Ministry of Environment

LOWER MAINLAND REGION

Water Quality Assessment and Objectives

Okeover Inlet.

Technical Report

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ENVIRONMENTAL QUALITY

PREFACE

This report is one in a series of water, groundwater, and air quality reports that are being issued by the Lower Mainland Regional Office, of the Ministry of Environment in fiscal year 2004/05. It is the intention of the Regional Office to publish water, groundwater and air quality reports on our website (http://wlapwww.gov.bc.ca/sry/p2/eq/index.htm) in order to provide the information to industry and local government, other stakeholders and the public at large. By providing such information in a readily understood format, and on an ongoing basis, it is hoped that local environmental quality conditions can be better understood, and better decisions regarding water, groundwater and air quality management can be made.

SUMMARY

This document is one in a series that presents ambient water quality objectives for British Columbia. It has two parts: this overview, which is available as a separate document, and the full report. This overview provides general information about water quality in Okeover Inlet. It is intended for both technical readers and for readers who may not be familiar with the process of setting water quality objectives. It includes tables listing water quality objectives and recommended monitoring. The main report presents the details of the water quality assessment for these waterbodies and forms the basis of the recommendations and objectives presented in this overview. Water quality objectives are recommended to protect aquatic life and primary-contact recreation in Okeover Inlet. Provincial Water Quality Objectives are not used for shellfish classification and harvesting which is the mandate of the federal Canadian Shellfish Sanitation Program. Water Quality Objectives, rather, are used as an indicator for aquatic health which includes the ability for shellfish growing and harvesting values.

There are a variety of human activities in the watershed which could degrade water quality. Of primary concern is the absence of a land use plan or zoning which leaves the inlet vulnerable to non-point sources of pollution if development increases without consideration of downstream impacts. Of additional concern is the large number of recreational users, including boaters and kayakers, potentially discharging wastes directly into the Inlet. As the data used in this report is limited, additional sampling would be required to more fully document the nature of these effects and to determine attainment of the water quality objectives specified for the protection of the most sensitive water use.

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's 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 on 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, licenses 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, license, order, or regulation, such as the Forest Practices Code Act, Water Act regulations or Environmental Management Act regulations.

It is important to note that the sanitary water quality of shellfish growing areas in Canada is assessed by the Canadian Shellfish Sanitation Program (CSSP). The CSSP is jointly administered by the Department of Fisheries and Oceans, the Canadian Food Inspection Agency and Environment Canada. Under the CSSP, Environment Canada's Shellfish Water Quality Protection Program is responsible for monitoring the water quality of growing areas and for classifying these areas with respect to shellfish harvesting based on the survey results. The Department of Fisheries and Oceans is responsible for formally closing contaminated areas as well as posting and patrolling closed areas. Under the CSSP, the Canadian Food Inspection Agency (CFIA) regularly tests molluscan bivalve tissue for the presence of paralytic shellfish poisoning (PSP).

Therefore, any information related to *shellfish classification* and *shellfish harvesting approval* must come from the CSSP. Provincial Water Quality Objectives, on the other hand, are used as *indicators* to protect a healthy aquatic environment which includes the safe use of that waterbody for the ability to grow and harvest shellfish.

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. Monitoring for shellfish classification is conducted under a separate mandate by the Canadian Shellfish Sanitation Program, see: www.pyr.ec.gc.ca/en/shellfish/index.shtml .

Monitoring usually takes place at a critical time when a water quality specialist has determined that the water quality objectives may not be met i.e. worst-case scenario. 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 assesses Okeover Inlet, a marine inlet on the west coast of the BC mainland north of Powell River (Figure 1). This area is a popular destination for recreational boaters, and includes the Desolation Sound Marine Provincial Park, Malaspina Provincial Park and Okeover Arm Provincial Park. As well, shellfish farming and harvesting are important economic activities throughout the Inlet, and a large number of mariculture tenures have been issued for the area.

As the primary water uses for the Okeover Inlet are for recreational purposes, mariculture and aquatic life and wildlife, the designated water uses are primary-contact recreation and aesthetics, the ability for shellfish growing and harvesting, and marine aquatic life. These are the uses that are most sensitive to impacts that might occur to marine water quality, based on existing activities within the watershed.

Potential impacts to water quality in Okeover Inlet are primarily linked to untreated sewage discharges from pleasure craft, residences and businesses including failed on-site septic systems, as well as from possible fuel spills from pleasure craft or at refilling stations on private docks.

The project consisted of five phases: water quality data collection, gathering information on water use, determination of land use activities that may influence water quality, assessment of water quality based on land use influences, and establishment of water quality objectives. This report is based primarily on data collected between 1999 and 2004, although water quality data from as early as 1980 is also considered.

WATERSHED PROFILE

HYDROLOGY

This report focuses on the marine waters of Okeover Inlet. Freshwater tributaries to Okeover Inlet are generally small and do not have a large impact on flushing rates or water movement. Tides are mixed diurnal with maximum amplitudes of about 5 metres, and currents are generally weak throughout the Inlet. These factors, coupled with the long, narrow shape of the inlet and the narrow passage between the Gifford Peninsula and the Malaspina Peninsula, result in low flushing rates in many areas, allowing contaminants to accumulate.

WATER USES

The primary water uses in Okeover Inlet are for mariculture activities including the ability for shellfish growing and harvesting, primary-contact recreation and aesthetics, and marine aquatic life.

WATER QUALITY ASSESSMENT AND OBJECTIVES

WATER QUALITY ASSESSMENT

Water quality throughout Okeover is generally good for most parameters measured as part of this study. Nutrient levels were generally very low, and concentrations of metals were generally well below guideline limits. Sediment samples occasionally contained relatively high concentrations of arsenic, cadmium, zinc and copper, but there are no anthropogenic sources of these metals within the watershed and it is thought that they reflect the natural geomorphology or geochemistry of the area rather than impacts from human activities. The water quality indicator parameters most likely to be impacted by human activities are the bacteriological indicators such as fecal coliforms and enterococci, from untreated sewage discharged directly from pleasure craft, residences and from upland development with failed on-site septic systems. While fecal coliform and enterococci concentrations were generally low at most marine sites, occasional high values caused the Provincial guidelines for the ability for shellfish growing and harvesting to be exceeded on a few occasions.

WATER QUALITY OBJECTIVES

A water quality objective has been proposed for fecal coliforms and enterococci, as these indicator parameters may be symptomatic of impacted water uses. The objective is that the median concentration of at least five samples collected within a 30-day period should not exceed 14 MPN/100 mL for fecal coliforms and 4 MPN/100 mL for enterococci. Similarly, the 90th percentile of at least five samples collected within a 30-day period should not exceed 43 MPN/100 mL for fecal coliforms and 11 MPN/100 mL for enterococci. In addition, shellfish harvested from within Okeover Inlet must have fecal coliform concentrations not exceeding 230 fecal coliforms per 100 grams of wet weight. These guidelines apply to all good or medium, beach or deep water shellfish capability areas as defined in the Malaspina Coastal

Plan. Note that these objectives are not used for shellfish harvest area classifications. For areas where shellfish harvesting is not feasible but that include bathing beaches or typical bathing areas, the geometric mean of at least five samples collected within a 30-day period should not exceed 200 MPN/100 mL for fecal coliforms and 20 MPN/100 mL for enterococci. This objective will protect primary contact recreation that might occur in those areas.

Freshwater quality objectives have not been included at this time due to a lack of data. While, it is recognized that many contaminants of concern, including bacteriological parameters, originate from upland activities and are carried to marine waters by freshwater streams and drainages, a land-use planning approach is recommended to prevent or minimize contaminant inputs to marine waters. Many local community volunteers have contributed to a freshwater database over the past three to four years that has been instrumental to developing the marine water quality objectives and recommended monitoring program.

Table 1. Summary of Water Quality Objectives proposed for Okeover Inlet.

