This document is Chapter 5 of the Volunteer Estuary Monitoring Manual, A Methods Manual, Second Edition, EPA-842-B-06-003. The full document be downloaded from: http://www.epa.gov/owow/estuaries/monitor/

Voluntary Estuary Monitoring Manual

Chapter 5: Quality Assurance Project Planning

March 2006

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Quality Assurance Project Planning

While information about an estuary's health is valuable, many government agencies, universities, and other groups are reluctant to use volunteer data. Why? Volunteer monitoring organizations sometimes overlook a critical fact: reliable data means everything. Unless data are collected and analyzed using acceptable methods, potential users are less likely to employ the data. A quality assurance project plan (QAPP) is vital to overcoming this obstacle.

Photos (l to r): Tillamook Bay National Estuary Project and Battelle Marine Science Lab, U.S. Environmental Protection Agency, U.S. Environmental Protection Agency

Overview

While information about an estuary's health is valuable, many government agencies, universities, and other groups are reluctant to use volunteer data. Why? Volunteer monitoring organizations sometimes overlook a critical fact: **reliable data means everything**. Unless data are collected and analyzed using acceptable methods, potential users are less likely to employ the data. A quality assurance project plan (QAPP) is vital to overcoming this obstacle.

This chapter examines the elements of a QAPP. In the process, it reviews basic concepts that must be understood before developing any QAPP.

For comprehensive instructions and useful examples for creating a QAPP, along with a sample QAPP form, the reader should refer to *The Volunteer Monitor's Guide to Quality Assurance Project Plans* (USEPA, 1996).

The Importance of High Quality Data

Although the goals and objectives of volunteer projects vary greatly, virtually all volunteers hope to educate themselves and others about water quality problems and thereby promote a sense of stewardship for the environment. Many projects, in fact, establish these as their goals. Such projects might be called primarily *education*-oriented.

Other projects seek a more active role in the management of local water resources and therefore strive to collect data that can be used in making water quality management decisions. Common uses of volunteer data might include local planning decisions (e.g., identifying where to route a highway); local priority setting (e.g., determining which seagrass beds require restoration); screening for potential pollution problems (which might then be investigated more thoroughly by water quality agencies); and providing data for state water quality reports (which might then be used for statewide or national priority setting). Projects doing this type of monitoring are called primarily *data*-oriented.

One of the most difficult issues facing data-oriented volunteer monitoring programs today is data credibility. Some potential users of volunteer data mistakenly believe that only professionally trained scientists can conduct sampling and produce accurate and useful results. Potential data users are often skeptical about volunteer data—they may have doubts about the goals and objectives of the project; how volunteers were trained; how samples were collected, handled, and stored; or how data were analyzed and reports written. Given proper training and supervision, however, **dedicated volunteers CAN collect high quality data** that is:

- consistent over time throughout the project's duration, regardless of how many different monitors are involved in collecting the data;
- collected and analyzed using standardized and acceptable techniques; and
- comparable to data collected in other assessments using the same methods.

The quality assurance project plan is a key tool in breaking down this barrier of skepticism. ■

What Is a Quality Assurance Project Plan?

The QAPP is a document that outlines the procedures necessary to ensure that collected and analyzed data meet project requirements. It serves not only to convince skeptical data users about the quality of the project's findings, but also to record methods, goals, and project implementation steps for current and future volunteers and for those who may wish to use the project's data over time.

Volunteer monitoring projects must adopt protocols that are straightforward enough for volunteers to master, yet sophisticated enough to generate data of value for resource managers. This delicate and difficult path cannot be successfully navigated without a QAPP that details a project's standard operating procedures (SOPs) in the field and lab, outlines project organization, and addresses issues such as training requirements, instrument calibration, and internal checks on how data are collected, analyzed, and reported. **Just how detailed such a plan needs to be depends to a large extent on the goals of the volunteer monitoring project**. For example, if you want to use your data to screen for problems so that you can alert water quality agencies, you may need only a basic plan. If, however, you want your data to support enforcement, guide policy decisions, or survive courtroom scrutiny, then a detailed plan is essential (Mattson, 1992).

Developing a QAPP is a dynamic, interactive process that should ideally involve quality assurance experts, potential data users, and members of the volunteer monitoring project team. The process is most effective when all participants fully contribute their talents to the effort, know their individual responsibilities for developing the QAPP, and understand the group's overall purpose and goals.

While it is a challenging and somewhat difficult process, the successful development and institution of a QAPP can be extremely rewarding. This chapter encourages and facilitates the development of volunteer estuary QAPPs by presenting explanations and examples. Readers are urged to consult the resources listed at the end of this chapter and to contact their state or U.S. Environmental Protection Agency (EPA) regional quality assurance staff for specific information or guidance on their projects. ■

Why Develop a QAPP?

The QAPP is an invaluable planning and operating tool that should be developed in the early stages of the volunteer monitoring project.

Any monitoring program sponsored by EPA through grants, contracts, or other formal agreement must have an approved QAPP. The purpose of this requirement is to ensure that the data collected by monitoring projects are of known and suitable quality and quantity.

Even if a volunteer monitoring project does not receive financial support from government agencies, the coordinating group should still consider developing a QAPP. This is especially true if it is a data-oriented project and seeks to have its information used by state, federal, or local resource managers. Few water quality agencies will use volunteer data unless methods of data collection, storage, and analysis have been documented.

Clear and concise documentation of procedures also allows newcomers to the project to quickly become familiar with the monitoring, using the same methods as those who came before them. This is particularly important to a volunteer project that may see volunteers come and go, but intends to establish a baseline of water quality information that can be compared over time.

Finally, written procedures in a QAPP can help ensure volunteer safety (Williams, 1999). Field safety requirements can be made part of standard operating practices, and proper training for equipment operation—a key element in any QAPP—takes user safety into account. ■

QAPPs and STORET

An updated, user-friendly version of EPA's national water and biological data storage and retrieval system, STORET, is now available. With STORET, volunteer programs can "feed" data to a centralized file server which permits national data analyses and through which data can be shared among organizations. A specific set of quality control measures is required for any data entered into the system to aid in data sharing. For more information, see the EPA Web page at www.epa.gov/storet.

