Water Quality

Principles for Preparing Water Quality Objectives in British Columbia

Original signed by Ben Marr
Deputy Minister
Environment, Lands and Parks (now called Ministry of Environment)
September 3, 1986

Updated: August 7, 2001

Introduction

Water quality objectives are prepared for specific bodies of fresh, estuarine, and coastal marine surface waters of the province, as a part of the Ministry of Environment's mandate to manage water quality. To limit the scope of the task, objectives are only prepared for waterbodies and for water quality characteristics which may be affected by man's activity, now or in the foreseeable future. This paper describes the role of these objectives in British Columbia, and discusses factors which must be considered in preparing them.

Objectives for waterbodies are prepared on a site-specific basis, with due regard for the water quality, water uses, including aquatic life, water movement, waste discharges, and socio-economic factors at a given location. The objectives are physical, chemical, or biological characteristics of water, biota, or sediment that protect the most sensitive designated water uses. The objectives are policy guidelines for resource managers to use in protecting water users in specific waterbodies. For example, they can be used to prepare waste management permits and plans, regulate water use, or plan fisheries management. The objectives have no legal standing, and their direct enforcement would not be practical. This is due to the difficulty of accurately measuring contaminants in receiving waters and attributing to particular sources for legal purposes contamination exceeding an objective, and thus of proving violations and their causes. Hence, the objectives should serve as a guide for issuing permits, licences, and orders by the Ministry of Environment and for the management of the Province's land base, but they should not be incorporated directly as a part of the conditions of the permits, licences, and orders. To control diffuse sources of wastes (from ground water seepage or surface runoff) waste management permits sometimes include receiving water values or ambient limits, which must be met at a particular site. The water quality objectives may be used, in part, to derive such ambient limits. Objectives also serve as benchmarks for assessing the Ministry's performance in protecting water uses.

Definitions

Water quality objectives are based on scientific guidelines called water quality criteria, which relate the physical, chemical, or biological characteristics of water, biota, or sediment to their effects on water use, including aquatic life. Objectives are derived from criteria by considering the local water quality, water uses, water movement, waste discharges, and socioeconomic factors. Figure 1 illustrates the relationship between criteria and objectives. The following definitions of these terms are used:

Water Quality Criterion: a maximum and/or minimum value for a physical, chemical, or biological characteristic of water, biota, or sediment, applicable province-wide, which must not be exceeded to prevent specified detrimental effects from occurring to a water use, including aquatic life, under specified environmental conditions.

Water Quality Objective: a criterion adapted to protect the most sensitive designated water use at a specific location with an adequate degree of safety, taking local circumstances into account. (In a given waterbody, each objective may be based on the protection of a different water use, depending on the water uses that are most sensitive to the characteristics of concern in that waterbody).

Designated Water Use: a water use that is protected at a specific location, and that is one of the following:

- drinking, public water supply, and food processing
- aquatic life and wildlife
- agriculture (livestock watering and/or irrigation)
- recreation and aesthetics
- industrial water supplies

Development of Water Quality Criteria

The development of water quality criteria and methods for their application to produce site-specific objectives has a province-wide scope. Criteria are developed for the following water uses for fresh, estuarine, and coastal marine waters as appropriate:

- Drinking, public water supply, and food processing (for raw water sources prior to treatment*)
- Aquatic life and wildlife
- Agriculture (livestock watering and irrigation)
- Recreation and aesthetics**
- Industrial uses

**** The responsibility for regulating the quality of domestic water as supplied by a water purveyor lies with the Ministry of Health.***

***** The Ministry of Health has the responsibility for regulating the use of public bathing beaches with respect to the public health aspects.***

There are other valid water uses (e.g. power generation. storage, waste assimilation, navigation, etc.), but they are not as sensitive as those listed above, and indeed may impair the more sensitive water uses.

Criteria and methods from the literature and other jurisdictions are evaluated. Criteria and methods that are appropriate to British Columbia conditions are adopted or developed from this analysis. Criteria and methods are subject to wide review prior to finalization, and will be reviewed from time

to time as new knowledge becomes available.

As there are a virtually limitless number of characteristics for which criteria could be established, criteria are developed first for those characteristics that are most important for the waterbodies being considered at any given time.

