Chesapeake Bay National Estuarine Research Reserve in Virginia

GUIDELINES

SHALLOW WATER QUALITY MONITORING

CONTINUOUS MONITORING STATION: SELECTION, ASSEMBLY & CONSTRUCTION

Eduardo J. Miles
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CHESAPEAKE BAY
NATIONAL ESTUARINE RESEARCH RESERVE
IN VIRGINIA

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By Eduardo J. Miles

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PREFACE

Multi-parameter sondes are becoming the standard instrument to assess water quality in shallow waters. Their ability to measure a number of different water quality parameters in situ, unattended, and in short time intervals, makes them the ideal monitoring equipment to characterize water quality variability in of various types of water bodies.

In order for the multi-parameter sonde to fulfill its capabilities, site and station configuration selection must be properly addressed. The monitoring and data quality objectives provide the basic information for site selection. Once the site is selected, the station configuration can be defined.

Research has shown that most of the project's life-cycle quality and cost are committed by the decisions taken by the end of the planning and design stages. One of the best practices employed to improve quality, prevent errors, and minimize cost during the planning and design stages is by adapting, or reviewing, known techniques or processes that have shown through experience to achieve the desired results in a reliable, efficient, and effective way.

CBNERRVA has been performing continuous shallow water quality monitoring for more than ten years. During this time, several monitoring platforms have been developed that take into account certain design characteristics that are considered important when a proper balance between cost and operational performance is desired.

The purpose of this manual is to provide monitoring teams with guidelines to enable them maximize the effectiveness and efficiency of the station configuration selection process. Based on experience gathered at CBNERRVA, it is a good practice to review, at the beginning of the station selection process, the different types of platform configurations, and assess which configuration can work best in the specific monitoring environment. The manual provides basic information on monitoring platforms that can either be used to select a specific configuration or to define new design features to meet the particular needs of the monitoring program.

Reference in this manual to a specific multiparameter sonde is for the purpose of illustration only and should not be regarded as an endorsement of a particular brand.

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INTRODUCTION

i. WATER QUALITY MONITORING: PURPOSE

Water quality monitoring projects are executed to answer a variety of questions, or address concerns, that managers, researchers, policy makers, and other stakeholders have with regard to biological or physical interactions, water usage, recreation and aesthetics, or status of water bodies among many other water issues or concerns.

As any other type of monitoring project, there are some critical success factors that must be properly addressed for a water quality-monitoring project to be successful. A clear understanding of the monitoring purpose by the monitoring team is one of these critical factors (*i.e.*, what is or are the problems to be analyzed? and what are the questions to be answered?). It is crucial to understand that the monitoring objectives are defined by the monitoring purpose. The entire water quality monitoring effort may be unsuccessful if the objectives are not clearly defined, or understood by those conducting the project and those receiving the final results (Spooner and Mallard, 2003).

One problem facing the water monitoring community is the lack of consensus among the different agencies, institutions and organizations on the definition of the different types and terminology of water quality monitoring (Ward2 *et al*.). In this regard, the Intergovernmental Task Force on Monitoring Water Quality (ITFM) carried out a review of water-quality monitoring activities from 1992 to 1997, recommending several improvements concerning water quality monitoring terminology, process and methodology. In 1997, the ITFM was reconstituted with representatives of both public and private sectors, as the National Water Quality Monitoring Council, with the objective to provide a national forum for the coordination of consistent and scientifically defensible methods and strategies to improve water quality monitoring, assessment and reporting. This endeavor will have positive results in the near future. Meanwhile, there are some terms being used that are worthy of mention:

> *The International Organization for Standardization (ISO) defines monitoring as "the programmed process of sampling, measurement and subsequent recording or signaling, or both, of various water characteristics, often with the aim of assessing conformity to specified objectives".*
>
> *Water-quality monitoring is defined by the Intergovernmental Task Force on Monitoring Water Quality (ITFM) 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".*

The Intergovernmental Task Force on Monitoring Water Quality (ITFM) (1995), as well as the Environmental Protection Agency (USEPA), defines five major monitoring purposes:

1. *Characterize waters and identify changes or trends in water quality over time.*

2. *Identify specific existing or emerging water quality problems.*

3. *Gather information to design specific pollution prevention or remediation programs.*

4. *Determine whether program goals, such as compliance with pollution regulations or implementation of effective pollution control actions, are being met.*

5. *Respond to emergencies, such as spills and floods.*

These major monitoring purposes are not mutually exclusive and some monitoring endeavors can meet more than one of these purposes at the same time.

