Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects

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All photos by Government of Yukon

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Prepared by Bill Slater, Slater Environmental Consulting, based on *Guidance Manual for Developing Water Quality Objectives for Freshwater Ecosystems in Yukon*, *Final Report, October 2016* (MacDonald et al. 2016) and with assistance for Chapter 6 from Leslie Gomm, Water Quality Objectives Guidance Working Group.

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List of Abbreviations

AMP:	Adaptive management plan
AEMP:	Aquatic effects monitoring program
BATT:	Best available treatment technology
BCP:	Background concentration procedure
BLM:	Biotic ligand model
BTMF:	Bioavailability and toxicity modifying factors
CCME:	Canadian Council of Ministers of the Environment
COPC:	Contaminant of potential concern
ECCC:	Environment and Climate Change Canada
EEM:	Environmental effects monitoring
EQS:	Effluent quality standard
MDMER:	Metal and Diamond Mining Effluent Regulations
UCLM:	Upper confidence limit of the mean
WER:	Water effect ratio
WQG:	Water quality guideline
WQO:	Water Quality Objective
YESAA:	*Yukon Environmental and Socio-economic Assessment Act*
YESAB:	Yukon Environmental and Socio-economic Assessment Board

Glossary of Terms

Adaptive management plan: A plan developed to support project management that includes specific triggers for management actions and clearly defined response schedules (i.e., to ensure that unacceptable changes in the concentrations of toxic substances in surface water and/or adverse effects on aquatic organisms are addressed through the timely implementation of specific mitigation measures). It provides a basis for addressing unanticipated issues related to the release of toxic chemicals at the site.

Aquatic effects monitoring program: A comprehensive monitoring program for the aquatic ecosystem including, but not limited to, aquatic ecosystem monitoring described in Sections 7.2 and 7.6 of *Plan Requirement Guidance for Quartz Mining Projects* (Yukon Water Board and Yukon Energy Mines and Resources, 2013), and *Metal Mining Technical Guidance for Environmental Effects Monitoring* (Environment Canada, 2012).

Assimilative capacity: The quantity of a substance that can be released into a water body during a specific period of time without exceeding Use-Protection maximum Water Quality Objectives (WQOs), calculated as the difference between background water quality and the Use-Protection maximum Water Quality Objective.

Background concentration procedure: A method for developing WQOs that are based on the natural background concentrations of Contaminants of Potential Concern in water as determined through implementation of a background monitoring program.

Background water quality: Water quality conditions in a watercourse before the onset of any effects of local human activities. Characterization of these water quality conditions can be developed based on conditions in the potentially affected watercourse before the onset of human disturbance that affects water quality, or on conditions in upstream areas or reference areas.

Baseline water quality: Water quality conditions in a watercourse before the initiation of any project activities that may affect water quality. Baseline water quality is equivalent to background water quality if the water quality in the watercourse is not already measurably affected by local human activities.

Bioaccumulative substances: Chemicals that tend to accumulate in the tissues of aquatic or terrestrial organisms.

Bioavailability and toxicity modifying factors: Water quality characteristics that affect the bioavailability or toxicity of another contaminant.

Contaminant of potential concern: A substance that a project may release into surface waters at concentrations that may adversely affect achievement of the narrative WQOs.

Continuous improvement plan: A plan that is developed and implemented to facilitate reductions in loadings of Contaminants of Potential Concern to receiving waters. Such plans are usually implemented at sites where releases of Contaminants of Potential Concern pose potential risks to human health and/or the environment.

Designated water use: Specific water uses that occur or may occur in a watercourse. Designated uses of water may include raw water for drinking water supplies and food processing, recreation and aesthetics, aquatic life, wildlife, agriculture (including livestock water and irrigation), and/or industrial uses.

Effluent: Water released from a quartz mining project into a watercourse.

Effluent Quality Standard: The maximum allowable concentrations or other measures of Contaminants of Potential Concern or other substances that can be released to the environment in effluent.

Exceed: Exceed or Exceedance in relation to water quality conditions refers to conditions greater than a specified threshold (e.g., WQO) where the threshold defines upper limit conditions (e.g., WQOs for metals), or conditions less than a specified threshold (e.g., WQO) where the threshold defines lower limit conditions (e.g., WQOs for dissolved oxygen). Exceed or Exceedance can also refer to conditions outside of a specified range (e.g., WQOs for pH).

Loading: The rate of flow of substances in water as a mass per unit of time (e.g., kg/yr,), calculated as the concentration times the flow rate.

Management Response Plan: Documentation of the mitigation and management actions that is prepared in response to an action level trigger being reached in an Adaptive Management Plan.

Mixing Zone: The area contiguous with a point source (effluent discharge) where the discharge mixes with ambient water and within which concentrations of COPCs may not comply with the WQOs.

Non-degradation approach: A water management approach in which WQOs are established based on the baseline concentrations of Contaminants of Potential Concern at the site. Implementation of this approach ensures that environmental receptors are not exposed to elevated levels of Contaminants of Potential Concern and, hence, should have no incremental risk of adverse effects due to water quality degradation.

One-tailed 95% upper confidence limit of the mean: The value for which there is a 5% probability of exceedance by the mean of a data set.

Recalculation procedure: A method for developing WQOs that accounts for any real differences between the sensitivity range of the species of aquatic organisms represented in the complete toxicological data set and that of the species that occur at the site under consideration.

Receiving waters: A watercourse that receives or will receive contaminant loading through either direct or indirect discharges of effluent.

Resident species: The organisms that occur or ought to occur in a particular watercourse. See Appendix 3, Section 2.1 for details about identification of organisms that occur or ought to occur.

Resident species procedure: A method for developing WQOs that involves the generation of a complete data set on the toxicity of the substance under consideration using site water and resident species thereby accounting for the major factors affecting the derivation of site-specific WQOs, including the sensitivity of the species that occur at the site, and the influence of site-water characteristics on toxicity.

Sensitive species: Those organisms that are known to be among the most responsive when exposed to toxic or bioaccumulative substances (e.g., freshwater mussel species).

Site-specific Water Quality Objectives: WQOs that account for local physical and/or biological characteristics, and water management approaches.

Species at risk: Threatened species, endangered species, or species of special concern, as defined under the *Species at Risk Act*.

Surrogate species: Species which are phylogenetically and autecologically similar to, and therefore representative of, other species.

Toxic substances: Chemicals that are known to adversely affect the survival, growth, or reproduction of ecological and/or human receptors due to direct contact, or with inhalation of air, or ingestion of water, sediment, or soil, when they exceed a certain dose or concentration.

Use-protection Approach: A water management approach that is applied to protect the designated uses of a receiving watercourse.

Use-restoration Approach: A water management approach that is applied to restore water uses, where feasible, in a receiving watercourse where water quality has been degraded by effluent discharges or other releases of Contaminants of Potential Concern.

Watercourse: a natural watercourse, body of water or water supply, whether usually containing water or not, and includes groundwater, springs, wetlands and gulches (Revised from *Waters Regulation*, Government of Yukon, 2014: 1. although groundwater is included in the *Waters Regulation* definition of watercourse, this Guide does not apply to establishment of WQOs for groundwater, and 2. the word ‘swamp’ in the *Waters Regulation* has been replaced here with the more contemporary and encompassing term ‘wetland.’

Water effect ratio: The ratio of the toxicity of substance contaminant of potential concern in water from the site to its toxicity in laboratory water, based on the assumption that the physical and/or chemical characteristics of water can vary among sites and can influence the bioavailability and, hence, toxicity of environmental contaminants.

Water effect ratio procedure: A method for deriving WQOs that relies on the results of acute and/or short-term chronic toxicity tests conducted with indicator and/or resident species in both site water and laboratory water. The information generated in these toxicological investigations is used to determine the water effect ratio, which is used in conjunction with water quality guidelines to establish the WQOs for a contaminant of potential concern.

Water quality guidelines: Benchmarks established by a government agency that indicate levels of physical, biological, or chemical parameters for the protection of a designated water use.

Water Quality Objectives: Thresholds of acceptable water quality conditions in specific receiving waters that may be affected by a project, including both narrative descriptions of expectations for acceptable water quality conditions and numerical benchmarks that define specific chemical or physical characteristics of acceptable water quality.

Executive Summary

This *Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects* (the "Guide") provides technical and scientific guidance about approaches and procedures for developing Water Quality Objectives (WQOs) for freshwater ecosystems in Yukon. It also describes methods for using the WQOs to derive Effluent Quality Standards (EQSs) that can be applied in water licences. The Guide was developed for application to quartz mining projects but the approaches and procedures are equally relevant to other types of activities that may affect water quality.

WQOs provide narrative and numerical definitions of acceptable water quality conditions in specific receiving waters that may be affected by a project. The narrative WQOs depend on the water management approach that is applied to the receiving waters. The water management approach is based on the social, economic and environmental values, and existing water quality of the receiving waters. It not only defines the narrative WQO, but also forms the foundation for selecting procedures for developing numerical WQOs. The Guide identifies the following three water management approaches and associated narrative WQOs:

1. The **Non-Degradation Approach** aims to maintain water quality in a condition that is unchanged from pre-project conditions. As a principle, waters of Yukon are managed to maintain natural water quantity and quality, unless a compelling sustainable and wise use of water by people warrants application of an alternative water management approach. The narrative objective for waters managed using the Non-Degradation Approach is as follows:

    > *Baseline water quality must be maintained at all times. Any permitted discharges shall be regulated in a manner that prevents degradation of the quality of receiving waters.*

2. The **Use-Protection Approach** aims to maintain water quality in a condition that will not adversely affect designated water uses (e.g., aquatic life, drinking water). The narrative objective for waters managed using the Use-Protection Approach is as follows:

    > *Water quality must be maintained to protect the most sensitive designated water use at all times. Any permitted discharges shall be regulated in a manner that provides protection for the most sensitive designated water uses in the receiving waters.*

3. The **Use-Restoration Approach** aims to improve the quality of impaired waters to support restoration of water uses (e.g., aquatic life, agricultural uses). It applies to waters where designated uses have been adversely affected by historic or ongoing human-induced changes in water quality. The narrative objective for waters managed using the Use-Restoration Approach is as follows:

> *Water quality conditions must be managed to avoid any further degradation of baseline water quality, and to facilitate restoration of designated uses to the extent practical over time.*

The Guide describes five methods for developing numerical WQOs for specific Contaminants of Potential Concern (COPCs). COPCs are the substances that a project may release into surface waters at concentrations that may adversely affect the achievement of the narrative WQOs. Identification of COPCs, as described in Chapter 3 of the Guide, relies on a thorough understanding of baseline conditions, and existing and potential contaminant sources. The five methods for developing numerical WQOs include:

1. **Adoption of Generic Water Quality Guidelines (WQGs) as WQOs**, for example adoption of WQGs specified by the Canadian Council of Ministers of the Environment (CCME). Appendix 1 describes a framework for selecting WQGs for application in Yukon.
2. **Background Concentration Procedure (BCP)**, whereby acceptable water quality conditions are defined based on the background concentrations of a COPC. Appendix 2 describes detailed procedures for the BCP.
3. **Recalculation Procedure**, in which a WQG is adjusted to account for the differences between the sensitivity of the species of aquatic organisms used to generate the WQG for a COPC, and that of the specific species that occur or ought to occur in the watercourse under consideration. Appendix 3 describes detailed procedures for the Recalculation Procedure.
4. **Accounting for Bioavailability and Toxicity Modifying Factors (BTMF), whereby a WQO accounts for the unique water quality characteristics of the watercourse. This approach includes the Water Effect Ratio (WER) Procedure**, in which a WQG is adjusted to account for unique water quality characteristics. Appendix 4 describes detailed procedures for the WER Procedure.
5. **Resident Species Procedure**, involving the generation of a complete toxicity data set that meets the requirements for deriving a WQG in accordance with CCME protocols (CCME, 1991; 2007). The data set can be used to develop WQOs that are specifically relevant to the species at the site and the water quality characteristics.

The following table summarizes the relationship between the three water management approaches and the five methods for developing numerical WQOs.

Water management approach	Decision factors	WQO methods
Non-Degradation		BCP
Use-Protection	Background water quality exceeds WQG.	BCP
	WQG protective of most sensitive species, and predicted COPC concentrations less than WQG.	Adopt WQG
	Watercourse hosts species that are more or less sensitive than those considered for deriving WQG.	Recalculation Procedure
	Watercourse has water quality conditions that may affect toxicity.	Accounting for BTMF
	Watercourse hosts species that are more or less sensitive than those considered in the WQG, and has water quality conditions that may affect toxicity.	Resident Species Procedures
Use Restoration	Initial WQOs.	BCP
	Staged WQOs.	Any Use-Protection Method

The identification of COPCs and implementation of some WQO development methods rely on comprehensive understandings of baseline and background water quality, and in some cases, toxicity testing programs. To support efficient collection of sufficient, high-quality data, the Guide recommends preparation of a detailed work plan early in the WQO's development process. This is supported by Appendix 6, which describes requirements for baseline and background water quality monitoring programs, including a requirement to have at least three years of baseline and/or background water quality data to support WQO development.

EQSs are the maximum concentrations or other measures (e.g., pH range) of COPCs that a project is authorized to release in liquid effluent, usually specified in water licences. Chapter 6 of the Guide describes recommended methods for developing EQSs that are intended to achieve WQOs in receiving waters. The methods rely on calculation of EQSs based on the dilution available in the receiving environment, consideration of the portion of the assimilative capacity that may be allocated to a specific discharge, and the extent of acceptable mixing zones. Assimilative capacity is the difference between background water quality and the Use-Protection maximum Water Quality Objective. Allocation of assimilative capacity considers a range of factors, including existing and anticipated future uses and needs. In Yukon, it has also been used to address water quality related treaty and/or Aboriginal rights of First Nations and transboundary Indigenous organizations.

The development of WQOs and EQSs includes several steps and activities that require input from affected parties, communities and/or relevant government (federal, territorial, First Nation) agencies. Detailed input from a range of parties will be particularly relevant for selection of water management approaches and allocation of assimilative capacity because these decisions must consider societal and ecological values. Input will also be beneficial during planning stages for developing WQOs and baseline monitoring programs.

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This document was developed to articulate the Government of Yukon's guidance for the development of WQOs. It is based on recommendations received from MacDonald Environmental Sciences Ltd. and Slater Environmental Consulting in a report entitled *Guidance Manual for Developing Water Quality Objectives for Freshwater Ecosystems in Yukon, Final Report, October 2016* (MacDonald et al. 2016). Much of the text and many of the recommendations in this Guide and its appendices come from that report. The Government of Yukon and Slater Environmental Consulting acknowledge the work completed in preparing those recommendations, especially by D.D. MacDonald, J. Sinclair, A. Schein and all of MacDonald Environmental Sciences Ltd.

The October 2016 Report integrated principles and guidance on development of WQOs from several sources, including *Methods for Deriving Site- Specific Water Quality Objectives in British Columbia and Yukon*, which was published by BC Ministry of Environment, Lands, and Parks (MacDonald 1997); *Site-Specific Application of Water Quality Guidelines* (CCME Water Quality Guidelines Task Force and Kemper and Associates 2001); *Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedure for Deriving Numerical Water Quality Objectives* (CCME 2003); and *Guidance for the Derivation and Application of Water Quality Objectives in British Columbia* (BCMOE 2013). Many of the principles and guidance from these documents are now reflected in this Guide.

A Water Quality Objectives Guidance Manual Development Team provided ongoing advice, support and review during the development of the Guide. Members of that team included Amelie Janin, Department of Environment; Brendan Mulligan, Department of Environment; Jean Beckerton, initially on behalf of the Department of Environment and later the Yukon Water Board; Mark Nowosad, Department of Energy, Mines and Resources; Leslie Gomm, initially on behalf of the Yukon Water Board and later Gomm Environmental Engineering Consulting as an advisor for the Council of Yukon First Nations; Nicole Novodvorsky, Department of Environment; Mitch Heynen, Department of Environment; John Miller, Department of Energy Mines and Resources; Bengt Pettersson; Department of Environment; Richard Cherepak, Department of Environment; Julia Ahlgren, Department of Environment; Erin Dowd, Department of Energy, Mines and Resources; Andrea Kenward, Department of Energy, Mines and Resources; Adam Wrench, YESAB; and Steve Caram, YESAB.

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1.0 Introduction

1.1 Purpose and Scope

The purpose of this *Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects* (the "Guide") is to provide technical and scientific guidance about approaches and procedures for:

1. Developing and applying Water Quality Objectives (WQOs) for freshwater ecosystems in Yukon.
2. Deriving Effluent Quality Standards (EQSs) that are based on the WQOs.

The Guide was developed specifically for application to surface water affected by all phases of quartz mining projects (e.g., construction, operation, care-and-maintenance, closure and reclamation, and post-closure). The Guide focuses on water quality issues that are typically related to quartz mining. However, the same approaches and procedures can be applied, subject to specific water quality issues, for other types of activities that may affect water quality. The Guide is intended to provide enhanced clarity about requirements for developing WQOs and deriving EQSs that will be protective of Yukon waters.

WQOs provide narrative and numerical definitions of acceptable water quality conditions in specific receiving waters that may be affected by a quartz mining project. The social, economic and environmental value and condition of receiving waters give rise to three different water management approaches: Non-Degradation, Use-Protection, and Use-Restoration. These approaches provide the foundation for WQOs and lead to different methods for development of WQOs. Depending on the selected water management approach, numerical WQOs can often be based on Water Quality Guidelines (WQGs), for example the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME). Site-specific WQOs developed in accordance with this Guide can be considered where the receiving water values or conditions warrant definitions of acceptable water quality that are more or less stringent than those defined by WQGs.

Because the Guide is fundamentally focused on management of aquatic ecosystems, it is these ecosystems that drive the technical WQO processes that are described in the Guide and any need for development of site-specific WQOs. Establishment of these science-based WQOs does not directly consider what a project can or cannot achieve. In some cases, there may be technical or other limitations for a project in achieving the ecosystem-focused WQOs. These challenges can only be discussed once the ecosystem-based WQOs have been defined.

The WQO methods described in this Guide are generally consistent with methods described by the Canadian Council of Ministers of the Environment (CCME) in *Canadian water quality guidelines for the protection of aquatic life: Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives* (CCME 2003). The appendices in this Guide provide additional details about application of the CCME methods, and in some cases, Yukon prescribes specific approaches for applying the methods. Risk-based approaches used for defining objectives and toxicity reference values, such as the ones presented in the *Yukon Contaminated Site Regulation,* should not be applied for developing WQOs for quartz mining projects.

EQSs are the water quality limits defined in water licences, restricting the concentrations of Contaminants of Potential Concern (COPCs) and other substances in effluent streams at the final points of control. Water quality at the final points of control (EQSs) and in the receiving environment (WQOs) are correlated through dilution, attenuation mechanisms and any decisions about allocation of available assimilative capacity. This Guide describes methods for deriving EQSs that are expected to achieve the WQOs defined for aquatic ecosystems, including consideration of dilution, mixing zones and allocation of assimilative capacity.

1.2 Yukon Water Management Context

For quartz mining projects in Yukon, water management decision-making occurs through application of environmental and socio-economic assessment and regulatory processes, and with an important context provided by the rights and interests of First Nation people, including rights and interests defined in the comprehensive land claims agreements in Yukon and section 35 of the *Constitution Act*.

Environmental and socio-economic assessment is carried out in accordance with the federal *Yukon Environmental and Socio-economic Assessment Act* (YESAA) that arises from the Yukon First Nations Final Agreements. The purposes of YESAA envision protection and maintenance of important environmental and socio-economic values through application of sustainable development principles. Water licensing under the territorial *Waters Act* is the primary regulatory instrument for water management decision-making for quartz mining projects. The *Waters Act* establishes and relies on the Yukon Water Board whose objects are "*to provide for the conservation, development, and utilization of waters in a manner that will provide the optimum benefit from them for all Canadians and for the residents of the Yukon in particular*."

Decision-making under both YESAA and the *Waters Act* is influenced and guided by the rights of Indigenous people, including Yukon and transboundary First Nations and the Inuvialuit. These rights are constitutionally protected in accordance with section 35 of the *Constitution Act, 1982*, and provide overarching guidance for governments' water management decisions.

For First Nations governments with comprehensive land claims agreements, Chapter 14 of the Final Agreements is "*to maintain the Water of the Yukon in a natural condition while providing for its sustainable use*." It also defines specific rights that apply for First Nations and other parties on First Nations' Settlement Lands. For example, subject to certain provisions "*a Yukon First Nation has the right to have water which is on or flowing through or adjacent to its Settlement Land remain substantially unaltered as to quantity, quality and rate of flow, including seasonal rate of flow*." Other chapters of the Final Agreements address rights related to other resources (e.g., wildlife), values (e.g., cultural values) and traditional activities (e.g., harvesting) that may also be relevant to water management decisions. In accordance with the Final Agreements and other broader responsibilities, other governments have obligations to consult with First Nations before making decisions that may affect their rights and interests.

The *Yukon Water Strategy and Action Plan* (Government of Yukon 2014) establishes a vision for management of Yukon's water resources: "*the quality, quantity and overall health of waters flowing through Yukon lands are sustained for all living things now and in the future*." To achieve this vision, the strategy articulates two overarching goals that focus on: (1) preservation of water for nature, and (2) promotion of sustainable and wise use of water by people. These goals provoke water management decisions and actions that will achieve an effective balance between the sometimes-competing interests for preservation and use of water.

The use of WQOs and EQSs is one tool for achieving the goals of the Strategy. WQOs and EQSs define water quality characteristics, in this case for application to mining projects and based on decisions about the water management approach. Achieving the goals of the Strategy and the narrative objectives for Non-Degradation, Use-Protection and Use-Restoration requires an ecosystem-based custodial approach at the watershed and sub-watershed level, applying a variety of tools to maintain water quality and aquatic ecological integrity. WQOs and EQSs are to be applied within the context of this ecosystem-based custodial approach.

Guidance for developing and applying WQOs, as described in this Guide, supports several of the priority activities identified in the Strategy for addressing the goals, including:

- **Promote the Sustainable Use of Water**, including a focus on providing more guidance that will support increased use of best management practices for water management.
- **Plan for Water Needs Now and in the Future**, including a focus on supporting water management decision-making by enhancing the use of best available science, and local and Indigenous knowledge.
- **Maintain/Improve Access to Safe Drinking Water**, including a focus on better protection of drinking water sources.

The establishment of WQOs in accordance with this Guide supports the government's need to balance multiple priorities, while providing enhanced certainty for regulated quartz mining uses.

There is also federal legislation, including the *Metal and Diamond Mining Effluent Regulations* (MDMER) and the *Fisheries Act* that pertain to water quality management for water quality management at mine sites and protections of freshwater ecosystems.

Effective application of WQOs developed in accordance with the Guide will help to achieve water management decisions and outcomes that are consistent with the requirements, goals and objectives of YESAA, the *Waters Act*, the First Nation Final Agreements, First Nation rights and interests, the *Yukon Water Strategy and Action Plan*, the MDMER and the *Fisheries Act*.

1.3 Engagement with Affected Parties

Yukon people and governments place a high value on water quality. As a result, they have a strong interest in the establishment of WQOs and EQSs for any proposed quartz mining project. Engagement with interested and affected parties should be an important component of any initiative to develop WQOs or EQSs. Such engagement will provide an opportunity for proponents to understand the value of aquatic ecosystems, and any potential concerns and issues related to water quality. Engagement should begin early in any WQO or EQS development process and continue through all stages.

The types of engagement activities and the parties engaged will depend on the stage of the WQO or EQS processes, and the activities and decisions being discussed. While engagement is important for all aspects of the WQO or EQS development process, it is particularly critical in relation to subjective and values-based steps and decisions. Proponents must understand the perspectives of local people and governments, including First Nations people and their governments, in order to reach conclusions about these steps and decisions. For example, the selection of a water management approach (Chapter 2) relies on an understanding of the values that people and governments assign to the watercourses that are being considered. The allocation of assimilative capacity for calculation of EQSs (Chapter 6) also requires a comprehensive understanding of public and government views about the value of the specific aquatic ecosystem.

Engagement on technical and scientific aspects of the WQO and EQS development processes will be especially important during the planning stages. This will provide an opportunity for technical and other reviewers to provide input on the plan for developing WQOs and EQSs before irrevocable decisions are made, thus helping to avoid costly and time-consuming additional work. For example, proponents should seek early input about baseline data collection, selection of COPCs, and proposed procedures for developing WQOS.

1.4 Guiding Principles

There are several guiding principles that underlie the development of this Guide. These principles, as stated below, provide important context for interpretation and application of the Guide:

1. Consistent with the overarching goals of the *Yukon Water Strategy and Action Plan* (Government of Yukon 2014), waters of Yukon are managed to maintain natural water quantity and quality, unless a compelling sustainable and wise use of water by people warrants application of an alternative water management goal. An alternative water management goal must, at a minimum, be protective of existing water uses.
2. The value of the aquatic ecosystem, and its characteristics and conditions, and the value of other designated uses are the primary drivers for establishing WQOs, including whether WQOs (either site-specific WQOs or application of generic WQOs) are warranted, and what constituents and methods should be considered in developing WQOs. Whether or not a project can achieve certain water quality conditions is not a primary driver for establishing WQOs, but can provide important context for decision-making.

3. Water management decisions must consider the rights and interests of Indigenous people, including Yukon and transboundary First Nations and the Inuvialuit that may be affected by the decision.
4. Proponents will take all reasonable and practical measures to minimize pollution and protect water quality conditions, whether or not these measures are needed to achieve WQOs.
5. Proponents will actively engage with interested and affected parties (e.g., First Nations, communities, and Government of Yukon) throughout the process of developing WQOs and EQSs.
6. The development of WQOs and EQSs will consider planning initiatives where they are relevant to watercourses, and potential cumulative effects of multiple activities affecting the same watercourse.

1.5 Water Quality Objectives Development Process Overview

Figure 1 illustrates the systematic process that is described in this document for developing WQOs for freshwater ecosystems in Yukon, and applying the WQOs in receiving waters. The elements of the process for developing WQOs for specific watercourses are introduced below, with additional details provided in the referenced Chapters of the document.

1. **Identify the water management approach:** Chapter 2, *Water Management Approaches*, describes three overarching approaches for water management – Non-Degradation, Use-Protection and Use-Restoration – and the conditions in which they should be applied. Decisions about selection of a water management approach are dependent on the specific site conditions or watercourse being considered, and are prerequisite to identifying the narrative WQOs and the methods that should be applied for developing numerical WQOs.
2. **Identify Contaminants of Potential Concern:** Chapter 3, *Identifying Contaminants of Potential Concern*, describes methods for identifying which contaminants should be addressed when developing WQOs for specific watercourses. The methodology relies on comparison of predicted or measured concentrations from contaminant sources against WQGs, and baseline and background water quality. Appendix 1 describes a framework for selecting appropriate WQGs to apply in Yukon.
3. **Derive numerical WQOs:** Chapter 4: *Deriving Numerical Water Quality Objectives*, describes how to select and implement methods for deriving numerical WQOs. Potential methods include adoption of WQGs and four procedures for deriving site-specific numerical WQOs – Background Concentration Procedure, Recalculation Procedure, Accounting for Bioavailability and Toxicity Modifying Factors (BTMF) including the Water Effect Ratio (WER) Procedure, and Resident Species Procedure. Chapter 4 also describes requirements for baseline data collection, and recommended

planning approaches for developing WQOs. Chapter 4 is supported by five appendices. Appendix 1 provides guidance about which guidelines to consider when adopting WQGs as WQOs in Yukon. Appendices 2 through 4 provide detailed procedures for deriving WQOs using the Background Concentration, Recalculation and WER Procedures. Appendix 5 describes procedures for deriving WQOs for bioaccumulative substances.

4. **Validation and attainment of numerical WQOs:** Chapter 5: *Validation and Attainment of Water Quality Objectives*, describes approaches for validating whether numerical WQOs achieve the narrative WQOs. It also defines the thresholds for attainment of numerical WQOs.
5. **Derive EQSs:** WQOs play a key role in the establishment of EQSs for quartz mining projects. *Chapter 6: Deriving Effluent Quality Standards* describes the approach for deriving proposed EQSs based on the WQOs.
6. **Reporting**: *Chapter 7: Reporting*, describes expectations for documentation of the derivation of WQOs and EQSs.
7. **Develop and implement aquatic effects monitoring:** An Aquatic Effects Monitoring Program (AEMP) that evaluates the condition of the aquatic ecosystem – e.g., benthic invertebrates, periphyton, fish, fish habitat, water quality – is a key tool for evaluating attainment of the WQOs, and understanding the long-term effectiveness of the WQOs within the context of the broader aquatic conditions. Development of detailed AEMPs is not addressed in this Guide, but relevant guidance is provided in *Plan Requirement Guidance for Quartz Mining Projects* (Yukon Water Board and Yukon Energy Mines and Resources 2013), and *Metal Mining Technical Guidance for Environmental Effects Monitoring* (Environment Canada 2012). Additional guidance is available in Guidelines for *Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the Northwest Territories* (INAC 2009a-g).
8. **Develop and implement Adaptive Management Plan/Management Response Plan:** An Adaptive Management Plan (AMP) is a key tool for addressing uncertainty about attainment of WQOs. The plan should be integrated with the AEMP and identify areas of uncertainty about performance, establish triggers for response, and describe detailed monitoring required to support the AMP. It should also describe the process for developing Management Response Plans for addressing unexpected performance before unacceptable effects occur. In the case of waters that are impaired by human activities, continuous improvement plans may be required. AMPs are not addressed in detail in this Guide.

While the above elements are presented in the general order in which they will occur, the process will be iterative so the elements will not proceed directly in sequence. For example, initial information about COPCs will be required in order to complete a work plan, but the results obtained during implementation of the work plan will likely inform final selection of COPCs.

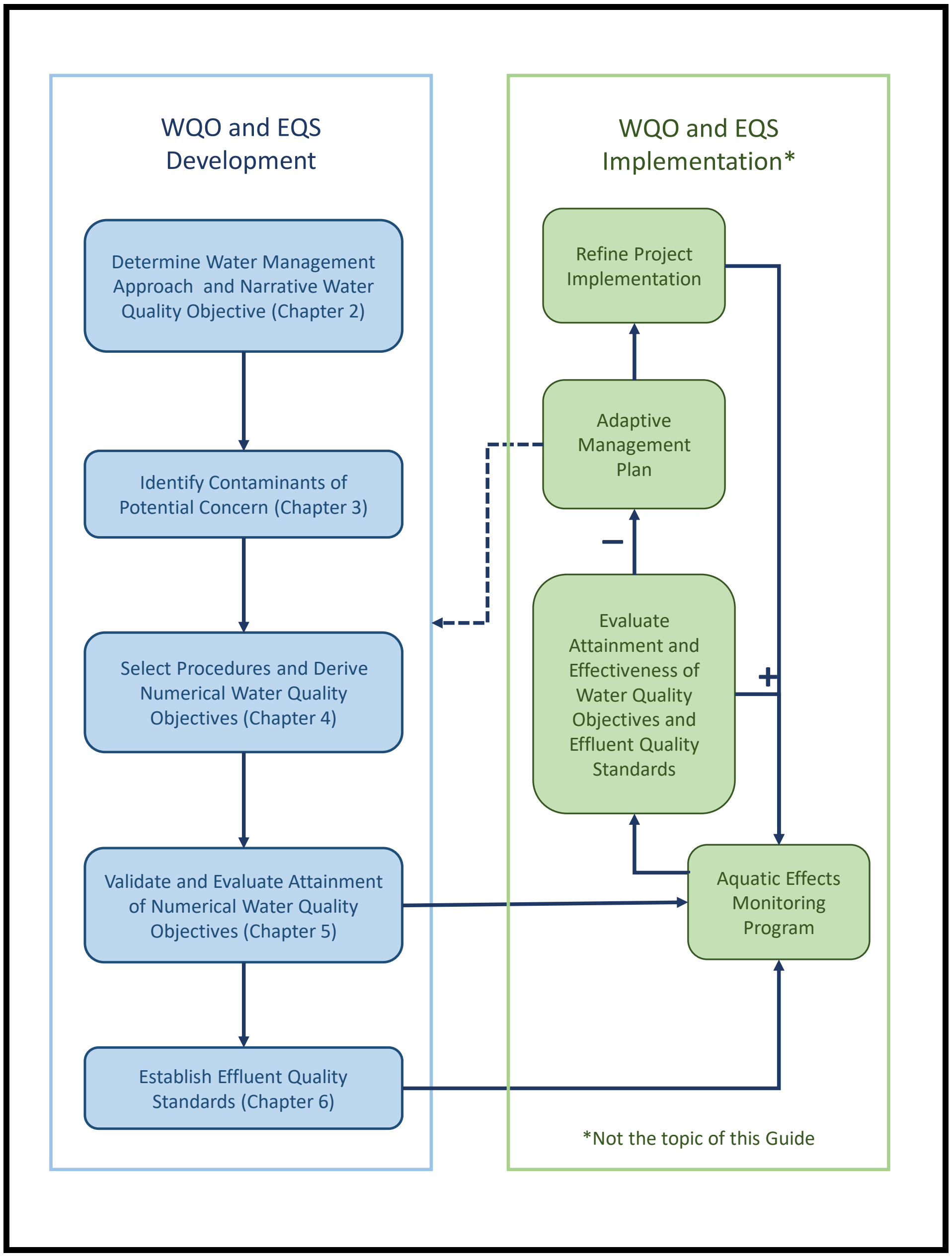


Figure 1 Process for Developing and Implementing WQOs and EQSs.

