Water Quality

RESOURCE QUALITY SECTION
WATER MANAGEMENT BRANCH
MINISTRY OF ENVIRONMENT

AMBIENT WATER QUALITY OBJECTIVES FOR BURRARD INLET COQUITLAM-PITT RIVER AREA

OVERVIEW REPORT

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SUMMARY

This report assesses the water quality of Burrard Inlet, False Creek and some selected tributaries. Provisional water quality objectives are set to protect aquatic life, wildlife and primary-contact recreation in Burrard Inlet, Lynn Creek and School House Brook; aquatic life and wildlife in False Creek (and recreation near its mouth); and aquatic life, wildlife, primary-contact recreation and drinking water supplies in the Capilano River.

Burrard Inlet sustains runs of salmonids while the tributaries provide important habitat for these runs.

Most of the water contamination comes from bulk loading facilities, oil refineries, chemical plants, combined sewer overflows and stormwater discharges. As a result, there are areas with lower than desirable levels of dissolved oxygen, bacteriological contamination which on occasion can require that beaches be closed for swimming and high concentrations in the water column and sediments of metals which can be passed along the food chain. Burrard Inlet is closed to shellfish harvesting based on sanitary considerations of the tributary area.

Provisional water quality objectives have been set for metals, nutrients, chlorophenols, PCBs, PAHs, tributyltin, microbioloical indicators and some other variables. Attainment of these objectives will protect all used including aquatic life and recreation. A strategy to reduce the sources of contaminants to Burrard Inlet will need to be developed to achieve these objective consistently.

