Marine Monitoring Guidance

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Table of Contents

Acronyms

AEMP	Aquatic Effects Monitoring Program
BACI	Before-After-Control-Impact
BC	British Columbia
CCME	Canadian Council of Ministers of the Environment
COPC	Contaminant of Potential Concern
CSM	Conceptual Site Model
DO	Dissolved oxygen
EMA	*British Columbia Environmental Management Act*
ENV	British Columbia Ministry of Environment and Climate Change Strategy
FLNRO	Ministry of Forests, Lands and Natural Resource Operations
IDZ	Initial Dilution Zone
MWR	*Municipal Wastewater Regulation*
QP	Qualified Professional
REMP	Receiving Environment Monitoring Program
WQG	British Columbia Water Quality Guidelines
WQO	Water Quality Objective

Glossary

Aquatic Life
Any living component of the marine ecosystem, including phytoplankton, zooplankton, benthos, macrophytes and fish.

Benchmark
A point of reference against which measurement endpoints (e.g., water quality parameter) may be compared or assessed. For the purpose of impact assessment under waste discharge permitting, these benchmarks include provincial water quality guidelines, water quality objectives or science based environmental benchmarks.

Bioaccumulative
A substance that can accumulate in various tissues of an organism when exposed to or ingested through water or ingested through food. Bioaccumulation occurs within an organism when the rate of uptake is greater than the rate of excretion or metabolic transformation of that substance.

Contaminant of Potential Concern
Any physical, chemical, or biological substance in water or sediment at concentrations that exceed benchmarks and are at risk to result in adverse effects on human health or aquatic life receptors.

Initial Dilution Zone
The 3-dimensionl zone around a point of discharge where mixing of the effluent and the receiving environment water occurs.

Persistent
A chemical that does not readily biodegrade and remains in the environment for extended periods of time.

Qualified professional
An applied scientist or technologist specializing in an applied science or technology applicable to the duty or function including, if applicable, and without limiting this, agrology, biology, chemistry, engineering, geology, or hydrogeology and who is registered with the appropriate professional organization, is acting under the organization's code of ethics and is subject to disciplinary action by that organization. A qualified professional (QP), through suitable education, experience, accreditation and/or knowledge, may be reasonably relied on to provide advice within their area of expertise (ENV 2019b).

Receptor
Any individual organism, species, population, community, habitat, or ecosystem that may be exposed to contaminants of potential concern.

Water Quality Guidelines
British Columbia Water Quality Guidelines (WQGs) are science-based levels of substances that are protective of given water uses such as aquatic life, drinking water, recreation, agriculture and industry. WQGs provide a consistent basis for assessing water quality conditions throughout the province of British Columbia. The province has also adopted working water quality guidelines to indicate safe levels in the environment for substances that have not been fully assessed by the Ministry of Environment and Climate Change Strategy.

Water Quality Objective

Water Quality Objectives (WQO)s are scientifically-derived numerical concentrations or narrative statements considered to be protective of the water values and uses for a specific waterbody, in ambient conditions. WQOs are established on a priority basis for waterbodies (fresh, estuarine, and marine) of regional, provincial, inter-provincial, and international significance. WQOs are set with the goal of protecting aquatic habitats by maintaining existing water quality, improving existing water quality, or protecting water quality for a specific value or use. Recognized water values and uses include:

- Drinking water sources;
- Aquatic life and its habitat;
- Wildlife and its aquatic habitat;
- Agriculture (livestock watering and irrigation);
- Recreational use and aesthetics; and
- Traditional, cultural, and social values.

1.0 Introduction

This document provides guidance for designing marine environment monitoring programs, including baseline and operational monitoring, in support of all types of effluent permitting in British Columbia (BC) under the *Environmental Management Act* (EMA). This document is intended to inform proponents who plan to discharge effluent, and existing operators who discharge effluent to the marine environment (i.e., estuaries, bays, and open marine waters), and guide Qualified Professionals (QPs) who design and execute marine monitoring programs. Minimum requirements and design considerations for monitoring programs that evaluate the impacts of discharges on the marine environment are described. The guidance provided in this document does not supersede conditions or requirements of authorizations or regulations enacted under EMA. Throughout the document, various other guidance documents are referred to that detail specific requirements related to certain industries or provide general guidance on monitoring methods and program design.

Baseline studies and operational monitoring programs are described in Section 1.1 and Section 1.2, respectively. Baseline studies are typically completed prior to project approval to assess current ambient condition and evaluate the potential environmental impacts of the project. Subsequently, an operational monitoring program is initiated to monitor the influence of the project on the receiving environment and inform adaptive management decisions. Ideally, the knowledge gained from the baseline study is used to inform and refine the design of the operational monitoring program.

There are instances where proponents are operating without having completed a baseline study, and/or their operational monitoring program is deficient or non-existent. It is a goal of the BC Ministry of Environment and Climate Change Strategy (ENV) to implement standardized monitoring requirements for all effluent discharges to the marine environment and maintain those standards for future projects. As such, this guidance document is intended to be used to design monitoring programs for projects that are in their pre-application phase (i.e., pre-discharge) and/or operational phase (i.e., discharge). The guidance can be used to design new monitoring programs or enhance current programs. Thus, Sections 2 through 10 apply to all monitoring programs (including baseline studies). There are several caveats throughout the document that will guide proponents on additional considerations if they are operating without sufficient baseline or monitoring data currently available.

The monitoring program must collect data for both abiotic and biotic measurement endpoints to evaluate the impact of a project on marine environment receptors. Table 1 presents an example of the various abiotic and biotic measurement endpoints that should be considered, however, additional receptors and or measurement endpoints may be applicable based on effluent characterisation and/or receiving environment attributes. Abiotic measurement endpoints include water quality (Section 7) and sediment quality (Section 8) parameters. Biological (Section 10) measurement endpoints include assessment of community assemblages (e.g., benthic invertebrate or plankton communities), macrophyte coverage (e.g., eelgrass mapping), and concentrations of contaminants in tissue (e.g., fish, crustaceans, bivalves).

Table 1. Examples of Measurement Endpoints relevant for evaluating risks to marine environment receptors.

Measurement Endpoint	Receptor							
	Aquatic Plants	Aquatic Invertebrates		Fish		Aquatic-Dependant		Humans
		Benthic	Pelagic	Benthic	Pelagic	Birds	Mammals	
Surface water chemistry (<1 m depth)	✓	✗	✓	✗	✓	✓	✓	✓
Water column chemistry (>1 m depth)	✓	✓	✓	✓	✓	✓	✓	✓
Water Toxicity	✓	✗	✓	✓	✓	✗	✗	✗
Sediment Chemistry	✗	✓	✗	✓	✗	✗	✗	✗
Porewater Chemistry	✗	✓	✗	✓	✗	✗	✗	✗
Sediment Toxicity/ Porewater Toxicity	✗	✓	✗	✓	✗	✗	✗	✗
Benthic Invertebrate Community Structure	✗	✓	✗	✗	✗	✗	✗	✗
Fish Community Structure	✗	✗	✗	✓	✓	✗	✗	✗
Macrophyte Community Structure	✓	✓	✓	✓	✓	✓	✓	✗
Tissue Chemistry	✗	✓	✓	✓	✓	✓	✓	✓*

Source: Table adapted from the Revised CRD Wastewater and Marine Environment Monitoring Program (Lowe et al. 2012)
✗ = measurement endpoint is not relevant to the receptor
✓ = measurement endpoint is relevant to the receptor
* = human consumption of tissue (e.g. fish, shellfish)

KEY POINTS

- Guidance is supplement to, not a replacement for, conditions and requirements of authorizations.
- Guidance is applicable to projects in pre- or operational discharge phase.
- Guidance document to be used in conjunction with other referenced documents that provide further details applicable to specific project attributes and industries.

- Marine monitoring programs should monitor abiotic (water quality and sediment quality) and biotic (invertebrates, fish, plankton, macrophytes) measurement endpoints.

1.1 Baseline Study

The two key objectives of a baseline study are:

1. To characterize background (i.e., pre-disturbance/discharge) conditions to determine the guidelines or benchmarks that are most applicable for the receiving environment, and
2. To characterize current ambient conditions prior to the proposed project being initiated to measure future effects of the project on the receiving environment.

It is imperative that the baseline study describes the background conditions in the receiving environment. Background, in this context, means conditions prior to any anthropogenic disturbances in the area or prior to any new discharge in an area. It can be difficult to describe background in areas with a long history of anthropogenic influences. However, this information is still critical for the baseline study to confirm whether provincial water quality or sediment quality guidelines are the appropriate protective target for the receiving environment. The provincial guidelines are not intended to be used as a “pollute up to” benchmark and more stringent protection goals, including non-degradation (i.e., no change from background) may be applicable to the site. As such, it cannot be assumed that as long as parameters are below guidelines the project will have a negligible impact. Conversely, if the guideline is lower than the upper limit of background concentrations then a site-specific water quality objective (WQO) may need to be developed. The process for setting WQOs is described in the *Guidance for the Derivation and Application of Water Quality Objectives in British Columbia* (MOE 2013). While the development of WQOs is the responsibility of the ENV, project proponents can submit data for consideration in this process.

Baseline data are also required to define the natural variability of each parameter in order to accurately measure the influence of future activities on the receiving environment and set appropriate triggers for the operational monitoring program. Monitoring triggers will need to be established that assist the proponent during operations to ascertain when a change, outside of natural variability, is occurring and have a predetermined timeframe established to implement appropriate mitigative measures to prevent exceedances of benchmarks and/or adverse effects on the receiving environment.

At least two years of monitoring data (absolute minimum one year of data) is recommended to inform the baseline study (MOE 2016b). The data should also have recently been collected (i.e., collected within five years of the application). If data older than five years are to be incorporated into the baseline dataset, a detailed rationale must be provided that describes how the conditions at site have not changed due to either anthropogenic influences or natural conditions (e.g., increasing water temperatures, reduced flows, invasive species, etc.). For example, if there are fifteen years of water quality data available for a bay, but a pulp and paper mill ceased operation within the most recent five years, then only the most recent five years of data should be included in the baseline study to characterize current conditions.

The results of the baseline study should be used to refine the design of the operational monitoring program. A multi-year dataset that adequately characterizes natural variability will yield useful triggers and provide greater confidence in the conclusions made from operational monitoring. Ultimately, a robust baseline dataset will lead to an effective and efficient operational monitoring program.

KEY POINTS

- The baseline study should characterize background conditions (i.e., pre-disturbance conditions).
- The baseline study should characterize current ambient conditions.
- At least two years (absolute minimum one year) of baseline data are recommended to capture natural variability (i.e. seasonal, tidal).
- Baseline data should have been collected recently (i.e., within five years of prior to discharge), or a strong argument must be presented to use older data in areas where ambient conditions have remained unchanged.
- A robust baseline study leads to an effective and efficient operational monitoring program.