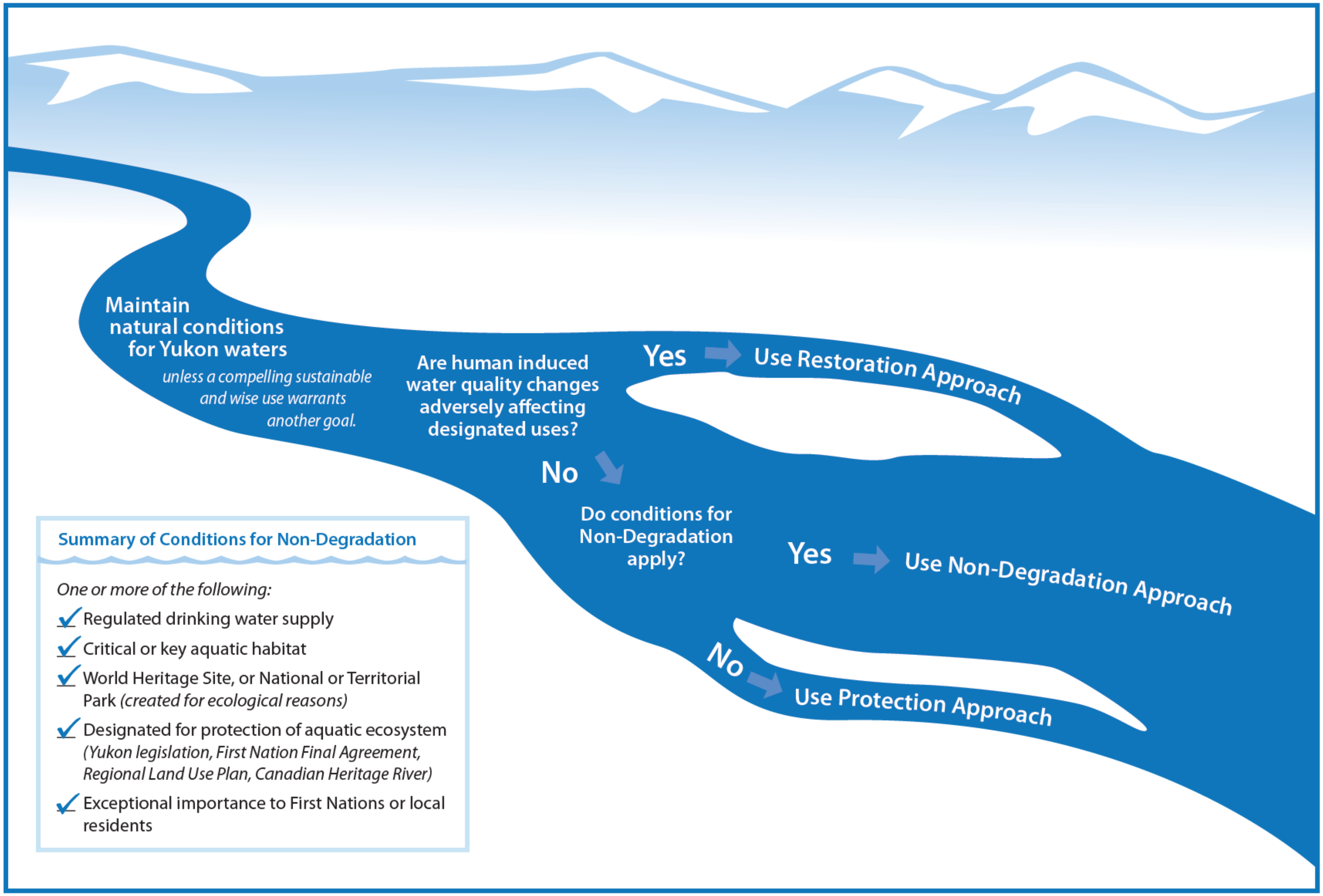
2.0 Water Management Approaches

In Yukon, the overall water management approach for specific projects, watercourses and substances is founded on the social, economic and environmental value and condition of receiving waters that may be affected by the project. Depending on these values and conditions, there are three water management approaches that can be applied: Non-Degradation, Use-Protection, and Use-Restoration approaches.

The selection of the water management approach leads to certain narrative WQOs and identification of appropriate methods for developing numerical WQOs. This chapter describes the three water management approaches, the conditions in which each approach should be applied, the narrative objectives for each approach, and the appropriate methods for developing numerical WQOs for each approach. Figure 2 illustrates the framework for selection of the appropriate water management approach.

The use of water management approaches is intended to provide flexibility to establish WQOs that reflect the biological, social and cultural value and sensitivity of specific water bodies. To achieve this, a single project may apply more than one water management approach. Approaches can vary among individual watercourses, specific locations in a single watercourse, seasons at the same location, phases of the project, or specific water quality parameters.

Because the selection of a water management approach relies on a combination of scientific, social and cultural factors, engagement with relevant governments, communities, groups and individuals about the water management approach is essential. The selection of the water management approach must occur early in the process of developing WQOs because it influences many of the other steps and procedures for developing WQOs. As a result, engagement with relevant parties must begin early in the WQO development process.



Summary of Conditions for Non-Degradation

One or more of the following:

- ✓ Regulated drinking water supply
- ✓ Critical or key aquatic habitat
- ✓ World Heritage Site, or National or Territorial Park *(created for ecological reasons)*
- ✓ Designated for protection of aquatic ecosystem *(Yukon legislation, First Nation Final Agreement, Regional Land Use Plan, Canadian Heritage River)*
- ✓ Exceptional importance to First Nations or local residents

Figure 2 Framework for selection of water management approaches.

2.1 Non-Degradation Approach

The Non-Degradation Approach aims to maintain water quality in a condition that is unchanged from pre-project conditions. As stated in the Guiding Principles, waters of Yukon are managed to maintain natural water quantity and quality, unless a compelling sustainable and wise use of water by people warrants application of an alternative water management goal.

The narrative objective for waters managed using the Non-Degradation Approach is as follows:

> ***Baseline water quality must be maintained at all times. Any permitted discharges shall be regulated in a manner that prevents degradation of the quality of receiving waters.***

When seeking approvals for quartz mining projects, the Non-Degradation Approach applies for waters that meet one of the following conditions:

1. Provides or may provide water – either surface water or groundwater from an aquifer that is recharged by the affected surface water – for a drinking water supply that has or requires a permit or licence under either the *Drinking Water Regulation* or the *Waters Act*.
2. Provides critical aquatic habitat for threatened species or endangered species as listed under Yukon's *Wildlife Act* and Schedule 1 of the federal *Species at Risk Act* (SARA). Critical aquatic habitat is defined as the aquatic habitat that is necessary for the survival or recovery of a listed wildlife species under SARA and that is identified as the species' critical habitat in the Recovery Strategy or in an Action Plan for the species. Critical habitat may include spawning grounds and nursery, rearing, food supply, migration, and any other areas on which aquatic organisms or aquatic-dependent wildlife depend directly or indirectly to carry out their life processes. Areas where threatened species or endangered species formerly occurred and have the potential to reoccupy are included in this definition of critical habitats.
3. Located within a World Heritage Site, a National Park or a Territorial Park, where the site or park was designated for ecological reasons.

In addition, the Non-Degradation Approach may apply for waters that meet the following additional conditions. Engagement with appropriate governments, communities, groups and individuals will be essential for understanding perspectives and interests related to these conditions, and guiding decision-making about the selected water management approach.

4. Provides key aquatic habitat for threatened, endangered or sensitive species as listed under Schedules 1, 2 or 3 of the SARA, and species of conservation concern identified by the Yukon Conservation Data Centre. Key aquatic habitat is aquatic habitat that is used by a species for necessary, seasonal life functions.

5. Located within an area designated for the protection of aquatic species or aquatic habitat under Yukon legislation, in accordance with a management plan developed and approved under a First Nation Final Agreement, in accordance with an approved Regional Land Use Plan as specified in Chapter 11 of First Nation Final Agreements, or in accordance with a Canadian Heritage River management plan.
6. Identified as being of importance to First Nations and transboundary Indigenous organizations or local residents (e.g., a unique watercourse that supports culturally – or spiritually-important water uses, such as medicine-making or spiritual activities). This identification could be determined through consultation with affected First Nations

When applying the Non-Degradation Approach, the development of WQOs relies on a comprehensive understanding of baseline water quality (Section 4.4). Derivation of WQOs follows analysis methods that are described for the BCP (Section 4.3.2 and Appendix 2), with numerical WQOs defined for both maximum[1] and central tendency conditions.

2.2 Use-Protection Approach

The Use-Protection Approach aims to maintain water quality in a condition that will not adversely affect designated water uses. Yukon identifies five designated water uses, four of which are identified by the CCME and the fifth (wildlife) that has been applied in other Canadian jurisdictions (e.g., British Columbia): water quality for drinking water supplies, recreational use and aesthetics, freshwater ecosystems, and agricultural uses (i.e., irrigation and livestock water) (CCME 2001), and consumption of water by wildlife. The Use-Protection Approach is commonly applied for establishment of WQGs and WQOs in Canada. For example, the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* apply a Use-Protection Approach: "*Guideline values are meant to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term*" (CCME, 1999).

The narrative objective for waters managed using the Use-Protection Approach is as follows:

> ***Water quality conditions must be maintained to protect the most sensitive designated water use at all times. Any permitted discharges shall be regulated in a manner that provides protection for the most sensitive designated water uses in the receiving waters.***

There are several methods that can be used to establish Use-Protection WQOs. The methods should be applied on a contaminant-specific basis, with selection of the method depending on the baseline and background conditions and predicted project contaminant sources, as follows:

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[1] Maximum conditions can refer to upper limit and/or lower limit conditions, depending on whether elevated conditions present aquatic risks (e.g., metals),depressed conditions present aquatic risks (e.g., dissolved oxygen) or there are risks for both elevated and depressed conditions (e.g., pH).

- The first and simplest method considered should be the adoption of WQGs as WQOs. Appendix 1 provides guidance about which guidelines to consider when adopting WQGs as WQOs in Yukon.
- If, after application of practical measures to minimize loading from project related sources, contaminant loading from the project is expected to cause exceedance of WQGs, the Recalculation Procedure (Section 4.3.3 and Appendix 3), Accounting for BTMF including the WER Procedure (Section 4.3.4 and Appendix 4), or Resident Species Procedure (Section 4.3.5) may be applied.
- For conditions in which background contaminant concentrations are naturally elevated above the WQGs, the BCP (Section 4.3.2 and Appendix 2) can be applied as a Use-Protection Approach because the natural pre-project conditions are considered protective of existing uses. The BCP cannot be applied as a Use-Protection Approach where water quality has already been degraded by human activities, unless WQOs are developed based on background (not baseline) water quality.
- For bioaccumulative substances the primary exposure pathway for aquatic organisms is typically through diet. The relationship between contaminant concentrations in water and aquatic organisms must be considered in the establishment of WQOs. The relationships are often site-specific. Section 4.3.6 and Appendix 5 describe procedures that should be used to develop numerical WQOs for bioaccumulative substances.

No matter which use-protection method is selected for deriving WQOs, the final result must be WQOs that define conditions that are protective of designated uses. Use-protection WQOs define the upper limit of assimilative capacity for contaminant release to the receiving environment when deriving EQSs. As described in Chapter 6, *Deriving effluent quality standards*, the development of EQSs in the context of the Use-Protection Approach must consider the proportion of assimilative capacity that can be consumed by any individual quartz mining project.

2.3 Use-Restoration Approach

The Use-Restoration Approach aims to improve the quality of impaired waters to support restoration of water uses (e.g., aquatic life, drinking water, recreational, or agricultural uses). The Use-Restoration Approach applies to waters where designated uses have been adversely affected by historic or ongoing human-induced changes in water quality.

The narrative objective for waters managed using the Use-Restoration Approach is as follows:

> ***Water quality conditions must be managed to avoid any further degradation of baseline water quality conditions, and to facilitate restoration of designated uses to the extent practical over time.***

Recognizing the challenges associated with restoration of aquatic ecosystems, the Use-Restoration Approach will often be applied over a long time period, based on a continuous improvement plan and monitoring and management of cumulative effects. WQOs defined for a specific project as part of a continuous improvement plan will usually vary over time, driving progressive improvement of water quality conditions as restoration actions proceed. Initial WQOs will likely focus on avoiding further degradation of water quality (similar to the Non-Degradation Approach) followed, where practical, by staged WQOs that are intended to achieve specific water use outcomes. For example, early stages may establish WQOs that will be protective of the least sensitive of the impaired uses or species. Ideally, the WQOs in the final stages of a continuous improvement plan will be protective of all designated uses (similar to the Use-Protection Approach).

The application of the Use-Restoration Approach is intended to provide flexibility for water management while aiming to improve the impaired water quality. Where there are existing projects outside of a proponent's control that are actively contributing to cumulative effects and the impairment of designated uses, these can be considered in the establishment of WQOs. Continuous improvement plans may consider total contaminant loading, degree of overlap of contaminant influences, attenuation of contaminants, and other relevant factors.

3.0 Identifying Contaminants of Potential Concern

One of the most important steps in the development of WQOs involves identification of COPCs. COPCs are the substances that a project may release into surface waters at concentrations that may hinder achievement of the narrative WQOs. The procedure for identifying COPCs is of fundamental importance because it focusses work on the substances for which it is appropriate to derive WQOs. The COPCs can be identified by conducting a systematic evaluation of the baseline and background conditions, and potential project-related sources of contaminants within the area that may be affected by the project.

A provisional list of COPCs is needed early in planning for development of WQOs and will likely rely on an understanding of typical contaminants associated with quartz mining projects along with some limited site-specific data. This list of provisional COPCs will support the development of monitoring programs and should therefore be inclusive, listing all of the chemical classes and associated substances that could potentially be released to receiving waters via effluent discharge, site runoff, aerial deposition, or other pathways. The final list of COPCs should rely on strong characterization of receiving water conditions and a comprehensive understanding of predicted project contaminant sources.

Information on the nature and scope of land and water use activities within the watershed, the locations and characteristics of any existing effluent discharges, the expected activities associated with the proposed project(s), and any existing environmental monitoring data for the site provide a basis for identifying provisional COPCs that may be associated with the existing and proposed activities. Quartz mining projects can affect the following water quality constituents, which should be initially considered in establishing a provisional list of COPCs:

- physiochemical parameters (pH, Total dissolved solids, Conductivity, Total suspended solids);
- major ions;
- nutrients;
- metals; and
- radionuclides.

Additional constituents including hydrocarbons, cyanides, process reagents and microbiological variables should also be considered if they are relevant for the project. The list of potential COPCs should be re-evaluated if project plans change, or if monitoring indicates that other contaminants may be relevant.

The inclusive provisional list of COPCs can be refined by identifying those variables for which there is no available WQG. The availability of a WQG can be evaluated in accordance with the framework described in Appendix 1. If there is no WQG and a proponent demonstrates that there is no known risk to a designated use, a constituent can be removed from the provisional list of COPCs.

As additional site-specific and project-specific information becomes available, the list of COPCs can be further refined to focus on substances that are relevant for the specific proposed project. The screening process requires site-specific environmental monitoring data gained through a baseline monitoring program. It also requires a thorough understanding of expected project-related contaminant sources, gained through measurement of existing sources and/or prediction of project-related water quality (i.e., source terms). The refinement of the list of provisional COPCs can be undertaken in stages as data and predictions become available, but each provisional COPC must be retained until data and predictions are sufficient to clearly demonstrate that a substance is not a COPC. Also, monitoring results or changes in project plans may trigger the need consider addition of contaminants in some circumstances.

COPC screening should be based on comparison of measured and/or predicted water quality in the watercourse with baseline water quality, background water quality, and in some cases, WQGs. The necessary comparisons, and the criteria for identification of COPCs vary, depending on the water management approach. For the Non-Degradation Approach, comparison with baseline water quality is the only screening necessary. For the Use-Protection and Use-Restoration approaches, comparisons with background and/or baseline water quality, and WQGs are necessary.

Table 1 lists the appropriate comparisons and provides the recommended criteria for identifying COPCs. Proponents may propose alternative criteria for selection of COPCs along with a strong rationale that demonstrates how the alternatives will achieve the Guiding Principles and intent of this Guide. Following the screening, all substances that meet the criteria specified in Table 1 (or alternative criteria) should be retained as COPCs for which WQOs should be developed. This may include the adoption of WQGs as WQOs, or the development of site-specific WQOs. In accordance with the Guiding Principles, development of WQOs should not be viewed as an alternative to waste prevention or wastewater treatment. All reasonable and practical waste prevention and minimization strategies must be pursued as the first step towards addressing potential water quality issues before proceeding with development of site-specific WQOs.

Table 1: Screening for COPCs.

	Non-Degradation Approach	Use-Protection Approach	Use-Restoration Approach
Comparisons:	Compare measured or predicted concentrations of provisional COPCs in project contaminant sources to baseline concentrations (95th percentile and mean) in the watercourse.	1. Compare measured or predicted concentrations of provisional COPCs in project contaminant sources to baseline concentrations (95th percentile) in the watercourse. 2. Compare measured or predicted concentrations of provisional COPCs in the watercourse to: a. Background and/or baseline concentrations (95th percentile). b. WQGs selected in accordance with Appendix 1.	Comparisons as described for Use-Protection Approach.
Criteria: Substances are retained as final COPCs in any of the following conditions:	• Measured or predicted concentrations in sources exceed the 95th percentile of baseline concentrations in the watercourse in more than 5% of samples or more than 5% of predicted conditions; or • measured or predicted annual mean concentrations in sources exceed the annual mean of baseline concentrations in the watercourse; or • measured or predicted concentrations in sources exceed the 95th percentile of baseline concentrations in the watercourse by a factor of two or more at any time.	1. Measured or predicted concentrations in sources exceed the 95th percentile of baseline concentrations in the watercourse in more than 5% of samples or more than 5% of predicted conditions; or 2. Measured or predicted concentrations in the watercourse exceed any of the following: a. The 95th percentile of background and/or baseline concentrations in more than 5% of samples or more than 5% of predicted conditions. b. The 95th percentile of background and/or baseline concentrations by a factor of two or more at any time. c. The WQGs in two or more months within a three-year period, or for any period exceeding 30 days. Appropriate WQGs should apply as WQOs for all COPCs that are identified according to Comparison “1” but are not identified according to Comparison “2.”	Criteria as described for Use-Protection Approach, with the following caveat: • Only those COPCs for which baseline concentrations exceed thresholds for both background concentrations and WQGs may be managed with the Use-Restoration Approach. All other COPCs are to be managed with Use-Protection Approach.

4.0 Deriving Numerical Water Quality Objectives

This chapter summarizes several methods for establishing WQOs, including the adoption of WQGs as WQOs, as well as methods to derive site-specific WQOs: the BCP, Recalculation Procedure, Accounting for Bioavailability and Toxicity Modifying Factors (BTMF) (e.g., WER Procedure) and Resident Species Procedure. The procedures for developing site-specific WQOs are generally consistent with the procedures described in *Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives* (CCME 2003). This Guide does not reiterate the content of the CCME Guidance. Instead, it provides details about how the CCME Guidance is to be applied in Yukon. Additional details about the BCP, Recalculation Procedures and WER Procedure are provided in Appendices 2, 3 and 4.

The derivation of WQOs for bioaccumulative substances (e.g., mercury and selenium) creates an additional challenge that is not addressed by the CCME procedures for site-specific WQOs because the primary exposure pathway for these substances is typically through an organism's diet. As a result, exposure is dependent on site-specific relationships between concentrations in water and tissues of affected organisms. Methods for deriving WQOs for bioaccumulative substances are discussed in Section 4.3.6 and Appendix 5.

4.1 Selection of Methods for Deriving Numerical Water Quality Objectives

The selection of the appropriate method for deriving WQOs depends on the water management approach selected (Chapter 2) and the site-specific conditions. Table 2 summarizes the process for selection of methods for deriving WQOs for each water management approach. For Use-Protection and Use-Restoration approaches, methods should be selected on a COPC-specific basis, depending on site conditions. In all cases, numerical WQOs must be intended to achieve the narrative WQOs defined in Chapter 2 for the selected water management approach.

Table 2: Selection of Methods for Deriving WQOs.

Water Management Approach[1]	Decision Factors	WQO Methods	Considerations
Non-Degradation	Any water subject to Non-degradation.	BCP	Use baseline water quality. Numerical WQOs should be defined for both maximum and central tendency water quality conditions.
Use-Protection	WQG protective of most sensitive species, and predicted COPC concentrations less than WQG.	Adopt WQG	WQGs to be selected in accordance with Appendix 1.
	Background water quality exceeds WQG for COPC (i.e., 95th percentile of background water quality exceeds chronic WQG or one-tailed 95% UCLM exceeds acute WQG).	BCP	Use background water quality.
	Watercourse hosts species that are more sensitive than those considered for deriving WQG, or watercourse does not host sensitive species that were considered for deriving WQG.	Recalculation Procedure	Consider species that occur or ought to occur.
	Watercourse has water quality characteristics that may affect toxicity of COPCs, including: • Presence of BTMF (e.g., organic carbon) that have not been considered in the WQG; or • Concentrations of BTMF that are higher or lower than those applicable for the WQG.	Accounting for BTMF (e.g., WER Procedure)	The development of WQOs that account for BTMF may only consider BTMF that are contributed by mine sources if those sources will be present at all times when mine-related contaminant sources may affect water quality in the receiving environment. Testing and derivation should rely on conservative estimates of BTMF concentrations.
	No WQG is available, or the watercourse (1) hosts species that have different sensitivities than those considered in the WQG, and (2) has water quality characteristics that may affect toxicity of COPCs.	Resident Species Procedure.	Consider species that occur or ought to occur.
Use-Restoration	Initial WQOs	BCP	Use baseline water quality.
	Staged WQOs	BCP (background water quality), and/or Recalculation	Early Use-Restoration aimed at protection of less sensitive, previously impacted species,

		Procedure, Accounting for BTMF (e.g., WER Procedure) and Resident Species Procedure, and/or Adopt WQG.	progressing towards protection of more sensitive species.

Note 1: For all water management approaches, COPCs that are bioaccumulative substances should use methods described in Section 4.3.6 and Appendix 5.

4.2 Adoption of Water Quality Guidelines

When applying the Use-Protection Approach, a WQG should be adopted as a WQO if the background concentration of a COPC is lower than the WQG (i.e., 95th percentile of background water quality meets the chronic WQG and/or one-tailed 95% UCLM meets the acute WQG) and the project is not predicted to cause exceedance of the WQG. Appendix 1 describes the framework for selection of WQGs for application in Yukon, and provides background information about key sources of WQGs. The framework is fundamentally a hierarchy of WQG sources, but with provisions that allow flexibility to consider WQGs outside of the hierarchy if they are more relevant or up-to-date. The primary sources for WQGs to apply in Yukon are the *Canadian Environmental Quality Guidelines* (CCME 1999; 2016), *Guidelines for Canadian Drinking Water Quality* (Health Canada 2014) and *Guidelines for Canadian Recreational Water Quality* (Health Canada 2012). The methodologies that these organizations use for developing WQGs provide the benchmark for comparing and evaluating the adequacy of WQGs from other sources.

WQGs established by the British Columbia Ministry of Environment (BCMOE) provide a secondary source for substances and/or uses where WQGs are not provided by the primary sources. BCMOE WQGs may also be used if they rely on more up-to-date toxicity testing and analysis, or are more relevant to specific conditions in a Yukon watercourse, when compared with WQGs from the primary sources.

WQGs from other sources may be used when:

1. The substance/use is not addressed by the primary or secondary sources of WQGs.
2. A proponent provides a compelling rationale for applying an alternative WQG and demonstrates that the alternative WQG achieves a protection goal that is similar to the goal defined by the CCME (i.e., "*the protection and maintenance of all forms of aquatic life and all aquatic life stages in the aquatic environment for indefinite exposure periods*" [CCME 2007]).

Any proposal to adopt an alternative WQG as a WQO must be accompanied by detailed information about the methods and data used to derive the alternative WQG. Proposals for adoption of an alternative WQG as a WQO will be considered when:

- The WQG was developed using methodology that is consistent with CCME methodology and applies a compatible protection goal.
- The WQG is relevant for the characteristics of Yukon aquatic ecosystems.
- The ecotoxicity effects and thresholds in the toxicity tests used to develop the WQG are generally consistent with the types of effects and thresholds required in CCME protocols.
- The WQG incorporates more up-to-date and/or more relevant ecotoxicity data.
- The WQG incorporates consideration of relevant toxicity modifying factors.
- The WQG was developed using a more up-to-date methodology (i.e., probabilistic rather than deterministic).

The extent to which the supporting data for the WQG fulfil the minimum toxicity test data requirements established by the CCME (CCME, 2007) will also be an important factor when considering adoption of an alternative WQG.

Many of the CCME and BCMOE WQGs are expressed as total concentrations of contaminants. However, measured total concentrations of contaminants in receiving waters can be heavily influenced by metals associated with suspended sediment, while dissolved forms may have little contribution to the overall contaminant concentrations. Dissolved forms of contaminants are often more biologically relevant and show much less variability in natural systems. The toxicity tests underlying the WQGs almost always use dissolved contaminants, and many discharges from mine facilities contribute contaminants primarily in dissolved form. Yukon will consider modification of WQGs for application to dissolved forms of contaminants where proponents can demonstrate that the use of a WQG for dissolved contaminants will achieve the protection goal defined by the CCME, and that the contaminant risk from a mine is associated with dissolved forms of contaminants.

The approaches and considerations for selection of appropriate WQGs are described in Appendix 1.

4.3 Development of Site-specific Water Quality Objectives

4.3.1 Guiding Principles for Deriving Site-Specific Water Quality Objectives

The following guiding principles for the development of site-specific numerical WQOs are based on the philosophy established by the CCME (1991; 1993; 2003; 2007) and other regulatory agencies (MacDonald 1997; BCMOE 2013), and apply to the development of numerical WQOs in Yukon:

1. WQOs apply to the watercourse under consideration and any potentially-affected downstream waters, unless otherwise stated.

2. For all water management approaches, numerical WQOs must be consistent with the narrative WQOs.
3. For the protection of aquatic life, the numerical WQOs must be developed *"to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term"* (CCME 1999).
4. In general, two types of numerical WQOs should be established for each COPC, including an average WQO (i.e., long- term WQO; applicable to a relevant time interval) and a maximum WQO (i.e., short-term WQO).
5. Temporally-relevant WQOs must be derived for each COPC. In some cases, a single WQO that is protective at all times may be appropriate. In other cases, WQOs may be derived for each month of the year, for specific periods of streamflow (e.g., clear-flow periods, turbid- flow periods), or for other periods, which are determined based on detailed analysis of the background water quality.
6. At sites that have atypical characteristics (e.g., high concentrations of toxicity modifying factors like hardness) or receptors, WQGs may be modified to establish WQOs that account for these site-specific factors.
7. The defined procedures for developing WQOs specify the conditions under which the WQGs may be modified or site-specific WQOs may be developed (see Sections 4.3.2 – 4.3.6, and Appendices 2, 3, 4 and 5 for more information);
8. Monitoring to evaluate attainment of narrative WQOs in the watercourse under consideration may include physical and chemical indicators (e.g., numerical WQOs), toxicological indicators (e.g., toxicity test results), and biological indicators (e.g., aquatic ecosystem community structure). In general, all three types of indicators should be used to evaluate attainment of the narrative WQOs.

4.3.2 Background Concentration Procedure

In the BCP, acceptable water quality conditions for a watercourse are defined based on the background or baseline concentrations of a COPC in water. The procedures for applying the BCP in Yukon are somewhat more prescriptive than those described by the CCME, and are detailed in Appendix 2. Most applications of the BCP in Yukon must rely on background water quality. When applying the BCP in the Non-Degradation water management approach or to develop Non-Degradation WQOs for conditions in which degraded water quality has impaired designated uses (i.e., Use-Restoration Approach), some modification of the procedure is required. In these cases, the WQOs can be developed using baseline water quality in the watercourse, while applying the same analysis methods as described for the typical application of the BCP.

Using the BCP, numerical WQOs are derived by conducting statistical analyses of the surface water chemistry data that have been collected to define background or baseline concentrations of COPCs. Data should be examined and sorted to identify any relatively homogenous populations (e.g., turbid-flow vs. clear flow conditions, seasonal, or high flow vs. low flow conditions, etc.), and separate WQO analyses can be conducted for each of these populations.

The forms of contaminants (i.e., total vs. dissolved) should also be considered when applying the BCP. Decisions about the form of a contaminant to use when applying the BCP need to consider which form(s) of the contaminant are biologically relevant or may affect a designated use, which form(s) of the contaminant will be released by the project, and whether the form of the contaminant may change upon release or in the mixing zone. If the mine will be discharging a contaminant in dissolved form, then a WQO developed using the BCP should usually be based on dissolved concentrations of the contaminant in the baseline or background conditions. Also, concentrations of dissolved forms may be less variable in the baseline or background data set, potentially eliminating the need to establish WQOs that vary seasonally or for different flow regimes.

The one-tailed 95% upper confidence limit of the mean (UCLM) and the 95th percentile concentration are calculated for each water quality variable for each population of data. In the Non-Degradation approach, these statistics are then adopted as the average and maximum preliminary WQOs, respectively (see Appendix 2 for more information) for the population of data for which they are developed (e.g., turbid-flow period average and maximum concentrations). In the Use-Protection approach, these statistics can also be adopted as the average and maximum preliminary WQOs. However, if the 95% UCLM of a population of data would result in an average WQO that is more stringent than the chronic WQG, then the WQG may be adopted as an average WQO.

The BCP relies on a good understanding of both upper limit and central tendency concentrations of contaminants for establishing WQOs that are applicable to site-specific conditions. To support this level of understanding and reduce uncertainty about the applicability of WQOs, application of the BCP requires a data set that includes at least three consecutive years of recent (i.e., within the past five years) water quality data with monthly sample collection. The monthly samples should be augmented by one or more annual intensive sampling programs, collecting at least five samples in 30 days during periods of high natural variability. In most cases, the period of highest variability will occur during freshet, but intensive sampling should be included to address any other periods of high natural variability.

Before finalizing WQOs developed using the BCP, the preliminary WQOs should be compared with WQGs (selected in accordance with Appendix 1). If a preliminary WQO is less stringent than an applicable WQG, it may be necessary to refine the WQO to specifically address contaminants in the form that will be release by a proposed project. For example, dissolved metals may warrant consideration since they are the forms of metals released from most quartz mining projects. Additional guidance about this final step of the BCP is provided in Appendix 2.

4.3.3 Recalculation Procedure

The Recalculation Procedure is a method for deriving WQOs that accounts for differences between the sensitivity range of the species of aquatic organisms represented in the complete toxicological data set used to generate the WQG for a COPC and that of the species that occur in the watercourse under consideration (USEPA 1983; 2014; MacDonald 1997; CCME 2003; BCMOE 2013). The procedures for applying the Recalculation Procedure in Yukon are consistent with those described by the CCME (2003). Appendix 3 provides some additional detail about application of the Recalculation Procedure. The procedure provides a practical means of modifying the WQGs to reflect the sensitivities of the species that are present or ought to be present at the site and is likely to be relevant when the most sensitive species represented in the complete toxicological database does not occur at the site (i.e., the WQG may be too stringent) or when the toxicological data set does not include toxicity data for sensitive species that are present at the site (i.e., the WQG may be too permissive).

The application of the Recalculation Procedure relies on a comprehensive understanding of the aquatic species that occur or ought to occur (Appendix 3, Section 2.1) in the watercourse. These include species (genera, families, orders, etc.) that:

- Are usually present at the site.
- Are seasonally present at the site (e.g., due to migration patterns).
- Are intermittently present at the site because they periodically return to or extend their range into the site.
- Would usually be present at the site, but are not currently due to the presence of degraded conditions.
- Are present in nearby reference sites and, hence, are likely to use habitats at the site, even if they have not been observed at the site.
- Were present at the site in the past.

When applying the Recalculation Procedure, proponents must demonstrate that their Baseline/Background Monitoring program and additional research have thoroughly characterized the species that occur or ought to occur in the watercourse.

Using the Recalculation Procedure, data on species that do not occur and are not expected to occur in the watercourse may be eliminated from the data set that was assembled to formulate the WQG. At the same time, the toxicological data set should be refined to include data for relevant species that were not considered during development of the WQG. Species should not be removed from the data set if they are surrogate species for species that are present at the site for which there are no toxicological data. The underlying toxicological data set that was assembled to support WQG derivation should be updated to include toxicity data that have been published in the literature since the WQG was derived. Only after the complete toxicological data set has been assembled, it can be trimmed by removing data for species that do not occur and are not expected to occur at the site. Following refinement of the toxicological data set, a site-specific WQO is calculated using the same methodology that was employed to derive the WQG, as described in *A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2007). Appendix 3 describes a series of specific steps that should be followed when using the Recalculation Procedure.

The Recalculation Procedure may be used to derive site-specific WQOs only if the minimum toxicity test data requirements established for formulating Canadian WQGs are met (CCME, 2007). For many substances, the data required to derive the site-specific WQOs are likely to be available in the toxicological data set that was used to develop the WQGs. Additional data can often be compiled from the scientific literature by searching for results that have been published since the WQG was produced. If the minimum toxicity test data requirements (CCME, 2007) are not met or if sensitive species occur at the site that are not reflected in the toxicological data set, data can be generated by conducting acute and/or chronic toxicity tests on resident or indicator species.

4.3.4 Accounting for Bioavailability and Toxicity Modifying Factors

Proponents may develop WQOs that account for unique water quality characteristics of a watercourse (i.e., BTMF) taking into consideration how these characteristics may influence the effects of a contaminant on a designated use. In many cases, these BTMF that influence the effects of toxic substances have been identified and are included in WQGs. For example, relationships between water hardness and acute toxicity to fish have been established for several metals (e.g., cadmium, copper, lead, nickel, and zinc; CCREM 1987; Nagpal 1999; CCME 2016). Likewise, the toxicity of ammonia to fish is known to be a function of pH and temperature (MacDonald et al. 1987; BCMOE 2016; CCME 2016). The presence of other chemicals (e.g., dissolved organic carbon) and other factors (e.g., total suspended solids) in a watercourse can also affect the bioavailability and toxicity of the COPC. Therefore, consideration of the BTMF that could influence the toxicity and/or bioavailability of a COPC can be used to develop site-specific WQOs. Some methods are described is this section of the Guide, but BTMF can also be considered when applying the Resident Species Procedure that is described in Section 4.3.5.

The WER Procedure is a simple method for modifying WQGs to account for the unique water quality characteristics of a watercourse. The procedures for applying the WER Procedure in Yukon are consistent with the procedures described by the CCME (2003). Appendix 4 provides some additional detail about application of the WER Procedure. This procedure is based on the understanding that the physical and/or chemical characteristics of water can vary among sites and that such differences can influence the bioavailability and toxicity of COPCs.

The WER Procedure can be considered when the toxicity of a COPC is dependent on specific water characteristics that are not accounted for in the WQG, or the watercourse has atypical characteristics that may affect COPC bioavailability or toxicity. The procedure relies on acute and/or short-term chronic toxicity tests with indicator and/or resident species using both site water and standard reconstituted laboratory water (i.e., water that is adjusted for COPC concentrations, but with concentrations of BTMF that are not specifically adjusted to be consistent with site water characteristics).

