Applying knowledge to improve water quality
Volunteer Water Quality Monitoring
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Building Credibility:
Quality Assurance and Quality Control for Volunteer Monitoring Programs

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The ultimate goal of most volunteer monitoring programs is to ensure that well-trained volunteers collect high quality data and that the data are used. Despite decades of demonstrating that volunteers can and do collect representative data, government agencies, scientists and often the general public are sometimes reluctant to use data not collected by "experts". Therefore volunteer water quality monitoring programs must work especially hard to build and maintain credibility – some have even said, "twice as hard for half the recognition." This factsheet provides an overview of quality assurance and quality control issues and provides examples of methods used by Cooperative Extension and other volunteer monitoring programs to substantiate the credibility of their data.

Water quality monitoring data are typically gathered to support decision-making, whether it is for encouraging waterfront residents to convert lawns into vegetated buffers, for enacting local ordinances to strengthen wetlands protection or storm water management, or for regulatory action. In order to be useful, monitoring data must provide relevant information - if the concern is potential bacterial contamination, measuring turbidity or dissolved oxygen won't help much. And the data must be credible, which usually means that it is documented and defensible. Data of unknown quality are essentially useless, and useless data can potentially corrupt the decision-making process. Therefore incorporating a Quality System into your monitoring program is necessary for generating useful data.

Quality System Components: Assurance, Control and Assessment

Generating reliable data requires adherence to an overall quality policy or system, but what exactly makes up that system? The Quality System can most easily be thought of in terms of what you need to do *Before*, *During* and *After* your monitoring effort (Table 1). Three elements combine to form the Quality System: Quality assurance, control and assessment[1]. Developing your Quality System should be an iterative process and focused on how you intend for the data to be used. This system should be incorporated into every aspect of your monitoring program - the bedrock upon which your program is based.

Table 1. Data Quality System

Before - Plan	During - Implement	After - Assess
Quality Assurance	Quality Control	Quality Assessment
Study design Quality Assurance Project Plan Develop training program and materials	Training Follow the written monitoring manual Follow standard operating procedures (SOPs) Document changes Proficiency testing	Data proofing/review Outside performance evaluation Reconcile data with objectives Revise SOPs as needed

This is the sixth in a series of factsheet modules which comprise the Guide for Growing CSREES Volunteer Monitoring Programs, part of the *National Facilitation of Cooperative State Research Education Extension Service (CSREES) Volunteer Monitoring Efforts* project. Funded through the USDA CSREES, the purpose of this four-year project is to build a comprehensive support system for Extension volunteer water quality monitoring efforts nationally. The goal is to expand and strengthen the capacity of existing Extension volunteer monitoring programs and support development of new groups. Please see http://www.usawaterquality.org/volunteer/ for more information.

Quality System Components - continued

The phrase "quality assurance and quality control (QA/QC)" is so ubiquitous that it is easy to forget that the two components are not the same.

Quality assurance is the broad plan for maintaining quality in all aspects of a program. It guides the selection of parameters and methods, how data will be managed, analyzed and reported, and what steps will be used to determine validity of the selected procedures.

Quality control procedures are the mechanisms established to control errors and make analyses more accurate and precise (see glossary of quality terms on page 6-4). Quality control procedures help you discover a problem quickly, allowing timely action to be taken to remedy problems. They also offer confirmation that you are doing your work correctly.

Quality assessment is the process by which the various phases of data generation are reviewed after data collection. Assessment provides verification that sampling and analytical processes operated within analytical or operational limits and that enough data were collected to permit reasonable interpretation. Together these three components help ensure that the data will be reliable.

The Minnesota Pollution Control Commission's *Volunteer Surface Water Monitoring Guide* (http://www.pca.state.mn.us/water/monitoring-guide.html) is an excellent resource for understanding the quality system and its role in making your data useful.

Credible Data Laws

In recent years, a number of states have enacted "credible data" laws to ensure that data used for a variety of purposes, including development of impaired waters (303d) lists and Total Maximum Daily Load (TMDL) studies and other regulatory purposes, come from sources able to produce data of known quality. Typical language in these laws defines credible data as only data originating from studies and samples collected by a designated state agency or department, a professional designee of that governmental entity, or a qualified volunteer. The laws usually specify what information (i.e., monitoring or quality plan) and/or training is needed to be considered a "qualified volunteer." Some state laws also specify the types of data needed for various uses.

If you intend for your data to be used by your state agency, it is imperative that you determine early in the monitoring design process if your state has any such laws. If there are, work with potential data users to ensure that your methods and study design meet those requirements if possible.

