Monitoring and Tracking Techniques

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Knowledge of land management activities and water quality conditions is important in many ways to efforts involving implementation of management measures and practices. As discussed in Chapter 5, the watershed planning process includes an understanding of the hydrologic resources, an assessment of environmental problems, goal setting, and priority setting. The development of action plans and implementation follow, with evaluation of effectiveness and revisions of plans as needed. Good water quality data are essential to problem identification and characterization, goal setting, priority setting, development of implementation plans, and evaluation. In order to have an understanding of what goals have to be met, a baseline must be established. Without good data regarding land management activities, including the control of point sources, accurate interpretation of the causes of water quality problems and improvements is not possible.

Water Quality Monitoring

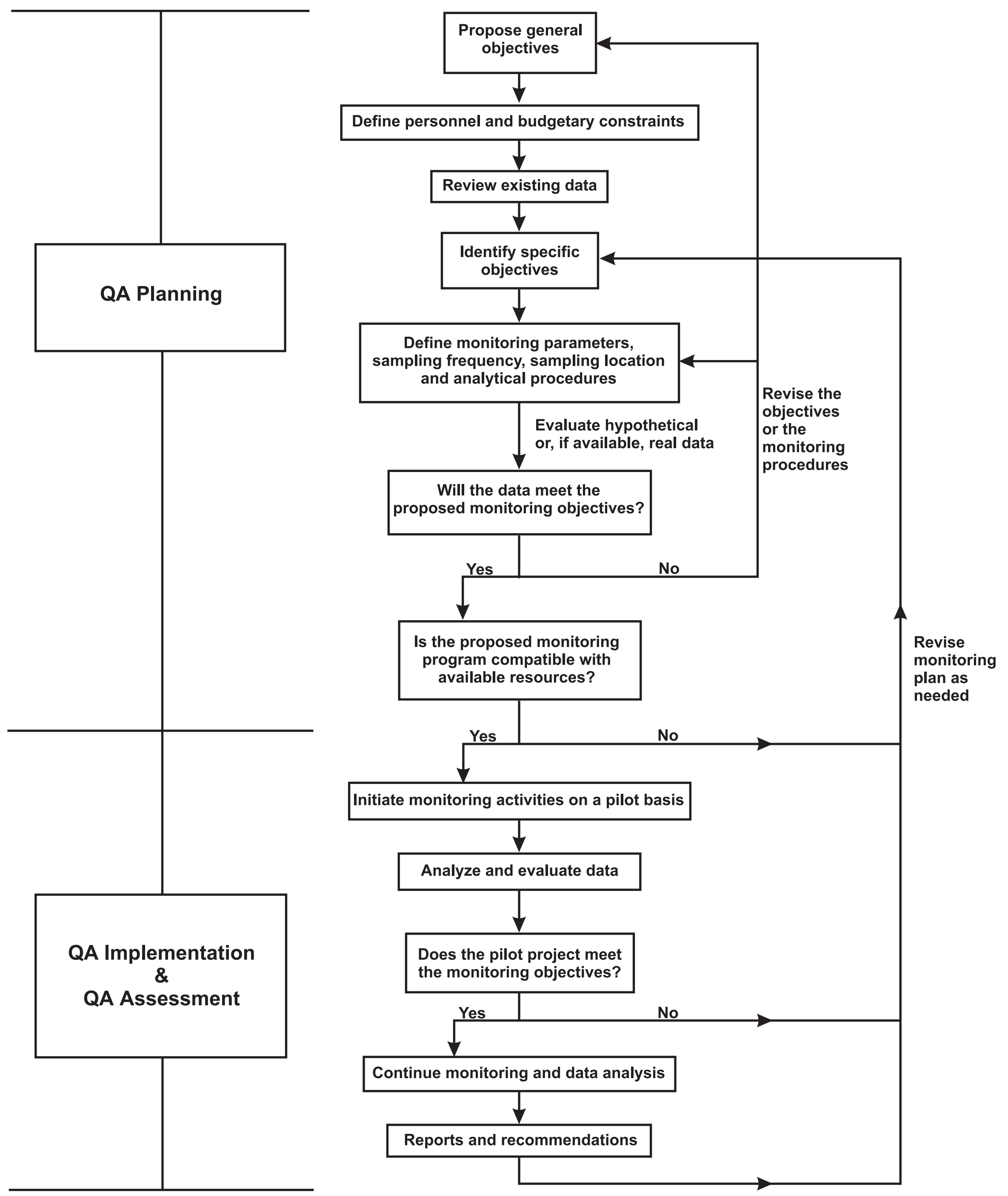
Since the relationship between public health and water quality began to influence legislation in the early 1900s, water quality management and its related information needs have evolved considerably. Today, the Intergovernmental Task Force on Monitoring Water Quality (ITFM, 1995) defines water quality monitoring as an integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions, and designated water uses. Water quality monitoring for nonpoint sources (NPS) of pollution facilitates the important element of relating the physical, chemical, and biological characteristics of receiving waters to land use characteristics. Without current information on water quality conditions and pollutant sources, effects of land-based activities on water quality cannot be assessed, effective management and remediation programs cannot be implemented, and program success cannot be evaluated.

