Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the Northwest Territories

Recommended Procedures for Developing Data Quality Objectives and a Conceptual Study Design

AEMP Technical Guidance Document Volume 3

Indian and Northern Affairs Canada
Yellowknife, Northwest Territories

June 2009 Version

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List of Acronyms

AEMP	-	Aquatic Effects Monitoring Program
CCME	-	Canadian Council of Ministers of the Environment
CEAA	-	Canadian Environmental Assessment Act
DQO	-	data quality objective
EEM	-	Environmental Effects Monitoring
EQG	-	environmental quality guideline
EQO	-	environmental quality objective
FSP	-	field sampling plan
GIS	-	geographic information system
GLWB	-	Gwich'in Land and Water Board
HSP	-	health and safety plan
INAC	-	Indian and Northern Affairs Canada
K_{oc}	-	organic carbon partition coefficient
K_{ow}	-	octanol water partition coefficient
LWB	-	the Land and Water Board
MRP	-	Management Response Plan
MVEIRB	-	Mackenzie Valley Environmental Impact Review Board
MVLWB	-	Mackenzie Valley Land and Water Board
MVRMA	-	Mackenzie Valley Resource Management Act
NTWA	-	Northwest Territories Water Act
NTWB	-	Northwest Territories Water Board
NWT	-	Northwest Territories
QAPP	-	quality assurance project plan
QA/QC	-	quality assurance/quality control
SLWB	-	Sahtu Land and Water Board
TK	-	Traditional Knowledge
USEPA	-	U.S. Environmental Protection Agency
VEC	-	valued ecosystem component
WLWB	-	We'eezhii Land and Water Board
WQG	-	water quality guideline
WQO	-	water quality objective

1.0 Introduction

In the environment, a variety of plant and animal species can be exposed to stressors of potential concern (these species are referred to as receptors potentially at risk). Each of these receptors may be exposed to a stressor through different exposure routes and have the potential to exhibit different types and severities of effects. While information on the effects of each stressor on each component of the ecosystem would provide comprehensive information for evaluating water quality conditions, it is neither practical nor feasible to directly evaluate status and/or trends for every component of the ecosystem. For this reason, monitoring activities must be focussed on evaluating conditions relative to the receptors that represent valued ecosystem components (VECs; e.g., subsistence fish species forming part of a traditional diet) and on the receptors that support valued ecosystem functions (e.g., carbon processing by the microbial community, which is needed to support healthy fish populations). Of particular interest are those receptors that are most likely to be adversely affected by the presence of the stressors that occur in the study area.

The results of the problem formulation process provide essential information for designing the Aquatic Effects Monitoring Program (AEMP) by identifying the stressors that are likely to be associated with a project, determining how these stressors could alter the physical and/or chemical characteristics of receiving waters, and evaluating how such alterations could affect aquatic organisms, aquatic-dependent wildlife, and/or human health. Accordingly, problem formulation informs the conceptual study design of the AEMP for a development project. The steps involved in developing the conceptual study design for the AEMP include:

- Development of data quality objectives (DQOs); and,
- Selection of a conceptual sampling design for environmental data collection.

These steps in the development of the conceptual study design for the AEMP are described in the following sections of this Technical Guidance Document.

Recommended procedures for developing a detailed AEMP design from the conceptual study design are described in Technical Guidance Document Volume 4.

2.0 Development of Data Quality Objectives

The DQOs process, which is briefly described below, provides a systematic framework for designing AEMPs that are sufficiently robust to support decisions regarding the management of industrial developments. More specifically, the DQOs process is a seven step planning approach that is used to establish performance or acceptance criteria that serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the goals of the study (i.e., to monitor for management purposes). The process uses systematic planning and statistical hypothesis testing to differentiate between two or more clearly defined alternatives and, in so doing, is consistent with the scientific method (i.e., the process by which scientists endeavour to construct an accurate representation of the world. It has four steps, including observation of phenomena, formulation of a hypothesis to explain the phenomena, use of the hypothesis to predict other phenomena, and performance of experiments to test the predictions; Tables 1 and 2). The seven steps in the DQOs process include (Figure 1):

1. State the problem to be investigated;
2. Identify the goals of the study;
3. Identify the information inputs required to achieve the study goal;
4. Define the boundaries of the study;
5. Develop the analytical approach;
6. Specify performance or acceptance criteria; and,
7. Develop the conceptual design for obtaining data.

DQOs are qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that will be used for establishing the quality and quantity of data needed to support management decisions. Data quality objectives define the performance criteria that limit the probabilities of making decision errors by considering the purpose of collecting the data, defining the appropriate type of data needed, and specifying tolerable probabilities of making decisions errors. Some of the key benefits associated with applying the DQOs process to support the development of AEMPs include:

- The DQOs process provides a convenient way to document the activities and decisions used to design an AEMP.
- The DQOs process provides a framework for clearly defining data requirements and optimizing the design of an AEMP to meet these needs.
- The DQOs process is an effective planning tool that can save resources by making data-collection activities more resource effective.
- The DQOs process enables data users and technical experts to participate collectively in planning and to specify their needs prior to data collection. In this way, the DQOs process helps to focus studies by encouraging data users to clarify vague objectives and to document the intended use of the data.
- The DQOs process support the preparation of sound, comprehensive field sampling plans (FSPs) and quality assurance project plans (QAPPs).
- The DQOs process results in the development of clearly defined analysis plans that will support decisions regarding management of the project.
- The DQOs process provides a method for defining performance requirements appropriate for the intended use of the data by considering the consequences of drawing incorrect conclusions and then placing tolerable limits on them.

The following guidance on the development of DQOs for AEMPs was adapted from the guidance that has been issued by the Canadian Council of Ministers of the Environment (1993); Environment Canada (2002), and the U.S. Environmental Protection Agency (USEPA 2001; 2006). The reader is directed to these guidance documents for further information and more detailed guidance on the development of DQOs. Appendix 1 provides an example of the DQOs that were established to support the conceptual study design for an area affected by historic mining activities. This example is provided to illustrate the DQOs process, such that users of the AEMP Guidelines can more easily develop DQOs for development projects in the NWT.

2.1 Stating the Problem

Step one in the DQOs process involves stating the problem. Successful completion of this step in the DQOs development process necessitates that project proponents undertake a series of activities. Since developmental projects can have diverse and sometimes unexpected effects on aquatic ecosystems, it is recommended that a multi-disciplinary team of experts and interested parties be engaged in formulating the problem and establishing a plan for obtaining the information needed to evaluate project-related effects (i.e., the AEMP). Importantly, both Traditional Knowledge (TK) and western scientific data and information are required to adequately evaluate the effects of a development project on the aquatic environment. For this reason, it is strongly recommended the AEMP Working Group, described in Technical Guidance Document Volume 1, plays an active role in DQO development.

Next, one or more meetings of the AEMP Working Group should be convened to facilitate description of the project, its potential effects on the aquatic ecosystem, and the questions that will be posed relative to project-related effects. As part of this activity, the AEMP Working Group should organize and review all of the relevant information, determine the source of the information, and evaluate its reliability. An efficient and cost-effective monitoring program needs to be developed to establish baseline conditions in the vicinity of a proposed development and to support evaluation of the effects of the project on the aquatic ecosystem. The AEMP also needs to provide the data and information required to evaluate the accuracy of impact predictions, assess the effectiveness of impact mitigation measures, and to identify additional mitigation measures to reduce or eliminate environmental effects. To do so, Action Levels must be established, based on the accepted levels of change agreed upon in the environmental assessment (or AEMP development stage in the case of no assessment). Such Action Levels are incorporated into Management Response Plans (MRPs), that describe the actions that will be taken if Low, Moderate, or High Action Levels are exceeded. The narrative intent of such Action Levels could be:

- Low Action Level - To identify conditions that have deviated significantly from background;
- Moderate Action Level - To identify conditions that have deviated from background and are approaching levels sufficient to impair designated water uses; and,
- High Action Level - To identify conditions that have deviated from background and are predicted to impair designated water uses.

During this step of the DQOs process, it is critical for the AEMP Working Group to use the conceptual site model developed in the problem formulation step and ensure it is complete and accurate (see Technical Guidance Document Volume 2). This model will serve as the basis for subsequent inputs and decisions.

The information assembled during the development of the conceptual site model helps to define the types of data that need to be collected under the AEMP. For example, if the proposed development activity is expected to release copper into the receiving water system, the information on the fate and effects of copper in aquatic ecosystems make it clear that data on the levels of copper in surface water and in sediment will need to be collected under the AEMP. It is important for the AEMP Working Group to help identify and discuss alternative approaches to investigating project-related effects at this stage of the process. In addition, a summary of the available resources (i.e., budget and personnel) and relevant deadlines for the study (i.e., schedule for planning, data collection, data analysis, and reporting) should be prepared and distributed by the proponent to the AEMP Working Group.

This step in the DQOs process should result in the preparation of a concise description of the problem, refinement of the conceptual site model, description of the types of data that need to be collected and how they will be used to evaluate project-related effects, a list of AEMP Working Group members and their responsibilities, and a summary of the available resources and relevant deadlines for the study.

2.2 Identifying the Goals of the Study

The second step in the DQOs process involves identifying the key questions that the study attempts to address, along with the alternative actions that may be taken based on the answers that the AEMP results provide to these key questions. Subsequently, a decision statement or estimate statement is developed from the principal study question and the alternative actions that have been identified. Finally, the multiple decision problems are organized in order of sequence or priority, and multiple estimation problems are organized according to their influence on one another and their contribution to the overall study goals. Each of these activities are briefly described below.

Formulation of the principal study question and identification of alternative actions represent the first activities in this step of the DQOs process. Principal study questions can address either decision problems or estimation problems. Resolution of decision problems require both collection of monitoring data and development of Action Levels. For example, measured concentrations of a chemical may be compared to the Action Levels that were established for that substance. In this context, an Action Level is the concentration or level of a measurement endpoint that is associated with an effect on an assessment endpoint (e.g., the level of copper in water that causes growth effects on fish). Such Action Levels are incorporated into Management Response Plans (MRPs; this is a new term that will be used by some regulatory boards instead of the term adaptive management. The term Management Response Plan is used consistently throughout the AEMP Guidelines to replace the term Adaptive Management Plan) that describe the actions that will be taken if effects of various magnitudes (i.e., High, Moderate, or Low) are observed or predicted (see Appendix 2 and 3 for more information). An example of a study question that could be posed to resolve a decision problem could be: "Do releases of a contaminant from the site under consideration pose unacceptable risks to human health or ecological receptors?" By comparison, estimation problems are those that require only monitoring data to resolve. An example of a study question that could be posed to resolve an estimation problem could be: "What is the distribution of a particular chemical in surface water over time and space?"

Once the principal study questions have been formulated, the proponent needs to identify, in consultation with the AEMP Working Group, a series of actions that could be taken once the question is answered (i.e., management responses). To do this, possible answers to the principal study question need to be considered and the most appropriate management actions that would be taken for each scenario need to be identified (see Section 2.5 for more information). The proponent should confirm that, the alternative actions would be likely to resolve the problem, and that, such actions could be taken within the prevailing regulatory framework. If, for example, a project proponent proposed to develop a copper smelter on the Coppermine River and that smelter was expected to release substantial quantities of copper into the Coppermine River in association with effluent discharges, a principal study question might be:

> "Are the levels of copper in the Coppermine River downstream of the Coppermine smelter sufficient to make water from the river unsafe to drink?"

In the above example, alternative actions could include lowering effluent quality criteria for the smelter, providing an alternate water source for the downstream community, or taking no action. All of these alternative actions could be applied within the prevailing regulatory framework in the NWT. Again, type and narrative intent of the Action Level will influence the nature of the management actions that are contemplated, should the Action Level be exceeded.

Next, the principal study question and the alternative actions are combined into a decision statement such as, "Determine whether or not the concentrations of copper in the Coppermine River downstream of the Coppermine smelter support a reduction in the effluent quality criteria for copper, provision of potable water to the community from another source, or no management action." One of the possible decisions that could be taken in this example would be to refocus the monitoring program design to address data gaps or other issues.

Many projects in the north will present complex decision problems that will need to be addressed through the development and implementation of AEMPs. In these cases, it will be necessary to formulate more than one decision statement, determine how each decision relates to the others, and make a list of priorities for resolving the problem. When such multiple decisions are possible, it is helpful to develop a decision tree that describes the actions that will be taken based on the results of each of the elements of the AEMP.

The principal outputs from this step in the DQOs process include one or more well-defined study questions and a listing of alternative actions that could be taken as a result of addressing the principal study questions. For decision problems, a list of decision statements that address the principal study questions will have been prepared. Similarly, a list of estimation statements that address the study questions will have been prepared for estimation problems.

2.3 Identifying the Information Inputs

The third step in the DQOs process involves identifying information inputs. More specifically, this step in the DQOs process necessitates:

- Identification of the types and sources of information needed to support management decisions or produce estimates of population parameters;

- Identification of preliminary Low Action Levels (i.e., that can be used to identify the detection limits that need to be achieved for the data generated under the AEMP. In general, preliminary Low Action Levels are established an order of magnitude or more lower than toxicity screening values; see MacDonald *et al*. 2008 for more information); and,
- Selection of appropriate sampling and analysis methods for generating the data.

The kinds of information needed to support the decision must be identified at this stage of the AEMP development process (i.e., a list of environmental characteristics that will be measured under the AEMP should be prepared). The measurement endpoints that were identified following problem formulation define the indicators and metrics that will be included in the AEMP. However, other types of data and information may also be required to evaluate project-related effects or to support utilization of the AEMP results in management response planning and implementation. For example, data collected under surveillance network programs (effluent chemistry data) may also be needed to support interpretation of the AEMP results and/or support the determination of cause and effect relationships.

As part of this step in the DQOs development process, the sources of the requisite data and information are identified and documented. These sources may include historical data, regulatory guidance, professional judgement, scientific literature, and/or collection of new data. For new data, the AEMP represents the primary source of data and information that will be used to evaluate project-related effects on the aquatic ecosystem. Section 3.0 provides detailed guidance on the design of AEMPs that will generate the data and information required to evaluate such project-related effects.

Next, the basis for setting an Action Level is determined. In this context, an Action Level is a value for a measurement endpoint that provides a basis for choosing one or more of the various management alternatives (as described in Section 2.2). The objective of this activity is to determine how the Action Levels will be selected and to identify preliminary Low Action Levels that can be used to evaluate the adequacy of candidate analytical methods. Low level actions will generally be derived based on an understanding of background conditions in the study area, as determined using the results of a baseline monitoring program. By comparison, Moderate and High Action Levels can be established by adopting Canadian water quality guidelines (WQGs), by deriving site-specific water quality objectives (WQOs), or, by using other means (the information sources and methods used to establish Action Levels are described in Step 5 of the DQO process). For example, 0.1 µg/L could be established as the preliminary Action Level for copper in surface water if this was determined to be the upper limit of background concentrations. This step of the process is particularly important because it provides a technical basis for establishing the detection limits that need to be achieved to generate data useful for making a management decision. In general, analytical detection limits should be established at levels that are least a factor of 10 lower than the lowest Action Level to ensure that usable data are generated in the AEMP. More specific guidance on the selection of analytical detection limits is provided in MacDonald *et al.* (2008).