Data Quality System: Planning

Study Design – The Foundation of Credibility

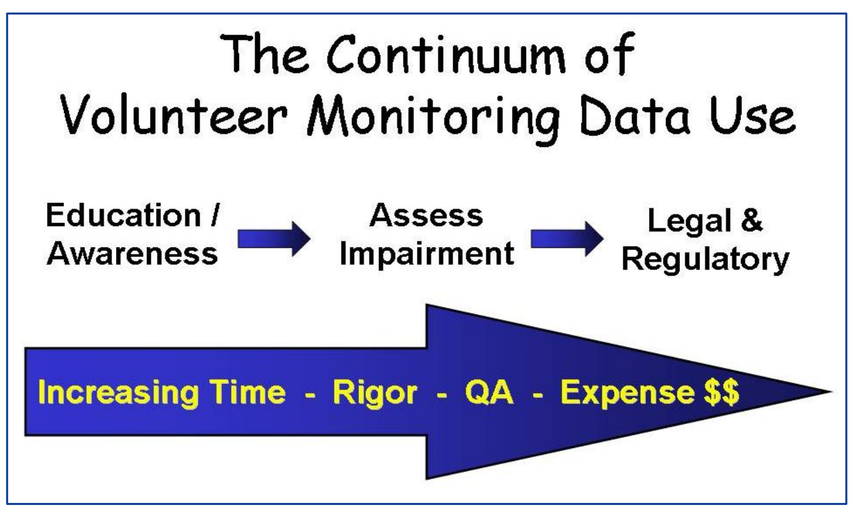
Building credibility begins with the study design process which is outlined in our *Factsheet IV Designing Your Monitoring Strategy* (http://www.usawaterquality.org/volunteer/Outreach/DesigningYourStrategy.pdf). By developing clear monitoring goals and questions, adhering to established monitoring procedures, and documenting all monitoring activities, a written study design document provides the framework for a strong monitoring program. An integral part of the study design process should be the development of your Data Quality Objectives.

Data Quality System: Planning (continued)

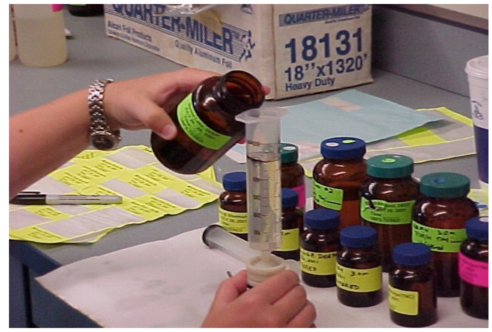
Data Quality Objectives

Data quality objectives (DQOs) are the quantitative and qualitative statements regarding the precision, bias, representativeness, completeness and comparability needed for your data to be considered acceptable (see glossary box for definitions page 6-4). These should be established prior to collecting the first sample. You will need to establish DQOs for both *sampling* and *analytical* activities. The USEPA provides detailed guidance for developing DQOs (available on-line at http://www.epa.gov/quality/qs-docs/g4-final.pdf.) Your data quality objectives should guide selection of sampling and analytical methods – match your methods to your data quality needs.

The *Continuum of Volunteer Monitoring Data Use* highlights an important consideration in identification of your DQOs - it takes significant resources to generate data of the highest quality, which depending on your data uses, may not be necessary. In essence - *the most important factor determining the level of quality is the cost of being wrong.* If the principle goal of your monitoring effort is to demonstrate the scientific process and to get students actively involved, using field kits with a low degree of resolution and high limit of detection may be acceptable - and reasonably priced. Identification of sites that should be further investigated by water resource agencies, often called “targeting,” is a common goal of volunteer monitoring programs, and requires a fair amount of QA/QC. The data have to be reliable enough for the agencies to be concerned that there is a potential problem, and divert their resources. But its often enough to know that a particular value “significantly exceeds the standard” rather than expending the resources to know that the value is exactly “1214.5.” However, if your goal is to identify areas of the watershed in need of installation of storm water management structures - the cost of installing those structures requires that your monitoring data be of high enough quality to justify that expense. Your data needs to be good enough to ensure that the areas contributing the most contamination are the areas being dealt with. In short, working with potential data users is critical for developing DQOs that meet potential uses without requiring excessive resources.



Geoff Dates - River Network



Glossary of Data Quality Terms

Chapter 3 of *The Volunteer Monitor's Guide to Quality Assurance Project Plans* contains detailed explanations of these concepts (http://www.epa.gov/owow/monitoring/volunteer/qapp/qappch3.pdf).

Comparability: The extent to which data from one study can be compared directly to either past data or data from a similar project.

