An Evaluation of Sediment Quality Conditions in the Vicinity of the Macaulay Point and Clover Point Outfalls

Submitted to:

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Prepared – *May, 2006* – by:

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Chapter 1 Introduction and Background

1.0 Introduction

On November 10, 2005, the Environmental Management Branch of British Columbia Ministry of the Environment (B.C. MOE) received an urgent request for designation of aquatic habitats in the vicinity of the Macaulay and Clover Point outfalls as contaminated sites pursuant to the provisions of the British Columbia *Environmental Management Act (EMA)*. This request, which was submitted by the Sierra Legal Defence Fund, was made because monitoring conducted by the Capital Regional District (CRD) during the years 2000 to 2003 demonstrated that certain prescribed substances listed in Schedule 9 of the Contaminated Sites Regulation (CSR) occurred in marine sediments at elevated levels in the vicinity of the two outfalls.

The question as to whether or not sediments in the vicinity of one or both of these outfalls are sufficiently contaminated to warrant designation as a contaminated site is germane because such a designation by the Director may necessitate further investigation and/or site management planning to address concerns related to the contamination at the site. This chapter:

- Discusses the role of sediments in aquatic ecosystems;
- Provides an overview of sediment quality issues and concerns; and,
- Describes the purpose of this report.

1.1 Role of Sediments in Aquatic Ecosystems

The particulate materials that lie below the water in aquatic ecosystems are called sediments (ASTM 2005). Sediments represent essential elements of aquatic ecosystems because they support both autotrophic and heterotrophic organisms. Autotrophic (which means self-nourishing) organisms are those that are able to synthesize food from simple inorganic substances (e.g., carbon dioxide, nitrogen, and phosphorus) and the sun's energy. Green plants, such as algae, bryophytes (e.g., mosses and liverworts), and aquatic macrophytes (e.g., sedges, reeds, and pond weed), are the main autotrophic organisms in freshwater ecosystems. In contrast, heterotrophic (which means other-nourishing) organisms utilize, transform, and decompose the materials that are synthesized by autotrophic organisms (i.e., by consuming or decomposing autotrophic and other heterotrophic organisms). Some of the important heterotrophic organisms that can be present in aquatic ecosystems include bacteria, epibenthic and infaunal invertebrates, fish, amphibians, and reptiles. Birds and mammals can also represent important heterotrophic components of aquatic and aquatic-dependent food webs (i.e., through the consumption of aquatic organisms).

Sediments support the production of food organisms in several ways. For example, hard-bottom sediments, which are comprised largely of gravel, cobbles, boulders, and bedrock, provide stable substrates to which periphyton (i.e., the algae that grows on rocks) can attach and grow. Soft sediments which are comprised largely of sand, silt, and clay, can provide substrates in which aquatic macrophytes can root and grow. The nutrients that are present in such sediments can also nourish aquatic macrophytes. By providing habitats and nutrients for aquatic plants, sediments support autotrophic production (i.e., the production of green plants) in aquatic systems. Sediments can also support prolific bacterial and meiobenthic communities, the latter including protozoans, nematodes, rotifers, benthic cladocerans, copepods, and other organisms.

Bacteria represent important elements of aquatic ecosystems because they decompose organic matter (e.g., the organisms that die and accumulate on the surface of the sediment, as well as anthropogenically-derived organic chemicals) and, in so doing, release nutrients to the water column and increase bacterial biomass. Bacteria represent the primary heterotrophic producers in aquatic ecosystems, upon which many meiobenthic organisms depend. The role that sediments play in supporting primary productivity (both autotrophic and heterotrophic) is essential because green plants and bacteria represent the foundation of food webs upon which all other aquatic organisms depend (i.e., they are consumed by many other aquatic species).

In addition to their role in supporting primary productivity, sediments also provide essential habitats for many sediment-dwelling invertebrates and benthic fish. Some of these invertebrate species live on the sediments (termed epibenthic species), while others live in the sediments (termed infaunal species). Both epibenthic and infaunal invertebrate species consume plants, bacteria, and other organisms that are associated with the sediments. Invertebrates represent important elements of aquatic ecosystems because they are consumed by a wide range of wildlife species, including fish, birds, and mammals. For example, virtually all fish species consume aquatic invertebrates during all or a portion of their life cycle. In addition, many birds and mammals consume aquatic invertebrates to satisfy, at least, a portion of their energy requirements. Therefore, sediments are of critical importance to many wildlife species due to the role that they play in terms of the production of aquatic invertebrates.

Importantly, sediments can also provide habitats for many wildlife species during portions of their life cycle. For example, a variety of fish species utilize sediments for spawning and incubation of their eggs and larvae. In addition, juvenile fish often find refuge from predators in bottom substrates and/or in the aquatic vegetation that is supported by the sediments. Therefore, sediments play a variety of essential roles in terms of maintaining the structure (i.e., assemblage of organisms in the system) and function (i.e., the processes that occur in the system) of aquatic ecosystems.

1.2 Sediment Quality Issues and Concerns

Considering the important roles that they play, it is apparent that sediments represent essential elements of aquatic ecosystems. Yet, the available information on sediment quality conditions indicate that sediments in many water bodies are contaminated by a wide range of toxic and bioaccumulative substances, including metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides (OC pesticides), a variety of semi-volatile organic chemicals (SVOCs), and polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs; FRAP 1997; MESL 1997; USEPA 1997). The nature and extent of such sediment contamination depend on a variety of factors, such as the types of contaminant sources that are present in the system under investigation, the loadings of contaminants from the various sources, proximity to sources, and the fate of the contaminants once they are released into the aquatic system.

Contaminated sediments represent an important environmental concern for several reasons. First, contaminated sediments have been demonstrated to be toxic to sediment-dwelling organisms and fish (i.e., aquatic life; Ingersoll *et al.* 1997). As such, exposure to contaminated sediments can result in decreased survival, reduced growth and/or impaired reproduction in benthic invertebrates and fish. Additionally, some contaminants in the sediments are taken up by benthic organisms through a process called bioaccumulation (Ingersoll *et al.* 1997). When larger animals feed on these contaminated prey species, the pollutants are taken into their bodies and are passed along to other animals in the food web in a process called biomagnification. As a result of the effects of toxic and bioaccumulative substances, benthic organisms, fish, birds, and mammals can be adversely affected by contaminated sediments (i.e., aquatic-dependent wildlife; MacDonald *et al.* 2002).

Contaminated sediments can also adversely affect human health and the human uses of aquatic ecosystems. First, human health can be adversely affected due to direct exposure to contaminated sediments while engaging in primary contact and/or secondary contact recreation (e.g., windsurfing and boating, respectively) and during wading or swimming in affected waterbodies. Consumption of contaminated fish and shellfish also poses a risk to human health. Human use of aquatic ecosystems can be compromised by the presence of contaminated sediments through reductions in the abundance of food or sportfish species or due to the imposition of fish consumption advisories (i.e., when fish or shellfish tissues are found to contain unacceptable levels of bioaccumulative substances). As such, contaminated sediments in aquatic ecosystems pose potential hazards to sediment-dwelling organisms (i.e., epibenthic and infaunal invertebrate species), aquatic-dependent wildlife species (i.e., fish, birds, and mammals), and human health.

1.3 Purpose of Report

The CRD has discharged raw sewage and other municipal wastewater (e.g., leachate from the Hartland Road municipal landfill) to the marine environment in the vicinity of the Macaulay Point and Clover Point outfalls for roughly 100 years (CRD 2005a). A variety of chemical substances have been measured in the wastewater discharged from these outfalls, including metals, PAHs, phthalates, phenol and chlorinated phenolics, ketones, and volatile organic compounds [Note: discharges from these outfalls are also likely to include personal care products, endocrine disrupting compounds, and other substances, that are not commonly included as chemicals of potential concern (COPCs)]. As many of these substances tend to form associations with particulate matter (either in the effluent or in the marine environment following discharge), sediments in the vicinity of the Macaulay Point and Clover Point outfalls have the potential to be contaminated by a variety of toxic and/or bioaccumulative substances. The results of sediment quality monitoring conducted by CRD during 2000-2004 (CRD 2002; 2003; 2004; 2005a) provide a basis for determining if sediments in the vicinity of the two outfalls under consideration have become sufficiently contaminated to warrant designation of these areas as contaminated sites. This report was prepared to provide B.C. MOE with an independent evaluation of sediment quality conditions in the vicinity of the Macaulay Point and Clover Point outfalls. To support a determination of whether or not designation as a contaminated site(s) is warranted, a review of the framework for managing contaminated sites was conducted (Chapter 2). The results of this review was used, in conjunction with other applicable guidance, to develop a study approach for this evaluation (Chapter 3). A preliminary investigation of the Macaulay Point and Clover Point outfall sites was then undertaken using the data collected by CRD between 2000 and 2004 (Chapter 4). A summary of the results of this evaluation is provided (Chapter 5), along with a discussion of the implications of the investigation. Finally, the documents that supported this investigation are identified in the references cited section of this report (Chapter 6).

Chapter 2 Framework for Managing Contaminated Sites in British Columbia

2.0 Introduction

The procedures for assessing and remediating contaminated sites that fall under provincial jurisdiction are specified in two components of the *EMA*, including the CSR and the Hazardous Waste Regulation. The site management process specified under the CSR is intended to establish rules for assessing and remediating contaminated sites in the province. The process consists of five main elements, including site identification and screening; site investigation and determination/decision; site management planning; remediation; and, monitoring and evaluation. However, every site need not proceed through each component of the process (MacDonald and Ingersoll 2003a; 2003b). The following summary of the framework in intended to provide an overview of the existing contaminated site management process (Figure 1). More detailed information on the elements of this framework is included in the CSR and in a series of associated Fact Sheets that have been published by the Ministry.

2.1 Site Identification and Screening

The first step in the site assessment and management process involves screening the site under consideration. This step in the process is initiated through the preparation of a site profiles. In British Columbia, site profiles must be submitted to the responsible government agency when an application for subdivision, zoning, development, demolition of a structure, or removal of soil is received by a local government or when ordered by a regional manager. Following its submission, the site profile is assessed by provincial or local government officials and a determination is made regarding the need for further investigations at the site. No further action is required at sites that are considered not to be potentially contaminated.

2.2 Site Investigation and Determination

Information from the site profile or other sources may indicate that a site is potentially contaminated. In this situation, preliminary and/or detailed site investigations (i.e., PSIs and DSIs) may be required to determine if the site is contaminated, as defined under the CSR. Initially, a Stage I PSI is conducted to determine the probability that a site is contaminated. This assessment is conducted using archival records, conducting site visits, and relying on knowledge of the historical activities that were conducted on site. Next, a Stage II PSI or a DSI is conducted to provide the additional information needed to confirm or refute the potential for site contamination, primarily by sampling and chemical analysis of environmental media. The results of the Stage II PSI and/or DSI are used to determine if a site is contaminated. More specifically, the measured concentrations of COPCs in soils, sediments, and/or water from the site are compared to the applicable standards and/or criteria to determine if the site is contaminated. The determination of whether a site is contaminated (as defined under the CSR) is generally made by the Director. In addition, the results of the DSI are used to evaluate the nature, extent, and severity of contamination at the site. Detailed guidance on the information requirements for PSIs and DSIs is provided in MacDonald and Ingersoll (2003a; 2003b).

2.3 Site Management Planning

The first priority in the planning stage of the site management process is to determine who is potentially responsible for the contamination and who is potentially liable for clean-up costs. In addition, the need for and relative priority for remediation is assessed at this stage of the process. Other important planning steps include activating the remediation process (either through a voluntary remediation agreement or a remediation order), developing a remediation action plan, and initiating the approvals process.

At sediment contaminated sites, the development of sediment quality standards (SedQS) represents another important step in the site management planning process. The legislation provides for the use of two distinct approaches to the establishment of SedQS at sediment contaminated sites, including the criteria-based approach and the risk-based approach. Using the criteria-based approach, SedQS may be established by directly adopting the generic numerical sediment criteria (SedQC) or by deriving site-specific SedQS. By comparison, risk-based SedQSs can be established at risk levels that are less than or equal to those upon which the sediment quality criteria are based (i.e., a 20% probability of an EC_{20} or greater for sensitive sites and a 50% probability of an EC_{50} or greater for typical sites). Such numerical or risk-based standards may be used for determining if remedial measures are required at the site and if they have been satisfactorily completed.

2.4 Remediation

The remediation step in the process covers all of the activities that are associated with cleaning-up or securing a contaminated site. The legislation defines two broad types of remediation, including removal of contaminated materials (so that they no longer remain at the site) and treatment of the contaminated materials on-site. The legislation also provides environmental quality standards that are used to determine when the cleanup is complete. Alternatively, risk-based procedures may be used to determine the level of contamination that can remain on-site. In such situations, additional institutional controls may have to be established to ensure that uses of the site and the designated uses of nearby areas are not unacceptably impacted.

2.5 Monitoring and Evaluation

Following the implementation of remedial measures, confirmatory sampling and analysis is normally conducted to determine if the selected remedial actions have reduced the level of contamination or risk to tolerable levels. A Certificate of Compliance (COC) is issued if the numerical standards in the CSR have been satisfied or if risk-based standards and related assessment procedures have been appropriately applied. When the contamination is managed on-site, certain conditions must be met by the site manager. Such conditions are generally established to assure the protection of the environment and human health, or the notification of potentially affected parties (e.g., future site owners).

2.6 Management of Sediment Contaminated Sites

The existing framework for managing contaminated sites in the province is intended to provide explicit rules for assessing and remediating surface water, groundwater, soil, and sediment at contaminated sites. To assist practitioners and responsible persons in the application of these rules, B.C. MOE has developed a series of guidance manuals to support the assessment of contaminated sediments in freshwater, estuarine, and marine ecosystems in British Columbia (MacDonald and Ingersoll 2003a; 2003b; 2003c; Ingersoll and MacDonald 2003). In addition, B.C. MOE has issued guidance on the application of the criteria for managing contaminated sediment in British Columbia (B.C. MOELP 2004; Macfarlane *et al.* 2004). Collectively, these guidance documents describe the framework for managing sediment contaminated sites in the province (Figure 2).

Chapter 3 Study Approach

3.0 Introduction

A PSI is required at any site that is suspected of having contaminated sediments. The PSI is intended to provide additional information for assessing the probability that contaminated sediments exist at the site and is comprised of two stages. The two stages of the PSI (i.e., Stage I and Stage II) may be undertaken sequentially or may be combined, depending on the interests and needs of the project proponent. This chapter describes the approach that was used to conduct a preliminary investigation of the Macaulay Point and Clover Point outfall sites, which included:

- Delineation of the geographic scope of the study area;
- Identification of chemicals of potential concern;
- Identification of water uses/receptors of interest;
- Identification of indicators of sediment quality and associated targets;
- Compilation of data and information; and,
- Determination if sediments in the study area are sufficiently contaminated to warrant designation as a contaminated site.

3.1 Delineation of the Geographic Scope of the Study Area

This study was conducted to evaluate sediment quality conditions in the vicinity of two major municipal wastewater outfalls (i.e., discharging liquid waste) in the vicinity of Victoria, British Columbia. The municipal wastewater outfalls under investigation include the Macaulay Point outfall and the Clover Point outfall, which are both operated by the Capital Regional District (CRD). This section of the report provides background information on the locations and history of these outfalls. The geographic scope of the study area is also described.

The Macaulay Point outfall is located roughly 1.8 km due south of Macaulay Point, and roughly equidistant between Albert Head to the west and Clover Point to the east. Municipal wastewater has been discharged from the Macaulay Point outfall since 1915 (CRD 2005a). Initially, wastewater was discharged from the shoreline at low tide; however, concerns related to shoreline pollution resulted in the discharge being moved offshore in 1971. The outfall pipe is now 1800 m long and terminates at a depth of 60 m, with the wastewater discharged through a multiport diffuser (roughly 150 m in length; CRD 2005a). The average annual flow rate for this outfall was 30,182 m^3/d in 2004 (CRD 2005a).

The Clover Point outfall is located roughly 1.2 km due south of Clover Point, and roughly 3 km west of the south end of Trial Island. At the Clover Point site, municipal wastewater has been discharged to the marine environment since 1894 (CRD 2005a). As was the case for the Macaulay Point outfall, wastewater was discharged from the shoreline at low tide for the bulk of the period of operation. However, an offshore outfall was completed in 1981. The Clover Point outfall pipe is now roughly 1160 m in length and wastewater is discharged through a multiport diffuser at a depth of 65 m (the diffuser is roughly 200 m in length; CRD 2005a). The average annual flow rate for this outfall was 62,577 m^3/d in 2004 (CRD 2005a).

Prior to release to the Strait of Juan de Fuca, the wastewater from both outfalls is screened to 6 mm to remove large particles. The freshwater wastewater then mixes with marine water in the Strait of Juan de Fuca, and is dispersed within the marine environment. In accordance with the Municipal Sewage Regulation (MSR), the initial dilution zones (IDZs) for the outfalls define a radius of 100 m around the diffusers. As multiport diffusers are used at each outfall location, the IDZs are oval in shape (i.e., roughly 350 - 400 m in length and 200 m in width). The province required that applicable water quality criteria/guidelines (WQC and/or WQG) be met outside the IDZ.

For this investigation, the study area is defined as the area where hazardous substances originating from the Macaulay Point and Clover Point outfalls have come to be located. From a theoretical perspective, this provides the most inclusive definition of the geographic scope of the study area. From a practical perspective, however, the assessment of the effects of wastewater discharges on sediment quality conditions is constrained by the spatial extent of sampling conducted by the CRD (i.e., as defined in CRD 2002; 2003; 2004; 2005a).