Finally, a list of sampling and analytical methods is developed that may be appropriate for the problem being investigated. These methods should be selected to avoid the ten major sources of biases in environmental sampling and analysis (see Technical Guidance Document Volume 4 for more information), including:

1. Non-representative sampling;
2. Instability of samples between sampling and analysis;
3. Interferences and matrix effects in analysis;
4. Inability to determine the relevant forms (i.e., species) of a chemical being measured;
5. Failure to calibrate instrumentation;
6. Failure to correct for analytical results of blank samples;
7. Sample misidentification;
8. Pseudo-replication;

9. Use of data below the level of quantification; and,
10. Method differences between labs and method changes over time.

This final activity in this stage of the DQOs process is intended to provide a basis for confirming that appropriate analytical methods exist to meet the required detection limits (given the magnitude of the lowest Action Level) and other quality assurance criteria for the project (i.e., accuracy, precision, and representativeness). This activity involves comparing the target detection limits that have been established for the project to the reported performance of the various candidate analytical methods. The analytical methods that are ultimately selected for use in the AEMP, which are based on such comparisons and, potentially, other factors, must be described in detail (see Technical Guidance Document Volume 5 for more details). The use of certified personnel and accredited laboratories (Association for Laboratory Accreditation) or performance-based measurement systems is also emphasized in this step of the DQOs process.

The following outputs are anticipated upon completion of this step in the DQOs process. First, types of data and information that are required to support the management decision or the estimation of a population parameter will have been identified. In addition, the sources of the requisite data and information will have been identified. Furthermore, preliminary Low Action Levels will have been identified for each variable (i.e., measurement endpoint), which will support subsequent identification of performance or acceptance criteria for the resultant data. Finally, analysis methods will have been identified, based on their ability to achieve detection below the lowest Action Level.

2.4 Defining the Boundaries of the Study

The fourth step in the DQOs process involves defining the boundaries of the study. The activities that need to be undertaken during this step of the DQOs development process include:

- Defining the target population;
- Determining the spatial and temporal boundaries for sampling from the target population; and,
- Identifying practical constraints on sampling activities.

Defining the target population represents the first activity in this step of the DQOs process. The target population is usually defined as the set of all environmental samples about which the decision maker wants to draw conclusions. For the water quality component of an AEMP, for example, the target population consists of all possible samples of surface water that, collectively, comprise the total volume of the surface water system under investigation (e.g., the Coppermine River). A sampling unit from this target population would correspond to a 250 mL sample of surface water to accommodate laboratory analysis for total metals.

Next, the spatial and temporal boundaries of the AEMP are defined. Spatial boundaries define the physical area to be studied and the general locations where samples will be collected. By comparison, temporal boundaries define the time frame within which the AEMP will conducted and when the samples should be collected. The conceptual site model that was developed during problem formulation (see Technical Guidance Document Volume 2) will provide essential information for defining the spatial boundaries of the study area (e.g., the range of arctic char within a river system). More specifically, this information is needed to define the entire geographic area within which the samples are to be collected (i.e., as defined using unambiguous location coordinates and/or distinctive physical features). In addition, this information is required to divide the target population into subsets that have relatively homogeneous characteristics (e.g., river reaches or strata). Determination of the period of time that the data are intended to represent and the time frame for which the decision or estimate is relevant provides a basis for establishing the temporal boundaries of the decision statement. Diurnal, seasonal, and interannual variability in environmental conditions are all important factors that must be considered in the conceptual study design.

Historic data and information (i.e., baseline data and/or data collected for other purposes) are important for establishing the spatial and temporal boundaries of target populations because they can help define the extent of the problem in time and space (i.e., for existing developments). In addition, such information is important for understanding variability in the system (i.e., in time and space) and, hence, defining spatial boundaries and time frames appropriate for collecting data and making management decisions.

Finally, the practical constraints associated with the proposed data collection activities also need to be identified during this step in the DQOs development process. For example, environmental factors must be considered in the design of AEMPs for arctic locations. Clearly, freezing temperatures or unstable ice conditions (i.e., during freeze-up or break-up) could restrict water sampling on a lake, thereby potentially constraining implementation of the elements of an AEMP that were to be conducted when these conditions occur. Similarly, issues related to the availability and operation of equipment when sampling need to be identified and, if possible, addressed. In this way, an AEMP can be developed that is practical to implement under the conditions that prevail within the study area. In most cases, solutions to these practical constraints can be found once they have been identified.

2.5 Developing the Analytical Approach

The fifth step in the DQOs process involves developing the analytical approach that will be used to draw conclusions from the AEMP results. This step in the DQOs development process typically involves the following activities:

- Selecting the population parameter(s) that will be used to make inferences about the target population. The parameters that are commonly used in this respect include mean, median, and various percentiles;
- Selecting Action Levels and generating decision rules that define how the decision maker would choose among alternative management responses,

assuming that the data are sufficient to define the characteristics of the population; and,

- Specifying the estimator and estimation procedure for estimation problems.

The first activity in this step involves specifying the population parameter that will be used to make decisions about the target population. In some cases, the population parameter will be specified in the relevant regulation; otherwise it is selected based on project-specific needs and regulations. For AEMPs, a variety of population parameters may be selected, depending on the measurement endpoint under consideration and the Action Levels that are chosen. A water quality guideline may specify the population parameter by the way in which it is written. For example, the water quality for ammonia in British Columbia indicates that the level recommended for the protection of aquatic life should be compared to the geometric mean concentration calculated for five water samples collected in a 30-d period. In this case, the population parameter would be the geometric mean concentration of ammonia. If, on the other hand, an Action Level is established as the upper limit of background concentrations (defined as, for example, the 95th percentile concentration of ammonia calculated from the baseline data), the population parameter would be the 95th percentile concentration of ammonia calculated using the AEMP data collected for a specific geographic area (i.e., the river reach located immediately downstream of the initial dilution zone). Decisions regarding the selection of the population parameter for each measurement endpoint included in the AEMP will be made by the AEMP Working Group and approved by the responsible regulatory board.

Next, Action Levels are established for each measurement endpoint that guides the selection of appropriate management actions. As indicated previously, three types of Action Levels should be established for each measurement endpoint (i.e., High, Moderate, and Low Action Levels; the narrative intent of each of these types of Action Levels is described in Section 2.1). Several approaches can be taken to establish Action Levels for use in analysis of data collected under an AEMP. For example, Low Action Levels can be established using baseline data for the study area and provide an estimate of background conditions in the study area. As such Action Levels will typically be established using an indicator of central tendency (e.g., arithmetic mean, geometric mean, median) or of the upper limit of background (i.e., 95^{th} percentile value). For certain variables (such as total suspended solids in water), Action Levels may need to be normalized to flow or established on a seasonal basis (e.g., chlorophyll a). Second, Moderate Action Levels can be established as a multiple (e.g., 0.5 times) of the water quality guidelines or site-specific water quality objectives and signify conditions that are changing to such an extent that impairment of water uses is likely to occur in the foreseeable future. Finally, High Action Levels should be set at levels that correspond to maximum acceptable changes in environmental conditions, as established by the results of the environmental assessment or by other means if an environmental assessment was not conducted. As the High Action Levels define conditions that are associated with impairment of water uses, they are likely to be based on water quality guidelines or site-specific water quality objectives. More information on the development of Action Levels in provided in Appendix 2.

Subsequently, decision rules are established that describe how the results of the AEMP and the associated Action Levels will inform adaptive management of the project. More specifically, the decision rules describe the management actions that will be taken if each type of Action Level is exceeded. For example, exceedance of a Low Action Level signifies that conditions have deviated from background. Some of the candidate management actions that could potentially be taken in this event include:

- Development of a Management Response Plan;
- Identify and quantify sources of problematic stressors (i.e., chemicals that exceed the Action Level);
- Identify a variety of source control measures and/or of possible mitigative measures;
- Initiate feasibility study to evaluate candidate mitigation options;
- Implement any mitigation measures that represent best management practices (e.g., lining blast holes to reduce nitrogen losses); and,
- Evaluate the efficacy of any source control measures implemented.

Conceptually, exceedance of a Low Action Level indicates that the project may be causing changes in the receiving environment. The appropriate management response is to take steps to better understand the emerging problem and determine if it is related to the project. If so, options for addressing the emerging problem are identified, evaluated, and implemented, if it is cost effective to do so. In the above example, lining blast holes to reduce nitrogen losses also increases blasting efficiency, potentially reducing the quantity of explosives that are being used at the site. In this case, lining blast holes represents a best management practice for nitrogen-based explosives use in wet situations. Ongoing monitoring under the AEMP will provide the data needed to determine if this, or any other types of mitigation, was effective.

Conceptually, exceedance of a Moderate Action Level signifies that conditions have deviated from background and have the potential to impair one or more water uses in the foreseeable future. When a Moderate Action Level is exceeded, management responses should be focussed on implementing mitigation measures that arrest or reverse the trend in environmental quality condition, such as:

- Revising and refining the MRP to better reflect managements' understanding of the problem and the actions needed to address it;
- Developing a detailed mitigation plan;
- Implementing appropriate mitigation measures within a time frame that ensures that the High Action Level is not exceeded; and,
- Evaluating the efficacy of mitigative measure.

When considering various management responses, the results of the environmental assessment and the measured temporal and spatial trends in environmental quality conditions need to be considered. For example, a project could discharge a consistent amount of nitrate into a water body that increases concentrations beyond background levels but are within environmental assessment predictions and are not changing over time. In this case, the appropriate management response is to continue monitoring to confirm that the aquatic environment is not being adversely affected by such discharges. On the other hand, a project that is discharging increasing quantities of nitrate to the environment that results in deviation from background conditions and a temporal trend that indicates that environmental assessment predictions (i.e., High Action Level) will be exceeded within three years. In this case, the appropriate management response may be to construct a wastewater treatment plant that will effectively reduce loadings of nitrate to the receiving environment to acceptable levels.

High Action Levels should be established at concentrations of levels that are consistent with environmental assessment predictions. That is, environmental assessment predictions describe the maximum change from baseline conditions that is considered to be acceptable to stakeholders. Exceedance of a High Action Level should not be permitted and the appropriate management response would be to take immediate action to reverse the problem.

In general, decision rules can be established by developing "if"... "then" statements regarding the problem under investigation (i.e., if a Moderate Action Level is exceeded, then the following management responses will be taken). By establishing such decision rules prior to collecting the requisite data, it is possible to establish a high level of transparency in the environmental quality management process. In addition, establishment of such a decision rule provides further clarity on the sampling needed to support decision making. The decision rule is considered to be theoretical because the value of the population parameter can be estimated, but can never be known.

For estimation problems, a specification for the estimator of the population parameter (e.g., geometric mean concentration of a chemical at a sampling site) is also developed during this step of the process. This activity is completed by combining the selected population parameter with the scale of estimation and other population boundaries. For example, "the geometric mean concentration of copper in the Coppermine River downstream of Lac de Gras, but upstream of the smelter site, will be estimated for open-water condition and under-ice each year between 2008 and 2015. This estimate of the central tendency of the copper concentration data (i.e., the population parameter) will be compared to the geometric mean concentrations calculated for the open-water and under-ice period estimated using the baseline data set (i.e., collected during the pre-smelter development period, 2002 to 2006). These results will be used to determine if the concentrations of copper in water during the open-water or under periods have increased significantly as a result of smelter operations at the site.

One of the key outputs of this step in the DQOs process is the identification of the population parameters that are most relevant for making inferences and conclusions regarding the target population. For decision problems, theoretical decision rules are also established, based on the selected Action Levels. For estimation problems, the estimator that will be used to describe the selected population parameter is identified, including the scale of estimation and other population boundaries.

2.6 Specifying Performance or Acceptance Criteria

The penultimate step in the DQOs process involves the derivation of the performance or acceptance criteria that will be used to specify tolerable limits on decision errors (also known as Type I and Type II error rates - see Technical Guidance Document Volume 4 for more information). In general, decision-making problems are addressed by applying statistical hypothesis testing to the collected data. That is, a decision will be made based on whether or not the data provide sufficient evidence to reject the null hypothesis and accept an alternate hypothesis (e.g., the null hypothesis might be that the concentrations of copper in surface water following three years of smelter operation are not different from those that occurred under baseline conditions). The null hypothesis would be rejected if, for example, the average concentration of copper in surface water at a sampling site located downstream of the smelter during the third year of operation was significantly higher that the average concentration of copper at the site calculated for the site under baseline conditions.

The first activity in this step involves determining the sources of variability in the sample data set. While there may be many contributing factors to total study error (or total variability; see Figure 2 for an example of how total study error can be broken down by components), sampling design error [which can lead to imprecision (i.e., random errors) or bias (i.e., systematic errors) in the estimates of population parameters] and measurement error (which arise from imperfections in the measurement and analysis system) are usually the two main components. Next, the plausible range of values for each variable is estimated by determining the likely upper and lower bounds based on the available data, professional judgement, and/or other information.

The two types of decision errors than can occur in the decision-making process must be identified during this step of the DQOs process. These errors include concluding that the Action Level has been exceeded when it actually has not been exceeded (i.e., false positive or false rejection of the null hypotheses) and concluding that the Action Level has not been exceeded when it actually has been exceeded (i.e., false negative or false acceptance of the null hypothesis; Table 4). The consequences of making each type of error should then be evaluated. This information provides a basis for developing a strategy for managing such decision errors (e.g., collecting a larger number of samples, developing a better sampling design, utilizing more accurate and precise analytical methods). Importantly, the cost of sampling and the probability of making decision errors are directly linked. For this reason, it is necessary for the AEMP Working Group to propose acceptable probabilities of making false positive and false negative errors (i.e., decision performance goals) at this stage of the process (see Figure 3) and ensuring that the AEMP provides the necessary statistical rigour to provide the required level of certainty in the decision process and to evaluate the performance of the decision process. The reader is directed to Technical Guidance Document Volume 4 for more detailed information on the sources of study errors and on the approaches that can be used to control them.

This step in the DQOs process should culminate in the preparation of a decision performance goal diagram to communicate the performance or acceptance of criteria to the AEMP Working Group and other interested parties (See Figures 4 and 5).

2.7 Developing the Conceptual Design for Obtaining Data

The final step in the DQOs process involves developing a plan for obtaining data under the AEMP. More specifically, the goal of this step is to develop a resource-efficient design for collecting and analysing environmental samples or for generating other types of information needed to support the AEMP. This corresponds to developing either:

- The most resource-effective data collection process that is sufficient to fulfill the study objectives; or,
- A data collection process that maximizes the amount of information available for synthesis and analysis within a fixed budget.

In either case, the design must provide a basis for achieving the performance or acceptance criteria that are established for the AEMP. The activities involved in this step of the DQOs process include (USEPA 2006):

- Gathering information that is required to develop an efficient and effective design of the AEMP;
- Identifying constraints that will impact the design of the AEMP;
- Describing the sampling and analysis methods that will be used to generate data under the AEMP;
- Identifying one or more candidate designs from which to select the final AEMP design;
- Determining the "optimal" amount of information to collect for the potential design, considering both cost and other factors (i.e., such as Type I and Type II error rates and effect sizes); and,
- Preparing a resource-efficient information collection plan that meets the requirements for the AEMP.