Completeness: A measure of the number of samples and/or time period over which you must collect samples in order to be able to use the data.

Representativeness: The extent to which the measurements depict the true environmental condition. This term typically relates to where in your waterbody, how or how often you collect samples.

Precision: The repeatability of a measurement (how close your results are to each other; does not indicate how close they are to the true value).

Bias: The systematic or persistent distortion of a measurement process which causes errors in one direction (i.e., the expected sample measurement is consistently higher or lower than the sample's true value).

Detection Limit: The lowest concentration of a given constituent that a method or instrument can detect and report as a value greater than zero.

Sensitivity: The capability of a method or instrument to differentiate between different measurement levels, often expressed as resolution.

Accuracy: The closeness of a measurement to the true value. Accuracy includes a combination of random error (precision) and systematic error (bias) due to sampling and analytical operations. USEPA recommends that this term not be used. Instead, precision and bias should be used to describe the information usually associated with accuracy (EMAP 2002)

Put It in Writing – Developing a Quality Assurance Project Plan (QAPP)

A commonly stated obstacle to acceptance of volunteer-generated water quality data is concern about the ability of volunteers to monitor "properly." Uncertainty about the goals and objectives of the program, knowledge and ability of trainers, how training was done, methods used, how samples were collected, stored and analyzed may prevent data use. Having a detailed written record addressing all of those issues, commonly called a Quality Assurance Project Plan or QAPP, can help break through that skepticism.

In simple terms, a QAPP should document the QA/QC of your monitoring efforts - the *Who, What, When, Where, Why*, and *How*. Through documentation you help confirm the quality of your data, and allow others to determine if it meets their own data quality requirements. Just how detailed your QAPP needs to be may depend on the goals of your monitoring project and your anticipated data use.

In many states an approved QAPP is required for the data to be used by state agencies. For any project receiving USEPA funds, an EPA approved QAPP is required. Guidance for developing an EPA approved QAPP is available online (http://www.epa.gov/owow/monitoring/volunteer/qapp/qappch1.htm), and the New England Region website (http://www.epa.gov/region01/measure/qapp_examples/index.html) has examples of USEPA approved QAPPs. A number of volunteer monitoring programs also publish their QAPPs on-line, several of which are listed on page 6 - 5. Whether you are required to develop a QAPP or not, it is a useful planning tool which should flow from your study design process.

Briefly, an acceptable QAPP documents a logical thought process, identifies environmental questions to be answered, the step-by-step process to answer those questions, and includes checks to make sure it all works. Just copying someone else's QAPP or your standard operating procedures, monitoring methods or project work plan will *not* produce an acceptable QAPP. The process is as important as the product!

Selected Quality Assurance Project Plan On-line Resources:

Please consider these example QAPPs as guidance. Don't let them limit your thought process or your documentation of it (Table 2.) And never copy another program's QAPP – your data users and data needs will be different.

Alabama Water Watch (AWW) Quality Assurance Plan for Chemical Monitoring (1994, 63 pp.) http://www.alabamawaterwatch.org/Docs/manuals/chem-qaqc.pdf

AWW Quality Assurance Plan for Chemical Monitoring (2004, 37 pp.) http://www.alabamawaterwatch.org/Docs/manuals/NewAWWQAPlan211-2.pdf

AWW Quality Assurance Plan for Bacteriological Monitoring (1999, 63 pp.) http://www.alabamawaterwatch.org/Docs/manuals/QA%20Bact%20Manual_2004.pdf

Cook Inlet Keeper Citizens Environmental Monitoring Program QAPP (20 pp.) This USEPA approved plan was prepared for a marine ecosystem baseline monitoring program. http://www.inletkeeper.org/2005/Monitoring/qapp.htm

Data Quality Objectives (DQOs). Developed by Montana State University – Bozeman, this ecosystem restoration based web site provides stepwise guidance on developing DQOs. http://ecorestoration.montana.edu/mineland/guide/data/default.htm

Estuary-Net Project, a National Estuarine Research Reserve based program in South Carolina has the outline for their QAPP on-line, as well as sample quality control protocols for biological monitoring, including macroinvertebrates, fecal coliform bacteria, aquatic plants and intertidal organisms. http://inlet.geol.sc.edu/qaqchp.html

Instructions for the use of the Clean Water Team (CWT) Model Quality Assurance Project Plans (QAPPs) (12 pp.) Created by the California Environmental Protection Agency State Water Resources Control Board to assist volunteer monitoring groups developing QAPPs. Available as a Word document http://www.waterboards.ca.gov/water_issues/programs/nps/docs/mod_qapp_instr_deg1101.doc