Characteristics	Okeover Inlet Shellfish Areas for all good or medium beach or deep water shellfish capability areas as described in the Malaspina Coastal Plan	Okeover Inlet Bathing Areas
Designated water uses	For the protection of the ability for shellfish growing and harvesting, marine aquatic life and wildlife (Not shellfish classification)	Primary-contact recreation, marine aquatic life and wildlife
Fecal coliforms	Less than or equal to 14 MPN/100 mL median concentration … Less than or equal to 43 MPN/100 mL 90th percentile	Less than or equal to 200 MPN/100 mL geometric mean
Enterococci	Less than or equal to 4 MPN/100 mL median concentration … Less than or equal to 11 MPN/100 mL 90th percentile	Less than or equal to 20 MPN/100 mL geometric mean

Monitoring Recommendations

We recommend that water samples be collected on an annual basis, at least five times within a 30-day period, ideally during the summer months of July and August as this appears to be the time when the water quality objectives are most likely to be exceeded. Samples should be collected in each of the sampling locations monitored in this study (Freke Anchorage, Wootton Bay, Penrose Bay, Trevenen Bay, Cochrane Bay, Grace Harbour, Government Wharf and Okeover Central). Monitoring of sediment bacteriology, chemistry and toxicity in embayed areas is recommended to identify whether conditions are improving or worsening over time.

While not all water quality parameters summarized in this report are being made into Objectives, this document is intended to summarize baseline conditions that can be used for comparisons to future water quality monitoring. A number of both short- and long-term recommendations were made as part of the Okeover Inlet Water Quality 2001-2003 Interim Water Quality Report (Freyman, 2004). Following these recommendations would make a significant contribution towards protecting the resources dependent upon good marine water quality.

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ACKNOWLEDGEMENTS

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1.0. INTRODUCTION

1.1. BACKGROUND

The BC Ministry of Environment (hereafter referred to as MOE) prepares water quality assessments and objectives for priority water basins in British Columbia. This report describes and assesses the water quality of Okeover Inlet, located on the west coast of the BC mainland north of Powell River, and opposite Campbell River on Vancouver Island. The majority of the data used in this assessment was collected between 1999 and 2004.

Okeover Inlet is an important recreational boating area, containing the largest marine park in BC, and a popular boat launch for canoes and kayaks accessing Desolation Sound. Other important values include mariculture (primarily oysters and clams), fisheries and other aquatic life, wildlife, and culturally significant First Nations resources and sites. Potential impacts to water uses include discharges from pleasure craft, potential contamination from shore-based recreation (including campgrounds and hiking trails) and residences, forestry activities (including active marine log dumps), and mariculture operations.

1.2. WATER QUALITY OBJECTIVES – BASIC PHILOSOPHY

Water quality objectives are established in British Columbia for water bodies on a site-specific basis. The objective can be a physical, chemical or biological characteristic of water, biota or sediment, which will protect the most sensitive designated water use at a specific location with an adequate degree of safety. The objectives are set at a level which should protect the most sensitive designated water use with due regard for ambient water quality, aquatic life, waste discharges and socio-economic factors. Provincial Water Quality Objective, however, are not used for shellfish classification and harvesting which is the mandate of the federal Canadian Shellfish Sanitation Program. Water Quality Objectives, rather, are used as an indicator for aquatic health which includes the ability for shellfish growing and harvesting values.

Water quality objectives are based upon the provincial approved and working water quality guidelines (criteria) (Nagpal *et al.* 1998) and Canadian Council of Ministers of the Environment (CCME) water quality guidelines (CCME 1998). The guidelines describe characteristics of water, biota or sediment that must not be exceeded to prevent specified detrimental effects from occurring to a water use. The working guidelines upon which many of the proposed provisional objectives are based come from the literature, and are referenced in the following sections. BC MOE is in the process of developing approved guidelines for water quality characteristics throughout British Columbia, to form part of the basis for permanent objectives.

As a general rule, objectives are only set in water bodies where man-made influences may threaten a designated water use, either now or in the near future. The reason for this is that objectives will only be set for water bodies where resource management is required to protect existing water quality or where remediation is required and sufficiently practical to improve water quality. As well, promulgating water quality objectives where there is an uncertain possibility of future human influences would lead to a large number of objectives for variables which may not be important in the long term, and would lead to an expectation that those values would be measured at some frequency through time to determine attainment of the objectives. This could lead to an unrealistic belief that the waters were being protected, albeit by dated objectives.

The objectives proposed in this report take into account the use of the water to be protected and the existing water quality. They allow for increases over background which can be tolerated, or for upgrading water quality which may be required. Any increase over background which is allowed indicates that some waste assimilative capacity can be used while still maintaining a good margin of safety to protect designated water uses. However, all reasonable efforts should be exercised to maintain conditions superior to the objectives. These objectives are to be reviewed as more monitoring information becomes available and as BC MOE establishes more approved water quality guidelines.

Water quality objectives do not apply to the initial dilution zones of effluents. These zones may be site specific but in rivers are normally defined as extending up to 100 m downstream from a discharge, and occupying no more than 50 percent of the width of the river, from its bed to the surface. Direct discharges to smaller streams such as those described in this report require specific studies to determine an appropriate initial dilution zone. There is only one permitted discharge in the Okeover Inlet area and it allows the discharge of 34 m^3/day of treated sewage to the ground. Treatment at this site includes a secondary treatment plant and a biological sand filter. As there are no discharges to water, no initial dilution zones have been set.

In cases where there are many effluents discharged, there could be some concern about the additive effect of dilution zones in which water quality objectives may be exceeded. Waste discharges pursuant to the Environmental Management Act (formerly the Waste Management Act) control effluent quality which in turn determines the extent of initial dilution zones and the severity of conditions within them. In practice, small volume discharges or discharges with low levels of contaminants will require mixing zones much smaller than the maximum dilution zone allowed. The concentrations of contaminants permitted in effluents are such that levels in the dilution zones will not be acutely toxic to aquatic life or create objectionable or nuisance conditions. Processes such as chemical changes, precipitation, absorption and microbiological action, as well as dilution, take place in these zones to ensure that water quality objectives will be met at their border.

1.3. DESCRIPTION OF WATERSHED

Okeover Inlet is located on the west coast of the BC mainland, approximately 30 kilometers northwest of Powell River (Figure 1). The inlet is approximately 15 kilometers long and less than 500 metres wide at its narrowest point.

The watersheds that feed Okeover Inlet are part of the Coastal Mountain Range, and are generally small with relatively low relief and maximum altitudes of about 1500 m. The area is underlain by intrusive granitic rocks (MSRM 2004).

Two primary biogeoclimatic zones occur within Okeover Inlet, with a total of four subvarients. The lowest elevations are comprised of the Coastal Western Hemlock eastern very dry maritime zone (CWHxm1), giving way to the dry maritime (CWHdm), and montane very wet maritime (CWHvm2) subvarients with increasing elevation. Higher elevations (above about 1000 m) are dominated by the Mountain Hemlock windward moist maritime (MHmm1) subvarient.

2.0. HYDROLOGY AND PRECIPITATION

This report is concerned primarily with the marine waters of Okeover Inlet, and fresh water (including tributaries to the sound and small lakes such as Unwin Lake) are considered only peripherally, with respect to how they might impact marine water quality.

Little hydrometric data has been collected in the Okeover Inlet area, with the exception of Theodosia River. Flow from this river is controlled by a hydroelectric dam operated by Powell River Energy, which has resulted in a 70% reduction in the natural flows of the river between the date of construction (1956) and 2004. Recently the Sliammon (Tla'amin) First Nation negotiated the partial restoration of discharge within the river in an attempt to enhance salmonid habitat and spawning grounds.

Tributaries to Okeover are generally small, especially on the west side of the inlet where the height of land on the Malaspina Peninsula is often quite close to the shoreline. Significant tributaries include the Theodosia River and Okeover Creek. Of these, hydrometric data is available only for the Theodosia River. Due to the relatively small size of all of the watersheds draining into Okeover Inlet, coupled with the fact that a very small percentage of overall precipitation falls as snow (see Table 2-1), flows are closely related to precipitation and do not show summer peaks due to snowmelt. Figure 2 shows the average daily flow for each month for the Theodosia River between 1956 and 1993 compared with average monthly precipitation measured at nearby Cortes Island – while the relationship between flow and precipitation is evident, it is muted by the fact that the flow regime of the Theodosia River is controlled by the hydroelectric dam. The highest volumes of precipitation fall between October and February, while the driest period is between June and August. Air temperatures measured at Cortes Island (elevation 6m) were moderate, with average daily temperatures ranging from about 3°C in January to 18°C in July and August.

Table 2-1. Average monthly precipitation measured as rain and snow at Cortes Island, BC (Environment Canada Precipitation Data, 1976 to 2000).