Several types of data and information are needed to support the design of an efficient and effective AEMP. More specifically, the following information needs to be considered at this stage of the process:

- The objectives of the AEMP and the intended uses of the resultant data (e.g., statistical hypothesis testing, estimation of population parameters);
- The outputs of the previous steps (Steps 1 through 6) of the DQOs process;
- Background information on the problem, including site properties, technical characteristics of the contaminants and media, regulatory requirements, spatial and temporal patterns of contamination (including any predictions and modelling of the expected effluent plume);
- Expected variability for the data based on similar studies and/or professional judgement; and,
- Preliminary information on the underlying statistical distributions of the data that will impact calculations on the minimum amounts of data to collect.

Collectively, this information provides a basis for identifying the types of data that need to be collected, for selecting a temporal and spatial sampling design to reduce sampling variability, and for choosing analytical measurement techniques that will reduce analytical variability. Overall, the objective is to limit the total variability associated with the data generated under the AEMP.

One of the key decisions that the AEMP Working Group will need to be involved in during this step of the DQOs process is the selection of sampling design type. Two basic types of sampling designs can be considered for use in AEMP development, including probability-based sampling designs and judgmental (i.e., biassed) sampling designs. In probability-based sampling designs, each possible sampling unit has a known probability of being selected and only those sampling units selected will provide data for the study (USEPA 2006). Probability-based sampling designs are required when statistical inference techniques are to be applied to the resultant data (e.g., hypothesis testing, confidence interval calculations). In contrast, the sampling units are not assigned a known probability of being selected in the judgmental sampling design. Rather, sampling units are selected at the discretion of the AEMP Working Group. While judgmental sampling designs are appropriate for certain applications (e.g., compliance monitoring), they do not support proper characterization of the status of the target population or the associated uncertainty in such estimates. The advantages and disadvantages of probabilistic and judgmental sampling designs are described in Table 5 (USEPA 2002; Environment Canada 2009).

3.0 Development of a Conceptual Study Design

Sampling design needs to be a fundamental component of the data collection process if the results of an AEMP are to provide scientifically-defensible information to support decision-making relative to development projects. As sound, science-based decisions are based on accurate information, the following issues must be addressed in the AEMP design (USEPA 2002; Environment Canada 2009):

- The appropriateness and accuracy of the sample collection and handling methods;
- The effect of measurement error on the results;
- The quality and appropriateness of the laboratory analyses; and,
- The representativeness of the data with respect to the objectives of the study.

While the first three issues can be effectively addressed through Steps 1 to 6 of the DQOs process, representativeness must be addressed through the selection of an appropriate sampling design (i.e., Step 7 of the DQOs process). In this context, representativeness can be considered as a measure of the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition (USEPA 2002;

Environment Canada 2009). Development of an appropriate sampling design supports the collection of defensible data that accurately address the problem being investigated.

The DQOs process provides a systematic basis for developing several alternative sampling designs and for selecting among these alternatives to establish a conceptual design for the AEMP. Technical Guidance Document Volume 4 provides further guidance that will facilitate detailed AEMP design. Technical Guidance Document Volumes 3 and 4 are, therefore, intended to be used together to support the design of efficient and effective AEMPs.

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Tables

Table 1. Elements of systematic planning (USEPA 2006).

Elements
Organization: Identification and involvement of the project manager, sponsoring organization and responsible official, project personnel, stakeholders, scientific experts, etc. (e.g., all customers and suppliers).
Project Goal: Description of the project goal, objectives, and study questions and issues.
Schedule: Identification of project schedule, resources (including budget), milestones, and any applicable requirements (e.g., regulatory requirements, contractual requirements).
Data Needs: Identification of the type of data needed and how the data will be used to support the project's objectives.
Criteria: Determination of the quantity of data needed and specification of performance criteria for measuring quality.
Data Collection: Description of how and where the data will be obtained (including existing data) and identification of any constraints on data collection.
Quality Assurance (QA): Specification of needed QA and quality control (QC) activities to assess the quality performance criteria (e.g., QC samples for both field and laboratory, audits, technical assessments, performance evaluations, etc.).
Analysis: Description of how the acquired data will be analyzed (either in the field or the laboratory), evaluated (i.e., QA review/verification/validation), and assessed against its intended use and the quality performance criteria.

Table 2. When activities performed within the systematic planning process occur within the data quality objective process and/or the project life cycle (USEPA 2006).

Activities Performed within the Systematic Planning Process (as featured among the eight elements in Table 3)	**When These Activities Occur Within the DQO Process and/or the Project Life Cycle**
Identifying and involving the project manager/decision maker, and project personnel	Step 1. Define the problem Part A of the Project Plan (Chapter 8)
Identifying the project schedule, resources, milestones, and requirements	Step 1. Define the problem
Describing the project goal and objectives	Step 2. Identify the goal of the study
Identifying the type of data needed	Step 3. Identify information needed for the study
Identifying constraints to data collection	Step 4. Define the boundaries of the study
Determining the quality of the data needed	Step 5. Develop the analytic approach Step 6. Specify performance or acceptance criteria Step 7. Develop the plan for obtaining data
Determining the quantity of the data needed	Step 7. Develop the plan for obtaining data
Describing how, when, and where the data will be obtained	Step 7. Develop the plan for obtaining data
Specifying quality assurance and quality control activities to assess the quality performance criteria	Part B of the QA Project Plan (Chapter 8) Part C of the QA Project Plan (Chapter 8)
Describing methods for data analysis, evaluation, and assessment against the intended use of the data and the quality performance criteria	Part D of the QA Project Plan (Chapter 8) The Data Quality Assessment Process (Chapter 8)

Table 3. An example of a principal study question and alternative actions (USEPA 2006).

Principal Study Question	Alternative Actions
Are there significant levels of lead in floor dust at a residence, accompanied by deteriorated lead-based paint?	Remove any children from the residence and initiate lead-based paint abatement activities by certified workers. Conduct lead-based paint interventions on selected painted building components followed by extensive dust cleaning. Conduct specialized dust cleaning, provide educational materials to the household on cleaning techniques and other actions that will keep lead in dust to acceptable levels, and return in six months for more testing. Take no action.

Table 4. Statistical hypothesis tests lead to four possible outcomes

Decision You Make by Applying the Statistical Hypothesis Test to the Collected Data	True Condition (Reality)	
	Baseline Condition is True	**Alternative Condition is True**
Decide that the Baseline Condition is True	Correct Decision	*Decision Error (False Acceptance)*
Decide that the Alternative Condition is True	*Decision Error (False Rejection)*	Correct Decision

Table 5. Probability-based versus judgmental sampling designs (USEPA 2002).

Probability-Based	Judgmental
Advantages	
• Provides ability to calculate uncertainty associated with estimates • Provides reproducible results within uncertainty limits • Provides ability to make statistical inferences • Can handle decision error criteria	• Can be less expensive than probabilistic designs. Can be very efficient with knowledge of the site • Easy to implement
Disadvantages	
• Random locations may be difficult to locate • An optimal design depends on an accurate conceptual model	• Depends upon expert knowledge • Cannot reliably evaluate precision of estimates • Depends on personal judgment to interpret data relative to study objectives

Figures

Figure 1. The data quality objective (DQO) process (USEPA 2006).

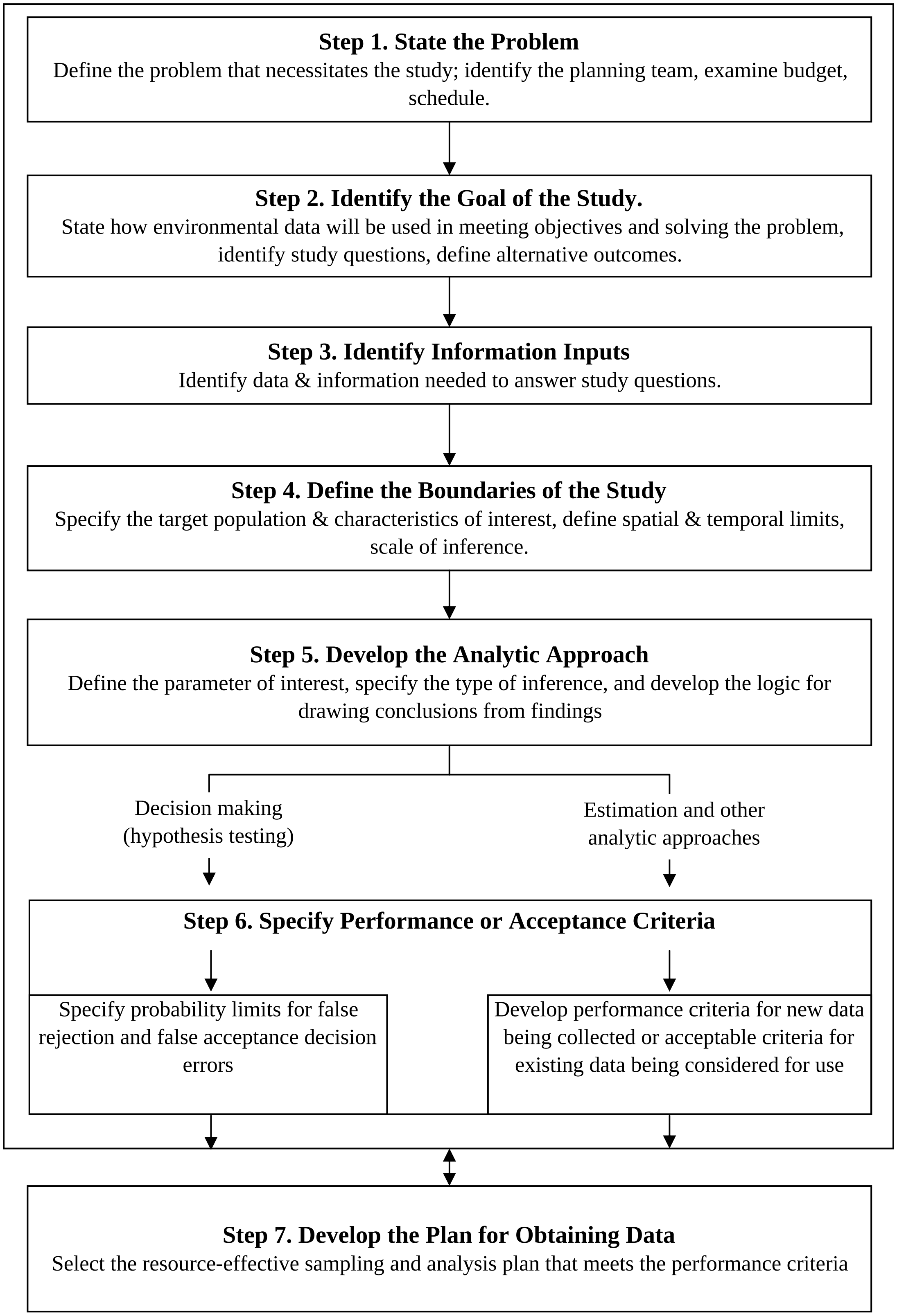


Figure 2. An example of how total study error can be broken down by components (USEPA 2006).

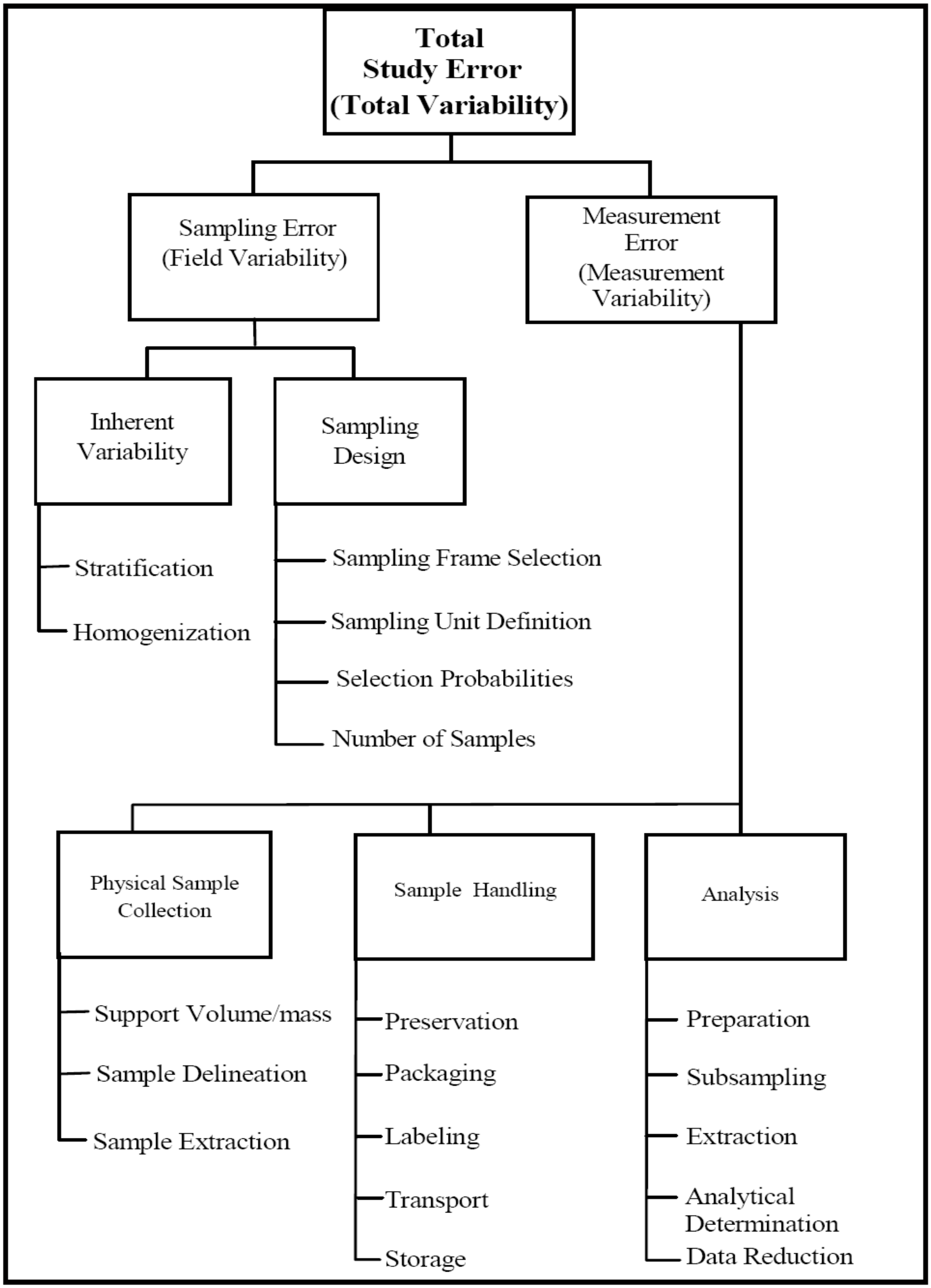


Figure 3. Example of decision performance goals (USEPA 1997).

