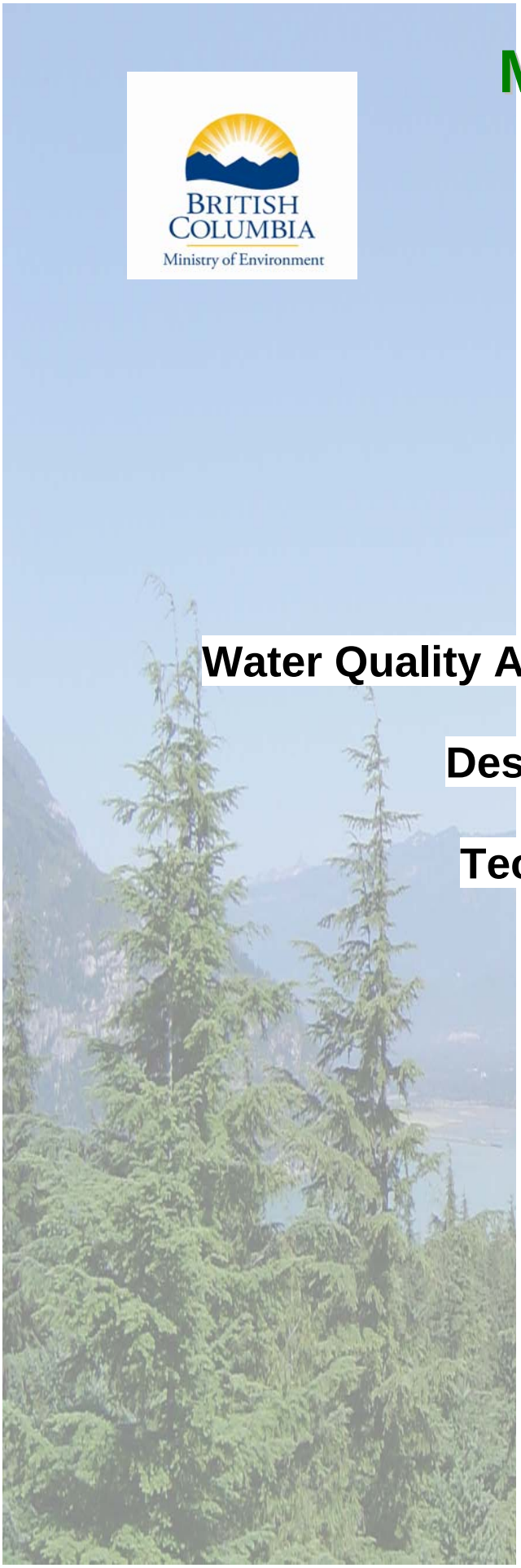

Ministry of Environment

LOWER MAINLAND REGION

Water Quality Assessment and Objectives

Desolation Sound.

Technical Report

ENVIRONMENTAL QUALITY

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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. 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 the Desolation Sound. 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 Desolation Sound. 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 are the relatively high concentrations of recreational boaters utilizing Desolation Sound and potentially discharging wastes directly into the Sound, especially embayed areas with limited flushing. 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 are 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 selected embayed areas within the Desolation Sound area, a marine inlet on the west coast of the BC mainland opposite Campbell River on Vancouver Island (Figure 1). The boundaries of the sound are not precise, but for the purposes of this report, Desolation Sound describes the marine waters east of Cortes Island, extending from Okeover Inlet in the south to Raza Passage in the north (Figure 1). However, this report will focus primarily on the southern portion of Desolation Sound, in the area between West Redonda Island and the Malaspina Peninsula, and bounded to the north by the southern end of East Redonda Island (Figure 4). This area is a popular destination for recreational boaters, and includes the Desolation Sound Marine Provincial Park, Tux'wnech Okeover Arm Provincial Park, Roscoe Bay Provincial Park, and Malaspina Provincial Park. As well, shellfish farming and harvesting are important economic activities throughout the Sound, and a large number of mariculture tenures have been issued for the area.

As the primary water uses for the Desolation Sound 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 Desolation Sound are primarily linked to untreated sewage discharges from pleasure craft and residences, as well as from possible fuel spills from pleasure craft or at refilling stations on private docks. Increases in upland development could lead to increased non-point sources of pollution to marine waters.

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 Desolation Sound. There are no major freshwater tributaries to the Sound that 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 Sound. These factors, coupled with the many embayments that make Desolation Sound a popular boating destination

and provide sheltered areas for mariculture tenures, result in low flushing rates in many areas, potentially allowing contaminants to accumulate.

WATER USES

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

WATER QUALITY ASSESSMENT AND OBJECTIVES

WATER QUALITY ASSESSMENT

Water quality throughout Desolation Sound is generally good for most parameters measured as part of this study. Nutrient levels were generally very low, and there were no elevated concentrations of metals. Sediment samples often 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 of the area rather than impacts from human activities. The water quality 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 and residences. While fecal coliform and enterococci concentrations were generally low at most marine sites, occasional high values caused the 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 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 Desolation Sound 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 (MSRM 2004). 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 (swimming) that might occur in those areas.

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 most popular moorages (Galley Bay, Prideaux Haven, Tenedos Bay, Refuge Cove, Grace Harbour and Roscoe Bay), as well as in representative areas throughout Greater Desolation Sound in close proximity to mariculture tenures. Monitoring of sediment bacteriology, chemistry and toxicity in embayed areas is recommended to identify whether conditions are improving or worsening over time.

Table 0-1. Summary of Water Quality Objectives proposed for Desolation Sound.

Characteristics	Desolation Sound Shellfish Growing/Harvesting Areas	Desolation Sound 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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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 Desolation Sound, 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.

Desolation Sound is an important recreational boating area, containing the largest marine park in BC. 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. 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. Objectives, therefore, 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. As no direct discharge of a permitted waste occurs to Desolation Sound, no initial dilution zones have been set.

1.3. DESCRIPTION OF WATERSHED

Desolation Sound is located on the west coast of the BC mainland, approximately 30 kilometers northwest of Powell River (Figure 1). The sound stretches for approximately 32 kilometers from south to north, and about 26 kilometers from east to west. Toba Inlet extends a further 32 kilometers inland in the north west. Desolation Sound includes East and West Redonda Islands, as well as Raza Island in the north, and a large number of embayments including Okeover Inlet, Pendrell Sound, Toba Inlet and Ramsay Arm. However, this report will focus primarily on water quality in the southern portion of the sound, between the Malaspina Peninsula and the southern portion of East Redonda Island. Okeover Inlet is dealt with in detail in a separate Water Quality Assessment and Objectives report (Phippen, 2005), and is therefore discussed only briefly in this report.

The watersheds that feed Desolation Sound 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, although a few areas to the west (including Texada, Twin and Hernando Islands) are primarily sedimentary composites (MSRM 2004).