Precipitation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall)	147.9	121.0	110.6	88.6	70.2	65.1	50.5	58.8	71.7	149.6	207.0	167.8
Snowfall	24.8	12.2	5.5	2.0	0.0	0.0	0.0	0.0	0.0	0.6	4.9	19.9

Tides within Okeover Inlet are mixed diurnal, with two uneven tides each day. The larger daily tide ranges from about 2.1 to 5.0 metres, while the smaller tide ranges from about 0.6 to 1.4 metres (WXTide32, 2005). While there are tidal currents between 2 and 4 knots in narrower portions of the Malaspina Inlet, currents are described as weak elsewhere (MSRM 2004). These low currents, coupled with sills at many of the inlet entrances (see Table 2-2), the long, narrow nature of the inlets, and the low volumes of freshwater being introduced, results in little mixing and long retention times in some areas of the inlet. Therefore, any contaminants introduced to these areas would be present for a significant amount of time before being flushed out into the Georgia Strait.

Table 2-2. Depths of various basins and sills within Okeover Inlet (Canadian Hydrographic Service 1990).

Basin Location	Depth (m)	Sill Depth (m)
Malaspina Inlet	68	13
Grace Harbour	22	14
Okeover & Lancelot Inlets	135	20
Theodosia Inlet	37	2

3.0. WATER USES

3.1. RECREATION

Recreation is one of the two most important uses for the Okeover Inlet area (the other being mariculture). As mentioned in the introduction, Okeover Inlet contains two provincial parks (Okeover Arm and Malaspina) as well as the Desolation Sound Provincial Marine Park. There are also three other provincial parks in Desolation Sound (Walsh Cove, Teakerne Arm and

Roscoe Bay), two other provincial parks on nearby Cortes Island (Mansons Landing and Smelt Bay provincial parks), and the Copeland Islands Provincial Marine Park is located on the outside of Malaspina Peninsula. The presence of all of these parks in a relatively small area, coupled with the relative accessibility of the area (canoes, kayaks and other small vessels can be launched from of the southern end of Okeover Inlet, which has paved road access) as well as the fact that the terminus of the Sunshine Coast Trail is located in Desolation Sound, make this area an extremely popular tourist destination. A recent tourism opportunity study of the Desolation Sound – Okeover Inlet area ranked the area as having “high potential for tourism development” (MSRM 2004).

Many people access Okeover Inlet by boat, either self-propelled (canoes, kayaks etc. that are usually launched at the head of the inlet) or pleasure craft such as yachts and sailboats. The most popular types of recreational activities that occur on or around the water include boating, swimming, fishing and diving. The busiest periods are between July and September, with the lowest visitor traffic occurring during the winter months.

3.2. FISHERIES

Fisheries values in the Okeover Inlet area can be divided into two main categories – shellfish and finfish. These can further be subdivided into wild stocks and reared stocks. The following statistics are based on the Department of Fisheries and Oceans Fisheries Management Area 15-4 (Figure 3), which is composed of Malaspina Inlet and Okeover Inlet.

The harvesting of wild shellfish and invertebrates, including clams, geoducks and prawns, represent an important industry in the Okeover Inlet area. The area has a commercial fishery opening for clams (mostly Littleneck and Manila) for an average of twenty days per year, and approximately 20 to 30 harvesters harvest about 50,000 pounds of clams each year (MSRM 2004). There is also an important aboriginal and recreational fishery for clams in the area. Approximately 4,500 pounds of geoducks are harvested each year on a three-year rotation, and an average of five vessels land approximately 6,900 pounds of prawns annually during a 10-12 week period (MSRM 2004). There is also a commercial crab fishery, but no harvest statistics are available (MSRM 2004).

While many of the tributaries to Okeover Inlet are too small to serve as spawning grounds for salmon, Okeover Creek and the Theodosia River are listed in the federal/provincial salmon spawning database as supporting escapements of sockeye, coho, pink, chum and chinook salmon, as well as a resident population of coastal cutthroat trout. Theodosia River also supports a population of Dolly Varden, rainbow trout and steelhead. In Okeover Creek, the maximum escapement numbers on record are 8987 chum, 12 pink, 150 coho, and no estimates for sockeye or chinook. In the Theodosia River, the maximum escapement numbers are 35,000 chum, 750 pink, 7500 coho, 12 sockeye and 100 chinook. However, peak escapements of chum, pink and coho salmon all occurred in the early 1950's, and much smaller numbers have been reported in more recent years. Okeover Inlet is not considered a significant groundfish area.

Aquaculture is also an important industry for the Okeover Inlet area. While the overall shellfish tenured area in Okeover Inlet has decreased over the last 20 years, this is due to a number of tenures being extinguished from inside of the Desolation Sound Marine Provincial Park boundaries. Outside of the park, the shellfish tenured area has increased by 60% between 1983 and 2003. At present, there are a total of 40 beach and off-bottom tenures covering 185 ha. within Okeover Inlet. The area has one of the highest concentrations of tenured land in the province, and represents 9% of the total number of shellfish aquaculture tenures in BC.

Marine water quality within Okeover Inlet has had an impact on the ability for shellfish growing and harvesting. The Department of Fisheries and Oceans has imposed year-round sanitary closures on shellfish harvesting in Freke Anchorage and Theodosia Inlet, as well as a seasonal sanitary closure between May 31 and September 30 in Grace Harbour. There is also a year-round biotoxin closure in effect for all of Okeover Inlet for butter clams only.

3.3. WILDLIFE

As Okeover Inlet is relatively pristine, it supports a number of important wildlife values. Upland species are typical of low-elevation coastal areas and include black bear, black-tailed deer, numerous smaller mammals, amphibians and reptiles, as well as raptors and a variety of upland birds. Much of Okeover Inlet is considered important habitat for marbled murrelets, a species on the Conservation Data Centre Red List. It is also considered an important resting and feeding area for spring and fall migratory marine and shore birds. Other species at risk occurring in the area include the coast tailed frog, grizzly bear, Keens long-eared bat, the Pacific great blue heron, the Olympia oyster, Pacific sardine, and the North-east Pacific transient population of Killer Whale (COSEWIC database, 2005).

3.4. DESIGNATED WATER USES

Designated water uses are sensitive water uses that are designated for protection in a watershed or waterbody. Water quality objectives are then designed for the substances or conditions of concern in a watershed so that attainment of the objectives will protect the designated uses. Designated water uses are not the same as shellfish harvesting approvals which are a federal responsibility under the CSSP and the DFO.

As the primary water uses for Okeover Inlet are for recreational purposes and for mariculture, aquatic life and wildlife, the designated water uses are primary-contact recreation and aesthetics, and marine aquatic life including the ability for shellfish growing and harvesting. These are the uses that are most sensitive to impacts that might occur to marine water quality, based on existing activities within the watershed.

4.0. Influences on Water Quality

Okeover Inlet is a relatively pristine area, with only one permitted discharge (allowing a maximum of 34 m^3/day of treated sewage to ground from a secondary treatment plant and biological treatment sand filter). Potential impacts to marine water quality are generally related to human waste discharged by boaters and residences with direct discharges or failed on-site septic systems, as well as possible contamination from camping activities. The following sub-sections outline existing land uses within the Okeover Inlet area, as well as potential impacts from these activities on marine water quality. Actual impacts will be discussed in further detail in Section 6.

4.1. Recreation

As recreation is one of the key anthropogenic activities within Okeover Inlet, there are a number of important potential impacts to marine water quality resulting from these activities that we must consider. The most significant impact with regards to designated water uses in Okeover Inlet (*i.e.* the ability for shellfish growing and harvesting and primary-contact recreation) is that of bacteriological contamination. There are a number of potential sources for this, including direct discharges from pleasure craft, as well as run-off from land from: failed on-site septic systems from upland residences and businesses; direct depositions on the foreshore area by pets; improper disposal of wastes by hikers on the foreshore or upland areas.

4.2. Land Ownership

A significant portion of Okeover Inlet consists of Crown Land, including Desolation Sound Provincial Marine Park, Malaspina Provincial Park and Okeover Arm Provincial Park. However, as discussed in Section 3.2, there are a number of mariculture leases in the area, as well as processing plants, other businesses and private residences, that may have some impact on water quality. Potential contamination might occur from untreated sewage from businesses or residences being discharged directly into marine waters or seeping into the ocean from malfunctioning septic fields. As boats are a very common means of transportation in the area, there is also the potential for fuel or oil spills, especially in refueling locations, which could impact water quality.

