Canadian Council of Ministers of the Environment
Le Conseil canadien des ministres de l'environnement

Technical Supplement 2

Canada-wide Strategy for the Management of Municipal Wastewater Effluent

Environmental Risk Management: Framework and Guidance

June 2008

Table of Contents

Boxes

List of Figures

List of Tables

List of Acronyms

BOD_5	Biochemical Oxygen Demand
CAEAL	Canadian Association of Environmental Analytical Laboratories
$CBOD_5$	Five day Carbonaceous Biochemical Oxygen Demand
CCME	Canadian Council of Ministers of the Environment
CEAEQ	Centre d’Expertise en Analyse Environnementale du Québec
CEQG	Canadian Environmental Quality Guidelines
CSO	Combined Sewer Overflow
CWA	Clean Water Act (United States)
DO	Dissolved Oxygen
EDO	Effluent Discharge Objective
EQO	Environmental Quality Objective
I/I	Inflow and infiltration
LC_{50}	Lethal Concentration for 50% mortality
MWWE	Municipal Wastewater Effluent
N	Nitrogen
NDEP	Nevada Division of Environmental Protection
NPDES	National Pollutant Discharge Elimination System
P	Phosphorus
POTW	Publicly Owned Treatment Works
SSO	Sanitary Sewer Overflow
TIE	Toxicity Identification Evaluation
TKN	Ammonia + organic nitrogen
TMDL	Total Maximum Daily Load
TRC	Total Residual Chlorine
TRE	Toxicity Reduction Evaluation
TSS	Total Suspended Solids
TU	Toxicicity Unit
US EPA	United States Environmental Protection Agency
WET	Whole Effluent Toxicity
WQG	Water Quality Guidelines
WQS	Water Quality Standards (United States)

1. Environmental Risk Management Model

Environmental risk management is a key element of the Canada-wide strategy for the management of municipal wastewater effluent (MWWE) (hereafter 'Strategy'). This document is a technical supplement, providing guidance to implement the Strategy and explaining its requirements in further detail. Where discrepancies appear between the Strategy and this technical supplement, the Strategy prevails.

1.1 Environmental Risk Management Framework

The environmental risk management framework set out in this document (see Figure 1) is a decision-making process that will help manage municipal wastewater effluent to protect the environment and human health, while taking into account site-specific factors. The framework

- Identifies a list of substances of national concern and develops achievable and desirable performance standards for them.
- Integrates the characteristics of the site specific receiving environment into the development of these standards.
- Includes a risk-based decision-making process where performance standards can be adjusted depending on risk. The onus is on the discharger to demonstrate the absence of adverse effects.

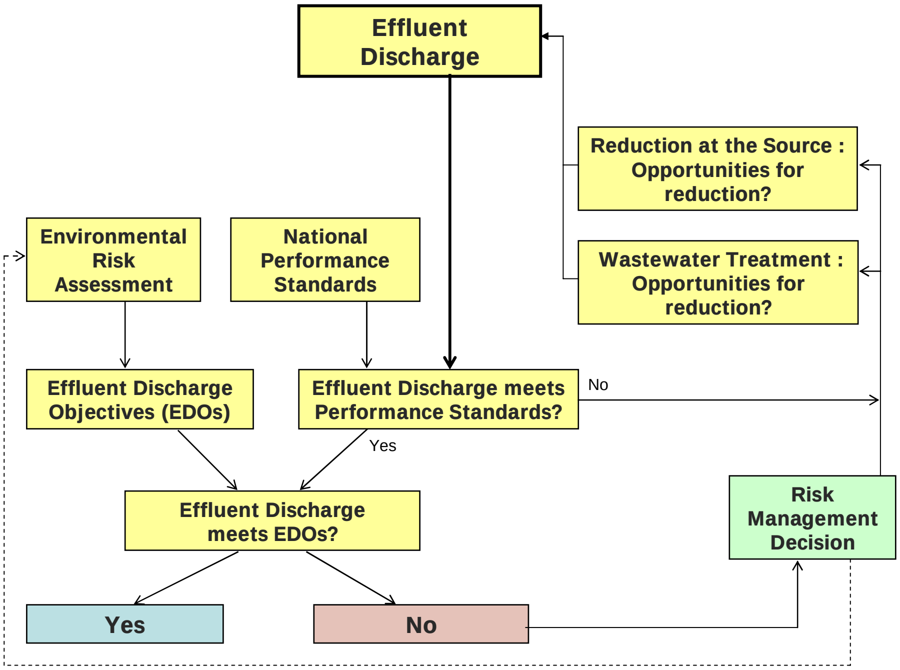


Figure 1. Environmental Risk Management Framework

The environmental risk management framework includes National Performance Standards (i.e., minimum discharge limits) for common substances. These Standards are applicable to all MWWE discharges in Canada and are achievable by commonly available technology. They are equivalent to what can be achieved with a minimum of conventional secondary treatment for five day carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS) and total residual chlorine (TRC).

In some instances, the National Performance Standards may not achieve the effluent quality needed to avoid unacceptable risks to human and ecosystem health or to fishery resources. Thus, the framework includes an environmental risk-based approach that enables more stringent requirements than the National Performance Standards to be established, where needed, as well as discharge requirements for substances not covered by the National Performance Standards. The approach considers the characteristics and uses of the site-specific receiving environment.

The environmental risk management framework starts with the effluent monitoring. The characteristics of the effluent are compared with the National Performance Standards. The quality of the effluent must meet the National Performance Standards. If it does not, the wastewater facility must look for opportunities to reduce the discharge of substances at the source and/or look for opportunities to improve the wastewater facility or its operation so the National Performance Standards can be achieved. The facility must submit an action plan to the regulatory authority (under a one-window approach) and timelines to achieve the National Performance Standards are established based on the risk level of the facility (high, medium, low risk; see section 9).

The effluent quality is also compared with the effluent discharge objectives (EDOs) determined through the environmental risk assessment. If the effluent discharge meets all of its EDOs, no other actions are required as the environment is considered protected based on environmental quality objectives. If EDOs are not achieved, actions need to be taken and a risk management decision must be made to improve the quality of the effluent discharge. Again, the first actions are to look for opportunities to reduce the discharge of substances at the source and/or look for opportunities to improve the wastewater facility or its operation.

Once a facility has examined different opportunities to reduce the discharge of substances of concern in the effluent, it must submit an action plan to the regulatory authority. Once the facility has implemented improvements, the new effluent discharge is again compared with the EDOs. If the EDOs still have not been achieved, further improvements should be made. When the wastewater facility cannot improve its system for technical, financial, societal or other reasons, then a risk management decision may indicate nothing further can be done at the time. In such cases, EDOs become long-term goals that the wastewater facility must continue to strive to attain. EDOs will be reviewed when new information becomes available or when deemed necessary.

Where combined sewer overflows (CSOs) occur, facilities must produce a long term CSO reduction plan and submit it to the regulatory authority. This plan may be combined with the action plan to achieve the National Performance Standards. Where multiple actions are required to meet the requirements of the Strategy, the action plan will address prioritization of all work to be completed. This may include work needed to meet Effluent Discharge Objectives.

Where whole effluent toxicity tests fail, owners must go through a toxicity identification and reduction evaluation, and submit an action plan to the regulatory authority.

1.2 Using This Document

This document presents the general concepts of the environmental risk management framework. It is intended to provide information and guidance on the requirements identified in the Strategy and the implementation of the environmental risk management framework. It provides guidance on the environmental risk assessment process for single discharges in section 3 and at a watershed level in section 4. Guidance on effluent monitoring is provided in section 5, including the initial characterization of effluent needed to determine which substances in the discharge are of concern. When the effluent does not achieving EDOs for substances of concern, a risk management decision is needed. Guidance on risk management decisions is provided in section 6. Section 7 examines environmental monitoring. Combined and sanitary sewer overflow requirements and collection system information are found in section 8. Section 9 provides a system for the initial risk ranking of each facility to determine the timelines for facilities to implement the National Performance Standards. Section 9 also provides a decision making tool to assist in prioritizing and managing combined sewer overflows and wastewater facility discharges.

Figures 2 and 3 below identify where pertinent information about the different parts of the environmental risk management framework can be found within the Technical Supplement. Figure 2 describes the process to complete the environmental risk assessment and establish EDOs. Figure 3 describes effluent monitoring and what to do when the effluent discharge is not achieving the National Performance Standards or EDOs. The boxes on the left describe the process and the boxes on the right reference the relevant sections of the document where detailed information can be found.

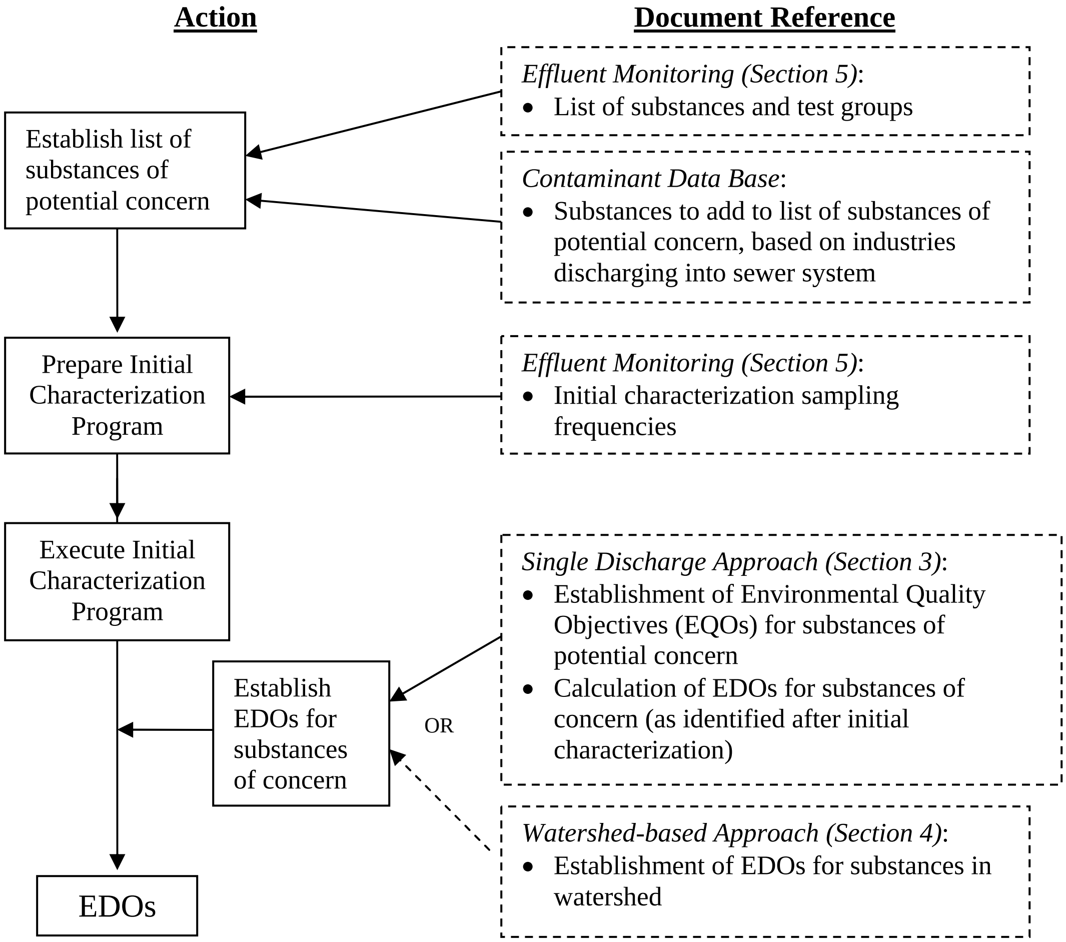


Figure 2. Environmental Risk Assessment

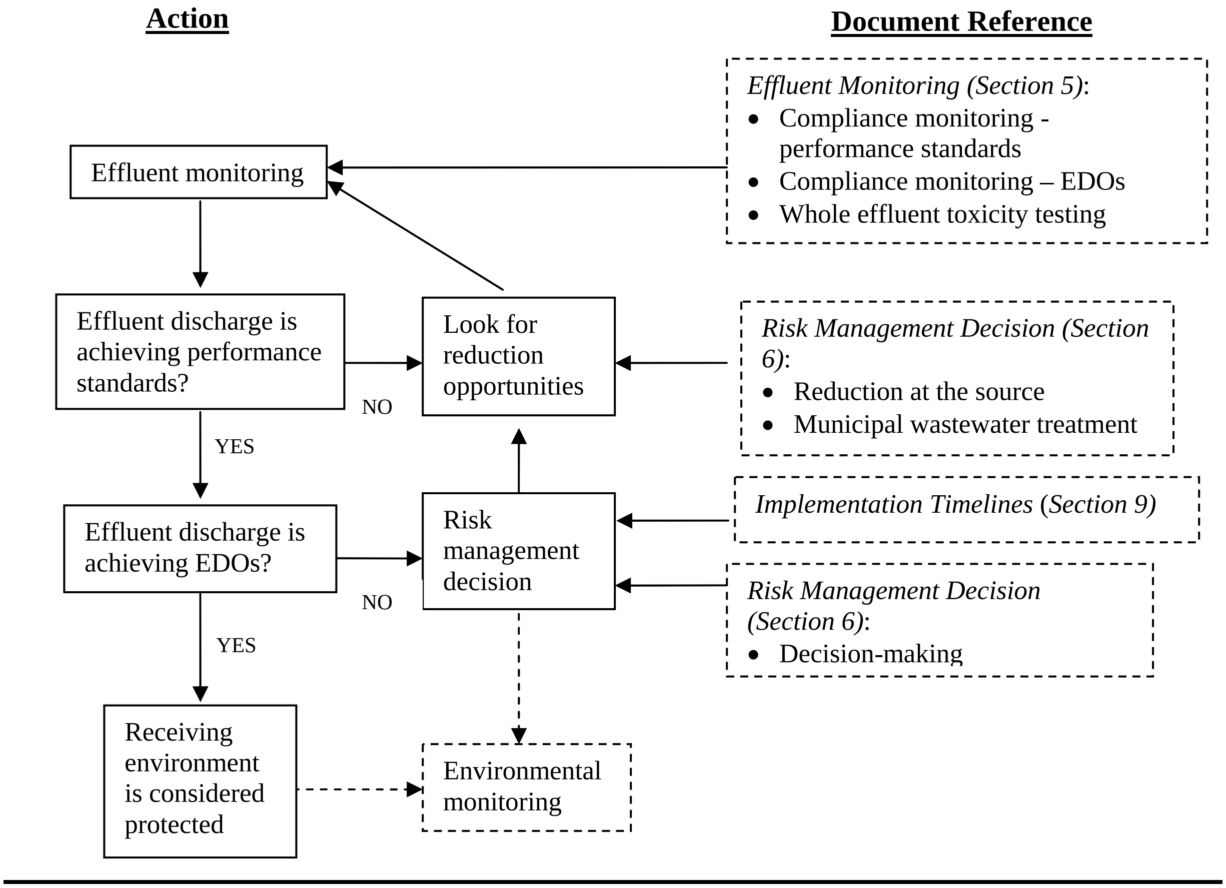


Figure 3. Effluent Monitoring and Risk Management Decision-Making

2. National Performance Standards

Two approaches can be used to develop discharge requirements or standards for MWWE: a technology-based approach and an environmental risk-based approach. The technology-based approach establishes performance standards based on technology selection and/or currently best available technology. The environmental risk-based approach establishes discharge requirements based on the level of protection for the receiving environment. Regulators have used both approaches, or a combination of approaches, to establish discharge requirements for MWWE.

Traditionally, performance standards have been set for biochemical oxygen demand (BOD_5) and total suspended solids (TSS). The intent of a technology-based approach is to require a minimum level of treatment for MWWE based on available and proven treatment technologies. Technology-based approaches have been used to establish minimum acceptable standards for the reduction of other substances in MWWE. The physical and chemical strengths and limitations of a selected treatment technology could lead to discharges that do not meet or exceed EDOs derived by assessing acceptable risk to the environment.

Existing discharge requirements in each jurisdiction in Canada have been analyzed as a starting point for assessing achievable technology-based performance standards. A number of jurisdictions use secondary treatment or produce an effluent quality equivalent to that achieved by secondary treatment as part of their regulatory requirements. Actual implementation, however, is sometimes done on a case-by-case basis.

For the Strategy, secondary treatment has been selected as the minimum level of treatment that all wastewater facilities should eventually achieve. This level of treatment is normally prescribed in permits, regulations, codes of practice and other authorizations, covering BOD_5 and TSS through effluent quality or discharge limits. Total residual chlorine (TRC) has also been selected for a National Performance Standard because of its toxicity to aquatic organisms and, more specifically, because it is added to the wastewater at the wastewater facility, making it easy to control or remove.

The National Performance Standards under the Strategy are:

- **25 mg/L for five day carbonaceous biochemical oxygen demand ($CBOD_5$);**
- **25 mg/L for total suspended solids (TSS); and**
- **0.02 mg/L for total residual chlorine (TRC).**

National Performance Standards must be met at the end-of-pipe as periodic averages (see Section 5.2). TSS may exceed the National Performance Standard if exceedances are caused by algae. It should be noted that $CBOD_5$ is used instead of traditional total BOD_5 because of concerns about the effect of nitrogenous oxygen demand during the BOD_5 test.

All new and upgraded wastewater facilities are required to meet the National Performance Standards immediately. Existing facilities that already meet the National Performance Standards will be required to continue to do so. Existing facilities that do not meet the National Performance Standards will be required to meet the Standards within a number of years, depending on the level of risk. Implementation of the National Performance Standards will be based on risk, available funding and financial sustainability. Additionally, jurisdictions may establish more stringent limits than the National Performance Standards.

Nutrients, pathogens and other substances will be addressed through environmental risk assessments (see sections 3 and 4).

2.1 Considerations for Canada's Far North

The Strategy recognizes that Canada's far north faces unique concerns due to its extreme climatic conditions and remoteness. Alternative National Performance Standards for wastewater facilities in the Northwest Territories, Nunavut, Nunavik and Nunatsiavut will be proposed within five years. This extra time will allow further investigation of the constraints associated with meeting the National Performance Standards. A number of factors, such as ice-free-days, are being explored to determine which ones may affect the achievement of any proposed National Performance Standards. Data availability is a limiting factor.

The following interim measures will apply to Canada's far north:

- A risk-based approach will continue to be used to manage municipal wastewater effluent. The effluent quality standards in use in current permits in the far north will be retained.
- Further research will be conducted within the next five years to identify the factors that affect performance of lagoons and wetlands in arctic conditions and how lagoons and wetlands can be improved.
- Once adequate information is available within the five year period, performance standards appropriate for arctic conditions will be developed and implemented.

3. Environmental Risk Assessment – Single Discharge Approach

Establishing EDOs through environmental risk assessments (ERAs) is a key element of the framework, especially since National Performance Standards may not always sufficiently protect the environment. This section describes the framework proposed for developing MWWE discharge objectives using the environmental risk-based approach.

The requirements for completing an ERA are described in sections 3 and 4 below. In addition, a standard method (see technical supplement 3) has been developed to assist owners in completing an ERA. Some owners may have previously completed a site-specific assessment equivalent to the ERA required under the Strategy and should contact their jurisdiction to determine equivalency of process.

EDOs are expressed as concentrations and/or loads of substances in MWWE discharges that will ensure that environmental quality objectives (EQOs) are achieved in receiving waters outside of specified mixing zones. EQOs are concentrations of substances that are considered safe for aquatic life and for human uses that exist or should exist outside of mixing zones. An environmental risk assessment is done to establish EDOs, taking into account the characteristics of the site-specific receiving environment.

An ERA can be performed for a single discharge to establish its EDOs, or can be conducted at a watershed level (see section 4) or part thereof, to allocate loads for all discharges of the same substance through a watershed management plan. In both cases, the process starts with the *Canadian Environmental Quality Guidelines* (CEQGs) or their provincial equivalent. Site-specific EQOs for the receiving environment are established first, with EDOs for the discharge(s) established second. Although a watershed-based approach is recommended, especially for nutrients, establishing EDOs for single discharges is still acceptable.

Box1. Canadian Environmental Quality Guidelines

CCME has established generic water quality guidelines in the *Canadian Environmental Quality Guidelines* (CEQGs). CEQGs,

…are nationally endorsed, science-based goals for the quality of atmospheric, aquatic, and terrestrial ecosystems. Environmental quality guidelines are defined as numerical concentrations or narrative statements that are recommended as levels that should result in negligible risk to biota, their functions, or any interactions that are integral to sustaining the health of ecosystems and the designated resource uses they support.

These generic guidelines are recommended for substances of national concern that are found in the ambient environment. As national benchmarks or indicators of environmental quality, they are intended to protect, sustain and enhance the quality of the Canadian environment and its many beneficial uses. In Canada, CEQGs provide a consistent basis for assessing water quality conditions and, consequently, the health of water resources. Guidelines developed by CCME have been adopted/adapted by provincial and territorial jurisdictions to serve as a cornerstone for water resources management and environmental protection.

Although CEQGs are broadly used within Canada and elsewhere to assess and manage water quality conditions, they should not be regarded as blanket values for national environmental quality. Variations in environmental conditions across the country have the potential to influence the applicability of these generic guidelines. Some jurisdictions have opted to develop guidelines outside the scope of CCME's mandate for particular substances of concern (e.g., BOD_5, certain pesticides) or for other specific uses in their jurisdictions (e.g., fish consumption or shellfish harvesting). Guidelines developed by other jurisdictions, such as the United States Environmental Protection Agency (US EPA), may also be applied by provincial or territorial governments, if scientifically based (see section 3.2.2).

3.1 Completing an Environmental Risk Assessment

The goals of completing an ERA for a single discharge are two-fold:
(a) To determine the potential impact of MWWE in the receiving water; and
(b) To help limit substance concentrations or loads at the end of the discharge pipe in order to protect all uses of the receiving water.

EDOs are determined from:

- The characteristics of the effluent (its flow and the concentration of substances it may contain);
- The characteristics of the receiving environment;
- Water quality guidelines for a specific substance or for whole effluent toxicity, or site-specific water quality objectives for the particular receiving water;
- The current, potential or designated uses of the water resource; and
- Background levels of substances in the watershed.

The characteristics of the receiving water body are defined by its intrinsic conditions (i.e., water quality and quantity)—independent of human-caused (anthropogenic) inputs—as well as by its vulnerability and assimilative capacity. For example, a small water body cannot assimilate a discharge or load similar to that of a large water body without having its water quality degraded, nor can a lake with a slow flushing rate assimilate a load comparable to that of a river with a high flow. The approach should account for these differences, as well as restrict discharges into a receiving environment whose assimilative capacity is already exceeded due to existing sources of the substance(s) of concern in the watershed or naturally high background concentrations.

EQOs for water are defined by CCME (1987) as numerical concentrations or narrative statements that establish the conditions necessary to support and protect the most sensitive designated use of water at a specified site. The EQOs for receiving water provide the basis for evaluating the risks of MWWE to human and ecosystem health or to fisheries resources.

