Scientific and Technical Review

Capital Regional District Core Area Liquid Waste Management Plan

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Mark Servos, PhD, Co-Chair
Richard M. Gersberg, PhD
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Submitted to the Capital Regional District Victoria, BC

Submitted July 12, 2006, by the Scientific and Technical Review Panel

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Chair Alan Lowe
Capital Regional District Board
625 Fisgard Street
PO Box 1000
Victoria, British Columbia V8W 2S6

The Panel is pleased to present their technical and scientific report on the management of liquid waste to the Capital Regional District (CRD) Board.

The CRD's intent to conduct a technical and scientific review was implicit in their decision to choose the Society of Environmental Toxicology and Chemistry (SETAC) North America to establish and manage the independent panel. As a science-based group, the Panel was equipped to provide the CRD Board with technical advice. One of the challenges the Panel faced in its work was determining what was "in" and what was "out" of the Panel's scope of work. For example, there were many discussions about whether regulatory and policy issues should be considered in making conclusions and recommendations. The Panel decided that their role was technical in nature and that their report should be offered to the Board in that context. Our advice is best considered along with other kinds of information (e.g., societal, feasibility, engineering, and regulatory) that the CRD Board should seek in making decisions about liquid waste management.

This report represents the consensus of all Panel members. Thank you for the opportunity to engage in debate on the challenges that lie ahead.

Sincerely,

Dr. William A. Stubblefield
Panel Chair

Left to right: William Stubblefield, David Simpson, Peter Wells, Craig Riley, Richard Gersberg, Daniel Smith, and Mark Servos

Scientific and Technical Review Panel Members

William A. Stubblefield, PhD, (Panel Chair) is a senior environmental toxicologist with Parametrix, Inc., and serves as a faculty member at Oregon State University, Department of Molecular and Environmental Toxicology. He has more than 20 years of experience in environmental toxicology, ecological risk assessment, water quality criteria derivation, and aquatic and wildlife toxicology studies. Dr. Stubblefield has authored more than 50 peer-reviewed publications and technical presentations in aquatic and wildlife toxicology and environmental risk assessment. He is a co-editor of a recently published book, *Re-evaluation of the State of the Science for Water Quality Criteria*, which examines the issues and approaches to be used in the evaluation of environmental impacts associated with contaminants.

Mark Servos, PhD, (Panel Co-Chair) holds a Canada Research Chair in Water Quality Protection in the Department of Biology, University of Waterloo. He is the Scientific Director of the Canadian Water Network, a national Network of Centres of Excellence on innovation in the water sector. His research and teaching program is focused on ecotoxicology, integrated water resources management, risk assessment, and management of emerging threats to water quality. His research includes examination of the risk management of pharmaceuticals and endocrine disruptors in municipal and industrial effluents and agricultural best practices.

Richard M. Gersberg, PhD, is currently a Professor (and Head of the Division) of Environmental Health in the Graduate School of Public Health at San Diego State University (SDSU), and Director of the Coastal and Marine Institute at SDSU. He has an M.S. degree in biology from the University of Houston and a PhD degree in microbiology from the University of California, Davis. Dr. Gersberg specializes in water quality research and has broad experience working with both chemical and microbiological pollutants and human health risk assessments. He has more than 55 scientific publications in these areas. Dr. Gersberg has conducted a number of studies on the detection, quantification, and risk posed by pathogens, including hepatitis A virus and enterovirus in estuaries and the ocean. He has conducted watershed modeling to evaluate loading of fecal bacterial indicators to various environments.

Craig L. Riley, PE, holds bachelors and masters degrees in civil engineering from Montana State University. He is a registered professional engineer in two states with more than 30 years of professional experience in both private and public sectors. His experience includes all aspects of planning, design, construction, operation, and management of public municipal utilities, including potable water, wastewater, storm water, and water reclamation and reuse facilities. He is currently the Program Lead for the Washington State Department of Health, Water Reclamation and Reuse Program where he is involved in the review and approval of reclamation planning and construction documents, promotion of water reclamation in the development of technical policies, treatment standards, and new regulations. Mr. Riley is active on planning, water reuse and water resources committees of the Water Environment Federation and American Water Works Association as well as several publication review committees.

R. David Simpson, PhD, is an economist with the United States Environmental Protection Agency's National Center for Environmental Economics. Beginning in September 2006 he will take up an appointment as HRH Prince Sultan bin Abdul Aziz Chair in Environmental Policy at Johns Hopkins University's School of Advanced International Studies.

Previously Dr. Simpson was a Senior Fellow at Resources for the Future and a Visiting Professor at University College London. His work has focused on the economics of biological diversity and biological resources, as well as technology and industrial policy. He participated in the Millennium Ecosystem Assessment and other international undertakings, has edited several books, and written many journal articles, book chapters, and contributions to policy publications. Dr. Simpson received his PhD in economics from Massachusetts Institute of Technology and his BA in economics from Whitman College.

Daniel W. Smith, PEng, PhD, is the Canada Research Chair in Environmental Engineering and a Fellow of the Academy of Science of The Royal Society of Canada. As a Professor of the Environmental Engineering and Science Program at the University of Alberta, he has guided more than 80 masters and 20 doctorate graduate students to the completion of their degrees and has published more than 400 scientific and technical articles. Dr. Smith is one of three Co-Directors of the new Alberta Ingenuity Centre for Water Research and a Co-Principal Investigator in the Forest Watershed and Riparian Disturbance Project. Following receipt of his doctorate in Environmental Health Engineering from the University of Kansas and 8 years of service for various agencies, Dr. Smith joined the University of Alberta in 1978. Dr. Smith has served in numerous other professional capacities, including President of the Canadian Society for Civil Engineering in 1987–88, the Rudolph Hering Medal 2002 for the best Journal of Environmental Engineering paper, Elbert F. Rice, Can-Am Awards and the Harold R. Peyton Award for Cold Regions Engineering (2004) from ASCE, and member of the Water Environment Federation Research and Program Committees.

Peter Wells, PhD, has worked as a Senior Research Scientist and Environmental Manager for Environment Canada (Dartmouth, NS) for more than 30 years. His long-term research interests are aquatic and marine ecotoxicology, coastal ecology, and science for integrated coastal management, most recently addressing issues in the Bay of Fundy and Gulf of Maine. Dr. Wells holds academic appointments at the School for Resource and Environmental Studies and the Marine Affairs Program, Dalhousie University, Halifax; the Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS; and the Bermuda Biological Station for Research, St. Georges, Bermuda. He teaches and supervises graduate students in marine ecotoxicology and ecological risk assessment. Dr. Wells has served on various technical committees in North America and has served Canada on the United Nations Joint Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP) for 16 years. He has written, contributed to, or edited more than 250 publications in his field. Dr. Wells is a Fellow of the American Association for the Advancement of Science (2000), a recipient of the Society of Environmental Toxicology and Chemistry (SETAC) Presidential Citation for Outstanding Service to the field (2002), and a recipient of Dalhousie University's highest award for Teaching Excellence by Part-Time Faculty (2003).

Panel Support

The Panel's work was supported by a number of individuals. **Beth Power, MSc RPBio,** of Azimuth Consulting Group Inc. was contracted to manage the overall project and provide liaison with the CRD. She is an environmental consultant with a strong interest in science policy and decision-making. **Leslie Rodgers** of Praxis Pacific coordinated the public submissions process and communications.

SETAC North America staff provided ongoing support during the Panel's work. **Taylor Mitchell** was responsible for administrative support, media contact, and document production, which was all much appreciated by the Panel. **Linda Stivers** handled invoicing and budget tracking. **Mimi Meredith** assisted with document production.

About SETAC

The Society of Environmental Toxicology and Chemistry (SETAC) is a nonprofit, worldwide professional society comprised of individuals and institutions engaged in:

- the study, analysis, and solution of environmental problems
- the management and regulation of natural resources
- environmental education
- research and development .

SETAC's mission is to support the development of principles and practices for protection, enhancement and management of sustainable environmental quality and ecosystem integrity.

The founding principles of SETAC are:

- Multidisciplinary approaches to solving environmental problems
- Sectorial balance: Academia, Business, Government
- Objectivity: Science-based.

For more information visit www.setac.org.



Contents

The Capital Regional District (CRD) established a Scientific and Technical Review Panel to review liquid waste management issues in the core area. Panel members were identified and selected by the Society of Environmental Toxicology and Chemistry North America (SETAC North America). The Panel was independent of the CRD and SETAC North America. The findings of the Panel do not represent the view of SETAC North America, the organizations of individual panel members, or the CRD.

1

Introduction

Background

The Capital Regional District (CRD) approached the Society of Environmental Toxicology and Chemistry North America (SETAC North America) to establish an independent Scientific and Technical Review Panel (hereafter referred to as “the Panel”) to evaluate aspects of the CRD’s Core Area Liquid Waste Management Plan (LWMP; CRD 2000). The physical extent of the Core Area is shown in Figures 1-1 and 1-2.

The provincially approved Core Area LWMP outlines the plans of the CRD and its municipal partners for the management of liquid waste from communities within the plan area for the next 25 years. Specific commitments are made in the following subject areas:

- Source control
- Management of inflow and infiltration
- Wastewater and marine assessment
- Stormwater quality management
- Harbours environmental action
- Management of trucked liquid waste
- Management of sewerage system overflows
- Wastewater treatment and disposal for areas serviced by municipal collection systems
- Wastewater treatment and disposal for areas not serviced by municipal collection systems.

The CRD considered that an independent review of aspects of the LWMP was necessary because

- the last independent analysis was conducted in the mid 1990s,
- new technologies have been developed, and
- there are new concerns related to emerging contaminants and their effects on the environment.

On 4 May 2004, the Core Area Liquid Waste Management Committee authorized CRD staff to commence negotiations with SETAC North America to coordinate the independent review. The Terms of Reference for the Panel were developed by the CRD and reviewed by the CRD Board (Appendix A). The purpose and values of the Panel and the principles of the review are described in Box 1.

Selection of the Scientific and Technical Review Panel

SETAC North America established an independent selections committee composed of Canadian and American members of the Society representing academia, business, and government (the 3 membership sectors of SETAC). The selections committee aimed for a panel composition that mirrored the cross-sectoral principles of SETAC.

A 7-person Panel was appointed in the winter of 2005. SETAC North America provided project management and administrative support for the Panel. The individuals on the

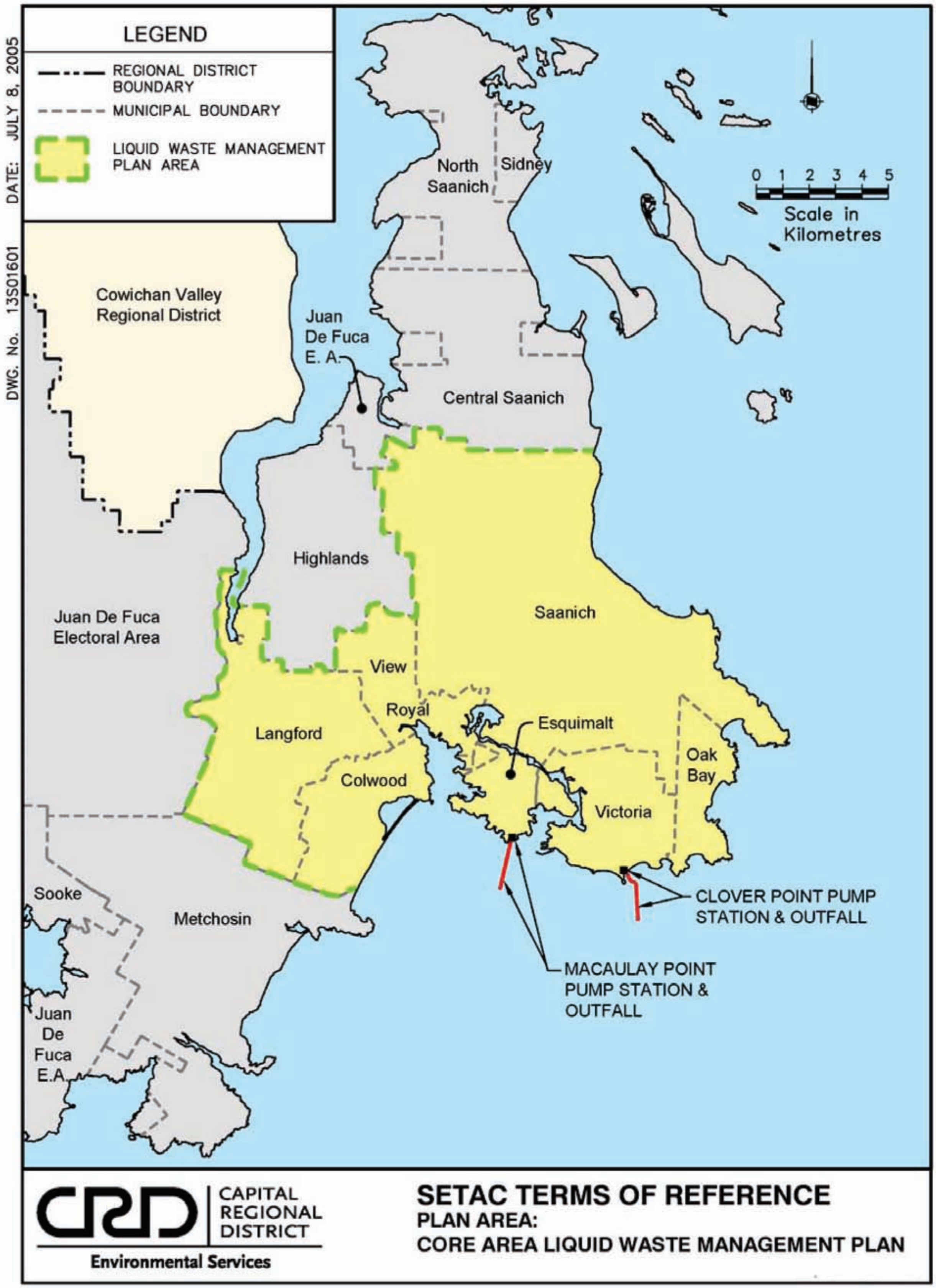


Figure 1-1: Physical extent of the Core Area LWMP (see Terms of Reference in Appendix A)

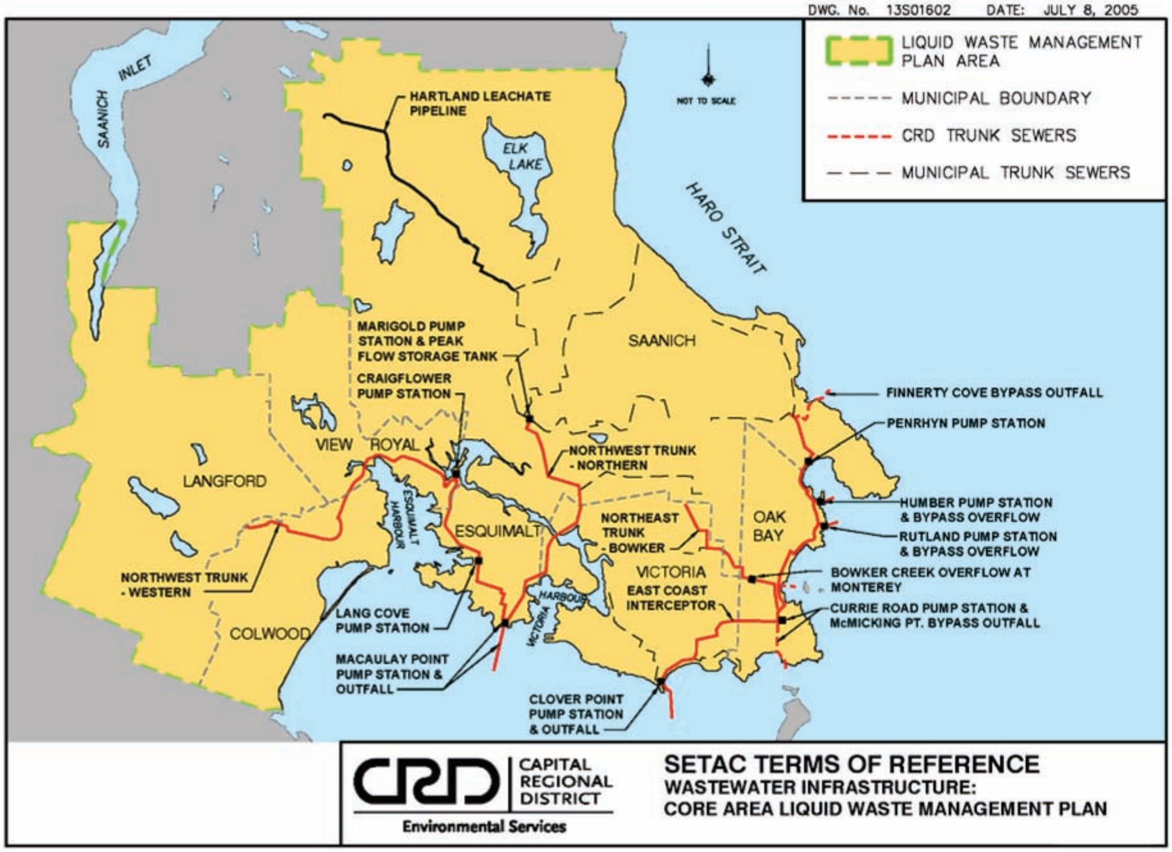


Figure 1-2: Wastewater infrastructure of the Core Area (see Terms of Reference in Appendix A)

Panel covered the main topics of the Panel's work:

- William A. Stubblefield, PhD, Chair: environmental toxicology
- Richard M. Gersberg, PhD: public health
- Craig L. Riley, PE: wastewater treatment, water reuse
- Mark Servos, PhD: risk assessment, effects of emerging chemicals
- R. David Simpson, PhD: economics of environmental systems
- Daniel W. Smith, PEng, PhD: wastewater treatment design
- Peter Wells, PhD: ecotoxicology and marine ecology

The Panel's Terms of Reference and Process

The CRD Scientific and Technical Review Panel was asked to conduct a broad review of the CRD's Core Area LWMP in 4 areas (within each of these areas, multiple questions were posed; see Terms of Reference in Appendix A):

A. The components of the CRD's Core Area LWMP (including leachate)

B. Future risks related to population growth, intensification of human uses of the environment, and emerging concerns related to specific chemicals

C. Alternative and new liquid waste management systems

D. The CRD's overall approach and assumptions regarding liquid waste management.

In December 2005, the Panel Chair and SETAC North America Project Manager met with CRD staff to clarify the Terms of Reference and the specific questions posed, begin the process of accessing technical information, and discuss the required site visit. At this time, the Panel signaled to the CRD that the responses to the questions would be technical,

Box 1: From the Panel's Terms of Reference

Purpose of Panel

The purpose of the scientific and technical review is

- to ensure the protection and quality of the environment and public health in the area of liquid waste management
- to engage a world-class, professional organization to review the Core Area LWMP and its assumptions
- to assess the adequacy of the approved LWMP to meet the needs of the region

Values of Panel

The scientific and technical review will be undertaken according to the following values:

- protection of public health
- protection of the environment
- sound scientific reasoning
- cost effectiveness

Principles of Review

The scientific and technical review will be guided by the following principles:

1. The CRD is committed to maintaining and enhancing the quality of the environment.
2. The CRD is committed to integrated coastal management whereby all sources of contaminant discharges to the coastal environment are evaluated and priority is given to solutions that produce the greatest benefits.
3. If any significant negative environmental effects are detected as a result of a CRD business practice, the organization will move immediately to correct the problem.

and as a result, the CRD would need to seek broader inputs on some issues.

After the initial meeting with the CRD, further liaison with CRD staff was always through the SETAC North America Project Manager. Early in the Panel's process, CRD staff or their consultants to the CRD were invited on two occasions to make presentations and answer questions on 1) an introduction to aspects of the LWMP and marine monitoring and 2) results of recent marine discharge plume modeling work. CRD staff also guided the site visit of CRD facilities on 20 February 2006 (Panel's trip report is provided as Appendix B).

Components of the Panel's work that required external technical support were identified early on, so that the additional work could get underway and be provided to the Panel. On behalf of the Panel, SETAC North America commissioned work from a number of consultants on specific topics or to fulfill specific contract requirements. A competitive process[1] was used. While most of the consultants to the Panel worked under the direction of the Panel, the Terms of Reference also required SETAC North America to identify and contract a third party to conduct a compliance review of the LWMP. Following a competitive process, Jacques Whitford was selected to conduct this review; they delivered their audit report (Appendix C) to SETAC North America, who then provided it to the CRD.

The following consultants' reports were prepared for the Panel, each of which is cited in the text as an appendix:

- Public Submissions Report (Praxis Pacific; Appendix D)
- Landfill Risk Assessment (Parametrix Inc., Appendix F)
- Wastewater Treatment Options Review (NAGM; Appendix H)

To facilitate their work, the Panel held four meetings in the first half of 2006, along with multiple conference calls. The schedule for the Panel's work was aggressive, necessitating consistent interaction among Panel members.

The Panel's Terms of Reference (Appendix A) identified a series of questions, each of which became the subject of the work of a subgroup composed of one or more Panel members. Some Panel members served on more than one subgroup. The CRD provided a bibliography of some 237 documents that might be relevant to the Panel's work, from which about 141

[1] The process used to select consultants was necessarily accelerated and included the following components: long-listing candidates on the basis of expertise; short-listing candidates on the basis of experience, proposed team members, absence of conflict of interest and availability; and then interviewing with standardized questions.

documents were downloaded to an FTP site for access by Panel members.

The Panel had extensive discussions about their methodology and approach, particularly on how to integrate the copious amount of existing and new information in the time available. The following principles were applied:

- A large number and a great variety of reports and publications were reviewed by the Panel. This review allowed for in-depth analysis in several areas where it was needed, with a high-level approach in others.
- The role of appointed panels (such as this Panel) is to provide added value to existing information by integrating what is known and then providing opinions and advice. Necessarily, the Panel often relied on the analysis and interpretation of others, as opposed to re-evaluating original data.
- The Panel believes that the CRD Board wants their consensus view to be based on their training and experience and wants the Panel to advise on key issues for liquid waste management in the CRD Core Area.

The "questions" posed to the Panel were a combination of general and specific with, in some cases, significant overlap. Therefore, the Panel has re-ordered the CRD's questions [original questions are in the Terms of Reference (TOR; Appendix A)] and combined two of the questions. The questions are given in Box 2; the Panel's response to the questions comprises Section 4.

Finally, the Panel felt strongly that some of the questions (particularly the "to treat or not to treat" question) were not questions that could be answered through technical and scientific input alone. The Panel's work was neither designed nor directed to account for social, political, regulatory, or policy considerations; however, the Panel has indicated in their responses to the questions where these other inputs would benefit any decision-making process.

Box 2: "Questions" from the Panel's Terms of Reference (see Appendix A)

- The CRD has a series of liquid waste management programs laid out in the Core Area LWMP. Evaluate the effectiveness of these programs to manage risks associated with the CRD's wastewater practices and provide recommendations on those programs that may need to be reprioritized or restructured. [Question A2; Section 4.1 in the Panel's report]
- Assess the current environmental and human health impacts of the Clover and Macaulay points wastewater discharges. Discuss the significance of these impacts. [Question A1; Section 4.2 in the Panel's report]
- Review and assess the effectiveness of the early indication process and seafloor trigger process to signal when advanced sewage treatment is required. [Question A3; Section 4.3 in the Panel's report]
- Review the need for treating leachate to protect human health and the environment before the leachate is discharged to the sewer from Hartland Landfill. Document the risks associated with the current practices. If treatment is necessary, recommend treatment options. [Question A4; Section 4.4 in the Panel's report]
- Identify and evaluate the future risks of the CRD's wastewater management practices under reasonably plausible scenarios. Discuss the significance of these risks. [Question B1; Section 4.5 in the Panel's report]
- Considering the CRD's current liquid waste management practices, analyze the significance of the risks associated with emerging chemical contaminants of concern and persistent organic chemicals on the receiving environment and public health, both now and in the future. Gauge how the impacts of the CRD's approach to liquid waste management practices and the risks associated with emerging chemicals of concern change with the implementation of sewage treatment. [Questions B2 and D2 combined; Section 4.6 in the Panel's report]
- Identify and rank the alternative and new liquid waste management systems that may be applicable to the CRD. [Question C1; Section 4.7 in the Panel's report]
- Review the effectiveness of the CRD's approach to liquid waste management compared to other coastal communities. [Question D1; Section 4.8 in the Panel's report]
- Determine if the CRD should implement sewage treatment to manage the discharge of wastewater at Clover and Macaulay points. If so, identify what level of sewage treatment is required and why. [Question D3; Section 4.9 in the Panel's report]

A schematic summarizing the Panel's process is shown in Figure 1-3, resulting in this report and its appendices.

Road Map to the Panel's Report

One of the challenges that the Panel faced was how to respond to the questions being posed (which are complex and technically difficult to answer) in a way that would be understandable to the public. This report is designed to have multiple layers of increasing complexity:

- Readers who want the highlights should read Section 3.
- Readers who are interested in more comprehensive findings should read blue-highlighted text in Section 4.
- Readers who want the detailed answers posed to the questions in the Panel's Terms of Reference should read Section 4. This section is aimed at persons who are familiar with the topics being addressed.
- The more detailed analyses and information that form the background of the Panel's work are provided as appendices on a CD-ROM inserted in the back cover of this report.

A glossary of terms and a list of acronyms are provided following the list of references cited.

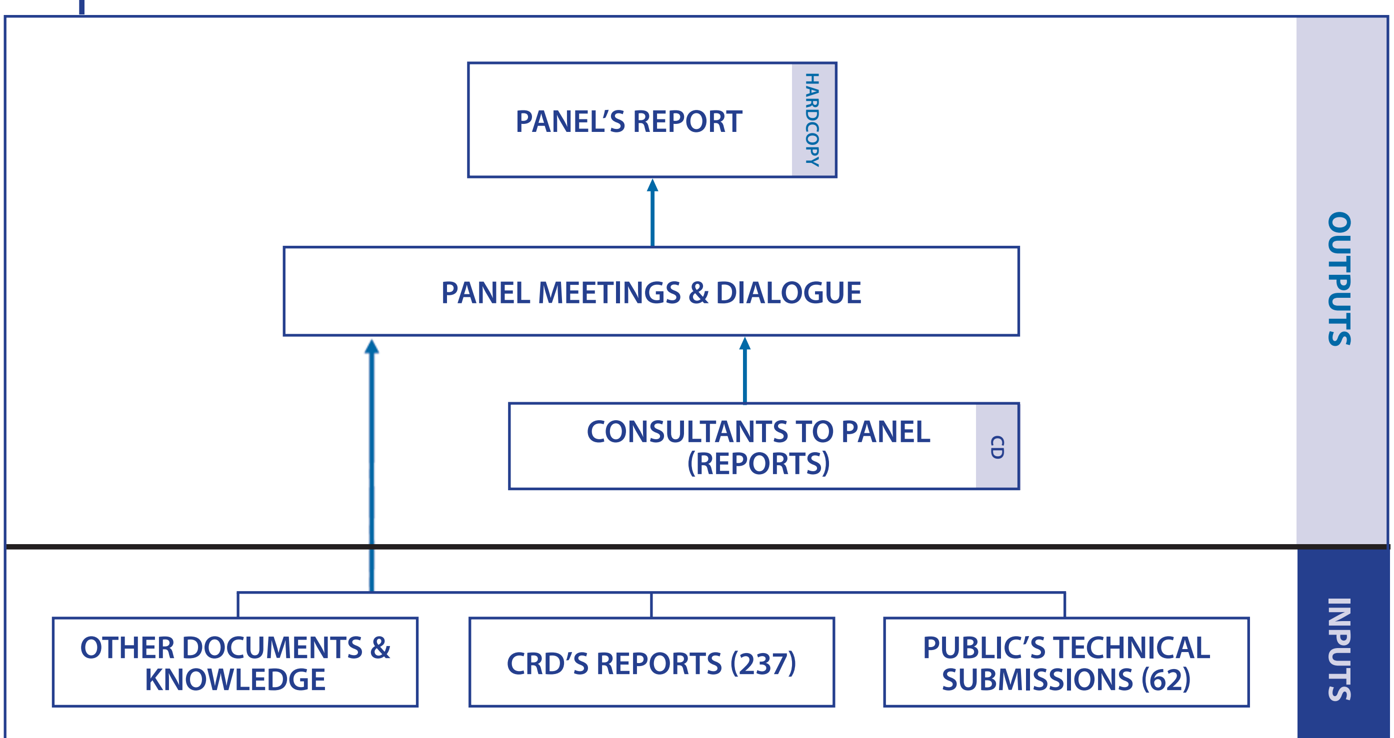


Figure 1-3: Schematic of Panel's process, showing inputs and outputs

2

Public Submissions

Process

The Panel's public submissions process was developed and managed in accordance with Item 2.3 of the Panel's Terms of Reference (TOR; see Appendix A):

> *SETAC will coordinate a process whereby the public is invited to make technical submissions for the Review Panel's consideration in relation to the Review Panel's scope of work. SETAC will work with the public consultation specialist to determine which submissions are relevant to the technical scope of work. Those submissions that are relevant will be compiled and forwarded to the Review Panel for its consideration and inclusion in the final report. Those submissions that are not directly relevant will be reviewed and compiled by the public policy consultant, with the assistance of SETAC, and the findings incorporated in the Review Panel's final report.*

To design and manage the submissions process, SETAC North America engaged the professional services of Praxis Pacific, a firm specializing in public involvement. In addition to meeting the TOR, the objective of the submissions process was to:

> *Provide an open, accessible and responsive public process while meeting the Review Panel's need for the most comprehensive science-based information on liquid waste issues currently available.*

Appendix D contains the full report describing the public submissions process. The process focused on eliciting written submissions from the public. Written submissions were felt to be the most efficient and appropriate mechanism for the Panel to amass, sift through, assimilate, and consider all available technical information. The 8-week public process was launched on 14 February 2006, with a submissions deadline of 7 April.

Activities to Support Public Submissions Process

Stakeholder database and contact

The Panel collaborated with CRD Environmental Services staff to identify a starting base of 41 stakeholder groups and individuals who might have interest and new or additional technical information relative to the review and/or be interested in participating in the submissions process. A letter from the Panel Chair inviting submissions was mailed to stakeholders on 10 February 2006 and emailed on 14 February. On 12 March, a follow-up email with a reminder of the 7 April submissions deadline was sent to all stakeholders who had not yet acknowledged receipt of the Chair's letter or submitted information. Additions to the stakeholder database were also solicited, and any new contacts identified were sent information about the Panel's process.