4.3. Forest Harvesting and Forest Roads

Okeover Inlet falls within the Sunshine Coast Timber Supply Area. Most of the tenured area along Okeover Inlet is managed by BC Timber Sales (formerly the Small Business Forest Enterprise Program), but Doman Industries and Canadian Forest Products Ltd. also have small tenures near Theodosia Inlet (SCBC 2005). Most timber is trucked to nearby mills, while the remainder is brought to marine log dumps in Okeover and Malaspina inlets. Between 2003 and 2008, approximately 900 hectares is expected to be harvested using single-tree and clumped retention methods. Potential impacts to marine waters from these activities might include increased localized turbidity from changed runoff patterns, bark and tree-waste accumulation on sediments below active log dumps, and potential fecal contamination from improperly disposed of sewage at logging camps. As future logging activities will likely continue to be relatively small-scaled and utilize single-tree and clumped retention methods, and generally do not take place very close to the coastline, impacts from these activities are likely to be minimal.

4.4. Wildlife

Wildlife can influence water quality because warm-blooded animals can carry pathogens such as *Giardia lamblia*, which causes giardiasis or “beaver fever”, and *Cryptosporidium* oocysts which cause the gastrointestinal disease, cryptosporidiosis. Virtually every mammal ever tested can carry *Giardia*, while aquatic mammals and domestic livestock carry *Cryptosporidium*. In addition, fecal coliforms and enterococci are a measurable indicator bacteria for the presence of warm-blooded animal wastes including humans. Fecal contamination of water by animals is generally considered to be less of a concern to human health than contamination by humans because there is less risk of inter-species transfer of pathogens. However, without DNA testing, it is impossible to determine the origins of coliforms.

In general, wildlife concentrations throughout the study area are not thought to be high enough to significantly affect bacteriological concentrations. However, in localized areas, high concentrations of waterfowl may contribute to bacteriological contamination.

5.0. Description of Water Quality Monitoring Project

5.1. Water Sampling Procedures

This report provides an assessment of water quality data collected from 1999 to 2004 in Okeover Inlet watershed. Fecal coliform data collected in 2003 and 2004 as part of Environment Canada’s Shellfish Sanitation Program is also examined. Key water quality characteristics such as fecal coliforms, nitrate, nitrite, phosphorus, and total metals, and sediment characteristics such as total metals and polycyclic aromatic hydrocarbons are considered for the protection of marine aquatic life including the ability for shellfish growing and harvesting. Shellfish harvesting is the most sensitive water use in Okeover Inlet for these characteristics. In addition, based on current knowledge of potential anthropogenic impacts to the watershed, these are the water quality parameters most likely to change should impacts occur.

A number of water and sediment quality monitoring sites were selected throughout the Okeover Inlet area. Samples were collected by MOE at Freke Anchorage, the Government Wharf, Penrose Bay, Trevenen Bay, and Cochrane Bay on the west side of Okeover Inlet, Wooton Bay and Grace Harbour on the Gifford Peninsula, and one site in the centre of Okeover Inlet (Figure 1).

Freke Anchorage (EMS Site E248646) is located at the southern tip of Okeover Inlet and falls within the Sliammon (Tla'amin) First Nation lands. It is a popular area for shellfish harvesting by band members, although there is a sanitary harvesting closure in effect (see Section 3.2).

Government Wharf (EMS Site E248652) was selected as it is the busiest area of Okeover Inlet, with the only paved road access. It has marine anchorages and is a popular launching area for kayakers and canoeists recreating in Okeover Inlet and Desolation Sound. It has a relatively high degree of residential development, as well as a restaurant and lodges.

Penrose Bay (EMS Site E248648) is the most heavily developed area of Okeover Inlet with several homes currently under construction and many more planned for the near future. While it is not commonly used as a marine anchorage, it is a popular launch area for kayaks and canoes.

Trevenen Bay (EMS Site E248649) is heavily utilized by the mariculture industry, with almost the entire shoreline used for anchoring lines and floats for oyster and mussel farming. There are also a few residences in the area.

Cochrane Bay (EMS Site E248650) is used as a kayak pull-out and campsite and is also the location of a Sunshine Coast Trail campsite.

Grace Harbour (EMS site E248651) is located on the Gifford Peninsula and portions of it are contained within the Desolation Sound Marine Provincial Park. It is heavily utilized as a pleasure boat anchorage, as well as a kayak pull-out and campsite.

Wootton Bay (EMS site E248647) is located at the north-east tip of Okeover Inlet, and was originally selected as a monitoring site because it is relatively remote. However, water quality here was not found to be pristine, and so an additional ambient site was selected in the centre of Okeover Inlet, south of Edith Island called Okeover Central (EMS site E248653), see Figure 1.

Finally, a number of freshwater and marine bacteriological samples were also collected by volunteers from the local community at a number of sites in an attempt to determine the level of bacteriological indicators in some areas as well as potential sources of contamination.

5.2. Quality Assurance / Quality Control

Water and sediment samples were collected in strict accordance with the Provincial Resource Inventory Committee (RIC) standards, by trained personnel. Quality assurance and quality control was also verified by collecting field blanks and duplicate and triplicate samples. Field blanks are collected by transporting deionized water and filling sample bottles at each site in a method similar to how standard samples are collected. The samples are otherwise handled in exactly the same way as regular samples, and give an indication of potential sources of field contamination. Similarly, duplicate and triplicate water samples are collected by filling two (or three) sample bottles in as close to the same time period as possible (one right after the other) at a monitoring location, and then calculating the percent relative difference (for duplicates) or percent relative standard deviation (for triplicates) between the laboratory results reported for the various samples. The maximum acceptable percent relative mean differences between duplicate water samples is 25%, while the acceptable percent relative standard deviation for triplicates is no more than 18%. However, this interpretation only holds true if the results are at least 10 times the detection limits for a given parameter, as the accuracy of a result close to the detection limit shows more variability than results well above detection limits. As well, some parameters (notably bacteriological indicators) are not homogeneous throughout the water column and therefore we expect to see a higher degree of variability between replicate samples. The Guidelines for Interpreting Water Quality Data (RIC, 1997) indicate that contamination has occurred when 5% or more of the blanks show any levels above the method detection limit. If the blanks are within the guidelines, the data is to be considered clean and the real sample data are to be treated as uncontaminated.

Sediment sample replicates were also collected on a number of occasions. Duplicate or triplicate samples were collected using a Ponar clamshell dredge to retrieve two (or three) samples, usually from close proximity to each other and at a similar depth. Due to the fact that sediment samples are much less homogeneous than water samples, the percent differences between the samples are interpreted differently than it is for water samples. In this case, the percent difference between samples gives us an idea of the variability of sediment composition in a given area as well as the range of values that we might expect to see for a given parameter.

In all instances and for all parameters, values reported at below detection limits were reported as equal to the detection limit for the purposes of calculating means and standard deviations.

Appendix A contains a number of tables that summarize QA/QC data collected for each year between 1999 and 2004. Duplicate samples collected on four occasions in 2002 had relative percent mean differences ranging from 0% for a number of samples to 119% for a set of fecal coliform samples (Table A-1). With the exception of fecal coliforms, the relative percent mean differences for all of the other parameters were within the acceptable limits of 25%.

For four sets of blank samples collected in 2002, 44 of 46 values were reported at below detection limits (Table A-2). Therefore the percentage of samples above detection limits (3.5%) is within the acceptable limit of 5%.

In 2003, three sets of duplicate samples were analyzed for residue, nutrients and fecal coliforms, and one of the sets of duplicates was also analyzed for metals (Table A-3). Relative percent mean differences ranged from 0% for most samples to as high as 111% for a nitrate + nitrite sample. In almost all instances, the concentration of parameters that exceeded the acceptable percent difference level for duplicates (25%) was less than 10 times their respective detection limits. The relative percent mean difference is meant to apply outside of this limit, because of the reduced confidence level for values measured near the detection limit.

Six sets of triplicate sediment samples were collected in both 2003 (Table A-4) and 2004 (Table A-5). As expected, there was often considerable variability between the triplicate samples, with relative percent standard deviations ranging from 0% to 139% for calcium in one sample. In total, 139 of 588 parameters had relative percent standard deviations exceeding 18%, and 93 of the 588 parameters had relative percent standard deviations exceeding 25%. This suggests that while there was some variability between the samples, in general the results from one sample can be said to give a good representation of the average concentration between replicate samples.

6.0. Water Quality Assessment and Objectives

Water and sediment quality data from the various sites are summarized in Appendix B.