The most fundamental step in the development of a monitoring plan is to define the goals and objectives, or purpose, of the monitoring program. In general, monitoring goals are broad statements such as “to measure improvements in Hojnacki Creek” or “to verify nutrient load reductions into Stumpe Lake.” In the past, numerous monitoring programs did not document this aspect of the design process and the resulting data collection efforts led to little useful information for decision making (GAO, 1986; MacDonald et al., 1991; National Research Council, 1986; Ward et al., 1990). As a result, the identification of monitoring goals is the first component of the design framework outlined by the ITFM (1995). Figure 6-1 presents one approach for developing a monitoring plan.

Monitoring programs can be grouped according to the following general purposes or expectations (ITFM, 1995; MacDonald et al., 1991):

- Describing and ranking existing and emerging problems

Figure 6-1. Development of a monitoring project (after MacDonald et al., 1991).



- ❒ Describing status and trends
- ❒ Designing management and regulatory programs
- ❒ Evaluating program effectiveness
- ❒ Responding to emergencies
- ❒ Describing the implementation of best management practices
- ❒ Validating a proposed water quality model
- ❒ Performing research

The importance of problem identification can not be underestimated. The water quality impairment (e.g., algal growth, sediment deposition, turbidity) must first be documented. Second, the pollutant(s) causing the impairments should be identified (e.g., nitrogen, phosphorus, soil erosion or streambank instability). This information can be used to facilitate the identification of pollutant sources. Water quality assessments and land use information are useful in identification of pollutant sources.

Unlike monitoring goals, monitoring objectives are more specific statements that can be used to complete the monitoring design process including scale, variable selection, methods, and sample size (Plafkin et al., 1989; USDA-NRCS, 1996b). Monitoring program objectives must be detailed enough to allow the designer to define precisely what data will be gathered and how the resulting information will be used. An example objective which would facilitate quantitative evaluations is “To detect a decrease in total phosphorus loading to Stumpe Lake via Hajnacki Creek by 50% over the next 6 years.” Vague or inaccurate statements of objectives lead to program designs that provide too little or too much data, thereby failing to meet management needs or costing too much.

The remainder of the design framework outlined by the ITFM (1995) includes coordination and collaboration, design, implementation, interpretation, evaluation of the monitoring program, and communication. Numerous guidance documents have been developed, or are in development, to assist resource managers in developing and implementing monitoring programs that address all aspects of the ITFM’s design framework. Appendix A in *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (EPA, 1997a) presents a review of more than 40 monitoring guidances for both point and NPS pollution. These guidances discuss virtually every aspect of NPS pollution monitoring, including monitoring program design and objectives, sample types and sampling methods, chemical and physical water quality variables, biological monitoring, data analysis and management, and quality assurance and quality control.

Appendix A in *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (EPA, 1997a) presents a review of more than 40 monitoring guidances for both point and NPS pollution.

Once the monitoring goals and objectives have been established, existing data and constraints should be considered. A thorough review of literature pertaining to water quality studies previously conducted in the geographic region of interest should be completed before starting a new study. The review should help determine whether existing data provide sufficient information to address the monitoring goals and what data gaps exist.