To support the evaluation of sediment quality conditions, the study area was divided into two areas of concern, the Macaulay Point Area of Environmental Concern (MP AEC) and the Clover Point Area of Environmental Concern (CP AEC). Each AEC was divided into two reaches, including one located within the IDZ and another located outside the IDZ. Again, the IDZ extends 100 m in every direction from the diffusers. The following maps of the study area show the locations of sampling sites in:

- MP AEC in 2001 (Figure 3);
- CP AEC in 2001 (Figure 4);
- MP AEC in 2002 (Figure 5);
- CP AEC in 2002 (Figure 6);
- MP AEC and CP AEC in 2003 (Figure 7); and,
- MP AEC and CP AEC in 2004 (Figure 8).

3.2 Identification of Chemicals of Potential Concern

Identification of chemicals of potential concern (COPCs) represents an essential element of the overall contaminated site assessment process. In the context of this report, COPCs are defined as those substances that are released into aquatic ecosystems as a result of human activities (including those originating from both point and non-point sources) and have the potential to adversely affect the designated uses of aquatic ecosystems (e.g., aquatic life, recreation and aesthetics). It is important to identify the COPCs because such information, when considered in conjunction with data on the environmental fate and persistence of these chemicals, provides a basis for determining which substances are likely to partition into sediments (i.e., the sediment-associated COPCs).

In general, COPCs are identified using information on the land and water uses within the waterbody under consideration. More specifically, information on existing and historic land and water uses is utilized to identify the probable sources of environmental contaminants within the waterbody. In turn, data on the chemical characteristics of point and non-point source discharges from these sources, the results of historic and ongoing environmental monitoring programs, and information on the environmental fate and persistent of the substances that have been or are likely to have been released into surface waters can be used to identify the substances that are likely to partition into sediments (i.e., sediment-associated COPCs).

In this study, COPCs were identified by reviewing several key monitoring studies that have been conducted within the study area (i.e., CRD 2002; 2003; 2004; 2005a). The analytes that were measured in whole-sediment samples and presented in these reports include a number of conventional variables and up to 209 Priority Toxic Pollutants (i.e., toxic substances that were originally identified by the U.S. Environmental Protection Agency; USEPA 2002). Any substance that was identified as a COPC in these studies (i.e., target analyte) was included as a COPC in this investigation, along with several other substances that occur in municipal wastewater. The classes of chemicals included as COPCs are identified below:

<u>Toxic Substances that Partition into Sediments</u>:

- Metals (e.g., arsenic, cadmium, chromium, copper, lead, mercury, and zinc);

- PAHs (e.g., acenaphthene, acenaphthylene, anthracene, fluorene, 2-methylnaphthalene, naphthalene, phenanthrene, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene, total PAHs, and other PAHs);
- PCBs (e.g., total PCBs);
- Phenol, non-chlorinated phenols, and chlorinated phenols;
- Phthalates;
- OC pesticides (e.g., chlordane; dieldrin, DDTs, endrin, heptachlor, heptachlor epoxide, and lindane); and,
- Volatile organic compounds (e.g., 1,4,-dichlorobenzene, chloroform).

Bioaccumulative Substances that Partition into Sediments:

- Metals (e.g., lead and mercury);
- PAHs (e.g., acenaphthene, acenaphthylene, anthracene, fluorene, 2-methylnaphthalene, naphthalene, phenanthrene, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene, total PAHs, and other PAHs);
- PCBs;
- PCDDs and PCDFs; and,
- OC pesticides (e.g., chlordane; dieldrin, DDTs, endrin, heptachlor, heptachlor epoxide, and lindane).

While it was not possible to evaluate the potential effects of all of these COPCs on ecological receptors or human health, it is useful to identify COPCs as comprehensively as possible to inform the design of a detailed site investigation that may be required subsequently. However, the current list of COPCs should not be considered to be comprehensive because they do not include various substances that are known to be associated with municipal wastewater discharges (e.g., pharmaceuticals and personal care products; endocrine disrupting compounds).

3.3 Identification of Water Uses/Receptors of Interest

The third step in the sediment quality evaluation process involves identification of the water uses and receptors of interest that are relevant in the study area. While designated water uses have not been explicitly identified for the Macaulay Point and Clover Point sites, the water uses that likely require protection in the study area include:

- Marine and aquatic life;
- Marine wildlife;
- Shell fish harvesting;
- Primary contact recreation (e.g., windsurfing);
- Secondary contact recreation (e.g., boating); and,
- Human health (i.e., associated with consumption of fish and shellfish).

Contaminated sediments can adversely affect these water uses in a number of ways (see Section 1.2 of this report for further information). Importantly, exposure to contaminated sediments can adversely affect a number of aquatic and aquatic-dependent receptor groups, including the microbial community, aquatic plant community, invertebrate community, fish community, and aquatic-dependent wildlife (i.e., sediment-probing birds, insectivorous birds, carnivorous wading birds, piscivorous birds, omnivorous mammals, and piscivorous mammals). Of these, the following receptor groups are the most likely to be adversely affected by contaminated sediments, including:

- Sediment-dwelling organisms (i.e., benthic macroinvertebrates);
- Fish (e.g., sole, rockfish, sand lance); and,
- Aquatic-dependent birds (e.g., piscivorus birds such as cormorants, loons, grebes, and mergansers) and mammals (e.g., piscivorus mammals such as harbour seals, sea lions, and porpoises) that occur or could occur in the study area.

Of the multiple water uses and receptor groups that could be considered, only effects on the benthic invertebrate community were evaluated in this investigation. The study is limited to evaluating effects on this receptor group because the generic numerical sediment criteria specified in Schedule 9 of the CSR were established to define effects thresholds for sensitive benthic invertebrates. Other receptor groups tend to be less sensitive to most of the prescribed substances, but should be considered in a detailed site assessment nevertheless.

3.4 Identification of Indicators of Sediment Quality and Associated Targets

The fourth step in the sediment quality evaluation process involves the identification of key indicators of sediment quality conditions. A variety of indicators have been used to assess sediment quality conditions in marine ecosystems, including whole-sediment chemistry, whole-sediment toxicity, pore-water chemistry, pore-water toxicity, benthic invertebrate community structure, and invertebrate-tissue chemistry. In this study, whole-sediment chemistry was used as the primary indicator of sediment quality conditions at the Macaulay Point and Clover Point sites. This line of evidence was selected for use in the preliminary site investigation to maintain consistency with guidance for determination of contaminated sites provided in the CSR and companion documentation. The generic numerical sediment criteria identified in Schedule 9 of the CSR was selected as the targets for assessing sediment quality conditions in this study (Table 1).

3.5 Compilation of Data and Information

In the fifth step of the process, the available information on the sediment quality conditions in the study area was compiled in a form that assisted the sediment quality evaluation. To ensure that all of the requisite data for assessing sediment quality conditions, CRD staff (Laura Taylor) was contacted and requested to provide the whole-sediment chemistry data that were collected between 2000 and 2004 by the CRD, as presented in CRD (2002; 2003; 2004; 2005a). Guidance was provided to CRD staff on the format in which to provide the data to facilitate development of the project database. Unfortunately, CRD staff were unable to provide the requested data and information within the required time frame. Accordingly, the data on the concentrations of selected prescribed substances (metals, PAHs, PCBs, and pentachlorophenol) in surficial sediments for 2000 to 2004 were compiled (as available) from the CRD (2002; 2003; 2004; 2005a) Annual Reports. The data used in this analysis is presented in a series of tables this report (Tables 2-16). These substances were selected because they were measured in sediment samples collected by the CRD and generic numerical sediment criteria have been established for these substances. All of the data compiled in the project database were verified against the data presented in the CRD Annual Reports to assure data accuracy.

The project database was designed to facilitate subsequent data analyses. Some of the key database design features and associated data treatment decisions included:

- Location descriptor codes were assigned to individual sediment samples. More specifically, the study area was divided into two AECs (i.e., Macaulay Point AEC and Clover Point AEC). Two reaches were identified within each AEC including one located within the IDZ and another located outside the IDZ. These location descriptor codes were added to the database to facilitate data retrieval and evaluation on a reach-by-reach basis;

- The non-detected results were screened against the generic numerical sediment criteria for sensitive sites and results with detection limits greater than the generic numerical sediment criteria were not used in the evaluation. All other non-detected results were set to one-half of the reported detection limit;
- Toxicity thresholds (generic numerical sediment criteria) were incorporated; and,
- Mean generic numerical sediment criteria-quotients (generic numerical sediment criteria-Qs) were calculated for each sample in accordance with Macfarlane *et al.* (2004).

3.6 Determination if Sediment Quality Conditions Warrant Designation as a Contaminated Site

This study was conducted to determine if the areas in the vicinity of the Macaulay Point and Clover Point wastewater outfalls ought to be designated as contaminated sites pursuant to the provisions of the *EMA* and associated CSR. As defined in Part 4 of the *EMA*, the term *contaminated site* means an area of the land in which the soil or any groundwater lying beneath it, or the water or the underlying sediment, contains: a) a hazardous waste; or, b) another prescribed substance, in quantities or concentrations exceeding risk-based or numerical criteria or standards or conditions. Under Part 5 of the CSR, an area is designated as a contaminated site if the concentration of any substance in sediment at the site is greater than the applicable generic numerical sediment criterion. The generic numerical sediment criteria are listed in Schedule 9 of the CSR (Table 1).

The generic numerical sediment criteria specified in Schedule 9 of the CSR identify the concentrations of COPCs that are associated with adverse effects on sediment-dwelling organisms utilizing benthic habitats in freshwater and marine ecosystems. More specifically, the generic numerical sediment criteria for sensitive contaminated sites are intended to define the concentrations of COPCs that are associated with a 20% probability of observing adverse effects on 20% of the exposed population (i.e., a 20% effect concentration; EC_{20}). By comparison, the generic numerical sediment criteria for typical contaminated sites are intended to define the concentrations of COPCs that are associated with a 50% probability of observing adverse effects on 50% of the exposed population (i.e., EC_{50}).

Sites that contain marinas, docks, wharves, or associated infrastructure may be assessed using the generic numerical sediment criteria for typical contaminated sites (Macfarlane *et al.* 2004). However, such structures and associated infrastructure do not exist in the vicinity of the Macaulay Point and Clover Point outfalls. In addition, aquatic habitats in the vicinity of these outfalls may represent important spawning areas for certain marine fish species and likely serve as important rearing areas for fish. Therefore, the generic numerical sediment criteria for sensitive contaminated sites are more appropriate for assessing sediment quality conditions outside the IDZs of these two outfalls than are the generic numerical sediment criteria for typical contaminated sites. The generic numerical sediment criteria for typical contaminated sites should be applied within the IDZs because these area are affected by permitted outfalls.

To ensure that the generic numerical sediment criteria are applied properly, the B.C. Ministry of the Environment has established administrative rules to guide determinations of sites as contaminated or uncontaminated (Macfarlane *et al.* 2004). The administrative rules for sensitive contaminated sites are:

1. A sensitive site is a contaminated site if any of the following conditions exist:
   - The 90th percentile concentration of one or more COPCs equals or exceeds their respective generic numerical sediment criteria for sensitive

contaminated sites (i.e., 9 of 10 measurements must be below the generic numerical sediment criteria to designate a site as uncontaminated) and exceeds upper limit of background for that substance (i.e., mean ± 2SD);

- The concentration of one or more analytes exceeds their respective generic numerical sediment criteria for sensitive contaminated sites by a factor of two or more in any sediment sample and exceeds upper limit of background for that substance (i.e., mean ± 2SD);
- The 90th percentile mean generic numerical sediment criteria for sensitive contaminated sites-quotient for the contaminant mixture equals or exceeds 1.0; or,
- The mean generic numerical sediment criteria for sensitive contaminated sites-quotient for the contaminant mixture in any sediment sample equals or exceeds 2.0.

2. The generic numerical sediment criteria for sensitive contaminated sites are to be applied to a depth of 100 cm (i.e., 0-100 cm) in areas where the sediment bed has been demonstrated to be stable (i.e., non-erosional, not subject to navigational dredging).

3. The generic numerical sediment criteria for sensitive contaminated sites apply to depths of greater than 100 cm in areas where the sediment bed has been demonstrated to be unstable (i.e., erosional, subject to navigational dredging) or the stability of the bed is unknown.

4. The generic numerical sediment criteria for sensitive contaminated sites apply to depths of greater than 100 cm in areas where it is demonstrated that there is on-going transport of COPCs from depth into the shallower portions of the sediment bed at rates capable of contaminating sediments in the top 100 cm to levels exceeding the generic numerical sediment criteria for sensitive contaminated sites.

5. The generic numerical sediment criteria for sensitive contaminated sites must be used during the site investigation process to determine if a sensitive site contains contaminated sediments.

6. The generic numerical sediment criteria for sensitive contaminated sites apply at sites that have sediments that border or include habitat protection or conservation zones, or where biological habitat mapping have designated the area as a high productivity zone.

7. The generic numerical sediment criteria for sensitive contaminated sites should be used to determine if remedial measures are needed at a sensitive site and to establish target cleanup goals for contaminated sediments.

8. The presence of sediments containing contaminant concentrations qualifying as Hazardous Wastes, as defined under the Hazardous Waste Regulation, necessitates exceptions to the limits of potential remedial actions. Where Hazardous Waste is present, remedial measures should focus on the removal of these wastes, to the extent feasible. The handling, treatment, and disposal of these materials is to be conducted in accordance with the provisions of the Hazardous Waste Regulation.

B.C. MOE has also established administrative rules to guide the application of the generic numeric sediment criteria for typical contaminated sites, as follows:

1. A typical site is a contaminated site if any of the following conditions exist:
    - The 90th percentile concentration of one or more COPCs equals or exceeds their respective generic numerical sediment criteria for typical contaminated sites (i.e., 9 of 10 measurements must be below the generic numerical sediment criteria to designate a site as uncontaminated) and exceeds upper limit of background for that substance (i.e., mean + 2SD);

- The concentration of one or more analytes exceeds their respective generic numerical sediment criteria for typical contaminated sites by a factor of two or more in any sediment sample and exceeds upper limit of background for that substance (i.e., mean + 2SD);
- The 90th percentile mean generic numerical sediment criteria for typical contaminated sites-quotient for the contaminant mixture equals or exceeds 1.0 (see Macfarlane *et al.* 2004 for more information on the calculation of mean sediment quality criteria for typical contaminated sites-quotients); or,
- The mean generic numerical sediment criteria for typical contaminated sites-quotient for the contaminant mixture in any sediment sample equals or exceeds 2.0.

2. The generic numerical sediment criteria for typical contaminated sites are to be applied to any sediment depth.

3. The generic numerical sediment criteria for typical contaminated sites must be used during the site investigation process to determine if a typical site contains contaminated sediments.

4. The generic numerical sediment criteria for typical contaminated sites should be used to determine if remedial measures are needed at a typical site and to establish target clean-up goals for contaminated sediments.

5. The presence of sediments containing contaminant concentrations qualifying as Special Wastes, as defined under the Hazardous Waste Regulation, necessitates the imposition of limitations on potential remedial actions. Where Special Waste is present, remedial measures should focus on the removal of these wastes, to the extent feasible. The handling, treatment and disposal of these materials is to be conducted in accordance with the provisions of the Hazardous Waste Regulation.

Chapter 4 Preliminary Evaluation of Sediment Quality Conditions in the Vicinity of the Macaulay Point and Clover Point Outfalls

4.0 Introduction

An evaluation of sediment quality conditions in the vicinity of the Clover Point and Macaulay Point outfalls was conducted to determine if sediments in one or more reaches within the study area are sufficiently contaminated to warrant designation as a contaminated site under the CSR. This evaluation was conducted in accordance with the procedures described in Chapter 3. This Chapter describes the results of that evaluation.

4.1 Site Profile

Under the CSR, preparation of a site profile represents the first step in the contaminated site assessment and management process. A site profile must be submitted to the responsible government agency when an application for subdivision, zoning, development, demolition of a structure, or removal of soil is received by a local government or when ordered by a regional manager. Following its submission, the site profile is assessed by provincial or local government officials and a determination is made regarding the need for further investigations at the site.

The CRD has not prepared a site profile for the area in the vicinity of the Macaulay Point and Clover Point outfalls because it is not used for scheduled industrial or commercial purposes or activities (i.e., as defined in Schedule 2 of the CSR; however, it could be argued that the sites have been or likely have been contaminated by substances migrating from other properties; e.g., municipal landfills). Rather, the area is used as a discharge site for permitted municipal wastewater outfalls. Although, this first step in the contaminated site assessment process has not been completed, the available data and information indicate that a variety of toxic and/or bioaccumulative substances have been released into the marine environment in the vicinity of the site (CRD 2005a). Therefore, there is reason to believe that sediments in the vicinity of the Macaulay Point and Clover Point outfalls have been contaminated by hazardous and/or prescribed substances, as defined under *EMA* and associated regulations. Hence, a preliminary site investigation should be conducted to determine if the study area or some portion thereof is a contaminated site, as defined under the CSR.

4.2 Description and Evaluation of Available Data

According to the *EMA*, a sediment contaminated site means an area of sediment that contains a hazardous or prescribed substance in quantities or concentrations exceeding the generic numerical sediment criteria. Therefore, identification of a sediment contaminated site requires data on the chemical composition of sediments in the vicinity of the site under investigation.

At the Macaulay Point and Clover Point outfall sites, monitoring of wastewater discharges, surface waters, and the seafloor environment has been conducted on a regular basis since the late 1980s (CRD 2005a). Between 1990 and 1999, sediment samples were collected for chemical analysis on an annual basis and samples were collected for benthic invertebrate community analysis every three years. Starting in 2000, the Wastewater Marine and Environment Program (WMEP) was revised in consultation with the Marine Monitoring Environment Group (MMAG; CRD 2005a). In terms of benthic sampling, changes in the frequency of sampling and the types of analyses conducted were made to support evaluation of conditions relative to the seafloor trigger (CRD 2005a). The seafloor trigger was established under the Liquid Waste Management Plan and is intended to provide a basis for determining the potential for adverse effects on benthic organisms, using the data collected in the monitoring. More specifically, the seafloor trigger determines when wastewater requires treatment to protect the environment.