Short-term toxicity tests are typically selected for use in the WER Procedure to expedite the WQO-derivation process, based on the assumption that the ratio of toxic concentrations would be similar for short-term or long-term tests. Testing is usually completed using indicator species that are commonly used for toxicity testing programs. In some cases, these species may be present in the Yukon watercourses, but if not, they are usually considered acceptable for use as representative surrogate species for resident species. Typically, rainbow trout (*Oncorhynchus mykiss*), fathead minnows (*Pimephales promelas*), the water flea *Ceriodaphnia dubia*, and the alga *Pseudokirchneriella subcapitata* are used to assess the influence of site water quality characteristics on the toxicity of COPCs because they are easy to culture, widely available, and consistently generate reliable data (Willingham 1988; MacDonald et al. 1989; Environment Canada 1996; 1998; 2007a; 2007b; 2007c; 2007d; 2011; ASTM International 2016a; 2016b; 2016c; 2016d; 2016e).

The information generated in these side-by-side toxicity tests is used to determine the ratio of the toxicity of the COPC in water from the site to its toxicity in laboratory water, which is known as the WER. Toxicity data on at least one fish and one invertebrate species are required to calculate the geometric mean WER. This calculated WER is then used to convert the WQG to a site-specific WQO by multiplying the WQG by the ratio of the toxic COPC concentration in site water to the toxic concentration in laboratory water. For example, if the toxic concentration in site water is double the toxic concentration in laboratory water, then the WQG would be multiplied by the WER of 2.

Appendix 4 describes a series of specific steps that should be followed when using the WER Procedure.

The WER Procedure is supported by toxicity tests that are easy to run, reasonably inexpensive, and available at most biological testing facilities. However, the simplicity leads to some limitations that must be considered when applying the WER Procedure.

A single testing program does not consider the temporal variability of water quality at the site (USEPA 1983; 2014; CCME 2003; SWRCB 2003). In general, the toxicity tests are conducted over a discrete time interval and the resulting WER is specific to the sampling program that was used to obtain the site water. As a result, the WQOs might not be applicable under other circumstances, such as during periods of altered streamflow. Therefore, information on the variability of water quality conditions at the site is needed to design a representative toxicity testing program, which may include multiple test programs. This may lead to development of different WQOs for application during different periods, or application of the most stringent of the identified WERs.

Also, the ratio of toxicity in different waters, and the relationship to the WQGs can be influenced by more than BTMF, sometimes resulting in WQOs that may not meet the protection goal. The WER can be affected by the characteristics of the laboratory control water used in the toxicity tests, with potential for different ratios to be calculated for tests done at different laboratories. The WER derives a single ratio using results from lethal endpoints (usually LC_{50}) and assumes that the same ratio applies for low effects level endpoints (e.g., EC_{20}), though this assumption is not well-tested. The toxicity tests for a WER are performed on a subset of the species that support the derivation of a WQG (e.g., through a species sensitivity distribution). The derived WER may not be relevant for species that fall near the lower end of the species sensitivity distribution.

The WER Procedures offers a simple approach for considering BTMF, without the need for a detailed understanding of the quantitative relationships between BTMF and toxicity of COPCs, but the simplicity leads to uncertainty about the WQOs. Any application of the WER needs to consider this uncertainty.

For some contaminants, Biotic Ligand Models (BLMs) provide an alternative method for considering the influence of BTMF in the development of WQOs. BLMs quantify the relationships between BTMF and toxicity of specific COPCs, based on understanding of competition for biological binding sites between the COPC and the BTMF. The CCME protocol for derivation of WQGs describes an approach for incorporating the influence of BTMF. Within this context, the CCME considers BLMs as tools that can be "*used to evaluate quantitatively the manner in which several water chemistry parameters affect the speciation and bioavailability of metals in aquatic systems*" (CCME 2007). The CCME proposes that BLMs "*can be used in the standardization of the data before a guideline is derived and, in the expansion and application of the guideline to specific environmental conditions*" (CCME 2007).

Yukon recognizes that the use of BLMs has merit for the development of WQOs for certain COPCs, though the CCME has not yet published any WQGs that incorporate use of a BLM. Environment and Climate Change Canada (ECCC) has developed a draft Federal Water Quality Guideline for copper relying on application of a BLM to consider the effects of pH, organic matter, alkalinity and ionic content on copper bioavailability (ECCC 2019). ECCC's process involved "*compilation and evaluation of chronic copper toxicity data, evaluation of model performance, utilizations of the BLM to normalize the chronic toxicity dataset to site specific conditions and construction of species sensitivity distributions*." The normalization process involved two steps. The first step entailed the use of a BLM and chronic toxicity test data to calculate critical accumulation values at biotic ligands in organisms. Then, these critical values were used to calculate dissolved copper concentrations that would result in the critical accumulation values by using the BLM with specific water quality conditions. These normalized values formed the basis for construction of species sensitivity distributions – from which a 5th percentile of the best fit sensitivity distribution was selected as the Federal Water Quality Guideline. The process followed by ECCC appears consistent with the approach described by the CCME (2007): using the BLM to standardize the data before deriving a WQG, and then to expand the application of the WQG to specific conditions. The methodology for relying on species sensitivity distributions is describes in Section 4.3.5 (Resident Species Procedure) and the CCME protocol for derivation of WQGs (CCME 2007).

In Yukon, development of WQOs by relying on quantitative models of relationships between BTMF and toxicity of COPCs will be considered when models are used as described by the CCME (2007) and as applied by ECCC (2019). At a minimum, proposals for WQOs that rely on a BLM must include the following:

1. BLMs developed, validated and calibrated on the basis of chronic toxicity data.
2. Use of models that have been validated by comparison of BLM predicted toxicity with measured toxicity in chronic toxicity tests.

3. Use of the BLM to develop normalized species sensitivity distributions to support selection of a WQO as the 5th percentile of a best fit distribution model, followed by application of the BLM to derive results for site-specific conditions.

Any use of a BLM for developing a site-specific WQO must be accompanied by detailed information describing the data, models, methods and rationale, and demonstrating the applicability for the specific circumstances.

4.3.5 Resident Species Procedure

The Resident Species Procedure is designed to account for both of the major factors affecting the derivation of site-specific WQOs: the sensitivity of the species that occur at the site; and, the influence of site water characteristics on toxicity (USEPA 1983; 2014). Because it addresses these two major factors, the resident Species Procedure is a very effective tool for deriving WQOs when WQGs may not be applicable for the watercourse, or when WQGs are not available. When applying the Resident Species Procedure for developing site-specific WQOs in Yukon, proponents should follow the CCME protocol for developing WQGs (CCME 2007). As a result, detailed procedures are not provided in this Guide, but this section summarizes some considerations for implementing the Resident Species Procedure in Yukon.

The Resident Species Procedure can be applied when using the Use-Protection or Use-Restoration Approach for water management. The Procedure entails development of WQOs based on the results of site-specific toxicity tests that evaluate the toxicity of the COPCs to resident species in site water. Where appropriate, the influence of BTMF can be considered in developing WQOs. WQOs derived using this highly specific data set are likely to be more relevant to the site.

Because of the intensive data requirements, the time and resources required to implement this Procedure are likely to preclude its application under most circumstances. However, the Procedure is likely to be relevant in some circumstances, including when:

- A high level of confidence in the resultant WQOs is required.
- WQG are not available for one or more of the relevant COPCs or designated water uses at the site and insufficient data are available to support their derivation.

To implement the Resident Species Procedure, the information in the site-specific toxicological data set must satisfy the minimum toxicological data set requirements for deriving Canadian WQGs. In accordance with the CCME (2007) protocol, at least seven species of aquatic organisms that are resident at the site must be represented in the data set, including at least three fish species, three invertebrate species, and one algae or aquatic vascular plant species. The CCME minimum toxicity test data requirements (CCME 2007) for deriving WQGs for long-term and short-term exposures are provided in Tables 1 and 2 of Appendix 3 (Recalculation). Based on the review of the available literature, the following tests are likely to be the most appropriate for determining WQOs using the Resident Species Procedure:

- 30-day early-life stage toxicity test with rainbow trout (*Oncorhynchus mykiss*; e.g., Environment Canada, 1998).
- 30-day early-life stage toxicity test with fathead minnows (*Pimephales promelas*; e.g., ASTM International, 2016b).
- 28-day to 42-day toxicity test with amphipods (*Hyalella azteca*; e.g., ASTM International, 2016c; USEPA, 2000).
- 28-day surface water toxicity tests with mussels (*L. siliquoidea*; e.g., ASTM International, 2016c; 2016e; USEPA, 2000).
- 7-day toxicity test with cladocerans (*Ceriodaphnia dubia*; e.g., Environment Canada, 2007c; ASTM International, 2016a).
- 72-hour toxicity test with algae (*Pseudokirchneriella subcapitata*; e.g., ASTM International, 2016d).

Similar to the Recalculation Procedure, the Resident Species Procedure requires a comprehensive understanding of species that occur or ought to occur (Appendix 3, Section 2.1) in the watercourse. Appendix 3 provides guidance about how to determine which species are relevant for the watercourse. Once this information is available, review of the existing toxicological data set for the COPC will provide rationale for selection of appropriate resident species for toxicity testing. Tests should include the fish and invertebrate species that are expected to be most sensitive to the COPC.

A significant challenge for the Resident Species Procedure can be the availability of appropriate species for toxicity testing. If it is not possible or feasible to acquire resident species from commercial sources, it may be necessary to collect the organisms from the site under investigation or from other locations where they occur. Detailed sampling plans will be required to facilitate acquisition of test organisms in this case. Plans should address any requirements for permits that may be required for collecting test organisms.

Toxicity to Resident Species can be determined using dilution water from several sources, including upstream water, actual downstream water, or simulated downstream water (USEPA 1994; SWRCB 2003). Appendix 4 (WER) provides some guidance about several detailed topics related to toxicity testing that is also relevant for the Resident Species Procedure, including the following:

- Rationales for using specific sources of dilution water for toxicity testing.
- Conducting range-finding and definitive toxicity tests.
- Selection and handling of test organisms.
- Spiking procedures.

Once data compilation and toxicity testing are complete, the WQO can be developed in accordance with procedures described in CCME (2007). Similar to the Recalculation and WER Procedures, finalization of WQOs should take into account the background conditions at the site.

The most serious drawback of the Resident Species Procedure is the cost of conducting the extensive suite of toxicity tests, potentially including additional costs if significant daily or seasonal variability in water quality is evident in the watercourse. Due to its high costs, the Resident Species Procedure is likely to have only limited application for developing WQOs in Yukon. Nevertheless, the procedure provides a consistent and reliable basis for deriving WQOs when WQGs are not available and insufficient toxicological information is available to support their derivation. Implementation of this procedure may also be warranted at sites where a high degree of confidence in the WQO is required (e.g., where designated uses have high value) or when the costs associated with addressing water quality issues are expected to be high. In all cases, however, application of the Resident Species Procedure must continue to address constraints established for Use-Protection.

4.3.6 Bioaccumulative Substances

Bioaccumulative substances (e.g., mercury and selenium) require a different method for the development of WQOs because the primary exposure pathway for these substances is typically through the diet (i.e., through consumption of aquatic organisms; Neely et al. 1974) rather than direct exposure to surface water. Bioaccumulative substances are substances that accumulate in the tissues of organisms, such that the concentrations within the tissues of the organisms exceed the average concentrations within the diet. These substances are typically evaluated using benchmarks for invertebrate and/or fish tissues (e.g., CCME 2000; BCMOE 2014; USEPA 2016a). Such benchmarks – usually based on tissue-residue guidelines for the protection of aquatic organisms, wildlife and/or human health – are often used as primary tools for evaluating the potential for adverse effects of bioaccumulative COPCs on aquatic life and aquatic-dependent wildlife.

In addition to the application of tissue-based benchmarks, there are valid reasons for establishing WQOs for bioaccumulative COPCs in the water column and monitoring contaminant concentrations. Changes in surface water chemistry can provide an early warning relative to potential exposure to bioaccumulative COPCs (Toll et al. 2005; Presser and Luoma 2010). In addition, determination of tolerable levels of bioaccumulative COPCs in surface water is required to calculate permit limits for regulating discharges into receiving waters. In Yukon there are typically regulatory requirements to measure relevant COPCs (e.g., dissolved selenium) in the water column to support loading calculations.

The factors that influence bioaccumulation are often site-specific and bioaccumulation rates are difficult to predict. As a result, the relationship between concentrations of bioaccumulative substances in tissue and the water column is site-specific. Development of WQOs for bioaccumulative substances must consider site-specific conditions and bioaccumulation rates. This requires a site-specific understanding of the relationship between concentrations in water and those in aquatic organisms.

WQGs have been developed for certain bioaccumulative substances, such as mercury, polychlorinated biphenyls, and selenium (e.g., BCMOE 2016; CCME 2016; USEPA 2016b), and these may be adopted as WQOs if background concentrations are expected to be less than the relevant WQGs. Alternatively, Appendix 5 describes procedures for determining protective concentrations of bioaccumulative substances in water, taking into consideration the site-specific relationships between contaminant concentrations in different components of the aquatic ecosystem. In most cases, dissolved forms of contaminants are likely to be more relevant for bioaccumulative substances because dissolved forms are more biologically available. If demonstrated to be protective and relevant, the application of WQGs and the derivation of site-specific WQOs for bioaccumulative substances can be based on dissolved forms of contaminants.

No matter which method is used to derive numerical WQOs for bioaccumulative COPCs, monitoring of attainment of the WQOs and of levels of bioaccumulative COPCs in the tissues of fish and/or other aquatic organisms should be considered to be a high priority. The WQOs should be revised if biological monitoring indicates that adverse effects on aquatic organisms or aquatic-dependent wildlife have occurred or are likely to have occurred due to accumulation of bioaccumulative COPCs in the tissues of aquatic organisms. Likewise, increased risks to human health should trigger revision of the WQOs for one or more COPCs.

4.4 Data Requirements

In all cases, the development of numerical WQOs requires a thorough understanding of relevant environmental conditions, relying on both biophysical investigations/monitoring and traditional Indigenous knowledge. The scope of data requirements varies depending on the water management approach and the method(s) selected for developing WQOs. For example:

- Selection of a water management approach requires a thorough understanding of the aquatic ecosystem and its resilience.
- Identification of COPCs requires a thorough understanding of baseline and background water quality as well as knowledge about the aquatic ecosystem.
- Application of the BCP requires a thorough understanding of background water quality (or baseline water quality in certain cases).
- Considering the effects of BTMF requires a thorough understanding of water chemistry, including BTMF.
- The WER Procedure will require specific toxicity test results.
- The Recalculation and Resident Species Procedures require information about species that are or ought to be present, and may require specific toxicity test results.
- Development of WQOs for bioaccumulative substances will require information about tissue concentrations of COPCs in aquatic species.
- Understanding of pre-project water quality and aquatic ecosystem conditions is required to support implementation of WQOs and evaluation of their attainment.

Because information about background and baseline conditions for all aspects of the aquatic ecosystem is important when developing WQOs, the overall goal of WQO Background/Baseline Monitoring is to provide the data and information that are required to understand and document aquatic ecosystem conditions and variability. The WQO Background/Baseline Monitoring must be sufficiently robust to document natural variability in the relevant physical, chemical (both total and dissolved forms of contaminants), and biological characteristics of water under background and baseline conditions. The resultant data provide a basis for distinguishing between natural variability and effects of land-use or water-use activities on aquatic ecosystems.

Collecting background and baseline information is straightforward for watercourses that have not been impacted by human activities. As described in Appendix 6, for watercourses where water quality has already been impacted, characterizing background conditions may rely on historically collected data, current conditions in upstream locations, or current conditions in appropriate reference locations.

Yukon has established minimum data requirements for characterizing background and baseline water quality when developing WQOs. These minimum requirements provide clarity about monitoring expectations, and support adequate characterization of variability in water quality conditions. Because the identification of COPCs and application of some WQO methods (e.g., BCP, Accounting for BTMF) require an understanding of extreme water quality conditions, a robust data set reduces the risk of developing WQOs that fall within the range of natural water quality conditions in a watercourse. Implementation of such WQOs would lead to excessive false positive exceedances during project implementation. The following minimum data requirements for background and baseline water quality, as described in Appendix 6, apply for development of WQOs:

1. Three consecutive years of recent (i.e., within the past five years) water quality data collected on a monthly basis at locations where WQOs are to be developed and applied, and at appropriate reference locations.
2. One or more intensive sampling programs during each of the three years, with at least five samples collected in 30 days during periods of high expected short-term water quality variability. In most cases, the period of highest variability will occur during freshet, but intensive sampling should be included to address any other periods of high natural variability.

Based on statistical analysis completed on natural Yukon streams, three years of data on dissolved metals is the minimum duration that can support a reasonable understanding of central tendency (i.e., mean or UCLM) and extreme (e.g., 95th percentile) conditions. Three years of data is also the minimum data required to identify any trends in natural conditions. Natural trends may result in WQOs that are not reasonable or applicable during project implementation.

The requirement for the annual intensive sampling program may be eliminated if the study design for the baseline monitoring program has included a pilot study specifically designed and implemented to estimate variability in support of defining monitoring frequency. The number of samples collected to support a pilot study should be as large as feasible to provide accurate estimates of variation (Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000).

The minimum data requirements for background/baseline water quality monitoring programs to support WQO development must be complemented with concurrent collection of high-quality flow data because these data are critical for understanding contaminant loading, and interpreting variability in water quality results.

Appendix 6 provides detailed guidance about minimum data requirements, and the design and implementation of WQO Baseline Monitoring programs. Proponents should seek input from relevant government (federal, territorial, First Nation) agencies during the design of a WQO Baseline Monitoring Program.

4.5 Water Quality Objectives Development Work Plan

Before initiating the development of numerical WQOs proponents should prepare a Water Quality Objectives Development Work Plan that will guide the activities for developing WQOs. Development of numerical WQOs can be a complicated process that requires collection, collation, evaluation and interpretation of a substantial quantity of site data and information. In all cases, development of numerical WQOs will require collection or compilation of data to understand the baseline conditions. The WQOs-derivation process could also require generation of aquatic toxicity data using indicator species, resident species, or a combination of both. Such toxicity data may be generated using standard laboratory water, site water, or both. Various other types of data may also be required to provide sufficient information for deriving WQOs. Data requirements will be influenced by the expected water management approach (Chapter 2), identified COPCs (Chapter 3), and procedures for developing numerical WQOs (Chapter 4). The WQOs Development Work Plan should include:

- Description and characterization of the watercourse.
- Summary of the proposed project and characterization of predicted effects on water quality. Identify waste minimization strategies, source control strategies and best management practices (i.e., measures intended to minimize pollution).
- Results and interpretation from existing background and baseline monitoring programs.
- Description of proposed background and baseline monitoring programs.
- Summary of engagement undertaken to support preparation of the WQO Development Work Plan, and description of plans for future engagement as the development of WQOs progresses. For example, describe past and proposed engagement related to water management approach, identification of COPCs, methods for developing site-specific WQOs, allocation of assimilative capacity, etc.
- The proposed water management approach and the rationale for its selection, including the results of any discussions with interested parties.
- Preliminary list of COPCs and a description of the process that will be used to refine the list.

- A rationale for developing any site-specific WQOs, and the proposed methods for deriving numerical WQOs.
- Description of monitoring and/or toxicity testing programs that will be used to support WQO development.

The preparation of the WQO Development Work Plan may be an iterative process, whereby the COPCs, WQO development methods, and monitoring/testing programs are refined as more information about the site becomes available. Proponents should seek input from relevant government (federal, territorial, First Nation) agencies, and other affected or interested parties during the preparation and refinement of a WQO Development Work Plan.

5.0 Validation and Attainment of Water Quality Objectives

Environmental monitoring programs associated with implementation of WQOs need to achieve two main purposes, both of which are illustrated in Figure 3 and described in more detail in this section. The purposes of monitoring in relation to WQO implementation are:

1. To validate the numerical WQOs and confirm their effectiveness in meeting the narrative WQOs, shown in the outer loop monitoring and response cycle of Figure 3.
2. To evaluate attainment of the numerical WQOs, shown in the inner loop monitoring and response cycle of Figure 3.

This chapter discusses both monitoring purposes and the monitoring that will be needed to address these purposes.

5.1 Validation of Numerical Water Quality Objectives

Numerical WQOs complement the narrative WQOs by defining the targets for key indicators of water quality conditions (e.g., copper concentrations) that need to be met in receiving waters. While such numerical WQOs provide precise estimates of the concentrations of COPCs in surface water needed to meet the narrative WQO, there are a number of uncertainties in the WQO development process that have the potential to influence the validity of the numerical WQOs. These uncertainties are most relevant for the Use-Protection Approach where the narrative WQO requires protection of sensitive water uses. For example, the Recalculation, WER and Resident Species Procedures all specifically rely on laboratory toxicity data, which also underlie the adoption of WQGs as WQOs. While use of site water and/or resident species in a toxicity testing program reduces uncertainty in the resultant WQOs, there is still some level of uncertainty when extrapolating such results to a specific watercourse and to a functioning ecosystem, particularly when sensitive taxa are known to occur in a watercourse. A more comprehensive understanding of the condition of the aquatic ecosystem is needed to confirm that the achievement of the numerical WQOs is correlated with achievement of the narrative WQOs. The same uncertainties extend to the Use-Restoration Approach when Use-Protection methods are used to develop numerical WQOs. For all water management approaches, there is uncertainty about whether all relevant COPCs have been identified. To address these uncertainties, implementation of numerical WQOs needs to include processes to confirm that the numerical WQOs are effective for achieving the defined narrative outcome.

The effects of COPC mixtures (e.g., synergistic or antagonistic) on fish and other aquatic organisms present a significant uncertainty about the validity of WQOs for most quartz mining projects that will release more than one contaminant. For this type of uncertainty, understanding the suitability of numerical WQOs for protecting aquatic life requires a toxicity testing program.

There can also be substantial uncertainty in the bioaccumulation models that are applied in the development of numerical WQOs for bioaccumulative substances. For example, organisms exposed to a bioaccumulative COPC through both water and sediment pathways may be adversely affected by cumulative contaminant loading in sediments even though concentrations in water meet the numerical WQO. For this type of uncertainty, understanding the suitability of numerical WQOs for protecting aquatic life requires a tissue sampling program.

The results from surface water toxicity testing can be used directly to assess the attainment of the narrative WQOs. Failure to achieve the narrative WQOs while meeting attainment requirements for numerical WQOs indicates that the numerical WQOs are not effective, and should be re-evaluated.

5.2 Attainment of Numerical Water Quality Objectives

Numerical WQOs define the specific targets for concentrations of COPCs that are intended to achieve the narrative WQOS. Surface water quality data provide information that is directly relevant for assessing attainment of the numerical WQOs. The interpretation of monitoring results to evaluate attainment of numerical WQOs relies on a clear articulation of the criteria that define attainment of the WQOs. In all cases, the design of the monitoring program needs to consider the frequency of monitoring required to evaluate attainment as defined for the WQOs. The criteria used to assess attainment of the numerical WQOs depend on the selected water management approach, as follows:

- **Non-Degradation Approach:** The surface water chemistry data should be compared to numerical WQOs derived using the BCP. In this respect, the concentration of each COPC in each grab sample is compared to the 95th percentile of background concentrations for the COPC. Each observation for a COPC is classified as “in compliance” or as “an exceedance,” depending on whether the observed concentration exceeds the 95th percentile of background concentrations. The frequency of exceedance is then calculated for each COPC using the surface water chemistry data for the 20 most recent sampling dates (i.e., where frequency of exceedance = number of exceedances/number of observations). The WQOs are exceeded if the frequency of exceedance of the 95th percentile of background concentrations is greater than 5% (i.e., two or more samples out of twenty exceed the 95th percentile concentration).

  In addition, the arithmetic mean is calculated for each COPC using the surface water chemistry data of the 20 most recent sampling dates for the relevant time period (e.g., annual, open-water, month). The mean concentration that is calculated for the relevant time period for each COPC is then compared to the one-tailed 95% UCLM that was generated using the data collected in the baseline monitoring program. The WQOs are exceeded if the resultant monitoring data indicate that the mean for the previous 20 sampling dates for the relevant time period exceeds the one-tailed 95% UCLM established under background conditions.

- **Use-Protection Approach:** Where the BCP forms the basis for a Use-Protection WQO, the same criteria as defined for the Non-Degradation Approach should be used to evaluate attainment. For other use-protection methods including adoption of WQGs, the surface water chemistry data should be compared to numerical WQOs. The long-term WQO for each COPC is compared to the mean of the 20 most recent measured concentrations for the relevant time period (e.g., annual, open-water, month) and to the mean that is calculated using the data generated during the 5-samples-in-30 days sampling events. If any one of these mean values exceeds the long-term WQO, the conditions have failed the attainment test.

  If a short-term WQO has been established for a COPC, then the measured concentrations of that substance in the monthly samples and the individual samples collected during the 5 samples-in-30 day events are compared to the short-term WQO. One or more exceedances of the short-term WQO is considered to represent non-attainment of the objective.
- **Use-Restoration Approach:** The surface water chemistry data should be compared to numerical WQOs established for encouraging recovery of water quality and restoration of designated uses. Because WQOs may be initially focused on avoiding any further degradation and subsequently on Use-Protection, the criteria for evaluating attainment should be applied as described for whichever approach is applicable at the time. Successful attainment of early stage WQOs in the Use-Restoration Approach should trigger establishment of new WQOs that encourage progressive improvement of water quality. The processes for evaluating attainment and adjusting WQOs should be described in a continuous improvement plan.

While the criteria for attainment define specific thresholds in relation to the WQOs, it is equally important to routinely evaluate water quality conditions for evidence of changes and trends, both spatially and temporally, that may indicate future onset of more serious challenges.

5.3 Monitoring for Validation and Attainment

Monitoring programs for WQOs should be designed to address data needs for validating numerical WQOs, evaluating their attainment, and proactively identifying adverse changes and trends. For most quartz mining projects in Yukon, protection of aquatic life is likely to be relevant for validation and attainment of WQOs. Ongoing monitoring of all components of the aquatic ecosystem forms the basis for confirming that conditions are achieving the numerical WQOs and that the WQOs are sufficient for achieving the narrative objectives for the selected water management approach.

Proponents should develop and implement comprehensive AEMPs that will provide ongoing confirmation of WQOs throughout project implementation, support ongoing evaluation of attainment of WQOs, and provide data to proactively identify changes and trends in water quality and aquatic conditions. The AEMP should address all components of the aquatic ecosystem so that water quality results can be evaluated together with the biological monitoring results to determine if the conditions are achieving the WQOs and if the WQOs are adequately protective of aquatic life.

In Yukon, there are existing requirements for AEMPs for quartz mining projects. Water licences include requirements for water quality and aquatic ecosystem monitoring, and reporting of results. Also, the MDMER require quartz mining projects to conduct Environmental Effects Monitoring (EEM) programs and report the results. These programs can provide the data needed to validate WQOs, and evaluate their attainment.

5.3.1 Monitoring for Validation of Numerical WQOs

With respect to validation of WQOS, EEM programs must include effluent and water quality monitoring studies and biological monitoring studies, as follows:

- **Effluent Characterization**, including effluent quality analysis and sub-lethal toxicity testing (fish, invertebrate, plant and algae).
- **Surface Water Quality Monitoring**, including water quality analysis for background and receiving water streams.
- **Biological Monitoring**, including a site characterization, and benthic invertebrate community study, and in some cases a fish population study and/or a fish tissue study. The fish tissue study is required specifically when COPCs include bioaccumulative substances.

AEMPs in water licences and EEM programs often include requirements similar to those required for validating WQOs. EEM programs and water licence AEMPs can be used to support validation of numerical WQOs for Yukon quartz mining projects. However, these programs evaluate actual conditions during mine operations and closure, and therefore do not specifically address what effects may occur if COPC concentrations in receiving environments reach those defined by the WQOs. As a result, using EEM programs and AEMPs to validate WQOs will require ongoing confirmation of validity as mine development progresses and water quality conditions change.

While validation of numerical WQOs is complementary to EEM programs and AEMPs, it does expand the purposes of these programs. Therefore, the validation of WQOs should be considered and addressed in the design of EEM and AEMP programs. Some key considerations include the following.

- Chronic toxicity testing for sensitive species may be needed in receiving water locations to specifically address whether the receiving water quality is protective of sensitive aquatic life.

- Water quality analysis may need to address additional parameters that are not specifically identified by the MDMER.
- Tissue sampling for both benthic invertebrates and fish may be needed whenever bioaccumulative substances (e.g., mercury, selenium) are identified as COPCs.

The results of EEM programs and AEMPs should be used to determine if any of the numerical WQOs require adjustment. Reporting about the validity of numerical WQOs should be included in annual regulatory reports (e.g., water licence annual reports). When designing EEM programs and AEMPs that are intended to address validation of numerical WQOs, proponents should seek input from relevant government (federal, territorial, First Nation) agencies.

5.3.2 Monitoring for Attainment of Numerical WQOs

Surface water monitoring is the primary tool for directly evaluating attainment of numerical WQOs and proactively identifying changes and trends. It also provides valuable information for evaluating effectiveness of numerical WQOs with respect to attainment of narrative WQOs. Surface water monitoring should be conducted in receiving waters to directly evaluate attainment, but is also required in areas that represent background conditions, to support interpretation of attainment data. In general, surface water monitoring to evaluate effectiveness and attainment of WQOs should include:

- Monthly water chemistry monitoring for physiochemical parameters, nutrients, major ions, total metals, and dissolved metals at reference and project-affected stations (any other COPCs identified during the Study Plan should also be measured). While some parameters may not be specifically identified as COPCs, they can be useful for interpreting water quality changes and trends.
- At least one 5-samples-in-30 days sampling event conducted each year during the period of highest expected variability in water quality conditions (usually freshet). Additional intensive sampling should be included to address any other periods of high natural variability
- High quality flow data are critical for understanding contaminant loading, and the relationship between effluent quality and receiving water quality. For the purpose of evaluating effectiveness and attainment of WQOs, flow monitoring should be included at the time of every water chemistry sampling event. The *Manual of British Columbia Hyrdrometric Standards* (BCMOE 2009) provides guidance about methods for collection of hydrometric data.

5.4 AMP for Non-attainment

The AEMP should be integrated with an AMP that is designed to provide a basis for addressing any non-attainment issues, whether for narrative or numerical WQOs. The AMP should be designed to proactively respond to changes in the concentrations of COPCs in surface water, and/or toxicity to aquatic organisms before the changes cause unacceptable conditions, referred to as the “significance threshold” in the *Yukon Guide for Developing Adaptive Management Plans for Quartz Mining Projects* (Gomm Environmental Engineering and Slater Environmental Consulting 2018). The AMP should describe the procedures that will be taken to avoid reaching WQOs and/or bring the system back into compliance with the WQOs including the process for developing Management Response Plans for addressing unacceptable performance before significance thresholds are exceeded. Importantly, the AMP should include triggers that ensure that management actions can be implemented in time and with sufficient effectiveness to ensure that significance thresholds are consistently met at the site.

Table 1 in the *Yukon Guide for Developing Adaptive Management Plans for Quartz Mining Projects* provides specific guidance about defining significance thresholds, which are dependent on the water management approach and the type of WQO that applies, as follows.

- For waters managed using the Non-Degradation Approach, the significance threshold is the Non-Degradation WQO.
- For the Use-Protection Approach where WQGs are adopted as WQOs, significance thresholds in an AMP can be greater than the WQO and depend on the methodology used to develop the WQG.
- For the Use-Protection Approach with site-specific WQOs developed using methods other than the BCP, the significance threshold can be the site-specific WQO.

For the Use-Protection Approach with site-specific WQOs developed using the BCP, significance thresholds must be established based on toxicity testing that demonstrates the degree of departure from background conditions that could result in measurable, adverse effects on the aquatic ecosystem. This additional requirement arises because developing WQOs using the BCP does not consider the results of any toxicity testing that characterizes potential risks to the aquatic ecosystem.

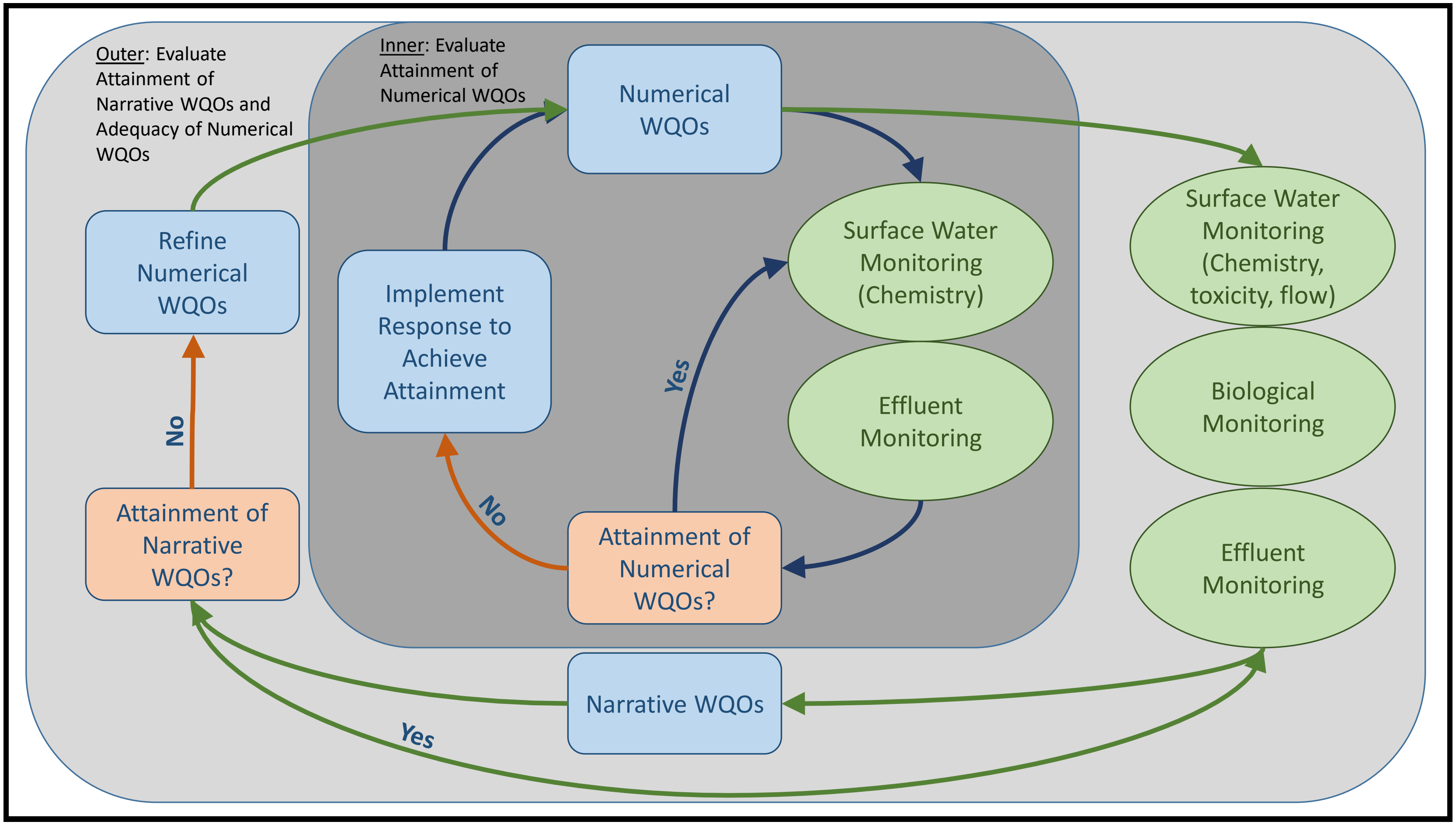

Figure 3: Monitoring and Response Cycles for WQO Implementation.