1.2 Operational Monitoring Program

The receiving environment must be monitored during operations to evaluate the impacts of the discharge on marine receptors. Monitoring programs are used to assess changes in the physical, chemical, and biological characteristics of the receiving environment at exposure areas relative to baseline conditions. Monitoring programs can also be used to validate and calibrate model predictions. In addition, an operational monitoring program allows operators to implement an adaptive management program that responds in a timely manner to any detected impacts before they become detrimental or irreversible.

Operational monitoring programs should begin once the discharge is operational. The operational monitoring program should sample the same sites and parameters as the baseline study. However, the number of sites and parameters may be reduced based on findings of the baseline study. The operational monitoring program sampling locations should be spatially comprehensive, including reference sites, near-field and far-field exposure sites. Over the life of the project, monitoring requirements may be further refined based on monitoring results.

In BC, proponents that discharge to freshwater or marine environments are typically requested to implement a Receiving Environment Monitoring Program (REMP) and/or an Aquatic Effects Monitoring Program (AEMP). An objective of the REMP is to ensure that the discharge or reclaimed water does not or will not cause water quality parameters, outside the initial dilution zone (IDZ), to exceed water quality guidelines (WQGs) and that acute WQGs are not exceeded within the IDZ (ENV 2019b).Typically, water and sediment endpoints are sampled at reference and exposure sites in the REMP, while the biological endpoints are incorporated into the AEMP.

Sometimes, the REMP is incorporated into the AEMP. For consistency, these monitoring requirements are collectively referred to in this guidance document as operational monitoring.

KEY POINTS

- The monitoring during operations is required to evaluate the impacts of the discharge on marine receptors.
- The operational monitoring program should be based on the baseline study and further refined through the life of the project based on monitoring results.
- Operational monitoring encompasses monitoring requirements typically referred to as AEMP and REMP.

2.0 Site Characterization & Information Compilation

The site should be characterized through an information compilation exercise before designing a monitoring program. Types of information to include, but not limited to, are climate, oceanography, aquatic plants and wildlife in the area, existing permitted discharges and any other unique features or information. This exercise is also useful for proponents currently monitoring the receiving environment, as it may help fill in data gaps or further refine and enhance the monitoring program design. The objectives of this process include:

- Gain general knowledge of the receiving environment,
- Identify current knowledge gaps,
- Gather local knowledge, and
- Understand the values that stakeholders, local communities, and First Nations attribute to the receiving environment.

This knowledge can then be applied to the study design, including selecting key monitoring parameters, site locations, and indicator species. Existing information on the ecology of the receiving environment, historical and current anthropogenic influences, current environmental concerns, current uses, and environmental data may be readily available from various sources, including:

- Local industry
- Local libraries
- Provincial government libraries (e.g., Ministry of Forests, Lands and Natural Resource Operations (FLNRO)/ENV library in Victoria)
- Regional ENV and FLNRO office representatives.
- Local First Nations
- Data from operators in the vicinity of the project area
- Community water stewardship groups
- BC Environmental Assessments website (EPIC) (environmental assessment or monitoring work completed by other operators): projects.eao.go.bc.ca
- Federal government offices and libraries

- Academic institutions
- BC ENV Environmental Monitoring System (EMS) (a database that includes environmental data collected by the ENV and selected waste discharge permittees)
- SITE (BC Contaminated Site Registry)
- BC Geographic Data & Services website
- BC Water Resource Atlas (water related data)
- BC HabitatWizard (data on fish and fish habitat)
- iMap BC (natural resource data)
- Canadian Environmental Assessment Registry website
- Environment and Climate Change Canada's National Water Data Archive: HYDAT
- Canadian Shellfish Sanitation Program (CSSP) (shellfish tissue concentration data)
- Health Canada's Environmental and Workplace Health
- Natural Resources Canada (NRCan) (information from existing mines)
- Pollution Tracker (monitoring program for coastal BC that documents levels and trends of contaminants in mussels and nearshore sediments)
- The Community Mapping Network's Fisheries Information Summary System (FISS) (fish and fish habitat data for waterbodies in BC)

KEY POINTS:
• Information should be collected to characterize the receiving environment before the baseline study or monitoring program is designed.

2.1 Open and Embayed Marine Waters

The *Municipal Wastewater Regulation* (MWR) defines embayed marine waters as:

- Located within a bay from which the access to the sea, by any route, has a maximum width of less than 1.5 km,
- Located, if a line less than 6 km is drawn between any 2 points on a continuous coastline, on the shore side of the line, or
- In which flushing action is identified in a notice given by a Director to be inadequate.

Open marine waters are any waters other than embayed marine waters. Aerial imagery of the discharge outfall location can help to define whether the receiving environment is open or embayed. The distinction is important as it helps to define the general risk of the discharge. Embayed marine waters are more sensitive to effluent than open marine waters, because they have less efficient flushing rates which can limit contaminant assimilation in the receiving environment. In addition, their sheltered waters typically provide critical habitat for sensitive species, and they are often more influenced by various land use activities within the local vicinity.

2.2 Water Values

Water values that may require protection at a specific location include aquatic life and wildlife, shellfish harvesting, aesthetics, and recreational water use. Traditional, cultural, and social values also need to be considered. Understanding the water values in the receiving environment will help proponents understand the attributes of the marine environment that are valued and require protection. Water values will determine which guidelines and/or benchmarks are appropriate for monitoring data interpretation. For example, if recreational and harvesting activities occur in the receiving environment then human health based WQGs, including WQGs associated with contact recreational use, and consumption of aquatic life should be used. Consumption of fish, shellfish, wildlife and wild plants should be considered in areas where Indigenous Peoples harvest for sustenance or traditional uses. In addition, popular fishing or aquatic life harvesting areas (e.g., shellfish beds or crab trapping) in the vicinity of the discharge should be identified. Areas of recreational use should be identified, including beaches, boat launches, and popular boating routes. All locations that have designated values should be mapped and considered in the monitoring program design.

Numerous BC marine waterbodies that are identified as having valued water uses have established WQOs. These WQOs are designed to protect the site-specific valuable water uses. WQOs are to be used as the appropriate benchmark for data interpretation, superseding the BC water quality guidelines and will be considered during the development of EMA authorizations. The proponent must also be aware of any site-specific WQOs designated for the receiving environment. A list of current approved WQOs reports can be found on ENV's Water Quality Objectives webpage (https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives).

Additional sources of water values information may include:

- Marine Planning Portal (MaPP) by SeaSketch (seasketch.org) displays data layers for marine spatial planning zones that include data on ecological, social, cultural and economic values.
- Tourist information material (e.g., maps, guides, and websites), local tourist centres, and information from local residents can be used to determine sites frequently used for recreation.
- Contacting First Nations, local governments, industry and other stakeholders within the area.

KEY POINTS:

- Proponents must compile information on water uses in the receiving environment to understand the values attributed to receptors and identify appropriate guidelines and benchmarks for data interpretation.
- Proponents must identify any WQOs that pertain to the receiving environment.

2.3 Conceptual Site Model

A conceptual site model (CSM) is a tool used to understand the pathways of effects from the project discharge to the receiving environment. The CSM collates information on contaminants sources, fate and transport pathways, exposure pathways and receptors (GoC 2012). The CSM helps assess pathways of effects to the receiving environment; thereby, highlighting the potential receptors and critical parameters to monitor. The CSM can be displayed in table, matrix, diagram, or pictorial format (GoC 2012).

ENV provides guidance for developing CSMs in the *Use of Conceptual Site Models to Support EMA Effluent Permit Applications* (ENV 2018). The Australian Online Coastal Information Conceptual Diagrams page (https://ozcoasts.org.au/conceptual-diagrams/) also provides guidance and examples for creating CSMs specific to coastal environments.

2.4 Currents, Tides, Bathymetry, Flushing Rates

Understanding the currents, tides, bathymetry, and flushing rates of the receiving environment is critical for accurate plume dispersion modelling and water quality prediction calculations at the IDZ. All modelling must be completed by a QP with relevant knowledge and experience. This information may be readily available in historical reports and various online resources. Alternatively, field measurements may be required to fill in data gaps. The bathymetry of the outfall location should be verified in the field using a depth sounder. The *Protocols for Marine Environmental Monitoring* (MWLAP 2002) presents methods for currents metering.

2.5 Receptors

A receptor is any individual organism, species, population, community, habitat, or ecosystem that may be exposed to contaminants. Examples of receptors in the marine environment include:

- Fish
- Shellfish
- Benthic invertebrates
- Marine mammals
- Seabirds
- Macrophytes

Areas where fish species or marine mammals spend significant amounts of time should be documented. In particular, areas inhabited by endangered, vulnerable, threatened, and species at risk should be monitored to assure they are not being altered by the discharge. It will also be important to map areas of important macrophyte coverage, such as eelgrass beds, especially if they are in the vicinity of the initial dilution zone of the proposed or current discharge. This information should be summarized, mapped and used in the consideration for developing the monitoring plan and site locations.

A key source of receptor information will be local resource managers and harvesters. Indigenous communities should be contacted to determine what species are harvested for sustenance and traditional uses. BC Conservation Data Centre and the Canada Species at Risk Public Registry have information on endangered, vulnerable, threatened, and species at risk. Sources of information for locating eelgrass beds include Herring Spawn Maps, aerial imagery, Orthophotos, and the Community Mapping Network website: https://www.cmnmaps.ca/SHIM/

KEY POINTS:

- The receptors in the marine environment must be identified.
- Important locations for receptors must be mapped and considered for monitoring.

2.6 Cumulative Effects

Proponents must consider the potential cumulative effects of the discharge on the receiving environment when combined with other local activities and conditions. To accomplish this, proponents must identify the location and nature of other potential sources of contaminants in the receiving environment. Current water quality issues should be understood to identify the risks of additional contributions from the proposed or current discharge. For example, it would be critical to assess the cumulative effect of a municipal wastewater discharge in an estuary that currently experiences elevated fecal coliform levels from upstream land use activities. If cumulative effects are identified, the proponent should speak with ENV representatives to incorporate a cumulative effects monitoring component into the study design (see Section 4.6).

Any identified cumulative effects will have to be assessed against receiving environment benchmarks and guidelines to validate the proposed effluent quality requirements. For example, a proponent may have to reduce the effluent nutrient concentrations if the receiving environment is already receiving elevated nutrient loadings.

Pollution Tracker (pollutiontracker.org) is a coastal BC monitoring program that provides data on levels and trends of COPCs in mussels and sediment. This source may be useful in gathering background information and assessing whether the receiving environment is already impacted by anthropogenic influences.