Maine Volunteer Lake Monitoring Program: The QAPP ("Quality Assurance Project Plan") (11 pp.) This plan has been reviewed and approved by the USEPA, and can serve as an example of how a formal Quality Assurance Plan should be constructed. http://mainevolunteerlakemonitors.org/qapp.pdf

Preparing Quality Assurance Project Plans (QAPPs) (2000, 6 pp.) Created by the Kansas Department of Health and the Environment to assist volunteer monitoring groups develop QAPP http://www.kdhe.state.ks.us/nps/QAPPGuidance.pdf

Quality Assurance/Quality Control Plan for the Macroinvertebrate Biomonitoring of Black Brook and Occooch Watersheds in the Town of Aquinnah, Massachusetts (31 pp.) This 1999 USEPA approved plan includes helpful tables for QA/QC issues unique to macroinvertebrate monitoring. http://www.wampanoagtribe.net/resource/pdfs/qaqc.pdf.

Rapid Bioassessment In Wadeable Streams and Rivers By Volunteer Monitors (14 pp.) This rapid bioassessment method was developed by the Connecticut Department of Environmental Protection to replace its earlier Stream Watch program. Approved by US EPA its available in pdf at http://www.ct.gov/dep/lib/dep/water/volunteer_monitoring/qapp.pdf

Water Quality Monitoring - A How-To Guide – A publication of the Chehalis River Council, includes many elements of a monitoring manual as well as a QAPP http://www.crcwater.org/wqmanual.html#340.

Water Monitoring Quality Assurance Project Plan for the Yuba Watershed Council Monitoring Committee (45 pp.) This 2003 QAPP was developed for a multi-watershed assessment and education program . http://www.friendsofdeercreek.org/documents/QAPP%20Nov%202003.pdf.

What Are Quality Assurance Project Plans? (4 pp.) Prepared by the Hazardous Substance Research Centers, this factsheet is a good overview of QAPPs. http://www.envirotools.org/factsheets/fs_quality_assurance.pdf.

Put It in Writing (continued)
- Methods and Manuals:

A monitoring strategy that adheres to established monitoring procedures increases the comparability of data and reduces the skepticism associated with a "new" method without a "track record." Established methods typically have a known range of variation, precision and bias, facilitating the development of data quality objectives, as well as standard quality control procedures. Many established professional methods have been modified for use by the volunteer monitoring community, so incorporating those methods can simplify both your study design and quality assurance process (see box below for resources.) Factsheet IV of this series, *Designing Your Monitoring Strategy* has an extensive listing of monitoring procedures resources, including a large number of monitoring manuals that are available online (http://www.uwex.edu/ces/csreesvolmon/Outreach/designingyourstrategy.pdf.)

Providing a detailed written monitoring manual or protocols is another essential component of assuring data quality. In addition to being able to document how the monitoring was done, a written manual helps reduce the introduction of variations in procedures. Small differences in procedures often occur when trained trainers or volunteers train others. Having a manual to refer back to provides support to volunteers if they have a question in the field or lab and helps build their confidence in what they are doing. Providing a written manual also improves consistency from year to year and between monitoring sites helping produce credible information.

Identifying clear quality assurance expectations and roles for volunteers, program coordinators and trainers is critical for assuring data quality, is an important element of your QAPP, and should be included in your written manual. Clear understanding of these roles, such as" volunteers will attend annual training sessions," also contributes to successful volunteer recruitment, training and retention. Virginia's Save Our Streams program includes that information in very succinct and easy to understand language at the beginning of its webpage describing its QA plan (http://www.vasos.com/qualityassurance.htm).

Standard and Approved Methods

- The National Environmental Methods Index (NEMI http://www.nemi.gov) is a clearinghouse of environmental monitoring methods. The NEMI database contains method summaries for laboratory and field protocols for regulatory and non-regulatory water quality analyses, including performance data such as precision, bias, and relative cost.
- USEPA approved methods are available at http://www.epa.gov/waterscience/methods/. To facilitate access to those methods, an index is maintained by Region I (http://www.epa.gov/epahome/index/).
- Created to "secure the adoption of more uniform and efficient methods of water analysis", *Standard Methods for Water and Wastewater Analysis,* prepared and published jointly by the American Public Health Association, American Water Works Association and Water Environment Federation, has become an indispensable (although somewhat expensive) resource in most water quality laboratories. In addition to detailed explanations of a wide range of analytical methods, this encyclopedic work contains comprehensive discussions of basic assessment issues such as QA/QC, as well as laboratory health and safety, and techniques for minimizing wastes.

