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Technical Supplement 3

Canada-wide Strategy for the Management of Municipal Wastewater Effluent

Standard Method and Contracting Provisions for the Environmental Risk Assessment

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Acknowledgements and Disclaimer

The Standard Method and Contracting provisions which follow were prepared for CCME by SENES Consultants Limited. The original documents have been modified to meet the needs of CCME. These provisions have not been developed to meet the needs of any particular municipality or community. Municipalities and communities should obtain proper legal advice before using any of the following provisions, for their own purposes.

List of Acronyms

BMP	Best Management Practice
CBOD₅	Carbonaceous Biochemical Oxygen Demand for 5 Days
CCME	Canadian Council of Ministers of the Environment
CEAEQ	Centre d'Expertise en Analyse Environnementale du Québec
CEQG	Canadian Environmental Quality Guidelines
CRM	Certified Reference Methods
DOC	Dissolved Organic Carbon
EC	Effects Concentration
EDO	Effluent Discharge Objective
EQO	Environmental Quality Objective
ERA	Environmental Risk Assessment
LC₅₀	Lethal Concentration for 50% mortality
LMDL	Laboratory Method Detection Limit
LOEC	Lowest Observable Effects Concentration
MDL	Method Detection Limit
MWWE	Municipal Wastewater Effluent
NEL	No Effect Level
NOEC	No Observable Effects Concentration
NPS	National Performance Standard
PCB	Polychlorinated biphenyls
QA	Quality Assurance
QC	Quality Control
SCC	Standards Council of Canada
TMDL	Total Maximum Daily Load
TRC	Total Residual Chlorine
TSS	Total Suspended Solids
TU	Toxic Unit
TU_a	Acute Toxic Unit
TU_c	Chronic Toxic Unit
US EPA	United States Environmental Protection Agency
WET	Whole Effluent Toxicity

PART A – Standard Method

Executive Summary

This document includes a step-by-step standard approach to ensure that the implementation of the Environmental Risk Assessment (ERA) is conducted in a consistent manner across Canada. Table ES-1 provides an outline of the activities to be performed by municipalities and approaches to be taken in developing an ERA for single or multiple Municipal Wastewater Effluent (MWWE) discharges. The key aspect is the incorporation of specific actions into the ERA framework which would allow a municipality to implement the ERA.

Table ES 1. Activities and Approaches Taken in Developing an Environmental Risk Assessment

Activity by Municipality	Approach
<p>REPORT SECTION 1</p> <p><i>Introduction</i></p>	<p>Present background and objective of the step-by-step standard method</p>
<p>REPORT SECTION 2</p> <p><i>Establish the List of Substances of Potential Concern</i></p>	<p>Facility categorization</p> <p>Step 2-1: categorize facility size</p> <p>Determine the list of substances of potential concern</p> <p>Step 2-2: select generic list of substances of potential concern according to facility size</p> <p>Step 2-3: add substances associated with industrial discharges to the generic list</p>
<p>REPORT SECTION 3</p> <p><i>Prepare the Initial Characterization Program</i></p>	<p>Prepare characterization of MWWE</p> <p>Step 3-1: select monitoring substances</p> <p>Step 3-2: select toxicity testing methods</p> <p>Step 3-3: determine sampling frequency</p> <p>Step 3-4: other considerations</p>
<p>REPORT SECTION 4</p> <p><i>Implement the Initial Characterization Program, including sampling, preservation and analytical requirements, according to substance</i></p>	<p>Implement characterization program</p> <p>Step 4-1: perform sample collection and analysis</p> <p>Follow protocols for sampling, preservation, storage and analyses of MWWE</p>
<p>REPORT SECTION 5 (SINGLE DISCHARGE)</p> <p><i>Establish EDOs for Substances of Concern</i></p>	<p>Review the specific steps applicable to the MWWE to set EQOs, then EDOs for a single discharge</p>

Activity by Municipality	Approach
	<p>Determine EQOs:</p> <p>Step 5-1: define water uses Step 5-2: determine generic EQOs Step 5-3: characterize the receiving environment Step 5-4: determine site-specific EQOs Step 5-5: determine toxicological EQOs</p> <p>Determine the mixing zone and assess dilution:</p> <p>Step 5-6: review the definition of the mixing zones Step 5-7: evaluate criteria for allocating the mixing zone Step 5-8: determine restrictions on mixing zones and dilution allowed for mixing</p> <p>Determine EDOs:</p> <p>Step 5-9: determine the need for EDOs Step 5-10: develop EDOs</p>
<p>REPORT SECTION 6 (MULTIPLE DISCHARGES)</p> <p><i>Establish EDOs for Substances of Concern with the Watershed Approach</i></p>	<p>Review the specific steps applicable to the MWWWE to set EQOs, then EDOs for the watershed, and thereafter determine water quality trading</p> <p>Determine EQOs and EDOs:</p> <p>Step 6-1: build partnership Step 6-2: define scope of watershed planning effort Step 6-3: gather existing data and create inventory Step 6-4: identify data gaps and collect additional data Step 6-5: analyze data to characterize the watershed and pollutants sources Step 6-6: estimate pollutants loads Step 6-7: set objectives and identify load reductions Step 6-8: identify possible management strategies Step 6-9: evaluate options and select final management strategies Step 6-10: design implementation program and assemble water plan Step 6-11: implement watershed plan and measure progress</p> <p>Follow the above framework, and when appropriate, determine water quality trading:</p> <p>Step 6-12: determine suitability of pollutant for trading</p>

Activity by Municipality	Approach
	<p>Step 6-13: analyze the financial attractiveness of trading</p> <p>Step 6-14: establish the trading market infrastructure</p>
<p>REPORT SECTION 7</p> <p><i>Selection of Substances for Compliance Monitoring</i></p>	<p>Determine the list of substances for compliance monitoring</p> <p>Step 7-1: selection of substances</p> <p>Step 7-2: selection of monitoring frequencies</p>

1.0 Introduction

1.1 Background

Supporting implementation of the *Canada-wide Strategy for the Management of Municipal Wastewater Effluent* (MWWEE) (the “Strategy”) is the development of an Environmental Risk Assessment (ERA) “standard method” to calculate Effluent Discharge Objectives (EDOs). These EDOs represent concentrations or loads of substances in MWWEE discharges that are expected to correspond to Environmental Quality Objectives (EQOs) in receiving waters, at the edge of specified mixing zones. An ERA can be performed for a single effluent discharge or for multiple discharges, in which case it must consider concentrations or loads for all dischargers of the same substance as per a watershed management plan (including nutrients). In both cases, the process begins with the Canadian Environmental Quality Guidelines (CEQGs) and/or the Provincial Guidelines to establish site-specific EQOs, which subsequently are used to calculate EDOs for the discharger(s). Both freshwater and marine environment are to be considered into the standard method.

This technical supplement is based on information found in Technical Supplement 2 of the Strategy.

1.2 Standard Method Objective

In this document, the objective is to present a step-by-step standard methodology to complete an ERA, which establishes EDOs based on ensuring that EQOs are achieved in receiving waters, at the edge of specified mixing zones.

1.3 A Step-by-Step Standard Method

The main task of this document is to translate information on the ERA included in the Strategy into an easily accessible and consistent approach, or “framework” that can be implemented by wastewater facilities (facilities) across Canada. As presented in this document, the pertinent activities to conduct the ERA and to establish EDOs are in the following order of sections (Figure 1-1), except for the last activity (i.e., Compliance Monitoring), which is presented thereafter:

- Establish the List of Substances of Potential Concern (**Section 2**);
- Prepare the Initial Characterization Program (**Section 3**);
- Execute Initial Characterization Program (**Section 4**);
- Establish EDOs from a Single Discharge Approach (**Section 5**), or
- Establish EDOs from a Watershed Approach (**Section 6**);
- Selection of Substances for Compliance Monitoring (**Section 7**).

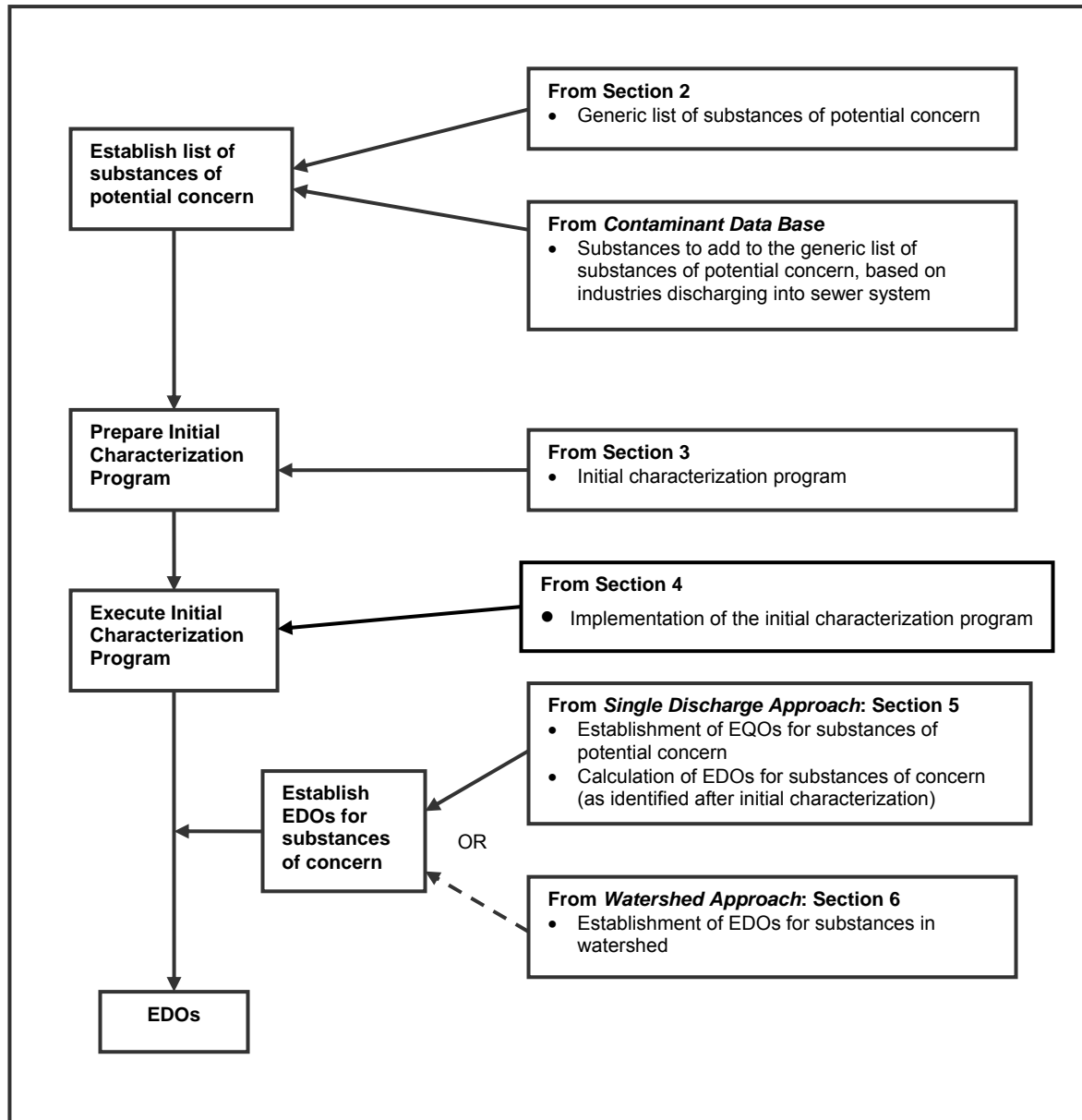


Figure 1-1. Pertinent Activities of an Environmental Risk Assessment

Facilities must meet the following National Performance Standards (NPSs):

- **Carbonaceous Biochemical Oxygen Demand (CBOD₅) for five days - 25 mg/L;**
- **Total Suspended Solids (TSS) - 25 mg/L; and**
- **Total Residual Chlorine (TRC) - 0.02 mg/L.**

It is of note that there might be different NPSs for Canada's Far North, which is to be determined by CCME.

If effluent discharge is not meeting the NPSs, opportunities for reduction are to be sought. Standards for other substances are set based on a site-specific ERA approach. Assimilative capacity in the receiving water and water-uses downstream of the discharge will be considered in the approach. Figure 1-2

describes effluent monitoring and what to do when the effluent discharge is not achieving performance standards or EDOs.

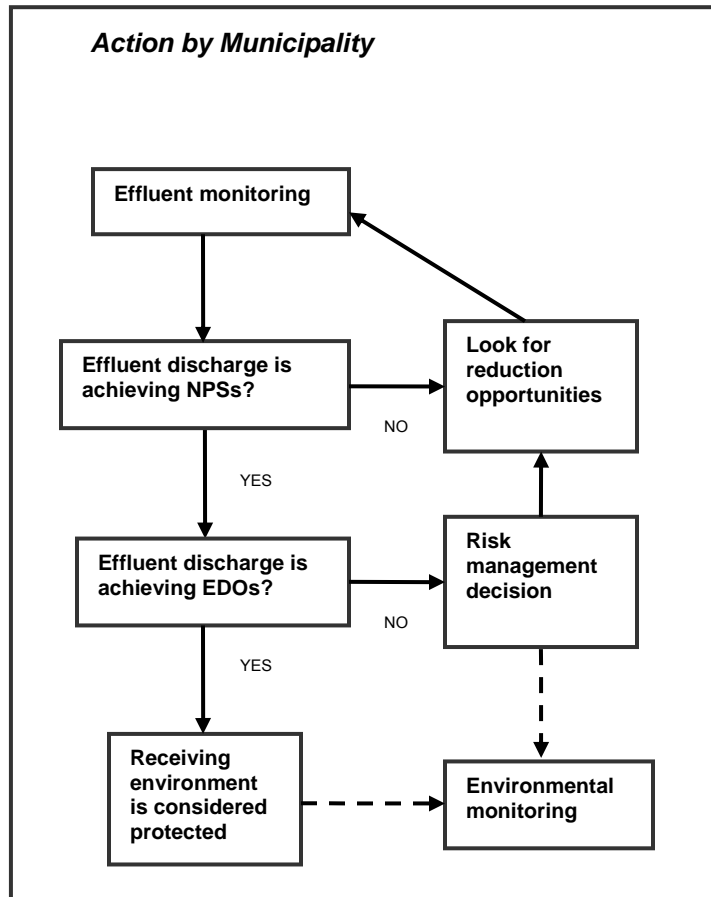


Figure 1-2. Effluent Monitoring and Risk Management Decision Making

2.0 Substances of Potential Concern

2.1 Introduction

MWWE contain grit, debris, suspended solids, pathogens, organic wastes, nutrients, and about 200 identified chemicals (EC 2001). CBOD₅ and TSS are the single largest constituents of MWWE. Primary treatment typically reduce CBOD₅ and TSS by 30% and 65% respectively (Metcalf and Eddy, 2003), whereas, secondary treatment is capable of reducing CBOD₅ and TSS by more than 80%. In 1999, releases of CBOD₅ and TSS from all Canadian facilities were estimated at 101,950 tonnes and 121,619 tonnes, respectively (EC 2001).

Nitrogen and phosphorus concentrations are an order of magnitude lower, with typical nitrogen concentrations in the 20–40 mg/L and phosphorus concentrations in the 7–15 mg/L range for primary treatment (EC 2001). In inland areas where eutrophication problems from phosphorus discharges have been widespread, tertiary treatment is often needed to reduce phosphorus concentrations to more benign levels (typically 1 mg/L or less, depending on the ecosystem characteristics that are exposed to the discharges).

Although microorganisms are found in large numbers in raw sewage, wastewater treatment is effective at reducing their numbers in effluents. Standard facilities with a well-functioning disinfection process can achieve a nearly 100% reduction in the number of microorganisms present in the final effluent. However, even with a 99% removal rate, 10,000–100,000 organisms per 100 mL may still remain in the treated effluent (EC 2001).

Aluminum and iron are the most abundant metals present as salts, and are often used in the wastewater treatment process. Other metals, including cadmium, copper, lead, zinc, manganese, molybdenum, and nickel, may be present at lower levels (CCME 2006a, EC 2001). Mercury, which is a metal of considerable environmental concern, may be present as well, although in trace quantities. Organic chemicals, such as polychlorinated biphenyls (PCBs), dioxins and furans, tetrachloroethylene and trichloroethylene tend to be present at even lower levels than those of the metals; however, some of these contaminants can be toxic at low levels and can remain in the environment for very long periods of time. MWWE, together with stormwater runoff, overshadow direct industrial discharges as the dominant source of waterborne PCBs and mercury entering lakes Superior and Ontario, according to estimates for 1991 and 1992 (EC 2001).

