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Handbook for Developing Watershed Plans to Restore and Protect Our Waters

Chapter 6. Identify Data Gaps and Collect Additional Data If Needed

March 2008

Handbook Road Map

6. Identify Data Gaps and Collect Additional Data If Needed

Chapter Highlights

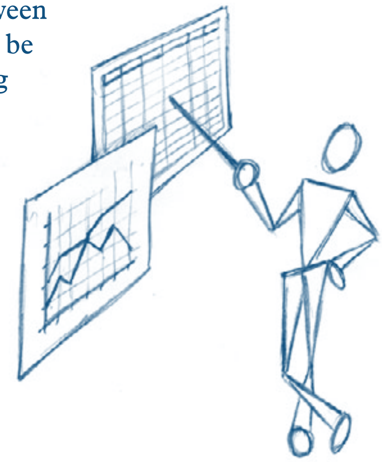
- Conducting a data review
- Identifying data gaps
- Determining acceptability of data
- Designing a sampling plan
- Collecting new data

Read this chapter if...

- You want to determine whether you have enough data to start your analysis
- You'd like to review your data
- You want to determine whether you need to collect new data
- You want to design a sampling plan for collecting additional data
- You need to collect new data

6.1 How Do I Know If I Have Enough Data to Start My Analysis?

One of the most difficult challenges in watershed planning is knowing when you have enough data to identify relationships between impairments and their sources and causes. There will always be more data to collect, but you need to keep the process moving forward and determine whether you can reasonably characterize watershed conditions with the data you have. Once you've gathered all the necessary data related to the watershed goals identified by the stakeholders, you must examine the data to determine whether you can link the impairments seen in the watershed to the causes and sources of pollutants. Although you will develop a monitoring component as part of your watershed implementation plan (↳ chapter 12), it's often necessary to collect additional data during the planning phase to complete the characterization step. The additional data will help you to develop management measures linked to the sources and causes of pollutants.



6.2 Conduct a Data Review

The first step is to review the data you've gathered and ask the following questions:

- Do I have the right types of data to identify causes and sources?
- What is the quality of the data?

The answers to these questions will tell you whether you need to collect additional data before proceeding with data analysis. For example, you might have gathered existing monitoring information that indicates the recreational uses of a lake are impaired by excessive growth of lake weeds due to high phosphorus levels. The permit monitoring data might show that wastewater treatment plants are in compliance with their permit limits, leading to speculation that nonpoint source controls are needed. This kind of information, although adequate to define the broad parameters of a watershed plan, will probably not be sufficient to guide the selection and design of management measures (USEPA 1997a, 1997d) to be implemented to control the as-yet-unidentified nonpoint sources. Therefore, further refinements in problem definition, including more specific identification and characterization of causes and sources, will be needed and can be obtained only by collecting new data.

You'll review the data to identify any major gaps and then determine the quality of the data. ◎Be careful to first determine whether the data are essential to the understanding of the problem. For example, although it might become obvious during the inventory process that chemical data are lacking, this lack should be considered a gap only if chemical data are essential to identifying the possible sources of the impacts and impairments of concern. If the necessary datasets are available, you should then compare the quality of the information with the data quality indicators and performance characteristics. If the data quality is unknown or unacceptable (that is, it doesn't meet the needs of the stakeholders for watershed assessment), you should not use the existing dataset. Using data of unknown quality will degrade the defensibility of management decisions for the watershed and could, in the long run, increase costs because of the increased likelihood of making incorrect decisions.

Remember that collecting existing and new data, identifying data gaps, and analyzing data are parts of an iterative process. Although obvious data gaps can be identified during the data inventory process, more specific data needs are often discovered only during data analysis and subsequent activities, such as source assessment or modeling.

6.2.1 Identify Data Gaps

Several different types of data gaps might require that you collect additional information. What constitutes a gap is often determined by the information needed to adequately identify and characterize causes and sources of pollutants in the watershed. There are three major types of data gaps—informational, temporal, and spatial.

Informational Data Gaps

First, you need to determine whether your data include the types of information needed. For example, if one of the goals stakeholders identified was to restore the aquatic resources of a waterbody and you have only flow and water quality data, you should conduct biological assessments to get baseline information on the biology of the waterbody and obtain habitat data. Information gaps can also result if there are no data addressing the indicators identified by stakeholders to assess current watershed conditions. For example, stakeholders might want to use the amount of trash observed in a stream as an indicator of stream health. If you don't have any baseline data on trash, you should collect data to assess the amount of trash in the stream (e.g., volume of trash per mile). Without baseline data, you'll have little against which to measure progress. A common data gap is a lack of flow data that specifically correspond to the times and locations of water quality monitoring.

Temporal Data Gaps

Temporal data gaps occur when there are existing data for your area(s) of interest but the data were not collected within, or specific to, the time frame required for your analysis. Available data might have been collected long ago, when watershed conditions were very different, reducing the data's relevance to your current situation. The data might not have been collected in the season or under the hydrologic conditions of interest, such as during spring snowmelt or immediately after crop harvest. In addition, there might be only a few data points available, and they might not be indicative of stream conditions.

Spatial Data Gaps

Spatial data gaps occur when the existing data were collected within the time frames of interest but not at the location or spatial distribution required to conduct your analyses. These types of data gaps can occur at various geographic scales. At the individual stream level, spatial data gaps can affect many types of analyses. Samples collected where a tributary joins the main stem of a river might point to that tributary subwatershed as a source of a pollutant load, but not specifically enough to establish a source. Measuring the effectiveness of restoration efforts can be difficult if data are not available from locations that enable upstream and downstream comparisons of the restoration activities.

Data collected at the watershed scale are often used to describe interactions among landscape characteristics, stream physical conditions (e.g., habitat quality, water chemistry), and biological assemblages. The reliability of these analyses can be affected by several types of spatial data gaps. Poor spatial coverage across a study region can hinder descriptions of simple relationships between environmental variables, and it can eliminate the potential for describing multivariate relationships among abiotic and biotic parameters. In addition,

Example Performance Criteria for Determining Acceptability of Data

Accuracy: The measure of how close a result is to the true value

Precision: The level of agreement among multiple measurements of the same characteristic

Representativeness: The degree to which the data collected accurately represent the population of interest.

Bias: The difference between an observed value and the "true" value (or known concentration) of the parameter being measured

Comparability: The similarity of data from different sources included within individual or multiple datasets; the similarity of analytical methods and data from related projects across areas of concern.

Detection Limit: The lowest concentration of an analyte that an analytical procedure can reliably detect.

Practical quantification limit: The lowest level that can be reliably achieved with specified limits for precision and accuracy during routine sampling of laboratory conditions.

underrepresentation of specific areas within a study region can affect the reliability and robustness of analyses. For instance, in a landscape that is composed of a wide range of land uses and has large variations in topography, preferential sampling in easily accessible areas can bias the dataset and subsequent analyses.

6.2.2 Determine Acceptability of Data

In many cases, the existing data were collected to address questions other than those being asked in the watershed assessment. Also, sufficient data are rarely available from a single source, particularly if the watershed is large. As a result, you might have to rely on data from different sources, collected for different purposes and collected using a variety of sample collection and analysis procedures. Therefore, it's critical that you review existing data to determine their acceptability before you use them in your analyses.