6.1. Coliform bacteria

Coliform bacteria are present in large numbers in the feces of warm-blooded animals, and although rarely pathogenic themselves, they are used as indicators of fecal contamination in water. Fecal coliforms are quite specific to the feces of warm-blooded animals and *E. coli* are even more specific, whereas total coliforms have many non-fecal sources (e.g. soils, plants), and thus are less indicative of fecal contamination. Coliforms generally do not survive long in cold, fresh or marine waters (Brettar and Höfle, 1992), but can survive for prolonged periods in stream sediment, soils or fecal material, when associated with particulate matter, or in warmer water

(Howell *et al.*, 1996; Tiedemann *et al.*, 1987). Disturbance of bottom sediments can therefore result in coliforms appearing in overlying water for extended periods (Jawson *et al.*, 1982; Stephenson and Rychert, 1982). The inclusion of a small piece of fecal matter in a sample can result in extremely high concentrations (>1000 /100 mL), which can skew the overall results for a particular site. It is therefore important to consider the range of values, as well as the standard deviation, to determine if numbers are consistently high or if one value "artificially" inflated the mean. For this reason, 90th percentile, median and geometric mean values are generally used to determine if water quality guidelines is exceeded, as extreme values would have less effect on the data.

Based on existing water uses (the ability for shellfish growing and harvesting, marine aquatic life, and primary contact recreation), the most stringent guidelines for bacteriological indicators are a 90th percentile of 43 /100 mL and a median of 14 /100 mL for fecal coliforms, and a 90th percentile of 11 /100 mL and a median of 4 /100 mL for enterococci. These guidelines are for the protection of the ability for shellfish growing and harvesting but are not to be confused with the federal shellfish classification of harvest openings and closures. Other applicable guidelines are a geometric mean of 100 /100 mL for enterococci for the protection of secondary contact recreation and the ability for crustacean harvesting, and a geometric mean of 20 /100 mL for enterococci and 200 /100 mL for fecal coliforms, both for the protection of primary-contact recreation.

Enterococci and fecal coliform concentrations were measured a number of times at each of the monitoring sites in Okeover Inlet (Tables B-1 to B-8). Data for the monitoring period (generally between 2002 and 2004) are summarized in Table 6-1. Median and 90th percentile values calculated for those instances where there was sufficient sampling frequency (*i.e.* at least five samples within a 30-day period) are shown in Table 6-2. For all samples, values reported at the detection limit (<2 MPN/100 mL) were considered equal to 2 MPN/100 mL for the 90th percentile calculations.

Table 6-1. Summary of median and 90th percentiles for all samples collected at Okeover Inlet sites.

	Minimum	Maximum	Median	90th %ile	Number of Samples
Freke Anchorage					
Enterococci	<2	17	<2	13.4	10
Fecal coliforms	<2	13	2	5	16
Wootton Bay					
Enterococci	<2	2	<2	2	9
Fecal coliforms	<2	20	<2	3.8	15
Penrose Bay					
Enterococci	<2	2	<2	2	10
Fecal coliforms	<2	20	2	6	16
Trevenen Bay					
Enterococci	<2	2	<2	2	10
Fecal Coliform	<2	49	2	3.8	15
Cochrane Bay					
Enterococci	<2	7	<2	5.2	10
Fecal Coliform	<2	49	<2	6.7	10
Grace Harbour					
Enterococcus	<2	20	<2	2	12
Fecal coliforms	<2	46	2	33	17
Government Wharf					
Enterococci	<2	2	<2	2	10
Fecal Coliform	<2	240	2	11.5	14
Okeover Central					
Enterococci	<2	2	<2	2	7
Fecal coliforms	<2	23	<2	16.4	13

Median concentrations of both fecal coliforms and enterococci were at or near the detection limit for most groups of five samples collected within 30 days. Exceptions were the fecal coliform samples collected at Freke Anchorage between July 16 and July 3, 2002, which had a median value of 5 MPN/100 mL, as well as the enterococci samples collected at this site between August 9 and 13, 2004 (which also had a median value of 5 MPN/100 mL). There was also one group of fecal coliform samples collected at the Government Wharf between August 9 and 13, 2004, which had a median value of 8 MPN/100 mL. While the median enterococci value of 5 MPN/100 mL measured at Freke Anchorage in August 2004 exceeded the guideline for the protection of the ability for shellfish growing and harvesting (maximum allowable median value of 4 MPN/100 mL), all other median values were below their respective guidelines.

The 90^{th} percentile values calculated for the enterococci data were also generally below Provincial shellfish growing and harvesting guideline levels (less than 11 MPN/100 mL) with the exception of one set of samples collected at Freke Anchorage in August 2004.

Table 6-2. Summary of median and 90th percentiles for 5-in-30 days samples collected at Okeover Inlet sites. Each value is based on five samples collected between the dates indicated.

	Enterococci (MPN/100 mL)		Fecal coliforms (MPN/100 mL)	
Freke Anchorage	Median	90th %ile	Median	90th %ile
July 16 - 30, 2002	<2	2	5	5
July 8 - 17, 2003			<2	2
August 9 - 13, 2004	5	15.4	2	2
Wootton Bay				
July 16 - 30, 2002	<2	2	2	2
July 8 - 17, 2003			<2	2
Penrose Bay				
July 16 - 30, 2002	<2	2	2	4
July 8 - 17, 2003			<2	2
August 9 - 13, 2004	<2	2	<2	6.4
Trevenen Bay				
July 16 - 30, 2002	<2	2	2	30.2
July 8 - 16, 2003			2	2
August 9 - 13, 2004	<2	2	<2	3.8
Cochrane Bay				
July 16 - 30, 2002	<2	6.2	2	30.2
August 9 - 13, 2004	<2	2	<2	2
Grace Harbour				
July 16 - 30, 2002	<2	2	2	40.8
July 8 - 17, 2003			<2	20.6
August 9 - 13, 2004	<2	2	2	5
Government Wharf				
July 16 - 30, 2002	<2	2	<2	3.8
July 8 - 17, 2003				
August 9 - 13, 2004	<2	2	8	149.2
Okeover Central				
July 8 - 17, 2003			<2	2
August 9 - 13, 2004	<2	2	<2	14.6

Samples collected by the volunteer samplers (Table B-15) were not collected frequently enough to enable us to evaluate them with regards to the Provincial shellfish growing and harvesting guidelines (*i.e.* the threshold of a minimum of five samples in thirty days was not met), but these samples can still serve to give an indication of where elevated coliform levels may be occurring. A summary of these data are presented in Table 6-3, and these clearly show that in the majority of instances, concentrations of bacteriological indicators (both fecal coliforms and enterococci) were much higher in fresh water than marine waters. The exception to this was Freke Anchorage, where elevated coliform levels were seen in both fresh and marine waters. This suggests that land-based contamination (rather than discharges directly into the marine environment from boats or wildlife) can be a significant contributor to elevated bacteriological levels in marine waters in Okeover Inlet.

The low levels of contamination measured at the Okeover Central site indicate that ambient levels of bacteriological indicators are low and the elevated levels are caused by localized contamination resulting from anthropogenic activity. For this reason, a water quality objective is proposed for both fecal coliforms and enterococci throughout the Okeover Inlet where medium or good beach or deep water shellfish capability areas are described in the Malaspina Coastal Plan (MSRM, 2004). ***The objective is that the median concentration of at least five samples collected within a 30-day period should not exceed 14 MPN/100 mL for fecal coliforms and 4 MPN/100 mL for enterococci. Similarly, the 90th percentile of at least five samples collected within a 30-day period should not exceed 43 MPN/100 mL for fecal coliforms and 11 MPN/100 mL for enterococci.***

For areas where shellfish harvesting is not feasible but that include bathing beaches or typical bathing areas, the geometric mean of at least five samples collected within a 30-day period should not exceed 200 MPN/100 mL for fecal coliforms and 20 MPN/100 mL for enterococci. This objective will protect primary contact recreation that might occur in those areas.

Table 6-3. Summary of bacteriological data collected by volunteer samples from various sites throughout Okeover Inlet between May 10, 2001 and December 6, 2004 in freshwater and marine water sites.