KEY POINTS:

- Proponents must identify other anthropogenic activities that pose risks to the receiving environment.
- Cumulative effects monitoring should be incorporated into the study design as directed by ENV representatives.

3.0 Identifying Contaminants of Potential Concern

Contaminants of Potential Concern (COPCs) are any physical, chemical, or biological substance in water, sediment, or tissue at concentrations that exceed guidelines or benchmarks, or may have an adverse effect on human health or aquatic life receptors. Tables in Appendix A, Appendix B, and Appendix C list the typical parameters to consider for specific discharge types. These tables are a useful reference for parameters that will likely be COPCs for a specific discharge. However, the final COPC list will be refined based on the effluent characterization, site-specific water uses, and receptors. Modelling the plume mixing and dilution ratios will further elucidate COPCs based on the areas the plume may reach (e.g., proximity to areas sensitive to nutrient loading). ENV's *Parameters of Concern Fact Sheet* (ENV 2019a) provides steps for refining the list of COPCs (referred to as parameters of potential concern [POPCs] in the fact sheet).

3.1 Effluent Characterization

The effluent must be characterized to provide an indication of the seasonal and temporal variability of effluent quality and evaluate how the effluent may impact the receiving environment. Effluent characterization should provide the range of COPC concentrations expected in the effluent. The effluent quality and end-of-pipe water quality should be predicted for the most sensitive times of the year (i.e., when parameters are anticipated to be highest in the effluent) or when most sensitive life stage or uses occur in the receiving environment, and then be compared to WQGs and applicable benchmarks. The effluent characterization should also describe the volume and frequency (e.g., event-based, seasonal, or continuous) of discharges to further assess the potential impacts on the receiving environment.

3.2 Modelling: Plume Mixing and Dilution Ratios

The plume is the physical extent within the receiving environment where effluent mixing is occurring, but the effluent is still distinguishable from the ambient water conditions (ENV 2019b). Both the chemical and volumetric dilution must be modelled. The chemical dilution is the ratio of effluent concentration (measured at the end-of-pipe) to the effluent plume concentration at selected distances from the outfall location (ENV 2019b). The volumetric dilution is the ratio of receiving environment flow volume to effluent flow volume in the effluent plume at selected distances from the outfall location (ENV 2019b). These models are required to predict the effluent concentration at the IDZ, which is critical for understanding the risks of the discharge to the receiving environment throughout the year and tidal cycle (e.g. seasonal variations, spring and neap tides).

A QP with relevant modelling experience should complete the models for the plume mixing and dilution ratios. QPs should refer to *Technical Guidance 11: Development and Use of Initial Dilution Zones in Effluent Discharge Authorizations* (ENV 2019b) to ensure they are following standardized protocols for these models. The IDZ guidance document provides direction specific to modelling in the marine environment, which tends to be more complex than modelling the freshwater environment. In addition, the *Revised Technical Guidance on How to Conduct Effluent Plume Delineation Studies* (Environment Canada 2003) provides techniques for effluent plume delineation, including considerations for marine waters.

KEY POINTS:

- Modelling the plume mixing and dilution ratios is critical to understanding the risks of the discharge to the receiving environment.
- A QP with relevant experience must complete the models.

4.0 Risk Classification & Supporting Studies

The information outlined in sections 2 and 3 is required to inform the risk classification of the discharge. The risk of the discharge is classified by assigning a score based on effluent volume, dilution factor and the discharge location through the Risk Classification Process (Table 2). The Risk Classification Process is used to determine monitoring requirements, including sampling frequency and locations. Proponents should also refer to Table 3 for project attributes that trigger supporting studies beyond the basic monitoring program, which are required to address additional risks. These attributes are based on effluent characterization, cumulative effects and sensitive areas (Table 3).

Table 2. Risk Classification Process

Category	**Sub-category**	**Score**	**Rating**
Effluent Volume	<10 m^3/day	5	
	10-50 m^3/day	10	
	50-1,000 m^3/day	15	
	>1,000 m^3/day	20	
Dilution Factor	≥ 40:1	0	
	< 40:1	5	
Discharge Location	Open	0	
	Embayed	5	
Scoring		5-10	Low
		15	Medium
		20-30	High

Table 3. Triggers & Supporting Studies

Category	Trigger	Supporting Study
Effluent Characterization	Bioaccumulative or Persistent Substances	Sediment Bioaccumulation Testing Invertebrate Tissue Chemistry Fish/Bivalve Tissue Chemistry
	Complex mixture with multiple COPCs above WQGs	Toxicity Testing
	Microbiological	Microbiological sampling Source Tracking
	Nutrient Over-**e**nrichment	Eutrophication monitoring
	Contaminants of Emerging Concern	Research the risks of contaminants of emerging concern detected or predicted in the effluent
Cumulative Effects	Yes	Cumulative effects monitoring in areas that may be affected by project activities in conjunction with other anthropogenic activities
	No	
Sensitive Area	Yes	Monitoring to assess sensitive receptors (e.g. eelgrass beds)
	No	

4.1 Bioaccumulative & Persistent Substances

Proponents must address the potential for bioaccumulation and/or bioconcentration of COPCs and their associated risks to identified receptors (e.g., fish health and human health). The potential for bioaccumulation is particularly important where fish, shellfish, and marine mammals spend considerable time, including spawning and foraging areas (ENV 2019b). The *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (DEQ 2007) describes several methods for evaluating if COPCs in sediment have the potential to bioaccumulate and threaten the health of receptors. Appendix E of the DEQ guidance describes considerations when using marine or estuarine organisms. The *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (MOE 2016b) provides general methodology for collecting invertebrate and fish tissue that can be used for bioaccumulation studies. Sediment bioaccumulation testing (e.g., USEPA test method 100.3 with the oligochaete, *Lumbriculus variegatus*) may be warranted in cases where sediment concentrations exceed benchmarks.

4.2 Toxicity Testing

Toxicity testing is required when effluent concentrations exceed WQGs and an evaluation of protectiveness at the edge of the IDZ is required. As such toxicity testing is typically completed at the end of pipe and IDZ. Toxicity testing measures survival, growth, and/or reproduction endpoints in marine organisms in controlled laboratory experiments. The objective of toxicity testing is to predict the potential effects of the effluent on marine receptors in the exposure area. Site-specific toxicity testing on species known to be present in the vicinity of the discharge may be required if there is potential for chronic effects to aquatic life through effluent exposure (ENV 2019b). Proponents discharging municipal wastewater must refer to the MWR (Section 58) for specific toxicity monitoring requirements and methods. Proponents should also discuss the need for toxicity testing with their regional ENV contact.

Section F (Toxicity Test Methods) in the *British Columbia Environmental Laboratory Manual* (ENV, 2020) presents methods for marine water and sediment bioassays. The *British Columbia Field Sampling Manual* (MWLAP 2013) describes methods for collecting bioassay samples. The *Metal Mining Technical Guidance for Environmental Effect Monitoring* (Environment Canada 2012) provides guidance on marine and estuarine sublethal toxicity tests that use fish, invertebrate and algal species. The *2010 Pulp and Paper Environmental Effects Monitoring (EEM) Technical Guidance* (Environment Canada 2010) describes sublethal toxicity testing specific to pulp and paper mill effluent.

4.3 Microbiological

Microbiological sampling must be completed for any discharge releasing effluent containing fecal contaminants. The methodology for collecting bacteria samples from lakes in Sub-section 4.1.1 of Part C in the *British Columbia Field Sampling Manual* (MWLAP 2013) can be applied to collecting bacteria samples in the marine environment. Depending on the risk posed to receptors (e.g., human health), microbiological sampling may have to occur more frequently than the standard sampling. For current discharges, source tracking studies are recommended if other sources of microbiological contamination are influencing the receiving environment. Source tracking can elucidate the relative contribution of fecal contamination in the receiving environment that is from the discharge.

4.4 Nutrient Enrichment

Nutrient enrichment can pose a serious risk to coastal marine waters (CCME 2007). Nitrogen and phosphorous are the typical causes of marine water nutrient-enrichment (Ngatia et al. 2019). Nitrogen is typically more limiting in marine waters than freshwater; however, phosphorus can also be limiting in marine waters (Ngatia et al. 2019), especially in estuarine and embayed waters. Excessive nutrients can cause algae blooms and anoxic conditions that result in dead zones, fish kills, toxin production, and changes to aquatic plant community assemblages and human health concerns (Ngatia et al. 2019). Nutrient enrichment is particularly concerning for embayed waters with reduced flushing rates.

CCME has developed a national nutrient guidance framework for nearshore Canadian marine waters. The *Canadian Guidance Framework for the Management of Nutrients in Nearshore*

Marine Systems (CCME 2007) provides a table that lists eutrophication survey parameters, including:

- Chlorophyll *a*
- Nuisance algae
- Toxic algae
- Macroalgae abundance
- Epiphyte abundance
- Dissolved oxygen
- Planktonic community
- Spatial coverage of submerged aquatic vegetation

These parameters should be considered for any program monitoring the impacts of effluent that contains elevated levels of nutrients and/or is released to an area susceptible to nutrient over-enrichment. CCME (2007) provides methods for determining the susceptibility of marine waters to eutrophication. The *Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters* (USEPA 2001) provide further details on monitoring methods for nutrient enrichment in marine waters.

4.5 Contaminants of Emerging Concern

Contaminants of emerging concern (CECs) are chemicals that are not currently regulated or routinely monitored. These include pharmaceuticals, personal care products, microplastics, and nanoparticles (CWN 2018). The proponent should investigate the potential risks to the receiving environment of any CEC identified in the effluent. Investigations may include literature reviews of the current research available for each CEC, and monitoring concentrations of CECs in water column, sediment and biological tissues. It is the proponent's responsibility to ensure the most recent research is used to characterize and identify CECs and monitor their impacts.

4.6 Cumulative Effects

Section 2.6 discusses the need for proponents to assess the cumulative effects of the effluent discharge in relation to other anthropogenic activities influencing the receiving environment. If the potential for cumulative effects is identified, proponents should establish monitoring sites that are designated to describe their contribution to the cumulative impact. For example, if municipal effluent is to be discharged to an estuary already receiving fecal coliform contamination from upstream sources, then sites should be established directly upstream and downstream of the outfall to measure the fecal coliform concentrations with and without the discharge. There may be opportunities for cumulative effects monitoring to be incorporated into regional assessments and Proponents should discuss this with their ENV representatives.