Facilities must use an ERA approach to set appropriate EDOs. This approach is to be used to set EDOs for all substances of potential concern (e.g., CBOD₅, TSS, TRC, nutrients, metals, pathogens and other chemicals) present in MWWE. A list of substances of potential concern has been established and can be found in Table 2-3.

2.2 Facility Categorization

Step 2-1: Categorize Facility Size

To differentiate the risk posed by various levels of MWWE discharged to surface waters, facilities are categorized into five categories as shown in Table 2-1. Categories are based on annual average daily flow rates for the previous year.

Table 2-1. Municipal Wastewater Facility Size Categories

Size Category	Flow [m ³ /day]
<i>Very Small</i> ¹	≤ 500
<i>Small</i> ¹	> 500 – 2,500
<i>Medium</i>	> 2,500 – 17,500
<i>Large</i>	> 17,500 – 50,000
<i>Very Large</i>	> 50,000

Note: ¹ *Very small* and *small* facilities which have industrial input associated with wastewater will be considered in the *medium* size category

Very small and *small* facilities with industrial input are considered *medium* facilities and must assume medium facility requirements. Wastewater facilities may be reclassified from medium to small or very small if pre-treatment of the industrial input before it is discharged to the sewer produces an effluent quality comparable to domestic wastewater or better, or if the industrial input is removed from the sewer. Industrial input is defined as non-domestic process water from industry categories specified below that together exceeds 5% of total dry weather flow in the sewer shed, on an annual average basis:

- resource exploration and development (e.g. mining, forestry, oil and gas);

- manufacturing/ fabrication;
- processing (including food);
- marine or air transport (including container cleaning);
- landfill leachate; and,
- hospitals and laboratories (but not nursing stations).

2.3 Determine List of Substances of Potential Concern

The following steps are defined in order to obtain a list of substances of potential concern for MWW.

Step 2-2: Select the Generic List of Substances of Potential Concern According to Facility Size

There is a list of conventional substances that all facilities must measure. This list is presented in Table 2-2. However, the list of substances of potential concern must be selected based on the size of the facility (see Step 2-1). More specifically, Table 2-2 presents the list of substances of potential concern for *very small* and *small* facilities. Table 2-3 presents the list of substances of potential concern for *medium*, *large* and *very large* facilities.

Table 2-2. List of Potential Substances of Concern for MWW – Very Small and Small Facilities

Test Group	Substances
General Chemistry / Nutrients	Total Suspended Solids (TSS) Carbonaceous Biochemical Oxygen Demand (CBOD ₅) Total Residual Chlorine (TRC) if chlorination is used Total Ammonia Nitrogen Total Kjeldahl Nitrogen (TKN) Total Phosphorus (TP) pH Temperature
Pathogens	<i>E. coli</i> (or other pathogen, as directed by the jurisdiction)

Table 2-3. List of Substances of Potential Concern for MWW – Medium, Large and Very Large Facilities

Test Group	Substances
General Chemistry / Nutrients	Fluoride Nitrate Nitrate + Nitrite Total Ammonia Nitrogen Total Kjeldahl Nitrogen (TKN) Total Phosphorus (TP) Total Suspended Solids (TSS) Carbonaceous Biochemical Oxygen Demand (CBOD ₅) Total Residual Chlorine (TRC) Chemical Oxygen Demand (COD) Cyanide (total) pH Temperature
Metals	Aluminum, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, silver, strontium, thallium, tin, titanium, uranium, vanadium, zinc as well as arsenic, antimony, selenium and mercury
Pathogens	<i>E. coli</i> (or other pathogen, as directed by the jurisdiction)
Organochlorine Pesticides	Alpha-BHC, endosulfan (I and II), endrin, heptachlor epoxide, lindane (gamma-BHC), mirex, DDT, methoxychlor, aldrin, dieldrin, heptachlor, a-chlordane and g-chlordane, toxaphene
Polychlorinated Biphenyls (PCBs)	Total PCBs
Polycyclic Aromatic Hydrocarbons (PAHs)	Acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i,)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, methylnaphthalene, naphthalene, phenanthrene, pyrene
Volatile Organic Compounds (VOCs)	Benzene, bromodichloromethane, bromoform, carbon tetrachloride, chlorobenzene, chlorodibromomethane, chloroform, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloroethane, 1,1-dichloroethene, dichloromethane, ethylbenzene, 1,1,1,2-tetrachloroethane, 1,1,2,2-tetrachloroethane, tetrachloroethene, toluene, trichloroethene, vinyl chloride m/p-xylene, o-xylene
Phenolic compounds	2,3,4,6-tetrachlorophenol, 2,4,6-trichlorophenol, 2,4-dichlorophenol, pentachlorophenol
Surfactants	Non-ionic surfactants and anionic surfactants (others may be added by the jurisdiction)

Step 2-3: Add Substances Associated with Industrial Discharges to the Generic List

Monitoring programs should be reviewed with respect to industrial effluent being discharged to the sewer system. Industrial effluent characterizations may be consulted where available or the CCME contaminant database can be used to identify substances possibly associated with the industrial processes present. The list of potential substances of concern is augmented based on those substances associated with industrial activity.

3.0 Initial Characterization Program

This section provides guidance on the requirements for the initial characterization program to commence with the ERA. Initial characterization is to be tailored according to facility categorization. Facilities that discharge less than 10³/day are not required to complete initial characterization.

3.1 Prepare MWWE Characterization

Step 3-1: Select Monitoring Substances

The first step in conducting the ERA is the identification of substances of potential concern in the MWWE. The steps outlined in Section 2.0 – Substances of Potential Concern, must be completed prior to commencing **Step 3-1**.

Furthermore, TRC needs to be monitored in facilities where chlorine or chlorine compounds are used in the treatment process. In the case where an effluent is chlorinated and subsequently dechlorinated, the effluent may be tested for the dechlorination chemical instead of TRC on the basis that the presence of the dechlorination substance is indicative of no residual chlorine.

Step 3-2: Select Toxicity Testing Methods

Toxicity tests should be carried out according to facility size as shown in Table 3-1. For acute toxicity testing, either single concentration or multiple concentration rainbow trout and *Daphnia magna* tests are required. For chronic toxicity testing the fathead minnow and the *Ceriodaphnia dubia* tests are required.

Table 3-1. Toxicity Testing at Difference Size Facilities

Facility Size	Acute Toxicity Tests	Chronic Toxicity Tests
<i>Very Small</i>	n/a ¹	n/a
<i>Small</i>	- Rainbow Trout - <i>Daphnia magna</i>	- Fathead Minnow - <i>Ceriodaphnia dubia</i>
<i>Medium</i>	- Rainbow Trout - <i>Daphnia magna</i>	- Fathead Minnow - <i>Ceriodaphnia dubia</i>
<i>Large</i>	- Rainbow Trout - <i>Daphnia magna</i>	- Fathead Minnow - <i>Ceriodaphnia dubia</i>
<i>Very Large</i>	- Rainbow Trout - <i>Daphnia magna</i>	- Fathead Minnow - <i>Ceriodaphnia dubia</i>

Note:

¹ n/a – not applicable

Step 3-3: Determine Sampling Frequency

Continuous Discharge

For the purpose of this sampling guide, quarterly monitoring may be conducted during the specified period as shown in Table 3-2. For continuous discharges, the monitoring frequency will vary according to facility size. Table 3-3 details the monitoring frequency required for different substances according to facility size. Monitoring frequencies are given in daily, weekly, monthly, and quarterly increments.

Table 3-2. Quarterly Monitoring

Quarter	Period
1 st	October – December
2 nd	January – March
3 rd	April – June
4 th	July – September

Table 3-3. Monitoring Frequencies

Facility Size ¹	TRC ² (or dechlorination agent)	CBOD ₅ , TSS, Pathogens and Nutrients ³	Substances and Test Groups ⁴	Acute Toxicity	Chronic Toxicity
<i>Very Small</i>	Daily	Monthly	n/a	n/a	n/a
<i>Small</i>	Daily	Monthly	n/a	Quarterly	Quarterly
<i>Medium</i>	Daily	Every two weeks	Quarterly	Quarterly	Quarterly
<i>Large</i>	Twice per day	Weekly	Quarterly	Monthly	Monthly
<i>Very Large</i>	Three times per day	5 days/week	Quarterly	Monthly	Monthly

Note:

¹ Facilities that discharge less than 10³/day are not required to complete initial characterization

² TRC or the dechlorination chemical that is used. Only required if chlorine is used in the wastewater facility.

³ Nutrients include total ammonia nitrogen, TKN (ammonia + organic N) and total phosphorus. Temperature and pH must also be measured to determine the level of toxicity of ammonia. Pathogens could include *E. coli*

⁴ Substances and test groups will include the following: Fluoride, Nitrate, Nitrate + Nitrite, Total Extractable Metals and Metal Hydrides (full range), COD, Organochlorine Pesticides, PCBs, PAHs, Cyanide (total), pH, Volatile Organic Compounds, Mercury, Phenolic compounds and Surfactants (see Table 2.3), plus other substances specifically associated with industrial or commercial activities that discharge into the sewer system (see Contaminant Data Base)

All Test Groups and substances associated with industrial or commercial activities must be completed for each effluent from *medium*, *large*, and *very large* facilities.

Intermittent Discharge

For intermittent discharges in each size classification, two samples are required during each discharge period, with the total number of tests not exceeding the number required for continuous discharges:

- One sample near the start of the discharge period; and
- One sample near the end of the discharge period.

Step 3-4: Other considerations

Flow Monitoring

On each day of sampling, the average daily flow rate must be recorded along with the samples. Annual average flows may be calculated using the total volume of effluent discharged each day. The average daily flow should be recorded for each facility. Flows may be monitored with a system that takes continuous measurements or by using a method that meets generally accepted engineering principles, such as those in the standards for the measurement of liquid flow in open channels or measurement of fluid flow in closed conduits published by the International Organization for Standardization. Flow monitoring equipment should have an accuracy of $\pm 15\%$ over the entire range of expected flows, and should be calibrated.

Sampling Weather Conditions

Facilities collect wastewater from residential, industrial, commercial, and institutional establishments. During wet weather conditions, rain, snow, and ice enter the sewer system and also become part of the facility influent. The composition of the runoff that washes into the sewer from roads, highways, rooftops, and other surfaces can contain any substances that the precipitation encountered as it made its way towards the sewer (e.g., : road salt, oil, gasoline, pesticides). Predominantly, precipitation will contain sulphate, chloride, sodium, calcium, and potassium ions. Thus, the influent during wet weather will be of a different quality than that during dry weather.

Sampling Type and Techniques

Because the water detention time for mechanical treatment facilities is usually about 2-4 days, it is recommended that sampling be done at least 2 days after rainfall or a rise in temperature that would cause the melting of ice and snow.

For continuous discharges, the monitoring frequency for each facility size is listed in Table 3-3 in **Step 3-3**. Samples are a 24-hour composite sample, except when grab samples are required or unless directed otherwise by the jurisdiction. Continuous discharges include regular discharges from batch treatment processes, such as a sequencing batch reactor, that discharge on a frequent and regular basis.

Very large facilities may, instead of collecting one 24-hour composite sample for substances/test groups, collect three consecutive 24-hour composite samples of the final effluent. Sampling three continuous days is expected to better represent variations especially for the compounds in the substances/test groups. Final effluent samples should be taken at the outfall of the facility, after chlorination/dechlorination (or after UV disinfection) and prior to discharge to the receiving water bodies.

Automated composite samples can be taken either proportional to the sewage stream flow (in which case there must be flow-sensing devices connected to the sampler) or on an equal volume/equal time basis. Both of these methods require fully automated, programmable sampling devices.

Protocols for sampling, preservation and storage, and sample analysis are described in Section 4.0 – Implementation of the Initial Characterization Program.

4.0 Implementation of the Initial Characterization Program

Step 4.1: Perform Sample Collection and Analysis

MWWE initial characterization is performed over the period of a year, based on substances of potential concern, toxicity tests, monitoring frequencies, and other considerations identified in the previous steps.

The following sections contain information regarding sampling, sample preservation and storage and analytical methods summarized from *Standard Methods for the Examination of Water and Wastewater* (APHA 2005), *Water and Air Monitoring and Reporting - Sampling, Methods and Quality Assurance, Part E Water and Wastewater Sampling* (BC MoE 2003), *Analysis of Industrial/Municipal Wastewater* (MOE 1999), Environment Canada (2000a-d), and Ministère du Développement Durable de l'Environnement et des Parcs du Québec, Centre d'Expertise en Analyse Environnementale du Québec (MDDEP-CEAEQ 2003, 2007).

4.1 Guidelines for Sampling

All samples obtained for analysis must be from a point in the MWWE stream that is representative of the whole stream composition. The sample should closely resemble the population being measured and should be handled in a manner that prevents or minimizes changes from its original form. The volume of the sample taken must be sufficient to allow for analysis of all required analytes plus associated quality control samples (e.g., field duplicate, laboratory replicate and spiked sample).

It is recommended that all automated and manual sampling devices and equipment, their containers and all tubing, valves and contact components be dedicated to a particular sampling site in order to minimize the possibility of cross contamination. As an alternate to this dedicated application, it is the user's responsibility to demonstrate that the sampling equipment is clean, free from contamination, and suited to the sampling and analysis needs at the next location. Generally, the cleaning and preparation of relocated equipment should include hot water, phosphate free detergent washing, hot and cold water rinsing, distilled water rinsing, and finally, multiple rinses with the actual MWWE being sampled. This is especially important where trace levels of contaminants are being analyzed.

Appendix A lists the sampling requirements for each test group identified in Section 2. The International Standard *ISO 5667 Water Quality – Sampling – Part 10: Guidance on sampling of waste waters* may also be used for guidance.

4.1.1 Field Notes/Observations

Detailed field notes should be carried out during sampling activities to include:

- Facility name;
- Date and time;
- Weather;
- Names of all the personnel on the sampling crew;
- Influent, effluent or sludge; and
- Preservatives used (for each sample).

All information should be recorded in a logbook and should be initialed by the data recorder and entered into a database as soon as possible upon return from the field.

4.1.2 Sample Types and Techniques

MWWE samples are often obtained by the use of automated equipment capable of either flow or time proportional sub-sampling of a MWWE stream. These automated sampling devices (autosamplers) must be mechanically and electrically suited to the environment in which they will operate and in consideration of safety and accessibility, be physically located to facilitate routine use, maintenance and inspection by field staff.

Grab Samples

A grab sample is meant to represent the MWWE stream at a given point in time as opposed to a composite sample which represents the MWWE stream over a longer time period (e.g., 24 hours). Grab samples should be collected by dipping an appropriate container, bucket, bottle or vial, into the MWWE stream using an appropriate retrieval device, such as a chain or pole.

Grab samples may be taken from a valved slipstream; after purging the sample line, the samples should be collected into appropriate laboratory containers.

Grab sampling may also be conducted using an automated sampler in manual mode when the automatic function fails. Three grab sampling techniques are outlined below:

- a) MWWE is collected in a bucket or other container and immediately transferred to the appropriate laboratory container(s), preserved as necessary, and capped.
- b) The appropriate laboratory sample container is submerged in the MWWE stream on a chain or pole until it is full; it is retrieved, preserved as necessary, and capped.
- c) MWWE is collected in a bucket as for grab technique a) and the appropriate clean (outside as well) laboratory container (e.g., volatiles vial) is held at an angle and submerged into the liquid until it is full and air bubbles have been expelled at which time it is carefully retrieved, preserved as necessary, and capped.

4.1.3 Composite Samples

As stated in Section 3, composite samples are required for continuous discharges. Composite samples can be collected either by automated or manual methods.

A manual composite sample consists of grab samples typically taken at equally spaced time intervals and combined (composited) once all sub-samples have been collected. Grab samples may also be composited proportional to the stream flow. Flow records must be recorded at the time of sampling and the volume for each sampling event is adjusted proportionally to the flow.

Generally, composite samples are collected by the following techniques:

Flow Proportional Samples

There are two methods to collect flow proportional samples:

- a) Automatic equipment collecting samples proportional to the MWWE stream flow at time intervals of at least once per hour over the sampling period (typically 24 hours), under typical flow conditions. For example, if the collection of 1% of the effluent discharge is required, and the total discharge is 100 L, 1000 mL should be collected for the sample.
- b) A minimum of 8 grab samples taken at equally spaced time intervals over the sampling period (e.g., every 3 hours in a 24 hour period) combined in proportion to the MWWE stream flow.

Equal Time/Equal Volume Samples

There are two methods where equal time/equal volume sampling can be carried out:

- a) Automatic equipment collecting samples of equal volume at equally spaced time intervals of 15 minutes or less over the sampling period.

- b) A minimum of 8 grab samples taken at equally spaced time intervals over the sampling period (e.g., every 3 hours in a 24 hour period) combined in equal volumes.