Data acceptability is determined by comparing the types and quality of data with the minimum criteria necessary to address the monitoring questions of interest. For each data source, focus on two areas: *data quality* and *measurement quality*. Data quality pertains to the purpose of the monitoring activity, the types of data collected, and the methods and conditions under which the data were collected. These characteristics determine the applicability of the data to your planning effort and the decisions that can be made on the basis of the data. The main questions to ask are the following:

- **What were the goals of the monitoring activity?** Consider whether the goals of the monitoring activity are consistent with and supportive of your goals. Daily fecal coliform data collected at a swimming beach document compliance with recreational water quality standards but might not help in linking violations of those standards to sources in the watershed. Monthly phosphorus concentration data collected to evaluate long-term trends might or might not help you to relate phosphorus loads from concentrated animal feeding operations (CAFOs) to storm events in your watershed.
- **What types of data were collected?** Determine whether the types of data collected are relevant to your needs. Data on stream macroinvertebrate communities might be useful only if physical habitat data were also collected. Water quality data without associated land use and management data might not be useful in linking impairments to source areas.
- **How were the data collected?** Data collected at random sites to broadly characterize water quality in the watershed might present a very different picture from data deliberately collected from known hot spots or pristine reference sites. Data from a routine, time-based sampling program typically underestimate pollutant loads compared to data collected under a flow-proportional sampling regime (collecting more samples at high flows, fewer at base flow).

Measurement quality describes data characteristics like accuracy, precision, sensitivity, and detection limit. These are critical issues for any monitoring activity, and you'll consider them in detail when you design your own data collection program (↪ section 6.4). For pollutants like metals, toxic substances, or pesticides that are of concern at very low concentrations, the detection, or reporting, limit of the analytical method is one of the most readily distinguished measurement quality parameters in all monitoring programs. Existing data are of little value in evaluating compliance with water quality standards if the method detection limits used were higher than the standard.

There are several levels of measurement quality, and these should be determined for any data source before interpreting the data or making decisions based on the data. State and federal laboratories are usually tested and certified, meet EPA or other applicable performance standards, employ documented analytical methods, and have quality assurance data available to be examined. Analytical results reported from consultants and private laboratories might or might not meet similar standards, so documentation needs to be obtained. Data from citizen groups, lay monitoring programs, school classes, and the like might not meet acceptable measurement quality criteria; in most cases, they should be considered qualitatively if proper documentation can't be obtained.

Ideally, information on the methods used to collect and analyze the samples, as well as the associated measurement quality attributes, should be associated with the data in a database so you can easily determine whether those data are acceptable for your purposes. The Quality Assurance Project Plan (QAPP) associated with a data collection effort is an excellent source of information if available (↪ section 6.4.4). In some cases, sufficient information might be readily available, but you'll have to dig deeply to obtain the best information. For example, even though most published analytical methods have performance characteristics associated with them, the organization conducting the analyses and reporting the data might not have met those performance characteristics. Some laboratories, however, report performance characteristics as part of the method, making it easier for data users to identify the potential quality of data collected using those methods. ↪ An example illustrating the use of a performance-based approach for bioassessment methods is presented in chapter 4 of EPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish,* available at **www.epa.gov/owowwtr1/monitoring/rbp/ch04main.html**.

For some types of parameters, method performance information might be limited, particularly if the data obtained are dependent on the method used. For example, parameters like chemical oxygen demand (COD), oil and grease, and toxicity are defined by the method used. In such cases, you might need to rely on a particular method rather than performance characteristics per se. (↪ See Methods & Data Comparability Board COD Pilot at **http://wi.water.usgs.gov/methods/about/publications/cod_pilot_v.4.4.3.htm** or the National Environmental Methods Index (NEMI) at **www.nemi.gov**.)

Other critical aspects of existing data quality are the age of the data and the format of the database. Old data might be highly valuable in understanding the evolution of water quality problems in your watershed and are likely to be impossible to recreate or re-measure today. However, old data might have been generated by laboratory methods different from those in use today and therefore might not be entirely comparable to current data. Detection limits for organics, metals, and pesticides, for example, are lower today than they were even a decade ago. It might be difficult to adequately document measurement quality in old datasets. In addition, older data might not be in an easily accessible electronic form. If the quality of such data is known, documented, and acceptable, and the data are useful for your purpose, you'll need to consider the effort and expense necessary to convert them into an electronic form.

6.3 Determine Whether New Data Collection Is Essential

At this point, you've collected existing data for your watershed, assessed its quality and relevance, and identified gaps. Compare your available resources against your tasks:

- Can we identify and quantify the water quality problems in the watershed?
- Can we quantify pollutant loads?
- Can we link the water quality impairments to specific sources and source areas in the watershed?
- Have we identified critical habitat including buffers for conservation, protection, and restoration?
- Do we know enough to select and target management measures to reduce pollutant loads and address water quality impairments?

If you were able to answer "yes" to each of these questions, congratulations! You're ready to move on to the next phase and begin to analyze the data. If you answered "no," the next step is to come up with a plan to fill the gaps. Although this might seem like a short-term task, it is critical to consider data collection requirements in the context of your overall watershed plan. The kind of sampling plan you initiate now could well become the foundation of the later effort to monitor the effectiveness of your implementation program, and therefore the plan should be designed with care.

6.4 Design a Sampling Plan for Collecting New Data

If you've determined that additional data must be collected to complete your watershed characterization, you should develop a sampling plan. The sampling plan will focus on immediate data collection needs to help you finish the watershed characterization, but it's very important to consider long-term monitoring needs in this effort. Once data collection and analysis is complete and management strategies have been identified, your implementation efforts should include a monitoring component designed to track progress in meeting your water quality and other goals (chapter 12). Many of the data tools developed to support the sampling plan, including data quality objectives (DQOs), measurement quality objectives (MQOs), and a QAPP, can be modified or expanded on for the monitoring component of the implementation plan. For more information on designing a sampling plan, visit **www.epa.gov/quality/qs-docs/g5s-final.pdf**.

> **Quality Assurance Project Plans**
>
> A QAPP documents the planning, implementation, and assessment procedures for a particular project, as well as any specific quality assurance and quality control activities. It integrates all the technical and quality aspects of the project to provide a blueprint for obtaining the type and quality of environmental data and information needed for a specific decision or use. All work performed or funded by EPA that involves acquiring environmental data must have an approved QAPP. For more information on QAPPs, visit **www.epa.gov/quality/qapps.html**.

Before collecting any environmental data, you should determine the type, quantity, and quality of data needed to meet the project goals and objectives (e.g., specific parameters to be measured) and to support a decision based on the results of data collection and observation. Failure to do so risks expending too much effort on data collection (more data collected than necessary), not expending enough effort on data collection (not enough data collected), or expending the wrong effort (wrong data collected). You should also consider your available resources. Water quality monitoring and laboratory testing can be very expensive, so you need to determine how best to allocate your resources.

A well-designed sampling plan clearly follows the key steps in the monitoring process, including study design, field sampling, laboratory analysis, and data management. Sampling plans should be carefully designed so that the data produced can be analyzed, interpreted, and ultimately used to meet all project goals. Designing a sampling plan involves developing DQOs and MQOs, a study design, and a QAPP, which includes logistical and training considerations, detailed specifications for standard operating procedures (SOPs), and a data management plan. Because a variety of references on designing and implementing water quality monitoring programs are available, this section provides only a general overview and resources available for further information. ↳ For more information visit EPA's *Quality Management Tools* Web site at **www.epa.gov/quality/qapps.html**.

6.4.1 Select a Monitoring Design

The specific monitoring design you use depends on the kind of information you need. Water quality sampling can serve many purposes:

- Defining water quality problems
- Defining critical areas
- Assessing compliance with standards or permits
- Determining fate and transport of pollutants
- Analyzing trends
- Measuring effectiveness of management practices
- Evaluating program effectiveness
- Making wasteload allocations
- Calibrating or validating models
- Conducting research

Depending on the gaps and needs you've identified, monitoring to define water quality problems, assess compliance with standards, and define critical areas might be most appropriate for your watershed. For example, synoptic or reconnaissance surveys are intensive sampling efforts designed to create a general view of water quality in the study area. A well-designed synoptic survey can yield data that help to define and locate the most severe water quality problems in the watershed, and possibly to support identification of specific major causes and sources of the water quality problem. Data collected in synoptic surveys can also be used to help calibrate and verify models that might be applied to the watershed (USEPA 1986).