4.7 Sensitive Areas

A greater number of sites and increased sampling frequency may be required if the discharge poses a risk to sensitive areas (e.g., harvesting sites, conservation areas, nursery habitat). These areas should be revealed when collecting water use information (Section 2.2). If sensitive areas are identified, then additional sample sites should be added to monitor these areas of special concern (Section 6.3). Special studies may be required depending on the reason for the area's sensitivity (e.g., eelgrass monitoring, bivalve tissue monitoring). Local and regional governments, First

Nations and local stewardship or community groups can be a resource for identifying sensitive marine areas.

5.0 Study Design

Monitoring can be resource-intensive, so it is important to ensure that there is a clear objective for all data being collected. This can be achieved by designing a monitoring program that has a set of well-defined questions that are to be answered with the data being collected. A purpose should be assigned to every parameter being measured. Proponents with existing monitoring programs should assess if the original objectives and questions are still relevant.

5.2 Sample Size

There should be a rationale for the sample size (i.e., number of transects, sites, grabs, or quadrats) selected for each parameter. A sufficient sample size will allow for natural variability to be quantified, and a reasonable degree of confidence in statistical analyses completed to assess spatial and temporal differences. The appropriate sample size depends on variability (standard deviation), level of significance required (typically 0.05), power, and effect size (i.e., how big a change you need to be able to detect) (as per comm. Dr. Kelly Munkittrick, Campus Alberta Innovation Program, Chair in Aquatic Ecosystem Health, University of Calgary August 13, 2018). The sufficient sample size can be determined through a power analysis. However, a power analysis requires data to have already been collected. Baseline data or previous operational monitoring data can be used to perform a power analysis. If data have not yet been collected, then monitoring programs should be designed to over sample initially and then scale down the sample size overtime.

Refer to the Power Analysis section of the *Metal Mining Technical Guidance for Environmental Effects Monitoring* (Environment Canada 2012) for further details on how to complete a power analysis. Vanderbilt University provides a power sample size calculator (http://biostat.mc.vanderbilt.edu/wiki/Main/PowerSampleSize). The *Protocols for Marine Environmental Monitoring* (Statistical Power Analyses section) presents techniques used to raise statistical power, and considerations for marine monitoring programs (e.g., $1-\beta \geq 80\%$, and use $\alpha = 0.10$ instead of 0.05).

5.3 Quality Assurance & Quality Control

Quality Assurance and Quality Control protocols must be followed and described in the study design. QA/QC protocols are intended to ensure meaningful and scientifically defensible data are collected. QA/QC includes collecting samples intended to test the analytical process and identifying errors in the sampling methodology. A general requirement is that QA/QC samples make up 10% of all samples collected. Part A Quality Control and Quality Insurance of the *British Columbia Field Sampling Manual* (MWLAP 2013) provides detailed instructions for how to design and execute a monitoring program that has thorough QA/QC protocols and design considerations. Media-specific QA/QC protocols are discussed in sections 7, 8, and 9.

5.3.1 Replicates

Replicate samples are multiple samples collected at the same site and time, by the same field personnel using the same sampling methodology (MWLAP 2013). Replicate samples are collected to:

- Assess the precision of the measurements to understand analytical and sampling uncertainty.
- Define local natural variability (i.e., heterogeneity in the receiving environment) of each analyte.
- Allow for statistical analyses that can detect spatial and temporal differences (e.g., analysis of variance).

Typically, the minimum number of replicates collected should be 10% of the total number of samples analysed or more, especially if no historical data are available, to complete a power analysis to determine sample size (see Section 5.2). Replicate samples are an important consideration in developing the cost estimate for any monitoring program. Part A of the B.C. Field Sampling Manual sets out QA/QC requirements that must be followed by proponents for environmental monitoring and sample collection.

5.4 Before-After-Control-Impact (BACI) Study Design

The Before-After-Control-Impact (BACI) design is a common study design for aquatic monitoring programs. However, a BACI design can only be considered if a baseline study is completed, and the operational monitoring program design can be linked to the baseline (e.g., same sites, measurement endpoints, and parameters). In a BACI study, an environmental impact is defined as a change in the difference between environmental data at a reference and exposure site following development (Roach and Walker 2017). This analysis helps to elucidate if any detected changes can be attributed to the discharge, or if changes are due to natural variability or other exterior influences. Ideally, there will be multiple sampling periods during the baseline and operational monitoring program (MWLAP 2002).

5.5 Multiple Control/Impact (MCI) Study Design

The MCI study design can be used for projects that do not have a baseline dataset. However, it requires multiple reference sites that are highly comparable to exposure stations. In an MCI study, exposure site data are compared directly to reference site data (MWLAP 2002).

5.6 Simple Gradient Design

The simple gradient design can be used for projects that do not have a baseline dataset and are located in narrow estuaries and constricted embayed waters (Environment Canada 2010). This design involves a single gradient from the outfall through declining levels of effluent with exposure sites located along the transect and reference sites at the end where there is little or no effluent (Environment Canada 2010).

5.7 Radial Gradient Design

The radial gradient design can be used for projects that do not have a baseline dataset. The radial gradient design is similar to the simple gradient design; however, it is meant for open waters and coastal areas that can accommodate several radially orientated transects (Environment Canada 2010).

5.8 Multiple Gradient Design

The Multiple Gradient Design can be used for projects that do not have a baseline dataset. The multiple gradient design is recommended for non-homogenous open bays and coastal areas (Environment Canada 2010). In a Multiple Gradient study, data are collected from sites along multiple transects that extend outward from the outfall along prevailing currents (MWLAP 2002). There should be several reference sites located on a transect that traverses a similar environmental gradient in the exposure area, but with no effluent (Environment Canada 2010). Exposure sites should radiate in a grid from the outfall to determine if a contamination gradient can be attributed to the effluent discharge.

KEY POINTS:

- A BACI design should be used for monitoring programs with baseline data.
- MCI, Simple Gradient, Radial Gradient or Multiple Gradient designs can be used to monitor programs without baseline data.

6.0 Site Selection

Sites should be selected based on information gathered through the information data compilation and effluent characterization steps (sections 2 and 3). Proposed sites should be discussed with ENV representatives before a large expenditure is made on the program. As many sites as possible should be included early in the monitoring program, with the intent of eliminating some sites once potential and actual impacts from discharge are better understood. Consideration should also be given to the potential influence of nearby freshwater inputs/freshets on sampling locations. All selected sites should be geo-referenced, mapped, and photographed from various angles.

6.1 Reference Sites

Reference sites are used to asses if changes detected at exposure sites can be attributed to the project impacts, natural variability, or other exterior influences. As such, reference sites must be located outside the project footprint and outside the area potentially influenced by the effluent. Ideally, reference sites should be located in areas with similar physical, chemical, and biological attributes as the exposure sites, and where disturbance is minimal (Environment Canada 2004, Zajdlik et al. 2009). In marine environments, reference sites should be located in areas with similar tidal regime, habitat types, shoreline structure, bottom topography, substrate type, depth, current regimes, physical water properties, and drainage characteristics as the exposure sites (Environment Canada 2010).

Reference sites are also used to characterize baseline conditions if historical data for pre-development conditions are not available. As described in the *Guidance for the Derivation and Application of Water Quality Objectives in British Columbia* (MOE 2013), if historical data for pre-development or pre-discharge conditions are not available, then reference sites unimpacted by the anthropogenic influences must be established to characterize background conditions. These reference sites should be located in a nearby system that has similar geological, ecological, topographical, physiographical, and climatological characteristics.

It may take several site visits and sampling events to determine if a location is an appropriate reference site. As such, it is best to locate several candidate reference sites for assessment, and then reduce the number of reference sites based on the results. If the baseline results for the reference and exposure sites are comparable then future results can be directly compared to determine if discharge-related changes are occurring. Alternatively, if the reference site is not directly comparable to exposure sites then a BACI design may be required.

The *Protocols for Marine Environmental Monitoring* (MWLAP 2002) describes methods to validate reference sites for marine sediment collection. There should be two reference stations, each should have a depth within 25% of the depth of the exposure stations, and the % silt/clay fraction should be within 15% of the exposure stations (MWLAP 2002).

KEY POINTS:

- Appropriate reference sites are critical to the success and effectiveness of a monitoring program.
- Reference sites should be located in unimpacted areas that have similar physical, chemical and biological attributes as the exposure sites.

6.2 Exposure Sites

6.2.1 End-of-Pipe

Samples are collected at the end of pipe to measure effluent quality before it is released and diluted with marine receiving waters. Typically end-of-pipe samples are collected in the facility after treatment works. Data collected from the end-of-pipe site can be compared with data at the IDZ to assess the accuracy of dilution models. This is generally referred to discharge or effluent monitoring within an authorization.

6.2.2 Outfall Terminus

Sampling at the outfall terminus in the receiving environment may be required based on effluent characterization to ensure acute WQGs are met.

6.2.2 Initial Dilution Zone (IDZ)

The Initial Dilution Zone (IDZ) is a 3-dimensionl zone around a point of discharge where mixing of the effluent and the receiving environment water occurs (Figure 1). The IDZ does not necessarily encompass the entire area where mixing occurs, since the effluent plume may extend beyond the edge of the IDZ before it completely mixes with the marine waters (ENV 2019b). The extent of the IDZ is site-specific, but is typically small (i.e., ≤100 m from the point of discharge) (MOE 2014). The MWR Section 92 sets the radius of the IDZ at the smaller of: 100 m from the point of discharge or 25% of the width of the water body for all municipal wastewater discharges. The height of the IDZ is the distance from the bed to the water surface. The MWR also regulates the location of the IDZ in embayed and open marine waters, relative to the shore, shallow water zones, recreational areas, shellfish harvesting areas, water intakes, and any sensitive area identified by a director. For all other discharges, defining the allowable extent of an IDZ depends on the sensitivity and values of the receiving environment (MOE 2014), and should be as small as possible (ENV 2019b). Monitoring the IDZ should involve collecting samples at four to six locations (generally north, south, east, and west) to ensure the plume is being captured. The locations should include two to three sites in the predominant current direction (downstream), one to two sites in the opposite direction (upstream) and two locations perpendicular to the predominant current direction. This can be refined based on effluent volume and plume dispersion modelling. Once sufficient data is collected, the IDZ sampling may be reduced to only sampling in the predominant current(s). Refer to the *Technical Guidance 11 Environmental Management Act: Development and Use of Initial Dilution Zones in Effluent Discharge Authorizations* (ENV 2019b) for further guidance related to IDZs.