EQOs can be determined using one of three approaches: a physical/chemical/pathogenic approach, a whole effluent toxicity (WET) approach, or a biological criteria or bioassessment approach. The relevant data inputs from these approaches, as well as several other variables (e.g., upstream water quality or background, critical low-flow periods in the receiving environment, effluent flow) are considered when developing the EDO. EDOs are developed to specify the concentrations/loads of substances in the effluent discharge that will result in achieving the corresponding EQOs in the receiving environment, at the edge of the allocated mixing zone, when there is one.

Independently, these three approaches are good predictive tools of unacceptable risks to human and ecosystem health. An integrated approach, however, builds on the limitations of the individual approaches and provides greater assurance of the risks being further minimized. Other advantages and limitations are discussed in detail in section 3.2.2.

Figure 4 illustrates the process of establishing science-based EDOs using a single discharge ERA approach. The basic steps involved in developing EDOs are as follows:

1. Identify the uses and site specific factors of the receiving waters.

2. To preserve designated water uses, determine the EQOs for the substances of potential concern. For instance, to protect aquatic life, a chronic toxicological EQO should be established as 1TU$_c$ and applied at the edge of the mixing zone. EQOs should also include physical/chemical/pathogenic substances.
3. Perform an initial characterization of the effluent (see section 5). Identify which substances have a reasonable potential to exceed the EQOs at the edge of the mixing zone. Perform a mixing zone assessment.
4. Establish EDOs for the substances of concern and the chronic WET EDO by back calculating (modeling) from the EQOs. An acute WET-based EDO should also be established for the effluent, such that effluent acute toxicity does not exceed 1TU$_a$ (e.g., a 96-hour rainbow trout test).

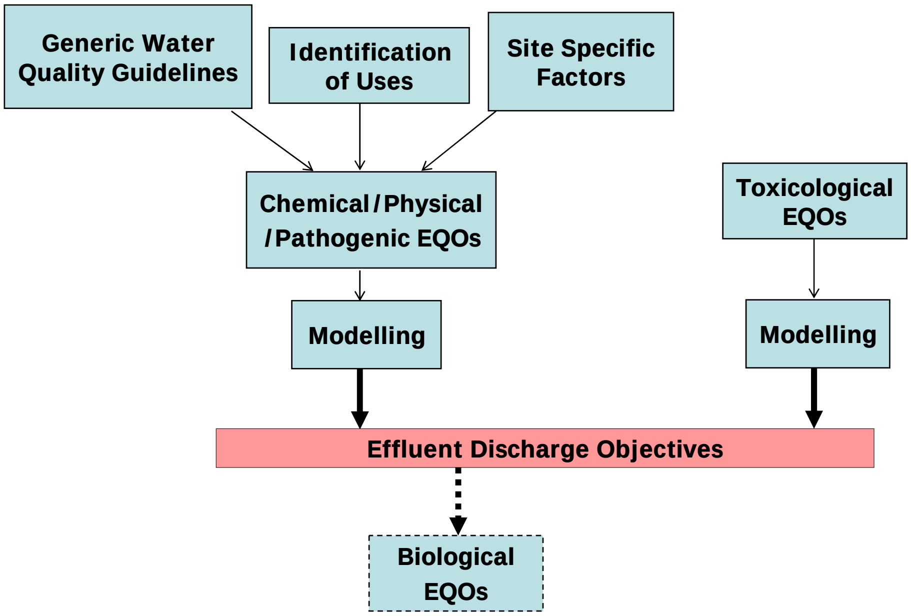


Figure 4. Environmental Risk Assessment - Single Discharge Approach

3.2 Environmental Quality Objectives

3.2.1 Water Uses

The first step in developing an EQO is to define all the uses of a particular water body; the derivation of EQOs is inherently tied to these uses.

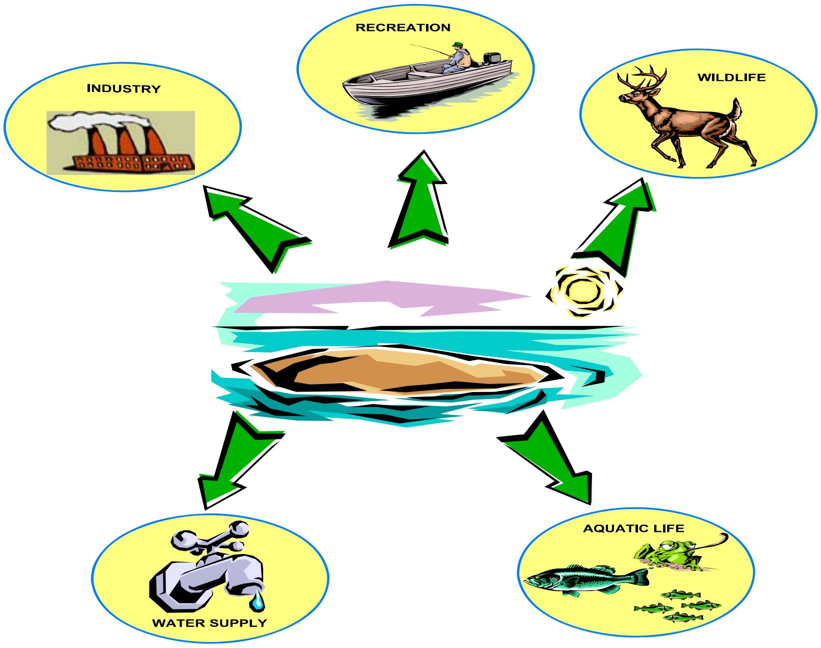


Figure 5. Beneficial Uses of Water

Box 2. Beneficial Uses of Water

Aquatic systems are valuable natural resources that support many beneficial uses. They are sources for drinking water, the foundation of fish and shellfish fisheries, the source of irrigation and livestock water for agriculture, the source of process water for various industrial activities, and places for both contact (e.g., swimming, wading) and non-contact (e.g., fishing, boating) recreational activities (see Figure 5). Above all, they support broader ecosystem health, including the protection of aquatic life and wildlife.

Aquatic systems are also the receiving environment for the disposal of treated MWWE. Various effluent components have been linked to changes in aquatic habitats and species composition, decreases in biodiversity, the impaired use of recreational waters and fish and shellfish harvesting areas, and contaminated drinking water. Ultimately, these changes lead to a less prosperous economy, human health and environmental concerns, and a diminished quality of life.

3.2.2 Overview and Development of Environmental Quality Objectives

Generic guidelines may be modified for a specific location or area by considering the characteristics of the receiving water downstream from the discharge or other site-specific factors. Other guidelines could also be considered for the protection of other designated water uses and for toxicological criteria. The process results in EQOs, which are objectives to be met in the specific receiving environment. An EQO for a particular substance becomes an input to a model used to back-calculate an EDO that applies to the effluent discharge (end-of-pipe).

The condition of the receiving environment can be best characterized using a combination of approaches: chemical/physical/pathogenic, toxicological, and biological indicators. The physical/chemical/pathogenic approach describes the level of a particular substance of concern (i.e., pathogens, metals) that will not adversely impact water quality. The toxicological approach specifies the proportion of the effluent discharge that may enter the water body without toxicological impact. The biological approach describes the level of ecological integrity that must be maintained, using parameters such as diversity. Objectives for each of these approaches can be established to describe a desirable level of environmental quality or condition of the receiving environment. For all approaches, at no time should an EQO be established that will result in degradation of water quality.

EQOs within each approach can take many forms, including:

- Qualitative (or narrative) statements: for instance, Canada's *Fisheries Act*, 36(3) states "…no person shall deposit or permit the deposit of a deleterious substance …" while the United States *Clean Water Act* has requirements for waters that are commonly described as drinkable, swimmable, or fishable.
- Quantitative measures: physical/chemical/pathogenic water, tissue, or sediment quality guidelines (i.e., the concentration of a substance in water, tissue, or sediment); toxicological criteria (i.e., verified with toxicity tests on whole effluent or on ambient waters); or biocriteria (e.g., less than 30 per cent change in fish gonad size, population or community structure, or species diversity).

Each approach has strengths and weaknesses as a tool for characterizing water quality, as summarized in Table 1 at the end of this section. The primary purpose of this section is to explore how physical/chemical/pathogenic, toxicological, and biological objectives are developed and implemented in the assessment and characterization of environmental quality and, ultimately, the management of complex effluent.

Physical/Chemical/Pathogenic EQOs

This approach is intended to protect the quality of the receiving water by ensuring that environmental quality guidelines and/or objectives are met. It involves evaluating the discharge and its predicted effect on the receiving water. Guidelines are the ideal tool for use in this approach because a standardized but flexible framework is used to develop generic or site-specific water, sediment and aquatic organism tissue residue guidelines for any Canadian context. These guidelines can support use-protection goals established in MWWE management and will demonstrate the environmental relevance of management decisions.

Site specific factors can limit the direct applicability of CEQGs as EQOs. These factors include elevated background levels of substances of concern (natural or due to past contamination), atypical levels of water quality variables that influence the bioavailability and/or toxicity of these substances, specific human or natural uses of the area, and sensitivity ranges of resident species (compared to species used to develop the CEQG). Therefore, it may be necessary to establish site-specific EQOs that account for such variations in environmental conditions.

Several provincial/territorial jurisdictions use physical/chemical/pathogenic EQOs to assess the potential for ecological effects in waters receiving effluent discharge. In Canada, the most commonly used EQOs are the CEQGs, although some jurisdictions have in place other guidelines and EQOs developed independently to suit their specific environmental needs.

Development of Site-specific EQOs

Site-specific EQOs are numerical concentrations or narrative statements that support and maintain a designated use at a specific site. Objectives are typically based on generic water quality guidelines (WQGs), which may be modified to account for local environmental conditions or other factors. For instance, if natural ambient upstream levels of the substance of concern at the site exceed the generic WQG, the site would not adopt the generic national WQG as the EQO for that particular substance. Instead, the ambient level of the substance would become the EQO for the site. In this scenario, site-specific objectives would stipulate that water quality should not be degraded beyond the ambient level and that all practical measures should be taken to upgrade the water quality. Exceptions may be made on a case-by-case basis in areas where this is not practical or feasible.

Site-specific EQOs are derived using one of four procedures: the background concentration procedure, the recalculation procedure, the water effect ratio procedure, or the resident species procedure. A discussion of these methods is beyond the scope of this document (see CCME, 2003).

Toxicological EQOs

MWWE is a complex mixture that may contain unknown or unidentified substances for which guidelines do not yet exist. Little or no understanding of chemical interactions (e.g., synergism) in these mixtures makes it nearly impossible to precisely predict their collective environmental effect. WET tests can be used to determine the potential toxicity of chemical mixtures through short-term acute toxicity or long-term chronic toxicity tests on either end-of-pipe effluent or receiving environment media (i.e., water or sediments). WET tests are bioassays used to determine the degree of response of aquatic organisms, such as fish, crustaceans, and algae, exposed to an effluent. WET tests are generally conducted in laboratories, where effluent water is serially diluted and selected organisms are exposed to concentrations of effluent water for a predetermined period of time. Dilution water is either standard laboratory water or receiving water.

Two types of WET tests exist to qualify toxicity: acute and chronic. Acute tests allow screening for concentrations high enough to cause effects over a short exposure period. The 96-hour rainbow trout test is a standard acute WET test. The endpoint is commonly mortality, expressed as LC_{50}, which is the concentration of effluent that is lethal to 50% of exposed organisms. Chronic tests are used to determine sublethal effects, such as inhibited growth or reproduction, over durations of seven or more days depending on the lifespan of the organism. Endpoints include lowest observable effects concentrations, no observable effects concentrations, and effects concentrations.

WET test results are expressed as the percentage of the effluent that produces an effect (e.g., 16% by volume of effluent kills 50% of the exposed organisms or 16% is the LC_{50}). The lower the volume percentage of effluent that causes an effect, the greater the toxicity of the effluent. WET test results are also expressed in toxicity units (TU). Toxicity units are an inversion of the percentage of effluent: as effluent toxicity increases, toxicity unit values increase. Toxicity units may be used to express EQOs, to calculate EDOs, and to compare effluent toxicity to these EDOs. 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 $100\%/LC_{50}$. If an LC_{50} 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.

EQOs may be expressed as effect (acute) or no effect (chronic) concentrations, or in TUs. They serve to protect aquatic life from the combined effects of all substances in the whole effluent. Samples are commonly considered acutely toxic when the TU_a is equal to or greater than 1. Chronic toxicity is defined as equal to or greater than 1 TU_c, based on a no effect level on reproduction or growth (n.b., measurements of chronic effect vary with jurisdiction, but should be expressed so that chronic toxicity does not exceed this no effect level). Therefore, the acute toxicological EQO is 1 TU_a, and is applied directly at the end-of-pipe, without dilution, to prevent acute lethality inside the mixing zone. The chronic toxicological EQO is 1 TU_c, and is applied at the edge of the allocated mixing zone in the same way EQOs are derived from chemical guidelines.

The acute whole effluent toxicity EDO will therefore always be 1 TU_a at the end-of-pipe (without dilution), and the chronic whole effluent toxicity EDO will be back-calculated from 1 TU_c applied at the edge of the allocated mixing zone, using the established dilution factor. The result of a chronic WET test is therefore compared to the chronic WET EDO of this particular effluent.

The advantage of implementing the WET approach is that it addresses the potential for additive, synergistic, or antagonist toxicity effects and provides a level of direct protection for aquatic organisms from effluent discharge. WET tests are limited in their interpretation; however, as the direct toxicity of particular substances is not investigated and guidelines are not developed for the specific substances of concern. In some jurisdictions, WET testing is often incorporated into the permitting process.

Biological EQOs

When chemical, physical, and biological integrity is protected and EQOs are not exceeded, ecological integrity should be preserved. Biological assessments, or bioassessments, are tools used to gauge ecological integrity. Biological EQOs are based upon biocriteria, which in turn are derived using bioassessments. Biological EQOs differ from toxicological EQOs in that they often focus on adverse effects at higher levels of organization, such as population and community structures, rather than toxicity effects in individuals, although the latter could be included. They are also the only EQOs that examine actual impacts on receiving waters.

Biological assessments are studies of biota carried out within an area exposed to MWWE discharges, as well as in reference areas unexposed to these discharges but having similar physical and chemical characteristics. Typically, significant differences between exposed and reference locations are used to determine the nature and severity of effects caused by the discharge. From a regulatory perspective, the principal indicator organisms are generally fish and benthos. Plants, algae, and zooplankton are used to a lesser extent. Whenever impacts are observed, even though EDOs are being achieved, an ERA should be undertaken to establish new EDOs that will better protect the receiving environment. Criteria should focus on effects on higher trophic levels, with management decisions based on the level of effect (Kilgour *et al.*, 2005). Specifically, conditions that may indicate impairment of the fish community are warning-level effects that may or may not be associated with the exceedance of EQOs, while unacceptable effects occur when measurable effects show a trend that surpasses the warning level. These effects require identification of cause (Kilgour *et al.*, 2005). Several leading agencies have implemented biomonitoring in the receiving environment to more fully characterize environmental effects associated with industrial or municipal effluent.

Biocriteria are developed from bioassessments that integrate measures (indices) of the composition, diversity and functional organization of a reference aquatic community. The reference conditions are considered the foundation for biocriteria. Bioassessments are then conducted to determine if a water body is attaining its designated aquatic-life use. This is done by comparing the assessment results with the biocriteria. Biological EQOs are not universally used in Canada and no standard approach has been established. The CCME Water Quality Task Group has scoped out issues related to biocriteria and the report is available on the CCME website (www.ccme.ca). Once developed, provincial or CCME biocriteria could become the third pillar of EQOs (along with physical/chemical/pathogenic and toxicological objectives) to be used in the environmental risk management framework for MWWE.

Table 1. Capabilities and Limitations of Water Quality Evaluation Tools

Control Approach	Capabilities	Limitations
Physical/ chemical/ pathogenic guidelines	Human health protection, aquatic and wildlife protection	Does not consider all toxics present
	Complete toxicology	Bioavailability not measured
	Straightforward treatability	Interactions of mixtures unaccounted for
	Fate understood	Complete analyses can be expensive
	Less expensive testing if only a few toxicants are present	Direct biological impairment not measured

	Prevents or predicts impacts	
Whole effluent toxicity	Aggregate toxicity	No direct human health or wildlife protection
	Unknown toxicants addressed	Incomplete toxicology (few species and few effects may be tested)
	Bioavailability measured	No direct cause-effect relationship established
	Accurate toxicology	No persistency or sediment coverage
	Prevents impacts	Ambient conditions may be different
		Incomplete knowledge of causative toxicant
Bioassessments	Measure actual receiving water effects	Critical flow effects not always assessed
	Historical trend analysis	Difficult to interpret impacts
	Assess level of ecological quality above standards	Cause of impact not identified
	Total effect of all sources, including unknown sources	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, and MENV, 2001)

3.3 Mixing Zone and Dilution Assessment

3.3.1 Definition of the Mixing Zone

Physical mixing zone

Many effluent discharges do not mix instantaneously with the receiving water, resulting in mixing zones adjacent to the outfall. The physical mixing zone may be defined as the area outside of which effluent and receiving waters have mixed completely. For a sufficiently large body of water, the physical process of mixing continues indefinitely and the physical mixing zone contains the area up to the point where there is virtually no measurable difference between receiving water and effluent mixed with receiver. In a river or stream, the physical mixing zone is the area within which the effluent discharge is not fully or completely mixed with the receiving water. It is possible that the plume may not occupy the entire width of the stream, although “complete” mixing over the entire depth and cross section of the river may occur at some distance further downstream. Beyond that point, the entire river flow is of similar make-up and hence no further mixing occurs. In a small lake, a sufficiently large discharge may mean that the whole lake is the physical mixing zone. The physical process of “mixing” also has two distinct phases: near field and far field mixing processes. Near field is where mixing is dominated by the effluent/outfall characteristics and is more controllable through design. Far field is where mixing is more dominated or controlled by ambient processes such as turbulence and wave action.

The size of the physical mixing zone is not fixed but varies over time with factors such as: effluent flow rate and concentration, design of the outfall, ambient properties (depth, velocity, density, etc.), and concentrations of the substances in both the receiving environment and the effluent. Additionally, the size of the physical mixing zone also may differ for each contaminant because the mixing process itself may differ for different parameters (e.g., some substances may decay over time while others may be conservative).

Allocated mixing zone

In some circumstances, a mixing zone smaller than the physical mixing zone may be allocated for dilution of an effluent discharge. For instance, an allocated mixing zone may be used to determine if ambient guidelines are met, for the calculation of the assimilation capacity of a water body, and for back calculation to an EDO. The allocated mixing zone may be set by regulators. It differs from the physical mixing zone because its purpose is to calculate reasonable assimilative capacity for the effluent discharge, rather than to allow the entire dilution capacity of the stream or lake to be used for the calculation of complete mixing.

The allocated mixing zone, also called the initial dilution zone, is defined as “the area contiguous with a point source (effluent discharge site) or a delimited non-point source where the discharge mixes with ambient water and where concentrations of some substances may not comply with water quality guidelines or objectives (CCME, 1996).” A typical allocated mixing zone is shown in Figure 6. For the purposes of this document, the simplified term ‘mixing zone’ is used from this point forward. It refers to the allocated mixing zone.

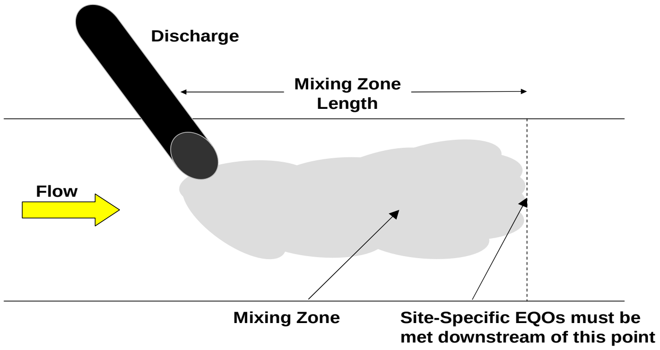


Figure 6. Conceptual Diagram of an Allocated Mixing Zone

Mixing zones are therefore areas in which the initial dilution of the effluent occurs and concentrations of some substances may not comply with EQOs (which are generally based on preventing chronic effects). The mixing zone is an area of acceptable, but not acutely toxic, impact that does not affect the overall quality of the receiving water. In general, the integrity of the water body as a whole is protected even if EQOs are exceeded within the mixing zone, as long as the effluent does not cause significant mortality inside the zone and respects the EQOs at the edge of the zone.

Mixing zones are considered for the EDO calculation because some assimilation of the substance occurs in the water body. Dilution is considered because, for the most part, the immediate concentration of a substance at the end-of-pipe will not be an adequate representation of the concentration of the substance in the water body as a whole. For instance, for the most part, aquatic life will not be exposed to the concentration of the substance in the pipe but rather to the receiving waters mixed with effluent. Similarly, for the most part, humans will be exposed at the site of a particular use, such as recreation, rather than at the end-of-pipe. This means that comparing concentrations at the end-of-pipe to long term guidelines for aquatic or human health may be too conservative. Mixing zones are therefore allocated so long term guidelines, in the form of EQOs, will be applied to protect specific water uses under realistic conditions. The mixing zones may be used to back calculate from the EQOs to EDOs that will estimate the assimilative capacity of the water body. Where a mixing zone is allowed, the EDO represents the maximum concentration and load of a substance, or the WET, in the point-source effluent that will enable receiving water to meet the EQO at the edge of the allocated zone.

The mixing zone must meet certain requirements in order to prevent inappropriate impacts on the receiving waters. In no case should the mixing zone impair the water body as a whole. Mixing zones should not be used as a replacement for adequate treatment. Dilution is not treatment. To prevent inappropriate impacts, mixing zones may vary from one water body to another due to factors such as the speed of the mix. Mixing zones may also vary in the same water body from one water use to another. For instance, the mixing zone for a use close to the discharge would not extend as far as the mixing zone for another use located farther away. Finally, the allocation of a mixing zone varies from one substance to another: degradable substances are allowed to mix in a portion of the receiving water, whereas toxic, persistent and bioaccumulative substances are not allowed a mixing zone (EDOs will match EQOs). This is because no dilution is allowed for persistent, toxic and bioaccumulative substances such as chlorinated dioxins and furans, PCBs, mercury and toxaphene. In addition, no mixing zone may be allocated where other circumstances, such as the requirement for greater protection of certain water uses, exist. Mixing zones are only considered for treated and monitored effluent, not for spills or for voluntary or accidental discharges.