There are a variety of approaches to conducting synoptic surveys. Less-expensive grab sampling approaches are the norm for chemical studies. Rapid Bioassessment Protocols and other biological assessment techniques can be used to detect and assess the severity of impairments to aquatic life, but they typically do not provide information about the causes or sources of impairment (USEPA 1997a, 1997d). Walking or canoeing the course of tributaries can also yield valuable, sometimes surprising information regarding causes and sources. It's important to recognize that, because synoptic surveys are short in duration, they can yield results that are inaccurate because of such factors as unusual weather conditions, intermittent discharges that are missed, or temporal degradation of physical or biological features of the waterbody. Follow-up studies, including fate and transport studies, land use and land treatment assessments, and targeted monitoring of specific sources, might be needed to improve the assessment of causes and sources derived from synoptic surveys.

Sampling network design refers to the array, or network, of sampling sites selected for a monitoring program and usually takes one of two forms:

- ***Probabilistic design:*** Network that includes sampling sites selected randomly to provide an unbiased assessment of the condition of the waterbody at a scale above the individual site or stream; can address questions at multiple scales.
- ***Targeted design:*** Network that includes sampling sites selected on the basis of known, existing problems; knowledge of coming events in the watershed or a surrounding area that will adversely affect the waterbody, such as development or deforestation; or installation of management measures or habitat restoration intended to improve waterbody quality. The network provides for assessments of individual sites or reaches.

Compliance monitoring might focus on regular sampling at specific locations, depending on the source, constituent, and relevant standard. Although typically associated with point source discharges, compliance monitoring can be used effectively to characterize and isolate pollutant loads from relatively defined sources such as stormwater outfalls or concentrated runoff from a concentrated animal feeding operation (CAFO). Monitoring to define critical areas can also be focused on specific locations, chosen on the basis of land use patterns or in response to known or suspected problem areas.

Fate and transport monitoring is designed to help define the relationships between the identified water quality problems and the sources and causes of those problems. This type of monitoring typically involves intensive sampling over a relatively short period, with frequent sampling of all possible pollutant pathways within a fairly small geographic area. The limited geographic scope of fate and transport monitoring, coupled with the required sampling intensity, makes it an expensive venture if applied broadly within a watershed. Because of its cost and relatively demanding protocols, fate and transport monitoring is best used in a targeted manner to address the highest-priority concerns in a watershed. For example, the preferential pathways of dissolved pollutants (e.g., nitrate nitrogen) that can be transported via surface or subsurface flow to a receiving waterbody might need to be determined and quantified to help identify the critical area, design effective management measures, and estimate potential pollutant load reductions.

Because nonpoint source contributions are often seasonal and dependent on weather conditions, it's important that all sampling efforts be of sufficient duration to encompass a reasonably broad range of conditions. Highly site-specific monitoring should be done on reasonably representative areas or activities in the watershed so that results can be extrapolated across the entire area.

Station location, selection, and sampling methods will necessarily follow from the study design. Ultimately, the sampling plan should control extraneous sources of variability or error to the extent possible so that data are appropriately representative and fulfill the study objectives.

In the study design phase, it's important to determine how many sites are necessary to meet your objectives. If existing data are available, statistical analysis should be conducted to determine how many samples are required to meet the DQOs, such as a 95 percent confidence level in estimated load or ability to detect a 30 percent change. If there are no applicable data for your watershed, it might be possible to use data from an adjacent watershed or from within the same ecoregion to characterize the spatial and temporal variability of water quality. ↳ For more on statistical analyses, see EPA's "Statistical Primer" on power analysis at **www.epa.gov/bioindicators/statprimer/index.html**.

In addition to sampling size, you should also determine the type of sampling network you'll implement and the location of stations. The type of sampling network design you choose depends on the types of questions you want to answer. Generally, sampling designs fall into two major categories: (1) random or probabilistic and (2) targeted. In a probabilistic design, sites are randomly chosen to represent a large sampling population for the purpose of trying to answer broad-scale (e.g., watershed-wide) questions. This type of network is appropriate for synoptic surveys to characterize water quality in a watershed. In a targeted design, sites are allocated to specific locations of concern (e.g., below discharges, in areas of particular land use, at stream junctions to isolate subwatersheds) with the purpose of trying to answer site-specific questions. A stratified random design is a hybrid sampling approach that deliberately chooses parts of the watershed (e.g., based on land use or geology) to be sampled and then selects specific sampling points within those zones at random.

For more information on sampling designs, see EPA's *Guidance on Choosing a Sampling Design for Environmental Data Collection* at **www.epa.gov/quality/qs-docs/g5s-final.pdf**.

Your monitoring plan should focus not only on water quality, but also on the land-use activities that contribute to nonpoint source loads. You might need to update the general land use/land cover data for your watershed or gather information on specific activities (e.g., agricultural nutrient management practices or the use of erosion and sediment control plans in construction projects). Monitor not only where implementation might occur, but in all areas in the watershed that could contribute to nonpoint source loads. Part of this effort should focus on collecting data on current source activities to link pollutant loads to their source.

In addition, you should generate baseline data on existing land-use and management activities so that you can better predict future impairments. One tool that can be used to predict where impairments might occur, allowing you to target monitoring efforts, is U.S. EPA's Analytical Tools Interface for Landscape Assessments (ATtILA). ATtILA provides a simple ArcView graphical user interface for landscape assessments. It includes the most common landscape/watershed metrics, with an emphasis on water quality influences. (To read about or download ATtILA, see **www.epa.gov/nerlesd1/land-sci/attila/index.htm**.)

Leveraging Resources for Monitoring Efforts

Local watershed groups in Baltimore, Maryland, have long been troubled by the aging, leaky sewage pipes that run through the beds of city streams. They were interested in tracking the raw sewage entering the stream system, especially after storm events, but didn't have the resources for the required equipment. The city's Department of Public Works was also interested in the problem but had the time and resources for only weekly screenings. They decided to partner: the City agreed to provide the groups with ammonia test kits (high levels of ammonia can indicate the presence of sewage) in return for screening of additional stations and a greater sampling frequency. Now both parties have the data they need to better understand the problem.

The result of a good land-use/land-treatment monitoring program is a database that will help you explain the current situation and potential changes in water quality down the road. The ability to attribute water quality changes to your implementation program or to other factors will be critical as you evaluate the effectiveness of your plan.

Another important consideration during study design is how other groups and partners can be enlisted to support your monitoring effort. Think back to the issues of concern expressed by the different groups and the potential partnerships you can build among local governments, agencies, private organizations, and citizen groups. Collaborative monitoring strategies can effectively address multiple data needs and resource shortfalls.

Finally, it's also important to consider how this initial monitoring might be used to support a long-term monitoring program that addresses evaluation of watershed condition and restoration. The sampling and analysis done during this phase can be used to provide an evaluation of baseline or existing conditions. As long as continued monitoring during implementation is done consistently, it can be used to track trends, evaluate the benefits of specific management measures, or assess compliance with water quality standards (chapter 12).

6.4.2 Develop Data Quality Objectives

DQOs are qualitative and quantitative statements that clarify the purpose of the monitoring study, define the most appropriate type of data to collect, and determine the most appropriate methods and conditions under which to collect them. The DQO process, developed by EPA (GLNPO 1994, USEPA 2000a), is a flexible planning framework that articulates project goals and objectives, determines appropriate types of data, and establishes tolerable levels of uncertainty. The purpose of this process is to improve the effectiveness, efficiency, and defensibility of decisions made, based on the data collected. A team of data users develops DQOs based on members' knowledge of the data's richness and limits, and their own data needs. You'll use the information compiled in the DQO process to develop a project-specific QAPP, which should be used to plan most of the water quality monitoring or assessment studies.

Seven Steps In the DQO Process

Step 1. State the problem. Review existing information to concisely describe the problem to be studied.

Step 2. Identify the decision. Determine what questions the study will try to resolve and what actions might result.

Step 3. Identify inputs to the decision. Identify information and measures needed to resolve the decision statement.

Step 4. Define the study boundaries. Specify temporal and spatial parameters for data collection.