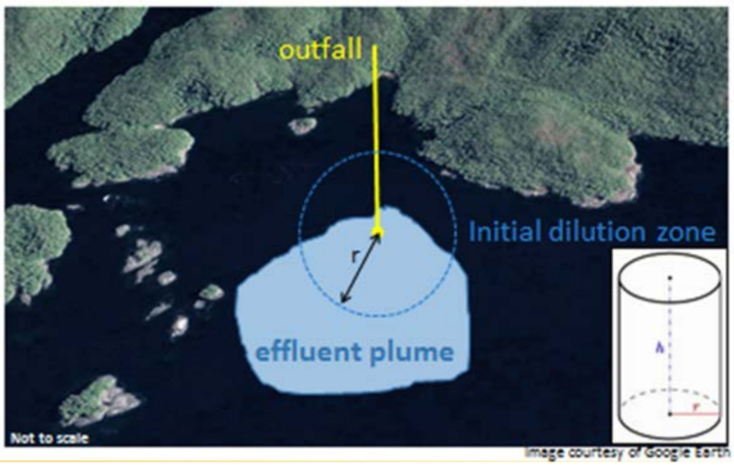

Figure 1. Initial Dilution Zone.

6.2.3 Far-Field

Far-field sites are established to assess changes in the receiving environment past the IDZ to selected distances where the release is predicted to influence water and sediment quality. Low risk discharges are not required to establish far-field sites, as it is not anticipated that the effluent plume will influence water quality past the IDZ. For tidal areas, such as estuaries, far-field exposure sites can be located both upstream and downstream of the discharge due to the potential influence of tidal mixing (DES 2014). For bays or open marine waters, exposure sites can be spread in any direction from the discharge, although factors such as dominant wind, currents, and bathymetry should be factored into the site selection. (DES 2014).

6.3 Areas of Special Concern

The information compilation process may reveal areas of special concern that local community members and/or stakeholders perceive as being threatened by the discharge. Even if models indicate these areas will likely be unimpacted by the discharge, it is wise to designate monitoring sites that will provide explicit evidence that the resource is being unimpacted. For example, it may be useful to monitor bivalve tissue at the closest shellfish harvesting site.

KEY POINTS:

- Establish monitoring sites at areas of special concern to provide explicit evidence that the valued use is not being impacted by the effluent.

6.4 Environmental Monitoring System (EMS)

The Environmental Monitoring System (EMS) is ENV's environmental data repository. Data are uploaded to the EMS via an electronic data transfer accessed through the EMS webpage. ENV staff, permit holders, laboratories and select third parties are granted access to upload monitoring data. The EMS data are made available to the public through an interactive web application. It is important to speak with regional ENV representatives once sample sites are selected to determine which sites should have EMS numbers. The raw data collected through marine monitoring programs should be provided along with the annual report. Where possible analytical data should be uploaded into EMS by the laboratory doing the analysis.

7.0 Water Quality Monitoring

Water is a valuable natural resource essential to the healthy functioning of life and the environment. Water quality portrays the physical, chemical, biological, and aesthetic characteristics of water, which strongly influence its suitability for aquatic life, wildlife, livestock, irrigation, human consumption, and industrial use. Contaminants may be dissolved or suspended in the water column. Once in the water column, contaminants can be transported off site, taken up by organisms, or transferred to other matrices (e.g., sediment, soil, air, tissue) where they may cause adverse effects. Thus, water quality information is a crucial component of baseline and operational monitoring programs.

The objectives of water quality monitoring include:

- Assess the ambient surface water conditions before effects from the proposed discharge occur (i.e., baseline).
- Identify whether baseline concentrations naturally exceed provincial water quality guidelines and whether site-specific WQOs need to be established.
- Use baseline information to predict and assess impacts.
- Determine the need for monitoring and adaptive management during discharge operation.
- Allow the comparison of baseline data with operational water quality data in order to identify whether water quality is affected by the project and to verify that established water quality guidelines or benchmarks are being met and water quality is being protected.
- Determine whether management/mitigation actions were effective.

Key documents to review when designing a water quality monitoring program include:

- *BC Field Sampling Manual* (MWLAP 2013)
- *Guidelines for Interpreting Water Quality Data* (MELP 1998)
- *Guidance Manual for Optimizing Water Quality Monitoring Program Design* (CCME 2015)
- *Technical Guidance 6 Water and Air Baseline Monitoring Guidance for Mine Proponents and Operators* (MOE 2016b)

- *Technical Guidance 11 Development and Use of Initial Dilution Zones in Effluent Discharge Authorizations* (ENV 2019b)

When using data from the above sources, the proponent must keep in mind that relatively recent baseline information will be required for baseline development and impact assessment, particularly of surface water.

7.1 Parameters

The water quality parameters that should be included in the monitoring program will be industry and project specific. The parameter list will include any identified COPCs and the typical parameters recommended for the discharge type. Appendix A presents a table, adapted from various guidance documents, that lists the water quality parameters recommended for each type of discharge.

In-situ water quality measurements should include:

- Specific Conductance
- Temperature
- Dissolved oxygen (DO)
- Salinity
- pH

7.2 Sampling Frequency

The proposed sampling frequency for water quality is the number of monitoring events required within one year following a 5-in-30 sampling regime (i.e., 5 consecutive weekly samples collected in 30 days). The 5-in-30 sampling is required so that results can be compared to long-term (i.e., chronic) WQGs, which use an averaging approach. The averaging approach allows for concentrations to fluctuate above and below the guideline as long as the average concentration of five samples collected within 30 days is below the guideline (MOE 2016b). The timing of the monitoring should also be considered to capture "worst-case" conditions of the effluent and/or ambient conditions in the receiving environment.

The monitoring frequency may change over the life of the project. For example, an increase in contaminant concentration effluent or the receiving environment, confirmed by repeat samples, may trigger changes in the monitoring program (MOE 2016b). Conversely, multiple years of data may indicate certain parameters have a low risk of increasing, so they can be removed from the sampling program (once approved).

Table 4 presents the minimum sampling frequencies required for the discharge based on risk level. However, the baseline, or long-term operational data still need to be analysed to provide evidence that the minimum sampling is sufficient. Likewise, if a monitoring program has been operating for several years, data analysis can be used to justify why seasonal variability has been characterized to reduce sampling requirements.

Table 4. Water Quality Sampling Frequency

Sample Site	Risk Level		
	Low	**Medium**	**High**
Outfall terminus*	Annual 5-in-30	Biannual 5-in-30	Quarterly 5-in-30
IDZ	Annual 5-in-30	Biannual 5-in-30	Quarterly 5-in-30
Far-Field	None	Biannual 5-in-30	Quarterly 5-in-30
Reference	Annual 5-in-30	Biannual 5-in-30	Quarterly 5-in-30

*may be required based on effluent characterization

7.3 Sampling Methodology and Equipment

A certified laboratory must analyse the water quality samples. Each laboratory may have unique sample containers and preferred sampling methodology. It is important to discuss sampling methodology, equipment, and sample shipment with the selected laboratory when planning field sampling. In particular, sample holding time is an important consideration for field logistics, especially when sampling in remote areas where transporting samples within a short timeframe can be challenging. It is also important to define the detection limits the laboratory can provide, which should be less than or equal to 1/5th of the respective WQG or, when those are not available, less than or equal to 1/5th of the lowest background concentrations measured by the laboratory in typical samples (MOE 2016b). Refer to the laboratory requirements and standards in the *British Columbia Field Sampling Manual* (MWLAP 2013) and *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (MOE 2016b) prior to selecting a laboratory.

Water quality sampling must be carried out in accordance with standard practices. Refer to Part E in the *BC Field Sampling Manual* (MWLAP 2013) for specific instructions on collecting water quality samples. In particular, the directions on collecting water samples from lakes can be applied to sampling in the marine environment. The Van Dorn sampler is a good option for use in the marine environment. Similar to lake monitoring, the collection of water column profile data should occur at each site during each sampling event.

Water quality profile data are collected using a hand-held water quality meter equipped with probes that measure temperature, pH, dissolved oxygen (DO), electrical conductivity (EC) and salinity. When sampling in the deeper waters of the marine environment, it is useful to use a weighted meter that is equipped with a depth sensor to accurately record the depth of each measurement. The sampling intervals for the profile should be specified to characterize the effluent plume. In general, collect profile data at 1 m intervals until a depth of 20 m, then coarser measurements at 5 m intervals can be collected. However, 1 m intervals should be collected when profiling within the trapping depth of the plume.

When collecting water quality samples from the marine environment, samples should be collected at three depths at each sample site (1 m below surface, mid plume, and 1 m above bottom sediments). Collecting a sample from the mid plume depth will ensure the influence of the plume on the ambient conditions are being monitored. The middle of the effluent plume should be midway between the bottom sediments and the effluent trapping depth modelled for the season in which the samples are being collected. Alternatively, the water quality profile information at the IDZ can be used to determine the depth of the plume during the sampling event. If plume depth has not been modelled and it cannot be detected during the profile measurements, then collect the sample at the mid depth between the surface and the bottom sediments. Additional considerations for collecting water quality samples from the marine environment include:

- Tide heights (high, low), samples should be collected at different tide heights within a 5-in-30 sampling event.
- Concurrent sampling of receiving environment (e.g. IDZ sites) and effluent discharge (e.g. end-of-pipe site) to evaluate the achievable dilution at the IDZ.

KEY POINTS:

- Samplers should discuss sampling methodology with the selected laboratory prior to field sampling.
- Sample hold times must be considered in trip logistics.
- Samplers must confirm with the selected laboratory the volume required for each water sample.
- Three water quality samples are to be collected at each site, from three different depths.
- Water quality profiles need to be completed during each water sampling event at each site.
- Proponents are responsible for ensuring that updated and appropriate detection limits are used.

7.3.1 Quality Assurance & Quality Control

Field QA/QC water quality samples include replicates (i.e., duplicates) and blanks. Duplicates are independent samples collected at the same location and time and are intended to be identical. Duplicate samples verify if the sample is reproducible, allow for the precision of the sampling and measurement process to be estimated, and are an additional check on sample contamination. (MWLAP 2013). Blanks are sample containers filled with deionized water to assess sample contamination caused by either the sample containers or sample handling in the field. Blanks include field, trip, equipment, and filtration blanks. Replicate samples are particularly important for QA/QC programs, as they provide more information than blanks (MWLAP 2013). Refer to the *BC Field Sampling Manual* (MWLAP 2013) Ambient Freshwater and Effluent Sampling QA/QC section for further details on QA/QC methods for water quality sampling programs.

8.0 Sediment Quality Monitoring

Sediments support aquatic life by providing habitat for aquatic plants, microorganisms, burrowing or sediment-feeding invertebrates, and demersal fish. Fine-grained sediments can bind contaminants (e.g., metals, nutrients, and organics). COPC accumulation in sediment can have a direct impact on the health of benthic-dwelling organisms and pose a risk to water quality through re-mobilization (MacDonald and Ingersoll 2003). Consequently, COPCs in sediment also pose a risk to the health of humans who consume organisms exposed to bioaccumulative contaminants.