Paid advertising

The Panel's call for submissions was advertised via paid ads in the 15 and 22 February and 1 March 2006 editions of the Victoria Times Colonist and 6 Vancouver Island News Group (VING) papers: Esquimalt, Oak Bay, Peninsula, Saanich, Victoria, and Goldstream News. An additional ad (part of a 4-ad package) appeared in the VING newspapers on 8 March 2006.

Press releases and media liaison

Press releases and media liaison were initiated in an effort to augment paid advertising about the call for submissions and to keep the Victoria-area public informed of key milestones in the process. The Panel issued 3 press releases, and the Review Panel Coordinator (SETAC North America representative) responded to, and in several cases initiated, media contact, resulting in several telephone interviews over the course of the process.

Website

A website (www.setaccrdpanel.org) was developed for the Panel's public submission process and managed through the SETAC server. It included information about the process, the Panel's Terms of Reference and background, instructions for Web-based submissions, a form to download for mail-in submissions, and a direct email link. The website was launched on 13 February 2006 and opened for online submissions on 20 February through midnight on 7 April, the submissions closing date. Online submitters were guided to a user-friendly Data Submission Form. People submitting via the website were sent an automated reply acknowledging receipt and assigning a file number.

Contact options

A dedicated postal box was established and publicized for mail-in submissions. A link from the website was provided to the Panel email address. The Praxis Pacific phone number with voice mail was publicized in paid ads and in press releases as the contact number for any phone inquiries.

Processing

The public consultation coordinator, in liaison with the SETAC North America project manager, reviewed all submissions[1] to sort them as "technical" and "other". Submissions were deemed to be "technical" if they provided scientific or technical data or information that might help inform the Panel's scope of review, and "other" if they dealt with social or public values or opinions.

Response

The process garnered submissions from 52 different groups and individuals for a total of 82 submissions, as summarized in Table 2-1.

Table 2-1: Summary of submissions to the Panel

	Technical	Other	Total
Number of submitters	32	20	52
Number of submissions	62	20	82

Submitters were made up of 9 groups or organizations and 43 individuals, the latter including scientists, university professors, medical doctors, engineers, consultants, and concerned citizens. The submitting organizations were as follows:

- Non-government organizations:
  - BC Sustainable Energy Association
  - Georgia Strait Alliance
  - Portage Island Protection Society
  - Sierra Legal Defense Fund
  - T Buck Suzuki Environmental Foundation
  - Victoria Sewage Alliance
- Government agencies
  - Environment Canada
  - Ministry of Environment
  - Vancouver Island Health Authority

[1] A "submission" is defined as a contribution to the Panel that arrived together on a given date/time. Some contributors submitted multiple submissions.

The topic garnering the greatest interest was sewage waste, its treatment and discharge.

Similarly, the keywords submitters used to characterize their submissions largely reflected data, information, interest in, and/or concerns about the effects of wastewater on the marine environment. Several technical submissions described new or emerging technologies for wastewater treatment.

Technical submissions

All technical submissions were reviewed by one or more Panel members. No new site-specific data were provided, although the 62 technical submissions added to the breadth of technical opinions on the issues the Panel was mandated to consider. The submissions provided a sense of completeness and confirmation of the points of current scientific debate concerning liquid waste management, particularly within the context of the CRD. The Panel has integrated the results of their review of these submissions into this report to the CRD Board.

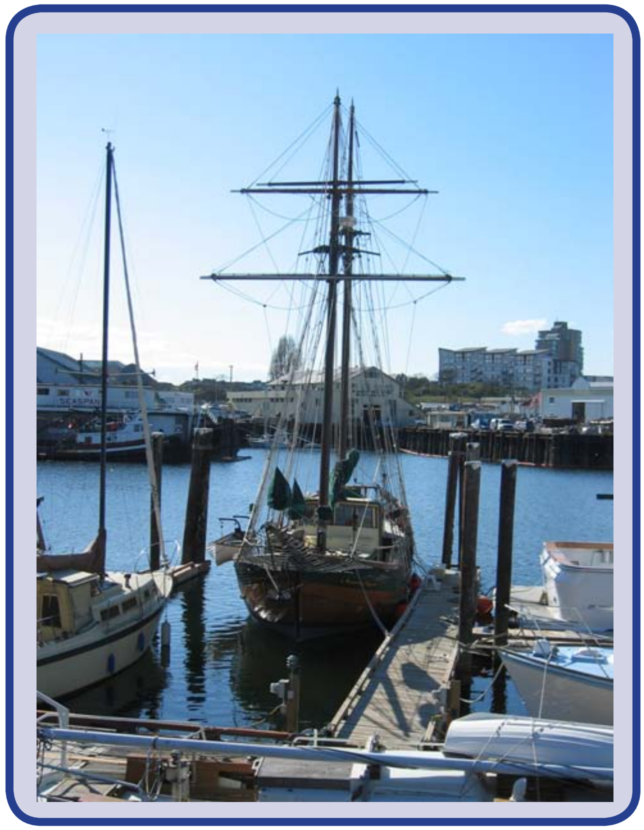
Summary of "other" submissions

All 20 of the submissions dealing with public and social values addressed some aspect of sewage treatment in the CRD.

Support for treatment

Seventeen people spoke in favour of sewage treatment, several using strong adjectives to describe their sense of outrage that raw sewage is discharged into the ocean, for example, "embarrassing", "arrogant", "disgusted", "ashamed", "appalled", and "unbelievable". People spoke of concerns about impacts in the immediate CRD area ("sewage smells" near outfalls, plastic tampons washed up on Cadboro Beach, skin and eye infections for divers), the surrounding Straits (pollutants in the seabed, depleted fish stocks, high levels of toxicity in whales), and cumulative effects on the ocean as a whole (the diminishment and toxicity of sea-floor life, affecting the food chain, and an increasingly fragile oceanic system).

Several submitters suggested that the lack of sewage treatment tarnishes Victoria's reputation provincially, nationally, and internationally, resulting in bad press, reduced tourism, and closed beaches. One found it grating that smaller, less wealthy coastal British Columbia communities treat their sewage, while wealthy urban Victoria does not.



A number of people suggested that treatment is the "morally right thing to do" no matter what the scientific community says; they do not perceive science to be entirely accurate or complete. As one person put it, "there is no equation that can capture the entire cost of pollution from raw sewage to the environment".

Three people said that dilution, perhaps appropriate at one time in the past, is no longer adequate, given a larger and growing population, better knowledge about detrimental environmental effects, and an increase in toxic non-human wastes being flushed down sinks and toilets (for example, household and industrial cleaners) and off roadways.

Four submitters encouraged investigation into new and emerging treatment technologies (transform biosolids into healthy compost, capture and use methane gas produced in digestion). One said the CRD should provide information on environmentally friendly toilets and ways to deal with household grey water.

Four people said they were willing to pay higher taxes (one said “considerably higher”) for sewage treatment. One person urged action now, rather than in the future, when the cost of clean-up “will be too great”.

Caution about investing in sewage treatment

Three submitters cautioned against focusing on sewage when other discharges may be responsible for greater environmental impacts. One favoured an objectives-based approach to eliminating environmental impacts, believing that sewage treatment would be far down the list of effective strategies. Further, this submitter felt federal and provincial funding would be forthcoming for effective solutions on the cutting edge of alternative waste management. Another submitter said that the highly oxygenated water at the mouth of the outfalls in effect provides “very thorough primary treatment”.[2] The third asserted that dilution works if it is coupled with effective source control and upgraded filtration and separation equipment.

[2] Due, in the submitter’s words, to the exceptional currents and up to 4 daily tides churning the water at the mouths of the outfalls.

3

Synthesis of Panel's Findings

The Capital Regional District (CRD) is responsible for the programs that manage liquid wastes in the Victoria area. To meet these responsibilities, the CRD developed the Core Area Liquid Waste Management Plan (LWMP), which was approved by the British Columbia Ministry of the Environment in March 2003 and is still in effect. The plan makes a number of specific commitments to protect human health and the environment against adverse effects associated with liquid wastes, including the following:

- Control contaminant inputs at their source, for example, photographic shops and dentist offices.
- Develop and conduct a wastewater and marine monitoring program to assess the environmental consequences of wastewater discharged into the Strait of Juan de Fuca.
- Manage and control inflow and infiltration of groundwater and/or surface water into the region's sewer system.
- Develop a stormwater quality management program to minimize stormwater-related detrimental effects to human health and the environment.[1]
- Develop an environmental action program to remediate and protect Victoria and Esquimalt Harbours.
- Ensure that trucked liquid wastes (non-domestic and septage liquid wastes) are handled and disposed of in an appropriate and responsible manner to protect human health and the environment.
- Eliminate overflows of wastewater to the environment.
- Treat and dispose of wastewater for areas served by the municipal collection systems.
- Treat and dispose of wastewater for areas not served by the municipal collection systems.

CRD faces similar issues to those being addressed in other urban coastal communities in Canada that are responsible for the development, administration, operation, and management of multiple liquid waste programs. CRD differs from most other coastal communities in North America in the level of wastewater treatment; virtually all other communities provide a minimum of primary treatment, while the CRD only "screens" its wastewater before it is discharged to the environment. Also, in a review of other coastal jurisdictions, only the CRD and the Greater Vancouver Regional District (GVRD) were identified as relying on an environmental trigger process as the basis for wastewater treatment decisions.

[1] Stormwaters are the flows that collect on surfaces (for example, roads, parking lots, and agricultural areas) and then go into ditches and drains leading to streams and marine waters

Liquid Waste Management Plan

The Core Area LWMP provides a comprehensive management program for addressing all aspects of liquid waste management in the CRD, and the Panel commends the CRD for the scope and magnitude of the plan. Results of the recent independent audit[2] indicate that the LWMP, for the most part, is being implemented successfully. The Panel encourages the CRD to implement the recommendations in that audit and to ensure that any future commitments are "SMART" (**S**pecific, **M**easurable, **A**chievable, **R**ealistic, and **T**ime-bound).

As part of the Panel's scope of work, we reviewed the effectiveness of the LWMP. One key finding is that, although adequate liquid waste management policies are formulated and described in the LWMP, the CRD lacks the authority to properly implement and/or enforce some of these policies. Any effective management plan not only must describe a program of action but also must award the necessary authority for its implementation.

The Panel offers these additional, specific comments regarding the LWMP:

- The Source Control Program is well developed and represents the current "state of the science". The CRD should continue to support and expand the program. However, the CRD should consider that such programs are effective only for targeted contaminants and will only reduce the amount of selected contaminants discharged to the environment, not totally eliminate them.
- Some areas of the CRD have high inflow and infiltration flows into the sewer system. Reducing these flows is an important component of total sewerage management.
- Like other jurisdictions, the CRD faces the common dilemma of how to assess, prioritize, and manage stormwaters because of their variability and potential for adverse environmental effects. Because stormwater discharges occur intermittently, the public health and environmental risks often are perceived as minimal. In fact, stormwater quality can be very poor; therefore, the risks to the public and to the environment may be much greater than expected. While the CRD is responsible for stormwater quality management, it lacks the authority to enforce stormwater bylaws.
- The decision-making process in the Core Area LWMP related to the need for wastewater treatment is highly dependent on the trigger process, which the Panel has reviewed in detail (see below). Fundamentally, the Panel is not of the view that the seafloor trigger process will function as designed.
- The CRD coordinates harbour environmental protection and improvement efforts with its partners, but it lacks the authority to enforce related LWMP commitments. Given the extent and magnitude of contamination in the harbours, and given their potential contribution to contaminant issues in the region, the CRD should focus additional attention on coordination efforts, ensuring that the stressors are managed in relative priority to the waterways they affect.
- Although the CRD operates a program to inventory and manage trucked liquid waste, it apparently lacks the authority to ensure proper disposal of that waste.
- With significant potential to contaminate land and near-shore environments and to expose humans to wastewater, sanitary and combined sewer overflows deserve particular attention from the CRD.

The Panel challenges the CRD to move forward and manage the LWMP within an overall design that respects the watershed and considers water to be an integrated resource within our ecosystems. The Panel recommends that the management of liquid wastes should em-

[2] The Panel's Terms of Reference required SETAC North America to identify and contract a third party to conduct a compliance review of the LWMP. The audit is Appendix C of the Panel's report.

phasize the relationships between the various components of the LWMP, particularly when it comes to coastal zone management.

CRD Environmental Monitoring Program

Since the late 1980s, the CRD has been monitoring the wastewater discharges, the surface waters, and the communities of seafloor-dwelling organisms in the vicinity of the Clover and Macaulay Point discharges. The marine monitoring program is comprehensive and is designed to evaluate the effects of sewage in the marine environment in and around the discharge points. The breadth and scope of the program is impressive, and the Panel commends the CRD for their intent to incorporate the best available science in the monitoring program. The existence of a voluntary, independent panel of experts, the Marine Monitoring Advisory Group (MMAG), as advisers to the CRD is an important strength of the program; the Panel encourages their continued involvement as well as adequate resourcing for the MMAG's function.

Fate and distribution

Approximately 130 megalitres of screened sewage are discharged daily from the combined outputs of Clover and Macaulay Points into the marine environment of the Strait of Juan de Fuca. The effluents contain a wide variety of chemical and microbiological constituents, are rich in nutrients, and have, at times, been shown to be toxic. Upon release at the outfalls, the constituents of the discharges disperse according to their physical and chemical properties and the prevailing environmental conditions of the Strait. There is no doubt that the effluents are rapidly diluted and transported away from the discharge location; however, we do not have a complete understanding of the fate and distribution of the effluents. There is conclusive chemical, microbiological, and observational evidence that, under certain environmental conditions, the diluted sewage plumes or their constituents reach the ocean's surface.

Human health concerns

A great deal of uncertainty surrounds the human health effects of sewage discharged by the CRD into the Strait, with respect to both bacterial contamination in water and chemical contamination in seafood. Anecdotal information suggests that few persons frequent the areas in and around the discharge points, and therefore, human exposure and its related risks are limited. Despite the uncertainty and the perceived infrequency of exposure, data indicate that when the diluted plume (and therefore bacteria) does come to the water's surface, persons exposed to the water are at increased risk for adverse health effects. This uncertainty about human health risk is due, in part, to the sampling regime and the choice of bacterial indicators. The Panel therefore recommends reducing the uncertainly by increasing the frequency of monitoring and by including *Enterococci* as a monitoring parameter. In addition, fish tissue monitoring and risk assessment is also recommended, particularly for chemicals with the potential to accumulate in animals and move up the food chain.

Environmental concerns

Overall, the CRD's program to evaluate the effects of sewage in marine environments is one of the more comprehensive programs being implemented anywhere in the world. Like many monitoring programs, it focuses on the seafloor. Documented impacts on seafloor organisms and communities are restricted to those areas immediately around the outfalls. Sediments and mussel tissues close to the outfalls reflect the burden of discharged chemicals, specifically:

1) At Macaulay Point, community diversity is reduced and pollution-tolerant invertebrates dominate the sediment-dwelling organisms.
2) At Clover Point, mussel tissue monitoring for chemical bioaccumulation shows that levels of a number of substances (for example, copper and lead) are elevated in

mussels at the outfall (and in some cases, at both the near-field and far-field stations), compared to the reference stations. In terms of chemicals with the potential to move up the food chain (for example, persistent chemicals that are not broken down in the environment and can get concentrated in animals), polychlorinated biphenyl (PCB) concentrations show a small increase near the outfall, where concentrations in mussel tissues were low, but they are nearly double the concentrations at the far-field stations. Polybrominated diphenyl ether (PBDE) concentrations have the widest footprint in mussels tissues around the outfall; levels at the outfall and at both near-field and far-field monitoring sites (out to 800 m) were elevated, compared to the reference station. Available ecological thresholds or screening-level risk assessments for these chemicals indicate that observed tissue concentrations are well below those shown to cause adverse effects. Although Victoria's contribution of persistent organic contaminants is undoubtedly minor, the concern about these contaminants is heightened in the local area because Orca whales in the Georgia Basin have been identified as among the most contaminated cetaceans in the world.

However, because the present monitoring program is highly focused on seafloor sediments, it overlooks some other key components of the marine ecological community. While the CRD's marine monitoring program is a comprehensive one, given the effluent is untreated and a higher degree of caution is merited, there are numerous gaps:

- direct toxicity of the effluent,
- effect of the effluent on water-column–dwelling organisms,
- effect on the surface micro-layer,
- monitoring of far-field effects,
- predictive capability for estimating fate and distribution of the plumes,
- sufficient reference sites to use for comparison (additional sites are needed with increased replication), and
- potential effects and risks of persistent organic contaminants through food chain transfer.

The CRD's analytical monitoring program includes a wide range of contaminants, but given the lack of significant sewage treatment, the Panel felt it prudent that the CRD's monitoring program be more inclusive than similar programs for other jurisdictions. The CRD has recently added high-resolution analyses of persistent organics such as PCBs and PBDEs; the Panel commends this approach and believes it should continue. The Panel noted that some of the "traditional" contaminants are missing from the monitoring program (for example, chlorinated pesticides), and their addition should be considered. Additionally, the Panel appreciates the CRD's initiative to monitor new "compounds of concern", such as pharmaceuticals and endocrine-disrupting compounds,[3] and urges them to include new compounds in the program as appropriate.

Seafloor Trigger process

A "triggering process" incorporated in the CRD monitoring program and the Core Area LWMP is intended to signal when unacceptable biological consequences occur in the sediments adjacent to the sewage outfalls and to indicate when wastewater treatment is necessary. Conceptually, the trigger process is based on sound marine sediment and environmental monitoring principles, and the data collected to date and their analyses have been consistent with these same sound scientific principles. However, the difficulties associated with designing and implementing a trigger process create considerable uncertainty about the program's potential effectiveness to protect the ecosystems near the CRD outfalls. As designed, the magnitude of environmental effects necessary to indicate the need for treatment and the time necessary to observe and confirm

[3] Substances that cause adverse biological effects by interfering with the endocrine system and disrupting the physiologic function of hormones

these environmental impacts seems lengthy. Further, the time specified to implement remedial actions as a result of observed adverse environmental effects is underestimated. Additional specific concerns the Panel identified in the triggering process are these:

- The Panel was concerned with the validity of the mussel length and weight-at-age endpoint as a sensitive and/or predictive (that is, time-responsive) tool.
- The Panel felt that the use of mussel reproductive development as an early indicator, as is currently done, is inappropriate because the results cannot be interpreted.
- The selection and location of the sites within the compliance zone do not appropriately account for the area influenced by the effluent plume. If the plume is not uniformly distributed, requiring 4 of 8 sites (100 m) in the compliance zone to exceed triggers may underestimate effects to the receiving environment.
- Reference sites must be added and replication must be increased in order to establish reliable reference conditions and to improve the interpretation of the monitoring results.

Future Concerns

What will happen in the future, with respect to population growth and emerging issues? Because of its desirability as a city, Victoria's population will no doubt increase substantially in the future. This increase will result in a concomitant increase in sewage load to the wastewater systems. Prudent planning that incorporates the most current and accurate population forecasts allows communities to prepare for future needs. For public utilities, conservative planning is considered the best approach. Due to the length of time required to plan, design, and implement essential public utilities, the future literally begins tomorrow.

The Panel does not view reducing selected contaminants through source control as a means to significantly lower the annual discharge of such chemicals in the long term. While some sources can be eliminated and the chemical concentrations can be reduced, the increase in flows containing reduced concentrations generated by new residents will likely carry nearly the same annual mass of these chemicals to the discharge sites. The Panel concludes that the environmental "footprint" of the wastewater discharges will increase proportionately with an increase in volume of discharged wastes. The location of the release and the overall quality of the wastewater will also affect the footprint. Source control efforts will help reduce inputs of certain contaminants, and these programs should continue to be supported and expanded. However, adequate control of all potentially toxic wastewater constituents via source control efforts is unlikely, and alternative approaches must be considered. Wastewater disposal inherently creates public health and environmental risks, and those risks increase with the generation and disposal of more wastewater resulting from urban growth, particularly when the wastewater is not treated.

Emerging contaminants

A wide variety of emerging contaminants (for example, endocrine-disrupting compounds) have been identified in municipal wastewaters; however, the importance of many of the newer substances from an environmental risk perspective remains unclear. These chemicals have varying physical, chemical, and toxicological properties, making it extremely difficult to characterize and/or generalize their fate, distribution, and effects in the environment, especially as complex mixtures. Many of the emerging chemicals will be difficult or impossible to control in the current CRD collection system if deemed necessary. The weight of evidence suggests that untreated effluents will result in estrogenic responses in exposed organisms.[4] Chemicals that bind to sediments will

[4] A biological response controlled through the estrogen receptor, for example, when male fish develop female characteristics such as egg development in male sex organs.

be bioavailable[5] to local species and also to marine ecosystems (through the food chain). The majority of emerging chemicals can be greatly reduced or removed from effluents with a combination of sewage treatment processes and oxidation techniques. Treatment of wastewater effluents reduces the risk of environmental impacts. However, treatment will produce sludges that must also be treated and managed.

To Treat or Not to Treat: A Risk Management Decision

How to handle the disposal of wastewater in the CRD now and in the future is a "risk management" decision that should involve inputs from a variety of disciplines. The Panel provides the CRD with scientific, technological, and engineering perspectives, but other important inputs include social and political considerations, economic concerns, and regulatory drivers (see Figure 3-1). The CRD Scientific and Technical Review Panel emphasizes that the Panel's advice must be viewed in the context of these other inputs.

The Panel expended considerable effort in addressing the "to treat or not to treat" question, as documented in this report. Scientific risk concerns, public values, and the prevailing regulatory climate argue for the CRD to improve the overall quality of its discharged wastewater. Relying on the dilution and natural dispersion processes of the Strait of Juan de Fuca is not a long-term answer to wastewater disposal, especially considering the growth predicted for the CRD and adjacent communities that also contribute contaminant loads to the Strait and to Puget Sound.

Improvements to wastewater effluents could be made using a variety of approaches that should include not only a continuation of existing programs (for example, source control) but also consideration of approaches not currently in effect, such as wastewater treatment. Our review of waste management and treatment technologies found a wide range of plausible options with a range of post-treatment wastewater qualities. Human and environmental health concerns should establish the minimum criteria for wastewater quality that would be considered acceptable. The Panel suggests that any decisions about liquid waste management should take into account the local watershed and its ecosystems. Specific efforts should be made to address the "responsibility" versus "authority" issues highlighted previously.

Information made available to the panel underlies the notion that the populace of the CRD, the province of British Columbia, and Canada support the concept of wastewater quality improvement in the CRD. In recent years, the CRD has taken significant steps toward controlling risks to human health and the environment in the Victoria area, and many of the programs implemented to date represent the state of the science. Future improvements in wastewater handling in the CRD no doubt will reflect this "cutting-edge" approach and will result in significant reductions in risk to human health and the biologically rich marine environment in the Strait of Juan de Fuca.

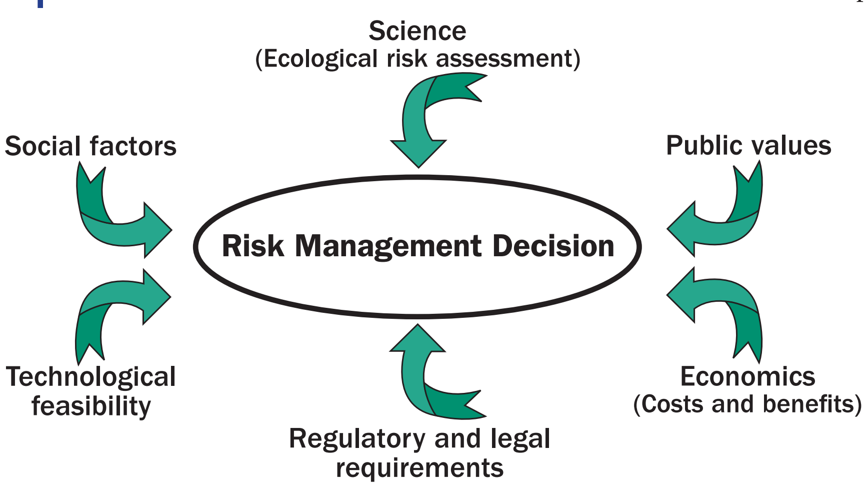


Figure 3-1: Inputs to risk management decisions (adapted with permission from Stahl et al. 2001, Risk Management: Ecological Risk-Based Management, ©SETAC)

[5] The degree to which a substance is absorbed or becomes available at the site of physiological activity after exposure; chemicals bind to environmental media in varying degrees or are present in different forms, thus altering their availability to organisms.

4.1

Review of Liquid Waste Management Plan

The CRD has a series of liquid waste management programs laid out in the Core Area LWMP. Evaluate the effectiveness of these programs to manage risks associated with the CRD's wastewater practices and provide recommendations on those programs that may need to be reprioritized or restructured.

Introduction

The Capital Regional District (CRD) Core Area Liquid Waste Management Plan (CRD 2000) provides a thorough approach to many aspects of liquid waste management in the Core Area, aiming to protect public health, protect environmental health, and maintain and improve the aesthetic environment.

The Panel reviewed the major sections of the Liquid Waste Management Plan (LWMP), as described in the following sections, but there are some overarching comments from the Panel:

- Where possible, future updates to the LWMP should establish goals and commitments that are SMART, meaning Specific, Measurable, Achievable, Realistic, and Time-Bound.
- While the LWMP is thorough and detailed, CRD's ability to affect practices differs greatly across the different aspects of the LWMP. Of significant concern is that the LWMP identifies several areas of program responsibilities without corresponding authority; the Panel believes there is a weak system of power for program implementation in some cases. CRD can be most effective in managing those elements which it controls most directly; at a minimum, for those aspects where CRD shares responsibility with other bodies, coordination among the participating bodies is key to effectiveness. In this regard, the Panel recommends that the watersheds making up the region be managed by a common authority. Adequate management requires coordination among the many aspects of the plan, and this would best be accomplished by a common authority with an ecosystem- and watershed-level perspective.

A brief review and evaluation of the elements of the LWMP follows, after which conclusions are provided.

Core Area Liquid Waste Management Plan

Source control

A source control program must consist of several components, including point source identification, enforcement of controls, sampling to confirm control, and disposal programs for managing the material removed from the wastewater streams. The CRD's Regional Source Control Program (RSCP) has a set of goals, including the following:

1) Point source identification—The RSCP has made an excellent effort at identification of various non-domestic wastes dischargers. The Waste Discharge Permits, the Codes of Practice for 11 commercial and institutional sectors, and the letters of authorization provide a system for understanding variations in the quantity and quality of the wastewater and imposing requirements for discharges from particular sources.
2) Enforcement of controls—Enforcement through the Sewer Use Bylaw by identification as a Discharger Under Review (DUR) and the ability to issue tickets or file charges provide a strong deterrent and encouragement for waste discharge control at the sources. The annual reports of the RSCP testify to what has been, generally, an effective program with high levels of compliance among affected businesses.
3) Sampling to confirm control—Random sampling without prior notification, in combination with the self-monitoring program, provides a comparative step to ensure compliance. Also, the key access-hole monitoring program aids in the location and identification of other pollution sources.
4) Disposal programs—The disposal of the material separated from the wastewater flow is the last of the steps to make a source control program work. Report keeping and tracking disposal practices are critical to the program and must continue to be important enforcement steps.

This program has developed very well and is making a difference in the quality of the discharges to the receiving environment. **The RSCP has been effective and should be continued, but because it cannot be applied to households, it cannot fully address all issues in the management of wastewater in the CRD. Also, source control only reduces the amount of selected contaminants discharged into the environment; it does not eliminate them.** Many organic and inorganic, hydrophilic, and hydrophobic materials will not be eliminated by source control activities.

Inflow and infiltration control

The CRD has been pursuing an aggressive inflow and infiltration (I&I) evaluation program which has produced some very enlightening results. The ratio of peak wet-weather flow to average dry-weather flow in the sewers is an indication of the degree of I&I experienced. A ratio that exceeds 4.5 indicates that I&I is a concern (July 2005 Core Area Inflow and Infiltration Program). Table 4.1-1 indicates that this ratio is often greatly exceeded in the CRD sewers.

The areas of Colwood, Oak Bay, and Victoria have very high ratios, indicating a serious need for significant I&I corrective action. Also, note that at some locations, there were suspected upstream overflows (where the sewer capacity was exceeded) which were not accounted for in the analysis. The reduction of high I&I flows is a very important sewerage management effort that will influence any wastewater treatment plant design and that must continue.

Also, the portion of the inflow coming from the environment controls of large buildings, like cooling and other intermittent or continuous-flow units, should be identified. The water from these units is usually clean and does not require wastewater treatment, and it should be diverted elsewhere.

Another important source of inflow is the penetrations in the access-hole covers. Depending on the topography of the area around an access hole, water may flow through access holes and run into the sewerage. In locations with large or long rain events, this can be a major source of inflow. Sewer inspection and monitoring through camera systems help to identify serious infiltration locations. A sewer repair and replacement program will reduce the magnitude of the I&I problem.

In summary, **some areas of the CRD have high inflow and infiltration flows into the sewer system; reducing these flows is important to sewerage management. An ongoing, prioritized sewer repair and replacement program will reduce the magnitude of the I&I problem.**

Table 4.1-1: Ratios of peak wet-weather to average dry-weather flows in sewers

Area	Ratio (PWWF / ADWF)	Flow-weighted average
Colwood	4.3 to 9.8	8.0
Oak Bay	13.8 to 34.5	19.0
Saanich	3.1 to 14.5	4.9
Victoria	5.6 to 22.0	9.9
View Royal	3.3 to 5.3	4.7

PWWF = peak wastewater flow
ADWF = average dry-weather flow

Wastewater and marine assessment

The CRD's program for wastewater and marine assessment at Macaulay and Clover Point outfalls consists of

- the trigger process (which includes seafloor monitoring),
- effluent monitoring and analysis,
- surface water monitoring and analysis for human health risk, and
- water column investigations.

The LWMP's goals for this component of the program are largely based on implementation of the trigger process and a monitoring program. The reader is referred to the Panel's detailed review of both these aspects (Sections 4.2 and 4.3). **In that review, the Panel found that the monitoring work being conducted is generally sound and consistent with best practice in other jurisdictions. The issues that the Panel identified (see Sections 4.2 and 4.3) relate to how the monitoring tools are being used, rather than to issues with the tools themselves.** The Panel concurs that an ongoing annual monitoring program is appropriate and that one-time investigations should be used to fill in information gaps, as needed, in consultation with the Marine Monitoring Advisory Group. The Panel is very supportive of a rotating review (every 6 years) of the marine monitoring aspects of the LWMP, providing it is adequately resourced and can bring in independent specialists.