FIGURES

FIGURE 1. The Burrard Inlet Study Area

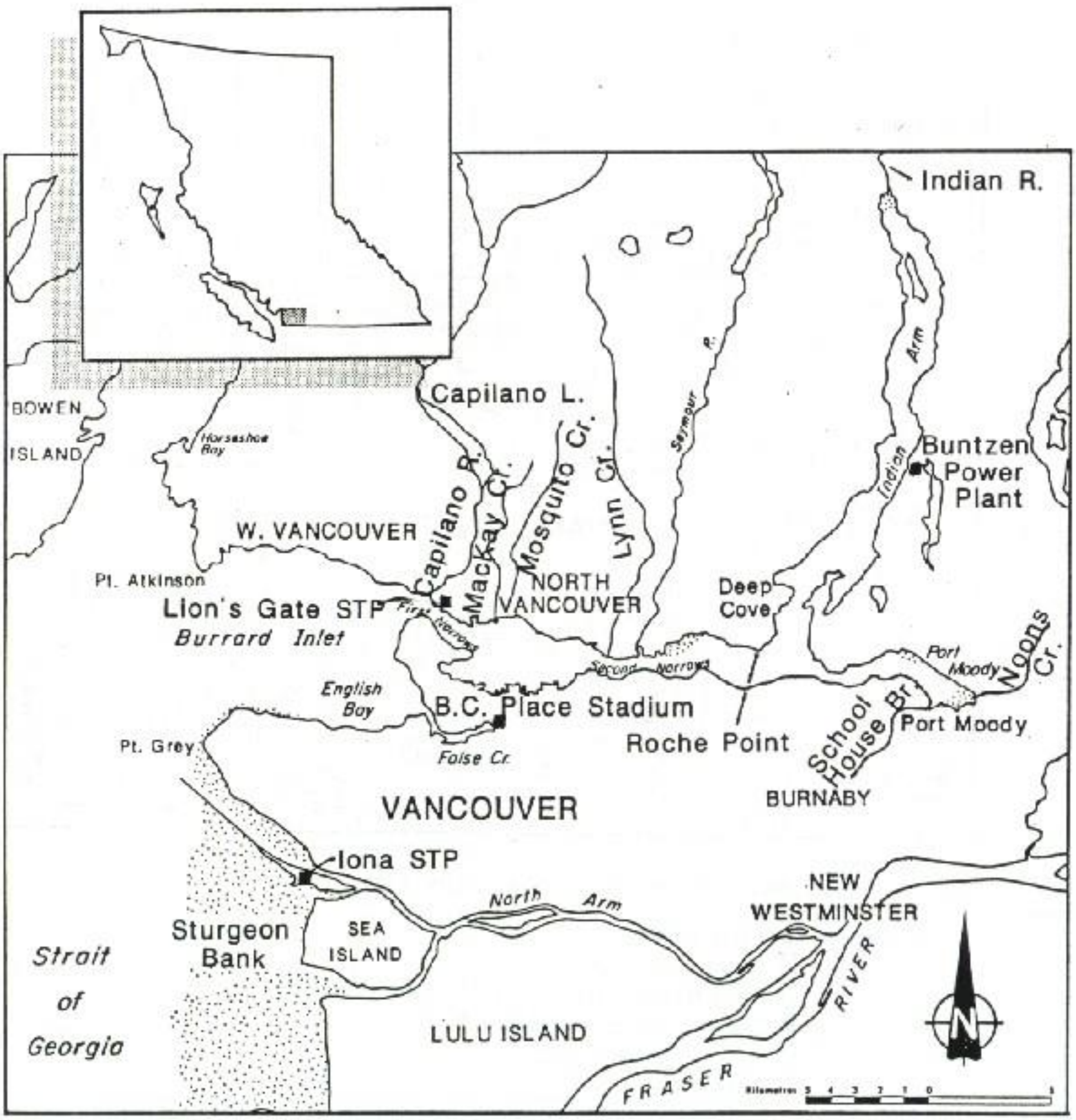

FIGURE 2. Sub-Basins in the Burrard Inlet Study Area

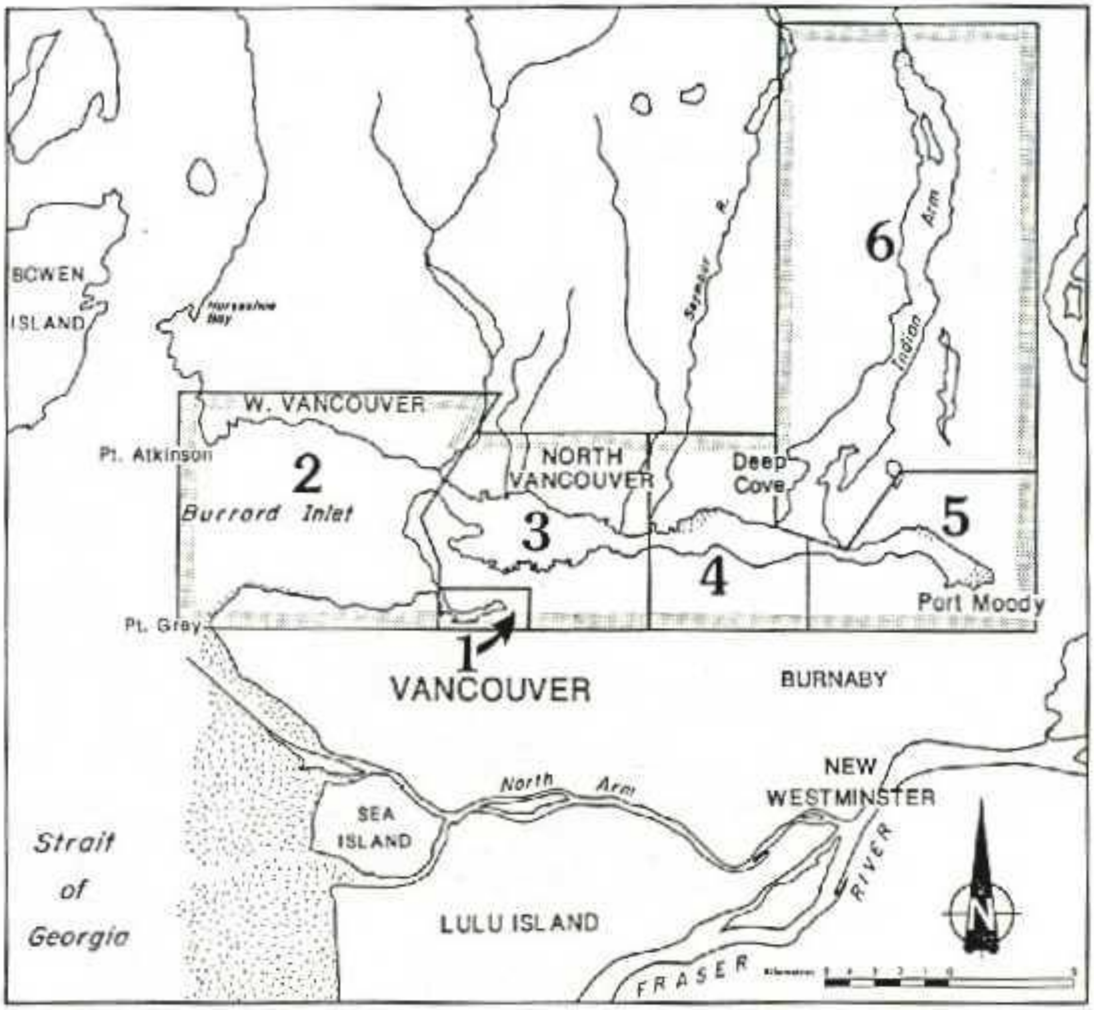

Figure 2. Sub-Basins in the Burrard Inlet Study Area

Legend
1 False Creek
2 Outer Burrard Inlet
3 First Narrows to Second Narrows (Vancouver Harbour)
4 Second Narrows to Roche Point
5 Port Moody Arm
6 Indian Arm

PREFACE

Purpose of Water Quality Objectives

Water quality objectives are prepared for specific bodies of fresh, estuarine and coastal marine surface waters of British Columbia as part of the Ministry of Environment, Lands and Parks' mandate to manage water quality. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the near future.

How Objectives Are Determined

Water quality objectives are based the BC approved and working criteria as well as national water quality guidelines. Water quality criteria and guidelines are safe limits of the physical, chemical, or biological characteristics of water, biota (plant and animal life) or sediment which protect water use. Objectives are established in British Columbia for waterbodies on a site-specific basis. They are derived from the criteria by considering local water quality, water uses, water movement, waste discharges, and socio-economic factors.

Water quality objectives are set to protect the most sensitive designated water use at a specific location. A designated water use is one that is protected in a given location and is one of the following:

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

Each objective for a location may be based on the protection of a different water use, depending on the uses that are most sensitive to the physical, chemical or biological characteristics affecting that waterbody.

How Objectives Are Used

Water quality objectives routinely provide policy direction for resource managers for the protection of water uses in specific waterbodies. Objectives guide the evaluation of water quality, the issuing of permits, licences and orders, and the management of fisheries and the province's land base. They also provide a reference against which the state of water quality in a particular waterbody can be checked, and help to determine whether basin-wide water quality studies should be initiated.

Water quality objectives are also a standard for assessing the Ministry's performance in protecting water uses. While water quality objectives have no legal standing and are not directly enforced, these objectives become legally enforceable when included as a requirement of a permit, licence, order, or regulation, such as the Forest Practices Code Act, Water Act regulations or Waste Management Act regulations.

Objectives and Monitoring

Water quality objectives are established to protect all uses which may take place in a waterbody. Monitoring (sometimes called sampling) is undertaken to determine if all the designated water uses are being protected. The monitoring usually takes place at a critical time when a water quality specialist has determined that the water quality objectives may not be met. It is assumed that if all designated water uses are protected at the critical time, then they also will be protected at other times when the threat is less.

The monitoring usually takes place during a five week period, which allows the specialists to measure the worst, as well as the average condition in the water.

For some waterbodies, the monitoring period and frequency may vary, depending upon the nature of the problem, severity of threats to designated water uses, and the way the objectives are expressed (*i.e.*, mean value, maximum value).

INTRODUCTION

This report examines the water quality in Burrard Inlet which encompasses three main bodies of water (see Figure 1. and Figure 2.): the eastern basin, Vancouver Harbor and outer Burrard Inlet.

The eastern basin of the inlet starts at Port Moody, continuing west for about thirteen kilometres to Second Narrows. The major volume of water in the eastern portion of the inlet is Indian Arm, which opens at the mid point of Port Moody and extends north for about 22 kilometres.

Vancouver Harbor is that basin of water between First and Second Narrows. Second is about 600 m wide, while the width of First Narrows is about 450 m with a depth of 15 m. Vancouver Harbor is about 2.5 kilometres wide and is about eight kilometres long.

Outer Burrard Inlet is that portion to the west from First Narrows, which opens to the Strait of Georgia for a width of about six kilometres between Point Atkinson and Point Grey. This basin, which lies between Vancouver on the south shore and West Vancouver on the north, has a length of about eight kilometres. English Bay is formed at the southeast corner and False Creek forms an easterly extension of that Bay.