Three primary biogeoclimatic zones occur within Desolation Sound, with a total of six subvarients. The lowest elevations are composed of the Coastal Western Hemlock eastern very dry maritime zone (CWHxm1), giving way to the dry maritime (CWHdm), submontane very wet maritime (CWHvm1) 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, and Alpine Tundra (ATp) can be found on a few of the highest peaks.

2.0. HYDROLOGY AND PRECIPITATION

This report is concerned primarily with the marine waters of Desolation Sound, 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 Desolation Sound area, with the exception of Theodosia River at the top of Okeover Inlet. 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 Desolation Sound are generally small, especially on the east side of the inlet where the majority of water flows south through Powell River. Significant tributaries include the Quatam River (which flows into Ramsay Arm), the Toba River and Brem Creek (which flow into Toba Inlet), and the Theodosia River (which flows into Okeover Arm). Of these, hydrometric data is available only for the Theodosia River. Due to the relatively small size of all of the watersheds draining into Desolation Sound, 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 Desolation Sound are mixed diurnal, with two uneven tides each day. The larger daily tide in Prideaux Haven ranges from about 2.7 to 5.4 metres, while the smaller tide ranges from about 0.7 to 1.6 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 many of the natural inlets, and the low volumes of freshwater being introduced into the inlets, results in little mixing and long retention times within some of these inlets. Therefore, any contaminants introduced to these inlets 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 Desolation Sound (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 Desolation Sound area (the other being mariculture). As mentioned in the introduction, Desolation Sound contains three provincial parks (Walsh Cove, Teakerne Arm and Roscoe Bay, all on West Redonda Island) as well as the Desolation Sound Provincial Marine Park. There are also 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 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.

Most people access Desolation Sound by boat, either self-propelled (canoes, kayaks etc. that are usually launched in Okeover Inlet) or pleasure craft such as power boats 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 in July and August, with the lowest visitor

traffic occurring during the winter months. Table 3-1 shows BC Parks boat counts for some of the parks in and around Desolation Sound for May through September, 1998 to 2003.

Table 3-1. Summary of monthly boat counts for various Provincial Parks in and around Desolation Sound, 1998 to 2003 (from BC Parks, 2005 pers. comm.).

	May	June	July	August	September	Total
Copeland Islands Marine Park						
1998	4	13	130	516	78	**741**
1999	6	20	102	88	30	**246**
2000	10	94	31	67	16	**218**
2001	22	26	68	121	14	**251**
2003		68	35	149		**217**
Desolation Sound Marine Park						
1998	64	261	1839	4179	326	**6669**
1999	15	105	1508	1852	350	**3830**
2000	40	879	1642	2088	164	**4813**
2001	48	427	2051	2567	244	**5337**
2003		320	1700	2586	271	**4024**
Teakerne Arm Park						
1998	12	10	22	444		**488**
1999	6	14	49	78	22	**169**
2000	10	24	30	20	14	**98**
2001	15	18	62	78	26	**199**
2003		18	16	27		**61**
Roscoe Bay Park						
1998	8	40	109	1153	43	**1353**
1999	10	60	100	169	44	**383**
2000	10	140	203		70	**423**
2001	18	48	187	312	64	**629**
2003		48	262	175		**485**

3.2. FISHERIES

Fisheries values in the Desolation Sound area can be divided into two main categories – shellfish and finfish. These can further be subdivided into wild stocks and reared stocks.

The harvesting of wild shellfish and invertebrates, including clams, geoducks and prawns, represent an important industry in the Desolation Sound area. The following catch statistics have been provided by Fisheries and Oceans Canada (Kerry Marcus, 2005 pers. comm.) for the Pacific Fisheries Management Area (PFMA) 15-05, which encompasses the waters of Desolation Sound, the Redonda Islands and the eastern side of Cortes Island (Figure 3).

The area is important in the commercial shellfish industry for intertidal clam, geoduck, and prawn harvesting, with a smaller history of recorded sea cucumber harvest, and small amounts of crab,

green sea urchin and shrimp by trawl landings reported since the early 1980's when harvest log programs began to track landings by subarea.

The harvest of intertidal clams has been important both for the commercial fishery as well as for First Nations food, social and ceremonial harvesting. As well, there is a significant recreational harvest of both clams and oysters in the Desolation Sound area. The commercial clam fishery is active in Prideaux Haven, outside Redonda Bay, the shoreline on Cortes Island above and below Squirrel Cove and specifically just north of Mary Point on Cortes Island.

The area is very important in the commercial prawn fishery with landings of greater than two millions pounds reported since 1980. The annual average landings between 2000 and 2004 are reported at 160,000 lb per year, with ten to thirty vessels harvesting annually.

There are seven documented geoduck harvests from the area with a total of approximately 165,000 lbs between 1979 and 2003. Small landings (< 100 lb /year) of sidestripe shrimp have been recorded since 1997.

The majority of tributaries to the lower Desolation Sound (south of the Redonda Islands) are too small to serve as spawning grounds for salmon. One tributary, Forbes Creek (a.k.a. Small Creek) is listed in the federal/provincial salmon spawning database as supporting escapements of sockeye, coho, pink, chum and chinook salmon. The maximum numbers on record are 7,500 chum, 400 pink, 40 coho, and no estimates for sockeye or chinook. Desolation Sound is not considered a significant groundfish area, and both the Gifford Peninsula (Desolation Sound Provincial Marine Park) and Teakerne Arm are designated rockfish conservation areas.

Another marine resource that is commercially harvested in Desolation Sound is euphausiids, or krill, that are typically used to manufacture commercial fish food and, to a lesser extent, aquarium pet food. The annual quota for PFMA 15-05 is 50 tonnes, about 10% of the total provincial quota of 500 tonnes.

Aquaculture is also an important industry for the Desolation Sound area. At present, there are a total of 31 aquaculture tenures within PFMA 15-05 (Table 3-2). Two of these tenures are for salmon farms: one located at the mouth of Homfray Creek in Homfray Channel and the other in Doctor Bay on West Redonda Island. There is also a salmon farm on the north shore of Raza Island, in the northern part of Desolation Sound. The remaining 29 tenures are for shellfish production, including clams, mussels and oysters, with the majority located on West Redonda Island. This represents approximately 6% of the total number of shellfish tenures within the province.

Table 3-2. Summary of mariculture tenures for Desolation Sound (PFMA 15-05) as of January 2005 (Source: MAFF, 2005).

Culture Type*	Tenure Area ($m^{2)}$	Tenure Area (ha)	Site Count
Bottom	383,762	38.4	12
Net Cages	422,415	42.2	2
Off Bottom	1,464,103	146.4	12
Off Bottom & Bottom	255,179	25.5	4
Off Bottom & Near Bottom	141,722	14.2	1
Total for 15-05	2,667,181	266.7	31

*Net Cages refer to marine finfish farm sites all other culture types are for marine shellfish farm sites.