The trigger process described in the LWMP includes a step (if "warning levels" are exceeded) for source identification and trends analysis to aid in the determination of the most appropriate course of action. If warning levels were exceeded, the first step would be to identify the chemicals of concern and their sources. In real life, this would likely be very difficult to achieve, particularly in the indicated 3-month time period. Again, this speaks to the issue of how the monitoring tools are applied for decision-making, as opposed to the tools themselves.

An early warning process for surface water levels of indicator bacteria is under development, but it was not available for review by the Panel.

Stormwater

Background

Stormwater issues involve both quantity and quality. With regard to quantity, several factors must be accounted for in the analysis, such as the types of storms, the pattern of the storms, and soil or surface characteristics. With regard to quality, precipitation events can flush a number of contaminants through drainage systems and into marine and other environments. The range of contaminants in stormwater is astounding (Makepeace et al. 1995; Novotny 2003). Each element of a flow event will have a different effect on stormwater quality. The period identified as the "first flush" may contain a major portion of the washed-off contaminants. Because the composition of stormwater depends so much on the rate and volume of flow of previous rain events and the length of dry periods, it is important that sampling programs intended to assess stormwater draw from a detailed series of data that will characterize the breadth of its variation.

Stormwater monitoring

The Panel's review of data collected for stormwater monitoring by the CRD identified several issues:

- The stormwater monitoring program measures fecal coliforms in stormwater using an extensive program, which is appropriate. However, for beaches that are moderately to highly used by the public and that are under the influence of stormwaters, enterococci should be the measurement of choice and is recommended by Canadian authorities (see discussion in Section 4.2).
- The stormwater monitoring program measures sediment quality in the stormwater system, as opposed to the stormwater itself (which is appropriate for prioritization but which is not representative of the stormwater's contaminant concentrations and form).
- At nearly a third of the access holes used for sampling (10 out of 33), no sediments were present for sampling. This is to be expected because properly designed access holes should result in little or no sediment accumulation. However, the lack of sediment results in an inability to characterize the stormwater.
- Sediments contain only materials with a density–size relationship that allows them to settle in the hydrodynamic environment of the access hole. Finally, only a portion of the water column materials that preferentially attach to sediments (for example, depending on speciation and the adsorption relationships between the solids and the water column).
- The ecological consequences of the stormwater discharges to the harbour do not appear to have been evaluated, particularly in context of other stressors (for example, contaminated harbour sediments, habitat alteration).

In summary, while the CRD's existing stormwater monitoring approach does have merit, it should be augmented with

1) collection of enterococci data in marine areas frequented by humans,
2) monitoring that describes stormwater quality and quantity with respect to chemical contaminants (this is likely to involve automated time-series sampling over various stormwater scenarios, perhaps initially for high-priority stormwater discharges), and
3) consideration of assessing the ecological effects of stormwater, in context with other stressors and overall harbour quality.

Stormwater infrastructure

The common problem of cross-connection control requires attention in the Core Area. At some locations, sanitary wastewater pipes may be connected into the stormwater sewers. This situation leads to contamination of stormwater that would otherwise have been relatively clean. Such cross-connection sources can often be detected by elevated fecal coliform values in the low-flow condition in the stormwater sewer. Other cross-connection situations involve quantity and/or quality variations which can be identified only through collection and analysis of data.

It is also important that the CRD has a georeferenced inventory of the stormwater system, in relation to other major utilities and the environment, the stormwater outfall capacities, and their discharge characteristics. Realizing that all types of wastes deposited in the drainage area of each outfall will make their way to the discharge point, it is important to ensure that the location of each discharge point is compatible with public health and environmental protection objectives. The discharge rating system used by the CRD (Drinnan 1997) allows classification of discharges based on public health and environmental concerns. The rating system incorporates fecal coliform and sediment metals along with flushing and human use estimates for determining the need for monitoring and mitigative measures. As in any ranking approach, the importance of individual factors may be missed. The 2005 report by Cameron and Green addresses the magnitude of the effort to understand and initiate corrective measures where concerns were identified.

Stormwater management

Based on the information the Panel reviewed, the CRD's approach to stormwater has evolved positively over time. The CRD is committed to working in partnership with the municipalities and other stakeholders to address stormwater issues, and significant progress has been made. The Panel understands that the CRD is facing the same dilemma as other jurisdictions: how to assess, prioritize, and manage stormwaters, given their variability and potential for effects. Perhaps the most significant challenge the CRD faces is that it appears to have responsibility for stormwater, while at the same time it does not have authority to regulate stormwater. In addition, the LMWP identifies that additional statutory powers may be required by municipalities and regional districts to implement stormwater strategies.

The LWMP Audit (Appendix C) highlighted this issue, stating "It appears that only one municipality out of 7 has adopted the CRD model stormwater quality bylaw, while another municipality reported that it is before their administration for review. Barriers to implementation seem to include:

- modification of the bylaw to reflect the new Riparian Areas regulations;
- varying priorities between the involved parties; and
- the increase in workload that would result from bylaw implementation and enforcement.

The CRD recognizes that revisions to reflect the Riparian Areas regulations are required and is in the process of revising the bylaw."

The CRD is responsible for stormwater, but only the municipal authorities appear to have the authority to enforce stormwater bylaws. Watershed management plans seem to be approved at a political level. **The Panel poses the question to the CRD about whether their effectiveness in delivering on their commitments in the LWMP is hindered by present institutional arrangements.**

Also of particular importance is the CRD's commitment to provide input and information on stormwater quality to the harbours' environmental enhancement and marine assessment programs. It was difficult for the Panel to assess the CRD's effectiveness in meeting this commitment. If no mechanism exists among the various stakeholders in the Victoria and Esquimalt Harbours Environmental Action Program (VEHEAP) to consider the human and ecological effects of stormwater relative to other stressors (for example, habitat changes, existing seabed sediment contamination, food chain effects of contamination), then this should be remedied. **The CRD should consider expanding on their commitment to provide "input and information" to the harbours' environmental enhancement and marine assessment programs. This is in view of one of the CRD's stated goals (see Box**

1) to practice "integrated coastal management". Integrated assessment can be achieved only by drawing information and practitioners together to discuss how to achieve the optimal environmental quality for the agreed water uses and for the effort and monies expended (see also next section on the CRD's Harbours' program).

The Panel's view is that ongoing stormwater monitoring and management by the CRD needs to remain a high priority (coordinated with other harbour environmental programs), regardless of any decision taken by the CRD on treatment of wastewater.

Harbours' environmental action

The CRD's Harbours Environmental Action program is implemented through a multi-party organization called the "Victoria and Esquimalt Harbours Environmental Action Program" (VEHEAP). The CRD coordinates harbour environmental protection and improvement efforts among the VEHEAP partners, within a memorandum of understanding (MOU) signed in 1994 by

- Capital Regional District,
- Ministry of Environment,
- Department of National Defence,
- Environment Canada,
- Fisheries and Oceans Canada,
- Transport Canada, and
- Public Works & Government Services Canada.

The CRD has shown leadership in its role with VEHEAP, and the fundamental principles of the program are sound. The Environmental Management Strategy (VEHEAP 1999) establishes a sensible purpose and clear goals and objectives. In 2004, based on feedback from a program review, VEHEAP shifted to an area-based structure with different initiatives in various waterways.

The VEHEAP experience demonstrates that re-focusing efforts to work with multi-stakeholder groups that are largely community-driven is an effective approach to watershed and harbour management. CRD itself appears to be very active in implementation of this approach, as do a number of the partners, as evidenced by the Panel's review of various documents and meeting minutes; however, it is not clear to what extent the partners in VEHEAP embrace the concept of integrated coastal zone management in assessing and protecting the health of the harbours.

Similar to the finding of the LWMP audit report (Appendix C), the Panel finds that the CRD's involvement in VEHEAP is only as effective as the real commitments of the VEHEAP partners. The CRD has a responsibility but no authority to address the issue if a VEHEAP member does not live up to the commitments made in the VEHEAP MOU. For example, stormwater clearly has a strong influence on harbour quality, but it is the primary responsibility of the municipalities. Seabed sediments also influence the environmental health of the harbours, but the harbour floor is largely owned and managed by federal departments (Department of National Defence, Public Works and Transport Canada). Significant studies are underway and will be reporting in 2006 and 2007, and the Panel encourages the CRD to aid in sharing and integrating findings into watershed-level planning.

While good work is being done, it may be that a higher level of resourcing and action is needed to integrate that work at an ecosystem or watershed level and to achieve a net benefit to the health of Victoria, Esquimalt, and other harbours. Any decision by the CRD or other members of VEHEAP to go beyond the status quo with respect to the harbours' action program should be taken in view of relative priorities, in a watershed or ecosystem context. The Panel's review of CRD's documents did not shed light on whether the various stakeholders have agreed goals for protection for the harbours, which would harmonize and prioritize their various activities.

The Panel recommends that the CRD's Stormwater, Harbours and Watersheds program, in conjunction with VEHEAP members and other CRD programs, should consider the relative priority of different environmental stressors in their work to improve environmental quality (not only with respect to harbours but also with respect to stormwater runoff to the harbour). **The goals for protection for the harbours should be clearly stated and agreed in terms of the measurements being made and interpreted by the various stakeholders (for example, benthic community health, food chain transfer of contaminants, stormwater quality, habitat quality, sediment toxicity).**

Trucked liquid waste

The CRD has initiated and progressed efficiently with a program to inventory and manage liquid, non-domestic wastes which must be trucked to a suitable treatment and/or disposal location (Earth Tech [Canada] 2002: Beauchemin and Rahman 2003). Rough estimates indicate that about 25 ML of trucked liquid wastes (TLW) are generated annually in the CRD, with 85% as oily material, 11% as engine coolants, and the remaining 4% from other commercial sectors. The food industry produces about 1.3 ML per year, of which about 60% is collected and 0.36 ML per year is TLW. The overall program appears to be working to protect the environment and reduce contaminant loadings going to wastewater treatment.

More effort is needed to insure proper disposal of the TLW and the wastes from catchbasins and oil-water separators (Earth Tech 2002). The CRD does not have the needed regulatory authority to reduce problems and improve the management of the TLW system (Beauchemin and Rahman 2003). **The CRD has a program to inventory and manage trucked liquid waste but does not have the authority to ensure its proper disposal.**

Wastewater overflows

Overflows of wastewater to the environment occur periodically at several locations in the CRD and municipal systems (CRD 2000). The overflows occur primarily because wastewater flow exceeds system capacity during heavy rainfall, or because mechanical or electrical systems fail. As a source, overflows can result in the greatest contamination of land and near-shore environments, resulting in exposure of both humans and important ecological systems to contaminants.

Based on the January 2004 summary prepared by the CRD, 21 overflow facilities exist in the District, and the LWMP (CRD 2000) presents a table of receiving environment sensitivities, mitigation, and action plans for some of the overflows. It appears that limited sampling has been done on these sources, and no treatment has been implemented. Reduction of I&I upstream would help in reducing the contamination of nearshore areas. **One of the greatest potential sources for contamination of land and nearshore environments and human exposure to wastewater is from overflows.**

As for other liquid waste issues, the Panel recognizes that the municipalities are responsible for some of the overflows. Both the CRD and the municipalities should continue with their policies to design or replace trunk sewers, reducing overflows, on a prioritized basis.

Treatment and disposal in areas served by municipal collection systems

In the LWMP, the Capital Regional District commits to

- use the trigger process to determine, in advance, when the health of the receiving environment in the vicinity of the Macaulay Point and Clover Point outfalls is threatened and additional source control measures or additional wastewater treatment is required;
- acquire land at Clover Point and Macaulay Point to hold in reserve for provision of treatment, subject to the agreement of the owners to sell the land; and
- commence a process for the acquisition of land for sludge processing when a decision is made to proceed with treatment.

The decision-making process in the Core Area LWMP related to the need for wastewater treatment is highly dependent on the trigger process, which the Panel has reviewed the seafloor trigger in detail (see Section 4.3). Fundamentally, the Panel is not of the view that the seafloor trigger process will function as designed. Also, in our review of LWMP practices for other jurisdictions, the Panel found (Section 4.8), that only one other jurisdiction uses a trigger process in this manner. Guidance on preparing LWMPs from the BC Ministry of Environment (MOE, undated) discusses how wastewater treatment "can be implemented in stages, taking into account the assimilative capacity of the receiving environment, the ability to finance the upgraded sewage facilities, and public input to the waste management planning process". This perspective dovetails with the Panel's independent view (see Section 4.9), that a decision on wastewater treatment needs to take into account more than technical and scientific factors (as suggested by the CRD's LWMP). **The fact that the trigger process is fundamentally a scientific–technical input into decision-making, and may be flawed (based on the Panel's analysis, Section 4.3), highlights the Panel's concern that the trigger process should not be the sole mechanism to determine the need for wastewater treatment. The CRD has a substantial and well-designed annual monitoring program that should also be used as the basis for decision-making.**

It is instructive to review, in principle, the decision process that is generally used for most jurisdictions. The goals of wastewater treatment and disposal are, generally,

1) protection of public health,
2) protection of environmental health, and
3) maintenance and improvement of the aesthetic environment.

All 3 goals require evaluation of existing knowledge, both locally developed and from the international scientific community. A great deal of the data collection and modeling that is needed to evaluate the need for wastewater treatment (WWT) before discharge, as practiced in the CRD, has been undertaken. This database underlines 3 principal elements of such a program:

1) The collection of a scientifically complete and sound data set is very complicated and expensive in time and personnel.
2) It is wise to tap into the results of the many published works that focused on many of the details of wastewater treatment and wastewater disposal in the marine environment.
3) It is very difficult to develop the detailed database required to verify a dynamic hydrotechnical and contaminant transport model in a complex marine environment.

These factors, in combination with public values and legislative or regulatory initiatives by many governments, have resulted in many communities deciding to return water to the environment at a quality similar to that used by humans. If the CRD were to take the decision to treat their wastewater, the final decision as to the quality required and the challenges to be met by the treatment facility would have to be carefully investigated.

The location of a plant or series of WWT plants requires careful consideration of the degree of treatment and the space required, and the time period for its operation. In the latter case, the time should be very long in a practical sense (100 to 200 years). Also, it would make sense to plan for the likely eventuality that higher effluent quality standards will be imposed in the future. Thus, the capacity and space for potential future treatment improvements should be planned for. Third, the quality of life in Western society is highly influenced by the availability of water to the individual, so retaining this service must be a high priority of all communities. Water conservation efforts will impact water consumption, and as a result, wastewater strength characteristics. Also, reducing inflow and infiltration will reduce flow to the WWTP during and after storm events.

As recognized in the Core Area LWMP, sludge collection, treatment, and disposal are critical components of the wastewater treatment process. There will not be uncontrolled losses to the environment because the majority of the contaminants will be consolidated into the sludge and treated or disposed safely, and the liquid from the sludge will be returned to the wastewater treatment plant (WWTP).

All of the above lead to the need for total system management; the Core Area LWMP addresses these issues and is in need of adjustments in only a few areas. In the Panel's view, the LWMP's decision-making process related to the need for wastewater treatment should be revisited.

Treatment and disposal in areas not served by municipal collection systems

Collection, treatment, and disposal of septage (septic tank contents), and in some cases wastewater, by pump-out truck from areas not serviced by sewerage are critical to public and environmental health as well as to aesthetics. This issue is properly identified in the Core Area LWMP (2000) and thousands of papers in the literature. Assuming septic tank and absorption field designs meet standard design requirements (as installed), maintenance becomes the critical management component. Accepted practice calls for a 2- to 5-year pump-out requirement. Proposed by-law development and enforcement might establish this practice. When population density and geology allow it, the best management is generally to place sewers in the community.

Septage pumped from septic tanks in areas not served with sewers must be treated prior to its return to the environment. Septage is similar to incompletely treated sewage. It consists of a collection of settleable and floatable materials that have experienced some degree of biological stabilization but contains the full range of contaminants.

The most common treatment in areas operating sewage treatment plants is to feed the septage into the treatment plant and stabilize the contaminants or incorporate them into the plant sludge for further treatment. This option could be adopted for septage from areas not served by sewers, should wastewater treatment be put in place.

Adequate septage policies exist; however, it appears that the CRD lacks the authority to properly implement the policies.

4.2

Assessment of Impacts of Wastewater Discharges

Assess the current environmental and human health impacts of the Clover and Macaulay points wastewater discharges. Discuss the significance of these impacts.

Human Health

Two main types of contaminants in sewage have the ability to affect human health: 1) pathogens (agents that might cause infectious diseases) and 2) chemicals in seafood that might be consumed by humans. Both of these were evaluated by the Panel.

Risks from pathogens

There is conclusive evidence that the diluted sewage plume from the Macaulay and Clover Point outfalls reaches the surface. This conclusion is based upon fecal coliform measurements taken as part of the Capital Regional District's (CRD's) ongoing monitoring program. The diluted sewage plume surfaces (on certain occasions) in the area of both outfalls, leading to contaminant levels that exceed those known to cause health effects if people are exposed. This fact is substantiated by the CRD's statement (CRD 2002) that "Dilute sewage does reach the surface during winter slack tide. Slack tide occurs off both outfalls for very short periods of time each day". Recent modeling analysis performed by Hodgins (2006) also predicts plume surfacing to occur in winter, during slack water on the turn of the tide; the average duration of surfacing predicted by the model is 92 minutes at Macaulay Point and 69 minutes at Clover Point. Given this situation, there is potential for the transfer of a variety of pathogens (including viruses, bacteria, and parasites) from the sewage to humans who come in contact with the marine waters in the vicinity of the sewage outfalls during these times of plume surfacing.

Analyses by Golder Associates (2002) of the 1995–1999 bacterial monitoring data show that at Clover Point, particularly during the wet season (October through March), fecal coliform values exceeded 400 colony fecal units (CFU)/mL (the maximum acceptable concentration in the "Guidelines for Canadian Recreational Water Quality" [Health and Welfare Canada 1992]) as much as 20% of the time at Station 1 (closest to outfall diffuser), but also 10%, 13%, and 17% of the time at Clover Point stations 5, 6, and 7, respectively. Maximum fecal coliform values observed at these stations during this period were 10,000 CFU/100 mL at Clover Point Station 1, and as high as 4400 to 6400 CFU/100 mL at Stations 5, 6, and 7. A similar analysis of data for the Macaulay Point outfall showed that at 2 stations near the outfall (Stations 1 and 5), fecal coliform values exceeded 400 CFU/100 mL 10% of the time during the wet season (October–March), with maximum values as high as 6700 CFU/100 mL. On the other hand, for the period 1995–1999, at both Clover and Macaulay Points, exceedences above 200 CFU/100 mL and/or 400 CFU/100 mL levels were very rare in the dry season (April–September), with no exceedences above 400 CFU/100 mL at Macaulay Point and only a 3% exceedence frequency at Clover Point (Station 4) during the dry season when recreational use would be expected to be highest.

Because the level of fecal coliform bacteria is extremely high in undisinfected, screened raw sewage (levels in the range of 3 to 13×10^6 CFU/100 mL), the maximum fecal coliform densities in the range of 4×10^3 to 1×10^4 CFU/100 mL observed in surface waters at both Clover and Macaulay points (Golder Associates 2002) indicate the following:

- The sewage plume is not always efficiently trapped at depth but at times does come to the surface of the ocean and can negatively and significantly impact water quality.
- Under these scenarios (during the breakdown of stratification in the winter), dilution of the sewage plume in these surface waters is in the range of 1000:1.

Finally, low-density materials (fats, oils, and grease) are continuously reaching the surface and may carry a variety of wastewater solids and fecal microbes with them.

There is a great deal of uncertainty about the human health effects of raw sewage discharged by CRD due to the infrequent sampling regime and the choice of fecal indicators. The CRD (2002) has stated their conclusion that "the receiving environment and modeling data indicate that the outfalls do meet primary contact recreation criteria". But this analysis may overstate the situation. The CRD is following an amended protocol to the British Columbia (BC) Water Quality Criteria which allows them to limit sampling to only once each month, rather than the 5 times per month mandated in the BC Approved Water Quality Guidelines (Criteria) (1998)**.** Calculating the geometric means based on a single monthly sample rather than the otherwise required 5 samples per month leads to a lower degree of "power" to detect difference, a high degree of uncertainty, and a misleading conclusion that the recreational criterion is being met. This uncertainty in evaluating the risk could be markedly reduced had the BC Water Quality Guidelines mandating 5 samples per month been followed.

The CRD (2002) recognizes that "Dilute sewage does reach the surface during winter slack tide. Slack tide occurs off both outfalls for very short periods of time each day". Based on the CRD's data and modeling, the degree of surface water contamination might be changing dramatically on a daily basis; in the Panel's opinion, the CRD's protocol of sampling the outfalls 1 time per month is inadequate to represent the variations that occur in water quality as a response to the changing tides, currents, and seasonal stratification.

Moreover, a number of physical and temporal variables have not been incorporated into the present CRD monitoring program design. For instance, the influence of tidal cycles on surface water quality near the outfalls has not been assessed, nor have the temporal variations in the flow of sewage been evaluated. Future sampling programs need to be more "science-based" and to be able to factor in these temporal variables (as well as other physical forcing factors such as currents) in order to predict "worst-case" scenarios and ensure that they are sampled.

In addition to the uncertainties in the CRD sampling regime mentioned above, the fecal indicator that CRD uses to gauge the degree of human health risk may be inadequate. A series of prospective epidemiological studies, conducted by the United States Environmental Protection Agency (USEPA 1986) at both freshwater and marine beaches, established that the indicator, enterococci, displayed the best correlation with human health effects at marine beaches. This is true because fecal coliform bacteria do not survive well in marine waters (Fattal et al. 1983), and thus may not be as reliable an indicator of fecal contamination as enterococci, especially when there is a considerable time or distance between the source of fecal pollution and the area of recreational bathing. Based upon these results, the "Guidelines for Canadian Recreational Water Quality" (1992) recommend the use of enterococci and set a mean density of 35 enterococci/100 mL as the limit in marine waters.

Monitoring fecal coliforms may significantly underpredict the degree of contamination, especially if the sewage plume persists at the surface. Therefore, based on the recommendation from Health and Welfare Canada (which is technically based) and the fact that the "state of the science" is to measure enterococci, the CRD should not be using fecal coliform bacteria as their sole bacterial monitoring indicator for human health effects.

Despite the uncertainties described above, bacterial data indicate that when the plume surfaces, persons exposed to water would be at increased risk for adverse health effects. Available data suggest that such exposures are limited.

The "Canadian Guidelines for Recreational Water Quality" state that "if it can be demonstrated that *E. coli* or fecal coliforms can adequately demonstrate the presence of fecal contamination in marine waters, then the *E. coli* or fecal coliform maximum limit for fresh waters may be used." In this case, the maximum acceptable concentration of 400 fecal coliforms/100 mL can be calculated to correspond to a gastrointestinal illness rate of 1% to 2% (Guidelines for Canadian Recreational Water Quality 1992).

The Panel's analysis of monitoring data for the period 1995–2005 (CRD 2006) , found that when the 400 FC/100 mL limit was exceeded, the mean (geometric) level of the fecal coliform indicator was 1145 FC/100 mL) for all stations at Clover Point and 1085 FC/100 mL for all stations at the Macaulay Point outfall during the wet season. For this same period, though dry weather (April–September) exceedences are less common, when the levels exceeded the 400 FC/100 mL limit, the mean level was 1211 FC/100 mL) at Macaulay Point and 765 FC/100 mL at Clover Point.

Due to the uncertainty introduced by the use of fecal coliform bacteria as the indicator of choice (as opposed to enterococci), poor temporal resolution of the monitoring program (only 1 sample per month), and only qualitative estimates of actual human exposure, a quantitative risk characterization for water contact in the area of the Macaulay and Clover Point outfalls cannot be realistically performed. However, the few studies in the literature which relate dose–response data for human health effects to levels of fecal coliform bacteria in marine waters find that, at near 1000 fecal coliforms/100 mL (close to the geometric means for the exceedences of "Canadian Water Quality Guidelines" at the outfalls), the gastrointestinal illness rate can be in the range of about 5% of exposed persons (Fattal et. al 1987) and non-enteric illnesses (for example, ear infections) in the range of as high as 20% (Fleisher et al. 1996). Therefore, despite the considerable uncertainties, CRD's existing data do not rule out the potential for adverse health effects if humans are exposed to the surface waters in the area of the sewage outfalls at the time of plume surfacing.

Currently, we do not know the fate of the surfaced sewage plume or its far-field effects on human health.

When sampling is done only once a month as with the CRD Monitoring Program, there is no temporal resolution to determine how long a particular episode of plume surfacing may have persisted or where the surface water plume goes. Additionally, there are major drawbacks to using coliforms as an indicator of far-field health effects of sewage discharge. In recreational exposure scenarios in bathing waters, it has long been recognized that the survival rate of virus that cause gastroenteritis is much longer than that of fecal coliforms, particularly in the marine environment (Fattal et al. 1983). The level of total and fecal coliforms, therefore, may not necessarily be the best predictor of risk because of their different behavior and fate in the environment, compared to viruses. As the plume moves, the fecal coliforms will tend to die off differentially, compared to pathogenic viruses such as hepatitis A. In this regard, Griffin et al. (2003) in a comprehensive review on viruses found "that in the majority of the studies that monitored marine waters for both bacterial indicators and bacterial pathogenic viruses, viruses were detected when indicator levels were below public health water quality threshold levels". They go on to state that this creates a "significant dilemma" for those responsible for marine water-quality monitoring and further state that such results "warrant investigating the use of human viruses as indicators of marine water quality". Unfortunately, the technology for testing human viruses in marine waters, while possible, remains a "state-of-the-art" research methodology and has not been incorporated into most marine outfall monitoring programs, including those of CRD.

Although it has been possible to spatially distinguish between the sewage outfall-derived sources of fecal contamination at Clover Point and the stormwater sources of contamination discharged at outfalls along the shoreline (particularly at Ross Bay; Golder Associates 2002), the spatial and temporal resolution of the fecal coliform dataset does not allow a complete analysis of far-field fate of the plumes, and whether and where the sewage plume may impact the nearshore. Based on the levels of fecal coliform bacteria, these stormwater discharges at Ross Bay have been designated as discharges requiring action for public health concerns (Cameron and Green 2004).

The Panel notes that these shoreline discharges of fecally contaminated stormwaters will continue even in the event that more advanced treatment of the sewage at the Macaulay and Clover Point outfalls is initiated, and such contaminated runoff discharges directly to the shoreline where the probability of human exposure is likely much higher than at the ocean outfalls. It is also important to note that the value of the fecal indicator bacteria (such as fecal coliforms) as indicators of human health effects, where non-point sources of contamination are the predominant pollution sources, is not well established. It is not clear that the health relationships for bacterial indicators will remain the same when non-human sources predominate (Calderon et al. 1991). In fact, nearly all previous epidemiological studies demonstrating the value of fecal indicator bacteria have been conducted at locations where human sewage was predominant. Because animals shed these same bacterial indicators without some of the accompanying pathogens, there is considerable uncertainty in extrapolating present water-quality guidelines, based on risk in human sewage-contaminated waters, to non-point source situations. Only a poor correlation has been found between fecal indicator bacteria and viruses when urban runoff is examined (Jiang et al. 2001; Noble and Fuhrman 2001). Therefore, the degree of human health risk from runoff-based contamination sources in the shoreline area of the outfalls is not well established. This has important implications for the harbours within CRD's jurisdictions, where the CRD and municipalities have a significant ongoing stormwater monitoring program in nearshore environments.

Risk from consumption by humans of contaminants in seafood

Levels of chemicals of concern in seafood (for example, fish) have not been measured in the area of the sewage outfalls. While Golder (2005) conducted a risk assessment for the effects of contaminants on wildlife, a formal human health risk assessment has not been done. One of Golder's recommendations is that the CRD collect data on fish tissue contaminant levels which could be used to support a human health risk assessment.

In the absence of fish tissue data, the Panel made screening-level calculations on risk for a limited number of contaminants, with a focus on the persistent, bioaccumulative substances: total polychlorinated biphenyls (PCBs) and mercury. To represent contaminant levels in seafood, the horse mussel (*Modiolus modiolus)* data at Clover Point was used. Despite the fact that there is a harvesting closure for all bivalve mollusks due to wastewater contamination throughout the project area, this analysis served as an indicator of potential adverse effects on human health. **The screening-level risk assessment indicated that, for the bioaccumulative and toxic chemicals, total PCBs and mercury posed negligible risks from**

consumption of resident mussels. However, the Panel cautions that this analysis was preliminary in nature and was used only as a screen for their own purposes.

Technical recommendations

Characterization of the risk to public health posed by exposure to sewage discharged to surface waters of the ocean at Macaulay and Clover points is made difficult by the large uncertainties or outright gaps in monitoring data. These are described below, along with technical recommendations:

1) Bacterial indicator monitoring design:
    a) Calculating the geometric means based on a single monthly sample rather than the otherwise-required 5 samples per month leads to both a high degree of uncertainty and a misleading conclusion that the recreational criterion is being met. The CRD should consider reducing this uncertainty by sampling as described in the BC Water Quality Guidelines.
    b) The Guidelines for Canadian Recreational Water Quality (1992) recommend the use of enterococci, with a mean density of 35 enterococci/100 mL as the limit in marine waters; this recommendation is in alignment with the state of the science, and the CRD should consider measuring enterococci as a supplement or replacement for fecal coliform bacteria as their marine monitoring indicator for human health effects.
2) Currently, no data exist on levels of any chemical of concern in fish tissue in the area of the sewage outfalls throughout the project area. Any characterization of human health risk from chemicals through exposure via consumption of resident biota would necessarily include such analyses of chemical risks posed by fish (near the top of the food chain) consumption. It is recommended that the CRD use the recently collected high-resolution data in mussels, supplemented with fish tissue data and consumption data, to conduct a formal human health risk assessment for all the contaminants of potential concern.
3) Associated with this, is the nearly total lack of data for some important persistent organic pollutants (POPs) in tissue of any resident biota in the area of the outfalls. Although the recent report "Macaulay and Clover Point Additional Investigations-High Resolution Chemical Analyses" (Golder Associates 2006) measured PCBs and PBDEs in tissue of the horse mussel, that study did not include analyses of other POPs, for example, organochlorine pesticides and dioxins in mussel tissue (or fish tissue), despite the fact that such analyses were done on the wastewater effluent itself. Such analyses of all major POPs in mussel (and fish tissue) should be considered by the CRD for future asessments.
4) The fate of the surfaced sewage plume or its far-field effects have not been well studied using field data. The CRD should consider more extensive monitoring with better spatial and temporal resolution in the far-field to provide a better understanding of the fate of sewage plume. For example, consideration could be given to tracking the consequences on water quality of a worst-case (as predicted by the model) plume surfacing event at a finer temporal scale of resolution.

Wastewater Effluent Composition

The effluents that are being discharged are complex in composition, large in quantity, and toxic at the source.