The time periods described above may be modified, depending on site-specific situations. Regardless which sampling mode is selected, it should be documented and adhered to, so as to provide consistency in the data produced.

4.1.4 Automated Sampler Considerations

Three important characteristics of autosamplers are discussed in this section.

Materials Composition

All wettable surfaces that contact the MWW sample must be inert (i.e., must not contaminate, absorb or adsorb chemicals required to be analyzed in the MWW sample). This requirement can generally be met through consistent use of materials such as Teflon®, glass, stainless steel, and where dictated by sampler design and function (e.g., peristaltic type pumps, pinch valves, volume control tubes), short sections of surgical grade silicone rubber tubing. This type of tubing should be preferentially replaced by Teflon® or other chemically inert materials as far as possible without impairing the performance of the sampling device. Where surgical grade silicone rubber tubing is used the total length should be kept to an absolute minimum and it is generally accepted that this should be less than 2 m. Particular care should be taken to ensure that this tubing and all other wettable parts are cleaned or replaced appropriately.

Temperature Stability

A requirement for autosamplers is that they maintain the sample storage environment at a temperature between the freezing point of the sample and 10°C. This may require cooling and/or heating capabilities depending on location and time of year. The temperature must be monitored daily during sample collection and storage and the readings documented. A min-max thermometer may be used for this purpose. Sampling records must be maintained such that all data including repair, inspection, use, maintenance and temperature records are available for inspection.

Ability to Obtain a Representative Sample

Automated sampling devices can provide either a single large sample composite which can be further subdivided at the end of a predefined sampling period, as suitable, for the analysis to be performed or multiple individual composites each of which can be individually assigned to specific test groups. The latter capability can provide better flexibility and accommodate a wider range of analysis requirements by providing the option of individual container preservation, and multiple composite samples for specialty testing needs.

The choice of autosampler design and capability will be dictated by specific sampling and analysis requirements. It is, however, essential that the autosampler take the sample from a location in a MWW stream that will provide a representative sample. This requirement will typically be met by sampling at a point of thorough mixing with no excessive turbulence, and at a point away from walls or surfaces of a pipe or channel that may cause insufficient mixing due to currents and eddies. The sampling location must be determined by preliminary testing to evaluate the impact of any site specific turbulence and mixing phenomena.

The sampler must maintain the sample integrity when transferring effluent from the stream to the sample container, in particular by maintaining adequate velocities (1 m/s) in the transport system to exceed the scour and settling velocities of the constituents of interest.

4.1.5 Compositing Techniques

Where a sample is collected in a large container and requires analysis for several groups of compounds,

the MWWWE must be transferred to appropriate laboratory containers. Teflon® or other suitable tubing and gravity suction is recommended for transfer of the MWWWE to the individual laboratory container. A peristaltic pump may be used to transfer the aliquots into the appropriate laboratory containers. The sample may also be poured into the individual laboratory containers. Sample transfer must be accompanied by continuous mixing of the composite sample by using a mechanical stirrer, manual swirling or other appropriate means. Use of magnetic stirring bars should be avoided since they may adsorb suspended solids containing metals, thus affecting the sample integrity.

The laboratory should be consulted prior to sampling to determine minimum sample volumes required for all required analyses. The volume used for analysis must be sufficient to meet all the analytical requirements including laboratory and field QC obligations and also be sufficient for the laboratory to achieve its analytical Method Detection Limit (MDL).

4.1.6 On-Line Analyzers

On-line analyzers may also be used to continuously monitor and report the presence and concentration of selected constituents in the MWWWE stream. The sampling equipment and instrumentation must however satisfy requirements identified in Section 4.1.3. The procedures must also meet the analytical principles criteria set out in Section 4.4.

4.1.7 Unique Sampling Requirements

Sampling for almost all test groups should be carried out using the *flow proportional techniques* (Section 4.1.3). However, sampling requirements may be altered to suit the nature and sensitivity of certain chemicals to be analyzed:

- **pH** - Where the characteristics of the MWWWE may lead to changes in pH over the sampling period, an on-line analyzer must be used or grab samples must be collected and analyzed as soon as reasonably possible.
- **Ammonia** - Samples containing strong oxidizing agents (e.g., chlorine) should be neutralized as soon as possible after sample collection to prevent oxidation/degradation.
- **Volatiles** - Grab samples must be collected for volatile organics analysis and composite samples must be taken by manual sampling techniques. Use of automated samplers in manual mode or pumps for volatiles sampling is not allowed. A volatiles sample should be obtained at a location of quiescence and uniform concentration upstream of turbulence which might strip volatile constituents from the MWWWE. To minimize losses of target parameters, the sample should be collected directly into the laboratory container with no headspace and the container sealed, refrigerated and analyzed as soon as possible. Where the water collected is below 4°C, some headspace may be needed to accommodate increasing pressure within the sealed containers.
- **TRC** - Must be sampled and analyzed using an on-line analyzer or by collecting a grab sample (see Section 4.1.2) and analyzing it as soon as reasonably possible (within 15 minutes).
- **E. coli** - *E. coli* samples must be collected by the grab sampling technique as outlined in Section 4.1.2. Where disinfection is accomplished through the use of oxidizing agents (e.g., chlorine or sodium hypochlorite), sodium thiosulphate must be added to *E. coli* samples as soon as possible after sample collection (if the sample container is not pre-charged with sodium thiosulphate).

4.1.8 Changes in Sampling Techniques

Any changes in sampling techniques must be documented and reported.

4.2 Guidelines for Preservation and Storage

Appendix A lists common sampling preservation and storage requirements for each test group and other test groups identified in Section 2. In some jurisdictions or regulatory programs, the measures taken to

prevent reduction or loss of target analytes can be somewhat different, but they are generally well documented and satisfy the objective.

4.2.1 Preservation

Some samples require preservation to ensure stability of target compounds during transportation and storage or to eliminate substances which may interfere with the analysis. In some cases preservation of the sample is optional, and if selected, will allow for a longer storage period before analysis must be initiated.

Generally, samples requiring preservation must be preserved immediately upon collection, either at the end of the collection period for samples collected with an automated sampling device or after collection of each grab sample.

Where a composite sample is collected in a large container for analysis for test groups, some of which require preservation, the samples must be preserved immediately following their transfer into laboratory containers.

Where samples are to be preserved to a fixed set-point (pH, colour) care must be taken that the set point has been reached by using detection techniques such as confined range pH paper, pocket/portable pH meters, standard colour comparison charts, among others. The use of these techniques and/or devices must not contaminate the sample and should be employed after the sample and preservative have equilibrated.

It is recommended that the volume of preservative not exceed 1% of the total sample volume.

4.2.2 Storage

Storage time is defined as the time interval between sample pick-up (typically at the end of the 24 hour composite sampling period) and the initiation of analysis.

All samples must be stored for as short a time interval as possible and under conditions that will minimize sample degradation. Samples must be maintained at temperatures above the freezing point of the MWW and under 10°C, preferably under 4°C, with minimal exposure to light.

In the case where analysis is considered to be initiated by the sample extraction step, the extracts should be completely analyzed within 40 days. Samples digested for metals analysis may be maintained in a sealed container and analyzed within 30 days.

4.3 Test Methods for Toxicity Testing

Toxicity tests may be conducted following test methods as referenced in the following documents:

- Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to *Daphnia magna*. Environment Canada, 2000. EPS 1/RM/14 Second Edition.
- Détermination de la toxicité létale CL₅₀48h *Daphnia magna*. Centre d'expertise en analyse environnementale du Québec (CEAEQ, 2000). Ministère de l'Environnement. MA 500 – D.mag. 1.0.
- Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout. Environment Canada, 2000. EPS 1/RM/13 Second Edition.
- Détermination de la létalité aiguë chez la truite arc-en-ciel (*Oncorhynchus mykiss*). Environnement Canada, 2000. Méthode d'essai biologique : méthode de référence pour la détermination de la létalité aiguë d'effluents chez la truite arc-en-ciel. Environnement Canada, Conservation et Protection, Ottawa. SPE 1/RM/13 deuxième édition.

- Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows. Environment Canada, 1992. EPS 1/RM/22.
- Essai de croissance et de survie des larves de tête-de-boule (*Pimephales promelas*). Environnement Canada, 1992. Méthode d'essai biologique: essai de croissance et de survie des larves de tête-de-boule. Environnement Canada, Conservation et Protection, Ottawa. SPE 1/RM/22.
- Biological Test Method: Test of Reproduction and Survival Using the Cladoceran *Ceriodaphnia dubia*. Environment Canada, 1992. EPS 1/RM/21.
- Biological Test Method: Acute Lethality Test Using *Daphnia* spp. Environment Canada, 1996. EPS 1/RM/11 Amended.

Routine monitoring requires the conduct of single concentration acute toxicity tests (i.e., exposures of aquatic organisms to the undiluted effluent). However, toxicity investigations may require the conduct of multi-concentration tests (i.e., exposure of aquatic organisms to the undiluted effluent as well as a series of dilutions of the effluent) in order to estimate an LC₅₀ (concentration estimated to cause mortality to 50% of the test organisms).

It is understood that another rainbow trout acute lethality test procedure may be added to include pH stabilizations in order to minimize / eliminate artificial lethality as a result of the aeration process.

4.4 Guidelines for the Analysis of Samples

4.4.1 Principles of Analysis

This section describes and provides guidance on the general principles and procedures to be followed in sample preparation, clean-up and instrumental analysis.

All laboratories conducting analyses are required to be accredited. Key requirements that should be met are:

- Analysis should be carried out by competent laboratory personnel in a properly equipped and maintained laboratory environment.
- Analytical procedures should meet generally accepted principles of good laboratory practice and quality control.
- Analytical techniques should be appropriate for the sample matrix and must lead to adequate separation and accurate identification of the compounds to be analyzed.
- Recovery of target parameters should be optimized.
- Only standard methods recognized by the jurisdiction may be used.

4.4.2 Analytical Methodology

Analysis must be done according to standard methods recognized by the jurisdiction. Method Detection Limits (MDL) must be sufficiently low to enable comparison with EDOs to be established for the facility.

Any new method should be validated prior to use and all methods should be re-evaluated periodically to ensure their continued validity. Instrumental measurement methods must meet performance criteria. All analytical instruments must also be calibrated.

4.4.3 Analytical Performance Criteria

Laboratory Method Detection Limits

To ensure that all laboratories performing analyses have the capability to perform these analyses at appropriate levels, they are required to determine a Laboratory Method Detection Limit (LMDL) for each parameter to be analyzed.

An analytical method should not be used for samples until all LMDLs have been demonstrated to fall at or below MDL values needed to enable comparison with EDOs. The LMDLs should be re-determined whenever a significant change is made to a method.

LMDLs should be determined using the routine sample aliquot and dilution factor that will be applied to “real” samples because the size of sample analyzed and associated changes in dilution will affect the LMDL value proportionately. If a dilution factor is applied to the LMDL, a sample where the measurement is near or below this adjusted LMDL should be reanalyzed using a larger aliquot to meet the requirement to measure down to a LMDL which is less than the MDL.

Precision

Precision is the degree of agreement among independent measurements of a quantity under specified conditions. Both within-run (repeatability) and between-run (reproducibility) precision should be established. This can be done by using replicate sample analysis (within-run) and analysis of spiked blank samples or certified reference materials, if available (between-run). Control limits for these should be established and maintained as part of the analytical performance criteria.

Accuracy

Accuracy represents the degree of agreement of individual measurements with an accepted reference value. Certified Reference Materials (CRM), if available, can be used to assess laboratory accuracy. If suitable CRMs are not available, samples spiked with known amount of analytes may be substituted. Results obtained must be compared with the true or designed value. A sample size of 10 or more and performance of the *Student's t-test* are recommended to demonstrate “no bias”.

4.5 Quality Management

4.5.1 Quality Assurance

Quality Assurance (QA) encompasses those activities which define the level of quality required, the critical system components which may impact quality, the procedures whereby quality status will be determined, and the nature and timing of any remedial action required. A comprehensive QA program will ensure that the quality of the process and its product is monitored, documented, and controlled on a continuing basis.

4.5.2 Quality Control

Quality Control (QC) encompasses those activities which specifically monitor and control discrete laboratory tasks or systems to produce the information that is required to verify and demonstrate that they meet predefined operating criteria or to substantiate the need for remedial action.

Field QC Samples

Field QC samples include duplicate samples and optional travel blanks that indicate sampling variability and the presence of field contamination: A *duplicate sample* is one of two separate samples collected at the same time and in similar conditions in a manner that minimizes differences. A *travel blank* is a sample of uncontaminated reagent water, free of the analytes of interest which is prepared by the laboratory performing the analysis. It is brought to the sampling site, opened during sampling activities, preserved as necessary, and returned to the lab as necessary. Appendix A contains field QC sampling requirements for different test groups.

Laboratory QC Samples

Laboratory QC samples may include bench quality control, such as method blanks, certified reference materials, spiked samples and replicate samples, and run quality control, such as certified reference materials, calibration, baseline, and sensitivity checks. A *method blank* is an uncontaminated sample of

reagent water, free of the target parameters and any substance which may interfere with the analysis. A *replicate sample* is an additional or second aliquot of a randomly selected sample in the analytical run. A *spiked blank* is a method sample blank to which known quantities (i.e., concentrations 2-5 times the individual MDLs) of each target parameter have been added. A *spiked sample* is a randomly selected sample in the analytical run to which known quantities of each target parameter has been added.

5.0 Environmental Risk Assessment – Single Discharge Approach

5.1 Introduction

An ERA is a risk-based decision-making process where MWWWE substances are measured and evaluated in order to develop EDOs taking into consideration risk to human and ecosystem health or fishery resources.

An ERA can be performed for a single discharge or for multiple discharges based on a watershed approach. This section deals with the single discharge ERA approach.

5.2 Determine Environmental Quality Objectives (EQOs)

The single discharge ERA begins with the CEQGs, or their provincial equivalent, to first establish the EQOs for the receiving environment. EQOs for water are defined as numerical concentrations or narrative statements to protect the most sensitive designated use at a site. In some jurisdictions, other EQOs have been developed independently to suit their specific environmental needs. The following steps are defined to set EQOs, which will be used thereafter to set EDOs.

Step 5-1: Define Water Uses

As presented in the list below and in Figure 5-1, define all beneficial uses of water in the particular water body where the MWWWE discharge is occurring as EQOs are tied to these uses.

- Water supply - drinking-water supply area (source water);
- Ecosystem health - fisheries, aquatic life or marine life, and wildlife area;
- Agriculture – irrigation;
- Farming – livestock;
- Industrial - process water for industrial activities;
- Recreation - contact recreational activities (swimming, wading);
- Recreation - non-contact recreational activities (fishing, boating).

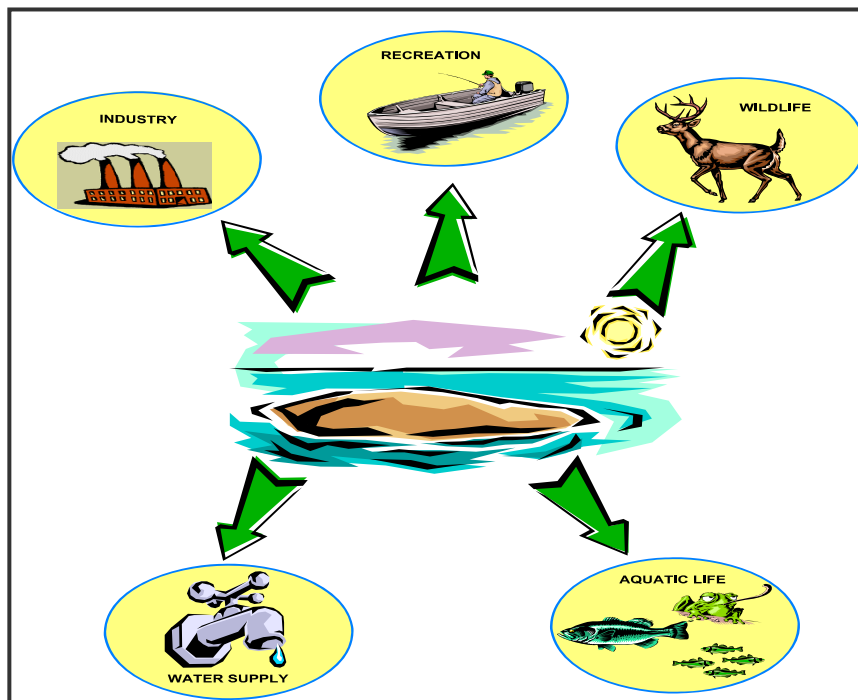


Figure 5-1. Beneficial Uses of Water

Step 5-2: Determine Generic EQOs

EQOs can be determined from one of three approaches:

- **Physical/chemical/pathogenic** – describing the level of a particular substance of concern (metals, pathogens) that will protect water quality;
- **Whole Effluent Toxicity (WET)** – specifying the proportion of the effluent discharge that may enter the water body without toxicological effect; and
- **Biological criteria or bio-assessment** – describing the level of ecological integrity that must be maintained.