Basic Concepts

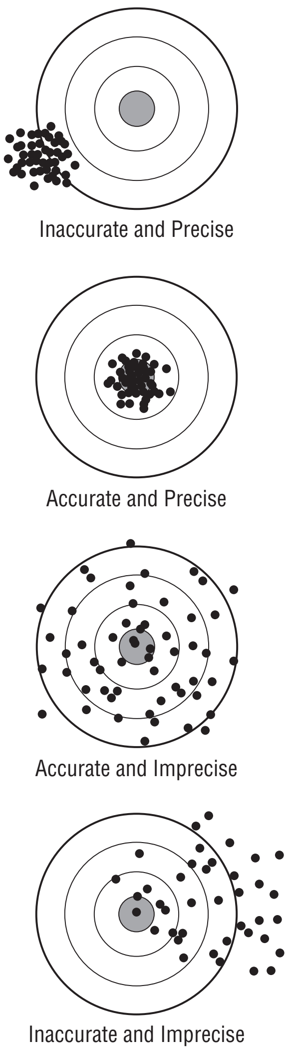


Figure 5-1. Accuracy and precision.

The coordinator of a volunteer monitoring program is likely to be involved in many aspects of project planning, sample collection, laboratory analysis, data review, and data assessment. The coordinator should be considering quality assurance and quality control in every one of these steps.

Quality assurance (QA) refers to the overall management system that includes the organization, planning, data collection, quality control, documentation, evaluation, and reporting of your group's activities. QA provides the information you need to ascertain the quality of your data and whether it meets the requirements of your project. It also ensures that your data will meet defined standards of quality with a stated level of confidence.

Quality control (QC) pertains to the routine technical activities in a project. The purpose of QC is, essentially, error control. Since errors can occur in the field, the laboratory, or the office, QC must be part of each of these functions and should include:

<u>Internal quality control</u>: a set of measures that the project undertakes among its own samplers and within its own lab to identify and correct analytical errors. Examples include:

- lab analyst training and certification;
- proper equipment calibration and documentation;
- laboratory analysis of samples with known concentrations or repeated analysis of the same sample; and
- collection and analysis of multiple samples from the field.

<u>External quality control</u>: a set of measures that involves both laboratories and people outside of the program. Measures may include:

- performance audits by outside personnel;
- collection of samples by people outside the program from a few of the same sites and at the same time as the volunteers; and
- splitting some of the samples for analysis at another lab.

Together, QA and QC help you to produce data of known quality, enhance the credibility of your group in reporting monitoring results, and ultimately save time and money. However, a good QA/QC program is only successful if everyone consents to follow it and if all project components are available in writing. The QAPP is the written record of your QA/QC program.

When formulating a QAPP, several measures will help to evaluate sources of variability and error and thereby increase confidence in the data. These measures are precision, accuracy, representativeness, completeness, comparability, and sensitivity.

Precision

Precision is the level of agreement among repeated measurements of the same parameter on the same sample or on separate samples collected as close as possible in time and place (Figure 5-1). It tells you how consistent and reproducible your methods are by showing how close your measurements are to each other. It does not mean that the sample results actually reflect the "true" value, but rather that your sampling and analysis are giving consistent results under similar conditions.

Precision can be measured by calculating the standard deviation, relative standard deviation (RSD), or the relative percent difference (RPD). Examples of each calculation are shown in Tables 5-1, 5-2, and 5-3.

The standard deviation (Table 5-1) is used to describe the variability of your data points around their average value. In case you're a bit put off by the math in Table 5-1, you might be happy to know that many calculators can calculate standard deviation for you! Very similar data values will have a small standard deviation, while widely scattered data will have a much larger standard deviation. Therefore, a small standard deviation indicates high data precision.

The RSD, or coefficient of variation (Table 5-2), expresses the standard deviation as a percentage. This measurement is generally easier for others to understand. Similar to standard deviation, your measurements become more precise as the RSD gets smaller.

When you have only two replicate samples, determine precision by calculating the relative percent difference (RPD) of the two samples (Table 5-3). Again, the smaller the relative percent difference, the more precise your measurements will be.

Table 5-1. Example calculation of standard deviation. A low value for standard deviation indicates high precision data. *(Adapted from USEPA, 1996.)*

The Volunteer Estuary Monitoring Project wants to determine the precision of its temperature assessment procedure. They have taken 4 replicate samples:

Replicate 1 (X_1) = 21.1°C
Replicate 2 (X_2) = 21.1°C
Replicate 3 (X_3) = 20.5°C
Replicate 4 (X_4) = 20.0°C

To determine the **Standard Deviation (S)**, use the following formula:

$$S = \sqrt{\sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n-1}}$$

where X_i = measured value of the replicate; $\bar{X}$ = mean of replicate measurements; n = number of replicates; and Σ = the sum of the calculations for each measurement value—in this case, X_1 through X_4.

First, figure out the mean, or average, of the sample measurements. Mean = (X_1 + X_2 + X_3 + X_4) ÷ 4. In this example, the mean is equal to 20.68°C.

Then, for each sample measurement (X_1 through X_4), calculate the next part of the formula. For X_1 and X_2, the calculation would look like this:

$$\frac{(21.1 - 20.68)^2}{4-1} = \frac{(-0.42)^2}{3} = \frac{0.1764}{3} = 0.0588$$

For X_3, the calculation would be 0.0108; and for X_4, it would be 0.1541.

Finally, add together the calculations for each measurement and find the square root of the sum: 0.0588 + 0.0588 + 0.0108 + 0.1541 = 0.2825. The square root of 0.2825 is 0.5315. So, the standard deviation for temperature is 0.532 (rounded off).

Table 5-2. Example calculation of relative standard deviation (RSD). A low RSD value indicates high precision data. *(Adapted from USEPA, 1996.)*

If we use the same measurements as in the standard deviation example (Table 5-1), we can determine the **Relative Standard Deviation (RSD)**, or coefficient of variation, using the following formula:

$$RSD = \frac{S}{\bar{X}} \times 100$$

where S = standard deviation, and $\bar{X}$ = mean of replicate samples.

We know that S = 0.5315 and that $\bar{X}$ = 20.68. So, the RSD = 2.57. This means that our measurements deviate by about 2.57%.

Table 5-3. Example calculation of relative percent difference (RPD). A low RPD indicates high precision data. *(Adapted from USEPA, 1996.)*

If the project had only two replicates (21.1°C and 20.5°C, for example), we would use the **Relative Percent Difference (RPD)** to determine precision, using the following formula:

$$RPD = \frac{(X_1 - X_2) \times 100}{(X_1 + X_2) \div 2}$$

where X_1 = the larger of the two values, and X_2 = the smaller of the two values. In this example, X_1 = 21.1° and X_2 = 20.5°. The calculation would look like this:

$$RPD = \frac{(21.1 - 20.5) \times 100}{(21.1 + 20.5) \div 2} = \frac{60.00}{20.8} = 2.88$$

So, in this example, the RPD between our sample measurements is 2.88%.