Identification of project constraints should address financial, staffing, and temporal elements. Clear and detailed information should be obtained in the time frame within which management decisions need to be made, the amounts and types of data that must be collected, the level of effort required to collect the necessary data, and equipment and personnel needed to conduct the monitoring. From this information it can be determined whether available personnel and budget are sufficient to implement or expand the monitoring program.

As with monitoring program design, the level of monitoring that will be conducted is largely determined when goals and objectives are set for a monitoring program, although there is some flexibility for achieving most monitoring objectives. Table 6-1 provides a summary of general characteristics of various types of monitoring.

The overall scale of a monitoring program has two components—a temporal scale and a geographic scale. The temporal scale is the amount of time required to accomplish the program objectives. It can vary from an afternoon to many years. The geographic scale can also vary from quite small, such as plots along a single stream reach, to very large, such as an entire river basin. The temporal and geographic scales, like a program's design and monitoring level, are primarily determined by the program's objectives.

If the main objective is to determine the current biological condition of a stream, sampling at a few stations in a stream reach over 1 or 2 days might suffice. Similarly, if the monitoring objective is to determine the presence or absence of a NPS impact, a synoptic survey might be conducted in a few select locations. If the objective is to determine the effectiveness of a nutrient management program for reducing nutrient inputs to a downstream lake, however, monitoring a subwatershed for 5 years or longer might be necessary. Collection of baseline information prior to implementation of improved management practices is important so that an improvement can be quantified. If the objective is to calibrate or verify a model, more intensive sampling might be necessary.

Depending on the objectives of the monitoring program, it might be necessary to monitor only the waterbody with the water quality problem or it might be

Table 6-1. General characteristics of monitoring types (MacDonald et al., 1991).

Type of Monitoring	Number and Type of Water Quality Parameters	Frequency of Measurements	Duration of Monitoring	Intensity of Data Analysis
Trend	Usually water column	Low	Long	Low to moderate
Baseline	Variable	Low	Short to medium	Low to moderate
Implementation	None	Variable	Duration of project	Low
Effectiveness	Near activity	Medium to high	Usually short to medium	Medium
Project	Variable	Medium to high	Greater than project duration	Medium
Validation	Few	High	Usually medium to long	High
Compliance	Few	Variable	Dependent on project	Moderate to high

necessary to include areas that have contributed to the problem in the past, areas containing suspected sources of the problem, or a combination of these areas. A monitoring program conducted on a watershed scale must include a decision about a watershed's size. The effective size of a watershed is influenced by drainage patterns, stream order, stream permanence, climate, number of landowners in the area, homogeneity of land uses, watershed geology, and geomorphology. Each factor is important because each has an influence on stream characteristics.

There is no formula for determining appropriate geographic and temporal scales for any particular monitoring program. Rather, once the objectives of the monitoring program have been determined, a combined analysis of them and any background information on the water quality problem being addressed should make it clear what overall monitoring scale is necessary to reach the objectives.

Other factors that should be considered to determine appropriate temporal and geographic scales include the type of water resource being monitored and the complexity of the NPS problem. Some of the constraints mentioned earlier, such as the availability of resources (staff and money) and the time frame within which managers require monitoring information, will also contribute to determination of the scales of the monitoring program.

For additional details regarding NPS monitoring techniques, including chemical and biological monitoring, the reader is referred to *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (EPA, 1997a). This technical document focuses on monitoring to evaluate the effectiveness of management practices, but also includes approximately 300 references and summaries of more than 40 other monitoring guides. In addition, Chapter 8 of EPA's management measures guidance for Section 6217 contains a detailed discussion of monitoring with emphasis on coastal areas (EPA, 1993a). Another useful reference for monitoring design is the National Handbook of Water Quality Monitoring (USDA-NRCS, 1996b).

Tracking Implementation of Management Measures

The implementation of management measures may be tracked to determine the extent to which management measures are implemented in a watershed, recharge area, or other geographic area.