Step 5. Develop a decision rule. Define statistical parameters, action levels, and a logical basis for choosing alternatives.

Step 6. Specify tolerable limits on decision errors. Define limits based on the consequences of an incorrect decision.

Step 7. Optimize the design. Generate alternative data collection designs and choose the most resource-effective design that meets all DQOs.

The DQO process addresses the uses of the data (most important, the decisions to be made) and other factors that will influence the types and amount of data to be collected (e.g., the problem being addressed, existing information, information needed before a decision can be made, and available resources). The products of the DQO process are criteria for data quality, measurement quality objectives, and a data collection design that ensures that data will meet the criteria. For more information on DQOs, see EPA's *Guidance for the Data Quality Objectives Process* at **www.epa.gov/quality/qs-docs/g4-final.pdf**.

The purpose of the study, or the question that needs to be answered, drives the input for all steps in the DQO process. Thus, sampling design, how samples are collected and manipulated, and the types of analyses chosen should all stem from the overall purpose of the study.

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

6.4.3 Develop Measurement Quality Objectives and Performance Characteristics

A key aspect of your sampling plan design is specifying MQOs—qualitative or quantitative statements that describe the amount, type, and quality of data needed to address the overall project objectives. These statements explicitly define the acceptable precision, bias, and sensitivity required of all analyses in the study, and therefore they should be consistent with the expected performance of a given analysis or test method (ITFM 1995). You'll use this information to help derive meaningful threshold or decision rules, and the tolerable errors associated with those rules. MQOs are used as an indicator of potential method problems. Data are not always discarded simply because MQOs are not met. Instead, failure to met MQOs is a signal to further investigate and to correct problems. Once the problem(s) are rectified, the data can often still be used.

MQOs should be realistic and attainable. For example, establishing an MQO of less than 10 percent relative percent difference (RPD) for biological data would most likely result in failure simply because of the data's natural variability. Often, the best way to establish MQOs is to look at reliable existing data and choose MQOs that can be met by existing data. They can be adjusted (made more or less stringent) if protocol and program capabilities are improved.

Every sampling program should find a balance between obtaining information to satisfy the stated DQOs or study goals in a cost-effective manner and having enough confidence in the data to make appropriate decisions. Understanding the performance characteristics of methods is critical to the process of developing attainable data quality goals, improving data collection and processing, interpreting results, and developing feasible management strategies. By calculating the performance characteristics of a given method, it is possible to evaluate the robustness of the method for reliably determining the condition of the aquatic ecosystem. A method that is very labor-intensive and requires a great deal of specialized expertise and, in turn, provides a substantial amount of information is not necessarily the most appropriate method if it lacks precision and repeatability. A less-rigorous method might be less sensitive in detecting perturbation or have more uncertainty in its assessment. All of these attributes are especially important to minimizing error in assessments. The number of samples collected and analyzed will reflect a compromise between the desire of obtaining high-quality data that fully address the overall project objectives (the MQOs) and the constraints imposed by analytical costs, sampling effort, and study logistics. The ultimate question resides in a firm balance between cost and resolution, i.e., Which is better—more information at a higher cost or a limited amount of the right information at less cost?

Remember that you still might need to identify funding sources for the new sampling effort. When determining the number of samples and constituents to be analyzed, consider the resources available, cost and time constraints, and quality assurance and quality control requirements to ensure that sampling errors are sufficiently controlled to reduce uncertainty and meet the tolerable decision error rates. For a list of links to DQO-related items, go to **http://dqo.pnl.gov/links.htm**.

6.4.4 Develop a Quality Assurance Project Plan

A QAPP is a project-specific document that specifies the data quality and quantity requirements of the study, as well as all procedures that will be used to collect, analyze, and report those data. EPA-funded data collection programs must have an EPA-approved QAPP before sample collection begins. However, even programs that do not receive EPA funding should consider developing a QAPP, especially if data might be used by state, federal, or local resource managers. A QAPP helps monitoring staff to follow correct and repeatable procedures and helps data users to ensure that the collected data meet their needs and that the necessary quality assurance (QA) and quality control (QC) steps are built into the project from the beginning.

A QAPP is normally prepared before sampling begins, and it usually contains the sampling plan, data collection and management procedures, training and logistical considerations, and their QA/QC components. The intent of the QAPP is to help guide operation of the program. It specifies the roles and

> ***Quality control*** (QC) is a system of technical activities that measure the attributes and performance of a process, product, or service against defined standards to verify that they meet the stated requirements.
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> ***Quality assurance*** (QA) is an integrated system of management activities involving planning, quality control, quality assessment, reporting, and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence.

QA and QC Procedures, Detailed in the QAPP, Address...

- The sampling (data collection) design
- The methods to be used to obtain the samples
- How the samples will be handled and tracked
- What control limits or other materials will be used to check performance of the analyses (quality control requirements)
- How instruments or other equipment used will be calibrated
- How all data generated during the monitoring program will be managed and how errors in data entry and data reduction will be controlled (Keith 1991).

responsibilities of each member of the monitoring program team from the project manager and QA/QC officer to the staff responsible for field sampling and measurement. Project management responsibilities include overall project implementation, sample collection, data management, and budget tracking. Quality management responsibilities might include conducting checks of sample collection or data entry, data validation, and system audits. The QAPP also describes the tasks to be accomplished, how they will be carried out, the DQOs for all kinds of data to be collected, any special training or certification needed by participants in the monitoring program, and the kinds of documents and records to be prepared and how they will be maintained.

A key element of a QAPP is the SOP. SOPs help to maintain data comparability by providing a step-by-step description of technical activities to ensure that project personnel consistently perform sampling, analysis, and data-handling activities. The use of standard methods of analysis for water quality parameters also permits comparability of data from different monitoring programs.

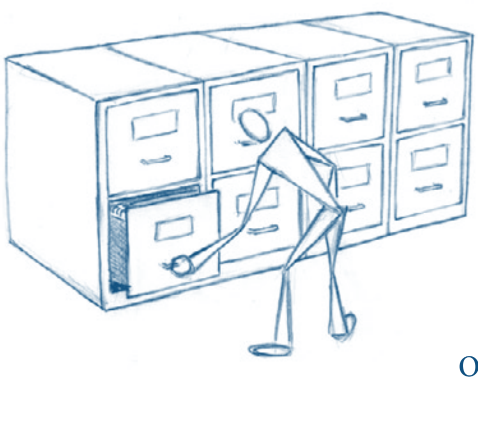
The QAPP also contains the types of assessments to be conducted to review progress and performance (e.g., technical reviews, audits), as well as how nonconformance detected during the monitoring program will be addressed. Finally, procedures are described for reviewing and validating the data generated; dealing with errors and uncertainties identified in the data; and determining whether the type, quantity, and quality of the data will meet the needs of the decisionmakers. QAPPs should be continually refined to make them consistent with changes in field and laboratory procedures. Each refinement should be documented and dated to trace modifications to the original plan.

For assistance in developing an effective QAPP, visit EPA's Web site to read *Quality Management Tools—QA Project Plans* at **www.epa.gov/quality/qapps.html**, *The Volunteer Monitor's Guide to Quality Assurance Project Plans* at **www.epa.gov/volunteer/qapp/vol_qapp.pdf**, or *Guidance for Quality Assurance Project Plans for Modeling* at **www.epa.gov/quality/qs-docs/g5m-final.pdf**.

An excerpt from the sampling plan for Spa Creek, Maryland, is provided as figure 6-1.

6.4.5 Develop a Plan for Data Management

Any monitoring program should include a plan for data management. You should determine how data will be stored, checked, and prepared for analysis. Often, these issues are addressed in the QAPP. This type of plan usually dictates that data be entered into databases that can help keep track of information collected at each site and can be used to readily implement analyses.