As indicated previously, B.C. MOE staff contacted CRD staff on January 23, 2006 to obtain the seafloor monitoring data that were collected between 2000 and 2004. Over the next month, CRD staff were provided with a number of clarifications of the request for data and information related to the WMEP. Unfortunately, CRD staff indicated on February 21, 2006 that it would take at least two weeks to assemble the whole-sediment chemistry data needed to support the current evaluation of sediment quality conditions and that CRD staff would be unlikely to have the time needed to process the request in the near-term. For this reason, the data from the WMEP Annual Reports (i.e., CRD 2002; 2003; 2004; 2005a) on the levels of metals and PAHs in sediments from the study area were compiled in the project database in Microsoft Access format (Tables 2-16).

All of the data in the database were verified at the 100% level to ensure the accuracy of data transcription. However, it was not possible to verify the whole-sediment chemistry data in the project database against the original laboratory bench sheets, against the electronic data deliverables provided by various analytical laboratories, or against the information contained in the various sampling and data reports that were used to generate the WMEP Annual Reports. Any transcription errors that were introduced during the preparation of the sediment analysis results presented in the CRD Annual Reports could, potentially, influence the outcome of this evaluation.

An evaluation of the adequacy of the available data was conducted to determine if sufficient data were available to characterize the chemical composition within each of the AECs and reaches. The results of this evaluation indicated the following:

- Whole-sediment chemistry data have been collected by CRD (2002; 2003; 2004; 2005a) in the vicinity of the Macaulay Point and/or Clover Point outfalls for 29 of the 33 prescribed substances listed in Schedule 9 of the

CSR. No data were collected on the concentrations of hexachlorocyclohexane or polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans. Therefore, the whole-sediment chemistry data needed to comprehensively evaluate exceedances of the generic numerical sediment criteria are not available;

- Between 2000 and 2004, five samples were collected to evaluate whole-sediment chemistry within the IDZ at the MP AEC. All of these samples were collected at a single location, presumably to represent sediment quality conditions within the roughly 8 ha area encompassing the IDZ. While B.C. MOE has not provided guidance on minimum sampling density and frequency for assessing sediment quality conditions, our experience at other sites (e.g., MacDonald and Ingersoll 2000; MacDonald *et al.* 2002; 2005) indicates that the available data are not sufficient to fully characterize sediment quality conditions within the IDZ;
- Between 2000 and 2004, 110 samples were collected to evaluate whole-sediment chemistry outside the IDZ at the MP AEC. Assuming that the locations of the sampling stations are used to define the area of this reach, these samples represent sediment quality conditions within an area of roughly 104 ha. While B.C. MOE has not provided guidance on minimum sampling density and frequency for assessing sediment quality conditions, our experience at other sites (e.g., MacDonald and Ingersoll 2000; MacDonald *et al.* 2002; 2005) indicates that the available data may be sufficient to characterize sediment quality conditions outside the IDZ.
- Between 2000 and 2004, five samples were collected to evaluate whole-sediment chemistry within the IDZ at the CP AEC. All of these samples were collected at a single location, presumably to represent sediment quality conditions within the roughly 7 ha area encompassing the IDZ. While B.C. MOE has not provided guidance on minimum sampling density and frequency for assessing sediment quality conditions, our experience at other sites (e.g., MacDonald and Ingersoll 2000; MacDonald *et al.* 2002;

2005) indicates that the available data are not sufficient to fully characterize sediment quality conditions within the IDZ;

- Between 2000 and 2004, 13 samples were collected to evaluate whole-sediment chemistry outside the IDZ at the CP AEC. All of these samples were collected in 2003 and were intended to characterize an area of roughly 85 ha. While B.C. MOE has not provided guidance on minimum sampling density and frequency for assessing sediment quality conditions, our experience at other sites (e.g., MacDonald and Ingersoll 2000; MacDonald *et al.* 2002; 2005) indicates that the available data are not sufficient to fully characterize sediment quality conditions outside the IDZ; and,

- The general lack of information on sampling methods; on sample handling, preservation, and transport methods; on analytical methods employed; on data quality objectives; and, on the potential for data transcription errors during the preparation of the CRD Annual Reports (CRD 2002; 2003; 2004; 2005a) preclude evaluation of the quality of the underlying data used in this assessment.

Overall, the results of this evaluation show that insufficient data were available to thoroughly characterize sediment quality conditions within the IDZ at the Macaulay Point AEC and within and outside the IDZ at the Clover Point AEC. Nevertheless, we proceeded to the final step in the sediment quality evaluation process for all of the reaches, with the understanding that data limitations for three of the reaches would not allow us to conclude that they did not contain contaminated sediments. However, the available data can be used to determine that contaminated sediments do exist within one or more reaches within the study area.

4.3 Evaluation of Sediment Quality Conditions in the Vicinity of the Macaulay Point Outfall

Between 2000 and 2004, whole-sediment samples have been collected at a total of 23 sampling stations in the vicinity of the Macaulay Point outfall (Figures 3, 5, 7 and 8). One of these sampling stations (M0) was located within the IDZ, while the reminder of the sampling stations were located 100 m or more from the diffuser (i.e., outside the IDZ). Therefore, data on the chemical composition of five whole-sediment samples are available to evaluate sediment quality conditions within the IDZ (Tables 2 to 6). By comparison, whole-sediment-chemistry data are available for 110 samples located outside the Macaulay Point IDZ (Tables 2 to 6). In addition, the CRD (2002; 2003; 2004; 2005a) has generated information on the chemical characteristics of sediments collected at three reference stations in Parry Bay for the Macaulay Point Outfall. Over the five year period of monitoring (2000 to 2004), a total of 15 whole-sediment samples were collected from these reference stations (Tables 7-11). The CRD (2002; 2003; 2004; 2005a) did not provide any information on the methods that were used to collect the sediment samples nor on the sediment depth that the samples represented. Sample handling, preparation, and transport methods were also not described in CRD (2002; 2003; 2004; 2005a).

Information provided subsequently by CRD (2005b) indicates that sediment samples in 2004 were collected using the protocols set out for the Puget Sound Estuary Program (PSEP 1987). A 0.1 m^2 Young-modified Van Veen sampler was used to collect sediment samples in 2004. Only the top 2 cm of material was retained for chemical analysis. Retained sediment samples were homogenized prior to sub-sampling to support various chemical analyses [except for simultaneously extracted metals/acid volatile sulfides (SEM/AVS) and volatile organic compounds, for which the material was obtained directly from the sampler].

The whole-sediment samples collected in the vicinity of the Macaulay Point outfall and the Parry Bay reference area were analysed for a variety of chemical constituents.

More specifically, the list of target analytes included various conventional variables (e.g., percent moisture, TOC, AVS), metals, PAHs, PCBs, organochlorine pesticides, phenol and chlorinated phenols, phthalates, monoaromatic hydrocarbons (MAHs), a variety of semi-volatile organic chemicals (SVOCs), and certain volatile organic compounds (VOCs). Data quality objectives were not presented in CRD (2002; 2003; 2004; 2005a), nor were data presented to support evaluation of the accuracy or precision of the whole-sediment chemistry data. However, the reported analytical detection limits were generally within the range that would support comparison to the generic numerical sediment criteria (i.e., detection limits for metals or PAHs exceeds the generic numerical sediment criteria in only two samples). Information provided subsequently by CRD (2005b) indicates that quality criteria for measurement data have been established for the WMEP. This information indicates that 10% of the sediment samples collected in 2004 were split to facilitate triplicate analysis for various analytes and that criteria for analytical precision have been established to evaluate the resultant data. In addition, standard reference materials and/or matrix-spiked samples (i.e., samples spiked with surrogate analytes) were analysed to evaluate analytical accuracy. Finally, CRD (2005b) indicated that the data were accepted if no more than 10% of the variables within an analytical group (e.g., metals) failed the quality assurance/quality control criteria.

The available whole-sediment chemistry data were used in conjunction with the generic numerical sediment criteria to determine if sediments in the vicinity of the Macaulay Point outfall had concentrations of one or more prescribed substances sufficient to warrant designation as a contaminated site, as defined under the CSR. More specifically, the available whole-sediment chemistry data (i.e., the data on the concentrations of metals and PAHs in whole-sediment samples) were used to calculate the 90th percentile concentration for each of the COPCs within the IDZ and outside the IDZ. The 90th percentile concentration of each COPC within the IDZ was compared to the generic numerical sediment criteria for typical sites, while the 90th percentile concentration of each COPC outside the IDZ was compared to the generic numerical sediment criteria for sensitive sites. The generic numerical sediment criteria for sensitive sites were applied outside the IDZ because the areas adjacent to the IDZ are not characterized by the presence of marinas, docks, wharves, or associated infrastructure, because benthic habitats within this AEC would be virtually uncontaminated but for the presence of the CRD outfalls, and because benthic habitats in this area likely serve as important rearing habitat for fish [see Schedule 2 of Macfarlane *et al.* (2004) for a description of factors for consideration in the application of the sediment criteria for typical and sensitive sites]. In addition, the concentration of each COPC in each sediment sample collected within the IDZ was compared to two-times the corresponding generic numerical sediment criteria for typical sites, while COPC concentrations in sediment samples collected outside the IDZ were compared to two-times the corresponding generic numerical sediment criteria for sensitive sites. Sediment quality conditions sufficient to warrant designating a reach as contaminated, as defined under the CSR, were identified when the 90th percentile concentration of one or more COPCs exceeded the selected generic numerical sediment criteria or the concentration of one or more COPCs in one or more samples exceeded two-times the selected generic numerical sediment criteria.

The results of this evaluation indicate that sediments within the IDZ of the Macaulay Point outfall are sufficiently contaminated to warrant designation as a contaminated site, as defined under the CSR. More specifically, the 90th percentile concentrations of 10 prescribed substances (i.e., three trace metals and seven individual PAHs) exceeded the generic numerical sediment criteria for typical sites in the whole-sediment samples collected within the IDZ (Table 17). In addition, the 90th percentile mean generic numerical sediment criteria-quotient value calculated for samples collected within the IDZ exceeded 1.0 (Table 17). Furthermore, the concentrations of five prescribed substances (i.e., three trace metals and two individual PAHs) exceeded two-times the generic numerical sediment criteria for typical sites and the upper limit of background concentrations (ULB) in one or more whole-sediment samples collected within the IDZ (Table 18). Therefore, the area within the IDZ of the Macaulay Point outfall should be designated as a contaminated site, as defined under the CSR (i.e., both the frequency and magnitude of exceedance of the selected generic numerical sediment criteria exceed the threshold conditions identified in the CSR and further defined in Macfarlane *et al.* 2004). [Note: the ULB was calculated as the mean plus two standard deviations using data on all of the reference area samples, including those from Parry Bay and Constance Bank].

The results of this evaluation indicate that sediments outside the IDZ of the Macaulay Point outfall are also sufficiently contaminated to warrant designation as a contaminated site, as defined under the CSR. For the 110 whole-sediment samples collected outside the IDZ, the 90th percentile concentrations of 11 prescribed substances (i.e., three trace metals, and eight individual PAHs) exceeded the generic numerical sediment criteria for sensitive sites (Table 2). In addition, the concentrations of 19 prescribed substances (i.e., five trace metals, 13 individual PAHs, and total PAHs) exceeded two-times the generic numerical sediment criteria for sensitive sites and the ULB (Table 3). The mean generic numerical sediment criteria-quotients calculated for samples collected outside the IDZ also exceeded two-times the generic numerical sediment criteria and the ULB (Table 3). Therefore, the area outside the IDZ of the Macaulay Point outfall should be designated as a contaminated site, as defined under the CSR (i.e., both the frequency and magnitude of exceedance of the selected generic numerical sediment criteria exceed the threshold conditions identified in the *EMA* and further defined in Macfarlane *et al.* 2004).

4.4 Evaluation of Sediment Quality Conditions in the Vicinity of the Clover Point Outfall

Between 2000 and 2004, whole-sediment samples have been collected at a total of 14 sampling stations in the vicinity of the Clover Point outfall (i.e., one location in 2000, 2001, 2002, and 2004; 14 locations in 2003; Figures 4, 6, 7, and 8). One of these sampling stations (C0) was located within the IDZ, while the reminder of the sampling stations (13) were located 100 m or more from the diffuser. Therefore, data on the chemical composition of five whole-sediment samples are available to evaluate sediment quality conditions within the IDZ. By comparison, whole-sediment-chemistry data are available for 13 samples located outside the Clover Point IDZ. In addition, the CRD (2002; 2003; 2004; 2005a) has generated information on the chemical characteristics of sediments from up to four reference stations on Constance Bank. Over the five year period of monitoring (2000 to 2004), a total of seven whole-sediment samples were collected from these reference stations. The CRD (2002; 2003; 2004; 2005a) did not provide any information on the methods that were used to collect the sediment samples nor on the sediment depth that the samples represented. Sample handling, preparation, and transport methods were also not described in CRD (2002; 2003; 2004; 2005a).

Information provided subsequently by CRD (2005b) indicates that sediment samples in 2004 were collected using the protocols set out for the Puget Sound Estuary Program (PSEP 1987). A 0.1 m^2 Young-modified Van Veen sampler was used to collect sediment samples in 2004. Only the top 2 cm of material was retained for chemical analysis. Retained sediment samples were homogenized prior to sub-sampling to support various chemical analyses [except for simultaneously extracted metals/acid volatile sulfides (SEM/AVS) and volatile organic compounds, for which the material was obtained directly from the sampler].

The whole-sediment samples collected in the vicinity of the Clover Point outfall and the Constance Bank reference area were analysed for a variety of chemical constituents. More specifically, the list of target analytes included various conventional variables (e.g., percent moisture, TOC, AVS), metals, PAHs, PCBs, organochlorine pesticides, phenol and chlorinated phenols, phthalates, monoaromatic hydrocarbons (MAHs), a variety of semi-volatile organic chemicals (SVOCs), and certain volatile organic compounds (VOCs). Data quality objectives were not presented in CRD (2002; 2003; 2004; 2005a) nor were data presented to support evaluation of the accuracy or precision of the whole-sediment chemistry data. However, the reported analytical detection limits were generally within the range that would support comparison to the generic numerical sediment criteria (i.e., only two measurements of metal or PAH concentrations exceeded the generic numerical sediment criteria). Information provided subsequently by CRD (2005b) indicates that quality criteria for measurement data have been established for the WMEP. This information indicates that 10% of the sediment samples collected in 2004 were split to facilitate triplicate analysis for various analytes and that criteria for analytical precision have been established to evaluate the resultant data. In addition, standard reference materials and/or matrix-spiked samples (i.e., samples spiked with surrogate analytes) were analysed to evaluate analytical accuracy. Finally, CRD (2005b) indicated that the data were accepted if no more than 10% of the variables within an analytical group (e.g., metals) failed the quality assurance/quality control criteria.

The available whole-sediment chemistry data were used in conjunction with the generic numerical sediment criteria to determine if sediments in the vicinity of the Clover Point outfall had concentrations of one or more prescribed substances sufficient to warrant designation as a contaminated site, as defined under the CSR. More specifically, the available whole-sediment chemistry data (i.e., the data on the concentrations of metals and PAHs in whole-sediment samples) were used to calculate the 90th percentile concentration for each of the COPCs within the IDZ and outside the IDZ. The 90th percentile concentration of each COPC within the IDZ was compared to the generic numerical sediment criteria for typical sites, while the 90th percentile concentration of each COPC outside the IDZ was compared to the generic numerical sediment criteria for sensitive sites. The generic numerical sediment criteria for sensitive sites were applied outside the IDZ because the areas adjacent to the IDZ are not characterized by the presence of marinas, docks, wharves, or associated infrastructure, because benthic habitats within this AEC would be virtually uncontaminated but for the presence of the CRD outfalls, and because benthic habitats in this area likely serve as important rearing habitat for fish [see Schedule 2 of Macfarlane *et al.* (2004) for a description of factors for consideration in the application of the sediment criteria for typical and sensitive sites]. In addition, the concentration of each COPC in each sediment sample collected within the IDZ was compared to two-times the corresponding generic numerical sediment criteria for typical sites, while COPC concentrations in sediment samples collected outside the IDZ were compared to two-times the corresponding generic numerical sediment criteria for sensitive sites. Sediment quality conditions sufficient to warrant designating a reach as contaminated, as defined under the CSR, were identified when the 90th percentile concentration of one or more COPCs exceeded the selected generic numerical sediment criteria or the concentration of one or more COPCs in one or more samples exceeded two-times the selected generic numerical sediment criteria.

The results of this evaluation indicate that sediments within the IDZ of the Clover Point outfall are sufficiently contaminated to warrant designation as a contaminated site, as defined under the CSR. More specifically, the 90th percentile concentrations of 10 prescribed substances (i.e., three trace metals and seven individual PAHs) exceeded the generic numerical sediment criteria for typical sites in the whole-sediment samples collected within the IDZ (Table 19). In addition, the concentrations of three prescribed substances (i.e., one trace metals and two individual PAHs) exceeded two-times the generic numerical sediment criteria for typical sites and the upper limit of background concentrations (ULB) in one or more whole-sediment samples collected within the IDZ (Table 20). Therefore, the area within the IDZ of the Clover Point outfall should be designated as a contaminated site, as defined under the CSR (i.e., both the frequency and magnitude of exceedance of the selected generic numerical sediment criteria exceed the threshold conditions identified in the CSR and further defined in Macfarlane *et al.* 2004). [Note: the ULB was calculated as the mean plus two standard deviations using data on all of the reference area samples, including those from Parry Bay and Constance Bank.]