Table 5-1 presents a summary of each of the approaches, capabilities and limitations.

The three approaches can be used separately or in combination to provide greater assurance in the risk assessment. The most commonly used approach is the physical/chemical/pathogenic approach based on the CEQGs. However, the appropriate provincial guidelines should also be included in determining EQOs. The most stringent guidelines are to be used, which are typically those based on the protection of aquatic life. Results from **Step 5-1** should be used in deciding on the type of guidelines. Finally, establishing the list of EQOs appropriate to a specific MWE must be according to the substances occurring in the effluent as per the effluent characterization.

The physical/chemical/pathogenic and the WET approaches are described in **Steps 5-4** and **5-5**. As for the biological EQOs approach, the CCME Water Quality Task Group is presently developing bio-criteria that are expected to be a third set of EQOs to be used in a near future.

Table 5-1. Capabilities and Limitations of Water Quality Evaluation Tools

Control Approach	Capabilities	Limitations
Physical / Chemical / Pathogenic	<ul style="list-style-type: none"> • Human health protection, aquatic life and wildlife protection • Complete toxicology • Straightforward treatability • Fate understood • Less expensive testing if only a few toxicants are present • Prevents or predicts impacts 	<ul style="list-style-type: none"> • Does not consider all toxics present • Bioavailability not measured • Interactions of mixtures unaccounted for • Complete analyses can be expensive • Direct biological impairment not measured
Whole Effluent Toxicity	<ul style="list-style-type: none"> • Aggregate toxicity • Unknown toxicants addressed • Bioavailability measured • Accurate toxicology • Prevents impacts 	<ul style="list-style-type: none"> • No direct human health or wildlife protection • Incomplete toxicology (few species and few effects may be tested) • No direct cause-effect relationship established • No persistency or sediment coverage • Ambient conditions may be different • Incomplete knowledge of causative toxicant
Bio-assessments	<ul style="list-style-type: none"> • Measures actual receiving water effects • Historical trend analysis • Assesses level of ecological quality above standards • Total effect of all sources, including unknown sources 	<ul style="list-style-type: none"> • Critical flow effects not always assessed • Difficult to interpret impacts • Cause of impact not identified • No differentiation of sources • Impact has already occurred • No direct human health or wildlife protection • Expensive and labour / time intensive

Adapted from US EPA (1991)

Step 5-3: Characterize the Receiving Environment

To characterize the MWW receiving environment, relevant information to gather includes:

- Upstream water quality to determine background levels of targeted substances and physico-chemical characteristics (e.g. hardness and pH);
- Critical low-flow and periods in receiving environment; and
- Other data, such as current speed and water depth, when dilution modeling is used.

Step 5-4: Determine Site-Specific EQOs

Variations in environmental conditions across Canada may be such that site-specific EQOs are needed instead of generic EQOs. Site-specific EQOs are developed as numerical concentrations or narrative statements recommended to support and maintain the designated water use at a specific site. From the list of generic EQOs obtained at **Step 5-2**, compare that with the list of concentration values for the upstream water quality substances obtained at **Step 5-3**.

According to the background procedure, for any one substance, if the natural concentration in the upstream location is higher than the generic EQO equivalent, that concentration will apply as a site-

specific EQO for the MWW, and the generic EQO must be set aside. Otherwise, site-specific EQOs are not needed. It is of note that for some substances, the EQO is dependent of the water characteristics (e.g., pH, T°, hardness).

Step 5-5: Determine Toxicological EQOs

As per **Step 5-2**, toxicological EQOs may be based on acute or chronic toxicity bioassays. These EQOs are determined using the two sets of WET tests.

MWW shall be non-acutely toxic at end-of-pipe (unless it is determined that ammonia is the cause of toxicity, for which there may be an exception when the ammonia EQO is achieved at the edge of a specific mixing zone). MWW shall also be non-chronically toxic after mixing in an allocated mixing zone.

Acute tests are expressed as the Lethal Concentration (LC₅₀), which is the concentration of effluent that is lethal to 50% of exposed organisms. Chronic tests of inhibited growth or reproduction are expressed as Impairment Concentration, Lowest Observable Effects Concentration (LOEC), No Observable Effects Concentration (NOEC), or Effects Concentration (EC), depending upon the jurisdiction.

Toxicological EQOs can be expressed as Toxic Units (TUs), which are defined as the inverse of the percentage of effluent: as effluent toxicity increases, toxicity unit values increase. They are obtained by dividing 100% by the percentage of effluent that produces an effect. TUs are intuitive: the higher the number, the more toxic the effluent. For instance, an acute TU for an effluent is calculated as 100%/LC₅₀. If an LC₅₀ for an effluent is determined as 25%, the TU is 100/25 = 4 TUs. Any test endpoint may be converted to TUs, but the toxicity of several samples may only be compared to TUs calculated from the same test endpoint and test duration. TUs should be designated as acute (TU_a) or chronic (TU_c) and cannot be directly compared.

Samples are considered:

- acutely toxic when TU_a is ≥ 1; and
- chronically toxic when TU_c is ≥ 1, based on a No Effect Level (NEL).

Therefore, toxicological EQOs are always 1 TU_a at end-of-pipe, or 1 TU_c at the edge of the allocated mixing zone. These definitions remain as acute toxicity EDO (acute WET) is < 1 TU_a at end-of-pipe (without dilution), whereas chronic toxicity EDO is calculated from < 1 TU_c at the edge of the mixing zone (with dilution).

5.3 Determine the Mixing Zone and Assess Dilution

In this section, the mixing zone is defined, the criteria for allocating the mixing zone are presented, and the restrictions on mixing zones and dilution allowed for mixing are specified.

Step 5-6: Review the Definition of Mixing Zones

The mixing zone is the portion of the receiving water that dilutes the effluent in the aquatic or marine environment. The water quality beyond the mixing zone boundary should meet the EQOs, as illustrated in Figure 5-2. The allocated mixing zone is set or approved by regulators. It is of note that the mixing zone will vary from one substance to another. Degradable substances will be allowed to mix in a proportion of the receiving water, whereas toxic, persistent and bioaccumulative substances, such as chlorinated dioxins and furans, PCBs, mercury and toxaphene, will not be allowed a mixing zone (EDOs = EQOs).

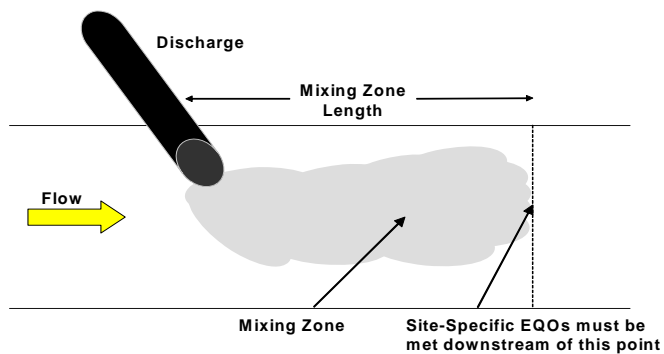


Figure 5-2. Conceptual Diagram of a Mixing Zone

Step 5-7: Evaluate Criteria for Allocating the Mixing Zone

The general criteria recommended for allocating a mixing zone are listed below.

- The dimensions of a mixing zone should be restricted to avoid adverse effects on the designated uses of the receiving water system (i.e., the mixing zone should be as small as possible)
- The mixing zone should not impinge on critical fish or wildlife habitats (e.g., spawning or rearing areas for fish, over-wintering habitats for migratory water fowl)
- Conditions outside the mixing zone should be sufficient to support all of the designated uses of the receiving water system
- Mixing zones must not be established such that drinking water intakes are contained therein
- Wastewaters that are discharged to the receiving water system must not be acutely toxic to aquatic organisms
- Conditions within the mixing zone should not cause acute toxicity to aquatic organisms
- Conditions within a mixing zone should not result in the bioconcentration of substances of concern to levels that are harmful to the health of organisms, aquatic-dependent wildlife, or humans
- A zone of passage for mobile aquatic organisms must be maintained
- Placement of mixing zones must not block migration into tributaries
- Changes to the nutrient status of the water body as a result of an effluent discharge should be avoided; eutrophication or the presence of toxic blooms of algae are unacceptable impacts
- Mixing zones for adjacent wastewater discharges should not overlap
- Mixing zones should not unduly attract aquatic life or wildlife, thereby causing increased exposure to substances of potential concern
- Mixing zones should not be used as an alternative to reasonable and practical pollution prevention, including wastewater treatment (pollution prevention principle)
- Accumulation of toxic substances in sediment to toxic levels should not occur in the mixing zone
- Adverse effects on the aesthetic qualities of the receiving water system (e.g., odour, colour, scum, oil, floating debris) should be

- No mixing zones should be allocated for persistent, toxic and bioaccumulative substances avoided

Step 5-8: Determine Restrictions on Mixing Zones and Dilution Allowed for Mixing

The spatial dimensions allotted to the mixing zone should be restricted in order to protect the water body as a whole. This may be achieved through physical/spatial restrictions or restriction of the flow allocated for the mixing of the effluent into the receiving water. The dimensions serve to delineate where the EQOs would be attained and therefore where the dilution factor should be estimated in order to back calculate from the EQO to the EDO.

Although mixing zones vary from time to time, regulators have fixed some default limits to simplify the process. These limits are for critical conditions of an environment. For streams, critical conditions imply low flows. Contact your jurisdiction to obtain mixing zone limits.

The limits of the mixing zone may be defined for the following three categories of aquatic environments based on their physical characteristics: streams and rivers; lakes, reservoirs and enclosed bays; and estuarine and marine waters. In all cases, the limits for each aquatic environment may be modified to account for site-specific characteristics such as the existence of a particular water use that requires more protective measures. Where several limits are in place, the first one to be reached sets the maximum extent of the mixing zone allowed for the dilution assessment. Criteria from **Step 5-7** may also force a smaller mixing zone.

Nutrients and fecal coliforms are not allocated any maximum dilution. For nutrients, a case-by-case analysis may be necessary to address particular conditions of a receiving environment such as the meeting of salt and fresh water masses. For fecal coliforms, the location of the water use must be considered and protected by the limits of the mixing zone.

Streams and rivers – These systems have continuous or intermittent flow which critical environmental conditions for mixing correspond to periods of lowest flow or no flow. In the latter flow case, a mixing zone is not allocated and the EDOs = EQOs. However, in some cases, the jurisdiction may decide to apply the mixing zone where the stream empties into a larger, year-round receiving body of water.

When a discharge mixes slowly with receiving waters (for instance, in large rivers with laminar flow), complete mixing will not be reached in a short distance. Therefore, mixing zones should be limited in length (e.g., 100 m, 300 m, or at the site of the water use). The dilution assessment is then done by modeling or by using a dilution ratio.

When a discharge mixes rapidly with receiving waters (for instance, in small streams with turbulent flow), the complete mix will occur within a short distance. The full stream flow may dilute the effluent before any length limit to the dilution is reached. However, only a portion of the stream flow should be allocated for mixing. The dilution factor used to calculate the EDO should therefore be based on a limited portion of the stream flow (e.g., 25%, 33%, 50%), also called the fraction of flow (*ff*). This fraction could be reduced in situations where multiple discharges use a stream. The fraction of flow is applied to a low flow condition (e.g., a seven-day low flow with a ten year return period).

In large rivers, where dilution may be very high, a maximum dilution factor may be allocated.

$$\text{Dilution Factor} = \text{Effluent Flow} / [ff \times \text{Stream Flow} + \text{Effluent Flow}]$$

Lakes, reservoirs and enclosed bays - These systems are particularly sensitive to addition of substances. Their hydrodynamics generally favor slow effluent mixing and long retention times which may prolong the presence of substances in the entire body of water. The mixing zone should have a length limit that applies in all directions, including for each discharge port in a diffuser. Additionally, a dilution factor limit should also be allocated.

Estuarine and marine waters (other than enclosed bays) - These systems are characterized by currents which fluctuate in intensity and direction. Determining effluent mixing in estuaries and marine waters is often complex because the hydrodynamics are influenced by the inflow of fresh water, wind intensity and direction, the depth of the water, the nature of the substrate, and the stratification of the water column. A thorough understanding of the mixing zone may be obtained for these systems by hydraulic modeling and/or tracer studies.

Mixing zones should be thoroughly evaluated to ensure integrity of the water body as a whole is intact. A mixing zone assessment, which predicts the dilution process of the substance through a mixing zone, is recommended for situations in which the effluent does not mix rapidly or completely with the receiving waters (US EPA 1996).

5.4 Determine EDOs Using a Single Discharge Approach

Once the EQOs have been established for the receiving environment, the EDOs for the MWW discharge can be determined. EDOs are the maximum concentrations or load of substances at the end-of-pipe that will enable the receiving water to meet the EQOs at the edge of the mixing zone. EDOs provide guidance on the desired characteristics of the effluent discharge, preventing the existence of substances in excess of EQOs beyond the mixing zone. It is of note that while NPSs represent minimum requirements for CBOD₅, TSS, and TRC, the risk assessment may require EDOs to be more stringent than NPSs. EDOs are developed using EQOs, receiving water and effluent conditions and appropriate modelling.

Water quality models may be used to predict whether the effluent will cause levels to exceed EQOs for the substances of potential concern in the receiving environment. The simplest water quality model uses a basic mass-balance approach to determine the concentration of effluent in the receiving water. The mass-balance equations are developed below and their parameters are illustrated in Figure 5-3. More complicated models incorporating water-fate-and-transport are also recommended. Worst-case scenarios of periods of high effluent discharge and low flow in the receiving water should be modeled.

Mass-Balance Equations

The mass-balance approach assumes a complete mixing of the effluent in the receiving water and allows the resultant substance concentration/load to be calculated such that, after dilution:

$$\begin{array}{l} \text{The resulting load of a} \\ \text{substance at the edge of the} \\ \text{mixing zone} \end{array} = \begin{array}{l} \text{the load of the} \\ \text{substance in the} \\ \text{effluent} \end{array} + \begin{array}{l} \text{the background} \\ \text{load of the} \\ \text{substance in the} \end{array}$$

Where:

load = flow x concentration

This basic mass-balance equation is presented as:

$$Q_r C_r = Q_e C_e + Q_s C_s$$

Where:

Q_e = effluent discharge flow (m^3/s)

C_e = substance concentration in discharge ($\mu g/L$ or TU)

Q_s = background stream flow above point of discharge (m^3/s)

C_s = concentration of substance in stream above point of discharge ($\mu g/L$ or TU)

Q_r = resultant stream flow after point of discharge, or $Q_d + ff Q_s$ (m^3/s)

C_r = resultant concentration after point of discharge ($\mu g/L$ or TU) Should be the EQO

ff is fraction of flow

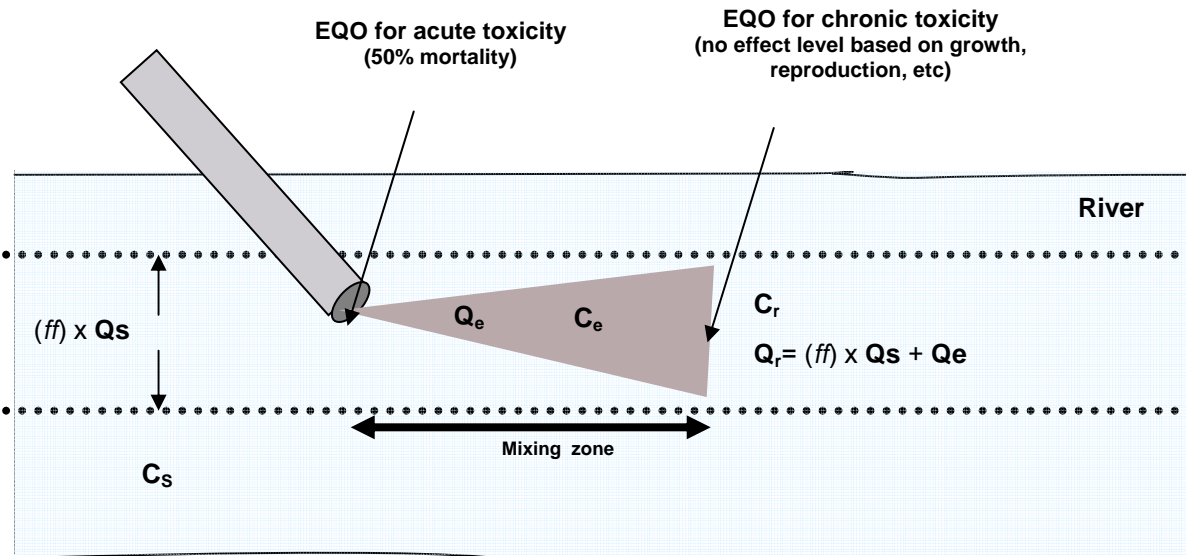


Figure 5-3. The Mass-balance Equation

This equation can be rearranged, as shown below, to calculate the EDO (in concentration) that will not exceed the EQO in downstream receiving waters:

$$C_e = \frac{Q_r C_r - Q_s C_s}{Q_e}$$

The resulting equation may be further modified to take into consideration only the fraction of the background stream flow (ff) that is designated for the mixing zone:

$$C_e = \frac{C_r(Q_e + ff \cdot Q_s) - ff \cdot Q_s C_s}{Q_e}$$

Step 5-9: Determine the Need for EDOs

EDOs should be implemented in situations where it is projected or calculated that EQOs may be exceeded at the edge of the mixing zone. This is referred to as an assessment of “reasonable potential.” To determine whether there is reasonable potential that EQOs may be exceeded at the edge of the mixing zone, the effluent must be characterized. Initial characterization of the effluent, as described in sections 3 and 4, will determine which substances are of concern for that particular facility.