There are many types of platforms to house databases. The simplest databases are spreadsheets, which might be adequate for small projects. For more complex watershed measurements involving many sites or variables, a relational database is usually preferable. The biological/habitat database EDAS (Ecological Data Application System; Tetra Tech 2000) runs on a Microsoft Access platform. Very large databases often use ORACLE as a platform or a similar type of relational database that

Located in Annapolis, Maryland, Spa Creek begins at a large stormwater pipe and includes a few major tributaries before it opens into the Chesapeake Bay. Spa Creek provides recreational opportunities for boating, fishing, and hiking; it also provides habitat for Chesapeake Bay wildlife. The watershed has been developed with urban land uses, including residential, commercial, open space, and institutional uses (e.g., schools). Impairments associated with bacteria, pH, and dissolved oxygen exist in Spa Creek. A field observation revealed little evidence of a healthy aquatic life community and stream site habitat. However, there are insufficient data to understand the magnitude of the impairments and the sources and causes of impairment. As a result, a preliminary sampling plan was developed to better understand the quality of Spa Creek, its tributaries, and stormwater from a few targeted developed areas. The proposed monitoring will help stakeholders to develop a watershed management plan with specific water quality goals and actions.

The preliminary sampling plan recommends a minimum of two dry weather sampling events and two wet weather sampling events. Dry weather samples help to understand the instream water quality under minimal dilution conditions (when estuarine impacts are expected to be dominant), while wet weather samples help to understand the quality of stormwater from the surrounding watershed and its impact on Spa Creek. To understand the spatial distribution of impairment and to isolate hot spots, five instream locations and seven storm drain outlets were identified for sampling. Proposed locations and sampling frequency were recommended in the interest of developing a watershed plan with specific actions and restoration.

Parameters proposed for monitoring include flow, temperature, pH, dissolved oxygen, conductivity, turbidity, fecal coliform bacteria, total suspended solids, carbonaceous oxygen demand, total organic carbon, ammonia, nitrate + nitrite, total Kjeldahl nitrogen, orthophosphate, total phosphorus, copper, zinc, lead, hardness, and oil and grease. Ecological monitoring was proposed in the sampling plan to assess the ecological condition of Spa Creek. As part of the assessment, biological, physical habitat, and chemistry samples would be collected from three to five streams sites in the watershed. For example, benthic invertebrates and fish would be collected, and in situ toxicity testing would be performed using a caged oyster study.

The proposed plan emphasizes the importance of continuing to monitor Spa Creek to understand long-term water quality trends and to measure progress once the plan is implemented. Potential options to consider for long-term monitoring (every 3 years) include flow, metals, benthics/fish, dissolved oxygen, oyster baskets, and *E. coli*. Anticipated costs for monitoring are included in the table below.

Alternative Monitoring Description	Basic Chemistry and Biology	Benthic/Fish and Oyster Basket (3–5 locations)	Priority Pollutant Scan (4 locations)	Sampling in Tidal Area (4 locations)	Total Estimated Cost
Phase I (5 instream dry, 5 instream wet, and 3 outlet wet)	$20,000	$15,000	$14,500	$6,000 (1 dry, 1 wet)	$55,500
Complete screening level (2 dry and 2 wet at all locations)	$52,000	$15,000	$14,500	$11,000	$92,500
Only model parameter data collection (2 dry and 2 wet at 8 locations)	$33,000	$15,000			$48,000
Long-term trend monitoring, every 3 years (1 dry and 1 wet at 3–5 locations)	$12,000	$15,000			$27,000

Figure 6-1. Excerpt from Spa Creek Proposed Sampling Plan

is more readily Web-accessible. In a relational database, data, metadata, and other ancillary information reside in a series of relational tables including station information, sample information, analyses, methods used, and QC information. In this type of database, data can be organized in many different ways depending on how they are to be used (the types of analyses to be performed). It is useful to consider any requirements or options for uploading your data to other databases, such as EPA's STORET or a state agency database, as part of your overall data management process.

As mentioned earlier with respect to existing data, documentation of metadata (information about the data) is critical to ensure the proper understanding and use of the data now and in the future. Many organizations have recognized that adequately characterized data have more value to the program that collected the data, as well as to other organizations and programs, than inadequately characterized data. The Methods and Data Comparability Board and the National Water Quality Monitoring Council have developed a list of metadata categories that should be included in database design and should be reflected in all field sampling forms and other field and laboratory documentation generated as part of the monitoring (NWQMC 2005). These elements address the who, what, when, where, why, and how of collecting data. For more information on metadata and data elements, go to **http://acwi.gov/methods** or **www.epa.gov/edr**.

6.5 Collect New Data

Sampling plans often include a mixture of different types of data, including biological (e.g., benthic, fish, algae), physical (e.g., visual habitat assessment, geomorphic assessment), chemical (e.g., conductivity, nitrate, dissolved oxygen), and hydrologic measurements. Numerous methods are available for collecting these data, but the achieved data quantity and quality differ. Therefore, data collection techniques should be carefully selected to ensure that the data produced can be used to meet project goals completely.

6.5.1 Watershed Overview/Visual Assessment

A watershed survey, or visual assessment, is one of the most rewarding and least costly assessment methods. By walking, driving, or boating the watershed, you can observe water and land conditions, uses, and changes over time that might otherwise be unidentifiable. These surveys help you identify and verify pollutants, sources, and causes, such as streambank erosion delivering sediments into the stream and illegal pipe outfalls discharging various pollutants. (Note, however, that additional monitoring of chemical, physical, and biological conditions is required to determine whether the stressors observed are actually affecting the water quality.) Watershed surveys can provide a very accurate picture of what is occurring in the watershed and also can be used to familiarize local stakeholders, decisionmakers, citizens, and agency personnel with activities occurring in their watershed. For general information, read section 3.2, The Visual Assessment, in EPA's *Volunteer Stream Monitoring: A Methods Manual* (EPA 841-B-97-003), **www.epa.gov/owow/monitoring/volunteer/stream/vms32.html**. Included is a Watershed Survey Visual Assessment form, **www.epa.gov/owow/monitoring/volunteer/stream/ds3.pdf**.

Examples of Sources That Might Be Unidentifiable without a Watershed Survey

- Streambank erosion in remote areas
- Pipe outfalls with visible discharges
- Livestock (near or with access to streams)
- Wildlife (e.g., waterfowl populations on lakes and open streams)
- Small-scale land-disturbing activities (e.g., construction, tree-cutting)

Several agencies and organizations have developed visual assessment protocols that you can adapt to your own situation. For example, the Natural Resources Conservation Service (NRCS) has developed a Visual Stream Assessment Protocol (VSAP), which is an easy-to-use assessment tool that evaluates the condition of stream ecosystems. It was designed as an introductory, screening-level assessment method for people unfamiliar with stream assessments. The VSAP measures a maximum of 15 elements and is based on visual inspection of the physical and biological characteristics of instream and riparian environments. Go to **www.nrcs.usda.gov/technical/ECS/aquatic/svapfnl.pdf** to download a copy of the tool.

Some watershed survey tools are designed to examine specific issues in the watershed. For example, the Rapid Stream Assessment Technique (RSAT), developed for Montgomery County, Maryland, is a simple, rapid, reconnaissance-level assessment of stream quality and potential pollutant sources. In this technique, visual evaluations are conducted in various categories—including channel stability, physical in-stream habitat, riparian habitat conditions, and biological indicators—to gauge stream conditions. Additional information about RSAT is available at **www.stormwatercenter.net/monitoring%20and%20assessment/rsat/smrc%20rsat.pdf**.

Watershed planners often incorporate photographs into their surveys. Photographic technology is available to anyone, does not require intensive training, and is relatively inexpensive considering its benefits. Photos serve as a visual reference for the site and provide a good "before" image to compare with photos taken after restoration, remediation, or other improvements or changes. In addition to illustrating problems that need to be corrected, photos provide a watershed portrait for those that might not have the opportunity to visit monitoring sites. They help generate interest in the watershed, and they can be used in reports, presentations, grant proposals, and on Web sites and uploaded to GIS programs. In addition to taking your own photographs, you can also obtain aerial photographs from USGS (Earth Science Information Center), USDA (Consolidated Farm Service Agencies, Aerial Photography Field Office), and other agencies. California's State Water Resources Control Board Clean Water Team produced *Guidance Compendium for Watershed Monitoring and Assessment*, which contains a section on SOPs for stream and shoreline photo documentation: **www.swrcb.ca.gov/nps/cwtguidance.html#42**.