Marine water quality within the Desolation Sound 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 a number of areas including the east and northwest portions of Refuge Cove on West Redonda Island and the embayed area on Mink Island. As well, seasonal sanitary closures between May 31 and September 30 have been imposed on Prideaux Haven and Tenedos Bay on the mainland and Allies Inlet and Roscoe Bay on West Redonda Island. There is also a biotoxin closure in effect for the entire area of PFMA 15-05 for butter clams only.

3.3. WILDLIFE

As Desolation Sound 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 Desolation Sound 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 the Desolation Sound 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

Desolation Sound is a relatively pristine area, with no permitted waste discharges. 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 facilities at campsites. The following sub-sections outline existing land uses within the Desolation Sound 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 Desolation Sound, 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 Desolation Sound (*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: direct depositions on the foreshore area by pets; improper disposal of wastes by hikers on the foreshore or upland areas; and seepage from existing outhouses within the parks.

4.2. LAND OWNERSHIP

Much of the land area in Desolation Sound consists of Crown Land. Provincial parks (Desolation Sound Provincial Marine Park, Walsh Cove Provincial Park, Teakerne Arm Provincial Park and Roscoe Bay Provincial Park), as well as an ecological reserve covering most of East Redonda Island, occupy a significant portion of the land base. However, as discussed in Section 3.2, there are a number of mariculture leases in the area, as well as private residences, that may have some impact on water quality. Potential contamination might occur from untreated sewage from these residences being discharged directly into marine waters or seeping into the ocean from malfunctioning septic fields. As boats are the only feasible 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. Finally, in the case of salmon farms, biological waste from the fish could result in elevated nutrient levels in the immediate area as well as accumulations of decomposing waste in the sediments beneath the net pens.

4.3. Forest Harvesting and Forest Roads

Desolation Sound falls within the Sunshine Coast Timber Supply Area. There are a number of forest tenures within the area, including Terminal Forest Products Ltd. on West Redonda Island, International Forest Products on the mainland north of Desolation Sound Provincial Marine Park, and BC Timber Sales (formerly the Small Business Forest Enterprise Program) on both West Redonda Island and the mainland. Potential impacts to marine waters from these activities might include increased localized turbidity and suspended solids, 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, 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 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 Desolation Sound watershed. Fecal coliform data collected between 1994 and 2004 as part of Environment Canada's Shellfish Sanitation Program is also examined. Key water quality parameters such as fecal coliforms, nitrate, nitrite, phosphorus, and total metals, and sediment parameters such as total metals and polycyclic aromatic hydrocarbons are considered to protect marine aquatic life including the ability for shellfish growing and harvesting. Shellfish harvesting is the most sensitive water use in Desolation Sound for these parameters. Based on current

knowledge of potential anthropogenic impacts to the watersheds (generally associated with recreation and mariculture), and with the small number of waste discharges to any of the watersheds, these are the water quality parameters most likely to change should anthropogenic activities increase.

A number of water and sediment quality monitoring sites were selected throughout the greater Desolation Sound area. We've subdivided the area based on relative levels of use (and therefore potential impacts). Focus Area B (Figure 5) is typically the area with highest use and includes sampling sites at Galley Bay, Tenedos Bay, Roscoe Bay, Grace Harbour and Refuge Cove (all of which are popular anchorages). Desolation South is also located in Focus Area B, and represents a less-impacted site used to describe ambient conditions. Focus Area A is slightly less utilized by pleasure craft, and includes monitoring sites at Frances Bay, Attwood Bay, Forbes Bay, Pendrell Sound and Redonda Bay (Figure 4). Toba South, Toba Centre, Toba North, Bute North, Bute Centre, Bute South, Ramsey Arm, Frederick Arm, and Phillips Arm are relatively remote sites located in the Greater Desolation Sound Focus Area (Figure 1).

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 detectable limits for a given parameter, as the accuracy of a result close to the detectable limit shows more variability than results well above detectable 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. For the 1999 sediment sampling program, triplicate samples were combined and one composite sample was submitted for analysis, while in other years, samples were kept separate and analyzed independently. 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 detectable limits were reported as equal to the detection limit for the purposes of calculating means and standard deviations.

Appendix 1 contains a number of tables that summarize QA/QC data collected for each year between 1999 and 2004. Triplicate bacteriological samples collected at five sites in 1999 and analyzed for both fecal coliforms and enterococci had percent relative standard deviations ranging from 0% to 57% (Table A-1). In 2000, one set of triplicate fecal coliform samples had a percent relative standard deviation of 0% (Table A-2).

In 2000, one set of sediment samples was collected from three different depths, ranging from 12 to 75 metres, in Prideaux Haven (Table A-3). However, even from these different depths, the relative percent standard deviations were generally low, ranging from 0% to 23%. Only three parameters (cobalt, nickel and selenium) had relative percent standard deviations above the acceptable limit of 18%.

In 2002, one set of triplicates and five sets of duplicates were analyzed for nutrients and bacteriological indicators (Table A-4). Relative percent differences ranged from 0% (for a number of parameters) to 143% (for fixed non-filterable residue). For all of the higher percent mean differences, results were within 10 times the detectable limits for each parameter.

Five sets of field blanks were collected in 2002 (Table A-5) and results for these were generally below detectable limits. Exceptions to this were for two samples that had total nitrogen, total Kjeldahl nitrogen and total organic nitrogen levels of between 0.13 mg/L and 0.14 mg/L, while the detection limits for all of these parameters is 0.02 mg/L. This suggests that some nutrient contamination may be occurring in some samples. However, these levels are far below any concentrations that might be of concern (the most sensitive applicable water quality guideline for ammonia is for the protection of marine aquatic life at 2.5 mg/L).

One duplicate sediment sample was collected in 2002, and percent relative mean differences ranged from 0% to 100% (Table A-6). The average percent mean difference for the 33 parameters tested was quite high, at 48%, suggesting a relatively high degree of variability between the duplicate samples. However, due to the lack of homogeneity amongst sediment samples, this is more likely an indication of natural variability rather than problems with laboratory analyses or collection methods.

One set of duplicate water samples was collected in 2003, and relative percent mean differences ranged from 0% to 67% (Table A-7). The higher values were all associated with filterable and non-filterable residue at levels near detectable limits, and these parameters tend to show variability at lower concentrations.

Two sets of triplicate sediment samples were collected in 2003, and relative percent standard deviations for the samples ranged from 0% (for most polycyclic aromatic hydrocarbons and a few metals) to 115% for naphthalene (Table A-8). Again, concentrations were less than 10 times the detectable limit for most relative percent standard deviations above 18%, and the overall mean for the relative percent standard deviations calculated for the 49 variables measured in each sample ranged from 12% to 21%.