The results of this evaluation indicate that sediments outside the IDZ of the Clover Point outfall are not sufficiently contaminated to warrant designation as a contaminated site, as defined under the CSR. For the 13 whole-sediment samples collected outside the IDZ, the 90th percentile concentrations of none of the prescribed substances investigated exceeded the generic numerical sediment criteria for sensitive sites (Table 19). Likewise, none of the samples collected outside the IDZ had concentrations of any of the prescribed substances considered that exceeded two-times the generic numerical sediment criteria for sensitive sites (Table 20). Therefore, the available data do not indicate that sediments outside the IDZ of the Clover Point outfall are sufficiently contaminated to warrant designation as a contaminated site, as defined under the CSR. However, it should not be concluded that the area outside the IDZ of the Clover Point outfall is not a contaminated site since sampling density was generally low, sediment samples were collected in one year only (i.e., 2003), apparently only surficial sediments were sampled, and data were not available on all of the prescribed substances listed in Schedule 9 of the CSR.

Chapter 5 Summary, Conclusions, and Recommendations

5.0 Introduction

On November 10, 2005, the Environmental Management Branch of British Columbia Ministry of the Environment (B.C. MOE) received an urgent request from the Sierra Legal Defence Fund for designation of the Macaulay and Clover Point outfalls as contaminated sites pursuant to the provisions of the British Columbia *Environmental Management Act (EMA)*. This request was made because monitoring conducted by the Capital Regional District (CRD) during the years 2000 to 2004 demonstrated that certain prescribed substances listed in Schedule 9 of the Contaminated Sites Regulation (CSR) occurred in marine sediments at elevated levels in the vicinity of the two outfalls. This report was prepared to provide B.C. MOE with an independent evaluation of sediment quality conditions in the vicinity of the Macaulay Point and Clover Point outfalls to determine if such a designation is warranted.

5.1 Summary

The evaluation of sediment quality conditions in the vicinity of the Macaulay Point and Clover Point outfalls was conducted using a step-wise approach. As a first step, the available documentation on the assessment and management of contaminated sites in British Columbia was reviewed. This review included the *EMA*, the CSR, and supporting documentation (MacDonald and Ingersoll 2003a; 2003b; 2003c; Ingersoll and MacDonald 2003; B.C. MOELP 2004; Macfarlane *et al.* 2004). The results of this review provided a basis for structuring the evaluation of sediment quality conditions such that it would be consistent with provincial regulations, guidance, and administrative rules.

In the second step of the evaluation, the study area was divided into two Areas of Environmental Concern, including the Macaulay Point AEC and the Clover Point AEC. Each of these AECs was further divided into two reaches, including the area within the initial dilution zone (IDZ; i.e., within 100 m of the diffusers) and the area outside the IDZ. Each of these reaches was classified as sensitive or typical sites, based on the B.C. MOE guidance (i.e., Schedule 2 of Macfarlane *et al.* 2004). Application of this guidance resulted in the areas contained within the IDZs being classified as typical sites and the areas outside the IDZs being classified as sensitive sites.

In the third step of the process, the available whole-sediment chemistry data for each of the AECs and reaches was compiled. While every effort was made to obtain the complete data set from the CRD (i.e., the whole-sediment chemistry data for all years, all stations, and all chemical analytes that had been used by CRD's consultants to assess risks and temporal trends in the vicinity of the outfalls; Golder Associates Limited 2005; Paine, Ledge, and Associates 2004), CRD was unable to provide the data in electronic format in time to support the current evaluation. For this reason, the available data on the key prescribed substances identified in Schedule 9 of the CSR that were measured by CRD and had detected results were compiled from the CRD Annual Reports (CRD 2002; 2003, 2004; 2005a; i.e., metals and PAHs). An evaluation of these data was conducted to determine if sufficient data were available to characterize the chemical composition within each of the AECs and reaches. The results of this evaluation indicated that sufficient data were not available to thoroughly characterise sediment quality conditions within the IDZ at the Macaulay Point AEC and within and outside the IDZ at the Clover Point AEC. Nevertheless, we proceeded to the final step in the sediment quality evaluation process for all of the reaches, with the understanding that data limitations for three of the reaches would not enable us to conclude that they did not contain contaminated sediments.

In the final step of the evaluation, the whole-sediment chemistry data available for each reach of each AEC was compared to the generic numerical sediment criteria listed in Schedule 9 of the CSR and Macfarlane *et al.* (2004). Consistent with the

EMA, CSR, and associated B.C.MOE guidance (i.e., Macfarlane *et al.* 2004), a reach was considered to have conditions sufficient to warrant designation as a contaminated site if the 90th percentile concentration of one or more prescribed substances exceeded the corresponding generic numerical sediment criteria or if the concentration of one or more prescribed substances exceeded two-times the corresponding generic numerical sediment criteria and the upper limit of background (ULB) in one or more whole-sediment sample.

The results of this evaluation showed that both of the reaches within the Macaulay Point AEC had sediment quality conditions sufficient to warrant designation as contaminated sites, as defined under the CSR (Tables 17 and 18). Within the IDZ, the 90th percentile concentrations of three trace metals and seven individual PAHs exceeded the generic numerical sediment criteria for typical sites. Similarly, the 90th percentile concentrations of five trace metals, 13 individual PAHs, and total PAHs exceeded the generic numerical sediment criteria for sensitive sites in whole-sediment samples collected outside the IDZ. Both the frequency and magnitude of the exceedances of the generic numerical sediment criteria within and outside the IDZ indicate that sediment quality conditions are sufficiently contaminated to warrant designation as contaminated sites. Sediments located outside the IDZ appeared to be more contaminated than those located inside the IDZ. The concentrations of a number of COPCs in sediment samples collected outside the IDZ also exceeded the provincial water quality guidelines (B.C. MOELP 1998), in contravention of the Municipal Sewage Regulation.

The results of this evaluation also showed that portions of the Clover Point AEC had sediment quality conditions sufficient to warrant designation as a contaminated site, as defined under the CSR (Tables 19 and 20). More specifically, the 90th percentile concentrations of three trace metals and seven individual PAHs exceeded the generic numerical sediment criteria for typical sites in whole-sediment samples collected within the IDZ. However, exceedances of the generic numerical sediment criteria for sensitive sites were not observed outside the IDZ for any of the metals or PAHs considered in this evaluation. Therefore, both the frequency and magnitude of the exceedances of the selected generic numerical sediment criteria within the IDZ indicate that sediment quality conditions are sufficiently contaminated to warrant designation as a contaminated site. While contaminated sediments (i.e., sediments with 90th percentile COPC concentrations in excess of the generic numerical sediment criteria for sensitive sites) were not observed outside the IDZ, limitations on the available data preclude concluding that this portion of the CP AEC is not sufficiently contaminated to warrant designation as a contaminated site.

5.2 Conclusions

An evaluation of sediment quality conditions in the vicinity of the Macaulay Point and Clover Point outfalls was conducted in accordance with B.C. MOE guidance (i.e., MacDonald and Ingersoll 2003a; 2003b; 2003c; Ingersoll and MacDonald 2003; B.C. MOELP 2004; Macfarlane *et al.* 2004). The results of this evaluation lead to the following conclusions:

- Insufficient data have been collected in the vicinity of the Macaulay Point and Clover Point outfalls to thoroughly evaluate sediment quality conditions. Nevertheless, the available data can be used to conduct a preliminary evaluation of sediment quality conditions in the vicinity of the two outfalls (i.e., a preliminary site investigation-type evaluation);

- The results of the preliminary evaluation demonstrate that the provincial water quality guidelines (B.C. MOELP 1998) are not being met outside the initial dilution zone at the Macaulay Point outfall, as indicated by numerous exceedances of working guidelines for sediment;
- The results of the preliminary evaluation indicate that sediments located within and outside the initial dilution zone at the Macaulay Point outfall are sufficiently contaminated to warrant designation of both reaches as

contaminated sites under the CSR. The results of a study that was recently commissioned by CRD confirms that sediments located within 200m of the Macaulay Point outfall are sufficiently contaminated to pose moderate risks to the benthic community (Golder Associates Limited2005);

- The results of the preliminary evaluation indicate that sediments located within the initial dilution zone at the Clover Point outfall are sufficiently contaminated to warrant designation of the reach as a contaminated site under the CSR. The results of a study that was recently commissioned by CRD confirms that sediments located within 200m of the Clover Point outfall are sufficiently contaminated to pose moderate risks to the benthic community (Golder Associates Limited 2005);

- The nature, severity, and spatial extent of contamination and associated effects on ecological receptors have not be thoroughly evaluated in the vicinity of the Macaulay Point and Clover Point outfalls. Therefore, it is not possible to develop a contaminated sediment management plan for the site. Nevertheless, the existing data suggest that source control and wastewater treatment, rather than active remediation of contaminated sediments, may provide a cost-effective basis for achieving sediment management objectives at the site; and,

- The seafloor trigger that was established to determine when treatment of wastewater discharged from the Macaulay Point and Clover Point outfalls would be required is not reliable in terms of identifying conditions that have unacceptable impacts on the marine environment (i.e., under agreement with the Minister, wastewater treatment must be provided within three years of the trigger being reached).

5.3 Recommendations

The results of this preliminary evaluation indicate that additional investigations are required to provide the data and information needed to conduct a thorough assessment of sediment quality conditions in the vicinity of the Macaulay Point and Clover Point outfalls and to develop an effective plan for managing contaminated sediments at the site. Some of the recommendations that emerge from this preliminary evaluation of sediment quality conditions include:

- The CRD should develop an electronic data management system that facilitates provision of data collected under the WMEP to regulators in real time and in a form that is suitable to support data analysis (i.e., in GIS-compatible relational database format that can be directly incorporated into the provincial Environmental Management System; EMS);

- The CRD should conduct a detailed site investigation to provide the information needed to evaluate the nature, severity and spatial extent (including with depth) of contamination at the Macaulay Point and Clover Point outfall sites. The detailed site investigation should be conducted in accordance with B.C. MOE guidance and provide the information needed to thoroughly evaluate sediment quality conditions at the site. At minimum, such an investigation should be designed to facilitate the collection of detailed information on whole-sediment chemistry, whole-sediment toxicity, laboratory bioaccumulation, and invertebrate-tissue chemistry in the vicinity of the two outfalls. The results of the detailed site investigation will provide B.C. MOE with the information needed to make a final determination on the site and CRD with the information needed to manage contaminated sediments at the site; and,

- The seafloor trigger should be revised and refined to provide a more effective tool for identifying conditions that are having unacceptable impacts on the marine environment and, hence, for identifying when wastewater treatment needs to be provided. Alternatively, the seafloor trigger could be abandoned and arrangements made for providing wastewater treatment of these sites within three years.

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Table 1. Generic Numerical Sediment Criteria (Schedule 9 of the Contaminated Sites Regulation; Government of British Columbia 1997).

Substance	Freshwater Sediment[2]		Marine and Estuarine Sediment[3]	
	Sensitive[4] ($SedQC_{SCS}$)	Typical[5] ($SedQC_{TCS}$)	Sensitive[4] ($SedQC_{SCS}$)	Typical[5] ($SedQC_{TCS}$)
Inorganic Substances				
Arsenic	11	20	26	50.0[6]
Cadmium	2.2	4.2	2.6	5
Chromium (total)	50.0[6]	110	99	190
Copper	120	240	67	130
Lead	57	110	67	130
Mercury	0.3	0.58	0.43	0.84
Zinc	200	380	170	330
Organic Substances				
Chlorinated Hydrocarbons; chlorinated aliphatics				
Hexachlorocyclohexane[7]	0.00086[6]	0.0017[6]	0.00061	0.0012[6]
Miscellaneous Chlorinated Hydrocarbons				
PCBs[9](total)	0.17	0.33	0.12	0.23
PCDDs and PCDFs[8]	0.00013[6]	0.00026[6]	0.00013	0.00026[6]
Phenolic Substances				
Chlorinated Phenols				
Pentachlorophenol	0.4[10]	0.8[10]	0.36[11]	0.69[11]
Polycyclic Aromatic Hydrocarbons (PAHs)				
Akylated Low Molecular Weight PAHs				
2-methylnaphthalene	0.12	0.24	0.12	0.24
Low Molecular Weight PAHs				
Acenaphthene	0.055	0.11	0.055	0.11
Acenaphthylene	0.08	0.15	0.079	0.15
Anthracene	0.15	0.29	0.15	0.29
Fluorene	0.089	0.17	0.089	0.17
Naphthalene	0.24	0.47	0.24	0.47
Phenanthrene	0.32	0.62	0.34	0.65
High Molecular Weight PAHs				
Benz(a)anthracene	0.24	0.46	0.43	0.83
Benzo(a)pyrene	0.48	0.94	0.47	0.92
Chrysene	0.53	1	0.52	1
Dibenz(a,h)anthracene	0.084	0.16	0.084	0.16
Fluoranthene	1.5	2.8	0.93	1.8
Pyrene	0.54	1.1	0.87	1.7

Table 1. Generic Numerical Sediment Criteria (Schedule 9 of the Contaminated Sites Regulation; Government of British Columbia 1997).

Substance	Freshwater Sediment[2]		Marine and Estuarine Sediment[3]	
	Sensitive[4] ($SedQC_{SCS}$)	**Typical[5] ($SedQC_{TCS}$)**	**Sensitive[4] ($SedQC_{SCS}$)**	**Typical[5] ($SedQC_{TCS}$)**
Total PAHs				
PAHs (total) [12]	10	20	10	20
Pesticides				
Chlordane	0.0055	0.011	0.003	0.0057
DDD (total) [13]	0.0053	0.01	0.0048	0.0094
DDE (total) [14]	0.0042	0.0081	0.23	0.45
DDE (total) [15]	0.003	0.0057	0.003	0.0057
Dieldrin	0.0041	0.008	0.0027	0.0052
Endrin	0.039	0.075[6]	0.039	0.075[6]
Heptachlor and heptachlor epoxide	0.0017	0.0033[6]	0.0017	0.0033
Lindane [7]	0.00086[6]	0.0017[6]	0.00061	0.0012[6]

[1] All values are in µg/g dry weight (dwt) unless otherwise stated. Substance must be analyzed using methods specified in a Director's protocol or alternate methods acceptable to a Director.

[2] Criteria to protect freshwater aquatic life.

[3] Criteria to protect marine and/or estuarine aquatic life.

[4] Sensitive site means a sediment site with sensitive aquatic habitat and for which sensitive sediment management objectives apply. Consult Director for further advice.

[5] Typical site means a sediment site which is not a sensitive sediment site. Consult Director for further advice.

[6] Denotes a sediment quality criteria which is considered less reliable or that could not be fully evaluated.

[7] Criteria is specific to gamma isomer.

[8] Calculated using data for PCDDs, PCDFs, PCBs and associated PCDD, PCDF and PCB toxicity equivalency factors.

[9] Total PCBs includes either the sum of four to seven Arochlor mixtures (i.e. Aroclor 1016, 1221, 1232, 1242, 1248, 1254 and/or 1260) or the sum of $\geq$ 20 individual PCB congeners. No discrete criterion for Arochlor 1254 was derived, since the existing Canadian Council of Ministers of the Environment interim Probable Effects Level (PEL) for that substance was inconsistent with the PEL provided for total PCBs and the Probable Effects Level (PEL) for Arochlor 1254 was derived using methods different from those used to derive the criterion for total PCBs listed in this schedule.

[10] Criterion is set equal to the State of New York, Department of Environmental Conservation, 1994 criterion for the substance.

[11] Criterion is set equal to the Washington State, Department of Ecology, 1991 criterion for the substance.

[12] Total PAHs includes:
2-methylnaphthalene, acenaphthalene, acenaphthylene, anthracene, benz[a]anthracene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, fluorene, fluoranthene, naphthalene, phenanthrene, and pyrene.

[13] DDD is 2,2-bis(p-chlorophenyl)1,1-dichloroethane

[14] DDE is 2,2-bis(p-chlorophenyl)-1,1-dichloroethylene

[15] DDT is 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane

Table 2. Whole-sediment data for Macaulay Point stations collected in 2000.

Chemical of Potential Concern (COPC)	M1E	M1N	M1NE	M1NW	M1S	M1SE	M1SW	M1W	M2E	M2N	M2NE	M2NW	M2S	M2SE
Metals (mg/kg)														
Arsenic	10	5	5.1	4.7	20	12	5.5	6.8	6.9	6.2	6.3	5	1.9	8
Cadmium	0.54	0.19	0.18	0.15	0.22	0.74	0.27	0.42	0.25	0.14	0.21	0.15	0.13	0.36
Chromium	87	37	37	35	36	38	48	38	36	35	38	35	26	35
Copper	387	21	23	19	153	74	38	90	30	21	22	21	21	64
Lead	255	12.4	332	9.3	14600	103	22.4	50.3	36.7	13.5	10.8	10.2	10.3	75.3
Mercury	1.42	0.068	0.06	0.058	0.112	8.77	0.273	0.245	0.144	0.076	0.144	0.074	0.119	0.388
Zinc	163	62	64	62	104	146	81	106	91	69	70	68	52	111
PAHs (µg/kg)														
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	350	<10	20	<10	2700	180	40	90	110	<10	20	<10	<10	50
Acenaphthylene	20	<10	<10	<10	<500*	30	20	20	30	10	<10	<10	<10	20
Anthracene	930	20	50	<10	7600	320	90	160	320	20	40	10	<10	270
Fluorene	260	10	20	10	2100	180	30	70	100	10	20	10	10	50
Naphthalene	180	30	30	20	<500*	2200	40	70	420	40	50	20	30	70
Phenanthrene	2520	80	180	50	20700	1260	300	530	960	90	150	60	60	560
Benz(a)anthracene	2530	60	130	10	19600	560	190	330	530	80	60	20	20	780
Benzo(a)pyrene	2430	70	120	10	16900	530	170	300	660	80	70	40	20	880
Chrysene	2390	60	120	20	16600	540	180	310	550	80	60	30	20	740
Dibenz(a,h)anthracene	240	<10	10	<10	2	60	20	40	0.11	<10	<10	<10	<10	10
Fluoranthene	5170	90	250	20	35300	1210	420	640	1380	140	150	50	40	2030
Pyrene	4150	80	220	20	28200	1000	330	580	1010	130	110	50	40	1700
Total PAHs	21170	515	1155	180	149702	8070	1830	3140	6070.11	690	740	305	260	7160

* These concentrations were not included in the analysis because they had detection limits greater than the generic numerical sediment criteria.
NA = not analysed (this substance was not analysed during this sampling period).