Accuracy

Accuracy is a measure of confidence in a measurement (Figure 5-1; Table 5-4). As the difference between the measurement of a parameter and its “true” or expected value becomes smaller, the measurement becomes more accurate. Repeated measurements that result in values at or near the “true value” would be considered accurate and precise.

Measurement accuracy can be determined by comparing a sample that has a known value, such as a standard reference material or a performance evaluation sample, to a volunteer’s measurement of that sample. Increasingly, however, some scientists, especially those involved with statistical analysis of measurement data, have begun to use the term “bias” to reflect this error in the measurement system and to use “accuracy” as indicating both the degree of precision and bias. For the purpose of this document, the term “accuracy” will be used to describe how close a measurement is to a standard value or the true value.

Table 5-4. Example calculations of accuracy. *(Redrawn and adapted from USEPA, 1996.)*

Attendance at QC training sessions is required for Volunteer Estuary Monitoring Project field teams. In the field, monitors use a pH kit, which covers a full range of expected pH values. During a recent training session, the monitors recorded the following results when testing a pH standard buffer solution of 7.0 units:

7.5	7.2	6.5	7.0
7.4	6.8	7.2	7.4
6.7	7.3	6.8	7.2

In this example, the volunteer coordinator may wish to evaluate accuracy in two ways:

Group Accuracy

To determine the accuracy of the full group of volunteers, the coordinator can compare the average of all sample values to the true value, according to the equation:

$$\textit{Group accuracy} = \textit{average value} - \textit{true value}$$

In this case, the average of these measurements is equal to 7.08 units. Since we know that the reference or "true" value is 7.0 units, the difference between the average pH value is "off" or biased by + 0.08 units. The volunteer program's QAPP should specify whether this level of accuracy is satisfactory for the data quality objectives of the project.

Individual Accuracy

While the average pH value calculated above is 7.08 units, a quick scan reveals that several measurements are up to 0.5 units from the true value. Such individual differences from the true value may not fall within an acceptable limit of accuracy, but they are somewhat "hidden" when the group accuracy is calculated. Simply calculating the group accuracy could overlook particularly erroneous data that should be addressed.

To assess the accuracy of individual measurements, the coordinator should use the following equation:

$$\textit{Individual accuracy} = \textit{individual value} - \textit{true value}$$

The possible cause(s) of individual accuracy values that do not fall within the program's QAPP should be determined and remedied.

For many parameters such as Secchi depth, no standard reference or performance evaluation samples exist. In these cases, the trainer's results may be considered the reference value to which the volunteer's results are compared. This process will help evaluate if the volunteer measurements are biased as compared to the trainer's.

If you are monitoring biological conditions by collecting and identifying specimens, maintaining a **voucher collection** is a good way to determine if your identification procedures are accurate. The voucher collection is a preserved archive of the organisms that your volunteers have collected and identified. An expert taxonomist can then provide a "true" value by checking the identification in the voucher collection. In addition to preserved specimens, the collection may involve photography or microscopy.

It is important to note that the relationship between a voucher collection and accurate identification cannot be expressed numerically in your QAPP. Rather, the QAPP should indicate that you have a voucher collection and describe how it is used to evaluate identification accuracy in your program.

Representativeness

Representativeness is the extent to which measurements actually depict the true environmental condition or population you are evaluating. The questions asked in your QAPP will be the guide for defining what constitutes a representative sample.

A number of factors may affect the representativeness of your data. Are your sampling locations indicative of the waterbody? Data collected just below a pipe outfall, for example, is not representative of an entire estuary. Similarly, a sample collected in August is not representative of year-round conditions. Other potential errors, such as lab mistakes, data entry errors, or the use of the wrong type of sample container, may also affect data representativeness.

Completeness

Completeness is a measure of the number of samples you must take to be able to use the information, as compared to the number of samples you originally planned to take. Since there are many reasons why your volunteers may not collect as many samples as planned (e.g., equipment failure, weather-related problems, sickness, faulty handling of the samples), as a general rule you should try to take more samples than you determine you actually need. This issue should be discussed with your QAPP team and by peer reviewers before field activities begin.

Completeness requirements can be lowered if extra samples are factored into the project. The extra samples, in turn, increase the likelihood of more representative data.

Completeness is usually expressed as a percentage (Table 5-5), accounting for the number of times that the volunteers did not collect data. An 80-90 percent rate of collection is usually acceptable.

Table 5-5. Example calculation of completeness. *(Adapted from USEPA, 1996.)*

The Volunteer Estuary Monitoring Project planned to collect 20 samples, but because of volunteer illness and a severe storm, only 17 samples were actually collected. Furthermore, of these, two samples were judged invalid because too much time elapsed between sample collection and lab analysis. Thus, of the 20 samples planned, only 15 were judged valid.

The following formula is used to determine **Percent Completeness (%C)**:

$$\%C = \frac{v}{T} \times 100$$

where v = the number of planned measurements judged valid, and T = the total number of measurements.

In this example, v = 15 and T = 20. In this case, percent completeness would be 75 percent. Notice that this percent completeness does not fall within the usually accepted range of 80-90 percent.

Comparability

Comparability is the extent to which data from one study can be compared directly to either past data from the current project or data from another study. For example, you may wish to compare two seasons of summer data from your project or compare your summer data set to one collected ten years ago by state water quality scientists. The key to data comparability is to follow established protocols or standard operating procedures. Comparing data also requires you to consider the conditions under which the samples were collected, including, for example, the season, time of day, and adjacent land uses.

Using standardized sampling and analytical methods, units of reporting, and site selection procedures helps ensure comparability. However, it is important to keep in mind that some types of monitoring rely heavily on best professional judgment and that standard methods may not always exist.

Sensitivity

Sensitivity refers to the capability of a method or instrument to discriminate between different measurement levels. The more sensitive a method is, the better able it is to detect lower concentrations of a water quality variable.

Sensitivity is related to **detection limit**, the lowest concentration of a given pollutant that your methods or equipment can detect and report as greater than zero. Readings that fall below the detection limit are too unreliable to use in your data set. Furthermore, as readings approach the detection limit (i.e., as they go from higher, easier-to-detect concentrations to lower, harder-to-detect concentrations), they become less and less reliable. Manufacturers generally provide detection limit information with their high-grade monitoring equipment, such as meters; however, volunteer groups should test the equipment themselves—using standards of progressively lower concentrations—to understand where the meter or method begins to have unacceptable accuracy.