  Because most of the methods used by volunteer programs have been around for quite some time, using older editions of *Standard Methods* are acceptable. Reasonably priced used copies of past editions are widely available through book dealers, including on-line vendors. It is sometimes possible to get governmental or commercial laboratories to donate older editions. If you must remain current, subscriptions are also now available for the on-line format at http://www.standardmethods.org/. This subscription ensures that you are always up-to-date with the current methods but costs in excess of $200/year. Individual sections can also be downloaded for a fee, which is an inexpensive way of keeping up on specific methods.

Data Quality System: Implementing

Volunteer monitoring programs depend on the same mechanisms used by professional programs to control errors and make analyses more accurate and precise. These include monitor training and Quality Control (QC) procedures, both internal and external components, addressing both field and laboratory activities. Internal QC procedures are those that are performed within the monitoring programs by volunteers or professional staff. External QC procedures rely on an outside laboratory or non-volunteer field staff.

Monitor Training and Certification

Factsheet V of our series, *Training Volunteer Water Quality Monitors Effectively* (http://www.uwex.edu/ces/csreesvolmon/Outreach/EffectiveTraining.pdf), reviews some basic elements of successful training and provides some tips for improving your training strategy. It also includes links to many websites with more in-depth information about the science of learning and suggestions for developing more effective training programs.

Certification of volunteer monitors can be a formal or informal process. Some programs incorporate a formal procedure for certifying their volunteers, requiring documentation of participation in training activities and perhaps even successful passage of a certification exam. For example, the Alabama Water Watch program requires that volunteers monitoring chemical parameters complete both initial and annual recertification training workshops (https://www.auburn.edu/awwp/workshop_types.aspx). Maine Volunteer Lake Monitoring Program volunteers must attend a ½ day orientation, training and certification workshop before collecting and submitting data, then must attend a re-certification workshop at least once every three years. To facilitate recertification, a *Secchi Simulator & Virtual Secchi Re-Certification* tool was created (http://www.mainevolunteerlakemonitors.org/recertify/). If volunteers wish to receive advanced training to monitor other indicators, they must submit at least one year of Secchi transparency data first.

The Cook Inlet Keeper Citizens Environmental Monitoring Program uses a detailed Monitor Training Record to document successful completion of training in specific monitoring activities (http://www.inletkeeper.org/ 2005/ Monitoring/cemp_training%20_record.htm). Monitors with the Oklahoma Water Watch program complete quality control assessment forms annually (http://www.owrb.ok.gov/quality/monitoring/watch/wwatch.php#volunteer).

Many programs use a somewhat less formal approach with required attendance at classroom or field training sessions documented through the use of an attendance sheet rather than completion of an individual training report or log. Annual refreshers may be either formal training sessions, demonstrations at conferences or other events, or supplements to training manuals. Regardless of the degree of documentation, requiring participation in hands-on training is considered an essential element of quality control by most volunteer monitoring programs.

Internal Quality Control Procedures

Calibration with standards, analysis of reagent blanks, and analysis of duplicates and replicates, are internal QC procedures which can be used with both field kits and in the laboratory. Table 2 (page 6-11) includes common quality control measures and their applicability to some water quality parameters. These procedures can be performed by program volunteers, staff or a contract laboratory.

Internal controls should be incorporated into all phases of your program, both field and laboratory components (see glossary on page 6-10). For example, volunteers collecting and analyzing two or more samples from a site (often called field replicates or duplicates) assesses volunteer performance and natural variation in the environment and of the monitoring methods used. For instance, URI Watershed Watch program – URIWW (http://www.uri.edu/ce/wq/ww/index.htm) volunteers collect two separate samples for dissolved oxygen and for chlorophyll (field duplicate samples). Then two subsamples from each of those are in turn processed (sample replicates), a total of four analyses.

While the values used in water quality summaries are typically the average of those results, the values from each of those replicate analyses are stored in the program database. Having the volunteers provide the individual results (rather than the averaged results) provides documentation of inherent variations and can help spot any problems with the volunteers' sampling technique or field kit (either usage or reagents). For highly variable parameters such as chlorophyll concentrations, the use of multiple field samples is important for ensuring that data are most representative of actual conditions.

Another way of assessing volunteer performance with field kits is the use of test standards – samples made up in a lab to known concentrations. For example, the Massachusetts Water Watch Partnership (MWWP - http://www.umass.edu/tei/mwwp/index.html) sends dissolved oxygen test standards to its volunteers each season. The volunteers analyze the sample in the usual way, reporting their results to MWWP. The use of these test standards allows the MWWP to document that the volunteers are using the kits correctly and that the reagents are good. It can also help them spot and more importantly, correct problems during the season!