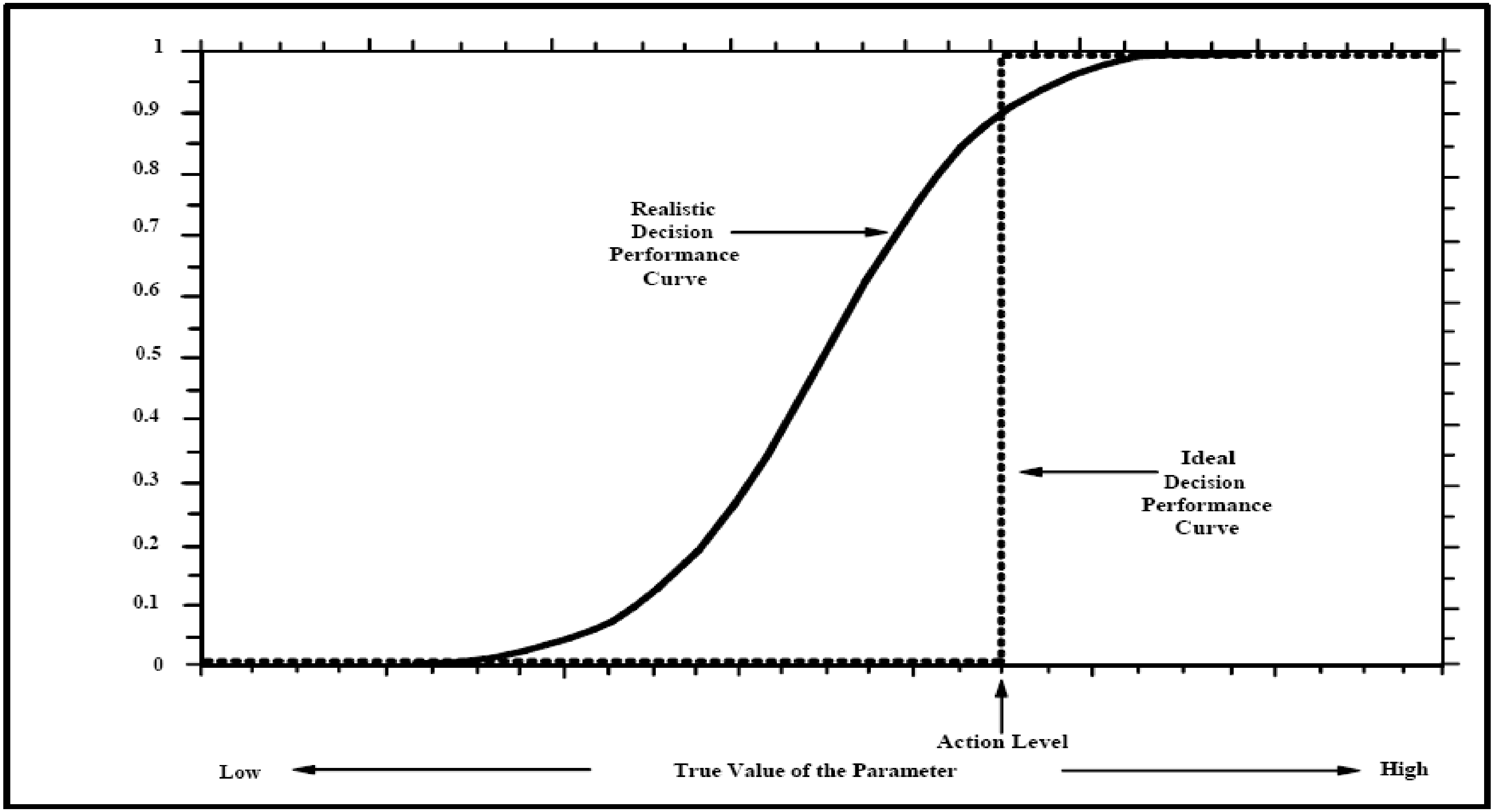


Figure 4. Decision performance goal diagram for the urban air quality compliance case study (USEPA 2006).

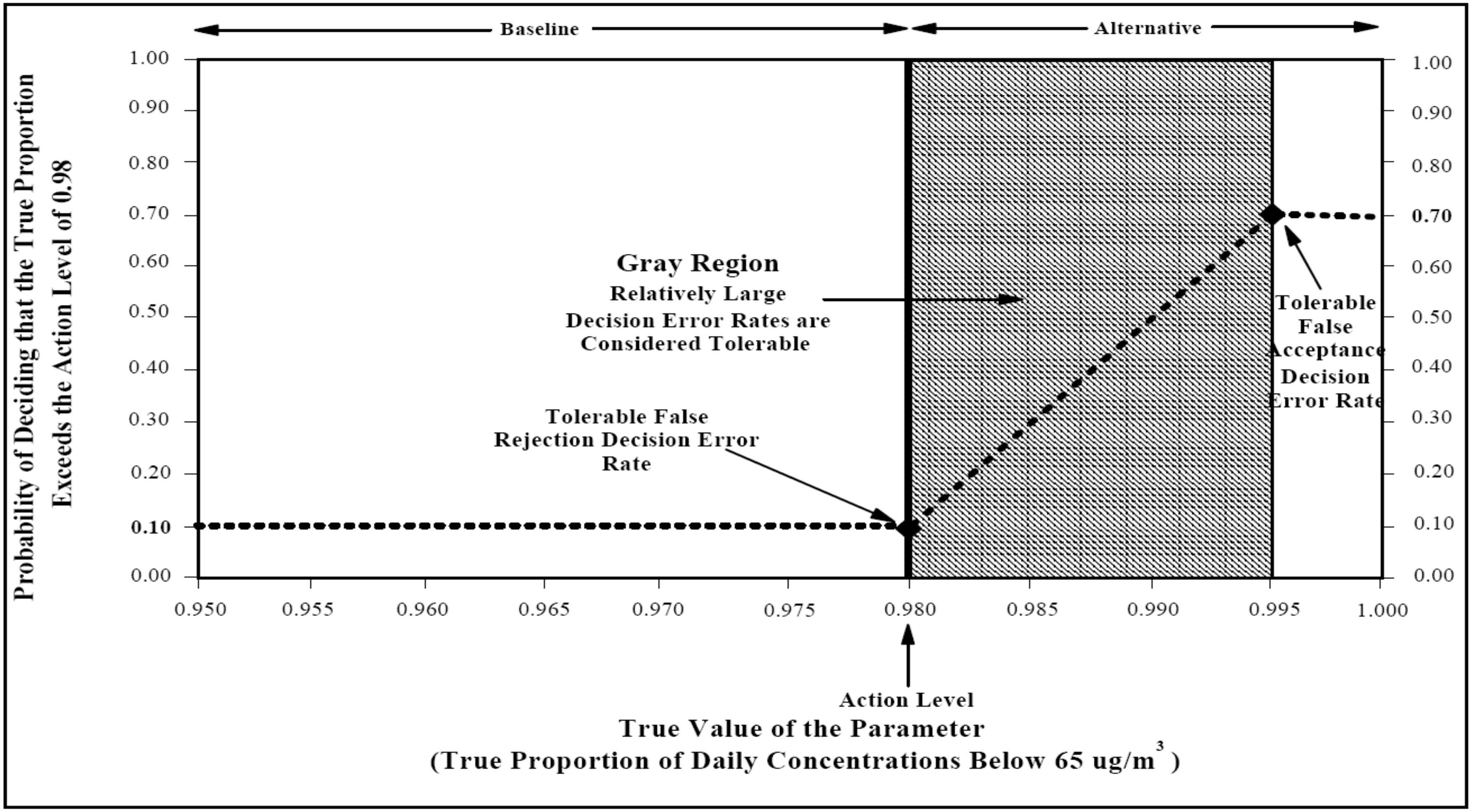
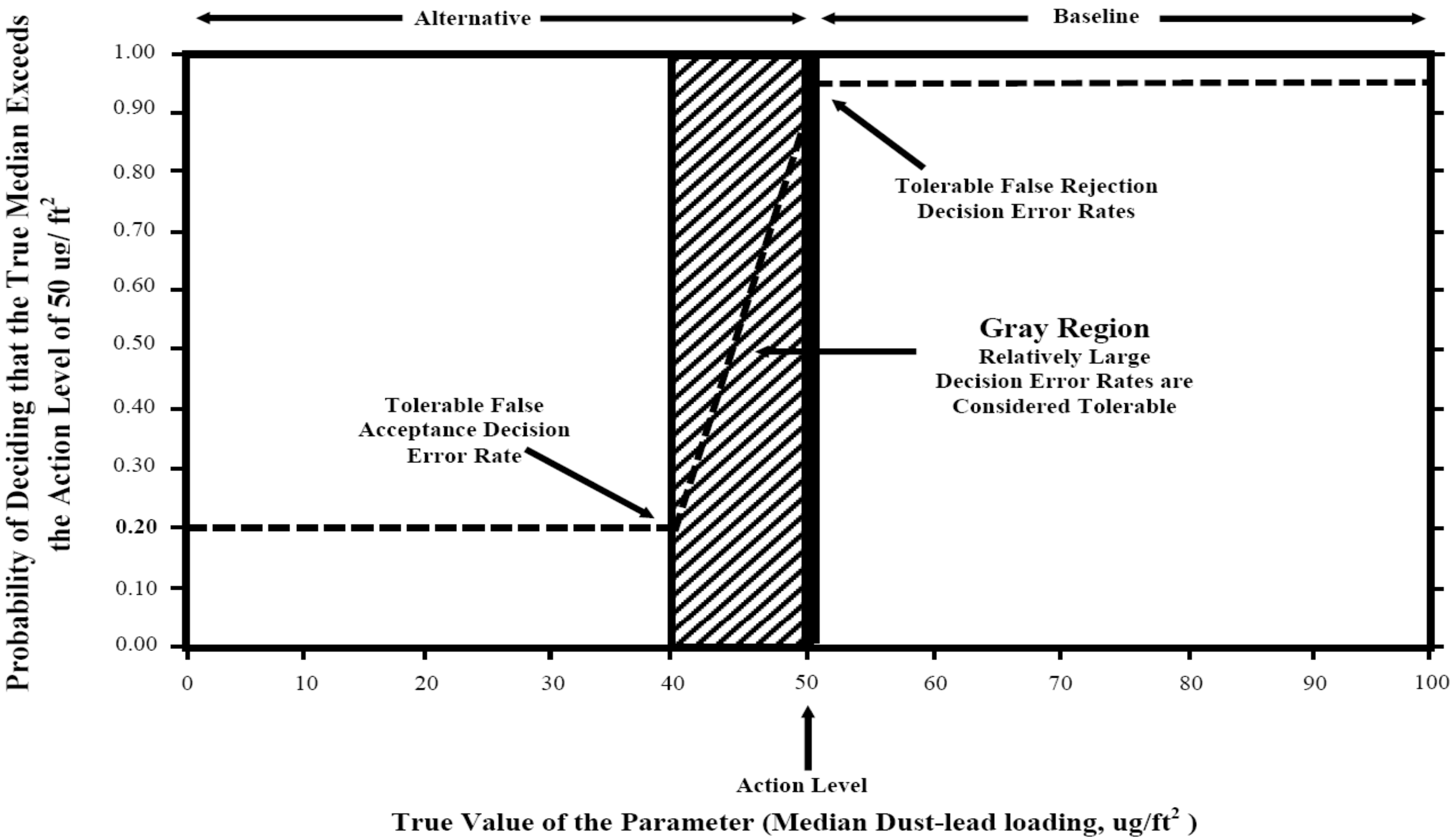


Figure 5. Decision performance goal diagram for lead dust loading (USEPA 2006).



Appendices

Appendix 1 Data Quality Objectives for the Ecological Risk Assessment of Aquatic Ecosystems in the Tri-State Mining District

A1.0 Introduction

The data quality objective (DQO) process is a series of planning steps based on the scientific method that is designed to ensure that the type, quality, and quantity of environmental data used in decision making are appropriate for the intended application. DQOs are qualitative and quantitative statements developed using the DQO process that:

- Clarify the study objectives and intended use of the data;
- Define the type of data needed to support the decision;
- Identify the conditions under which the data should be collected; and,
- Specify tolerable limits on the probability of making a decision error due to uncertainty in the data (USEPA 2000a; 2006).

The DQO process (USEPA 2000a; 2006) represents an essential element of the overall site investigation process and consists of the following seven steps:

1. State the problem;
2. Identify the goals of the study;
3. Identify information inputs;
4. Define the boundaries of the study;
5. Develop the analytical approach;
6. Specify performance or acceptance criteria; and,
7. Develop the plan for obtaining data.

Consistent with the guidance provided in USEPA (2000a; 2006), the DQO process has been used to guide the collection of the data and information needed to evaluate risks to aquatic receptors in the Tri-State Mining District (TSMD). Importantly, the DQOs established herein were used to guide the development of a field sampling plan (FSP; Pehrman *et al.* 2007) and this quality assurance project plan for the 2007 field sediment sampling program for the TSMD. This field sediment sampling program is targeted on the collection of the data and information needed to evaluate the bioavailability of chemicals of potential concern (COPCs) in the study area, to evaluate relationships between whole-sediment and pore-water chemistry and whole-sediment toxicity, and to support the development of site-specific toxicity thresholds of COPCs for the benthic invertebrate community (Section A6). In addition, the data and information collected during the 2007 field sampling program will be used to evaluate the reliability of generic sediment quality benchmarks and the site-specific toxicity thresholds.

The results of the reliability evaluation will be used to select the toxicity thresholds that are ultimately used for assessing risks to aquatic organisms associated with exposure to whole sediments in the study area. In addition, these results will be used to identify preliminary remediation goals (PRGs) that can be used to guide source control activities in the near-term and to establish clean-up goals for whole-sediments in the long-term. The individual steps of the DQO process are described in the following sub-sections.

A1.1 Step 1 - State the Problem

The purpose of this step of the DQO process is to delineate and describe the problem and the resources available for investigating it. This includes identifying the planning team members and the decision makers. The primary decision makers for this project are the Regional Project Managers (Mark Doolan for USEPA Region 7 and John Meyer for USEPA Region 6), who will solicit input from their Technical Team (consisting of the Natural Resources Trustees - NRTs, USGS personnel, and USEPA Region 6 and 7 consultants). Stating the problem also involves providing a description of the problem, which is provided below, and a conceptual model of the environmental hazards to be investigated.