Preassembled monitoring kits also usually come with information indicating the **measurement range** that applies. The measurement range is the range of reliable measurements of an instrument or measuring device. For example, you might purchase a kit that is capable of detecting pH between 6.1 and 8.1. If acidic conditions (below 6.0) are a problem in the waters you are monitoring, you will need to use a kit or meter that is sensitive to the lower pH readings.

Because all projects have different goals, data users and uses, capabilities, and methods, there are no universal levels of precision, accuracy, representativeness, completeness, comparability, and sensitivity that are acceptable for every monitoring project. You should consult your advisory panel, data users, support laboratory, and peer reviewers to determine acceptance criteria for your monitoring project. ■

Quality Control and Assessment

Contamination is a common source of error in both sampling and analytical procedures. QC samples help you identify when and how contamination might occur and assess the overall precision and accuracy of your data. The decision to accept data, reject it, or accept only a portion of it should be made after analysis of all QC data.

For most projects, there is no set number of field or laboratory QC samples which must be taken; the general rule is that 10 percent of all samples should be QC samples. Any participating laboratory must also run its own QC samples. For a new monitoring project or analytical procedure, it is a good idea to increase the number of QC samples (up to 20 percent) until you have full confidence in the procedures you are using.

Several different types of QC and assessment measures are presented below (USEPA, 1996; USEPA, 1997).

Internal Checks

Internal checks are performed by the project field volunteers, staff, and lab.

Field Blanks

A field blank (also known as a trip blank) is a "clean" sample, produced in the field, used to detect analytical problems during the whole process (sampling, transport, and lab analysis). To create a field blank, take a clean sampling container with "clean" water (i.e., distilled or deionized water that does not contain any of the substance you are analyzing) to the sampling site. Other sampling containers will be filled with water from the site. Except for the type of water in them, the field blank and all site samples should be handled and treated in the same way. For example, if your method calls for the addition of a preservative, this should be added to the field blank in the same manner as the other samples. When the field blank is analyzed, it should read as being free of the **analyte** (parameter being tested) or, at a minimum, the reading should be a factor of 5 below all sample results.

Negative and Positive Plates (for Bacteria)

A negative plate results when the buffered rinse water (the water used to rinse down the sides of the filter funnel during filtration) has been filtered the same way as a sample. This is different from a field blank in that it contains reagents used in the rinse water. There should be no bacteria growth on the filter after incubation. Bacteria growth indicates laboratory contamination of the sample.

Positive plates result when water known to contain bacteria (such as wastewater treatment plant influent) is filtered the same way as a sample. There should be plenty of bacteria growth on the filter after incubation. It is used to detect procedural errors or the presence of contaminants in the laboratory analysis that might inhibit bacteria growth.

Field Replicates

Replicate samples are obtained when two or more samples are taken from the same site, at the same time, using the same method, and independently analyzed in the same manner. When only two samples are taken, they are sometimes referred to as duplicate samples. These types of samples are representative of the same environmental condition and can be used to detect the natural variability in the environment, the variability caused by field sampling methods, and laboratory analysis precision.

Lab Replicates

A lab replicate is a sample that is split into subsamples at the lab. Each subsample is then analyzed using the same technique and the results compared. They are used to test the precision of the laboratory measurements. For bacteria, they can be used to obtain an optimal number of bacteria colonies on filters for counting purposes.

Spiked Samples

Spiked samples are samples to which a known concentration of the analyte of interest has been added. Spiked samples are used to measure accuracy. If this is done in the field, the results reflect the effects of preservation, shipping, laboratory preparation, and analysis. If done in the laboratory, they reflect the effects of the analysis procedure. The percent of the spike material that is detected in the sample is used to calculate analytical accuracy.

Calibration Blank

A calibration blank is deionized water processed like any of the samples; it is the first "sample" analyzed and is used to set the instrument to zero. A calibration blank is also used to check the measuring instrument periodically for "drift" (the instrument should always read "0" when this blank is measured). It can also be compared to the field blank to pinpoint where contamination might have occurred.

Calibration Standards

Calibration standards are used to calibrate a meter. They consist of one or more "standard concentrations" (made up in the lab to specified concentrations or provided by any number of supply houses—see Appendix C) of the indicator being measured, one of which is the calibration blank. Calibration standards can be used to calibrate the meter before running the test, or they can be used to convert the units read on the meter to the reporting units (e.g., converting absorbance to milligrams per liter).

> **Helpful Hint**
> *In addition to being used for meter calibration, standard reference material (in the form of solids or solutions with a certified known concentration of pollutant) can be used to check the accuracy of a procedure and the freshness of the reagents (chemicals) in test kits. If a known standard solution is tested and gives the correct concentration test result, the reagents are working properly and the procedure is being followed correctly.*

External Checks

Non-volunteer field staff and a lab (also known as a "quality control lab") perform external checks. The results are compared with those obtained by the project lab.

External Field Duplicates

An external field duplicate is a duplicate sample collected and processed by an independent (e.g., professional) sampler or team at the same place and the same time that the volunteers collect and process their regular water samples. It is used to estimate sampling and laboratory analysis precision.

Split Samples

A split sample is one that is divided equally into two or more sample containers and then analyzed by different analysts or labs. The results are then compared.

Samples should be thoroughly mixed before they are divided. Large errors can occur if the analyte is not equally distributed into the two containers. A sample can be split in the field, called a field split, or in the laboratory—a lab split. The lab split measures analytical precision, while the field split measures both analytical and field sampling precision. Split samples can also be submitted to two different laboratories for analysis to measure the variability in results between laboratories independently using the same analytical procedures.

Outside Lab Analysis of Duplicate Samples

Either internal or external field duplicates can be analyzed at an independent lab. The results should be comparable with those obtained by the project lab.

Knowns

The quality control lab sends samples for selected indicators, labeled with the concentrations, to the project lab for analysis prior to the first sample run. These samples are analyzed and the results compared with the known concentrations. Problems are reported to the quality control lab.

Unknowns

The quality control lab sends samples to the project lab for analysis for selected indicators, prior to the first sample run. The concentrations of these samples are unknown to the project lab. These samples are analyzed and the results reported to the quality control lab. Discrepancies are reported to the project lab and a problem identification and solving process follows.