3.3.2 Criteria for Allocating the Mixing Zone

The following general criteria, adapted from those established by CCME (1996), are recommended for allocating a mixing zone:

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

Prevention of acute toxicity within the mixing zone
Acute toxicity to organisms passing through the mixing zone should be prevented, as this constitutes an unacceptable impact. To prevent significant mortality inside the zone, acute toxicity (defined by greater than 50 per cent mortality) should not occur at end-of-pipe. In order to protect passing organisms from acute toxicity, undiluted effluent should pass an LC_{50} test; in other words, it should not exceed $1TU_a$ (see Section 3.2.2). This may be expressed as:

$$EDO < 1TU_a$$

3.3.3 Restrictions on Mixing Zone Dimensions

The spatial dimensions allocated to the dilution should be restricted in order to protect the water body as a whole. This may be achieved through physical/spatial restrictions or a 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.

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
Streams and rivers are water bodies with continuous or intermittent flows that do not present a natural density gradient. In this type of environment, the critical conditions of the effluent and receiving environment mixing generally correspond to periods of lowest water flow.

The fraction of flow allocated to the mixing zone in a river depends on the extent to which mixing occurs. Small discharges into rivers of non-turbulent flow will not mix with the entire stream flow for considerable distances. At the opposite end of the spectrum are very turbulent small streams and effluent-dominated streams. Here, large amounts of effluent discharge into a small stream of low flow. In these situations, full mixing occurs but the mitigating effects of dilution are minimal. In intermittent streams, a mixing zone is not allocated and the EDOs are set as equivalent to the 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 (see section 6.1).

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. It could take many kilometres before a plume is completely dispersed through the receiving waters to the point that no distinction can be made between the mixed water and the receiving water. Without a limit on the length of the zone allowed for mixing, high concentrations of substances may stay in a portion of the water body for long distances. 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 (see below).

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, one hundred per cent of the stream flow should not be allocated to a single discharge in order to allow for future development and to maintain a zone of passage for fish, among other considerations. 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).

As mentioned previously, the dilution of an effluent is not treatment. In large rivers, where dilution may be very high (e.g., St. Lawrence River, Saguenay River), it is difficult to take the presence of all the discharges to the river into account. Even if the concentrations of substances are not measurable individually because of the dilution factors, the summation of all the loads discharged may result in deleterious concentrations of substances in some compartment of the environment. Therefore, a maximum dilution factor may be allocated.

Lakes, reservoirs and enclosed bays

Lakes, reservoirs and enclosed bays are especially sensitive to the 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.

As with rivers and streams, mixing zone limits must be respected to protect the water uses throughout almost the entire receiving environment. 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)

Estuaries and marine waters are characterized by the presence of currents that fluctuate in intensity and direction (e.g., under the influence of tides). 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 zones of estuarine or marine waters may be obtained by hydraulic modeling and/or the use of tracer studies.

Mixing zone models

Mixing zones should be thoroughly evaluated to ascertain whether the 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).

Mixing zone assessment models vary in complexity. The simplest is a basic equation that estimates the dilution predicted during the first phase of discharge-induced mixing and the distance from the outlet at which the EQO is attained under worst-case conditions (US EPA, 1991). More detailed modeling is necessary where there is a dispute over proximity to spawning grounds or overlapping plumes. Several mixing zone assessment computer models, such as PLUME and CORMIX, are available through the US EPA (1991) for this purpose; however, they require a user with knowledge of mixing concepts and model input substances.

Mixing zone assessments based on empirical measurements should supersede those based on modeling calculations.

3.4 Determining the Need for Effluent Discharge Objectives

EQOs are desired characteristics or benchmarks that, if attained, will protect all water uses for a particular water body over the long-term. Once EQOs have been developed, the next step is to assess whether EDOs are required. 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." Jurisdictions may define their own approach to determine "reasonable potential."

EDOs provide guidance on the desired characteristics of the effluent discharge, thereby preventing substances in excess of EQOs to exist beyond the mixing zone. 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.

Depending on the characteristics of the site, the effluent discharge and the specific EQOs, the need for EDOs may be determined based on EQOs developed for WET, for physical/chemical/pathogenic substances or both.

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 section 5, will determine which substances are of concern for that particular facility.

3.5 Developing Effluent Discharge Objectives

EDOs represent the maximum concentration and load of the substance at the end-of-pipe that will enable the receiving water to meet the EQOs at the edge of the mixing zone. From the established EQOs, EDOs must be calculated, using a model that integrates site-specific factors, such as design stream and effluent flows, background concentration levels in the receiving environment, dilution capacity in the mixing zone, and so on. Mass-balance and water-fate-and-transport models are used to establish a quantitative relationship between the substance concentration/load and the receiving water quality. EDOs should be calculated for all substances, WET and uses where reasonable potential of exceeding the EQO is demonstrated. The general principles are outlined below.

EDOs calculated from chemical/physical/pathogenic EQOs are concentrations and/or loads of substances in the effluent that will enable the receiving water to meet the EQOs at the edge of a mixing zone. Mixing zones are discussed in section 3.3.1.

EDOs for whole effluent toxicity (WET) are defined for acute and chronic toxicity. An acute toxicity criterion of not more than 50% mortality is applied at the end-of-pipe. This limit normally prevents significant mortality anywhere in the receiving environment. A mixing zone is considered when establishing chronic toxicity EDOs, meaning that no noticeable chronic effects should show beyond the mixing zone. No mixing zone is allowed for persistent toxic and bioaccumulative substances. Other mixing zones are calculated based on the location and occurrence of drinking water intakes and specific activities such as shellfish harvesting and swimming, among others.

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. Wastewater facilities should be designed to achieve EDOs or to come as close as possible based on what is achievable by treatment.

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. The lower the sampling frequency, the lower the discharge limits have to be to achieve the same level of confidence that EDOs are being met.

To help with establishing statistically-based discharge limits, the US EPA published a *Technical Support Document for Water Quality Based Toxics Control* (1991). Some provinces also have guidance documents based on the US EPA method.

3.5.1 Background Concentration of a Substance

The background concentration of a substance—the concentration that naturally occurs upstream from a point-source discharge—should be established prior to determining the EDO. The choice of which water quality model to use to derive the EDOs will be influenced by the availability of receiving environment and effluent data sets. Where receiving environment information is limited, steady-state models may be used. In this case, available receiving environment monitoring data may be used to estimate worst-case, steady-state conditions. When large datasets are available, a more sophisticated model, such as a dynamic one, may be selected. These models allow information on background levels of a substance detected over a certain time period to be incorporated.

To satisfy data requirements, monitoring may be recommended at a location upstream of a discharge point. Provinces and territories have monitoring networks that may be consulted first, as generic quality data are usually available for the most important rivers and streams. For toxics, data from specific studies are available for some water bodies. Default values are defined and used by jurisdictions. The extent of the information on background concentrations will also depend on the designated uses of the receiving waters. Stringent monitoring may be necessary in areas where multiple discharge points exist in the watershed.

3.5.2 Selecting an Appropriate Model

A representative model is selected based on the receiving water characteristics, substances and effluent characteristics. Receiving water characteristics include stream and effluent flows, background concentrations in the receiving environment and dilution capacity in the mixing zone. The level of sophistication required is also an important consideration. Simplified modeling approaches, such as steady-state modeling, require limited data and computing resources. Sophisticated methods, such as dynamic models, have detailed requirements, but are preferred because they provide more accurate estimates than the more stringent worst-case scenario estimates provided by simplistic methods. Where sophisticated modeling tools and resources are not available, however, simplistic approaches are acceptable.

Based on these considerations, both steady-state and dynamic water-transport models may be applied.

Steady-state models

Steady-state modeling is a simplistic method commonly 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. In reality, however, 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 (see Figure 7):

The resulting load of a substance at the edge of the mixing zone = **the load of the substance in the effluent** + **the background load of the substance in the stream**

Where:
load = flow x concentration

This basic mass-balance equation is presented as:

$$Q_rC_r = Q_eC_e + Q_sC_s$$

Where:
Q_e = effluent discharge flow (m^3/s)
C_e = substance concentration in discharge (µg/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 (µg/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 (µg/L or TU) Should be the EQO
ff = fraction of flow

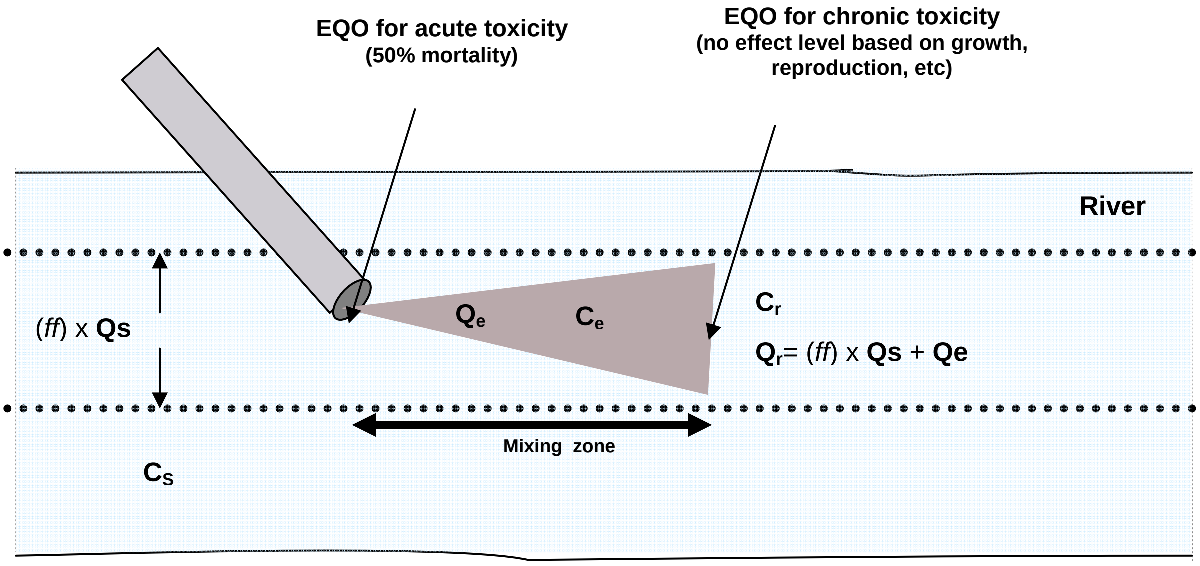


Figure 7. The Mass-balance Equation

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:

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

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:

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

and

$$EDO(load) = EDO(concentration) \cdot Q_e$$

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).

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 (defined in section 3.2.2) 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 0. 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 $1TU_c$:

$$\text{EQO} \le 1\text{TU}_c$$

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:

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

may be rewritten as

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

where the EDO is expressed in TU_cs.

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

Dynamic modeling

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 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 offer 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 log-normal 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 log-normal probabilistic dilution model predicts the probability distribution of receiving water concentrations from the log-normal 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 dilution and mixing.

3.5.3 Intermittent Discharge Lagoons

For lagoon systems that only discharge periodically, typically once or twice per year (or less frequently), the same approach to selecting and using a model as described above is used, even though discharges do not occur all year. Chronic toxicity data can be obtained within a relatively short period of time (chronic toxicity tests typically last only one week). However, the selection of the low flow condition is different since the discharges typically do not occur during the driest periods of the year. The low flow conditions to be used are those that occur during the months when discharges occur (usually during the spring and/or fall).

Box 3. Case Study – Effluent Discharge Objectives

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

Aquatic-life Use Designation

Assume that a MWWE 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 MWWE discharge.

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

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 of 2 to 4 µg/L 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 µg/L. The site's EQO for the purpose of protecting aquatic life from chronic exposure to copper is therefore 3 µg/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 µg/L.

Development of the EDO

The EDO is developed next. 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, is used. This model consists of the modified mass-balance equation previously presented:

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

Assume that the background concentration of copper in the stream is 0.70 µg/L, that 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 dilution of 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 the receiving waters meet the EQO of 3.0 µg/L at the edge of the mixing zone will be:

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

EDO (conc) = 107.3 µg/L

EDO (load) = (107.3 µg/L) (10^{-9} kg/µg) (0.04 m^3/s) (10^3L/m^3) (86400 s/d)
= 0.37 kg/d

Therefore, the EDO for copper for this MWWE discharge is 107 µg/L in concentration and 0.37 kg/d as expressed as loading.

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 100% effluent. The effluent therefore meets the objective of no acute toxicity at the end-of-pipe. A value of 75 per cent 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:

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

$$\mathrm{EDO} = 1\mathrm{TUc}\,\frac{(0.04 + 0.33 \cdot 5.5)}{0.04}$$

$$\mathrm{EDO} = 46\ \mathrm{TU_c}$$

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:

$$\mathrm{TUc} = \frac{100}{75}$$

Effluent $\mathrm{TUc} = 1.3$

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

46 TU_c > 1.3 TU_c

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

4. Environmental Risk Assessment – Watershed Approach

MWWE discharges are often one of several sources of pollutant loadings influencing the quality of water bodies. The need to recognize the other users of the water and to integrate MWWE into the total loadings of the watershed is an important new perspective for MWWE management.

When viewed as part of a broader management system, MWWE management allows for innovative and more cost effective approaches to pollutant reduction. The watershed approach follows the same basic steps to environmental risk assessments as the single discharge approach, but the geographic scope, water quality objectives and participation of stakeholders are broader.

4.1 Background

Canada's traditional and current approach to managing MWWE involves assessing each facility on an individual (single discharge) basis. Regulatory controls for discharges are normally applied through a permit or approval system. Requirements may differ between provincial and territorial jurisdictions and are further varied among municipalities. As a result, MWWE discharges are evaluated and managed on an individual basis depending on their specific location and the applicable requirements.

Due to intensified farming practices and the rapid increase in worldwide population over the last 50 years, the cumulative impacts of MWWE discharges have escalated, raising concerns. In order to address these cumulative impacts, various jurisdictions have adopted a "systems approach" to managing MWWE discharges. The new trend steers away from the current fragmented approach of managing MWWE discharges on an individual basis and towards managing discharges holistically throughout the watershed. A review of trends in watershed management in the United States, United Kingdom, France, Australia and New Zealand indicates that managing water resources on a watershed basis is a widely accepted concept in many developed countries.

This section presents the rationale, guiding principles and the when and how for using a watershed approach. It also gives examples of successful implementation of the approach and its associated benefits.

4.2 What is a Watershed Approach?

A watershed approach is tailored to the site-specific circumstances evident in the watershed. It may include:

- Synchronized permits within a basin for several MWWE discharges.
- Synchronized permits within a basin for MWWE and other point source discharges.
- Water quality-based effluent limits, or EDOs, developed using a multiple-discharge modeling analysis.
- Permits which include provisions for non-point dischargers which help meet environmental water quality objectives.

The ultimate goal of the watershed permits approach is to issue permits that consider the conditions of the entire watershed and address the diverse sources of substances within it, not just individual point source discharges.

4.3 When to Use a Watershed Approach

A watershed approach can be used to manage all substances. It simply formalizes a process to allocate a loading limit and assign parts of that limit to known inputs into the system. This approach is highly recommended when targeting substances such as nutrients, because they travel great distances in a watershed and impact larger geographic areas than other substances (such as metals). The levels of these kinds of substances may not be at acutely toxic at the end of the discharge pipe, but over time, and often in concert with other inputs, they can cause unacceptable changes to the receiving environment, such as eutrophication.

A watershed approach is also suggested for managing discharges that meet the following criteria:

- MWWE and other point sources clustered geographically close together.
- MWWE discharges that are impacting downstream users.
- High loadings from agricultural areas.

The approach is also suggested when the assimilative capacity of the receiving water has been reached from one MWWE discharge which has not dissipated before the next water intake.

4.4 Benefits of a Watershed Approach

Because the watershed approach examines the many upstream influences on water quality (other MWWE, other point sources, agricultural loadings, storm water management areas), it has a number of administrative and cost benefits:

- Decision-making between point sources with respect to priority and level of reduction of discharges is optimized.
- Cost for improved water quality is reduced by considering non-point sources.
- Monitoring costs can be reduced due to coordination.
- Public awareness and support is increased.
- Subtle and chronic problems such as cumulative effects can be addressed.

4.5 Guiding Principles

Various principles support a watershed approach to address the increasing cumulative impacts from MWWE discharges. These principles are guided by core environmental values of long-term sustainability and the protection of the natural environment. They are grounded in the development of sound management techniques that are supported by research and science.

Guiding principles:

- MWWE will be managed within the context of watershed water quality objectives.
- Watershed objectives will be set by the water users and managers who regulate the inputs into the water system.
- In establishing the individual discharge limits, the inputs of upstream users and the requirements of downstream users will be considered.
- Source control efforts will benefit from discussion with users, i.e., industries.

4.6 Determining Effluent Discharge Objectives Using a Watershed Approach

This process of developing EDOs for a watershed uses the mass-balance approach to determine appropriate loadings of substances. However, it extends the scope of the loadings beyond one MWWE discharge to include several discharges, storm water discharge areas and non-point sources.

The steps involved in developing a watershed approach are to:

1. Determine the scale and boundaries of the proposed watershed (or portion thereof) where water quality goals will be set and identify existing watershed programs to co-ordinate with and/or build on.
2. Assemble water managers and water users or expand existing watershed management bodies.
3. Establish watershed objectives with water managers and water users. Within these objectives, define key substances of concern, either single substances or critical substances of concern.
4. Measure substance inputs from point and non-point sources.
5. Develop management options and action plans while considering all point and non-point loadings. Identify areas requiring strict load management. Make sure allocations take into account the individual mixing zones within the watershed.
6. Establish permit limits for the watershed, for each contributor and substance.
7. Conduct annual monitoring and feedback to objectives.

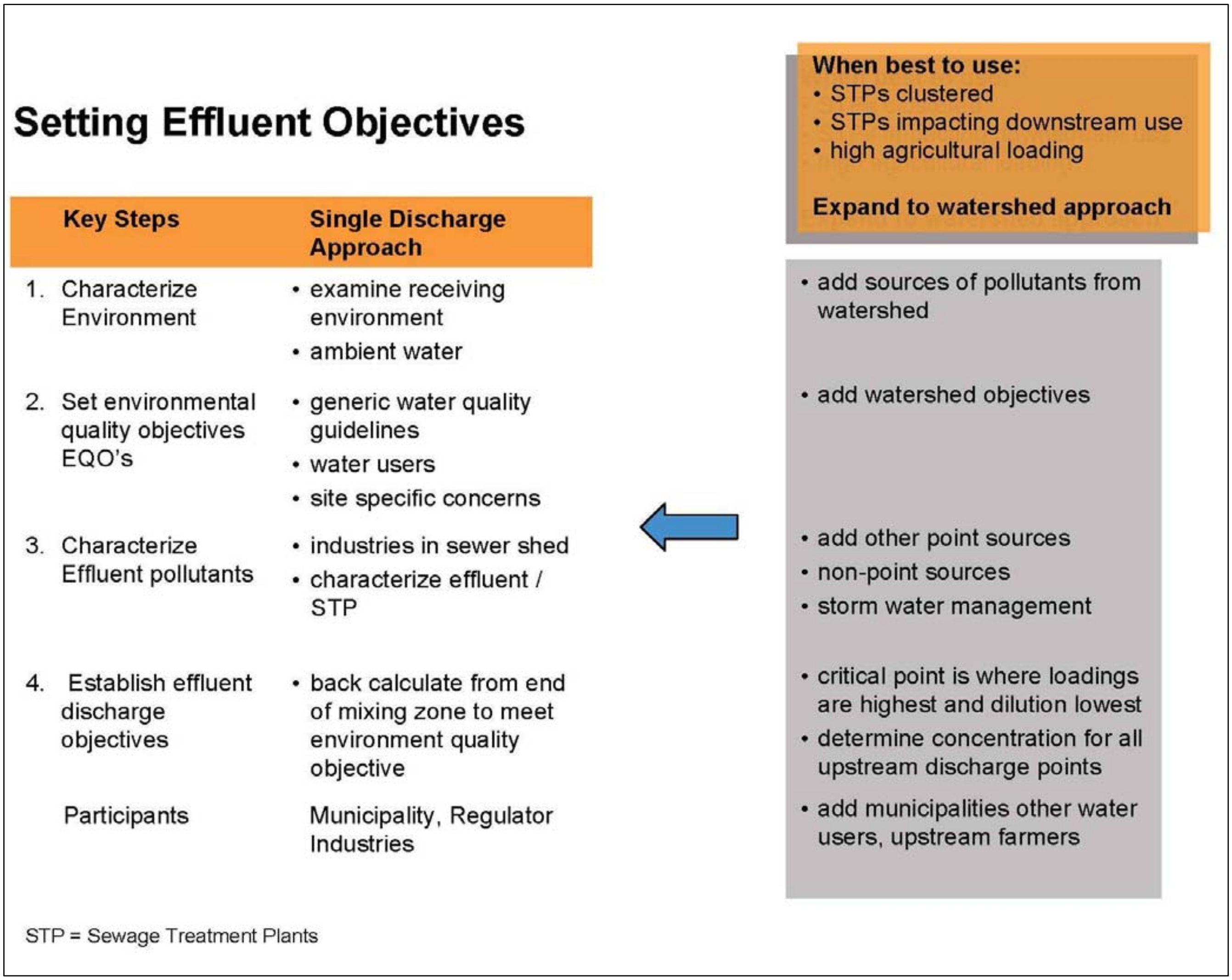
4.7 Integrating the Single Discharge and Watershed Approaches

Whether the single discharge or watershed approach is applied, the same basic steps are used to determine the EDOs:

1. Characterize the environment.
2. Set environmental objectives.
3. Characterize the pollutant sources.
4. Set effluent discharge objectives.

The scope of investigation/interaction differs between the watershed and single discharge approaches; the two processes are easily integrated. Figures 8 and 9 illustrate the additional considerations used in the watershed approach. Essentially, the single discharge approach can be easily expanded to include aspects of the watershed approach, with the following advantages:

- Sources are managed from “up the watershed” as well as “up the pipe.”
- Other point and non point sources (other plants, storm sewers, farm run–off) are integrated.
- A broader range of water users is included in setting objectives. These users can include:
  - other municipalities,
  - industrial, agricultural and recreational users,
  - water managers,
  - monitoring agencies.