6.0 Deriving Effluent Quality Standards

A proponent's proposed EQSs must be developed to ensure that the numerical WQOs for the receiving environment are achieved. While the Yukon Water Board is the authority that sets the EQSs as part of the water licence process, the guidance in this section provides proponents with the recommended procedures that should be used to derive their proposed EQSs (Section 6.1). This section also provides guidance about allocation of assimilative capacity (Section 6.2) and application of mixing zones (Section 6.3).

6.1 Procedures for Deriving Effluent Quality Standards

A multi-step approach, as described in this Chapter and illustrated in Figure 4, is recommended for the development of receiving-water-based EQSs for quartz mining projects in Yukon, intended to ensure WQOs will be met in the receiving environment. If applicable, this approach should be used to derive proposed EQSs for each season or project phase, and for the full range of possible discharge volumes.

1. **Back-calculation of Maximum Effluent Concentrations**

   The maximum allowable concentration of COPCs in effluent discharge can be back-calculated using the following conservative mass-balance equation that is based on the flow in the receiving environment, discharge volume, WQO, the background concentration of the COPC, and, in the case of the Use-Protection approach, the portion of the receiving environment's assimilative capacity allocated to a discharge:

$$C_e = \frac{AC[WQO(Q_e + Q_s) - (Q_s \times C_s)]}{Q_e}$$

Where:

C_e = Maximum concentration of COPC in effluent (mg/L)

Q_e = Effluent discharge flow rate (m^3/s)

C_s = Background concentration of the COPC (mg/L) – One-tailed 95% UCLM of background water quality

Q_s = Background stream flow above point of discharge. The low flow statistic 7Q10 (m^3/s), 7-day low flow with 10-year return period, is to be used as the basis for this calculation. For discharges that are seasonal, the 7Q10 should be based on the flow data for the specific discharge period.

WQO = Maximum Water Quality Objective as determined using guidance (95th percentile-WQO [Non-Degradation]/maximum-WQO [Use-Protection]).

AC = Portion of the receiving environment's assimilative capacity allocated to a discharge (See Section 6.2). In some situations, setting aside reserve assimilative capacity may be required for existing and anticipated future use and needs. Allocation of assimilative capacity is only relevant for the Use-Protection approach.

2. Pro-rated Discharges

EQSs for discharges set proportional to the receiving environment stream flow must be back-calculated using the same approach under the full range of discharge scenarios. For these situations, the proponent may be required to include continuous receiving stream flow monitoring at the discharge location in their proposed site monitoring program.

3. Predictive Modelling of Project Performance

The next step is to predict the water quality in the receiving environment in response to the proposed back-calculated EQSs and compare the results with the WQOs. As per the Yukon Water Board Quartz Mining Undertaking Information Package for Applicants (Yukon Water Board, 2012), the water quality and water balance models used must be suitable for making predictions for all phases of the project and should account for variability in both the discharge effluent streams and the receiving environment. The sensitivity of the model to its input parameters and assumptions should be examined and reported.

The suitability of the proposed EQSs should be assessed based on criteria similar to those laid out in Section 5.2 for attainment of WQOs. Specifically, this will be based on the water management approach used for derivation of the WQOs: Non-Degradation, Use-Protection or Use-Restoration.

a. Non-Degradation

- Predicted water quality less than 5% exceedance of 95th percentile-WQO
- Mean of predicted results below UCLM-WQO

b. Use-Protection

- Predicted water quality less than 5% exceedance of 95th percentile-WQO
- Mean of predicted results less than average WQO

c. Use –Restoration

- When WQO based on Non-Degradation – same approach as a)
- When WQO based on Use-Protection – same approach as b)
- During interim period between application of Non-Degradation WQO and Use-Protection WQO – predicted water quality is showing a statistically significant decreasing trend towards Use-Protection value.

4. Refinement of Back-Calculated EQSs

If a proposed EQS is predicted to not meet the WQO based on the criteria outlined in Step 3, the EQS should be modified, re-modelled and re-evaluated as per Step 3. This process is to be repeated until the EQS delivers water quality conditions that are predicted to meet the criteria in Step 3.

5. Comparison to BATT-based EQSs and *Metal and Diamond Mining Effluent Regulations*

The EQSs developed based on WQOs should be compared to effluent discharge concentrations based on best available treatment technology (BATT) and the standards stipulated in the federal *Metal and Diamond Mining Effluent Regulations*. For each COPC, the lowest of the three values should be adopted as the proposed EQS.

6. Mixing Zones

The above noted method is used to determine EQSs based on meeting the WQOs at the edge of the mixing zone (See Section 6.3). The mixing zone is defined at the area contiguous with a point source (effluent discharge) where the discharge mixes and may react with ambient water and where concentrations of COPCs may not comply with the WQOs (CCME, 2008).

The following additional factors must also be considered during the development of proposed EQS.

1. For BTMF-based EQSs the values should be based on the 95% lower confidence limit of the mean (LCLM) BTMF concentration in the receiving environment.
2. All effluent discharges must be non-toxic (100% 96-hour LC_{50} using Rainbow trout).

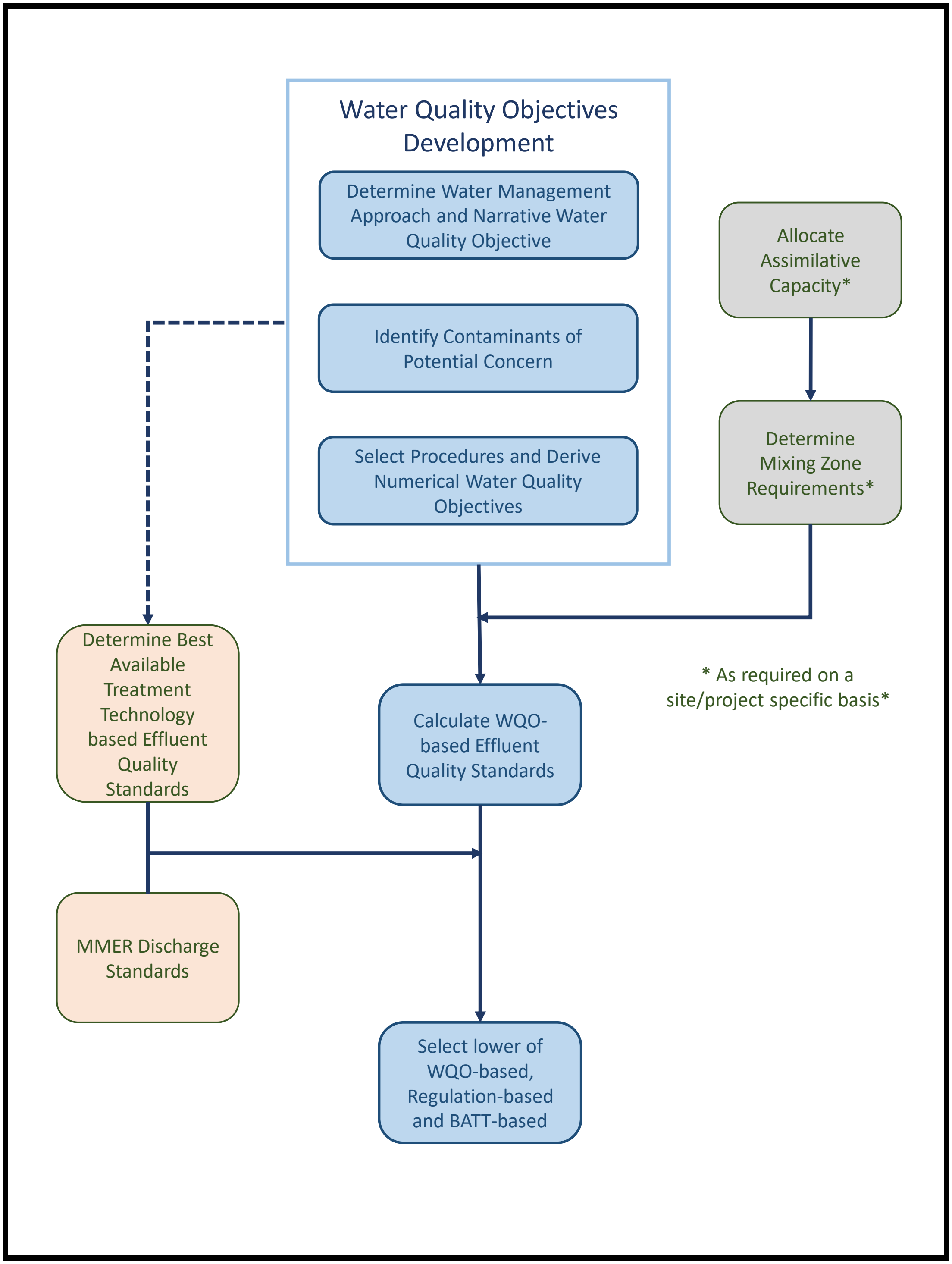

Figure 4: Derivation of effluent quality standards.

6.2 Allocation of Assimilative Capacity

In the Use-Protection Approach, derivation of EQSs must consider how much of the assimilative capacity in a watercourse can be allocated to a proposed project. The assimilative capacity is calculated as the difference between background water quality and a Use-Protection Water Quality Objective. In many cases, the allocation of assimilative capacity will be influenced by values and perspectives of affected and interested parties. Therefore, engagement with communities and relevant government agencies is a critical part of decision-making about allocation of assimilative capacity. The following general principles apply to allocation of assimilative capacity for quartz mining projects.

- Assimilative capacity for deposit of waste into watercourses is a resource. Allocation of the resource should follow a planning approach.
- Minimizing pollution through application of best available practical technology is a priority over consumption of assimilative capacity.
- The allocation of assimilative capacity may vary on both spatial and temporal scales. Allocation may be different during operations and closure phases, for example communities may accept short-term use of all assimilative capacity during operations, but expect return of some capacity during closure. Allocation may also vary seasonally, with more capacity retained at ecologically sensitive times for example. Spatially, allocation may be different at more or less sensitive locations in a watercourse. Allocation may also consider the application of mixing zones.
- Assimilative capacity should be applied on a parameter-specific basis.
- Allocation of assimilative capacity does not apply when using the Non-Degradation water management approach. It is not relevant when using the Use-Restoration Approach because COPC concentrations that have led to degradation of a designated use have already consumed all available assimilative capacity.

Engagement with communities and governments may identify a wide range of factors that should be considered when defining proposed allocation of assimilative capacity. The following factors may be relevant and should be considered during decision-making about allocation of assimilative capacity:

- Other uses or potential uses of assimilative capacity:
  - Existing uses.
  - Potential future uses.
  - Potential growth of the proposed project.
  - Other potential cumulative effects.
- Socio-economic considerations:
  - Results and recommendations of any watershed planning and/or land use planning.
  - Concerns of communities, governments, interested parties.
  - Potential loss of future opportunities.

    - Projects for public good.
- Treaty and Aboriginal rights.
- Ecological conditions:
    - Potential for bioaccumulation, biomagnification, or synergistic effects.
    - Consideration of higher duty of care for species at risk or species of conservation concern, when applying the Use-Protection approach.
    - Discharges to areas where natural attenuation may occur.
- Uncertainty:
    - Uncertainty about project performance.
    - Potential effects of changing climate (e.g., permafrost degradation).

6.3 Mixing Zones

EQSs should be established such that water quality at the edge of a mixing zone meets the WQOs including any adjustment for assimilative capacity. A mixing zone is defined as "*the area contiguous with a point source (effluent discharge) where the discharge mixes with ambient water and within which concentrations of COPCs may not comply with the WQOs.*" While mixing of effluent and receiving water will continue outside of the defined mixing zone, for the purposes of this guidance the edge of a mixing zone defines the location where WQOs and allocation of assimilative capacity will apply.

The specific spatial limits of a mixing zone (i.e., length and width) should be determined on a case-by-case basis and take into consideration water quality, streamflow characteristics, physical factors in area of discharge, aquatic resources and habitat in and adjacent to discharge area, and downstream water uses. The following guiding principles, as revised from "*Guidelines for Effluent Mixing Zones*" (MVLWB/GNWT 2017) and "*Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives*" (CCME 2003), should be considered with respect to the establishment of effluent mixing zones in Yukon:

- The size of mixing zones should be minimized to the extent practical.
- Mixing zones must not impair the designated uses of a watercourse.
- Mixing zones are not to be applied as an alternative to reasonable and practical treatment of effluent.
- Effluent discharged to a mixing zone must never be acutely toxic to aquatic life or cause acute toxicity to aquatic life.
- Conditions in a mixing zone should not result in bioconcentration of COPCs to levels that are harmful to aquatic life, aquatic dependent wildlife, or human health.
- Mixing zones should not overlap with any key aquatic habitat for aquatic species or aquatic-dependent wildlife species.
- Mixing zones must not overlap with or affect any drinking water supplies.
- Mixing zones for adjacent effluent discharges should not overlap with each other.

- Mixing zone sizes may vary on the basis of site-specific conditions.
- Establishment and size of mixing zones may vary from one substance to another, based on the substances' characteristics and behaviours in the environment.
- Mixing zones must provide an adequate, safe zone of passage for the movement or drift of all stages of aquatic life.
- Placement of mixing zones should not interfere with migratory routes, including into tributaries.
- Mixing zones should not unduly attract aquatic life or aquatic-dependent wildlife, or result in increased exposure to COPCs.
- Loading in mixing zones should not result in local accumulation of toxic substances in sediment or biota to toxic levels.
- The mixing zone must have characteristics that will support effective mixing in all conditions expected throughout the project life.

The characteristics of a watercourse are a key consideration when establishing mixing zones. In Yukon, the following factors should be considered for relevant watercourses:

- For mixing zones in rivers and streams at locations that support fish or other mobile aquatic life, a zone of safe passage must be maintained for migrating aquatic organisms, and water quality outside of the mixing zone must not impair any designated water use. Where possible, the mixing zone should not span the full width of the stream or river. If the mixing zone spans the full width of the stream of river, the outfall must be designed to achieve rapid mixing of effluent with the watercourse.
- Where effluent mixing zones include the confluence of two natural streams/rivers, the effluent mixing zone must consider the mixing characteristics of the two natural streams/rivers (e.g., clear-water zones where tributary streams enter major rivers).
- Where a quartz mining project is located in the headwaters of a stream and mine effluent will comprise all or most of the stream flow at the discharge location, the width of a mixing zone may include the full stream width for areas that do not provide habitat for fish, and/or during seasons when the stream does not provide habitat for fish. The edge of the mixing zone cannot extend into areas that provide habitat for fish, taking into consideration seasonal use.

For discharge into lakes, the physical characteristics of the mixing zone must support ongoing mixing throughout the project life, without resulting in progressive accumulation of substances in the water or aquatic environment within the mixing zone. "*Guidelines for Effluent Mixing Zones*" (MVLWB/GNWT 2017) provide guidance about sizing for mixing zones in lakes. Consistent with that Northwest Territories guidance, mixing zones in lakes should have a maximum radius of 100 m or 25% of the width of the lake (whichever is smaller) unless proponents demonstrate that a larger zone can achieve the narrative WQOs, and is consistent with the criteria listed in this section.

7.0 Reporting

Proponents should describe in detail the process used for development of numerical WQOs and EQS, along with the results, in a comprehensive report. Development of WQOs and EQSs usually entails extensive collection, collation, evaluation and interpretation of data. This includes decisions about usability, treatment, applicability and use of data, as well as assumptions about how to address data gaps. Data will include water chemistry, and should also include results of toxicity testing (as required) and data about all components of the aquatic ecosystem. The development of WQOs will include decisions about water management approach, COPC selection, methods for deriving WQOs, and criteria for evaluating attainment, among other things. The derivation of EQSs requires consideration of factors that influence the allocation of assimilative capacity and the spatial limits of a mixing zone. All of this information must be clearly presented to support evaluation, acceptance and approval of proposed WQOs and EQSs during assessment and regulatory processes. WQO and EQS information will be relevant for assessment and licensing. The approach and timing of the reporting may be influenced by the information that is relevant for assessment and/or regulatory processes. Proponents can submit one report detailing the development of both WQOs and EQSs, or alternatively, the WQO development can be described in an initial report that is subsequently updated to incorporate results of the EQS work. A WQO/EQS report should build on the information included in the WQO Development Work Plan (Section 4.5), and include at least the following:

1. **Introduction:** Provide the name and location of the watercourse. Summarize the reasons for developing WQOs, the proposed water management approach and the rationale for selection of that approach. List the COPCs for which WQOs and EQSs were derived, and the method that was used to derive the WQOs for each of the COPCs. Describe factors that influenced allocation of assimilative capacity.
2. **Description of the Study Area:** Provide detailed information on the following:
    a. **Background and Baseline Water Quality Assessment:** Provide a description and evaluation of background and baseline water quality conditions in the study area.
    b. **Sediment Quality Conditions:** Provide a description and evaluation of background and baseline sediment quality conditions in the study area, if relevant to the WQOs.
    c. **Biological and Ecological Conditions:** Provide a description and evaluation of background and baseline conditions for relevant biological and ecological components in the study area.
    d. **Identify Aquatic Species and Aquatic-Dependent Wildlife Species:** List threatened and endangered species, and locations of their critical and key aquatic habitats; and sensitive species (listed in Schedules of SARA) and species of conservation concern, and locations of their key aquatic habitat.

   e. **Water and Land Uses:** Describe all of the water and land use activities that may have overlapping or cumulative effects on the same watercourse (i.e., in the watershed and in downstream waters).
   f. **Special Designations:** Identify and describe any special land-use classifications within the watershed (e.g., World Heritage Sites, National Parks, Territorial Parks, First Nations Settlement areas, and Special Management Areas).
3. **Water Management Approach:** Identify the water management approach(es) that will be used for the project, and provide rationale for selection of proposed approach(es). Describe results of engagement activities to support identification of proposed water management approach(es).
4. **Contaminants of Potential Concern:** Identify the COPCs and provide detailed rationales for selection of COPCs.
5. **Methods for Deriving Numerical WQOs:** For each COPC, identify the method selected for selecting or deriving numerical WQOs, and describe the rationale for selection of that method.
6. **Proposed Water Quality Objectives:** List the proposed WQOs and summarize the rationale for each proposed WQO. For each COPC for which a site-specific WQO was developed, provide an appendix that documents how the recommended WQO was developed and presents all of the data that were used in the process.
7. **Proposed Effluent Quality Standards:** List the proposed EQSs. Identify proposed allocation of assimilative capacity and provide the rationale for the proposed allocation. Describe results of engagement activities to support proposed allocation. Identify and describe the specific spatial limits of any proposed mixing zones and provide the rationale for their selection.
8. **Validation and Attainment of Water Quality Objectives:** Summarize the processes and thresholds that will be used for evaluating attainment of WQOs and validating that numerical WQOs achieve the narrative WQOs.
9. **Aquatic Effects Monitoring:** Provide an overview of the Environmental Effects and Aquatic Effects Monitoring Programs that will be conducted, focusing on how the EEM program and AEMP will support validation and attainment of the WQOs.
10. **Summary and Conclusions:** Briefly summarize the document and any associated conclusions or recommendations.

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Appendix 1: Selection of Water Quality Guidelines

January 4, 2019

Prepared by Bill Slater, Slater Environmental Consulting, based on *Guidance Manual for Developing Water Quality Objectives for Freshwater Ecosystems in Yukon, Final Report, October 2016* (MacDonald et al. 2016).

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List of Abbreviations

ACR:	Acute-to-chronic ratio
BCMOE:	British Columbia Ministry of Environment
CCC:	Criterion continuous concentration
CCME:	Canadian Council of Ministers of the Environment
CMC:	Criterion maximum concentration
COPC:	Contaminant of potential concern
ECCC:	Environment and Climate Change Canada

EC_x:	Effective concentration affecting x percent of the population
FAV:	Final acute value
FCV:	Final chronic value
FEQG:	Federal Environmental Quality Guideline
GMAV:	Genus mean acute value
GMCV:	Genus mean chronic value
IC_x:	Inhibitory concentration causing and x percent inhibition in tested organisms
LC_x:	Lethal concentration affecting x percent of the population
LOEC:	Lowest observed effect concentration
MAC:	Maximum acceptable concentration
MATC:	Maximum acceptable toxicant concentration
MCL:	Maximum contaminant level
SMATC:	Species maximum acceptable toxicant concentration
SMAV:	Species mean acute value
SMCV:	Species mean chronic value
SSD:	Species sensitivity distribution
TDI:	Tolerable daily intake
USEPA:	United States Environmental Protection Agency
WQC:	Water quality criteria
WQG:	Water quality guideline
WQO:	Water Quality Objective

1.0 Introduction

Water quality guidelines (WQG) play an important role in the development of Water Quality Objectives (WQOs). For waters that are managed using the Use-Protection and Use-Restoration Approaches, adoption of WQGs is the simplest approach for deriving numerical WQOs. Derivation of numerical WQOs using the Recalculation Procedure and the Water Effect Ratio Procedure is also dependent on generic WQGs and/or the underlying toxicity data that were used to derive them. WQGs are needed to evaluate WQOs that are derived using the Background Concentration Procedure to ensure that all designated water uses will be adequately protected by WQOs that are established at background levels for a receiving waterbody. Given the importance of WQGs to the WQO-development process, it is essential to establish a consistent procedure for selecting WQGs that are applicable for Yukon waters. This appendix describes the framework for selecting WQGs for application in Yukon and provides background information on key sources of WQGs.

2.0 Recommended Procedure for Selecting WQGs

The Use-Protection and Use-Restoration approaches for water management are based on the identification of existing or expected water uses in a waterbody. WQGs are generally developed to define water quality conditions that are protective of specific uses, for example:

- drinking water;
- recreation and aesthetics;
- fish and aquatic life;
- irrigation and livestock watering;
- wildlife;
- industrial water uses.

When developing WQOs, WQGs should be identified for each designated use of a waterbody and each contaminant of potential concern (COPC). Guidelines that apply for the most sensitive use for each parameter should be selected as the relevant WQG.

Because Yukon does not have its own WQGs, the selection of applicable WQGs relies on other sources. The framework for selection of WQGs is fundamentally a hierarchy of sources, but with provisions that allow flexibility to consider WQGs that are outside of the hierarchy if they are more relevant or up-to-date.

The primary sources for WQGs to apply in Yukon are the Canadian Council of Ministers of the Environment (CCME) and Health Canada, including the following guidance and any relevant updates:

- The *Canadian environmental quality guidelines* (CCME 2016).
- The *Guidelines for Canadian recreational water quality* and *Guidelines for Canadian drinking water quality* (Health Canada 2012; 2014).

The methodologies for development of WQGs by these organizations provide the benchmark for comparison and evaluation of methodologies for other sources of WQGs.

WQGs established by the British Columbia Ministry of Environment (BCMOE) provide a secondary source for substances and/or uses where WQGs are not provided by the primary sources. BCMOE WQGs may also be used if they rely on more up-to-date toxicity testing and analysis, or are more relevant to specific conditions in a Yukon watercourse, when compared with WQGs from the primary sources.

WQGs from other sources may be used when a substance/use is not addressed by the primary or secondary sources of WQGs.

Alternative WQGs may also be used when a proponent provides a compelling rationale for applying an alternative WQG and demonstrates that the alternative WQG achieves a protection goal that is similar to the goal defined by the CCME (i.e., "*the protection and maintenance of all forms of aquatic life and all aquatic life stages in the aquatic environment for indefinite exposure periods*" [CCME 2007]). Application of an alternative WQG may be considered, for example, if the alternative WQG was developed more recently than a WQG from the primary and secondary sources, using methods that are consistent with CCME methods and incorporating updated toxicity results. An alternative may also be considered if it is more directly applicable to the aquatic characteristics of an affected water body (e.g., toxicity testing on more relevant species or life stages).

When considering application of an alternative WQG, proponents should begin by identifying all relevant WQGs for the specific substance/use, providing evidence of the range of WQGs values that may be in use. Proposals to apply alternative WQGs must always be accompanied by detailed information about the basis for the proposed WQG. This should include details about the methods and data used to derive the WQG. Sufficient information must be available to evaluate the following.

- The methodology used to derive the WQG, and the consistency of the methodology with the probabilistic (species' sensitivity distributions – SSDs) or deterministic methodologies used by the CCME.
- The relevance of the species tested for Yukon aquatic conditions. Where testing does not include Yukon species, then toxicity tests must include species that are acceptable surrogates for Yukon species.
- The type of ecotoxicity effects data that supports the WQG. CCME protocols rely on toxicity tests that evaluate survival, growth, reproduction, germination/fertilization and hatching, using laboratory tests that evaluate a single species. Guidelines developed using other types of endpoints (e.g., behavioural) or relying on toxicity-based models rather than experimental results may be less consistent with CCME guidelines.
- The ecotoxicity thresholds that are used for deriving WQGs. WQGs can be developed using a range of effect thresholds (e.g., low-effect, no-effect, and on up to lethal effects). The selection of effect thresholds considered in the data that supports the WQG will influence its effectiveness for achieving a protection goal similar to that of the CCME.
- Data reliability and quality. Applying the CCME protocol requires categorization of data into primary, secondary and unacceptable data sources. The processes used by other jurisdictions may be less rigorous in some cases.
- Minimum data requirements. The CCME establishes minimum data requirements and evaluation of alternative WQGs should consider the extent to which these have been met.
- Safety factors. Many jurisdictions apply safety factors when establishing WQGs. This includes CCME for deterministic methodologies. The evaluation of alternative WQGs needs to consider any safety factor applied, and the rationale for the selected safety factor.

- Toxicity modifying factors. Details about consideration of toxicity modifying factors when establishing a WQG will be needed to evaluation relevance to Yukon aquatic conditions, and for comparison with any CCME methods.

Proposals for application of an alternative WQG will be considered when:

- The WQG was developed using methodology that is consistent with CCME methodology and applies a compatible protection goal.
- The WQG is relevant for the characteristics of Yukon aquatic ecosystems.
- The ecotoxicity effects and thresholds in the toxicity tests used to develop the WQG are generally consistent with the types of effects and thresholds required in CCME protocols.
- The WQG incorporates more up-to-date and/or more relevant ecotoxicity data.
- The WQG incorporates consideration of relevant toxicity modifying factors.
- The WQG was developed using a more up-to-date methodology (i.e., probabilistic rather than deterministic).

The extent to which the supporting data for the WQG fulfil the minimum data requirements established by the CCME will also be an important factor when considering adoption of an alternative WQG.

WQGs from other jurisdictions should not be proposed if they were not developed using that jurisdiction’s current protocol for developing WQGs, unless there is no other WQG available. Also, WQGs from other jurisdictions should not be proposed if they have not been published (e.g., they are interim WQGs) or been subject to some form of regulatory or scientific review.

3.0 Primary WQG Sources: CCME and Health Canada

The CCME and Health Canada are the primary sources for WQGs for application in Yukon. The CCME develops environmental quality guidelines to protect the uses of water, sediment, and soil, and for the tissues of aquatic organisms in Canada. There are CCME WQGs for the protection of aquatic life and agriculture (i.e., irrigation and livestock watering). Health Canada publishes drinking water guidelines for the protection of human health and guidelines for recreational water quality. The CCME WQGs for the protection of aquatic life, and the Health Canada guidelines for drinking water are described in the following sections. These are the WQGs that are most frequently relevant in Yukon. Details about the CCME WQGs for agricultural uses are available in the *Canadian environmental quality guidelines* (CCME 2016). Details about WQGs for recreational uses are available in the *Guidelines for Canadian recreational water quality* (Health Canada 2012).

3.1 WQGs for the Protection of Aquatic Life

The narrative intent of the CCME WQGs for the protection of aquatic life is "to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term, from the negative effects of anthropogenically altered environmental parameters (e.g., pH, temperature, and dissolved oxygen) or exposures to substances via the water column" (CCME 2007). The CCME uses two approaches for deriving WQGs: Type A and Type B (CCME 2007). The application of these approaches is dictated by the available toxicity data. Type A long-term guidelines are based on statistical SSD of toxicity data that meet the acceptability requirements (CCME 2007). Each species is represented by only one point in the SSD, with the most sensitive effect/endpoint combination for a species (preferably a no-effect value) selected for inclusion in the SSD. If there is more than one comparable record for a life history stage and set of test conditions, the geometric mean of the effect concentrations is included in the SSD. If there are inadequate or insufficient toxicity data to model an SSD, yet the minimum number of toxicity studies are met, Type B guidelines are derived (CCME 2007). For deriving either type of guideline, available toxicity data for a substance are first classified as primary, secondary, or unacceptable based on criteria that assess the reliability, suitability, and usefulness of the data. Primary studies are preferred, but secondary studies can also be used in the derivation of WQGs (CCME 2007).

Although CCME (2007) states that the WQGs are intended to protect the most sensitive life stage of the most sensitive species over the long term, the Type A guideline is defined as the estimated concentration corresponding to the 5th percentile of the modelled distribution, based on the fitted SSD (CCME 2007). Therefore, by definition 5% of the species represented in the SSD may not be protected by the WQG. CCME (2007) acknowledges this issue, and attempts to compensate for it by including a protection clause. The protection clause may be invoked when there is a compelling reason to believe that the Type A long-term exposure guideline is not protecting all life stages of all species of aquatic life over an indefinite exposure period. For example:

- If a no-effect or low-effect endpoint for a species at risk is lower than the intercept of the 5th percentile to the fitted curve of the SSD, then that endpoint should be selected as the WQG. If the endpoint is a lethality endpoint (e.g., LC$_x$ – the concentration lethal to x% of the tested organisms) or has an effect level greater than 50% (i.e., EC$_x$ or IC$_x$ where $x > 50$), then a safety factor should be applied to the value to derive an appropriate guideline (CCME 2007).
- If there is an estimated LC$_x$, where $x > 15$ for any species, that falls below the proposed Type A guideline, then that value should be selected as the recommended WQG (CCME 2007).

Nonetheless, the protection clause does not protect ordinary species (i.e., species not listed as "at risk") that have EC$_x$/IC$_x$ values below the intercept of the 5th percentile to the fitted curve of the SSD. The minimum data requirements for Type A guidelines (see CCME 2007 for additional information) are:

- Three fish species, including at least one salmonid and one non-salmonid species.
- Three aquatic or semi-aquatic invertebrates (e.g., insects with an aquatic life stage), at least one of which must be a planktonic crustacean. For semi-aquatic invertebrates, the life stages tested must be aquatic.
- At least one study on a freshwater vascular plant or freshwater algal species (required for long-term guidelines, highly desirable but not necessary for short-term guidelines; CCME 2007).

When the minimum data requirements needed to derive a Type A guideline are not met, a Type B1 or B2 guideline may be derived. Type B1 and B2 guidelines are derived by applying the lowest endpoint derivation approach. A minimum number (i.e., same required data as the Type A procedure) of primary toxicity studies conducted with fish, invertebrates and plants is required to develop a Type B1 guideline (CCME 2007). From the available primary toxicity data, the lowest acceptable endpoint from a long-term exposure is used as the basis for the long-term guideline, while the lowest acceptable LC$_{50}$ or equivalent from a short-term toxicity test is used as the basis for the short-term guideline. Both of these values are divided by a safety factor (usually 10) to obtain the recommended long-term and short-term guidelines, respectively (CCME 2007). By dividing the lowest acceptable toxicity endpoint by a safety factor, the Type B1 method should protect the most sensitive species of aquatic organisms. However, this method is only used when the Type A procedures cannot be used (CCME 2007).

If there are not enough primary data available then a Type B2 guideline can be derived. The minimum data requirements can be met with primary and/or secondary data when deriving a Type B2 guideline and include:

- Two fish species, including at least one salmonid and one non-salmonid.

- Two aquatic or semi-aquatic invertebrates (e.g., insects with an aquatic life stage), at least one of which must be a planktonic crustacean. For semi-aquatic invertebrates, the life stages tested must be aquatic (CCME 2007).

The Type B2 guideline follows the same methodology as the Type B1 guideline, except either primary or secondary data can be selected as the lowest acceptable endpoint. As for a Type B1 guideline, a Type B2 short-term guideline is derived by dividing the lowest acceptable LC_{50} or equivalent from a short-term exposure by a safety factor of 10 (CCME 2007). The safety factors used to derive the guidelines are intended to account for uncertainty in the applicability of the underlying data to define guidelines that are protective of all aquatic species.

3.2 WQGs for the Protection of Drinking Water

Health Canada establishes WQGs for a variety of contaminants in drinking water, for the protection of human health. These are based on scientific research regarding the health effects and aesthetic effects, and on operational considerations for practical removal of contaminants (Health Canada 2014). A Federal-Provincial-Territorial Committee on Drinking Water establishes these WQGs for contaminants that meet the following criteria:

- Human exposure to the contaminant could lead to adverse health effects.
- The contaminant is detected frequently or could be expected to be found in a large number of drinking water supplies in Canada.
- The contaminant is detected, or could be expected to be detected, in drinking water at a level that is of possible significance to human health (Health Canada 2014).

If a contaminant does not meet all of these criteria, the Committee on Drinking Water may develop a guidance document instead of a numerical guideline. Guidance documents provide information and guidance to drinking water authorities related to contaminants, drinking water management issues, or emergency situations. For example, there is a guidance document on controlling corrosion in drinking water distribution systems (Health Canada 2014).

Establishing a WQG for drinking water requires following a documented process that includes a literature review, internal and external peer-reviews, public consultations, and Federal-Provincial-Territorial approval processes (Health Canada 2014). This results in a technical document for each contaminant that has a drinking water guideline. The technical documents provide details about the contaminant, including health effects and exposure pathways, as well as rationale for the guideline. For developing drinking water guidelines, contaminants are put into one of three classes: microbiological parameters, chemical and physical parameters, or radiological parameters (Health Canada 2014). Microbiological parameters are a high priority and guidelines take the form of treatment goals or maximum acceptable concentrations (MACs). Guidelines for chemical and physical parameters take one of three forms:

- MAC, based on health effects (e.g., for lead).
- Aesthetic objective, based on aesthetic considerations (e.g., for chloride).