The European Union (Working Group 2.7 – Monitoring, under the Water Framework Directive, 2003) describe three types of monitoring for surface waters: surveillance, operational and investigative monitoring. Ward *et al.* (2003) summarizes very well these three types of monitoring "*Surveillance monitoring is done to supplement and validate impact assessment procedures, for the design of future monitoring programmes, and for the assessment of long-term changes both in natural conditions and changes resulting from anthropogenic activities. This monitoring is done to keep track of changes in the water body. Operational monitoring is carried out for all those bodies of water, which on the basis of either the impact assessment or surveillance monitoring, are identified as being at risk of failing to meet their environmental objectives and for those bodies of water into which priority list substances are identified as being discharged. Investigative monitoring, finally, is carried out when the reason for any exceedance of standards is unknown, when surveillance monitoring indicates that the environmental objectives for a body of water are not likely to be achieved in order to ascertain the causes of the failing, or to ascertain the magnitude and impacts of accidental*".

Another classification is given by Cavanagh *et al*. (1998) who classify the purposes of the monitoring programs into four broad categories: compliance, trend, impact assessment, and survey. Each monitoring program involves a series of water quality measurements intended to detect short, or long-term variability of the water body studied (see appendix i).

The California Rangelands Research and Information Center (1995) gives another classification defining seven types of monitoring according to the parameters being measured, the frequency and duration of monitoring, and the data analysis. The seven types are: trend, baseline, implementation, effectiveness, project, validation, and compliance. It is emphasized that the seven types of monitoring are not mutually exclusive and the difference between them is due to the monitoring goal rather than the intensity, or type of measurements. In general, a water quality-monitoring project would involve a mixture of these seven types of monitoring. Thus, the same measurements can be used to comply with different monitoring goals (see appendix i).

ii. WATER QUALITY MONITORING: PROCESS

Even though is not the purpose of this manual to address all the necessary steps to design an effective water quality monitoring program, it is important to outline certain points that must be considered in order to collect data that consistently represent the existing environmental conditions.

In general, water quality monitoring is performed to answer a question that is linked, in one way or another, to a management concern (*e.g.* policy formulation, environmental protection, compliance, development concerns). Therefore, one of the main objectives of a water quality-monitoring endeavor is to provide the necessary information to answer specific questions in decision-making. In order to achieve this objective, a systematic process must be followed to address the monitoring project. The systematic process will ensure that the data collected can answer the questions with the degree of confidence required.

There are several systematic processes that have being designed for water quality monitoring projects, among them, the following processes are worth to mention:

1. The National Water Quality Monitoring Council (2003) proposed a framework for water quality monitoring programs composed of six phases considered critical to the establishment of a reliable water quality monitoring program: develop monitoring objectives; design monitoring program; collect field and lab data; compile and manage data; assess and interpret data; convey results and findings. In addition, the framework contains 3C's: collaborate, communicate, and coordinate; which are an integral part to each of the elements of the framework (appendix ii).

2. The EPA (2003) recommends ten basic elements of a State water monitoring and assessment program which serves also as a tool to help EPA and the States determine whether a monitoring program meets the prerequisites of CWA Section 106(e)(1). The ten elements are: monitoring program strategy; monitoring objectives; monitoring design; core and supplemental water quality indicators; quality assurance; data management; data analysis/assessment; reporting; programmatic evaluation; and general support and infrastructure planning.

3. The UN/ECE Task Force on Monitoring & Assessment (2000) proposes a monitoring cycle composed of: water management; information needs; assessment strategies; monitoring programmes; data collection; data handling; data analysis; assessment and reporting and information utilisation (appendix ii).

4. The Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand (2000) propose monitoring guidelines, which lay out the framework and general principles for a water quality-monitoring program. The guidelines have the following elements: determining the primary management aims; setting monitoring program objectives; study design; field sampling program; laboratory analyses; data analysis and interpretation; reporting and information dissemination (appendix ii).

It is crucial that a systematic planning process is followed in the development of any type of water quality monitoring program. By executing a systematic planning process, the interested party will ensure that the data collected is of the appropriate type and quality for the intended use, and will accurately represent the water body. In addition, it will ensure that the appropriate monitoring and analysis technologies are used to yield unbiased and reproducible results (EPA, 2000).