Water quality criteria for aquatic life are the most difficult to develop. These criteria are based mainly on the science of ecotoxicology, or the effect of toxicants on various life forms. This is a new and fairly immature science which is continually evolving as research progresses. Some criteria derived from this work may be little better than educated guesses, and this leads to conservative safety factors being used.

Factors to consider in developing criteria for aquatic life include:

- acute (short-term) toxicity to various species and life stages, usually expressed as a 96h LC_{50} value
- chronic (long-term) toxicity to various species and life stages, including sub-lethal effects and stress, carcinogenesis, mutagenesis, and teratogenesis
- persistence, pathways, and transformations in the environment
- accumulation in biota and sediment
- antagonistic, additive, or synergistic effects of other substances or conditions on toxicity
- chemical forms of substances, their occurrence, and their toxicity
- distribution of contaminants between the water column, biota and sediment

Ideally, criteria should be derived from long-term tests on many sensitive species. In practice, many data are for short-term tests for a few species. To derive safe limits from short-term data, application or safety factors are used. For example: the application factors for 96h LC50 data range from 0.1 to 0.05 with non-persistent or noncumulative toxicants, to 0.05 to 0.01 with persistent or cumulative toxicants. Such factors offer a quick way of solving the complex problem of extrapolating laboratory data, but they should only be used as a guide. Long-term toxicity data should be used whenever possible.

Water quality criteria for man's direct uses of water are generally simpler to develop than those for aquatic life. Some factors to consider for these uses include:

- drinking — type of water treatment required
- irrigation — crop type, soil type, soil chemistry, and amount of water applied
- livestock watering — type of animals
- recreation — water contact versus non-water contact activities
- industrial — type of industry or process

The water quality criteria being developed for British Columbia provide the basis for establishing site-specific objectives (along with information on local conditions), and provide benchmarks for the evaluation of data on water, biota, and sediment quality where objectives have not yet been established.

Development of Water Quality Objectives

Recognizing that there is a virtually limitless number of waterbodies and characteristics for which objectives could be established, objectives are developed on a priority basis for waterbodies and water quality characteristics which may be affected by man's activity, now and in the foreseeable

future.

Factors to Consider

To develop water quality objectives for a waterbody, a knowledge of the following is required:

- Water quality criteria, which relate the physical, chemical or biological characteristics of water, biota, or sediment to their effects on aquatic life and human use of water such as drinking, recreation, and irrigation. Criteria provide, insofar as is possible, information on short-term (acute) and long-term (chronic) effects, persistence, accumulation in biota or sediment, antagonism or synergism with other substances and environmental fate of substances.
- The existing and potential quality of the waterbody, which is described by the physical, chemical, and biological characteristics of the water, biota, sediment of the waterbody.
- The temporal and spatial variability of water, biota, and sediment characteristics.
- The existing and potential aquatic life in the waterbody, including species, geographic distribution of species, life history or stage use (e.g. spawning, rearing, migration), the presence of rare or endangered species and the importance of the aquatic life to man.
- The flow or circulation pattern of the waterbody, and its relation to the quality of water, sediments and aquatic life.
- The existing and potential loadings of contaminants from point and diffuse sources, and their relation to water movement and quality, including the behaviour of the contaminants in the local water.
- The existing and potential uses of the water by man.

The above points form a water quality assessment. A general format for making water quality assessments is contained in Appendix A. The water quality assessment, criteria and objectives process is illustrated in Figure 1.

Assimilative Capacity

Assimilative capacity is the ability of a waterbody to receive contaminants without impairing the use of the water by man, plants, and animals. The concept of using assimilative capacity in managing the water resource is controversial, mainly because it is difficult to define. It is different for each contaminant, or mixture of contaminants, and a thorough understanding of the aquatic ecosystem is required. Interrelated measurements of water quantity and quality, sediments, and aquatic life must be made. The pressure to use assimilative capacity can be high, especially in cases requiring costly pollution control measures to maintain water quality.

Two approaches are used in setting objectives in British Columbia, depending on the local circumstances. For waterbodies with exceptionally valuable resources of provincial significance and good existing water quality, the objectives are set to avoid degradation of the existing water quality. For all other waterbodies, the objectives are set to protect the water quality for the designated water uses. This approach may allow some degradation of existing water quality while still protecting the designated water uses (i.e. use of the assimilative capacity), but it may also entail enhancement of water quality where it is currently poorer than that desired for the designated water uses.