Problem Statement:

- The Tri-State Mining District (TSMD) is comprised of a total of four National Priorities List (NPL) sites in Missouri, Kansas, and Oklahoma, including the Jasper County Site, MO, Newton County Site, MO, Cherokee County Site, KS, and the Ottawa Country Site, OK;
- Ores baring lead, zinc, and other base metals were mined, milled, and smelted within the Spring River and Neosho River watersheds between 1850 and 1970;
- During this period, metals may have been released from a vast number of mining, milling, and smelting operations in the study area;
- Data collected by USEPA in 2006 and information from other sources indicates that surface water, surficial sediments, and/or pore water within the TSMD have been contaminated by metals and, potentially, other COPCs;
- Comparison of the measured concentrations of metals in surface water, sediment, and/or pore water to ambient water quality criteria and/or generic sediment quality benchmarks suggests that exposure to surface water or sediments within the TSMD is likely to adversely affect aquatic organisms;
- As the effects of metals and other COPCs can be influenced by the physical and chemical properties of the sediments [e.g., total organic carbon (TOC)

concentration, acid volatile sulfide (AVS) concentration, grain size], the bioavailability of these substances in TSMD sediments is uncertain;

- For this reason, it is necessary to evaluate the bioavailability of sediment-associated COPCs in the TSMD, to assess the toxicity of TSMD sediments, and to develop relationships between the concentrations of COPCs in whole sediment and pore water and the responses of sediment-dwelling organisms in controlled, laboratory toxicity tests; and,
- Information on the toxicity and bioavailability of sediment-associated COPCs is also needed to support the establishment of site-specific toxicity thresholds that can be used as a basis for assessing risks to aquatic organisms and for establishing preliminary remediation goals (PRGs) for the site.

Figure A1.1 provides an overview of the conceptual site model (CSM) for the TSMD. The CSM shows that aquatic organisms and aquatic-dependent wildlife can be exposed to COPCs within the TSMD via several exposure pathways, including direct contact with contaminated water, sediment, and/or soil, consumption of contaminated water and/or prey organisms, incidental ingestion of sediments and/or soil, and/or inhalation of contaminated air. For aquatic organisms (such as microbiota, aquatic plants, aquatic invertebrates, fish, and amphibians), direct contact with contaminated environmental media and consumption of contaminated prey represent the most important exposure routes.

The 2007 field sampling program for the TSMD is focussed on the collection of data and information needed to evaluate risks to aquatic organisms associated with exposure to contaminated sediment. Accordingly, exposure of ecological receptors to contaminated sediments represents the primary exposure pathway that will be addressed in this study. The data and information needed to assess risks to human health and aquatic-dependent wildlife either have already been collected or will be collected in future field sampling programs. Likewise, the data and information needed to evaluate risks to aquatic organisms that are exposed to COPCs via other exposure routes either have already been collected or will be collected later during the RI process.

The last component of this step of the DQO process is to identify the available resources, constraints, and deadlines that apply to the project. The financial resources available to carry out this project include:

- Direct funding from USEPA and/or the NRTs to USGS - $425,000;
- Matching funds provided by USGS - $80,000;
- Direct funding to USEPA Region 7 contractors - $25,000
- Direct funding to USEPA Region 6 contractors - $45,000.
- In-kind funding provided by USEPA Region 7 - $60,000.
- In-kind funding provided by USEPA Region 6 - $60,000.
- Direct funding provided by the NRTs - $50,000.

- In-kind funding provided by NRTs - $30,000.

The key constraints that have been identified for this project include: (1) lack of information on the bioavailability of sediment-associated metals; (2) lack of information on the toxicity of TSMD sediments; 3) insufficient information to develop site-specific toxicity thresholds for sediment-associated COPCs (i.e., that are required to support establishment of PRGs for the TSMD).

A1.2 Step 2 - Identify the Goal of the Study

The purpose of this step of the DQO process is to identify the principal study question and define alternatives for addressing this question. The principal study questions for the project are:

- Is surface water in the TSMD contaminated by metals and/or COPCs to levels that would adversely affect the survival, growth, or reproduction of aquatic organisms?
- Are sediments in the TSMD contaminated by metals and/or COPCs to levels that would adversely affect the survival, growth, or reproduction of aquatic organisms?
- Is pore water in the TSMD sediments contaminated by metals and/or COPCs to levels that would adversely affect the survival, growth, or reproduction of aquatic organisms?
- Are sediment in the TSMD toxic to selected benthic invertebrates (i.e., amphipods, midge, and/or mussels)?;
- Are COPCs in TSMD sediment bioavailable to selected benthic invertebrates (i.e., amphipods, midge, mussels, and/or oligochaetes)?
- Are the concentrations of COPCs in whole-sediment and/or pore water correlated with the responses of selected benthic invertebrates (i.e., amphipods, midge, and/or mussels) or to bioaccumulation of metals by oligochaetes?
- What are the concentrations of COPCs in sediments and/or pore water that are associated with adverse effects on the survival, growth, or reproduction of benthic invertebrates (i.e., toxicity thresholds)?
- What are the PRGs that correspond to low risk and high risk thresholds for benthic invertebrates in TSMD sediments?

The following alternative actions could be implemented to solve the problem:

- Conduct further investigations to further delineate the nature, magnitude, and spatial extent of risks to aquatic organisms;
- Implement source control measures to reduce the levels of COPCs in environmental media;

- Remove and dispose of all sediments with COPC concentrations higher than the selected PRGs;
- Remove and dispose of sediment hot spots to reduce exposure to contaminated sediments;
- Cap some or all of the sediments with COPC concentrations higher than the selected PRGs;
- Implement a combined sediment removal and capping action to reduce exposure to COPCs; and/or,
- Implement monitored natural recovery of contaminated sediments.

The resultant decision statement is as follows:

- Determine whether risks to aquatic receptors associated with exposure to surface water and/or surficial sediments are sufficiently high to warrant taking one or more of the alternative actions listed above.

A1.3 Step 3 - Identify Information Inputs

The purpose of this step of the DQO process is to identify the information required to investigate the problem. In order to resolve the decision statement, a sediment quality sampling program will be implemented in 2007 to provide high quality, matching whole-sediment chemistry, pore-water chemistry, whole-sediment toxicity, and whole-sediment bioaccumulation data for resolving the decision statement.

In this study, generic sediment quality benchmarks (i.e., which are typically referred to as Action Levels in the DQOs process) will be evaluated and used to assess sediment chemistry data. The sediment quality benchmarks that will be considered have been published in agency reports and/or the published scientific literature, including threshold effect levels (TELs), probable effect levels, mean PEC-Quotients (mean PEC-Qs), equilibrium sediment benchmark toxic units (∑ESB-TUs), and simultaneously extracted metals minus acid volatile sulfides on a dry-weight basis or normalized to the fraction organic carbon (foc) in sediment [∑SEM-AVS and ∑(SEM-AVS)/f_{oc})]. Ambient water quality criteria or functionally-equivalent values will be used as Action Levels for evaluating surface-water quality and pore-water quality.

The Action Levels for assessing sediment quality conditions are intended to provide the scientific basis for establishing numerical PRGs for the TSMD. However, there is some unresolved uncertainty regarding the applicability of generic sediment quality benchmarks within the TSMD. For this reason, the results of the 2007 sediment quality investigation will be used to validate the Action Levels prior to implementation and/or to develop site-specific Action Levels that reflect the concentration-response relationships that are established for the TSMD [see MacDonald *et al.* (2003; 2005) for descriptions of procedures for deriving site-specific concentration-response relationships].

The last component of this step of the DQO process involves identifying sampling and analysis methods that can meet the data requirements. Sampling methods that will meet the data requirements identified for this project are detailed in the Field Sampling Plan (FSP; Pehrman *et al.* 2007) and in Section B.1 of this Quality Assurance Project Plan for the 2007 sediment quality investigation. In addition, Table 12 in Appendix BB.1 (Summary of responsibilities, key contacts, volume requirements, and bottle types for the July 2007 TSMD field sampling program.) specifies the required sample volumes and sample preservation methods for each type of sample. Furthermore, the FSP and/or QAPP specify the required detection limit, accuracy, precision, and completeness for each analyte (Table 5). The standard operating procedures cited in this QAPP describe the analytical procedures that will be used to generate measurement data that meet these performance criteria for measurement data (Appendix BB).

The FSP and the various elements of this QAPP describe a number of approaches that will be pursued to minimize bias in the resultant data. First, standard methods for preserving, transporting, and holding sediment samples will be used to assure their stability between sampling and analysis (Table 5, ASTM 2006). Next, the analytical laboratories will employ suitable procedures for cleaning-up the sediment and/or pore water samples to minimize the potential for matrix interference and associated effects on data quality (see Section B.3 of this QAPP for descriptions of these procedures). Third, care has been taken to identify the COPCs that occur or potentially occur within the TSMD, the forms of the chemicals (e.g., total metals and simultaneously extracted metals) that may be present, and the ancillary variables (e.g., total organic carbon, acid volatile sulfides, grain size) that ought to be measured to facilitate data interpretation. Furthermore, all laboratory instruments will be calibrated before use.

A1.4 Step 4 - Define the Boundaries of the Study

The purpose of this step of the DQO process is to define the target population to be sampled to identify the spatial and temporal boundaries of the study, to examine constraints to collecting data, and to define the scale of decision making.

The target population for the ERA of aquatic habitats in the TSMD consists of all of the surface-water chemistry, whole-sediment chemistry, pore-water chemistry, whole-sediment toxicity, invertebrate-tissue chemistry, and benthic invertebrate community structure data collected between January 1, 2003 and December 31, 2007. By focussing on the data collected within the last five years, it is anticipated that the data used in the ERA will be reflective of current (i.e., baseline) conditions in the study area. For the 2007 field sampling program, the target population consists of all of the sediment samples that are collected within the TSMD during the July and August field programs.

The spatial boundaries of the study will be limited to the eight areas of interest (AoIs) that were identified in the TSMD [See MacDonald *et al*. (2007) for a description of the AoIs that were identified within the TSMD]. However, information on sediment quality conditions in the adjacent reference areas will also be collected to support interpretation of the data from the TSMD (i.e., using a reference envelope approach).

Data collected in 2007 represent the primary source of information for evaluating the reliability of the generic sediment quality benchmarks and/or for developing site-specific toxicity thresholds for benthic invertebrates. However, other relevant data sets may also be used in this application if they are shown to be directly relevant to the TSMD (i.e., site-specific data).

For the 2007 field sampling program, the practical constraints could compromise the collection of matching sediment-chemistry and sediment-toxicity data include:

- Individual sediment grab samples may not provide sufficient volumes of sediment to support chemical and toxicological analysis. For this reason, multiple sediment grabs will be collected from each sampling location and composited to obtain sufficient volumes of material (Section B.1);
- Relatively low levels of fine material at certain sites may restrict the collection of sediments using standard sampling equipment. For this reason, sampling personnel will be trained to operate are number of sampling devices that, collectively, provide a means of collecting representative sediment samples from a wide range of substrate types; and,
- Differences in the levels of fine material between sites may make it difficult to compare the concentrations of COPCs that are measured in each sample. For this reason, all sediment samples will be sieved in the field to achieve a uniform maximum particle size (i.e., 2 mm; Section B.1).

A1.5 Step 5 - Develop the Analytical Approach

The purpose of this step of the DQO process is to define the population parameter, determine what action is needed, and confirm that the Action Level exceeds minimum detection limits.

Determining the population parameter (e.g., mean, median, percentile) that identifies the environmental characteristics that will be compared to the selected Action Level is a key component of the process for assessing risks to aquatic organisms in the TSMD. Table AA.1.1 provides a listing of the indicators, metrics, and action levels that will be used to assess risks to aquatic organisms in the TSMD. For each chemical analyte, the 95 percent upper confidence limit (UCL) of the mean will be calculated for each environmental media type (i.e., surface water, pore water, whole sediment) and compared to the corresponding Action Level for that substance.

As part of the decision rule development process, it is necessary to confirm that the Action Level exceeds the measurement detection limits for each of the COPCs. Tables AA.1.2 and AA.1.3

provide a listing of the preliminary Action Levels for each COPC in surface water and pore water and in sediment, respectively. The corresponding analytical detection limits for each COPC are also presented in these tables. To ensure that detection limits greater than the Action Levels do not bias the results of the evaluation of surface-water, pore-water, or sediment-quality conditions, any non-detected results that are greater than the selected Action Levels will be excluded from subsequent data analyses. The decision rule for this project is a follows:

- If the 95th percentile concentrations of all measured COPCs that are calculated for an AoI or the study area, as a whole, are below the selected Action Levels, then it will be concluded that risks to aquatic organisms are tolerable within the geographic area under consideration. No further action to mitigate risks to aquatic organisms utilizing habitats within the geographic area will be deemed necessary if these conditions are met.
- If the 95th percentile concentrations of one or more of the measured COPCs exceed the selected Action Level, then it will be concluded that risks to aquatic organisms may be unacceptable within the geographic area under consideration. In this case, actions to control the sources of COPCs may be identified and implemented within the geographic area. In addition, further investigations may be conducted to better delineate the magnitude and spatial extent of any adverse effects on aquatic organisms that are predicted based on exceedances of the Action Levels. Furthermore, a feasibility study may be conducted to identify the most appropriate remedial actions for mitigating risks to aquatic organisms in the subject geographic area.

A1.6 Step 6 - Specify Performance or Acceptance Criteria

The purpose of this step of the DQO process is to specify tolerable limits on decision errors for the problem. “A decision error occurs when the sample data set misleads you into making the wrong decision and, therefore, taking the wrong response action” (USEPA 2000a; 2006). This step involves setting the baseline condition, specifying the gray region (the range of possible true parameter values where the consequences of a false acceptance decision error are considered tolerable), and setting tolerable decision error limits (points above and below the Action Level that reflect the tolerable probability for the occurrence of decision errors).

The first step of this part of the DQO process is to set the baseline condition, which involves considering the population parameter that identifies the environment characteristics that will be compared to the selected Action Level. In this study, surface water chemistry data will be compared to ambient water quality criteria to identify conditions that pose unacceptable risks to aquatic organisms. Water samples with COPC concentrations less than 80% of the WQC (final chronic values) will be considered to have conditions sufficient to support aquatic communities (i.e., which generally represents the uncertainty in the chemical analyses). By comparison concentrations greater than the WQC will be considered to have conditions sufficient to adversely affect aquatic organisms. Samples with COPC concentrations that fall between 80% and 100% of the ambient WQC will be considered to have conditions that fall within the grey zone. Risks to aquatic organisms will be considered to be tolerable within this range of COPC concentrations. The range of the grey zone was selected to reflect the average level of uncertainty in the chemical concentrations, based on the analytical methods that were selected.

In this project, mean probable effect concentration-quotients (mean PEC-Qs) and equilibrium-based sediment benchmark-toxic units (ESB-TUs) models will form the primary tools for assessing sediment quality conditions relative to the potential for adverse effects on sediment-dwelling organisms. For both of these parameters, matching sediment chemistry and toxicity data will be used to develop concentration-response relationships that are specific to the TSMD. These concentration-response models will define how the probability of observing sediment toxicity changes with increasing concentrations of COPCs. Based on evaluations of data from numerous sites in the United States, the probability of observing toxicity to freshwater amphipods, *Hyalella azteca*, in 28-d toxicity tests is <10% at sites with COPC concentrations reflective of background conditions (Ingersoll et al. 2005).