This review covers water quality and effluent quality data for the period 1972 to about December 1985. However, some more recent data are also referenced. This review was undertaken at the request of the regional office of the Ministry of Environment, when the Greater Vancouver Regional District undertook the preparation of a liquid waste management plans in late 1985. A detailed technical appendix was prepared and forms the basis for the conclusions presented in this report. As with many areas of the province, a large number of data were available from different sources on which to base objectives; however, these data had often been collected over varying time periods for different purposes, resulting in an incomplete "snapshot" of environmental conditions throughout the area at any one time.

OCEANOGRAPHY

Unlike the typical coastal inlets of British Columbia, Burrard Inlet is relatively shallow between First Narrows and the head at Port Moody, with a mean depth of 21 m and a maximum depth of 66 m occuring in Vancouver Harbor. The shorelines are of moderate slope. Port Moody is a relatively shallow arm of Burrard Inlet, with little direct freshwater inflow. Its oceanography is influenced mostly by the rest of Burrard Inlet and Indian Arm. In contrast, Indian Arm is a typical deep inlet, or fjord, with a mean depth of about 120 m, a maximum depth of 218 m, a sill at the entrance and steep mountain walls.

Fresh water drainage to Indian Arm includes the Indian River at the head of the Arm, numerous peripheral streams and the Buntzen Power Plant that diverts water from the Coquitlam Lake drainage to supply about 40% of the total runoff into the Arm. Drainage to the remainder of Burrard Inlet includes that from the north shore and about half from the urban areas of Vancouver, Burbnaby and Port Moody. The main runoff to this area is from the Seymour RIver with a range of monthly mean discharges from 3.8 m^3/s to 24.9 m^3/s and the Capilano River (Outer Burrard Inlet) with a range from 5.7 m^3/s to 42.8 m^3/s. Other significant sources of inflow include Lynn Creek near the Seymour River, Mosquito and Mackay Creeks in North Vancouver and Noons Creek in Port Moody.

The last source of freshwater to Burrard Inlet and especially out Burrard Inlet, is the Fraser River whose runoff usually peaks in the early summer. The Fraser River influences Burrard Inlet through tidal movement independently of local runoff which is heaviest from autumn through spring.

Tidal currents in Burrard Inlet contributes the most towards mixing and flushing, although wind-stirring, evaporation and internal waves are also factors. The mean tide is about 3 m although the maximum can reach 4.9 m. Tides have both diurnal and semi-diurnal oscillations. The maximum current speed is about six knots at both the First and Second Narrows where most of the mixing occurs. Current speeds are much less elsewhere in the inlet, about one-half to two knots. Flood currents are generally up-inlet with ebb currents down-inlet, although well defined eddies can produce reverse flows, the result of indentations in the inlet.

The esturaine circulation in Burrard Inlet includes the seaward movement of freshwater and entrained salt water together with the compensating up-inlet flow of deep water from the Strait of Georgia. It is enhanced by predominant easterly winds which drive surface water towards the mouth of Burrard Inlet.

The salinity of deeper water is usually 29-30 ppt, while the surface salinity can vary from 20-25 ppt during the winter local runoff period and to less than 10 ppt during the summer when Fraser River runoff is the major dilution factor. The most saline surface waters in Burrard Inlet occur between the First and Second Narrows due to turbulent mixing associated with estuarine and tidal flows through the shallow areas.

The temperature of surface water in Burrard Inlet in the summer is generally higher than deeper water, with a maximum of about 20 degrees Celsius. Winter temperatures of surface water are about 5 degrees Celsius or less and are lower than that of deeper water. Deep water temperatures fluctuate less than surface water. An isothermal condition can result from vertical mixing during very cold winters. Turbulent mixing due to estuarine and tidal flow through the First and Second Narrows can also yield surface temperatures lower during the summer and higher during the winter than those which would be found in simpler estuarine environment.

WATER USES

Water usues to be protected in most areas include aquatic life and wildlife and primary-contact recreation. Exceptions to this are a lack of primary-contact recreation in False Creek, except near its mouth due to lack of coarse sediments. Drinking water is licenced for withdrawal from the Capilano and Seymour Rivers and from Lynn Creek. In fact, the Capilano and Seymour watersheds provide most of the metro Vancouver water supply.

WASTE DISCHARGES

Commercial activities in Vancouver Harbor are chiefly concerned with the trans-shipment of goods and bulk commodities. Production facilities are present on a limited scale and are usually associated with ship repair and the forest products and petroleum industries.

Waste discharges to the Burrard Inlet area have been categorized by three types: those under permit from the Waste Management Act, those not under permit and those which do not require a permit. Water quality objectives are proposed considering all of these types of discharges. Objectives would also be useful in cases of accidental spills, the potential for which is quite great in Burrard Inlet since it is a busy harbor.

Combined sewer overflows and stormwater outfalls have localized impacts, including some impact on benthic organisms and sediments. These could be expected to reduce dissolved oxygen and increase concentrations of metals and microbiological organisms, thereby possibly restricting primary-contact recreation at nearby beaches. Boats have localized impact due to small quantities of oil from emissions, from tributyl tin used in antifouling paint which can peel or be removed with cleaning/painting, or through sanitary waste discharges which could contribute to microbiological contamination, especially in marinas.

False Creek:
Three discharges to False Creek are covered under permit. These consist of a combined sewer overflow, two stormwater outfalls and cooling waters from a ready-mix cement plant and from BC Place Stadium. The major anticipated impacts from these discharges are increased bacteriological contamination from the combined sewer outfall and oily films from cooling water.

Discharges not yet under permit or not requiring are seven combined sewer overflows, a number of stormwater discharges and discharges from a number of marinas. The volume of stormwater discharges is minor in comparison to that from combined sewer overflows. Impacts from the stormwater and combined sewer outfalls would be greater during the winter and closet to the outfalls due to larger precipitation volumes at those times.

Outer Burrard Inlet:
The Lion's Gate sewage treatment plant (STP) is the only permitted discharge to this area of the Inlet. Leachate from a closed landfill which was never under permit can enter the Capilano River. Digested sludge from the primary-treated sewage from the Lion's Gate STP is discharged on out-going tides. Normally, the sewage is afforded a dilution of about 5000:1 at a distance of only 50 m from diffusers. This high dilution should help protect aquatic life from acute toxicity except at locations immediately adjacent to the outfall. The landfill operation could possibly impacted levels of dissolved solids, ammonia, iron and manganese in the Capilano River.