More detailed visual assessment tools to determine aquatic habitat conditions or stream stability are provided below.

6.5.2 Physical Characterization

The physical conditions of a site can provide critical information about factors affecting overall stream integrity, such as agricultural activities and urban development. For example, runoff from cropland, pastures, and feedlots can carry large amounts of sediment into streams, clogging existing habitat and changing geomorphological characteristics. An understanding of stream physical conditions can facilitate stressor identification and allow for the design and implementation of more effective restoration and protection strategies. Physical characterization should extend beyond the streambanks or shore and include a look at conditions in riparian areas.

6.5.3 Geomorphic Assessment

Geomorphic assessments range from cursory evaluations that provide general descriptions of channel shape and pattern to rigorous assessments designed to describe the geomorphic features in detail and assess stream channel alterations over time. They can help you answer various questions about the streams and rivers in your watershed, such as these used by the Vermont Department of Environmental Conservation:

- What are the physical processes and features that characterize the stream and its watershed?
- How have human activities affected these processes and features over time?
- Which of these physical processes and features are more sensitive to change, and how are they likely to change in the future?
- Which of these processes and features are important for creating and sustaining quality habitat for fish and other aquatic biota?
- Which of these processes and features present high erosion and flood hazard risks?

Geomorphology protocols commonly describe such stream and river characteristics as channel dimensions, reach slope, channel enlargement and stability, and bank-full and related measurements. The measures will help you understand current stream conditions and can be evaluated over time to describe stream degradation or improvements. The measures can also be used to predict future stream conditions, which can help you choose appropriate restoration or protection strategies.

For examples of standard geomorphic protocols, see EPA's Environmental Monitoring and Assessment Program (EMAP), **www.epa.gov/emap**, or Vermont's Stream Geomorphic Assessment Protocols, **www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm**.

The Rosgen geomorphic assessment approach (Rosgen 1996) groups streams into different geomorphic classes on the basis of a set of criteria. The criteria include entrenchment ratio, width/depth ratio, sinuosity, channel slope, and channel materials. This method is commonly used throughout the country. The Rosgen stream types can be useful for identifying streams at different levels of impairment, determining the types of hydrologic and physical factors affecting stream morphologic conditions, and choosing the best management measures to implement if necessary. For a summary of the Rosgen Stream Classification System, go to **www.epa.gov/watertrain/stream_class/index.htm**.

One of the common goals of a Rosgen assessment and other types of geomorphic assessments is to compare site-specific data from a given stream reach to data from other reaches of similar character to help classify a stream reach and determine its level of stability. A good way to do this is to use a reference channel reach near the watershed or stream reach being evaluated. When looking for a representative reach in your watershed, it is possible that one has already been surveyed, but it is often unlikely that you will be able to find the data. Therefore, it might be necessary to survey a local reference reach by determining its longitudinal profile, representative cross sections, bed materials, and meander pattern. It might be difficult to find a quality channel that exists locally. However, local data from a similar watershed are valuable to use for comparison purposes. For more information on stream channel reference sites, go to **www.stream.fs.fed.us/publications/PDFs/RM245E.PDF**.

Another common geomorphic assessment method is the Modified Wolman Pebble Count, which characterizes the texture (particle size) in the stream or riverbeds of flowing surface waters. It can be used in conjunction with Rosgen-type physical assessments or as a stand-alone method. The composition of the streambed can tell you a lot about the characteristics of the stream, including the effects of flooding, sedimentation, and other physical impacts. ➥ For detailed descriptions of the Modified Wolman Pebble Count, see Harrelson et al. (1994) and Rosgen (1996) or check out the Virginia Save Our Streams pebble count factsheet and worksheets at **www.vasos.org/pebblecountandworksheets.pdf** or the *Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring* document on the USDA Forest Service's Stream Team Web site at **www.stream.fs.fed.us/index.html**.

The Ohio Department of Natural Resources and Ohio State University developed a suite of spreadsheet tools (the STREAM Modules) that is commonly used across the country for stream assessments, including the Rosgen classification described earlier in this section. This ongoing project provides the following module at present: (1) Reference Reach Spreadsheet for reducing channel survey data and calculating basic bank-full hydraulic characteristics; (2) Regime Equations for determining the dimensions of typical channel form; (3) Meander Pattern, which dimensions a simple arc and line best fit of the sine-generated curve; (4) Cross-section and Profile, which can be used to illustrate the difference between existing and proposed channel form; (5) Sediment Equations, which includes expanded and condensed forms of critical dimensionless shear, boundary roughness and common bed load equations (can be used with the Wolman Pebble Counts); and (6) Contrasting Channels, which computes hydraulic and bed load characteristics in a side-by-side comparison of two channels of different user-defined forms. ➥ The spreadsheet is available at **www.ohiodnr.com/soilandwater/streammorphology/default/tabid/9188/Default.aspx**.

6.5.4 Hydrologic Assessment

Nonpoint source pollution is driven by climate and watershed hydrology. Hydrologic assessments deal specifically with measuring stream flow, which can provide important information about streams, lakes, and even watersheds. Stream flow data are essential to estimate nonpoint source loads. Good hydrologic data are also useful in assessing relationships between precipitation and stream flow, potentially an important indicator of watershed development. Some management measures in both agricultural and urban settings directly affect the stream flow regime, so hydrologic data from before and after implementation of BMPs can be an important element of plan evaluation.

Weather data are relatively easy to obtain from existing National Weather Service stations, or the cooperative network. ➥ For information on weather data available for your watershed, see the National Climatic Data Center Web site at **www.ncdc.noaa.gov/oa/ncdc.html** or the National Water and Climate Center at **www.wcc.nrcs.usda.gov**.

Streamflow data are more difficult to obtain. USGS conducts most of the routine streamflow monitoring in the United States, usually in cooperation with state agencies. ➥ For information on available USGS streamflow data for your region, see **http://waterdata.usgs.gov/nwis**, which contains current-condition, real-time data transmitted from selected surface water, ground water, and water quality monitoring sites. ➥ You can also visit **http://water.usgs.gov/osw/programs/nffpubs.html** to find information on regional regression equations that were developed for states and regions and can be used to predict peak flows. If you're lucky enough to have a USGS stream gauging station in your watershed, both current and historical data will be available to help estimate pollutant loads. Otherwise, you might need to look for USGS stations in adjacent, similar watersheds (similar in terms of size, topography, stream type, and so forth) to provide estimates of hydrologic behavior. For example, you might need to apply long-term average annual runoff estimates to your situation. If you need detailed streamflow monitoring, it is possible (but expensive) to install a new gauging station. If you go this route, consider installing a full-flow monitoring station at your watershed outlet and supplementing it with periodic manual measurements at the upstream locations to derive a relationship between the outlet and upstream locations. Such a relationship could be useful in estimating flow at ungauged sites.

↳ Washington State's Department of Ecology put together *A Citizen's Guide to Understanding and Monitoring Lakes and Streams*, which has an entire chapter devoted to hydrology. ↳ Go to **www.ecy.wa.gov/programs/wq/plants/management/joysmanual/chapter5.html**.

6.5.5 Water Quality Assessment

Water quality can be assessed using a variety of different methods for a multitude of analytes. The types of analytes measured should reflect the DQOs specified, as well as previously collected data for the watershed if available. For water quality assessments in support of Total Maximum Daily Loads (TMDLs), the specific pollutants identified in the TMDLs will be analyzed. For nonpoint source assessments, a variety of parameters might be analyzed, depending on the specific questions being asked and the land uses in the watershed. It is often appropriate to analyze pesticides, nutrients, and biochemical oxygen demand in agricultural areas, for example, whereas oil and grease, polycyclic aromatic hydrocarbons (PAHs), metals, and dissolved solids are more useful in urban areas. The form of the analyte being measured might need to be carefully considered; for example, if dissolved metals concentrations are needed, filtering the sample before preservation is required.