Table 2. Whole-sediment data for Macaulay Point stations collected in 2000 (continued).

Chemical of Potential Concern (COPC)	M2SW	M2W	M4E	M4SE	M4SW	M4W	M8E	M8W	MO
Metals (mg/kg)									
Arsenic	5.3	5.5	6.4	7.2	5.1	4.7	5.4	5.5	6
Cadmium	0.12	0.15	0.19	0.18	0.13	0.16	0.14	0.11	0.61
Chromium	36	35	35	37	35	35	35	34	57
Copper	23	27	40	49	19	18	23	16	152
Lead	12.6	11.1	95.6	2000	10.5	8.9	18.7	7.7	1573
Mercury	0.057	0.072	0.19	0.113	0.079	0.05	0.05	0.05	1.32
Zinc	74	69	97	145	75	62	65	60	233
PAHs (µg/kg)									
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	<10	<10	50	50	<10	<10	20	<10	40
Acenaphthylene	<10	<10	30	40	<10	<10	50	<10	90
Anthracene	<10	<10	210	110	<10	<10	50	20	110
Fluorene	10	10	60	100	<10	10	30	10	30
Naphthalene	20	20	60	110	20	20	50	20	160
Phenanthrene	50	60	480	940	40	50	190	70	360
Benz(a)anthracene	10	30	250	280	<10	20	200	30	270
Benzo(a)pyrene	10	20	240	240	10	20	180	30	270
Chrysene	20	40	270	400	20	20	220	30	260
Dibenz(a,h)anthracene	<10	<10	30	30	<10	<10	30	<10	40
Fluoranthene	20	50	530	990	20	30	260	60	580
Pyrene	20	50	550	760	20	30	300	50	460
Total PAHs	180	300	2760	4050	160	220	1580	335	2670

* These concentrations were not included in the analysis because they had detection limits greater than the generic numerical sediment criteria.
NA = not analysed (this substance was not analysed during this sampling period).

Table 3. Whole-sediment data for Macaulay Point stations collected in 2001.

Chemical of Potential Concern (COPC)	M1E	M1N	M1NE	M1NW	M1S	M1SE	M1SW	M1W	M2E	M2N	M2NE	M2NW	M2S	M2SE
Metals (mg/kg)														
Arsenic	14	7	5	4	6	12	6	7	7	5	5	4	5	7
Cadmium	0.57	0.18	0.13	0.08	0.28	0.66	0.36	0.48	0.22	0.16	0.16	0.14	0.16	0.47
Chromium	35	35	32	33	38	34	35	54	33	34	31	35	36	35
Copper	97	20	17	17	29	86	50	71	32	18	22	18	20	68
Lead	52	13	10	20	27	52	30	39	20	12	12	10	19	88
Mercury	0.538	0.1	0.111	0.078	0.802	0.585	0.511	0.661	0.093	0.053	0.049	0.067	0.051	0.746
Zinc	90	64	57	61	71	108	91	216	63	59	58	61	64	98
PAHs (µg/kg)														
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	60	<10	<10	<10	30	240	20	10	3100	<10	<10	<10	<10	20
Acenaphthylene	<10	<10	<10	<10	10	10	<10	20	20	<10	<10	<10	<10	<10
Anthracene	180	20	<10	<10	70	480	50	30	6100	<10	<10	<10	<10	90
Fluorene	50	10	<10	<10	20	190	20	20	1800	<10	<10	<10	<10	20
Naphthalene	60	20	<10	10	30	160	40	30	20	10	<10	10	10	50
Phenanthrene	610	90	40	50	230	1910	210	100	16500	70	50	40	60	320
Benz(a)anthracene	630	130	20	10	230	1310	110	100	8600	50	10	10	<10	310
Benzo(a)pyrene	560	130	20	<10	240	1130	90	80	6900	50	<10	<10	<10	360
Chrysene	510	100	20	<10	210	1100	100	130	6800	40	<10	<10	<10	290
Dibenz(a,h)anthracene	90	10	<10	<10	30	170	10	20	1070	10	<10	<10	<10	40
Fluoranthene	1070	150	40	20	430	2260	190	160	16000	80	20	20	30	660
Pyrene	910	140	30	20	350	1810	190	150	12600	60	10	10	20	570
Total PAHs	4735	810	200	145	1880	10770	1035	850	79510	390	130	125	160	2735

NA = not analysed (this substance was not analysed during this sampling period).

Table 3. Whole-sediment data for Macaulay Point stations collected in 2001 (continued).

Chemical of Potential Concern (COPC)	M2SW	M2W	M4E	M4SE	M4SW	M4W	M8E	M8W	MO
Metals (mg/kg)									
Arsenic	5	4	8	7	6	5	8	6	11
Cadmium	0.13	0.14	0.21	0.25	0.14	0.21	0.11	0.15	1.34
Chromium	34	32	30	28	34	32	29	34	72
Copper	23	19	34	70	18	18	16	16	266
Lead	13	10	17	61	13	11	16	9	100
Mercury	0.068	0.09	0.078	0.343	0.052	0.05	0.048	0.102	1.81
Zinc	63	59	60	198	63	59	56	58	237
PAHs (µg/kg)									
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	<10	<10	<10	60	<10	<10	<10	<10	40
Acenaphthylene	<10	<10	<10	170	<10	<10	<10	<10	20
Anthracene	<10	<10	30	110	<10	<10	20	<10	140
Fluorene	<10	<10	20	80	<10	<10	<10	<10	30
Naphthalene	20	10	30	740	<10	20	30	20	30
Phenanthrene	60	70	140	440	50	50	100	60	430
Benz(a)anthracene	20	10	50	290	20	<10	80	<10	440
Benzo(a)pyrene	20	<10	40	230	20	<10	90	<10	410
Chrysene	20	<10	50	240	20	10	90	<10	400
Dibenz(a,h)anthracene	<10	<10	<10	30	<10	<10	<10	<10	50
Fluoranthene	40	30	90	500	30	20	140	20	870
Pyrene	40	20	100	440	30	20	140	10	760
Total PAHs	245	175	565	3330	200	155	710	150	3620

NA = not analysed (this substance was not analysed during this sampling period).

Table 4. Whole-sediment data for Macaulay Point stations collected in 2002.

Chemical of Potential Concern (COPC)	M1E	M1N	M1NE	M1NW	M1S	M1SE	M1SW	M1W	M2E	M2N	M2NE	M2NW	M2S	M2SE
Metals (mg/kg)														
Arsenic	6.4	5	5.3	4.6	5.4	10.7	8	7.2	7.5	5.1	5.2	6.1	4.9	7.5
Cadmium	0.65	0.26	0.54	0.21	0.32	0.88	83.5	1.12	0.48	0.23	0.24	0.23	0.19	1.65
Chromium	42	39	38	36	35	41	42	52	44	37	35	37	37	33
Copper	58	21	22	17	52	81	80	80	32	19	44	17	25	55
Lead	53.4	40.4	13.5	9.2	20.8	98.3	43.6	38.8	41.1	18.5	11.9	10.1	17.9	58.9
Mercury	0.255	0.026	0.056	0.033	0.058	0.142	0.091	0.264	0.167	0.032	0.224	0.028	0.032	0.521
Zinc	156	64	67	58	79	95	431	116	211	64	64	64	62	104
PAHs (µg/kg)														
2-Methylnaphthalene	50	30	30	20	20	60	60	50	160	40	20	40	30	50
Acenaphthene	25	54	12	<5	10	96	17	59	106	10	<5	<5	<7	48
Acenaphthylene	<5	8	<5	8	6	13	<6	36	110	14	<5	<5	<5	15
Anthracene	50	90	20	<10	20	170	40	120	200	30	<10	<10	<10	120
Fluorene	30	40	10	<10	10	90	20	50	290	20	<10	10	10	50
Naphthalene	40	20	20	20	20	50	30	40	100	40	10	20	20	60
Phenanthrene	160	330	80	40	60	710	160	480	1800	170	30	40	60	380
Benz(a)anthracene	120	270	30	30	70	390	140	340	410	100	<10	<10	20	380
Benzo(a)pyrene	110	250	20	20	60	370	120	350	450	110	<10	<10	20	360
Chrysene	110	340	30	40	90	390	120	390	520	130	20	10	30	350
Dibenz(a,h)anthracene	14	43	<5	<5	12	47	16	45	57	18	<5	<5	<5	46
Fluoranthene	250	630	60	40	90	1100	270	910	1500	200	20	20	40	770
Pyrene	210	490	50	40	90	780	230	710	1300	180	20	20	40	620
Total PAHs	1171.5	2595	367	273	558	4266	1226	3580	7003	1062	147.5	182.5	283.5	3249

Table 4. Whole-sediment data for Macaulay Point stations collected in 2002 (continued).

Chemical of Potential Concern (COPC)	M2SW	M2W	M4E	M4SE	M4SW	M4W	M8E	M8W	MO
Metals (mg/kg)									
Arsenic	5.5	5.9	7.1	9.1	5.3	4.9	8	4.9	9.4
Cadmium	0.29	0.23	0.24	0.27	0.19	0.21	0.2	0.18	0.76
Chromium	38	36	34	32	37	35	38	39	44
Copper	17	18	29	46	17	17	22	15	158
Lead	11	9.3	23.3	44.6	11.2	10.7	22.4	10.6	130
Mercury	0.032	0.025	0.071	0.037	0.025	0.293	0.21	0.03	0.186
Zinc	60	62	72	88	63	63	106	61	132
PAHs (μg/kg)									
2-Methylnaphthalene	40	30	150	100	30	30	120	40	80
Acenaphthene	26	<20	70	<30	<5	<5	51	<5	166
Acenaphthylene	<5	<5	6	<7	<5	<5	<20	<5	54
Anthracene	50	10	130	40	<10	<10	90	<10	370
Fluorene	20	10	120	70	10	10	60	10	100
Naphthalene	20	20	190	50	20	20	70	40	80
Phenanthrene	140	70	430	240	40	40	340	40	1190
Benz(a)anthracene	190	30	170	90	<10	10	240	<10	1170
Benzo(a)pyrene	170	20	140	70	<10	<10	260	<10	1080
Chrysene	170	30	150	120	10	20	300	20	1010
Dibenz(a,h)anthracene	22	<5	19	15	<5	<5	43	<5	130
Fluoranthene	330	60	320	150	20	20	450	20	2170
Pyrene	280	50	330	130	20	20	440	20	1910
Total PAHs	1460.5	345	2225	1093.5	172.5	187.5	2474	212.5	9510

Table 5. Whole-sediment data for Macaulay Point stations collected in 2003.

Chemical of Potential Concern (COPC)	M1E	M1N	M1NE	M1NW	M1S	M1SE	M1SW	M1W	M2E	M2N	M2NE	M2NW	M2S	M2SE
Metals (mg/kg)														
Arsenic	10.9	5	5.1	4.6	6.2	9.6	6.2	6.3	7	5.5	5.4	4.7	5.1	8
Cadmium	0.785	0.184	0.237	0.179	0.43	0.739	0.382	0.506	0.368	0.274	0.227	0.208	0.174	0.496
Chromium	32	34.3	32.3	28	32.3	30.6	34.2	33.4	34.4	34.7	34.8	32.9	34	32.3
Copper	85.1	20.3	19.5	14.1	76.8	99.6	62.5	29.8	32.5	29.9	23.5	17.6	24.7	51.9
Lead	55	11	9.8	8.4	69.4	186	40.8	45.4	55.2	24.2	11.7	8.4	12	79.5
Mercury	0.276	0.0396	0.037	0.0325	0.127	0.4637	0.492	0.395	0.233	0.0694	0.549	0.0654	0.347	0.231
Zinc	95.9	70.7	59.7	48.9	65.3	118.9	93.1	76.7	75.5	67.3	57.9	55.8	61.3	74.2
PAHs (µg/kg)														
2-Methylnaphthalene	440	20	28	31	41	49	51	71	29	47	22	35	41	49
Acenaphthene	204	<5	<8	<10	48.6	3439.3	29.6	70.1	62.4	<5	<6	<4	<3	<30
Acenaphthylene	160	2.3	2.8	2.3	10.5	11	11.2	8.3	7.6	18	9.6	2.4	2	<20
Anthracene	390	<10	14	16	89	6836	49	207	172	35	15	<10	<10	36
Fluorene	520	<10	<10	11	41	2222	22	58	49	<20	16	<20	<20	<60
Naphthalene	780	12	31	17	22	50	45	58	26	32	23	18	26	43
Phenanthrene	3940	25	74	74	377	19287	177	623	493	125	78	51	42	598
Benz(a)anthracene	1100	<10	37	45	<300	9747	79	514	501	94	24	17	<10	98
Benzo(a)pyrene	1380	<10	38	38	246	8815	99	397	515	85	19	15	<10	85
Chrysene	1480	12	39	44	<200	9017	83	436	504	94	26	20	12	131
Dibenz(a,h)anthracene	211	<2	6	7	48	1104	17	51	71	14	3	3	<2	15
Fluoranthene	4020	20	100	90	560	20620	200	1050	1000	150	50	40	20	150
Pyrene	2970	16	79	72	402	17117	167	801	994	139	50	33	19	159
Total PAHs	17595	130.8	457.8	452.3	2135.1	98314.3	1029.8	4344.4	4424	845.5	338.6	251.4	189.5	1419

Table 5. Whole-sediment data for Macaulay Point stations collected in 2003 (continued).

Chemical of Potential Concern (COPC)	M2SW	M2W	M4E	M4SE	M4SW	M4W	M8E	M8W	MO
Metals (mg/kg)									
Arsenic	4.6	5.1	5.6	8.4	5	5	6.4	5.1	6.4
Cadmium	0.208	0.261	0.228	0.342	0.153	0.182	0.191	0.165	0.803
Chromium	32.1	31.8	32.1	31.2	36.1	35	34.7	34.6	56.7
Copper	22.2	27.3	35	44.8	16.8	16.2	21.1	16.1	273
Lead	10.7	9.2	27	190	10.4	8.6	14.7	9.2	64.6
Mercury	0.209	0.0458	0.102	0.233	0.0342	0.038	0.047	0.0369	0.114
Zinc	58.8	60.3	127	88.1	59.3	57.2	61.1	58.4	369
PAHs (µg/kg)									
2-Methylnaphthalene	29	35	31	55	26	24	221	25	69
Acenaphthene	<9	<8	<4	<20	<3	<4	174	9.1	382
Acenaphthylene	4.7	<2	4.1	17.5	4.8	4.6	40.5	5.7	11.7
Anthracene	27	17	11	25	11	12	290	21	409
Fluorene	16	14	<10	<50	<10	<10	221	<20	212
Naphthalene	18	17	21	38	14	11	185	12	58
Phenanthrene	121	81	58	298	58	62	931	66	1890
Benz(a)anthracene	63	34	22	47	33	26	330	26	775
Benzo(a)pyrene	51	27	21	39	30	23	255	22	682
Chrysene	66	37	34	58	28	30	384	24	762
Dibenz(a,h)anthracene	8	4	4	7	4	4	33	3	108
Fluoranthene	130	80	50	90	70	50	420	50	2020
Pyrene	111	66	50	86	65	44	589	45	1830
Total PAHs	649.2	417	313.1	795.5	350.3	297.6	4073.5	318.8	9208.7

Table 6. Whole-sediment data for Macaulay Point stations collected in 2004.

Chemical of Potential Concern (COPC)	M1E	M1N	M1NE	M1NW	M1S	M1SE	M1SW	M1W	M2E	M2N	M2NE	M2NW	M2S	M2SE
Metals (mg/kg)														
Arsenic	9.73	4.96	4.26	4.36	5.61	7.35	5.00	5.66	5.22	4.82	4.27	4.42	5.75	5.98
Cadmium	0.738	0.191	0.251	0.204	0.276	0.548	0.396	0.929	0.306	0.592	0.269	0.229	0.189	0.425
Chromium	29.1	33.6	31.1	32.1	32.1	41.2	32.2	34.8	29.3	34.9	29.0	30.8	29.3	27.5
Copper	43.3	25.4	26.3	19.5	37.7	52.2	37.6	117	49.3	24.3	20.3	17.5	18.8	266
Lead	168	10.2	14.5	11.0	16.7	25.6	288	21.4	45.2	243	19.1	8.18	11.3	28.7
Mercury	0.447	0.0498	0.0563	0.0393	0.213	0.485	0.122	0.369	0.3983	0.228	0.0591	0.0662	0.0429	0.147
Zinc	125	70.3	63.9	61.8	69.4	76.3	72.9	197	69.0	77.1	62.1	61.6	66.1	66.0
PAHs (µg/kg)														
2-Methylnaphthalene	46	29	33	36	35	92	34	76	30	52	26	25	19	75
Acenaphthene	106	<6	<5	<5	12.7	183	15.9	105	10.7	<5	<6	7.3	<5	47.1
Acenaphthylene	<9	<7	<5	<5	<5	<6	<7	22.3	4.7	<5	<5	<5	<5	16.5
Anthracene	290	33	11	<10	25	341	38	251	31	<10	11	12	<10	116
Fluorene	88	14	10	12	18	128	25	80	18	<10	10	<10	<10	44
Naphthalene	49	30	18	19	32	56	32	59	27	31	19	17	<10	61
Phenanthrene	781	70	61	58	122	1260	199	839	116	36	82	76	30	374
Benz(a)anthracene	592	55	33	13	54	647	69	461	79	11	25	24	<10	189
Benzo(a)pyrene	484	98	28	11	46	536	65	392	72	12	21	19	<10	159
Chrysene	508	89	31	15	51	586	82	391	69	12	21	21	<10	165
Dibenz(a,h)anthracene	71.2	14.4	<5	<5	6.8	78.2	9.8	53.7	9.6	<5	<5	<5	<5	21.3
Fluoranthene	1170	64	65	30	115	1390	202	972	160	24	71	68	21	348
Pyrene	905	55	54	26	97	1050	160	749	144	23	62	57	19	338
Total PAHs	5094.7	557.9	351.5	232.5	617	6350.2	935.2	4451	771	218.5	356	336.3	126.5	1953.9

Table 6. Whole-sediment data for Macaulay Point stations collected in 2004 (continued).

