, they suggest using significance tests such as the binomial test (also called the quantile test) to evaluate the probability that a frequency is truly below or above 10 percent.

USE SOFTWARE WITH SUFFICIENT ACCURACY AND PRECISION TO ACCOMPLISH GOALS

Statistical software is expensive in relation to most common office software that is in much wider use. Therefore, it is tempting to cut costs by purchasing software capable of only "business statistics" – simple spreadsheet computations lacking modern statistical tools for proper analysis of environmental monitoring data.

In 2002 the American Statistical Association set out guidelines for the teaching and use of statistics. Within their recommendations document (*available at* http://www.amstat.org/education/ASAendorsement.html) they make this statement:

> "Efficient computing tools are essential for statistical research, consulting, and teaching. Generic packages such as Excel are not sufficient even for the teaching of statistics, let alone for research and consulting."

Statistical routines necessary for adequate analysis of environmental data include the attributes described below. Obtaining software that includes these attributes is a small investment in comparison to the large potential costs resulting from flawed monitoring decisions. Business statistics software generally does not include these attributes.

Continuity Corrections – Instead of storing exact tables for distributions of test statistics, software approximates these "p-values" using standard statistical distributions such as the normal, the t, and the chi-square. Continuity corrections increase the precision of these approximations for the smaller (less than 50) sample sizes common to environmental studies.

Tie Corrections – Statistical tests are developed for the situation where no data are tied. Environmental data often contain many tied values, especially where nondetects are present. Corrections for the occurrence of tied data can change the outcome of a test.

Ability to Handle Unequal Numbers of Observations – Formulae that account for unequal numbers of samples common to environmental studies are not available in most business statistics software.

Modern Graphics – Modern methods for graphical analysis, including boxplots, smooths, and residual and probability plots, are required to understand what data are saying.

Regression Diagnostics – Diagnostic measures such as Mallow's Cp, PRESS, and influence statistics allow the investigator to quickly build a good regression model describing the system under study.

Methods for Censored Data – Simplistic methods such as substitution of one-half the detection limit for censored data often leads to erroneous conclusions (Helsel, 1990).

Kaplan-Meier and maximum likelihood methods are standard practice for analyzing censored data in other disciplines.

CONCLUSIONS

Objectives of the study should be the primary determinant of the statistical methods to be employed. Clarify the question being asked, and use an analysis method that addresses the question. Account for the noise inherent in all data when making a decision on compliance. Use adequate software to save time, and ultimately money, by avoiding inaccurate results, poor models, and decisions based on inadequate information.

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CONVEYING RESULTS AND FINDINGS

Mary Ambrose, Abby Markowitz, and Charles Job

Well you have gotten this far – you have identified your objectives and purpose, you have designed your monitoring program/study, successfully collected and analyzed your samples, created a data base that allowed you to analyze the data and assess the results of your program/study – now it is time to communicate the results of your monitoring program/study. Most of us have experience in writing papers, giving speeches, and briefing management. This paper serves as a reminder of the some of the key components that you should keep in mind as you go through this phase of the NWQMC Monitoring Framework.

Most water quality reporting describes the water quality situation in terms that can be readily understood by the target audience. Many, if not most, of the people who read reports of water quality conditions are not specialists. Simple, clear explanations and graphics are essential for effective communication. However, communicating monitoring results in a format that can be understood by a variety of audiences goes beyond charts, graphs, and plots. Citizens in the watershed need to understand the results to understand the causes and sources of water quality impairments. Decision makers need to understand the results to develop effective management strategies. Managers need to understand the results to support future monitoring efforts.

By examining the building blocks of effective outreach we can begin to create a strategy that will communicate our results to a variety of people and communities. When developing communication strategies, we need to ask – and answer – these questions: What is our *objective*? Who is our *targeted audience*? What is the overall *message* we want to convey? What *format* are we going to use to convey the message? How will we *distribute* the message? How will we *evaluate* the success of this strategy? The answers to these questions will provide us with a blueprint for developing effective ways to communicate results to the widest possible audience (Council of State Governments, 1998; Markowitz, 2002; USEPA, 1996).

As you develop your communication strategy, you should communicate with those who conduct the monitoring. Hopefully as part of the initial monitoring design phase (Cog No. 2 of the Framework), consideration was given to how you were going to communicate the results of your study and the monitoring include the gathering of appropriate data for this message. After we have conveyed the information to the target audience, we also need to give feed back to the monitors to let them know if the data are adequate for the message.

WHAT IS OUR OBJECTIVE?

It is important to begin with a clearly articulated objective for communicating the results of your monitoring. Objectives should be put into statements and should be specific, results oriented, and include the desired outcome of the communication or outreach tool.

What is the main goal or objective for the communication tool you want to develop – what do you want to achieve? Do you want to use monitoring results to build watershed stewardship at the local level. Do you want to develop implementable TMDLs? Do you want to make people aware of a specific water quality problem? Do you want to use the information to address management or community concerns regarding the effectiveness of certain best management practices? These objectives should have been articulated at the time the monitoring project was formulated. If not, then you should give feedback to those who organize the monitoring program.

Existing water quality data are often analyzed to answer questions outside the initial design's purpose. In other words, existing data are being "mined" or "found" to obtain desired information. In this case, we need to understand that the resulting information may be challenged since it was not obtained from data collected for the information purpose now being communicated. We need to determine what we tell decision makers about the quality of the data and how it can (should) be used.

... developing increasingly successful communication strategies requires that we evaluate how well we did at each stage of the process and then use that evaluation to improve on future efforts

WHO IS THE TARGETED AUDIENCE?

Once you have a clear set of objectives, you can begin to identify the group – or groups – of people that you want to reach. Are they colleagues, managers, stakeholders, interested public, legislators, local and state government, or potential partners for future action? What is their interest?