The sewage (municipal wastewater effluent) discharged at the two outfalls is a complex mixture of nutrients and hundreds of organic and inorganic chemicals. Nutrients include organic (carbon) and inorganic (nitrogen and phoshorus) compounds. Chemicals are dissolved and in suspension, including metals and metalloids, oil and grease (of both mineral and vegetable origin), persistent organic pollutants (POPs[1]; such as PPCPs, PCBs[2], chlorinated pesticides and PBDEs), and others. Some of the compounds released in a sewage effluent are synthetic industrial or pharmacological agents; these compounds are discussed in detail in Section 4.6. The effluent is freshwater and has low levels of oxygen, high levels of ammonia, and variable pH. It is complex and variable, in both strength and composition, by day and by season.

Due to elevated levels of ammonia and oxygen-demanding organic materials, raw sewage discharges are typically acutely lethal to fish and other aquatic organisms. This was shown for the CRD's effluents (EVS 1992) early in the marine monitoring program.

The effluent in Victoria is largely from households and small businesses. The present preliminary wastewater treatment (that is, screening at 6 mm and grit reduction) removes only bigger objects such as plastics, paper, vegetative matter, and organic lumps.

Loadings

Total loadings of effluent from outfalls are estimated at 129 million litres/day (2005) into the Victoria Bight, Strait of Juan de Fuca. Clover Point facility discharges at 67 m depth and 1.1 km from land. Macaulay Point discharges at 60 m depth and 1.7 km from land.

Given that Victoria Harbour is in near proximity with Victoria Bight and the location of the two outfalls, the Panel was interested in the relative loadings of the two areas to the local marine environment. Based on limited enquiries, it does not appear that any organization has evaluated the relative contributions of contaminants, despite the two systems being linked.

Consideration of loadings of contaminants and nutrients to any receiving environment raises the issue of "assimilative capacity"—how much introduction of materials can a given environment sustain before adverse effects begin to show, and then at what point do they become unacceptable? The issue of loadings is of particular relevance for future increases in the population of the CRD (discussed in Section 4.5) and POPs and possibly for some of the emerging chemicals (discussed in Section 4.6).

Upon release at the two outfalls, constituents of the discharges disperse into the marine environment of the Strait of Juan de Fuca.

A freshwater-based, screened sewage effluent is being discharged, at depth, from numerous ports at each outfall, into a colder, well-mixed marine environment. The heavier particulate components and less water-soluble constituents settle to the seafloor in the vicinity of the outfalls, and the finer particles and dissolved constituents rise with the plume, staying in the water column and diluting and dispersing, presumably mostly below the halo and thermoclines (at the so-called "trapping depth"). There has been extensive modelling of the sewage plumes coming out of the diffusers at the outfalls using a model developed for the outfalls (Hodgins 2006; Lorax Environmental 2006). This modelling accounts for the oceanographic conditions of currents, temperature, salinity, pressure, and density, which would determine

[1] POPS are of particular concern because they can move from the physical environment and into the food web, where they can be transferred up to predators (such as the southern resident population of Orca whales which are a species at risk and under special protection) and humans.

[2] It is important to note that numerous jurisdictions, including Canada, have taken greater measures to prevent discharge of PCBs into marine waters.

how the plumes interact with the water column upon release, and at distance from the outfalls.

Dilutions of the effluents are considerable—minimally, 400× at 55 m depth, and 600× at 5 m depth, in the winter. Winter dilutions are much less than summer dilutions, due in part to differences in freshwater influence. However, relying on dilution and dispersion to reduce the concentrations of sewage to acceptable levels will only work as a strategy to some point in the future, as is discussed later.

The sewage effluent complex is discharged into the habitat of a wide range of organisms, both in the water column and on the sea floor. These include microbes, phytoplankton (plants), zooplankton (invertebrates, and fish eggs and larvae), benthos (animals that live at the seafloor), fish, and marine mammals.

The various organisms and communities in the food web in the vicinity of the sewage outfalls are exposed to sewage constituents through various pathways, such as via the water column, via seabed sediments, and through eating organisms that have taken contaminants into their tissues.

The sewage inputs, large as they are in volume, are not major contributors to nutrient levels in the Strait of Juan de Fuca.

Nutrients are substances containing nitrogen, phosphorus, and carbon that organisms acquire from the environment because they do not make the substances themselves. Sewage provides nutrients, which in moderation can benefit sea life, but nutrients become pollutants when they are too abundant, ruining large areas for fisheries, recreation, and tourism, and causing major economic loss (GESAMP 2001). In the recent "Tides of Change" report (Pesch and Wells 2004), it was stated that "most impacts on living resources are as a result of eutrophication, which is the accelerated production of organic matter, particularly algae, in a water body causing increased oxygen demand, decreased dissolved oxygen in the water, and hypoxia (lack of oxygen) in fish tissue as the organic matter decays. The extent to which nutrients cause these problems depends upon such variables as tidal flushing, freshwater inflow, the depth and configuration of coastal embayments, and loadings from other sources".

Local British Columbia scientists have considered the significance of nutrient inputs into the waters surrounding Victoria. An early study by Goyette et al. (1979) at the Macaulay Point sewage outfall "revealed that the discharge had a small measurable but localized effect. Major nutrients (i.e. nitrate and orthophosphate) did not significantly differ between sampling stations…….The sewage discharge appeared to have a negligible impact on natural substrate and biota". The BC/Washington Marine Science Panel (1994) concluded that the Clover and Macaulay Point outfall discharges to the Strait go into waters with strong currents and mixing processes, and therefore would disperse quickly. "Discharges were believed to be contributing negligible quantities of nutrients and BOD to an already nutrient rich area". Research by Harrison et al. (1994) and Mackas and Harrison (1997) concluded that "the sewage discharges have only a minor influence on the eutrophication status of JFS, the Strait of Georgia, and most of Puget Sound. Direct sewer inputs of nitrogen were considered very small compared to natural nitrogen inputs from entrained, nutrient rich water arising from the Georgia Basin estuarine circulation". They concluded that the extra nitrogen from the sewage outfall in Victoria would not cause increased phytoplankton blooms because of rapid seaward flushing in Juan de Fuca Strait.

Large-scale eutrophication is unlikely for two reasons. First, ambient nitrate and ammonia concentrations are high over much of the total area, so that total primary productivity is relatively insensitive to moderate increases or decreases. Second, exchange of water by estuarine and tidal currents is rapid (c. 1 year turnover time), and entering water carries naturally high nutrient concentrations. Natural nitrogen inputs by the estuarine circulation are very much higher than all the other sewage inputs". Hence the sewage inputs, large as they are in volume, are not major contributors to nutrient levels in the JFS.

The monitoring program is highly focussed on contamination of the seafloor and the health of those communities and does not thoroughly address other important groups within the marine ecosystem.

The surface and subsurface waters, sediments, and shorelines of the Strait of Juan de Fuca and surrounding waters are home to a great diversity of organisms. In considering the impacts that sewage discharge might be having on the high biodiversity of marine systems in the Strait, scientists are somewhat short of data. There are only so many "indicator species" measures or other data that can be collected to represent the health and quality of marine ecosystems.

Benthic (that is, bottom-dwelling) community assessment, which is employed in the CRD's monitoring program, is a standard tool used by scientists to represent effects of stressors on marine biodiversity. However, beyond this tool, standardized methods for other biodiversity measures are not well developed.

While Golder (2005) identifies receptors over and above seafloor communities in a conceptual model for the discharge zones, the datasets for organisms other than seafloor invertebrate communities tend to be older and weaker, with related uncertainties. Golder (2005) stated that "marine waters in the Victoria region support a diverse community of pelagic invertebrates"; pelagic invertebrates are animals without backbones that live in the water column. The response of these organisms (for example, the gelatinous invertebrates or jellies, the many planktonic crustaceans, young stages of fish) is very difficult to assess. The Panel recommends that toxicity testing of dilutions of the effluent be conducted, taking into account the recommendations of Golder (2005).

In addition, it is difficult to assess the effects of the sewage discharges on the surface micro-layer of the ocean. It is widely known that fats, oils, and greases surface in the vicinity of both the CRD discharges to the surface micro-layer of the ocean. Their effects on the marine community (for example, birds, wildlife, fish, and likely invertebrates) are unknown. In 1993, CRD commissioned sampling and analysis of "fat globules" from both facilities (ALS and EVS 1994); the fat was found to be toxic in the test endpoint (echinoderm sperm cell fertilization), but the results were too limited to extrapolate to field effects. During the Panel's field trip, seabirds were observed congregating in the zone where fats, oils, and greases would be surfacing—clearly there is a route of exposure to marine organisms and avian species. The risks are unknown.

The Panel acknowledges that evaluation of the effects of the effluent on pelagic and surface micro-layer communities is difficult, due to the state of the science. Direct monitoring of effects to water column and surface micro-layer communities is not widely practiced; however, given that the effluents are presently untreated, a greater degree of caution in monitoring is prudent. CRD's Marine Monitoring Advisory Group (MMAG) has also advised that these issues be explored, but it would be unreasonable to expect firm answers to result in the near-term.

Therefore, any decision about future sewage treatment needs to take this uncertainty into account, that is, are we really measuring the impact of current discharges accurately, and if not, what is the ecological cost to the rest of the marine ecosystem?

Finally, the impact of the discharges to higher-level organisms (for example, fish, seabirds, and cetaceans) also has not been examined until recently. As far as the Panel could ascertain, no work on fish body burdens and health has been conducted by the CRD; the Panel concurs with Golder's (2005) conclusion that such work should be done. Food chain modelling work by Golder (2005) was recently conducted to look at the potential for food chain transfer to higher-level organisms (discussed in the next section).

There are impacts on benthic organisms and communities in the close proximity to the outfalls. Sediments close to the outfalls have elevated concentrations of discharged chemicals. At Macaulay Point, community diversity is depressed, with pollutant-tolerant

invertebrates dominating the benthos. There are also elevated concentrations in some benthic organisms. At Clover Point, there are elevated concentrations of a number of chemicals in mussel tissues, the mussels being the dominant organism at that location.

Contamination of the seafloor sediments

Seafloor sediments in vicinity of the outfalls are contaminated[3] with many compounds attributed to the sewage effluents being discharged. The CRD's reports describe the contaminants (CRD 2003, 2004, 2005); they include heavy metals, phenolic compounds, PAHs, chlorinated organics, and semivolatile and volatile organics.

Interpretation of sediment chemistry data is often contentious because various parties have sediment quality values (for example, guidelines, criteria, or standards) that they believe are useful for screening the data. Often, differences of opinion cloud the real issue, which is how the chemical concentrations are manifested in terms of the response of biological communities to those concentration (if any) and their effects further up the food chain. The Panel has chosen not to be drawn into the evaluation of sediment chemistry data for this reason and, instead, places greater emphasis on the biological endpoints and tissue chemistry data.

Trends in sediment chemistry over time have been conducted by various consultants, and findings indicate that there is considerable variability in the data but no reason to suggest that concentrations are changing over time. The direction of outfall effect is to the east and southeast, consistent with plume predictions.

Contaminants in mussel tissue at Clover Point

CRD has monitored mussel tissue bioaccumulation in horse mussels *(Modiolus modiolus)* on an annual basis. Mussel tissue bioaccumulation provides a useful tool to evaluate exposure for the Clover Point invertebrate community to chemicals in the discharged sewage. Because mussels are filter-feeding organisms, their tissue concentrations of selected chemicals reflect both exposure to these chemicals through this food chain pathway and an indication of the bioavailability of chemicals of concern.

Monitoring results for mussels at Clover Point, to date, have shown that besides copper and lead, none of the other toxic heavy metals are elevated near the outfall. In fact, they often exhibit the opposite pattern, with higher metal accumulation observed at the reference stations than at sites closer to the outfall (Golder 2005). This reverse gradient was observed (to varying extent) for arsenic, chromium, mercury, nickel, silver, selenium, and zinc. Paine (2004) hypothesized that the increased growth of mussels in the vicinity of the outfall, due to organic enrichment, may result in the reduced ratio observed near the outfall between metal contaminant and tissue mass, referred to as "growth dilution".

On the other hand, levels of copper and lead have been shown to be elevated at the outfall relative to the far-field stations, which were similar to each other and to the reference stations. This pattern tended to reflect that seen for copper and lead in the bulk sediment (Golder 2005). Despite this fact, the spatial extent of these elevated copper and lead levels in mussel tissues is rather small, and for most of the years monitored, only copper and lead levels in mussel tissue at the outfall sites (C0) were significantly above the reference sites. Furthermore, differences in concentrations for the 100 m to 800 m groups were minor and similar to the reference stations.

Polychlorinated biphenyls (PCBs) levels show a small enhancement near the outfall, where levels in mussel tissues were nearly double those of the far-field concentrations. Levels of polybrominated diphenyl ethers (PBDEs) showed the widest footprint of spatial distribution in mussels around the outfall, with levels at the outfall and both

[3] Note that contamination does not imply effects, but merely that concentrations are above background levels.

near-field and far-field monitoring sites (out to 800 m) elevated relative to the reference station.

Paine (2004) conducted a trend analysis of selected substances for both the Macaulay and Clover Point sewage effluents and found that concentrations and loads of copper and lead (as well as mercury, nickel, silver, and zinc) have decreased between 1996 and 2003; however, their results also showed that the copper and lead load reductions at Clover Point have been much less (and not significant) during this 7-year period, compared to those at Macaulay Point. Similarly, trends in mussel copper and lead concentrations from 1995 to 2004 at Clover Point showed that levels of copper and lead in mussels in 2004 were nearly the same as in 1995 (although higher values of these two metals were observed in 2000 and 2001) (Golder 2005).

Effects on mussels at Clover Point

Elsewhere in this report (Section 4.3), the CRD reviews the effectiveness of the Seafloor Trigger process which, in part, includes mussel biology metrics as endpoints. Golder (2005) analyzed temporal and spatial trends in these metrics and generally found no adverse effects in mussels that could reliably be related to the effluent discharges. Although not interpreted as adverse, there was a distinct pattern indicating increased weight at age for mussels associated with the outfall.

There were no differences in mussel size or growth, reproduction, or tissue concentrations of contaminants that were interpreted as adverse impacts. **However, the mussel biology metrics data should be re-interpreted in light of the Panel's review of the seafloor trigger process.**

Effects on the benthic community at Macaulay Point

The CRD has conducted annual field surveys for benthos associated with their effluent discharges at Macaulay Point since the 1970s (Paine 2004), although reliable data for temporal comparisons are available only for 1994, 1997, and 1999 to 2004. Methodological differences make the 1992 data[4] inconsistent with the other years. The monitoring program associated with the Macaulay Point discharge included an assessment of the benthic community at several sites around the outfall, including immediately adjacent to the outfall, the IDZ (100 m), farfield 200 to 800 m, and a reference site (Parry Bay). The analysis includes the collection and analysis of 2 to 4 samples using Puget Sound Protocols (see Golder 2004).

The monitoring program includes consideration of total organism abundance, abundance of segmented worms (polychaetes), total number of unique organisms (richness), and numerical dominance in each benthic grab sample (biodiversity). In recent years, the analysis also has included assessments of different types of organisms and multivariate statistics. Stations near the outfall exhibited total abundances that were higher than reference stations, due primarily to an increase in the abundance of amphipods and segmented worms (mobile and sedentary), compared to the far-field sites. The differences appear to be associated primarily with an increase in the total organic carbon and associated tolerant species that are able to exploit the organic enriched environment close to the outfall. Although taxonomic richness does not change with distance from the outfall, there is a change in the dominance of selected species as reflected in a change in the Swartz's Dominance Index (SDI; the minimum number of species that makes up 75% of the sample abundance). Lower SDI is observed at the sites within 200 m of the outfall, especially toward the west and southeast of the outfall and diffusers.

The majority of the stations (100, 200, 400 m) had elevated mean abundance and polychaete abundance greater than the reference (statistically different at 100 and 200 m in 2004). There was a significant negative correlation

[4] The 1992 data are intriguing because the sampling methods for that year obtained greater diversity and abundance than other years. The Panel has not looked into this in any detail, but standardization of methods since that time has seen a drop in these measures; perhaps this is not to the advantage of the discriminatory power of the data or the representativeness of the data?

($p < 0.01$) between these metrics and distance from the outfall. In contrast, there was no relationship between taxonomic richness and distance from the outfall, although relatively low taxonomic richness is observed for the site southeast of the outfall consistent with the increased polychaete abundance and lowered SDI.

Contaminants detected in sediment also indicate deposition of effluent-derived chemicals and sediments to the south and east, consistent with the known currents and depth profiles of the area. There was a correlation between total organic carbon and abundance of taxa such as polychaetes. The recent sampling in 2004 suggests that there may be a temporal trend toward decreasing abundance of polychaete worms and echinoderms and a corresponding increase in the abundance of bivalves and amphipods near the outfall since the 1990s (Golder 2004). This may suggest a trend toward improving environmental conditions near the diffuser, or the replacement of more sensitive species with more tolerant ones. However, the annual variability and methodological issues make clear trends very difficult to discern.

The program uses only 1 reference site with only 3 replicates, which makes a comparison to the normal expected benthic community difficult. There is considerable natural spatial and temporal variability in benthic communities. The structure of the habitat, such as the physical sediment characteristics, can alter the communities but without appropriate reference sites, this is difficult to separate from other factors. **The program would benefit greatly from an expansion of the number of reference sites at Macaulay Point and replication within these sites.** These sites should be characterized to allow appropriate comparisons to the outfall sites. In addition, there have been changes in the methodologies used to collect, screen and enumerate the biota, and efforts made in recent years towards using standardized protocols.

Contaminants in the food chain

The ecological significance of these mussel tissue bioaccumulations of lead and copper were evaluated by using a food chain model and ecological risk assessment, which was intended to provide a highly conservative estimate for the potential for adverse effects to wildlife receptors associated with the outfall (Golder 2005). Four representative metals were selected for screening using this food chain model, including copper, zinc, lead, and mercury. In applying the model, it was assumed that the average metal concentrations in the mussels were representative of the average concentrations in pelagic fish likely to be consumed by wildlife. Risk estimates were then made on the basis of a hazard quotient (HQ) approach, involving a comparison of the estimated dose to a wildlife receptor to a toxicity reference value (TRV) which was chosen from the literature to represent the "no observable adverse effect level" (NOAEL).

This assessment indicated that for most of the metal contaminants (including copper, lead, and mercury), bioaccumulation-based risks to wildlife were negligible (that is, hazard quotients were <1.0). Zinc showed a hazard quotient slightly greater than 1.0 ($HQ = 1.1$) for double-crested cormorants, but this was deemed unlikely to indicate significant adverse effects, due to the number of highly conservative assumptions inherent in this food chain model risk assessment (Golder 2005).

Until very recently, most of the spatial analyses of tissue chemistry were based on metal concentrations, but recent high-resolution analysis of persistent organic pollutants in mussel tissue at Clover Point allows similar spatial analyses for PCBs, PAH, PBDE, and phthalates (Golder Associates 2006; Macaulay and Clover Point Additional Investigations-High Resolution Chemical Analyses). In 2003, mussel tissue samples were analyzed for all 23 Clover Point near-field and far-field monitoring stations, as well as 3 Constance Bank (CB) reference stations. In 2004 and 2005, the high-resolution analyses were performed only on mussel tissue for 14 Clover Point stations and the 3 reference stations.

In general, the levels of PAHs in mussels decreased with distance from outfall, with most of the decrease within the first 100 m. Phthalates did not exhibit any significant trends with distance from the outfall. PCB levels showed a small enhancement of PCB levels near the outfall, where levels in mussel tissues were nearly double that of the far-field concentrations, but the far-field concentrations did not significantly differ from the reference station. On the other hand, PBDEs showed a general pattern of decreasing concentration from the outfall, with levels at the outfall and both near-field and far-field monitoring sites (out to 800 m) elevated, relative to the reference station.

Using multivariate statistical analysis, Golder (2006) found that for total PBDEs (as well as benzo(a)anthracene and fluoranthene), there were significant differences between the far-field as compared to reference groups. Moreover, principal component analysis (PCA) performed on both the 2003 and 2004 high-resolution mussel tissue data, identified several station groupings: the 3 near-field stations (C0, C1E, and C2E); the CB reference stations; and the remaining stations located between 100 and 800 m from the Clover Point outfall. This PCA analysis for the trace organics was very similar to the station groupings by PCA using select metals (CRD, Macaulay and Clover Point Wastewater and Marine Environment Program, 2004 Annual Report), which also showed stations C0, C1E, and C2E all grouped together, indicating that these stations are dissimilar from the rest. This pattern is also similar to the Macaulay Point outfall sediment results, which show the chemical footprint largely confined to a particular direction and distance (Golder 2005).

For substances detected in one or more of the mussel tissue samples, screening against tissue residue guidelines and/or ecologically relevant thresholds were conducted. Golder Associates (2006) found that "although effects information is limited for several of the analytes investigated in this program, the available information indicates that observed tissue concentrations of PAHs, phthalates, PBDEs, and PCBs are well below concentrations shown to cause adverse effects".

Although Golder Associates (2005) state that the emphasis of the CRD monitoring program on "benthic and sessile organisms (e.g. benthic community and mussel community) appears to be appropriate", they also state that "monitoring of fish tissue burdens in the vicinity of the outfalls would assist in reducing the uncertainty of this assessment". The Panel strongly supports this recommendation and emphasizes that **for certain highly bioaccumulative chemicals such as methylmercury, PCBs, and PBDEs, fish tissue burdens are an important and necessary way to evaluate ecological risk, not only in fish and fish-eating birds but also in a number of marine mammals that consume pelagic fish.**

Persistent, organic pollutant (POPs), notably PCBs and PBDEs, are present in the sewage effluents. The concern about these contaminants is heightened in the local area because the southern resident Orcas, a popular symbol of ocean health, have been identified as among the most contaminated cetaceans in the world. There are many sources of PCBs to the Georgia Basin, among which the CRD's discharges are likely a minor contributor.

The significance of PCB contamination of BC coastal waters is exemplified by the public's and scientists' concerns over the Orcas. A recent study by Ross et al. (2000) concluded that "the PCBs present the greatest 'dioxin-like' risk to killer whales, and are present at levels in the majority of both resident and transient individuals which surpass those (levels) found to be immunotoxic and endocrine disrupting in the harbour seals". "Current concentrations of PCBs represent a significant toxicological risk to the populations in British Columbia".

Golder (2005) makes a strong argument that the CRD is not a significant contributor to the Straits of Juan de Fuca, and the Panel has no reason to dispute this point of view. However, for persistent contaminants such as PCBs and PBDEs, the overall management goal is virtual elimination. In many situations, this is not possible because PCBs are ubiquitous, persistent, and transported via air, but the argument can be made that, where we can control bioaccumulative compounds (such as PCBs) through practical means, we should do so.

Overall, the CRD's marine monitoring program is one of the more comprehensive programs being implemented to evaluate the effects of sewage in marine environments. However, there are numerous gaps related to the sewage effluents—these include the toxicity of the effluent, the effect on water column and surface micro-layer organisms, the monitoring of far-field effects, and further work on the risks of persistent organic contaminants through transfer to the food chain. Regular review of the monitoring program is important and should be well-resourced.

The CRD already has a process in place to evaluate their monitoring program (through input from a Marine Monitoring Advisory Group; MMAG). Some of the above issues are already under consideration by that group. The Panel encourages the CRD to continue to incorporate new ideas on monitoring tools that may be effective in reducing key uncertainties.

The CRD has indicated that there are regular reviews of their monitoring program (on the order of every 6 years), and the Panel recommends that this review be well-resourced for expert, independent review to complement the MMAG, particularly if the status quo for sewage non-treatment (or screened sewage discharge) is maintained. The Panel's review of the monitoring data should not be considered a formal review of the monitoring program, but rather a contribution to a more in-depth future review process.

4.3

Review of Early Indication and Seafloor Trigger Processes

Review and assess the effectiveness of the early indication process and seafloor trigger process to signal when advanced sewage treatment is required.

The Capital Regional District (CRD) has established a Seafloor Trigger process as a mechanism to ensure that wastewater discharged through the Clover and Macaulay Point outfalls do not cause adverse effects to the receiving environment (CRD 2005). The Seafloor Triggers provide numerical "parameter effects levels" for sediment-dwelling organisms and a spatial and temporal framework for interpreting them. If the triggers are exceeded, then action will be required to install treatment to remediate the impacts. A specific set of triggers were established at each of the outfalls to monitor for significant changes and trends. The approaches at the 2 outfalls differ because of the physical habitat and ecology of the sites.

The trigger process was cautiously accepted by the Provincial Ministry of Environment, in lieu of a firm schedule to provide treatment at the time of approval of the Core Area Liquid Waste Management Plan in 2003. The process was to result in provision of treatment within 3 years of the trigger point being reached. A revised trigger process includes voluntary use of warning levels (Early Indication Process) to guide the CRD Source Control Program (CRD 2005). This Early Indication Process is intended to allow steps such as source control to be taken to remediate the impacts before the Seafloor Triggers are exceeded.

The Trigger Process should not be used in lieu of a weight-of-evidence approach (including social, economic, and environmental considerations). The trigger process should be used as just one additional tool in the decision-making framework. There is so much uncertainty associated with the measurement of environmental impacts at the outfalls that no simple combination of triggers can be used exclusively with complete confidence. A monitoring program should be used to guide and support management decisions, not to be the decision tool itself. In the opinion of the Panel, the current triggers as well as the early indicators are incomplete and are neither sufficiently robust, rapid, nor reliable measures to adequately protect the ecosystem in the long term.

Seafloor Triggers and Early Indicators

The Seafloor Trigger Process was developed by a working group and reviewed by an independent scientific panel established by the CRD: the CRD Marine Monitoring Advisory Group (MMAG). The development of the triggers and early indicators included a rigorous examination of the potential options and selected a series of endpoints based on available scientific literature, analysis of previous monitoring data, and a number of assumptions. It is designed to incorporate biological, spatial, and temporal variability. At both outfalls, a Compliance Zone of 100 to 130 m from the diffuser was established, and an exceedance of the Effect Level at 4 out of 8 stations is required as the trigger point for 3 consecutive years.

Macaulay Point

At Macaulay Point, the seafloor is fine-grained sediments, and the triggers have been established based on the Pearson and Rosenberg (1978) model of organic enrichment (Figure 4.3-1). The model predicts that, closer to the diffuser, there will be a decrease in species richness, and a few pollution-tolerant species such as polychaetes and amphipods will become dominant as they exploit the organically enriched environment. Very close to the diffusers, however, even pollution-tolerant organisms will decrease in abundance as they are affected by the excessive enrichment and/or toxicity of the effluent. The effect level is therefore set on the basis of abundance only when there is elevated total organic carbon (TOC). The early indicators are based on the same principles and endpoints as Pearson and Rosenberg (1978) but are set at more sensitive levels. In addition, the Swartz's Dominance Index (SDI) is a num-

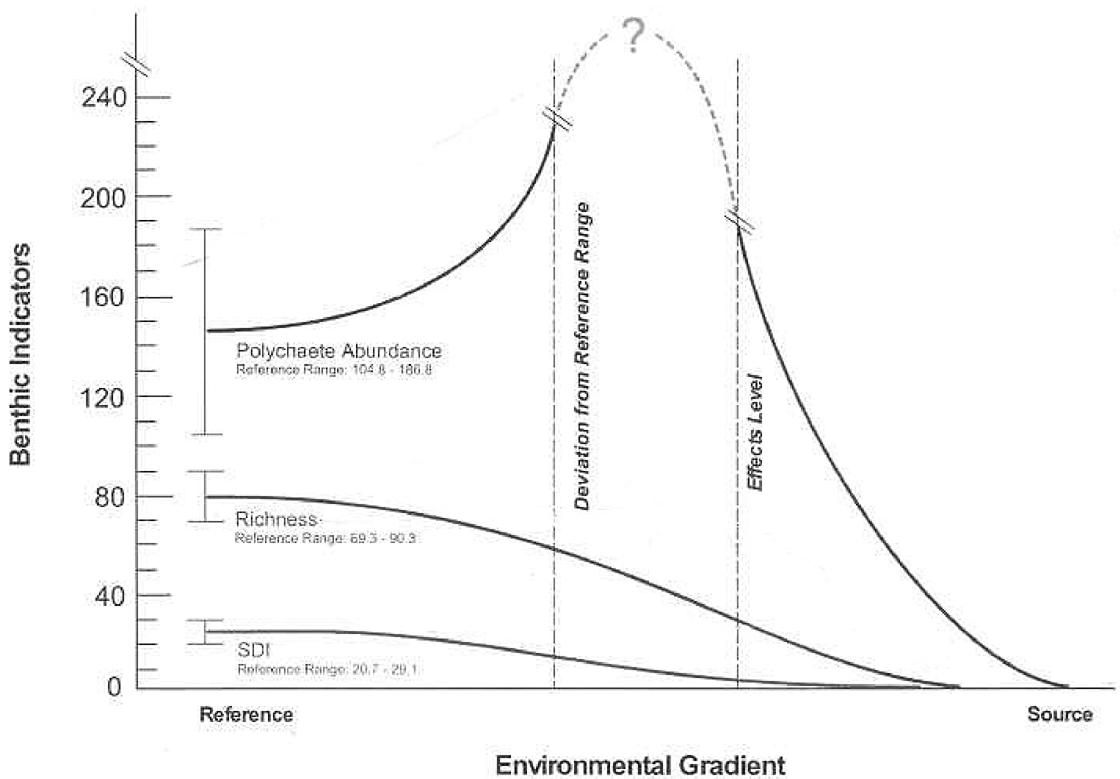


Figure 4.3-1 Hypothetical relationship of reference ranges and parameter effects levels to benthic community endpoints superimposed on the Pearson-Rosenberg model of organic enrichment (bars represent reference range for each endpoints. The units for SDI and richness are taxa per 0.1 m^2, and the units for polychaete abundance are individuals per 0.1 m^2.

erical representation of the reduced richness and the increasing dominance of a few species in the benthic community (that is, the number of species that makes up 75% of the individuals).

Clover Point

Different organisms live in the swift currents sweeping the coarse-grained sediments and cobble at Clover Point. The monitoring program there was based on the growth (length and weight at age) of a common and abundant deep water mussel species (*Modiolus modiolus*) living on the bottom (epibethic). Similar monitoring programs using other marine mussel species have been used in many jurisdictions, for example, mussel watch programs, although few have used *M. modiolus.* The trigger points for each of the selected endpoints in *M. modiolus* were established on the basis of a statistical analysis of data from reference populations unaffected by the outfalls. A decrease of 20% in both weight and length at age is considered the Effect Level. The early indicators are based on the same principle but a more sensitive response level (10% of reference) as well as an assessment of reproduction. In addition, Early Indicators for bioaccumulation of contaminants are included, although levels have been set only for copper (40 mg/kg wet weight).