Chemical of Potential Concern (COPC)	M2SW	M2W	M4E	M4SE	M4SW	M4W	M8E	M8W	MO
Metals (mg/kg)									
Arsenic	4.82	5.19	4.80	4.67	4.10	4.13	5.31	3.58	11.9
Cadmium	0.293	0.293	0.215	0.232	0.165	0.223	0.178	0.135	0.739
Chromium	35.3	31.5	30.8	24.5	33.0	30.7	26.9	28.1	43.9
Copper	24.0	22.1	29.9	37.3	16.8	18.2	202	15.5	143
Lead	11.0	24.7	80.7	38.0	11.6	7.99	183	8.23	193
Mercury	0.0493	0.0489	0.0531	0.0486	0.0410	0.0402	0.0817	0.0364	2.27
Zinc	83.0	75.5	75.6	61.1	60.3	59.9	273	54.2	148
PAHs (µg/kg)									
2-Methylnaphthalene	22	29	28	189	19	26	49	24	49
Acenaphthene	<5	<5	11.2	<30	<5	<5	<8	<5	16
Acenaphthylene	<5	<5	3.8	<20	<5	<5	10	<5	8.3
Anthracene	<10	14	34	28	<10	<10	18	<10	68
Fluorene	<10	<10	17	66	<10	<10	13	<10	19
Naphthalene	11	18	23	41	<10	14	34	14	40
Phenanthrene	40	67	120	398	30	47	100	31	195
Benz(a)anthracene	12	34	56	73	<10	16	46	<10	218
Benzo(a)pyrene	10	27	51	60	<10	13	38	<10	185
Chrysene	14	35	51	74	<10	13	38	<10	193
Dibenz(a,h)anthracene	<5	<5	6.6	9.1	<5	<5	<5	<5	26.6
Fluoranthene	28	72	114	126	12	32	105	20	450
Pyrene	23	58	107	116	11	33	104	18	365
Total PAHs	177.5	366.5	622.6	1205.1	109.5	211.5	561.5	139.5	1832.9

Table 7. Whole-sediment data for Clover Point stations collected in 2000.

Chemical of Potential Concern (COPC)	CO	C1NE	C1NW	C1SE	C1SW	C2E	C2S	C2W	C4E	C4SE	C4SW	C4W	C8E	C8W
Metals (mg/kg)														
Arsenic	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.35	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	47	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead	18.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	0.13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	53	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PAHs (µg/kg)														
2-Methylnaphthalene	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benz(a)anthracene	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	230	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total PAHs	1140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = no data (no samples were collected from these sites in 2000).
NA = not analysed (this substance was not analysed during this sampling period).

Table 8. Whole-sediment data for Clover Point stations collected in 2001.

Chemical of Potential Concern (COPC)	CO	C1NE	C1NW	C1SE	C1SW	C2E	C2S	C2W	C4E	C4SE	C4SW	C4W	C8E	C8W
Metals (mg/kg)														
Arsenic	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.53	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	107	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	112	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead	59	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	2.77	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	224	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PAHs (µg/kg)														
2-Methylnaphthalene	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	<10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	190	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	560	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benz(a)anthracene	1090	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	610	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	1220	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	2100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	1700	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total PAHs	7625	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = no data (no samples were collected from these sites in 2001).
NA = not analysed (this substance was not analysed during this sampling period).

Table 9. Whole-sediment data for Clover Point stations collected in 2002.

Chemical of Potential Concern (COPC)	CO	C1NE	C1NW	C1SE	C1SW	C2E	C2S	C2W	C4E	C4SE	C4SW	C4W	C8E	C8W
Metals (mg/kg)														
Arsenic	5.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.62	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	47	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	133	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead	128.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	0.512	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	147	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PAHs (µg/kg)														
2-Methylnaphthalene	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	31	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	40	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	90	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	40	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	260	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benz(a)anthracene	250	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	270	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	210	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	35	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	480	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	420	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total PAHs	2176	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = no data (no samples were collected from these sites in 2002).

Table 10. Whole-sediment data for Clover Point stations collected in 2003.

Chemical of Potential Concern (COPC)	C1NE	C1NW	C1SE	C1SW	C2E	C2S	C2W	C4E	C4SE	C4SW	C4W	C8E	C8W	CO
Metals (mg/kg)														
Arsenic	3.9	4	4.8	4.4	7.1	4.9	4.1	4.3	5.1	5.2	4.4	4.6	5.1	7.1
Cadmium	0.184	0.197	0.221	0.171	0.436	0.152	0.179	0.151	0.145	0.135	0.167	0.134	0.165	0.613
Chromium	22.3	22.6	24.8	22.1	25.8	28.3	22.3	20.8	32.3	26.6	24.6	25	26	37.6
Copper	12.3	14.9	13.4	11.1	17.3	12.3	12.1	10.1	13.8	15.7	15.1	12.3	13.6	172
Lead	5.3	6.2	5.7	4.7	8.9	6.1	4.8	5.1	6.9	55	4.7	5	6.4	58.6
Mercury	0.0261	0.0282	0.063	0.298	0.441	0.0261	0.025	0.0223	0.0259	0.0253	0.0231	0.0187	0.0311	0.158
Zinc	35.5	37.8	39.5	32.7	43.6	39.5	31.6	30	43.9	37.4	43.8	34.2	39.5	105
PAHs (µg/kg)														
2-Methylnaphthalene	16	16	22	12	19	13	40	11	14	<10	12	<10	18	21
Acenaphthene	<7	<8	<20	<7	<20	<3	<5	<9	<7	<2	<2	<6	<5	294
Acenaphthylene	3.4	<2	3.4	<2	4.6	<2	<2	2.3	<2	<2	<5	<2	3.2	33.5
Anthracene	13	<10	47	<10	55	<10	<10	20.05	<10	<10	<10	20	<10	522
Fluorene	<10	<10	11	<10	13	<10	<10	<10	<10	<10	<10	<10	<10	192
Naphthalene	24	10	15	<10	13	<10	23	<10	<10	<10	<10	<10	<10	28
Phenanthrene	56	20	130	17	136	17	23	33	19	16	25	69	35	2070
Benz(a)anthracene	12	<10	99	<10	142	<10	<10	45	<10	<10	14	63	59	1140
Benzo(a)pyrene	13	<10	108	<10	185	<10	<10	50	<10	<10	26	41	52	945
Chrysene	13	<10	121	<10	129	<10	<10	61	<10	<10	20	74	64	1100
Dibenz(a,h)anthracene	2	<2	16	<2	32	<2	<2	8	<2	<2	3	5	11	173
Fluoranthene	40	<10	220	<10	320	<10	10	160	<10	<10	30	120	70	2360
Pyrene	33	<10	205	<10	250	<10	13	156	<10	<10	38	119	82	1840
Total PAHs	233.9	87	1007.4	74.5	1308.6	73.5	138.5	560.85	78.5	64	186.5	530	411.7	10718.5

Table 11. Whole-sediment data for Clover Point stations collected in 2004.

Chemical of Potential Concern (COPC)	CO	C1NE	C1NW	C1SE	C1SW	C2E	C2S	C2W	C4E	C4SE	C4SW	C4W	C8E	C8W
Metals (mg/kg)														
Arsenic	1.93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.512	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	57.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	254	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead	155	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	0.876	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	167	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PAHs (µg/kg)														
2-Methylnaphthalene	<10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	<5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	32.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	35	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	<10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	<10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	80	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benz(a)anthracene	134	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	121	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	18.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	241	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	216	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total PAHs	1025.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = no data (no samples were collected from these sites in 2004).

Table 12. Whole-sediment data for reference stations collected in 2000.

Chemical of Potential Concern (COPC)	Parry Bay 1	Parry Bay 2	Parry Bay 3	CB1	CB2	CB3
Metals (mg/kg)						
Arsenic	4.2	5.6	5.5	3.9	ND	ND
Cadmium	0.07	0.07	0.07	0.13	ND	ND
Chromium	31	32	33	23	ND	ND
Copper	12	14	14	12	ND	ND
Lead	6.2	6.3	6.7	4.6	ND	ND
Mercury	0.055	0.035	0.032	0.023	ND	ND
Zinc	50	55	55	37	ND	ND
PAHs (μg/kg)						
2-Methylnaphthalene	NA	NA	NA	NA	ND	ND
Acenaphthene	<10	<10	<10	<10	ND	ND
Acenaphthylene	<10	10	<10	<10	ND	ND
Anthracene	<10	30	<10	<10	ND	ND
Fluorene	<10	20	<10	<10	ND	ND
Naphthalene	10	20	20	10	ND	ND
Phenanthrene	30	100	40	60	ND	ND
Benz(a)anthracene	<10	30	<10	20	ND	ND
Benzo(a)pyrene	<10	30	<10	20	ND	ND
Chrysene	10	40	10	20	ND	ND
Dibenz(a,h)anthracene	<10	<10	<10	<10	ND	ND
Fluoranthene	<10	90	10	30	ND	ND
Pyrene	<10	90	10	50	ND	ND
Total PAHs	95	470	125	235	ND	ND

ND = no data (no samples were collected from these sites in 2000).
NA = not analysed (this substance was not analysed during this sampling period).
[1]Stations referred to as Constance Bank or CB were assumed to be equivalent to station CB1 as reported in later years, however no coordinates were available to confirm this assumption.

Table 13. Whole-sediment data for reference stations collected in 2001.

Chemical of Potential Concern (COPC)	Parry Bay 1	Parry Bay 2	Parry Bay 3	CB1	CB2	CB3
Metals (mg/kg)						
Arsenic	6	6	6	5	ND	ND
Cadmium	0.16	0.07	0.06	0.23	ND	ND
Chromium	34	32	31	24	ND	ND
Copper	14	12	13	11	ND	ND
Lead	7	7	8	5	ND	ND
Mercury	0.032	0.033	0.035	0.024	ND	ND
Zinc	50	48	51	36	ND	ND
PAHs (µg/kg)						
2-Methylnaphthalene	NA	NA	NA	NA	ND	ND
Acenaphthene	<10	<10	<10	<10	ND	ND
Acenaphthylene	<10	<10	<10	<10	ND	ND
Anthracene	<10	<10	<10	<10	ND	ND
Fluorene	<10	<10	<10	<10	ND	ND
Naphthalene	10	10	<10	<10	ND	ND
Phenanthrene	30	30	20	10	ND	ND
Benz(a)anthracene	<10	<10	<10	<10	ND	ND
Benzo(a)pyrene	<10	<10	<10	<10	ND	ND
Chrysene	<10	<10	<10	<10	ND	ND
Dibenz(a,h)anthracene	<10	<10	<10	<10	ND	ND
Fluoranthene	<10	<10	<10	<10	ND	ND
Pyrene	10	<10	<10	<10	ND	ND
Total PAHs	95	90	75	65	ND	ND

ND = no data (no samples were collected from these sites in 2000).
NA = not analysed (this substance was not analysed during this sampling period).
[1]Stations referred to as Constance Bank or CB were assumed to be equivalent to station CB1 as reported in later years, however no coordinates were available to confirm this assumption.

Table 14. Whole-sediment data for reference stations collected in 2002.

Chemical of Potential Concern (COPC)	Parry Bay 1	Parry Bay 2	Parry Bay 3	CB1[1]	CB2	CB3
Metals (mg/kg)						
Arsenic	5.5	6.1	5.8	4.3	ND	ND
Cadmium	0.13	0.13	0.12	0.15	ND	ND
Chromium	36	36	37	25	ND	ND
Copper	12	12	15	10	ND	ND
Lead	8.8	7.2	8.3	7.1	ND	ND
Mercury	0.025	0.02	0.022	0.063	ND	ND
Zinc	48	53	58	34	ND	ND
PAHs (µg/kg)						
2-Methylnaphthalene	20	20	20	10	ND	ND
Acenaphthene	<5	<5	<5	<5	ND	ND
Acenaphthylene	<5	<5	<5	<5	ND	ND
Anthracene	<10	<10	<10	<10	ND	ND
Fluorene	<10	<10	<10	<10	ND	ND
Naphthalene	10	<10	10	<10	ND	ND
Phenanthrene	30	20	20	20	ND	ND
Benz(a)anthracene	<10	<10	<10	<10	ND	ND
Benzo(a)pyrene	<10	<10	<10	<10	ND	ND
Chrysene	<10	10	<10	<10	ND	ND
Dibenz(a,h)anthracene	<5	<5	<5	<5	ND	ND
Fluoranthene	<10	10	<10	<10	ND	ND
Pyrene	<10	10	<10	<10	ND	ND
Total PAHs	102.5	102.5	92.5	77.5	ND	ND

ND = no data (no samples were collected from these sites in 2000).

[1]Stations referred to as Constance Bank or CB were assumed to be equivalent to station CB1 as reported in later years, however no coordinates were available to confirm this assumption.

Table 15. Whole-sediment data for reference stations collected in 2003.

Chemical of Potential Concern (COPC)	Parry Bay 1	Parry Bay 2	Parry Bay 3	CB1	CB2	CB3
Metals (mg/kg)						
Arsenic	5.9	5.8	5.6	5.1	3.6	3.6
Cadmium	0.129	0.125	0.112	0.128	0.105	0.117
Chromium	35.1	33.7	36.3	27	19.8	16.7
Copper	13.5	13.4	16.7	12.1	8.7	7.8
Lead	6.6	6.9	7.8	5.3	3.8	3.3
Mercury	0.0319	0.0316	0.036	0.0262	0.0151	0.0152
Zinc	53.2	50.5	59	39.4	28.5	27.6
PAHs (µg/kg)						
2-Methylnaphthalene	15	23	24	<10	<10	<10
Acenaphthene	<3	<2	<2	<2	<5	<5
Acenaphthylene	<2	<2	5.6	<2	<2	<2
Anthracene	<10	<10	<10	<10	13	<10
Fluorene	<10	<10	<10	<10	<10	<10
Naphthalene	<10	10	11	<10	<10	<10
Phenanthrene	21	34	37	<10	24	11
Benz(a)anthracene	<10	<10	23	<10	21	<10
Benzo(a)pyrene	<10	<10	19	<10	10	<10
Chrysene	<10	12	25	<10	28	<10
Dibenz(a,h)anthracene	<2	<2	2	<2	<2	<2
Fluoranthene	<10	20	20	<10	40	<10
Pyrene	<10	14	24	<10	10	<10
Total PAHs	79.5	136	201.6	<106	165.5	60.5

ND = no data (no samples were collected from these sites in 2000).

Table 16. Whole-sediment data for reference stations collected in 2004.

Chemical of Potential Concern (COPC)	Parry Bay 1	Parry Bay 2	Parry Bay 3	CB1	CB2	CB3
Metals (mg/kg)						
Arsenic	4.63	4.44	4.52	4.17	ND	ND
Cadmium	0.125	0.125	0.112	0.154	ND	ND
Chromium	30.9	30.5	33.1	26.8	ND	ND
Copper	13.5	12.9	18.9	15.1	ND	ND
Lead	6.89	6.19	7.74	6.09	ND	ND
Mercury	0.0337	0.0301	0.0395	0.0333	ND	ND
Zinc	53.0	51.3	63.5	44.1	ND	ND
PAHs (µg/kg)						
2-Methylnaphthalene	18	19	26	11	ND	ND
Acenaphthene	<5	<5	<5	<5	ND	ND
Acenaphthylene	<5	<5	<5	<5	ND	ND
Anthracene	<10	<10	<10	<10	ND	ND
Fluorene	<10	<10	<10	<10	ND	ND
Naphthalene	<10	<10	10	<10	ND	ND
Phenanthrene	25	29	42	18	ND	ND
Benz(a)anthracene	<10	14	<10	<10	ND	ND
Benzo(a)pyrene	<10	<10	<10	<10	ND	ND
Chrysene	<10	11	<10	<10	ND	ND
Dibenz(a,h)anthracene	<5	<5	<5	<5	ND	ND
Fluoranthene	<10	32	<10	<10	ND	ND
Pyrene	<10	29	<10	<10	ND	ND
Total PAHs	90.5	161.5	120.5	76.5	ND	ND

ND = no data (no samples were collected from these sites in 2000).

Table 17. Comparison of 90th percentile COPC concentrations in sediment samples from the Macaulay Point Area of Environmental Concern (MP AEC) to the generic numerical sediment criteria.

Chemical of Potential Concern (COPC)	MP AEC Within IDZ				MP AEC Outside IDZ			
	$GNSC_{TCS}$	n	90th percentile concentration	Concentrations sufficient to warrant designation as a contaminated site?[1]	$GNSC_{SCS}$	n	90th percentile concentration	Concentrations sufficient to warrant designation as a contaminated site?[1]
Metals (mg/kg)								
Arsenic	50	5	11.54	NO	26	110	8.04	NO
Cadmium	5	5	1.1252	NO	2.6	110	0.5978	NO
Chromium	190	5	66	NO	99	110	38.1	NO
Copper	130	5	270.2	**YES**	67	110	80.1	**YES**
Lead	130	5	1021	**YES**	69	110	98.77	**YES**
Mercury	0.84	5	2.086	**YES**	0.43	110	0.4857	**YES**
Zinc	330	5	316.2	NO	170	110	125.2	NO
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg)								
2-Methylnaphthalene	240	3	77.8	NO	120	66	96	NO
Acenaphthene	110	5	295.6	**YES**	55	110	106	**YES**
Acenaphthylene	150	5	75.6	NO	79	109	20.46	NO
Anthracene	290	5	393.4	**YES**	150	110	272	**YES**
Fluorene	170	5	167.2	NO	89	110	102	**YES**
Naphthalene	470	5	128	NO	240	109	70	NO
Phenanthrene	650	5	1610	**YES**	340	110	931.9	**YES**
Benz(a)anthracene	830	5	1012	**YES**	430	110	533	**YES**
Benzo(a)pyrene	920	5	920.8	**YES**	470	110	516.5	**YES**
Chrysene	1000	5	910.8	NO	520	110	511	NO
Dibenz(a,h)anthracene	160	5	121.2	NO	84	110	54.03	NO
Fluoranthene	1800	5	2110	**YES**	930	110	1174	**YES**
Pyrene	1700	5	1878	**YES**	870	110	994.6	**YES**
Total PAHs	20000	5	9389.48	NO	10000	110	5192.241	NO
Mean $GNSC_{SCS}$-Q	NA	5	NA	NA	1	110	0.9692	NO
Mean $GNSC_{TCS}$-Q	1	5	1.1472	**YES**	NA	110	NA	NA

$GNSC_{TCS}$ = generic numerical sediment criteria for typical sites; $GNSC_{SCS}$ = generic numerical sediment criteria for sensitive sites; IDZ = initial dilution zone.