It is important to learn about your intended audience by identifying and exploring some of the characteristics of that group, or community – learning about what is their common interest, what makes them tick, and what is their level of environmental awareness and values. The communication tools you develop should focus on their areas of interest and concern. Management concerns may focus on data completeness and quality and usability of the information for particular decisions while the interested public may be more concerned about the safety of their children or the clarity of the water.

Information, issues, ideas, and conclusions should be expressed and articulated in the context of the intended audience's values and concerns. Many characteristics are relevant in developing outreach tools, such as: geographic boundaries; demographic data; economic conditions and trends; employment; education; environmental awareness and values; governance; infrastructure and public services; local arts, history, and traditions; local leisure and recreation; natural resources and landscape; property ownership; existence of endangered species; and public safety and health.

WHAT IS THE MESSAGE YOU WANT TO CONVEY?

The next step is to articulate the overall message that you want to communicate. It is crucial to remember that the message needs to be specific to the target audience and have a direct connection or benefit to them. People are motivated by many things, including what they define for themselves as self-interest. For many folks, healthy streams, watersheds, and aquifers *are* part of their defined self-interest. But many people probably do not see the direct benefit to them of the water quality monitoring data. Keep the following acronym in mind – WIFM, better known as *what's in it for me*. In framing a message or messages, focus on the economic, cultural, and safety benefits, such as safe sources of drinking water, as well as the environmental benefits.

Often it is useful to frame the message in terms of *problems* (degraded water quality, erosion, storm water impacts, decreased biological diversity, violations public drinking water standards) and *solutions* (developing and implementing TMDLs, permit discharge limits, and best management practices). The monitoring results themselves are your primary tool for expressing the problem – use them to illustrate the problem. Strive to include specific actions that can be taken to resolve the identified problem. Make your message relevant to your audience by avoiding jargon and using examples that connect to people's real-life experiences – such as everyone drinks water.

Environmental indicators can be helpful to communicate complex results to the public. Developing easily understood indicators is critical to ultimately having environmental information appear in the public media (e.g., newspapers) on a regular basis. The concept and use of indicators to describe water quality conditions is a first step toward wide spread understanding of water quality conditions. The use of indicators addresses the multiple dimension problem associated with reporting information about the quality of the environment by reducing the complex to a concept that is easier to grasp. However, computation of indicators can take large volumes of data to accurately describe environmental behavior.

WHAT FORMATS WILL YOU USE
TO CONVEY THE MESSAGE?

The next question to be answered is: "What is the best way to convey the desired information to the intended audience?" This question addresses the ability of the user (audience) to understand information. What are the alternative ways of presenting water quality information? Your objectives, targeted audience, and message will all contribute to how you decide to package the information.

Most likely, any outreach strategy will include many communication formats. Examples include: newspaper articles, fact sheets, flyers, posters/displays, slide or video presentations, web sites, reports, data summaries, technical articles, technical conferences, development of educational lesson plans, public service announcements (PSAs), TV or radio interviews, and signs/billboards. Use what you know about your audience to help determine how to communicate your message. A report may not be the best way to reach to the local community. Those people might be best served by a permanent display in the park, or fact sheets posted in kiosks at the park entrances. However, a video presentation or graphic report might be a good way to educate managers on the results of your monitoring.

EPA has a web site (http://www.epa.gov/owow/monitoring/reporting.html) that contains information about reporting water quality data and includes additional links to various types of reports. The Consumer Confidence Reports for public drinking water systems have been evaluated (www.pirg.org/reports/enviro/water) and comments on these reports can provide insight into reporting water quality conditions to the public.

Communicating your results in a format that can be understood by a variety of audiences goes beyond charts, graphs, and plots. You have to match the format to the objective for the outreach or communication strategy. For example: a 30-second PSA does not allow for in-depth discussion of your data. However, that same PSA can be used to familiarize your audience with a environmental indicator and introduce a water quality objective. Fact sheets and brochures are also good vehicles for briefly identifying problems and solutions and showing some graphics (charts, data graphs, photographs) illustrating the message. Web sites are another excellent way to graphically display information – including monitoring results. With a series of links and menus, users can customize the amount of information they get – a lot or a little.

Reports are very useful formats for conveying lots of information in small pieces – through sections and chapters. Think of a report as a story or novel – with a beginning, a middle, and an end. Often, report chapters and sections can then be used as foundations for other tools – flyers, fact sheets, newspaper articles. Again, use your report structure to emphasize the problems/challenges and solutions/opportunities for change. The reporting format, selected to convey monitoring information, can influence the methods chosen to analyze the data. Thus, identifying the reporting format, before selecting data analysis methods, may help the monitoring system designer in narrowing the data analysis methods to be considered.

Another challenge is how can statistical results be presented in an easily understood manner? If tables of data or statistical findings are reported, these must be tailored to the user's ability to understand the information. Tables and statistical findings must also be related to the information goal so that the information users can readily 'see' the information he/she is to receive. Are indicators, such as suggested by EPA, more desirable for meeting the information goals? Or can 'water quality' be defined in a few key, indicator variables, using plots and tables for individual variables?

Another communication problem is the lack of standardization in water quality reporting formats. Consequently, there are probably as many reporting formats as there are communication goals. The lack of standardization in reporting water quality information places considerable responsibility upon the monitoring system designer in choosing an effective and concise manner for reporting water quality information. How long should the report be? How should the report be organized? What should it contain?

HOW SUCCESSFUL WAS THE COMMUNICATION EFFORT?

Distributing the message is not the end of the process. Developing increasingly successful communication strategies requires that we evaluate how well we did at each stage of the process and then use that evaluation to improve on future efforts. Finding ways to quantitatively measure changes in the environment due to outreach is very difficult. However it is possible to explore if people report any changes in the ways they interact with the physical environment. What were the connections between the message and any decisions to change the way people behave or to pass new regulations?