The water uses designated for protection are the existing uses and the potential uses that might reasonably be made of the water in the future. The waterbody must be inherently capable of supporting these water uses, and the costs of protecting a water use should bear a reasonable relationship to the benefits derived from the water use.

Initial Dilution and Mixing Zones

Objectives do not apply within an initial dilution zone, which is the initial portion of the larger effluent mixing zone. The extent of initial dilution zones is defined on a site-specific basis, with due regard to water uses, aquatic life, including migratory fish, and other waste discharges. Initial dilution zones are normally relatively small (e.g., up to 100 m from the point of effluent discharge, but not exceeding 25 to 50% of the width of the waterbody), and are essential to allow for the initial mixing between effluents and the receiving water. If initial dilution zones did not exist, it would mean that effluent quality would have to meet water quality objectives, which would be costly and impractical.

Within initial dilution zones, water quality may exceed criteria for various water uses and sub-lethal effects on aquatic life may occur, but effluent quality and dilution in the initial dilution zone should be such that acutely toxic conditions, objectionable sludge deposits and floating materials, harmful bioconcentration in biota, and nuisance conditions do not occur. Initial dilution zones should not impinge on water intakes, bathing beaches, shellfish beds, fish spawning beds, or aquatic macrophyte beds serving as a nurture area for important aquatic species.

Outside of initial dilution zones, water quality should be suitable for all designated water uses, and should protect aquatic life from sub-lethal effects, as a minimum.

Compliance with Objectives

Objectives have no legal standing, and their direct enforcement would not be practical. They serve as a guide for issuing permits, licences, and orders, and for assessing performance in protecting water uses, including aquatic life. Consequently, direct compliance with objectives by waste dischargers is not applicable, but waste dischargers will have to abide by permits, licences, and orders issued by the Ministry of Environment to ensure that the objectives are met.

Assessing whether objectives are being met can be difficult because of the temporal and spatial variability of water quality, and the occurrence of isolated high values that may be due to analytical or sampling error, natural events, or waste discharges. Several principles should be observed to reduce the difficulty of assessing whether objectives are being met.

1. The natural variability and extremes of water quality should be considered when establishing objectives.
2. Both upstream or control sites and downstream or test sites should be monitored simultaneously when possible to account for natural influences on water quality.
3. Waste discharges should be monitored at the same time as receiving water to determine their influence on water quality.

Coordinated monitoring of effluents and receiving water will aid in assessing cause-effect relationships and the significance of water quality values that do not meet the objectives. A monitoring program to assess whether objectives are being met will be specified whenever objectives are established.

To aid in this assessment, the objectives should specify the following:

- the statistical values (e.g., maximum, minimum, 90th percentile, median, geometric mean, etc.) that are to be met by the concentration or level of a substance, in water, biota or sediment;
- the exact form of the substance to be measured (e.g., dissolved, total, etc.), including the analytical methods to be used and detection limits where appropriate;
- the geographic locations and times of the year for which the objectives apply;

- the type of samples (e.g., grab or composite), the minimum number of samples, and the sampling period.

Types of Objectives

1. Provisional objectives are set where the information available about the local conditions (e.g., water quality, water use, aquatic life, waste discharges, etc.) and/or the water quality criteria for a substance are inadequate for the establishment of scientifically defensible objectives. Provisional objectives are deliberately conservative, and a monitoring or study program is specified that will lead to the establishment of permanent objectives.

2. Permanent objectives are established when the information available about the local conditions and water quality criteria is adequate. A monitoring program is specified with permanent objectives to assess the degree of their attainment. Both provisional and permanent objectives are subject to wide review before they are adopted, and permanent objectives will be reviewed from time to time and are subject to revision, as new information becomes available.

3. Short-term and long-term objectives may be used where existing water quality does not suit all desired water uses, and it is feasible to improve the water quality over time. The short-term objectives would protect water uses to a certain degree until the long-term objectives can be achieved.

Objectives specify a range of values when possible; generally maximum and/or minimum values that are not to be exceeded, and average values for the longer term (e.g., 30 days) that may be exceeded for short periods (e.g., a few days), providing that the maximum and/or minimum are not exceeded.