In this study, sediment samples with COPC concentrations that correspond to a >20% magnitude of observing sediment toxicity will be considered to have conditions that do not adequately support benthic invertebrate communities, whereas those with COPC concentrations that correspond to a <10% magnitude of observing sediment toxicity will be considered to be reflective of background conditions. Samples for which the magnitude of sediment toxicity is between 10 and 20% will be considered to fall within the grey region and samples that have these characteristics will be considered to have conditions that pose tolerable risks to sediment-dwelling organisms.

A1.7 Step 7 - Develop the Plan for Obtaining Data

The purpose of this step of the DQO process is to review existing environmental data, evaluate operational decision rules, develop data collection design alternatives, calculate the number of samples to be taken, and select the most resource-effective data collection design.

The existing data will be compiled and reviewed as a work plan task for this project, which will assist with the design of the 2007 field sampling program. Importantly, a structure for the project database has been established in order to optimize the design for ***compiling*** data. The design of the project sediment quality database will be patterned after MacDonald Environmental Sciences Ltd sediment toxicity databases, in which sediment chemistry, sediment toxicity, and tissue chemistry data are routinely compiled (MacDonald et al. 2002). A key component of this design is that each sample is georeferenced to facilitate spatial analyses of the underlying data and presentation of the information on appropriate base maps (i.e., using ArcView software).

The project database will be a relational database, which means that the database consists of several tables that can be linked together (i.e., relationships have been defined) to facilitate retrieval of the data in a wide variety of ways. The purpose of defining relationships is to coordinate the retrieval of information in the different tables (i.e., different types of data on a single sample). The main advantage of a relational database is that queries, forms, and reports can be created to display information from several tables at once. A relationship works by matching data in key fields (usually a field with the same name in both tables), and these matching fields provide a unique identifier for each data record. The key fields that will be used to match the data in different tables, and thus provide a unique identifier, are the SITEID, STUDYID, STATIONID, SAMPLEID, FIELDREP, LABREP, and CHEMCODE fields.

The operational decision rule (i.e., which uses an *estimate* of the true value of the population parameter; i.e., the actual data) will replace the theoretical decision rule (i.e., stated in terms of the *true* value of the population parameter) that was developed in Step 5. As the theoretical rule will be developed as part of the work plan task of developing site-specific toxicity thresholds, the construction of the operational decision rule will also need to be formulated as part of the project work plan task.

The last three components of this step of the DQO process (develop data collection design alternatives, calculate the number of samples to be taken, and select the most resource-effective data collection design) are specific to sample collection activities. First, the historic patterns of contamination, estimates of variance, and the technical characteristics of the COPCs and sediments were considered in the data collection design alternatives described in the conceptual field sampling design (MacDonald *et al.* 2007). Consideration of this information facilitated the development of a series of sampling designs for acquiring the data needed to develop the concentration-response relationships. These design alternatives were evaluated by the USEPA and its Technical Team and the most effective alternative was selected for the 2007 sediment quality sampling program. This sampling program will consist of collection and analysis of:

- Grab sediment samples that are randomly selected from 70 locations within the TSMD study area; and,
- Associated QA samples (i.e., field duplicates).

The final sampling program design is documented in the conceptual field sampling design and FSP that were prepared for this project (MacDonald *et al.* 2007; Puhrman *et al*. 2007). Some of the key assumptions that underlie this sampling program design include:

- The data collected during the 2006 field sampling program provide an adequate basis for identifying the locations to be sampled in 2007;
- Reference samples can be identified based on mean PEC-Q of <0.1;
- Metals represent the principal COPCs (i.e., can drive the sampling design);
- Metals are likely to exert additive effects on sediment-dwelling organisms;

- The toxicity of metals can be influenced by levels of TOC, AVS, and fines in the sediment;
- Mean PEC-Qs, ∑SEM-AVS, and ∑(SEM-AVS)/f_{oc} represent the most useful metrics for interpreting sediment chemistry data;
- Simultaneously extracted metal concentrations can be estimated based on total metal concentrations;
- Average levels of AVS can be assigned for samples for which AVS was not reported;
- The biologically-active depth in the TSMD sediments is about the top 8 cm; and,
- Field duplicate sediment samples provide a basis for assessing small-scale spatial variability in sediment quality conditions and/or analytical precision.

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Table A.1.1. Action levels for assessing risks to aquatic receptors in the Tri-State Mining District.

Assessment Endpoint	**Key Sediment Quality Indicators** (Measurement of exposure)	**Candidate Metrics** (Measurement of effects)	**Action Levels**
Protection of Benthic Invertebrate Community	Pore-Water Chemistry	COPC Concentrations	> Final Chronic Value
	Surface-Water Chemistry	COPC Concentrations	> Final Chronic Value
	Whole-Sediment Chemistry (surficial)	Mean PEC-Q	> 1.0 (USEPA 2000b)
		PAH ESB-TU	> 1.0 (USEPA 2003)
		SEM-AVS	> 0.0
	Whole-Sediment Toxicity (surficial)	28-d *Hyalella azteca* S&G	>90% (CAS; USEPA 2000b)
		10-d *Chironomus dilutus* S&G	>80% (CAS; USEPA 2000b)
		28-d *Lampsilis siliquoidea* S&G	>80% (CAS; USEPA 2000b)
Protection of Fish Community	Whole-Sediment Chemistry (surficial)	COPC concentration	> SQGs for > 5 COPCs (MacDonald *et al.* 2005)
	Invertebrate or Fish Tissue Chemistry	COPC concentration	> TRGs (background; Jarvinen and Ankley 1999)
	Surface-Water Chemistry	COPC Concentrations	> Final Chronic Value

COPC = chemical of potential concern; SEM = simultaneously extracted metals; AVS = acid volatile sulfides; PAH = polycyclic aromatic hydrocarbons; TRGs = tissue residue guidelines; ESB-TU = equilibrium-partitioning sediment benchmark-toxic units; PEC-Q = probable effect concentration-quotient; CAS = control adjusted survival; S&G = survival and growth.

Table A.1.2. Toxicity thresholds for surface water and pore water (freshwater; asterix indicates substances for which the TDL is > the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (μg/L)[1]	Target Detection Limit (μg/L)[1]	
Metals				
Aluminum	7429-90-5	88.4	8.84	
Arsenic	7440-38-2	154	15.4	
Cadmium	7440-43-9	0.39	0.039	
Chromium_III	16065-83-1	79.2	7.92	
Chromium_VI	18540-29-9	10.8	1.08	
Copper	7440-50-8	4.17	0.417	
Iron	7439-89-6	887	88.7	
Lead	7439-92-1	1.16	0.116	
Mercury	7439-97-6	0.182	0.0182	*
Methylmercury	22967-92-6	0.00277	0.000277	
Molybdenum	7439-98-7	395	39.5	
Nickel	7440-02-0	60.5	6.05	
Selenium	7782-49-2	4.96	0.496	
Silver	7440-22-4	0.098	0.0098	
Thallium	7440-28-0	9.85	0.985	
Tin	7440-31-5	84.8	8.48	
Tributyltin	56573-85-4	0.0465	0.00465	
Triphenyltin	668-34-8	0.0223[3]	0.022	*
Uranium	7440-61-1	2.6	0.26	
Vanadium	7440-62-2	17.7	1.77	
Zinc	7440-66-6	60.8	6.08	
Nutrients				
Ammonia	7664-41-7	3.87	0.387	
Chloride	16887-00-6	230000	23000	
Chlorine	7782-50-5	10.1	1.01	
Cyanide (labile)	57-12-5	5.55	0.555	
Hydrogen sulfide	7783-06-4	2	0.2	
Nitrate	14797-55-8	13000[3]	13000	*
Nitrite	14797-65-0	60[3]	60	*
Oxy halides (chlorate, chlorite, bromate)		NBA		
Phosphorous (elemental)?	7723-14-0	NBA	NBA	
Unclassified				
Perchlorate	14797-73-0	NBA	NBA	
Sulfate	14808-79-8	NBA	NBA	
Carbamate Pesticides				
Aldicarb	116-06-3	1[3]	1	*
Carbaryl	63-25-2	0.2	0.02	
Carbofuran	1563-66-2	1	0.1	

Table A.1.2. Toxicity thresholds for surface water and pore water (freshwater; asterix indicates substances for which the TDL is > the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (µg/L)[1]	Target Detection Limit (µg/L)[1]	
Chlorinated Benzenes				
1,2,3,4-Tetrachlorobenzene	634-66-2	1.8[3]	1.8	*
1,2,3-Trichlorobenzene	87-61-6	8[3]	8	*
1,2,4-Trichlorobenzene	120-82-1	61.7	6.17	
1,2-Dichlorobenzene	95-50-1	18.4	1.84	
1,3-Dichlorobenzene	541-73-1	59	5.9	
1,4-Dichlorobenzene	106-46-7	16.9	1.69	
Chlorobenzene	108-90-7	57	5.7	*
Hexachlorobenzene	118-74-1	0.00692	0.000692	*
PCNB (pentachloronitrobenzene)	82-68-8	NBA	NBA	
Pentachlorobenzene	608-93-5	0.564	0.0564	*
Glycols				
Ethylene glycol	107-21-1	500000	50000	
Nitrogen/Phosphorus/Sulfur Pesticides				
Azinphos methyl	86-50-0	0.00926	0.000926	
Bromacil	314-40-9	5[3]	5	*
Bromoxynil	1689-84-5	5[3]	5	*
Captan	133-06-2	1.3[3]	1.3	*
Chlorothalonil	1897-45-6	0.18[3]	0.18	*
Chlorpyrifos	2921-88-2	0.041	0.0041	
Demeton-A/B	8065-48-3	0.1	0.01	
Demeton-O	298-03-3	NBA	NBA	
Demeton-S	126-75-0	NBA	NBA	
Dimethoate	60-51-5	6.2[3]	6.2	*
Ethyl parathion	56-38-2	0.013	0.0013	
Glyphosate	1071-83-6	65[3]	65	*
Linuron	330-55-2	7[3]	7	*
Malathion	121-75-5	0.0792	0.00792	
Metribuzin	21087-64-9	1[3]	1	*
Picloram	1918-02-1	29[3]	29	*
Tebuthiuron	34014-18-1	1.6[3]	1.6	*
Trifluralin	1582-09-8	0.2[3]	0.2	*
Persistent Organochlorine Pesticides				
4,4'-DDD	72-54-8	0.00548	0.000548	
4,4'-DDE	72-55-9	0.141	0.0141	*
4,4'-DDT	50-29-3	0.000823	0.0000823	*
Aldrin	309-00-2	0.663	0.0663	*

Table A.1.2. Toxicity thresholds for surface water and pore water (freshwater; asterix indicates substances for which the TDL is > the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (μg/L)[1]	Target Detection Limit (μg/L)[1]	
Persistent Organochlorine Pesticides (cont.)				
Alpha-BHC	319-84-6	32.2	3.22	*
Beta-BHC	319-85-7	41.3	4.13	*
Chlordane	57-74-9	0.00427	0.000427	
Delta-BHC	319-86-8	237	23.7	
Dieldrin	60-57-1	0.0123	0.00123	*
Endosulfan I	959-98-8	0.0555	0.00555	
Endosulfan II	33213-65-9	0.0555	0.00555	
Endrin	72-20-8	0.0176	0.00176	
Endrin aldehyde	7421-93-4	13.5	1.35	*
Endrin ketone	53494-70-5	NBA	NBA	
Gamma-BHC (Lindane)	58-89-9	0.154	0.0154	
Heptachlor	76-44-8	0.00403	0.000403	
Heptachlor epoxide	1024-57-3	0.0038	0.00038	
Kepone	143-50-0	0.132	0.0132	
Methoxychlor	72-43-5	0.0276	0.00276	
Mirex	2385-85-5	0.001	0.0001	
Toxaphene	8001-35-2	0.000373	0.0000373	
Phenols				
2,3,4,6-Tetrachlorophenol	58-90-2	1.2	0.12	
2,3,6-Trichlorophenol	933-75-5	NBA	NBA	
2,4,5-Trichlorophenol	95-95-4	64	6.4	
2,4-Dichlorophenol	120-83-2	34	3.4	
2,6-Dichlorophenol	87-65-0	NBA	NBA	
2-Chlorophenol	95-57-8	43	4.3	
4-chlorophenol	106-48-9	NBA	NBA	
m-Cresol	108-39-4	62	6.2	
o-Cresol	95-48-7	35.9	3.59	
p-Cresol	106-44-5	195	19.5	
Pentachlorophenol	87-86-5	2.9	0.29	
Pentachlorophenol	87-86-5	14.1	1.41	
Phenol	108-95-2	182	18.2	
Phenoxyacetic Acids				
Dicamba	1918-00-9	10[3]	10	*
Dinoseb	88-85-7	0.48	0.048	
MCPA	94-74-6	NBA	NBA	
Phthalates				
1,2-Benzenedicarboxylic acid, dihexyl ester	84-75-3	NBA	NBA	
bis(2-Ethylhexyl) phthalate	117-81-7	1.66	0.166	
Butyl benzyl phthalate	85-68-7	24.2	2.42	

Table A.1.2. Toxicity thresholds for surface water and pore water (freshwater; asterix indicates substances for which the TDL is > the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (μg/L)[1]	Target Detection Limit (μg/L)[1]	
Phthalates (cont.)				
Diethyl phthalate	84-66-2	293	29.3	
Dimethyl phthalate	131-11-3	330	33	
Di-n-butyl phthalate	84-74-2	17.4	1.74	
Di-n-octyl phthalate	117-84-0	94.8	9.48	
Polychlorinated Biphenyls (PCBs)				
PCB-1016	12674-11-2	0.014	0.0014	
PCB-1221	11104-28-2	0.132	0.0132	
PCB-1232	11141-16-5	0.229	0.0229	*
PCB-1242	53469-21-9	0.038	0.0038	
PCB-1248	12672-29-6	0.0522	0.00522	
PCB-1254	11097-69-1	0.0266	0.00266	
PCB-1260	11096-82-5	3.56	0.356	*
Total PCBs	1336-36-3	0.00473	0.000473	*
Polychlorinated Dibenzo-p-dioxins and Dibenzofurans				
2,3,7,8-Tetrachlorodibenzo-*p*- dioxin	1746-01-6	0.000000392	0.0000000392	*
Polycyclic Aromatic Compounds				
2-Methylnaphthalene	91-57-6	31.2	3.12	
Acenaphthene	83-32-9	21.9	2.19	
Acenaphthylene	208-96-8	168	16.8	*
Anthracene	120-12-7	0.391	0.0391	*
Benz(a)anthracene	56-55-3	0.0754	0.00754	
Benzo(a)pyrene	50-32-8	0.014	0.0014	
Benzo(b)fluoranthene	205-99-2	0.495	0.0495	*
Benzo(g,h,i)perylene	191-24-2	7.64	0.764	
Benzo(k)fluoranthene	207-08-9	0.027	0.0027	
Biphenyl	92-52-4	14	1.4	
Chrysene	218-01-9	0.172	0.0172	
Dibenz(a,h)anthracene	53-70-3	0.367	0.0367	*
Fluoranthene	206-44-0	8.35	0.835	
Fluorene	86-73-7	4.23	0.423	
Indeno(1,2,3-cd)pyrene	193-39-5	0.341	0.0341	*
Naphthalene	91-20-3	23.9	2.39	
Phenanthrene	85-01-8	11.5	1.15	
Pyrene	129-00-0	1.3	0.13	
Semivolatile Chlorinated Organic Compounds				
Hexachlorobutadiene	87-68-3	0.584	0.0584	*

Table A.1.2. Toxicity thresholds for surface water and pore water (freshwater; asterix indicates substances for which the TDL is > the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (µg/L)[1]	Target Detection Limit (µg/L)[1]	
Triazine Herbicides				
Atrazine	1912-24-9	1.8[3]	1.8	*
Cyanazine	21725-46-2	2[3]	2	*
Metolachlor	51218-45-2	7.8[3]	7.8	*
Simazine	122-34-9	10[3]	10	*
Volatile Chlorinated Organic Compounds				
1,2-Dichloroethane	107-06-2	1340	134	
1,1,1-Trichloroethane	71-55-6	60.5	6.05	
1,1,2,2-Tetrachloroethane	79-34-5	378	37.8	
Carbon tetrachloride	56-23-5	34.1	3.41	
Tetrachloroethene	127-18-4	101	10.1	
Trichloroethene	79-01-6	98.4	9.84	
Vinyl chloride	75-01-4	2290	229	
Volatile Organic Compounds				
Acetone	67-64-1	3470	347	
Aniline	62-53-3	4.1	0.41	
Benzene	71-43-2	64.8	6.48	
Chloroform	67-66-3	80.6	8.06	
Ethanol	64-17-5	NBA	NBA	
Ethyl acetate	141-78-6	NBA	NBA	
Ethylbenzene	100-41-4	38.7	3.87	
Methanol	67-56-1	NBA	NBA	
Methyl ethyl ketone	78-93-3	10200	1020	
Methylene chloride	75-09-2	1640	164	
m-Xylene	108-38-3	1.8	0.18	
o-Xylene	95-47-6	NBA	NBA	
p-Dioxane	123-91-1	22000	2200	
p-Xylene	106-42-3	NBA	NBA	
Styrene	100-42-5	137	13.7	
Toluene	108-88-3	62.9	6.29	

CAS = chemical abstracts; NBA = no benchmark available; USEPA United States Environmental Protection Agency.