To evaluate the success of your communication strategy, go back to your original monitoring and communication objectives – and think about ways to determine if those objectives were met. Many of the strategies used to research and learn about an audience can be used as evaluation tools. Asking questions – through interviews, surveys, questionnaires, focus groups, polls – can tell us how well the message was received. Did the audience understand what we were trying to convey? Did the message reach the targeted audience? Were members of the audience able and motivated to take the message and convey it to others. Evaluations should also examine ways to improve. Ask members of your targeted audience what they might do differently. Would they choose other formats or distribution mechanisms? Finally, we need to give feedback to those who are developing the next round of monitoring objectives and designing the monitoring program and let then know if the data were adequate to convey the message.

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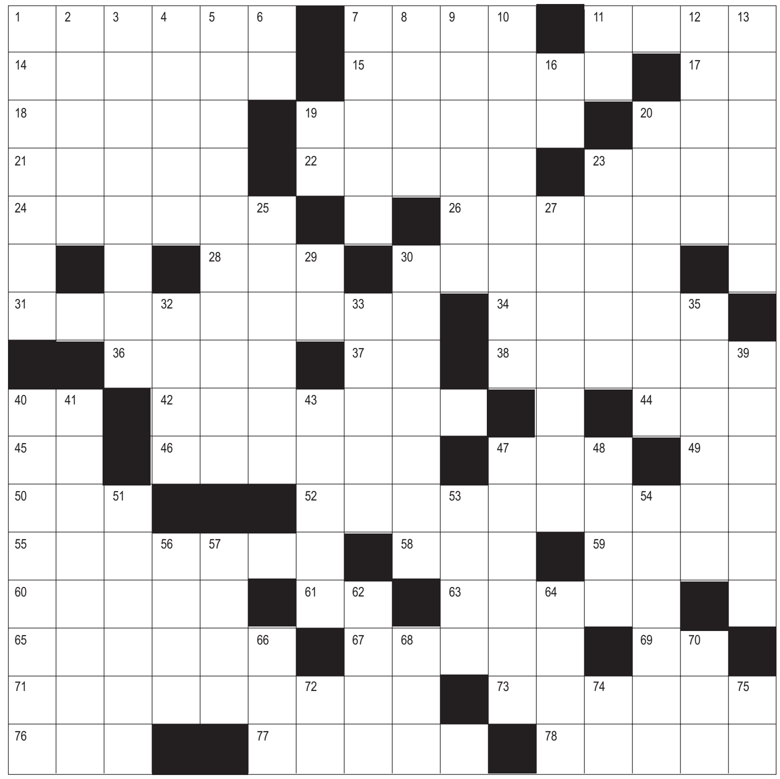
Water Resources Puzzler (answers on pg. 37)



ACROSS

1 *Water Resources* _____
7 hoopla
11 weathercock
14 almost
15 city in Italy
17 precedes suite or route
18 Carrie's dad
19 responsible person
20 our uncle?
21 "Easy _____"
22 follow
23 Seeger or Rose
24 Shaq to "the Answer"
26 Innocent and Urban
28 Ready! _____! Go!
30 a coming
31 emergency landing areas
34 organic compounds
36 followed by tree or horn
37 predecessor of a CD
38 degrade
40 college degree
42 Platte R. tribe
44 "A Boy Named _____"
45 Laotian monetary unit
46 predecessor of 1 ACROSS
47 be ill
49 symbol for chlorine
50 reserved
52 Hale and Hubble
55 artificial tears
58 Edison's inv.
59 an edible rootstock
60 to thrash
61 Palmetto st.
63 _____ common denominator
65 a reprimand
67 type of beam
69 second tone
71 traveling
73 aces
76 anagram for sew
77 Sadat's dam
78 fandango or bunny hug

DOWN

1 moment of _____
2 press
3 canoers
4 Shakespearian spirit
5 a raised construction
6 The GA Peach
7 homonyn for sent
8 anagram for sent
9 synonyn for sent
10 antonyn for sent
11 active verb (gram.)
12 below (poet.)
13 to entangle
16 the Granite st.
19 the Pine Tree st.
20 colonizes
23 _____ Penh
25 peruse again
27 commonly available
29 calculator brand
30 mineral pitch
32 Iranian monarch
33 preceded by home or boiler
35 it flies?
39 Admiral or Ozzie
40 low river stage
41 C_2H_4
43 they are beaten?
47 napping
48 land parcels
51 fermenting fungi
53 congers
54 benefactor
56 to long fo
57 _____ vera
62 chela
64 dry
66 gun lobbying org.
68 dentist's org.
70 et al.'s cousin
72 an esker
74 the sixth tone
75 symbol for atomic no. 34

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WATER ON WALL STREET

Clay J. Landry and Rachel Cardone

The water sector at a global level has appeared sluggish over the last few months, perhaps reflecting the doldrums of summer, maybe due to the ongoing wars in Afghanistan and Iraq. Possibly the lag is a result of increased awareness about the risks to providing public services in developing countries that lack strong governance and regulatory mechanisms. This would suggest that Wall Street is taking notice of the challenges faced by the major water companies rather than the sector as a whole.

In spite of the sluggishness within water stocks, slow changes within the water sector are beginning to have an impact on the business. For example, the French and British giants have been on a path to reduce their operations and exposure in developing countries as well as a few developed countries. The companies are unwinding contracts with large capital requirements and have extended currency risks. The water sector took notice of the contract failures such as Manila, Buenos Aires, and Atlanta, and can be considered twice shy about pursuing more large scale deals. Some interesting numbers . . . in the first half of the year 2003, contracts serving 8 million people around the world have effectively been "lost" – not including the additional 12 million people whose services are expected to be "lost" by the pending partial deconsolidation of Northumbrian Water in the UK.

That said, in the same time frame, 13.9 million people have been "gained" in terms of contracts for water and wastewater services. In the current investment climate, where the larger private water companies, such as Veolia and Suez, are shying away from high risk ventures in developing countries, and where, seemingly, the big deals in the developed world have already been done.