Setting Effluent Objectives

When best to use:
- STPs clustered
- STPs impacting downstream use
- high agricultural loading

Expand to watershed approach

Key Steps	**Single Discharge Approach**	
1. Characterize Environment	• examine receiving environment • ambient water	• add sources of pollutants from watershed
2. Set environmental quality objectives EQO's	• generic water quality guidelines • water users • site specific concerns	• add watershed objectives
3. Characterize Effluent pollutants	• industries in sewer shed • characterize effluent / STP	• add other point sources • non-point sources • storm water management
4. Establish effluent discharge objectives	• back calculate from end of mixing zone to meet environment quality objective	• critical point is where loadings are highest and dilution lowest • determine concentration for all upstream discharge points
Participants	Municipality, Regulator Industries	• add municipalities other water users, upstream farmers

STP = Sewage Treatment Plants

Figure 8. Setting Effluent Discharge Objectives

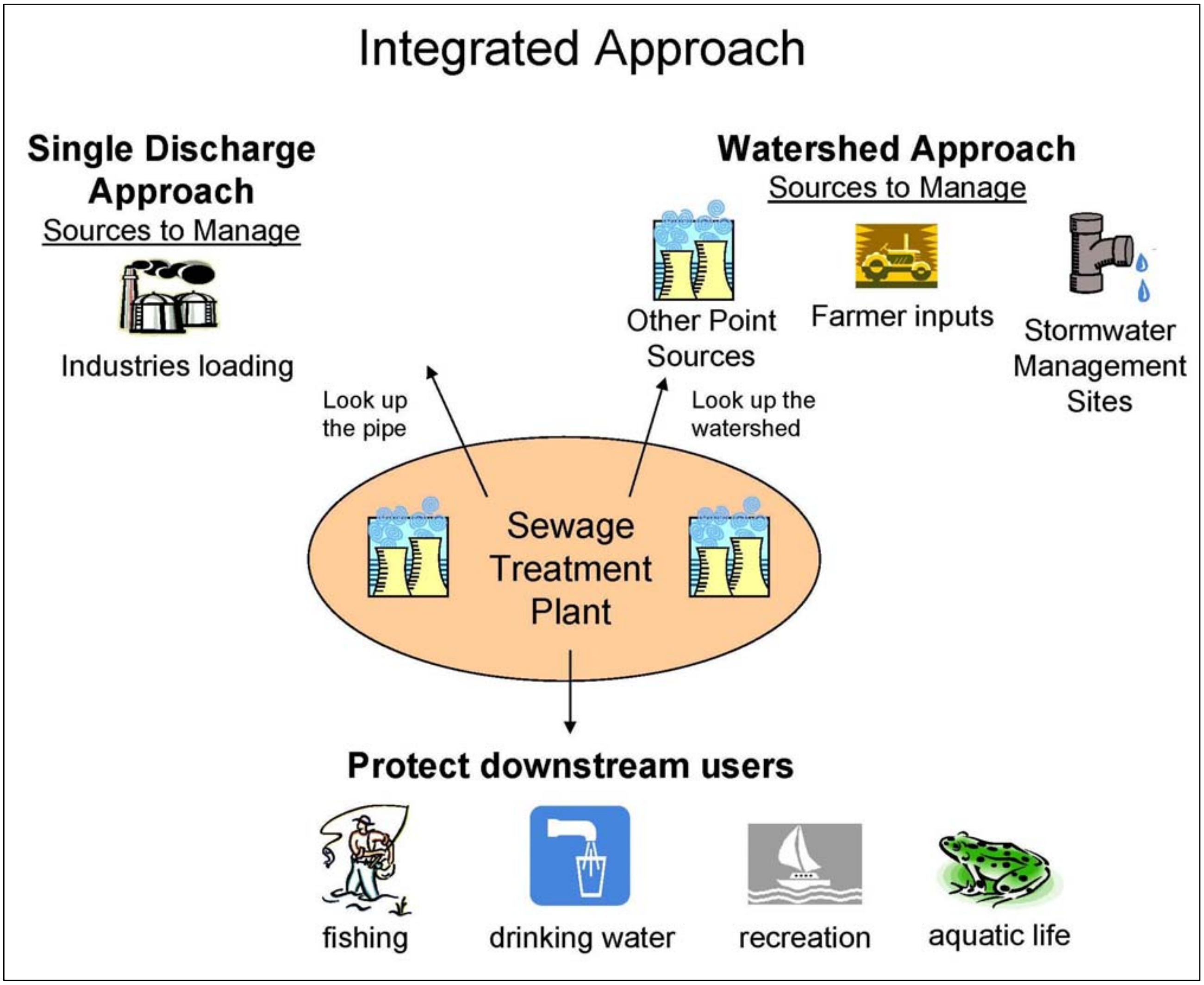


Figure 9. An Integrated Approach

4.8 Implementation and Examples

A watershed approach allows greater flexibility in meeting water quality objectives than a single discharge approach. It includes several factors so costly plant upgrades are only one of several options to improve water quality. Three variations on watershed management of pollutants are examined below:

1. US EPA – Total Daily Maximum Load
2. Watershed Management for Several Plants
3. Water Quality Trading

4.8.1 US EPA – Total Maximum Daily Load

Over the last 20 years, the United States has actively participated in watershed-based management. It has substantially reduced 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 (TMDL) approach to setting effluent objectives accounts for all loadings into a water body. The objective of a TMDL approach is to allocate allowable loads among all of the substance sources throughout a watershed so appropriate control measures can be implemented and water quality standards achieved. If they are not achieved, a water body can be declared 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). 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.

One example of a US initiative that is supporting watershed management is the modification of requirements to the National Pollutant Discharge Elimination System (NPDES) permit program. The NPDES permit program allows states to reorient programs on a watershed basis and 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.

Box 4. Watershed Approach – Truckee River, Nevada

In recent years, 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. 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. 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 TMDLs 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.

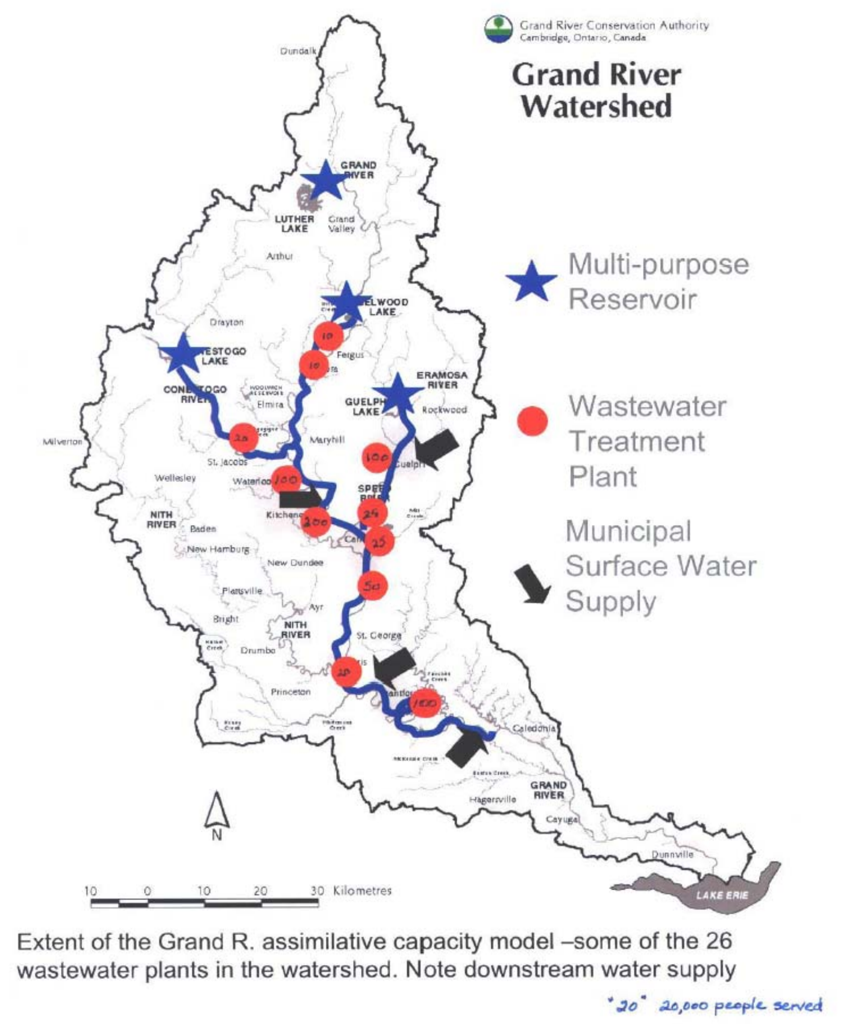
4.8.2 Watershed Management of Several Dischargers

When several wastewater facilities release effluent into a watershed, they can collaborate in setting effluent limits for one substance (phosphorus) to ensure watershed objectives are met.

Box 5. Watershed Approach – Grand River Conservation Authority, Ontario

The Grand River Conservation Authority, as a coordinating body, undertakes monitoring and modeling of dissolved oxygen (DO), nitrogen and phosphorus. Reports of monthly loadings are made regularly to the Water Management Committee which decides on the effluent limits to ensure protection of downstream users. The number of water intakes and wastewater treatment plants serving various populations can be seen in Figure 10. The Regional Municipality of Waterloo, which is responsible for nine 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.

The Grand River Conservation Authority's watershed management strategy involved collaborating with water management agencies and six municipalities situated along the Grand River. Due to the sensitivities of DO 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, 55% of the time.



Extent of the Grand R. assimilative capacity model –some of the 26 wastewater plants in the watershed. Note downstream water supply

"20" 20,000 people served

Figure 10. Grand River Watershed (used with permission of the Grand River Conservation Authority)

4.8.3 Water Quality Trading

In January 2003, the US EPA began recognizing the practice of trading pollutant loads between point sources or mixing point and non-point sources when it 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 exists which motivates wastewater facilities to seek pollutant reductions.
- Sources have significantly different costs associated with pollutant reductions.
- Necessary levels of substance reduction are 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 US, estimated cost savings for the regulated community ranges from hundreds of millions to billions of dollars.

Box 6. Watershed Approach – Lake Simcoe, Ontario

The local municipality of Lake Simcoe recently had to address demands to increase its 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 its local wastewater facility was already operating at maximum efficiency and its Certificate of Approval required the facility 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. First, they determined whether sufficient opportunities existed for urban storm water retrofit trades within the sub-watershed to ensure that the water quality of the local watercourse would not be further degraded. Then, the trading option was evaluated using a trading ratio of 8:1, based on a unit cost phosphorus reduction of $2,500/kg for storm water retrofits. In other words, for every kg of P allowed to be discharged by the plant, 8 kg would need to be reduced from urban runoff through storm water control best management practices. The total cost to the municipality for the trade would therefore be:

8 (trading ratio) X 20 (kg P to trade) X $2,500 (cost/kg P)

= $400,000

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

Box 7. Watershed Approach – 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. The environmental assessment included:

1. An assessment of the current situation and future conditions.
2. Options for treatment.
3. Public consultation.
4. Preferred options for environmental, economic and social reasons.

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 was calculated to be $300/kg P removed. Phosphorus reductions would be administered through the existing Clean Water Program. The cost was calculated based on program experience and was dependent on the amount of phosphorus to be removed as approved by the 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:

160 kg P (discharge) X 4 (offset ratio)
= 640 kg P

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

The cost was calculated as follows:

640 kg P (offset target) X $300/kg P (Clean Water Program Delivery Costs)
= $192,000

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.

Box 8. Watershed Approach – 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. The other half were from non-point sources, primarily individual septic systems and urban runoff. The State of Colorado estimated that in order to maintain the health of Lake Dillon, the amount of phosphorus coming from the four major wastewater facilities would need to be reduced. 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 enough phosphorus would be reduced in the basin to allow the wastewater facilities and new non-point-sources to grow given 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 to 70 per cent 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 of the phosphorus credits allocated to it annually and donated its surplus credits to offset increased phosphorus discharges 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 demonstrates that it is possible to directly measure non-point source loads and, in addition, that trading does not necessarily need a tangible cash transaction for cost savings to occur.

Box 9. Watershed Approach – New Hamburg, Ontario

New Hamburg’s wastewater facility had to address environmental concerns associated with phosphorus effluent discharges, as it had recently reached its 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 offers incentives for local landowners to control the phosphorus discharging into the surface waters. The cost of this program was \$85/kg P reduced, a significant savings over traditional treatment upgrades.

4.9 Potential Challenges

As with any approach used in the management of MWWE, various barriers need to be acknowledged when implementing a watershed-based approach:

1. **Accurate measurement of non-point source discharges.** Approaches commonly used to tackle this barrier include the use of site-specific modeling or the use of monitoring/sampling stations to measure non-point dischargers.
2. **Legal implications of upgrades.** Users who make investments may feel they own the resultant loading reductions.
3. **Lack of sustainable funding.** Strategies for addressing sustainable funding issues include user pays/polluter pays models.
4. **Excessive bureaucracy and politics.**
5. **Weak environmental legislation.** Challenges include inadequate penalties for environmental violations and a lack of national water quality standards and guidelines.
6. **Lack of up-to-date watershed data and useful decision-support tools.**
7. **Lack of technical expertise.** This includes a lack of expertise to tackle the biophysical, social and economic complexities of watershed management.
8. **Resistance to change.** The prevailing focus is typically on a supply-oriented biophysical approach rather than a conservation/efficiency approach.
9. **Unrealistic expectations.** Stakeholders may demand immediate results.

4.10 Future Directions

Water management bodies (Conservation Authorities in Ontario, the BC Watershed Stewardship Alliance, Saskatchewan Watershed Authority, Organismes de basins versants in Quebec*)* currently provide direction for water management. However, many of these agencies focus on water quantity rather than looking at water quality from a watershed perspective.

Operating and coordinating programs on a watershed basis makes good sense for environmental, financial, social and administrative reasons. Because a watershed-based approach puts choice and control in the hands of those who directly manage the watershed, actions are based on shared information and a common understanding of the roles and priorities of the stakeholders involved. It allows managers from all levels of government to better understand the cumulative impacts of various human activities and determine the most critical problems within each watershed. This encourages decision-making in areas where information is available and promotes analysis and scientific verification in areas where information is incomplete.

A watershed-based approach raises environmental awareness and promotes public support. Both acute and chronic effects can be effectively dealt with. Most importantly, managing MWWE from a watershed perspective ensures the most cost effective methods for improving water quality are examined.

5. Effluent Characterization and Monitoring

This section offers guidance on characterizing and monitoring MWWE to determine:

- Which substances in MWWE are of concern (initial characterization).

- If the MWWE complies with the National Performance Standards and other site-specific discharge limits.
- If the MWWE is achieving its EDOs.

It also offers guidance on sampling, preservation and testing procedures and standards, as well as responses to toxicity test failures.

Wastewater facilities are classified into five categories based on annual average daily flow rates for the previous year, as presented in Table 2.

Table 2. Facility Size Categories

Facility Size	**Flow (m^3/d)**
Very Small	≤ 500
Small	> 500 – 2,500
Medium	> 2,500 – 17,500
Large	> 17,500 – 50,000
Very Large	> 50,000

Very small and small facilities which have industrial input associated with MWWE flow are classified as medium size facilities. 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 the industry categories specified below that together exceeds 5% of total dry weather flow in the sewershed 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
- Hospitals and laboratories (but not nursing stations)

Process water from any industry from another category may also be designated as industrial input by a jurisdiction when there is reasonable potential that it may adversely affect the wastewater facility’s operation or capacity to meet discharge requirements or EDOs.

5.1 Initial Characterization of Effluent

A one year initial characterization of the effluent discharge will determine which substances are of concern for the particular wastewater facility and whether EDOs will be needed for those substances (see section 3). Initial characterization of MWWE is the first step in conducting the environmental risk assessment (ERA) (see sections 3 and 4). All facilities will be required to monitor a basic list of substances as set out in Table 3. For medium, large and very large facilities, additional substances and test groups are added, plus any other substances specifically associated with industrial or commercial activities that discharge into the sewer system. Substances of concern are those that are present in the MWWE discharge at concentrations with “reasonable potential” to cause EQOs to be exceeded at the edge of the mixing zone. Once the substances of concern are identified, based on initial characterization results, they should be added to the MWWE regular monitoring program so improvements can be monitored. All substances with mean effluent values over 80% of the EDO value should be monitored. Discharge limits should also be established, whenever possible or practical.

All samples for effluent characterization must be taken at the discharge, before the effluent enters surface waters.

Table 3. Monitoring for Substances and Test Groups for **Initial Characterization** (1 year), Continuous Discharge

Facility Size[1]	**TRC**[2] **(or dechlorination agent)**	**CBOD$_5$, TSS, Pathogens and Nutrients**[3]	**Substances and Test Groups**[4]	**Acute Toxicity**	**Chronic Toxicity**
Very Small	Daily	Monthly	n/a	n/a	n/a
Small	Daily	Monthly	n/a	Quarterly	Quarterly
Medium	Daily	Every two weeks	Quarterly	Quarterly	Quarterly
Large	Twice per day	Weekly	Quarterly	Monthly	Monthly
Very Large	Three times per day	5 days/week	Quarterly	Monthly	Monthly

1. Facilities that discharge less than 10^3/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 such as *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, Surfactants, plus other substances specifically associated with industrial or commercial activities that discharge into the sewer system

For continuous discharges, the monitoring frequency for each wastewater facility size is listed in Table 3. Samples are 24-hour composites, 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. For intermittent discharges in each size classification, two samples should be taken during each discharge period: one sample near the start of the discharge period and one near the end. For facilities with more than one discharge per year, each discharge should be sampled but the number of tests required need not be more than that required for continuous discharges for the same size facility.

All test groups and substances associated with industrial or commercial activities must be completed for each effluent from medium, large and very large facilities over a one year period as shown in Table 3. Very small and small facilities with industrial input are classified as medium facilities and are required to conduct initial characterization of the effluent as per the requirements of a medium facility. Additional information on potential substances in wastewater may be found at http://www.epa.gov/safewater/swp/sources1.html and http://cfpub.epa.gov/npdes/pretreatment/pstandards.cfm#categorical.

Since very small and small facilities typically represent a small risk, they are not required to complete the series of tests required for larger facilities. In these facilities, the risks usually relate to nutrients (TKN [ammonia and organic N], nitrate and nitrite, total phosphorus) and pathogens. Therefore, very small and small facilities are required to monitor only these substances (in addition to CBOD$_5$, TSS and TRC) to determine if EDOs will be required. In some situations, site-specific risk factors may increase the risk. Such factors include the presence of sensitive areas in the nearby receiving water (e.g., fish spawning areas, water intakes, recreational usage, fishing, shellfish harvesting areas) and cumulative impacts from other nearby sources. Where these risks are present, an initial characterization of effluent for substances other than nutrients and pathogens should be conducted in order to confirm the nature of any risk posed by even very small facilities.

Initial whole effluent toxicity testing is included in the monitoring for all but very small facilities. Toxicity testing assesses the integrated effect of the wide variety of substances in an effluent. For both acute toxicity and chronic toxicity, a minimum of two species must be included to address different trophic levels. Recommended acute toxicity tests use rainbow trout and *Daphnia magna* as test species and use either single concentration or multiple concentration test methods. Chronic toxicity tests include both fathead minnow and *Ceriodaphnia dubia* as standard test organisms (see Appendix B for the recognized methods for each recommended test). Other chronic tests may be used, with prior approval of the jurisdiction, to replace the ones listed above or as additional tests when required by site-specific conditions.

Each sample should be flow-weighted and composite in nature, where currently practiced, and taken during days of full commercial and industrial activity when the wastewater facility is operating normally and effluent is being discharged. Days with flows strongly affected by storm or thaw events should be avoided. Samples for all types of tests (see Table 3) should be collected at the same time at the outfall or discharge point. An owner may use existing information, collected within the previous three years, to satisfy all or part of this requirement, provided that no major change has occurred in the wastewater system in the intervening period. Major changes include 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.

Every ten years, or earlier at the discretion of the jurisdiction, an evaluation must be done to determine if significant change that may affect effluent quality has occurred in the wastewater system. If so, the facility must redo the initial characterization of its effluent. If the effluent's character has changed, new or modified EDOs may need to be developed.

5.2 Compliance Monitoring – National Performance Standards

Effluent quality must be compared with the National Performance Standards through effluent compliance monitoring. When National Performance Standards are not achieved, wastewater facilities must look for opportunities to reduce the discharge of substances at the source and/or improve the facility or its operation so the standards can be achieved. Effluent may not be diluted to achieve National Performance Standards or any other discharge limit.

All monitoring samples are taken at the discharge, before the effluent enters surface waters.

5.2.1 Continuous Discharge Facilities

Compliance with the National Performance Standards must be continuous and therefore requires regular and continuing monitoring. Table 4 identifies the minimum monitoring frequencies for National Performance Standard substances.

Table 4. Minimum Compliance Monitoring Frequencies for National Performance Standards, Continuous Discharge

Facility Size	TRC[1] (or dechlorination agent)	TSS and $CBOD_5$	Period for calculation of 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 m^3/d, in which case averaging period would be annual.
3. For compliance with the National Performance Standards for $CBOD_5$ and TSS. Period is based on facility size and does not change for facilities that may have a higher monitoring frequency.

TRC is monitored only if chlorine or chlorine compounds are used in the treatment process. It must be measured on site, owing to its rapid degradation. If dechlorination is also practiced, the dechlorination substance may be monitored; measuring any residual amount of the dechlorination substance is considered to be equivalent to no TRC present.

Effluent flow from each outfall must also be monitored each day to calculate the total volume of effluent discharged each day and the annual daily average flow. Flow may be monitored with a system that takes continuous measurements or by using a method that meets generally accepted engineering principles, such as standard methods for measuring liquid flow in open channels or measuring fluid flow in closed conduits. These standard methods are published by the International Organization for Standardization. Flow monitoring equipment should have an accuracy of ±15% over the entire range of expected flows and should be calibrated at least once per year.

5.2.2 Intermittent Discharge Lagoons

For lagoon systems that only discharge periodically, typically once or twice per year, one sample is required during each discharge period. The sample must be taken during the last half of the discharge period and analysed for TSS, $CBOD_5$ and, if chlorination is practised, TRC or the dechlorination chemical used. For discharge periods of more than one month, samples should be taken every two weeks, with at least 5 days between samples.

Compliance with the National Performance Standards for $CBOD_5$ and TSS is based on yearly averages of the bi-weekly results obtained during the discharge or on a single result for discharges of less than one month. For discharges that do not occur every year, the National Performance Standards for $CBOD_5$ and TSS apply when there is a discharge.

As with continuous discharge facilities, effluent flow from each outfall must be monitored each day during which effluent is discharged in order to calculate the total volume of effluent discharged each day and the annual average daily flow. Flow may be monitored with a system that takes continuous measurements or by using a method that meets generally accepted engineering principles, such as standard methods for measuring liquid flow in open channels or measuring fluid flow in closed conduits. These standard methods are published by the International Organization for Standardization. Where wastewater is trucked rather than piped, flow may be estimated using generally accepted engineering principles.

5.3 Monitoring of Effluent Discharge Objective Substances

Based on the initial characterization results and the ERA, EDOs are established for certain substances on a site-specific basis (see sections 3 and 4 for details). All substances with mean effluent values over 80% of the EDO value should be monitored. Monitoring frequency would not necessarily be the same for all substances since some substances are very expensive to measure and/or analytical expertise may not be available locally. Monitoring requirements are specified in site-specific regulatory instruments (e.g., permits, certificates, licenses, regulations) issued by the jurisdiction.