[1]The toxicity threshold is the geometric mean of the Draft Freshwater Benchmarks by USEPA Region (USEPA compilation; June 16, 2004 draft; received from Marc Greenberg on September 16, 2004).

Table A.1.3. Toxicity thresholds for freshwater sediments (an asterisk indicates substances for which the target detection limit is greater than the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (mg/kg DW)[1]	Target Detection Limit (mg/kg DW)[1]	
Metals				
Arsenic	7440-38-2	7.15	0.715	
Cadmium	7440-43-9	0.991	0.0991	
Chromium	7440-47-3	20.2	2.02	*
Copper	7440-50-8	25.2	2.52	
Lead	7439-92-1	35.3	3.53	
Mercury	7439-97-6	0.158	0.0158	
Nickel	7440-02-0	18.7	1.87	
Zinc	7440-66-6	124	12.4	
Carbamate Pesticides				
Aldicarb	116-06-3	NBA	NBA	
Carbaryl	63-25-2	NBA	NBA	
Carbofuran	1563-66-2	0.002	0.0002	
Chlorinated Benzenes				
1,2,3-Trichlorobenzene	87-61-6	NBA	NBA	
1,2,4-Trichlorobenzene	120-82-1	8.16	0.816	
1,2-Dichlorobenzene	95-50-1	0.173	0.0173	
1,3-Dichlorobenzene	541-73-1	1.61	0.161	
1,4-Dichlorobenzene	106-46-7	0.247	0.0247	
Chlorobenzene	108-90-7	0.363	0.0363	*
Hexachlorobenzene	118-74-1	0.0552	0.00552	
PCNB (pentachloronitrobenzene)	82-68-8	NBA	NBA	
Nitrogen/Phosphorus/Sulfur Pesticides				
Azinphos methyl	86-50-0	0.00001	0.000001	
Bromacil	314-40-9	NBA	NBA	
Captan	133-06-2	NBA	NBA	
Chlorothalonil	1897-45-6	NBA	NBA	
Chlorpyrifos	2921-88-2	0.053	0.0053	
Demeton-A/B	8065-48-3	NBA	NBA	
Demeton-O	298-03-3	NBA	NBA	
Demeton-S	126-75-0	NBA	NBA	
Dimethoate	60-51-5	NBA	NBA	
Ethyl parathion	56-38-2	0.000757	0.0000757	
Linuron	330-55-2	NBA	NBA	
Malathion	121-75-5	0.000495	0.0000495	
Metribuzin	21087-64-9	NBA	NBA	
Tebuthiuron	34014-18-1	NBA	NBA	
Trifluralin	1582-09-8	NBA	NBA	

Table A.1.3. Toxicity thresholds for freshwater sediments (an asterisk indicates substances for which the target detection limit is greater than the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (mg/kg DW)[1]	Target Detection Limit (mg/kg DW)[1]	
Organometallic Compounds				
Tributyltin chloride	1461-22-9	NBA	NBA	
Persistent Organochlorine Pesticides				
4,4'-DDD	72-54-8	0.00509	0.000509	
4,4'-DDE	72-55-9	0.00261	0.000261	
4,4'-DDT	50-29-3	0.00266	0.000266	
Aldrin	309-00-2	0.002	0.0002	
alpha-BHC	319-84-6	0.006	0.0006	
beta-BHC	319-85-7	0.005	0.0005	
Chlordane	57-74-9	0.00262	0.000262	
delta-BHC	319-86-8	71.5	7.15	
Dieldrin	60-57-1	0.00493	0.000493	
Endosulfan I	959-98-8	0.00297	0.000297	
Endosulfan II	33213-65-9	0.00943	0.000943	
Endrin	72-20-8	0.0046	0.00046	
Endrin aldehyde	7421-93-4	0.48	0.048	
Endrin ketone	53494-70-5	NBA	NBA	
gamma-BHC (Lindane)	58-89-9	0.00233	0.000233	
Heptachlor	76-44-8	0.00537	0.000537	*
Heptachlor epoxide	1024-57-3	0.00173	0.000173	
Kepone	143-50-0	0.00331	0.000331	
Methoxychlor	72-43-5	0.0141	0.00141	
Mirex	2385-85-5	0.007	0.0007	
Toxaphene	8001-35-2	0.00279	0.000279	*
Phenols				
2,3,4,6-Tetrachlorophenol	58-90-2	0.129	0.0129	
2,3,5,6-Tetrachlorophenol	935-95-5	NBA	NBA	
2,3,5-Trichlorophenol	933-78-8	NBA	NBA	
2,3,6-Trichlorophenol	933-75-5	NBA	NBA	
2,4,5-Trichlorophenol	95-95-4	NBA	NBA	
2,4-Dichlorophenol	120-83-2	0.0817	0.00817	
2,6-Dichlorophenol	87-65-0	NBA	NBA	
2-Chlorophenol	95-57-8	0.0319	0.00319	
m-Chlorophenol	108-43-0	NBA	NBA	
m-Cresol	108-39-4	0.0524	0.00524	
o-Cresol	95-48-7	0.0316	0.00316	
p-Cresol	106-44-5	0.333	0.0333	*
Pentachlorophenol	87-86-5	0.733	0.0733	
Phenol	108-95-2	0.0667	0.00667	

Table A.1.3. Toxicity thresholds for freshwater sediments (an asterisk indicates substances for which the target detection limit is greater than the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (mg/kg DW)[1]	Target Detection Limit (mg/kg DW)[1]	
Phenoxyacetic Acids				
Dicamba	1918-00-9	NBA	NBA	
Dinoseb	88-85-7	0.0145	0.00145	
MCPA	94-74-6	NBA	NBA	
Polychlorinated Biphenyls				
PCB-1016	12674-11-2	0.00442	0.000442	
PCB-1221	11104-28-2	0.0988	0.00988	
PCB-1232	11141-16-5	0.6	0.06	
PCB-1242	53469-21-9	0.17	0.017	
PCB-1248	12672-29-6	0.03	0.003	
PCB-1254	11097-69-1	0.06	0.006	
PCB-1260	11096-82-5	0.005	0.0005	
Total PCBs	1336-36-3	0.0404	0.00404	
Polychlorinated Dibenzo-p-dioxins and Dibenzofurans				
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	0.00000138	0.000000138	*
Polycyclic Aromatic Compounds				
2-Methylnaphthalene	91-57-6	0.114	0.0114	
Acenaphthene	83-32-9	0.0983	0.00983	*
Acenaphthylene	208-96-8	0.0783	0.00783	*
Anthracene	120-12-7	0.151	0.0151	*
Benzo(a)anthracene	56-55-3	0.132	0.0132	
Benzo(a)pyrene	50-32-8	0.205	0.0205	
Benzo(b)fluoranthene	205-99-2	4.74	0.474	
Benzo(g,h,i)perylene	191-24-2	0.252	0.0252	
Benzo(k)fluoranthene	207-08-9	0.139	0.0139	
Biphenyl	92-52-4	1.1	0.11	
Chrysene	218-01-9	0.195	0.0195	
Dibenzo(a,h)anthracene	53-70-3	0.0596	0.00596	
Fluoranthene	206-44-0	0.505	0.0505	*
Fluorene	86-73-7	0.0841	0.00841	
Indeno(1,2,3-cd)pyrene	193-39-5	0.193	0.0193	*
Naphthalene	91-20-3	0.176	0.0176	*
Phenanthrene	85-01-8	0.234	0.0234	*
Pyrene	129-00-0	0.36	0.036	
Semivolatile Chlorinated Organic Compounds				
Hexachlorobutadiene	87-68-3	0.0205	0.00205	

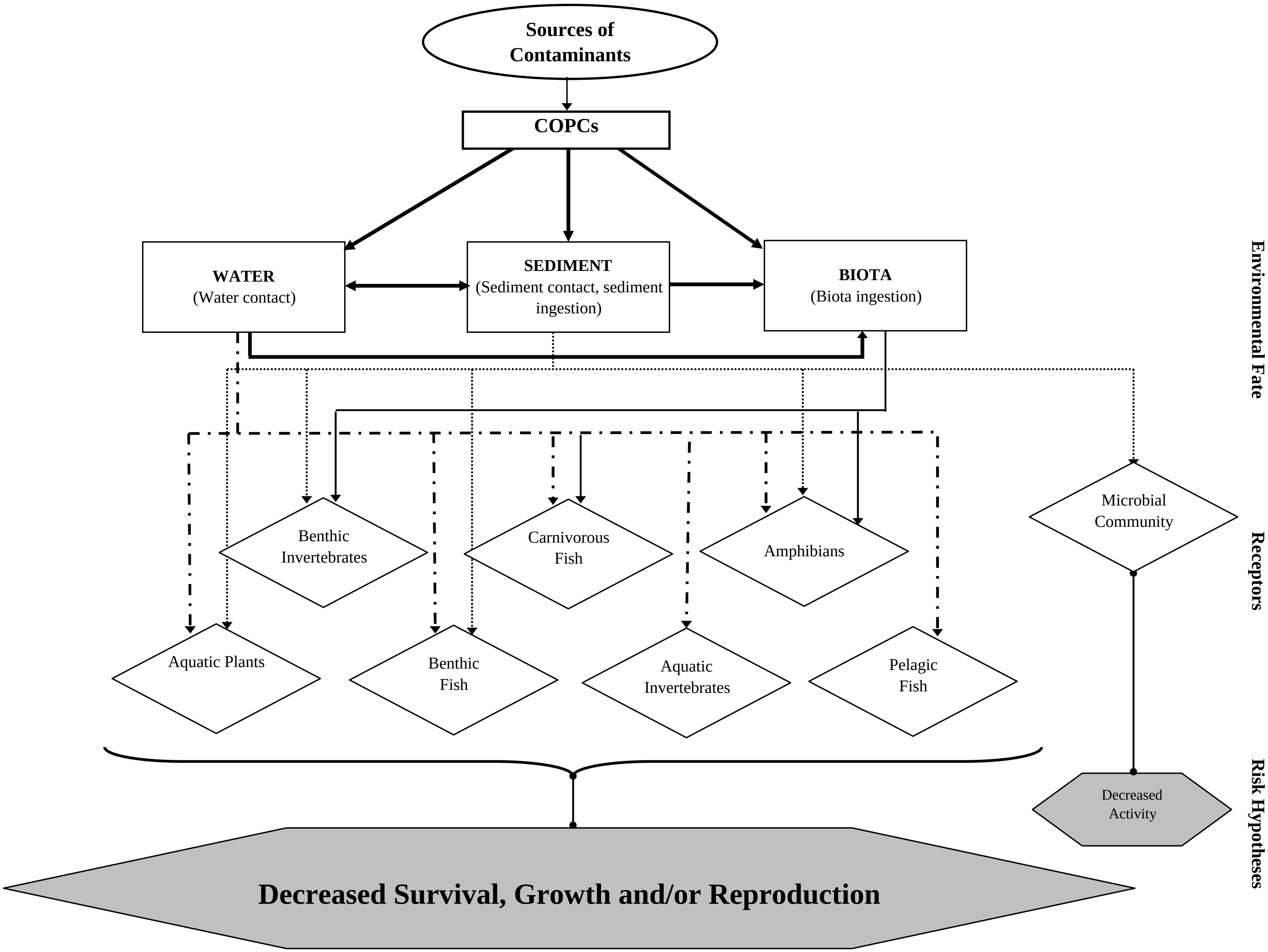
Table A.1.3. Toxicity thresholds for freshwater sediments (an asterisk indicates substances for which the target detection limit is greater than the minimum USEPA Regional Benchmark).

Class/Analyte Name	CAS Number	Toxicity Threshold (mg/kg DW)[1]	Target Detection Limit (mg/kg DW)[1]	
Triazine Herbicides				
Atrazine	1912-24-9	NBA	NBA	
Simazine	122-34-9	NBA	NBA	
Volatile Chlorinated Organic Compounds				
1,1,1-Trichloroethane	71-55-6	0.126	0.0126	
1,1,2,2-Tetrachloroethane	79-34-5	0.921	0.0921	
Volatile Chlorinated Organic Compounds (cont.)				
1,2-Dichloroethane	107-06-2	0.253	0.0253	
Carbon tetrachloride	56-23-5	0.56	0.056	*
Tetrachloroethene	127-18-4	0.397	0.0397	
Trichloroethene	79-01-6	0.738	0.0738	
Vinyl chloride	75-01-4	0.59	0.059	
Volatile Organic Compounds				
Acetone	67-64-1	0.0144	0.00144	
Benzene	71-43-2	0.117	0.0117	
Chloroform	67-66-3	0.388	0.0388	*
Ethanol	64-17-5	NBA	NBA	
Ethyl acetate	141-78-6	NBA	NBA	
Ethylbenzene	100-41-4	0.471	0.0471	*
Methanol	67-56-1	NBA	NBA	
Methyl ethyl ketone	78-93-3	0.146	0.0146	
Methylene chloride	75-09-2	0.279	0.0279	
m-Xylene	108-38-3	0.025	0.0025	
o-Xylene	95-47-6	NBA	NBA	
p-Dioxane	123-91-1	0.119	0.0119	
p-Xylene	106-42-3	NBA	NBA	
Styrene	100-42-5	0.254	0.0254	
Toluene	108-88-3	0.581	0.0581	*

CAS = chemical abstracts; NBA = no benchmark available; DW = dry weight.