Yet the absence of the large firms in the international market is opening new opportunity for smaller providers of niche services, whether for municipal and/or industrial supply, industrial and/or wastewater treatment, or for technology. These smaller firms are not the large private utilities that dominated the water sector in the 1990s and into 2000; instead they are smaller, often local firms who neither face large currency risks, nor are expected to raise capital themselves. Instead, investment banks and groups – often from within a country itself – are charged with financing the project (with or without multilateral or other support), thus separating out what was a more challenging aspect of the earlier incarnation of private sector participation.

Some examples of these include two privatization deals in China, where expatriate, Chinese run firms used local finance to reduce the often inherent currency risks associated with financing infrastructure. In Singapore's Singspring desalination deal, originally 70 percent was owned by Hyflux, a locally operated firm, while Suez Ondeo held 30 percent. Suez eventually sold its entire stake to Hyflux as part of its global strategic rethinking.

In the last month, some significant news items include United Utilities (UU), in the United Kingdom, looking to reduce its debt to equity ratio by GBP 1 billion by announcing a five for nine rights issue. United Utilities is challenged with raising enough capital to support the infrastructure required to meet the water and environmental services components of the EU Water Framework Directive. As they operate under heavy regulations for tariffs and price increases as well as for environmental considerations, financial gymnastics have become increasingly necessary to maintain a tenable cash flow position. As a result of the announcement, UU lost 8.8 percent of its value in one day.

The United Utilities' move had an impact on other water companies in the UK who are also struggling through the current review period that lasts through 2005. AWG, Pennon, Kelda, and Severn Trent's stock dropped on the same day due to thinking that the additional funding raised by United would reduce the amount of available financing to these other firms. Kelda managed to pick up an additional 3.9 percent in July, however, reflecting its streamlining strategy to focus on the core water business.

In Italy, the Galli Law that mandated aggregation of small towns at the local level several years ago is finally materializing into action. No less than six contracts have been signed between municipalities and companies – Acea with Suez Ondeo controlling three of the six, serving a population of nearly 5 million people. Ondeo Industrial Solutions has also won outsourcing contracts for industrial water services throughout Europe, and boasts over 200 contracts worldwide.

In the United States, second quarter earnings were released at the end of July: Calgon Carbon and Middlesex Water, two smaller companies, gained 9.3 percent and 10.3 percent respectively in the second quarter, with gains in sales of 15.7 percent and 3.04 percent, respectively. Although reported revenues from Ionics rose over US$11 million over the last year, the company reported a net loss of US$4.9 million for the quarter – netting out any gains. Artisan Resources reported second quarter growth of 9.4 percent compared with 2002 data. Artisan also underwent a stock split in June, increasing the number of shares outstanding by 1.3 million, although stock price fell in July by 4.3 percent.

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Water Industry Market Watch

Company	Ticker	Aug 11 Close	Share Price % Change	Exchange	52-Week High	52-Week Low	Yield	P/E	Revenues* Last Reported	Revenues* Year Ago	June 30 Close
Water Supply Sector											
American States Water	AWR	$24.00	-13.64%	NYSE	29.01	20.25	3.31	20.69	51.8	52.8	$27.79
Artesian Resources	ARTNA	$24.51	-32.85%	NASDAQ	36.5	24.75	3.21	20.62	9.5	8.6	$36.50
Birmingham Utilities	BIW	$17.25	-3.63%	American	20.75	16	3.38	-	3.4	3.5	$17.90
California Water Services	CWT	$25.89	-10.79%	NYSE	29.02	20.45	4.02	29.76	68	60.31	$29.02
Connecticut Water	CTWS	$25.62	-1.95%	NASDAQ	31.09	20.35	3.01	23.09	10.9	10.28	$26.13
Consolidated Water	CWCO	$14.15	-10.44%	NASDAQ	16	10.77	2.86	22.95	4.02	3.02	$15.80
Middlesex Water Co.	MSEX	$25.28	4.20%	NASDAQ	24.26	22.38	3.21	28.47	16	15.5	$24.26
Pennichuck Corp.	PNNW	$24.21	-1.78%	NASDAQ	32.39	23.22	3.55	31.49	4.05	3.95	$24.65
Philadelphia Suburban	PSC	$23.12	-5.25%	NYSE	25	16.02	2.34	24.18	80.49	71.7	$24.40
Suez	SZE	$15.18	-3.00%	NYSE	29.95	9.49	5.09	-	8248.69	8670.82	$15.65
Southwest Water	SWWC	$13.74	-2.62%	NASDAQ	18.19	11.24	1.67	30.82	36.11	28.2	$14.11
York Water Co.	YORW	$18.24	1.05%	NASDAQ	20.17	12.3	3.05	30.5	4.76	4.68	$18.05
Vivendi Environnement	VE	$18.76	-8.84%	NYSE	34	15.95	3.26	20.26	3019.67	3179.74	$20.58
Water Technology Sector											
Calgon Carbon Corp	CCC	$5.90	0.00%	NYSE	9.89	4	1.86	322.5	78.1	67.5	$5.90
Ionics Inc.	ION	$20.48	-10.57%	NYSE	31	15.7	-	104.14	90.9	79.5	$22.90
Millipore Corp.	MIL	$42.08	-5.03%	NYSE	44.31	27.25	-	26.17	196.37	176.12	$44.31
Pall Corp.	PLL	$22.31	-0.18%	NYSE	23.9	14.68	1.6	49.07	421.49	302.37	$22.35
Water Development Sector											
Cadiz Inc.	CLCIE.OB	$0.08	-44.29%	NASDAQ	11	0.1	-	-	-	-	$0.14
Intergrated Water Resources	IWRI.PK	$0.22	-12.00%	OTC	-	-	-	-	-	-	$0.25
Layne Christensen Co.	LAYN	$8.29	1.47%	NASDAQ	10.8	5.47	-	34.75	38.77	40.99	$8.17
Pico Holdings Inc.	PICO	$13.16	-0.30%	NASDAQ	17	8.05	-	-	5.9	5.1	$13.20
Southwestern Water Exploration	SWWE.PK	$0.20	0.00%	OTC	-	-	-	-	-	-	$0.20
Western Water Co.	WWTR	$0.15	-28.57%	OTC	1.21	0.17	-	-	-2.58	-4.25	$0.21

**Revenues presented are in $ millions and reflect cumulative second quarter revenues ended June 30

Suez reflects first half 2003 Ondeo cumulative revenues, VE reflects first half 2003 Veolia Water cumulative revenues both ending June 30, 2003.