Bioaccumulation-based tissue concentrations

Deepwater mussels are being used as surrogates for other food resources in which contaminants may bioaccumulate. The measurement endpoint is the level of chemicals in the mussel tissue. The tissue levels are intended to protect higher consumers of benthic and epibenthic organisms, including fish, aquatic birds, marine wildlife, and humans. The concentrations of chemicals in mussel tissue to be examined were developed through a review of the literature and established regulatory criteria for the protection of human health and wildlife. A review of the available tissue contaminant data in *M. modiolus* at Clover Point identified only copper and lead as bioaccumulative chemicals of concern (based on available data). The intention is to re-evaluate the list as more data become available.

A tissue concentration of 40 mg/kg wet weight (ww) was set for copper as the level of concern, based on 1/10 of the risk-based levels established by the United States Environmental Protection Agency (USEPA). A level of 0.8 mg/kg ww was established for lead, based on the same criteria. However, the concentrations of lead are generally elevated above this level throughout the Victoria Bight, and the levels will therefore be evaluated based on a comparison to the reference sites.

Limitations to Seafloor Triggers and Early Indicators

The trigger process is based on some very sound marine sediment and monitoring principles, and the data collected to date and its analysis have been fairly comprehensive. However, there are some serious limitations to the program and the interpretation of the annual monitoring data being collected. In particular, the Seafloor Triggers appear to be very insensitive to changes in effluent quality, and it is not clear that the Early Indication Process is robust enough to actually predict future exceedances or identify the source of potentially toxic chemicals in the effluents. It is also not clear that the current design would lead to the trigger being exceeded until there was potentially a severe and widespread impact of the effluent. However, it is assumed that the Early Indication Process (annual monitoring) would give an early indication that biological changes were occurring in the populations.

The triggers were formulated assuming that the impacts of concern would be a result of sediment contamination linked to effluent quality (for example, nutrients, metals). For organic enrichment and hydrophobic contaminants close to the source, this may be a relatively good assumption (that is, effluent composition correlates with sediment contamination), but for emerging contaminants, especially those that are relatively hydrophilic, this assumption may not be valid.

The aspects of the receiving environment that could be affected by sediment-related exposure pathway were identified as part of the trigger development and included

- health of the benthic community,
- health of the epibenthic community, and
- bioaccumulation of contaminants and food resources.

Although the final triggers selected cover each of these elements, the physical habitat and ecology preclude all of these aspects to be covered at both sites. Although bioaccumulation is addressed in the Early Indication Process, it is not included as part of the Seafloor Triggers.

Macaulay Point

The benthic monitoring at Macaulay Point is based on an assumption that the major effect will be chronic organic enrichment and is based on the model of Pearson and Rosenberg (1978). The endpoints selected for monitoring the benthic community are all valuable, although they are all nonspecific indicators of biological or community change. Organic enrichment clearly occurs near the outfalls, and a general response is seen in the benthic community (for example, altered species abundance and growth). A key consideration, however, is whether enrichment leads to effects that impair the productivity and function of the benthic community. The triggers assume that even a dramatic change in species composition—such as increased dominance and abundance of polychaetes—is acceptable, even though it is recognized as a significant change in the biological community. Using multivariate analysis of the monitoring data, it is evident that the species composition is clearly different in reference, nearfield, and initial dilution zone (IDZ). Taxonomic richness provides a measure of biodiversity but is very limited as an indicator of ecological health. The taxonomic richness (number of taxa or phyla per area) does not measure the structure or function of the community. It is a simple count and does not reflect the species distribution or dominance or the causes of change. In addition, these measures are very sensitive to methodological considerations, including sampling design and methods, natural variability, preparation, and taxonomic precision. This is evident in the CRD monitoring data at Macaulay Point when there was a change in the methodologies used, resulting in differences in the parameters at reference stations relative to other years (for example, 2001, highlighting the importance of standardizing methods and understanding how they drive the data collected). Although there is a strong rationale behind the selection of the triggers, the linkage of the trigger to impacts at the community and ecosystem levels is poor.

Clover Point

At Clover Point the triggers are based on a decrease in the weight and length at age of the mussel *M. modiolus.* Based on the monitoring data and the extreme variability of both weight and length with age, this would also appear to be a relatively insensitive endpoint. It is unlikely that even relatively large reductions in growth could be detected. This is related to several factors:

- There is very large variability of both length and weight at age of *M. modiolus*.
- The most rapidly growing and sensitive animals, those under 50 cm in size, are excluded from the collections.
- The animals in the population live up to 15 years and grow relatively slowly.
- A major negative change in growth may take several years to become evident.
- The enrichment of the environment may mask toxic effects associated with the effluent.
- Tissue weight generally has the highest correlation with reproductive effects, but the trigger requires both length and weight to change before it is considered an effect. The addition of length may make the trigger more insensitive.

It has not been demonstrated that the length and weight at age is an endpoint that would result in being able to detect a meaningful biological changes in a reasonable time frame in the population of *M. modiolus.* **It is recommended that a statistical analysis or model be used to assess how much change in length or weight would be detectable using different sample sizes and to determine how many years it would take to observe a change.**

The staging for reproductive development of *M. modiolus* is one of the early indicators. It is based on examination of the reproductive stage of development of the mussels. This program was established with very little specific information about the reproductive biology of this species from either the literature in general or from the Victoria Bight. It was based on some early studies reported in the literature and similar monitoring programs in intertidal zones using other mussel species. Assessment of the monitoring data collected to date and the scientific literature suggest that the current sampling program for reproductive development in *M. modiolus* is not suitable as an early indicator.

The Panel conducted a literature review to support their analysis (Appendix E, from which references from the following text are found). Based on the literature, *M. modiolus* appears to be a relatively plastic species that is able to adapt its reproductive cycle to a variety of conditions. It is often not a synchronous spawner, which means that, within a population, the individuals can be in very different development stages. This difference is evident with *M. modiolus* collected at the reference sites and near the Victoria outfalls. Therefore, the interpretation of reproductive health of the population based on a comparison of reproductive development, as done by the CRD, is inappropriate unless it can be demonstrated that the variability can be standardized. The animals are collected at very low sample sizes (only 10 per site and split between 2 sexes), not standardized by age, and collected at only one time during the season (and that timing does not appear to have been selected based on the biology of *M. modiolus*). The reproductive pattern and variability of these populations is unknown in terms of seasonal development, sex, age, or spatial distribution. Examination of the available data in the Victoria Bight suggests that these populations are asynchronous spawners, and there are no data available to assess temporal or spatial patterns. Therefore, even a major reproductive disruption of this species may be undetectable using the current approach. **The interpretation of the reproductive development endpoint as an early indicator is inappropriate for the intended purpose.** In the Panel's opinion, a detailed study of the reproductive development and geographic (including depth) variability in *M. modiolus* is required before it is considered further as an early indicator.

Bioaccumulation-based tissue concentrations

The selection of bioaccumulative chemicals of concern selected for the Early Indication Process is very limited in scope, being only 2 metals (copper and lead). The analysis is based on a single composite from each of the sites. The monitoring program includes a variety of chemicals. However, **the chemicals monitored in this process should be expanded to include broader representation of POPs (at low detection limits) and emerging chemicals of concern.** Regular monitoring of the effluents may also be a reasonable consideration, given that the 2 effluents being discharged are untreated.

General considerations

The trigger process requires 4 of 8 of the Compliance Sites (100 to 130 m) to reach an established Effects Levels before the trigger is considered valid. The flow and depth profiles at the outfalls result in the effluent exposure at the compliance sites not being uniform. Contamination tends to move south of the outfalls to both the east and the west (particularly the southeast). There tend to be lower impacts and contamination toward the shallower waters to the north. The outfalls could therefore have relatively large far-field effects without triggering action. In fact, the monitoring data suggests that the impacts are more widely dispersed than indicated by mean distance (that is, includes the generally less impacted sites to the north). A significant impact may be developing and extending to a wider area in one or more directions without triggering the effects level.

A weight-of-evidence approach must be taken to the Early Indication Process. At Macaulay Point, the indicators, such as SDI and species richness, supported by sediment chemistry, suggest that in repeated years there is an effect at 3 of the 100-m stations, and this effect consistently extends out to the 200-m station to the southeast. This is consistent with ocean currents and the depth profile at the site. **The requirement of 4 of 8 sites (100 m) in the compliance zone for the trigger process has the potential to underestimate effects to the receiving environment if the plume is not uniformly distributed, spatially.**

Consideration should be given to including whole-effluent bioassay testing of the effluent and/or sediments as part of the Early Indication Process. The numerous sources of uncertainty make it very difficult to rapidly assess and monitor natural population in a complex environment. Although monitoring of the effluent does not account for the environmental factors such as fate and species variability, it does allow standardization and assessment of trends. The current Early Indicators, with the exception of bioaccumulation, are nonspecific endpoints that will be difficult to link to mechanisms and therefore to specific chemicals. A monitoring strategy that includes a variety of approaches and tools would allow the CRD to respond more rapidly and effectively. It is not clear how the current indicators would be used to implement additional source control.

Variability is inherent in benthic community data, resulting in considerable uncertainties. Natural variability occurs in habitat and community assemblages ranging from very small (centimetres) to regional scales (kilometres). It is very important that assessment of benthic community data use a weight-of-evidence approach that incorporates multiple lines of evidence and is based on a scientifically defensible monitoring program. A monitoring program therefore requires appropriate replication within each sampling station and comparison to relevant reference sites. The CRD program includes only 1 reference site with minimal replication within it. It is therefore difficult to assess the regional and temporal variability of the outfalls sites. **Additional reference sites and increased replication are needed in the program to establish reliable reference conditions and support the interpretation of the monitoring results.**

The Early Indicators are designed to allow the early detection of biological changes so that remedial actions such as source control can be taken and implementation of treatment delayed. When the Core Area LWMP was approved, the trigger process was established in lieu of a firm schedule to provide treatment, but with the provision of treatment within 3 years of the trigger point being reached. It is noted that the Environment Canada representative on the original group did not endorse the Trigger Process (CRD 2005). It has generally proven very difficult in complex receiving environments to measure adverse biological and ecological effects in the field and relate them back unequivocally to discharge quality. End-of-pipe control is often considered a first step to pollution control and is widely accepted as an effective strategy, especially in combination with environmental monitoring. **The CRD has established a trigger process to monitor and determine when an investment in treatment will be required. However, the difficulties associated with designing and implementing a responsive environmental assessment and monitoring program create considerable uncertainty. Although the tools being used in the program are based on good science, their application in this situation may not be fully effective for their intended purpose.**

4.4

Risk Assessment of Landfill Leachate

Review the need for treating leachate to protect human health and the environment before the leachate is discharged to the sewer from Hartland Landfill. Document the risks associated with the current practices. If treatment is necessary, recommend treatment options.

To respond to this question, the Panel commissioned a screening-level risk assessment (SLRA). The SLRA, conducted by Parametrix, Inc. (Parametrix 2006; Appendix F) used methods that are consistent with the state-of-the-science in risk assessment. The focus of the SLRA was on leachate releases or spills and subsequent receptor exposures to untreated landfill leachate outside of the actual landfill boundary[1].

Screening-Level Risk Assessment Methods

Conceptual site model and exposure potential

Characteristics of the environmental media (soil, water, etc.) immediately surrounding the landfill were evaluated in the SLRA because these are key to understanding how leachate could move through the environment and affect chemical exposure. This SLRA included identification of leachate migration pathways along the leachate pipeline. The spill response plan (CRD 2006) identified ecological habitat within 250 m on either side of the leachate pipeline that could potentially be impacted following a leak or spill, and this information was used to ensure that appropriate ecological receptors and human activities that could influence exposure were selected. The habitats included riparian areas, rivers, creeks, and streams; lakes and ponds; wetlands; floodplains; and marshes. Representative human and ecological "receptors"[2] were selected by considering ways that people and animals use and interact with their environments. The way people and animals use and interact with the potentially affected environment were defined through a series of "exposure pathways" describing how released chemicals could be contacted through ingestion, inhalation, or skin. The relationship between landfill leachate releases, the environmental media surrounding the landfill that would receive leachate releases, the representative receptors, and the defined receptor exposure or contact

[1] Leachate exposures of people and ecological receptors onsite at the landfill are not within the scope of this assessment.
[2] Receptors are defined operationally in the SLRA as those representative organisms that may be affected by the landfill releases.

pathways represent the general framework for the SLRA.

Leachate exposure concentrations

The Hartland Landfill maintains an environmental program to monitor and evaluate the effects of landfilling operations on the environment. This program monitors the actual leachate for a large suite of chemical parameters, as well as groundwater and surface water, though the latter media are evaluated for mostly conventional parameters. Monitoring data for bacteria or other pathogens in leachate is not occurring, and therefore these parameters could not be evaluated in the SLRA. The SLRA initially evaluated exposure or contact of people and ecological receptors to undiluted leachate as a conservative way of identifying chemicals that were clearly not of further concern and could safely be eliminated from further evaluation. Following this initial screen, leachate spill and migration scenarios to offsite surface- or groundwater were evaluated under more realistic conditions that addressed dilution of landfill leachate in the receiving environment. Real data were unavailable on the actual amount of dilution that would occur following accidental leachate releases to nearby waterbodies or to groundwater, but significant dilution can reasonably be expected to occur, depending on the size of the release[3]. For the purposes of the SLRA, 2 leachate dilution scenarios (10-fold and 100-fold in surface- and groundwater) were evaluated for chemicals retained following the initial undiluted leachate screen. These dilution scenarios were used to evaluate groundwater and surface water impacts from leachate releases because, as previously noted, leachate monitoring data are available for only a limited number of leachate constituents in adjacent groundwater wells and surface water bodies. All leachate concentration data used in the SLRA were provided by the CRD (cited in Appendix F).

Human and ecological receptors and exposure pathways

Several ecological receptors representing different exposure regimes were evaluated in the SLRA, including aquatic life (fish, invertebrates), terrestrial and aquatic birds (red-winged blackbird, mallard, great blue heron), terrestrial and aquatic mammals (deer mouse, river otter, black-tailed deer), and terrestrial and riparian plants. It was assumed that people could be exposed long-term to leachate released offsite via drinking contaminated groundwater or through recreational exposures to leachate following migration to downgradient surface waters. Aquatic life and wildlife (birds, mammals) were similarly assumed to be exposed to leachate following migration to downgradient surface waters. For aquatic life, the primary exposure pathway to leachate was assumed to be direct contact (gill uptake) under both short-

[3] Releases, should they occur, are expected to be small in volume, given the presence of an automatic alarm system that alerts operators to changes in pipeline pressure that would occur during a spill.

term and long-term exposures, while for wildlife, the primary exposure pathway to leachate (short- and long-term exposure) was assumed to be through surface water ingestion. Given the transient nature of the leachate, spills or releases are unlikely to result in significant chemical concentrations accumulating in the food web over extended periods of time. Terrestrial and riparian vegetation was also assumed to be exposed to leachate via subsurface or surface leaks and spills.

Toxicity reference values

Toxicity reference values (TRVs), or “safe” levels, for chemicals in leachate in the receiving environment were identified from regulatory databases (for example, British Columbia, Health Canada, United States Environmental Protection Agency [USEPA]) for each receptor (human health, aquatic, and terrestrial life). Where TRVs were not available from these regulatory sources, they were calculated using Health Canada or USEPA methods, using data identified from the primary scientific literature.

Risk characterization

Potential non-cancer risks to human health and risks to ecological receptors were evaluated using a hazard quotient (HQ) approach, which is simply the ratio of the exposure concentration or dose for a receptor to its respective TRV. An HQ below 1.0 suggests that a chemical poses negligible risk to a given receptor from a given exposure pathway. Excess individual lifetime cancer risks were also estimated for human health for carcinogenic chemicals. In British Columbia, the *de minimus* cancer risk level is 10^{-5} (1 excess cancer per 100,000 exposed individuals).

SLRA Findings

The number of chemical parameters with leachate HQs greater than 1.0, and cancer risks greater than the 10^{-5} *de minimus* cancer risk level for human health, are summarized in Table 4.4-1. **With the exception of aquatic life, potential risks predicted were largely negligible for human health, plants, and wildlife following just a 10-fold dilution.**

For aquatic life, the chemical parameters with HQs greater than 1.0 are largely metals and conventional parameters (for example, ammonia, sulfide). As shown in Table 4.4-1, if a 10-fold dilution were to occur following a spill, several metals had predicted acute risks, many based on maximum leachate concentrations (including aluminum, cadmium, chromium, copper, iron, and zinc). For these metals, this result reflects what may be considered a true worst-case exposure scenario with minimal dilution and maximum leachate concentrations. For the remaining 3 metals (chromium, iron, and sulfide), the lower 75th percentile leachate concentration posed potential acute risk to aquatic life. Most of the metals with identified chronic risk following a 10-fold dilution (Table 4.4-1) were based on the upper percentile leachate concentrations (that is, >75th percentile). However, upper percentile concentrations are not expected to persist over a chronic exposure duration as was conservatively assumed in the SLRA; so these potential chronic risks may be overstated. For example, if the 50th percentile leachate concentrations were considered a chronic exposure concentration rather than the higher percentile concentrations, only cadmium and ammonia would be considered chronically toxic to aquatic life.

Assuming a leachate dilution of 100 results in only 2 chemicals (chromium, sulfide) having maximum acute HQs greater than 1.0 for aquatic life, indicating they have the potential to pose elevated risk. However, the chromium HQ may be biased high, depending on its speciation in the leachate and ultimately in surface waters following a spill. In this SLRA, it was assumed that chromium was present as the more toxic chromium (VI); limited speciation data for leachate suggests that not all chromium is present as chromium (VI). Further, the maximum chromium concentration measured in leachate (1.79 mg/L) is 45 times greater than the 95th percentile chromium concentration, suggesting that the maximum concentration is anomalous for chromium and the predicted risk biased high. The sulfide

Table 4.4-1 Number of leachate chemicals with maximum HQs >1.0 or cancer risks[1] >10^{-5}

Receptor		Exposure type	Undiluted	10-fold dilution	100-fold dilution
Human health					
	Non-cancer	Chronic	6	1	0
	Cancer	Chronic	0	0	0
	Aquatic life	Acute	22	12[2]	2[4]
		Chronic	25	15[3]	3
Wildlife					
	Red-winged blackbird	Acute & chronic	0	0	0
	Mallard	Acute & chronic	0	0	0
	Great blue heron	Acute & chronic	0	0	0
	Deer mouse	Acute	0	0	0
		Chronic	1	0	0
	River otter	Acute	0	0	0
		Chronic	1	0	0
	Black-tailed deer	Acute	0	0	0
		Chronic	2	0	0
Terrestrial/riparian vegetation		Chronic	11	3	0

[1] Cancer risks apply only to human health.
[2] For 6 of these chemicals, only the maximum leachate concentration resulted in predicted risk. The 75th percentile leachate concentration exceeds the risk threshold for only 3 chemicals (chromium, iron, sulfide).
[3] The two chemicals are chromium and sulfide. For chromium, only the maximum chromium concentration results in an HQ >1.0, which appears to be based on an outlier chromium concentration.
[4] For most of these chemicals, only the upper percentile (≥75th percentile) leachate concentrations resulted in potential risk to aquatic life. Upper percentile concentrations are not expected to persist over a chronic exposure duration. If the 50th percentile leachate concentrations are considered, only cadmium and ammonia pose a potential chronic aquatic life risk.

HQs are also likely biased high because some sulfide following a spill is likely to volatilize or be oxidized to the less toxic sulfate under oxidizing conditions. **Overall, the potential risks predicted for aquatic life from leachate releases are more likely than not negligible under most spill scenarios** for the following reasons:

1) Leakage warning devices (alarms) are built into the leachate conveyance system, and thus, most spill volumes are likely to be relatively small before the conveyance system is shut down, making it less likely that leachate would reach surface water.

2) For spilled subsurface leachate to reach surface water supporting aquatic life, some degree of dilution is expected during groundwater transport, well before the leachate reaches surface water. This dilution in groundwater would be in addition to the dilution that will be achieved in the receiving zone of the surface water exposure medium evaluated. Therefore, diluted concentrations that were used in surface water may tend to overstate real-

istic exposure concentrations, though this assumption would require verification.

3) Because leachate spill volumes are expected to be relatively small and exposures by aquatic life are likely to be to diluted concentrations, these exposures would be most accurately characterized as acute rather than chronic. Therefore, the chronic exposure scenario evaluated for aquatic life is probably not a representative scenario for a spill or short-term leak scenario.

Technical Recommendation

The need for treatment of Hartland Landfill leachate and the type of treatment that might needed is a risk management decision that requires consideration of a number of factors. The SLRA (Appendix F) is one piece of information to be used in making the decision. Beyond that, the Panel recommends a careful, stepwise and comparative evaluation of risks versus benefits.

The overall risk versus benefit analysis should include the following, in order:

1) Address the additional data and/or information needed to deal with key uncertainties identified in the SLRA. This information and data should be used to refine the SLRA predictions of risk associated with no leachate treatment and may require actual toxicity testing of various dilutions of the leachate to ensure that aquatic life risks in receiving waters for leachate are adequately addressed.
2) If risk is not predicted following more refined assessments of untreated landfill leachate, with the desired margin of safety, then a decision to not consider treatment is more transparent and better supported technically.
3) If risk is identified during the refined risk assessment of untreated landfill leachate, the findings should then be folded into a comparative assessment of the risk reduction conferred by a range of likely treatment options. Data for the latter would result from bench scale studies initially.
4) The risk-versus-benefit analysis should consider other factors that will affect the decision to implement leachate treatment, including the costs of implementation. The findings from a comparative assessment of risk versus benefit will then provide a clear path for the CRD to make an informed decision on the need for and type of leachate treatment.

4.5

Future Risks of Wastewater Management

> Identify and evaluate the future risks of the CRD's wastewater management practices under reasonably plausible scenarios. Discuss the significance of these risks.

The Review Panel was asked to address the potential human health and environmental risks associated with future community growth, intensification of human uses, and emerging concerns related to specific chemicals. Given the range of possible alternatives for addressing wastewater concerns, the Panel sought guidance from the CRD to identify the "most plausible" growth and wastewater management scenarios.

The CRD currently discharges community wastewater to the Strait of Juan de Fuca (via outfalls located at Clover and Macaulay Points). As the community increases in size, the implications for human health and the environment will need to be considered, as will modifications to existing practices or alternate approaches to wastewater handling.

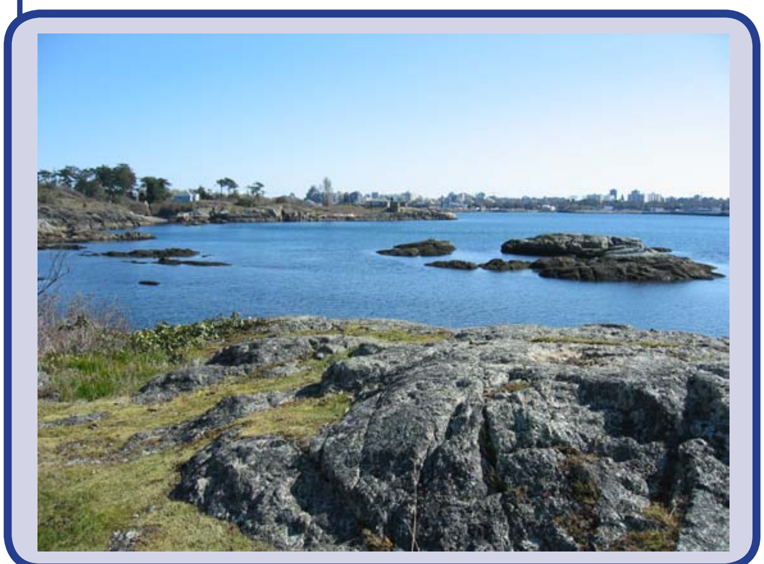
CRD Staff provided the following insight regarding estimated growth in the region:

- The residential population of the community covered by the plan is currently 265,000 and is anticipated to increase to 355,000 by the year 2025.
- The equivalent residential population of the sewer service area is currently around 325,000 and is projected to increase to 502,000 under growth scenarios adopted by the Core Area plan[1].
- The Panel has assumed that projected growth will likely continue in the area at a similar rate beyond 2025.
- Certain baseline contaminant concentrations that result from human food consumption and excretion will likely remain about the same; however, baseline contaminant loads will gradually increase along with population and flows, and these increases will compete with source control reductions over the foreseeable future.
- Population growth is likely to occur chiefly in the communities surrounding Victoria; minimal growth is anticipated in Victoria proper, given current land uses and availability of undeveloped land. However, the Panel points out that any future development in currently developed areas (for example, Victoria) may result in "higher-density", increasing the total waste load from the current service area.

[1] Core Area Liquid Management Plan, 2000, Chapter 5

- Significant population increases occur seasonally due to tourism, and this is not expected to change in the future. Tourism is, and is expected to remain, very important to the economy in Victoria near-term.

The Pacific Northwest is seen as a high growth region because of its quality of life; many of the top housing markets in the US and Canada are in this region, and growth in one location drives growth in adjacent communities. Current regional growth pressures support the reliance on higher growth projections rather than lower.



Projected industrial, commercial, and institutional growth and their future effects on wastewater quality were based on the fundamental assumption that institutional and business sectors are expected to increase proportionally with projected population growth. No substantial increase in industry or changes in the composition of industry is anticipated. The Panel has assumed that the combined proportion of industrial–commercial–institutional wastewater contribution to residential flows will remain approximately the same as the 2005 contribution over the next 25 years. The Panel further assumed that the current source-control program, based on the issuance of waste discharge permits, will remain in place and that all new industrial sources of contaminants will be required to operate under a permit. Any new industries are likely to discharge very low levels of contaminants because appropriate treatment will be required to be installed during the construction of the new business. An anticipated move to cleaner production technologies and sustainability will mean fewer contaminants of concern are discharged to the sewer system. Finally, it is expected that the number of discharges from contaminated remediation sites will gradually decrease as sites continue to be cleaned up. The Panel made these fundamental assumptions regarding CRD's Source Control Program and the impact of industrial and commercial contaminants:

- The 11 codes of practice will remain in place to control discharges from smaller businesses. Code implementation has been phased in from 2000 to 2005. The full extent of related reductions is expected to appear over the next 5 to 10 years. There may be some improvements in separation or reduction technologies in the future, and the codes could be amended, producing further reductions.
- Some contaminants will reduce more strongly due to marketplace and technological changes; for example, silver use in photo-processing will continue to decline as digital imagery takes over. Placement and removal of dental mercury-containing amalgams will continue to decline as the use of alternative materials increases and the population ages. Copper may also slowly decline as copper plumbing is gradually replaced by plastic piping.
- Increased community education efforts aimed at reducing the common contaminants in residential wastewater will likely result in some additional reductions in the future, largely in organics, because metals discharges are already minimal.

CRD is making a significant effort to reduce targeted contaminants and remove them from the waste stream through the source control program. The CRD goals for reductions to commercial and industrial contaminants through the source control program (Table 4.5-1).

Table 4.5-1: Predictions of Core Area contaminant reductions (2005–2030)[1]

Contaminant	Load reductions 1996 – 2003	Predicted load reductions (2005–2030)[2]	Comments
Metals (As, Cd, Cr, Cu, Pb, Ni, Ag, Zn)	36%–70%	10%–50%	Targeted by several codes – full code implementation will produce further reductions. Marketplace and clean technology changes will assist.
PAH's	—	50%–75%	High priority for reduction through application of auto, vehicle wash, lab and printing codes, residential outreach. Cleaner automotive technologies will add to reductions in the long term.
1,4-dichlorobenzene	63%	30%–35%	ICI and residential use as a deodorizer & disinfectant strongly discouraged through outreach.
Tetrachloroethene (perc)	—	80%–95%	New dry cleaning code implemented in 2004 – close to zero discharge expected when sector is fully compliant.
Phenols	—	25%–50%	ICI and residential outreach expected to target phenol-containing products for reduction. Other sources to be investigated for reduction.
Cyanide	—	25%–50%	Decreasing use of photo development chemicals with further increase in digital imagery use. Other sources to be investigated for reduction.
Oil and grease	—	40%–60%	Full implementation of Food Services code and residential education is expected to produce significant reductions

[1] Provided by the CRD.
[2] Note: The load reductions in this column are in addition to any load reductions listed for the period 1996-2003 in the previous column.
ICI = industrial commercial institutional

Contaminant reductions through source control programs are challenging, and CRD is to be commended for these goals. However, because prudent wastewater planning is conservative in nature, the Panel feels that planning to achieve such reductions through source control alone is over-ambitious.

Various emerging chemicals and persistent organic compounds (POPs) will also likely be targeted for reduction in the near future, including pharmaceuticals, endocrine-disrupting compounds, and personal care products. For many of these chemicals, there are no data currently available from CRD's core area wastewater to evaluate current contributions, let alone to make predictions about reductions for these emerging chemicals.

The Panel does not view selected contaminant reductions through source control as a means to significantly lower the annual discharge volume of such chemicals long term. While some sources can be eliminated, and the chemicals concentrations can be reduced, the increase in flows containing reduced concentrations generated by new residents will likely carry nearly the same annual mass of these chemicals to the sewage discharge sites.

Population Forecasts

The Panel recognizes the importance of accurate forecasts of population, flow, and contaminants loads but also is aware of the difficulties inherent in forecasting. Several population and economic projections are available, and new or updated forecasts are developed for different needs. A conservative and likely scenario was developed. The Panel feels that the assumptions used as the basis for the Core Area Plan are likely and justified by the data and experience of other municipalities in this geographic region. Prudent planning that incorporates the most current and accurate population forecasts allows communities to have at least some preparation for future needs. **For public utilities, conservative planning is considered the best approach. Due to the length of time required to plan, design, and implement essential public utilities, the 20-year future literally begins tomorrow.**

Future growth will require modification of current wastewater handling approaches. A number of options regarding modifications to the existing wastewater handling practices and development of new treatment and effluent discharge locations are available for consideration. For example, the existing wastewater handling and discharge systems located at Clover and Macaulay Points are not at full capacity under average-day operating conditions, and with some enhancement of existing systems, it may be possible for these systems to handle the projected growth adequately. Alternatives that could be considered include

- expansion of the existing discharge locations by lengthening pipes or increasing the size of existing diffuser configurations,
- development of one or more alternative discharge locations,
- incorporation of a variety of treatment options that would result in improved effluent quality, and
- reduction in effluent volume.