The use of lab replicates – or splitting samples for analysis in the lab is an effective means of assessing and documenting the precision of laboratory procedures. The use of calibration blanks and standards can be used in the lab or sent to the field with volunteers to assess both laboratory and field kit precision. Blanks are used to help set an instrument or meter to zero as well as checking for drift. They can also be effective for assessing potential contamination. Calibration standards, or samples of known concentrations made up in a lab, are also used to calibrate instruments, document accuracy or to test volunteer performance.

Quality is Mostly Assured by Repetition: The measurement of a single sample tells us nothing about its environment, only about the sample itself.

External Quality Control Methods

Proficiency testing or analysis of standards and unknowns from outside laboratories, and external data review are external QC methods that are critical for volunteer programs and significantly enhance the integrity of the data. **External quality control techniques typically require the participation of outside partners, laboratories or agencies.**

Participation in proficiency testing or performance evaluations through programs such as those promoted through the National Environmental Laboratory Accreditation Conference's (NELAC) Institute (TNI) is an effective means of gaining an unbiased third-party evaluation and recognition of laboratory performance (http://www.nelac-institute.org). Laboratories are able to purchase prepared samples for proficiency testing (PT) through TNI accredited providers. These "blind" laboratory tests occur during specific times each year. Typically there is a two-month window to analyze samples and return results to the PT laboratory for comparison against the results of other laboratories and the "true value". In addition to documenting your laboratory's performance, participating in TNI proficiency testing such as the Water Pollution or Water Supply tests provides useful information for helping you establish acceptable data ranges for replicates and duplicates for a variety of parameters. Information on laboratories providing these chemical calibration services can be found at http://www.nelac-institute.org/PT.php. Many of these companies also sell standards of known value which can be used to help calibrate instruments and to run regular checks of both instruments and field test kits reagents.

Enlisting outside partners or agencies to review your data is another effective quality control measure that can be especially important if they are potential data users. An external review can help identify potential oversights in your quality control efforts and address questions early on. It also ensures that your data collection and reporting activities are sufficiently logical for others to understand and are therefore more likely to be of value to others.

Working with outside partners to collect and process external field duplicates, samples collected at the same time and place as samples collected and processed by your volunteers, can help estimate both sampling and laboratory analytical precision. By demonstrating that they are capable of collecting data that are comparable to those data collected by professionals, external field duplicates can also be very effective at building the confidence of your volunteers and in your data (professionals trust their own data – and can see that yours are comparable). Setting up external field duplicate sampling events can be simplified if a few of your monitoring sites overlap with those of your state or a federal monitoring agency.

Suggestions for Assuring Accuracy

- Analyze blanks (field and lab)
- Analyze samples of known concentrations (standards)
- Participate in performance testing (from outside source)
- Collect & analyze duplicates
- Replicate 10-20% of samples
- Perform new analyses $\geq$ 7 times to familiarize yourself and establish acceptable

Glossary of Quality Control Checks

Detailed descriptions of these quality control techniques or checks can be found in Volunteer Estuary Monitoring: A Methods Manual (http://www.epa.gov/owow/estuaries/monitor/pdf/monitoring_manual.pdf; Chapter 5, starting on page 81 of the pdf). Most of these concepts apply to chemical, physical and biological monitoring (Table 2).

Internal Checks:

Field Blank: Also known as a "trip blank", a "clean" sample that is used to detect analytical problems throughout the whole monitoring process (sampling, transport, and analysis). A sample bottle is filled with distilled or deionized water, then treated exactly as the field samples are (kept in the same cooler, or having the same preservative added, etc.) A field blank should read as being free of the substance being tested for.

Field Replicates: Two samples collected at the same site, at the same time, using the same method and equipment, analyzed independently using the same methods. Often called 'duplicate samples' when only two samples are collected, these samples help define natural variability in the environment, variability caused by field sampling methods, and laboratory analysis precision.

Lab Replicates: A field sample that is split into two or more subsamples in the laboratory for analysis using the same techniques and instruments. A comparison of the results provides information about the precision of the laboratory measurements.

Spiked Samples: A known concentration of a substance (analyte of interest) is added to a sample. If done in the field, this assesses preservation, shipping, lab preparation and analysis. If done in the lab, it reflects the analytical procedure. The percent of the spike material recovered is used to calculate analytical accuracy.

Calibration Blanks: Deionized water processed like any other sample, which should always read as "0" when analyzed. Used as the first sample analyzed, this sets the instrument to zero. It also helps detect 'drift', and if compared to the field blank can help determine where contamination may have occurred.