SUBMITTING ARTICLES FOR FUTURE ISSUES OF IMPACT (see pg. 29)

Contact the Associate Editor who is working on an issue that addresses a topic about which you wish to write. Associate Editors and their e-mail addresses are listed on the inside front cover. You may also contact the Editor-In-Chief Earl Spangenberg and let him know your interests and he can connect you with an appropriate Associate Editor. Our target market is the "water resources professional" – primarily water resources managers and such people as planning and management staffers in local, state, and federal government and those in private practice. We don't pay for articles or departments. Our only recompense is "the rewards of a job well done."

Water Resources Continuing Education Opportunities

MEETINGS, WORKSHOPS, SHORT COURSES

OCTOBER 2003

5-10/Fluvial Geomorphology: Principles and Applications Short Course. Univ. CA White Mtn. Research Station, Owens Valley Lab., CA. **Contact** (760/872-4214; e: geomorph@wmrs. edu)

12-15/Strathkelvin Instruments Launching the ASR at WEFTEC. **Contact** James D. G. Lamond (+44 (0)141 576 5080; e: info@strathkelvin.com; w: www.strathkelvin.com)

17-18/9th Xeriscape Conf. – Water: Our Future - Our Legacy. Albuquerque, NM. **Contact** http://www.xeriscapenm.com

19-22/2003 AIH Annual Meeting & Conf. Atlanta, GA. **Contact** AIH, 2499 Rice St., Ste. 135, St. Paul, MN 55113 (651/484-8169; f: 651/484-8357; e: AIHydro@aol.com)

20-24/Wetland 2003 – Landscape Scale Wetland Assessment & Mgmt. Nashua, NH. **Contact** Assn. of State Wetland Managers (518/872-1804; e: aswm@aswm.org)

28-30/2003 Advanced Technical Seminar II "Seepage for Earth Dams". Boulder, CO. **Contact** ASDSO, 450 Old Vine St., Flr. 2, Lexington, KY 40507-1544 (859/257-5104; f: 859/323-1958; e: info@damsafety.org)

NOVEMBER 2003

2-5/AWRA's Annual Water Resources Conf. San Diego, CA. Contact AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; f: 540/687-8395; e: info@awra.org)

3-7/N. American Lake Mgmt. Soc.-Ann. Sym. Mashantucket, CT. **Contact** (w: http://www.nalms.org)

13-14/Conf. on Water Projects in Thailand. Bangkok, Thailand. **Contact** Ms. Nuchada Paradeevisut (+66 (0) 2254 8321-4; f: +66 (0) 2254 8320; w: www.abf-asia.com)

16-18/TMDL 2003. Chicago, IL. **Contact** (w: http://www.wef.org/TMDL03Call.pdf)

23-26/Banff Mtn. Summit 2003 – Mountains as Water Towers. Banff, AB. **Contact** Banff Mtn. Summit Office (403/762-6227; e: mountainculture@banffcentre.ca)

FEBRUARY 2004

2-4/6th Intn'l. Sym. on Hyd. Applications of Weather Radar. Melbourne, Australia. **Contact** Dr. Alan Seed, Bur. of Meteor. Res. Ctr., GPO Box 1289K, Melbourne, Australia (e: hawr2004@bom.gov.au; w: www.bom.gov.au/announcements/conferences/hawr2004/)

MARCH 2004

29-April 2/2004 Annual Conf. of the U.S. Society on Dams. St. Louis, MO. **Contact** U.S. Society on Dams, 1616 Seventeenth St., No. 483, Denver, CO 80202 (303/628-5430; f: 303/628-5431; e: stephens@ussdams.org; w: www.ussdams.org)

JULY 2004

11-14/Watershed 2004. Dearborn, MI. **Contact** Water Environment Federation (w: www.wef.org/Conferences)

CALLS FOR ABSTRACTS

OCTOBER 31, 2003 (Abstracts Due) – AWRA Spring Specialty Conference on "GIS and Water Resources III." May 17-19, 2004. Nashville, TN. Contact AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; f: 540/687-8395; e: info@awra.org)

DECEMBER 1, 2003 (Abstracts Due) – Joint AWRA/IWLRI-Univ. of Dundee Conf. on "Good Water Governance for People and Nature: What Roles for Law, Institutions, and Finance?" Aug. 29-Sept. 1, 2004. Dundee, Scotland. Contact AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; f: 540/687-8395; e: info@awra.org) **(see pgs. 38 & 39 for details)**

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AWRA Future Meetings

2003 MEETINGS

NOVEMBER 3-6, 2003
SAN DIEGO, CALIFORNIA • HILTON SAN DIEGO RESORT
AWRA's ANNUAL WATER RESOURCES CONFERENCE
Preliminary Program now available at www.awra.org

2004 MEETINGS

MAY 15-19, 2004
NASHVILLE, TENNESSEE • GAYLORD OPRYLAND HOTEL
AWRA'S SPRING SPECIALTY CONFERENCE
"GIS and Water Resources III"
Call for Papers on www.awra.org

JUNE 28-30, 2004
OLYMPIC VALLEY, CALIFORNIA
RESORT AT SQUAW CREEK
AWRA'S SUMMER SPECIALTY CONFERENCE
"Riparian Ecosystems and Buffers: Multiscale Structure, Function, and Management"

AUGUST 29-SEPTEMBER 1, 2004
DUNDEE SCOTLAND • APEX CITY QUAY HOTEL
2004 INTERNATIONAL SPECIALTY CONFERENCE
"Good Water Governance for People and Nature: What Roles for Law, Institutions, and Finance?"
Call for Papers on www.awra.org