Two sets of duplicate water samples were collected in 2004, and relative percent mean differences were generally below the 25% threshold (Table A-9). Exceptions included total phosphorus in one sample which had a relative percent mean difference of 100%, and nitrate+nitrite and total copper, each of which had relative differences of 67%.

Finally, two sets of duplicate sediment samples were collected in 2004 (Table A-10). There was a low degree of variability for most of the parameters, with a mean relative percent standard deviation of 4% for the 49 variables measured in both 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 these 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 are 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.

Environment Canada uses similar guidelines under their Canadian Shellfish Sanitation Program (CSSP). Under the program, shellfish growing areas may be designated as Approved when the following conditions set forth in the CSSP are met:

> **The area is not contaminated with fecal material, poisonous or deleterious substances or marine biotoxins to the extent that consumption of the shellfish might be hazardous; and**
>
> **The median or geometric mean fecal coliform Most Probable Number (MPN) of the water does not exceed 14/100 mL and not more than 10% of the samples exceed fecal coliforms MPN of 43/100 mL.**

6.1.1. Focus Area B

Enterococci and fecal coliform concentrations were measured a number of times at each of the monitoring sites in Focus Area B (Tables B-1 to B-6, Appendix B). 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 6-1.

Median enterococci values ranged from below detectable limits (<2 MPN/100 mL) at Tenedos Bay (July 19 – 29, 2002), Prideaux Haven (July 17 – 29, 2002), Roscoe Bay (August 9 – 13, 2004), Refuge Cove (August 9 – 13, 2004), Grace Harbour (July 16 – 30, 2002 and August 9 – 13, 2004) and Desolation South (July 19 – 29, 2002 and August 9 – 13, 2004), to a maximum of 5 MPN/100 mL at Refuge Cove (July 17 – 29, 2002). The 90th percentiles calculated for the Area B sites ranged from below detectable limits (<2 MPN/100 mL) for Grace Harbour (August 9 – 13, 2004) and Desolation South (August 9 – 13, 2004) to 22.6 MPN/100 mL for Refuge Cove (July 17 – 29, 2002). Enterococci concentrations for the samples collected at Refuge Cove in July, 2002 exceeded both the median and 90th percentile guidelines, and the August, 2004 samples from this site had a 90th percentile that also exceeded the h guidelines.

Median fecal coliform values ranged from below detectable limits (<2 MPN/100 mL) at Galley Bay (July 19 – 29, 2002), Tenedos Bay (July 19 – 29, 2002), Grace Harbour (July 8 – 16, 2003) and Desolation South (July 19 – 29, 2002, July 8 – 16, 2003 and August 9 – 13, 2004), to a maximum of 14 MPN/100 mL at Roscoe Bay (August 9 – 13, 2004). The 90th percentiles calculated for these sites ranged from below detectable limits (<2 MPN/100 mL) for Desolation South (July 19 – 29, 2002, July 8 – 16, 2003 and August 9 – 13, 2004) to 330.8 MPN/100 mL for Roscoe Bay (August 9 – 13, 2004). Fecal coliform concentrations for the samples collected at Roscoe Bay in August, 2004 met the median guideline for the protection of the ability for shellfish growing and harvesting of 14 MPN/100 mL and the 90th percentile of 330.8 MPN/100 mL was well above the 90th percentile guideline. The August, 2004 samples from Refuge Cove also had a 90th percentile value that exceeded the guideline, with a value of 108.8 MPN/100 mL. These high 90th percentile values were the result of a single elevated sample at both Roscoe Bay (540 MPN/100 mL on August 12, 2004) and Refuge Cove (170 MPN/100 mL on August 11, 2004). While we do not have boat counts at those sites for those dates, mid-August corresponds with the busiest time of the year for pleasure craft in Desolation Sound, and this was likely the source for the elevated values.

6.1.2. Focus Area A

Five water samples were collected in each of Forbes Bay, Attwood Bay and Redonda Bay between July 17 and July 29, 2002. Median concentrations for both fecal coliforms and enterococci were <2 MPN/100 mL for all three sites, and 90th percentiles ranged from<2 MPN/100 mL to 4 MPN/100 mL for both fecal coliforms and enterococci.

6.1.3. Greater Desolation Sound Focus Area

No coliform samples were collected at the Greater Desolation Sound sites.

6.1.4. Historical Data

While there are concerns with bacteriological contamination in areas of Desolation Sound, it appears that conditions may actually have improved slightly over historical conditions. Fecal coliform samples collected as part of the Environment Canada Shellfish Growing Water Control Program in 1980 showed elevated levels for a number of sites throughout Desolation Sound. In Prideaux Haven, two of eight sites had 90th percentiles exceeding the shellfish guidelines (79 – 378 MPN/100 mL), in Tenedos Bay, two of six samples exceeded the guidelines (90th percentiles 64 – 101 MPN/100 mL), in Roscoe Bay one of two samples exceeded the guideline (90th percentile 962 MPN/100 mL), and at the head of Refuge Cove (where a shellfish closure was, and still is, in effect) all three of the sites had coliform levels well above the guidelines (90th percentiles 279 – 940 MPN/100 mL). As part of this project, they attempted to correlate bacteriological data with boat counts, but for six areas tested, they found a significant correlation for only one area (Tenedos Bay).

Fecal coliform concentrations measured once a month in June, August and October of 1991 for Roscoe Bay, Prideaux Haven and Tenedos Bay showed maximum concentrations of only 4 CFU/100 mL (Millar, 1991). None of the sites were sampled at sufficient frequency to determine median or 90th percentile values.

Fecal coliforms were also collected between 1994 and 2000 as part of the Environment Canada Shellfish Sanitation Program. Seven sets of five samples from a 30-day period were collected in Refuge Cove, with median values of <2 MPN/100 mL for all of the data sets and 90th percentile values ranging from <2 MPN/100 mL to 103 MPN/100 mL. Only the maximum 90th percentile value exceeded the shellfish guideline, due to an anomalous value of 170 MPN/100 mL measured on January 20, 1997. Five sets of data measured with the requisite frequency were collected from Prideaux Haven, with median values ranging from <2 MPN/100 mL to 5 MPN/100 mL, and 90th percentile values ranging from 2 MPN/100 mL to 18 MPN/100 mL. Two sets of samples were collected from Tenedos Bay, both with median values of <2 MPN/100 mL and 90th percentiles of 4 MPN/100 mL. Finally, two sets of data were collected from Galley Bay, both with median values of <2 MPN/100 mL and 90th percentile values of 2 MPN/100 mL.

Although conditions measured as part of the more recent water quality monitoring programs appear to have improved somewhat over those measured in the early 1980's, the relatively small number of samples and short period of record do not permit a definite assessment of trends to be made.

Table 6-1. Summary of median and 90th percentiles for samples collected at the Focus Area B sites. Each value is based on five samples collected between the dates indicated.