If ongoing monitoring results for a substance are consistently less than 80% of the EDO value, the monitoring frequency for that particular substance can be reduced when the regulatory instrument is periodically reviewed or the instrument allows it. Should the average effluent discharge quality subsequently exceed 80% of the EDO, the monitoring frequency must return to the initial, more frequent one. On the basis of at least twenty consecutive results spread over at least one year that measure less than 80% of the EDO value, monitoring for that substance can be eliminated. Every ten years, or earlier at the discretion of the jurisdiction, an evaluation must be done to determine if significant change has occurred in the wastewater system that may affect effluent quality. If so, the facility must return to the initial monitoring frequency. Reduced monitoring frequencies or elimination of monitoring cannot be applied to phosphorus, ammonia and pathogens.

When all substance EDOs are being achieved, no other action with respect to those substances is required. Otherwise, risk management is needed (see section 6).

5.4 Toxicity Testing

Medium to very large facilities, including very small and small facilities with industrial input, must conduct acute and chronic toxicity tests on an ongoing basis. The same requirements apply to both continuous and intermittent discharges. Toxicity testing may also be required on a site-specific basis for small and very small facilities where a risk has been identified and regulatory authorities incorporate the requirement into their regulatory instrument. Toxicity test samples must be collected at the end-of-pipe as either composite samples or as grab samples. Samples must be taken at least three weeks apart for monthly testing and at least two months apart for quarterly testing.

For acute toxicity testing, either the single concentration or multiple concentration rainbow trout test following method EPS 1/RM/13 and *Daphnia magna* test following method EPS 1/RM/14 is required. Test failures are defined as effluent at 100% concentration that kills more than 50% of the test organisms during the specified test period.

For chronic toxicity testing, the fathead minnow test following method EPS 1/RM/22 and *Ceriodaphnia dubia* test following method EPS 1/RM/21, both using serial dilutions, are required. Test failures are defined as observed chronic effects during the specified test period and a result, expressed in TU_Cs, higher than the chronic WET EDO. Toxicity testing species and minimum testing frequencies are presented in Table 5.

Table 5. Toxicity Testing Requirements

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 -*Daphnia magna*	Quarterly	-Fathead minnow -*Ceriodaphnia dubia*	Quarterly
Large	-Rainbow trout -*Daphnia magna*	Quarterly	-Fathead minnow -*Ceriodaphnia dubia*	Quarterly
Very Large	-Rainbow trout -*Daphnia magna*	Monthly	-Fathead minnow -*Ceriodaphnia dubia*	Monthly

The test methods for acute and chronic testing are listed in Appendix B.

When the effluent has been found to meet the EDO (i.e., no failed test) for a particular toxicity test over the previous 12 months for continuous discharge facilities or over four discharge periods for intermittent discharge facilities, the facility can reduce its frequency for that test. Medium facilities can reduce the frequency of toxicity testing to quarterly tests once every three years. For large and very large facilities, toxicity testing frequency can be reduced to quarterly testing every second year and quarterly testing every year, respectively. If the effluent fails a test during any period of reduced toxicity testing frequency, the facility must return to the testing frequency set out in Table 5 until the effluent is again non-toxic over 12 months of testing for continuous discharge facilities or over four discharge periods for intermittent discharge facilities.

The first year of toxicity testing is considered to occur during the initial characterization phase (see section 5.1).

Further work is needed to determine when a species can be eliminated from regular toxicity testing. Conditions which may allow for the elimination of a test species may include when the test has 20 consecutive passes spread over at least one year.

Every ten years, or earlier at the discretion of the jurisdiction, an evaluation must be done to determine if significant change has occurred in the wastewater system that may affect effluent quality. If significant change has occurred, the facility must return to the initial species and frequencies, as described in Table 5.

5.5 Sampling and Analytical Testing Methods

Sampling should be done by qualified personnel and in accordance with ISO 5667-10, *Water quality – Sampling - Part 10: Guidance on sampling of waste waters* or another recognized guidance document. Except for substances like fecal coliforms or TRC, where instantaneous samples are necessary, effluent samples should be 24 hour composite samples preferably collected proportional to flow. For lagoons or other very long hydraulic retention treatment processes, instantaneous grab samples can be accepted if it is demonstrated that the quality of the wastewater does not change during the day. Samples for the National Performance Standards, EDOs and toxicity testing should be collected at the same time insofar as possible.

Effluent from a wastewater facility must be sampled upstream of the point where the effluent enters the receiving water body and downstream of any treatment process, including disinfection. Sample handling, preservation and testing should be done in accordance with the most recent edition of the *Standard Methods for the Examination of Water and Wastewater*, or other recognized standards. All testing should be done by an accredited laboratory (e.g., Standards Council of Canada, CAEAL, Canadian Association of Environmental Analytical Laboratories, or CEAEQ, Centre d’Expertise en Analyse Environnementale du Québec).

The test to determine the $CBOD_5$ of an effluent is described in subsections 5210A and 5210B, with the inhibition of nitrification, of *Standard Methods for the Examination of Water and Wastewater*, 21st Edition, 2005, published jointly by the American Public Health Association, the American Water Works Association and the Water Environment Federation, as amended from time to time. An equivalent test method required by or authorized under the law of the province or territory where the wastewater facility is located may also be used. The quantity of $CBOD_5$ should be measured in an unfiltered sample.

The test to determine the presence and quantity of TSS in effluent is described in subsections 2540A to 2540E of *Standard Methods for the Examination of Water and Wastewater*, 21st Edition, 2005, published jointly by the American Public Health Association, the American Water Works Association and the Water Environment Federation, as amended from time to time. An equivalent test method required by or authorized under the law of the province or territory where the wastewater facility is located may also be used.

The test to determine the presence and quantity of TRC in effluent is the applicable method described in subsections 2350A to 2350B of *Standard Methods for the Examination of Water and Wastewater*, 21st Edition, 2005, published jointly by the American Public Health Association, the American Water Works Association and the Water Environment Federation, as amended from time to time. An equivalent test method required by or authorized under the law of the province or territory where the wastewater facility is located may also be used.

Where an effluent is chlorinated and subsequently dechlorinated, the effluent may be tested for the dechlorination substance instead of TRC since any excess or presence of the dechlorination substance is indicative of complete dechlorination and the absence of residual chlorine. The test method for the dechlorination substance must be a standard method.

Tests to determine other substances must be done according to standard methods recognized by regulators. Detection limits must be sufficiently low to enable comparison with EDOs established for the facility.

5.6 Toxicity Failures and Toxicity Reduction Evaluation

5.6.1 Toxicity Test Failure

When a facility fails an acute toxicity test or the chronic toxicity test result exceeds the EDO, it is required to determine and correct the cause of the failure through a Toxicity Reduction Evaluation (TRE). A TRE is a site-specific study conducted in a stepwise fashion to achieve this end. A TRE may be as simple as reviewing the treatment plant operations and effluent chemistry and making minor adjustments, or may involve a more complicated series of laboratory investigations and extensive corrective measures. The first step in the TRE is a requirement to immediately (within 5 days) conduct another toxicity test using the same species that failed the first test. The second test must be a multiple concentration test in order to provide additional information on the nature and cause of the toxicity. If the second test passes, the cause may be transient and thus difficult to identify. A third multiple concentration test, with sampling one week after the second test was started, is required. If both the second and third tests pass, the facility can return to its regular testing frequency set out in Table 5. If either the second or third test fails, further TRE activities must be undertaken.

Facilities that do not yet meet the National Performance Standards, where the cause of toxicity is known and control measures to address the cause are not yet implemented, do not have to conduct additional tests (i.e., second and third tests described above). Typically, this would occur where an upgrade in treatment level is required, but has not yet been implemented. When upgrade of treatment to meet the National Performance Standards is necessary in order to eliminate toxicity, the toxicity elimination timeline becomes the same timeline as for the National Performance Standards. In the mean time, facilities continue normal testing frequencies.

A generalized process on the implementation of a TRE is shown in Figures 11-A and B and explained in more detail in the text that follows. If there is more than one species failure, the facility must go through the process for each species.

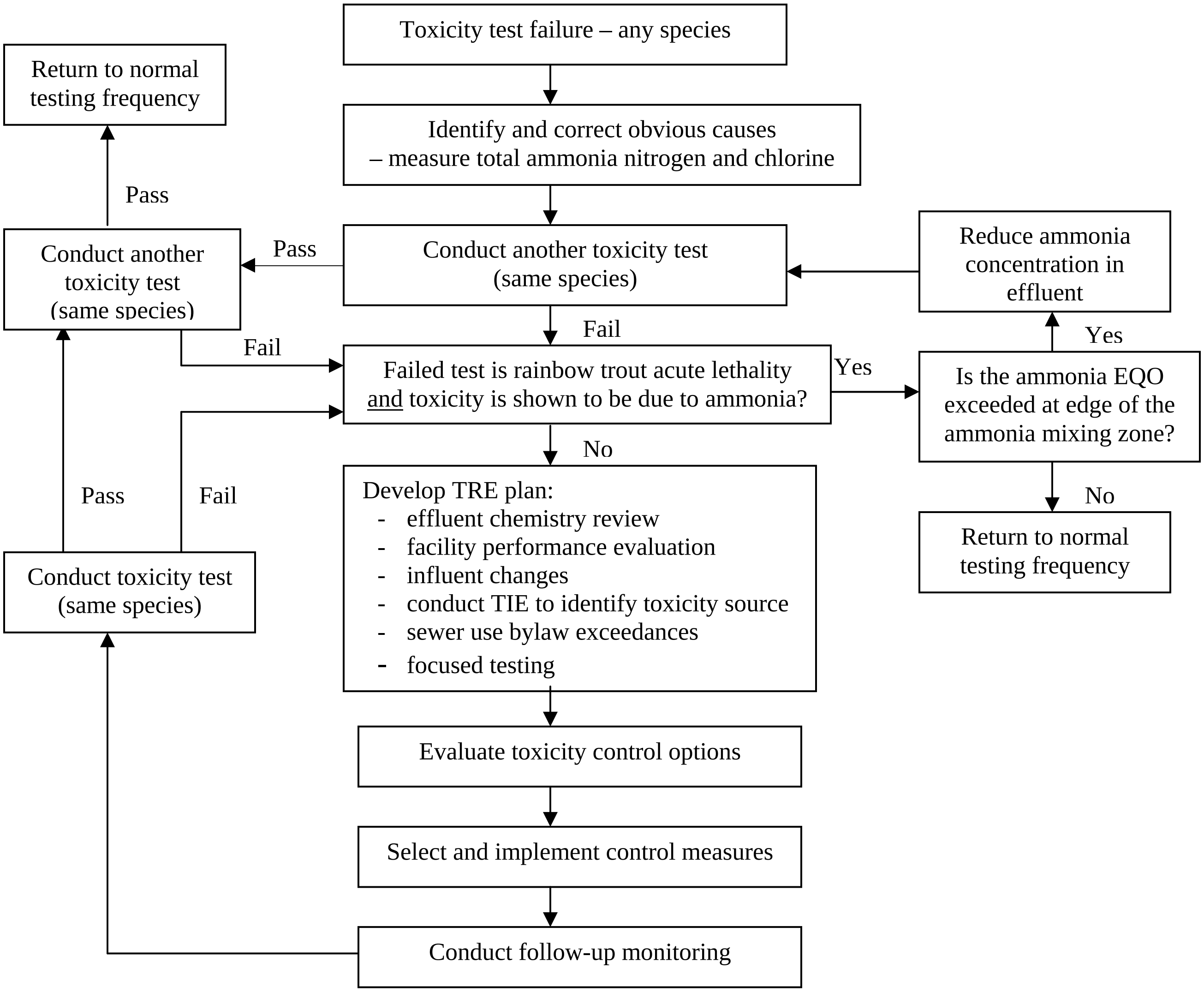
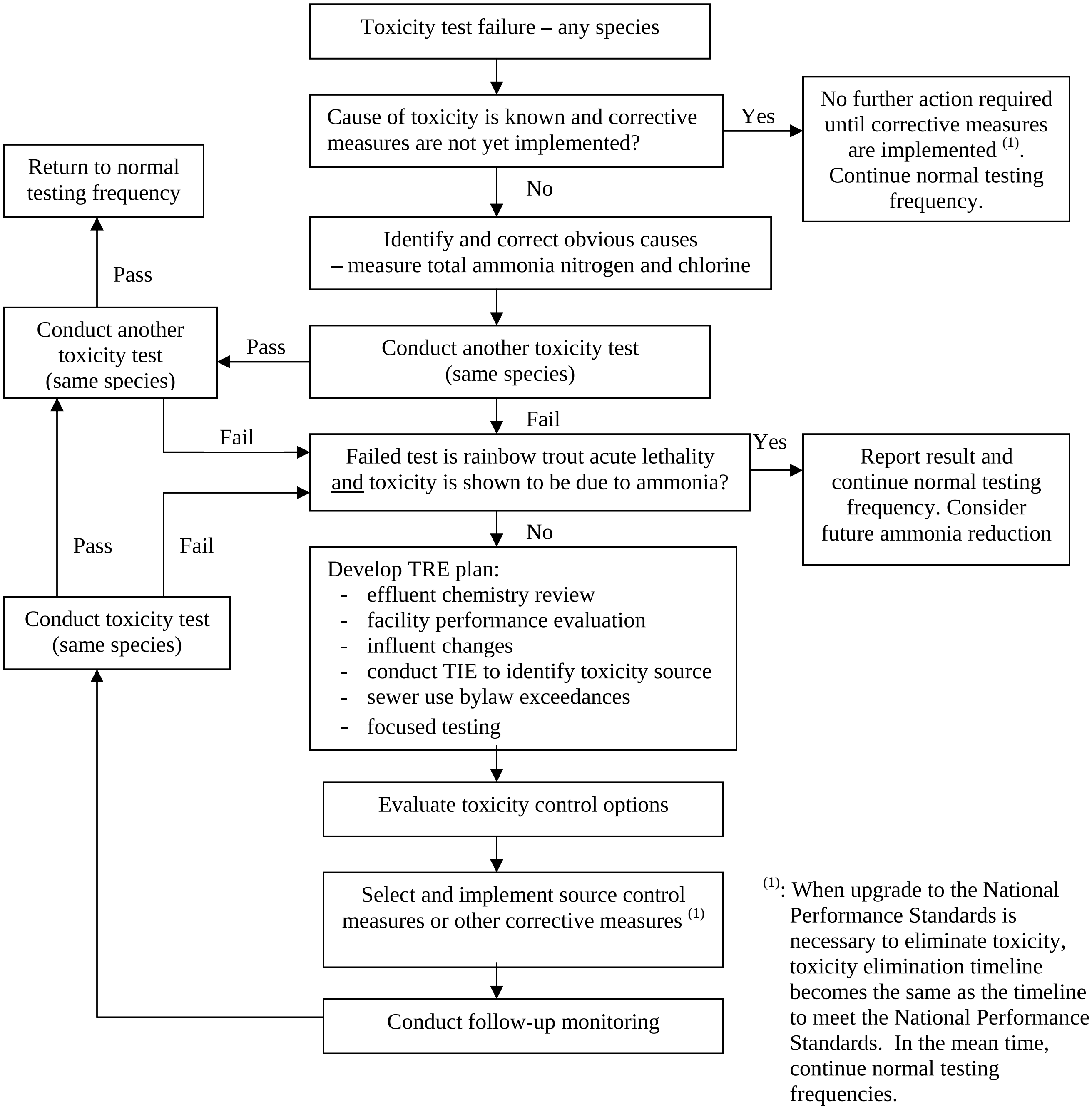


Figure 11-A. TRE Process for facilities **that meet the National Performance Standards**



(1): When upgrade to the National Performance Standards is necessary to eliminate toxicity, toxicity elimination timeline becomes the same as the timeline to meet the National Performance Standards. In the mean time, continue normal testing frequencies.

Figure 11-B. TRE Process for facilities that **do not yet meet the National Performance Standards**

5.6.2 Initial Toxicity Reduction Evaluation Response

Following the first toxicity test failure, the facility should review available data to determine if there is a readily apparent cause for the failure(s), such as a malfunction or a change in the influent. The operator should have data on system operations, flow rates, unusual or upset conditions, or other information that may quickly and easily identify the cause and suggest corrective action(s). It is prudent to sample and analyze the toxicity samples for TRC and ammonia since the data may assist in quickly confirming or ruling out the most common causes of toxicity. Subsequent toxicity tests may confirm that the effluent is no longer toxic (the facility may return to the testing frequency in Table 5) or may be used to further investigate the cause of the toxicity. If the cause is not apparent from available data or the corrective action(s) is (are) not successful in eliminating the cause of the toxicity, further investigation is warranted.

5.6.3 Ammonia as a Potential Toxicant

Ammonia is commonly associated with acute toxicity in MWWE. Since fish are more sensitive than invertebrates to ammonia, their response is assessed most often in investigations of ammonia toxicity.

In the case of a rainbow trout acute lethality test failure, the wastewater facility should determine, if not already available, the concentration of ammonia (total ammonia expressed as nitrogen) in, and the pH of, the effluent during the test. Referencing these values to the curve in Figure 12 (abstracted from Environment Canada's *Guideline for the Release of Ammonia Dissolved in Water Found in Wastewater Treatment Plants*) will indicate if ammonia is a likely cause for concern with the effluent. The ammonia concentration (y) corresponding to any pH (the points on the curve) may also be calculated using the following equation:

$$y = 306132466.34 \text{ x } (2.7183^{(-2.0437 \text{ x } pH)})$$

If the concentration-pH data point falls on or above the threshold concentration curve, the effluent is considered to contain an acutely toxic concentration of ammonia (i.e., the effluent ammonia concentration is above the estimated LC_{50} at the pH of the exposure). Since the curve was developed using pH-adjusted data, such an ammonia concentration would be high, and the wastewater facility should consider actions to reduce the ammonia concentration to a non-acutely toxic level. If the concentration-pH data point falls below the threshold concentration curve (in the shaded area), the effluent may not contain an acutely toxic concentration of ammonia.

When it is determined that acute toxicity is due to ammonia, based on the curve in Figure 12, the wastewater facility must then determine whether the ammonia chronic water quality guideline (or EQO) is exceeded at the edge of a mixing zone. This mixing zone (not necessarily the same as for calculating EDOs) is established based on criteria presented in section 3.3.2 and the following limits: does not exceed 100 m in any direction from the discharge (including each discharge port in a diffuser) and does not exceed 33% of the stream or river flow at a low flow of 7Q10 (seven-day low flow over 10 years). The ammonia concentration at the edge of this mixing zone is estimated by theoretical modeling using the measured ammonia concentration at the end-of-pipe and comparing it to the applicable water quality guideline (such as the *Canadian Water Quality Guidelines*) for ammonia. If the estimated ammonia concentration at the edge of the mixing zone is below the water quality guideline, there is no concern for chronic toxicity and the discharge is acceptable with respect to ammonia. If the estimated ammonia concentration at the edge of the mixing zone is above the water quality guideline, there is concern for chronic toxicity and actions must be taken to reduce the ammonia concentration in the effluent such that (1) the effluent is no longer acutely toxic or (2) there is no chronic toxicity at the edge of the above described mixing zone.

Facilities need to be aware of the fact that although the process described above may be followed and fully implemented to manage acute toxicity due to ammonia at the end-of-pipe, the nature of the discharge and of the receiving environment may also lead to the establishment of an ammonia EDO to deal with the chronic toxicity outside an allocated mixing zone Facilities may still have to do what they can to reduce ammonia concentrations when the ammonia EDO has not yet been achieved (see Section 6).

When it is determined that toxicity is not due to ammonia, based on the curve in Figure 12, or when toxicity is to species other than rainbow trout, the wastewater facility must undertake a toxicity reduction evaluation (TRE), as shown in Figures 11-A or -B.

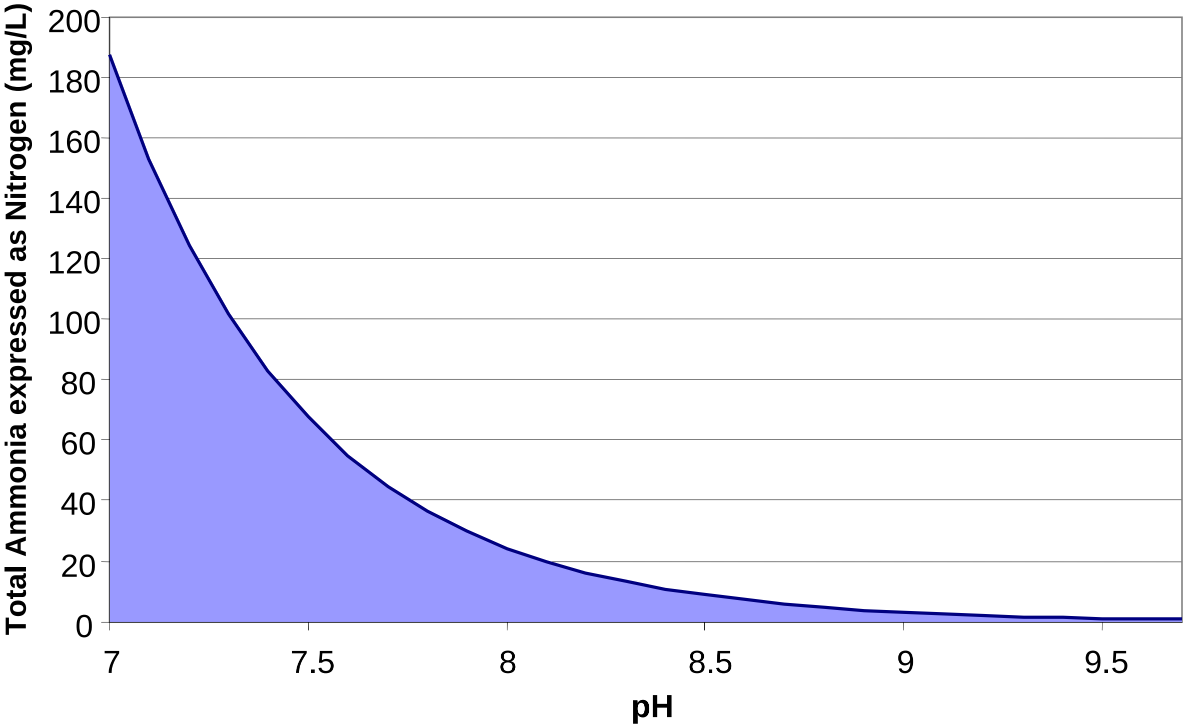


Figure 12. Threshold Acute Concentration of Total Ammonia Nitrogen versus pH

5.6.4 Subsequent Toxicity Reduction Evaluation Response

If the toxicity of the effluent cannot be attributed to a cause or source in a preliminary investigation, further efforts are required. The following general steps may be taken when developing and implementing a TRE plan:

- Evaluate the operation and performance of the wastewater facility to identify and correct treatment deficiencies contributing to effluent toxicity (e.g., operational problems, chemical additives, incomplete treatment).
- Review effluent chemistry for likely toxicants.
- Carry out a laboratory Toxicity Identification Evaluation (TIE) to characterize, identify and confirm the toxicant(s).
- Trace the effluent toxicant(s) and/or toxicity to its sources.
- Evaluate, select and implement toxicity reduction methods or technologies to reduce effluent toxicity to an acceptable level.