NOVEMBER 1-4, 2004
ORLANDO, FLORIDA • SHERATON WORLD RESORT
AWRA's ANNUAL WATER RESOURCES CONFERENCE

Additional Info – www.awra.org

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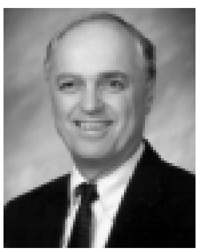
▲ 2003 Election Results
(take office effective January 1, 2004)

The AWRA Tellers Committee met on Friday, August 15, to compile the results of the 2003 election for Officers and Directors. Those persons elected for terms beginning January 1, 2004, are as follows:

PRESIDENT-ELECT
MELINDA (Mindy) M. LALOR
UNIVERSITY OF ALABAMA-BIRMINGHAM
BIRMINGHAM, ALABAMA

SECRETARY-TREASURER
D. BRIANE ADAMS
U.S. GEOLOGICAL SURVEY (RETIRED)
SNELLVILLE, GEORGIA



DIRECTOR
ROBERT BESCHTA
OREGON STATE UNIVERSITY
CORVALLIS, OREGON

DIRECTOR
DAVID R. WATT
ST. JOHNS RIVER WATER
MANAGEMENT DISTRICT
PALATKA, FLORIDA

▲ Ken Reckhow Resigns From Board

Kenneth H. Reckhow, AWRA Director since January 2002, has regretfully submitted his resignation from the AWRA Board of Directors, effective August 6, 2003. At its meeting on November 1, 2003, the AWRA Board will appoint a replacement to fulfill Ken's term, which runs through December 2004. One of Ken's focuses during his tenure as a Board member was bringing AWRA together with UCOWR and LIWR. This happened at the 2002 AWRA Annual Conference in Philadelphia. Thank you Ken for your services on the AWRA Board of Directors. You will be missed!

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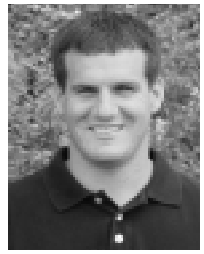
▲ AWRA Awards Herbert Scholarship for 2003-2004



JON E. SCHOONOVER of Auburn, Alabama, is the recipient of the 2003 Richard A. Herbert Memorial Educational Scholarship-Graduate Student Category. He is a Ph.D. student in the School of Forestry and Wildlife Sciences at Auburn Univ. Jon attended two years at Kaskaskia Junior College before transferring to Southern Illinois Univ. in Carbondale, Illinois. While at SIUC, he received his B.S. and M.S. degrees in the Dept. of Forestry. The emphasis of Jon's master's research was to compare giant cane and forest riparian buffers for their abilities to attenuate nutrients and sediment from overland flow, soil water, and ground water in an agricultural watershed. Currently, Jon's Ph.D. research is part of a large interdisciplinary effort looking at the effects of urbanization on forest sustainability. Jon's responsibilities include collecting water quality and geomorphology data from 30 watersheds across an urban/rural land use gradient. The data will be used to create regression relationships between water quality variables and land use. His career goal is to remain in academia and become a professor in the water resources field. "Continuing research would also be a high priority in my future," says Jon. He was the founding member and treasurer of the AWRA Student Chapter at SIUC, and is currently assisting with the organization of a student AWRA chapter at Auburn Univ. Jon is a member of the Society of Wetland Scientists (SWS), the Soil and Water Conservation Society (SWCS), and Xi Sigma Pi, a National Forestry Honor Society.

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Solution to Puzzle on pg. 33

I	M	P	A	C	T	■	S	T	I	R	■	V	A	N	E
N	E	A	R	L	Y	■	C	E	S	E	N	A	■	E	N
E	D	D	I	E	■	M	E	N	S	C	H	■	S	A	M
R	I	D	E	R	■	E	N	S	U	E	■	P	E	T	E
T	A	L	L	E	R	■	T	■	E	I	G	H	T	H	S
I	■	E	■	S	E	T	■	A	D	V	E	N	T	■	H
A	I	R	S	T	R	I	P	S	■	E	N	O	L	S	■
■	■	S	H	O	E	■	L	P	■	D	E	M	E	A	N
B	E	■	A	R	A	P	A	H	O	■	R	■	S	U	E
A	T	■	H	Y	D	A	T	A	■	A	I	L	■	C	L
S	H	Y	■	■	■	T	E	L	E	S	C	O	P	E	S
E	Y	E	W	A	S	H	■	T	E	L	■	T	A	R	O
F	L	A	I	L	■	S	C	■	L	E	A	S	T	■	N
L	E	S	S	O	N	■	L	A	S	E	R	■	R	E	■
O	N	T	H	E	R	O	A	D	■	P	I	L	O	T	S
W	E	S	■	■	A	S	W	A	N	■	D	A	N	C	E

AMERICAN WATER RESOURCES ASSOCIATION
Community, Conversation, Connections

IWLRI Water law • Water for all
international • national • transnational

Meeting Announcement & Call for Papers

AMERICAN WATER RESOURCES ASSOCIATION

In cooperation with
International Water Law Research Institute, IWLRI-University of Dundee

Presents an

INTERNATIONAL SPECIALTY CONFERENCE

GOOD WATER GOVERNANCE FOR PEOPLE & NATURE: WHAT ROLES FOR LAW, INSTITUTIONS, & FINANCE?

APEX City Quay Hotel • 29 August – 1 September, 2004 • Dundee, Scotland

OVERVIEW – Governance is a reemerging issue on the global agenda. It was a dominant issue at the Kyoto World Water Forum where major governance-relevant themes were carried forward from declarations and agendas from Johannesburg, Bonn, and The Hague. Debates over governance intensified in the 1990s over globalization and democratization, and with increasing concerns over economic inequality and quality of life. Clearly, "good" governance is an important prerequisite, together with political stability and transparency, in the global quest to alleviate poverty and, as part of this task, to increase real investments in the water sector – investments that will address the water needs of humans and the environment.