One approach for deciding whether an EDO is necessary involves predicting effluent concentrations in the receiving environment by characterizing the effluent and considering the receiving water

characteristics and site-specific factors. Predicted concentrations are then compared with those specified by the EQOs. Another simpler approach is to compare effluent concentrations directly with EQOs. When effluent concentrations for a substance are lower than the EQO, there is no need to establish an EDO for that substance.

Step 5-10: Develop EDOs

Develop EDOs for substances with reasonable potential that EQOs may be exceeded at the edge of the mixing zone (substances of concern), as identified in Step 5-9, and for whole effluent toxicity (WET).

EDOs for new discharges are calculated in the same way as for existing discharges (i.e., based on EQOs and available dilution), but with estimated effluent characteristics. Facilities should be designed to achieve EDOs or come as close as possible.

Since end-of-pipe concentrations and WET will vary from day to day for a number of reasons, statistical analyses should be performed to determine which effluent requirements are conservative enough to assure, with a minimum level of confidence, that the EDOs are being achieved. This means that discharge limits should be lower than EDOs and the lesser the sampling frequency, the lower the discharge limits have to be for the same level of confidence that EDOs are being achieved. As an example, the United States Environmental Protection Agency (US EPA 1991) published its *Technical Support Document for Water Quality Based Toxics Control* to aid with establishing statistically-based discharge limits. Some provinces also have guidance documents based on the US EPA method.

As expressed in the basic mass-balance equation above, the background concentration of a substance should be established prior to determining the EDO. The background concentration of a substance is the concentration that naturally occurs upstream from a MWWWE point of discharge. The datasets available on the effluent and the receiving water will influence the selection of the water quality model used to derive the EDOs.

- A receiving water with limited data - steady-state models may be used to estimate worst-case steady-state conditions (example: PLUME and CORMIX models);
- A receiving water with large datasets – dynamical models may be used, allowing incorporation of background concentrations of substances over time (example: WASP models).

Finally, both steady-state and dynamic water-transport models may be applied. Where municipal resources are rather limited, simplified modeling approaches such as a basic mass-balance approach and a CORMIX approach are acceptable. To obtain the data, Provinces and Territories, and specific studies may have monitoring data that may be consulted first. A more thorough discussion of steady-state and dynamic models, including development of EDO equations for chemical substances and WET using steady-state models, is presented below.

Steady-State Modelling

Steady-state modeling is a simple approach used to ensure the basic protection of water quality. Less data and resource intensive than more sophisticated methods, it assumes complete mixing and constant conditions for effluent input, background levels in receiving water, design stream flow, and environmental conditions (i.e., temperature). The disadvantage of steady-state models is that they can be too conservative when using worst-case scenarios in their calculations; however, in reality, the receiving water and effluent are variable. To compensate for this limitation, reasonable and realistic but yet protective scenarios should be used. The objective is to simulate the critical conditions of the receiving water, where critical conditions are where the risk that the effluent will have an effect on the receiving environment is the highest – it does not mean using the highest effluent flow, the lowest river flow and the highest background concentration simultaneously. The use of reasonable and realistic worst-case

conditions at a steady state provides a level of protection that should allow the EQO to be attained even when actual substance levels vary.

Development of EDO equations for chemical substances using steady-state models

The premise of the steady-state model is the mass-balance equation. This equation can be rearranged, as shown below, to calculate the EDO (in concentration) that will not exceed the EQO in downstream receiving waters:

$$Q_e C_e + Q_s C_s = Q_r C_r$$

becomes

$$C_e = \frac{Q_r C_r - Q_s C_s}{Q_e}$$

The resulting equation may be further modified to take into consideration only the fraction of the background stream flow that is designated for the mixing zone:

$$C_e = \frac{C_r(Q_e + ff \cdot Q_s) - ff \cdot Q_s C_s}{Q_e}$$

This equation may be used to determine the EDO. The concentration of a chemical in the effluent, C_e , represents the EDO where C_r (the resultant concentration in the stream after mixing of effluent discharge) is given the value of the EQO:

$$EDO(\text{conc}) = \frac{EQO \cdot (Q_e + ff \cdot Q_s) - ff \cdot Q_s C_s}{Q_e}$$

and

$$EDO(\text{load}) = EDO(\text{concentration}) \cdot Q_e$$

This basic steady-state model assumes that dilution is the only mitigating factor; however, steady-state models can be adapted to include processes such as degradation or sorption of the substance (US EPA 1991). The EDO may be expressed as the substance concentrations/loads at the effluent discharge that will result in a concentration / load at the edge of the mixing zone (C_r) that will not exceed the EQO.

Development of EDO equations for WET using steady-state models

The same equations may be used to determine a chronic WET EDO:

$$C_e = \frac{C_r(Q_e + ff \cdot Q_s) - ff \cdot Q_s C_s}{Q_e}$$

To develop an EDO from WET-based EQOs, toxicity units should be used. The EQO and EDO should be expressed as chronic toxic units, because exposure at the edge of the mixing zone is predicted to be chronic. The background toxicity of a receiving water body is assumed to equal zero. The EDO is represented by C_e , where:

$$EDO = \frac{EQO(Q_e + ff \cdot Q_s)}{Q_e}$$

To prevent chronic toxicity at the edge of the mixing zone, the WET-based EQO may be defined as $1TU_c$:

$$EQO \leq 1TU_c$$

This specifies that no chronic effects should result from exposure to the effluent, after dilution, at the edge of the mixing zone. Taking this into account, the equation:

$$EDO(\text{conc}) = \frac{EQO \cdot (Q_e + ff \cdot Q_s) - ff \cdot Q_s C_s}{Q_e}$$

may be rewritten as:

$$EDO = 1TU_c \frac{(Q_e + ff \cdot Q_s)}{Q_e}$$

where the EDO is expressed in TU_c s.

The acute WET EDO is equivalent to the acute WET EQO, as it should be met at the end-of-pipe directly. Therefore, the acute WET EDO = $1 TU_a$.

Dynamic Modelling

Dynamic modeling may be applied where sufficient information exists to account for the variability of environmental substances and stream and effluent flow. These methods calculate a complete probability distribution that an EQO will be exceeded in receiving waters. Dataset requirements are more rigorous than for steady-state modeling, but may be more accurate. An additional advantage of dynamic modeling methods is that they determine the effluent concentration frequency distribution that is required to attain the EQO. The EDO may be easily selected from this output. The dynamic models used by the US EPA include continuous simulation, Monte Carlo simulation, and Log-normal probabilistic dilution (US EPA 1996).

Continuous simulation models use time series input data to predict receiving water quality concentrations in the same chronological order as the input data (US EPA 1996). They provide several advantages over steady-state models. Rather than provide a single, worst-case scenario estimate, continuous simulation models incorporate the variability and interaction of pH, flow, temperature and substance discharge over time. In addition, long simulation times can prevent the initial conditions used in the model from affecting the interpretation of fate and transport processes (US EPA 1991).

Monte Carlo simulations involve the random selection of sets of input data for use in repetitive model runs to predict the probability distribution of receiving water quality concentrations (US EPA 1996). Unlike the continuous simulation model and the lognormal dilution method, the Monte Carlo simulation does not require a time series for model input data or a specific statistical distribution (US EPA 1991).

The lognormal probabilistic dilution model predicts the probability distribution of receiving water concentrations from the lognormal probability distributions of input variables. This method is not dependent on time-series data and is practical, as in-stream water quality data are often log-normally distributed. The US EPA (1991) presents these models in greater detail.

The output of the dynamic modeling method is the predicted substance load / concentration allocated to the point source under certain conditions that will not exceed the EQO after the effects of dilution and mixing.

Appendix B presents a simple case study which demonstrates the steps that may be followed in developing EDOs.

6.0 Environmental Risk Assessment – Watershed Approach

6.1 Introduction

In many cases, an individual MWWWE discharge is only one of several sources of pollutant loadings that may influence the quality of receiving streams and lakes. As a result, the single discharge approach to environmental risk assessment and determining EDOs may overlook significant sources of impairment of designated uses or impose EDOs on a discharger that are more stringent than necessary. The watershed approach follows the same basic steps to environmental risk assessment as the single discharge approach, but the geographic scope, water quality objectives, and stakeholder involvement are significantly broader. The watershed approach also encourages innovative and cost-effective strategies to overall reduction of pollutant loadings to the aquatic or marine environment.

Canada's traditional approach to managing MWWWE dischargers is based on addressing each facility on an individual basis. This approach is simple and unambiguous, and allows for timely issuance of discharge permits that are specifically tailored to local environmental conditions, facility characteristics, and regulatory requirements.

In recent years, however, the potential interaction of multiple dischargers on a receiving water system has been recognized. In addition, the significant contribution of non-point sources of pollution loadings has been measured in many aquatic and marine ecosystems around the world. These non-point sources include, but are not limited to, agriculture (both crops and livestock management), urban and suburban runoff, and air deposition. Further, other point-source discharges, such as storm water conveyances and combined sewer overflows, may also contribute significant pollutant loadings in wet weather. As a result, many jurisdictions in numerous countries have begun to apply a watershed approach to environmental risk assessment. Examples of watershed approaches include the following, presented in increasing order of complexity:

- Synchronized permits within a basin for several MWWWE;
- Synchronized permits within a basin for one or more MWWWE and other point source discharges;
- Developing water-quality based effluent limits using a multiple-discharge modeling analysis; and
- Permits and plans that include provisions for reductions in pollutant loadings from non-point sources.

6.2 Benefits of the Watershed Approach

Among the benefits of the watershed approach to environmental risk assessment are the following:

- Holistic approach to environmental management;
- Optimization of pollutant discharge reduction among point sources;
- Increased effectiveness through consideration of non-point sources;
- Overall increased cost-effectiveness of controls and monitoring;
- Increased involvement of all stakeholders, including the public.

6.3 Guiding Principles

There are several principles based on the core environmental values of long-term sustainability and the protection of the natural environment that support the use of a watershed approach. These are:

- The management of a MWWE will be based on the watershed water quality objectives;
- Watershed objectives will be set by the users and managers who regulate the inputs into the water system, as well as the affected public;
- In establishing the individual discharge limits, the inputs of upstream users and the needs of downstream users will be considered; and
- The approach will be beneficial to the discussion of source control with industrial users of the municipal treatment facility.

6.4 When to Use a Watershed Approach

The use of a watershed approach to environmental risk assessment may be required by the jurisdiction that issues discharge permits. Even if the approach is not required, however, there are a number of circumstances in which it may be recommended, including:

- When assessing pollutants (e.g., nutrients) that are common to many sources (both point and non-point) and impact large geographical areas with non-lethal effects;
- Where MWWE and other point sources are clustered together geographically;
- Where MWWE discharges impact downstream uses, including water intakes;
- When non-point sources, such as agriculture, are known to contribute significant loadings of pollutants of concern.

6.5 Determine EDOs Using a Watershed Approach

The following approach is based on US EPA's *Handbook for Developing Watershed Plans to Restore and Protect our Waters* (US EPA 2005). A thorough discussion of all aspects of the recommended approach is beyond the scope of this document. This reference should be consulted for more detail. More information and an on-line version of the document can be found at <http://www.epa.gov/owow/watershed/>. Other helpful information can be found at the web sites for US EPA's Total Maximum Daily Load (TMDL) program (<http://www.epa.gov/owow/tmdl/>) and NPDES permitting program (<http://cfpub.epa.gov/npdes/wqbasedpermitting/wspermitting.cfm>).

At the outset, it should be recognized that a watershed plan is highly site-specific and that the approach used may be modified based on local environmental, regulatory, or other factors. However, each of the following steps should be evaluated as a plan is developed. In addition, note that watershed planning is an iterative and adaptive process. After the initial plan is implemented, the evaluation process may lead to changes to the plan. This process could continue for several cycles. This allows improvement to the initial plan which might need to be modified over time as more complete information becomes available.

Step 6-1: Build Partnerships

Engaging stakeholders, establishing priorities, and using policies within a watershed approach enables the blending of science and regulatory responsibilities with social and economic considerations. Each potential stakeholder has different concerns, goals, and ideas. In addition, sharing resources allows for a more economical watershed plan development process. The eventual success of the plan depends on involving all relevant stakeholders from the very beginning. Among tasks are the following:

- Identify driving forces:
 - Regulatory issues (e.g., laws, regulations, permit requirements);

- Government issues (e.g., federal or provincial initiatives);
- Community-driven issues (e.g., local environmental and human health concerns).
- Identify and engage relevant stakeholders:
 - Identify categories of stakeholders (e.g., MWW and industrial dischargers, farmers, landowners, local public officials, environmental organizations);
 - Determine roles and responsibilities and identify structure of stakeholder group; and
 - Initiate outreach activities and encourage participation and involvement.
- Integrate relevant local, provincial, and federal programs into planning process.

Step 6-2: Define Scope of Watershed Planning Effort

It is very important to define an appropriate scope from the outset of the watershed planning process. The scope must be defined both in terms of geographical extent and the issues to be addressed. Too broad a scope may overtax the available human and financial resources and lead to problems in implementation. On the other hand, too narrow a scope may not allow addressing the goals successfully. All of these factors, in turn, will affect the time scope of the plan. Among the tasks are the following:

- Obtain background information from stakeholders;
- Identify issues of concern and design a conceptual model;
- Define the geographic extent of the watershed:
 - Identify the level of geographical coverage (e.g., small stream drainage area or large river drainage basin);
 - Map geographical extent of selected watershed.
- Develop preliminary goals;
- Select quantitative EQOs (e.g., CEQGs, provincial guidelines, or site-specific values).

Step 6-3: Gather Existing Data and Create Inventory

At this stage, the characterization of the watershed begins. In order to develop the watershed plan in a timely and cost-effective manner, it is important to build on existing data and information. Among the tasks are the following:

- Identify sources of data and information:
 - Investigate local, municipal, provincial and federal sources;
 - Utilize universities and non-governmental organizations.
- Identify types of data and compile available information:
 - Physical and natural features (e.g., hydrology, soils, fish and wildlife, habitat);
 - Land use and human population characteristics (e.g., land use and cover, land management practices, demographics);
 - Waterbody and watershed conditions (e.g., water quality reports);
 - Pollutant sources (e.g., point and non-point sources);
 - Waterbody monitoring data (e.g., chemistry, biology).
- Select tools for data management (e.g., geographical information systems (GIS));
- Create data inventory.

Step 6-4: Identify Data Gaps and Collect Additional Data as Needed

A balance must be struck between the desire to collect as much information as possible and the time and resource constraints of the watershed plan development process. Typically, existing information is inadequate in one or more respects and the collection of some additional data is necessary. Among the tasks are the following:

- Conduct data review:

- Identify key parameters of concern for your watershed;
- Identify data gaps (e.g., parameters, location, time);
- Determine data quality / acceptability.
- Determine whether additional data collection is necessary;
- Design sampling plan for collecting new data:
 - Select monitoring program design (e.g., parameters, location, time, number of samples);
 - Develop data quality objectives and Quality Assurance Project Plan (QAPP);
 - Collect new data.

Step 6-5: Analyze Data to Characterize the Watershed and Pollutant Sources

Once sufficient data have been collected and inventoried, they must be analyzed to characterize the watershed. The goal of this step is to identify potential causes and sources of impairment due to the pollutant(s) of concern. Among the tasks are the following:

- Analyze instream and watershed data:
 - Confirm impairment(s) and identify problems (e.g., exceedances of EQOs);
 - Calculate summary statistics (e.g., mean and standard deviation, standard error, median, range);
 - Conduct spatial analysis (e.g., areas of concern, relationship to individual point sources and categories of non-point sources);
 - Conduct temporal analysis (e.g., seasonal variations, relationship to precipitation);
 - Look for other trends or patterns (e.g., flow vs. water quality, relationships between pollutants);
 - Conduct visual assessments and apply local knowledge.
- Evaluate data analysis results to identify causes and sources:
 - Group sources for further assessment (e.g., categories of point sources or non-point sources).