Implementation and trend monitoring can be used to address the following goals:

- ❒ Determine the extent to which management measures and practices are implemented in accordance with relevant standards and specifications.
- ❒ Determine whether there has been a change in the extent to which management measures and practices are being implemented.
- ❒ Establish a baseline from which decisions can be made regarding the need for additional incentives for implementation of management measures,
- ❒ Measure the extent of voluntary implementation efforts,

See EPA's *Monitoring Guidance for Determining Effectiveness of Nonpoint Source Controls* for details on NPS monitoring techniques.

- ❒ Support work-load and costing analyses for assistance or regulatory programs,
- ❒ Determine the relative adoption rates of various management measures across different geographic areas,
- ❒ Determine the extent to which management measures are properly maintained and operated.

Methods to assess the implementation of management measures are a key focus of technical assistance provided by EPA and NOAA.

Implementation assessments can be performed on several scales. Site-specific assessments can be used to assess individual management measures or practices, and watershed assessments can be used to look at the cumulative effects of implementing multiple management measures. With regard to "site-specific" assessments, individual practices must be assessed at the appropriate scale for the practice of interest. For example, to assess the implementation of management measures and practices for animal waste handling and disposal on a farm, only the structures, areas, and practices implemented specifically for animal waste management (e.g., dikes, diversions, storage ponds, composting facility, and manure application records) would need to be inspected. In this instance, the animal waste storage facility would be the appropriate scale and "site." To assess erosion control, the proper scale might be fields over 10 acres and the site could be 100-meter transect measurements of crop residue. For nutrient management, the scale and site might be an entire farm. Site-specific measurements can then be used to extrapolate to a watershed or statewide assessment. It is recognized that some studies might require a complete inventory of management measures and practice implementation across an entire watershed or other geographic area.

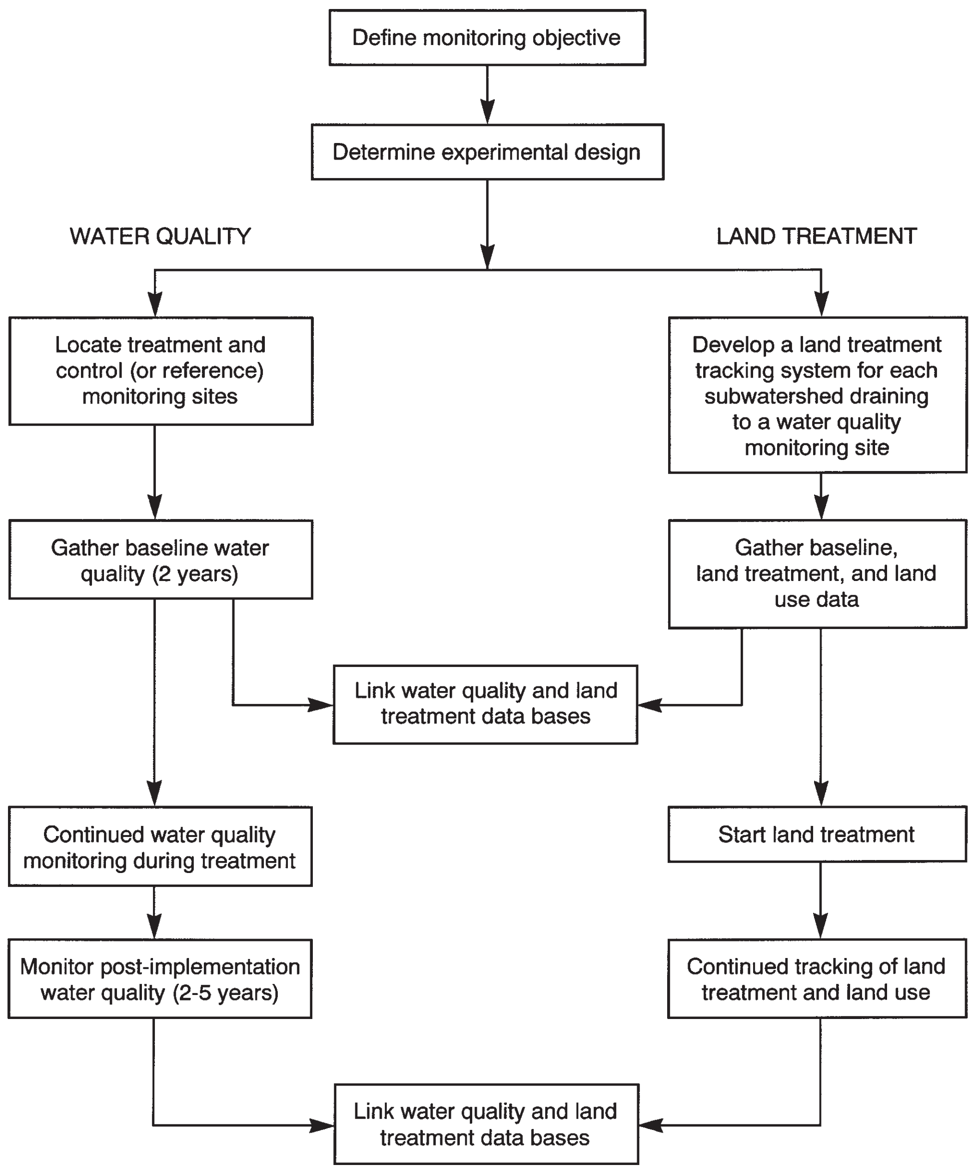
Sampling design, approaches to conducting the evaluation, data analysis techniques, and ways to present evaluation results are described in EPA's *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures – Agriculture* (EPA, 1997b). Chapter 8 of EPA's management measures guidance for Section 6217 contains a detailed discussion of techniques and procedures to assess implementation, operation, and maintenance of management measures (EPA, 1993a).