Table 5-6 shows the applicability of common quality control measures to several water quality variables covered in this manual. ■

Table 5-6. Common quality control measures and their applicability to some water quality parameters. *(Adapted from USEPA, 1997.)*

	Dissolved Oxygen	Nutrients	pH	Total Alkalinity	Temp.	Salinity/ Conductivity	Turbidity	Total Solids	Bacteria
Internal Checks									
Field blanks		X				X	X	X	X
Neg./ pos. plates									X
Field replicates	X	X	X	X	X	X	X	X	X
Lab replicates	X	X	X	X		X	X	X	X[b]
Spiked samples		X		X					X
Calibration blank		X				X	X		
Calibration standard	X[a]	X	X			X	X		
External Checks									
Ext. field duplicates		X	X	X		X	X	X	X
Split samples		X	X	X		X	X	X	X
Outside lab analysis	X	X		X		X	X	X	X
Knowns	X	X	X	X		X	X		X
Unknowns	X	X	X		X	X		X	X

a—using an oxygen-saturated sample
b—using subsamples of different sizes

Developing a QAPP

Developing a QAPP is a dynamic, interactive process. Seek as much feedback as possible from those who have gone before you in the QAPP development process. You will be investing a substantial amount of time and energy, but don't be discouraged: the person who writes the QAPP is usually the one who ends up with the most technical expertise and monitoring insights. Your efforts will pay off in a living document that helps current and future volunteers, staff, and data users understand exactly how your project works.

The purpose of this section is to discuss the steps a volunteer monitoring program might take in preparing a QAPP (Table 5-7). It is recommended that you consult your data users, such as the state or county water quality agency, regarding their QAPP requirements. In fact, many states have prepared QAPPs that, if adopted by your group, can save a great deal of time. If you are receiving EPA grant or contract money to conduct your monitoring, you must also submit your QAPP to EPA for approval. Working with water quality agencies, EPA, and other potential data users to develop your QAPP increases the likelihood that your data will actually be used to make management decisions.

Table 5-7. Steps to develop a QAPP *(USEPA, 1996).*

1. Establish a QAPP team.
2. Determine the goals and objectives of your project.
3. Collect background information.
4. Refine your project.
5. Design your project's sampling, analytical, and data requirements.
6. Develop an implementation plan.
7. Draft your standard operating procedures and QAPP.
8. Solicit feedback on your draft SOPs and QAPP.
9. Revise your QAPP and submit it for final approval.
10. Begin your monitoring project.
11. Evaluate and refine your QAPP.

Step 1: *Establish a QAPP Team*

Pull together a small team of 2-3 people who can help you develop the QAPP. Include representatives from groups participating in the monitoring project who have technical expertise in different areas of the project.

Take time to establish contact with your state, local, or EPA quality assurance officer or other experienced volunteer organizations. Remember: If you are receiving any EPA funding through a grant or contract, EPA must approve your QAPP. However, even if EPA approval isn't needed, you can consult with EPA representatives for advice; they may have resources that can help you. Ask your contacts if they will review your draft plan.

Step 2: *Determine the Goals and Objectives of Your Project*

Why are you developing this monitoring project? Who will use its information, and how will it be used? What will be the basis for judging the usability of the data collected? If you don't have answers to these questions, you may flounder when it comes time to put your QAPP down on paper.

Project goals could include, for example:

- identifying trends in an estuary to determine if non-indigenous species occurrences are on the rise;
- monitoring in conjunction with the county health department to be sure a beach is safe for swimmers;
- monitoring the effectiveness of a submerged aquatic vegetation (SAV) restoration project; or
- teaching local high school students about water quality.

Write down your goal. The more specific your project's goal, the easier it will be to design a QAPP. Identify the objectives for your project—that is, the specific statements of how you will achieve your goal. For example, if your project's goal is to monitor an SAV restoration project, your objectives might be to collect three years of data on SAV beds, turbidity, algae, and nutrients, and to develop yearly reports for state water quality and fish and wildlife agencies.

Each use of volunteer data has potentially different requirements. Knowing the use of the collected data will help you determine the right kind of data to collect and the level of effort necessary to collect, analyze, store, and report the data.

While sophisticated analyses generally yield more accurate and precise data, they are also more costly and time consuming. One should closely examine the program budget when forming the data quality objectives. Decisions regarding the ultimate objectives must always strike a balance between the needs of the data users and the fiscal constraints of the program (Figure 5-2). If the program's main goal is to supplement state-collected data, for example, the extra expense may be worthwhile. Programs with an educational or participatory focus can often use less sensitive equipment, analyses, or methodologies and still meet their data objectives.

Step 3: Collect Background Information

As you learn more about the area you are choosing to monitor, you will be better able to design an effective monitoring project. Begin by contacting programs and agencies that might already monitor in your area. Talk to the state water quality agency, the county and/or city environmental office, local universities, and neighboring volunteer monitoring programs. Ask about their sampling locations, the parameters they monitor, and the methods they use.

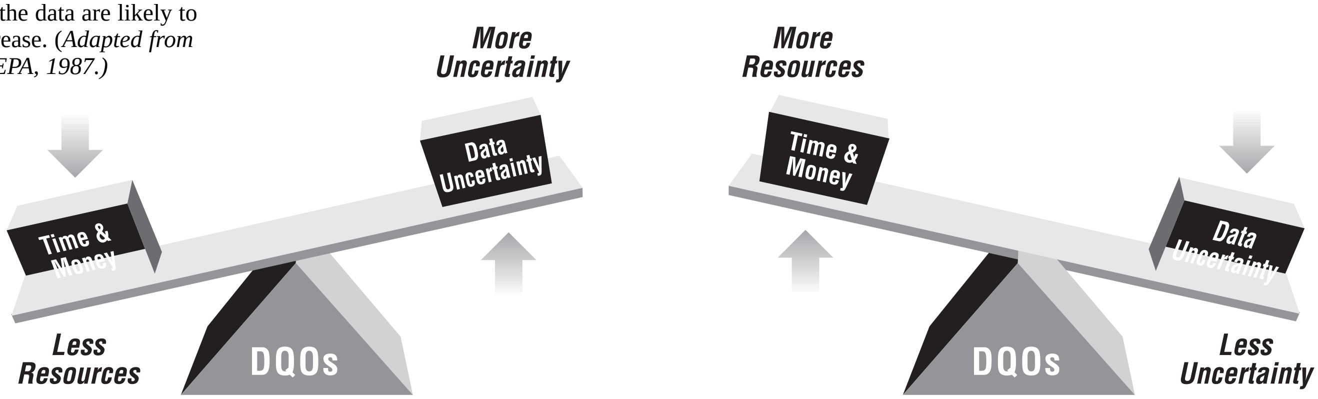
If those groups are already monitoring in your chosen area, find out if they will share their data, and identify what gaps exist that your project could fill. If no monitoring is ongoing, find out what kind of data your local or state agencies could use (if one of your goals is that these agencies use your data), where they would prefer you to locate your sampling sites, and what monitoring methods they recommend. **Government agencies are not likely to use your data unless it fills a gap in their monitoring network and was collected using approved protocols.**

A watershed survey can help you set the foundation for your monitoring project design. This is simply a practical investigation of how the watershed works, its history, and its stressors. For information on conducting a watershed survey, consult the USEPA (1997) and Maine DEP (1996) references listed at the end of this chapter.