- Operational guidance value, based on operational considerations (e.g., for aluminum; Health Canada 2014).

Guidelines for radiological parameters apply to routine operational conditions of water supplies and do not apply if a large amount of radionuclides are released into the environment during an emergency (Health Canada 2014). There are MACs for the natural and artificial radionuclides that are most commonly detected in Canadian drinking water sources. These MACs are based on health considerations and are established using internationally accepted equations and principles (Health Canada 2014).

4.0 Secondary WQG Source: British Columbia Ministry of Environment

The BCMOE (2015; 2016) develops WQGs to protect a variety of designated uses, including aquatic life, wildlife, agriculture (i.e., irrigation and livestock watering), industrial water supplies, recreation and aesthetics, and raw drinking water (before it is diverted or treated for domestic use; BCMOE 2016). BCMOE WQGs are intended to represent safe concentrations of a substance in water. The BCMOE definition of a guideline is "*a maximum and/or a minimum value for a physical, chemical or biological characteristic of water, sediment or biota, which should not be exceeded to prevent detrimental effects from occurring to a water use under given environmental conditions*" (BCMOE 2016). When establishing WQGs, BCMOE considers the scientific literature, existing guidelines from other jurisdictions, and environmental conditions in British Columbia (BC; BCMOE 2016). The methods of derivation of the WQGs for different designated uses are described in the following sections.

4.1 WQGs for the Protection of Aquatic Life

The BCMOE derives WQGs using a science-based approach that is intended to protect all forms of aquatic life in BC and all aquatic stages of their life cycle during indefinite exposure (BCMOE 2012). While CCME WQGs are based on the lowest endpoint derivation approach only when a limited amount of acceptable data are available (Section 3.1), BCMOE uses this type of approach as the default method when there is a robust set of good quality data (BCMOE 2012). Therefore, BCMOE WQGs are likely more conservative relative to CCME WQGs derived using an SSD-based procedure.

A minimum number of primary quality studies including fish, invertebrates, and plants is required to derive a BCMOE WQG:

- Three studies on three or more freshwater fish species resident in BC, including at least two cold-water species (e.g., trout).
- Two studies on two or more invertebrate species from different classes, one of which includes a planktonic species resident in BC (e.g., daphnid).
- One study on a freshwater vascular plant or freshwater algal species resident in BC (BCMOE 2012).

If limited data are available (meeting appropriate data requirements), then interim WQGs can be derived. From the primary studies, the lowest reliable low-effects threshold EC_x (i.e., concentration affecting x% of the tested organisms) from a long-term study is selected as the basis of the long-term average WQG, while the lowest reliable LC_{50} or EC_{50} from a short-term test is selected as the basis for the short-term maximum WQG (BCMOE 2012). An uncertainty factor is then applied to the lowest reliable effect value to derive the long-term and short-term WQGs, respectively. An uncertainty factor between two and ten is generally used, and is decided on a case-by-case basis using scientific judgment (BCMOE 2012). The magnitude of the uncertainty factor depends on the quantity of the toxicity data (e.g., tests conducted with sensitive species, measuring multiple endpoints and effects), the quality of the toxicity data (e.g., met test acceptability criteria, measured concentrations at multiple times during the test), the severity of toxic effects, and the toxicity and bioaccumulation potential of the contaminant. The uncertainty factor helps to compensate for various sources of uncertainty, including differences in toxicity among species, between field and laboratory conditions, between life-cycle stages, and due to exposure to multiple chemicals at one time (BCMOE 2012). The order of preferred endpoints for deriving a long-term BCMOE guideline is the same as for CCME (2007) Type B1 and B2 guidelines and is as follows: most appropriate EC_x/IC_x representing a low-effects threshold > EC_{15-25}/IC_{15-25} > LOEC > maximum acceptable toxicant concentration (MATC; also known as a chronic value) > EC_{26-49}/IC_{26-49} > non-lethal EC_{50}/IC_{50} > LC_{50} (BCMOE, 2012). Regression-based toxicity estimates (e.g., EC_x) are preferred to hypothesis-based toxicity values (e.g., LOEC; BCMOE 2012). See BCMOE (2012) for more details on the derivation of guidelines.

4.2 WQGs for Other Designated Uses

For designated uses other than the protection of aquatic life, BCMOE does not have formal derivation protocols. BCMOE reviews WQGs from other jurisdictions and data in the scientific literature to establish WQGs for the protection of drinking water, agriculture, wildlife, recreation and aesthetics, and industrial uses in BC. When data from the scientific literature are used as the basis of a WQG, a safety factor is applied to the reported effect concentration to account for the uncertainty associated with the toxicological study (BCMOE 2016). Often the CCME WQGs for the protection of agricultural uses are adopted or modified for use in BC (BCMOE 2016). Unless scientific data exist suggesting that wildlife are more sensitive to a COPC than livestock, the WQG for the protection of livestock is typically adopted for the protection of wildlife as well (BCMOE 2016). Disinfection is the only form of treatment for most water supplies in BC, so the raw water supply must meet the BCMOE WQGs for the protection of drinking water (BCMOE 2016). The BC Ministry of Health regulates the quality of drinking water after it is treated and supplied to the user (BCMOE 2016).

5.0 Alternative WQG Sources

This section provides information about the methodologies used by some alternative sources of WQGs, including the Federal Environmental Quality Guidelines (Environment and Climate Change Canada [ECCC] 2018) and the USEPA. These are only examples of alternative sources and any proposal to apply an alternative WQG should be based on the framework described in Section 2.0 of this Appendix.

5.1 Federal Environmental Quality Guidelines

ECCC has established Federal Environmental Quality Guidelines (FEQGs) for several substances with a focus on substances for which CCME WQGs do not yet exist. The FEQGs are intended to establish "*a concentration so that where the concentration of a given chemical is at or below the FEQG, there is low likelihood of direct adverse effects from the chemical on aquatic life exposed via the water or sediment, or where chemicals may bioaccumulate, in wildlife (birds and mammals) that consume aquatic life*" (ECCC 2018).

FEQGs are developed using approaches that are consistent with CCME, though minimum data requirements may not always be met. *A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life 2007* (CCME 2007) is compatible with the process used to develop the FEQGs. Guidelines can be developed using methodologies consistent with either Type A or Type B CCME methodologies, depending on the amount and quality of data available. Peer review is considered an essential part of the process for developing FEQGs (ECCC 2018).

5.2 United States Environmental Protection Agency Water Quality Criteria and Drinking Water Standards

The USEPA establishes acute and chronic national ambient water quality criteria (WQC) for the protection of aquatic life in American waters. Drinking water standards for the protection of human health are also established by USEPA. Brief descriptions of the methods used to derive WQC and drinking water standards are provided in the following sections.

5.3 Water Quality Criteria

The USEPA establishes acute and chronic national ambient WQC for the protection of aquatic life in American waters. The USEPA WQC are developed by evaluating relationships between the concentrations of contaminants in water and their effects on aquatic organisms and are used by federal, state, tribal, and other agencies to create water quality standards and control releases of pollutants to the environment. These national criteria are developed based on the assumption that aquatic ecosystems can withstand some stress and tolerate occasional adverse effects (Stephan et al. 1985). By design, the national criteria are intended to protect 95% of tested taxa (Stephan et al. 1985).

The USEPA WQC are derived using data generated from standard toxicity tests and the methodology described in Stephan et al. (1985). First, all of the available data on the toxicity and bioaccumulation of the substance to aquatic organisms are compiled. These data must be accompanied by sufficient information to allow the reviewer to evaluate acceptability of test procedures and conclude that the data are reliable and useable. In order to help ensure that species representative of the aquatic community are included in the data set, Stephan et al. (1985) established minimum data requirements for the derivation of USEPA WQC. Numerical criteria are not developed for substances for which the minimum data requirements are not met. The acute and chronic USEPA WQC have distinct derivation methods. The procedures for deriving acute and chronic USEPA WQC are briefly described separately in the following sections.

5.3.1 Acute Water Quality Criteria

The acute WQC, referred to as the criterion maximum concentration (CMC), is defined as the 1-hour average concentration of a substance in water that should not be exceeded more than once within a three-year period in order to protect against adverse effects on aquatic life. To derive the CMC, data generated from acute toxicity tests, including LC_{50}s and/or EC_{50}s, are required for a minimum of eight diverse taxonomic groups (see Stephan et al., 1985 for further details). These data must meet the usability criteria outlined in Stephan et al. (1985), for example, tests conducted using procedures outlined in ASTM methods documents, acceptable control mortality, and total organic carbon in dilution water < 5 mg/L. A species mean acute value (SMAV) is determined for each species, calculated as the geometric mean of the effect concentrations (i.e., LC_{50}/EC_{50}) from short-term (i.e., < 96-hours) toxicity tests performed under flow-through conditions (with the exception that static-renewal is acceptable for daphnids) in which the concentration of the test analyte was measured at appropriate intervals. If no studies meet these test conditions, the SMAV is calculated using all available test results including using the results from static or static-renewal tests, and results in which nominal concentrations were presented (i.e., concentrations of the test analyte were not measured at appropriate intervals during the test). A genus mean acute value (GMAV) is then determined for each genus, calculated as the geometric mean of the SMAVs. The GMAVs are ranked from lowest to highest, and the four GMAVs closest to the 5th percentile are used to determine the final acute value (FAV). The FAV is then divided by two to obtain the CMC.

5.3.2 Chronic Water Quality Criteria

The chronic WQC, referred to as the criterion continuous concentration (CCC), is defined as the 4-day average concentration of a substance in water that should not be exceeded more than once within a three-year period in order to protect against sub-lethal effects on aquatic organisms. To derive the CCC, low-effect thresholds generated from longer-term toxicity tests (i.e., > 96-hours), including EC_{15-25} and MATCs (also known as chronic values, and defined as the geometric mean of the NOEC and LOEC) are used. The chronic dataset needs to include data from toxicity tests that demonstrate a reduction in survival, growth, or reproduction associated with exposure to the COPC. The method used to calculate the CCC is dependent on the number of taxa represented in the chronic dataset. If sufficient chronic data are available to meet the minimum eight diverse taxonomic groups listed in Stephan et al. (1985), the final chronic value (FCV) is determined by calculating the species mean chronic values (SMCVs) for each tested species, as the geometric mean of the low-effect concentrations from toxicity tests that meet the data usability criteria. A genus mean chronic value (GMCV) is then determined for each genus, calculated as the geometric mean of the SMCVs. The GMCVs are ranked from lowest to highest, and the four GMCVs closest to the 5th percentile are used to determine the FCV. Otherwise, the FCV can be derived by dividing the FAV by the ACR, using data from a minimum of three taxa (see Stephan et al., 1985 for methods for calculating the ACR). The FCV is used directly as the CCC.

5.3.3 Drinking Water Standards

The USEPA sets two types of drinking water standards to control the concentration of contaminants in drinking water in the United States (USEPA, 2016c). National primary drinking water regulations define legally-enforceable Primary Standards for public water systems. Primary Standards are written as maximum contaminant levels (MCLs) or treatment technique rules. They limit the concentrations of certain contaminants that are known or anticipated to occur in water in public water systems and that can have adverse effects on human health (USEPA, 2016c). National secondary drinking water regulations are non-enforceable Secondary Standards that are recommended, but are not required to be met. Secondary Standards are guidelines for limiting the effects of contaminants that may cause cosmetic effects (e.g., tooth discolouration) or aesthetic effects (e.g., taste, odour, colour) in drinking water (USEPA, 2016c). Secondary Standards can also include guidance based on corrosion, staining, scaling, and sedimentation (USEPA 2016b).

The first step in setting Primary Standards is establishing an MCL goal. Allowing for a margin of safety, no known or anticipated adverse effects on human health would occur at or below the MCL goal, but might occur above it. Maximum contaminant level goals are non-enforceable goals based on health effects only, not on treatment technology or detection limits (USEPA 2016c). Enforceable Primary Standards are then established by USEPA to be as close to the MCL goal as technically possible, taking into consideration cost and the best available technology. These enforceable standards are usually MCLs, which are the maximum level of a contaminant that is allowed in water that is delivered to users through a public water system (USEPA 2016c). If there is not an economically and technically feasible way to meet standards for a contaminant at concentrations that would cause no public health concern, then a “treatment technique” is established instead of an MCL. A treatment technique is an enforceable protocol or level of technological performance that must be followed to ensure a contaminant is controlled (USEPA 2016c).

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Appendix 2: Background Concentration Procedure

December 30, 2019

Prepared by Bill Slater, Slater Environmental Consulting, based on *Guidance Manual for Developing Water Quality Objectives for Freshwater Ecosystems in Yukon, Final Report, October 2016* (MacDonald et al. 2016).

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List of Abbreviations

BCP:	Background concentration procedure
BTMF:	Bioavailability and toxicity modifying factors
CCME:	Canadian Council of Ministers of the Environment
COPC:	Contaminant of potential concern
TSS:	Total suspended solids
UCLM:	Upper confidence limit of the mean
WQO:	Water Quality Objective

Glossary of Terms

Background concentration procedure: A method for developing water quality objectives that are based on the natural background concentrations of Contaminants of Potential Concern in water as determined through implementation of a background monitoring program.

Background water quality: Water quality conditions in a waterbody before the onset of any effects of local human activities. Characterization of these water quality conditions can be developed based on conditions in the potentially affected waterbody before the onset of human disturbance that affects water quality, or on conditions in upstream areas or reference areas.

Baseline water quality: Water quality conditions in a waterbody before the initiation of any project activities that may affect water quality. Baseline water quality is equivalent to background water quality if the water quality in the waterbody is not already measurably affected by local human activities.

Water quality objectives: Thresholds of acceptable water quality conditions in specific receiving waters that may be affected by a project, including both narrative descriptions of expectations for acceptable water quality conditions and numerical benchmarks that define specific chemical or physical characteristics of acceptable water quality.

1.0 Introduction and Overview of the Background Concentration Procedure

This appendix describes the methods for, and application of, Background Concentration Procedure (BCP) for deriving numerical Water Quality Objectives (WQOs) that are based on the background water quality conditions in a waterbody.

1.1 When to Apply the BCP

The BCP can be applied for all Water Management Approaches, as follows:

- The BCP is the only method specified for the Non-Degradation Approach, and must rely on baseline water quality.
- The BCP is one of several methods that may be applied for the Use-Protection Approach, where it must rely on background water quality.
- The BCP may be applied to define initial stage WQOs for the Use-Restoration Approach, and may rely on baseline water quality in affected waterbodies. WQOs derived using the BCP and background water quality may be relevant for later stages of the Use-Restoration approach.

1.2 Overview of the BCP

The BCP relies on a comprehensive understanding of baseline and/or background water quality conditions in potentially affected waterbodies, specifically the concentrations of Contaminants of Potential Concern (COPCs) in water. Numerical WQOs derived using the BCP must be established at levels that are reflective of either:

- Background water quality if the procedure is applied in the Use-Protection Approach, or
- Baseline water quality if the procedure is applied in the Non-Degradation or Use-Restoration Approach.

Information, collected as part of a baseline/background monitoring program (Appendix 6), is used to define acceptable water quality conditions for a waterbody. The BCP relies on a good understanding of both upper limit and central tendency concentrations of COPCs (both dissolved and total forms) for establishing WQOs that are applicable to site-specific conditions. To support this level of understanding and reduce uncertainty about the applicability of WQOs when using the BCP Yukon requires a data set that includes at least three consecutive years of recent water quality data with monthly sample collection. The monthly samples must be augmented by one or more annual intensive sampling programs, collecting at least 5 samples in

30 days during periods of highest natural variability. In most cases, the period of highest variability will occur during freshet.

Appendix 6 (Section 1.2) describes three broad approaches for designing monitoring programs to understand background conditions, relying on water quality data from one of the following:

- Background water quality in the relevant waterbody.
- Water quality data from upstream locations.
- Water quality data from appropriate reference locations.

Determination of the most appropriate method for establishing background water quality requires consideration of a number of factors related to the waterbody. For example, one of the major difficulties associated with the implementation of the BCP relates to the variability of water quality over time and space. Flowing waters can be subject to large variations in water quality on daily, seasonal, and annual bases (Clark et al. 2010). In these types of water bodies, substantial sampling effort is required to accurately define background water quality. In addition, it may be difficult to identify suitable reference sites in areas that have been influenced by anthropogenic activities for extended time periods (e.g., in areas affected by mining or urban development; Runnels et al. 1992; SFF 2008). In such cases, it may be necessary to identify nearby reference areas with similar geological, topographical, physiographical, climatological and ecological features to define background levels of naturally-occurring substances.

Using the BCP, numerical WQOs are derived by conducting statistical analyses of the surface water chemistry data that have been collected to define background water quality for COPCs. As a first step, the background water quality data are examined and, if necessary, sorted into relatively homogenous populations (e.g., turbid-flow vs. clear-flow conditions, or high-flow vs. low-flow conditions, etc.). For metals and certain nutrients (e.g., phosphorus), variability in the underlying data can be reduced by considering the dissolved form of each element. Decisions about the form of a contaminant to use when applying the BCP need to consider which form(s) of the contaminant are biologically relevant or may affect a designated use, which form(s) of the contaminant will be released by the project, and whether the form of the contaminant may change upon release or in the mixing zone (e.g., oxidation resulting in precipitation). If the mine will be discharging a contaminant in dissolved form, then a WQO developed using the BCP should usually be based on dissolved concentrations of the contaminant in the baseline or background conditions. Also, concentrations of dissolved forms may be less variable in the baseline or background data set, potentially eliminating the need to establish WQOs that vary seasonally or for different flow regimes.

The one-tailed 95% upper confidence limit of the mean (UCLM) and the 95th percentile concentration are calculated for each water quality variable for each population of data. These statistics are then adopted as the average and maximum preliminary WQOs, respectively. Final WQOs are confirmed after comparison with WQGs and, in some instances, consideration of the form of COPCs associated with a project.

2.0 Deriving Water Quality Objectives Using the BCP

Application of the BCP involves the following 4 Steps:

1. Determine Background Water Quality Conditions
2. Evaluate Surface Water Chemistry Data
3. Derive Preliminary Water Quality Objectives
4. Finalize Recommended Water Quality Objectives

The Sections below describe each of these steps. Additional guidance on the BCP methodology is provided in CCME (2003) and MacDonald (1997).

2.1 Determine Background Water Quality Conditions

The first step in the BCP WQOs-derivation process involves determination of baseline/background water quality conditions for the waterbody under consideration. This step in the process necessitates design and implementation of a baseline/background monitoring program at the site under consideration. Baseline/background monitoring programs need to evaluate the temporal and spatial variability of water quality conditions, which requires collection of at least three years of data for water quality variables. Both total and dissolved forms of contaminants should be included. Appendix 6 provides guidance on the design and implementation of baseline monitoring programs to support WQOs development in Yukon.

2.2 Evaluate Surface Water Chemistry Data

The BCP, like all other WQO development procedures, requires a careful evaluation of data quality.

If not already addressed by the data performance and acceptance criteria, the following rules should be applied when evaluating datasets for use in the BCP:

- Less-than-detection-limit results may be used in the derivation of WQOs using the BCP provided that detection limits are <0.1 times the Water Quality Guidelines for the most sensitive water use and less-than-detection-limit values do not comprise more than 30% of the data records for a COPC. If data do not meet these standards, application of the BCP must be accompanied by a rationale for why the data set is suitable.
- Numeric values may be substituted for less-than-detection-limit results to support the derivation of WQOs using the BCP. However, substitution of zero values or the detection limit is not recommended. One-half the detection limit may be used in the substitution process or alternative methods that are clearly described and rationalized may be used.

2.3 Derive Preliminary Water Quality Objectives

In the third step of the BCP WQOs-derivation process, preliminary WQOs are derived based on an analysis of the baseline/background water quality data. A series of analyses should be conducted using the baseline/background water quality data that were collected at the site, including:

- Develop figures or tables that illustrate months and years of sampling events for each COPC. These figures provide a basis for confirming if minimum data requirements have been met for all COPCs.
- For each COPC, plot the measured concentrations against the ordinal date. These plots should provide a basis for identifying general patterns of water quality, including both within year and between year variability. This information should be used to support subsequent data analyses.
- For COPCs with concentrations that are substantially different at different times of the year, plot the measured concentrations against flow and/or total suspended solids (TSS) concentrations. These plots should provide a basis for identifying baseline/background concentrations of COPCs that are correlated with TSS concentration and those that are likely correlated with groundwater inflows (i.e., concentrations are highest during baseflow conditions).
- For each COPC, determine if the variability in the underlying data can be reduced by normalizing concentrations to other variables (e.g., TSS concentration) and/or considering an alternative form of the substance (e.g., dissolved metal vs. total metal). Where background/baseline data are heavily correlated with TSS, WQOs based on concentrations of dissolved contaminants should be established if dissolved forms are known to be the cause of effects on designated uses, and the proposed project will discharge contaminants in dissolved form. Establishment of WQOs for both total and dissolved forms of contaminants may also be warranted in some cases.

Using the results of the preliminary data analyses, it should be possible to identify relatively homogenous populations of data for each COPC (e.g., turbid-flow period; clear-flow period; August to March; etc.). Numerical WQOs should be derived for each COPC using the data that comprise the relatively homogenous populations. Specifically, the average WQO and maximum WQO for each COPC are calculated by determining the central tendency (i.e., one-tailed 95% UCLM) and upper limit (i.e., 95th percentile) of COPC concentrations of the selected background water quality dataset, respectively. To maintain transparency in the WQOs-derivation process and support independent analyses of underlying data, it is essential that the results of the data evaluation be reported, that any decisions to remove data from the baseline data set be fully documented, that all data transformation procedures be completely described and rationalized, and that all of the underlying data be provided to reviewers in a readily-accessible electronic format.

2.4 Finalize Recommended Water Quality Objectives

The final step in deriving WQOs using the BCP requires consideration of Water Quality Guidelines (WQGs) and the forms of COPCs that may be released from quartz mining projects versus the forms that may be present in a potentially affected waterbody. WQGs for all relevant water uses should be considered. If a preliminary WQO derived using the BCP is higher than the applicable WQG for the waterbody, it is important to confirm that the form of COPC that will be released is the same as the form that is naturally present in the affected waterbody. Potential changes in COPC forms (e.g., oxidation of iron) once they are released may also need to be considered.

The forms of COPCs (e.g., dissolved vs. total metals, or different valence forms of COPCs) can substantially influence how they affect environmental receptors. Also, the underlying toxicity tests used to derive the generic WQGs are usually conducted using dissolved substances. Concentrations of total metals are also highly variable and often depend on water flow or concentrations of suspended sediments. As a result, WQOs developed using the BCP may not be applicable for dissolved COPC releases from a mine where the WQOs rely on total COPC concentrations in the affected waterbody. Similar issues may arise where the toxicity of different valence forms of substances varies, for example chromium III versus chromium VI.

Unless a preliminary WQO developed using the BCP is lower than the relevant WQG, WQOs derived using the BCP should be based on the same form of COPC that will be released by a proposed project. For example, if a project is expected to release metals in dissolved form, then the BCP should be applied using dissolved concentrations of COPCs in the potentially affected waterbody. If a project may produce COPCs in multiple forms, then WQOs should address the form that is of greatest concern. Alternatively, multiple WQOs may be needed.

This step should begin with a systematic comparison of preliminary WQOs (both central tendency and upper limit) to relevant WQGs, relying on the WQGs selected in accordance with Appendix 1, "*Selection of Water Quality Guidelines*." For some substances, the WQGs may need to be adjusted to account for bioavailability and toxicity-modifying factors (BTMF). In making these adjustments, conservative estimates of the concentrations of the BTMF should be used (e.g., the lower 95% confidence limit of the mean for water hardness for the corresponding time period when the WQGs for metals are adjusted). The WQG for the most sensitive water use for each water quality variable is then identified to support evaluation of the preliminary WQOs.

If the preliminary WQOs derived using the BCP are lower than the WQGs, then these can be recommended as final WQOs. On the other hand, if any preliminary WQO is higher than the WQG, the derivation described in Section 2.3 should be repeated, relying on background water quality for the specific form of COPCs that will be released from the proposed project. If this results in a lower WQO, then the WQO for the specific form of COPC should become the final WQO if it still exceeds the WQG.

When finalizing WQOs for the Non-Degradation approach, the one-tailed 95% UCLM and the 95th percentile concentrations for the COPC or specific form of the COPC represent the average and maximum WQOs respectively. In the Use-Protection approach, these statistics can also be adopted as the average and maximum preliminary WQOs, provided that the average WQO exceeds the WQG. If the WQG exceeds the average WQO, then the WQG may be adopted as an average WQO.

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Appendix 3: Recalculation Procedure

December 30, 2019

Prepared by Bill Slater, Slater Environmental Consulting, based on *Guidance Manual for Developing Water Quality Objectives for Freshwater Ecosystems in Yukon, Final Report, October 2016* (MacDonald et al. 2016).

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List of Abbreviations

BCMOE:	British Columbia Ministry of Environment
BTMF:	Bioavailability and toxicity modifying factors
CCME:	Canadian Council of Ministers of the Environment
COPC:	Contaminant of potential concern
EC_x:	Effective concentration affecting x percent of the population
LC_x:	Lethal concentration affecting x percent of the population
LOEC:	Lowest observable effect concentration
USEPA:	United States Environmental Protection Agency
WQG:	Water quality guideline
WQO:	Water Quality Objective

1.0 Introduction and Overview of the Recalculation Procedure

This appendix describes the methods for, and application of, the Recalculation Procedure for deriving numerical Water Quality Objectives (WQOs) that are directly relevant to the aquatic organisms that are, or ought to be, present in a waterbody. The appendix describes the key steps involved in the Procedure and Annex 1 provides three case studies to illustrate its application.

1.1 When to Apply the Recalculation Procedure

The Recalculation Procedure can be applied when using the Use-Protection or Use-Restoration Approach for water management:

- When using the Use-Protection Approach, the application of the Recalculation Procedure must consider species that are, or ought to be, present in a waterbody.
- When using the Use-Restoration Approach, WQOs developed using the Recalculation Procedure may be part of a staged approach. Initial application of the Procedure may consider only those species that are currently present. As restoration progresses, WQOs derived using the Recalculation Procedure could be refined to consider additional species that were previously present in the waterbody, or would be expected to be present in the waterbody.

The Recalculation Procedure should be considered when it can be demonstrated that the species represented in the toxicological dataset used to derive the Water Quality Guidelines (WQGs) are not representative of the species that occur in the waterbody.

Because the Recalculation Procedure is based on datasets used to develop WQGs, the Procedure can only be used if there are WQGs for all designated water uses for a waterbody, unless it can be demonstrated that the available guidelines include the most sensitive water uses (protection of fish and aquatic life is generally the most sensitive water use).

1.2 Overview of the Recalculation Procedure

The *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2007a) are intended to protect all life stages of all aquatic species that occur in Canadian waters against long-term exposures to contaminants. To achieve this goal, all of the available data in the scientific literature on the toxicity of a contaminant to aquatic organisms are acquired and evaluated. Data that meet the CCME's selection criteria are compiled in a toxicological database and used to derive the WQG. This process is guided by *A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2007b). Numerical WQGs derived using the approved protocol are considered to be generally applicable at sites located throughout the country. However, for several reasons the toxicological dataset used to develop the WQG may not provide an appropriate level of protection at a specific site, including:

- The WQG may have been derived a number of years ago, in which case it may not have been derived using the current protocol or it may have been based on an incomplete toxicological dataset. In this case, an alternative WQO may developed that is specifically applicable for protection for the species that occur at the site.
- The toxicological dataset upon which the WQG is based may include data on sensitive species of aquatic organisms that do not occur at the site under consideration. In this case, a higher WQO may provide adequate protection for the species that occur at the site.
- The toxicological dataset upon which the WQG is based may not include data on sensitive species of aquatic organisms that occur at the site under consideration (e.g., freshwater mussel species). In this case, a lower WQO may be required to provide adequate protection for the species that occur at the site.

The Recalculation Procedure is a method for refining the toxicological dataset that underlies a WQG to derive WQOs that are more directly applicable to a specific waterbody. In this way, the Recalculation Procedure accounts for any real differences between the sensitivity range of the species of aquatic organisms represented in the complete toxicological dataset that was assembled to support WQG development and the sensitivities of the species that occur or ought to occur in the specific waterbody (USEPA 1983; 2014; MacDonald 1997; BCMOE 2013; CCME 2003; SWRCB 2003).

Using this procedure, data on species that are not resident in the waterbody may be eliminated from the dataset that was assembled to formulate the WQG. In addition, the toxicological dataset should be refined to include species that were not considered during development of the WQG. In both cases, the underlying toxicological dataset that was assembled to support WQG derivation should be updated to include toxicity data that have been published in the literature since the WQG was derived. Following refinement of the toxicological dataset, a site-specific WQO is calculated using the same methodology that was employed to derive the WQG.

The Recalculation Procedure may be used to derive site-specific WQOs only if the revised data set still meets minimum data requirements established for formulating Canadian WQGs (CCME 1991; CCME 2007b). For many substances, the data required to derive the site-specific WQOs are likely to be available in the toxicological dataset that was used to develop the WQGs. Additional data can often be compiled from the scientific literature by searching for results that have been published since the WQG was produced. If the minimum data requirements are not met or if sensitive species occur at the site that are not reflected in the toxicological dataset, data can be generated by conducting acute and/or chronic toxicity tests on resident or indicator species. Thus, the Recalculation Procedure provides a method to derive site-specific WQOs for many substances

There are several limitations that should be considered with applying the Recalculation Procedure. First, when WQGs are derived using species sensitivity distributions (CCME, 2007b), reductions in the number of families represented in the toxicological data can result in a lowering of the WQO. This is particularly evident when the four most sensitive species remain unchanged. Second, elimination of information on non-resident species from the dataset may necessitate the generation of additional toxicological information on resident species to support the derivation of site-specific WQOs. Depending on the number of species and chemicals for which data are required, this process could be costly and time-consuming.

Finally, the Recalculation Procedure does not directly consider bioavailability and toxicity modifying factors (BTMF) and does not account for multiple uptake routes, pulsed doses, or non-steady state conditions. However, there are methods for integrating BTMF into the resultant WQOs. Where a strong science-based rationale can be provided, WQOs may be modified to account for levels of the factors that are considered to affect the bioavailability and/or toxicity of a substance that are different than those that were used in the development of the WQGs. For example, the preliminary WQO for copper could be modified to account for high levels of humic acids in a waterbody in some circumstances.

2.0 Deriving Water Quality Objectives Using the Recalculation Procedure

Application of the Recalculation Procedure involves the following seven Steps:

1. Identify Species That Occur or Ought to Occur.
2. Acquire and Evaluate the Toxicological Dataset Used to Derive WQG.
3. Compile and Evaluate Additional Toxicity Data.
4. Compile the Complete Toxicological Dataset.
5. Develop the Site-Specific Toxicological Dataset.
6. Derive Preliminary Numerical WQOs.
7. Finalize Recommended Numerical WQOs.

The Sections below describe each of these steps. Additional guidance on the Recalculation Procedure methodology is provided in CCME (2003) and MacDonald (1997).

2.1 Identify Species that Occur or Ought to Occur

The first step in the application of the Recalculation Procedure is to assemble a list of the taxonomic groups that occur or ought to occur in the waterbody. Usually, development of such a list requires intensive sampling at the site and/or extensive sampling at nearby reference sites to evaluate temporal and spatial distributions of aquatic organisms. Information on the distribution of aquatic-dependent wildlife species may be obtained from the scientific literature and by conducting wildlife surveys in the vicinity of the site. Guidance on the design and implementation of biological sampling programs is provided in Cavanagh et al. (1998) and BCMOE (2009). When the biological survey at the site is complete, a detailed list of aquatic species that occur or ought to occur at the site is compiled. For the purpose of WQOs derivation, the aquatic species that occur at the site include those taxonomic groups (i.e., genera, families, orders) that:

- Are usually present at the site.
- Are seasonally present at the site (e.g., due to migration patterns).
- Are intermittently present at the site because they periodically return to or extend their range into the site.
- Would usually be present at the site, but are not currently due to the presence of degraded conditions.
- Are present in nearby reference sites and, hence, are likely to use habitats at the site, even if they have not been observed at the site (see INAC, 2009) for specific guidance on reference site selection).

- Were present at the site in the past.

2.2 Acquire and Evaluate the Toxicological Dataset Used to Derive WQG

The second step in applying the Recalculation Procedure involves compilation and evaluation of the aquatic toxicity data that were assembled to support the derivation of the generic WQG. The information that must be compiled for each study as identified in CCME (2007b) and includes:

- Study design (e.g., flow-through, renewal, single species, mesocosm).
- Species and life stages tested.
- Endpoints measured (e.g., survival, growth, reproduction).
- Duration of exposure (e.g., 96-hours).
- Concentrations of BTMF.
- Effect values determined or calculated (e.g., LC_{50}; EC_{20}; lowest observed effect concentration [LOEC]).
- Reference (i.e., the source of the toxicity data).

Once the dataset has been compiled, it should be evaluated to assess its adequacy for developing a WQO. Dated or limited toxicological datasets should be considered to be inadequate for supporting application of the Procedure. In addition, the toxicological dataset should be considered to be of uncertain relevance to the site if key taxa that occur at the site are not reflected in the dataset (e.g., freshwater mussels). Furthermore, the relevance of the dataset to the site may be questioned if the four most sensitive species tested were not found at the site. Datasets that are considered to be incomplete or of uncertain relevance to the site under consideration must be updated prior to WQOs derivation.

2.3 Compile and Evaluate Additional Toxicity Data

Step 3 of the Recalculation Procedure entails a thorough review of the scientific literature to obtain more recent information on the toxicity of the Contaminants of Potential Concern (COPCs) to aquatic organisms, including aquatic plants, aquatic invertebrates, fish, and amphibians. The results of the literature search should be used to identify aquatic toxicity studies that could be used to augment the toxicological dataset that was used to derive the WQG(s). The steps that are undertaken to acquire supplemental toxicity data on the COPCs must be reported and included in the documentation of the WQOs. The same information as that listed for the existing dataset (Section 2.2) should be compiled for additional toxicity data.