Determining Effectiveness of Implemented Management Measures

By tracking management measures and water quality simultaneously, analysts will be in a position to evaluate the performance of those management measures implemented. Management measure tracking will provide the necessary information to determine whether pollution controls have been implemented, operated, and maintained adequately. Without this information, analysts will not be able to fully interpret their water quality monitoring data. For example, analysts cannot determine whether the management measures have been effective unless they know the extent to which these controls were implemented, maintained, and operated.

A major challenge in attempting to relate implementation of management measures to water quality changes is determining the appropriate land management attributes to track. For example, a "bean count" of the number of management measures implemented in a watershed has little chance of being useful in statistical analyses that relate water quality to land treatment since the count will be only remotely related (i.e., a mechanism is lacking) to the measured water quality parameter (e.g., phosphorus concentration). Land treatment and land use monitoring should relate directly to the pollutants or impacts monitored at the water quality station (Coffey and Smolen, 1990). For example, the tons of animal waste managed may be a much more useful parameter to track than the number of confined animal facilities constructed. Since the impact of management measures on water quality may not be immediate or implementation may not be sustained, information on other relevant watershed activities (e.g., urbanization, growth in animal numbers) will be essential for the final analysis.

Figure 6-2. Land treatment and water quality monitoring program design (Coffey et al., 1995).



Water quality and land treatment monitoring must be coordinated to maximize the chance of meaningful results. In order to provide the manager with a sense of the nature of the coordination needed, an overview of monitoring program design is provided in Figure 6-2.

Monitoring program design, as shown in Figure 6-2, begins by defining the monitoring objective. Once the objective is defined, the experimental design (e.g., upstream/downstream, pre- and post-BMP, and paired watershed) is determined. Based on the experimental design, separate but coordinated parallel water quality and land treatment activities are specified.

Appropriately collected water quality information can be evaluated with trend analysis to determine whether pollutant loads have been reduced or whether water quality has improved. Valid statistical associations drawn between implementation and water quality data can be used to indicate:

(1) Whether management measures have been successful in improving water quality in a watershed or recharge area, and

(2) The need for additional management measures to meet water quality objectives in the watershed or recharge area.

Greater detail regarding methods to evaluate the effectiveness of land treatment efforts can be found in EPA's NPS monitoring guidance (EPA, 1997a) and management measures guidance for section 6217 (EPA, 1993a).

Quality Assurance and Quality Control

Introduction

Quality assurance (QA) and quality control (QC) are commonly thought of as procedures used in the laboratory to ensure that all analytical measurements made are accurate. Yet QA and QC extend beyond the laboratory and are essential components of all phases and all activities within each phase of a NPS monitoring project. This section defines QA and QC, discusses their value in NPS monitoring programs, and explains EPA's policy on these topics. The following sections provide detailed information and recent references for planning and ensuring quality data and deliverables that can be used to support specific decisions involving NPS pollution.