Step 4: Refine Your Project

Once you have collected background information for your project and coordinated with potential data users, you may find it necessary to refine your original goals and objectives. You might have found, for example, that your state already monitors SAV and algae in your estuary. In that case, your project might better examine nutrient inputs from tributaries or other parameters.

Figure 5-2. The balancing act of data quality objectives. Volunteer programs must balance data quality needs with financial limitations, understanding that as data quality becomes more important, the resources necessary to get the data are likely to increase. (*Adapted from USEPA, 1987.)*



Don't hesitate to reevaluate your project goals and objectives. Now is the best possible time to do so-*before* you invest time, money, and effort in equipment purchases, training, grant proposals, and QAPP development.

Step 5: Design Your Project's Sampling, Analytical, and Data Requirements

Once you feel comfortable with your project's goals and objectives and have gathered as much background information as possible on the area you will be monitoring, it is time to focus on the details of your project. Convene a planning committee consisting of the project coordinator, key volunteers, scientific advisors, and data users, along with your QAPP team. This committee should address the following questions:

- What parameters or conditions will you monitor, and which are most important to your needs? Which are of secondary importance?
- How good does your monitoring data need to be?
- How will you pick your sampling sites, and how will you identify them over time?
- What methods or protocols will you use for sampling and analyzing samples?
- When will you conduct the monitoring?
- How will you manage your data and ensure that your data are credible?

As a general rule, it is a good idea to start small and build to a more ambitious project as your volunteers and staff grow more experienced.

A Word About Metadata

The term **metadata** is loosely defined as "data about data." It is information that helps characterize the data that volunteers collect. Metadata answer who, what, when, where, why, and how about every facet of the data being documented (USGS Web site). This information will help others understand exactly how the data was obtained.

Most shared datasets require metadata. This helps users of the data—who may be unfamiliar with the monitoring site—understand the details behind the data.

Examples of metadata include *(from Williams, 1999):*

- name of organization;
- name of the estuary;
- monitoring station identification number;
- monitoring site location;
- site elevation;
- latitude, longitude;
- source describing how latitude and longitude were determined; and
- date and time of collection.

Volunteer leaders—especially those who want to share their data with government and other organizations—should include metadata on their field data sheets and emphasize the importance to volunteers of recording this information.

Step 6: Develop an Implementation Plan

Decide the particulars—the who's and when's of your project. Determine who will carry out the individual tasks such as volunteer training, data management, report generation, assuring lab and field quality assurance, and recruiting volunteers. If you send your samples to an outside lab, choose the lab and specify why you chose it.

Set up schedules for when you will recruit and train volunteers, conduct sampling and lab work, produce reports, and report back to volunteers or the community.

Step 7: Draft Your Standard Operating Procedures and QAPP

Now is the time to actually write your standard operating procedures (SOPs) and develop a draft QAPP. SOPs are the details on all the methods you expect your volunteers to use. They can serve as the project handbook you give your volunteers. There are many SOPs already available for sampling and analytical procedures—check with your state water quality agency or other volunteer monitoring groups for pointers. Where possible, adapt your procedures from existing methods and modify them as needed to fit your project objectives. Be sure to reference and cite any existing methods and documents that you use in your project.

You should append your SOPs to your QAPP and refer to them throughout the QAPP document. Your written plan can be elaborate or simple, depending on your project goals.

Step 8: *Solicit Feedback on Your Draft SOPs and QAPP*

Your next step is to get the draft reviewed by people "in the know." These include state and EPA regional volunteer monitoring coordinators and quality assurance officers and any other potential data users. Ask for feedback and suggestions from as many sources as possible. Expect their reviews to take up to two or three months (times will vary). In addition, expect some resistance from some reviewers who might be overburdened with other duties. Don't be offended by this; instead, call back a reasonable time after submitting your plan and inquire if you should submit the draft elsewhere for review.

While waiting for comments, you should try out your procedures with volunteers on a trial basis. Don't plan to use the data at this early stage; data users generally will not accept your data until the QAPP has been approved and accepted. Rather, use this opportunity to find quirks in your plan.

Step 9: *Revise Your QAPP and Submit It for Final Approval*

Based on the comments you receive, you may have to revise your QAPP. This could involve simply being more specific about existing methods and quality control procedures in the plan, or actually modifying your procedures to meet agency requirements.

Once you have revised or fine-tuned your QAPP, submit it to the proper agency for formal approval. If you are developing a QAPP simply to document your methods and are not working in cooperation with a state, local, or federal agency, you do not need to submit a QAPP for review and approval.

Step 10: *Begin Your Monitoring Project*

Once you've received formal approval of your QAPP, your monitoring project can begin. Follow the procedures described in your QAPP to train volunteers and staff, conduct sampling, analyze samples, compile results, and develop any reports.

Step 11: *Evaluate and Refine Your Project over Time*

As time goes on, you may decide to improve on sampling techniques, site selection, lab procedures, or any of the other elements of your monitoring project design. Project evaluation should occur *during* the course of your project rather than after the project or a sampling season is completed.

If you make any substantive changes to your QAPP, document them and, if necessary, seek approval from the appropriate agency. A phone call to your quality assurance official can help you determine if the changes require a new QAPP. Also, always be prepared for formal audits or QC inquiries from data users during the course of your project.

Ongoing experience may require small changes to the QAPP. These can be made without having to rewrite the entire plan, as long as the original reviewers approve the changes. One helpful way to make changes without rewriting the entire plan is to have the pages individually dated; changes to the document can then be made on a page-by-page basis. ■

Elements of a QAPP

A QAPP helps your group determine responsibilities, training, methods, equipment and other resources needed to ensure that data quality is good enough to meet its intended use. This section discusses the 24 elements of a QAPP (Table 5-8), which can guide the QAPP team as it determines whether all necessary aspects are covered.