		Fecal Coliforms (MPN/100 mL)						Enterococci (MPN/100 mL)					
	Sites:	Maximum in FW	Maximum in MW	Geomean in FW	Geomean in MW	# samples in FW	# samples in MW	Maximum in FW	Maximum in MW	Geomean in FW	Geomean in MW	# samples in FW	# samples in MW
1	Freke Anchorage	410	1600	27.6	13.4	30	9	339	22	18.8	4.0	31	9
2	Sliammon Lease	114	7	6.4	2.4	9	11	97	13	7.8	2.4	10	11
3	Larson Landing	1400	5	5.0	2.0	30	10	510	8	3.7	2.3	31	9
4	Government Wharf Ditch	750	2	11.8	2.0	31	2	2580	33	11.2	8.1	32	2
5	D/S Park South	4700	0	62.4		16	0	4000	0	46.8		17	0
6	D/S Park North	670	5	15.4	2.3	17	6	3000	2	13.1	2.0	19	6
7	Penrose Bay	233	2	233.0	1.9	1	10	22	8	22.0	2.3	1	10
8	Trevenen Bay Head	0	2		1.9	0	11	0	2		2.0	0	10
9	Trevenen Bay	890	11	5.1	2.8	20	11	860	4	4.1	2.1	21	10
10	Cochrane Bay	3000	130	4.3	3.0	29	10	450	2	8.4	2.0	31	9
11	Cochrane Ck	250	2	5.8	1.9	9	10	355	5	8.5	2.2	10	9
12	Cochrane Bay north	0	2		1.7	0	4	0	2		2.0	0	4
13	Thorp Island	0	2		1.7	0	4	0	2		2.0	0	4
14	Parker Bay	24	2	3.3	1.7	4	4	27	2	5.2	2.0	4	4
15	Cavendish Bay	0	2		1.7	0	4	0	2		2.0	0	4
16	Jean Island W	0	2		1.7	0	5	0	2		2.0	0	5
17	Jean Is East	0	22		2.8	0	5	0	2		2.0	0	5
18	Grace Harbour Head	2200	13	9.8	3.2	29	11	3000	2	10.3	2.0	30	10
19	Edith Is. North	0	2		1.9	0	10	0	2		2.0	0	9
20	Edith Is. South	0	3		2.1	0	7	0	13		3.2	0	6
21	Isabel Bay	0	2		1.7	0	4	0	2		2.0	0	4
22	Madge Island	0	4		2.0	0	4	0	2		2.0	0	4
23	Wootton Bay	0	2		2.0	0	3	0	2		2.0	0	3
24	Grail Point	4300000	14	24.8	4.9	30	9	2800000	8	24.9	2.3	31	9
25	Thors Cove	0	8		2.3	0	9	0	2		2.0	0	8
26	Theodosia Inlet	78	49	2.5	9.0	26	9	110	8	3.6	3.1	27	9
27	Grace Harbour Ctr	0	13		2.3	0	10	0	5		2.2	0	10
28	Moss Point	0	5		2.1	0	4	0	2		2.0	0	4
29	Moss Point Bay	0	4		2.3	0	5	0	2		2.0	0	5
33	Hillingdon Point	2100	8	7.8	3.6	25	6	3000	23	5.9	3.0	26	6
34	Malaspina Rd Ditch U/S of Parking Lots	710	0	3.2		17	0	1800	0	3.5		17	0
35	Larson Landing: Creek thru residence	22	0	11.5		2	0	51	0	18.9		2	0

6.2. NUTRIENTS (NITRATE, NITRITE AND PHOSPHORUS)

Nitrogen (including ammonia, nitrate and nitrite) and phosphorus are important water quality parameters, since they tend to be the limiting nutrients in biological systems. Biological productivity is therefore directly proportional to the availability of these parameters. Nitrogen is usually the limiting nutrient in terrestrial systems and marine waters, while phosphorus tends to be the limiting factor in freshwater aquatic systems. Elevated nutrient levels can result in increased plant and algal growth, which in turn can deplete oxygen levels when they die and begin to decompose, or during periods of low productivity when plants consume oxygen (*e.g.*, at night). The presence of high concentrations of nutrients (especially ammonia and nitrite, which rapidly break down in the environment) are often an indication of contamination from either sewage or fertilizers. The guideline for the protection of aquatic life in marine waters for total ammonia is a maximum of 2.5 mg/L and a mean of 1.0 mg/L (based on at least five samples in 30 days). There are no proposed guidelines for nitrate, nitrite or phosphorus in the marine environment.

Nitrogen concentrations were measured fifteen times in Freke Anchorage between 1999 and 2004. Concentrations of ammonia ranged from below detection limits (<0.005 mg/L) for five of the samples to a maximum of 0.135 mg/L. Only three of the fourteen samples had nitrate concentrations higher than the detection limit (<0.002 mg/L), with a maximum value of 0.01 mg/L, and nitrite concentrations ranged from below detection limits (<0.002 mg/L) to a maximum of 0.008 mg/L. Total phosphorus concentrations at this site ranged from 0.021 mg/L to 0.039 mg/L for five samples collected in 2004.

Ammonia concentrations in Wootton Bay ranged from below detection limits (<0.005 mg/L) to a maximum of 0.112 mg/L. Concentrations of both nitrate and nitrite were generally below detection limits (<0.002 mg/L), with maximum concentrations of 0.014 and 0.009 mg/L, respectively. Total phosphorus concentrations at this site ranged from 0.023 mg/L to 0.132 mg/L.

In Penrose Bay, ammonia concentrations ranged from below detection limits (<0.005 mg/L) to 0.132 mg/L. Nitrate and nitrite concentrations were generally below detection limits, with maximum values of only 0.003 mg/L and 0.008 mg/L, respectively. Total phosphorus concentrations ranged from <0.002 mg/L to 0.025 mg/L.

Total ammonia concentrations in Trevenen Bay ranged from <0.005 mg/L to 0.085 mg/L, nitrate concentrations ranged from <0.002 mg/L to 0.03 mg/L, and nitrite concentrations ranged from <0.002 mg/L to 0.007 mg/L. Total phosphorus concentrations ranged from 0.019 mg/L to 0.031 mg/L.

For the nine samples analyzed for nutrients in Cochrane Bay between 2002 and 2004, total ammonia concentrations ranged from <0.005 mg/L to 0.113 mg/L, total nitrate concentrations ranged from <0.002 mg/L to 0.06 mg/L and total nitrite concentrations ranged from <0.002 mg/L to 0.008 mg/L. Total phosphorus concentrations at this site ranged from 0.023 mg/L to 0.035 mg/L for five samples collected in August 2004.

In Grace Harbour, half of the 16 samples collected between 1999 and 2004 had total ammonia concentrations below detection limits (<0.005 mg/L), and the maximum concentration was 0.114 mg/L. Total nitrate concentrations were consistently below detection limits (<0.002 mg/L), and total nitrite concentrations ranged from <0.002 mg/L to 0.007 mg/L. Total phosphorus concentrations ranged from 0.021 mg/L to 0.048 mg/L for 14 samples collected between 2002 and 2004.

Total ammonia concentrations at Government Wharf ranged from <0.005 mg/L to a maximum of 0.125 mg/L, nitrate concentrations ranged from <0.002 mg/L to 0.04 mg/L, and nitrite concentrations ranged from <0.002 mg/L to 0.007 mg/L.

Finally, at the Okeover Central site, ammonia concentrations ranged from <0.005 mg/L to 0.113 mg/L, nitrate concentrations ranged from <0.002 mg/L to 0.008 mg/L, and nitrite concentrations ranged from <0.002 to 0.005 mg/L.

The highest concentration of total ammonia (0.135 mg/L, measured in Freke Anchorage in August, 2004) was 19 times lower than the maximum total ammonia guideline of 2.5 mg/L and 7 times lower than the mean guideline of 1.0 mg/L for the protection of aquatic life. There are no applicable guidelines for nitrate or nitrite in marine waters, but concentrations of these parameters were also consistently low. The fact that in 17 of 21 instances (three parameters at each of seven sites) the highest concentrations occurred in August, 2004 might suggest that concentrations are increasing over time, but may also simply be due to the fact that prior to 2004, samples were all collected in July, which tends to be a less busy period for boaters and would therefore experience lower levels of sewage waste. Regardless, as ammonia concentrations are consistently well below guideline levels, no water quality objective is proposed for this parameter.

6.3. Temperature

Water temperature can affect the survival of marine organisms, as well as determine the appropriateness of primary-contact recreation in an area. The guidelines for temperature in marine waters are that temperatures should not be caused to increase or decrease more than 1°C from ambient conditions for the protection of marine life, and the thermal characteristics of the water should not cause an appreciable change in the deep body temperature of bathers and swimmers to protect primary contact recreation. As there are no activities occurring within Okeover Inlet that would appreciably affect water temperatures, these guidelines are not a concern.