[1]The toxicity threshold is the geometric mean of the Draft Freshwater Sediment Benchmarks by USEPA Region (USEPA compilation; February 12, 2004 draft; received from Marc Greenberg on September 16, 2004). Benchmarks that were expressed on an organic carbon (OC) normalized basis were converted to units on a dry weight basis at 1% OC prior to calculating the geometric mean.

Figure A.1.1. Conceptual model diagram illustrating exposure pathways and potential effects for all categories of chemicals of potential concern.



Appendix 2 Development and Use of Action Levels to Guide Management Response Planning

A2.0 Development of Action Levels

Action Levels are defined as the concentrations of chemicals of potential concern in water, sediment, or biota that are used to identify the need for management intervention(s) to reduce or eliminate the adverse effects on the aquatic ecosystem associated with project-related activities. In addition, Action Levels can be established for other indicators of aquatic environmental quality, such as water quantity, effluent, surface water, or sediment toxicity, and structure and/or abundance of communities of aquatic organisms.

A variety of approaches can be used to establish Action Levels for various indicators of the status of the aquatic ecosystem. However, most of these approaches involve development of environmental quality objective (EQOs) for the receiving water body as a first step. Such EQOs can be derived by:

- Adopting *generic* environmental quality guidelines (EQGs);
- Deriving *site-adapted* EQOs; and,
- Developing *site-specific* EQOs.

The simplest of these approaches involve direct adoption of generic EQGs, such as those that have been established by the Canadian Council of Ministers of the Environment (CCME 1999). Such generic EQGs can be adapted for use at the site by adjusting them to account for site-specific conditions. Four methods have been developed to facilitate the derivation of site-adapted EQOs, including the background concentration procedure, analytical limit of quantification procedure, recalculation procedure, and water effect ratio procedure [see MacDonald *et al.* (2002) for detailed guidance on the development of EQOs in Canada].

It is essential that the EQOs for the receiving water system be derived in a manner that reflects the long-term ecosystem goals and objectives that have been articulated by Aboriginal governments/organizations, regulatory agencies, and other interested parties. The federal non-degradation policy should also be considered in the EQOs derivation process. More specifically, CCME (1987) indicated that "EQGs should not be regarded as blanket levels for national water quality. Variations in environmental conditions across Canada will affect water quality in different ways and many EQGs will need to be modified according to these local conditions. For waters of superior quality, impairment to EQG concentrations should not be acceptable." Therefore, the background concentration procedure may be the most appropriate method for deriving EQOs for many northern waters.

Once the EQOs have been established for the receiving water body, Action Levels can be established that will support management of the project as a whole. In developing such Action Levels, it is important to acknowledge that considerable lead time may be required to implement the mitigation measures needed to address impending or emerging issues associated with project activities. For example, design, construction, testing, and optimization of a wastewater treatment plant to remove metals or ammonia from an effluent stream could require three years or more to complete. Therefore, the Action Levels that are established for evaluating the levels of metals or ammonia in receiving waters in the facility of a facility must be sufficiently conservative to ensure that EQOs are not exceeded before mitigation measures can be fully implemented.

In general, Action Levels should be established at levels that fall between the upper limits of background and the EQOs. In addition, Action Levels should be established at levels that are appropriate for management action that will be taken if the Action Level is exceeded. Such progressive Action Levels could include:

- Upper limit of background conditions;
- Multiple of average background conditions;
- Multiple of the upper limit of background conditions;
- Fraction of the EQO; and/or,
- EQO.

Decisions on the selection of Action Levels should be made in consultation with Aboriginal governments/organizations, regulatory agencies, and other interested parties. Ultimately, these Action Levels will also be subject to regulatory approval because the AMP must be approved by the responsible land and water board. Ideally such Action Levels would be developed prior to the environmental assessment to increase consistency between the environmental assessment, the AEMP and the AMP.

A2.1 Establishment of Decision Rules

In accordance with the DQOs process, Action Levels represent key tools for choosing between alternative courses of action. After selecting the indicators of interest (e.g., the concentration of copper in surface water) and establishing Action Levels for each indicator, decision rules (i.e., “if”...”then” statements) can be constructed to guide project management based on the results of the AEMP. An example of a theoretical decision rule is as follows (USEPA 2006):

> “If the 95th percentile concentration of dissolved copper in surface water within the near-field area during any year exceeds 0.5 µg/L (i.e., the upper limit of background conditions) and a significant temporal trend is observed in the AEMP data, then candidate mitigation measures will be evaluated to facilitate identification of the most effective means of reducing dissolved copper concentrations to acceptable levels.”

Such a decision rule may be complemented by a companion decision rule that describes the management action that would be taken if elevated levels of copper are detected in the vicinity of the development project. For example:

> “If the 95th percentile concentration of dissolved copper in surface water within the near-field area during any year exceeds 1.0 µg/L (i.e., 0.5 times the EQO) and temporal trend assessment indicates that the EQO is likely to be exceeded within five years, then the most effective means of reducing dissolved copper concentrations to acceptable levels will be fully implemented within a three-year period.”

Figure A2.1 provides an example of how data from the AEMP can be used in conjunction with various Action Levels to make decisions regarding the need for mitigation to address project-related effects on the aquatic ecosystem. In this hypothetical example, baseline conditions were established using baseline monitoring data collected prior to mine construction. The upper limit of background concentrations of copper was calculated as the 97.5 percentile of the baseline data. The AEMP results show an increasing trend in copper concentrations, exceeding the upper limit of background (Low Action Level) during mine construction. In this example, candidate options for reducing loadings of copper to the receiving water system would be evaluated prior to the initiation of mine operations (i.e., when the upper limit of background was exceeded). Additional monitoring data showed that concentrations of copper in receiving waters continued to increase after the onset of mining, at an even higher rate than was the case during mine construction. Based on extrapolation of the trend line, it is expected that copper concentrations would exceed the Moderate Action Level and the EQO during mine life. The results of water quality modelling activities show that source control measures could reduce loadings of copper to the receiving water system, but Moderate Action Level and the EQO would still be predicted to be exceeded during mine life. Water quality modelling results also show that construction and operation of a metals-specific wastewater treatment plant would result in copper levels between Low Action Level and Moderate Action Level for the remainder of mine life. The results of such an evaluation of mitigation options, triggered by actual or projected exceedances of the Action Levels, provide the information needed to select among the alternatives and implement the mitigation needed to protect the aquatic ecosystem and its uses.

Importantly, the decision rules in the AMP should explicitly address the key issues that were identified during the environmental assessment, water licencing, and/or problem formulation processes. As AEMP data are collected during the life of the project, a number of emerging issues may be identified that were not anticipated in the original impact predictions or in subsequent planning steps. The AMP should be revised annually to ensure that any such emerging issues are adequately addressed in the plan.

An AMP represents a useful management tool only if it appropriately identifies key issues relative to effects on the aquatic ecosystem and its uses, establishes Action Levels that are sufficiently conservative to provide adequate time to implement any required mitigation measures, and presents decision rules that are sufficiently specific to ensure that all participants in the process understand what actions will be taken by the project proponent when each Action Level is exceeded. Accordingly, it is not appropriate to include risk assessments as one on the options that be considered if the Action Levels are exceeded. Because background conditions are likely to be used to define certain types of Action Levels, it is essential that adequate baseline monitoring data are available to establish background conditions prior to water licencing and that procedures for calculating background concentrations are defined on an *a priori* basis.

A2.2 References Cited

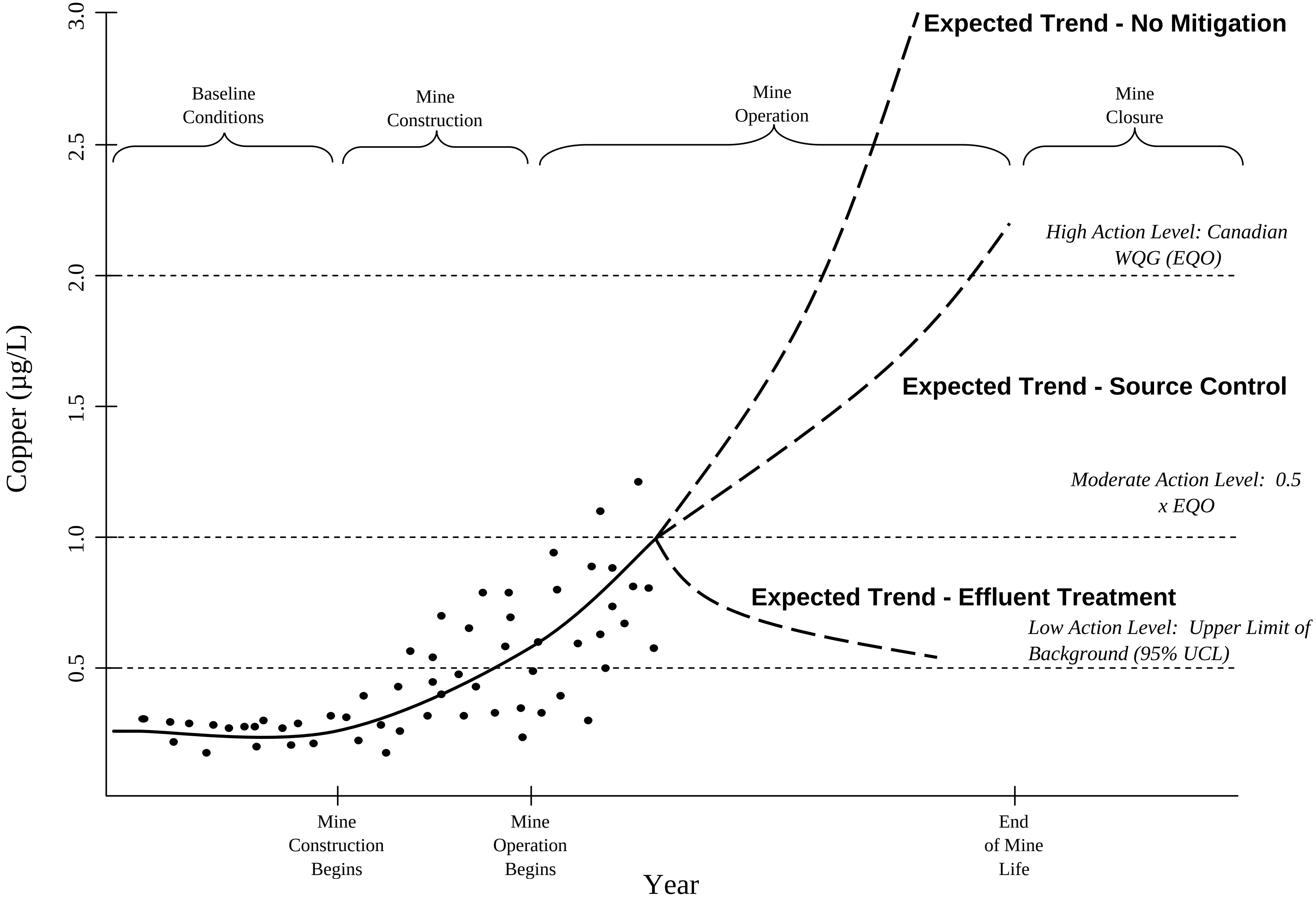
CCME (Canadian Council of Ministers of the Environment). 1987. Canadian water quality guidelines. Eco-Health Branch. Environment Canada. Ottawa, Ontario.

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian environmental quality guidelines. Guidelines and Standards Division. Environment Canada. Winnipeg, Manitoba. (Updated annually).

MacDonald, D.D., D.E. Smorong, D.A. Levy, L. Swain, P.Y. Caux, and J.B. Kemper. 2002. Guidance on the site-specific application of water quality guidelines in Canada: Procedures for deriving numerical water quality objectives. Prepared for Canadian Council of Ministers of the Environment, Winnipeg, Manitoba and Environment Canada, Ottawa, Canada.

USEPA (United States Environmental Protection Agency). 2006. Guidance on systematic planning using the data quality objectives process. EPA QA/G-4. EPA/240/B-06/001. Office of Environmental Information. Washington, District of Columbia.

Figure A2.1. Hypothetical example to illustrate the application of aquatic effects monitoring data and action levels to support evaluation and selection of mitigation options.



Appendix 3 Development of Management Response Plans

Under the terms of Type A Water Licences, project proponents may be required to develop a Management Response Plan (MRP; previously referred to as Adaptive Management Plans) to support decisions relative to management of project-related activities that have the potential to adversely affect aquatic ecosystems and/or their uses. For example, the Wek'eezhii Land and Water Board (WLWB) in its guidance to water licensees has indicated that a MRP "should describe, in sufficient detail, how data in the AEMP will be used to identify the need for additional mitigation strategies to minimize the impacts of the project on the aquatic environment." Hence the WLWB recognizes the need to establish clear linkages between the results of the AEMP and decisions that are taken to mitigate project-related effects. The MRP represents a key tool for linking the AEMP results to the management of development project as a whole and particularly for those activities that have the greatest potential to adversely affect the water environment.

Development of an MRP is a logical outgrowth of the earlier steps in the AEMP development process. More specifically, key issues and concerns relative to potential effects of the project on the aquatic ecosystem are identified following dissemination of the project description and crystalized during the environmental assessment process. During problem formulation, the linkages between the development project (and/or multiple disturbance activities) and ecological receptors and/or human health are established. In turn, this information is used during the data quality objectives (DQOs) process to develop a conceptual AEMP Design that will provide information on the status of valued ecosystem components (VECs) and/or other indicators that have the potential to be affected by project-related activities. In turn, implementation of the detailed AEMP Design provides high quality data and information on water and sediment quality conditions, the status of aquatic and/or aquatic-dependent communities, tissue residue levels, and other key characteristics of the aquatic ecosystem in the vicinity of the development. These data and information can be used to make decisions regarding the need for additional mitigation by establishing and applying appropriate Action Levels for each of the selected indicators of aquatic environmental quality (e.g., copper concentration in water, total polycyclic aromatic hydrocarbon concentration in sediment, polychlorinated biphenyl concentration in lake trout fillets, lake whitefish populations). The decision rules (i.e., "if"... "then" statements) that are developed during the fifth step of the DQOs process can be incorporated directly into the MRP for the project. Therefore, the key elements of an effective MRP are:

- Monitoring data from a well-designed AEMP;
- Action Levels for each measurement endpoint included in the AEMP; and,

- Decision Rules that describe the actions that will be taken if the Action Levels are exceeded.

The procedures for designing an AEMP that will provide the data and information needed to evaluate project-related effects and to make decisions regarding the need for additional project mitigation are described in Volumes 2, 3, and 4 of the Technical Guidance Documents. Action Levels and Decision Rules are briefly discussed in Appendix 2.