Streamflows and Objectives

Waste treatment facilities in British Columbia are typically designed to meet water quality objectives for streamflows as low as the 7-day average low flow occurring once in 2 to 10 years (1.0% to 0.2% of the time), and for streamflows as high as the daily average flood occurring once in 10 years (0.03% of the time). The time between occasions when water quality objectives will be exceeded will be longer than 2 to 10 years because of the reduced probability that maximum design waste discharges will occur at the same time as the design streamflows. More stringent design conditions may be required to provide additional protection for water quality in waterbodies with high resource values. The design conditions that will apply to a given waste discharge are determined during the various environmental impact review processes and/or the permitting and licensing processes established in British Columbia.

In any event, there will be occasions when water quality objectives are exceeded because streamflows naturally fall below (or rise above) those used to design waste treatment facilities, even though the waste discharge is within its design (permit) limits. Water quality objectives do not apply on such occasions. If the frequency of such occasions becomes unacceptable for protecting water uses, then the waste treatment facilities would be upgraded to meet water quality objectives under more stringent conditions.

Pollution Control and Water Quality Objectives

Waste discharges in British Columbia are regulated by Waste Management Permits which specify the quantity and quality of waste that may be discharged. Pollution Control Objectives have been

established that provide a range of possible waste discharge concentrations. The more stringent values apply to sensitive environmental situations and the less stringent where it can be shown that unacceptable conditions will not occur. Intermediate values may be designated, and in special circumstances more or less stringent requirements may be applied. To help assess which values will apply to a waste discharge in a specific case, the Pollution Control Objectives contain Receiving Water Quality Objectives. These latter objectives are necessarily general, simple, and fairly restrictive because they apply to receiving waters province-wide.

The water quality objectives now being developed by the Ministry of Environment are a refinement and extension of the old Receiving Water Quality Objectives to bring them up-to-date and to make them site-specific to each receiving water. Where water quality objectives have been established for a waterbody, they supersede the Receiving Water Quality Objectives contained in the Pollution Control Objectives.

The new water quality objectives are intended to assist in determining the waste discharge concentrations from the Pollution Control Objectives that should be used in issuing permits, and in special cases, if more or less stringent requirements should apply. In short, the water quality objectives specify the desired quality for a waterbody, and then the waste discharges are regulated with these objectives in mind.

Figures

1. Water Quality Assessment, Criteria and Objectives Process

PROBLEM IDENTIFICATION AND DEFINITION

START HERE

- with input from Regional Waste Management and others, as appropriate
—
Identify and rank water bodies with present or future water quality problems.

- with input from Regional Waste Management and others, as appropriate
—
Select and rank priority waterbodies for assessment and objectives.

- with input from Regional Waste Management and others, as appropriate
—
Identify priority present and future waste discharges and variables for each waterbody.
Include all point and non-point land and water use activities that affect water quality.

WATER QUALITY ASSESSMENT

- with input from Regional Waste Management, Planning and Assessment and others, as appropriate

—

Map present and future, point and non-point waste discharges. Include all point and non-point land and water use activities that affect water quality.

- with input from Water Management, Planning and Assessment, Fish and Wildlife, Marine Resources and others, as appropriate

—

Map and describe water uses affected by, or affecting, present and future waste discharges.

- with input from Waste Management, Permittees, Database reports and others, as appropriate

—

Assemble data for waste discharges. Include all point and non-point land and water use.

Briefly describe the nature, treatment and permit limits of waste discharges. Include all point and non-point land and water use activities that affect water quality.

Determine present waste contaminants, concentrations and loadings. Include all point and non-point land and water use activities that affect water quality.

- with input from Planning and Assessment (population projections and future projects) and others, as appropriate

—

Estimate future waste loads. Include all point and non-point land and water use activities that affect water quality.

- with input from Water Management (stream flows and lake data), Federal Government (oceanography) and others, as appropriate

—

Predict the effects of present and future waste loads on the receiving waters.
Include all point and non-point land and water use activities that affect water quality.

- with input from Waste Management, Federal Government, Database, Developers and Consultants reports and others, as appropriate

—

Map and assemble water quality data for the water, sediments and biota.

Analyze key water quality data, the effects of wastes and suitability of the water for various uses.