The waters of Okeover Inlet are relatively shallow and protected, allowing elevations in water temperature that are not seen in many places on the west coast of British Columbia. Maximum summer temperatures at the various monitoring locations ranged from 19°C to 22°C. Water temperatures may be increasing over time in Okeover Inlet – a long-term study by the Department of Fisheries and Oceans shows an almost linear increase of about 1°C in deep water temperatures in nearby Bute Inlet between 1975 and 1999 (DFO 2002).

6.4. TOTAL SUSPENDED SOLIDS

Total suspended solids (TSS, also referred to as non-filterable residue or NFR) include all of the undissolved particulate matter in a sample. The TSS concentration is determined by filtering a quantity of the sample, drying and weighing the residue so a weight of residue per volume is determined. The guideline for the protection of marine aquatic life allows an increase of no more than 25 mg/L in 24 hours when background levels are less than 25 mg/L.

Total suspended solids concentrations were measured nine times at both Wootton Bay and Grace Harbour between 2002 and 2003. Concentrations ranged from 3 mg/L to 15 mg/L, with almost all samples below 10 mg/L. As there are no known significant sources of induced TSS within Okeover Inlet and because concentrations are generally low, TSS is not considered a concern and no objective is proposed.

6.5. METALS

Concentrations of total metals were measured between four and seven times at six of the Okeover Inlet sites. Concentrations of arsenic, copper, iron, manganese, and nickel were consistently well below guideline levels (Table 6-4).

Cadmium concentrations met or exceeded the guideline at all of the sites where it was measured, but because the detection limit for this metal is equal to the guideline (<0.1 µg/L), an accurate assessment of guideline compliance cannot be made. Detection limits should be at least ten times below the guideline to allow a proper assessment of guideline compliance. As well, it has been found that the west coast of British Columbia has naturally elevated concentrations of cadmium resulting both from local geomorphology as well as the upwelling of cadmium-rich waters (especially along the west coast of Vancouver Island) (Kruzinski, 2000), suggesting that elevated concentrations found in Desolation Sound are due to natural events and not anthropogenic activities.

The chromium concentration at Freke Anchorage, Penrose Bay and Government Wharf was higher than the guideline level for chromium (VI), but because we do not know the concentration of that specific form of chromium, an assessment cannot be made.

One water sample collected at Freke Anchorage in July 2003 had an elevated level of lead (4 µg/L), exceeding the average guideline for this metal. However, all other values measured at this site were below detection limits (<0.1 µg/L), so it is unlikely that these elevated levels would ever persist over a 30-day period (defined as the period over which the guideline for average concentration would apply).

Finally, the total zinc concentration for one sample collected in August 2004 at the Government Wharf was equal to the guideline level for the protection of marine life. Concentrations of the remaining six samples collected at this site between 2002 and 2004 ranged from below detection limits (<1 µg/L) to a maximum of 2 µg/L. More consistent monitoring is needed to determine whether this single elevated value was an anomaly.

There is no known anthropogenic source for any of these metals within Okeover Inlet, and therefore it would appear that the occasional elevated levels are due to the natural geomorphology of the area. For this reason, no water quality objectives are proposed for any metals in Okeover Inlet. However, as elevated metals levels occasionally occur, we recommend that monitoring continue in the future to determine if there are any increasing trends and, if so, further investigations should be conducted to determine the source of these metals.

Table 6-4. Comparison of maximum total metals concentrations measured at various Okeover Inlet sites with approved and working water quality guidelines for the protection of marine aquatic life (from Nagpal et al. 2001 and MWLAP 1998).

Parameter	Freke Anchorage	Wootton Bay	Penrose Bay	Grace Harbour	Government Wharf	Okeover Central	Guideline
Arsenic	0.6	0.6	0.6	0.6	0.6	0.6	12 µg/L
Cadmium	0.1	**1**	0.1	0.1	**0.2**	0.1	0.1 µg/L
Chromium (Cr(VI))	2.5	<0.5	2.3	<0.5	2.8	0.9	1.5 µg/L
Copper	0.5	0.3	0.5	0.5	0.9	0.5	2 µg/L average, 3 µg/L max
Iron	7	70	5	5	5	6	50 µg/L (minimal risk)
Lead	**4**	<0.1	<0.1	<0.1	<0.1	0.2	2 µg/L average, 140 µg/L max
Manganese	1	2	1	1	1	1	100 µg/L
Nickel	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	75 µg/L
Zinc	<1	<1	1	2	10	1	10 ug/L

*all units µg/L

6.6. Sediment Composition

A number of sediment samples were collected over the period of record for various sites throughout Okeover Inlet. Table 6-5 gives a summary of applicable sediment quality guidelines. While sampling and assessing water chemistry can be challenging due to the transient nature of marine waters, sediments are a good indicator of long term trends that may be occurring in a watershed.

Sediment samples collected at all sites had concentrations of chromium, lead, nickel and silver consistently below their respective guidelines.

The remaining metals for which guidelines exist (arsenic, cadmium, copper and zinc) were exceeded in at least one sediment sample from each of the sites.

In Freke Anchorage, two of the five samples tested for arsenic exceeded the guideline (values of 9 µg/g and 9.8 µg/g), and four of the five samples exceeded the cadmium guideline (values ranging from 0.92 µg/g to 2.02 µg/g.

In Wootton Bay, one of the five arsenic samples exceeded the guideline with a value of 9 µg/g, and five of the six cadmium samples exceeded the guideline (values ranging from 0.56 µg/g – 1.75 µg/g).

In Penrose Bay, all samples met all of the applicable metals guidelines.

One of five arsenic samples collected at Trevenen Bay exceeded the arsenic guideline with a value of 10 µg/g, and one of the six samples exceeded the cadmium guideline with a value of 1 µg/g.

In Grace Harbour, one of four samples exceeded the arsenic guideline with a value of 13.4 µg/g, all four of the cadmium samples exceeded the guideline (values ranging from 0.94 µg/g – 4.47 µg/g), and one sample exceeded the copper guideline with a value of 48.6 µg/g.

Finally, at the Okeover Central site, two of three samples exceeded the arsenic guideline (values of 12.7 µg/g and 17 µg/g), all three samples exceeded the cadmium guidelines (values ranging from 4.13 µg/g – 6.2 µg/g), all three samples exceeded the copper guidelines (values ranging from 35.6 µg/g – 61.3 µg/g), and one of three samples exceeded the zinc guideline with a value of 145 µg/g.

Table 6-4 summarizes exceedences of sediment guidelines for all sites in Okeover Inlet.

Table 6-5. Summary of Canadian Sediment Quality Guidelines (from Nagpal *et al.*, 2001).

Parameter	Canadian Sediment Quality Guideline (µg/L) Interim Sediment Quality Guideline	Probable Effects Level
Arsenic	7.2	42
Cadmium	0.68	4.2
Chromium	52	160
Copper	19	108
Lead	30	112
Nickel	30	50
Silver	1	2.2
Zinc	124	271
Acenaphthene	0.007	0.089
Acenapthylene	0.006	0.128
Anthracene	0.047	0.245
Benzo(a)anthracene	0.075	0.693
Benzo(b)fluoranthene	2.3	4.5
Benzo(k)fluoranthene	2.3	4.5
Benzo(g,h,i)perylene	0.31	0.78
Benzo(a)pyrene	0.089	0.763
Chrysene	0.108	0.846
Dibenzo(a,h)anthracene	0.006	0.135
Fluoranthene	0.113	1.494
Fluorene	0.021	0.144
Indeno(1,2,3-c,d)pyrene	0.34	0.88
Naphthalene	0.035	0.391
Phenanthrene	0.087	0.544
Pyrene	0.153	1.398
Total PAH's		
Total Low MW PAH's	3.7	7.8
Total High MW PAH's	9.6	53

A number of the exceedences are likely due to high detection limits used to analyze the samples. Samples collected prior to 2002 were analyzed for arsenic with a detection limit of 9 µg/g, and cadmium concentrations were analyzed with a detection limit of 0.8 µg/g, both of which exceed their applicable guidelines. Most of the arsenic exceedences and many of the cadmium exceedences occurred during this time period, and are likely due to the high detection limits. For guideline monitoring, it is necessary to have detection limits at least ten times lower than the applicable guideline for an accurate assessment to be made.