Discharges not yet under permit are five intermittent combined sewer overflows along the south shore into the English Bay area and a number of separate stormwater outfalls on the north shore from the West and North Vancouver area.

First to Second Narrows:
There are six permitted discharges into this portion of the Inlet and one to Lynn Creek. One of the operations with the greatest impact is a bulk loading terminal on the north shore located just east from the Lion's Gate Bridge. Discharges from it can impact pH, suspended solids and sediment/water column concentrations of sulphur, copper, zinc, lead and nickel. The sediment metal concentrations in a localized area are similar or higher than found in an area of Sturgeon Bank previously contaminated by the Iona STP. Copper and lead concentrations of resident biota indicate that bioaaccumulations is occurring.

A second bulk loading operation on the north shore discharges just west from the Second Narrows Bridge. It handles coal, potash and alfalfa. Some localized impacts are suspected to occur near this operation. A third bulk loading facility, near the second one, handles caustic soda, ethylene glycol and ethylene dichloride and discharges stormwater. It is not known if impacts adjacent to this operation occur.

A sugar refinery on the south shore uses once-through cooling water from Burrard Inlet. This discharge has had some high oil and grease concentrations which can impact an oily film to the water.

The public aquarium discharges water from the mammal pool and filter back-wash water without treatment, while a ready-mix cement operation discharges truck washwater and stormwater. These discharges are not expected to impact Burrard Inlet.

One permitted landfill adjacent to Lynn Creek has, in the past, discharged leachate into the creek. Increased concentrations in the creek were noted for metals, ammonia and nitrite. The leachate is now collected and discharged to the municipal sewerage system, although some leachate still appears to be entering the creek.

There are seven combined overflows from the south shore and two from the north shore into Burrard Inlet. In addition there are a large number of stormwater outfalls from North Vancouver that discharge into the Inlet.

Second Narrows to Roche Point:
Permitted discharges include an oil reprocessing facility, a sodium chlorate plant, a plant producing chlorine, hydrochloric acid and caustic soda, a ready-mix concrete batch plant, an oil shipment terminal and tank farm and two oil refineries. No impact is expected from the discharges from the oil reprocessing plant or the ready-mix operation.

The plant producing chlorine, hydrochloric acid and caustic soda potentially could cause localized impacts, most notably pH fluctuations and high chlorine values. As well, high metal concentrations discharged in the past may have impacted nearby sediments and benthic organisms. The sodium chlorate processing plant can potentially cause toxicity problems if sodium chlorate is discharge and converted to free chlorine. The oil shipment terminal/tank farm discharges ship-ballast water which is not expected to have a significant impact.

Two oil refineries on the south shore discharge treated stormwater runoff to the Inlet. The process waste water from both refineries is discharged to the municipal sewage system, while that from the petroleum bulk handling facility associated with one is discharged to the Inlet after treatment. Uncontaminated cooling water is also discharged from the latter site. These discharges can contain oil and grease which could give rise to oily surfaces in the receiving water, ammonia at concentrations less than those considered toxic to aquatic life, cyanide, heavy metals or phenols which can be acutely toxic or which can impart a taste to fish flesh and oxygen demanding substances.

There are four combined sewer overflows from Burnaby on the south side and a minimal number of other stormwater outfalls, near the Seymour River, which discharge to the Inlet on the north side.

Port Moody Arm:
Port Moody Arm appears to be the area of Burrard Inlet most highly impacted from wastewater discharges. For example, nearly 60% of English Sole caught in the area have liver lesions compared to 13% in Burrard Inlet.

There are thirteen permits issued to operations from wastewater discharges in this area. Eight of these operations have discharges to Port Moody Arm, one if landfill, one discharges to a creek and three are discharges to septic tank/tile field systems. These latter two are small-volume domestic sewage discharges well removed from Burrard Inlet, so these will not be considered further. One of the discharges to Port Moody Arm is chlorinated secondary-type sewage from about 50 homes. The large dilution for this discharge would result in it having only a minimal impact. Leachate from the landfill is entering the Inlet at the Reed Point Marina. The remaining permitted discharges are from a thermal electric generation plant, two oil refineries, a bulk storage facility, two chemical plants, a sawmill and a bulk loading terminal.

The thermal plant uses natural gas and discharges cooling water. Use of natural gas reduces the potential for oil and gas residues to reach the Arm. Chlorine is used to prevent bio-film formation in cooling circuits and could be of concern with respect to toxicity of cooling water. Otherwise, impacts are likely minimal.

Two oil refineries are located on the north and south shores of Port Moody Arm. Both now discharge process wastewater to the municipal sewage system but continue to discharge treated stormwater to Port Moody Arm. This water contains residues of oil and grease, phenolics and PAHs. A petroleum bulk loading facility discharges treated stormwater and some sanitary sewage. Although discharging similar contaminants as the oil refineries, the smaller volume minimizes the potential impact of this discharge.

The sawmill discharges once-through cooling water treated with chlorine and treated debarker effluent. The debarker effluent can cause hydrogen sulphide problems on the bottom. Chlorine is the only other variable of possible concern since the mill does not use chlorophenols as a wood preservative.

The bulk loading facility handles ethylene glycol and styrene monomer which can enter Port Moody Arm with treated stormwater. Sediments near this site seem to have high sulphur, lead and zinc levels, none of which could have come from the glycol or styrene cargoes.

One of the chemical plants produces synthetic and formaldehydes. Process effluent is discharged to the municipal sewer. Cooling water is actually discharged to School House Brook, a tributary to Port Moody Arm. This discharge may affect aquatic life. The second chemical plant produces alum, with stormwater and process effluent being discharged to exfiltration ponds within 100 m of the foreshore. Due to the low pH in the ponds, it is possible that metals can exfiltrate and cause localized impacts on Port Moody Arm.

Two combined sewer overflows and a small number of stormwater outfalls also discharge to Port Moody Arm.

Indian Arm:
No discharges under permit enter Indian Arm directly. There are no combined sewer overflows and only a few stormwater outfalls. Recreational water craft utilize the marina at Deep Cove and may cause localized effects.