Sediment monitoring assesses the insoluble particles discharged to water, and the dissolved contaminant fractions that preferentially bind to sediments (MOE 2016b). It is useful to measure the quality of the sediment pre-discharge to define historical contamination, as contaminants can accumulate over many years, and remain after the contamination source is removed. Sediment sampling is then useful to monitor what COPCs, if any, are accumulating from the discharge. One thing to consider when developing the sediment monitoring program is whether any dredging has or will be occurring near your sample stations that could affect the results. Sediment quality is also measured as a component of benthic invertebrate studies. Sediment quality data are used to assess if there are habitat differences that may contribute to differences in the benthic invertebrate communities (Environment Canada 2010).

8.1 Parameters

Typical sediment quality parameters that assess COPC concentrations include metals, organics, nutrients and total petroleum hydrocarbons. Marine sediment sample analyses should include particle size, total organic carbon (TOC), C:N ratio, redox potential (Eh), and sulphides analyses (Environment Canada 2010). Particle size distribution is important for interpreting the results of chemical or biological analyses (Environment Canada 2010). Particle size also has a significant impact on the structure of benthic invertebrate communities. TOC provides an indication of organic enrichment, and the C:N ratio indicates the source of organic enrichment (Environment Canada 2010). The C:N ratio will be high if the enrichment is caused by land-based sources and lower if the enrichment is caused by natural sources (e.g., decomposition of aquatic plants) (Environment Canada 2010). Sediment Eh and sulphides can indicate sediment degradation by describing oxygen conditions, and microbial response to organic enrichment (Environment Canada 2010).

Appendix B presents a table that lists the typical parameters to consider for each discharge type. However, sediment parameters should be determined on a site-specific basis, and historical data should be used in conjunction with the effluent characterization and water quality data to refine the parameter list for each discharge.

8.2 Sampling Frequency

Sediment samples should be collected according to the risk classification (see Table 5) in conjunction with water quality and biological sampling events. Sediment sampling should occur along with benthic invertebrate sampling. If baseline data have not been collected, then two years (absolute minimum of one year) of sediment quality data should be collected before beginning the sampling frequency outlined in Table 5.

Table 5. Sediment Quality Sampling Frequency

Sample Site	Risk Level		
	Low	**Medium**	**High**
Outfall terminus	None	Every 5 years	Every 3 years
IDZ	None	Every 5 years	Every 3 years
Far-Field	None	None	Every 3 years
Reference	None	Every 5 years	Every 3 years

8.3 Sampling Methodology and Equipment

A certified laboratory must analyse the sediment samples. Each laboratory may have unique sample containers and preferred sampling methodology. It is important to discuss sampling methodology, equipment, and sample shipment with the selected laboratory when planning field sampling. In particular, sample holding time is an important consideration for field logistics, especially when sampling in remote areas where transporting samples within a short timeframe to laboratories can be challenging. It is also important to define the detection limits the laboratory can provide, which should be less than or equal to 1/5th of the respective sediment quality guideline or less than or equal to 1/5th of the lowest background concentrations measured by the laboratory in typical samples (MOE 2016b). Refer to the laboratory requirements and standards in the *British Columbia Field Sampling Manual* (MWLAP 2013), *BC Protocols for Marine Monitoring* (MWLAP 2002) and *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (MOE 2016b) prior to selecting a laboratory.

Sediment samples should only be collected where fine-grained sediments are available. Samplers should target locations with silt and clay (particle size <63 μm), as this size fraction tends to accumulate greater concentrations of contaminants (MOE 2016b). The smaller sediment fractions also are more commonly ingested by benthic-dwelling organisms; therefore, present the greatest risk of contaminant bioaccumulation (MOE 2016b). It is important to note that the laboratory will have to explicitly be requested to analyze only the <63 μm fraction of samples received.

Sediment samples should be collected during low tide conditions if sites can be accessed by foot or slack tide conditions if boat-based sampling is required. Five replicate samples (minimum three) are recommended to be collected at each site to enable statistical analyses to test within and between site variability (MWLAP 2002, MOE 2016b).Depending on the questions you are trying to answer in your sampling program, and the sediment composition, the three to five replicate sediment grabs can either be used individually for sediment analysis or they can be combined into a composite sample, from which your sediment samples for analysis are taken. In either situation, generally the top 2-5 cm are collected from each grab for analysis. An Eckman Grab Sampler is not recommended for collecting sediment in the marine environment. Instead, a Petite-Ponar, Ponar, Smith-MacIntyr or van Veen are appropriate (MWLAP 2002). A winch could be installed on the boat to assist in operating the grab sampler in deep waters.

The *BC Protocols for Marine Monitoring* (MWLAP 2002) provides guidance on sediment sampling techniques in the marine environment. In addition, the *British Columbia Field Sampling Manual* (MWLAP 2013) describes the Spatial Variance Program design that can be applied to marine monitoring programs. In the manual, the Part D Soil and Sediment Sampling, Lake and Stream Bottom Sediment Sampling section provides general guidance on sediment sampling methodology and equipment. In particular, the directions on collecting sediment samples from lakes can be applied to the marine environment.

If exposure sites are rocky bottomed or lack sufficient volumes of sediment for complete samples video surveys may be required. Video surveys may be conducted by scuba divers or remotely operated vehicles (ROV). The *BC Protocols for Marine Monitoring* (MWLAP 2002) provides guidance on video survey equipment and monitoring procedures that can be adapted to fit the needs of the monitoring program.

KEY POINTS:

- Proponents must discuss detection limits with selected laboratories to ensure the appropriate analyses are completed.
- Samplers must confirm with the selected laboratory the mass required for each sediment sample.
- Replicate sediment samples should be collected at each site.
- Eckman grab samplers are not appropriate for use in the marine environment.
- Proponents are responsible for ensuring that updated and appropriate detection limits are used.

8.3.1 Quality Assurance & Quality Control

Field QA/QC sediment quality samples include replicate samples, which determine the degree of heterogeneity within the sediments. Sediment sample replicates can include multiple samples (grabs) from the same site, or portions of a single grab. Grab samples that are homogenized (physically stirred) in the field and then sub-sampled into replicates serve as a tool to estimate the analytical (laboratory) precision (MOE 2016b). Refer to Section 4 of the *Protocols for Marine Monitoring* (MWLAP 2002) for detailed guidance on QA/QC protocols for sediment sampling in the marine environment.

9.0 Biological Monitoring

Biological monitoring provides insight into the health of the marine ecosystem (MOE 2016b). The objective of biological monitoring is to define the link between COPCs and potential risks to receptors (DES 2014). Also, similar to sediments, biological tissues can absorb metal or organic contaminants. Contaminants can be taken up directly from the water column via facilitated diffusion (e.g., inorganic metals) or via dietary sources, stored in fat and proteins, and biomagnified up the food chain (MOE 2016b).

9.1 Parameters

Typical biological parameters include community structures, or tissue COPC concentrations. Generally, community assemblage studies include plankton, invertebrates (benthic or planktonic), fish, and macrophytes (e.g., eelgrass). The selection of biological monitoring parameters requires consideration of the potential discharge impacts and the organisms most sensitive to those impacts (DES 2014). It is important to note that the organisms most sensitive to these impacts do not need to be vulnerable, threatened, or endangered species (DES 2014). The specific species to be targeted will be based on the information gathered during the data compilation exercise outline in Section 2. Appendix C provides the parameters typically analysed in tissue samples based on discharge type.

9.2 Sampling Frequency

Multiple years of baseline data are recommended to characterize biological communities. If a baseline study was not completed, then proponents should collect two years (absolute minimum one year) of biological data prior to beginning the schedule presented in Table 6. It is important to note that not all biological monitoring should occur during the same sampling event. Rather, they should be conducted during the most biologically relevant seasons.

Table 6. Biota Sampling Frequency

Program	Risk Level		
	Low	Medium	High
Benthic Invertebrate Community	None	Every 5 years	Every 3 years
Benthic Invertebrate Tissue	None	Every 5 years	Every 3 years
Bivalve Tissue & Health	None	Every 5 years	Every 3 years
Fish Tissue & Health	None	None	Every 3 years
Plankton Community	None	None	Every 3 years*
Macrophyte Community	None	None	Every 3 years*

*Optional based environmental impact assessment.

9.3 Sampling Methodology and Equipment

A certified laboratory must analyse all tissue samples, and a certified taxonomist must identify benthic invertebrate samples. Each laboratory may have unique requirements, including minimum sample size (i.e., weight), and methods for sample storage and shipment (e.g., frozen with dry ice). It is important to discuss sampling methodology, equipment, and sample shipment with the selected laboratory and taxonomist when planning field sampling. In particular, sample holding time is an important consideration for field logistics, especially when sampling in remote areas where transporting samples within a short timeframe to laboratories can be challenging. Refer to the laboratory requirements and standards in the *British Columbia Field Sampling Manual* (MWLAP 2013) and *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (MOE 2016b) prior to selecting a laboratory.

It is important to define the detection limits the laboratory can provide for the tissue analyses, which should be less than or equal to 1/5th the respective tissue quality guideline, or less than or equal to 1/5th of the lowest background concentrations measured by the laboratory in typical samples (MOE 2016). Consensus detection limits proposed by the BC Environmental Laboratories Technical Advisory Committee are presented as the detection limits presented in Appendix C. Proponents are responsible for ensuring that updated and appropriate detection limits are used.

9.3.1 Benthic Invertebrate Community

Aquatic monitoring programs typically monitor benthic invertebrate community structures, because they respond to water and sediment quality, and provide an indication of food source availability for fish (Environment Canada 2012). Benthic invertebrate community structures are determined by collecting samples that are submitted to a certified taxonomist for identification to the lowest practical taxonomic level (MOE 2016b).

Benthic invertebrate samples are collected from the marine environment using similar equipment as sediment sampling. The grab sampler should generally cover an area of at least 0.1 m^2, such as the Smith-McIntyre, Van Veen, or Ponar grab samplers (Environment Canada 2010). The petite Ponar is recommended for use in shallow intertidal habitats (Environment Canada 2010). Section 4.1.4.1 of Part C in the *British Columbia Field Sampling Manual* (MWLAP 2013) provides more details on the methodology for collecting benthic invertebrate samples as does Section 3 of *BC Protocols for Marine Monitoring* (MWLAP 2002)

Three to five grab samples should be composited for each benthic invertebrate sample (MOE 2016b). Each grab sample should be immediately sieved to remove sediments and then placed into the sample jar. Section 4.5 in the *2010 Pulp and Paper Environmental Effects Monitoring (EEM) Technical Guidance* (Environment Canada 2010) describes specific methods for collecting benthic invertebrates from the marine environment, including appropriate mesh screen sizes. Each sample jar must also be filled with the appropriate preservative at the ratio specified by the selected taxonomist. It is important to discuss the recommended preservative with the taxonomist prior to sampling.