Calibration Standards: Consisting of one or more 'standard concentrations', either made up in the lab to a specified concentration or purchased from a scientific supply vendor. These are used to calibrate meters, check instrument accuracy, and convert the units read from the meter or instrument to the reporting units (i.e. standard curve.)

Voucher (confirmation) collection: For biological monitoring, preserving a set of at least one good specimen (preferably 3 - 5) of each taxa found at a site. This can then be confirmed by an expert, and/or maintained as a long-term record.

External Checks:

External field duplicates: Duplicate field samples are collected and processed by an independent sampler (often a professional) at the same time and place as the volunteer. These samples are used to estimate sampling and laboratory analytical precision.

Split samples: A single, thoroughly mixed sample is divided into two or more sample containers and then analyzed by different analysts or labs. Results are compared to assess analytical precision or variability between laboratories or methods.

Outside lab analysis of duplicate samples: Either internal or external field duplicates can be analyzed by an independent lab. The results are compared with the project lab to assess analytical accuracy.

Knowns: Samples of known concentration are analyzed to assure that the instrument and methods are producing accurate results. This permits problems to be addressed during the analytical process.

Unknowns: Samples of unknown concentration are provided by a Q.C. lab or as part of proficiency testing process. These samples are analyzed, with results reported back to the issuing lab. Any discrepancies are reported to the project lab, which can address any problems identified.

Table 2. Common quality control measures and their applicability to some water quality parameters (Adapted from USEPA 2002)

Internal Checks	Field blanks	Field replicates	Lab replicates	Spiked samples	Calibration blank	Calibration standard	Voucher Collections
Bacteria	✓	✓	✓[a]		✓	✓	
Dissolved Oxygen		✓	✓			✓[b]	
Macroinvertebrates		✓[c]	✓				✓
Nutrients	✓	✓	✓	✓	✓	✓	
pH		✓	✓			✓	
Salinity / Conductivity	✓	✓	✓		✓	✓	
Temperature		✓				✓[d]	
Total Alkalinity		✓	✓	✓			
Total Solids	✓	✓			✓	✓	
Turbidity	✓	✓	✓		✓		

a - Includes using subsamples of different sizes
b - Using an oxygen-saturated sample
c - At least 10% of all sites to evaluate precision of the sampling technique or the collection team
d - Comparing to a National Institute of Standards and Technology certified thermometer

External Checks	External field duplicates	Split samples	Outside lab analysis	Knowns	Unknowns
Bacteria	✓	✓	✓	✓	✓
Dissolved Oxygen				✓	✓
Macroinvertebrates[e]	✓		✓	✓	✓
Nutrients	✓	✓	✓	✓	✓
pH	✓	✓	✓	✓	✓
Salinity / Conductivity	✓	✓	✓	✓	✓
Temperature				✓	
Total Alkalinity	✓	✓	✓	✓	✓
Total Solids	✓	✓	✓	✓	✓
Turbidity	✓	✓	✓	✓	✓

e - Working with a macroinvertebrate expert or outside lab is vital to ensure all taxa are correctly identified.

Data Quality System: Quality Assessment

Ensuring that the data your volunteers have gathered are useful does not end once all the values are determined. Assessing the quality of that information is a critical element that is sometimes overlooked.

Proofing the data that has been entered into your data management system is a relatively simple but important process. Typically this involves comparing the entered data to the original field or laboratory datasheet. Typographic or transcription errors can be easily caught at this stage – and can have a huge impact on data quality (consider the difference between a dissolved oxygen level of 0.9 mg/L and 9.0 mg/L). Because it is so easy to type information incorrectly, maintaining paper copies of datasheets is recommended even for programs that have their volunteers enter data directly into a data management system via the web. Then either the volunteers or (preferably) program staff can proof the compiled data later.

Quality Assessment (continued)

This proofing process is also a good opportunity to **review the data** to make sure it makes sense. Problems with reagents, sampling errors or simply writing down the wrong information can be identified just by examining the data for reasonableness. Some of these issues can be addressed through development of a data management system that has built-in error indicators or data entry tools. For example, the URI Watershed Watch Excel-based system includes tools that return an error message when Secchi depths values are greater than the bottom depth. The Wisconsin Water Action Volunteers (http://clean-water.uwex.edu/wav) web-based data entry system prevents entering habitat assessment scores beyond the range of available scores and automatically calculates dissolved oxygen percent saturation when both water temperature and dissolved oxygen in mg/L are entered, to avoid mistakes in calculation.