Step 6-6: Estimate Pollutant Loads

At this stage, the pollutant loads source can be estimated. By estimating source loads, one can evaluate the relative magnitude of sources, the location of sources, and the timing of source loading. The loading analysis can help to plan restoration strategies, target load reduction efforts, and project future loads under new conditions. Among the possible approaches are the following:

- Use monitoring data to directly estimate loads;
- Use literature values to estimate loads (e.g., runoff rates from categories of land use);
- Conduct watershed modeling:
 - Select appropriate model(s) for watershed and pollutant(s) of concern;
 - Delineate watershed;
 - Assign land uses;
 - Select parameters;
 - Test model; and
 - Estimate existing conditions and baseline scenarios.

Watershed models utilize a set of equations to describe man-made or natural processes in a watershed system. These processes typically include rainfall/runoff, erosion and sediment transport, pollutant loading, stream transport, and management processes. The level of detail in which these processes are addressed depends on the model that is selected.

The key step is the selection of the appropriate watershed model for the task at hand. The model should; be relevant to the particular watershed, study objectives, and available data; have established technical credibility; and be relatively easy to learn to use. US EPA (2005) presents a useful inventory of available watershed models that evaluates the models across a set of key characteristics including:

- Model type;
- Level of complexity;
- Time step (i.e., the unit of time in which results are calculated);
- Hydrology;
- Water quality (i.e., the type(s) of pollutant(s) to be modeled; and
- Types of management practices.

Among the most commonly used models are:

- AGNPS (Agricultural Non-Point Source);
- STEPL (Spreadsheet Tool for Estimating Pollutant Load);
- GWLF (Generalized Watershed Loading Function);
- HSPF (Hydrologic Simulation Program – Fortran);
- P8-UCM (Urban Catchment Model);
- SWAT (Soil and Water Assessment Tool); and
- SWMM (Storm Water Management Model).

US EPA (2005) reviews and compares these models for a variety of capabilities and characteristics to help the user to choose the best model for the particular application.

Step 6-7: Set Objectives and Identify Load Reductions

The preliminary goals from **Step 6-2** can now be refined into more specific management objectives. The load reductions needed to achieve the EQOs can also be identified. Among the tasks are the following:

- Translate watershed goals into management objectives;
- Select specific environmental indicators and numeric targets to evaluate compliance with management objectives (e.g., instream concentration of a particular pollutant);
- Determine load reductions to meet targets using appropriate estimation methods (e.g., mass balance, empirical approaches, water quality modeling); and
- Focus load reductions on individual sources or categories of sources.

Step 6-8: Identify Possible Management Strategies

Depending upon the load reductions identified in **Step 6-7**, there may be a number of potential strategies for managing the major sources. These include approaches for both point and non-point sources. Among the tasks are the following:

- Identify existing management efforts in the watershed (e.g., discharge permits for point sources, ordinances for land usage);
- Quantify effectiveness of existing management programs;
- Identify critical areas in watershed where additional management efforts are needed;
- Identify possible management strategies:
 - Point source (e.g., new or more stringent EDOs – identical among multiple dischargers or allocated by treatability, etc.);
 - Non-point source (e.g., structural or non-structural **Best Management Practices (BMPs)**).
- Identify relative pollutant reduction efficiencies;
- Evaluate means of distributing load reductions among sources (e.g., equal reductions, proportional to treatability / reduction efficiencies); and
- Rank alternative strategies.

Step 6-9: Evaluate Options and Select Final Management Strategies

The final management strategies will likely be a combination of several different approaches for non-point sources and recommended EDOs for point sources. An important part of the evaluation process is a cost/benefit analysis with the goal of the most cost-effective set of strategies to meet the management objectives. For example, are stringent EDOs more or less cost effective than non-point source controls? Can some point sources economically achieve more stringent EDOs than others? Among the tasks are the following:

- Select approach to quantify effectiveness of management strategies (e.g., literature values, compilations spreadsheets, or water quality models);
- Identify costs and compare benefits of management strategies:
 - Identify cost considerations;
 - Compare costs and effectiveness.
- Select final management strategies.

Step 6-10: Design Implementation Program and Assemble Watershed Plan

The final management strategies form the heart of the watershed plan; however, the process by which these strategies will be implemented and evaluated must be established. Among the tasks are the following:

- Develop information/education component;
- Establish interim measurable milestones;
- Establish criteria to measure progress towards achieving EQOs;
- Develop monitoring component;
- Estimate financial and technical assistance needed:
 - Estimate costs;
 - Identify funding sources;
 - Identify technical assistance needs;
 - Identify relevant authorities needed for implementation.
- Develop evaluation framework:
 - Inputs (e.g., time, resources, stakeholder participation);
 - Outputs (e.g., implementing strategies, completing information / education efforts);
 - Outcomes (e.g., meeting interim goals, changed behaviours, attaining EQOs).

Step 6-11: Implement Watershed Plan and Measure Progress

The final step is the actual implementation of the watershed plan. The implementation process will have a profound effect on the ultimate effectiveness of the plan in achieving its objectives. An important component of the implementation is the evaluation process. This evaluation feeds the iterative process described previously, in which the watershed plan is refined based on the results of the evaluation.

Among the tasks are the following:

- Create organizational structure for implementation;
- Implement activities;
- Prepare work plans with schedules;
- Communicate results;
- Evaluate program:
 - Track progress against work plans;
 - Analyze monitoring data.
- Make adjustments if:
 - Implementation milestones are not met;

- Load reductions are not achieved.

6.6 Water Quality Trading

Water quality trading is an innovative approach to achieve water quality goals more efficiently. Trading is based on the fact that sources in a watershed can face very different costs to control the same pollutant. Trading programs allow facilities facing higher pollution control costs to meet their regulatory obligations by purchasing environmentally equivalent (or superior) pollution reductions from another source at lower cost, thus achieving the same water quality improvement at lower overall cost. Such trading programs can be considered as part of **Step 6-9** (Evaluate Options and Select Final Management Strategies).

Water quality trading works best when:

- There is a "driver" that motivates facilities to seek pollutant reductions (e.g., more stringent EDOs or a requirement for load reductions by a non-point source);
- Sources within the watershed have significantly different costs to control the pollutant of concern;
- The necessary levels of pollutant reduction are not so large that all sources in the watershed must reduce as much as possible to achieve the total reduction needed – in this case there may not be enough surplus reductions to sell or purchase; and
- Watershed stakeholders and the regulatory jurisdiction are willing to try an innovative approach and engage in trading design and implementation issues.

Trading is most appropriate for pollutants such as nutrients or suspended solids. It can be considered for some toxic pollutants if potential toxicity "hot spots" are not present and is discouraged for bioaccumulative substances. Trading is sometimes performed on a "pound for pound" basis. In order to address uncertainty in load reduction efficiency, however, trading ratios or offsets are sometimes used (e.g., 4 kg removed is equivalent to 1 kg purchased).

The following is a brief summary of the steps involved in establishing a water quality trading program. More detailed information is available in US EPA's *Water Quality Trading Assessment Handbook* (US EPA 2004) or online at: <http://www.epa.gov/owow/watershed/trading.htm>

Step 6-12: Determine Suitability of Pollutant for Trading

The first step in evaluating the potential for trading is to determine the suitability of the pollutant. The key characteristics to be evaluated are:

- **Type/form** - Trading can only occur in an "apples for apples" scenario. Different chemical forms of a pollutant should not be considered as equivalent for trading;
- **Impact** - Trading must not create locally high loadings or "hot spots";
- **Timing** – Production and purchase of load reductions should occur over the same time period. Seasonal variations in loads and removal efficiencies should be considered; and
- **Quantity** - The supply of tradable loads must be sufficient to meet the demand.

Step 6-13: Analyze the Financial Attractiveness of Trading

One of the primary incentives for water quality trading is financial. In order to determine whether a trading program is feasible and desirable, an evaluation of the costs of load reductions is necessary. This analysis has already been considered as part of **Step 6-9** above. Costs for incremental load reductions (e.g., dollars/kg removed) can be compared among point and non-point sources. Those sources with low incremental costs may be suitable "sellers", while those with high incremental costs may be interested "buyers".

Step 6-14: Establish the Trading Market Infrastructure

Establishing a trading market has many considerations common to any financial market. Some of the key factors to be considered are:

- Assure compliance with the EQOs and other environmental indicators, as well as other regulatory requirements;
- Define and execute the trading process;
- Define marketable reductions;
- Ensure water quality equivalence of trades and avoid hotspots;
- Establish communication among buyers and sellers;
- Track trades;
- Manage risk among parties to trades; and
- Provide information to the public and other stakeholders.

Appendix C presents three examples of variations on watershed management of pollutants:

- US EPA – Total Daily Maximum Load (TMDL);
- Watershed Management for Several Discharges; and
- Water Quality Trading.

7.0 Selection of Substances for Compliance Monitoring

Based on the initial characterization results and the ERA, EDOs are established for certain substances on a site-specific basis. In general, the monitoring requirements are specified as site-specific regulatory instruments (e.g., permits, certificates, licenses, regulations) issued by the jurisdictional regulatory agency.

The following steps may be followed by jurisdictions to develop compliance monitoring strategies:

Step 7-1: Selection of Substances

- TSS, CBOD₅ and TRC (when chlorination is used) must be selected for compliance monitoring regardless of initial characterization results;
- From the initial characterization, select other substances that exceed EQOs;
- Select the substances with mean effluent values $\geq 80\%$ of established EDOs; and
- Select surrogate substance(s) that can be used as an indicator substance. Surrogate substances are those that can be used as substitutes for other substances or groups of substances to improved monitoring cost savings. For example, Dissolved Organic Carbon (DOC) can be used as a surrogate substance for organic compounds; benzene is a surrogate for toluene and xylene.

Step 7-2: Selection of Monitoring Frequencies

- Compliance monitoring frequencies for TSS, CBOD₅, TRC and toxicity testing are outlined in Tables 7-1 and 7-2;
- Monitoring frequencies for TSS and CBOD₅ shown in Tables 7-1 and 7-2 represent minimum requirements. Jurisdictions may wish to monitor these substances more frequently since they reflect the conditions of well operated facilities;

- If nutrients and pathogens have EDOs, the same monitoring frequencies as for TSS and CBOD₅ should apply for nutrients and pathogens. No frequency reduction is allowed for CBOD₅, TSS, TRC, nutrients, and pathogens since removal of these substances depends on facility operation;
- Jurisdictions will establish monitoring frequencies for other substances of concern or their surrogates as required;
- When results have demonstrated that a substance concentration is consistently < 80% of the EDO value, the monitoring frequency can be reduced when the regulatory instrument is periodically reviewed or the instrument allows. Should the effluent discharge quality subsequently exceed 80% of the EDO, the monitoring frequency must return to the initial, more frequent one; and
- Monitoring must also return to the initial frequency if there is a major change in the wastewater system, such as the addition of significant lengths of new sewers, the addition of major new industrial discharges to the sewer system, or alterations or upgrades to the treatment system.

Table 7-1. Minimum Compliance Monitoring Frequencies for NPSs, Continuous Discharge

Facility Size	TRC ¹ (or dechlorination agent)	TSS and CBOD ₅	Period for calculation of periodic averages ³
Very Small	Daily	Monthly ²	Quarterly
Small	Daily	Monthly ²	Quarterly
Medium	Daily	Every 2 weeks	Quarterly
Large	Twice per day	Weekly	Monthly
Very Large	Three times per day	5 days per week	Monthly

- 1, TRC or the dechlorination chemical that is used. Only required if chlorine is used in the wastewater facility.
- 2, May be reduced to quarterly for lagoons and any facility with an average daily flow of less than 100 m³/d, in which case averaging period would be annual.
- 3, For compliance with the NPSs for CBOD₅ and TSS. Period is based on facility size and does not change for facilities that may have a higher monitoring frequency.

Table 7-2. Toxicity Testing

Facility Size	Acute Toxicity Tests	Acute Toxicity Testing Frequency	Chronic Toxicity Tests	Chronic Toxicity Testing Frequency
Very Small	n/a	n/a	n/a	n/a
Small	n/a	n/a	n/a	n/a
Medium	-Rainbow trout - <i>Daphnia magna</i>	Quarterly	-Fathead minnow - <i>Ceriodaphnia dubia</i>	Quarterly
Large	-Rainbow trout - <i>Daphnia magna</i>	Quarterly	-Fathead minnow - <i>Ceriodaphnia dubia</i>	Quarterly
Very Large	-Rainbow trout - <i>Daphnia magna</i>	Monthly	-Fathead minnow - <i>Ceriodaphnia dubia</i>	Monthly

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(French) <http://www.ceaeq.gouv.qc.ca/analyses/index.htm>
(English) http://www.ceaeq.gouv.qc.ca/analyses/index_en.htm
Also pertinent information about Sampling Methods, Sample Preservation, Quality Assurance, Accreditation and Proficiency Testing are available at:
(French) <http://www.ceaeq.gouv.qc.ca/index.htm>
(English) http://www.ceaeq.gouv.qc.ca/index_en.htm

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Appendix A Sampling, Preservation and Storage

Table A-1. Sampling, Preservation and Storage Requirements for Substances of Potential Concern

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
Fluoride	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	50 mL	DS, OT	None	n/a	up to 30 days	If sample is expected to have high (>5%) hydrocarbon or organic solvent content, use glass or Teflon® container only with Teflon® lined caps.
Nitrate + Nitrite	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	50 mL	DS, OT	None	at 5 ± 4°C	up to 5 days	If sample is expected to have high (>5%) hydrocarbon or organic solvent content, use glass or Teflon® container only with Teflon® lined caps.
Ammonia plus Ammonium, as Nitrogen (Total Ammonia Nitrogen)	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	50 mL min	DS	Sulphuric acid	at 5 ± 4°C	up to 28 days	n/a

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
Metals	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	50 mL	DS	Preserve samples immediately on collection (nitric acid to pH of < 2)	Preserved to pH <2	A holding time of 6 months for samples	If boron analysis is required, glass containers should not be used due to the potential for sample contamination.
Phosphorus	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	20 mL min	DS	Sulphuric acid	at 5 ± 4°C	up to 28 days	n/a
Total Suspended Solids	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	5 - 500 mL min	DS	None	at 5 ± 4°C	Up to 7 days	n/a
Carbonaceous Biochemical Oxygen Demand (5-day), CBOD₅	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	5 - 500 mL min	n/a	None	at 5 ± 4°C, in the dark	up to 48 hours	If natural samples are received frozen, they should not be analyzed due to the detrimental affect of freezing on cellular material which can lead to biased results.

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
Chemical Oxygen Demand	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	25 mL	DS, OT	H ₂ SO ₄ to pH between 1.5 and 2	Protect from light	up 30 days preserved, 48 hours unpreserved	If sample is expected to have high (>5%) hydrocarbon or organic solvent content, use glass or Teflon® container only with Teflon® lined caps.
Polychlorinated Biphenyls (PCBs), Organochlorines (OCs), Chlorobenzenes (Cbs)	Amber bottles, 1 litre, with Teflon®-lined caps. Prior to sample collection, bottles are washed with detergent, rinsed with dilute acetic acid, rinsed with hot tap water, rinsed with distilled water and baked for 4 hours at 300 ± 5°C. EPA and / on industry standard bottles with proof not contaminated	800 mL	n/a	None	2°-10°C, in the dark	up to 42 days	n/a

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
Acid / Base and Neutral Compounds (including Polycyclic Aromatic Hydrocarbons)	Amber bottles, 1 litre, with Teflon®-lined caps	200 mL min	n/a	None	at 4 ± 3°C, in the dark	up to 30 days	Refrigerate at 4 ± 3°C to avoid bacterial degradation, and store in the dark to avoid photo-decomposition, up to 30 days.
Total Cyanide	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	500 mL	DS, OT	NaOH to raise pH to 12	n/a	up to 14 days	If sample is expected to have high (>5%) hydrocarbon or organic solvent content, use glass or Teflon® container only with Teflon® lined caps.