WATER QUALITY ASSESSMENT

False Creek:
Concentrations of cadmium, mercury and lead in sediments from False Creek were often higher than criteria that would permit their disposal at a deep-sea site. Generally, contaminant levels decreased from the eastern extremity basin of False Creek towards the mouth. These high levels are a result of industrial operations which discharged to False Creek up to about 1970, mainly to the eastern end.

Concentrations higher than water quality criteria to protect aquatic life have been measured for total copper, iron, lead, mercury, nickel and zinc in the water column at both the east and west end of False Creek. Dissolved oxygen concentrations on occasion have been below the minimum needed to provide a moderate level of protection to aquatic life. Towards the mouth of False Creek, bacteriological quality during the summer months was usually adequate to allow primary-contact recreation.

Capilano River:
Capilano Lake, the headwaters of the Capilano River, is used as one of three water supplies by the GVRD. The Capilano River is characterized by soft water with low concentrations of suspended solids and turbidity. The pH was slightly acidic but met criteria for all possible water uses. Alkalinity was low, making the water highly sensitive to acidic inputs. Bacteriological quality would allow primary-contact recreation; more stringent drinking water quality criteria do not have to be met below the lake since there are no drinking water withdrawals and no reason to think that there will be any in the future.

Outer Burrard Inlet (English Bay):
Dissolved oxygen concentrations which can be low in marine waters with increased depth were occasionally below the minimum needed to provide a moderate level of protection to aquatic life. Total copper, iron, lean and zinc concentrations in the water did not always meet criteria for the protection of aquatic life; copper was the characteristic which most frequently exceeded criteria (about one-third of values), the high values usually occurring in deeper waters as opposed to surface waters. Fecal coliforms often exceeded criteria for primary-contact recreation in the winter and, on occasion, in the summer due to combined sewer overflows which occur more frequently than designed for.

Lynn Creek:
Lynne Creek had soft water with a slightly acidic pH which met water quality criteria for protection of aquatic life. High concentrations of dissolved oxygen were present, even downstream from the landfill when leachate still entered the creek. Concentrations of ammonia were below criteria to protect freshwater aquatic life. Some metals above criteria to protect aquatic life were iron, copper and mercury.

First to Second Narrows:
The bacteriological quality was usually adequate to permit primary-contact recreation. Occasionally, these criteria were exceeded, which likely reflected the presence of a combined sewer overflow near the beach in question. Dissolved oxygen concentrations were usually above

criteria which provide a moderate level of protection to aquatic life, but below those measured at the same time period in Indian Arm or in East Burrard Inlet.

In areas well removed from contaminant sources, dissolved oxygen concentrations occasionally were below criteria to provide a moderate level of protection to aquatic life. Surface samples were considerably lower near First Narrows than near Second Narrows, presumably as a result of the discharge from the Lion's Gate STP.

Metals which occasionally exceeded criteria were total copper, iron, lead and zinc. There were indications that copper and lead were accumulating in the benthic populations, with apparent bioaccumulation in anemone and mussel.

Second Narrows to Roche Point:
On infrequent occasions, the bacteriological water quality at some beaches was not suitable for primary-contact recreation.

Dissolved oxygen concentrations provided a moderate level of protection to aquatic life. At other non-beach sites, total copper and lead concentrations often exceeded water quality criteria to protect aquatic life.

Copper concentrations in sediments were lower than found between First and Second Narrows, while other metals were below deep-sea disposal criteria. Two notable exceptions were lead and cadmium, which were at levels comparable to those found in the contaminated area adjacent to the former discharge from the Iona STP which had been classified by an earlier study group as being impacted. These high concentrations were likely associated with paint scrapings from nearby shipyards.

In algae, copper concentrations were approximately the same at all sites. Metal concentrations were generally lower at the unaffected sites than at sites affected by discharges.

Some mussel samples showed accumulations of arsenic and cadmium, while some samples had lead and mercury which exceeded criteria for human consumption.

School House Brook:
There are generally a paucity of data for this water body. It would appear that the water can be acidic, with frequent occasions when the pH was below criteria to protect aquatic life. Occasionally elevated concentrations of total chromium, copper, iron, lead and zinc above criteria to protect aquatic life were also present. Some elevated (above criteria to protect aquatic life) phenol values have been recorded in the past but have not been measured recently.

Port Moody Arm:
As is the case for the remainder of Burrard Inlet, Port Moody Arm is closed to bivalve-mollusc harvesting due to coliform contamination as measured in a sanitary survey. However, bacteriological quality was such that primary-contact recreation can be permitted.

Total copper, iron and lead concentrations frequently exceeded water quality criteria to protect marine life. Infrequently, total nickel and zinc also exceeded criteria.

Dissolved oxygen concentrations were often less than criteria to provide moderate level of protection to aquatic life. As in other areas of Burrard Inlet, it is suspected that dissolved oxygen concentrations may be decreasing. Some elevated sulphide concentrations, above marine water quality, have been measured near a bulk loading facility. Associated sulphur concentrations in sediments were also high.

Cadmium values in all sediment samples were higher than criteria which would permit deep-sea disposal. Copper concentrations in sediments were about the same as from the area of Sturgeon Bank contaminated by the former discharge from the Iona STP, an area classified as being environmentally impacted.

Arsenic, copper, iron and lead in algae near one oil refinery and one chemical plant producing alum were similar or higher than in algae from the area contaminated by the former discharge from the Iona STP. Mussels collected in 1974 and 1980 had high zinc concentrations and had lead concentrations which exceeded criteria for edible tissue.

Indian Arm:
As with other areas of Burrard Inlet, some dissolved oxygen levels in Indian Arm provided less than a moderate degree of protection to aquatic life. Such a situation can occur naturally in deeper marine waters. Bacteriological quality was generally suitable for primary-contact recreation and approached a level where shellfish harvesting would be acceptable.

Five metals measured in the total state (copper, iron, lead, nickel and zinc) occasionally exceeded water quality criteria to protect aquatic life.

PROVISIONAL WATER QUALITY OBJECTIVES

A summary of designated water uses and proposed provisional water quality objectives is given in Table 1 for marine waters of Burrard Inlet exclusive of tributaries and in Table 2 for the fresh waters tributaries. The objectives are based on working and approved criteria for water quality and on available data on ambient water quality, waste discharges, water uses and river flows. The objectives will remain provisional until receiving water monitoring programs provide adequate data and the Ministry has established approved water quality criteria for all the characteristics of concern.