	Enterococci (MPN/100 mL)		Fecal coliforms (MPN/100 mL)	
	Median	90th Percentile	Median	90th Percentile
Galley Bay				
July 19 – 29, 2002	2	6.8	<2	2
Tenedos Bay				
July 19 – 29, 2002	<2	2	<2	5.6
Prideaux Haven				
July 17 – 29, 2002	<2	2	4	23
July 8 – 16, 2003			2	5
August 9 – 13, 2004	2	3.2	13	38.6
Roscoe Bay				
July 17 – 29, 2002	2	4.6	5	13.4
August 9 – 13, 2004	<2	3.2	14	330.8
Refuge Cove				
July 17 – 29, 2002	5	22.6	2	8
July 9 – 17, 2003			8	12
August 9 – 13, 2004	<2	11	6	108.8
Grace Harbour				
July 16 – 30, 2002	<2	2	2	40.8
July 8 – 16, 2003			<2	20.6
August 9 – 13, 2004	<2	2	2	5
Desolation South				
July 19 – 29, 2002	<2	3.8	<2	<2
July 8 – 16, 2003			<2	<2
August 9 – 13, 2004	<2	<2	<2	<2

Regardless of whether or not bacteriological contamination in Desolation Sound is improving, it is evident that there are still concerns associated with these indicators. The low levels of contamination measured at the Desolation South 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 Desolation Sound area. ***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.

6.2. NUTRIENTS (NITRATE, NITRITE AND PHOSPHORUS)

Nitrogen (including 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, while phosphorus tends to be the limiting factor in 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.

6.2.1. Focus Area B

Nitrogen concentrations were measured five times at Galley Bay in July, 2002, and concentrations of nitrate, nitrite and ammonia were consistently below detectable limits (<0.002 mg/L, <0.002 mg/L, and <0.005 mg/L, respectively). This was also the case for five water samples collected at Tenedos Bay between 1999 and 2002. Seventeen samples were collected at Prideaux Haven between 1999 and 2004, and the majority of these samples had nitrate, nitrite and ammonia concentrations below detectable limits. The maximum recorded values at this site were 0.054 mg/L for total ammonia, 0.007 mg/L for nitrite, and 0.008 mg/L for nitrate. Fourteen samples were analyzed from Roscoe Bay between 1999 and 2004, and all samples collected prior to August 2004 were below detectable limits. The maximum concentration measured during August 2004 was 0.066 mg/L for ammonia, 0.006 mg/L for nitrite and 0.005 mg/L for nitrate. Fifteen samples were collected at Refuge Cove between 2002 and 2004, and again all maximum values occurred during August, 2004. The highest concentration of ammonia was 0.088 mg/L, while the maximum nitrite and nitrate concentration was 0.004 mg/L and 0.005 mg/L, respectively. Sixteen samples were analyzed for nutrients at Grace Harbour between 1999 and 2004, with maximum ammonia concentrations of 0.114 mg/L for ammonia, for 0.007 mg/L for nitrite and all concentrations below detectable limits (<0.002 mg/L) for nitrate. The highest concentration of ammonia and nitrite occurred in August 2004. For the sixteen samples measured from Desolation South, the maximum nitrate value (0.007 mg/L) occurred in July,

2003, while the maximum nitrite concentration (0.006 mg/L) and ammonia concentration (0.073 mg/L) occurred in August, 2004.

6.2.2. Focus Area A

One set of samples was collected from Teakerne Arm in July, 2003, and ammonia, nitrate and nitrite concentrations were all below detectable limits. Five samples were collected in July, 2002 in each of Forbes Bay, Attwood Bay and Redonda Bay, and concentrations of ammonia, nitrate and nitrite were all consistently below detectable limits.

6.2.3. Greater Desolation Sound Focus Area

Concentrations of total ammonia measured at the various sites throughout the Greater Desolation Sound area were consistently below detectable limits (<0.005 mg/L) (Table B-20). Concentrations of nitrate ranged from below detectable limits (<0.002 mg/L) for surface samples collected at Bute Inlet Centre, Bute Inlet South, Ramsay Arm, Toba Inlet North and Toba Inlet Centre, as well as the 30 m deep sample for Toba Inlet Centre, to a maximum of 0.35mg/L in the 30 m sample from Bute Inlet Centre. Total nitrite levels at all sites ranged from below detectable limits (<0.002 mg/L) to 0.003 mg/L with the exception of the deep Toba Inlet North sample, which had a concentration of 0.011 mg/L.

The highest concentration of total ammonia (0.088 mg/L, measured in Refuge Cove in August, 2004) was 28 times lower than the maximum total ammonia guideline of 2.5 mg/L and 11 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 the highest concentrations of these parameters consistently 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

Desolation Sound that would appreciably affect water temperatures, these guidelines are not a concern.

The waters of Desolation Sound are relatively shallow and protected, allowing elevations in water temperature that are not seen in many other places on the coast. Maximum summer temperatures measured between 1999 and 2003 were 18°C in Tenedos Bay, 19°C in Desolation Central and Refuge Cove, and 20°C in Roscoe Bay, Grace Harbour and Prideaux Haven. Water temperatures may be increasing over time in Desolation Sound – 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 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 between one and nine times at 20 sites throughout Desolation Sound. Concentrations ranged from 2 mg/L to 37 mg/L, with almost all samples below 10 mg/L. As there are no known significant sources of induced TSS within Desolation Sound 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 for three samples collected from the Desolation Central site between August 10 and 12, 2004. Dissolved metals were measured at a number of sites in 1999, but these values cannot be compared to the guidelines as no determination can be made of the total metal concentration. All metals at the Desolation Central site were below guideline levels with the exception of cadmium, which was occasionally equal to the guideline level. As 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. However, 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) (Kruzynski, 2000). Because any potential elevated cadmium concentrations in Desolation Sound waters are likely due to natural phenomenon and because there are no anthropogenic sources of this or any other metal in the

area, no objectives are recommended for total cadmium or other metals in Desolation Sound. 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 6-2. Comparison of total metals concentrations measured at Desolation Central site with approved and working water quality guidelines for the protection of marine aquatic life (from Nagpal et al. 2001 and MWLAP 1998).

Parameter	Desolation Central Range of Values	Guideline
Arsenic	0.3 – 0.4 ug/L	12 µg/L
Cadmium	<0.1 – 0.1 ug/L	0.1 µg/L
Chromium (Cr(VI))	<0.5 ug/L	1.5 µg/L
Copper	0.2 – 0.4 ug/L	2 µg/L average, 3 µg/L max
Iron	<1 ug/L	50 µg/L (minimal risk)
Lead	<0.1 ug/L	2 µg/L average, 140 µg/L max
Manganese	<1 µg/L	100 µg/L
Nickel	<0.5 ug/L	75 µg/L
Zinc	<1 ug/L	10 ug/L

6.6. SEDIMENT COMPOSITION

A number of sediment samples were collected over the period of record for various sites throughout Desolation Sound (see Appendix B). Table 6-3 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, bottom sediments area good indicator of long term trends that may be occurring within a watershed.