The four systematic processes highlighted in this manual can be used to ensure a sound monitoring project.

Additional information in how to design a water quality-monitoring program can be found in:

- National Water Quality Monitoring Council (2003)
  http://water.usgs.gov/wicp/acwi/monitoring

- UN/ECE Task Force on Monitoring & Assessment (2000)
  www.unece.org/env/water/publications/ documents/guidelinestransrivers2000.pdf

- The Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand (2000).
  http://www.deh.gov.au/water/quality/nwqms

- U.S. Environmental Protection Agency (2003).
  http://www.epa.gov/owow/monitoring/elements

- MacDonald *et al*. (1991), MacDonald (1994), Sanders *et al*. (1983), DEQ (2003), White (1999). Ward, R.C., and Peters, C.A. (2003).

iii. CONTINUOUS WATER QUALITY MONITORING

There are many types of water sampling methods that can be used to collect water quality data. For example: collection by hand, automatic sampler, remote sensing, or direct field observations. The nature of the required information and the parameters to be measured will determine the best method to apply.

Continuous monitoring is becoming a standard to determine shallow water quality. Multiparameter sondes are increasingly being used to monitor water quality at fixed monitoring sites, to carry out vertical profiling, or to perform water quality mapping (dataflow).

Continuous monitoring is the sampling method of choice when water quality variations are to be characterized over time. Some characteristics of automated water quality monitoring are:

- → Capability of measuring a number of different water quality parameters in situ, unattended, and in short time intervals.
- → Provide continuous water quality data that can be accessible in a timely basis, be transmitted directly by telemetry, and be published on the web in real time.
- → The information can be used to track real time environmental events, *i.e.* algal blooms or hurricanes.
- → The sampling intervals can be set to detect water quality variations specific to the study site.
- → The data can be used in conjunction with remote sensing, *i.e.* atmospheric corrections.

Continuous water quality monitoring has certain critical factors that must be properly addressed in order to assure the quality of the data collected. Two of these critical factors are: site and station configuration selection.

Site selection is not a straightforward task. The monitoring sites must be selected to comply with the monitoring and data quality objectives. Given that it is not possible to sample the whole target area, it is essential that the stations be placed where representative samples can be obtained, and where the data measured represents accurately and precisely the water body.

One activity that is closely linked to site selection is the determination of the type of monitoring station to be used. Once a monitoring site is selected, certain station designs will be more suitable than others to achieve the monitoring and data quality objectives.

There are a great variety of continuous monitoring station configurations with different designs and construction methods to be considered during the monitoring platform selection process. Even though no universal design, assembly and construction procedure can be recommended, there are some stations configurations that are becoming the standard in shallow water monitoring. This document provides an overview of these shallow water quality monitoring platforms. Most of the configurations described here are based on the experience gathered over more than ten years of conducting continuous shallow water quality monitoring projects at the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERRVA).

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APPENDIX i

Cavanagh *et al.* (1998) classification of the monitoring programs purposes

1. Compliance

   USGS defines compliance monitoring as a type of monitoring done to ensure the meeting of immediate statutory requirements, the control of long-term water quality, the quality of receiving waters as determined by testing effluents, or the maintenance of standards during and after construction of a project (modified from Resh, D. M., and Rosenberg, V.H., eds., 1993, Freshwater Biomonitoring and Benthic Macroinvertebrates: New York, Chapman and Hall, 488 p)

2. Trend

   "*Tend monitoring is used to detect subtle changes over time that may result from a potential long-term problem. Measurements are made at regular time intervals to determine if long-term trends are occurring for a particular variable. Trend monitoring is a commitment that extends over a long period (i.e., usually 10 years or more) to ensure that true trends are detected. It is essential that the program minimizes variability through time. Therefore, as much as possible, the program should remain consistent in terms of frequency, location, time of day samples are collected, and the collection and analytical techniques that are used*."