Water quality objectives have no legal standing and would not be directly enforced. The objectives are policy guidelines for resource managers to protect water uses in the specified water bodies. They will guide the evaluation of water quality, the issuing of permits, licences and orders and the management of the fisheries and of the Province's land base. They also provide a reference against which the state of water quality in a particular water body can be checked and serve as guidelines on which to make decisions on whether to initiate basin-wide water quality studies.

Depending on the circumstances, water quality objectives may already be met in a water body or may describe water quality conditions which can be met in the future. To limit the scope of the work, objectives are only being prepared for water bodies and for water quality characteristics which may be affected by man's activity now and in the foreseeable future.

Designated water sues for protection of aquatic life and wildlife and for primary-contact recreation in all water bodies. Exceptions to this are the exclusion of recreation for False Creek for the foreseeable future upon the advise of the Medical Health Officer, except near its mouth to English Bay and the provision for drinking water in the Capilano River and Lynn Creek.

Objectives are proposed for microbiological indicators to protect primary-contact recreation in all these areas including False Creek (except at the mouth) and School House Brook. Objectives are also proposed for all saline water, except Indian Arm, for suspended solids and turbidity, due to the large number of stormwater discharges and combined sewer overflows.

Chlorine produces oxidants in seawater which are highly toxic. Chlorine is used by some industrial processes and as an anti-foulant for cooling water systems. For these reasons, water quality objectives are proposed for Port Moody Arm and for Burrard Inlet from the Second Narrows to Roche Point. The objectives are expressed as chlorine-produced oxidants, namely bromine.

Ammonia can be highly toxic to aquatic life and is present in combined sewer overflows and in effluent from the Lion's Gate STP. Objectives for ammonia are proposed in all saline water areas of Burrard Inlet except Outer Burrard Inlet and Indian Arm. In Lynn Creek and the Capilano River, water quality objectives are also proposed for ammonia and nitrite due to possible impacts of leachate from closed landfills. Leachate can cause algal growths, therefore water quality objectives are proposed for both Lynn Creek and the Capilano River to protect recreation.

Dissolved oxygen concentrations can be impacted by stormwater discharges, combined sewer overflows and the discharge from the Lion's Gate STP. In the saline waters of Burrard Inlet, oxygen concentrations are often below the level to provide a high level of protection to anadromous fish and occasionally below the level to provide a moderate level of protection. Therefore an objective is proposed to meet this lower level (6.5 mg/L). Higher values are proposed for Lynn Creek, where leachate has (prior to collection) had a higher oxygen demand. Two objectives are proposed, one for times of the year that fresh eggs and/or larvae are present (11.0 mg/L) and a second for the remainder of the year (8.0 mg/L).

A water quality objective has been proposed for weak-acid dissociable cyanide in Port Moody Arm since cyanide has been measured in the effluent from an oil-refinery. Ethylene dichloride can be emitted in stormwater from one operation located between First and Second Narrows, so an objective is proposed for that area.

Oil and grease can be present throughout Burrard Inlet. It comes from ships and marinas, as well as from some stormwater discharges, No objective for oil and grease is proposed but it is considered a nuisance condition which should not be present. Phenols can be present from oil refinery discharges or phenolic-type compounds in leachate from landfills. Objectives for phenols are proposed for Port Moody Arm, Burrard Inlet between Second Narrows and Roche Point and in Lynn Creek, the Capilano River and School House Brook.

One industrial operation on Port Moody Arm can discharge styrene, therefore a water quality objective is proposed for this characteristic. Bulk loading facilities can be responsible for high sulphide concentrations and an objective is proposed for both Port Moody Arm and First to Second Narrows.

The release of cooling water to School House Brook has resulted in water quality objective being proposed for a maximum temperature increase. Objectives have been proposed for pH from Second Narrows to Roche Point since one industrial discharge can have wide fluctuations, as can a second operation which discharges to School House Brook. Objectives have been proposed to protect aquatic life from several metals in the different water bodies, in the water column, sediments and fish tissue. These metals enter the water bodies from several sources: bulk loading facilities, landfill leachate, stormwater runoff, combined sewer overflows and several industrial operations.

Chlorophenols can enter the First to Second Narrows section of Burrard Inlet and Lynn Creek from two operations near the mouth of the creek. Objectives are proposed for the water column, sediments and fish tissue.

Objectives for PCB's are proposed for all the saline water bodies except Indian Arm since PCB's can be discharged in stormwater runoff. PCBs were also present in leachate entering Lynn Creek. Objectives for PCBs in sediments and fish tissue are those developed for the Fraser River. While an objective for the water column was not proposed for the Fraser River, one is proposed for Lynn Creek since it is felt that with the small dilution present, PCBs might be measurable in the water column, especially at the low levels selected for the objective.

Objectives have been proposed for several polycyclic hydrocarbons (PAHs) in sediments of all areas except Indian Arm since these can enter all areas of Burrard Inlet from stormwater discharges, combined sewer overflows and from oil refinery and storage areas. The objectives are based upon existing PAH concentrations in sediments in other areas of the Lower Mainland and on Apparent Effects Thresholds determined for PAHs in Puget Sound sediments. Since PAH concentrations in sediments frequently exceed the proposed objectives, these are long-term in nature.

MONITORING RECOMMENDATIONS

Several monitoring programs have been proposed in the technical appendix, to check proposed objectives or to enhance the data base for variables which possibly should be considered for objectives development in the future. Appropriate monitoring of waste discharges should be conducted at the same time as receiving water monitoring. The recommended monitoring is based upon technical considerations and actual programs will depends on budget allocations and project priorities.

These monitoring programs are necessary if the setting of water quality objectives is to be useful in preventing water quality problems.