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
Hydrogen Ion (pH)	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	50 mL	DS	None	at 5 ± 4°C	immediate analysis	<p>Analysis should be initiated as soon as possible (i.e. field measurement). When the characteristics of the wastewater may lead to rapid changes in pH, an on-line analyzer should be used.</p> <p>If sample is expected to have high (>5%) hydrocarbon or organic solvent content, use glass or Teflon® container only and Teflon® lined caps.</p>
Volatile Organic Compounds (VOCs) – 1,4 (Dichlorobenzene)	Clear on amber glass with airtight septa-type cap	Min 2, 40 mL vials	n/a	No preservatives added. Use sodium thiosulphate (Na ₂ S ₂ O ₃) if residual Chlorine is present	<10°C	<14 days	Samples should be analyzed as soon as possible after collection

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
Total Kjeldahl Nitrogen (TKN) - Organic Nitrogen + Total Ammonia Nitrogen	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	100 mL min	DS, OT	Sulphuric acid	at 5 ± 4°C	up to 28 days	<p>Samples may be preserved with sulphuric acid (H₂SO₄) to pH <2; preserved samples may be stored up to 14 days.</p> <p>Samples containing strong oxidizing agents (e.g., chlorine) should be neutralized as soon as possible after sample collection to prevent oxidation / degradation.</p>

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
Mercury	Glass container with plastic lids. Contact with metal foil is not recommended	25 mL	DS	Samples should be preserved in the field using 0.5 - 1.0 mL of concentrated nitric acid and 5 - 10 drops of 5% Potassium Dichromate Saturated Solution, sufficient for the sample to turn a bright yellow colour.	Room temperature	< 28 days	Storage of samples for more than 14 days can result in loss of mercury; therefore, analysis should be carried out as soon as possible.
Phenolic Compounds	Glass or Teflon® containers with phenolic-free caps	250 mL	DS, OT	H ₂ SO ₄ to pH between 1.5 to 2	n/a	up to 30 days	
Total Residual Chlorine (TRC)	Amber glass containers with ground-glass stoppers	1,000 mL	DS, OT	None; protect from light	n/a	< 1 hour	On-line analyzer is the preferred method of monitoring. If a Grab sample is taken, analysis must take place within 1 hour

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
Arsenic	PET, Teflon®, polypropylene, polyethylene, polystyrene or glass containers with plastic lids	50 mL	DS	Preserve samples immediately on collection (nitric acid to pH of < 2)	n/a	6 months for preserved samples	If sample is expected to have high (>5%) hydrocarbons or organic solvent content, use glass or Teflon®-lined caps
Chromium (Hexavalent)	Glass or Teflon® container with plastic lids. Contact with metal foil is not recommended	200 mL	DS	None	n/a	5 days	Unless specifically requested, analyze for Hexavalent Chromium only if total Chromium is > 1 mg/L.

Substances	Sampling			Preservation	Storage		Precautions / Notes
	Container	Volume ¹	Field QC ²		Conditions ³	Time	
<i>Escherichia coli (E.</i>	Sterile plastic or glass containers with plastic lids	200 – 250 mL (leave headspace to allow shaking of sample)	DS	30 mg Sodium thiosulphate (Na ₂ S ₂ O ₃) inhibits chlorine; this optional if there is no chlorination of the wastewater	at 5 ± 3°C	48 hours	<p>Transport chilled, not frozen. Do not touch the inside of the sample container or lid (aseptic technique).</p> <p>Sodium thiosulphate must be added as soon as possible after sample collection when chlorine or sodium hypochlorite has been used as a disinfectant. It is strongly recommended that suitable containers be used which are pre-charged with the preservative.</p>

Note:

¹: Confirm sample volume requirements with laboratory

²: *Field QC Legend* - DS: Duplicate Samples, OT: Optional Travel Blanks

³: During sampling and shipping to laboratory, all samples should be kept in a cool environment (around 4°C, and avoid freezing).

Appendix B Case Study: Single Discharge

The following simple case study demonstrates the steps that may be followed in developing EDOs.

B-1 Aquatic-Life Use Designation

Assume that MWWWE discharges into a water body with an aquatic-life use designation in which there are no protected spawning or nursery grounds for fish and no species at risk. The water body is not a source of drinking water nor does it have recreational uses. Monitoring information identifies copper as a substance of concern in the MWWWE discharge.

B-2 Mixing Zone Limits

Assume the following mixing zone limits:

- Fraction of flow (ff) is 33% of the receiving stream
- 100 m length limit
- Maximum 1:100 dilution factor

B-3 Development of a Physical/Chemical/Pathogenic Effluent Discharge Objective

A chemical/physical/pathogenic EQO is determined using a generic guideline for copper: a CEQG for the Protection of Aquatic Life is 2-4 $\mu\text{g/L}$ for copper, depending on water hardness. Since the water hardness of the receiving body is 120-180 mg/L (CaCO_3), the CEQG for copper is 3 $\mu\text{g/L}$; therefore, the site's EQO, for the purpose of protecting aquatic life from chronic exposure to copper, is 3 $\mu\text{g/L}$.

Implementation of the EQO

The EQO is applied at the edge of the mixing zone. Therefore, to protect aquatic life, copper levels at the edge of the zone should not exceed 3 $\mu\text{g/L}$.

Development of the EDO

The EDO is then developed to estimate the level of copper that may be present in the effluent at the point of discharge, so that it will not exceed the EQO of 3 $\mu\text{g/L}$ at the edge of the mixing zone. An appropriate model must be selected to determine the EDO based on the level of sophistication required, the characteristics of the stream and effluent flows and the background concentration and dilution capacity. For the purposes of this example, a basic steady-state model, considering dilution as the only mitigating factor, will be used. This model consists of the modified mass-balance equation:

$$EDO = \frac{EQO \cdot (Q_e + ff \cdot Q_s) - ff \cdot Q_s C_s}{Q_e}$$

Assume that the background concentration of copper in the stream is 0.70 $\mu\text{g/L}$, the design flow of the stream is 5.5 m^3/s , and that mixing occurs with 33 % of the receiving stream before the 100 m mixing zone limit is reached. For a discharge flow of 0.04 m^3/s , and using 33 % of the design flow of the stream, the effluent does not exceed the maximum 1:100 dilution factor. Therefore, the maximum effluent concentration of copper at the point of discharge that will ensure that receiving waters meet the EQO of 3.0 $\mu\text{g/L}$ at the edge of the mixing zone will be:

$$EDO = \frac{3.0 \cdot (0.04 + 0.33 \cdot 5.5) - 0.33 \cdot 5.5 \cdot 0.70}{0.04}$$

$$EDO (\text{conc}) = 107.3 \mu\text{g/L}$$

$$\begin{aligned} \text{EDO (load)} &= (107.3 \mu\text{g/L}) (10^{-9} \text{ kg}/\mu\text{g}) (0.04 \text{ m}^3/\text{s}) (10^3 \text{ L}/\text{m}^3) (86400 \text{ s}/\text{d}) \\ &= 0.37 \text{ kg}/\text{d} \end{aligned}$$

Therefore, the EDO for copper for this MWW discharge is 107 $\mu\text{g}/\text{L}$ in concentration, and 0.37 kg/d as expressed as loading.

B-4 Development of an Effluent Discharge Objective Based on Whole Effluent Toxicity Testing

Although the substances of concern were identified for the effluent, the additive toxicological properties of the effluent should also be determined. This involves WET testing.

Assume that acute and chronic tests are conducted. The effluent passes the 96-hr LC_{50} rainbow trout test and the 48-hr LC_{50} *Daphnia magna* test, with less than 50 per cent mortality observed after exposure to the 100% effluent. The effluent therefore meets the objective of no acute toxicity at the end-of-pipe. A value of 75% effluent is reported for a 14-day growth, no observable effects concentration, with fathead minnow.

Implementation of the EQO

The chronic WET-based EQO at the edge of the mixing zone should not exceed 1.0 TU_c .

Developing the EDO from a WET-test derived EQO

To develop an EDO from a chronic WET EQO, the simple steady-state model is again selected. Stream flow and discharge flow remain the same. The background level of effluent is given a value of 0. The EQO is defined as 1 TU_c . The EDO is calculated as:

$$\begin{aligned} \text{EDO} &= 1\text{TU}_c \frac{(Q_e + ff \cdot Q_s)}{Q_e} \\ \text{EDO} &= 1\text{TU}_c \frac{(0.04 + 0.33 \cdot 5.5)}{0.04} \end{aligned}$$

$$\text{EDO} = 46 \text{ TU}_c$$

Toxic units

To determine whether the chronic toxicity surpasses the EDO, the no-effect or low effect concentration (depending on jurisdiction) is determined through WET tests with the most sensitive species. The no-effect concentration is converted to TUs:

$$\begin{aligned} \text{TU}_c &= \frac{100}{75} \\ \text{Effluent TU}_c &= 1.3 \end{aligned}$$

The EDO for the MWW discharge is 46 TU_c s. The chronic testing in this example does not surpass the EDO and will, therefore, meet the EQO:

$$46 \text{ TU}_c > 1.3 \text{ TU}_c$$

As a result, the MWW discharge will meet both the objective for toxicity at the end-of-pipe and the EQO at the edge of the mixing zone.

Appendix C Case Study: Watershed Approach

A watershed approach allows greater flexibility in meeting water quality objectives as it includes several factors so that the costly upgrading of a plant would be only one of several options to improve water quality. Three variations on watershed management of pollutants will be examined:

1. United States Environmental Protection Agency (US EPA) – Total Daily Maximum Load (TMDL);
2. Watershed Management for Several Plants; and
3. Water Quality Trading.

C-1 US EPA – Total Maximum Daily Load

The United States has actively participated in watershed-based management over the last 20 years, making substantial reductions in pollutant discharges into the nation's air, lakes, rivers, wetlands, estuaries, coastal waters and ground water. These successes have been achieved primarily by controlling point sources of pollution.

The United States total maximum daily load approach to setting effluent objectives accounts for all loadings into a water body as a result of declaring a water body as impaired under section 303(d) of the *Clean Water Act*. The maximum amount of a substance a body of water can accommodate without becoming impaired is called the total maximum daily load (TMDL). The objective of a TMDL approach is to allocate allowable loads among all of the substance sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. All organizations within a watershed can trade pollution credits to either offset a greater than allocated pollution discharge or to gain reward from an especially clean operation.

An example of a U.S. initiative that is supporting watershed management is the alteration of requirements to the National Pollutant Discharge Elimination System (NPDES) permit program. The NPDES permit program allows States that are reorienting programs on a watershed basis to have short-term backlogs on NPDES permit reviews without penalty. This flexibility gives States time to synchronize the re-issuance of major and minor permits within a watershed. By managing NPDES permits on a watershed basis, all discharge permits can be coordinated and the most efficient and equitable allocation of pollution control responsibility can be made.

Truckee River, Nevada

The Truckee River flowing from Lake Tahoe, California, into Nevada's Northern Basin, has seen heavy growths of aquatic weeds and benthic algae caused by high nutrient loads and low flows in recent years. Plant respiration and decaying biomass have decreased dissolved oxygen (DO) levels in the river. In response to these problems, the Nevada Division of Environmental Protection (NDEP) developed the *Truckee River Strategy*, a plan to coordinate the activities of the agencies involved in restoring the quality of the Truckee River and Pyramid Lake. The strategy includes timetables for numerous non-point source control projects, such as storm water permitting, wetlands treatment systems, pasture improvements, riparian restoration and landowner education. Also, as part of the strategy, NDEP used DSSAM III, a water quality model, to develop nitrogen, phosphorus, and total dissolved solids TMDLs for the Truckee at Lockwood, Nevada. The TMDLs for total nitrogen, total phosphorus and total dissolved solids were approved in March 1994 by the US EPA. These include load allocations for non-point and background sources and one waste load allocation for the major point source discharger in the basin, the Truckee Meadows Wastewater Reclamation Facility. The Truckee River TMDLs provide quantitative goals for the improvement of water quality in the basin.

C-2 Watershed Management of Several Dischargers

In this case, several wastewater facilities in a watershed collaborate in setting effluent limits for one substance (phosphorus) to ensure watershed objectives are met.

Grand River Conservation Authority, Ontario

The Grand River Conservation Authority has established a Water Management Committee to address concerns in the watershed. This strategy involved collaboration of water management agencies and six municipalities that are situated along the Grand River. Due to the dissolved oxygen (DO) sensitivities to temperature in the river, phosphorus management was identified as a priority. The original basin study of the Grand River set an objective of maintaining the DO at not less than 5 mg/L for 55% of the time.

The Grand River Conservation Authority, as a coordinating body, undertakes monitoring and modeling of DO, nitrogen and phosphorus. Reports of monthly loadings are made regularly to the Water Management Committee who decides on the effluent limits to ensure protection of downstream users. From the map in Figure C-1, the number of water intakes and wastewater treatment plants serving various populations can be seen. The Regional Municipality of Waterloo, which is responsible for 9 plants within the watershed, plans to develop a wastewater master plan which will direct growth to the wastewater treatment plants with the most cost efficient operations and least environmental impact.

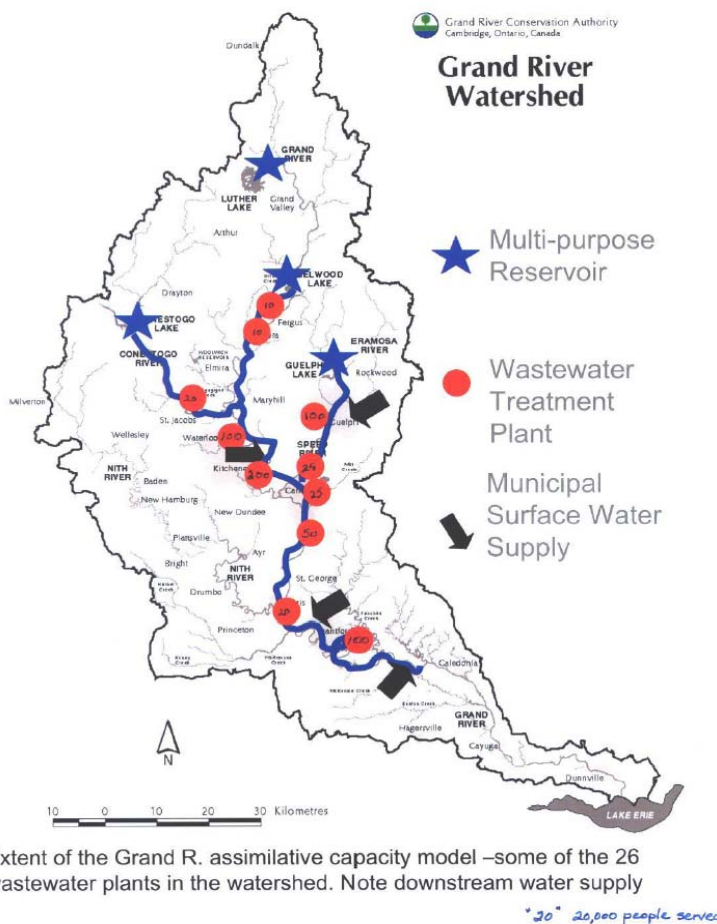


Figure C-1. Grand River Watershed

C-3 Water Quality Trading

Trading pollutant loads between point sources or mixing point and non-point sources has been recognized by the US EPA since January 2003, when they issued a *Water Quality Trading Policy*. The policy recognizes the costs and benefits of the program which encourages states and tribes to “develop and implement water quality trading programs for nutrients, sediments and other pollutant where opportunities exists to achieve water quality improvements at reduced costs.”

Trading works best when the following conditions apply:

- A driver which motivates wastewater facilities to seek pollutant reductions;
- Sources have significantly different costs associated with pollutant reductions;
- Necessary levels of substance reduction not so large that all sources must be reduced;
- Jurisdictions are willing to be innovative.

Water quality trading allows dischargers to take advantage of treatment efficiencies and various economies of scale leading to a more cost-effective achievement of water quality goals. In the U.S., estimated cost savings for the regulated community ranges from hundreds of millions to billions of dollars.

Lake Simcoe, Ontario

The local municipality of Lake Simcoe recently had to address demands to increase their urban area to accommodate a growing population. It was calculated that the proposed new development would contribute an additional phosphorus (P) load of 20 kg/year. As their local wastewater facility was already operating at maximum efficiency and their Certificate of Approval required them to maintain existing phosphorus loadings entering the watercourse, management action was required. After undertaking an engineering cost-benefit study to evaluate the costs of upgrading the plant, it was determined that the cost would be \$500,000 or \$25,000/kg P/year.

The municipality decided to approach the Lake Simcoe Region Conservation Authority to assess if a phosphorus trade was feasible. The following steps were followed:

1. Determine if there are sufficient opportunities for urban storm water retrofit trades within the sub-watershed to ensure that the water quality of the local watercourse is not further degraded.
2. If the capacity exists, the trading option is evaluated using a trading ratio of 8:1, based on a unit cost phosphorus reduction of \$2,500/kg for storm water retrofits, i.e. for every kg of P allowed to be discharged by the plant, 8 kg must be reduced from urban runoff through storm water control best management practices. The total cost to the municipality for the trade is:

$$\begin{aligned} & 8 \text{ (trading ratio)} \times 20 \text{ (kg P to trade)} \times \$2,500 \text{ (cost/kg P)} \\ & = \$400,000 \end{aligned}$$

Savings: about \$100,000 and reduction of an additional 140 kg of phosphorus per year from entering the local watercourse and Lake Simcoe.