For many types of pollutants, you'll want to analyze some specific parameters simultaneously to better interpret the potential effects of those pollutants (table 6-1). For example, the bioavailability and toxicity of many metals are regulated by the suspended solids, alkalinity, hardness, pH, or dissolved organic carbon present in the water. If metals are of concern, it is recommended that many of these other analytes be measured as well. Similarly, if ammonia is a concern, simultaneous pH and temperature measurements are needed to help interpret its potential effects.

Table 6-1. Sources and Associated Pollutants

Source	Common Associated Chemical Pollutants
Cropland	Turbidity, phosphorus, nitrates, temperature, total suspended solids
Forestry harvest	Turbidity, temperature, total suspended solids
Grazing land	Fecal bacteria, turbidity, phosphorus, nitrates, temperature
Industrial discharge	Temperature, conductivity, total solids, toxic substances, pH
Mining	pH, alkalinity, total dissolved solids, metals
Septic systems	Fecal bacteria (i.e., *Escherichia coli*, enterococci), nitrates, phosphorus, dissolved oxygen/biochemical oxygen demand, conductivity, temperature
Sewage treatment plants	Dissolved oxygen and biochemical oxygen demand, turbidity, conductivity, phosphorus, nitrates, fecal bacteria, temperature, total solids, pH
Construction	Turbidity, temperature, dissolved oxygen and biochemical oxygen demand, total suspended solids, and toxic substances
Urban runoff	Turbidity, total suspended solids, phosphorus, nitrates, temperature, conductivity, dissolved oxygen and biochemical oxygen demand

Source: USEPA 1997a, 1997d.

In most nonpoint source-dominated watersheds, the concentration of a constituent in the stream is positively related to flow; most nonpoint source activity occurs at high flows. Therefore, an appropriate sampling schedule should be followed to avoid bias in measuring concentrations of pollutants. Data from time-based sampling (e.g., weekly, monthly by the calendar) are nearly always biased to low-flow conditions because high-flow events occur relatively infrequently. Flow-proportional sampling produces less biased information on true concentration and load.

Sampling methods can range from intensive efforts that require analytical laboratory analyses to in situ (field) measurements using a multiparameter monitoring and data-logging system. For more information and detailed descriptions of water quality sampling methods, see the USGS's *National Field Manual for the Collection of Water-Quality Data* at **http://water.usgs.gov/owq/FieldManual**.

Consider specialized monitoring requirements for your watershed. For example, if sediment pollutants are being analyzed, methods for sediment sampling and processing might be critical (Refer to EPA's sediment manual at **www.epa.gov/waterscience/cs/collection.html,** USGS sediment sampling techniques at **http://water.usgs.gov/osw/techniques/sediment.html**, and the section on sediment monitoring in Edward's and Glysson's field manual at **http://water.usgs.gov/osw/techniques/Edwards-TWRI.pdf** for good reviews on techniques). Some sediment quality parameters such as pH; percent moisture; total organic carbon; and, in the case of metals, simultaneously extracted metals (SEM) and acid-volatile sulfide (AVS) should be analyzed to help interpret pollutant data.

6.5.6 Assessment of Stream Habitat Quality

When conducting biological assessments, you should assess physical habitat quality to supplement the biological data. Habitat quality characteristics such as stream substrate and canopy cover influence the biotic communities that can inhabit the site, regardless of water quality conditions. Alterations in stream and watershed hydrology can potentially lead to accelerated stream channel erosion, which, in turn, leads to habitat degradation and reduces the capacity of the stream to support a healthy biota. Though combining the results of biological and physical habitat assessments does not directly identify specific cause-effect relationships, it can provide insight into the types of stressors and stressor sources affecting watersheds of interest, allowing for more detailed diagnostic investigations based on the severity of observed biological responses.

Other Visually Based Habitat Assessments

The Mississippi Department of Environmental Quality developed a visually based approach (MDEQ 2001) that is similar to the EPA Rapid Bioassessment Protocols (RBPs) but is more regimented with respect to habitat quality categories; that is, the criteria used for defining optimal, suboptimal, fair, and poor habitat are divided in more detail. This strategy was intended to make the protocol more objective and less reliant on field training.

Maryland Biological Stream Survey methods for assessing habitat quality are also based on the RBPs, but the parameters are slightly different and are rated on various scales depending on the parameter. The individual habitat parameters in this protocol are assembled into a final physical habitat index that assigns different weights to the various parameters. For a complete description of these methods, go to **www.dnr.state.md.us/streams/pubs/2001mbss_man.pdf**.

Additional descriptions of state protocols for assessing habitat quality can be found in EPA's Summary of Assessment Programs and Biocriteria Development for States, Tribes, Territories, Interstate Commissions: Streams and Wadeable Rivers at **www.epa.gov/bioindicators**.

The Stream Mitigation Compendium can be used to help select, adapt, or devise stream assessment methods appropriate for impact assessment and mitigation of fluvial resources in the CWA section 404 program: **www.mitigationactionplan.gov/Physical%20Stream%20Assessment%20Sept%2004%20Final.pdf**.

As a necessary component of its Rapid Bioassessment Protocols (RBPs), EPA developed a very useful and simple method for conducting visual assessments of physical habitat. In this method, 10 parameters describing physical habitat, stream morphology, riparian zones, and streambanks are visually assessed and ranked as optimal, suboptimal, marginal, or poor. Each parameter is scored on a 20-point scale (20 = optimal; 0 = poor), and then the scores are summed for a total habitat score.

Many states have developed visual habitat assessments that are based on EPA's RBPs but are designed to account for regional stream habitat characteristics. Check with your state Department of Natural Resources or a similar state agency to determine whether it has its own visually based habitat assessment approaches. For example, Ohio EPA developed a visual habitat assessment approach, the Qualitative Habitat Evaluation Index, or QHEI (Ohio EPA 1989). The QHEI considers the ability of various habitat characteristics to support viable, diverse aquatic faunas. It assesses the type and quality of substrate, amount of instream cover, channel morphology, extent of riparian canopy, pool and riffle development and quality, and stream gradient. The individual habitat metric scores are then combined into an aggregate habitat score. It should be noted, however, that the QHEI was specifically designed to meet warm-water habitat requirements for aquatic organisms in Ohio and might not be suitable for all stream types or all ecoregions. For more information visit **www.epa.state.oh.us/dsw/bioassess/ohstrat.html**.

Many of these habitat assessment protocols contain components that qualitatively measure particular stream characteristics and provide useful descriptions of overall site conditions. These physical characteristics can also be documented during a watershed survey, as discussed in section 6.5.1. Such parameters include water and sediment odors, water color and clarity, presence of trash or algae, aesthetic quality of the site, conditions of riparian areas, adjacent land use activities, and other on-site observations that could indicate stream degradation.

6.5.7 Watershed Habitat Assessment

In addition to assessing stream habitat quality, you should also assess overall watershed habitat quality. There are many components of habitat assessment for your watershed. When looking at your watershed area, you must identify the different types of habitats that compose it. Are there areas that are part of a larger habitat that spans more than one watershed? What conditions are key in forming and maintaining the major habitats in your watershed? What is the optimal patch size (i.e., size of the fragmented habitat) and spacing for each habitat?

Your watershed could contain many small habitats that were once a part of a larger, uninterrupted habitat. In many cases, parts of habitat are destroyed by community infrastructure. Highways and roads might cut areas into many smaller pieces. Residential and commercial development might have altered the shape of former habitat. When a larger habitat is split by these kinds of activities, the smaller parts left over can act as biological islands. They are no longer a fully functioning habitat, but a smaller area where numbers of species can fluctuate depending on changes in the factors that control their colonization and extinction rates. Though these smaller areas are composed of the same type of habitat as the larger area was, the smaller size could limit the number of species the area can support.