TABLES

Table 1. Provisional Water Quality Objectives for Burrard Inlet Exclusive of Tributaries

<table>
<tr><th>Water Body</th><th>False Creek</th><th>Outer Burrard Inlet</th><th>First to Second Narrows</th><th>Second Narrows to Roche Point</th><th>Port Moody area</th><th>Indian Arm</th></tr>
<tr><td>designated use</td><td>aquatic life, wildlife</td><td colspan="5">recreation, aquatic life, wildlife</td></tr>
<tr><td>microbiological indicators</td><td colspan="6">fecal coliforms: ≤ 200/100 mL geometric mean
enterococci: ≤ 20/100 mL geometric mean</td></tr>
<tr><td>suspended solids</td><td colspan="5">10 mg/L maximum increase</td><td>N/A</td></tr>
<tr><td>turbidity</td><td colspan="5">5 NTU maximum increase</td><td>N/A</td></tr>
<tr><td>chlorine produced oxidants</td><td colspan="3">N/A</td><td colspan="2">≤ 3 µg/L average</td><td>N/A</td></tr>
<tr><td>total ammonia-nitrogen</td><td>≤ 1 mg/L average; 2.5 mg/L maximum</td><td>N/A</td><td colspan="3">≤ 1 mg/L average; 2.5 mg/L maximum</td><td>N/A</td></tr>
<tr><td>dissolved oxygen</td><td colspan="6">6.5 mg/L minimum</td></tr>
<tr><td>weak acid dissociable cyanide</td><td colspan="4">N/A</td><td>1 µg/L maximum</td><td>N/A</td></tr>
<tr><td>sulphide, undissociated H_2S</td><td colspan="2">N/A</td><td>2 µg/L maximum</td><td>N/A</td><td>2 µg/L maximum</td><td>N/A</td></tr>
<tr><td>pH</td><td colspan="3">N/A</td><td>6.5 to 8.5</td><td colspan="2">N/A</td></tr>
<tr><td>total barium</td><td colspan="3">N/A</td><td>0.5 mg/L</td><td colspan="2">N/A</td></tr>
<tr><td>total arsenic (in water)</td><td colspan="2">N/A</td><td colspan="2">10 µg/L maximum</td><td colspan="2">N/A</td></tr>
<tr><td>total cadmium (in water)</td><td colspan="2">N/A</td><td colspan="4">≤ 9 µg/L mean and 43 µg/L maximum</td></tr>
<tr><td>total copper (in water)</td><td colspan="6">≤ 2 µg/L mean and 3 µg/L maximum</td></tr>
<tr><td>total chromium (in water)</td><td>50 µg/L maximum</td><td colspan="2">N/A</td><td colspan="2">50 µg/L maximum</td><td>N/A</td></tr>
<tr><td>total arsenic (in sediments)</td><td colspan="5">20 µg/g dry weight maximum</td><td>N/A</td></tr>
</table>

<table>
<tr><td>total cadmium (in sediments)</td><td>1 µg/g dry weight maximum interim value: < 9 µg/g mean and 43 µg/g maximum</td><td colspan="4">1 µg/g dry weight maximum</td><td>< 9 µg/g mean and 43 µg/g maximum</td></tr>
<tr><td>total chromium (in sediments)</td><td colspan="5">60 µg/g dry weight maximum</td><td>N/A</td></tr>
<tr><td>total copper (in sediments)</td><td colspan="5">100 µg/g dry weight maximum</td><td>N/A</td></tr>
<tr><td>total lead (in sediments)</td><td colspan="5">30 µg/g dry weight maximum</td><td>N/A</td></tr>
<tr><td>total nickel (in sediments)</td><td colspan="5">45 µg/g dry weight maximum</td><td>N/A</td></tr>
<tr><td>total mercury (in sediments)</td><td colspan="5">0.15 µg/g dry weight maximum</td><td>N/A</td></tr>
<tr><td>total lead (in water)</td><td colspan="6">≤ 2 µg/L mean and 140 µg/L maximum</td></tr>
<tr><td>total lead (in fish muscle)</td><td colspan="6">0.8 µg/g wet weight maximum</td></tr>
<tr><td>total mercury (in water)</td><td colspan="4">0.02 µg/L mean and 2 µg/L maximum</td><td colspan="2">N/A</td></tr>
<tr><td>total mercury (in fish tissue)</td><td colspan="4">0.5 µg/g weight wet maximum</td><td colspan="2">N/A</td></tr>
<tr><td>total nickel (in water)</td><td>≤ 8 µg/L mean and 75 µg/L maximum</td><td>N/A</td><td colspan="2">≤ 8 µg/L mean and 75 µg/L maximum</td><td colspan="2">N/A</td></tr>
<tr><td>total zinc (in water)</td><td colspan="6">≤ 0.086 mg/L mean and 0.095 mg/L maximum</td></tr>
<tr><td>total zinc (in sediment)</td><td colspan="5">150 µg/g dry weight maximum</td><td>N/A</td></tr>
<tr><td>PCBs (in sediment)</td><td colspan="5">0.03 µg/g dry weight maximum</td><td>N/A</td></tr>
<tr><td>PCBs (in fish tissue)</td><td colspan="5">0.5 µg/g wet weight maximum</td><td>N/A</td></tr>
<tr><td>Chlorophenols (in sediment)</td><td colspan="2">N/A</td><td>0.01 µg/g dry weight maximum</td><td colspan="3">N/A</td></tr>
<tr><td>Chlorophenols (in fish tissue)</td><td colspan="2">N/A</td><td>0.1 µg/g wet weight maximum</td><td colspan="3">N/A</td></tr>
<tr><td>Chlorophenols (in water)</td><td colspan="2">N/A</td><td>0.2 µg/L maximum</td><td colspan="3">N/A</td></tr>
</table>

tributyl tin	10 ng/L maximum		N/A	10 ng/L maximum	
phenols	N/A		1 µg/L maximum		N/A
styrene	N/A			0.05 mg/L maximum	N/A
1,2-dichloroethane or ethylene dichloride	N/A	≤ 0.2 mg/L mean and 2 mg/L maximum	N/A		
total LPAHs (in sediment)	0.5 µg/g dry weight maximum in sediment, long-term				N/A
naphthalene (in sediment)	0.2 µg/g dry weight maximum in sediment, long-term				N/A
acenaphthylene (in sediment)	0.06 µg/g dry weight maximum in sediment, long-term				N/A
acenaphthene (in sediment)	0.05 µg/g dry weight maximum in sediment, long-term				N/A
fluorene (in sediment)	0.05 µg/g dry weight maximum in sediment, long-term				N/A
phenanthrene (in sediment)	0.15 µg/g dry weight maximum in sediment, long-term				N/A
anthracene (in sediment)	0.1 µg/g dry weight maximum in sediment, long-term				N/A
total LHAHs (in sediment)	1.2 µg/g dry weight maximum in sediment, long-term				N/A
fluoranthene (in sediment)	0.17 µg/g dry weight maximum in sediment, long-term				N/A
pyrene (in sediment)	0.26 µg/g dry weight maximum in sediment, long-term				N/A
benzo(a)anthracene (in sediment)	0.13 µg/g dry weight maximum in sediment, long-term				N/A
chrysene (in sediment)	0.14 µg/g dry weight maximum in sediment, long-term				N/A
benzo-fluoranthene (in sediment)	0.32 µg/g dry weight maximum in sediment, long-term				N/A
benzo(a)pyrene (in sediment)	0.16 µg/g dry weight maximum in sediment, long-term				N/A
indeno (1,2,3-c,d) pyrene (in sediment)	0.06 µg/g dry weight maximum in sediment, long-term				N/A
dibenzo (a,h) anthacene (in sediment)	0.06 µg/g dry weight maximum in sediment, long-term				N/A

benzo (g,h,i) perylene (in sediment)	0.07 µg/g dry weight maximum in sediment, long-term	N/A