Based on feedback from the CRD on plausible scenarios, the Panel has focused on a scenario based on the status quo with minor changes (that is, outfall locations and treatment levels will remain substantially as they are now until 2015, when additional outfall capacity will be required at Macaulay Point). A second, longer outfall will then be added at Macaulay Point or possibly at another, as yet undetermined, location (likely to the west of Macaulay Point). A second, longer outfall will also be required at Clover Point, but this will not be required until between 2030 and 2045. To the Panel's knowledge, this scenario is based on the need for improving hydraulic capacity, but not to address environmental triggers or early warning conditions at the present outfall locations.

Taking this scenario into the future, wastewater volumes at the two discharge points are expected to increase as a function of population, with the majority of the increase occurring at the Macaulay Point outfall even though a reduction in unit flows is predicted. A decrease in per capita flows is to be expected in the future. Per capita flows will reduce as population centers increase in density because more people will be served by the same sewers that are subject to the same or even slightly decreased infiltration and inflow (I&I). Further, as new construction extends sewers to new areas and as aging sewers are replaced or rehabilitated with new pipe materials and pipe joints, I&I will be reduced, reducing unit per capita flows.

Tables 4.5-2 and 4.5-3 illustrate the effect of population growth and the effect that unit flow reduction will have on the annual flows. While population growth can be planned, it cannot be controlled or curtailed, whereas unit flows can be reduced through I&I reduction pro-

Table 4.5-2: Average annual flow predictions

Year	Population	Clover Point (L/d)	% increase	Macaulay Point (L/d)	% increase	L/capita/d
2005	265,000	65,000,000	–	45,000,000	–	415
2025	355,000	70,205,557[1]	8	74,307,073[1]	65	407
2030	377,500[1]	70,700,000	9	84,000,000	86	410
2045	445,000[1]	76,300,000	17	101,000,000	124	398

[1]Value estimated from data provided by CRD. A linear relationship has been assumed

Table 4.5-3: Population and flows estimated (calculated based on data in CRD 2000; LWMP)

	Clover Point Flows			Macaulay Point Flows			Core Area Flows		
Year	Population	Unit flow	Total flow	Population	Unit flow	Total flow	Population	Unit flow	Total flow
1996	198,533	334	66.3	150,764	260	39.1	349,297	302	105.4
2025	226,428	321	72.6	275,524	251	69.2	501,952	228	114.7
2045	249,727	311	77.8	325,676	274	89.1	575,403	246	141.8

Unit Flows in litres/capita/day
Annual Flow in Megalitres/day
Unit and Annual Flow Data computed based on Table 5.3 (CRD, 2000)

grams and water supply conservation. These tables illustrate that greater growth, even with per capita flow reductions, will result in significant increases in wastewater.

The prediction of potential future environmental consequences resulting from continued inputs of wastes to the receiving system can only be made considering the assimilative capacity of the receiving system. This cannot be easily quantified with the extant data or with the state-of-the-science today or in the foreseeable future. The Strait of Juan de Fuca is a large body of water with high flows and a large dilution capacity. However, the Panel cautions the CRD that the capacity to assimilate waste input is finite. Also, Victoria is not the sole contributor to the receiving water system. Other large and small communities (for example, Vancouver, Seattle, and other communities on Puget Sound) contribute waste load to the system, and an evaluation of the scientific and societal acceptability of contributions to the system cannot be made on an individual community basis. The state-of-the-science is now moving in the direction of a more holistic watershed-based approach that recognizes local and regional benefits through integrated water resources planning and development. The Panel recommends this approach be considered by the CRD for liquid waste management.

As was discussed in Section 4.2, the environment has evolved in response to the discharge of CRD wastes into the receiving system. This is most obvious in the areas closest to the discharge, and the changes become less obvious with distance from the point of discharge owing to dilution and/or removal of waste contaminants via chemical, physical, and biological processes. The scenario under consideration suggests that predicted growth in the area will result in increased nutrient loads and a concomitant increase in contribution of waste constituents (Table 4.5-4). The likely result in the receiving environment is that the "Zone of waste dispersion" will increase in size commensurate with the volume of waste discharged, the effectiveness of the fate and distribution processes, and the ability of the environment to assimilate the waste. Incorporation of additional discharge pipes or lengthening of the diffuser may result in a decrease in the spatial extent of effluent-associated effects at the current outfall locations, but will do little to reduce the overall total effect of the discharged effluent. **The Panel concludes that the environmental "footprint" of the wastewater discharge will**

Table 4.5-4: Average annual BOD_5 predictions (Kg/d)

		Clover Point		Macaulay Point		Total
Year	Population	%	Kg/d	%	Kg/d	kg BOD/d[2]
2005	265,000	59	14,184	41	9,856	24,040
2025	355,000	49	15,780	51	16,425	32,205
2030	377,500[1]	46	15,753	54	18,493	34,246
2045	445,000[1]	43	15,799	57	20,942	36,741

[1] Value estimated from data provided by CRD using a linear relationship
[2] Value estimated from assumption of 0.09 kg BOD_5/capita/day

increase proportionately with an increase in volume of discharged waste. The location of release and the overall quality of the wastewater will also affect the footprint.

Future changes in wastewater handling (for example, reduction in I&I) will likely result in some reduction in wastewater volume which will, in turn, result in increased contaminant concentrations in waste components in the effluent. This may lead to an increase in the toxicity of the discharged effluent. **Source control efforts will help reduce inputs of certain contaminants, and these programs should continue to be supported and expanded. However, adequate control of all potentially toxic wastewater constituents via source control efforts alone is unlikely, and alternative approaches should be considered.** The discharge of a more concentrated effluent will potentially lead to an increase in the spatial extent and magnitude of environmental consequences adjacent to the discharge.

Wastewater disposal creates inherent public health and environmental risks, and those risks increase with the generation and disposal of more wastewater resulting from growth.

4.6

Emerging Chemicals of Concern

> Considering the CRD's current liquid waste management practices, analyze the significance of the risks associated with emerging chemical contaminants of concern and persistent organic chemicals on the receiving environment and public health, both now and in the future. Gauge how the impacts of the CRD's approach to liquid waste management practices and the risks associated with emerging chemicals of concern change with the implementation of sewage treatment.

Considering the CRD's current liquid waste management practices, analyze the significance of the risks associated with emerging chemical contaminants of concern and persistent organic chemicals on the receiving environment and public health, both now and in the future. Gauge how the impacts of the CRD's approach to liquid waste management practices and the risks associated with emerging chemicals of concern change with the implementation of sewage treatment. (Questions B2 and D2 combined, from the TOR)

A wide variety of emerging chemicals of concern have been identified in municipal wastewaters (Table 4.6-1) (Daughton and Ternes 1999; Kolpin et al. 2002; Birkett and Lister 2003; Krümmerer 2004; Servos and Servos 2006). This represents literally thousands of potential environmental contaminants. These diverse chemicals represent a wide variety of physical–chemical properties and toxicological mechanisms. They therefore will be difficult to characterize because their potential fate, distribution, and effects in the environment will be extremely variable. Many of these compounds, such as natural estrogens and pharmaceuticals, have not been traditionally considered environmental contaminants (Servos et al. 2001, 2002; Tarazona et al. 2005). However, with recent advances in analytical chemistry, these compounds have now been recognized as being widely distributed in the environment, particularly in municipal effluents. In addition, there are numerous industrial contaminants that have been recognized as a concern because of their persistence and toxicity. Recent concerns have been raised for many of these chemicals because of the recognition of their potential to cause subtle biological responses (for example, endocrine disruption) in humans and ecosystems at very low concentrations (NAS 1999; WHO 2002).

To respond to this question in the Panel's Terms of Reference, the Panel conducted a thorough literature review (Appendix G), upon which this response is based. The Panel recognizes that this topic, in particular, is complex and technical, making communica-

Table 4.6-1: Examples of emerging contaminants of concern in municipal treatment plant effluents. (The Panel defined "emerging" from the perspective of wastewater treatment, as opposed to that of environmental toxicology.)

Natural estrogens
17ß-estradiol, estrone, estriol, testosterone

Pharmaceuticals
17α-ethinylestradiol, indomethacin, gemfibrizil, propronanol

Personal Care Products
Fragrances (musks), sunscreens (uv filters)

Surfactants
Alkylphenol polyethoxylates and their metabolites (including nonylphenol and octylphenol)
Perfluorinated surfactants (including perflurorooctane sulonate (PFOS) and perfluorooctanoic acid (PFOA))

Industrial contaminants
Flame retardants (polybrominated diphenyl ethers)
Plasticizers (bisphenol-A, Di-(2-ethylhexyl)phthalate)
Polychlorinated biphenyls (PCBs)
Polychlorinated dibenzo-*p*-dioxins (PCDD)
Chlorophenols (2,4-dichlorophenol, 2,4,6-trichlorophenol)

Polycyclic aromatic hydrocarbons (PAHs)
Benzo(a)pyrene, Benz(a)anthrazene, Benzo(k) fluoranthene

Pesticides
Atrazine, lindane, 2,4-D

Heavy Metals
Cd, Hg, organotins (Sn)

Biologicals
Pathogens, viruses, prions

Other
Nanotechnology products, natural products, nutraceuticals

tion of the main ideas challenging. Readers are encouraged to read the key messages which are shown in boldface type.

The concentrations of emerging chemicals of concern in the two municipal outfalls of the CRD are likely to be similar to raw effluents in other Canadian jurisdictions. The distribution of emerging contaminants in raw effluents is relatively consistent across Canada and North America, with only minor differences in comparison to Europe (Ternes et al. 1999; Metcalfe et al. 2004; Servos et al. 2005). Although local variation in sources (industrial sites, source control, etc.) may influence amounts of emerging contaminants discharged into the collections system, a large proportion of the emerging chemicals are ubiquitous or not easily controlled. **The treatment processes can have a major influence on the distribution of various emerging contaminants, resulting in significant reductions and metabolism of selected compounds.** However, many of the compounds are resistant to degradation and are discharged in the final effluents or solids, depending on the process and physical–chemical properties (for example, hydrophobicity, pK_a) of the contaminants (Figure 4.6-1) (Birkett and Lester 2003; Auriol et al. 2006; Lishman et al. 2006.

Emerging contaminants can be metabolized in humans or by bacteria in the treatment plants such that they are conjugated with glucuronic acid or sulfate, making them considerably more water soluble (that is, dissolve in water) and less toxic (Figure 4.6-2). This can be a reversible process in the treatment plant or the environment (Ternes et al. 1999). In some cases, the contaminants in the treatment systems or environment are degraded (biodegradation, phototransformation, etc.) into other compounds which may also be toxic or exhibit biological activity (estrogenicity). This makes assessing the risk of these compounds very complex and associated with considerable uncertainty.

Assessing risks associated with emerging contaminants requires an integrated evaluation of both exposure and effects in the environments of concern (Figure 4.6-3). It is important therefore to consider the sources, fate, and composition of the wastewater as well as the potential effects of the effluent and its constituents. **The complexity of the wastewater and the high uncertainty associated with ecosystem effects lead to considerable uncertainty in predicting risks.**

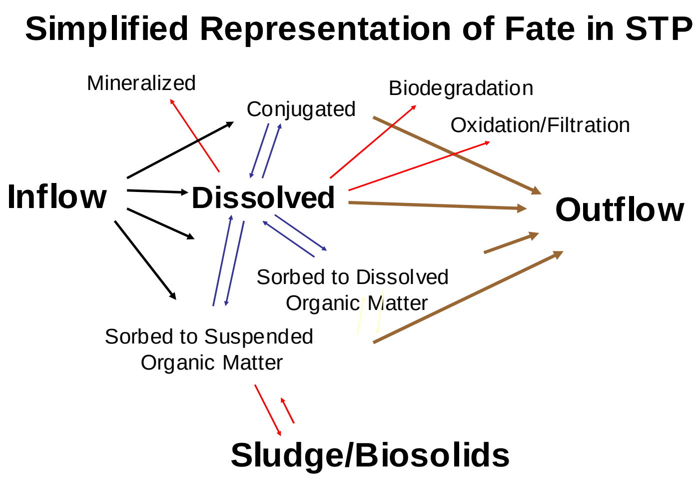


Figure 4.6-1: Simplified representation of the fate of emerging contaminants in municipal treatment plants

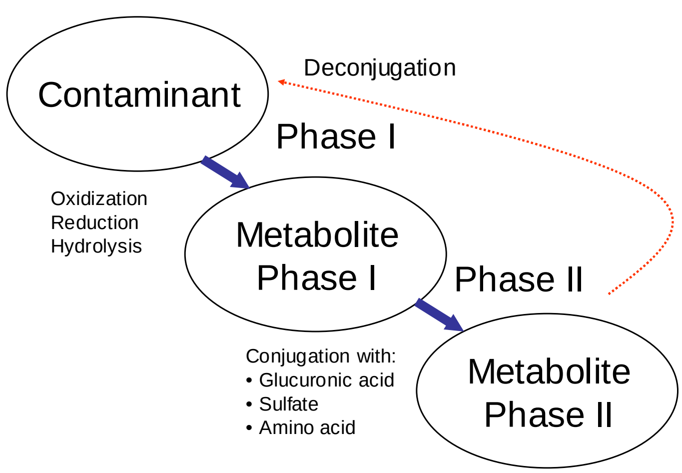


Figure 4.6-2: Biodegradation of emerging contaminants results in the formation of conjugates which may be reversible

The wastewater effluents from Core Area CRD are collected into two major outfalls which discharge untreated sewage into the marine environment. Exposure of the environment to emerging contaminants is dependent on numerous factors, including the source, degradation in the collection and treatment (for example, screens) systems, and the fate processes in the environment (Figure 4.6-4). The fate of the emerging contaminants in the environment is influenced by physical parameters such as outfall design, buoyancy of the freshwater plume, tides and currents. Depending on the chemical–physical properties of the contaminants, they will be associated with different components of the environment. For example, flame retardants (PBDEs), which are highly hydrophobic, will be associated primarily with the organic matter. They will therefore move and settle with the organic particles and sediments. In contrast, a highly water-soluble compound, such as the pharmaceutical, carbamazepine, will remain dissolved in the seawater and move with the plume and currents. The exposure and bio-availability of the compounds will therefore differ considerably. In addition, the ability of the environment to degrade (for example, by microbes, photolysis, hydrolysis) these contaminants differs dramatically. The mechanisms of toxicity for emerging contaminants also varies considerably (for example, narcosis, estrogenicity, oxidative stress), and effects on growth and reproduction may occur at very low doses (Lister and Van Der Kraak 2001; WHO 2002; Mills and Chichester 2005; Auriol et al. 2006).

Considering the diversity of emerging contaminants, it is not possible to make generalizations; each substance or group of substances needs to be considered individually.

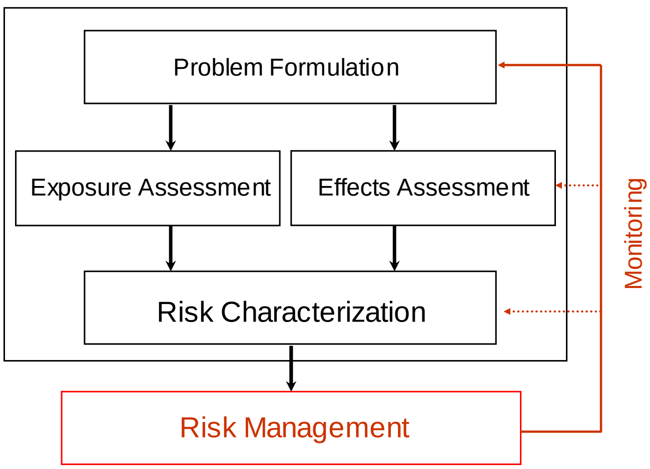


Figure 4.6-3: Traditional risk assessment framework

Unfortunately there is not currently adequate knowledge available to conduct a complete risk assessment for most of the emerging contaminants. The uncertainty is made even greater due to the lack of site-specific information on the exposure and fate of most of the contaminants of interest and their toxicology in the local environment and ecosystems. Despite this uncertainty, considerable information is available, and general conclusions can be made based on the

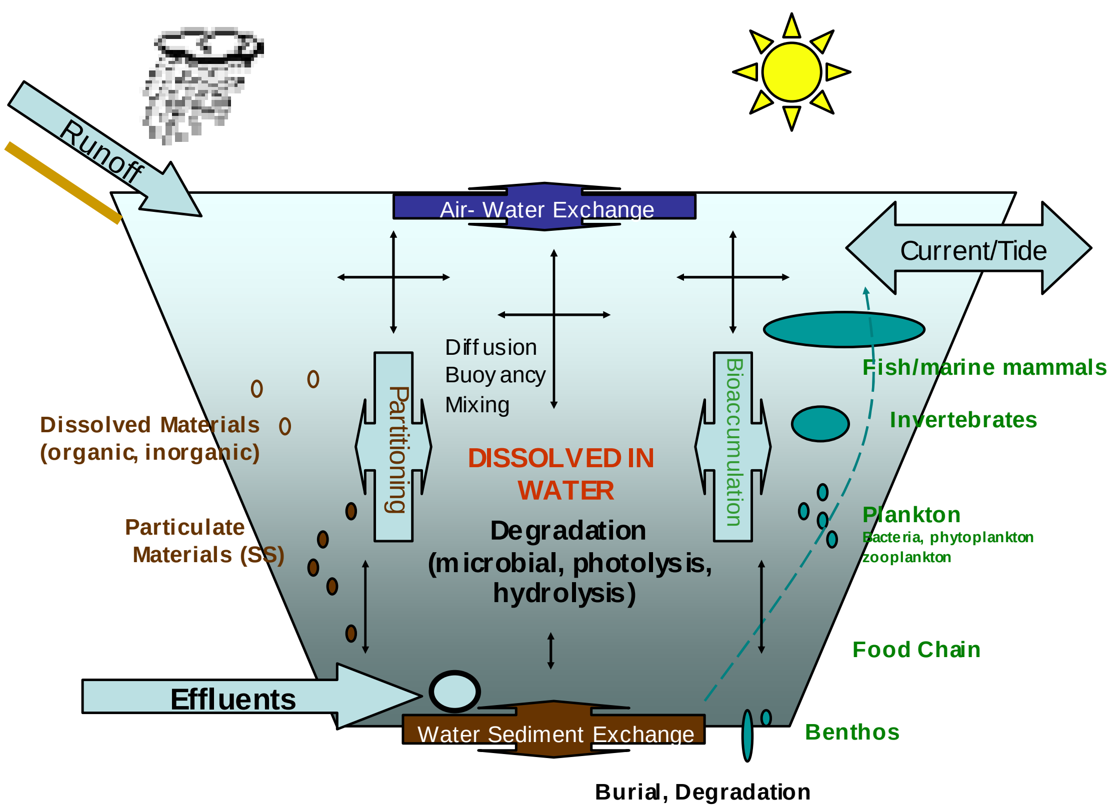


Figure 4.6-4: Representation of the fate processes influencing emerging contaminants in the marine environment

minimal data available locally and in the literature for other sites and species.

Natural and synthetic estrogens, as well as alkylphenol polyethoxylates (APEOs), and other industrial chemicals (for example, bisphenol A) have been identified as the major estrogenic components of municipal effluents across Canada (Bennie 1999; Ternes et al. 1999;Lee and Peart 2000; Metcalfe et al. 2003, 2004; Lee et al. 2004, 2005; Servos et al. 2005). Based on an extrapolation from other municipal treatment plants in Canada and elsewhere, raw effluent would be expected to contain levels of natural estrogens that would cause an estrogenic response in fish and other organisms.

Many of the emerging chemicals will be difficult or impossible to control in the current CRD collection system. The estrogenic chemicals will be dispersed into the environment depending on their properties as well as those of the environment. Compounds such as natural estrogens will move with the effluent and be diluted rapidly. In contrast, nonylphenol (NP), 17α-ethinylestradiol (EE2), and polybrominated diphenyl ethers (PBDEs) tend to be more hydrophobic and associated with the particulate organic matter which will tend to settle on the sea floor. In the environment, there may also be degradation of compounds such as APEOs to metabolites such as NP, which have different properties (much more hydrophobic) and potency (toxicity and estrogenic) (Metcalfe et al. 2001; Dussault et al. 2005). Partial treatment or conversion in the environment may increase the estrogenicity of the effluent by converting chemicals such as APEOs to more estrogenic forms (alkylphenols), deconjugating the chemicals (17β-estradiol, E2) or altering the partitioning to organic material, therefore making them more bioavailable. Untreated municipal effluents in various jurisdictions have consistently been found to be estrogenic and advanced treatment generally reduces or eliminates the estrogenicity (Servos and Servos 2006; Appendix H). **The weight of evidence suggests that untreated effluents (end of pipe) will likely be estrogenic and cause adverse effects in exposed biota.**

In the environment, effluents will be diluted rapidly, and contaminants may undergo further metabolism, degradation or association with particulate/dissolved organic matter or biota. Outside of the initial plume at the CRD outfalls, the natural estrogens are likely to be diluted to very low (<1 ng/L) concentrations and below the threshold for inducing estrogenic effects. Because natural estrogens are relatively hydrophilic they are unlikely to bioaccumulate. Synthetic estrogens, such as 17α-ethinylestradiol, are slightly more hydrophobic and may be partially associated with the organic particles. However, they are also expected to be diluted to the point where they are not likely to cause an estrogenic response (<<1 ng/L). **Although it is impossible to determine the potential responses in every organism, these compounds would represent a minimal risk once diluted. Within the plume, however, the raw effluents may be highly estrogenic to the animals exposed directly. Because they are unlikely to bioaccumulate, the natural and synthetic estrogens are unlikely to cause indirect responses through uptake in the water column.**

Pharmaceuticals and personal care products (PPCPs) represent a wide variety of chemicals that will be in the raw effluents (Metcalfe et al. 2004). Although many of these compounds are degraded through conventional treatment, some compounds such as carbamazapiene are only partially reduced (Metcalfe et al.2003). The concentrations of many of these compounds in the effluent plume may be at levels that may result in subtle responses in biota, especially if they act additively. Several pharmaceuticals can alter biological processes that influence growth, reproduction, and development. It is, however, very difficult to predict whether these responses would translate into effects at the whole-organism level. PPCPs will also operate through diverse mechanisms, and it is very difficult to predict how they may affect non-target organisms. Again, the rapid and high dilution at the CRD outfalls would reduce these compounds to very low concentrations. These concentrations would be similar to or less than those typically seen in treated effluents. **Although the risk is expected to be minimal, the diversity of chemicals and potential mechanisms in numerous non-target organisms makes the uncertainty large, and therefore, the risk of these compounds cannot be discounted.**

A variety of other chemicals in sewage effluents have been associated with effects on endocrine systems and other biological process. These include a wide variety of industrial chemical and byproducts. Compounds such as bisphenol-A and chlorophenols have been reported at low concentrations. These chemicals are also relatively hydrophilic and unlikely to bioaccumulate or biomagnify in the ecosystem. Flame retardants such as polybrominated diphenyl ethers (PBDEs) have become commonly reported in effluents, along with more traditional contaminants such as polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs), and polycyclic aromatic hydrocarbons (PAHs). These compounds (with many congeners) can be more hydrophobic and therefore behave differently in the environment. In particular, these compounds can be associated with sediment and bioaccumulate in food chains (Rayne et al. 2004; Cullon et al. 2005). Some of these compounds have been detected in municipal effluents, including the CRD outfalls. They will likely settle onto the sea floor, along with particulate organic matter, or be transported off site with the currents. If the concentrations in effluent are high enough, they may act as a source of these compounds to the surrounding ecosystem. However, the distribution of these compounds is expected to be concentrated in the areas adjacent to the outfalls, although, like metals, they will be dispersed much farther as they move with the sediments, especially under well-mixed conditions such as the CRD's receiving environment. There is considerable evidence that endocrine-disrupting substances will be bioavailable (food chain) from sediments associated with municipal effluents. **It is possible that chemicals in the CRD effluents will be bioavailable to local species as well as the adjacent ecosystems through the food chain.** However, the risk to the ecosystem is currently highly uncertain.

It is difficult to assess the implications for marine species which may spend short periods of time associated with the effluent or the contaminated sediments. Short-term exposure during a critical life stage can have lasting effects on individuals and possibly populations. Indirect exposure through food chains may contribute to the load of contaminants in invertebrates, fish, or marine mammals that frequent the area. Emerging contaminants that act through similar modes of action may act additively with the diverse array of chemicals (and their metabolites) in municipal effluents. **Although currently the environmental risk associated with the outfalls outside of the initial dilution zone appears to be small, this prediction is highly uncertain because minimal chemical and monitoring data are available.**

Human exposure to emerging contaminants is expected to be negligible through direct exposure (drinking water or dermal), either via effluents or sludge–biosolids management. Although many of the emerging contaminants are relatively hydrophilic (for example, estrogens), there is a potential for low-level indirect exposure (that is, ingestion) for persistent, bioaccumulating compounds (for example, PBPEs), but this would represent a minimal exposure and very localized in geographic scope.

Advanced treatment of municipal effluents greatly reduces the concentration of most emerging contaminants, therefore reducing the risk and uncertainty. Source control may reduce the entry of selected compounds such as APEOs into the collection system, but many of the emerging chemicals of concern (such as natural estrogens and PPCPs) will be difficult or impossible to control in the current CRD collection system.

Future Trends of Emerging Contaminants

Our understanding of the risks of a variety of emerging contaminants is rapidly expanding.

As additional knowledge is acquired, we will improve our assessment of the risk of these compounds and acquire an ability to design appropriate risk management strategies. For many compounds, such as alkyphenols, source control measures may be at least partially effective in reducing the toxicity or estrogenicity of the effluents. In contrast, effects associated with natural estrogens or pharmaceutical and ubiquitous industrial chemicals will be difficult, impractical, or socially unacceptable to control at the source.

As society changes and new technologies are developed, it can be expected that use patterns and exposure of existing substances will change and additional contaminants of concern will be identified. We are likely to continue to identify additional chemicals of concern that have previously not been recognized as a risk. For example, development and changing use patterns may lead to altered exposure to existing or new, more specific (toxic) pharmaceuticals, PCPPs, and industrial chemicals (for example, nanotechnology). In addition, we should consider the likelihood of emerging (either new or expanding range) biological agents such as pathogens, viruses, prions, and other threats. It is not possible to predict the significance of future emerging issues, and therefore great uncertainty exists. However, **the current liquid waste management practices of the CRD provide little flexibility to respond to emerging issues and protect human or ecosystem health.**

Implications of Treatment for the Risk of Emerging Contaminants

Our current understanding of the removal processes of emerging contaminants in sewage is limited. However, a number of recent studies and reviews have examined a variety of treatment plants and processes (Birkett and Lester 2003; Jones et al. 2005; Auriol et al. 2006; Servos and Servos 2006; Appendix H). The properties of emerging chemicals are very diverse, as are the processes used in wastewater treatment. The amount of information available is limited, but we can identify general trends in the ability of specific treatment processes to remove specific emerging contaminants.

Treatment has been shown to reduce the concentrations of a variety of emerging contaminants, such as natural and synthetic estrogens, from effluents and therefore reduces the risk and the associated uncertainty (Figure 4.6-5). Grit removal, screens, and primary treatment have only minimal effects on removal. Advanced primary can reduce organic matter and therefore reduce hydrophobic contaminants but has a minimal effect on most hydrophilic compounds, such as many natural estrogens and pharmaceuticals. Partially treated effluents may actually increase the free (bioavailable) concentrations of contaminants because bacteria deconjugate the compound or alter their association with organic matter during treatment. Effluent can therefore become more estrogenic or toxic with treatment (for example, decongugation of 17β-estradiol or metabolism of APEOs to NP).

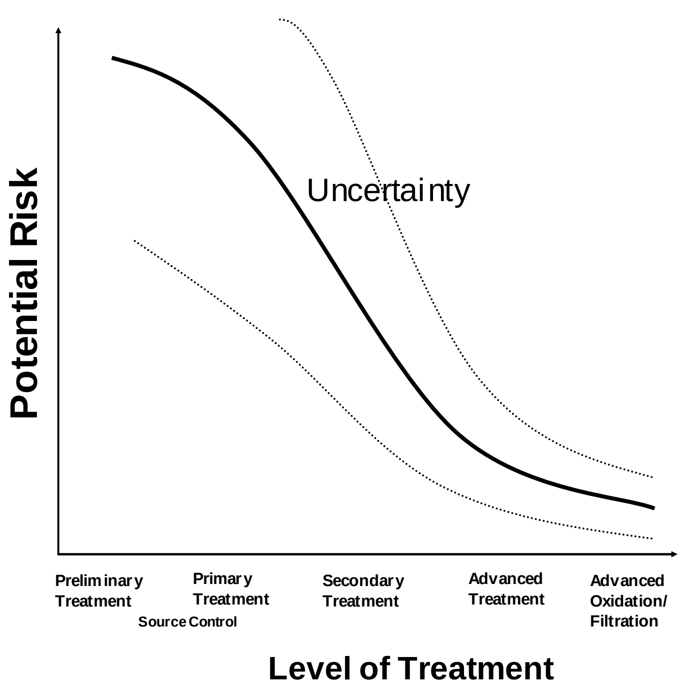


Figure 4.6-5: Conceptual figures showing reduction of potential risk and uncertainty associated with emerging contaminants in relation to increased levels of treatment

With additional treatment such as activated sludge, most estrogens and PPCPs are removed from the effluent, and the total estrogenicity measured using biological assays can be greatly reduced or eliminated. Selected compounds such as 17α-ethinylestradiol are resistant to degradation during conventional treatment and can remain in final effluents or sludges. Similarly, many of the PPCPs are significantly reduced in final effluent after secondary treatment, although some compounds are only partially degraded in the treatment systems. Compounds such as carbamazepine do not appear to be removed from the final effluents and are also very persistent in the environment . Ultrafiltration, commonly used in membrane bioreactors (MBRs), can reduce the concentrations of contaminants, but the dissolved form will still move across the membrane. Nanofiltration or reverse osmosis can totally remove environmental contaminants of concern, as long as the integrity of the membranes is maintained, but may be expensive to operate continuously because of biofouling. Advanced oxidation methods do appear to be capable of removing most of these compounds in wastewater as well as drinking water. Ultraviolet light is effective at removing many organic contaminants, especially in combination with other oxidants such as hydrogen peroxide, but it incurs high energy costs. Chlorine or chlorine dioxide only partially reduce the concentrations of emerging contaminants in effluents. Ozone is very effective at reducing residual contaminants but can be relatively expensive to generate for effluent treatment. Although combinations of these techniques may be very effective at removing essentially all of the emerging contaminant from final effluents, doing so may be cost prohibitive. **The majority of emerging contaminants can be greatly reduced or removed with a combination of treatment processes and oxidation techniques.**

There are several pathways by which emerging contaminants may enter the environment in addition to treated effluents. They may run off or bypass the treatment system during high flows, they may enter stormwater systems, or they may be incorporated into the sludges or biosolids (Figure 4.6-6). In addition, combined sewer outfalls (CSOs) and septic systems may represent additional sources to the environment. These pathways must also be considered when assessing the overall risk.