Predict future water quality based on future waste loads, the effects of these wastes and the suitability of the water for various uses.
Include all point and non-point land and water use activities that affect water quality.

WATER QUALITY CRITERIA

Identify and rank variables needed for assessments and objectives.

Assemble data or criteria and application methods.

Update water quality criteria database on a priority basis.

Develop criteria for each variable on a priority basis.

Develop methods for applying criteria to produce objectives.

- with input from Ministry of Environment, Federal Government, Ministry of Health, Ministry of Agriculture and Food and others, as appropriate

—

Review criteria and application methods.

Finalize criteria and methods.

Undertake periodic reviews to keep up with scientific progress.

WATER QUALITY OBJECTIVES

Identify assignable water uses and select key variables for objectives.

- with input from Regional Water and Waste Management, Regional Fish and Wildlife, Marine Resources and others, as appropriate

—

Designate water uses to be protected in each waterbody.

Design provisional or permanent objectives to protect water uses.

Recommend water and waste management options, monitoring, additional studies, objectives and water use designations.

- with input from Ministry of Environment, Federal Government, Ministry of Health, other Provincial agencies and others, as appropriate.

Review and finalize assessments, recommendations, objectives and water use designations.
These are subject to periodic review as necessary.

Appendices

Appendix A: A General Format for Making Water Quality Assessments

Identify and rank the waterbodies that have existing or potential water quality problems. The most important of these waterbodies become the priority waterbodies for water quality assessment.

For each priority waterbody the general format given below is followed as appropriate.

1. HYDROLOGY

Summarize stream flows at key points in the waterbody (summary may include an annual hydrograph showing the historical range of flows, and minimum flows such as the 7-day average flows, with a 2 or 10-year return periods, etc.).

Provide key lake or oceanographic data, such as flushing times, circulation patterns, or inflow and outflow data as needed for water quality assessment.

2. WATER USES

The following applies to present and future water uses and waste discharges projected over the planning period (next 5 to 20 years).

Prepare a map (scale about 1:100 000 to 1:250 000, with larger inset maps as needed) locating water uses, and showing the quantity used and its purpose (such as domestic, irrigation, industrial, fisheries, recreation, etc.).

The most important uses are those that will be affected by waste discharges, or uses that will affect streamflow and hence the dilution of a waste discharge further downstream. Additional information needed for important water uses includes:

Drinking water:

- type of water treatment provided (*e.g.*, chlorination, filtration, sedimentation, etc.)
- timing of use (*e.g*., year-round, seasonal)

Aquatic life and wildlife:

- species and life stages present or potentially present
- geographic distribution of species and life stages
- seasonal distribution of species and life stages (*e.g.,* spawning, rearing, migration)
- presence of rare or endangered species

Recreation:

- type of recreation (*e.g*., water contact versus non-water contact activities)
- timing of use (*i.e*., the recreation season)

Irrigation:

- timing of use (*i.e.*, the irrigation season)
- type of crops
- type of soils and soil chemistry
- water application rates (*i.e*., depth per year, short-term versus long-term irrigation)

Livestock watering:

- timing of use (*e.g.*, year-round, seasonal)
- type of animals

Industrial:

- timing of use
- type of industry and process (i.e., determine what the water is used for)

3. WASTE DISCHARGES

3.1 Point Sources

The following applies to present and future waste discharges, projected over the planning period (next 5 to 20 years).

Prepare a map (scale about 1:100 000 to 1:250 000, with larger inset maps as required) showing the location of discharges.

Describe briefly the nature of the discharges.

List the Waste Management Permit conditions such as flows, concentrations, loadings, treatment and monitoring required.

Summarize the present effluent monitoring data including flows, concentrations, and loadings.

Describe effluent dispersion in terms of initial dilution, dilution after complete mixing, time and distance to achieve complete mixing, and effluent plume behaviour.

Project future waste loadings for existing and future waste discharges. Population projections can be used to project future municipal waste loads. Industrial waste load projections require specific information about expanded or new operations, and existing waste loads or waste loads from similar operations elsewhere may provide a basis for projections.

Assess the effects on receiving waters in two ways:

1. by calculating the impact of various effluent loads at different river flows, or dilutions in the case of lakes and marine waters, for initial dilution and complete mixing cases
2. by summarizing observed water quality impacts under specific conditions (from Section 4). This analysis would pinpoint important contaminants and their effect on receiving waters.