The cause of the toxicity failure may be obvious, such as an operational failure in the wastewater facility or a marked change in the influent. Analysis of the facility performance logs or data should provide some insight into this kind of cause. If there is no obvious cause for the toxicity failure, the facility should consider whether it has sufficient information on the duration and magnitude of the toxicity to pose a reasonable opportunity to identify the cause. Additional chemical and toxicological sampling should be undertaken as soon as possible to better detail the magnitude and frequency of the toxicity and to help identify the toxicant. This may be a formal TIE or somewhat less formal as long as progress is made towards improved effluent quality.

It is not feasible to detail a universal work plan leading to specific TIE or TRE activities. Each case is unique and decisions on an appropriate approach should be made by individuals experienced in the application of these tools. Further guidance can be obtained from the US EPA publication *Toxicity Reduction Evaluation Guidance for Municipal Wastewater Treatment Plants* (available at http://cfpub.epa.gov/npdes/docs.cfm?document_type_id=1&view=1&program_id=13&sort=date_published). However, it is incumbent on wastewater facilities to develop a plan that presents a probable chance of identifying the toxicant(s) within a reasonable time period and to initiate actions to reduce the toxicity to an acceptable level as quickly as possible. Results from initial TRE activities should provide direction for subsequent testing and activities. Regular compliance monitoring with respect to National Performance Standards and EDOs must be continued during the development and implementation of a TRE program.

Intermittent or ephemeral toxicity may be difficult to identify and therefore to correct. In these cases, modifications to normal TIE and TRE procedures may be required in an attempt to identify and reduce the toxicity.

Where an effluent has failed a toxicity test and the owner has embarked on a TRE program, and even when an obvious cause of toxicity has been identified and corrected, the owner must conduct toxicity tests at least at the frequency indicted in Table 5 for at least one year after the cause of toxicity has been corrected, in order to confirm that the correction has been effective. Toxicity tests should be conducted as soon as possible after corrective measures have been taken. The effect of the corrective measures should be observable in the effluent.

In cases where the effluent continues to fail toxicity tests, all tests should be conducted using the multiple concentration (LC_{50} for example) approach in order to follow the progression of the magnitude and the rate of reduction of the effluent toxicity.

5.7 Overflows

Overflow events (CSOs and SSOs) must be recorded in order to assess the frequency and severity of overflows. There should be no dry weather overflow. Overflows may be monitored for frequency of flow through simple mechanical measures that clearly indicate flow has occurred and that are reset quickly after a storm event. Where possible and feasible, the volume or duration of an overflow should be recorded or estimated using more sophisticated methods and equipment, starting with major CSOs or those causing the greatest concern. The data should be recorded, along with information on storm event and snowmelt event occurrence (dates) and severity (rainfall), in order to help design any required mitigation of CSOs. Further guidance can be obtained from the US EPA publication *Combined Sewer Overflows Guidance for Monitoring and Modeling* (available at http://www.epa.gov/npdes/pubs/sewer.pdf).

6. Risk Management Decision-Making

This section offers guidance on how to make environmental risk management decisions when MWWE discharges are not meeting EDOs. The risk management decision process described below is directed at the main effluent discharge, but can be adjusted for use with overflows.

Since risk management decisions are based on the level of risk, wastewater facilities need to determine the level of risk posed by an exceedance. An EDO exceedance does not necessarily mean the receiving environment is in immediate danger. Rather, risk is related to the magnitude and frequency of exceedances. Monitoring in the receiving environment (water quality, biota, etc.) or of drinking water quality (for EDOs related to drinking water objectives) can be used to determine the real impacts of EDOs not being achieved. EDOs are objectives and should not automatically be translated into discharge requirements.

6.1 Risk Management Decision Process

When an EDO is exceeded, efforts must be made to reduce the discharge of the substance of concern (or frequency/volume of overflows) as much as possible, by looking for opportunities to reduce it at one or more stages of the wastewater system: sources, collection, and treatment. Owners should determine:

- The magnitude and frequency of the exceedance.
- The source of the excess contaminant (or the cause of excess overflow frequency/volume).
- The mechanisms available to reduce the contaminant discharge and their cost.
- The feasibility of using these mechanisms (i.e., is the technology available and at a reasonable cost).
- The side effects from using the corrective measure (effects on biosolids, effects on meeting other discharge limits, etc.).

Facility owners should also consider the relative importance of the substance in the wastewater discharge compared to other contributors in the watershed; the wastewater discharge could be comparatively insignificant. When upstream concentrations are already high, the discharge may be tolerated at concentrations equivalent to upstream concentrations, even if the objective remains the same. This situation could conversely indicate that no new discharge should be allowed in the watershed and that a watershed plan should be established.

In sewage dominated streams (i.e., when the effluent flow represents the total flow of the immediate receiving stream for more than 90% of the year), the jurisdiction could decide to apply the mixing zone where the stream empties into a larger, year round receiving body of water. This is likely the worst-case situation, as any flow in the intermittent stream will augment dilution of the effluent. Remember that compliance monitoring for the National Performance Standards takes place at the end of the discharge pipe.

Risk management decisions must also consider funding possibilities and availability, societal values and stakeholder input (see Figure 13). Owners should determine what internal and external funding sources are available to address the costs of reduction measures and to determine if the costs and measures are socially acceptable. Internal funding sources include tax rates or user fees based on full cost accounting.

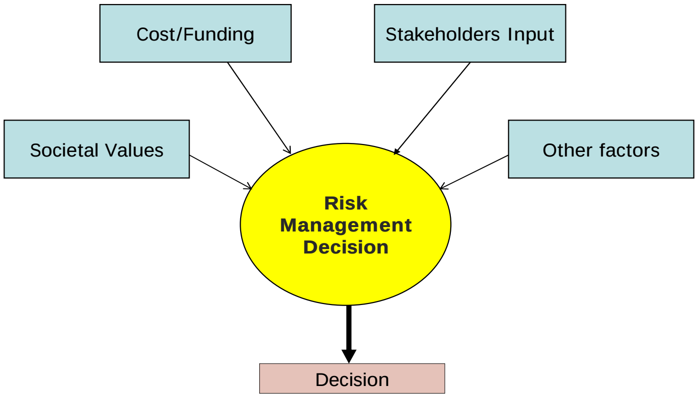


Figure 13. Risk Management Decisions

The analysis leading to risk management decisions is site-specific and cannot be specified in detail. The various factors involved in it are suggested above but the exact mechanism of how they are used, what weight each one carries, etc., must be left to discussion between the owner and the people the facility serves, and between the owner and the regulatory authorities. As a general rule, though, owners should address higher risks first.

After the analysis, facility owners have two options:

1. Implement contaminant reduction measures (see discussion on reductions later in this document):
    - After reduction measures are in place, compare the discharge quality to the EDO to ensure that measures have been effective. If the EDO is still not achieved, another risk management decision is needed. This process is repeated until all the EDOs are achieved.
2. Establish interim discharge limit(s):
    - Revisit the environmental risk assessment and the derivation of the EQO and EDO to ensure the EDO is still valid.
    - Establish interim discharge limit(s) for substance(s), based on the established level of performance for the available/affordable technology, and risk.
    - Periodically review the discharge limit(s), available technology and funding possibilities, in order to lower discharge limits to the EDO(s) as soon as feasible.

The first option is preferred, but in some cases the owner may not, with reasonable effort, be able to further improve the wastewater quality for technical, financial, societal or other reasons. A risk management analysis may indicate that nothing more can be done at the time. In these cases, the jurisdiction may specify an interim discharge limit in a permit. The EDO then becomes a long term goal that the owner must always strive to attain. The interim discharge limit must be reviewed periodically in order for it to be reset as soon as possible to a level as close as possible to the EDO.

All permitting authorities should have an instrument, such as a renewable permitting system, for periodically reviewing effluent discharge limits and improving progress toward EDOs. In the United States, for example, all MWWE discharges are required to have a permit under the National Pollutant Discharge Elimination System (NPDES). NPDES permits are typically issued at five-year intervals on a site-specific basis, taking into consideration the impact of the proposed discharge on the quality of the receiving water relative to the state Water Quality Standards (Minnow Environmental, 2005). Effluent limits, monitoring conditions, standard and special conditions are specified in the NPDES permit. Special conditions may include special studies, additional monitoring, pollution prevention, compliance schedules and other conditions related to the National Pretreatment Program, sewage sludge, combined sewer and sanitary sewer overflows, and separate storm sewer systems. For more information on the NPDES, see: http://cfpub.epa.gov/npdes/.

6.2 Reduction at the Source

Controlling substances at their source is usually the best solution, where practical. Preventing substances from entering the sewer system or treating small quantities of concentrated wastewater is simpler and less costly than treating large quantities of a dilute wastewater. Preventing substances from entering the sewer system means these substances won't wind up in the MWWE, in the sludge, in air emissions or in overflows, and won't affect treatment performance or worker safety at the wastewater facility.

Controlling sources of pollution can be done in a number of ways, including: substance prohibition, pollution prevention programs (P2 plans), sector control programs, use of the 'Local Limits' methodology developed by the US EPA, sewer use by-laws, demand side water reductions (water conservation), and public education (see Figure 14). A model sewer use bylaw has been prepared as a tool to support municipalities in implementing the Strategy (available at www.ccme.ca). Further details on controlling sources of pollution are described in *Source Control Tools* (Marbek, 2006), *Wastewater Source Control* (InfraGuide, 2003) and briefly in the sections that follow.

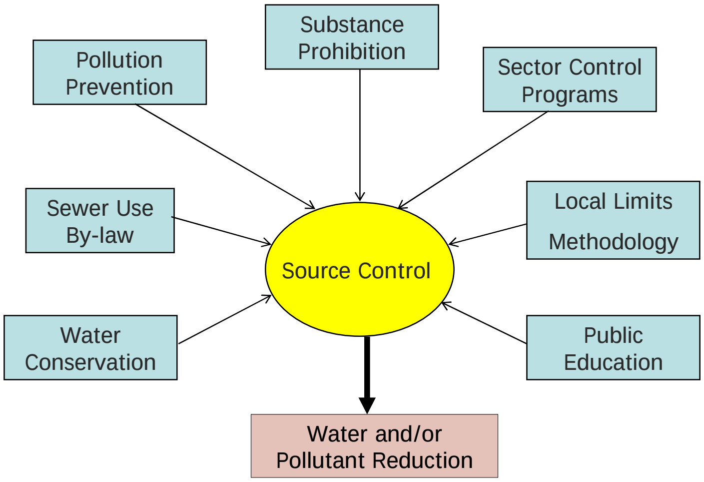


Figure 14. Reduction at the Source

Substance Prohibition
Under the *Canadian Environmental Protection Act (1999)*, the Canadian government can prohibit or restrict the use of substances that are considered toxic under the Act. Provincial, territorial and municipal governments can also restrict the use of substances within their jurisdictions, where they have the authority to do so.

Pollution Prevention Programs
Pollution prevention programs encourage industry, businesses, institutions and the public to eliminate, minimize or reduce sources of pollution, including those going into the wastewater collection system. Approaches that anticipate and prevent the generation of contaminants are preferred over other reduction methods such as treatment, reuse and recycling. The goal is to make pollution prevention the strategy of choice for protecting the environment and improving economic competitiveness.

CCME (1993) has developed the following principles to guide pollution prevention:

- All Canadians are individually and collectively responsible for the quality of the environment and should be involved in pollution prevention wherever they have the opportunity to do so.
- Prevention activities and associated costs should be borne by the producers of contaminants and waste.
- All jurisdictions should cooperate to harmonize their individual approaches to prevention.
- Voluntary action, regulation and economic instruments all have important, and often complementary, roles to play in pollution prevention. All approaches for prevention should be considered, with a view to using the most effective approach, or combination of approaches. Voluntary actions will be encouraged.
- Prevention should be considered at the earliest possible point in the development of any concepts, plans, policies, products, projects or processes.
- Pollution prevention planning should be a continuing process, incorporating opportunities for improvement on an ongoing basis, such as new scientific and technological developments.
- Prevention should apply throughout the entire life-cycle of a product.
- An ongoing effort should be made to ensure that prices better reflect the full costs of pollution (full cost accounting), in order to understand the real benefit of prevention.
- Full use should be made of pollution prevention opportunities to achieve greater domestic and international competitiveness.

All methods of source control should begin with and incorporate the principles of pollution prevention.

Sector Control Programs

Sector control programs target specific sectors that cause pollution and examine potential strategies for eliminating or reducing their contaminant discharges in wastewaters. Because specific sectors that contribute significant contaminant loads are targeted, early action is possible in a clean-up program. Since all industries within that sector are subject to the same controls and it is at the discretion of the producer to select the best method to achieve results, there is no competitive disadvantage for industries within the jurisdictions covered by the controls. Information on clean-up technologies specific to the sector can be cost shared and/or specifically developed for the particular waste reduction requirements. An example of this type of program is the pulp and paper sector’s efforts to eliminate or reduce pollution from its wastewater stream, which was adversely affecting the receiving waters and aquatic life.

Local Limits

The US EPA has developed a National Pretreatment Program to prevent contaminants that pass through, interfere with, or are otherwise incompatible with publicly owned treatment works (POTWs) from discharging to sewers. A local pretreatment program is required for all POTWs with:

- Design flow > 5 million gallons/day (MGD) (18 900 m^3/d)
- Design flow < 5 MGD, with significant industrial users

Three types of standards apply to discharges to sewer:

- Prohibited Discharges (general prohibitions)
- Categorical Standards (technology based – divided into 35 industrial sectors)
- Local Limits (take into account site-specific factors)

Local limits are developed by POTWs to protect their operations and to ensure that their discharges comply with state and federal requirements. These limits are necessary when greater control over industrial discharges is needed than provided by the general prohibitions and categorical standards. Factors to be considered when developing local limits include:

- The POTWs efficiency in treating wastes
- The POTWs history of compliance with permit limits
- The receiving water body’s condition
- Water quality standards that are applicable to the receiving water body

- The POTWs retention, use and disposal of sludge
- Worker health and safety concerns

Since the local limits methodology was developed to better control industrial users and is designed to take local conditions into consideration, it could be useful and readily adaptable to Canadian conditions. Pretreatment standards and limits, and a manual entitled *Local Limits Development Guidance*, can be found on the US EPA's website: http://cfpub.epa.gov/npdes/pretreatment/pstandards.cfm#local

Public Education

Public education is an essential component of all source reduction programs and is an effective means of reducing quantities of wastewater on its own. Public education programs need to be directed at all wastewater generators (residential, commercial, industrial and institutional) and to address both the quantity and quality of wastewater.

Wastewater quality can be improved and quantity reduced by implementing the three "R's" of pollution reduction: reduce, replace and recycle. Environmentally responsible procurement programs, such as the Environmental Choice Program[1] and Gippers Guide to Environmental Purchasing,[2] can help consumers and organizations select less toxic substances as substitutes in their use of cleaners and chemical processes, and water-saving fixtures and appliances that generate less wastewater.

Educational programs promote environmentally-friendly consumption and disposal habits through outreach activities that target audiences through radio, television, newspapers and magazines, the Internet, flyers, posters, newsletters, environmental and community groups, and schools and universities.

Water Conservation

Water conservation can reduce the demand for expanding wastewater facilities and improving the effectiveness of existing treatment operations by concentrating wastewater, making it easier to treat. It can also reduce the occurrence of sewer overflows.

Individuals and organizations can reduce the amount of water they use by replacing existing fixtures and appliances with water-conserving ones (e.g., toilets, taps, shower heads, dishwashers, washing machines). Industries can review processes to save, substitute, reuse or redirect uncontaminated water away from the sanitary sewer. By saving water, efficiencies are realized through reduced energy, water and wastewater collection and treatment costs.

Water conservation can be achieved by regulatory (bylaws, plumbing codes, CSA standards, etc.) and non-regulatory methods (public education, subsidies, incentives and user-fee schedules for water and wastewater treatment). Municipalities should implement a volume-based rate scheme and rates that reflect the true costs of water treatment and distribution, wastewater collection and treatment and other associated costs, to encourage water conservation.

Sewer Use Bylaws

Sewer use bylaws are an essential component of every wastewater source control program, but their success requires effective education, monitoring and enforcement programs (with penalties). They can limit the concentration and toxicity of wastewaters entering the system, prohibit discharge of some contaminants into the system, and require that users implement pollution prevention programs and pre-treat their wastewater. The City of Toronto has one of the most modern and comprehensive sewer use

---

[1] Available at www.environmentalchoice.com

[2] Available at www.pmac.ca/PDF/gipper.pdf

bylaws in Canada.[3] A model sewer use bylaw has been prepared as a tool to support municipalities in implementing the Strategy[4].

Permitting and Wastewater Rates

Municipalities can establish permit systems for major sewer users where discharge-to-sewer limits can be set (maximum daily loads, flows, etc.). This measure is important not only to promote reduction, but also to prevent wastewater treatment upsets. Wastewater rates should also be charged to users based on volumes of discharge. Economic incentives not only encourage users to reduce, but promote a user-pay approach that ensures a fair allocation of treatment costs.

6.3 Municipal Wastewater Treatment

In many cases, wastewater facilities provide adequate treatment; however, when improvements are required, certain factors must be considered (see Figure 15).

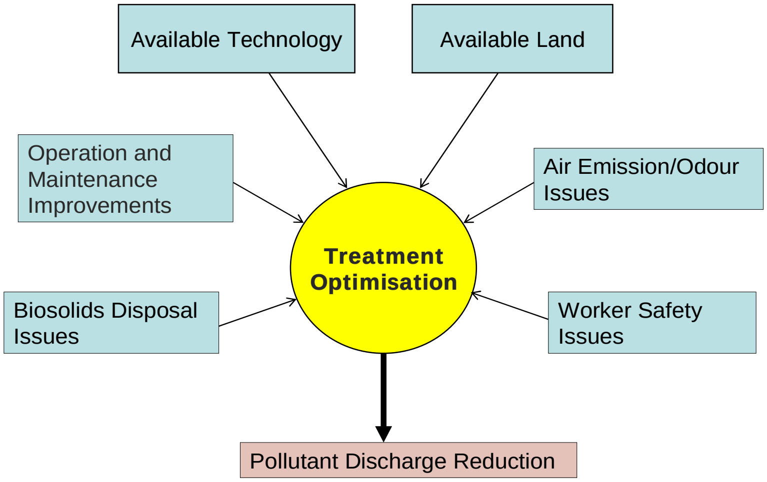


Figure 15. Factors to be Considered when Improving Wastewater Facilities

Wastewater facilities accelerate the natural process of degradation. Primary treatment is a physical process whereby solids are settled out of the system. Chemicals may be added to enhance the amount of solids that settle in a given period of time. Secondary treatment provides for biological degradation of particulate and dissolved wastes in wastewater. Tertiary treatment is any additional process, whether physical, biological or chemical, used on a site-specific basis to remove more of a particular contaminant and to address a specific risk. Often, a disinfectant such as chlorine or ultraviolet light is introduced as the final step to reduce the concentration of pathogenic organisms present in the effluent, thus protecting human and environmental health. Lagoon systems provide sufficient retention time for natural biodegradation to occur and can sometimes accomplish enough pathogenic organism reduction to meet EDOs without additional equipment. Wastewater facilities may also remove some of the additional contaminants (e.g., detergents, cleaners, solvents) deposited into sewers from households and from industrial, commercial and institutional sources, but they are incapable of removing many of the commercial and industrial wastes that are often discharged to the collection system. A report prepared by Hydromantis Inc. (2005) titled *Review of the State of Knowledge of Municipal Effluent Science and Research –Tasks 2 and 3*, provides additional information on wastewater treatment processes and what they can remove.

---

[3] Available at www.city.toronto.on.ca/legdocs/municode/1184_681.pdf
[4] Available at www.ccme.ca

Where EDOs are exceeded, owners should first look at ways to improve the operation and maintenance of their existing wastewater facilities. For example, better chemical dosing, aeration or control of the treatment process can lead to additional removal of substances. Computer programs can help simulate operational modifications.

The InfraGuide titled *Wastewater Treatment Plant Optimization* (2003) provides an overview of an approach for optimizing existing facilities. *Optimization of Lagoon Operation* (2004) is a similar guide that deals specifically with lagoon facilities. Tools such as benchmarking practices and the ISO 14001 certification for environmental management can help bring about continuous improvement of wastewater facility operations . Further details can be found in the *National Water and Wastewater Benchmarking Initiative* and in a Water Environment Research Foundation report titled *Benchmarking Wastewater Operations: Collection, Treatment, and Biosolids Management* (1997). Hydromantis (2005) provides additional information on wastewater treatment quality control practices.

When operational and maintenance improvements (and efforts to reduce substances at the source) are insufficient, the owner must then investigate modifying the wastewater facility with available technology. When further removal of suspended solids is needed, improvements could include adding filtration. When further removal of biochemical oxygen demand is needed, owners could consider additional aeration and residence time in the biological treatment unit. For further nutrient removal, it is generally necessary to add chemical precipitation for phosphorus removal, retrofit or add to an existing biological treatment system to provide for ammonia removal (nitrification) or install a tertiary treatment stage to reduce nitrogen and/or phosphorus levels.

Ammonia creates a unique site-specific issue because it is a nutrient (contributing nitrogen) for some organisms, but is toxic to fish at certain concentrations. Its toxicity is directly dependent on the pH and temperature of the receiving water, with critical conditions typically occurring in the summer period. Improved removal of ammonia can be achieved through the installation of secondary treatment with nitrification or retrofitting the existing secondary treatment system for additional nitrification. This can be done by providing media to which nitrifying bacteria can attach.

Additional wastewater treatment will generally create more solids and biosolids, which enhances the removal of metals and organics that tend to bind to solids. While this improves wastewater quality, appropriate disposal of contaminated solids and biosolids must be ensured to prevent degradation of other environmental media.

When modifications or additional treatment are considered, the different options have to be analyzed by a professional engineer to determine the costs, advantages and disadvantages of each. A description of this type of analysis is beyond the scope of this document.

Owners must take into account other impacts associated with the introduction of additional treatment, as well as the financial costs of improvements and the benefits of improved effluent quality. Issues associated with increased production of contaminated solids and biosolids, air emissions and odors, worker safety, and so on, must be considered. Owners should consider as many parameters as practicable when assessing the need for additional treatment.

7. Environmental Monitoring

The extent of environmental monitoring programs should be based on risk. For MWWE, the core risk elements can be identified as (1) sensitivity of the receiving environment, (2) size of the facility (flow of the effluent discharge) and (3) composition of the effluent. The proper design of a receiving environment monitoring program is a complex task which has not yet been completed. These details will be developed within 5 years.