Table 2. Provisional Water Quality Objectives for Tributaries to Burrard Inlet

Water bodies	**Capilano River and Lynn Creek**	**School House Brook**
designated water uses	drinking water, recreation, aquatic life and wildlife	recreation, aquatic life and wildlife
phenols	1 µg/L maximum	
total chromium	2 µg/L maximum	
total iron	3 µg/L maximum	
total zinc	15 µg/L maximum	
microbiological indicators	fecal coliforms: ≤ 200/100 mL geometric mean *Escherichia coli*: ≤ 77/100 mL geometric mean enterococci: ≤ 20/100 mL geometric mean	N/A
total ammonia-nitrogen	ammonia tables	N/A
total nitrite-nitrogen	nitrite table	N/A
periphyton chlorophyll-*a*	50 mg/m^2 maximum	N/A
dissolved oxygen	11 mg/L minimum for salmonid embryo and larval stages 8 mg/L minimum for all other salmonid life stages	N/A
total cadmium	0.2 µg/L maximum	N/A
total cobalt	2 µg/L average 0.094 (hardness) + 2 µg/L maximum	N/A
total mercury	0.5 µg/g wet weight in fish flesh	N/A
total mercury	0.02 µg/L average; 0.1 µg/L maximum in water	N/A
chlorophenols	0.2 µg/L in water 0.1 µg/g wet weight in fish tissue 0.01 µg/g dry weight in sediment	N/A
PCBs	1 ng/L in water 0.5 µg/g wet weight in fish flesh 0.03 µg/g dry weight in sediment	N/A
temperature	N/A	1^{o} C increase over the u/s site
pH	N/A	6.5 to 9.0
total lead	N/A	see footnote #12

These footnotes apply to both Table 1 and Table 2 above.

The objectives apply to discrete samples from all parts of the waterbodies, except from initial dilution zones of effluents. These excluded initial dilution zones in Lynn Creek and Schoolhouse Brook are defined as extending up to 100 m d/s from a discharge, and occupying no more than 50% of the stream width around the discharge point, from the bed of the stream to the surface. These excluded initial dilution zones in marine waters are defined as extending up to 100 m horizontally in all directions, but not to exceed 25% of the width of the waterbody. This exclusion does not apply to objectives for fish as noted in footnote #10 below.

1. For microbiological indicators the geometric mean is calculated from at least five weekly samples taken in a period of 30 days during the recreation season. The objective for microbiological indicators in False Creek applies only to bathing beaches at the mouth of False Creek.
2. For suspended solids and turbidity the increase (in mg/L or NTU) is over levels measured at a control site away from the discharge or series of discharges and as close to them as possible, and applies to areas affected by the discharge.
3. Since the objective for chlorine produced oxidants is less than the minimum detectable concentration it will be necessary to estimate the receiving water concentration using effluent load and available dilution. The objective applies only if sewage effluent is chlorinated.
4. For chlorine produced oxidants and total ammonia, copper, lead, mercury, nickel, zinc, ethylene dichloride and nitrite the average is calculated from at least five wekly samples taken in a period of 30 days.
5. The periphyton chlorophyll-a average is calculated from at least five samples from natural substrates.
6. pH measurements may be made "in situ" but must be confirmed in the laboratory if the objective is exceeded.
7. If strong-acid dissociable cyanide values are greater than the objective for weak-acid dissociable cyanide further sampling is recommended at the same site in bright sunlight and at sites further downstream.
8. The term chlorophenol means the sum of tri-, tetra- and pentachlorophenol which may be present in water, sediment or fish.
9. For total arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc and for chlorophenols and PCBs, the maximum value should not be exceeded in bottom surface sediments taken in any part of the sub-basin except in the initial dilution zone of effluents. The average of at least three replicate sediment samples taken from the same site should be used to check the objective.
10. Total lead and mercury, chlorophenols and PCBs objectives in fish apply only to muscle tissue, not the whole fish or organs, of any fish of any species caught in any part of the sub-basin, including the initial dilution zones of effluents.
11. The term PCBs applies to the sum of Aroclor 1242, 1254 and 1260 which may be present in water, sediment or fish.
12. For total lead in Schoolhouse Creek the objectives, in micrograms/L when hardness is measured as mg/L $CaCO_3$ are:

(i) 30-day average: none proposed at hardness less than or equal to 8
less than or equal to 3.31 + exp(1.273 ln (mean hardness) - 4.705) when hardness exceeds 8
80% of the values should be less than or equal to 1.5 x 30-day mean.
(ii) maximum: 3 when hardness is less than or equal to 8
exp (1.273 ln (hardness) - 1-460) when hardness exceeds 8.
13. For total cadmium, chromium and nickel, monitoring is proposed even though no fish tissue objective is set.
14. For tributyl tin, monitoring is proposed even though no fish tissue or sediment objectives are set.
15. The dissolved oxygen objective from the First Narrows through Port Moody Arm is a long-term objective.
16. The mercury objective in Lynn Creek is a long-term objective.
17. The total arsenic and cadmium objectives in the sediments of False Creek, the First to Second Narrows section of Burrard Inlet and Port Moody Arm are long-term objectives.
The total chromium and iron objectives in the sediments of False Creek; total iron in the sediments of Port Moody Arm and all sediment objectives for total lead and zinc are long-term objectives.
The total mercury objectives in the sediments of False Creek, Outer Burrard Inlet and the First to Second Narrows section of Burrard Inlet are long-term objectives.
The total mercury objectives in the sediments of False Creek, Outer Burrard Inlet and the First Narrows to Roche Point section of Burrard Inlet are long-term objectives.
All PAH objectives in sediments are long-term objectives.

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