Definitions of Quality Assurance and Quality Control

Quality assurance is

> an integrated system of management procedures and activities used to verify that the quality control system is operating within acceptable limits and to evaluate the quality of data (Taylor, 1993; EPA, 1994a).

Quality control is

> a system of technical procedures and activities developed and implemented to produce measurements of requisite quality (Taylor, 1993; EPA, 1994a).

Quality control procedures include proper collection, handling, and storage of samples; analysis of blank, duplicate, and spiked samples; and use of standard reference materials to ensure the integrity of analyses. QC procedures also include regular inspection of equipment to ensure proper operation. Quality assurance activities are more managerial in nature and include assignment of roles and responsibilities to project staff, staff training, development of data quality objectives, data validation, and laboratory audits. Table 6-2 lists some common activities that fall under the headings of QA and QC. Such procedures and activities are planned and executed by diverse organizations through carefully designed quality management programs that reflect the importance of the work and the degree of confidence needed in the quality of the results.

Table 6-2. Common quality management activities (adapted from Drouse et al., 1986, and Erickson et al., 1991).

Quality Assurance

- Organization of project into component parts
- Assignment of roles and responsibilities to project staff
- Use of statistics to determine the number of samples and sampling sites needed to obtain data of a required confidence level
- Tracking of sample custody from field collection through final analysis
- Development and use of data quality objectives to guide data collection efforts
- Audits of field and laboratory operations
- Maintenance of accurate and complete records of all project activities
- Personnel training to ensure consistency of sample collection techniques and equipment use

Quality Control

- Collection of duplicate samples for analysis
- Analysis of blank and spike samples
- Replicate sample analysis
- Regular inspection and calibration of analytical equipment
- Regular inspection of reagents and water for contamination
- Regular inspection of refrigerators, ovens, etc. for proper operation

Importance of Quality Management Programs

Although the value of a quality management program might seem questionable while a project is under way, its value should be quite clear after a project is completed. If the objectives of the project were used to design an appropriate data collection and analysis plan, all procedures were followed for all project activities, and accurate and complete records were kept throughout the project, the data and information collected from the project will be adequate to support a choice from among alternative courses of action. In addition, the course of action chosen will be defensible based on the data and information collected. Development and implementation of a quality management program can require up to 10 to 20% of project resources (Cross-Smiecinski and Stetzenback, 1994), but this cost can be recaptured in lower overall costs due to the project's being well planned and executed. Likely problems are anticipated and accounted for before they arise, eliminating the need to spend countless hours and dollars resampling, reanalyzing data, or mentally reconstructing portions of the project to determine where an error was introduced. QA procedures and QC activities are cost-effective measures used to determine how to allocate project energies and resources toward improving the quality of research and the usefulness of project results (Erickson et al., 1991).

EPA Quality Policy

EPA has established a quality policy that requires the implementation of a quality system by EPA and by non-EPA organizations receiving financial assistance from EPA to ensure that data used in research and monitoring are of known and documented quality to satisfy project objectives. A quality system is developed by an organization and documented in writing. The system provides the policies, objectives, responsibilities, and procedures to be followed to ensure the quality of work processes, services, or products. A quality system is typically documented in a quality management plan (QMP). When conducting monitoring or tracking the implementation of management measures by collecting environmental data, site-specific written plans are needed to describe the quality objectives (acceptance or performance criteria) to be met so that the data can be used to support the particular decision(s) for which the data are being collected. Such site-specific plans are known as quality assurance project plans (QAPPs). The use of different methodologies, lack of data comparability, unknown data quality, and poor coordination of sampling and analysis efforts can delay the progress of a project or render the data and information collected from it insufficient for decision making. Whether or not EPA funding is involved, quality practices should be used as an integral part of the development, design, and implementation of an NPS monitoring project to minimize or eliminate these problems (Erickson et al., 1991; Pritt and Raese, 1992; EPA, 1997a).

Additional information on developing quality programs can be found in EPA publications (e.g., EPA, 2000; 2001a, b;), available on the Internet at http://www.epa.gov/quality/qa_tools.html.