Table 18. Comparison of COPC concentrations in sediment samples from the Macaulay Point Area of Environmental Concern (MP AEC) to two times the generic numerical sediment criteria and the upper limit of background (ULB) concentrations.

Chemical of Potential Concern (COPC)	MP AEC Within IDZ			MP AEC Outside IDZ		
	Upper Limit of Background[1]	2 X $GNSC_{TCS}$	Does the concentration exceed 2X GNSC and the ULB Concentration in one or more samples?	Upper Limit of Background[1]	2 X $GNSC_{SCS}$	Does the concentration exceed 2X GNSC and the ULB Concentration in one or more samples?
Metals (mg/kg)						
Arsenic	6.756	100	NO	6.756	52	NO
Cadmium	0.1948	10	NO	0.1948	5.2	**YES**
Chromium	41.38	380	NO	41.38	198	NO
Copper	17.78	260	**YES**	17.78	134	**YES**
Lead	9.29	260	**YES**	9.29	138	**YES**
Mercury	0.0538	1.68	**YES**	0.0538	0.86	**YES**
Zinc	67.08	660	NO	67.08	340	**YES**
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg)						
2-Methylnaphthalene	30.46	480	NO	30.46	240	**YES**
Acenaphthene	6.18	220	**YES**	6.18	110	**YES**
Acenaphthylene	7.84	300	NO	7.84	158	**YES**
Anthracene	17.54	580	NO	17.54	300	**YES**
Fluorene	12.08	340	NO	12.08	178	**YES**
Naphthalene	17.43	940	NO	17.43	480	**YES**
Phenanthrene	69.2	1300	**YES**	69.2	680	**YES**
Benz(a)anthracene	23.87	1660	NO	23.87	860	**YES**
Benzo(a)pyrene	20.86	1840	NO	20.86	940	**YES**
Chrysene	29.4	2000	NO	29.4	1040	**YES**
Dibenz(a,h)anthracene	6.29	320	NO	6.29	168	**YES**
Fluoranthene	54.2	3600	NO	54.2	1860	**YES**
Pyrene	54.4	3400	NO	54.4	1740	**YES**
Total PAHs	305.2	40000	NO	305.2	20000	**YES**
Mean $GNSC_{SCS}$-Q	NA	NA	NA	0.1436	2	**YES**
Mean $GNSC_{TCS}$-Q	0.07442	2	NO	NA	NA	NA

$GNSC_{TCS}$ = generic numerical sediment criteria for typical sites; $GNSC_{SCS}$ = generic numerical sediment criteria for sensitive sites; IDZ = initial dilution zone.

[1]The upper limit of background concentration was calculated based on data from 22 samples (except for 2-Methylnaphthalene; n=14).

Table 19. Comparison of 90th percentile COPC concentrations in sediment samples from the Clover Point Area of Environmental Concern (CP AEC) to the generic numerical sediment criteria.

Chemical of Potential Concern (COPC)	CP AEC Within IDZ				CP AEC Outside IDZ			
	$GNSC_{TCS}$	n	90th percentile concentration	Concentrations sufficient to warrant designation as a contaminated site?[1]	$GNSC_{SCS}$	n	90th percentile concentration	Concentrations sufficient to warrant designation as a contaminated site?[1]
Metals (mg/kg)								
Arsenic	50	5	7.06	NO	26	13	5.18	NO
Cadmium	5	5	0.6172	NO	2.6	13	0.2162	NO
Chromium	190	5	87.08	NO	99	13	27.96	NO
Copper	130	5	221.2	**YES**	67	13	15.58	NO
Lead	130	5	144.32	**YES**	69	13	8.5	NO
Mercury	0.84	5	2.0124	**YES**	0.43	13	0.251	NO
Zinc	330	5	201.2	NO	170	13	43.76	NO
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg)								
2-Methylnaphthalene	240	3	20.8	NO	120	13	21.4	NO
Acenaphthene	110	5	188.8	**YES**	55	13	8.9	NO
Acenaphthylene	150	5	37.4	NO	79	13	3.4	NO
Anthracene	290	5	389.2	**YES**	150	13	41.61	NO
Fluorene	170	5	127.2	NO	89	13	9.8	NO
Naphthalene	470	5	52	NO	240	13	21.4	NO
Phenanthrene	650	5	1466	**YES**	340	13	117.8	NO
Benz(a)anthracene	830	5	1120	**YES**	430	13	91.8	NO
Benzo(a)pyrene	920	5	811	NO	470	13	96.8	NO
Chrysene	1000	5	1172	**YES**	520	13	111.6	NO
Dibenz(a,h)anthracene	160	5	127.8	NO	84	13	15	NO
Fluoranthene	1800	5	2256	**YES**	930	13	208	NO
Pyrene	1700	5	1784	**YES**	870	13	195.2	NO
Total PAHs	20000	5	9481.1	NO	10000	13	918.09	NO
Mean $GNSC_{SCS}$-Q	NA	5	NA	NA	1	13	0.1772	NO
Mean $GNSC_{TCS}$-Q	1	5	0.7928	NO	NA	13	NA	NA

$GNSC_{TCS}$ = generic numerical sediment criteria for typical sites; $GNSC_{SCS}$ = generic numerical sediment criteria for sensitive sites; IDZ = initial dilution zone.

Table 20. Comparison of COPC concentrations in sediment samples from the Clover Point Area of Environmental Concern (CP AEC) to two times the generic numerical sediment criteria and the upper limit of background (ULB) concentrations.

Chemical of Potential Concern (COPC)	CP AEC Within IDZ			CP AEC Outside IDZ		
	Upper Limit of Background[1]	2 X $GNSC_{TCS}$	Does the concentration exceed 2X GNSC and the ULB Concentration in one or more samples?	Upper Limit of Background[1]	2 X $GNSC_{SCS}$	Does the concentration exceed 2X GNSC and the ULB Concentration in one or more samples?
Metals (mg/kg)						
Arsenic	6.756	100	NO	6.756	52	NO
Cadmium	0.1948	10	NO	0.1948	5.2	NO
Chromium	41.38	380	NO	41.38	198	NO
Copper	17.78	260	NO	17.78	134	NO
Lead	9.29	260	NO	9.29	138	NO
Mercury	0.0538	1.68	**YES**	0.0538	0.86	NO
Zinc	67.08	660	NO	67.08	340	NO
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg)						
2-Methylnaphthalene	30.46	480	NO	30.46	240	NO
Acenaphthene	6.18	220	**YES**	6.18	110	NO
Acenaphthylene	7.84	300	NO	7.84	158	NO
Anthracene	17.54	580	NO	17.54	300	NO
Fluorene	12.08	340	NO	12.08	178	NO
Naphthalene	17.43	940	NO	17.43	480	NO
Phenanthrene	69.2	1300	**YES**	69.2	680	NO
Benz(a)anthracene	23.87	1660	NO	23.87	860	NO
Benzo(a)pyrene	20.86	1840	NO	20.86	940	NO
Chrysene	29.4	2000	NO	29.4	1040	NO
Dibenz(a,h)anthracene	6.29	320	NO	6.29	168	NO
Fluoranthene	54.2	3600	NO	54.2	1860	NO
Pyrene	54.4	3400	NO	54.4	1740	NO
Total PAHs	305.2	40000	NO	305.2	20000	NO
Mean $GNSC_{SCS}$-Q	NA	NA	NA	0.1436	2	NO
Mean $GNSC_{TCS}$-Q	0.07442	2	NO	NA	NA	NA

$GNSC_{TCS}$ = generic numerical sediment criteria for typical sites; $GNSC_{SCS}$ = generic numerical sediment criteria for sensitive sites; IDZ = initial dilution zone.

[1]The upper limit of background concentration was calculated based on data from 22 samples (except for 2-Methylnaphthalene; n=14).

Figure 1. General process for managing contaminated sites in British Columbia.

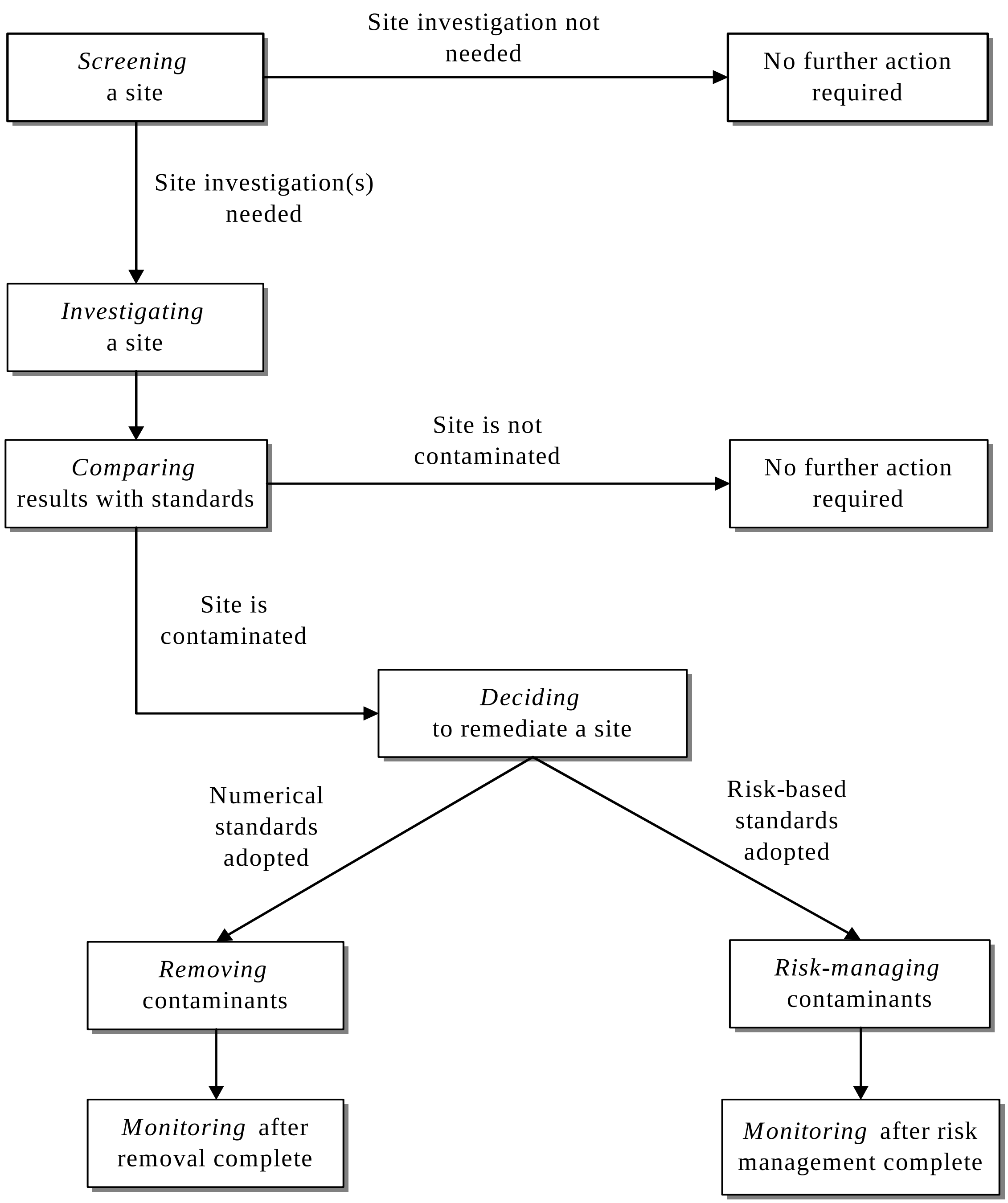

Figure 2. Overview of the recommended process for managing sediment contaminated sites in British Columbia.

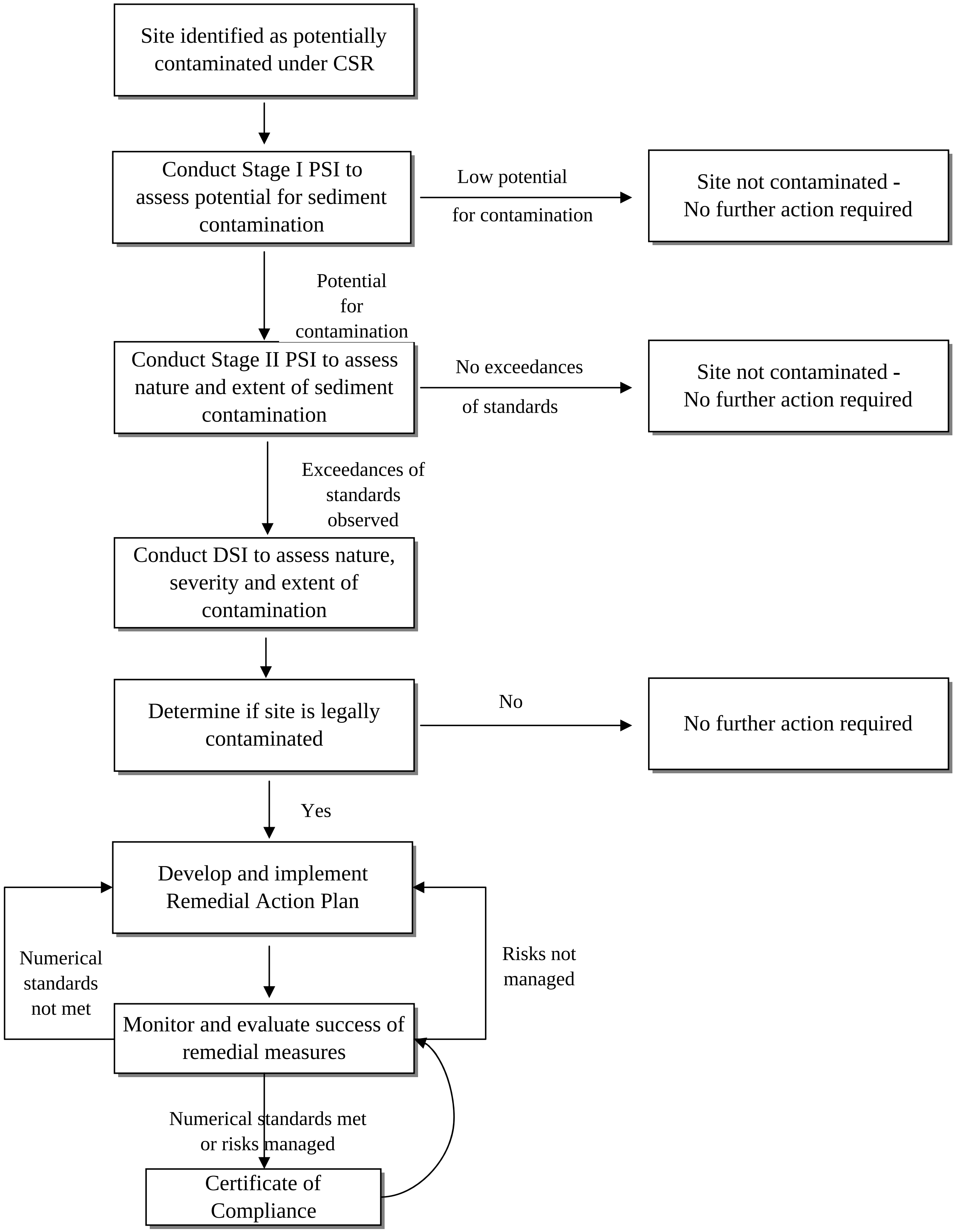

Figure 3. A map of the study area, showing sampling sites at Macaulay Point (CRD 2002).