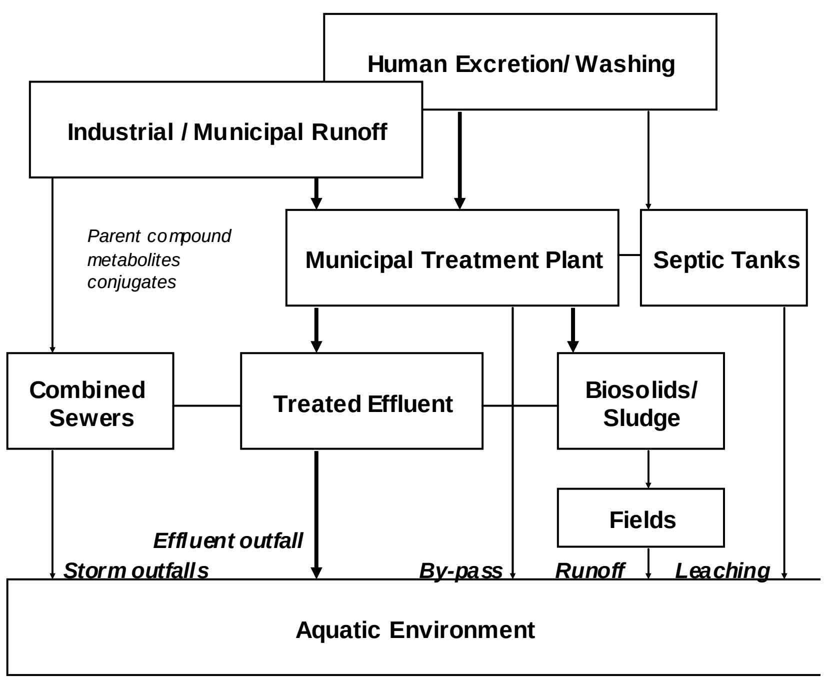


Figure 4.6-6: Pathways for movement of emerging contaminants into aquatic environments

With increased treatment, the risk as well as the uncertainty associated with the environmental impacts of the outfall will be reduced. However, treatment will produce sludges which must also be treated and disposed of. Part of the risk is therefore diverted to a different environment rather than being eliminated (Figure 4.6-7). Generally, sludges will be digested and then used as biosolids for soil amendments or incinerated. The chemicals of concern may therefore result in exposure to other aquatic environments through runoff from the fields. The compounds associated with biosolids will generally be those with high hydophobicity and sediment–water partition coefficients such as alkyphenols, musks, PBDEs, and heavy metals (Bennie et al. 1998; Lee et al. 2004; Rayne and Ikonomou 2005), Many of the estrogens and PPCPs are relatively hydrophilic and likely to be associated with the final effluents rather than biosolids. With appropriate treatment, many of the emerging chemicals (and pathogens) may be reduced to acceptable levels, and with Best Management Practices, runoff will be minimal. Unfortunately, our limited understanding of the behavior and potential effects of the diverse group of contaminants makes it difficult to predict or eliminate all risks from this exposure route. However, using Best Management Practices, the management of these materials is more controlled than is the case for the CRD's present system. **Treatment of wastewater effluents reduces the risk of environmental impacts. However, treatment will produce sludges which must be treated and managed using Best Management Practices.**

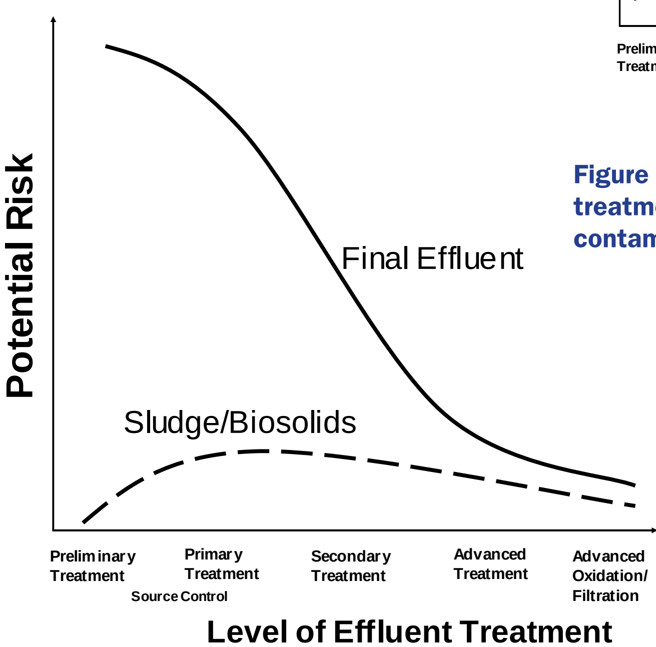


Figure 4.6-7: Representation of the change in risk associated with treatment

The addition of secondary treatment with extended solids retention times will result in a significant reduction in most emerging contaminants of concern in final effluents. Primary or enhanced primary treatment would not be adequate to reduce the risk represented by these compounds. The addition of advanced oxidation or nanofiltration/reverse osmosis can reduce the remaining chemicals and biological responses to trace or undetectable levels. However, the additional cost of advanced oxidation or nanofiltration might not be justified to remove the trace amounts of contaminants, which represent a minimal and undefined risk to humans or the environment (Figure 4.6-8).

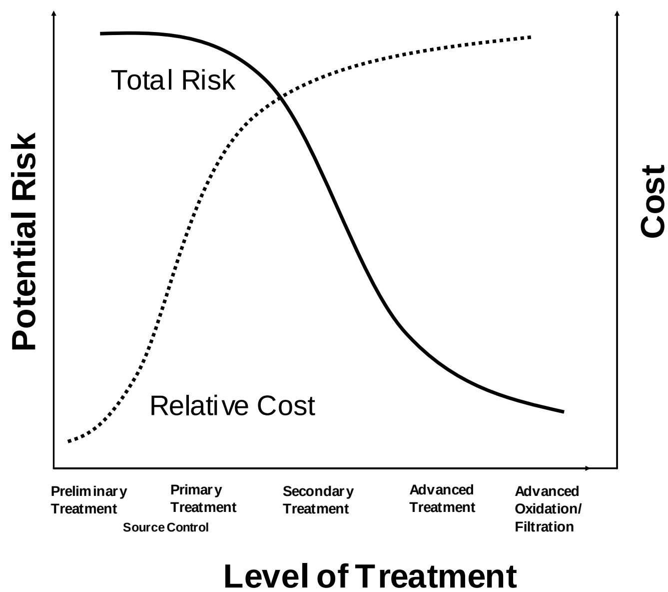


Figure 4.6-8: Representation of the relative cost of treatment in comparison to potential risk of emerging contaminants

4.7

Review of Liquid Waste Management Systems

Identify and rank the alternative and new liquid waste management systems that may be applicable to the CRD.

Introduction

The Panel was charged with identifying and ranking new and alternative wastewater treatment (WWT) and management technologies that may be applicable to the CRD. This was accomplished through a literature review (Appendix H), the content of which is the basis for this section.

This assessment includes descriptions of

- planning and plant site location considerations,
- wastewater contaminants, and
- WWT technologies.

The decision-making process for selecting a specific WWT process and using the selected technologies in an integrated treatment facility requires a myriad of considerations and decisions. There are important considerations which are beyond the scope of the Panel's review; the Panel has focused on providing descriptions of treatment processes and their performance in reducing or removing specific contaminants. However, fundamental considerations include the goals for prospective treatment, which are established from various inputs (discussed in Section 4.9), for example, determining which specific contaminants must be removed and the levels which might be considered acceptable.

Planning Considerations

The most important issues that must be considered in the development of plans for WWT facilities include the

- effluent quality in terms of contaminants and the level of contaminants the community and regulatory agencies will accept;
- most effective treatment processes to reduce or remove those contaminants;
- compatibility of unit processes to assure efficient plant operations and high quality treatment;
- schedule for implementation;
- impact of other protective barriers integrated into the overall management program, such as source control, combined sewer overflow and sanitary sewer overflow programs, infiltration and inflow reduction, the effect of trucked wastes on treatment processes, and wastewater sludge and biosolids management needs;

- costs associated with the treatment process construction, operation, maintenance, monitoring, and program administration; and
- impacts of the plant site decisions.

Treatment technologies are available to produce essentially any quality of water desired, but costs are highly variable. Decision-makers must determine not only how "clean" the wastewater is to be in terms of contaminants or toxicity, but also how "clean" they can afford to be. The costs driving affordability include not only the costs of construction and plant operations but also the utility administration, long-term financial obligations, subprogram activities (for example, source control), and the effects of regulatory requirements as they affect monitoring and reporting and implementation schedules imposed by the CRD's Seafloor Trigger process. Fast-tracked implementation schedules, such as the implementation required under the Trigger program will likely cost significantly more, and often will result in extended schedules and penalties.

Finally, the location of the treatment plant site must be carefully considered. The choice of technology greatly affects the minimum plant site size, and conversely, plant site size can limit the treatment alternatives available. It is important to recognize that site location decisions could last for generations or even lifetimes. The Panel recognizes that these choices are difficult to make, and in the face of challenges such as changing technology or location demands, land acquisition decisions should be made with great care.

Wastewater Contaminants

The raw wastewater generated in the CRD is similar to that of most urban areas with rural surroundings. As discussed in Section 4.5, the raw wastewater characteristics will likely change in the future as inflow and infiltration are reduced and as better water conservation and reuse concepts are developed and implemented.

Raw wastewater includes

- macro-contaminants—those for which specific regulations exist—include materials such as suspended solids, biochemical oxygen demand (BOD_5) causing materials, fats, oil, and grease (FOG), and nutrients such as nitrogen and phosphorus;
- micro-contaminants—those of concern to living organism (including humans) at low concentrations, such as pesticides, pharmaceuticals, or endocrine-disrupting contaminants (ECDs); and
- biological contaminants ("biologics")—normally include bacteria, viruses, protozoan parasites, and helminths.

The major categories of wastewater contaminants are presented in Table 4.7-1. The appendices provide further information on solids, chemicals, and microorganisms present in raw wastewater and treatment processes used to remove or reduce them.

Wastewater Treatment

All the materials present in an advanced industrial society are also present in its wastewater. Society has become more concerned about the impact of contaminants in wastewater on the receiving environment. As improving knowledge about contaminants in wastewater continues to confirm this fact, the field of WWT is undergoing significant change.

A wide variety of WWT technologies are in use today for oxidation and conversion to remove contaminants found in municipal wastewater. Interest in new technologies is intense, and development of new technologies is ongoing, as evidenced by a number of submissions to the Panel related to new technologies and energy conservation and re-use. A variety of factors need to be considered during the selection of treatment units and treatment trains, including site constraints, energy costs/benefits, solids handling, and disposal.

The myriad of treatment approaches generally all fall within 6 general categories, as described

Table 4.7-1: Summary of categories of wastewater contaminant

Contaminants	Major categories	
Macro[1]	Suspended solid Organic content Nitrogen	Microorganisms (indicator) Grease and oil Biochemical oxygen demand Phosphorus
Micro[2]	Endocrine-disrupting compounds Surfactants Organic solvents Personal care products	Pesticides and herbicides Flame retardants Anti-bacterial agents Pharmaceutical agents
Biologics[3]	Viruses Protozoans Prions	Bacteria Helminths

[1]Macro = Regulated contaminants, generally higher concentrations
[2]Micro = Contaminants normally found at lower concentrations may not be regulated
[3]Biologics = Contaminants of a biological nature

in detail in Appendix H, Appendix I and conceptually shown in Figure 4.7-1:

1) Preliminary—screening and grit removal,
2) Primary and enhanced primary treatment,
3) Secondary treatment,
4) Advanced or tertiary treatment,
5) Microorganism reduction, and
6) Advanced oxidation processes (AOP).

Full wastewater treatment plants (WWTPs) are comprised of combinations of various treatment technologies and treatment categories as shown in Figure 4.7-1. The combinations of WWT technologies available for a design can be divided into 3 categories based on their development status:

1) state of the practice: technologies successfully incorporated into one or more full-scale WWTPs;
2) state of the art: technologies still in the demonstration stage, possibly to the point of construction of a research-level, full-scale facility or a large pilot plant for proof of performance; and
3) research-based technologies: bench-top or small pilot-plant facilities built to prove and/or demonstrate the concept on which they are based.

Wastewater treatment technologies currently available are presented in Appendix H. While the technologies differ, certain basic principles of wastewater treatment are common to all:

- the main objective of wastewater treatment is to protect public health and the environmental needs (that is, humans, other living things, physical attributes, and aesthetics);
- the goal of treatment is to prevent contaminants from entering the environment;
- the methods revolve around either oxidizing contaminants or ensuring that they end up in the sludge to be treated separately; and
- sludge management (that is, treatment, disposal, or reuse) requires special attention and could control the final decision.

Treatment technologies require energy. Everything being equal, the best technologies and processes use the least amount of energy or even produce energy. Potential energy such as hydraulic head is the best energy source, although it is rarely available at WWTPs. Methane produced from anaerobic sludge treatment can be used for power generation and space heating and heat pumps can be used to extract heat from the plant effluent.

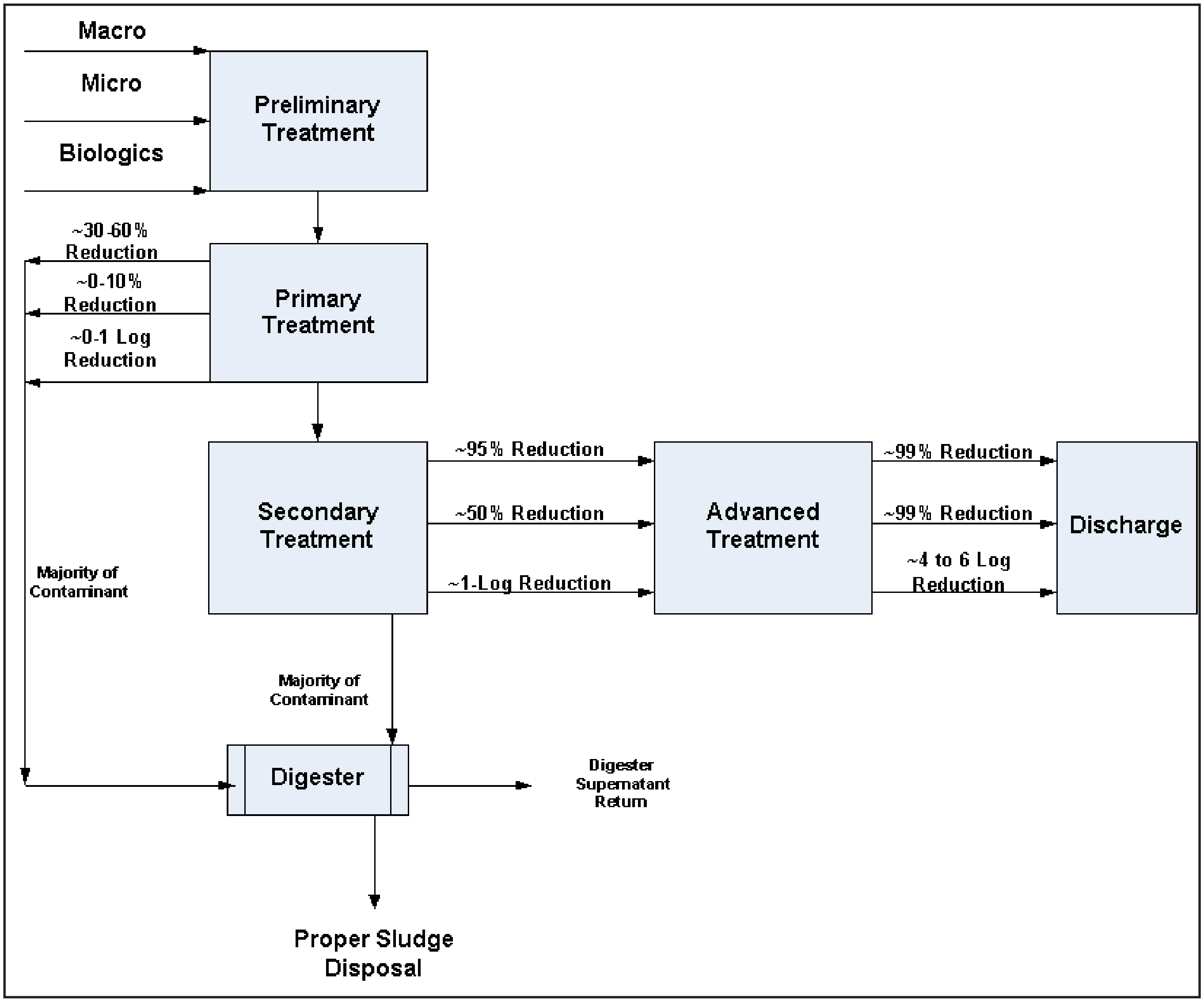


Figure 4.7-1: Conceptual diagram of treatment process showing removal capabilities (relative to influent) of each of macrocontaminant, microcontaminant, and biologics (in order top to bottom on all arrows). A log reduction is the method used to express reductions in biologics; one log removal is equivalent to a 10-fold reduction (see Appendices H and I for more details).

State-of-the-practice wastewater treatment

State-of-the-practice WWT includes several specific treatment trains resulting in different water quality levels:

- conventional,
- advanced conventional,
- conventional tertiary, and
- microorganism reduction.

Plant headworks

All treatment begins with preliminary operations at the entrance to the plant, the plant headworks. Common unit processes are bar screens, fine screens, grit reduction, and comminution (grinding and cutting). Flow metering and, if required, low-lift pumps are located at the headworks. These preliminary treatment options have very little effect on wastewater quality because their primary function is to remove large solid objects. Virtually no reduction is achieved in suspended solids, biochemical oxygen demand, dissolved chemicals, or microorganisms. The main purpose of preliminary treatment is to protect downstream treatment equipment and pumps from damage and clogging.

Conventional wastewater treatment

Following preliminary treatment, conventional WWTPs employ primary and secondary treatment steps and sludge treatment.

Primary treatment

In primary treatment, screened sewage is passed through large tanks where heavy materials sink to the bottom and are collected for subsequent treatment and disposal, while light materials that rise to the top are skimmed off for collection. Primary treatment reduces total suspended solids (TSS) by about 60% and biochemical oxygen demand (a measure of the organic matter present, abbreviated as BOD_5) by about 30%. Primary treatment achieves only very limited reduction of nutrients such as nitrogen and phosphorus and some hydrophobic chemicals (chemicals that do not dissolve readily in water). Primary treatment may be enhanced by treating wastes with chemicals intended to increase rates of coagulation and precipitation.

Enhanced primary treatment

Enhanced primary treatment leads to greater TSS reduction (70% to 90%), hydrophobic chemical (>50%), and greater BOD_5 reduction (50 to 70%). Depending on the coagulant used, some nutrient reduction may occur due to precipitation of phosphorus. This unit operation and process combination will yield considerably more sludge to be treated and a more dilute wastewater for biological treatment.

Secondary treatment

There are several forms of secondary treatment, all of which involve the further processing of wastes from primary treatment with microorganisms that use or break down contaminants. The most widely used secondary process is activated sludge. There are many variations of the activated sludge process, each with benefits and costs that may vary depending upon the types of treatment the wastes receive prior to secondary processing and other wastewater characteristics. When site space is limited, membrane biological reactors (MBRs) may be the most attractive alternative.

The main energy requirement in secondary processing involves the addition of oxygen to the reactors. Careful design and operation of this aeration step will result in the best performance at the lowest cost. As noted in Appendices H and I, secondary biological treatment provides good reduction in a number of the micro-contaminants. Micro-contaminants can be virtually eliminated by combining the proper amount of UV with an oxidant like ozone or hydrogen peroxide.

In addition, there is some reduction in human pathogenic microorganisms by the secondary treatment step. However, microorganism reduction through microorganism reduction processes such as ultraviolet (UV) light is needed to reduce the numbers significantly.

Sludge treatment

The sludge collected from the primary and secondary treatment steps will contain a great deal of the wastewater macro-contaminants. These include more than 95% of the TSS, BOD_5, and FOG. In addition, indicator fecal coliforms and related pathogens are reduced by a factor of between 10 and 100, and more than half of several metals and a number of the micro-contaminants are removed. The sludge can be treated using a number of anaerobic processes. Such processes generate methane as a by-product, and with gas cleaning, this methane can be used for power generation and space and process heating. The sludge must be treated to Class A quality (free of pathogens) and then will require proper disposal. The liquid from sludge processing must be returned to the headworks of the WWTP.

Advanced conventional wastewater treatment

Advanced conventional WWT is designed to reduce the concentration of nitrogen and phosphorus in the effluent. These elements are nutrients that can lead to the eutrophication of receiving water bodies. Advanced conventional treatment is normally designed as a part of the secondary treatment facilities. Nitrogen and phosphorus reduction can be achieved by chemical–physical processes, biological processes, and biological–physical processes. The latter two are the most popular because of the lower operating cost and smaller mass of sludge to be processed.

Conventional tertiary wastewater treatment

Conventional tertiary WWT is used to reduce residual suspended, colloidal, and dissolved materials after secondary biological treatment. The objective is a higher-quality effluent for greater environmental protection or reuse. A variety of coagulation or precipitation processes, followed by membrane filtration and possibly an advanced oxidation step, are used.

Micro-organism reduction

Micro-organism reduction (MOR; sometimes referred to as "disinfection") processes reduce microorganisms, and particularly pathogens, in wastewater. MOR technologies used in WWT fall into 3 categories based on their mode of action: chemical oxidation, physical removal, and energy inactivation. Ozone and UV with hydrogen peroxide are the most effective means of chemical oxidation and will substantially reduce micro-contaminants. Physical removal is normally accomplished by filtration, which does not kill microbes but re-directs them to a much more concentrated solution. Energy inactivation using heat, light, or radiation renders microbes non-infectious. It appears that UV processes require a smaller space and have less potential of by-product formation.

State-of-the-art wastewater treatment

State-of-the-art WWT involves processes like ozone and advanced oxidation processes (AOPs). These processes result in the chemical oxidation of all types of microorganisms, macro-contaminants, and micro-contaminants, as well as several materials that may result in odours, discolouration, and other aesthetically unappealing consequences. Various combinations of ozone, UV, and hydrogen peroxide are used for this type of treatment.

Research-based technologies

This category is limited to genuinely new theoretical concepts. Two types of processes are advancing into this category: struvite based nitrogen and phosphorus reduction, and new nitrogen reduction processes. See Appendix H for more information on these processes.

Decentralized versus Centralized Wastewater Treatment

The concept of decentralized WWT has gained a great deal of attention over the past few years. Decentralized treatment has been used most commonly to serve sparse housing and community centers that were too far from larger communities to have sewers extended to them. With the growth of cities and towns that has overtaken these outlying communities, decentralized treatment gave way to community systems. The driving forces were costs and public health protection. Large municipal utilities have a proven economy of scale: the large systems can deliver better service for a lower unit cost than small systems. Importantly, as the knowledge of public health and environmental issues grows, small systems have difficulty in constructing and operating the more sophisticated treatment schemes necessary to provide the level of protection derived.

Recently, decentralized treatment has seen resurgence for several reasons:

- The cost of constructing sewers is prohibitive, especially in relatively well-developed residential and community areas.
- Rights-of-way for locating and operating sewers are increasingly difficult and expensive to obtain.

- New on-site treatment technologies can offer adequate treatment in low-density rural areas.
- The reduction in price and greater availability of membrane-based treatment facilities supports high residential densities in smaller groups.

However, decentralized treatment currently has not been a good answer to the most perplexing and difficult concern facing small treatment sites: sludge management. Odours emanating from the wastewater inlet, created through sludge and solids management, or both, are the biggest source of complaints and concerns from neighbours. The only solution to these problems is to remove the sludge and send it to a central facility for treatment, processing, and disposal.

Satellite water reclamation plants

A great deal of the increased interest in decentralized treatment systems results from satellite reclaimed-water production facilities. Reclaimed water is a water supply produced from wastewater to replace or replenish non-drinking water uses in communities. With the increased availability and falling costs of membrane bioreactors (MBRs), satellite reclamation plants remove flows from nearby sewers to produce reclaimed water closer to the use area. This approach reduces backbone infrastructure such as pumps and pipes required to return reclaimed water from a central plant to use areas.

Satellite MBRs, if enclosed with off-gas treatment, can overcome serious limitations of decentralized WWTPs like odour problems, unattractive architecture associated with wastewater plants, and the difficulty of finding disposal sites for the discharge. Satellite reclamation plants are able to return solids to the sewers for transport to the centralized facility, greatly reducing the sludge source of odours. In addition, the compact footprint of MBR plants allows them to be installed inside a small land footprint. However, the sewers must flow with sufficient velocity to ensure that wastewater solids are flushed entirely to a centralized treatment plant.

While reclaimed water and wastewater effluents share the same source, the final outcome from decentralized facilities is drastically different. Decentralized WWTPs suffer from poor economic scale, the inability to conform to neighbourhood aesthetics, odour creation, and waste discharges in an urbanized area. Water reclamation plants, on the other hand, can be compact enough to hide in a neighbourhood home, remove odour-producing solids, and produce a valuable water supply that can ease the strain on local water supplies, especially during times of low stream flows and stress on groundwater supplies. Water reclamation, however, has additional challenges of effluent storage until it is needed and for dual distribution piping to deliver the water.

Decision process

The choice between construction of decentralized versus centralized wastewater treatment facilities for each community will depend on the goals for treatment, as well as a comparison of benefits and costs. Communities need to balance limited financial resources with their responsibilities to protect public health and the environment, as well as to maintain and improve their community's cultural amenities. The analysis of benefits and costs of wastewater treatment must consider long-term consequences. No option represents a viable "solution" if it shifts the costs of treating—or of not treating—wastewater to future generations. This issue is further evaluated in Section 4.9.

The selected alternative must be environmentally, socially, and economically sustainable. These considerations are sometimes formulated as a "triple bottom line" (TBL) evaluation perspective, as opposed to the more narrow "minimized self impact" concept that had traditionally been used in wastewater management. The TBL approach compels communities to adopt a broader and more inclusive notion of the issues that ultimately affect their interests and welfare.

The evaluation of decentralized facilities versus a centralized or regional WWTP involves a breadth of issues with a wide range of public objectives and policies in addition to health, environmental, and economic factors (technical components). However, without clearly stated community objectives and policies, only the technical components can be adequately assessed. Issues such as impacts to property values near decentralized WWTP sites, the value of reclaimed water as a new water supply, and the impact of the costs of operating multiple outfalls need to be considered in addition to technical components.

With the expectation that new knowledge will lead to better WWTPs, the consolidation of WWT services at a central location should result in reduced long-term capital and operating costs, reduced site requirements, and more reliable treatment producing higher quality effluent (protection of public, environmental, and aesthetic health objectives). Only an economic analysis based on technical components and actual site conditions can determine the difference in cost implementation over the short- and long-term evaluation periods. This is beyond the scope of the Panel's review.

4.8

Review of Other Coastal Communities

Review the effectiveness of the CRD's approach to liquid waste management compared to other coastal communities.

Approach

CRD is similar to other urban coastal communities, being responsible for the development, administration, operation and management of multiple utility liquid waste programs.

The Capital Regional District (CRD) (Figure 4.8-1) is responsible for providing the essential public utilities to the greater Victoria, British Columbia area, which encompasses 13 communities at the south end of Vancouver Island. These essential public works and utility services include operating the infrastructure for part or all of the systems of wastewater, solid waste, storm water, and potable water utilities. Although developing, operating, and maintaining these services appear to be managed as individual enterprises, they encompass a single set of municipal assets necessary for protecting public health and the environment.

CRD's Liquid Waste Management Plan (LWMP) was developed to address operations and construction needs for liquid wastes within CRD's service area. While the Core Area Plan is specific to the needs of the core portion of the service area, it also complements the Saanich Peninsula Liquid Water Management Plan that covers Central Saanich, North Saanich, and Sidney. CRD's Core Area service is divided fairly evenly between the Macaulay Point and Clover Point collection and treatment facilities, effectively creating two separate operating utilities under combined management. The Clover Point facilities serve Victoria, Oak Bay, and Saanich. The Macaulay Point facilities serve the remainder of the Core Area service area.

The Panel was tasked with reviewing and assessing the effectiveness of CRD's approach to liquid waste management as it compares to other coastal communities

- who have similar receiving environments, and
- who have or have attempted to manage environmental impacts using an environmental trigger process.

The intent of this assessment is to compare the ability of these utility enterprises to address local public health and environmental protection needs.

This evaluation compares CRD with Canadian and US utilities, plus international wastewater management entities. Direct, point-by-point comparisons were problematic due to the complexities of each of the programs considered. This review was limited to assessing whether or not the other utilities practiced the same individual waste management pro-

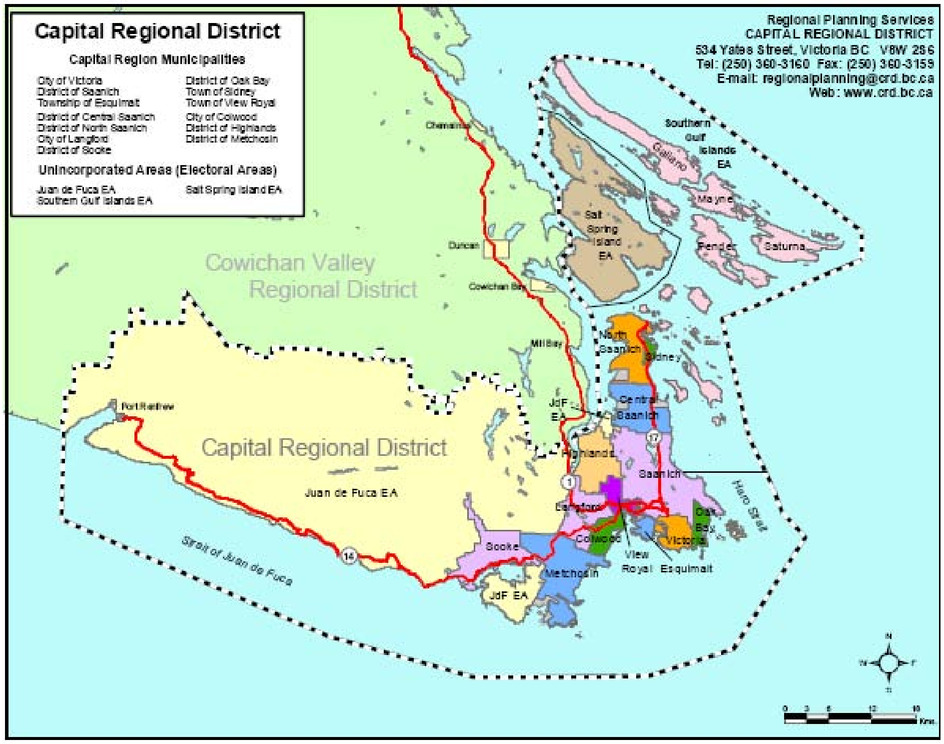


Figure 4.8-1: Capital Regional District (CRD) map

grams and a general assessment of the program capabilities, such as the determining type of treatment provided if any, or the approach to stormwater or source control. Appendix J provides more detailed information, upon which this section of the Panel report is based.