Following identification and retrieval of potentially-relevant studies, each candidate study needs to be evaluated using the selection criteria for primary and secondary data described in CCME (2007b). The following information must be provided for studies to qualify as primary or secondary data:

- Study design (e.g., flow-through, renewal, single species, mesocosm).
- Species and life stages tested.
- Endpoints measured (e.g., survival, growth, reproduction).
- Duration of exposure (e.g., 96-hours).
- Test conditions (i.e., water type used, temperature, conventional variables, solvents used, and concentrations of BTMF).
- Test concentrations.
- Test containers.
- Solubility limit of substance.
- Experimental design (e.g., analytical methods, quality assurance/quality control; replication).
- Data analysis methods (i.e., statistical methods).
- Effect values determined or calculated (e.g., LC_{50}; EC_{20}; LOEC).

2.4 Compile the Complete Toxicological Dataset

The fourth step in the Recalculation Procedure is to integrate any toxicity data that meet the selection criteria described in CCME (2007b) into the project database, along with the toxicological dataset that was used to generate the generic WQG. The objective of this step of the process is to ensure that the project database includes all of the toxicity data that could be relevant for deriving generic WQGs or site-specific WQOs. Therefore, all of the available toxicity data must be compiled into the project database, regardless of whether or not the tested species occurs at the site under consideration. It is expected that reviewers will critically evaluate the project database to ensure that all of the potentially-relevant toxicity data were compiled and that the underlying assumptions and decisions relative to each dataset were reasonable.

2.5 Develop the Site-specific Toxicological Dataset

In the fifth step of the Recalculation Procedure, refine the toxicological dataset for each COPC to enhance its relevance to the site. At this stage of the process, the toxicity data on the taxonomic groups or life stages that have not occurred, do not occur, and are not expected to occur at the site may be eliminated from the toxicological dataset in accordance with the following rules:

1. Toxicity data on species that are known to occur or have the potential to occur at the site may not be excluded from the toxicological dataset.
2. In assessing the potential for a species to occur at a site, information should be consulted on the historical and contemporary distribution of the species in Canada. For example, Freshwater Fishes of Canada (Scott and Crossman 1973) provides excellent information on the distribution of fish species. Information on the distribution of freshwater fish is also available on the internet (e.g., http://www.env.gov.bc.ca/fish and

www.fishbase.org). Data from field studies conducted at and nearby the site may also be used to identify site receptors.

3. If a member of a family of freshwater fish occurs or could occur at a site (e.g., rainbow trout from the family Salmonidae), then the toxicity data on any of the fish species within that family (e.g., rainbow trout, coho salmon, lake whitefish, arctic grayling, arctic char) must be included in the site-specific toxicological dataset. In some cases, it may be appropriate to include all of the available toxicological data on coldwater fish species or warmwater fish species in the site-specific toxicological dataset.
4. If a member of a family of amphibians occurs or could occur at a site (e.g., bullfrog from the family Ranidae), then the toxicity data on any of the amphibian species within that family (e.g., bullfrog, green frog, leopard frog) must be included in the site-specific toxicological dataset.
5. If a member of a class of freshwater invertebrates occurs or could occur at a site (e.g., water flea from the family Bosminidae), then the toxicity data on any of the invertebrate species within that class (e.g., water fleas, copepods, ostracods) must be included in the site-specific toxicological dataset.
6. If a member of a phylum of freshwater algae occurs or could occur at a site (e.g., *Chlamydomonas debaryana* from the phylum Chlorophyta), then the toxicity data on any of the algal species within that phylum (e.g., *Chlamydomonas debaryana*, *Chlorella variegata*, *Stichococcus bacillaris*) must be included in the site-specific toxicological dataset.
7. If a life stage of an aquatic organism does not occur and is not expected to occur at the site (e.g., eggs and alevins of rainbow trout are not expected to occur at sites with soft bottom sediments), then the toxicity data on that life stage may be excluded from the site specific toxicological dataset, provided that the data point is not the sole entry for a species or family that is known or expected to occur at the site.

The trimmed toxicological dataset is examined to determine if it meets the minimum data requirements for deriving WQGs defined in CCME (1991; 2007b), repeated in Tables 1 and 2. If the minimum data requirements are not met, an alternative procedure for deriving WQOs may be selected.

Alternatively, additional toxicity testing may be conducted to obtain the information necessary to support use of the Recalculation Procedure. Toxicity tests may be conducted on resident or appropriately-selected surrogate species in laboratory water and must meet the selection criteria described in CCME (2007b). Section 4.3.5 of the main Guide, describing the Resident Species Procedure also provides additional guidance about selection of relevant toxicity tests. Toxicity tests must be supported by adequate QA/QC procedures, including acceptable control and reference toxicant tests. Specific information on toxicity testing procedures is provided in ASTM International (2016a; 2016b; 2016c), Environment Canada (1996; 2000; 2007a; 2007b; 2007c; 2007d; 2011), and USEPA (2002a; 2002b; 2011).

This step in the process culminates in the development of a toxicological dataset that includes all of the data relevant to the toxicity of the COPC to all of the life stages of all of the aquatic plants, aquatic invertebrates, fish, and amphibians that have occurred, currently occur, or ought to occur in the waterbody.

2.6 Derive Preliminary Numerical WQOs

The sixth step of calculating preliminary numerical WQOs can proceed if the dataset meets the minimum data requirements for deriving numerical WQGs. Preliminary WQOs are calculated using the procedure outlined in the formal protocol for deriving WQGs for the protection of aquatic life (CCME, 1991;, 2007b). Both maximum and average WQOs can be derived using the protocol described by CCME (2007b). The maximum WQO should be derived using acute toxicity data (exposure duration < 96-hours), and the average WQO should be derived using chronic toxicity data (i.e., exposure duration > 96-hours).

2.7 Finalize Recommended Numerical WQOs

In the final step of the Recalculation Procedure, the preliminary WQOs are compared with the data collected to establish baseline conditions at the site. The preliminary WQOs should be adopted for use at the site if they are feasible to implement relative to baseline conditions at the site, as follows:

- If the preliminary maximum WQO exceeds the upper limit of baseline concentrations [i.e., 95th percentile], and
- If the preliminary average WQO exceeds the estimate of central tendency of baseline concentrations [i.e., 95% upper confidence limit of the mean]).

An alternative procedure for deriving numerical WQOs should be applied if it is not feasible to implement the preliminary WQOs that were developed using the Recalculation Procedure because the baseline conditions already exceed the preliminary WQOs.

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Table 1: Minimum data set requirements for the derivation of a long-term exposure guideline for freshwater environments (CCME 2007).

<table>
<tr><th></th><th colspan="3">Guide</th></tr>
<tr><th>Group</th><th>Type 1</th><th>Type B1</th><th>Type B2</th></tr>
<tr><td>Fish</td><td colspan="2">Three species, including at least one salmonid and one non-salmonid.</td><td>Two species, including at least one salmonid and one non-salmonid.</td></tr>
<tr><td>Aquatic Invertebrates</td><td colspan="2">Three aquatic or semi-aquatic invertebrates, at least one of which must be a planktonic crustacean. For semi-aquatic invertebrates, the life stages tested must be aquatic.
It is desirable, but not necessary, that one of the aquatic invertebrate species be a mayfly, caddisfly, or stonefly.</td><td>Two aquatic or semi-aquatic invertebrates, at least one of which must be a planktonic crustacean. For semi-aquatic invertebrates, the life stages tested must be aquatic
It is desirable, but not necessary, that one of the aquatic invertebrate species be a mayfly, caddisfly, or stonefly.</td></tr>
<tr><td>Aquatic Plants</td><td colspan="2">At least one study on a freshwater vascular plant or freshwater algal species.
If a toxicity study indicates that a plant or algal species is among the most sensitive species in the data set, then this substance is considered to be phyto-toxic and three studies on nontarget freshwater plant or algal species are required</td><td>Toxicity data for plants are highly desirable, but not necessary.
If a toxicity study indicates that a plant or algal species is among the most sensitive species in the data set, then this substance is considered to be phyto-toxic and two studies on nontarget freshwater plant or algal species are required.</td></tr>
<tr><td>Amphibians</td><td colspan="2">Toxicity data for amphibians are highly desirable, but not necessary. Data must represent fully aquatic stages.</td><td>Toxicity data for amphibians are highly desirable, but not necessary.
Data must represent fully aquatic stages.</td></tr>
<tr><td>Preferred Endpoints</td><td>The acceptable endpoints representing the no-effects threshold and EC_{10}/IC_{10} for a species are plotted. The other, less</td><td colspan="2">The most preferred acceptable endpoint representing a low-effects threshold for a species is used as the critical study; the next less preferred endpoint will be used sequentially only if the more preferred endpoint for a given species is not available.</td></tr>
</table>

	preferred, endpoints may be added sequentially to the data set to fulfill the minimum data requirement condition and improve the result of the modelling for the guideline derivation if the more preferred endpoint for a given species is not available.		
Preferred Endpoints (cont'd)	The preference ranking is done in the following order: Most appropriate EC_x/IC_x representing a no-effects threshold > EC_{10}/IC_{10} > $EC_{11\text{-}25}/IC_{11\text{-}25}$ > MATC > NOEC > LOEC > $EC_{26\text{-}49}/IC_{26\text{-}49}$ > nonlethal EC50/IC50. Multiple comparable records for the same endpoint are to be combined by the geometric mean of these records to represent the averaged species effects endpoint.	The preference ranking is done in the following order: Most appropriate EC_x/IC_x representing a low-effects threshold > $EC_{15\text{-}25}/IC_{15\text{-}25}$ > LOEC > MATC $EC_{26\text{-}49}/IC_{26\text{-}49}$ > nonlethal EC_{50}/IC_{50} > LC_{50}.	
Data Quality Requirement	Primary and secondary no-effects and low-effects level data are acceptable to meet the minimum data set requirement. Both primary and secondary data will be plotted. A chosen model should sufficiently and adequately describe data and pass the appropriate goodness-of-fit test.	The minimum data requirement must be met with primary data. The value used to set the guideline must be primary. Only low-effect data can be used to fulfill the minimum data requirement.	Secondary data are acceptable. The value used to set the guideline may be secondary. Only low-effect data can be used to fulfill the minimum data requirement.

EC_x = effective concentration affecting x percent of the population; IC_x - inhibition concentration affecting 50 percent of the population; LC_x = lethal concentration affecting x percent of the population; LOEC - lowest observed effect concentration; NOEC - no observed effect concentration; MATC = maximum acceptable toxicant concentration

Table 2: Minimum data set requirements for the derivation of a short-term exposure guideline for freshwater environments (CCME 2007).

	Guide		
Group	Type 1	Type B1	Type B2
Fish	Three species, including at least one salmonid and one non-salmonid.		Two species, including at least one salmonid and one non-salmonid.
Aquatic Invertebrates	Three aquatic or semi-aquatic invertebrates, at least one of which must be a planktonic crustacean. For semi-aquatic invertebrates, the life stages tested must be aquatic. It is desirable, but not necessary, that one of the aquatic invertebrate species be a mayfly, caddisfly, or stonefly.		Two aquatic or semi-aquatic invertebrates, at least one of which must be a planktonic crustacean. For semi-aquatic invertebrates, the life stages tested must be aquatic. It is desirable, but not necessary, that one of the aquatic invertebrate species be a mayfly, caddisfly, or stonefly.
Aquatic Plants	Toxicity data for aquatic plants or algae are highly desirable, but not necessary. However, if a toxicity study indicates that a plant or algal species is among the most sensitive species in the data set, then this substance is considered to be phyto-toxic and two studies on nontarget freshwater plant or algal species are required.		
Amphibians	Toxicity data for amphibians are highly desirable, but not necessary. Data must represent fully aquatic stages.		
Preferred Endpoints	Acceptable LC_{50} or equivalent (e.g., EC_{50} for immobility in small invertebrates).		
Data Quality Requirement	Primary and secondary LC_{50} (or equivalents) data are acceptable to meet the minimum data set requirement. Both primary and secondary data will be plotted.	The minimum data requirement must be met with primary LC_{50} (or equivalents) data. The value used to set the guideline must be primary.	The minimum data requirement must be met with primary LC_{50} (or equivalents) data. Secondary data are acceptable. The value used to set the guideline may be secondary.

	A chosen model should sufficiently and adequately describe data and pass the appropriate goodness-of-fit test.		

EC_x = effective concentration affecting x percent of the population; LC_x = lethal concentration affecting x percent of the population.

Appendix 4: Water Effect Ratio Procedure

December 30, 2019

Prepared by Bill Slater, Slater Environmental Consulting, based on *Guidance Manual for Developing Water Quality Objectives for Freshwater Ecosystems in Yukon, Final Report, October 2016* (MacDonald et al. 2016).

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List of Abbreviations

BCMOE:	British Columbia Ministry of Environment
BTMF:	Bioavailability and toxicity modifying factors
CCME:	Canadian Council of Ministers of the Environment
CCREM:	Canadian Council of Resource and Environment Ministers
COPC:	Contaminant of potential concern
ECCC:	Environment and Climate Change Canada
EC_x:	Effective concentration affecting x percent of the population

IC_x:	Inhibitory concentration causing and x percent inhibition in tested organisms
LC_x:	Lethal concentration affecting x percent of the population
USEPA:	United States Environmental Protection Agency
WER:	Water Effects Ratio
WQG:	Water quality guideline
WQO:	Water Quality Objective

1.0 Introduction and Overview of the Water Effects Ratio Procedure

This appendix describes the methods for, and application of the Water Effects Ratio (WER) Procedure. The WER Procedure is a simple method for deriving numerical water quality objectives (WQOs) that consider the site-specific characteristics of water in a waterbody, especially characteristics that may modify the bioavailability or toxicity of Contaminants of Potential Concerns (COPCs).

1.1 When to Apply the Water Effects Ratio Procedure

The WER Procedure can be applied when using the Use-Protection or Use-Restoration Approach for water management.

The WER Procedure may be considered when it can be demonstrated that:

1. The toxicity of a COPC is dependent on a specific water characteristic (e.g., water hardness, pH) that was not considered in the derivation of the water quality guideline (WQG), and
2. The waterbody has atypical levels of the relevant characteristic(s).

For example, the WQG for copper accounts for water hardness (CCREM 1987; CCME 2016). However, it does not account for the potential influence of high levels of humic acids on copper toxicity. Therefore, it would be appropriate to evaluate the applicability of the copper guideline at sites with high levels of humic acids and, if necessary, modify it to reflect site-specific water quality characteristics.

Application of the WER Procedure for the Use-Restoration Approach may require multiple iterations of the Procedure. Restoration of waters that have been previously impacted by human activities may lead to changes in the concentrations of bioavailability and toxicity modifying factors (BTMFs). If this occurs, any WQOs derived using the WER Procedure must be updated to consider the changing water characteristics.

1.2 Overview of the Water Effects Ratio Procedure

The *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2016) are intended to protect all life stages of all aquatic species that occur in Canadian waters against long-term exposures to contaminants. Numerical WQGs derived using the approved CCME protocols (CCME 1991; 2007) are considered to be generally applicable at sites located throughout the country. However, a specific waterbody may have water quality characteristics that can influence the toxicity of COPCs.

The WER Procedure is a tool for modifying WQGs to account for the unique water quality characteristics of the site under investigation. The procedure is based on the understanding that the physical and/or chemical characteristics of water can vary among sites and that such differences can influence the bioavailability and, hence, toxicity of environmental contaminants. In many cases, the factors that influence the effects of toxic substances have been identified. For example:

- Relationships between water hardness and acute toxicity to fish have been established for several metals (e.g., cadmium, copper, lead, nickel and zinc), and current WQGs address these relationships (CCREM 1987; Nagpal 1999; CCME 2016).
- Toxicity of ammonia to fish is known to be a function of pH and temperature (MacDonald et al. 1987; BCMOE 2016; CCME 2016).

The presence of other contaminants and other factors (e.g., suspended particulate matter) at a site can also affect the bioavailability of some COPCs. Therefore, consideration of the factors that could influence the toxicity and/or bioavailability of a substance at a site is likely to improve the applicability of the resultant WQO.

The WER Procedure relies on comparative toxicity testing using site water and laboratory water. Short-term toxicity tests are typically selected for the WER Procedure to expedite the WQO-derivation process, based on the assumption that the ratio of toxic concentrations would be similar for short-term or long-term tests. Testing is usually completed using indicator species that are commonly used for toxicity testing programs. In some cases, these species may be present in the Yukon waterbodies, but if not they are usually considered acceptable for use as representative surrogates for resident species. Typically, rainbow trout (*Oncorhynchus mykiss*), fathead minnows (*Pimephales promelas*), the water flea *Ceriodaphnia dubia*, and the alga *Pseudokirchneriella subcapitata* (formerly known as *Selenastrum capricornutum*) are used to assess the influence of site water quality conditions on the toxicity of COPCs because they are easy to culture, widely available, and consistently generate reliable data (Willingham 1988; MacDonald et al. 1989; Environment Canada 1996; 1998; 2007a; 2007b; 2007c; 2007d; 2011; ASTM International 2016a; 2016b; 2016c; 2016d; 2016e).

The WER Procedure is supported by toxicity tests that are easy to run, reasonably inexpensive, and available at most biological testing facilities. The methods for assessing the acute and short-term chronic toxicity of water-borne substances have been well established (see USEPA 2002a; 2002b; 2011; Environment Canada 1996; 2000; 2007a; 2007b; 2007c; 2007d; 2011) and provide a reliable basis for determining WERs. The quality of these toxicity tests is easily evaluated using the results of the positive (reference toxicant) and negative (solvent only) controls that must be run simultaneously. Toxicity tests may be performed on-site (both flow-through or static tests), or site dilution water can be shipped to a laboratory for off-site testing (static tests only).

The information generated in these side-by-side toxicity tests is used to determine the ratio of the toxicity of the COPC in water from the site to its toxicity in laboratory water. This ratio is known as the WER which can be used to convert the WQG to a site-specific WQO. For example, if a substance is twice as toxic in site water as it is in laboratory water, then the generic WQG would be divided by a factor of two to obtain the site-specific WQO. Toxicity data on at least one fish and one invertebrate species are required to calculate the geometric mean WER, which is then used to modify the generic WQG (USEPA 1994).

1.3 Limitations of the Water Effects Ratio Procedure

The WER Procedure is supported by toxicity tests that are easy to run, reasonably inexpensive, and available at most biological testing facilities. However, the simplicity leads to some limitations that must be considered when applying the WER Procedure.

A single testing program does not consider the temporal variability of water quality at the site (USEPA 1983; 2014; CCME 2003; SWRCB 2003). In general, the toxicity tests are conducted over a discrete time interval and the resulting WER is specific to the sampling program that was used to obtain the site water. As a result, the WQOs might not be applicable under other circumstances, such as during periods of altered streamflow. Therefore, information on the variability of water quality conditions at the site is needed to design a representative toxicity testing program, which may include multiple test programs. Diurnal variability in water quality may be accommodated by conducting flow-through bioassays, while seasonal changes in the characteristics of the site water may be assessed by performing tests at key periods throughout the year (e.g., under high flow and base flow conditions). This may lead to development of different WQOs for application during different periods, or application of the most stringent of the identified WERs.

Also, the ratio of toxicity in different waters, and the relationship to the WQGs can be influenced by more than BTMF, sometimes resulting in WQOs that may not meet the protection goal. The WER can be affected by the characteristics of the laboratory control water used in the toxicity tests, with potential for different ratios to be calculated for tests done at different laboratories. Care must be taken to ensure that potentially confounding factors, such as differences in calcium:magnesium ratios, alkalinity, and pH between site water and laboratory water, are adequately controlled during toxicity testing (Welch et al. 2000). The WER derives a single ratio using results from lethal endpoints (usually LC_{50}) and assumes that the same ratio applies for low effects level endpoints (e.g., EC_{20}), though this assumption is not well-tested. The toxicity tests for a WER are performed on a subset of the species that support the derivation of a WQG (e.g., through a species sensitivity distribution). The derived WER may not be relevant for species that fall near the lower end of the species sensitivity distribution.

The WER Procedures offers a simple approach for considering BTMF, without the need for a detailed understanding of the quantitative relationships between BTMF and toxicity of COPCs, but the simplicity leads to uncertainty about the WQOs. Any application of the WER needs to consider this uncertainty.

2.0 Deriving Water Quality Objectives using the Water Effects Ratio Procedure

Application of the WER Procedure involves the following 8 Steps:

1. Identify Species that Occur or Ought to Occur
2. Acquire Relevant Toxicological Data
3. Plan and Conduct Toxicity Tests
4. Evaluate Surface Water Chemistry and Toxicity Data
5. Calculate Species-Specific WERs
6. Calculate Final WERs
7. Derive Preliminary Numerical WQOs
8. Finalize Recommended Numerical WQOs

The Sections below describe each of these steps. Additional guidance on the WER Procedure methodology is provided in CCME (2003) and MacDonald (1997).

2.1 Identify Species that Occur or Ought to Occur

The first step in the application of the WER Procedure is to assemble a list of the taxonomic groups that occur or ought to occur in the waterbody. Usually, development of such a list requires intensive sampling at the site and/or extensive sampling at nearby reference sites to evaluate temporal and spatial distributions of aquatic organisms. Information on the distribution of aquatic-dependent wildlife species may be obtained from the scientific literature and by conducting wildlife surveys in the vicinity of the site. Guidance on the design and implementation of biological sampling programs is provided in Cavanagh et al. (1998) and BCMOE (2009). When the biological survey at the site is complete, a detailed list of aquatic species that occur or ought to occur at the site is compiled. For the purpose of WQOs derivation, the aquatic species that occur at the site include those taxonomic groups (i.e., genera, families, orders) that:

- Are usually present at the site.
- Are seasonally present at the site (e.g., due to migration patterns).
- Are intermittently present at the site because they periodically return to or extend their range into the site.
- Are not currently present at the site due to the presence of degraded conditions.
- Are present in nearby reference sites and, hence, are likely to use habitats at the site, even if they have not been observed at the site (see INAC (2009) for specific guidance on reference site selection).

- Were present at the site in the past.

2.2 Acquire Relevant Toxicological Data

The second step in applying the WER Procedure involves compilation of the aquatic toxicity data. This should include data that were assembled to support the derivation of the WQG and any additional toxicity data generated since the development of the WQG. This information will provide an understanding of which BTMF may be relevant, and support the design of the WER investigation, including the selection of toxicity tests and the selection of exposure ranges for range-finding and definitive toxicity tests.

2.3 Plan and Conduct Toxicity Tests

Toxicity testing to support development of a WER can be time consuming and costly. Producing reliable results that support defensible WQOs requires careful and systematic planning and implementation of toxicity testing programs. This following sections describe important considerations for designing and implementing a toxicity testing program for the WER Procedure.

2.3.1 Considerations for Designing Toxicity Testing Programs

The sampling strategy should be designed to facilitate determination of WERs at the locations and under the conditions that the contaminant is likely to be the most toxic. If information is available to identify these locations and conditions with some certainty, then it should be possible to streamline the sampling program appropriately. If, for example, the presence of humic acids are identified as the primary factor that could mitigate copper toxicity, then it should be possible to determine where and when the concentrations of humic acids are likely to be the lowest in receiving waters. Water effect ratios, determined for those locations and time periods, would likely result in the derivation of WQOs that would be protective at other sites and at other times. If some component of the wastewater is identified as the factor that is likely to mitigate toxicity (e.g., dissolved organic carbon), then it should be possible to determine when the concentrations of that BTMF in receiving water are likely to be the lowest (e.g., during extreme stream flows or low wastewater discharge volumes). The WQOs that are derived using the WERs for these conditions are likely to be protective under a variety of other conditions as well.

Decisions regarding the collection of grab or composite samples should be based on the objectives of the test, on the variability of water quality and flow conditions in the receiving water system, and on the variability of water quality and discharge volume of the wastewater, if applicable. Grab samples are easy to collect and provide an indicator of conditions at a specific time. However, such samples may not be representative of conditions over a longer period of time, which may necessitate additional testing under different conditions. Composite samples collected over a 24-hour period are likely to reflect short-term variability in water or wastewater quality. While composite sampling requires more resources and equipment to collect, it is likely to be more representative. Therefore, composite sampling should be used preferentially to collect samples for determining WERs.

Standard methods for collecting, handling, and storing water and wastewater samples for use in biological testing have been developed by various organizations. For example, the USEPA has developed detailed guidance for sampling and handling effluent and receiving waters for use in toxicity testing (USEPA 2000; 2002a; 2002b). Environment and Climate Change Canada (ECCC) has also developed specific procedures for sampling effluents, leachates, and receiving waters for use in toxicity testing with various aquatic organisms (e.g., Environment Canada 1996; 2000; 2007a; 2007b; 2007c; 2011). ASTM International has published standard methods for conducting a variety of toxicity tests, which include guidance on the collection, handling, and storage of receiving water and wastewater samples (e.g., ASTM International, 2016a). These guidance documents should be consulted for detailed information related to sample collection, handling and storage.

One of the challenges associated with the application of the WER Procedure is the selection of toxicity tests that are appropriate for determining WERs under the unique conditions that occur at each site. To assist practitioners in this field, the USEPA (1994; 2001) established criteria for selecting appropriate toxicity tests for determining WERs. These criteria were reviewed and evaluated to identify selection criteria that could be cost-effectively applied in Yukon, as follows:

- Toxicity tests should be conducted on at least two species to facilitate the determination of WERs, including one acute bioassay and one short-term chronic bioassay. A third toxicity test should be conducted if the results of the range-finding tests suggest that the two primary tests are likely to produce WERs that differ by more than a factor of three.
- The test species used to determine WERs should be in different orders and should include at least one vertebrate and one invertebrate.
- The toxicity tests should be conducted on sensitive life stages of sensitive species of aquatic organisms and measure sensitive endpoints for that life stage.
- The test organisms should be sensitive to the substance or substances that are being tested.
- The test organisms should be readily available throughout the duration of the testing period.
- Standard protocols for conducting each toxicity test should be available from recognized sources (e.g., ECCC, USEPA, ASTM International).
- The duration of each toxicity test should be appropriate for the species and life stage that is tested and for the endpoint that is being measured.
- Static renewal or flow-through tests must be used when exposure durations exceed 48 hours.
- Toxicity testing should be conducted using site water collected under different hydrological conditions, including clear-flow conditions and turbid-flow conditions.

The recommended toxicity tests for determining WERs fall into two general categories, depending on the duration of the bioassay relative to the life span of the test organism. Acute toxicity tests are conducted over a short period of time in relation to the organism's life span, generally lasting minutes, hours, or a few days (i.e., generally <96 hours). By comparison, chronic bioassays span a significant portion of the organism's life span (often more than 10%) and are particularly appropriate for evaluating substances that are persistent in the aquatic environment. Short-term chronic toxicity tests are of intermediate duration (e.g., seven days) and provide information on the lethal and/or sub-lethal effects on an aquatic organism associated with exposure to a COPC.

Aquatic toxicity tests are further categorized based on the type of system that is used to expose the test organism to the chemical substance under consideration. Static toxicity tests use the simplest test system, as the organism is exposed to the same test solutions for the duration of the test (i.e., the test solution is not replaced or renewed). In static renewal tests, the test solutions are renewed periodically during the test, usually at the beginning of each 24-hour period of testing (USEPA 2002a). The most complicated test system is employed in flow-through toxicity tests. In this type of bioassay, the test organism is exposed to "fresh" test solution throughout the duration of the tests by continuously pumping the solution directly to a diluter system (USEPA 2002a). The advantages and limitations of the various types of toxicity tests are listed in Table 1 (USEPA 2002a).

Based on the review of the available literature, the following tests are likely to be the most appropriate for application of the WER Procedure:

- 48-hour acute toxicity test using water fleas, including *Daphnia magna*, *Daphnia pulex*, or *Ceriodaphnia dubia* (static test; EC_{50} or LC_{50} as preferred endpoints; e.g., Environment Canada 1996).
- 7-day short-term chronic toxicity test using the water flea, *Ceriodaphnia dubia* (static renewal test; IC_{50} or IC_{25} for survival and reproduction as preferred endpoints; e.g., Environment Canada 2007c).
- 96-hour acute toxicity test using the amphipod, *Gammarus sp.* (static renewal test; EC_{50} or LC_{50} as preferred endpoints; e.g., ASTM International 2016b).
- 48-hour acute toxicity test using fathead minnows (*Pimephales promelas*; static test; LC_{50} as preferred endpoint; e.g., USEPA 2011).
- 96-hour acute toxicity test using fathead minnows (*Pimephales promelas*; static renewal test; LC_{50} as preferred endpoint; e.g., ASTM International 2016b).
- 7-day short-term chronic toxicity test using larval fathead minnows (*Pimephales promelas*; static renewal test; IC_{50} or IC_{25} for survival and growth as preferred endpoints; e.g., Environment Canada 2011).
- 96-hour acute toxicity test using a salmonid within the genus *Oncorhynchus* or *Salmo* (static renewal test; EC_{50} or LC_{50} as preferred endpoints; e.g., Environment Canada 2007a).

Any combination of these tests may be used to support the derivation of WERs, provided that the selection criteria listed above are met. A listing of the preferred toxicity tests for determining WERs for various metals and metalloids in freshwater systems is presented in Table 2 (USEPA 1994). Comparable recommendations for selecting toxicity tests for determining WERs for organic contaminants were not found in the literature.

Standard methods have been developed for each of the above, recommended toxicity tests. While such protocols provide detailed guidance for implementing toxicity tests, some additional guidance is required to adapt the procedures to WER determinations. The specific modifications that are required to implement the WER Procedure are identified in the following sections.

Table 1: The advantages and limitations of the static and flow-through toxicity tests.

STATIC TEST	
Advantages	Limitations
Simple and inexpensive. Very cost effective. Limited resources (space, manpower, equipment) required; permits staff to perform many sequential tests on samples collected over time. Small volume (1 to 20 L) of effluent required. Provides some measure of persistence of toxicity, (i.e., aging of the effluent in a non-renewal static test).	Results do not reflect temporal changes in effluent toxicity. Dissolved oxygen (DO) depletion may result from high chemical oxygen demand (COD), biological oxygen demand (BOD), or metabolic wastes. Possible loss of toxicants through volatilization and/or adsorption to the exposure vessels. Generally less sensitive than flow-through test, because the toxic substances may degrade or be adsorbed, thereby reducing the apparent toxicity. Also, there is less chance of detecting slugs of toxic wastes, or other temporal variations in waste properties.
FLOW-THROUGH TEST	
Advantages	Limitations
Provide a more representative evaluation of effluent acute toxicity, especially if toxicity varies with time. DO concentrations are more easily maintained in the test chambers. Higher loading rates (i.e., biomass) may be used.	Large volumes of effluent and dilution water are required. Test equipment is more complex and expensive, and requires more maintenance and attention. More space is required to conduct tests. Does not measure the effect of aging of the waste on toxicity.

The possibility of loss of toxicant due to volatilization, adsorption, degradation and uptake is reduced.	Because of resources required, it may be very difficult to perform multiple or overlapping sequential tests.

Table 2: Preferred toxicity tests for determining water effect ratios WERs for metals and metalloids in freshwater systems (from USEPA 1994).

Metal	Primary Tests	Secondary Tests
Aluminum	7-d IC$_{25}$ on survival and/or reproduction for *Ceriodaphnia* sp.	48-hr EC$_{50}$ for Daphnid (Ce, Da, or Si)
Arsenic (III)	48-hr EC$_{50}$ for Daphnid (Ce, Da, or Si) 96-hr EC$_{50}$ for *Gammarus* sp.	7-d IC$_{25}$ on survival and/or reproduction for *Ceriodaphnia* sp 7-d IC$_{25}$ on survival and growth for minnow (PP) larvae
Cadmium	96-hr EC$_{50}$ for Salmonid (On or Sa) or 48-hr EC$_{50}$ for Daphnid (Ce, Da, or Si) 96-hr EC$_{50}$ for *Gammarus* sp	7-d IC$_{25}$ on survival and/or reproduction for *Ceriodaphnia* sp 7-d IC$_{25}$ on survival and growth for minnow (PP) larvae
Chromium (III)	96-hr EC$_{50}$ for Salmonid (On or Sa) or 48-hr EC$_{50}$ for Daphnid (Ce, Da, or Si) 96-hr EC$_{50}$ for *Gammarus* sp.	7-d IC$_{25}$ on survival and/or reproduction for *Ceriodaphnia* sp 7-d IC$_{25}$ on survival and growth for minnow (PP) larvae
Chromium (VI)	48-hr EC$_{50}$ for Daphnid (Ce, Da, or Si) 96-hr EC$_{50}$ for *Gammarus* sp.	7-d IC$_{25}$ on survival and/or reproduction for *Ceriodaphnia* sp 96-hr EC$_{50}$ for *Gammarus* sp
Copper	48-hr EC$_{50}$ for Daphnid (Ce, Da, or Si) 48-hr LC$_{50}$ for minnow (PP) larvae or 96-hr EC$_{50}$ for *Gammarus* sp.	7-d IC$_{25}$ on survival and/or reproduction for *Ceriodaphnia* sp 48-hr LC$_{50}$ for minnow (PP) larvae
Lead	48-hr EC$_{50}$ for Daphnid (Ce, Da, or Si) 96-hr EC$_{50}$ for *Gammarus* sp.	7-d IC$_{25}$ on survival and/or reproduction for *Ceriodaphnia* sp
Mercury	48-hr EC$_{50}$ for Daphnid (Ce, Da, or Si) 96-hr EC$_{50}$ for *Gammarus* sp.	None identified

Nickel	48-hr EC50 for Daphnid (Ce, Da, or Si) 96-hr LC50 for minnow (PP) larvae	7-d IC25 on survival and/or reproduction for *Ceriodaphnia sp*
Selenium	None identified	None identified
Silver	48-hr EC50 for Daphnid (Ce, Da, or Si) 7-d IC50 on growth and survival for minnow (PP) larvae	7-d IC25 on survival and/or reproduction for *Ceriodaphnia sp* 7-d IC25 on survival and growth for minnow (PP) larvae
Zinc	48-hr EC50 for Daphnid (Ce, Da, or Si) 48-hr LC50 for minnow (PP) larvae	7-d IC25 on survival and/or reproduction for *Ceriodaphnia sp* 7-d IC25 on survival and growth for minnow (PP) larvae

2.3.2 Range-finding Tests

A range-finding test should be conducted for both of the toxicity tests initially selected for determination of WERs. The purpose of the range-finding test is to determine the range of chemical concentrations that are likely to cause a response in the test organism. This information is important for designing definitive toxicity tests that determine effective concentrations of the toxicant precisely in site water and laboratory water. Considerations for conducting range-finding tests include:

- Range-finding tests should be conducted using the type of site water that will be used in the definitive toxicity test (e.g., upstream water, actual downstream water, or simulated downstream water).
- For each species, life stage, and endpoint, the information in the toxicological data set should be used to estimate the effective concentration of the toxicant.
- Range-finding tests should be conducted for 8 to 96 hours using the same life stages of the same species that will be used in the definitive toxicity tests.
- Range-finding tests should include appropriate control treatments to support evaluation of test acceptability.
- The concentrations tested in the range-finding tests should increase from roughly a factor of 10 below the value indicated in the toxicological data set for the appropriate endpoint, life stage, and species. The concentrations in the dilution series should increase by a factor of 3.2 to 10 from the lowest concentration tested. Generally, six to eight concentrations should be tested to span the possible range of effective concentrations of the toxicant. For example, if the lowest 96-hour LC_{50} of copper to *Daphnia magna* in the toxicological data set was reported to be 6.5 µg/L, then the

dilution series for the range-finding test might include concentrations ranging from 0.6 to 201 µg/L (e.g., 0.0, 0.6, 1.9, 6.1, 19.7, 62.9, and 201 µg/L).