3. Impact Assessment

   "*Impact assessment monitoring measures the effects on water quality of a particular project (anthropogenic) or event (natural). Projects, in this case, refer to anything associated with industrial activities, resource extractive activities, impoundments (dams), agricultural activities, and urban or recreational developments. Events refer to fires, floods, landslides, volcanic activity, etc.*

   An ideal impact assessment monitoring program is one that has both test and control sites, is initiated prior to project start-up, continues while the project is operational, and extends for a defined post-project time period. In the case of anthropogenic impacts, it is ideal that the monitoring program be initiated prior to the start-up date of the proposed project. In this case, a baseline (pre-operation/treatment) assessment is carried out which can provide data to which post-treatment data can be compared, and allow for better estimates of the limits of normal variation. The baseline or pilot information should include an inventory of the existing ecosystem components (aquatic and terrestrial flora and fauna) and water uses in the project area. "

4. Survey

   "*Survey monitoring is used to characterize existing water quality conditions over a specified geographic area. As such, it is more of an inventory rather than a true monitoring process because it does not address changes over time. It is often conducted within watersheds that have not been previously sampled and which are so remote that there exists little or no direct anthropogenic activity. It is generally carried out in a limited manner (once or twice per lake or river) unless the resulting data promote cause for concern. Consequently, this type of inventory occasionally serves as the first step towards establishing one of the above, more extensive monitoring programs*."

The California Rangelands Research and Information Center (1995) classification

1. Trend monitoring

   "*In view of the definition of monitoring, this term is redundant. Use of the adjective "trend" implies that measurements will be made at regular, well-spaced time intervals in order to determine the long-term trend in a particular parameter. Typically the observations are not taken specifically to evaluate management practices (as in effectiveness monitoring), management activities (as in project monitoring), water quality models (as in validation monitoring), or water quality standards (as in compliance monitoring), although trend data may be utilized for one or all of these other purposes*."

2. Baseline monitoring

   "*Baseline monitoring is used to characterize existing water quality conditions, and to establish a data base for planning or future comparisons. The intent of baseline monitoring is to capture much of the temporal variability of the constituent(s) of interest, but there is no explicit end point at which continued baseline monitoring becomes trend monitoring. Those who prefer the terms "inventory monitoring" and "assessment monitoring" often define them such that they are essentially synonymous with baseline monitoring. Others use baseline monitoring to refer to long-term trend monitoring on major streams*."

3. Implementation monitoring

   "*This type of monitoring assesses whether activities were carried out as planned. The most common use of implementation monitoring is to determine whether Best Management Practices (BMP'S) were implemented as specified in an environmental assessment, environmental impact statement, other planning document, or contract. Typically this carried out as an administrative review and does not involve any water quality measurements. Implementation monitoring is one of the few terms which has a relatively widespread and consistent definition. Many believe that implementation monitoring is the most cost-effective means to reduce nonpoint source pollution because it provides immediate feedback to the managers on whether the BMP process is being carried out as intended. On its own, however, implementation monitoring cannot directly link management activities to water quality, as no water quality measurements are being made*."

4. Effectiveness monitoring.

   "*While implementation monitoring is used to assess whether a particular activity was carried out as planned, effectiveness monitoring is used to evaluate whether the specified activities had the desired effect. Confusion arises over whether effectiveness monitoring should be limited to evaluating individual BMPs, or whether it also can be used to evaluate the total effect of an entire set of practices. The problem with this broader definition is that the distinction between effectiveness monitoring and other terms, such as project or compliance monitoring, becomes blurred*.

   Monitoring the effectiveness of individual BMPs, such as the spacing of water bars on skid trails, is an important part of the overall process of controlling nonpoint source pollution. However, in most cases the monitoring of individual BMPs is quite different *from monitoring to determine whether the cumulative effect of all the BMPs results in adequate water quality protection. Evaluating individual BMPs may require detailed and specialized measurements best made at the site of, or immediately adjacent to, the management practice. Thus effectiveness monitoring often occurs outside of the stream channel and riparian area, even though the objective of a particular practice is intended to protect the designated uses of a water body. In contrast, monitoring the overall effectiveness of BMPs usually is done in the stream channel, and it may be difficult to relate these measurements to the effectiveness of individual BMPs*."

5. Project monitoring

   "*This type of monitoring assesses the impact of a particular activity or project, such as a timber sale or construction of a ski run on water quality. Often this assessment is done by comparing data taken upstream and downstream of the particular project, although in some cases, such as a fish habitat improvement project, the comparison may be on a before and after basis. Because such comparisons may, in part, indicate the overall effectiveness of the BMPs and other mitigation measures associated with the project, some agencies consider project monitoring to be a subset of effectiveness monitoring. Again, the problem is that water quality is a function of more than the effectiveness of the BMPs associated with the project*."