South Nation River, Ontario

The village of Winchester in North Dundas Township was under a development freeze pending an increase in water supply and expansion of their wastewater facilities. The village consulted with the Ontario Ministry of the Environment (MOE) and realized that policy requirements did not allow any new phosphorus discharges into the South Nation River. The village council passed a resolution to conduct a Phosphorus Management and Water Quality Environmental Assessment in December 2002. This would include:

1. Assess the current situation and future conditions;
2. Determine options for treatment;

3. Conduct public consultation;
4. Recommend preferred options environmentally, economically and socially.

Based on the environmental study report, the proposed resolution included an expansion of the wastewater facility and a reduction of phosphorus (P) from non-point sources. The cost to reduce phosphorus would be \$300/kg P removed and would be administered through the existing Clean Water Program. The cost was calculated based on program experience and dependent on the amount of phosphorus to be removed as approved by MOE. The new phosphorus loading was projected to be 160 kg from the treatment plant with an offset ratio of 4:1. The calculation for removal was:

$$\begin{aligned} &160 \text{ kg P (discharge)} \times 4 \text{ (offset ratio)} \\ &= 640 \text{ kg P} \end{aligned}$$

640 kg of phosphorus was to be removed from non-point source projects.

The cost was calculated as follows:

$$\begin{aligned} &640 \text{ kg P (offset target)} \times \$300/\text{kg P (Clean Water Program Delivery Costs)} \\ &= \$192,000 \end{aligned}$$

This project was supported by the province and funded over 5 years. Annual reports are submitted to the MOE as part of the certificate of approval reporting requirements until total monies are spent and the offset load is accounted for.

Lake Dillon, Colorado

Studies determined in the early 1980s that excessive phosphorus discharge was accelerating algae growth, causing low dissolved oxygen levels in Dillon Reservoir, 70 miles west of Denver, Colorado. Data collection and modeling results indicated that about half of the anthropogenic phosphorus loads entering the reservoir were contributed by point sources, mainly from four wastewater facilities, and half from non-point sources, primarily individual septic systems and urban runoff. The State of Colorado estimated that the health of Lake Dillon would require a reduction in the amount of phosphorus coming from the four major wastewater facilities. Rather than having to upgrade their own facilities, the plants were offered the option of implementing controls for existing urban non-point sources. Cost studies showed that wastewater facilities could achieve the same overall reductions in phosphorus for half the cost if they concentrated on non-point sources rather than solely on their own emissions.

The EPA approved a trade ratio of 2:1 so that there would be enough phosphorus reduction in the basin to allow for growth of the wastewater facilities and new non-point-sources on the basis of estimated population growth. The Frisco Sanitation District wastewater facility decided to address non-point source storm water runoff of phosphorus into the lake. The district built storm water control structures to guide the surface runoff back underground. Approximately 50-70 percent of the phosphorus was removed as the water filtered through the pipes. The number of credits gained from this project was set equal to the amount of phosphorus removed, determined by monitoring the flow and concentration of incoming and outgoing water – an example of a direct measurement of non-point source effluent discharge. The District was offered phosphorus credits for its non-point source reduction by the Colorado Water Control Commission. The District needed only a few phosphorus credits allocated to it annually and donated its surplus credits to offset increased phosphorus discharge associated with the construction of a new town golf course. Here, trading allowed further development while still improving lake water quality. The example of Dillon Reservoir demonstrated that the direct measurement of non-point source load is not impossible and, in addition, that trading does not necessarily need a tangible cash transaction for cost savings to occur.

New Hamburg, Ontario

The wastewater facility located in New Hamburg had to address environmental concerns associated with phosphorus effluent discharges, as their plant had recently reached their maximum allowable limit. The cost to increase treatment at the plant would have been approximately \$1000/kg P reduced. The municipality decided to take an alternate approach and target non-point sources through a water quality program which developed a program of incentives for local landowners to control the phosphorus discharging into the surface waters. The cost of this program was \$85/kg P reduced, representing significant savings compared to traditional treatment upgrades.

PART B - CONTRACTING PROVISIONS

1.0 Introduction

The following Contracting Provisions were prepared for CCME by SENES Consultants Limited. These provisions have not been developed to meet the needs of any particular municipality or community. Municipalities and communities should obtain proper legal advice before using any of the following provisions, for their own purposes.

The Canadian Council of Ministers of the Environment (CCME) has developed a strategy to improve the management of Municipal Wastewater Effluent (MWWE) in Canada. A key element of the strategy is the establishment of Effluent Discharge Objectives (EDOs) through an ERA.

This document is intended to assist Canadian municipalities, particularly *very small* and *small* municipalities, with the contracting process in obtaining professional services for the ERA for wastewater facilities. It contains general provisions that should be considered by owners of wastewater facilities and their lawyers when requesting, evaluating and contracting professional services for the completion of ERAs.

This document is not legal advice and is not intended as such. Owners of facilities should obtain proper legal advice before using any provisions herein for their own purposes.

2.0 Terms of Reference

2.1 Title

Development of an Environmental Risk Assessment for Municipal Wastewater Facilities.

2.2 Background

As part of the *Canada-wide Strategy for the Management of MWWE*, a risk management framework is proposed where National Performance Standards (NPSs) are the minimum performance requirements for substances commonly found in MWWE.

CCME has established NPSs for Total Suspended Solids (TSS) at 25 mg/L, Carbonaceous Biochemical Oxygen Demand (CBOD₅) at 25 mg/L and Total Residual Chlorine (TRC) at 0.02 mg/L. In addition, CCME has identified the need for facilities to conduct site-specific ERAs and manage those risks appropriately. A standard method has been developed for the completion of site-specific ERAs which take into account both the effluent and receiving surface waters (or environment). This ERA aims to determine site-specific Environmental Quality Objectives (EQOs) for receiving waters and establish site-specific EDOs to ensure that the environment is protected. Wastewater treatment facilities should be designed to achieve EDOs at the point of discharge, or as close as possible.

CCME has categorized wastewater facilities into 5 categories: *very small*, *small*, *medium*, *large* and *very large* based on flows (Table 2-1). *Very small* and *small* facilities with industrial input are considered *medium* facilities and must assume medium facility requirements, as described in Part A of this technical supplement.

For *small* and *very small* wastewater facilities that have no industrial input, complete characterization of the effluent is not deemed necessary. Facilities that discharge less than 10³/day are not required to

complete initial characterization. In all of these cases, EDOs are only established for nutrients and pathogens (in addition to NPS substances, when necessary).

Table 2-1. Municipal Wastewater Facility Size Categories

Size Category	Flow [m ³ /day]
<i>Very Small</i> ¹	≤ 500
<i>Small</i> ¹	> 500 – 2,500
<i>Medium</i>	> 2,500 – 17,500
<i>Large</i>	> 17,500 – 50,000
<i>Very Large</i>	> 50,000

Note: ¹ *Very small* and *small* facilities which have industrial input associated with wastewater will be considered in the *medium* size category

2.3 Purpose and Objective

The main objectives of the project are:

- Complete an ERA and establish EDOs that will not result in impairment to the receiving waters and/or environment.

2.4 Supporting Documentation

Documentation that should be reviewed prior to commencing the ERA includes:

- Canadian Council for Ministers of the Environment (CCME) (2008). *Technical Supplement 2 - Canada-wide Strategy for the Management of Municipal Wastewater Effluent – Environmental Risk Management: Framework and Guidance*.

A recommended supporting reference for MWWWE characterization is:

- American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation. 2005. *Standard Methods for the Examination of Water and Wastewater*.

2.5 Tasks

The project will be undertaken by a suitably qualified and experienced consultant. Table 2-2 provides the tasks required to perform an ERA. All tasks conducted for an ERA should follow the general guidelines of Part A of this technical supplement (Standard Method) and the *Technical Supplement 2 - Canada-wide Strategy for the Management of Municipal Wastewater Effluent – Environmental Risk Management: Framework and Guidance* (Strategy) (CCME 2008). The table also references the relevant sections in Part A. Procedural changes must be documented.

Table 2-2. Environmental Risk Assessment Task Matrix

Step #	Task	Reference ¹	ERA Activity
1	Identify any industrial input to MWWE and select list of substances to be sampled, as well as, the need for toxicity testing. Note that small and very small facilities without industrial input are required to only monitor TRC (if chlorination is used), CBOD ₅ , TSS, pathogens and nutrients, and not the complete series of tests as required by larger facilities.	Section 2 and Section 3	<i>List of Substances of Potential Concern</i>
2	Carry out sampling of identified substances in the effluent following recommended sampling, preservation and storage protocol, at the recommended frequency for one year.	Section 4, Appendix A	<i>Initial Characterization</i>
3	Complete sampling analysis, testing and reporting of all identified substances at an accredited laboratory, following recommended protocols.	Section 4,	
4	Select <i>Single Discharge</i> or <i>Watershed</i> approach, as applicable to the effluent discharge to receiving waters, and determine load allocation/mixing zone assessment modelling techniques.	n/a	<i>Establish EQOs, EDOs</i>
5	Determine site-specific EQOs (e.g., from Canadian Environmental Quality Guidelines, CEQG, or provincial equivalent)	Section 5 or Section 6	
6	Calculate EDOs for substances of concern at discharge location of effluent into receiving waters using <i>Single Discharge</i> or <i>Watershed</i> approach.	Section 5 or Section 6	
7	Design compliance monitoring program for all substances with mean effluent values over 80% of the EDO.	Section 7	<i>Risk Management Recommendations</i>
8	Provide recommendations for risk management for substances exceeding EDOs and cost estimates for any continued monitoring	See Strategy (CCME 2008)	

Note: ¹ See relevant sections in Part A (*Standard Method*).

2.6 Deliverables

Contractors should be expected to provide draft and final reports at a schedule determined by the contracting owner of the wastewater facility. Contracting owners may request the submission of a report containing at least the following sections:

- **List of Substances of Potential Concern**
- **Initial Characterization Program**
 - Report on results of initial characterization, providing statistical and graphical analysis of monitored substances;
- **Determination of EQOs and EDOs (based either on a Single Discharge or Watershed Approach)**
 - Describe the ERA methodology that was followed to set EQOs and EDOs;
 - Provide relevant water quality / mixing zone assessment modelling description, computer outputs and results; and
 - Provide list of all monitored substances, determined EQOs, substances of concern and EDOs.
- **Risk Management Recommendations**
 - Provide detailed compliance monitoring program for substances of concern; and,
 - Provide cost estimates for compliance monitoring.

2.7 Scheduling

Contracting owners should determine the timeframe that is suitable for the completion of the project, taking into account the size of the facility. As a guideline, the contracting municipality may expect at least one year for the completion of the initial characterization. Following the initial characterization, a further two months may be expected for a complete draft report for the ERA to be prepared.

2.8 Budget

Contracting owners should estimate the range of cost for the completion of the project. Considerations for total costs should include:

- *Sampling and Analysis* – This component will constitute a major portion of the cost. Travel time for sample collection for the entire monitoring period must also be considered; and
- *Modeling Techniques (single discharge or watershed approach)* – This component may also significantly contribute to the total cost, dependent upon modelling complexities.

3.0 Proposal Evaluation Criteria

Contracting owners may evaluate proposals from potential bidders based on the general criteria set out in this section.

3.1 General Criteria

Proposals from bidders should satisfy the following criteria on which they will be assessed:

- **Technical**
 - The bidder's proposal must demonstrate a clear understanding of the scope of work;
 - The bidder must provide a detailed description of its proposed methodology in relation to the Standard Method document set out by CCME and the specific wastewater facility;
 - The bidder must detail the technical methods it intends to use in regards to equipment, modelling software and other tools required to complete the ERA;
 - The bidder must describe anticipated problems and proposed solutions; and

- The bidder should note possible changes to the protocol in Part A.
- **Management, Team Organization and Experience**
 - The bidder must clearly define the *Project Team* and its organizational structure, including the *Project Manager* and *Key Personnel*. Resumes, relevant expertise and experience paragraphs should be provided;
 - The bidder must include at least one *Key Personnel* with an area of specialty in ERA;
 - The bidder must include examples of past projects in the areas of wastewater and risk assessment in which the Project Team members participated;
 - The bidder must identify all sub-contractors and their roles. Where applicable, qualifications of accredited laboratories or individuals carrying out sampling, testing and analysis should be provided;
 - The bidder must provide a preliminary work schedule detailing tasks for completion; and
 - The bidder must detail specific quality management measures to be implemented.
- **Financial**
 - The bidder must demonstrate an understanding of the cost factors and provide a full detailed breakdown including costs and fees showing the allocation of the proposed budget.

3.2 Enforcement of Mandatory Requirements

Contracting owners may choose to enforce relevant mandatory requirements which bidders must demonstrate in order to be considered for assessment.

Mandatory requirements are generally evaluated on a simple pass/fail basis. Failure by bidders to meet any of the mandatory requirements will render the bidder's proposal non-responsive. Table 3-1 provides an example of a possible *Mandatory Requirements Checklist* related to the ERA, which bidders must include with their proposals. Bidders must clearly identify relevant sections or pages within the proposal that address the mandatory requirements as set out in the table.

3.3 Point-Rating System

The contracting municipality or community may evaluate a bidder's proposal based on a weighted scoring system as shown in Table 3-2. This table separates the rating criteria into the 3 categories (Technical; Management, Team Organization and Experience; and Financial). Each criterion will be given a rated score out of a maximum 10 points, following a general semi-quantitative guideline as below:

0-2	<i>Unacceptable</i>
3-4	<i>Weak</i>
5-6	<i>Fair</i>
7-8	<i>Good</i>
9-10	<i>Excellent</i>

Each criterion is also provided with a weight factor to be multiplied with the rated score to give a weighted score. The *sum* of all weighted scores will provide the *final rating* of the bidder's proposal out of a maximum of 100 points. As can be seen in Table 3-2, the final rating of a proposal can be broken down to 40% Technical, 40% Management, Team Organization and Experience, and 20% Financial. Bidders may then be ranked according to their respective final ratings.

Table 3-1. Example of a Mandatory Requirements Checklist

#	Criteria	Bidder Response		
		YES	NO	Proposal Reference
1	The <i>Project Team</i> must include at least one qualified engineer, biologist or chemist.			
2	The <i>Project Manager</i> must demonstrate experience in managing at least two projects in the areas of water and wastewater.			
3	The <i>Project Manager</i> must demonstrate knowledge and expertise in wastewater collection and treatment processes.			
4	At least one member of the <i>Key Personnel</i> in the <i>Project Team</i> must demonstrate experience in relevant projects in conducting ERAs.			
5	The <i>Project Team</i> must demonstrate past experience in wastewater related projects.			
6	The <i>Project Team</i> must clearly demonstrate capabilities in the modelling and analysis of mixing zones in receiving waters (i.e., specify software to be used or other analytical methods).			

Table 3-2. Evaluation Criteria: Point-Rating system

Criteria	Maximum Score	Weight
Technical		
Proposal demonstrates understanding of scope of work	10	2
Proposal demonstrates understanding of methodology to be applied with regard to municipality and standard methods to be applied (including knowledge of alternate/changes in standard methods).	10	1.5
Proposal describes expertise with relevant modelling tools and mixing zone analysis methods.	10	0.5
Management, Team Organization and Experience		
<i>Project Manager</i> demonstrates managerial experience in managing relevant projects.	10	1
<i>Project Manager</i> demonstrates technical expertise and similar projects in wastewater related projects.	10	0.5
<i>Key Personnel</i> demonstrate expertise and experience in environmental risk assessment.	10	1
Qualifications and experience of the overall <i>Project Team</i> is diverse and ample to satisfy all project needs.	10	0.5
Proposal describes a reasonable and attainable work schedule for the completion of the project.	10	0.5
Proposal demonstrates specific quality management measures to be applied during the project.	10	0.5
Financial		
Proposal demonstrates understanding of cost factors through a detailed breakdown of expected costs and fees.	10	0.5
Proposal cost does not exceed upset limit and will result in best value to the municipality or community.	10	1.5

4.0 Contract Clauses

Since all owners of wastewater facilities are different and will have their own unique requirements when obtaining professional services, this section provides a general list of contract clauses that may be considered by the owners and their lawyers when preparing a Request for Proposal (RFP) or contract.

- Proposal Deadline and Submission Requirements;
- Awarding of Contract;
- No Payment for Pre-Contract Costs;
- Workplace Safety and Insurance Board;
- Insurance;
- Licensing;
- Safety Regulations and Labour Codes;

- Conflicts of Interest / Influence; and
- Indemnity.

Contracting owners should add additional contract clauses as applicable.