- Appropriate statistical procedures (e.g., Probit analysis) should be applied to the results of the range-finding test to determine median effective concentrations of the toxicant in site water.

2.3.3 Definitive Toxicity Tests

The definitive toxicity tests need to generate highly reliable data to reduce uncertainty in the calculation of WERs for modifying the WQGs. Some important considerations for conducting the definitive toxicity tests include:

- Definitive toxicity tests must be conducted using site water and appropriate laboratory dilution water (and be consistent with the waters used in range-finding tests). There must be no differences between the side-by-side tests conducted using site water and laboratory water, other than the composition of the dilution water and the concentrations of the substances tested.
- Definitive toxicity tests must include appropriate positive (reference toxicant) and negative (solvent only) control treatments to support evaluation of test acceptability.
- The recommendations in the toxicity test protocols concerning temperature, loading, feeding, dissolved oxygen, aeration disturbance, and controls must be followed.
- The results of the range-finding test and/or information in the toxicological database should be used to identify an appropriate dilution series for the definitive toxicity tests that are conducted using site and laboratory water. The concentrations in the dilution series should increase by a factor of 1.1 to 1.5 (recommend 1.4) from the lowest concentration tested. Generally, eight to nine concentrations should be tested to span the possible range of effective concentrations of the toxicant.
- Appropriate statistical procedures (e.g., Probit analysis) should be applied to the results of the definitive toxicity tests to determine median effective concentrations of the toxicant in site water and in laboratory water.

2.3.4 Dilution Water

Determination of WERs requires information on the toxicity of COPCs in both site water and laboratory water. Therefore, selection and preparation of both laboratory and site dilution water is a critical element of the test procedure and application of the WER Procedure.

Some of the considerations for selecting and preparing laboratory dilution water for conducting toxicity tests include:

- Laboratory dilution water should be available in adequate supply, acceptable to the test organisms, be of uniform quality, and not affect the results of the test.

- The laboratory dilution water must be a groundwater, surface water, dechlorinated tap water, diluted mineral water, or reconstituted water that has been demonstrated to be acceptable to aquatic organisms.
- Laboratory dilution water must satisfy the requirements identified in the protocol for the toxicity tests that will be used in the study. At minimum, test organisms should survive through acclimation and testing without showing signs of stress, such as discolouration, unusual behaviour, or death.
- The characteristics of the laboratory dilution water should be similar to those of the site water (e.g., water hardness, alkalinity, and pH) and should be matched for those variables that are known to modify the toxicity of the COPC under consideration (e.g., water hardness for metals).
- The concentrations of total organic carbon and total suspended solids must be less than 5 mg/L in laboratory dilution water.
- The results of the toxicity tests conducted in laboratory dilution water should be comparable to those conducted at other laboratories (i.e., similar to the data represented in the toxicological database).

Some of the considerations for selecting and preparing site dilution water include:

- Three types of site water may be used in toxicity tests, including upstream water, actual downstream water, and simulated downstream water. Considerations for using each type of dilution water are described below:
    - Upstream water represents the least complicated source of dilution water because plumes, mixing zones, and effluent variability do not have to be taken into account. This approach is particularly relevant for deriving WQOs for waterbodies that are not influenced by wastewater discharges. However, this approach does not consider the effects of wastewater quality on the toxicity of the substance or substances under investigation, and therefore will usually not be applicable for quartz mining projects.
    - Actual downstream water ought to provide the most relevant source of dilution water for determining WERs for waterbodies that are influenced by existing wastewater discharges. However, the application of this approach is limited by uncertainties regarding the size of the mixing zone, the extent of mixing at specific locations, and temporal variability in receiving water quality downstream of wastewater discharges (e.g., due to differences in effluent quality, effluent volume, and stream flows). While it may be possible to identify the most appropriate locations and time periods for obtaining dilution water from this source, logistical considerations may restrict sampling activities (e.g., due to ice cover or access problems).
    - Simulated downstream water would seem to be the most unnatural of the three types of dilution water. However, it offers several important advantages over

upstream water and actual downstream water. Specifically, upstream water and the effluent can be mixed in known ratios, potentially simulating conditions under a range of wastewater discharges and stream flows. Therefore, it is possible to simulate the conditions under which the contaminant is likely to be the most toxic and determine the corresponding WER. In addition, this approach provides operational flexibility in terms of the timing of sampling activities.

- Dilution water for the toxicity tests conducted using site water should be obtained at times when the WERs are likely to be the lowest (i.e., when the factors that are likely to mitigate toxicity are at the lowest levels). When simulated downstream water is used in toxicity testing, the ratio of effluent to receiving water should simulate conditions when WERs are likely to be the lowest.

2.3.5 Test Organisms

A wide variety of aquatic organisms may be used to determine WERs. Some of the factors that should be considered in the selection and handling of test organisms include:

- The organisms used in a pair of side-by-side tests must be drawn from the same population and tested under identical conditions.
- Test organisms must be assigned to treatment groups on a random or impartial basis.
- The test organisms must be added to the test chambers for the side-by-side tests at the same time.

2.3.6 Spiking Procedures

To determine WERs, toxicity tests must be conducted in both site water and laboratory water that have been spiked with a range of chemical concentrations. Some of the considerations for spiking laboratory and site water include:

- A stock solution should be prepared using a highly soluble form of the toxicant. For metals, nitrate, chloride, and sulphate, salts are generally acceptable.
- The same stock solution must be used to add the toxicant to all of the tests that are conducted at the same time (including the renewal of test solutions).
- Reagent or better grade chemicals must be used to prepare stock solutions for spiking water samples.
- For the toxicity tests conducted using site dilution water, the test solutions should be prepared using one of the four spiking procedures recommended by USEPA (1994). The preferred method involves the following steps:
    a. Prepare a large volume of simulated downstream water by mixing the effluent and the upstream water at the desired ratio.
    b. Divide the mixture into two portions.

  c. Prepare a large volume of the highest test concentration of the toxicant using one portion of the simulated downstream water.
  d. Perform serial dilution using the well-mixed spiked and unspiked samples of the simulated downstream water (i.e., using a graduated cylinder).
  e. Allow the samples to equilibrate for a period of 1 to 3 hours.
- For the toxicity tests conducted using laboratory dilution water, the test solutions should be prepared using one of the two spiking procedures recommended by USEPA (1994). The preferred method involves the following steps:
  a. Prepare a large volume of the highest test concentration of the toxicant in the laboratory dilution water.
  b. Perform serial dilution using the well-mixed spiked and unspiked samples of the laboratory dilution water (i.e., using a graduated cylinder).
  c. Allow the samples to equilibrate for a period of 1 to 3 hours.
- For each treatment group, sufficient identical replicates must be prepared to support both biological testing and chemical analyses (i.e., chemistry-only controls).

The foregoing guidance on spiking procedures applies directly to metals and metalloids. Significantly less information was located on spiking procedures for organic substances. While many of the recommended procedures will be appropriate for use with organic chemicals, modifications will be required for volatile organics. For example, it may be necessary to renew test solutions more frequently or conduct flow-through toxicity tests to determine WERs for certain substances. Such deviations from the recommended procedures should be highlighted in the study plan and discussed with government agencies and interested parties prior to implementation.

2.4 Evaluate Surface Water Chemistry and Toxicity Data

Determination of WERs requires high quality information on the toxicity of COPCs in site water and in laboratory water. The adequacy of both chemistry and toxicity data should be considered when evaluating the adequacy and usability of dataset. The test acceptability criteria that are established in the protocol for conducting each toxicity test should be used to evaluate the usability of the toxicity data that are generated during the investigation. In general, acute and short-term chronic toxicity tests should be considered unacceptable if (ASTM International 2016b):

- All test chambers and compartments (e.g., water baths) were not identical.
- Treatments were not randomly assigned to individual test chamber locations.
- A required dilution water or solvent control was not included in the test.
- The test was conducted with organisms that were treated for disease within 10 days of the initiation of the test.

- The test organisms were not appropriately acclimated to the dilution water prior to the test.
- Individual test organisms were not randomly or impartially assigned to test chambers.
- More than 10% of the organisms in the control treatment showed signs of disease or stress (in some tests, higher control mortality is acceptable).
- Dissolved oxygen and temperature were not measured at appropriate intervals during the test.
- Dissolved oxygen and temperature were not maintained within acceptable limits during some portion of the test.
- No treatment other than the control treatment killed or affected less than 37% of the test organisms exposed to it.
- No treatment killed or affected more than 63% of the test organisms exposed to it.
- The sensitivities of the test organisms were not evaluated within the seven days immediately preceding the toxicity tests. Recommended reference toxicants for evaluating the sensitivity of each test organism include sodium dodecylsulfate, sodium pentachlorophenate, and cadmium chloride (instructions for the use of reference toxicants and expected LC_{50} values are generally provided with the samples).

Additional test acceptability criteria are provided in the test methods that have been published by ECCC, USEPA, and ASTM International. Water chemistry and toxicity data that meet the performance criteria for measurement data and are demonstrated to be usable can be applied to support the determination of WERs. All of the data that are generated during the toxicity testing program must be reported, along with the results of the data evaluation process. In addition, all laboratory reports that are generated during the program must be provided.

2.5 Calculate Species-specific WER

If the results of the toxicity tests conducted using site water and laboratory water meet the data quality criteria, they can be used to calculate a preliminary WER.

For each water type (e.g., site water “a”, site water “b”, laboratory water, etc.) and species, calculate median effective concentrations (e.g., LC_{50}, EC_{50}, or IC_{50}) and 95% confidence limits using the average measured concentrations in the test chambers. Probit analysis should be used preferentially to determine median effective concentrations unless there is a strong rationale provided for using another methodology.

For each water type and species, calculate WERs by dividing the median effective/lethal concentration of the substance in site water by the higher of the median effective/lethal concentration of the substance in laboratory water or the species mean acute value. For metals, WERs may be calculated for both total and dissolved concentrations.

2.6 Calculate Final WER

Following the determination of species-specific WERs for each COPC and water type, the final WERs can be calculated.

Compare the WERs that were calculated for the selected toxicity tests. If the WERs for the two toxicity tests agree within a factor of three, no additional testing is required to revise the WQOs. Lack of agreement between the WERs for the same water type necessitates additional toxicity testing to generate at least one additional WER.

Calculate final WERs for each water type by determining the geometric mean of the comparable WERs obtained from the various toxicity tests. When more than two WERs have been determined (i.e., when the first two WERs were not comparable), the final WER should be calculated as the geometric mean of the two lowest WERs. For metals, final WERs should be determined for both total and dissolved concentrations.

The procedures recommended in this document for calculating the final WER are less complicated than those that have been applied in the United States (USEPA 1994). The recommended simplification of the procedures is intended to make the procedure more accessible and understandable to potential practitioners.

2.7 Derive Preliminary Numerical WQOs

Calculation of a preliminary WQO using the WER procedure is a straightforward process. For each water type, the preliminary WQO is calculated by multiplying the generic WQG by the final WER for that water type (e.g., location and/or hydrological condition).

2.8 Finalize Recommended Numerical WQOs

In the final step of the WER Procedure, the preliminary WQOs are compared with the data collected to establish baseline conditions at the site. The preliminary WQOs should be adopted for use at the site if they are feasible to implement relative to baseline conditions at the site, as follows:

- If the preliminary maximum WQO exceeds the upper limit of baseline concentrations [i.e., 95th percentile], and
- If the preliminary average WQO exceeds the estimate of central tendency of baseline concentrations [i.e., 95% upper confidence limit of the mean]).

An alternative procedure for deriving numerical WQOs should be applied if it is not feasible to implement the preliminary WQOs that were developed using the WER Procedure because baseline concentrations already exceed the preliminary WQOs.

If WQOs are developed for multiple COPCs, the resultant WQOs need to be further evaluated to assess their applicability. In such cases, the most sensitive species and endpoints need to be identified. Then, additional toxicity tests should be used to determine if the WQOs are protective when multiple COPCs are present at the WQO concentrations. The results of these toxicity tests should be used to adjust the WQOs, if required.

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Appendix 5:
Deriving Numerical Water Quality Objectives for Bioaccumulative Substances

March 31, 2018

Prepared by Bill Slater, Slater Environmental Consulting, based on *Guidance Manual for Developing Water Quality Objectives for Freshwater Ecosystems in Yukon, Final Report, October 2016* (MacDonald et al. 2016).

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List of Abbreviations

BAF:	Bioaccumulation factor
BCMOE:	British Columbia Ministry of Environment
CCC:	Criterion continuous concentration
CCME:	Canadian Council of Ministers of the Environment
CMC:	Criterion maximum concentration
COPC:	Contaminant of potential concern
DW:	Dry weight
PBDE:	Polybrominated diphenyl ethers
PCB:	Polychlorinated biphenyls
PCDD:	Polychlorinated dibenzo-p-dioxins
PCDF:	Polychlorinated dibenzofurans

USEPA:	United States Environmental Protection Agency
WQG:	Water quality guideline
WQO:	Water quality objective
WW:	Wet weight

1.0 Introduction

This appendix describes methods for developing Water Quality Objectives (WQOs) for bioaccumulative Contaminants of Potential Concern (COPCs), with a focus on mercury and selenium. Methods are identified for all three water management approaches.

The methods for WQO development described in the Main Document and Appendices 2, 3 and 4 are effective in circumstances where the principle pathway for exposure of aquatic organisms to a contaminant is through direct exposure to surface water. These circumstances generally occur for contaminants that tend to partition preferentially into surface water.

Because the primary exposure pathway for bioaccumulative substances like mercury and selenium is typically through the diet (i.e., through consumption of aquatic organisms; Neely et al. 1974) rather than direct exposure to surface water, they require a different approach for development of WQOs. These substances are typically evaluated using benchmarks for invertebrate and/or fish tissues (e.g., CCME 2000; BCMOE 2014; USEPA 2016a). Such benchmarks – usually based on tissue-residue guidelines for the protection of aquatic organisms, wildlife and/or human health – are often used as primary tools for evaluating the potential for adverse effects of bioaccumulative COPCs on aquatic life and aquatic-dependent wildlife.

In addition to the application of tissue-based benchmarks, there are valid reasons for establishment of WQOs for bioaccumulative COPCs in the water column and monitoring of contaminant concentrations. Changes in surface water chemistry can provide an early warning relative to potential exposure to bioaccumulative COPCs. In addition, determination of tolerable levels of bioaccumulative COPCs in surface water is required to calculate permit limits for regulating discharges into receiving waters. Furthermore, there may be regulatory requirements to measure certain COPCs (e.g., dissolved selenium) in the water column to support loading calculations (Toll et al. 2005; Presser and Luoma 2010).

Water Quality Guidelines (WQGs) have been developed for certain bioaccumulative substances including mercury, polychlorinated biphenyls (PCBs), and selenium (e.g., BCMOE 2016; CCME 2016; USEPA 2016b). However, the factors that influence bioaccumulation are often site-specific and bioaccumulation rates are difficult to predict. As a result the relationship between concentrations of bioaccumulative substances in tissue and the water column is often site-specific. This appendix describes tools that have been developed, validated, and applied to determine protective concentrations of bioaccumulative COPCs in the water column using information on site-specific factors or empirical data.

1.1 Bioaccumulative Contaminants of Concern

Bioaccumulative substances are substances that accumulate in the tissues of organisms, such that the concentrations within the tissues of the organisms exceed the average concentrations within the diet (i.e., the rate of uptake exceeds the rate of excretion). Bioaccumulative substances have log octanol-water partition coefficients (K_{ow}s) > 3.5 or water-to-tissue bioconcentration factors > 5000. An important consequence of bioaccumulation is the potential for biomagnification of these substances with increasing trophic levels in the food web. Bioaccumulative substances of importance in many aquatic ecosystems include mercury, selenium, PCBs, polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDDs/PCDFs), polybrominated diphenyl ethers (PBDEs), and organochlorine pesticides. Of these, mercury and selenium are likely to be the most important relative to quartz mining projects in Yukon.

1.2 Mercury in the Aquatic Environment

Mercury is typically transported to aquatic environments through deposition of emissions from both natural and anthropogenic sources. Natural sources of mercury include erosion of mercury-bearing soils and deposition of mercury mobilized from forest fires, volcanoes, and volatilization from freshwater bodies and oceans (Schroeder and Munthe 1998). Anthropogenic sources include deposition of mercury mobilized from chlor-alkali manufacturing facilities, coal-burning power plants, metal production facilities (e.g., smelters), refuse incineration facilities, and wood combustion (Nriagu and Pacyna 1988). In addition, direct discharges of process water from coal-burning power plants, metal manufacturing facilities, and other industries can release mercury into surface waters (Nriagu and Pacyna 1988). Flooding of forest land by creation of dams can also lead to release of mercury.

In the tissues of higher trophic-level aquatic organisms and aquatic-dependent wildlife, the majority (i.e., 90 – 100%) of the mercury in muscle tissue is in the form of methylmercury (CCME, 2003). In aquatic ecosystems, mercury undergoes transformation to methylmercury via microbial processes (Winfrey and Rudd 1990). Simultaneously, methylmercury may become demethylated via similar microbial processes (Winfrey and Rudd 1990) and photodegradation (Sellers et al. 1996). The rates of methylation and demethylation are largely controlled by water and sediment quality conditions, including redox potential, pH, water temperature, and the concentrations of mercury, iron, and sulfate (Winfrey and Rudd 1990). Due to the high rates of microbial activity, wetland ecosystems can represent important sources of methylmercury to surface waters (St. Louis et al. 1994).

1.3 Selenium in the Aquatic Environment

Selenium is a rare trace element that primarily originates from sedimentary rocks of marine origin and is typically found with coal and sulfur deposits (Adriano 2001; Sharma et al. 2014). Selenium is transported to aquatic ecosystems by erosion of selenium-rich soils and as a result of various anthropogenic activities, including power generation, oil refining, metal refining, coal mining, and irrigation drainage (Presser et al. 2004; Sharma et al. 2014).

Selenium is an essential nutrient for most organisms, but can be toxic at elevated concentrations. Exposure to elevated levels of selenium leads to adverse effects on reproduction (particularly in egg-laying organisms such as fish, amphibians, reptiles and birds) and growth, increases the incidence of developmental deformities, and decreases survival (BCMOE 2014). Inorganic selenium enters the food web through uptake by bacteria, fungi, and primary producers, replacing sulfur during protein synthesis (Stadtman 1974). This organic selenium subsequently bioaccumulates in aquatic organisms and aquatic-dependent wildlife. The uptake and transformation of selenium from the water column to the base of the food web is governed by a number of site-specific factors, including site hydrology, pH and redox potential (which affect selenium speciation), and the nature of the base of the food web (i.e., community composition; Presser and Luoma 2010). The dual nature of selenium as both an essential nutrient and a toxicant is an important consideration in the assessment of conditions in aquatic ecosystems. The “switch” between essentiality and toxicity (through bioaccumulation) occurs over a very narrow range of exposure concentrations.

1.4 Other Bioaccumulative Contaminants

Persistent, bioaccumulative, and toxic substances, such as PCBs, PCDDs/PCDFs, PBDEs, and organochlorine pesticides, are important concerns in the management of aquatic ecosystems. While the production of some of these substances (e.g., PCBs) has been banned in North America, they remain within many aquatic ecosystems due to their persistence in the environment (CCME 2001). In addition, other substances (e.g., PCDDs/PCDFs) are by-products of many industrial processes and continue to be produced today. Various Canadian and US agencies have developed tissue-based and diet-based thresholds for many of these substances. These benchmarks are more appropriate for evaluating hazards to aquatic organisms and aquatic-dependent wildlife associated with exposure to these bioaccumulative substances than are WQOs. For this reason, specific procedures for deriving WQOs for other bioaccumulative COPCs have not been proposed in this document. Nevertheless, the procedures identified below in Section 3.0 may be adapted for other bioaccumulative COPCs provided that the uncertainties are explicitly identified and addressed.

2.0 Options for Developing Site-specific Water Quality Objectives for Bioaccumulative Contaminants

Monitoring of the concentrations of bioaccumulative COPCs in the tissues of aquatic organisms and/or aquatic-dependent wildlife represents the most effective and reliable basis for measuring the effects of these COPCs on aquatic ecosystems. For this reason, establishment of environmental quality objectives should define the concentrations for bioaccumulative COPCs in fish and/or other aquatic organisms that provide the necessary level of protection for a waterbody. Baseline and background biological tissue monitoring data and/or tissue residue guidelines represent essential tools for establishing environmental quality objectives for bioaccumulative COPCs.

However, WQOs for bioaccumulative COPCs are required in addition to tissue-based benchmarks for projects that will contribute selenium or mercury to the receiving environment. Concentrations in water provide an early warning of changing conditions, and numerical WQOs provide a basis for calculating effluent quality standards for managing loadings of bioaccumulative COPCs to receiving waters. A variety of strategies can be used to establish WQOs for bioaccumulative COPCs. The selection of methods depends on the water management approach that applies to the waterbody:

- **Non-Degradation Approach:** The Background Concentration Procedure (BCP) is the only method that can be used to develop numerical WQOs for bioaccumulative COPCs when applying the Non-Degradation Approach. Appendix 2 provides guidance about how to apply the BCP for all COPCs. Section 3.1 of this Appendix provides specific details that apply to use of the BCP for bioaccumulative COPCs.
- **Use-Protection Approach:** Several procedures can be used to develop numerical WQOs for bioaccumulative COPCs when applying the Use-Protection Approach, including:
    1. Direct adoption of existing bioaccumulation-based WQGs as described in Appendix 1. A summary of WQGs, sediment quality guidelines, and tissue residue guidelines for selected bioaccumulative COPCs is provided in Table 1 and Table 2.
    2. The Background Concentration Procedure (BCP). Appendix 2 provides guidance about how to apply the BCP for all COPCs. Section 3.1 of this Appendix

    provides specific details that apply to use of the BCP for bioaccumulative COPCs.
    3. Development of *de novo* WQOs for bioaccumulative COPCs as described in Section 3.2.
- **Use-Restoration Approach:** When applying the Use-Restoration Approach, the same procedures can be used as those described for the Use-Protection Approach. For the Use-Restoration Approach, WQOs may be staged as part of a continuous improvement plan to drive progressive improvement of water quality conditions as restoration actions proceed.

No matter which method is used to derive numerical WQOs for bioaccumulative COPCs, monitoring of attainment of the WQOs and of levels of bioaccumulative COPCs in the tissues of fish and/or other aquatic organisms should be considered to be a high priority. The WQOs should be revised if biological monitoring indicates that adverse effects on aquatic organisms or aquatic-dependent wildlife have occurred or are likely to have occurred due to accumulation of bioaccumulative COPCs in the tissues of aquatic organisms. Likewise, increased risks to human health should trigger revision of the WQOs for one or more COPCs.

Table 1: Summary of selected bioaccumulation-based environmental quality guidelines for mercury.

Water Use	Media Type	Source				
		CCME / Health Canada1	BCMOE2	Health Canada	USEPA3	Dillon et al. (2010)
Aquatic Life	Water (µg/L)	0.0264	0.00125-0.065	-	0.77 / 1.46	-
	Sediment (µg/g DW)	0.170 / 0.4867	-	-	-	-
	Invertebrate Tissue (µg/g WW)	-	-	-	-	-
	Whole Fish (µg/g WW)	-	-	-	-	0.38 / 0.19
Wildlife	Water (µg/L)	-	0.00125-0.065	-	-	-
	Tissue Residue (for methylmercury; µg/g WW)	0.03310	0.03310	-	-	-
Human Health	Drinking Water (µg/L)	1	1	111	2	-
	Fish Consumption (µg/g WW)	-	0.1 - .512	0.513	0.314	-

BCMOE = British Columbia Ministry of Environment; CCME = Canadian Council of Ministers of the Environment; DW = dry weight; OMOE = Ontario Ministry of Environment; USEPA = United States Environmental Protection Agency; WW = wet weight; -- = no guideline.

1 Water quality guidelines for the protection of aquatic life and wildlife from CCME (2016). Water quality guideline for drinking water from Health Canada (2014).

2 All environmental quality guidelines from BCMOE (2016).

3 Water quality guidelines for the protection of aquatic life from USEPA (2016a). Water quality guideline for drinking water from USEPA (2016b).Water quality guideline for fish consumption from USEPA (2016c).

4 Water quality guideline for inorganic mercury. The guideline for methylmercury is 0.004 µg/L.

5 This water quality guideline (WQG) for total mercury depends on the percentage of methylmercury (MeHg). When MeHg is 0.5% of total mercury (THg), the WQG = 0.02 µg/L. When MeHg is 1.0% of THg, the WQG = 0.01 µg/L. When MeHg is 8.0% of THg, the WQG = 0.00125 µg/L. This is a 30-day average WQG for the protection of aquatic life and wildlife.

6 Water quality criteria apply to the dissolved fraction. 0.77 is the criterion continuous concentration (CCC); 1.4 is the criterion maximum concentration (CMC).

7 The interim sediment quality guideline (ISQG) is 0.170 µg/g DW and the probable effect level (PEL) is 0.486 µg/g DW. These apply to the total concentration of mercury in surficial sediment.

8 Whole-body tissue concentration corresponding to 8.2% lethal equivalent effects in juvenile and adult fish (Dillon et al. 2010).

9 Whole-body tissue concentration corresponding to 19.8% lethal equivalent effects in early life-stage fish (Dillon et al. 2010).

10 This is a tissue residue guideline for the protection of wildlife that consume freshwater, marine, and/or estuarine biota. BCMOE adopted the CCME guideline.

11 Guidelines for Canadian drinking water quality - summary table. Health Canada. 2014.

12 This guideline applies to the total mercury concentration in the edible portion of fish and shellfish. It varies based on the amount of fish consumed per week. See BCMOE (2016) for more details.

13 Updating the Existing Risk Management Strategy for Mercury in Retail Fish. Health Canada. 2007.

14 This fish tissue residue criterion is for methylmercury and is based on a total fish consumption rate of 0.0175 kg/day.

Table 2: Summary of selected bioaccumulation-based environmental quality guidelines for selenium.

Water Use	Media Type	Source		
		CCME / Health Canada[1]	BCMOE[2]	USEPA[4]
Aquatic Life	Water (µg/L)	1	2[5]	1.5 / 3.1[6]
	Sediment (µg/g DW)	-	0.0027	-
	Invertebrate Tissue (µg/g WW)	-	48	-
	Whole Fish (µg/g WW)	-	4	8.5
	Fish egg/ovary (µg/g DW)	-	11	15.1
	Fish muscle/muscle plug (µg/g DW)	-	48	113.99
Wildlife	Water (µg/L)	-	2	-
	Sediment (µg/g DW)	-	-	-
	Invertebrate Tissue (µg/g DW)	-	-	-
	Whole Fish (µg/g DW)	-	-	-
	Bird egg (µg/g DW)	-	6	-
Human Health	Drinking Water (µg/L)	50	50	50
	Consumption of Water & Organism (µg/L)	-	--	170
	Consumption of Organism Only (µg/L)	-	-	4200
	Fish Consumption			
	High fish intake (0.22 kg/day)	-	1.8 µg/g (WW), 7.3 (DW)[10]	-
	Moderate fish intake (0.11 kg/day)	-	3.6 µg/g (WW), 14.5 (DW)[10]	-
	Low fish intake (0.03 kg/day)	-	18.7 µg/g (WW), 75.0 (DW)[10]	-

BCMOE = British Columbia Ministry of Environment; CCME = Canadian Council of Ministers of the Environment; DW = dry weight; OMOE = Ontario Ministry of Environment;

USEPA = United States Environmental Protection Agency; WW = wet weight; -- = no guideline.

[1] Water quality guideline for the protection of aquatic life from CCME (2016). Water quality guideline for drinking water from Health Canada (2014).

[2] All environmental quality guidelines from BCMOE (2016); details are provided in the technical report for selenium, BCMOE (2014).

[3] Water quality guideline for the protection of aquatic life from OMOEE (1994). Water quality guideline for drinking water from OMOE (2003).

[4] Environmental quality guidelines for the protection of aquatic life are from (USEPA 2016a); see the document for more details on the application of these guidelines. Water quality guideline for the protection of drinking water from USEPA (2016c). Water quality guidelines for the consumption of organisms from USEPA (2016d).

[5] This is the guideline. An alert concentration of 1 µg/L has also been established.

[6] The water quality criterion is 1.5 µg/L in lentic aquatic systems and 3.1 µg/L in lotic aquatic systems. These values apply to a 30-day average exposure and are not to be exceeded more than once in three years on average. Water quality

criteria for intermittent exposure can be found in USEPA (2016a).

7 This is an alert concentration. There were insufficient data for a full guideline.

8 This is an interim guideline. There were insufficient data for a full guideline.

9 Applies to a skinless, boneless filet.

10 Guideline based on edible portions of tissue. Wet weight to dry weight conversion based on 75% moisture content.

2.1 Background Concentration Procedure

The BCP may be applied to develop WQOs for bioaccumulative COPCs for any of the water management approaches. Appendix 2 describes the methods for deriving WQOs using the BCP which can be used directly for bioaccumulative COPCs.

The final step in the BCP includes consideration of alternative forms of a COPC. This component can be important for both selenium and mercury, where certain forms are known to be more toxic than others. If the preliminary WQOs developed using the BCP are higher than the WQGs, they may not be protective if the source loading is primarily in a more toxic form. WQOs may need to be adjusted to consider the specific form of the COPC (e.g., dissolved selenium, total selenate, total selenite; methylmercury), as described in Appendix 2, Section 2.4.

2.2 Derivation of *de novo* Water Quality Objectives

In some cases, it may be appropriate to derive WQOs *de novo* for bioaccumulative COPCs. This approach to WQOs-development may be appropriate when site-specific factors are predicted to reduce or enhance bioaccumulation of a COPC, for example:

- When a WQG was developed for lacustrine conditions, but the site has flowing-water conditions.
- A waterbody has very low or very high productivity.
- High levels of sulphate occur in surface water, which could influence selenium accumulation.

The following steps are recommended for deriving WQOs for bioaccumulative COPCs that are protective of aquatic organisms and aquatic-dependent wildlife (for more information on bioaccumulation modelling, see Brix et al. 2005; Toll et al. 2005; Presser and Luoma 2010):

1. Compile generic tissue-based objectives that have been established for the protection of aquatic life, aquatic-dependent wildlife, and human health (i.e., following the approach to guideline selection as described in Appendix 1).
2. Select the lowest tissue-based objective to support the development of protective WQOs (e.g., 4.0 mg/kg dry weight [DW] selenium in fish eggs/ovaries).
3. Compile relevant bioaccumulation factors (BAFs, e.g., periphyton-to-fish tissue) from literature-based sources, focussing on the tissues for which the selected objectives apply. Calculate the 95% upper confidence limit of the mean of applicable BAFs to support site-specific WQO derivation. The 95% upper confidence limit of the mean is referred to as the mean BAF.
4. Calculate a protective concentration of the bioaccumulative COPC in periphyton tissue by dividing the selected tissue-based objective by the mean BAF.

5. Determine a site-specific water-to-periphyton partition coefficient (K_d) by conducting laboratory bioaccumulation tests with site water and an indicator algal species that is likely to be a food source for benthic invertebrates (e.g., stoneflies, mayflies, etc. that preferentially feed on diatoms). Site water should be collected at several times of the year and the results averaged to obtain a K_d for use in deriving WQOs.
6. Calculate the numerical WQO by dividing the protective concentration of the bioaccumulative COPC in periphyton tissue by the site-specific K_d.

3.0 Preliminary Compilation of Water Quality Guidelines and Other Information for Bioaccumulative Contaminants

This Section provides information on draft and promulgated thresholds that are recommended for use as candidate WQOs for mercury and selenium. A similar process could be used to develop candidate WQOs for other bioaccumulative COPCs (e.g., PCBs) that are not explicitly addressed in this document.

3.1 Environmental Quality Guidelines and Criteria for Mercury

The Canadian Council of Ministers of the Environment (CCME) has not promulgated tissue-based criteria for mercury or methylmercury in fish tissue to protect aquatic life. However, WQGs for the protection of aquatic life have been promulgated for both mercury and methylmercury. The guideline for total mercury in freshwater is 0.026 µg/L (CCME 2003; 2016). The guideline for methylmercury in freshwater is 0.004 µg/L (CCME 2003; 2016). Neither of these guidelines account explicitly for bioaccumulation and biomagnification. Therefore, concentrations below these guidelines could result in the accumulation of methylmercury in the tissues of fish and aquatic-dependent wildlife to levels that may result in adverse effects. To protect against adverse effects to aquatic-dependent wildlife, CCME has promulgated a tissue-based methylmercury guideline (0.033 mg/kg wet weight [WW]) that applies to the diet of aquatic-dependent wildlife species (i.e., concentrations of mercury in aquatic invertebrates and fish; Table 1; CCME 2000; 2016).

The British Columbia Ministry of Environment (BCMOE) has adopted the tissue-based guideline for the protection of wildlife of 0.033 mg/kg WW (BCMOE 2016). However, BCMOE has not developed tissue-based guidelines for the protection of aquatic life. Long-term average WQGs have been developed by BCMOE that are dependent upon the proportion of methylmercury relative to total mercury in the water column. To protect aquatic life, the WQGs for total mercury are: 0.02 µg/L at 0.5% methylmercury, 0.01 µg/L at 1.0% methylmercury, and 0.00125 µg/L for waters with 8% or greater methylmercury (BCMOE 2016).