Table 6-6. Summary of exceedences of sediment quality guidelines for metals in Okeover Inlet (from Nagpal *et al*. 2001).

Site Location	Arsenic (7.2 µg/g)* Concentration range (µg/g)	Cadmium (0.68 µg/g)* Concentration range (µg/g)	Copper (19 µg/g)* Concentration range (µg/g)	Zinc (124 µg/g)* Concentration range (µg/g)
Freke Anchorage	9 – 9.8	0.92 – 2.02		
Wootton Bay	9	0.56 – 1.75		
Trevenen Bay	10	1		
Grace Harbour	13.4	0.94 – 4.47	48.6	
Okeover Central	12.7 – 17	4.13 – 6.2	35.6 – 61.3	145

*Interim sediment quality guideline concentration for the protection of marine aquatic life

As elevated levels of metals were also seen at the Okeover Central site, the high levels of these metals are likely not due to localized contamination. Elevated concentrations of cadmium are likely due to local geomorphology as well as the upwelling of cadmium-rich waters (especially along the west coast of Vancouver Island) (Kruzynski, 2000). As well, there are no known anthropogenic sources for any of these metals within Okeover Inlet (see Section 6.5). For these reasons, no objective is recommended for total metals concentrations in sediment in Okeover Inlet.

Polycyclic aromatic hydrocarbons were measured in sediment samples from Wootton Bay, Grace Harbour and Okeover Central, and phthalates were measured at Freke Anchorage, Wootton Bay, Trevenen Bay and Okeover Central. Results for both of these groups of compounds were mostly below detection limits, and were well below their respective guidelines for the protection of marine aquatic life at all of the sites.

7.0. Monitoring Recommendations

Potential impacts to water quality in the Okeover Inlet area are likely to increase over the coming years, with increases in the number of seasonal and year-round residences, mariculture tenures, and pleasure craft utilizing the area. The primary concern for water quality are the levels of bacteriological indicators, which can have a detrimental impact on the mariculture industry and detract from the overall pristine atmosphere that attracts huge numbers of boaters and kayakers each year. While the Canadian Shellfish Sanitation Program has a regular water quality monitoring program for classification purposes, it is recommended that a complimentary monitoring program be implemented with a focus on overall marine and freshwater quality to compare to baseline conditions and water quality objectives. For Objective Attainment monitoring it is recommended that at least five samples be collected during a 30-day period in July and/or August. Based on past sampling, as well as park usage statistics, it appears that this is the period where fecal coliforms and enterococci are most likely to exceed the proposed objectives. Samples should be collected at each of the monitoring locations described in this report (Freke Anchorage, Wootton Bay, Penrose Bay, Trevenen Bay, Cochrane Bay, Grace Harbour, Government Wharf and Okeover Central). Monitoring of sediment bacteriology, chemistry and toxicity in embayed areas is recommended to identify whether conditions are improving or worsening over time.

While not all water quality parameters summarized in this report are being made into Objectives, this document is intended to summarize baseline conditions in Okeover Inlet that can be used for comparisons to future water quality monitoring. This information can be utilized by land use managers and decision makers as a way of ensuring that downstream water resources are being protected. A number of both short- and long-term recommendations were made as part of the Okeover Inlet Water Quality 2001-2003 Interim Water Quality Report (Freyman, 2004). Following these recommendations would make a significant contribution towards protecting the resources dependent upon good marine water quality.

8.0. Summary of Proposed Water Quality Objectives

Table 8-1. Summary of Water Quality Objectives proposed for Okeover Inlet.

Characteristics	Okeover Inlet Shellfish Areas for all good or medium beach or deep water shellfish capability areas as described in the Malaspina Coastal Plan	Okeover Inlet Bathing Areas
Designated water uses	For the protection of the ability for shellfish growing and harvesting, marine aquatic life and wildlife (not shellfish classification)	Primary-contact recreation, marine aquatic life and wildlife
Fecal coliforms	Less than or equal to 14 MPN/100 mL median concentration … Less than or equal to 43 MPN/100 mL 90th percentile	Less than or equal to 200 MPN/100 mL geometric mean
Enterococci	Less than or equal to 4 MPN/100 mL median concentration … Less than or equal to 11 MPN/100 mL 90th percentile	Less than or equal to 20 MPN/100 mL geometric mean

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Figure 1 Okeover Inlet Overview Map.

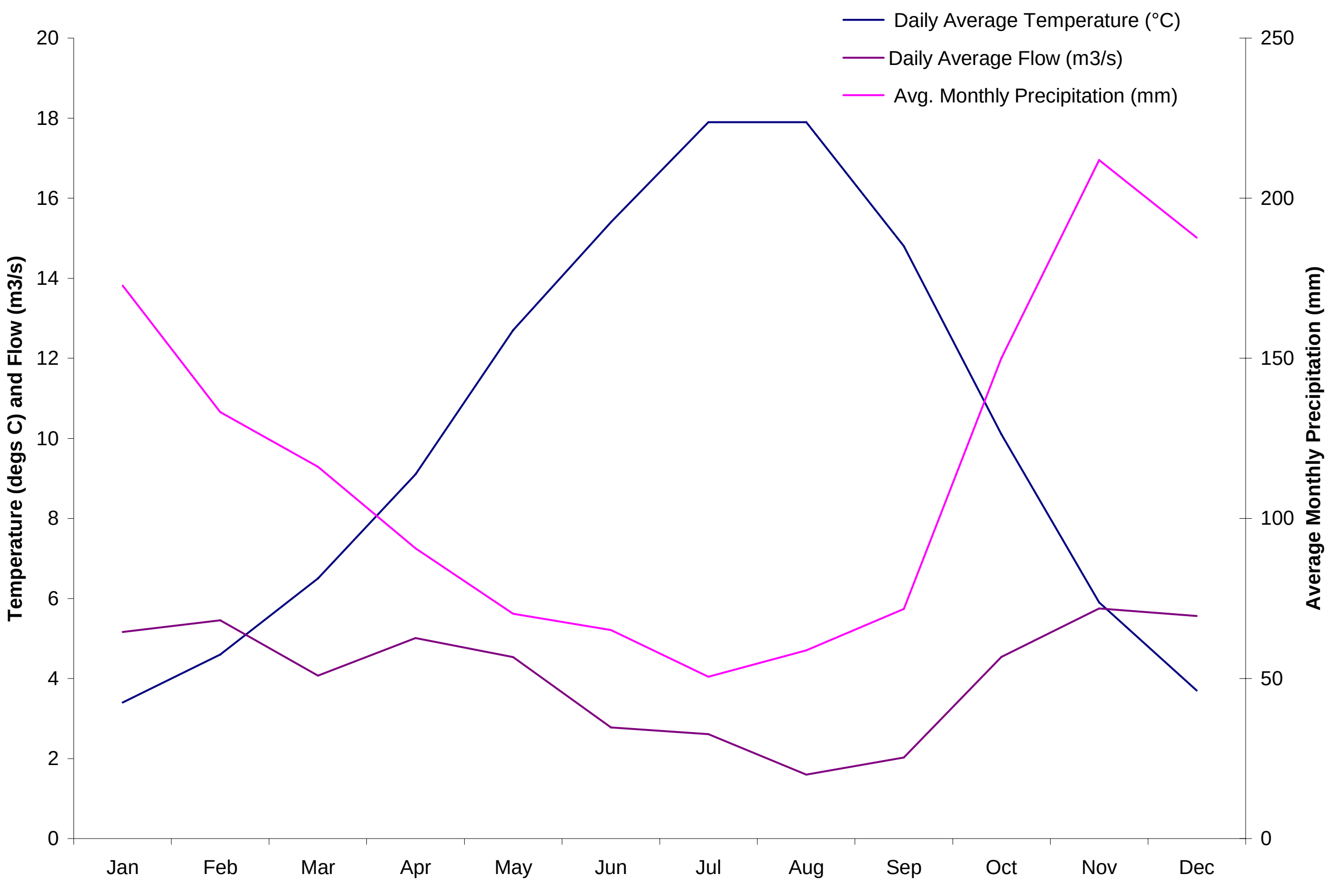

Figure 2. Comparison of daily average temperature and precipitation (measured at Environment Canada weather station on Cortes Island) with daily average flow rates on the Theodosia River (measured at Water Survey Canada station).

Figure 3. Department of Fisheries and Oceans Fisheries Management Area 15.

ENVIRONMENTAL QUALITY