If *a priori* statistical power cannot be determined with historical data, then a minimum of five replicate samples must be collected for each site (MOE 2016b). All replicate samples should be collected from similar habitat types (e.g., similar depth and substrate). Over time, if results provide evidence that community variability is low then replicate numbers can be reduced.

Seabed video inspections are required where hard substrates inhibit benthic invertebrate collection with grab samplers. The quadrats used should have a minimum area of 0.1 m^2 (Environment Canada 2010). The *Protocols for Marine Monitoring* (MWLAP 2002) provides guidance for completing seabed video inspections, including recommend video equipment, and quadrat types.

KEY POINTS:

- Five replicate samples, each comprised of three to five grab samples, must be collected for each site, unless a power analysis provides evidence for an alternate number of replicates.

9.3.2 Benthic Invertebrate Tissue

Benthic invertebrate tissue sampling typically requires the compilation of various invertebrate species, especially to collect a sufficient sample size. Since collecting the minimum weight of benthic invertebrates required for analysis can be difficult, the Basic Program described in Section 8.5.2 of the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (MOE 2016b) is recommended. This study design allows for a single composite sample (comprised of a minimum of three grab samples) to be collected at each site. However, up to five replicates should be collected at one site to test within site variability (MOE 2016b).

Each grab sample should be sieved to remove sediment and debris, and then samplers can collect individual invertebrates to place in the sample receptacle (typically a glass jar or Ziploc bag). A measurement scale is required to ensure the required sample size is obtained. Refer to Section 3.1.1 of Part C in the *British Columbia Field Sampling Manual* (MWLAP 2013) for general techniques to avoid contamination of tissue samples. Refer to Section 8.6 of the *Water and Air Baseline*

Monitoring Guidance Document for Mine Proponents and Operators (MOE 2016b) for guidance on tissue collection techniques and required sampling equipment.

KEY POINTS:
• Collect one composite sample, comprised of at least three grab samples, at each site. Additional grab samples may be required to ensure sufficient sample size/weight has been achieved.

9.3.3 Bivalve Tissue & Health

Bivalves are particularly susceptible to ingesting and accumulating COPCs, since they are filter-feeders. An indicator species should be selected from the bivalve species found within the vicinity of the outfall (if present). Bivalves can be collected using the same grab samplers as the benthic invertebrate community sampling. Collect a minimum of three grab samples at each site, from which 25 individuals (of a pre-determined size) should be randomly selected for a single composite sample (Lowe et al. 2012). From this composite sample, individuals are randomly selected for the tissue analysis and health surveys (Lowe et al. 2012). Parameters to consider for tissue analysis are presented in Appendix C. Measurement endpoints for the health survey should include:

- Growth metrics: shell length, shell width, shell weight, tissue wet weight
- Reproductive metrics: sex, gonad index, reproductive timing index

9.3.4 Fish Tissue & Health

Fish collection permits will need to be obtained by Fisheries and Oceans Canada prior to sampling (https://www.pac.dfo-mpo.gc.ca/fm-gp/licence-permis/scientific-scientifique-eng.html). Fish tissue studies should target two species (ideally, one sport and one non-sport fish species). The selected species should have high site fidelity, which will provide a better indication of contaminants at the site (MOE 2016b). Candidate indicator species should be discussed with a regional ENV representative prior to sampling.

The Spatial Variance Program described in Section 8.5.1 of the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (MOE 2016b) is recommended for fish tissue sampling. This program allows for the detection of within-site, between-site, and temporal variability (MOE 2016b). Eight replicate samples should be collected at each site if no historical tissue data are available to complete a power analysis (MOE 2016b).

Refer to Section 3.1.1 of Part C in the *British Columbia Field Sampling Manual* (MWLAP 2013) for general techniques to avoid contamination of tissue samples. Refer to Section 8.6 of the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (MOE 2016b) for guidance on tissue collection techniques and required sampling equipment. In addition, Section 4.1.6.4 of Part C in the *British Columbia Field Sampling Manual* (MWLAP 2013) describes protocols for collecting tissue samples from fish.

Fish surveys are required whenever there is a potential for a population-level impact, including habit loss or alteration (MOE 2016b). Fish surveys provide an assessment of difference in growth, reproduction, condition and survival of fish populations between the exposure and reference sites or within an exposure area along a gradient of effluent concentrations (Environment Canada 2010). Measurement endpoints can include:

- Age- and length-frequency distributions
- Size and length at age
- Gonad weight at body weight and length
- Fecundity
- Body weight at length
- Liver size and egg weight at body weight

The *2010 Pulp and Paper Environmental Effects Monitoring (EEM) Technical Guidance* (Environment Canada 2010) provides guidance for fish surveys to monitor effluent discharges, and considerations for surveys in the marine environment.

9.3.5 Plankton Community (Optional)

Plankton are an important indicator for changes in water quality. Phytoplankton sampling should occur weekly during the most productive season (March to September) to capture the significant short-term variability in phytoplankton biomass (Robinson et al. 1996). To assess the presence/absence of phytoplankton species, a water sample is collected, preserved, and submitted to a laboratory for analysis. Guidance for collecting phytoplankton samples for species analysis using a Van Dorn sampler is provided in Section 4.1.3 of Part C in the *British Columbia Field Sampling Manual* (MWLAP 2013). Water samples are also collected and filtered in the field to measure phytoplankton biomass. Section E in the *Standard Methods for Sampling Resources and Habitats in Coastal Subtidal Regions of British Columbia* (Robinson et al. 1996) describes the methods for collecting phytoplankton biomass samples and provides further considerations for collecting phytoplankton in the marine environment.

Zooplankton samples should be collected at least twice a month during the most productive season (March to September) to capture the temporal variability of the zooplankton species composition and abundance (Robinson et al. 1996). Zooplankton in the nearshore environment can be sampled using plankton nets (Robinson et al. 1996). Guidance for collecting zooplankton using the vertical tow method are provided in Section 4.1.2 of Part C in the *British Columbia Field Sampling Manual* (MWLAP 2013). Section F in the *Standard Methods for Sampling Resources and Habitats in Coastal Subtidal Regions of British Columbia* (Robinson et al. 1996) provides considerations for sampling zooplankton in the marine environment, including recommended mesh sizes.

9.3.6 Macrophyte Community (Optional)

Macrophyte communities, such as eelgrass and kelp, provide critical habitat for various marine organisms. Macrophyte distribution within the vicinity of the outfall should be mapped to allow an assessment of changes in abundance over time. In addition, there are various indices to determine the overall health and condition of the macrophytes present. The *Methods for Mapping and Monitoring Eelgrass Habitat in British Columbia* (Precision Identification 2002) and the *Guidelines and Methods for Mapping and Monitoring Kelp Forest Habitat in British Columbia* (Mayne Island 2010) describe methods for monitoring macrophytes in British Columbia. Part A in the *Standard Methods for Sampling Resources and Habitats in Coastal Subtidal Regions of British Columbia* (Robinson et al. 1996) provides further methods and considerations for sampling macrophytes in marine waters.

KEY POINTS:

- The selection of indicator species should be discussed with ENV representatives.

9.3.7 Quality Assurance & Quality Control

Field QA/QC for biological samples include replicate, field split, and reference samples. Replicates determine the degree of heterogeneity within the communities (WLAP 2003). These replicates can consist of multiple samples (grabs, tows, or whole fish) from the same general area, or portions of a single sample (WLAP 2003). At least one replicate should be field split to assess the sampler and laboratory QA/QC (MOE 2016b). In addition, reference samples are used to document the bias of the laboratory process (BC Field Sampling Manual). Reference materials for tissue samples should be sourced from a third-party laboratory. Refer to Section 3 of the Biological Sample Collection section in the *British Columbia Field Sampling Manual* (MWLAP 2013) and Section 8.6 of the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (MOE 2016b) for further details on QA/QC procedures.

10.0 Reporting

10.1 Monitoring Program Design Report

The marine monitoring program design will need to be reviewed and approved by ENV. The design report should also be provided to local First Nations communities for review and feedback. Ideally, conversations with local First Nations communities will have begun during the information compilation stage (Section 2) prior to designing the program. This way any concerns can be addressed upfront and traditional environmental knowledge can be incorporated into the monitoring program design.

The monitoring plan report should include the following information:

- Description of the discharge, including effluent source, description of any treatment process, results of impact assessment, COPCs, and outfall location.
- Objectives of the monitoring program and how the progress of the monitoring can be assessed.
- Description of the receiving environment, including maps, valued uses and receptors, any site-specific benchmarks, freshwater influences, nearby dredging activities, land use and other point source releases (cumulative effect assessment), historical and other relevant data sources.
- Description of the sampling sites, including justification for location, and suitability of reference sites. Include a map of all proposed sample sites, including the outfall location and any areas of concern (e.g., shellfish harvesting areas)
- Field sampling methodology, including parameters, sampling frequency, and QA/QC protocols
- Analytical methods and statistical approaches
- Reporting schedule

KEY POINTS:

- The marine monitoring program design must be reviewed and approved by ENV.
- The marine monitoring program design should also be provided to local First Nations communities for review and feedback.

10.2 Annual Report

Once operations begin, the Annual Receiving Environment Report must be submitted to ENV each year by the deadline specified in the discharge permit. The report should contain the receiving environment monitoring data, including profiles, tables, and graphs. Summary tables of COPC concentrations in water, sediment and tissue samples should be provided and compared to reference site data, baseline data and guidelines or applicable site-specific benchmarks (WQOS). Guidelines include:

- British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture (ENV 2019c).
- British Columbia Recreational Water Quality Guidelines (ENV 2019d)
- The Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME 1999a)
- *Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota* (CCME 1999b).
- Provincial sediment quality guidelines, or CCME interim sediment quality guidelines (threshold or probably effect levels)
- British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture (MOE 2017)

The results should not simply be presented as comparisons to the above guidelines. The water quality, sediment quality, and biological data must be discussed in an integrated fashion that explores the interactions of all three media and the implications of the results for the receiving environment as a whole. In addition, previous year data should be included to summarize trends over time. The following documents may also be useful for results interpretation:

- *Guidelines for Interpreting Water Quality Data* (MELP 1998)
- *BC Marine Monitoring Protocol* (MWLAP 2002) (Statistical Analyses for BACI, MCI, and multiple gradient design)
- Section 4.5 in *Technical Guidance 4 Annual Reporting Under the Environmental Management Act A Guide for Mines in British Columbia* (MOE 2016c)

The report should also include an adaptive management framework section that will identify what actions will be taken if there are exceedances or increasing trends in COPCs. Parameters of concern trending towards but not yet exceeding guidelines also should be noted with a proposed management action to address the trend. Contingency measures should be in place and additional monitoring may be required. This is also the section to provide the weight of evidence or justification for any proposed reduction in monitoring requirements.