At this stage it is also important to **compare your data to your data quality objectives**. Evaluating your actual results against your original goals and objectives (your DQOs) will help determine if your program is meeting those goals, and if not, how it should be modified in order to do so. This process includes calculating and comparing your program's actual data quality indicators (i.e. precision, bias, completeness, etc.) to those that you specified when you planned your project.

This process should help you to identify (and build upon) program successes, as well as problems that need to be addressed. It may lead to discarding some data, setting limits on how some of the data may be used, or perhaps even revising your project objectives. For example, if your goal had been to collect weekly samples for bacterial analyses, but you found that it was not possible with the number of volunteers you had you may decide to seek additional volunteers. Alternately if the data show that particular sites are less variable than others, you may opt to have those sites monitored less frequently than others, and move volunteers to sites where the data suggest the need to be monitored more frequently.

Inviting an **outside performance evaluation** can be an effective way of objectively assessing your program. Such a review might be performed by the data users that you consulted with when you were developing your program. By working with an outside reviewer, it is often easier to identify the source of any errors, problems or perhaps potential solutions. It is also an opportunity to discuss any departures from your DQOs and what impact that might have on the usefulness of your information.

Quality Assessment (continued)

Once your assessment is complete, it is important that you document any changes to your DQOs, your monitoring methods or your standard operating procedures. The rationale for those changes as well as the specific changes made should be included in a revised QAPP or as a supplement. This provides a record for those interested in using your data and can also ensure that you "don't make the same mistakes" in the future.

Then the process should start all over again - use the information gathered through your assessment to improve your training materials, update your data sheets, or clarify your "crystal clear" written monitoring manual to address any discrepancies that may have crept in during the monitoring season. Use this process to strengthen your monitoring program - not hinder it!

Conclusion

Volunteer monitoring programs across the nation have demonstrated that citizen scientists are capable of collecting high quality data. By adhering to established principles of quality assurance and quality control and incorporating accepted monitoring procedures, many of these programs have built robust programs, boasting long-term data sets that would have been difficult to amass without volunteer effort. In fact a considerable strength of volunteer monitoring is its ability to conduct repetitive, regular monitoring. Volunteer programs are generally able to sample more sites, more frequently and often monitor more indicators than would be possible through state agency or contract-based monitoring alone. These often more comprehensive and long-term aspects permit natural variations to be more fully taken into account, resulting in data that are more representative of the ecosystem being monitored. This also allows minor differences that may result from volunteer inexperience or multiple monitors at one site to be identified and eliminated over time.

Volunteer water quality monitoring programs must rely on the same principles that professional programs do to ensure data quality - the quality system of assurance, control and assessment. By incorporating and documenting these elements into the entire program, acceptance of volunteer generated data can be improved. Working with potential data users, data quality objectives should be developed at the monitoring design stage and included in a written quality assurance project plan. Adhering to established monitoring methods increases not only confidence in the data, but also comparability with data collected by others.

Credibility of volunteer-generated monitoring data is further enhanced by the extensive training and written monitoring manuals and protocols that are common to most programs. Combined with regular (weekly or monthly intervals of monitoring) and repetitive (two and three samples collected or processed per sampling event) monitoring, and integration of QC procedures such as staff field visits and testing of standards, volunteer monitoring programs are eminently capable of producing data that are appropriate to a variety of resource protection and restoration uses.

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Quality Assurance and Quality Control for Volunteer Monitoring Programs

Quality Is Assured Through:

- Training and more training
- Written monitoring procedures
- Adhering to established procedures
- Repetition (replicate and duplicate sampling)
- Routine sampling (high frequency)
- Monitoring multiple indicators
- QA/QC field and laboratory testing
- Addressing your volunteers' questions

Conclusion (continued)

So what do you do if despite all your best efforts and strong QA/QC your state agency won't use your data? Help your community put it to use locally! By working with local organizations such as watershed associations, municipal governments, soil and water conservation districts, scouting groups, etc. you can encourage action that protects and restores vital community water resources. (Future project fact sheets will provide examples and suggestions of how monitoring data can be put to work.) Public understanding and acceptance of monitoring data can lead to the adoption of local ordinances, planting of streamside buffers, installation of agricultural best management practices and other activities. Having data of known quality makes it more likely that others will draw on your information.

Sharing your successes with other volunteer monitoring programs also strengthens the overall acceptance of volunteer-generated data. Reporting on case studies where volunteer data have been instrumental in achieving water resource restoration or protection helps overcome some of the skepticism associated with volunteer programs, enhancing all of our efforts. We are always looking for projects to report on, and examples to include in fact sheets and on our project website!

[1] Minnesota Pollution Control Agency - http://www.pca.state.mn.us/programs/qa_p.html

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