8. Combined Sewer Overflows and Sanitary Sewer Overflows

Combined sewers are designed to carry both storm water and wastewater. They were popular in the 1800s when little or no treatment was required and populations were smaller. Currently, no jurisdiction in Canada allows new combined sewers or combined sewer extensions to be built. Today’s combined sewers remain from times past. Unfortunately, they combine the worst aspects of the problems associated with both wastewater and storm water. Wastewater contains domestic and industrial waste and therefore a large number of contaminants. Storm water is dilute but with very high volumes on an irregular basis. Because runoff volumes are high, large combined sewers are necessary to carry the storm water (and wastewater) away quickly to avoid flooding. Because the flows are so high and variable in combined sewers, interceptors and treatment plants cannot be designed for all storm or thaw events. Overflow structures and outfalls are located at strategic points within the sewer system to allow combined sewer overflows (CSOs) to occur when the capacity of the system is exceeded. Unless combined sewers are transformed into separate sewers, CSOs cannot be completely avoided.

Separate sanitary sewers convey only concentrated municipal wastewater, undiluted by extraneous water, to the wastewater facility. Because the wastewater is concentrated, treatment is very efficient. When the infiltration of groundwater and inflow of storm water (I/I) are kept low, flows are minimized and predictable, which makes facilities required to convey and treat the wastewater easy to design, dependable, smaller and cost effective. Correctly designed and constructed sanitary sewers should not have overflows. However, sanitary sewer overflows (SSOs) do occur from electrical or mechanical failure in pumping stations, blockage of sewers, or from I/I into the sanitary sewers. During storm events or high water table periods, old and poorly constructed and maintained sanitary sewers can experience problems with excess water in the sewer system.

In this document, partially separated sanitary sewer systems, in which inflow from roof leaders and/or foundation drains is conveyed to the sanitary sewer, are considered as part of a sanitary sewer system.

Box 10. Inflow and Infiltration

Inflow is storm water that enters the sewer system directly from roof downspouts, area and driveway drains, foundation drains, manhole covers or connections from public storm drains. It should not occur in a separated sanitary sewer. Inflow normally results in a rapid increase to the sanitary sewer flow during storm events. Infiltration is groundwater or storm water that enters the sewer system through defects in pipes and manholes. Groundwater infiltration typically causes relatively slow, long-term increases in flow corresponding to seasonal changes in groundwater levels. Infiltration from storm water can be rapid as the water moves through the ground and into the pipe and manhole defects and breakages.

A framework similar to that used for effluent discharges can be used for overflows (see Figure 16). Since overflows occur periodically, objectives for these are different from EDOs. Narrative statements, rather than concentrations and/or loads, are more practical.

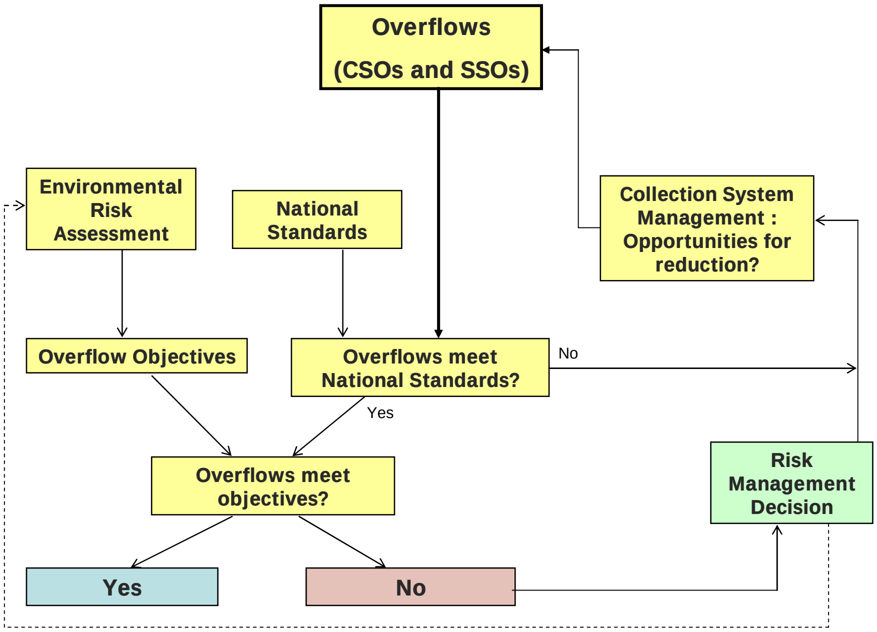


Figure 16. Environmental Risk Management Framework for Overflows

8.1 Combined Sewer Overflow Reduction

Under the Strategy, three national overflow standards are established for CSOs:

a. No increase in CSO frequency due to development or redevelopment, unless it occurs as part of an approved CSO management plan.
b. No CSO discharge during dry weather,[5] except during spring thaw and emergencies.
c. Floatable materials will be removed, where feasible.[6]

In addition to these standards, overflow objectives should be established to protect the beneficial uses of the receiving environment. For example, overflows should not occur upstream from designated areas such as fish spawning sites, beaches and drinking water intakes. Wastewater carrying industrial or hospital waste should not overflow either. Frequency, volume and/or treatment objectives should be set.

Some provinces have general overflow objectives. Ontario's *Procedure F-5-5: Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems* asks for the capture and treatment of all dry weather flow plus 90% of volume resulting from wet weather flow above the dry weather flow, for a seven month period starting within 15 days of April 1. It also asks for the primary treatment of overflows, even for satellite wastewater facilities. Ontario also has specific beach protection objectives. These include no violation of the body contact recreational water quality objective at swimming and bathing beaches and no more than two overflow events per season (June 1 to September 30). British Columbia's *Municipal Sewage Regulation* specifies that no CSO should occur during storm or snowmelt events with less than a five year return period. It also asks for an average of 1% per year total volume reduction of CSOs and at least primary treatment of discharges. Quebec has site specific objectives, including no CSOs within 1 km of drinking water intakes or shellfish harvesting sites, no CSOs into or immediately upstream from fish spawning sites, and a maximum of one CSO per

---

[5] Dry weather is defined as any time where flows in combined sewers are not affected by runoff generated by storm events or snow melt.

[6] Where feasible, every CSO structure should at least be equipped with a baffle or a screen that can separate floatable materials from discharge.

month in a continuous flow zone or one CSO per two months in an accumulation zone where human activities occur during periods where these activities occur.

Since facilities have no control over weather, frequency objectives may not be achieved every year. However, they should be achieved when comparing results obtained over a number of years.

The following steps are recommended to control CSOs:

1. Record CSO events, at least on an occurrence basis.
2. Achieve the national overflow standards (see above).
3. Demonstrate at a facility level that everything that can be done with existing equipment is being done to limit CSO occurrences.
4. Develop a long term plan to reduce CSOs and capture substances. The long-term plan should be based on achieving jurisdictional overflow objectives.

When overflow objectives are not achieved, wastewater facilities should consider several options in their long-term plans, including reducing overflows through sewer system separation and storage techniques, reducing substance release through treatment, and relocating outfalls (see Figure 17). Since the highest concentrations of substances in CSOs occur during what is called the "first flush" (the early part of a high rainfall event after a prolonged dry spell), as this is when many of the substances that have accumulated on the streets and in the sewers are washed away, it is particularly important to capture the early portions of CSOs.

Combined sewers should have CSO discharge limits (in the form of frequency and/or volume limits), or treatment requirements, as close as possible to established overflow objectives. Ontario's *Procedure F-5-5: Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems* and the *Combined Sewer Overflow Treatment Technologies Manual* (XCG Ltd, 2004), a report prepared for Environment Canada, have sections that can help owners prepare a long term CSO abatement plan. Long-term plans should establish priorities based on risk.

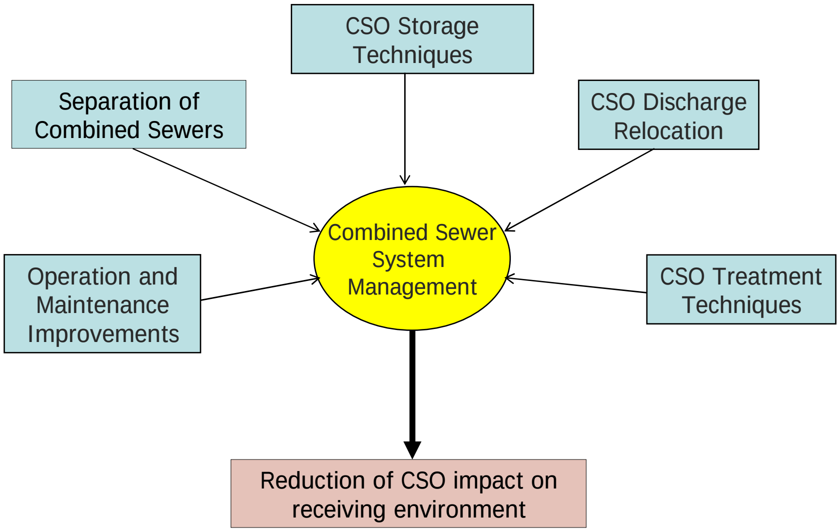


Figure 17. Combined Sewer System Management

8.1.1 Transformation to Separate Sewer System

The best way to reduce the occurrence of CSOs is to replace the combined sewer system with a separate sewer system. Most provinces encourage existing combined sewers to be transformed into separate systems. Even transforming part of the system is beneficial. Usually, the existing combined sewer becomes the storm water sewer since its capacity was designed for the larger storm water flows, and a new sanitary sewer is built. However, in highly urbanized areas, sewer separation may not be advisable as storm sewers may also be highly contaminated.

8.1.2 Outfall Location

CSOs should have a well located outfall to get the wastewater out into water bodies where the contaminants will not be problematic. When an existing outfall is located in an area where it is having an impact on the receiving environment and overflow reduction efforts are insufficient, relocation of the outfall should be considered.

8.1.3 Storage Facilities

Small storm volumes are sometimes stored in oversized sewer lines, tanks or tunnels which discharge to the wastewater facility when the storm flows abate. Real time management tools exist to optimize the storage of the excess wastewater. Long term plans should start with modeling the sewer system so options can be simulated. Options should include in-pipe storage, storage tanks placed in strategic locations and real time management of these during different events.

8.1.4 Treatment Facilities

Treatment facilities for CSOs are physical-chemical due to the intermittent nature of the flows. Disinfection can be included in the facility. Facilities most often store the sludge and floatables removed during the storm event to be sent to the wastewater facility when the storm flows subside. The *Combined Sewer Overflow Treatment Technologies Manual* (XCG Ltd, 2004) can help owners select a CSO treatment technology.

8.1.5 US EPA Combined Sewer Overflow Control Policy

Published in 1994, the US EPA has a very comprehensive CSO control policy (59 *Federal Register* 18688). It is intended to provide guidance to permittees with CSOs, permitting authorities, state water quality standards authorities and enforcement authorities. This very comprehensive policy can be used by jurisdictions as a model to help develop their own CSO control policy, and owners and permitting authorities to help build long term CSO reduction plans required by the Strategy.

The policy’s objectives include:

- Ensuring CSOs only occur as a result of wet weather, if at all.
- Bringing all wet weather CSO discharge points into compliance with the technology-based requirements of the Clean Water Act (CWA).
- Minimizing CSO impacts on water quality, aquatic biota and human health.

Its key principles are as follows:

- Clear levels of control that meet health and environmental objectives should be provided.
- Sufficient flexibility should be provided to municipalities, especially financially disadvantaged ones, to consider the site-specific nature of CSOs and to determine the most cost-effective means of reducing contaminants and meeting CWA objectives and requirements.
- A phased approach to implementation of CSO control should be allowed, considering financial capability.
- Water quality standards and their implementation procedures should be reviewed and revised to reflect site-specific wet weather impacts of CSOs when developing CSO control plans.

Under the policy, municipalities are obligated to implement the “Nine Minimum Controls” (see below) as soon as possible (initially by January 1, 1997) and to develop a long-term CSO control plan that will ultimately result in compliance with the requirements of the *Clean Water Act*. The nine minimum controls are the following (see US EPA, 1995):

1. Proper operation and maintenance programs for sewer system and CSOs
2. Maximum use of collection system for storage
3. Review and modification of pretreatment requirements to minimize CSO impacts
4. Maximization of flows to the POTW for treatment
5. Prohibition of CSOs during dry weather
6. Control of solid and floatable materials in CSOs
7. Pollution prevention
8. Public notification of CSO occurrences and impacts
9. Monitoring to characterize CSO impacts and efficacy of CSO controls

The minimum elements of a long-term CSO control plan are:

- Characterization, monitoring and modeling of combined sewer system
- Public participation
- Consideration of sensitive areas
- Evaluation of alternatives
- Cost/performance considerations
- Operational plan
- Maximizing treatment at the existing treatment plant
- Implementation schedule
- Post-construction compliance monitoring program

The permitting policy is implemented in two phases:

- Phase I permits – Requirements for Demonstration of Implementation of the Nine Minimum Controls and Development of the Long-Term CSO Control Plan.
- Phase II permits – Requirements for Implementation of a Long-Term CSO Control Plan.

8.2 Sanitary Sewer Overflow Elimination

Good design and construction techniques, combined with an adequate maintenance program, should ensure that SSOs are minimized. Corrective measures can be similar to those used for combined sewer systems or may involve rehabilitation of the sanitary sewer system so the problems with inflow and infiltration are corrected to the point where overflows from the system are avoided.

All SSOs should be monitored and reported, at least on an occurrence basis. Since SSOs should not occur, the objective is elimination through corrective measures. This may not always be possible in cases where inflow and infiltration problems are severe, but as a minimum, the following national overflow standards must be achieved:

- SSO frequencies should not increase due to development or redevelopment; and
- SSOs should not occur during dry weather, except during spring thaw and emergencies.

8.2.1 Inflow and Infiltration

Inflow and infiltration (I/I) related overflow reduction methods can be classified under two basic strategies or approaches. In the first strategy, I/I is accepted into the system and then accommodated by construction of relief sewers, storage, and/or additional pumping and treatment capacity, similar to combined sewer overflow control strategies. The second strategy involves using rehabilitation techniques to reduce the amount of I/I entering the sewer system and to eliminate I/I sources. Rehabilitation techniques include repair or replacement of defective sewer pipes and manholes and disconnection of inappropriate direct drainage connections to the sanitary sewer system.

Rehabilitation is the preferred overflow reduction method because it allows the sanitary sewer system to operate as it should, with no overflows and no degradation of wastewater treatment efficiency. However, some I/I problems are so severe that they require a combination of both of the above strategies. The extent to which each strategy is used is often determined by a technical and economic evaluation of all the possible alternatives and the available receiving environments. Usually a study needs to be done to document existing overflow locations, quantify the I/I flows and evaluate the capacity of the existing facilities prior to determining the best overall strategy to correct I/I problems. The InfraGuide on I/I called *Infiltration/Inflow Control/Reduction for Wastewater Collection Systems* (2003) can help owners develop an I/I control/reduction program.

8.2.2 Inflow Rehabilitation Techniques

Eliminating inflows into the sanitary sewer generally means disconnecting inappropriate connections. Inflow problems can generally be corrected by (a) disconnecting inappropriate inflow sources and (b) rehabilitating manholes. Inappropriate inflow sources include storm drain laterals, roof and area drains and foundation drains directly connected to the sanitary sewer system. These sources are usually located during smoke testing, dye testing and field inspection. Their disconnection is usually inexpensive and the benefits substantial. Foundation drains and sump pumps connected to the sanitary sewer are redirected to either a surface drain or a storm drain. Rehabilitation of manhole frames and covers minimizes the surface water flowing into the manhole and generally involves plugging holes in the cover, sealing the lid between the frame and cover and raising manhole frames to minimize water getting to the covers.

8.2.3 Infiltration Rehabilitation Techniques

Infiltration correction can involve excavating and replacing sewers and manholes, sliplining sewers (sliding a flexible liner pipe into an existing sewer), cured in place pipe lining (inserting resin impregnated felt tube into pipe and cure in place) or chemical grouting (applied under pressure to fill voids in background sewer material). Service lateral corrections can be made using similar techniques. The InfraGuide called *Selection of Technologies for Sewer Rehabilitation and Replacement* (2003) provides municipalities with a method of selecting the best technologies available to rehabilitate or replace sections of their collection systems based on current practices and on local issues and conditions.

9. Risk Level and Implementation Timeline

9.1 National Performance Standards

All new and upgraded wastewater facilities covered by this strategy are required to meet the National Performance Standards immediately. Existing facilities that are already meeting the National Performance Standards must continue to do so. Those that do not meet the National Performance Standards will be required to meet the standards within a number of years, depending on the level of risk and financial sustainability. Additionally, jurisdictions may establish more stringent limits than the National Performance Standards require.

For each existing facility that does not already meet the National Performance Standards, the implementation timeline to meet the Standards will be based on risk criteria that reflect characteristics of both the discharge and the receiving environment. The risk criteria use readily available, objective information to calculate a level of risk – high, medium or low – that corresponds to the overall timeline – 10, 20, 30 years – established for implementation.

A series of risk criteria have been developed, with various levels within each criterion being assigned a point value to indicate a relative level of risk. For any facility, the sum of the point values places the facility within a band that is assigned an overall risk level and to a corresponding time period to be in compliance with the National Performance Standards.

The risk criteria and point levels are shown in Table 6 and explained below.

Table 6. Criteria for Calculation of Risk Level for Facility Effluent

Facility Size (flow)	Very small	5 points
	Small	10 points
	Medium	15 points
	Large	25 points
	Very large	35 points
$CBOD_5$/TSS (average)	$\left(\frac{CBOD5}{25} + \frac{TSS)}{25}\right. \times 5$	as per formula
TRC	chlorination, no dechlorination	10 points
	i.e. TRC >0.02 mg/L	
Ammonia	Acutely lethal as per Figure 12	20 points
Receiving Environment Type or Affected Use – highest value that applies	Open marine	5 points
	Marine port	10 points
	Lake, reservoir	20 points
	Enclosed bay, marine estuary	20 points
	River with bulk flow ratio >100	15 points
	River with bulk flow ratio 10 - 99	20 points
	River with bulk flow ratio <10	25 points
	Drinking water intake within 500 metres downstream	25 points
	Shellfish harvesting area (past or present) within 500 metres	20 points
	Areas used for contact recreation within 500 metres downstream	20 points

The point values for the five criteria in Table 6 are added to indicate an overall risk level and consequent implementation timeline for each facility to achieve the National Performance Standards. High risk (greater than 70 points) corresponds to an implementation timeline of 10 years. Medium risk (50 to 70 points) corresponds to an implementation timeline of 20 years. Low risk (less than 50 points) corresponds to an implementation timeline of 30 years.

Where the owner of a facility is subject to the *Notice Requiring the Preparation and Implementation of Pollution Prevention Plans for Inorganic Chloramines and Chlorinated Wastewater Effluents* under the *Canadian Environmental Protection Act*, 1999 (i.e. any person who owns a wastewater facility where the effluent released to surface water is greater than or equal to 5 000 m^3 per day, based on an annual average, and where the concentration of total residual chlorine in the effluent exceeds 0.02 mg/L in any sample, based on representative sampling), the implementation timeline for the National Performance Standard of 0.02 mg/L TRC is December 31, 2010, notwithstanding the timeline calculated by the risk criteria above.

9.1.1 Criteria Definition

Facility Size

This criterion is based on size category which is based on flow as set out in Table 2, including the consideration that small and very small facilities with industrial input are to be treated as medium facilities. It is assumed that a larger flow inherently poses greater risk, from the perspectives of both volume and likely chemical composition of the effluent.

Level of $CBOD_5$ and TSS
The formula presented in Table 6 is used to calculate the points allocated for the $CBOD_5$ and TSS criterion. $CBOD_5$ and TSS values used in the formula are annual averages obtained for the year 2008, expressed as mg/L.

TRC
If the effluent is chlorinated and not dechlorinated, the TRC value would be greater than 0.02 mg/L, the National Performance Standard. Facilities that chlorinate their effluent but do not dechlorinate it before discharge will be contributing chlorinated substances and residual chlorine, both of which are toxic, to the environment. Effluents that are dechlorinated or disinfected by means other than chlorination would not score any points under this criterion.

Acutely Lethal Concentration of Ammonia
The determination of acute lethality is made from the equation in section 5.6.3 and/or Figure 12. Concentrations of ammonia above the line in Figure 12 are considered to be acutely lethal.

Receiving Environment
Large and/or open bodies of water that are not rivers are subdivided into four groups: open marine; marine port (well flushing harbour with port development and the capacity to handle large ships); lakes and reservoirs; and enclosed bays and marine estuaries. For rivers, the bulk flow ratio is used to assess risk. Bulk flow ratio is the ratio of the average annual flow of the river to the average annual flow of the effluent. For intermittent discharges, the flows used would be those that occur during a typical discharge period. For some large rivers where the site more closely resembles a lake or enclosed bay, it may be more appropriate to use the lakes, reservoirs, enclosed bays and estuaries category to represent the level of risk.

9.2 Combined Sewer Overflows

Facilities with CSO locations that have a risk level higher than the risk level of the main effluent may work on CSO reduction first, and therefore delay work on meeting the NPS. The objective is to reduce the risk levels associated with CSOs at least as low as the risk level of the main effluent, before starting work on meeting the NPS. The facility must still achieve the National Performance Standards within the 30 year timeline of the Strategy.

The approach consists of looking at every single CSO location and determining which ones have an unacceptable impact on the receiving environment and its uses. Those that accumulate more points than the main effluent (see section 9.1) are considered a higher risk and should be dealt with first. Points for CSO risk levels are allocated based on Table 7. If the risk associated with one or more CSO location is greater than that posed by the main effluent, an action plan is developed by the owner addressing how both the CSOs will be managed and the National Performance Standards achieved within the 30 year timeline of the Strategy. The action plan is then submitted for approval. CSO units with treatment (solids removal or disinfection) should not be considered in this exercise.

Table 7. Criteria for Calculation of Risk Level of Individual CSO Locations

% of total dry weather flow found in sewer at this location (or % of combined sewer served at this location)	≥ 50%	30 points
	≥ 25%	20 points
	≥ 10%	10 points
	< 10%	5 points
Frequency of CSO events[1] (excluding exceptional emergency events)	> 1 event/year during dry weather	50 points
	> 25 events/year	30 points
	> 15 events/year	20 points
	> 5 events/year	10 points
	5 events/year or less	0 points
Receiving environment type and affected uses - all that apply	Drinking water intake within 500 metres downstream	25 points
	Drinking water intake within 500 – 2 000 metres downstream	15 points
	Shellfish harvesting area (past or present) within 500 metres	20 points
	Endangered species/fish spawning area within 500 metres downstream	10 points
	Area used for contact recreation within 500 metres downstream	20 points
	Area used for contact recreation within 500 – 2 000 metres downstream	10 points
	Fish consumption advisory	5 points
	Discharge into lake, reservoir, marine estuary or enclosed bay	10 points
Industrial input[2]		15 points

1. Events are days where an overflow from a combined sewer has occurred. For overflows that last for more than one day, the number of events equals the number of days the overflow lasts. Numerous overflows occurring during the same day is considered as a single event. For smaller flows where no electronic equipment is available to record overflows and a floating device is used to detect overflow occurrences between visits (normally once a week), an event is when the floating device has been displaced between visits.
2. Industrial input (see definition) in sewershed upflow from CSO location.