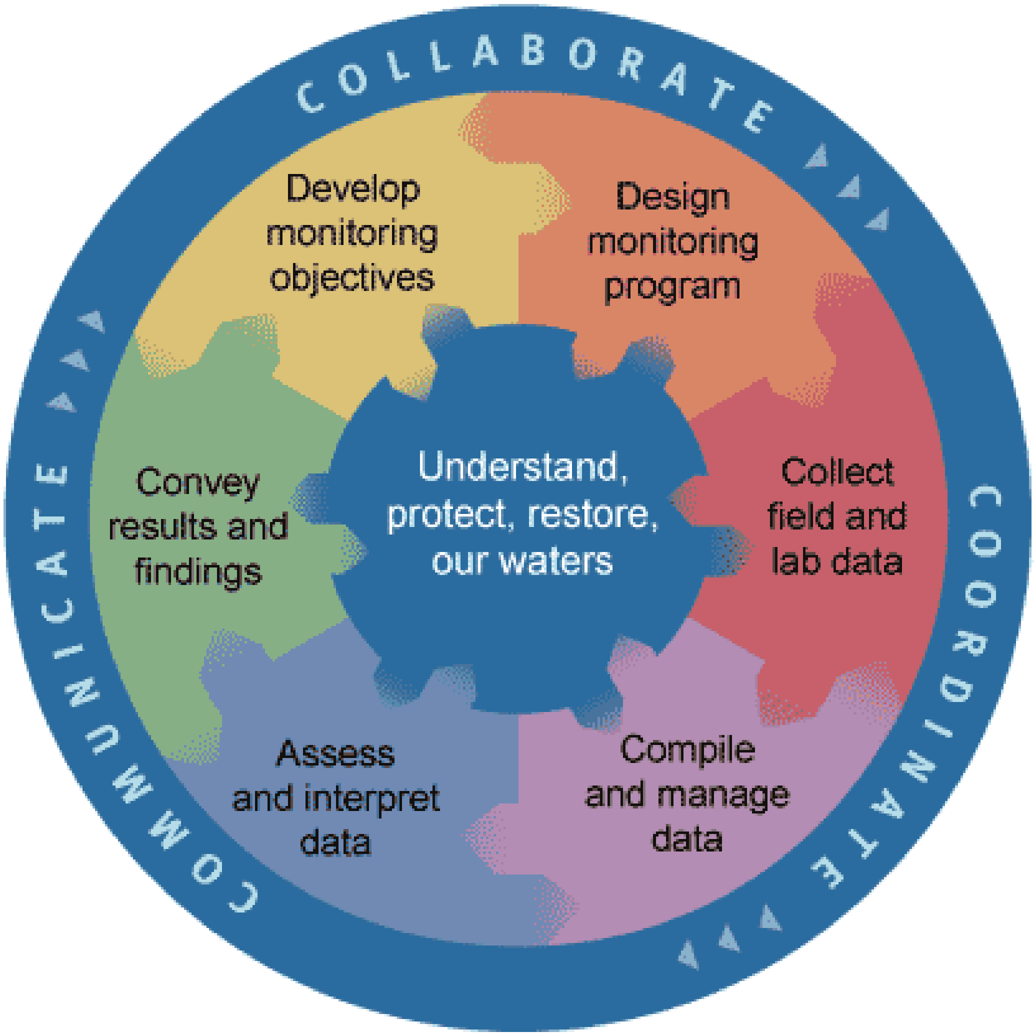
6. Validation monitoring.

   "*This refers to the quantitative evaluation of proposed water quality model. The data set used for validation should be different from the data set used to construct and calibrate the model. This separation helps ensure that the validation data will provide an unbiased evaluation of the overall performance of the model. The intensity and type of sampling for validation monitoring should be consistent with the output of the model being validated*."