Good governance requires a sound legal foundation on which to build effective management institutions. The fragmentation of water laws, institutions, and management has long been discussed at water resources conferences, in textbooks, and journals. However, limited attention has been given to transforming best practices into real tools of implementation. What tools are available to watercourse States to assist with good governance at the national, transnational, and international levels? How can these be used to meet the Millennium Development Goals at the national and global levels?

Good water governance is an integral aspect of implementing integrated water resources management, particularly for people around the world who lack access to safe drinking water and adequate sanitation. Good water governance is a tool for fighting corruption, promoting sustainable water resources management, and alleviating poverty at the national level. At the transnational level, legal and regulatory frameworks can attract investments and promote equitable and efficient water services. In addition, international law can facilitate cooperation, negotiation, and the peaceful avoidance and resolution of conflicts over shared international watercourses.

This conference will examine the past, present, and future of water governance, specifically focusing on the relationships between legal and regulatory frameworks and institutional arrangements that effectively contribute to "good" water governance. Particular attention will be given to identifying real tools of implementation that facilitate good water governance on the ground – especially for the poorest people of the world. Although governments have the primary responsibility for implementing good governance, they cannot do it alone. New forms of workable partnerships need to be developed to achieve these ends.

A number of case studies will serve to highlight these good governance issues, and a number of these case study contributions will be drawn from UNESCO's Hydrology, Environment, Life and Policy Programme (HELP) and the Global Environmental Facility's International Waters Project. Through these case studies, participants will gain a water governance toolkit of characteristics of good water governance, common barriers and pitfalls to good water governance, and tips for implementing and promoting good water governance. National, international, and transnational contexts will be examined.

All Abstracts Are Due December 1, 2003

Submittals should be made online at www.awra.org

SUGGESTED PRESENTATION TOPICS

The Contexts of Water Governance

- Historical Studies and Comparative Perspectives on Water Governance and Law
- The Roles of Governments, Water Utilities, and Water Users in Governance (focus on Poverty Alleviation)
- Water Governance, Corruption, and Democratization: Comparative, Institutional, and Legal Issues
- Lessons Learned From Conflicts Over Globalization, Privatization and Water Governance
- Poverty and Gender Issues in Water Governance
- Effective Water Governance and Policies for IWRM and Sustainability

Water Governance in Transition

- Institutional, Economic, and Legal Reforms That Meet Millennium Development Goals
- Case Studies of Changing Governance Policies and Implementation Issues
- Globalization and Good Water Governance
- Accountability, Transparency, and Public Participation
- Accountability and Transparency Issues for Private Providers of Water and Sanitation Services
- Rediscovering Institutions – Partnerships, Capacity Building, and Performance
- Human Rights Issues and Legalizing a Human Right to Water
- Defining and Measuring Good Water Governance
- Bridging Globalization, Sustainable Development, and Good Governance: Local, National, Regional and Global Perspectives
- The Role of Donors in Implementing Good Governance

The Future of Water Governance: What Tools and Techniques for Effective Implementation?

- Effective Leadership and Capacity Building for Good Water Governance
- Challenges of Good Water Governance for Science and Law
- Water Security, Equity, and Justice Issues in Water Governance
- Legal Frameworks for Protecting Water Quality, Watersheds and Ecosystems
- Knowledge and Information Management Challenges for Good Water Governance
- Tools for Enabling Cooperation for Managing Shared Water Resources
- Water's Role in Achieving Sustainable Development: Legal, Economic, and Cultural Perspectives
- Bridging and Transforming the Disciplines for Good Water Governance
- Overcoming Fragmented Institutions, Management, and Laws

SPONSORING ORGANIZATIONS

American Water Resources Association (AWRA)
International Water Law Research Institute (IWLRI) of the University of Dundee

CO-SPONSORING ORGANIZATIONS

Global Environment Facility (GEF)
International Waters LEARN (IW: LEARN)
Inter-American Water Resources Network (IWRN)
International Joint Commission – US/Canada (IJC)
United Nations Educational, Scientific, and Cultural Organization/Hydrology, Environment, Life, and Policy Programme (UNESCO/HELP)

ORGANIZING COMMITTEE

Faye Anderson, AWRA International Committee (Conf. Co-Chair)
Patricia K. Wouters, Director, International Water Law Research Inst. (IWLRI)-Univ. of Dundee, Dundee, Scotland (Conf. Co-Chair)
Andrew A. Allan, International Water Law Research Institute (IWLRI)-Univ. of Dundee, Dundee, Scotland
Michael Bonell, UNESCO/HELP, Paris, France
Jeff Delmon, Allen & Overy, London, United Kingdom
Maria C. Donoso, UNESCO/PI, Montevideo, Uruguay
Alfred Duda, Global Environment Facility (GEF), Washington, D.C.
Gerald E. Galloway, Enterprise Engineering Group, Arlington, Virginia
Kenneth J. Lanfear, AWRA Past President, U.S. Geological Survey, Reston, Virginia
David W. Moody, AWRA Past President, Beaverwood Associates, Alstead, New Hampshire

FOR ADDITIONAL INFORMATION CONTACT

Faye Anderson
AWRA
Email: info@awra.org
Web Site: www.awra.org

or

Patricia K. Wouters
IWLRI-University of Dundee
Email: p.k.wouters@dundee.ac.uk
Web Site: www.dundee.ac.ak/law/iwlri

More Detailed Information Is Available At www.awra.org

AMERICAN WATER RESOURCES ASSOCIATION MEMBERSHIP APPLICATION – 2003

MAIL THIS FORM TO . . . AWRA • 4 WEST FEDERAL ST. • P.O. BOX 1626 • MIDDLEBURG, VA 20118-1626
FOR FASTEST SERVICE . . . FAX THIS FORM (CREDIT CARD OR P.O. ORDERS ONLY) TO (540) 687-8395
QUESTIONS? . . . CALL AWRA HQ AT (540) 687-8390 OR E-MAIL AT INFO@AWRA.ORG

➤ COMPLETE ALL SECTIONS (PLEASE PRINT)

LAST NAME FIRST MIDDLE INITIAL

TITLE

COMPANY NAME

MAILING ADDRESS

CITY STATE ZIP+4 COUNTRY

IS THIS YOUR ❑ HOME OR ❑ BUSINESS ADDRESS?