Sediment samples collected at all sites had concentrations of chromium, lead, nickel and silver consistently below their respective guidelines. There was one exception to this, in that silver concentrations in 1999 and 2000 were measured with a detection limit of 2 µg/g, versus the guideline level of 1 µg/g. One sample at Roscoe Bay was reported as equal to the detection limit, thus exceeding the guideline but when the detection limit was decreased in later years, silver concentrations were well below guideline levels.

Table 6-3. Summary of Canadian Sediment Quality Guidelines (from Nagpal *et al.*, 2001).

	Canadian Sediment Quality Guideline (µg/L)	
Parameter	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

The remaining metals for which guidelines exist (arsenic, cadmium, copper and zinc) were exceeded in at least one sediment sample from one of the sites. While the single sediment sample collected at Pendrell Sound, Tenedos Bay, Refuge Cove, Attwood Bay, and Redonda Bay had concentrations consistently below guideline levels, each of the remaining sites where sediments were collected (Prideaux Haven, Roscoe Bay, Grace Harbour, Forbes Bay, Bute Inlet North, Frederick Arm, Phillips Arm and Toba Inlet North) exceeded at least one of the guidelines. In Prideaux Haven, all of the five samples tested for arsenic exceeded the guideline (values ranging from 9.1 µg/g – 14.8 µg/g), all of the five samples exceeded the cadmium guideline (values ranging from 14.3 µg/g to 27.5 µg/g), and one of five samples exceeded the zinc guideline (217 µg/g, on September 2, 1999). All five of the sediment samples collected at Roscoe Bay consistently exceeded the guidelines for arsenic (values ranging from 9 µg/g – 20 µg/g), cadmium (values ranging from 6.1 µg/g to 9.5 µg/g), and copper (values ranging from 54 µg/g to 84.2 µg/g), and three of five zinc samples exceeded the guideline (values ranging from 137 µg/g to 230 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. The single sample collected from Forbes Bay had a copper concentration of 25.7 µg/g which exceeded the guideline. Finally, in the outlying areas, the Bute Inlet North sample exceeded the guideline for copper (67.4 µg/g), the Frederick Arm sample exceeded both the arsenic and copper guidelines (values of 7.7 µg/g and 45.9 µg/g, respectively), Phillips Arm exceeded the arsenic, cadmium and copper guidelines with values of 11.4 µg/g, 1.78 µg/g and 42.8 µg/g, respectively, and the Toba Inlet North sample exceeded the copper guideline with a concentration of 39.4 µg/g. Table 6-4 summarizes exceedences of sediment guidelines for all sites in Desolation Sound.

Table 6-4. Summary of sediment quality guideline exceedences for sediment samples collected in Desolation Sound.

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)
Prideaux Haven	9.1 – 14.8	14.3 – 27.5		217
Roscoe Bay	9.0 - 20.0	6.1 – 9.5	54 – 84.2	137 - 230
Grace Harbour	13.4	0.94 – 4.47	48.6	
Forbes Bay			25.7	
Bute Inlet North			67.4	
Frederick Arm	7.7		45.9	
Phillips Arm	11.4	1.78	42.8	
Toba Inlet North			39.4	

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

It appears that the elevated levels of these metals occurs throughout Desolation Sound, suggesting that it is not due to localized contamination (see Section 6.5). As well, there are no known anthropogenic sources for any of these metals within Desolation Sound. As such, no guidelines are recommended for metals concentrations in sediments in Desolation Sound, but we recommend that they continue to be monitored and if increasing trends are noted, further investigations should be conducted to determine the source of the elevated metals.

Concentrations of polycyclic aromatic hydrocarbons measured in sediment samples from the various sites were mostly below detectable limits, and were well below their respective guidelines for the protection of marine aquatic life.

7.0. MONITORING RECOMMENDATIONS

Potential impacts to water quality in the Desolation Sound 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 shellfish classification purposes, it is recommended that a complimentary monitoring program be implemented with a focus on overall marine water quality to compare to baseline conditions and water quality objectives. For Water Quality Objectives 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 in each of the most popular moorages (Galley Bay, Prideaux Haven, Tenedos Bay, Refuge Cove, Grace Harbour and Roscoe Bay), as well as in representative areas throughout Greater Desolation Sound in close proximity to mariculture tenures. 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 Desolation Sound.

Characteristics	Desolation Sound Shellfish Growing/Harvesting Areas	Desolation Sound Bathing Areas
Designated water uses	For the protection of the ability for shellfish growing and harvesting, marine aquatic life and wildlife (not for 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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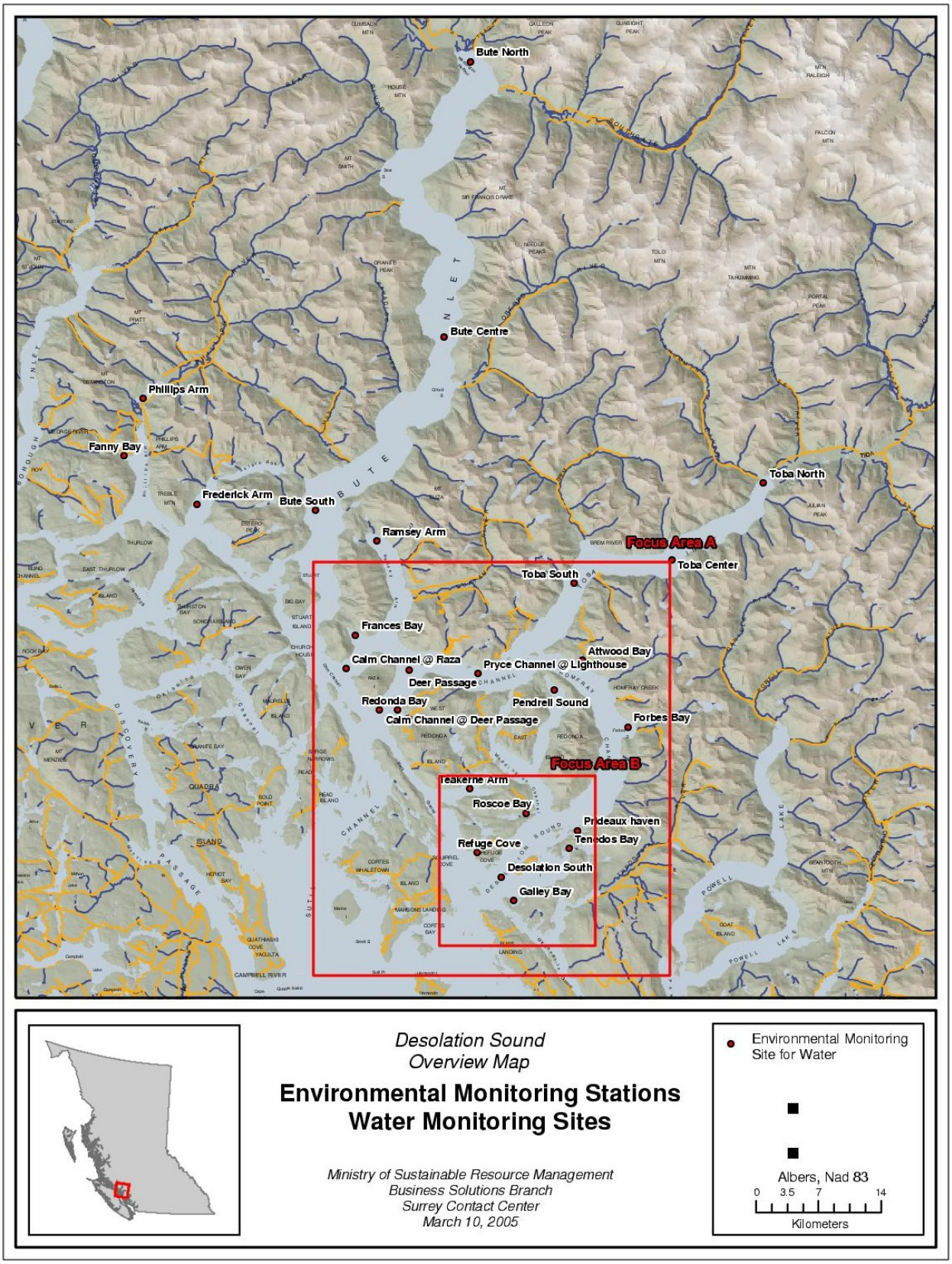