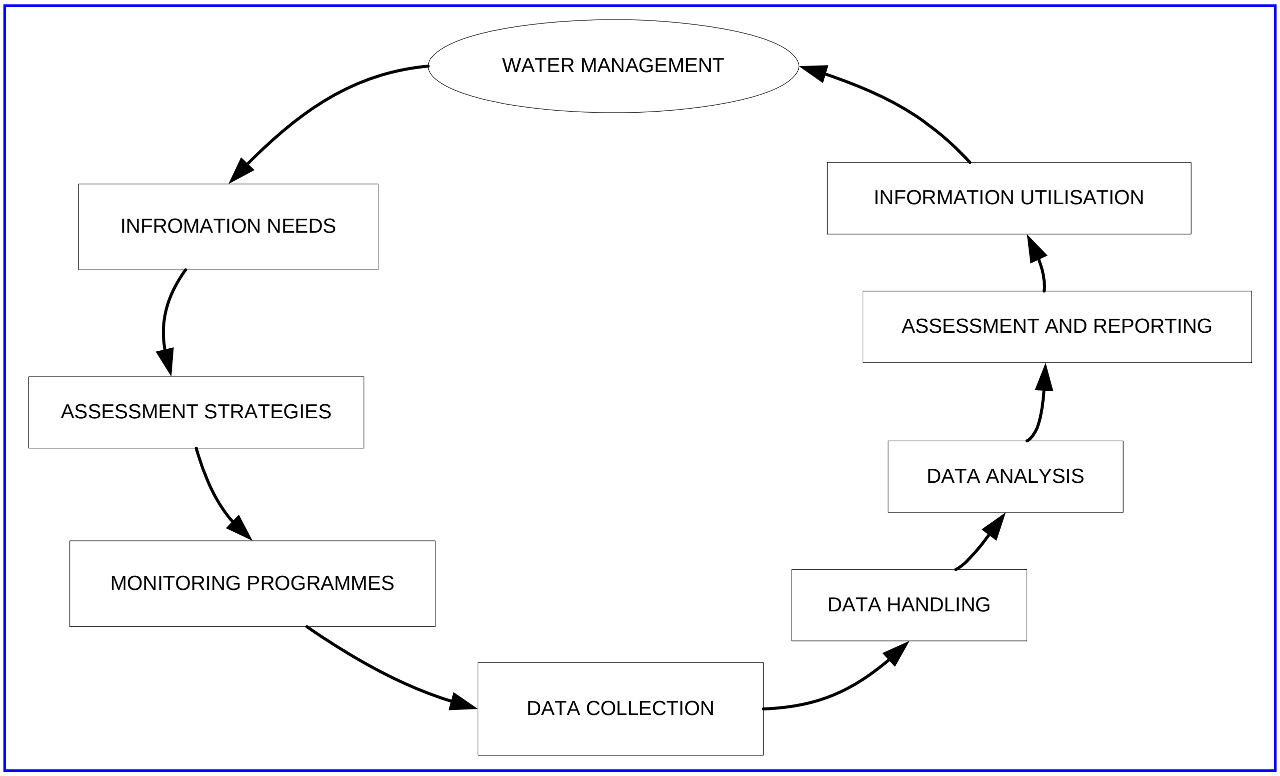
7. Compliance monitoring.

   "*This is the monitoring used to determine whether specified water-quality criteria are being met. The criteria can be numerical or descriptive. Usually the regulations associated with individual criterion specify the location, frequency, and method of measurement*."

APPENDIX ii



National Water Quality Monitoring Council (2003).



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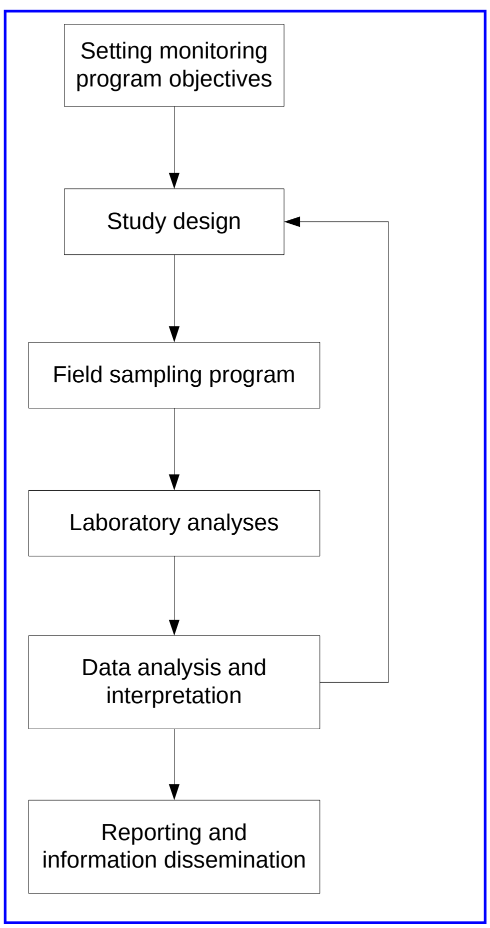

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