It is very likely that not all elements will apply to your project, and other elements may be required that are not addressed here. These issues should be discussed with your QAPP team and any group who will be approving your QAPP. If EPA must approve your QAPP and your project does not require all 24 elements, you should indicate in your QAPP which elements you will not be including. This will make review and approval of your QAPP faster and easier.

Readers should refer to the document, *The Volunteer Monitor's Guide to Quality Assurance Project Plans* (USEPA, 1996—see "References and Further Reading" in this chapter) for useful examples of developing a QAPP. The document also includes a sample QAPP form.

Table 5-8. Elements of a QAPP *(USEPA, 1996)*.

Project Management	**(elements 1-9)**
1. Title and Approval Page	
2. Table of Contents	
3. Distribution List	
4. Project/Task Organization	
5. Problem Identification/Background	
6. Project/Task Description	
7. Data Quality Objectives for Measurement Data	
8. Training Requirements/Certification	
9. Documentation and Records	
Measurement/Data Acquisition	**(elements 10-19)**
10. Sampling Process Design	
11. Sampling Methods Requirements	
12. Sample Handling and Custody Requirements	
13. Analytical Methods Requirements	
14. Quality Control Requirements	
15. Instrument/Equipment Testing, Inspection, and Maintenance Requirements	
16. Instrument Calibration and Frequency	
17. Inspection/Acceptance Requirements for Supplies	
18. Data Acquisition Requirements	
19. Data Management	
Assessment and Oversight	**(elements 20-21)**
20. Assessments and Response Actions	
21. Reports	
Data Validation and Usability	**(elements 22-24)**
22. Data Review, Validation, and Verification Requirements	
23. Validation and Verification Methods	
24. Reconciliation with Data Quality Objectives	

Element 1: *Title and Approval Page*

Your title page should include the following:

- title and date of the QAPP;
- names of the organizations involved in the project; and
- names, titles, signatures, and document signature dates of all appropriate approving officials, such as project manager, project QA officer, and if the project is funded by EPA, the EPA project manager and QA officer.

Element 2: *Table of Contents*

A table of contents should include section headings with appropriate page numbers and a list of figures and tables.

Element 3: *Distribution List*

List the individuals and organizations that will receive a copy of your approved QAPP and any subsequent revisions. Include representatives of all groups involved in your monitoring effort.

Element 4: *Project/Task Organization*

Identify all key personnel and organizations that are involved in your program, including data users. List their specific roles and responsibilities. In many monitoring projects, one individual may have several responsibilities. An organizational chart is a good way to graphically display the roles of key players.

Element 5: *Problem Identification/ Background*

In a narrative, briefly state the problem your monitoring project is designed to address. Include any background information such as previous studies that indicate why this project is needed. Identify how your data will be used and who will use it.

Element 6: *Project/Task Description*

In general terms, describe the work your volunteers will perform and where it will take place. Identify what kinds of samples will be taken, what kinds of conditions they will measure, which ones are critical, and which are of secondary importance. Indicate how you will evaluate your results—that is, how you will be making sense out of what you find. For example, you may be comparing your water quality readings to state or EPA standards, or comparing your submerged aquatic vegetation (SAV) evaluations to state-established reference conditions or historical information.

Include an overall project timetable that outlines beginning and ending dates for the entire project as well as for specific activities within the project. The timetable should include information about sampling frequency, lab schedules, and reporting cycles.

Element 7: *Data Quality Objectives for Measurement Data*

Data Quality Objectives (DQOs) are the quantitative and qualitative terms used to describe how good your data must be to meet the project's objectives. DQOs for water quality variables should address precision, accuracy, representativeness, completeness, comparability, and sensitivity (see "Basic Concepts" in this chapter for a discussion of these terms).

If possible, provide information on DQOs in quantitative terms. Since it is important to develop a QAPP prior to monitoring, it may not be possible to include actual numbers for some of the water quality measurement variables within the first version of the document. You will need, however, to discuss your goals or objectives for data quality and the methods you will use to make actual determinations after monitoring has begun. DQOs should be given for each parameter you are measuring and in each "matrix" (i.e., substance you are sampling from, such as

Table 5-9. Sample Data Quality Objectives (DQOs) for a volunteer estuary monitoring program. *(Adapted from USEPA, 1990 and USEPA, 1996.)*

Parameter	Method/Range	Units	Sensitivity	Precision	Accuracy
Temperature	thermometer -5.0° to 45°C	°C	0.5°C	±1.0°C	±0.2°C
pH	wide-range colorimetric field kit 3.0 to 10.0 units	standard pH units	0.5 units	±0.6 units	±0.4 units
Salinity	hydrometer	parts per thousand (ppt)	0.1 ppt	±1.0 ppt	±0.82 ppt
Dissolved Oxygen	Winkler titration 1 to 20 mg/l	mg/l	0.2 mg/l	±0.9 mg/l	±0.3 mg/l
Limit of Visibility	Secchi disk	meters	0.05m	NA	NA

water or sediment). A table is the easiest way to present quantitative DQOs (see Table 5-9).

In some types of monitoring, particularly macroinvertebrate monitoring and habitat assessment, some data quality indicators cannot be quantitatively expressed. In that case, you can fulfill this requirement of the QAPP by citing and describing the method used and by providing as many of the data quality indicators as possible (e.g., completeness, representativeness, and comparability) in narrative form.

DQOs should be set realistically. The volunteer program should closely examine its budget when forming its DQOs. Decisions regarding the ultimate objectives must always strike a balance between the needs of data users and the fiscal restraints of the program (Figure 5-2).

Element 8: Training Requirements/ Certification

Identify any specialized training or certification requirements your volunteers will need to successfully complete their tasks. Discuss how you will provide such training, who will conduct the training, and how you will evaluate volunteer performance.

Element 9: Documentation and Records

Identify the field and laboratory information and records you need for the project. These records may include raw data, QC checks, field data sheets, laboratory forms, and voucher collections. Include information on where and for how long records will be maintained. Copies of all forms to be used in the project should be attached to the QAPP.

Element 10: Sampling Process Design

Outline the experimental design of the project including information on types of samples required, sampling frequency, sampling period (e.g., season), and how you will select sample sites and identify them over time. (A discussion on how to select monitoring sites can be found in Chapter 6.) Indicate whether any constraints such as weather, seasonal variations, or site access might affect scheduled activities and how you will handle those constraints. Include site safety plans. In place of extensive discussion, you may cite the sections of your program's SOPs that detail the sampling design of the project.