PHONE NUMBER FAX NUMBER

E-MAIL ADDRESS

RECOMMENDED BY (NAME) AWRA MEMBERSHIP #

➤ STUDENT MEMBERS MUST BE FULL-TIME AND THE APPLICATION MUST BE ENDORSED BY A FACULTY MEMBER.

PRINT NAME SIGNATURE

ANTICIPATED GRADUATION DATE (MONTH/YEAR): ______

➤ KEY FOR MEMBERSHIP CATEGORIES:

JAWRA – JOURNAL OF THE AWRA (BI-MONTHLY JOURNAL)
IMPACT – IMPACT (BI-MONTHLY MAGAZINE)
PROC. – 1 COPY OF AWRA'S ANNUAL SYMPOSIUM PROCEEDINGS

ENCLOSED IS PAYMENT FOR MEMBERSHIP (PLEASE CHECK ONE)
❑ FULL YEAR ❑ HALF YEAR

❑ REGULAR MEMBER (JAWRA & IMPACT) $130.00
❑ STUDENT MEMBER (IMPACT) FULL YEAR ONLY............................$25.00
❑ INSTITUTIONAL MEMBER (JAWRA, IMPACT, & PROC.).................$275.00
❑ CORPORATE MEMBER (JAWRA, IMPACT, & PROC.)....................$375.00
❑ AWRA MEMBERSHIP CERTIFICATE $6.00

➤ FOREIGN AIRMAIL OPTIONS: CONTACT AWRA FOR PRICING.

➤ PLEASE NOTE

* MEMBERSHIP IS BASED ON A CALENDAR-YEAR; AFTER JULY 1ST REGULAR, INSTITUTIONAL, OR CORPORATE MEMBERS MAY ELECT A 6-MONTH MEMBERSHIP FOR ONE-HALF OF THE ANNUAL DUES.
* STUDENTS DO NOT QUALIFY FOR HALF-YEAR MEMBERSHIP.
* REMITTANCE MUST BE MADE IN U.S. DOLLARS DRAWN ON A U.S. BANK.

➤ PAYMENT MUST ACCOMPANY APPLICATION

PAYMENT MUST BE MADE BY CHECK OR ONE OF THE FOLLOWING CREDIT CARDS:
❑ VISA ❑ MASTERCARD ❑ DINERS CLUB ❑ AMEX ❑ DISCOVER

CARDHOLDER'S NAME ______

CARD NUMBER ______ EXPIRATION DATE ______

SIGNATURE (REQUIRED) ______

➤ YOUR PRIMARY REASON FOR JOINING? (CHECK ONE)

❑ TO RECEIVE INFORMATION THROUGH JAWRA AND IMPACT
❑ NETWORKING OPPORTUNITIES
❑ TECHNICAL COMMITTEE INTERACTIONS
❑ CONFERENCE DISCOUNT
❑ EMPLOYMENT OPPORTUNITIES
❑ OTHER: ______

➤ HOW DID YOU LEARN OF AWRA? (CHECK ONE)

❑ PROMOTIONAL MAILING
❑ INTERNET SEARCH
❑ JOURNAL (JAWRA)
❑ IMPACT
❑ BOSS/FRIEND/COLLEAGUE
❑ EMAIL RECEIVED
❑ OTHER: ______

AWRA
Community, Conversation, Connections

DEMOGRAPHIC CODES

(PLEASE LIMIT YOUR CHOICE TO ONE IN EACH CATEGORY)

JOB TITLE CODES

JT1	Management (Pres., VP, Div. Head, Section Head, Manager, Chief Engineer)
JT2	Engineering (non-mgmt.; i.e., civil, mechanical, planning, systems designer)
JT3	Scientific (non-mgmt.; i.e., chemist, biologist, hydrologist, analyst, geologist, hydrogeologist)
JT4	Marketing/Sales (non-mgmt.)
JT5	Faculty
JT6	Student
JT7	Attorney
JT8	Retired
JT9	Computer Scientist (GIS, modeling, data mgmt., etc.)
JT10	Elected/Appointed Official
JT11	Volunteer/Interested Citizen
JT12	Non-Profit
JT13	Other

EMPLOYER CODES

CF	Consulting Firm
EI	Educational Institution (faculty/staff)
ES	Educational Institution (student)
LR	Local/Regional Gov't. Agency
SI	State/Interstate Gov't. Agency
IN	Industry
LF	Law Firm
FG	Federal Government
RE	Retired
NP	Non-Profit Organization
TG	Tribal Government
OT	Other ______

EDUCATION CODES

HS	High School
AA	Associates
BA	Bachelor of Arts
BS	Bachelor of Science
MA	Master of Arts
MS	Master of Science
JD	Juris Doctor
PhD	Doctorate
OT	Other ______

WATER RESOURCES DISCIPLINE CODES

AG	Agronomy
BI	Biology
CH	Chemistry
EY	Ecology
EC	Economics
ED	Education
EG	Engineering
FO	Forestry
GR	Geography
GE	Geology
GI	Geographic Information Systems
HY	Hydrology
LA	Law
LM	Limnology
OE	Oceanography
PS	Political Science
OT	Other ______

PLEASE NOTE YOUR SELECTED CODE NUMBERS FROM ABOVE

JOB TITLE CODE .... ☐
EMPLOYER CODE .... ☐
WATER RESOURCES DISCIPLINE CODE............ ☐
EDUCATION CODE .... ☐

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