KEY POINTS:

- Monitoring results should be interpreted in an integrated fashion, rather than simply comparing all media results to their respective guidelines and benchmarks.
- An Adaptive Management Framework should be in place to address monitoring results, make recommendations, and implement monitoring changes.

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Appendices

Appendix A: Typical Water Quality Monitoring Parameters

Parameter	Industry						Recommended Detection Limit (µg/L)
	Municipal Wastewater	Aquaculture	Forestry	Mining	Pulp & Paper	Oil & Gas	
Conventional Variables							
Acidity				X			2 mg/L
Alkalinity				X			1 mg/L
Biochemical oxygen demand (BOD)	X	X	X	X	X	X	
Bromide (Br)				X			50
Chemical oxygen demand (COD)						X	
Chloride (Cl)				X			500
Colour				X	X		5
Conductivity, specific	X			X	X	X	2 µS/cm
Cyanide, total				X			
Dissolved solids, total				X		X	10 mg/L
Dissolved oxygen	X	X	X	X	X	X	
Enterococci	X		X				
Fecal coliform	X		X				
Fluoride (F)				X			20
Hardness (as $CaCO_3$)	X			X			1 mg/L
Oil & grease, mineral	X						
Oil & grease, total	X						
Organic carbon, dissolved (DOC)	X	X	X	X	X	X	0.5 mg/L
Organic carbon, total (TOC)	X	X	X	X	X	X	0.5 mg/L
pH	X	X	X	X	X	X	reported to 0.01 pH units
Salinity	X	X	X	X	X	X	
Sulphate	X			X	X	X	500
Sulphide	X						

Parameter	Industry						Recommended Detection Limit (µg/L)
	Municipal Wastewater	Aquaculture	Forestry	Mining	Pulp & Paper	Oil & Gas	
Total suspended solids (TSS)	X	X	X	X	X	X	2 mg/L
Temperature	X	X	X	X	X	X	
Turbidity	X	X	X	X	X	X	0.1 NTU
Nutrients							
Ammonia (NH3)	X	X	X	X			0.02 mg/L
Total Kjeldahl nitrogen (TKN)	X						
Nitrate	X	X	X	X		X	0.005 mg/L
Nitrite	X	X	X	X		X	0.005 mg/L
Nitrogen, total	X			X			0.05 mg/L
Phosphorus, Total	X	X	X	X			0.005 mg/L
Orthophosphate	X			X	X	X	0.005 mg/L
Metals Total/Dissolved							
Aluminum	X			X		X	1
Antimony	X			X		X	0.1
Arsenic	X			X		X	0.2
Barium	X			X		X	0.1
Beryllium	X			X		X	0.1
Bismuth	X			X		X	0.5
Boron				X		X	10
Cadmium	X			X		X	0.01
Calcium	X			X		X	50
Chromium	X			X		X	0.5
Chromium VI	X						1
Cobalt	X			X		X	0.1
Copper	X	X		X		X	0.2
Iron	X		X	X		X	10
Lead	X			X		X	0.1
Lithium	X			X		X	1
Magnesium	X			X		X	100
Manganese	X			X		X	0.2
Mercury	X			X		X	0.01
Mercury, methylated	X						
Molybdenum	X			X		X	0.1
Nickel	X			X		X	0.5

Parameter	Industry						Recommended Detection Limit (µg/L)
	Municipal Wastewater	Aquaculture	Forestry	Mining	Pulp & Paper	Oil & Gas	
Potassium	**X**			**X**		**X**	100
Selenium	**X**			**X**		**X**	0.3
Silver	**X**			**X**		**X**	0.01
Sodium	**X**			**X**		**X**	100
Strontium	**X**			**X**		**X**	0.2
Thallium	**X**			**X**		**X**	0.01
Tin	**X**			**X**		**X**	0.2
Tin, tributyl	**X**						
Titanium	**X**			**X**		**X**	10
Uranium				**X**			0.01
Vanadium	**X**			**X**		**X**	1
Zinc	**X**			**X**		**X**	1
Pesticides		**X**	**X**			**X**	
Polycyclic Aromatic Hydrocarbons (PAHs)	**X**			**X**		**X**	
Phthalates	**X**						
BTEX						**X**	

source: Environment Canada 2010, Lowe et al. 2012, MOE 2016b, CCME 2017, Harmac Pulp and Paper, Bish Cove LNG

Appendix B: Typical Sediment Quality Monitoring Parameters

Parameter	Industry			Recommended Detection Limit (µg/g)
	Municipal Wastewater	Mining	Pulp & Paper	
Conventional Variables				
Acid volatile sulphide	X			
C:N ratio			X	
Conductivity			X	
Cyanide, total	X			
Moisture content	X	X	X	1% wet weight
Ammonium (NH4)			X	
Total Kjeldahl nitrogen (TKN)			X	
Nitrogen, total			X	
Organic carbon, total (TOC)	X	X	X	0.05%
Particle size	X	X	X	
pH	X		X	
Phosphorous, total			X	
Redox potential (Eh)			X	
Sulphate			X	
Sulphide			X	
Sulphur, total		X		200
Metals, Total				
Aluminum	X	X	X	100
Antimony	X	X	X	0.1
Arsenic	X	X	X	0.2
Barium	X	X	X	1
Beryllium	X	X	X	0.1
Bismuth	X	X	X	0.1
Boron		X	X	5
Cadmium	X	X	X	0.05
Calcium	X	X	X	100
Chromium	X	X	X	1
Chromium VI	X			
Cobalt	X	X	X	0.3
Copper	X	X	X	0.5
Iron	X	X	X	100
Lead	X	X	X	0.1
Lithium	X	X	X	
Magnesium	X	X	X	10
Manganese	X	X	X	0.2
Mercury	X	X	X	0.05
Mercury, methylated	X			

Parameter	Industry			Recommended Detection Limit (µg/g)
	Municipal Wastewater	Mining	Pulp & Paper	
Molybdenum	X	X	X	0.1
Nickel	X	X	X	0.8
Phosphorus	X	X	X	10
Potassium	X	X	X	100
Selenium	X	X	X	0.1
Silver	X	X	X	0.1
Sodium	X	X	X	100
Strontium	X	X	X	0.1
Thallium	X	X	X	0.1
Tin	X	X	X	0.2
Tin, tributyl	X	X	X	
Titanium	X	X	X	1
Vanadium	X	X	X	2
Uranium		X		0.05
Zinc	X	X	X	2
Metals, Extractable				
Cadmium	X			
Copper	X			
Lead	X			
Mercury	X			
Nickel	X			
Zinc	X			
Semivolatile organics				
1,2,4-trichlorobenzene	X			
1,2-diphenulhydrazine	X			
2,4-dinitrotoluene	X			
2,6-dinitrotoluene	X			
3,3-dichlorobenzidine	X			
4-bromophenyl phenyl ether	X			
4-chlorophenyl phenyl ether	X			
benzidine	X			
bis(2-chloroethoxy)methane	X			
bis(2-chloroethyl)ether	X			
hexachlorobenzene	X			
hexachlorobutadiene	X			
hexachlorocyclopentadiene	X			
hexachloroethane	X			
isophorone	X			

Parameter	Industry			Recommended Detection Limit (µg/g)
	Municipal Wastewater	Mining	Pulp & Paper	
nitrobenzene	**X**			
N-nitrosodimethylamine	**X**			
N-nitrosodi-n-propylamine	**X**			
N-nitrosodiphenylamine	**X**			
Volatile organics	**X**			
Nonylphenols (NP)	**X**			
Organochlorine pesticdes (OP)	**X**			
Polychlorinated Biphenyls (PCBs)	**X**			
Polybrominated Diphenyl Ethers (PBDEs)	**X**			
Acrolein	**X**			
Phenols, total	**X**			
Polycyclic Aromatic Hydrocarbons (PAHs)	**X**	**X**	**X**	0.05

source: Environment Canada 2010, Lowe et al. 2012, MOE 2016b, CCME 2017, Harmac Pulp and Paper, Bish Cove LNG

Appendix C: Typical Biological Tissue Parameters

Parameter	Industry: Municipal Wastewater	Industry: Mining	Industry: Pulp & Paper	Recommended Detection Limit (µg/g)
Moisture	X	X	X	1% wet weight
Lipids	X	X	X	
Metals, Total				
Aluminum (Al)	X	X		0.4
Antimony (Sb)	X	X		0.002
Arsenic (As)	X	X		0.005
Barium (Ba)	X	X		0.01
Beryllium (Be)	X	X		0.002
Bismuth (Bi)	X	X		0.02
Cadmium (Cd)	X	X		0.002
Calcium (Ca)	X	X		2
Chromium (Cr)	X	X		0.01
Cobalt (Co)	X	X		0.004
Copper (Cu)	X	X		0.01
Iron (Fe)	X	X		1
Lead (Pb)	X	X		0.004
Magnesium (Mg)	X	X		2
Manganese (Mn)	X	X		0.02
Mercury (Hg)	X	X		0.002
Mercury, methylated (MeHq)	X	X		0.002
Molybdenum (Mo)	X	X		0.01
Nickel (Ni)	X	X		0.01
Phosphorus (P)	X	X		5
Potassium (K)	X	X		10
Selenium (Se)	X	X		0.02
Silver (Ag)	X	X		0.01
Sodium (Na)	X	X		2
Strontium (Sr)	X	X		0.01
Thallium (Tl)	X	X		0.001
Tin (Sn)	X	X		0.02
Titanium (Ti)	X	X		0.06
Uranium (U)	X	X		0.001
Vanadium (V)	X	X		0.02
Zinc (Zn)	X	X		0.1
Chlorinated Phenolics	X			
Semivolatile organics	X			
Misc. semi-volatile organics	X			

Parameter	Industry			Recommended Detection Limit (µg/g)
	Municipal Wastewater	Mining	Pulp & Paper	
Volatile organics	**X**			
Monocyclic Aromatic Hydrocarbons	**X**			
Phthalates	**X**			
Organochlorine pesticides	**X**			
Polychlorinated biphenyls (PCBs)	**X**			
Polcyclic Aromatic Hydrocarbons (PAHs)	**X**			
Dioxins (TCDD)			**X**	
Furans (TCDF)			**X**	
POLYCHLORINATED DIBENZODIOXINS (PCDDs)	**X**			
POLYBROMINATED DPHENYL ETHERS (PBDES)	**X**			

source: Environment Canada 2010, Lowe et al. 2012, MOE 2016b