The United States Environmental Protection Agency (USEPA) has not promulgated tissue-based criteria for mercury or methylmercury in fish tissue for the protection of aquatic life or for the protection of aquatic-dependent wildlife. However, the USEPA has established Ambient

Water Quality Criteria for total mercury in the water column. The criterion continuous concentration (CCC) for total mercury is 0.77 µg/L (USEPA 2016b). The CCC is defined as the concentration in the water column at which no adverse effects to aquatic life are expected during indefinite exposure (USEPA 2014). For the purposes of evaluating water quality conditions against the CCC, the four-day mean concentration should not exceed the CCC more than once in three years (USEPA 2014). The USEPA has also developed a short-term maximum criterion, the criterion maximum concentration (CMC). The current CMC for total mercury is 1.4 µg/L (USEPA 2016b). The CMC is defined as the maximum concentration at which no adverse effects to aquatic life are expected during brief exposure (USEPA 2014). For the purposes of evaluating water quality conditions against the CMC, the one-hour mean concentration should not exceed the CMC more than once in three years (USEPA 2014). Neither the CMC nor CCC has been derived to account for the potential of bioaccumulation and associated effects on higher-trophic-level organisms. In water bodies with a moderate to high potential for methylmercury production (e.g., reservoirs, wetlands), these criteria are likely to be under-protective (USEPA 2016b). The USEPA has developed a fish tissue residue criterion for methylmercury of 0.3 mg/kg WW for the protection of human health based on fish consumption (USEPA 2016c).

Ontario uses fish tissue concentrations of mercury to establish advisory and restriction levels for consumption of fish by general and sensitive populations. Also Health Canada applies a standard of 0.5 ug/g total mercury WW for all commercially-sold fish. This standard is part of a risk management approach (Health Canada. Updating the Existing Risk Management Strategy for Mercury in Retail Fish. March 2007)

To support the development of tissue-based dose-response curves for mercury in fish tissue, Dillon et al. (2010) conducted a meta-analysis of published data on the toxicity of mercury to freshwater and marine fishes. These data were integrated into an effects-based dataset and dose-response models were developed for both juvenile/adult fish and early life stages of fish. Percent mortality was estimated for a range of mercury concentrations in tissue. The effects thresholds from Dillon et al. (2010) were reviewed to support the selection of tissue-based objectives to protect aquatic life. For juvenile and adult fish, the lowest concentration that resulted in increased mortality to fish (based on the lower 95% confidence limit) was a whole-body concentration of 0.3 mg/kg total mercury WW, which resulted in 8.2% mortality (range of 0.6 - 15.8%). For early life stages of fish, the lowest concentration that resulted in increased mortality to fish (based on the lower 95% confidence limit) was a whole-body concentration of 0.1 mg/kg total mercury WW, which resulted in 19.8% mortality (range of 0.07 - 35.5%).

The mercury thresholds for water, sediment, and tissues that are recommended to support the establishment of WQOs for Yukon waters are presented in Table 1.

3.2 Environmental Quality Guidelines and Criteria for Selenium

The CCME has not established bioaccumulation-based WQGs for selenium or guidelines for selenium in fish or wildlife tissues. However, a WQG of 1 µg/L has been recommended for the protection of aquatic life. In addition, the CCME has established WQGs for irrigation (20 µg/L for continuous use and 50 µg/L for intermittent use). The CCME has also established numerical soil quality guidelines for the protection of a variety of land uses (CCME 2016).

In 2014, BCMOE promulgated WQGs for selenium for the protection of aquatic life (BCMOE 2014). The guidelines include thresholds for the water column, dietary concentrations (i.e., in invertebrate tissue) for the protection of fish health, and fish-tissue based benchmarks (egg and ovary tissue, whole-body tissue, and muscle tissue) for the protection of fish. Specifically, BCMOE (2014) has developed a 30-day average guideline of 2 µg/L for the water column (with attainment being evaluated with a minimum of 5 samples collected over 30 days). In addition, alert concentrations of 1 µg/L in the water column or 2 mg/kg dry weight (DW) in sediments have been established; exceedance of alert levels can trigger adaptive management scenarios or site-specific evaluations. The alert concentrations were included in the suite of benchmarks because, in some lentic environments, exposure to relatively low concentrations of selenium in water (i.e., < 2 µg/L) can result in bioaccumulation in fish and/or aquatic-dependent wildlife to levels that can result in adverse effects. Dietary thresholds for the protection of fish health of 4 mg/kg DW for invertebrate tissue have also been established by BCMOE. In addition, tissue-based benchmarks of 11 mg/kg DW for eggs or ovaries, 4 mg/kg DW in whole-body tissues, and 4 mg/kg DW in muscle tissues (interim guideline only) are provided to protect fish species (BCMOE, 2014). These BC dietary thresholds and tissue benchmarks are intended to apply to the mean of eight or more samples rather than to individual samples.

In 2016, USEPA released new ambient water quality criteria for selenium in freshwater ecosystems (USEPA 2016a). These criteria contain both tissue-based and water-based benchmarks for the protection of aquatic life (i.e., fish). Specifically, the tissue-based selenium thresholds include an instantaneous maximum (i.e., any single measured fish) for fish egg or ovary tissue (15.1 mg/kg DW), an instantaneous maximum for whole-body fish (8.5 mg/kg DW), and an instantaneous maximum for fish muscle tissue (11.3 mg/kg DW). In addition to the tissue-based criteria, USEPA (2016a) has proposed 30-day average water-based criteria of 1.5 µg/L dissolved selenium for lentic systems and 3.1 µg/L dissolved selenium for lotic systems. The tissue-based criteria are thresholds never to be exceeded, whereas the water-based criteria are not to be exceeded more than once in three years on average (USEPA 2016a).

The selenium thresholds that are recommended to support the establishment of WQOs for Yukon waters are presented in Table 2.

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Appendix 6: Guidance on the Design of Water Quality Objectives Baseline Monitoring Programs

December 30, 2019

Prepared by Bill Slater, Slater Environmental Consulting, based on *Guidance Manual for Developing Water Quality Objectives for Freshwater Ecosystems in Yukon, Final Report, October 2016* (MacDonald et al. 2016).

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List of abbreviations

BCP:	Background concentration procedure
BTMF:	Bioavailability and toxicity modifying factors
COPC:	Contaminant of potential concern
USEPA:	United States Environmental Protection Agency
WQG: -	Water quality guideline
WQO: -	Water quality objective

1.0 Introduction

Understanding baseline and/or background conditions in a waterbody is critical for several steps in the development of Water Quality Objectives (WQOs) including selection of the water management approach, identification of Contaminants of Potential Concern (COPCs), and the derivation and verification of numerical WQOs. This document provides detailed guidance on the design and implementation of baseline/background monitoring programs to support the development of numerical WQOs for Yukon's waters. As such, it focuses on environmental components that are specifically relevant to the development of WQOs.

For simplicity, this appendix uses the term "baseline" when referring to both baseline and background water quality, which are defined as follows in the main Guide:

- **Background water quality:** Water quality conditions in a waterbody before the onset of any effects of local human activities. Characterization of these water quality conditions can be developed based on conditions in the potentially affected waterbody before the onset of human disturbance that affects water quality, or on conditions in upstream areas or reference areas.
- **Baseline water quality:** Water quality condition in a waterbody before the initiation of any project activities that may affect water quality. Baseline water quality is equivalent to background water quality if the water quality in the waterbody is not already measurably affected by local human activities.

The need for monitoring programs to address background and/or baseline water quality will depend on specific circumstances for the project and waterbody. In most cases, characterization of background water quality will be required. Characterization of baseline may also be required, especially if baseline water quality at the location where WQOs will be applied is not representative of background water quality. The design of monitoring programs for both baseline and background water quality should follow the guidance provided in this appendix.

Systematic and logical design of baseline monitoring programs, as described in Section 2.0, should be completed prior to initiating collection of baseline data because this will help to define efficient monitoring programs that deliver high quality data that achieves monitoring objectives. The proposed baseline monitoring program should be designed and implemented by qualified professionals and documented in a detailed baseline monitoring program study plan (Section 2.7). The data and information generated through the implementation of baseline monitoring programs must be evaluated, compiled, managed, synthesized, and reported in an accessible manner that supports development of WQOs.

The planning and development of quartz mining projects require comprehensive baseline monitoring programs that address a range of aquatic, terrestrial and atmospheric environmental components. Such comprehensive programs provide data to support project design, environmental assessment and licensing. They also provide a foundation from which to design and implement environmental effects monitoring programs, and evaluate future performance of the project. This document is not intended to provide guidance for development of these comprehensive baseline monitoring programs. *Guidelines for Mine Waste Management Facilities, Draft* (Government of Yukon 2017) provides additional guidance for development and implementation of comprehensive baseline monitoring programs.

1.1 Purposes of Baseline Monitoring for WQO Development

Characterization of baseline conditions supports several different steps in the development of WQOs, and the design of baseline monitoring programs depends on the specific purposes. The overall goal of baseline environmental monitoring is to provide the data and information that are required to understand and document relevant environmental conditions. To achieve this, baseline monitoring must be sufficiently robust to document variability and trends in the relevant physical, chemical, and biological characteristics of water and the aquatic ecosystem under baseline conditions.

Purposes of baseline monitoring in the context of WQO development can vary, with some purposes common to all WQO development initiatives, and other purposes that are dependent on methods selected for derivation of WQOs. While the development of WQOs focuses on water quality, understanding of baseline conditions for other components of the aquatic ecosystem is often needed to support the WQO development process. The results of initial baseline monitoring and decisions made during the WQO development process will influence the baseline data requirements. For example, the selection of the water management approach and the results of initial baseline monitoring will influence decisions about methods for deriving WQOs. These will, in turn, influence the baseline data requirements. As a result, it is important that the design of the baseline monitoring program follow an iterative approach to address changes and additions to the purposes of monitoring.

Purposes for baseline monitoring programs to support WQOs may include the following:

- **Selection of the Water Management Approach:** In addition to water quality data, decisions about the water management approach require information about aquatic species and their habitat, especially for any threatened species, endangered species and species of special concern listed under Schedules 1, 2 or 3 of the *Species at Risk Act*, and any species of conservation concern identified by the Yukon Conservation Data Centre. Decisions about the water management approach can also require information about human activities and their effects on a waterbody.
- **Identification of COPCs:** An understanding of baseline water quality is the primary data requirement to support the identification of COPCs. Depending on the water management approach, data must be sufficient to interpret both central tendency (e.g., mean) and upper limit (e.g., 95th percentile) conditions and their variability. Identification of COPCs requires an understanding of pre-development conditions. Where there are other human activities adversely affecting a waterbody, baseline programs may need to

collect data related to the effects of those activities to provide rationale for application of a use-restoration approach.

- **Derivation of Numerical WQOs:** Each method for establishing numerical WQOs has its specific needs for understanding of baseline conditions.
    - Adoption of Water Quality Guidelines (WQGs) as WQOs and application of the Background Concentration Procedure (BCP) require an understanding of baseline water quality conditions including central tendency (e.g., mean) and upper (e.g., 95th percentile) conditions and their variability.
    - The Recalculation and Resident Species Procedures require an understanding about the aquatic organisms that are present in the waterbody that will be affected and their habitat.
    - Accounting for Bioavailability and Toxicity Modifying Factors (including the Water Effects Ratio Procedure) requires an understanding of baseline water quality conditions including central tendency (e.g., mean) and upper (e.g., 95th percentile) conditions and their variability for both COPCs and any potential bioavailability and toxicity modifying factors (BTMF).
    - Addressing bioaccumulative substances requires a site-specific understanding of the relationship between concentrations in water and those in aquatic organisms.

The results of baseline monitoring programs are also important during the implementation of WQOs, providing the basis for confirming the effectiveness of the numerical WQOs for achieving the narrative WQOs, and evaluating attainment of WQOs. In this context, baseline monitoring programs must provide the data necessary to support design and implementation of future aquatic effects monitoring programs. The design of aquatic effects monitoring programs is not the focus of this guidance.

1.2 Approaches to Designing Baseline Monitoring Programs

Development of WQOs requires an understanding of pre-development conditions for the aquatic ecosystem at the locations where WQOs will apply. For projects proposed in areas with pristine water quality and aquatic conditions (i.e., not measurably affected by human activities), background data can be collected from waterbodies that will potentially be affected. Where waterbodies are already affected by human activities, there are three alternative approaches that can be used to characterize background water quality conditions. Application of these approaches should be accompanied by a rationale that demonstrates the suitability of the approach. The three approaches include:

- Use historically-collected data on water quality for the site (i.e., prior to the commencement of activities that could alter water quality conditions).

- Monitor current water quality conditions at one or more stations located upstream of existing contaminant sources.
- Monitor current water quality conditions at one or more reference areas, which are generally located near the site under consideration and have similar physical and ecological characteristics, but have not been adversely affected by human activities.

In many cases, applying these approaches will benefit from local and traditional knowledge about species and habitat conditions. Issues of data quality, including detection limits, must be considered and addressed for all of the approaches, but will be particularly relevant when relying on historically-collected data.

In all cases, background monitoring programs should include monitoring at locations that will provide data about future conditions in areas not affected by proposed development activities. These data from reference areas will support data interpretation during project implementation.

1.3 Minimum Baseline Data Requirements

The scope of baseline monitoring programs will be influenced by the monitoring purposes and the specific needs of each WQO development initiative. *Guidelines for Mine Waste Management Facilities, Appendix A: Baseline Data Collection* (Government of Yukon 2017) provides additional guidance about planning and implementing comprehensive baseline monitoring programs, including identifying minimum data requirements for several environmental components.

For any development of numerical WQOs, Yukon has established minimum data requirements for characterizing baseline water quality. These minimum requirements provide clarity about baseline monitoring expectations, and support adequate characterization of variability in water quality conditions. Because the identification of COPCs and application of some WQO methods (e.g., BCP, Accounting for BTMF) require an understanding of extreme water quality conditions, a robust dataset reduces the risk of developing WQOs that fall within the normal range of natural water quality conditions in a waterbody. Implementation of such WQOs would lead to excessive false positive exceedances during operation. The following minimum data requirements for baseline water quality apply for development of WQOs:

- Three consecutive years of recent water quality data collected on a monthly basis at locations where WQOs are to be developed and applied, and at appropriate reference locations.

- One or more intensive sampling programs during each of the three years, with at least five samples collected in 30 days during periods of high expected short-term water quality variability. In most cases, the period of highest variability will occur during freshet, but intensive sampling should be included to address any other periods of high natural variability.

Based on statistical analysis completed on natural Yukon streams, three years of data on dissolved and total metals is the minimum duration that can support a reasonable understanding of central tendency (i.e., mean or UCLM) and extreme (e.g., 95th percentile) conditions. Three years of data is also the minimum duration required to identify any trends in natural conditions. Where water quality conditions exhibit natural trends, the data may result in WQOs that are not reasonable or applicable during project implementation.

The requirement for the annual intensive sampling program may be eliminated if the study design for the baseline monitoring program has included a pilot study specifically designed and implemented to estimate variability in support of defining monitoring frequency. The number of samples collected to support a pilot study should be as large as feasible to provide accurate estimates of variation (Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000).

Baseline water quality monitoring programs to support WQO development should be combined with collection of high quality flow data because these data are critical for understanding contaminant loading, and the relationship between effluent quality and receiving water quality. Flow monitoring should be completed at each water quality sampling event. The *Manual of British Columbia Hyrdrometric Standards* (BCMOE 2009) provides guidance about methods for collection of hydrometric data.

Development of WQOs for bioaccumulative COPCs requires characterization of baseline concentrations of bioaccumulative COPCS in tissues of aquatic organisms. Minimum data requirements for baseline tissue chemistry data to support development of WQOS for bioaccumulative COPCs are described below. For each environmental component, data should be collected at locations where WQOs will apply for bioaccumulative COPCs (e.g., mercury or selenium) and at appropriate reference locations that will not be affected by the proposed project.

- **Fish Tissue Chemistry:** Sampling fish at each station once/year for three years. Whenever possible, non-lethal sampling techniques (e.g., lipid-filled membrane bags, muscle plugs) should be used to evaluate or simulate fish tissue chemistry.
- **Invertebrate Tissue Chemistry:** Sampling invertebrates at each station once/year (i.e., in late summer) for three years.
- **Algal Tissue Chemistry:** Sampling algae (i.e., periphyton, phytoplankton) at each station once/year (i.e., in late summer) for three years.

Interpretation of tissue chemistry data to evaluate transfer factors will also require a detailed understanding of the aquatic ecology. Monitoring programs to address community structure will be required as part of an overall baseline monitoring program.

2.0 Design of Baseline Monitoring Programs

Like all monitoring programs, the design of a baseline monitoring program that will support development of WQOs requires a systematic approach that is founded on a clear understanding of the program's objectives, then progresses to define monitoring activities that will deliver data to achieve the program's objectives. The following sections describe the steps in a recommended framework for designing baseline monitoring programs. The steps are generally based on those described in *Guidance on Systematic Planning Using the Data Quality Objectives Process* (USEPA 2006), guidance that is aimed at design of efficient monitoring programs that provide good quality data to meet objectives and scientific requirements. The steps include:

1. Define the problem to be investigated.
2. Identify the objective(s) of the baseline program.
3. Identify the information inputs required to achieve the objective(s).
4. Define the boundaries of the baseline program.
5. Develop the analytical approach.
6. Specify performance or acceptance criteria.
7. Develop the plan for obtaining data.

Proponents of quartz mining projects in Yukon should engage the services of qualified professionals for the design and implementation of baseline monitoring programs that are intended to support WQO development.

2.1 Problem Definition

For baseline monitoring programs in the context of developing WQOs, the primary problem is how to characterize baseline conditions in sufficient detail to support development of WQOs, taking into consideration the purposes for the specific WQO development initiative. Baseline monitoring programs can be designed and implemented iteratively. When initially designing baseline programs to support WQO development, a wide range of substances and potential WQO development methods should be considered. The program can be refined as data become available to support decision-making about required baseline characterizations. Anticipating the purposes and objectives of the baseline monitoring program will require compilation of available information about the affected waterbody and potential impacts on the waterbody. This information will support development of a conceptual model of the environmental problem which can be used to identify which WQO development activities may be relevant for the proposed project, and therefore what baseline data requirements may arise.

Input from regulatory authorities and relevant stakeholders will likely be useful in defining the specific problem(s) to be addressed by the baseline monitoring program.

2.2 WQO Baseline Monitoring Objectives

The objectives of a baseline monitoring program to support WQOs should be based on the specific questions that the program needs to answer. For these questions, the results of the program would be used to make decisions about alternative actions. Developing a clear understanding of the objectives will be informed by preparing a complete listing of questions and alternative actions/decisions that are associated with the baseline monitoring purposes.

For WQO development there are likely to be multiple questions, some of which are dependent on the outcome of other questions. For example, determining the water management approach leads to questions about WQO development methods. Table 2-1 provides some examples of baseline monitoring purposes, questions, objectives and alternatives actions. Understanding the relationship between various questions and objectives will help to establish priorities for resolving questions. As baseline data becomes available, refinement and adjustment of the monitoring program to address changing needs can be addressed by periodically re-evaluating the status of monitoring purposes, questions and objectives. Logic diagrams and decision trees can be helpful for understanding and articulating the relationship between various objectives and study questions.

Table 2-1: Examples of Questions, Objectives and Alternative Actions.

Monitoring Purpose	Question	Baseline Monitoring Objective	Alternative Actions
Selection of Water Management Approach	Is there critical habitat or potential critical habitat for species at risk?	To identify any potentially-affected critical habitat or potentially critical habitat for species at risk.	If critical habitat or potential critical habitat for species at risk will be affected, apply non-degradation approach.
			If critical habitat or potential critical habitat for species at risk will not be affected, evaluate other criteria for applying non-degradation.
Identification of COPCs	Do predicted receiving water concentrations exceed baseline conditions?	To understand baseline conditions, including estimates of central tendency and upper limit concentrations.	For non-degradation approach, substances with concentrations predicted to exceed baseline conditions are COPCs.
			For use-protection approach, substances with predicted concentrations that exceed baseline conditions should be compared to WQGs.

Selection of methods for deriving numerical WQOs	Do baseline conditions exceed WQGs?	To understand baseline conditions, including temporal and spatial variability.	If COPC concentrations exceed WQGs, consider BCP.
			If COPC concentrations are less than WQGs, BCP does not apply.
Applying the BCP	What characteristics represent background conditions for a COPC?	To understand baseline conditions, including temporal and spatial variability, and central tendency and upper limit concentrations.	Identify appropriate measures of background conditions for application as WQOs.

The United States Environmental Protection Agency (USEPA) guidance (USEPA, 2006) identifies two types of study questions: decision problems and estimation problems. Decision problems are those that require both monitoring data and action levels to resolve (e.g., comparison of measured COPC concentrations to WQGs when deciding whether to apply the BCP). Estimation problems are those that require only monitoring data to resolve (e.g., characterizing baseline conditions in the study area to identify appropriate WQOs using the BCP).

2.3 Data Needs

The third step in the WQO baseline monitoring program design framework entails the identification of types and sources of data needed to characterize baseline conditions, including identification of the type of information that may be needed to meet data performance criteria, and identification of sampling and analysis methods that can deliver the required data. For most new proposed quartz mining projects, the source of data will be a new baseline data collection program. In some cases, there may be existing data that can supplement new programs.

Identify the characteristics or indicators that should be measured in the WQO baseline monitoring program to address each specified purpose and objective, and for each environmental component. For example, identifying COPCs will require data about physical and chemical characteristics of surface water. In the early planning stages, the listing of characteristics and indicators should be inclusive. It can be refined as early data collection provides information to answer initial monitoring questions.

Design of the WQO baseline monitoring program will require selection of appropriate sampling and analysis methods for generating the required data. Methods should be selected, and quality assurance/quality control programs developed, to avoid or minimize the following sources of bias in environmental sampling and analysis:

- Non-representative sampling
- Instability or contamination of samples between sampling and analysis

- Interferences and matrix effects in analysis
- Inability to determine the relevant forms of a COPC being measured
- Failure to calibrate instrumentation
- Failure to correct for analytical results of blank samples
- Sample misidentification
- Pseudo-replication
- Use of data below the level of quantification
- Method differences between labs and method changes over time.

2.4 Study Boundaries

The fourth step in the framework for design of WQO baseline monitoring programs involves defining the boundaries of the program. This includes the following activities (USEPA 2006):

- Defining the target population
- Determining the spatial and temporal boundaries for the target population of the baseline monitoring program
- Identifying practical constraints on sampling activities
- Defining the scale of inference.

In the case of WQO baseline programs, the target population is the water and relevant components of the aquatic ecosystem. Spatial boundaries define the physical area to be studied and the general locations where samples will be collected. For WQO baseline programs for proposed quartz mining projects, this must include both reference areas and areas that will be mine-affected, specifically the locations where WQO will be applied. Initial temporal boundaries define the time frame within which the baseline monitoring program will be conducted and when the samples will be collected. Yukon's minimum data requirements for water quality data to support WQO development specify a period of at least three years of monthly sampling. Spatial and temporal boundaries will also be defined by requirements to understand spatial and temporal variability in baseline characteristics. For WQO baseline programs, the scale of inference refers to the unit of time over which data will be collected analyzed and interpreted – generally the sampling interval. As described in Section 1.3, WQO baseline water quality programs in Yukon must include monthly sampling frequency throughout the year. One or more annual intensive sampling programs with five samples in 30 days should also be included during periods of high expected variability in water quality conditions (usually freshet).

The practical constraints associated with the proposed data collection activities also need to be identified during this step in design framework. For example, seasonal constraints on, and challenges for, data collection are common in Yukon and should be identified. Similarly, issues related to the availability and operation of monitoring equipment need to be identified and, if possible, addressed. In most cases, solutions to these constraints can be found once they have been identified.

2.5 Data Interpretation

The fifth step in the design framework for baseline monitoring programs involves developing the analytical approach that will be used to draw conclusions from the baseline monitoring program results. The analytical approach is influenced by what conditions of a specific indicator will define the action level for a "decision problem" or be used to characterize conditions for an "estimation problem" (See Section 2.2 re: decision and estimation problems).

For example, when deriving WQOs using the non-degradation approach, the objective of the baseline monitoring program is to characterize the levels of COPCs or other variables under baseline conditions (i.e., to support application of the BCP to derive WQOs). Derivation of numerical WQOs using the BCP requires estimation of both the central tendency and upper limit of background concentrations for each of the COPCs (an "estimation problem"). The estimate of central tendency of the background concentration of each COPC is used to establish a long-term WQO, while the upper limit of background conditions is used to establish the short-term WQO for each water quality variable. As such, the analytical approach entails determining the central tendency, calculated as the upper 95% confidence limit of the mean (or the arithmetic mean if fewer than 10 measurements are available), and upper limit of natural background conditions, calculated as the 95th percentile of concentrations.

The analytical approaches that will be used to interpret data should be addressed for all components of WQO baseline monitoring program.

2.6 Data Quality Criteria

The sixth step in the baseline monitoring program design framework involves derivation of the performance or acceptance criteria that will be used to specify tolerable limits on estimation or decision errors. The first activity in this step involves determining the sources of variability in the sample data set. While there may be many factors contributing to error, two main types of errors are typically identified. These are sampling errors, which can lead to imprecision (i.e., random errors) or bias (i.e., systematic errors) in the estimates of population parameters, and measurement errors, which arise from imperfections in the measurement and analysis system. 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 judgment, and/or other information.

USEPA (2006) provides detailed guidance about defining performance or acceptance criteria. The types of criteria will vary depending on the proposed uses of the data. Collecting baseline information to support WQO development usually entails an "estimation problem" for which performance criteria will relate to the uncertainty associated with the parameters used to characterize conditions (e.g., UCLM, or 95th percentile). On the other hand, monitoring programs to evaluate attainment of WQOs will entail a "decision problem" for which performance criteria need to be defined through statistical hypothesis testing.

Establishment of appropriate performance criteria provides an objective and consistent basis for evaluating the measurement data generated in the sampling program. Such performance criteria for measurement data typically are defined using five indicators of data usability:

- Accuracy: A measure of the bias of a system or measurement.
- Precision: A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions.
- Completeness: A measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions.
- Representativeness: 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 2000; ASTM International 2016).
- Sensitivity: A measure of the capability of methodology or instrumentation to discriminate among measurement responses for quantitative differences of a parameter of interest.

2.7 Develop the Plan for Collecting Baseline Data

The results and outcomes of all steps in the design framework should be compiled into a Detailed Baseline Monitoring Study Plan. The plan should describe a resource-efficient design for collecting and analysing environmental samples or for generating other types of information needed to support the baseline monitoring program, and ultimately to provide the baseline information needed to develop WQOs. In most cases, the overall baseline monitoring program will be designed to not only address the objectives related to WQOs, but also broader project planning needs. Nonetheless, it may be useful to define the specific baseline monitoring program components that are needed to support a WQO development initiative. Proponents should seek input from relevant government agencies during the development of the study plan.

2.8 Compile Supporting Information

The Study Plan should compile and summarize the information and outputs from the design framework. This information will clearly identify the purposes and objectives of the program, and provide the rationale for the proposed approaches and monitoring activities. At a minimum, the Study Plan should present the following supporting information:

- The objectives of the baseline monitoring program and the questions that the data will need to answer. Specific purposes, objectives and questions related to WQOs should be identified.
- Descriptions of the study area including spatial and temporal scopes.

- Identification of the environmental components that will be addressed in the monitoring program, and any existing information about these components within the study area.
- Description of the information requirements that must be addressed by the baseline monitoring program, and identification of indicators that will be used to address objectives and study questions.
- Description of procedures that will be used to collect, analyze and manage the data.
- Description of the analytical approaches that will be used to interpret the resulting data to address objectives and study questions.
- Description of methods and parameters that will be used to evaluate the adequacy of the resulting data.

2.9 Develop the Monitoring Program Study Plan

As sound, science-based decisions need to be based on accurate information, the following issues must be addressed in the conceptual baseline monitoring program design (USEPA, 2002):

- 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.
- The representativeness of the data with respect to the objectives of the study.

The first three issues can be effectively addressed through a detailed Sampling and Analysis Plan (USEPA 2012; 2014a) that should be part of the Study Plan. Representativeness must be addressed through the selection of an appropriate sampling design. 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). Considerations for sampling design for a baseline monitoring program include locations of sample sites, variability in monitoring data, sampling frequency, and sampling duration. Baseline water quality monitoring for WQO development must at least meet Yukon's minimum data requirements.

Water quality conditions are known to vary substantially on temporal and spatial bases. This underlying variability in water quality data makes it challenging to distinguish changes and trends in water quality conditions from apparent noise in the system. For this reason, a baseline monitoring program must incorporate design elements that facilitate characterization of the various sources of natural variability and support interpretation of the resultant data. Potential sources of variability that are relevant to WQO baseline monitoring programs, and strategies to address these sources of variability are identified below:

- **Small-scale spatial variability:** Conduct replicate sampling to assess homogeneity over small distances.
- **Variability with depth:** Conduct depth-integrated sampling and grab sampling at various water depths and compare the results using statistical methods. Alternatively,

conduct only grab sampling at various water depths and compare the results using statistical methods.

- **Cross-sectional variability:** Conduct a station evaluation to determine if water quality varies significantly along a cross-section of a river. Data collected along the transect are compared using statistical methods.
- **Longitudinal variability:** Conduct an intensive water quality survey to collect water samples at numerous locations within a watershed. Data collected at the various stations are compared using statistical methods.
- **Diurnal variability:** Conduct intensive sampling at multiple times during a 24-hour period during station evaluations under various flow conditions (i.e., high, moderate, and low).
- **Seasonal variability:** Conduct sampling over the course of a year, with intensive sampling (i.e., 5 samples in 30 days) conducted during periods of expected high short-term variability (e.g., freshet). Use graphical and statistical techniques to evaluate seasonal variability.
- **Inter-annual variability:** Conduct long-term sampling at a fixed frequency at fixed stations. Use graphical and statistical techniques to evaluate long-term trends.
- **Variability due to regional and global influences:** include reference stations in baseline monitoring programs. Conduct long-term monitoring at a fixed frequency at fixed reference stations. Use graphical and statistical techniques to evaluate long-term trends.

Acquisition and evaluation of data on the sources of variability in water quality conditions provide means of designing and optimizing sampling programs for assessing status and trends. In general, monitoring for characterizing baseline conditions involves the collection of water samples for analysis at a fixed frequency over an extended time period.

Programs should be designed to at least meet the minimum data requirements described in Section 1.3. Monitoring programs developed for the collection of baseline water quality data should consist, at minimum, of monthly sampling events conducted for a period of three years. In addition, the monitoring program should include at least one annual 5-in-30-day sampling event during periods of highest expected short-term variability in water quality, most likely during freshet. Additional intensive sampling should be included if necessary to address any other periods of high natural variability. These sampling events are defined as the collection of five samples at approximately six-day intervals over a 30 day period. The frequency of sampling for other types of data will also need to be defined during the conceptual design process.

The Study Plan must include a detailed sampling and analysis plan that describes the specific procedures and methods that will be used to collect, analyze and manage the data to address the requirements of the Study Plan (USEPA 2012; 2014a).

3.0 Implement the Baseline Monitoring Program

In addition to collection of data in accordance with the Study Plan, implementation of the Baseline Monitoring Program entails verification of the practicality of the Study Plan; evaluation, compilation and interpretation of data, and iterative design refinement.

3.1 Verify the Study Plan

As an initial step in the implementation of the baseline monitoring program, it is important to verify that samples specified in the Study Plan can be collected at the site. Furthermore, it is important to determine if the selected sampling methods are appropriate and applicable to the conditions at the site. In this way, the level of effort necessary to collect the required number of samples can be determined. At this stage of the process, it is prudent to develop a number of contingency plans that can be used to direct field sampling efforts if unexpected conditions are encountered.

3.2 Evaluate Baseline Monitoring Data

The data that are generated by the baseline monitoring program must be evaluated relative to the performance and acceptance criteria defined in the Study Plan to determine if they can be used to achieve the objectives related to development of WQOs. For example, do the data meet performance criteria that define acceptable levels of accuracy, precision, completeness, representativeness, and method sensitivity? In addition, any issues related to sample holding times, instrument calibration, and related factors need to be considered in the verification and validation of project data. The results of this evaluation should be used to identify the data that are useable for specific purposes associated with development of WQOs. In addition, this evaluation facilitates identification of data gaps that emerge as a result of data quality issues. The results of such an evaluation will determine if the data can be used directly, if the data need to be qualified prior to use, or if the data should be rejected. Guidance on data verification and validation is provided by Clark et al. (1996) and USEPA (1994; 1999; 2001; 2014b; 2014c).

3.3 Compile Baseline Monitoring Data

The data that are generated under the baseline monitoring program should be compiled in a format that facilitates use in the WQOs development initiative, including accessibility by all interested parties. Data compilation describes the activities associated with collating information collected in the field and the data generated in laboratory analyses. This activity represents a key step in the overall baseline water quality assessment because it assembles data and information in a form suitable to support data analysis and interpretation. All of the data that are compiled in the project database need to be verified against the original data source to ensure data quality. Such databases should be designed and populated with the needs of data users in mind. Because data are typically generated in multiple batches over the duration of the baseline monitoring program, databases must be constantly updated and users apprised of the changes that have been made. Periodic database auditing is also recommended to ensure that the underlying data used in data analyses are correct and internally consistent.

3.4 Interpret Baseline Monitoring Data

Interpretation of data should be undertaken in accordance with the analytical approaches identified in the study design. These approaches will be specific to the purposes and objectives of monitoring related to WQOs, and thereby are intended to answer to study questions and support specific activities in the development of WQOs. For example, when applying the non-degradation approach, one objective of the baseline monitoring program is to characterize the levels of COPCs or other variables under baseline conditions, in order to derive numerical WQOs using the BCP.

3.5 Iterative Study Plan Refinement

Refinement of the Study Plan in response to monitoring results, changing conditions or changing objectives is an important component of any baseline monitoring program. It is particularly important in relation to development of WQOs because results of initial baseline monitoring programs may lead to decisions that will change the monitoring objectives. For example, initial monitoring of baseline water quality conditions may confirm that the BCP is not an applicable approach for developing WQOs, leading to a requirement to consider another method. If the WER procedure is selected as a method, the application of this procedure may lead to requirements for additional data about baseline toxicity. The implementation phase of a baseline monitoring program to support WQO development should include systematic re-evaluation of the adequacy of the Study Plan on at least an annual basis. More frequent re-evaluation may be required as the WQO initiative progresses.

In addition to evaluating the Study Plan, the field sampling activities and sampling and analysis plan should be audited as sampling progresses to ensure that environmental samples are being collected using the appropriate methods and procedures. In addition, the laboratories that have been selected should be periodically audited to confirm that they are generating reliable data. Ultimately, the performance criteria for measurement data provide the basis for evaluating the extent to which the data generated meet the objectives of the baseline monitoring program.

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