References

Section 4 References

Conservation Ontario. Available Online: http://conservation-ontario.on.ca/news/pdf/Watershed.pdf, Accessed: January 22, 2006.

Conservation Ontario, Available Online: http://www.grandriver.ca/WalkertonInquiry/pdf/ConservationOntarioSubmission.PDF, Accessed: January 22, 2006. Last Updated: March 20, 2001.

Goldstein, Alan L. and G. J. Ritter. *A Performance-Based Non-Point Source Regulatory Program for Phosphorus Control in Florida, Animal Waste and the Land-Water Interface*, pp. 429-440, ed. Kenneth Steele. Boca Raton: Lewis Publishers, 1995.

National Institutes for Water Research. Available online: http://www.vwrrc.vt.edu/pdf/wsr.pdf#search='Watershed%20approach%20to%20effluent', Accessed: January 19, 2006.

Population Reference Bureau. Available Online: http://www.prb.org/Content/NavigationMenu/PRB/Educators/Human_Population/Population_Growth/Population_Growth.htm, Accessed: January 19, 2006.

United States Environmental Protection Agency (US EPA), TMDL Program. Available Online: http://www.epa.gov/OWOW/tmdl/cs13/cs13.htm, Accessed: January 20, 2006. Last Updated: January 6, 2005.

United States Environmental Protection Agency (US EPA), Watershed Approach Framework. Available Online: http://www.epa.gov/owow/watershed/framework.html, Accessed: January 21, 2006. Last Updated: April 1, 2005.

United States Environmental Protection Agency (US EPA), Why Watersheds. Available Online: http://www.epa.gov/owow/watershed/why.html, Accessed: January 22, 2006. Last Updated: April 1, 2005.

USGS Science for a Changing World, Market-Based Water Quality Programs, Available Online: http://geography.wr.usgs.gov/science/mercury/d2.html, Accessed: January 22, 2006, Last Updated: September 15, 2005.

Section 5 References

CCME (2003). *Canadian Water Quality Guidelines for the Protection of Aquatic Life: Guidance on the Site-specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives*. In: *Canadian Environmental Quality Guidelines*. CCME: Winnipeg, 1999.

CCME, Water Quality Guidelines Task Group. *A Framework for Developing Ecosystem Health Goals, Objectives, and Indicators: Tools for Ecosystem-Based Management*. CCME: Winnipeg, 1996.

Kilgour, B.W.; Munkittrick, K.R.; Portt, C.B.; Hedley, K.; Culp, J.; Dixit, S.; Pastershank, G. 2005. Biological Criteria for Municipal Wastewater Effluent Monitoring Programs. *Water Qual. Res. J.* 40(3): 374–387

United States Environmental Protection Agency (US EPA), Office of Water. *Technical Support Document for Water Quality Based Toxics Control*. US EPA: Washington DC, 1991.

United States Environmental Protection Agency (US EPA), Office of Water. *US EPA NPDES Permit Writer's Manual*. US EPA: Washington DC, 1996.

Section 6 References

CCME. *A National Commitment to Pollution Prevention.* (http://www.ccme.ca/assets/pdf/natl_commit_to_p2_web.pdf), November 1993.

InfraGuide. *Optimization of Lagoon Operation*, Issue No. 1.0, National Guide to Sustainable Municipal Infrastructure. (www.infraguide.ca), August 2004.

InfraGuide. *Wastewater Treatment Plant Optimization***,** Issue No. 1.0, National Guide to Sustainable Municipal Infrastructure. (www.infraguide.ca), November 2003.

InfraGuide. *Wastewater Source Control*, Issue No 1.0, National Guide to Sustainable Municipal Infrastructure. (www.infraguide.ca), March 2003.

Hydromantis Inc., University of Waterloo, Dept. of Civil Engineering. *Review of the State of Knowledge of Municipal Effluent Science and Research –Tasks 2 and 3*. Report prepared for the Canadian Council of Ministers of the Environment, 2005.

Marbek Resource Consultants. *Source Reduction Tools*. Report prepared for the Canadian Council of Ministers of the Environment, 2006.

Marbek Resource Consultants. *Model Sewer Use Bylaw of the Canadian Council of Ministers of the Environment*. Prepared for the Canadian Council of Ministers of the Environment, 2006.

Minnow Environmental Inc. *Environmental Risk-Based Approaches for Managing Municipal Wastewater Effluent*. Report prepared for the Canadian Council of Ministers of the Environment, 2005.

United States Environmental Protection Agency (US EPA). *Local Limits Development Guidance*, EPA 833-R-04-002 (A & B). http://cfpub.epa.gov/npdes/pretreatment/pstandards.cfm#local, 2004.

United States Environmental Protection Agency (US EPA). *US EPA NPDES Permit Writers' Manual*, EPA 833-B-96-003, 1996.

Water Environment Research Foundation report. *Benchmarking Wastewater Operations: Collection, Treatment, and Biosolids Management*, 1997.

Section 8 References

InfraGuide. *Infiltration/Inflow Control/Reduction for Wastewater Collection Systems*, Issue No 1.0, National Guide to Sustainable Municipal Infrastructure. (www.infraguide.ca), March 2003.

InfraGuide. *Selection of Technologies for Sewer Rehabilitation and Replacement*, Issue No. 1.0, National Guide to Sustainable Municipal Infrastructure. (www.infraguide.ca), March 2003.

Ontario Ministry of the Environment. *Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems (Procedure F-5-5)*, MOE.

United States Environmental Protection Agency (US EPA). *Combined Sewer Overflows – Guidance for Nine Minimum Controls*, EPA 832-B-95-003, 1995.

United States Environmental Protection Agency (US EPA). *Combined Sewer Overflow (CSO) Control Policy*, Federal Register/Vol. 59, No. 75/ Tuesday, April 19, 1994/ Notices, 1994.

XCG Ltd. *Combined Sewer Overflow Treatment Technologies Manual*. Report to Environment Canada, GLSF, Burlington, Ontario, 2004.

Appendix A Glossary

A

Acutely Lethal *(létal aigu)*
At 100 percent concentration of effluent, more than 50 percent of the test species subjected to it over the test period are killed when tested in accordance with the acute lethality test set out in the appropriate method. For rainbow trout this is Reference Method EPS 1/RM/13.

Ammonia *(Ammoniac)*
Total ammonia expressed as nitrogen. Total ammonia means the sum of the unionized ammonia (NH_3) and ionized ammonia (NH_4^+) species which exist in equilibrium in water. Analytical methods measure and typically report on ammonia nitrogen as opposed to total ammonia.

C

Canada's Far North *(Grand nord canadien)*
Far North is defined as all of the NWT and Nunavut, and the Nunavik region of Quebec and Nunatsiavik region of Newfoundland/Labrador.

Canadian Environmental Quality Guidelines *(Recommandations canadiennes pour la qualité de l'environnement)*
Nationally endorsed, science-based goals for the quality of atmospheric, aquatic, and terrestrial ecosystems. Environmental quality guidelines are defined as numerical concentrations or narrative statements that are recommended as levels that should result in negligible risk to biota, their functions, or any interactions that are integral to sustaining the health of ecosystems and the designated resource uses they support. Developed by CCME.

Carbonaceous Biochemical Oxygen Demand ($CBOD_5$, 5-day) *(Demande biochimique en oxygène des matières carbonées [DBO_5C, 5 jours])*
A measure of the quantity of oxygen used in the biochemical oxidation of organic matter in 5 days, at a specific temperature, and under specified conditions. The method of analysis is defined by Method 5210 in Standard Methods.

Chronic Toxicity *(Toxicité chronique)*
The ability of a substance or mixture of substances to cause harmful effects over an extended period, usually upon repeated or continuous exposure sometimes lasting for the entire life of the exposed organism. Chronic toxicity results in reduced reproductive capacity or reduced growth of young, in fish or invertebrate populations.

Combined Sewer *(Égout unitaire)*
A sewer intended to receive both sanitary waste and storm water.

Combined Sewer Overflow (CSO) *(Débordement d'égout unitaire [DEU])*
A discharge to the environment from a combined sewer system that occurs when the hydraulic capacity of the combined sewer system has been exceeded, usually as a result of rainfall and/or snow melt events.

Combined Sewer System *(Réseau d'égout unitaire)*
A wastewater collection system which conveys wastewater and storm water runoff through a combined sewer.

Community *(Collectivité)*
For the purposes of the strategy, same as municipality but may include recognized assemblages of dwellings and other facilities.

Continuous Discharge *(Rejets continus)*
Continuous discharges include regular discharges from batch treatment processes, such as a sequencing batch reactor, that discharge on a frequent and regular basis.

Conventional Parameters *(Paramètres conventionnels)*
Parameters common to all municipal wastewater effluent discharges. Conventional parameters include Carbonaceous Biochemical Oxygen Demand ($CBOD_5$), Total Suspended Solids (TSS), Total Residual Chlorine (TRC) when chlorine disinfection is used, Ammonia (NH_4).

D

Designated Area *(Zone désignée)*
Includes fish spawning sites, beaches, drinking water intakes, and other sensitive areas as identified by the regulator.

Disinfection *(Désinfection)*
Disinfection of MWWE is typically accomplished by using appropriate dosages of chlorine, hypochlorite or ultraviolet (UV) radiation. Disinfection systems are designed to achieve low levels of indicator microorganisms such as *E. coli* in the range of 100 counts per 100 mL.

Domestic Wastewater *(Eaux usées domestiques)*
Wastewater derived principally from dwellings, business buildings, institutions, and the like. It may or may not contain groundwater, surface water, or storm water.

E

Effluent Discharge Objective (EDO) *(Objectif environnemental de rejet [OER])*
Concentration, load or toxicity units that should be met at the municipal wastewater effluent discharge to adequately protect all water uses in the receiving environment. Effluent discharge objectives are obtained through an environmental risk assessment methodology using the principles of assimilative capacity and mixing zone, in conjunction with environmental quality.

Environmental Quality Objective (EQO) *(Objectif de qualité de l'environnement [OQE])*
Concentration of a substance considered safe for aquatic life and for the human uses that exist or should exist outside of a determined mixing zone. The *Canadian Environmental Quality Guidelines* (CEQG) are generic EQOs often used in Canada. The numerical concentrations or narrative statements that establish the conditions necessary to support and protect the most sensitive designated use of water at a specified site (CCME, 1987)

End-of-Pipe *(émissaire)*
A point between the end of the treatment process and the receiving environment.

Environmental Risk Assessment (ERA) *(Évaluation des risques environnementaux [ERE])*
A procedure that will enable the establishment of effluent discharge objectives for substances of concern. This process will take into account the characteristics of the effluent and of the site-specific receiving environment. The environmental risk assessment includes a one-year period where a facility will characterize its effluent (initial characterization).

Environmental Risk Management Model (ERMM) [or framework] *(Modèle ou cadre de gestion des risques environnementaux [MGRE])*
A comprehensive framework to guide the decision-making process for the management of municipal wastewater effluents within Canada. It includes National Performance Standards and an environmental risk-based approach that enables the establishment of effluent discharge objectives, while taking into account the characteristics and uses of the site-specific receiving environment.

Existing Facility *(Ouvrage existant)*
Existing collection system, on or before the signing of the Strategy, with a discharge to surface water (with or without treatment).

Expansion/Expanding *(Expansion)*
An increase in the hydraulic capacity of the system.

F

Facility Size *(Taille de l'ouvrage)*

Wastewater Facility Size	Flow (m^3/day)[2]	Estimated Population (for reference)
Very Small[1]	≤ 500	≤ 1,000
Small[1]	> 500 – 2,500	> 1,000 – 5,000
Medium	> 2,500 – 17,500	> 5,000 – 35,000
Large	> 17,500 – 50,000	> 35,000 – 100,000
Very Large	> 50,000	> 100,000

1. Very small and small wastewater facilities which have industrial input associated with municipal wastewater are to be treated as medium wastewater facilities.
2. Flow is the annual average daily flow of a wastewater facility.

Fresh Water *(Eau douce)*
Water that generally contains less than 1,000 milligrams per litre of dissolved solids.

I

Industrial Input *(Apport industriel)*
Non-domestic process water from industry categories specified below that together exceeds 5% of total dry weather flow:

- resource exploration or 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).

Infiltration *(Infiltration)*
The water entering a sewer system, including sewer service connections, from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections, or manhole walls.

Inflow *(Eaux de captage ou captage)*
The water discharged into a sewer system, including service connections, from such sources as, but not limited to, roof leaders, cellar, yard, and area drains, foundation drains, cooling-water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined

sewers, catch basins, storm waters, surface runoff, street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration.

J

Jurisdiction *(Gouvernement)*
All provincial, territorial and the federal governments in Canada.

L

Lagoon (*étang*)
A wastewater treatment system that consists of one or more engineered surface impoundments, including enhancement of natural features, where biological and physical treatment of wastewater occurs, but does not include mechanical aeration systems.

M

mg/L *(mg/l)*
Milligrams per litre

Mixing Zone *(Zone de mélange)*
Also called the initial dilution zone. The area contiguous with a point source (effluent discharge site) or a delimited non-point source where the discharge mixes with ambient water and where concentrations of some substances may not comply with water quality guidelines or objectives. For the purpose of the Strategy, "mixing zone" means the "allocated mixing zone" at the edge of which environmental quality objectives should be met.

Municipal/Municipality *(Municipalité/municipal(e)s)*
As identified in a jurisdictions local government or municipal legislation. For the purposes of the Strategy, the term municipality encompasses municipalities, communities (including First Nations and Métis communities) and federal entities.

Municipal Wastewater Effluent (MWWE) *(Effluents d'eaux usées municipales [EEUM])*
Wastewater discharged to a surface water body from a collection or treatment system by an owner. Wastewater is a mixture of liquid wastes composed primarily of domestic or sanitary sewage that may also include wastewater from industrial, commercial and institutional sources. Overflows of combined and sanitary sewers are included. Separate storm water and septic tank discharges to infiltration systems are not included.

N

National Performance Standard *(Norme de performance nationale)*
The minimum performance measure to which all MWWE wastewater treatment facilities are measured for common parameters associated with MWWE.

Nutrient *(Élément nutritif)*
Any substance that is assimilated by organisms and promotes growth; generally applied to nitrogen and phosphorus in wastewater, but also to other essential and trace elements.

Nutrient Removal *(Élimination des éléments nutritifs)*
Treatment steps used to remove nitrogen and phosphorous from MWWE. Common types of nutrient removal treatment methods include nitrification (conversion of ammonia to nitrates), denitrification (conversion of nitrates to nitrogen gas) biological excess phosphorous removal and chemical phosphorous

removal. Nutrient removal processes are commonly incorporated into either secondary or tertiary treatment for enhanced removal of nitrogen, phosphorous or both to protect sensitive receiving environments. Typical systems with nutrient removal can achieve MWWE concentration levels of total phosphorous down to 0.1 mg/L, total ammonia-nitrogen down to 5 mg/L in winter and less than 1 mg/L in summer.

O

Operator *(Exploitant)*
The person or company that operates the wastewater facility. May be the same as the owner.

Outfall *(Exutoire)*
The location at which and the equipment through which effluent is discharged to the environment.

Owner *(Propriétaire)*
A municipality, a community, or a federal or other government entity, that owns a wastewater facility. It also includes owners of wastewater facilities situated on federal or aboriginal land.

Overflow (*Débordement*)
A discharge to the environment from a collection system or treatment works at a location other than the final effluent outfall of a sewage treatment works.

P

pH *(pH)*
The logarithm to the base 10 of the reciprocal of the concentration of hydrogen ions in moles per litre of solution.

Phosphorus *(Phosphore)*
An essential chemical element and nutrient for all life forms. Occurs in orthophosphate, pyrophosphate, tripolyphosphate, and organic phosphate forms. Each of these forms and their sum (total phosphorus) is expressed as milligrams per litre (mg/L) elemental phosphorus.

Pollution Prevention Plan *(Plan de prévention de la pollution***)**
A plan that outlines methods to eliminate or prevent the introduction of contaminants into the sewer system. This may include laws limiting the amount of specified contaminants in a discharge, a system of effluent charges, an education program to inform dischargers of the effects of their discharges and plans to limit them.

Preliminary Treatment *(Traitement préliminaire)*
Preliminary treatment involves screening, shredding or grinding for the purpose of removing coarse solids such as sticks, rags and other debris from the incoming wastewater. The purpose of preliminary treatment is to protect downstream treatment components such as pumps and reduce maintenance or operational problems. Preliminary treatment is a common first step to all WWTP

Primary Treatment *(Traitement primaire)*
Primary treatment follows preliminary treatment and involves the use of primary devices that allow flows to be reduced and for solids to settle due to gravity. Commonly, sedimentation tanks that detain flows for 2 to 6 hours to allow settleable solids to settle and be drawn off for separate solids treatment. Typical BOD_5 and TSS removal rates in primary treatment are 30% and 60%, respectively. On stand alone primary treatment, primary effluents can be treated with chemical disinfection prior to release. Primary

treatment can also be enhanced using chemicals in which inorganic or organic flocculants are introduced into the wastewater to help improve the effluent quality over primary treatment alone.

R

Receiving Environment *(Milieu récepteur)*
The water body into which effluent is discharged.

Remote *(Éloignée)*
A community with a declining population, that may not be economically sustainable, and/or is isolated.

Residential Input *(Apport résidentiel)*
See domestic wastewater.

S

Sanitary Sewer *(Égout domestique)*
A sewer intended to receive wastewater.

Sanitary Sewer System *(Réseau d'égout domestique)*
A wastewater collection system conveying wastewater, infiltrated groundwater and limited amounts of storm water inflow in a sanitary sewer, where an adjoining storm sewer exists as the primary collection system to receive storm water flows from catch basins and other sources of storm water. Partially separated sanitary sewer systems, in which inflow from roof leaders and/or foundation drains is conveyed to the sanitary sewer, are considered as part of a sanitary sewer system.

Sanitary Sewer Overflow (SSO) *(Débordement d'égout domestique [DES])*
A discharge to the environment from a sanitary sewer system.

Secondary Treatment *(Traitement secondaire)*
Secondary treatment follows primary treatment and is specifically designed for the removal of biodegradable organic matter (in solution or suspension) and the removal of suspended solids. Secondary treatment can include nutrient removal. Typical MWWE quality achieved is a $CBOD_5$ and TSS of 15 mg/L. Compliance standards are commonly set at 25 mg/l to allow for operational variations. The physical, chemical and biological processes in the process design may also fortuitously (not by design) remove other trace contaminants at unpredictable levels. The activated sludge treatment process is the most widely used form of secondary treatment in Canada and the world due to its versatility and relatively low cost.

Sewer *(Égout)*
A pipe or conduit that carries wastewater and/or drainage water.

Sewer System *(Réseau d'égout)*
Collectively, all of the property involved in the operation of a sewer utility. It includes land, wastewater lines and appurtenances, pumping stations, treatment works, and general property. Occasionally referred to as a sewerage system.

Source Control *(Réduction à la source)*
Similar to pollution prevention, it outlines methods to eliminate or prevent the introduction of contaminants into the sewer system. This may include laws limiting the amount of specified contaminants in a discharge, a system of effluent charges, an education program to inform dischargers of the effects of their discharges and plans to limit them. Includes use and generation of harmful substances.

Storm Water *(Eaux pluviales)*
The excess water running off from the surface of a drainage area during and immediately after a period of rain. It is that portion of the rainfall and resulting surface flow that is in excess of that which can be absorbed through the infiltration capacity of the surface of the basin.

Substance *(Substance)*
Chemical substance or any other parameter associated with wastewater, including $CBOD_5$, TSS, temperature, pH, pathogens, etc.

Substances of Concern *(Substances préoccupantes)*
Those substances for which effluent discharge objectives are necessary, based on the results of initial characterization.

Substance of Potential Concern *(Substances potentiellement préoccupantes)*
Those substances that have been identified for initial characterization for a particular facility. They include the list of priority substances, plus any other substances associated with local industry.

Surface Water *(Eau de surface)*
A lake, pond, marsh, creek, spring, stream, river, estuary or marine body of water, or other surface watercourse.

T

Tertiary Treatment *(Traitement tertiaire)*
The additional treatment needed to remove suspended, colloidal, and dissolved constituents remaining after conventional secondary treatment. In Canada this term can refer to physical processes that further remove suspended solids, such as sand filtration. Tertiary treatment may include biological processes for removal of nutrients (see below). Typical tertiary effluent $CBOD_5$ and TSS values are 5 and 5 mg/L. The movement of trace contaminants and metals from the liquid to the slides streams is generally enhanced due the additional physical-chemical or extended processes which are involved.

Total Residual Chlorine (TRC) *(Chlore résiduel total)*
The concentration of free chlorine and combined chlorine (including inorganic chloramines), expressed as Cl.

Total Suspended Solids *(Matières en suspension)*
The quantity of material removed from wastewater in a laboratory test, as prescribed by Method 209C in Standard Methods and referred to as nonfilterable residue.

U

Upgrade *(Amélioration ou modernisation)*
Further development of existing infrastructure which results in expanded throughput capacity. Does not include the addition of disinfection.

W

Wastewater *(Eaux usées)*
A mixture of liquid wastes primarily composed of domestic sewage that can also include other liquid wastes from industrial, commercial and institutional sources.

Wastewater Facility *(Ouvrage d'assainissement)*
Any works for the collection or treatment and release of wastewater or any part of such works. Includes engineered wetlands and those with natural elements considered as design components.

Wastewater Lagoon
See lagoon.

Appendix B List of Acceptable Toxicity Test Methods

1. Biological Test Method: Reference Method For Determining Acute Lethality of Effluents to *Daphnia magna*. Environment Canada, December 2000. EPS 1/RM/14 Second Edition.
2. Détermination de la toxicité létale CL_{50}48h *Daphnia magna*. Centre d'expertise en analyse environnementale du Québec (CEAEQ, 2007). Ministère de l'Environnement. MA 500 – D.mag. 1.1 Édition 2007-09-18.
3. Biological Test Method : Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout. Environment Canada, December 2000 (with May 2007 amendments) EPS 1/RM/13 Second Edition.
4. Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows. Environment Canada, February 1992 (including November 1997 amendments). EPS 1/RM/22.
5. Biological Test Method: Test of Reproduction and Survival Using the Cladoceran *Ceriodaphnia dubia*. Environment Canada, February 2007. EPS 1/RM/21 Second Edition.
6. Biological Test Method: Acute Lethality Test Using *Daphnia* spp. Environment Canada, July 1990 (with May 1996 amendments). EPS 1/RM/11.