Figure 1 Desolation Sound Overview Map.

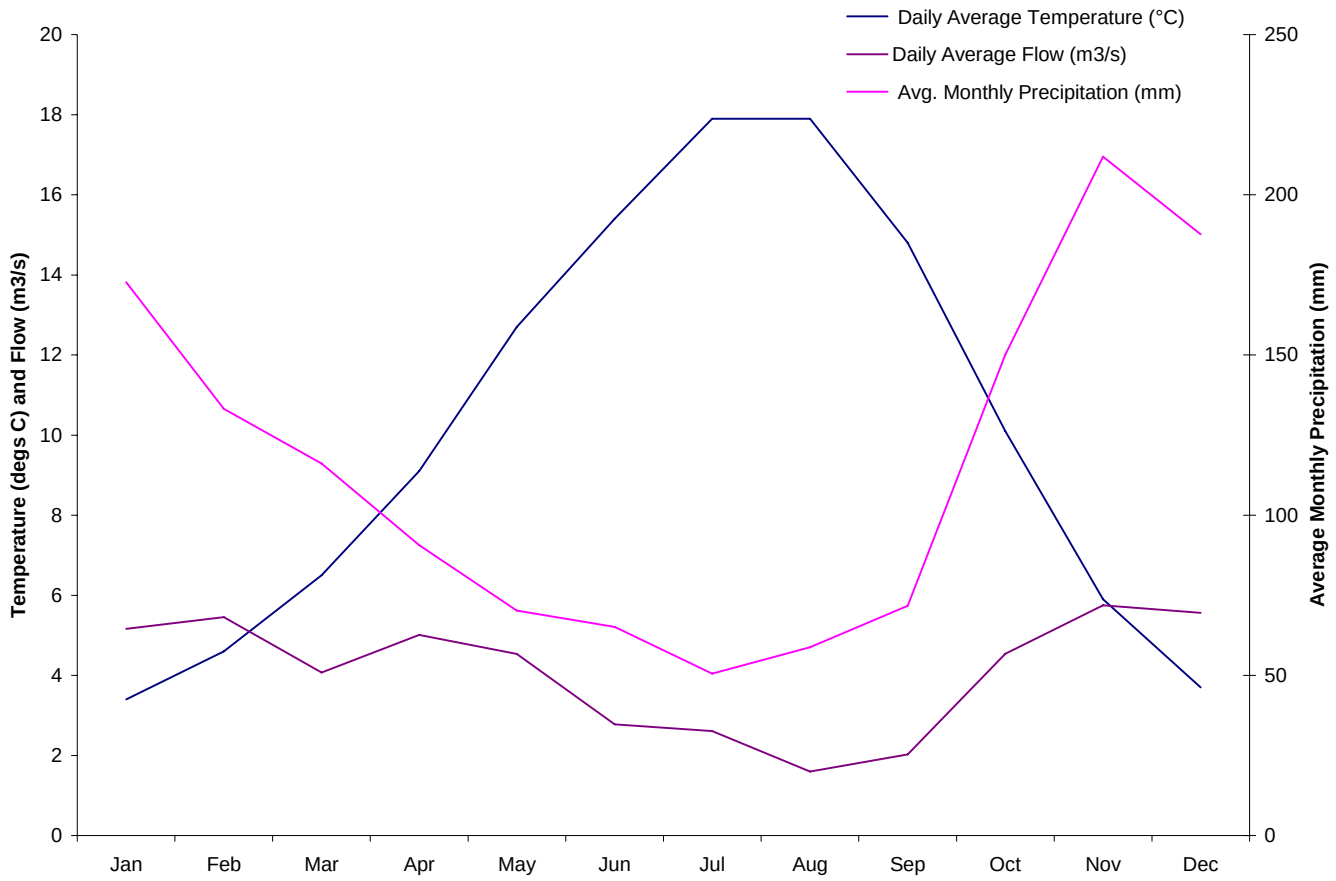

Figure 2. Comparison of daily average temperature and precipitation (measured at Environment Canada weather station on Cortes Island) with daily average flow rates on the Theodosia River (measured at Water Survey Canada station).