3.2 Diffuse (Non-Point) Sources

Map and quantify diffuse sources of wastes where appropriate. These can include agriculture, forestry, mining, septic tank fields, landfills, storage reservoirs, water diversions, dams, urban runoff, atmospheric deposition, boating, etc. (i.e., any air, land or water use activity that affects the aquatic environment).

Summarize any surface water, ground water, or precipitation quality data or other information quantifying the contaminant loadings from diffuse sources.

Determine where possible the actual or theoretical load of contaminants and/or the effects on water quality using models or measurements made in the area or elsewhere in similar cases. This analysis will indicate important contaminants and their effect on receiving waters.

Summarize any observed water quality impacts attributable to diffuse sources (from Section 4).

4. WATER QUALITY

Map water quality sites (at a scale of about 1:100 000 to 1:250 000, with larger inset maps as needed). Water uses, waste discharges, and water quality sites should be plotted on the same maps to show clearly their relationships.

Summarize water quality data, including biological and sediment data. Usually data will be arranged by site, giving maximum, minimum, and average, median, or geometric mean values for each variable, and the number of measurements made in a given time period. Other data presentation techniques will be used as appropriate.

Relate water quality to information on point and diffuse sources of contaminants. Effects of contaminants on water, sediments, and aquatic life will be part of the analysis. Compare the predicted effects of present waste loads (from Section 3) with the effects shown by water quality measurements, and discuss any significant discrepancies.

Summarize the predicted effects of future waste loads on water quality (from Section 3).

Assess the suitability of water quality for present and future water uses by comparing it to water quality criteria for water uses. Identify the water uses that can be supported by the present and future water quality, and recommend designated water uses that should be protected.

Prepare provisional water quality objectives for important variables in the waterbody to protect the designated water uses. Permanent objectives will be prepared if enough information is available and approved criteria have been developed. The water quality objective for a given substance will usually be similar to the water quality criterion to protect a specific water use. If the degree of protection required is higher than usual, and can be realistically achieved, the objective may be more restrictive than the criterion. Ideally, the objective will already be met by existing water quality, or the water quality can be upgraded within a reasonable time to meet the objective. Sometimes it may be unrealistic to upgrade water quality because natural water quality is worse than the criterion, or socioeconomic factors make upgrading impossible. In such a case the objective may be less restrictive than the criterion to protect a given water use, or the water use may not be designated for protection. In the case of an objective being less restrictive than the criterion, the objective will still protect the water use, although with a smaller margin of safety.

Recommend a short-term (e.g., 1 to 2 years, normally) monitoring program to collect the information required for setting permanent water quality objectives. When permanent objectives are set, a surveillance monitoring program will be recommended to determine whether objectives are being met or improvements are needed.

5. REPORT

Prepare a short report of the work including main findings, conclusions, maps of the area, and tables showing designated water uses, water quality objectives, and monitoring programs. The report will be supported by documentation in a technical appendix in which the assessment, derivation of water quality objectives, and supporting data and references will be presented in detail.

6. REPORT REVIEW

The short report and technical appendix for objectives will go through a five-step review process, each new draft incorporating appropriate corrections reflecting the review comments made.

1. The first draft will be for internal review by Resource Quality Section and Waste Management Branch.
2. The second draft, for regional review, will be sent to all interested parties in the Ministry in the region where the objectives apply.
3. The third draft will be sent to all interested government agencies including other provincial ministries and federal agencies such as Inland Waters Directorate, the Environmental Protection Service, and the Department of Fisheries and Oceans. The third draft may also be sent to specific municipalities, regional districts, and industries if the assessment shows that the water quality objectives will affect matters within their jurisdiction. Technical experts will also be included at this stage if there is a need to verify technical accuracy.
4. The fourth draft of the short report will then be reviewed by the Ministry Program Directors.
5. The fifth draft of the short report will be sent to the Ministry Executive for final approval following endorsement by the Program Directors.

The reports for water quality criteria will go through a similar review process, with a few exceptions. For the regional review all regions will be involved, and for the wider review specific municipalities, regional districts and industries will be omitted. These changes reflect the wider application of criteria, which cover all of the province rather than any specific body of water.