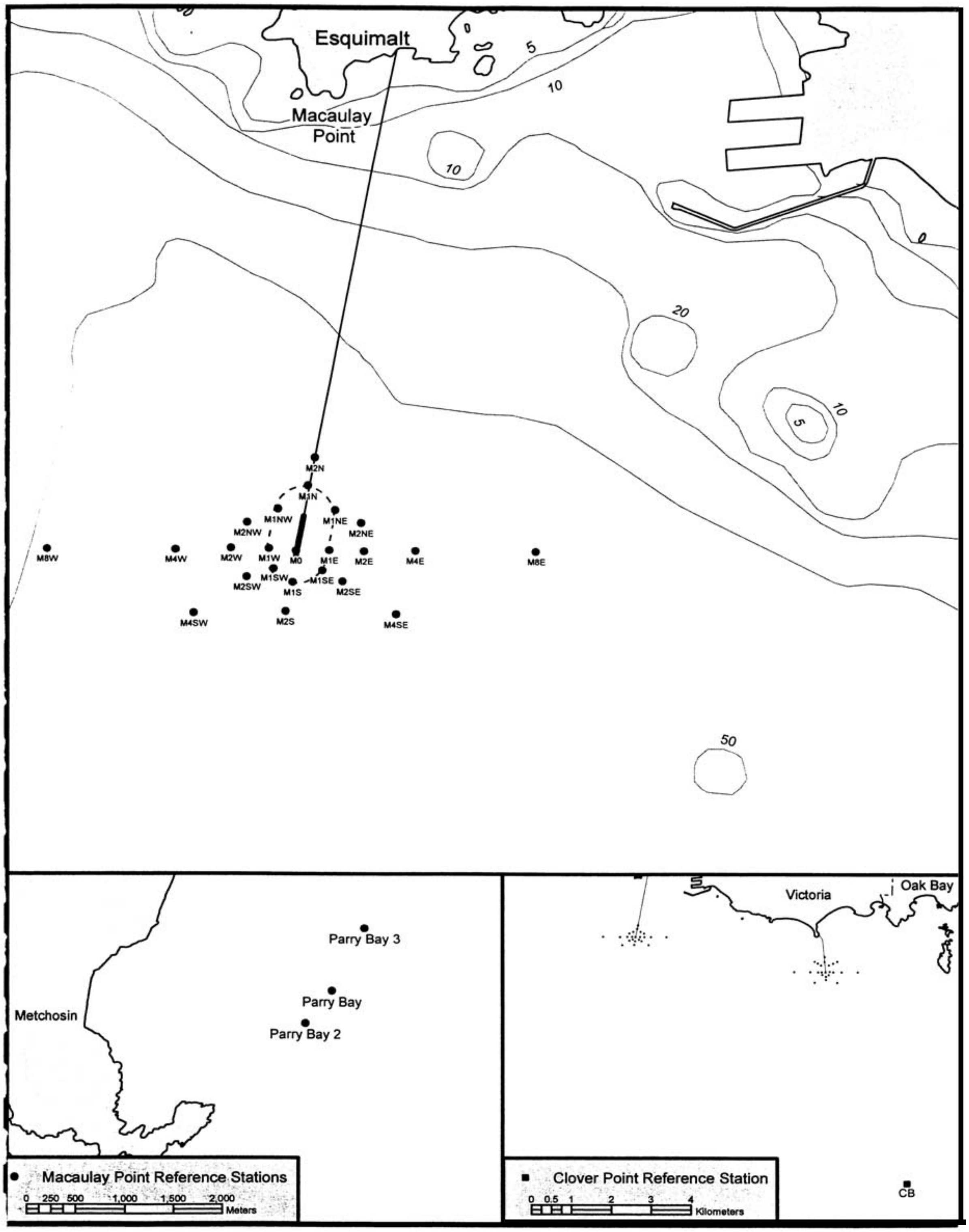

Figure 4. A map of the study area, showing sampling sites at Clover Point (CRD 2002).

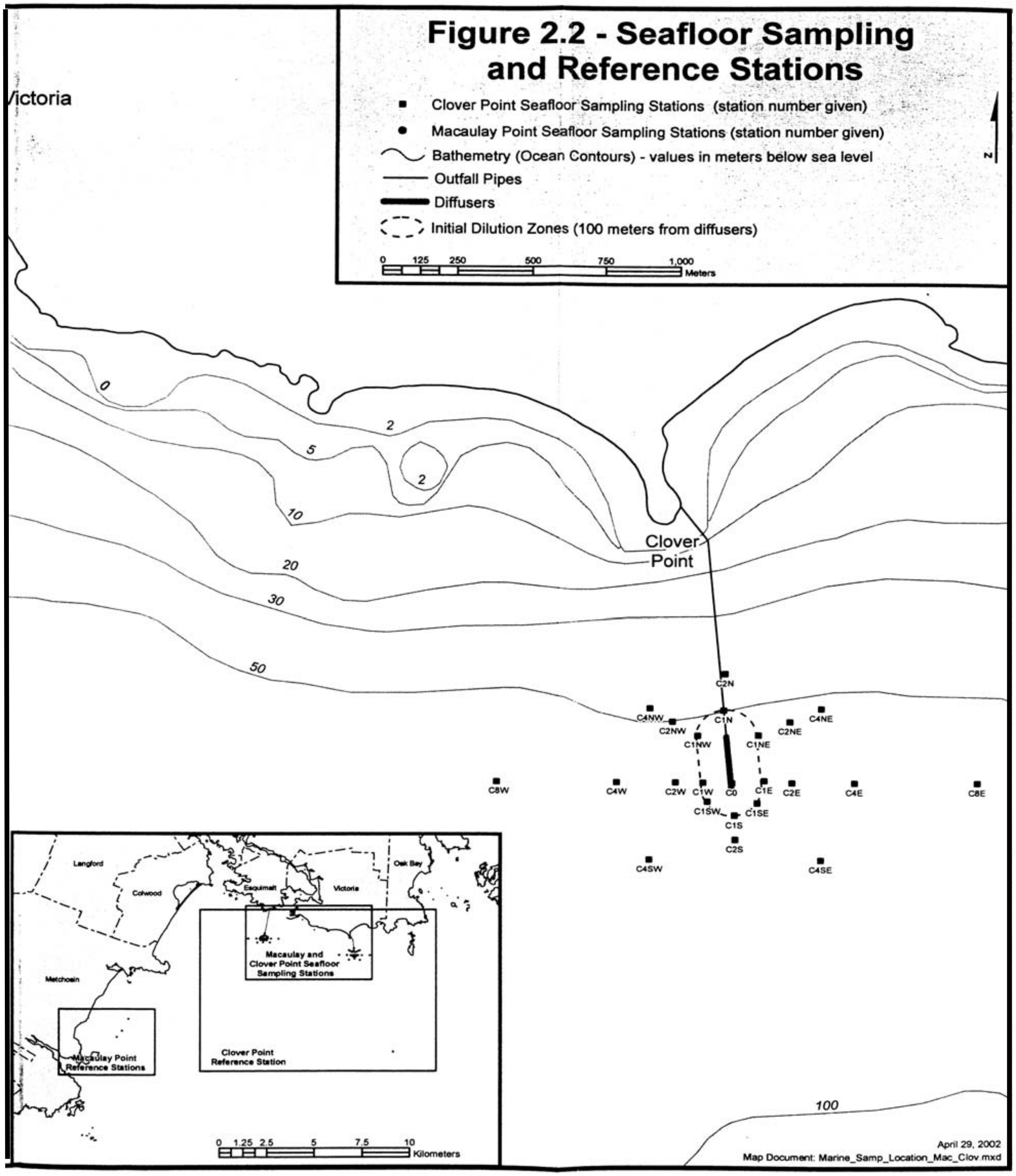

Figure 5. A map of the study area, showing sampling sites at Macaulay Point (CRD 2003).

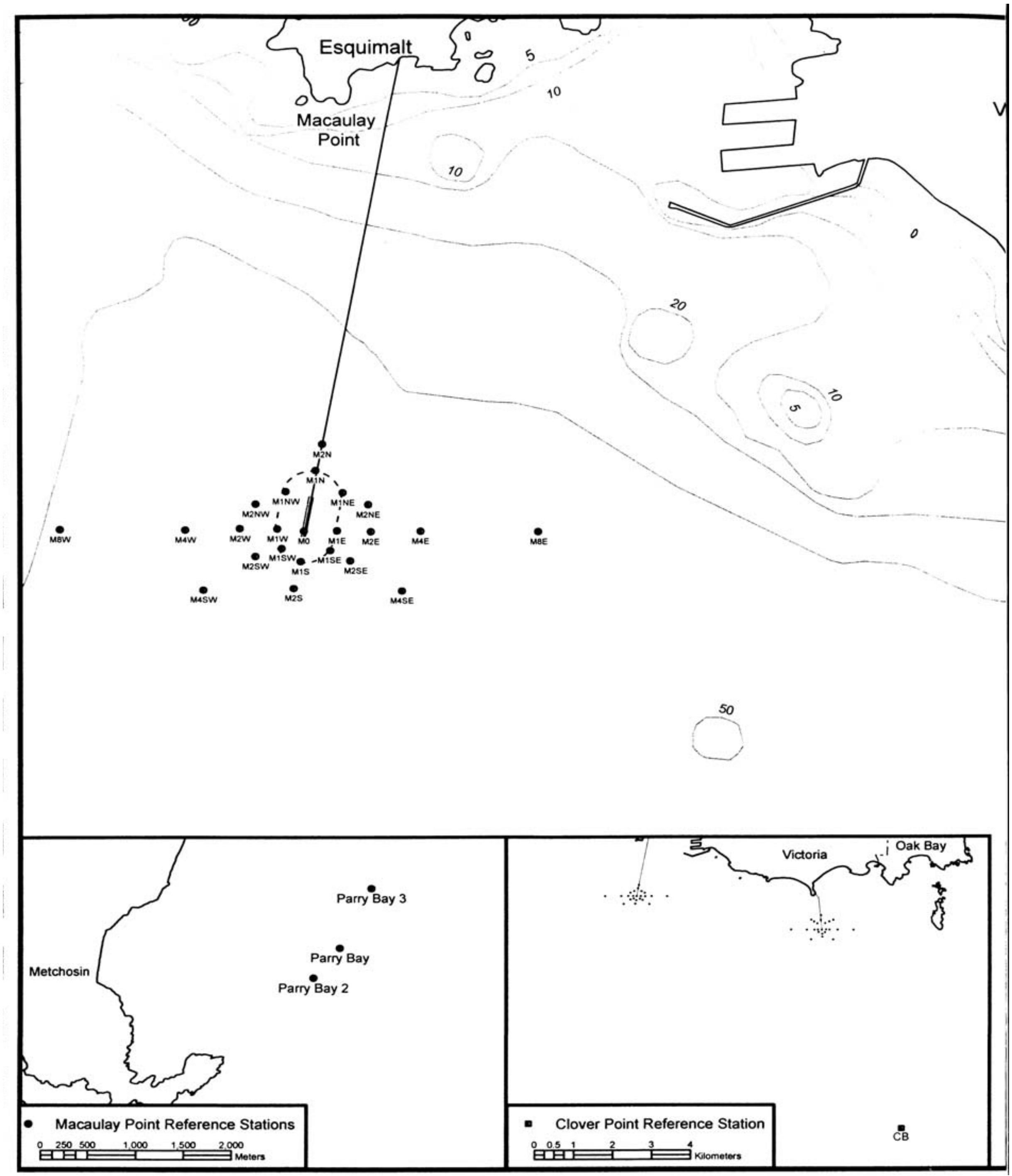

Figure 6. A map of the study area, showing sampling sites at Clover Point (CRD 2003).

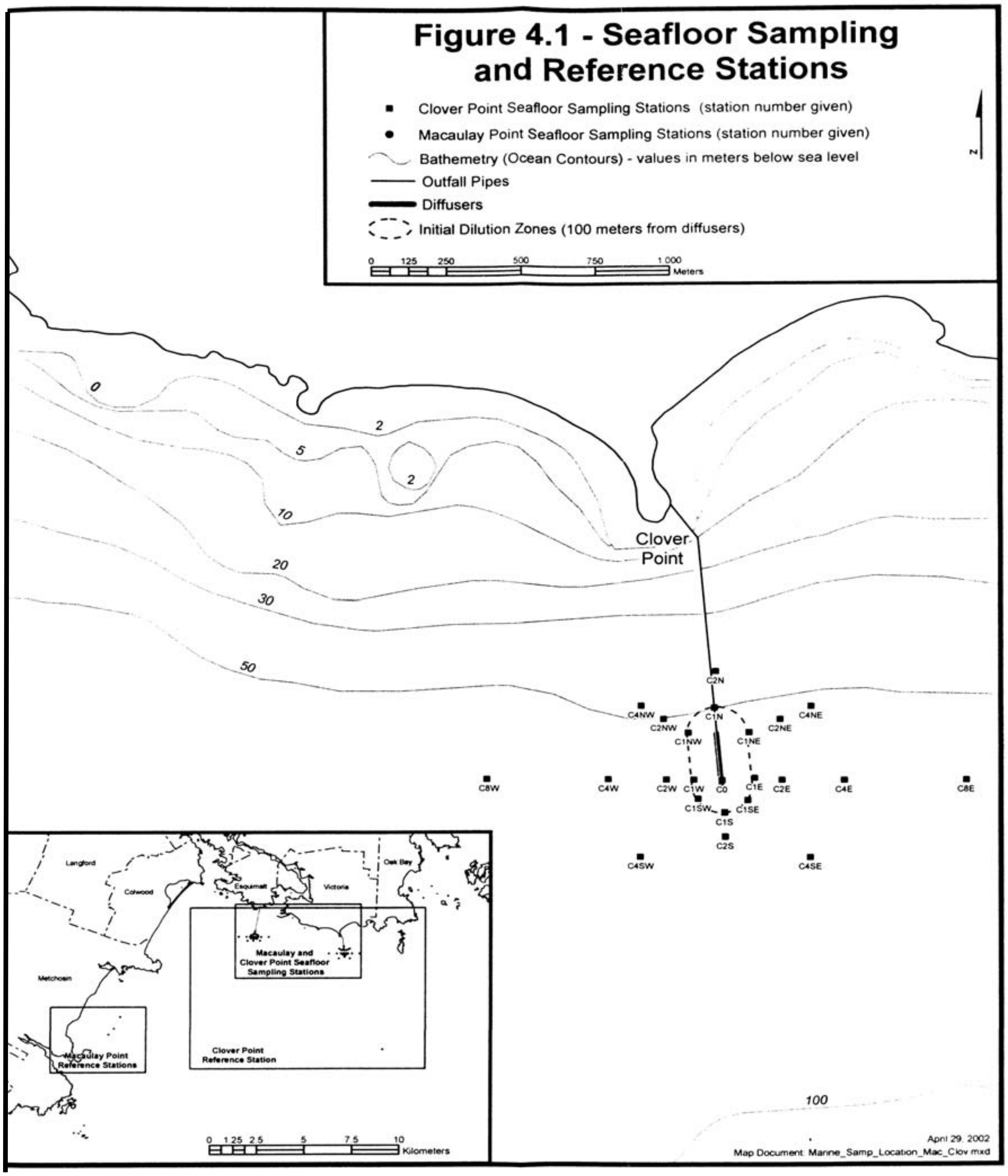

Figure 7. A map of the study area, showing sampling sites at Macaulay Point and Clover Point (CRD 2004).

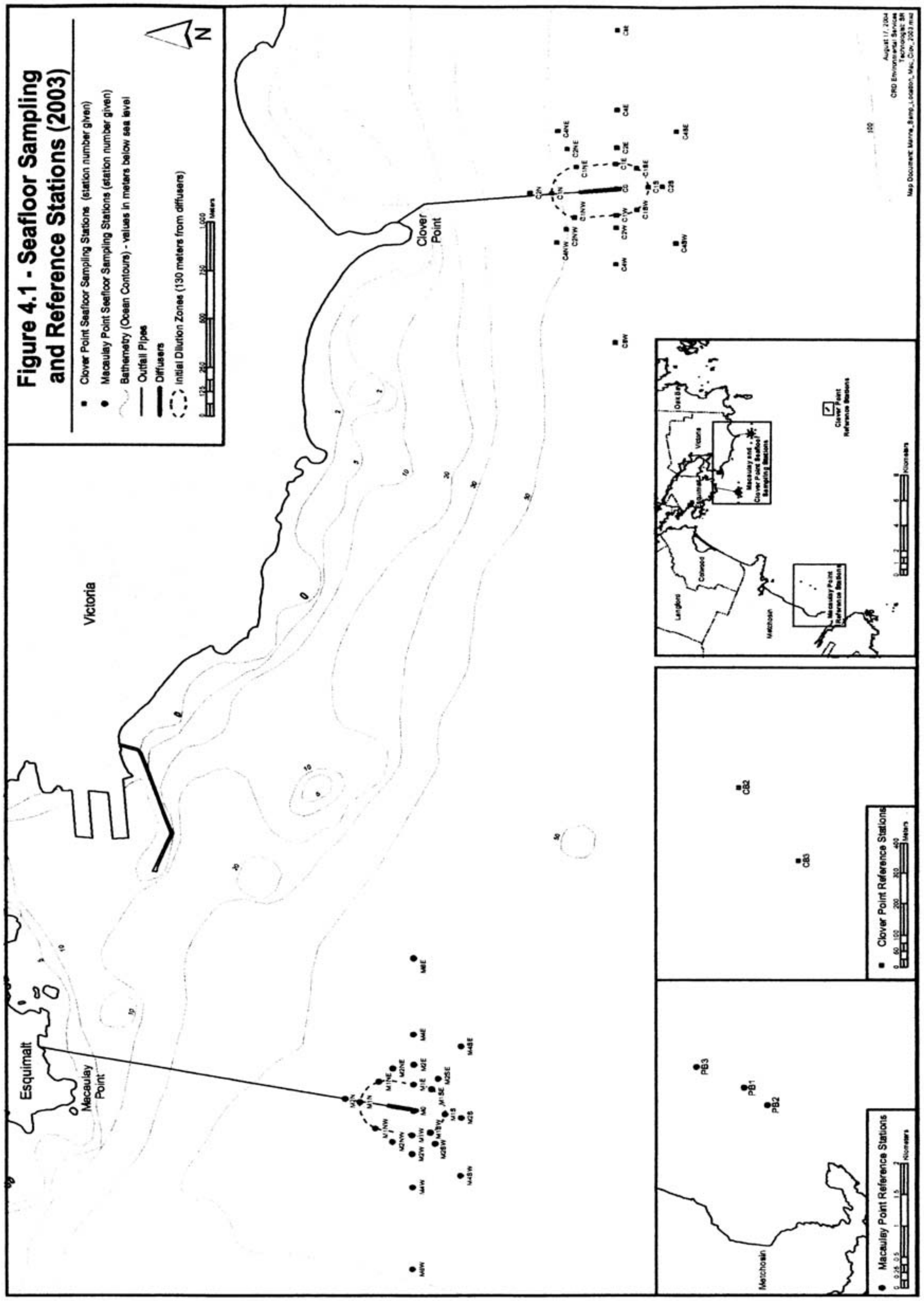

Figure 8. A map of the study area, showing sampling sites at Macaulay Point and Clover Point (CRD 2005a).