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

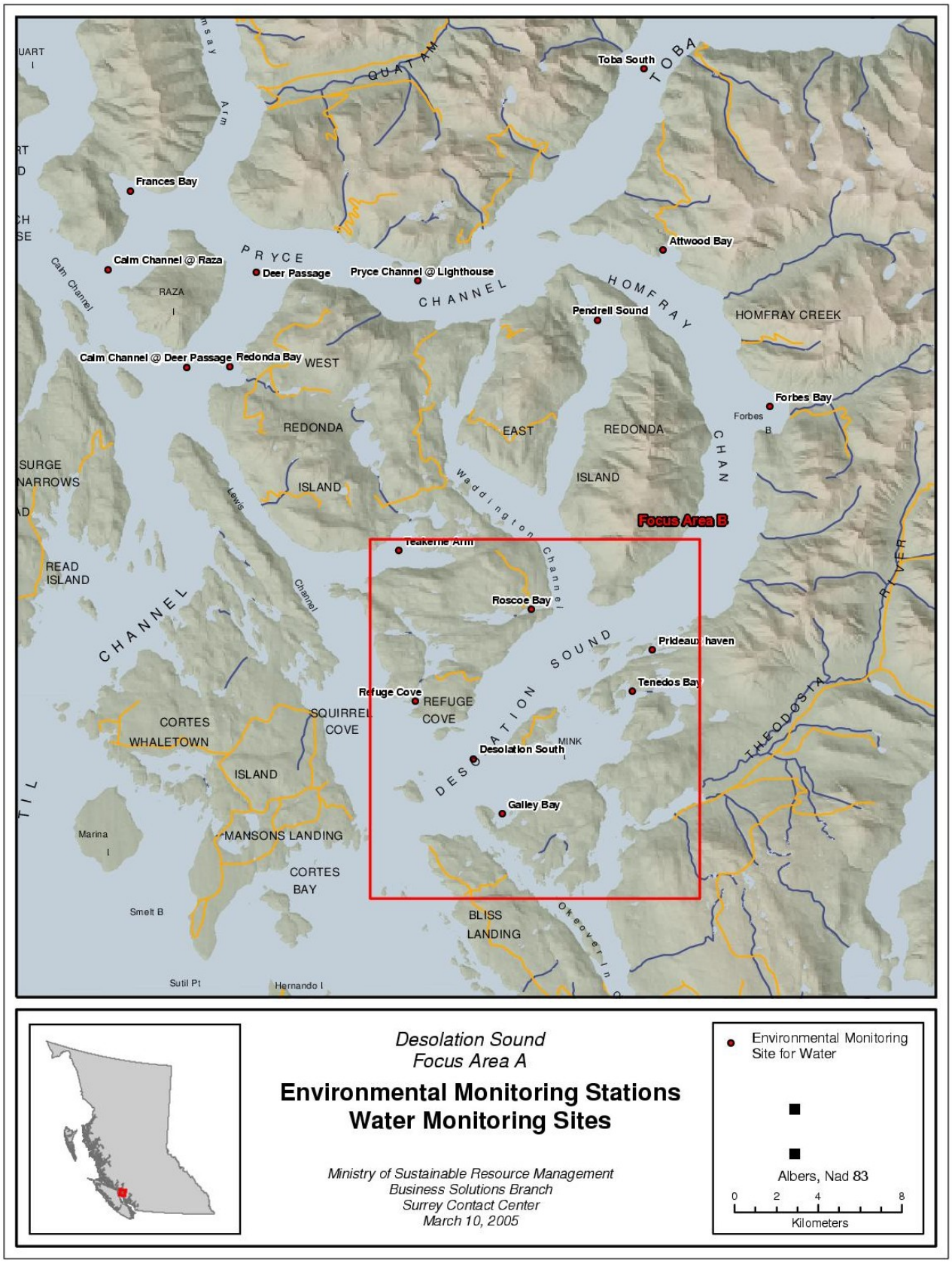

Figure 4. Map showing Desolation Sound area with Focus Area A sites.

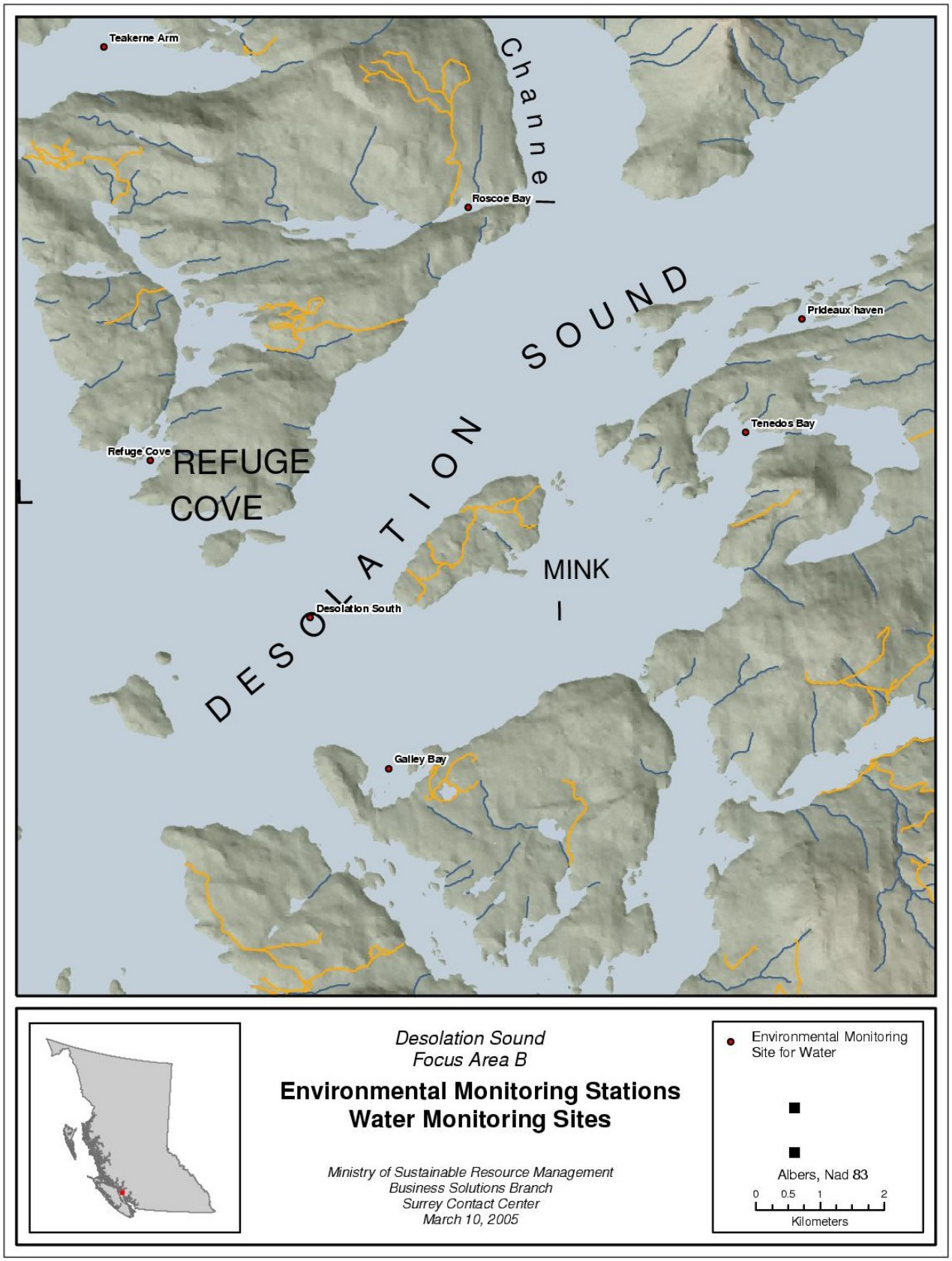

Figure 5. Map showing Desolation Sound area with Focus Area B sites.