In some cases, these smaller (fragmented) habitats have been joined to form a wildlife corridor. Corridors encourage more interbreeding and result in healthier, more sustainable populations. Riparian or streamside buffers can serve as habitat corridors. Knowing where your fragmented habitats are can help you decide if forming corridors should be a part of your management plan. ↬ As mentioned in section 5.4.8, The Wildlands Project (**www.twp.org**) is a nonprofit organization that is involved in numerous large-scale projects to create corridors between habitat areas all across the nation. In addition to its Minnesota Ecosystems Recovery Project, the project is extensively involved in the Comprehensive Everglades Restoration Project in southern Florida. The assessment tools used in those projects might be useful to you. In addition, the works of Reed F. Noss (↬ also mentioned in section 5.4.8) are good resources for further study of wildlife corridors. A good place to start would be *A Checklist for Wildlands Network Design* (↬ **www.twp.org/files/pdf/Noss_consbio_final.pdf**).

Your habitat assessment should consider locations of small isolated populations of species (particularly fish) that use specific critical habitat when there are drought conditions due to natural variations in climate. These areas of habitat are referred to as refugia.

Your habitat assessment should also consider the hydrological connections within your watershed. Hydrological connectivity is the process that transfers water, matter, energy, and organisms both within habitats themselves and between different habitats. Changes in this connectivity can have devastating consequences both locally and possibly at a larger, more national scale. For example, a series of dams on a river can result in negative impacts on the migration and reproduction of anadramous fish. Your watershed could be affected by these kinds of conditions.

Landscape composition and pattern measures are other tools that can be used to diagnose ecological and hydrological condition and thus can be used as an effective method for characterizing landscape vulnerability to disturbance associated with human-induced changes and natural stress, as well as assess watershed habitat quality. In the San Pedro River watershed, which spans southeastern Arizona and northeastern Mexico, EPA scientists are using a system of landscape pattern measurements derived from satellite remote sensing, spatial statistics, process modeling, and geographic information systems technology to develop landscape composition and pattern indicators to help evaluate watershed condition. One of the tools that the San Pedro River landscape assessment scientists are using is ATtILLA, ↬ described in section 6.4.1) to measure and detect landscape change over this broad watershed area of concern. ↬ For more information on the San Pedro River landscape assessment, go to **www.epa.gov/nerlesd1/land-sci/san-pedro.htm**). The landscape characterization and change detection work helped to identify the significant changes that have taken place in the last quarter century. The information was also used as input variables for hydrologic response models which demonstrated the affect landscape change has on stream runoff (erosion) and loss of ground water infiltration. Additionally, the information has been used to model for potential wildlife habitat and has been preliminary tested for development into a watershed assessment atlas. The information is also being used by the interagency San Pedro Partnership Committee as the data source for community planning and development decisions relative to watershed protection and wildlife corridors and thus provides a focus for exchanging ideas and building consensus on significant environmental issues.

Using an approach that considers green infrastructure[2] is also a good way to help assess watershed habitats. In addition to identifying ways to connect open space areas, this type of approach also helps to identify riparian and upland habitat as well as habitat restoration and linking opportunities. In the Beaver Creek watershed in Knox County, Tennessee, the Beaver Creek Task Force and its partners developed the Beaver Creek Green Infrastructure Plan

[2] The term "green infrastructure" is commonly used within the field of watershed management with several variations for its definition. In this example, the Beaver Creek watershed partners have defined green infrastructure as an interconnected system of natural areas and other open spaces managed for the benefits to both people and the environment. See page 10-4 for a full explanation of how EPA generally defines green infrastructure.

to help protect and restore naturally functioning ecosystems, propose solutions to improve water quality, and provide a framework for future development. The entire creek is listed on the state's list of impaired waters. The Task Force identified and assessed existing habitat using land cover data from the Tennessee Wildlife Resources Agency. They then ranked and scored upland and riparian areas based on patch size, connectivity to other habitat patches, distance to water, and species richness. Using the scores, they evaluated the spatial pattern of the existing habitat to identify gaps and focus areas for restoration and protection.

In summary, many technical tools are available when undertaking a habitat assessment. Habitat assessment tools used in state wildlife action plans, GAP and Aquatic GAP (discussed in section 5.4.7), as well as statewide wetland and riparian buffer habitat assessment tools might be helpful. In addition to field data and observational efforts, modeling and remote sensing information can also be invaluable. In addition, Wetlands Mapper from the USFWS provides easy-to-use tools to display, manipulate, and query data so that you can produce your own information. The Wetlands Mapper is intended to provide a map-like view of wetland habitat data that has been collected by the USFWS (**http://wetlandsfws.er.usgs.gov/NWI/index.html)**.

Another great resource is the USGS's National Biological Information Infrastructure (NBII) Web site (**http://www.nbii.gov/portal/server.pt**). NBII is a program that provides increased access to data and information on the nation's biological resources.

6.5.8 Biological Assessment

Biological assessments, or *bioassessments*, are highly effective for understanding overall water quality and watershed health. They consist of surveys and other direct measurements of aquatic life, including macroinvertebrates, fish, and aquatic vegetation. Changes in the resident biota are ultimately caused by changes in their surrounding environment. Therefore, by determining how well a waterbody supports aquatic life, bioassessments directly assess the condition of ecosystem health; that is, when a waterbody's biology is healthy, the chemical and physical components are also typically in good condition. To determine impairment in a waterbody of concern, the structure and function of the biological assemblages are compared with those of a known reference assemblage that approximates the undisturbed or natural condition. The greater the difference between conditions measured, the greater the extent of impairment.

In addition to benefits (see box), biological assessments have some shortcomings. Natural variability in biological communities is often extremely high, making it difficult to detect small or gradual changes in response to changes in pollutant loads. Conclusions drawn from a biological assessment might be somewhat ambiguous: Is a site poor in macroinvertebrate fauna because of a large sedimentation event, a transient toxic release, or continuously low dissolved oxygen? Finally, biomonitoring typically requires a significant investment in time and specialized skills. It is fairly easy to collect a water sample, submit it to a lab, and wait for the results; collecting, identifying, and counting benthic invertebrates is a more demanding task.

Benefits of Biological Information

Biological data can be used to track water quality trends, list and delist waters under section 303(d) of the Clean Water Act, and assess the effectiveness of TMDLs.

Biological organisms provide a measure of the combined impact of stressors because they're exposed to the effects of almost all the different stressors in a waterbody.

Biological organisms integrate stress over time and thus are good measures of fluctuating water quality conditions.

Routine bioassessments can be relatively inexpensive, especially compared to the cost of monitoring individual toxic pollutants.

The public views the status of aquatic life as a measure of a pollution-free environment.

Numerous protocols are available for conducting biological assessments. One of the most accepted and commonly used methods nationwide is EPA's *Rapid Bioassessment Protocols (RBPs) for Use in Wadeable Streams and Rivers* (Barbour et al. 1999). This guidance document outlines the methods and steps required for conducting rapid bioassessments of three different assemblages—periphyton, benthic macroinvertebrates, and fish. It also contains useful information on conducting physical habitat assessments, performing data analysis, and integrating data and reporting. Go to **www.epa.gov/owow/monitoring/rbp/download.html** to download a copy of the document. The Izaak Walton League also has materials available to help with bioassessment, including a bug card, video, and score sheet for rapidly determining relative water quality. It also conducts training workshops. Go to **www.iwla.org/index.php?id=412** for more information.

Some states, such as Connecticut, have developed and tested streamlined bioassessment protocols for volunteer monitors. Go to **http://www.ct.gov/dep/cwp/view.asp?a=2719&q=325606&depNav_GID=1654** for more information.

Once you've collected the additional data needed to adequately characterize your watershed, you'll add the results to your data inventory. You can now move on to the next step. In chapter 7, you'll analyze the data to determine sources and causes of water quality impairments.