Element 11: *Sampling Methods Requirements*

Describe your sampling methods. Include information on parameters to be sampled, how samples will be taken, equipment and containers used, sample preservation methods, and holding times (time between taking samples and analyzing them). If samples are composited (i.e., mixed), describe how this will be done. Describe procedures for decontamination and equipment cleaning. Most of this information can be presented in a table or you may also cite any SOPs that contain this information.

Element 12: *Sample Handling and Custody Requirements*

Sample handling procedures apply to projects that bring samples from the field or monitoring site to the lab for analysis, identification, or storage. These samples should be properly labeled in the field. At a minimum, the sample identification label should include sample location, sample number, date and time of collection, sample type, sampler's name, and method used to preserve the sample.

Describe the procedures used to keep track of samples that will be delivered or shipped to a laboratory for analysis. Include any chain-of-custody forms and written procedures that field crews and lab personnel should follow when collecting, transferring, storing, analyzing, and disposing of samples and associated waste materials.

Element 13: *Analytical Methods Requirements*

List the methods and equipment needed for the analysis of each parameter, either in the field or in the lab. If your program uses standard methods, cite these (see, for example, APHA, 1998). If your program's methods differ from the standard or are not readily available in a standard reference, describe the analytical methods or cite and attach the program's SOPs.

Element 14: *Quality Control Requirements*

List the number and types of field and laboratory quality control samples your volunteers will take (see "Quality Control and Assessment" earlier in this chapter). This information can be presented in a table. If you use an outside laboratory, cite or attach the lab's QA/QC plan.

What Is a Performance Based Measurement System (PBMS)?

Volunteer monitors may hear increased discussion about a fundamentally different approach to environmental monitoring, known as a "performance based measurement system," or PBMS. Rather than requiring that a prescribed analytical method be used for a particular measurement, PBMS permits any method to be used provided that it demonstrates an ability to meet required performance standards. In other words, PBMS conveys "what" needs to be accomplished, but not prescriptively "how" to do it.

Under PBMS, the U.S. Environmental Protection Agency (EPA) would specify:

- questions to be answered by monitoring;
- decisions to be supported by the data;
- the level of uncertainty acceptable for making decisions; and
- documentation to be generated to support this approach.

EPA believes that this approach will be more flexible and cost-effective for monitoring organizations. Volunteer groups should check with their data users (e.g., state water quality agencies) to determine acceptable performance based methods.

QC checks for biological monitoring programs can be described in narrative form, and, if appropriate, should discuss replicate sample collection, cross checks by different field crews, periodic sorting checks of lab samples, and maintenance of voucher and reference collections. Describe what actions you will take if the QC samples reveal a sampling or analytical problem.

Element 15: Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Describe your plan for routine inspection and preventive maintenance of field and lab equipment facilities. Identify what equipment will be routinely inspected, and what spare parts and replacement equipment will be on hand to keep field and lab operations running smoothly. Include an equipment maintenance schedule, if appropriate.

Element 16: Instrument Calibration and Frequency

Identify how you will calibrate sampling and analytical instruments. Include information on how frequently instruments will be calibrated, and the types of standards or certified equipment that will be used to calibrate sampling instruments. Indicate how you will maintain calibration records and ensure that records can be traced to each instrument. Instrument calibration procedures for biological monitoring programs should include routine steps that ensure equipment is clean and in good working order.

Element 17: Inspection and Acceptance Requirements for Supplies

Describe how you determine if supplies, such as sample bottles, nets, and reagents, are adequate for your program's needs.

Element 18: Data Acquisition Requirements

Identify any types of data your project uses that are not obtained through your monitoring exercises. Examples of these types of data include historical information, information from topographical maps or aerial photos, or reports from other monitoring groups. Discuss any limits on the use of this data resulting from uncertainty about its quality.

Element 19: Data Management

Trace the path of your data, from field collection and lab analysis to data storage and use. Discuss how you check for accuracy and completeness of field and lab forms, and how you minimize and correct errors in calculations, data entry to forms and databases, and report writing. Provide examples of forms and checklists. Identify the computer hardware and software you use to manage your data.

Element 20: Assessments and Response Actions

Discuss how you evaluate field, lab, and data management activities, organizations (such as contract labs), and individuals in the course of your project. These can include evaluations of volunteer performance (e.g., through field visits by staff or in laboratory refresher sessions); audits of systems (e.g., equipment and analytical procedures); and audits of data quality (e.g., comparing actual data results with project quality objectives).

Include information on how your project will correct any problems identified through these assessments. Corrective actions might include calibrating equipment more frequently, increasing the number of regularly scheduled training sessions, or rescheduling field or lab activities.

Element 21: Reports

Identify the frequency, content, and distribution of reports to data users, sponsors, and partnership organizations that detail project status, results of internal assessments and audits, and how QA problems have been resolved.

Element 22: Data Review, Validation, and Verification Requirements

State how you review data and make decisions about accepting, rejecting, or qualifying the data. All that is needed here is a brief statement of what will be done and by whom.

Element 23: Validation and Verification Methods

Describe the procedures you use to validate and verify data. This can include, for example, comparing computer entries to field data sheets; looking for data gaps; analyzing quality control data such as chain of custody information, spikes, and equipment calibrations; checking calculations; examining raw data for outliers or nonsensical readings; and reviewing graphs, tables, and charts. Include a description of how detected errors will be corrected and how results will be conveyed to data users.

Element 24: Reconciliation with Data Quality Objectives

Once the data results are compiled, describe the process for determining whether the data meet project objectives. This should include calculating and comparing the project's actual data quality indicators (precision, accuracy, completeness, representativeness, and comparability) to those you specified at the start of the project and describing what will be done if they are not the same. Actions might include discarding data, setting limits on the use of the data, or revising the project's data quality objectives. ■

References and Further Reading

Much of this chapter was excerpted and adapted from:

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Williams, K. F. 1999. "Quality Assurance Procedures." In: Meeting Notes—U.S. Environmental Protection Agency (USEPA)/Center for Marine Conservation (CMC) workshop: *Volunteer Estuary Monitoring: Wave of the Future.* Astoria, OR: May 19-21, 1999.

Web sites:

<u>Metadata Information</u>:

Federal Geographic Data Committee: http://www.fgdc.gov/metadata/

U.S. Geological Survey: http://geology.usgs.gov/tools/metadata/tools/doc/faq.html#1.1