Detailed task-by-task comparisons of management programs did not provide additional, useful information. Individual program elements developed by each utility are tailored to their specific service area and receiving environment needs as deemed necessary by the utilities, their constituents, and their respective regulatory authorities in order to assure minimum public health and environmental protection. The most useful information came from assessing how the utilities approached their responsibilities for public health and environmental protection.

The facilities selected to compare to CRD's program were

- Greater Vancouver Regional District – Iona Island & Lions Gate;
- King County, Washington – South Plant, West Point Plant, and Brightwater Plant (under design);
- San Diego – Point Loma Outfall;
- Massachusetts Water Resource Authority – Boston Harbor;
- Halifax Regional Municipalities; and
- Norwegian and Swedish National Programs.

Receiving Environments

Initially, public health concerns drove the development of sewage collection and disposal. Early programs chose to dispose their waste in the closest and most convenient water body that flushed away the waste. At first, the environment appeared to easily handle (assimilate) the wastes that were discharged, but as populations grew, effects on the water bodies and marine life became noticeable. The need to control pollutants at the source and through treatment arise from similar desires, but community programs are as dissimilar and varied as each separate community, simply because the marine or aquatic environment near each community is not the same. This is true even of the geographical neighboring marine environments at Victoria, Vancouver, and Puget Sound.

Comparative Success and Effectiveness

The first step in assessing the effectiveness of an individual program is to understand the reasons for the program. Communities are responsible to ensure the health and welfare of their citizens, which requires collecting and removing microbial and chemical agents that cause disease, which led to the first sewers. Sewers resulted in waste disposal in the environment at specific points, resulting in environmental degradation when nature could no longer process the wastes. Damage to the environment resulted in the need to remove the waste from the environment to the point that the receiving environment could sustain itself even with waste discharge. Therefore, the effectiveness of a community's liquid waste management programs must be judged at the community level as reflected by the health of the community and the local environment. The driving forces for each community are unique to that community.

This review of the existing management programs shows that all of these utilities, including CRD, administer successful programs. The only difference amongst all of the programs is the approach relied upon to address future treatment needs.

Public Controversy

One common element to all of the programs reviewed was local controversy. Although details of the controversies were not pursued in order to determine the reasons for (or resolution to) all of the local debate, it does appear that community ethics strongly influenced the final decisions.

CRD Management Programs

The individual programs encompassing CRD's full liquid waste management program provide the basis for comparison. The individual programs include the following:

- municipal wastewater management program,
- source management program,
- stormwater management program,
- trucked waste program,
- biosolids management program, and
- growth management and system expansion.

The Liquid Waste Management Plan provides an excellent summary of the management programs and their intended outcomes.

Summary of Program Management Activities

General

Table 4.8-1 summarizes a comparison of 6 wastewater utilities that appeared to be the most similar to the management programs provided by CRD. All of the utility groups own and operate numerous wastewater treatment plants. The majority of the plants provide secondary treatment or better, especially those that discharge to estuarine environments.

CRD's LWMPs closely parallel and address the fundamental task of all of the other programs. The most significant differences between CRD and the other utility programs lie in the level of treatment provided and the reliance on environmental triggers to initiate more intense treatment. CRD applies the least intensive treatment and, other than GVRD's marine discharges, is the only one to base future treatment decisions on formal environmental triggers.

Additional, more detailed information for each of these programs is provided as Appendix J.

Comparisons

CRD differs from the other coastal communities reviewed in the level of wastewater treatment provided. All other communities provide a minimum of primary treatment.

Table 4.8-1: Comparison of various aspects of liquid waste management across the jurisdictions reviewed

Management Program / Facility Characteristic Data	CRD-Victoria	GVRD-Vancouver	King County Washington	MWRA-Boston	Halifax	San Diego
Outfall Characteristics						
Name	Clover Point	Lions Gate	South Plant	Deer Island Outfall	Halifax	Point Loma
Length (km / ft)	1.1 / 3,600	no data	3.05 / 10,000	15.1 / 49,600	20 / 66	7.16 / 23,472
Depth (m / ft)	76 / 220	no data	189 / 620	30.7 / 100	75 / 246	94.5 / 310
Dilution rate	127:1	7:1 minimum	429:1 chronic	150:1	20:1 minimum	239.1: minimum
Name	Macauley Point	Iona Island	West Point		Dartmouth	
Length (km / ft)	1.7 / 5,580	7.2 / 23,615	1.04 / 3,400		17 / 56	
Depth (m / ft)	60 / 197	72-106 / 235-350	73 / 240		100 / 328	
Dilution rate	112:1	100:1 minimum	153:1 chronic		20:1 minimum	
Name			Brightwater		Herring Cove	
Length (km / ft)			1.43 / 4,700		20 / 66	
Depth (m / ft)			183 / 600		50 / 164	
Dilution rate			300:1 chronic		50:1 minimum	
Monitoring Program						
Marine environment	X	X	X	X	X	X
Sediments	X	X	X	X	X	X
Water column / fish		X	X	X	X	X
Biological diversity	X	X	X	X	X	X
Sewer System Source Control	X	X	X	X	X	X
Wastewater effluent	X	X	X	X	X	X
Treatment trigger	X	X				
Storm water management issues						
Combined sewer overflow program	X	X	X	X	X	X
I/I reduction	X	X	X	X	X	X
Combined sewer separation	X	X	X	X	X	X

Table 4.8-1 (cont'd): Comparison of various aspects of liquid waste management across the jurisdictions reviewed.

Management Program / Facility Characteristic Data	CRD-Victoria	GVRD-Vancouver	King County Washington	MWRA-Boston	Halifax	San Diego
Treatment processes						
Preliminary / Screening	X	X	X	X	X	X
Primary		X	X	X	X	X
Enhanced Primary					X	X
Secondary			X	X		
Tertiary			X			
Disinfection			X	X	X	
Sludge / biosolids management	X	X	X	X	X	X
Triggers for additional capacity / quality defined	X	X	X	X		X
Source control / pre treatment program						
Industrial / commercial	X	X	X	X	X	X
Storm water control	X	X	X	X	X	X
Water reuse (flow and waste load control)			X			X
Future capacity planning						
Active planning / significant growth potential	X	X	X	X	X	X
Integration with water supply / reuse	X	X	X	X		X
System operations						
Cross connection	X	X	X	X	X	X
Asset management / system re-placement	X	X	X	X	X	X
Un-sewered area management	X	X	X	X	X	X

Program management

Each of the utilities reviewed appear to approach the management of each individual water and waste program as separate, standalone utility functions. But it appears that the management of each utility recognizes that all of these individual utility functions are interrelated, with the success of the overall system depending on success of the individual programs.

Program effectiveness

Comparison of effectiveness of all these liquid management programs was challenging. It is clear that all of the utilities, including CRD, are providing effective liquid waste management in response to their current understanding of their unique environmental and health protection needs. The program outcomes are adapted to the local conditions to take advantage of particular conditions. For example, Halifax does not harvest fish through a sampling program, but because Halifax Harbour supports commercial fisheries for several marine species, Halifax Regional Municipality has access to continuous information about the health and degree of contamination of the harbour fisheries.

Program differences

This comparison confirms that the major differences between the CRD approach and the other utilities lie within the

- number of protective barriers,
- level of treatment provided,
- reliance on marine monitoring program (environmental triggers) as an effective protective barrier,
- integration of water resource management in source control, and
- level of reliability provided by the waste management program.

Municipal wastewater treatment program

CRD relies on the least intensive treatment process of any of the utilities investigated. At a minimum, all utilities provide enhanced primary treatment, if not secondary or advanced treatment for nutrient removal. Nutrients are a major concern in Norwegian and Swedish receiving waters and in Puget Sound. In addition, the King County, MWRA, and Halifax plants provide microorganism reduction in addition to the other treatment processes.

Source management program / stormwater management program / trucked waste program

CRD's approach to these management programs is similar to that of other jurisdictions, often facing the same limitations and dilemmas, especially local concerns, and appears to have the same level of success. All jurisdictions struggle with the effects that combined sewer overflows (CSO), sanitary sewer overflows (SSO), and trucked liquid wastes have on treatment or landfill disposal. All of the utilities appear to have had some success with storm water or CSO/SSO programs, but all have targeted these contamination sources as serious, high-priority programs for greater investment.

The details of the source control programs are unique to each community. The fundamental source control programs manage contaminant sources of particular concern within their communities. All of the programs appear to address common industrial or commercial waste sources.

A fundamental difference is the level of protection other utilities have dedicated to source control programs. Source control is the only specific protective barrier provided by CRD. In comparison, the other utilities do not rely solely on source control, but have installed a level of treatment that is intended to remove contaminants of concern in their local receiving environment. Treatment plants provide multiple barriers of protection in themselves because several levels of treatment can be provided: screening, primary, enhanced primary, secondary, tertiary, or pollutant-specific processes, plus disinfection. Additionally, treatment plants offer the opportunity to monitor the progress of contaminant removal throughout the treatment train, allow for modifications to more fully meet goals, and allow for additional liquid stream monitoring prior to the receiving environment. Because monitoring, in reality, provides only a snapshot of the quality of the water at the time the sample was taken, the ability to sample more frequently and at more locations and to modify treatment in response provides much greater reliability of contaminant removal, and increases the effective number of barriers for protection.

Finally, all of the other utilities or the respective governing agencies have recognized the need to seriously consider—and in several instances, implement—integrated water resource management as part of source control. Reducing flow, through infiltration and inflow removal, or reduction through potable water conservation, reduces treatment plant capacity and results in more stable waste loads entering the treatment facilities. In addition, if water resources can be recaptured and reused, wastewater flows can be reduced along with reductions on potable water demands.

Several of the utilities are developing water reclamation and reuse in response to limited water supplies; however, these same facilities recognize benefits to the wastewater utilities also as noted above. While water reuse is generally expected in cities such as San Diego, California, and Sydney, Australia, active reclamation programs in the Puget Sound area, the Greater Vancouver region, and Boston seem surprising. But, Puget Sound has 9 water reclamation and reuse facilities operating and 2 more under construction at this time. GVRD is actively considering the need for reclamation, and the State of Massachusetts is developing water reclamation regulations.

Water reclamation and reuse can be financially beneficial by reducing flows to treatment plants, and also by allowing reductions in the size of potable water facilities. Reclaimed water can substitute for large-quantity non-potable water demands such as residential irrigation, industrial water supplies, or fire fighting. However, that cost of the non-potable pipe distribution system may be significant.

Biosolids and sludge management program

All of the utilities manage active wastewater sludge / biosolids programs. The more sophisticated programs exist where active markets have been developed for the beneficial reuse of biosolids. Landfill disposal is not uncommon.

Growth management and system expansion

All of the utilities investigated have active growth prediction and utility response planning programs. Success of these programs can only be determined in the future to see how accurate the predictions of growth and impacts are.

Environmental / Treatment Triggers

CRD and the Greater Vancouver Regional District are the only two coastal communities of the communities reviewed to rely on the use of environmental triggers as the basis for future wastewater treatment decisions.

General

The CRD and the GVRD rely on the application of environmental triggers to implement future treatment. The other utilities will base decisions for wastewater treatment on effluent quality monitoring and established effluent water-quality limits. The monitoring programs of the other utilities are very similar.

For the other utilities, regulatory agencies have used information gained from the environmental monitoring programs as a basic part of the decision-making process to require treatment to specific levels, and continue to use similar environmental monitoring programs to assess the results of the treatment. Future treatment improvements, if required, will result from these monitoring programs, probably using the previous decision-making approaches that have led to current treatment requirements.

The following sections provide descriptions of the current environmental monitoring / trigger program in the other jurisdictions.

Greater Vancouver Regional District

The GVRD is the only one of the programs considered, other than CRD, that has retained a formal environmental trigger program. The program is explained by GVRD by the following statement:

"The Greater Vancouver Regional District (GVRD) has committed to the principle of managing liquid waste in a sustainable and cost effective manner that protects and enhances the receiving environment. This commitment is detailed in the District's Liquid Waste Management Plan (LWMP). Upon approval of the LWMP, the Minister of Water, Lands and Air Protection (WLAP) required that the GVRD 'Develop the environmental 'triggers' used in the monitoring process by January 31, 2004, recognizing that the environmental monitoring process in the LWMP is based on discharge indicator trend analysis such that action will be implemented before Water Quality Objectives or other criteria are met or exceeded'. A key component of the LWMP involves monitoring, assessing and forecasting to evaluate effects of GVRD's liquid waste discharges. Environmental monitoring will determine, through application of the cautions, warnings and trigger process, if and where discharges are contributing to environmental risk. If the results of the monitoring indicate effects in the receiving environment, the GVRD will respond via the process outlined in the LWMP" (Burd et al. 2005).

The monitoring program beginning in 2000 showed clear sediment exposure and related biotic effects related to the discharge. The monitoring data from 2000 to 2003 established biotic and chemical exposure zones from the Iona Island outfall:

- moderate impoverishment (MI): 0 to 1km N
- low impoverishment (LI): 1 to 3 km N
- biotically enriched (BE): 3 to 4 km N, 0 to 1 km S
- reference or background (R): 4 to 5 km N, 1 to 2 km S, 7 to 8 km S
- outside effects (OE): beyond outfall deposition.

Based on the program, GRVD set indicators for environmental triggers (Table 4.8-2).

Puget Sound – King County

The King County Department of Natural Resources currently operates 3 wastewater treatment plants and 2 CSO (combined sewer overflows) treatment plants that discharge wastewater directly into Puget Sound. The Clean Water Act states that all wastewater collection and treatment facilities that discharge effluent into surface waters are required to have a National Pollutant Discharge Elimination System (NPDES) permit.

An NPDES permit sets limits on the quality and quantity of treated wastewater that is discharged. As part of its NPDES requirements, King County has conducted an extensive point-source monitoring program for more than 20 years. The purpose of the program is to assess the quality of each facility's effluent, the receiving water around each outfall, and nearby beaches to ensure the facility is meeting the goals of the Clean Water Act.

King County's marine monitoring programs are constructed to assess potential effects to water quality from both point and non-point sources of pollution. Point source pollution is characterized by its entry into the aquatic environment from a specific facility, such as an outfall pipe. It can be generated from a variety of industrial and municipal facilities, including sewage treatment plants and manufacturing facilities. Non-point source pollution comes from any source that is not a point source, including runoff from agricultural and urban areas. Point source monitoring stations are in the vicinity of point source discharges, while most of the ambient monitoring stations are not in the vicinity of known point source discharges.

Both the ambient and point source monitoring programs focus on both marine waters

Table 4.8-2: Selected biotic, geochemical, and contaminant indicators, types, and zones of application[2]

	Zone of application		
Indicator	Caution	Warning	Trigger
Echinoderm abundance	R	BE	
Crustacean abundance R BE	R	BE	
% *Capitella capitata* complex	R	MI,LI,BE	MI,LI,BE
% *Heteromastus filobranchus*	R	MI,LI,BE	MI,LI,BE
% bivalves	R	MI,LI,BE	MI,LI,BE
Swartz Dominance Index	R		
Species richness	R	MI,LI,BE	MI,LI,BE
Bray-Curtis dissimilarity	R	BE	
Axinopsida serricata % adults with 0/1 stain on shell	R		
Sediment fecal coliforms	R		
Sediment AVS[1]	R	MI,LI,BE	MI,LI,BE
Sediment 4-nonylphenol[1]		MI,LI,BE	MI,LI,BE

[1]Note these are supporting indicators for biotic factors only: CCME (2002) has developed interim marine sediment quality guidelines for 4-NP of 1 mg/g for 1% TOC toxic equivalency units (TEU).
[2]Burd et al. 2005

and sediments. Many marine pollutants are in particulate form, and as these contaminated particles settle to the bottom, pollutant concentrations in the underlying sediments tend to increase. Most sources of contamination are in nearshore areas, and pollutants tend to accumulate in sediments close to these sources. Because these nearshore areas tend to be high contact areas for both marine organisms and people, contaminated sediments have an important impact on human health, marine life, and the marine environment (King County Department of Natural Resources and Parks).

City of San Diego

The City of San Diego operates the Point Loma Outfall under an NPDES permit and consent order. The permit and order included requirements for monitoring the marine environment in the area of the outfall. The main objectives of the ocean monitoring program are to provide data that satisfy the requirements of the NPDES permit, demonstrate compliance with the 2001 California Ocean Plan (COP), detect movement and dispersion of the wastewater field, and identify any biological or chemical changes that may be associated with wastewater discharge (City of San Diego 2004).

The monitoring program may be divided into the following major components:

- oceanographic conditions,
- microbiology,
- sediment characteristics,
- macrobenthic communities,
- demersal fishes and megabenthic invertebrates, and
- bioaccumulation of contaminants in fish tissues (City of San Diego 2004).

While the monitoring program closely mirrors the environmental monitoring and trigger program employed by CRD, no trigger conditions have been established that will automatically require additional treatment by the City of San Diego.

Massachusetts Water Resource Authority: Boston Harbor / Massachusetts Bay

The outfall permit for the metropolitan Boston area does not include a specific environmental or treatment trigger. However, MWRA must continue effluent toxicity testing, monitoring, and maintaining effluent limit requirements for the outfall and combined sewer overflows. MWRA is required under the NPDES permit to have a contingency plan to address potential water-quality changes that develop as a result of the discharges. Changes could involve additional monitoring or changes in the treatment process (Wu 2003).

Halifax Regional Municipality (HRM)

As a condition of approval for the Harbour Solutions Project (HSP) under the Canadian Environmental Assessment Act, HRM has undertaken a water quality sampling program for Halifax Harbour. Weekly samples are collected for fecal coliform bacterial analysis, and bi-weekly samples for more extensive chemical analyses. Samples are collected at the surface and at 10 m depths.

The program began in June of 2004 and is scheduled to run until at least 2009, at which point all three of the new HSP sewage treatment plants will be built and operating. The purpose of the program is to assess whether the defined water-quality objectives for the Harbour will be met after the new wastewater treatment plants have been in operation (Halifax Regional Municipality).

Sydney, Australia

Sydney Water publishes indicators of environmentally sustainable development (ESD) to judge the performance of the utility during the preceding year. The wastewater division measures several indicators, including sewer system overflows, sewer leaks, wastewater treatment plant effluent, and odour complaints.

Sydney Water operates 31 wastewater treatment plants. Treatment ranges from “high rate primary” (higher flow rates and less solids removal than primary treatment) to tertiary treatment with nutrient removal.

There are 10 coastal treatment plants that together treat around 88% of sewage from the Sydney region for discharge to the ocean. The 3 largest plants provide 93% of this discharge using primary treatment only.

In addition to water-quality and marine species monitoring to assess the effectiveness of outfall extensions, Sydney Water monitors 29 ESD indicators to assess the performance of the utility in providing such services as wastewater treatment, providing potable water supplies and meeting water supply needs through water reclamation and reuse. These indicators measure the extent to which the wastewater treatment plants are successful in removing nutrients and suspended solids from wastewater to prevent adverse impacts on receiving waterways. Environmental monitoring is not based on assuring compliance with conditions to delay additional wastewater treatment (Sydney Water 2004).

Future treatment needs will apparently be determined from results of Australia’s Department of Environment and Heritage’s *Integrated Coastal Zone Management Program.* This project has been created to provide the basis for all future decisions regarding water-quality protection requirements. In the meantime, Sydney Water continues to implement programs to reduce wastewater flows through reclamation and reuse in response to water supply concerns.

4.9

To Treat or Not to Treat Sewage: A Risk Management Decision

Determine if the CRD should implement sewage treatment to manage the discharge of wastewater at Clover and Macaulay points. If so, identify what level of sewage treatment is required and why.

The question of whether or not to implement sewage treatment in the CRD—and to what level and when—is essentially a risk management decision that should take into account multiple inputs. The Panel's report will contribute to the scientific and technical basis for a decision, particularly Section 4.7 and Appendices H and I, which lay out the incremental health and environmental benefits and costs for various treatment options. However, the science is only one aspect of decision-making. Other important inputs include social, public and political, feasibility, regulatory and legal, and economic considerations (see Figure 4.9-1).

"Non-scientific" considerations are particularly important because many of the concerns with the CRD's current wastewater management practices arise from uncertainties regarding long-term consequences rather than any effects that can presently be demonstrated. Some commentators maintain that current disposal practices are safe and sustainable and that money spent to improve upon them would be better applied elsewhere (see, for example, Stanwick et al. [2006] and Chapman [2006]). Others point to unquantified and poorly understood risks (see, for example, Ishiguru [2005]).[1]

Views may differ for several reasons. People may

- hold different values or be affected in different ways: some may be more concerned with possible health or ecological effects, while others may be more concerned with the costs they would bear if taxes increased to bear the costs of treatment;
- disagree as to the severity of harmful consequences;
- disagree as to the likelihood of harmful consequences; or
- differ in their willingness to bear the risks of harmful consequences.

The Panel cannot and does not judge the relative merits of people's concerns. But after carefully considering the scientific evidence (the Panel's mandate), the Panel concludes the following:

- The science is not sufficiently well developed to state with **certainty** whether

[1] Many of the submissions offered for the Panel's consideration by the T. Buck. Suzuki Foundation also address the uncertainties and risks inherent in releasing untreated sewage into the environment.

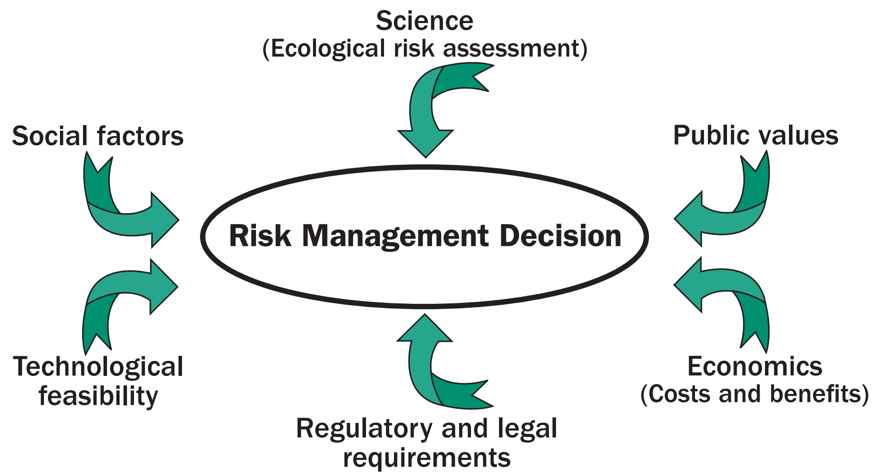


Figure 4.9-1: Inputs to risk management decisions.mainly related to "science", but also to some degree technical input related to "economics". (adapted with permission from Stahl et al. 2001, Risk Management: Ecological Risk-Based Management, ©SETAC)

or not harmful health or ecological consequences are likely to result from the continuing discharge of screened sewage from the Macaulay and Clover Point outfalls; in the views of some scientists, the present data demonstrate harmful consequences, but the opposite view is also held in the scientific community on the basis of the same information.

- Nor is it possible to objectively determine the probabilities of harmful outcomes in the future.
- There is no completely objective way in which to balance the costs of enhanced treatment with the risks of maintaining the present pre-treatment and screening program.
- Notwithstanding the above points, a reasonable case can be made that incurring the expenses of sewage treatment would be prudent public policy in line with the expression of public preferences.

The CRD's choice among treatment options boils down to a judgment regarding what risks the community, as well as British Columbians and Canadians, are willing to bear. There is no reason to believe that serious human health effects or severe ecological consequences not yet in evidence (as discussed in Section 4.2) will arise in the near future. Yet such consequences remain a possibility. It is extremely difficult to decide how to address risks that with very low probability but potentially significant consequences that may be somewhat irreversible.

The CRD has asked the Panel for their opinion on these difficult issues, which the Panel has found a challenging task. Choosing not to choose is opting for the *status quo*, and if this is the case, the choice ought at least to be made explicit. How should such difficult choices be made? Some criteria might include

- fair and transparent decision-making,
- avoiding an expensive policy if a cheaper one could have achieved the same results, and
- providing "the greatest good for the greatest number", while recognizing that no decision will fully please all constituencies, whatever course is decided upon.

The main focus of this section is a review of evidence that can be brought to bear on what constitutes "the greatest good for the greatest number". The section concludes with an observation that, in the final analysis, wastewater treatment is "worth" what citizens are willing to pay for it.

Benefits and Costs: The Challenges of Quantifying

When difficult choices must be made, like the one that CRD now faces about sewage treatment, one type of evidence is often presented: an analysis of benefits and costs. If the benefits arising from treatment exceeded its costs, a benefit–cost analysis (BCA) would argue for treatment. The Panel had neither the time nor the resources to perform a full BCA, nor does it believe that an expensive and lengthy study would necessarily resolve difficult issues. Nevertheless, it is helpful to review how a BCA would be accomplished *in theory*, along with what would make it so difficult *in practice*.

Treatment costs are relatively easy to quantify in terms of dollars, at least in comparison to putting a dollar figure on benefits, which is discussed below. Even in the estimation of costs, however, subtle issues can arise:

- Costs can include both capital (one-time) and operating (repeated) expenses. These costs must be discounted at an appropriate interest rate and totaled over time.
- Costs must be defined relative to a clearly specified baseline. One concern in the CRD is that, even if treatment facilities are not required now, they may need to be built later if triggers are tripped or regulatory or political decisions mandate treatment. The relevant cost of beginning work on treatment facilities now is not only the gross cost of construction and operation but also the difference between incurring that cost now or incurring that cost later.[2]

All costs should be included, such as the cost of processing and disposing of increased biosolids resulting from treatment, and the costs of an expanded monitoring program.

The distinction between costs and benefits is more one of convention and convenience than of substance. Many benefits are simply avoided costs, and a foregone benefit is an incurred cost. In the analysis of public programs, benefits are typically distinguished from costs because the latter generally accrue to the general public, while the former are typically concentrated within a particular site or operation.

The benefits of public investments are often public goods. A public good is something which is experienced by everyone. Sewage treatment is a public good because everyone in the community experiences a reduced risk of illness when sewage is treated. Similarly, everyone in the community might take some satisfaction from knowing that marine life is protected in the environs of Victoria, everywhere its waste water disperses, and everywhere the organisms exposed to that waste water migrate. Public policy in the CRD could therefore affect a very broad "public".

It is often fairly straightforward to estimate the costs of treatment options. Treatment facilities comparable to those that might be constructed in the CRD exist in other areas, and experts can offer their opinions as to how much money would be required to build and operate similar facilities in Victoria. While a significant expertise and identification of potential sites are required to derive reliable cost estimates, cost estimators do have the advantage of being able to see what other communities have paid

[2] To give an example, suppose the total cost of building and operating a treatment plant this year were \$100 million. If regulation required that the same plant had to be built 10 years from today anyway and the interest rate were 6%, the plant to be built 10 years from now would cost \$100 / (1.0610) = \$55.84 million. The real cost of building the plant today relative to the alternative of waiting 10 years would be \$100 – 55.84 = \$44.16 million.

for their facilities and what it would cost to acquire the labour, materials, energy, etc., needed to operate comparable facilities under local conditions.

Estimating costs becomes much more difficult when it comes to the less tangible values that may be more important in the choice of whether or not to treat wastewater in the CRD. One of the potential benefits of improved wastewater treatment is a reduction in the risk of ecological damage in the Strait of Juan de Fuca and other waters, or increased beach use by swimmers. What is this "worth"? People are generally unfamiliar, and sometimes uncomfortable, with the notion that natural organisms or systems would be assigned prices, particularly because the approach presumes that some prices could be deemed too high to afford. However, economists have generally argued that decisions concerning which natural assets to save and which are expendable cannot be avoided, and might as well be made in a transparent manner.[3] Still, the assertion that natural assets are "worth" what people are willing to pay for them is controversial.

Another important consideration in valuing benefits is that total values are derived by adding across benefit categories. For example, cleaner water will produce both health and ecological benefits. All benefits are additive in evaluating the overall benefits of water treatment. These different categories of benefits can accrue to different people. Health benefits may largely accrue to people in the near vicinity of the sewage outfalls. Ecological benefits could affect a much broader group of individuals. Responsible decision-making should consider the benefits accruing to all groups and relate them to the costs incurred by all groups. If only a single value, or a single affected community, were considered, too little treatment would be provided.

What Are the Benefits of Sewage Treatment?

In Section 4.2, the Panel describes the incremental health and environmental benefits from various levels sewage treatment. Here, we briefly review some of the broad categories of benefits.

Human health

Investigators often estimate the effects of environmental pollutants on human health in calculating the benefits of environmental improvement. One common approach is to estimate the cost of illness in terms of lost wages and medical expenses, although such costs may understate true losses for reasons detailed below. In order to estimate overall health effects, one would need to multiply the cost of illness times the number of cases of illness anticipated. The expected number of cases depends on the presence of dangerous pathogens in the environment and the number of people likely to be exposed to them. Human exposure to dangerous pathogen concentrations in the vicinity of the Macaulay and Clover Point outfalls is likely to be relatively infrequent. The cost of illnesses contracted from polluted water would be, if not entirely negligible, at least not of a magnitude that could justify expenses as great as those of proposed advanced treatment facilities.

The Panel believes it is unlikely that any premature deaths would result from exposure to pollutants from untreated wastewater in the CRD area.[4] There is no epidemiological evidence to suggest that there are significantly higher rates of serious infections in the Victoria area, let alone of potentially fatal diseases (Stanwyck et al. 2006).

The calculation of costs of illness may understate economic losses because people also sacrifice some satisfaction from enjoying activities that are prohibited, or which the public avoids,

[3] On the foundations of the economic valuation of environmental goods, see, for example, Freeman III (2003).

[4] At the time the Panel was preparing its report, however, the city of Honolulu, Hawaii, experienced a sewage spill that closed its beaches and caused the death from septic shock of 1 person unlucky enough to be exposed to the water (NY Times 25 April 2006). This is certainly a sobering reminder of the potential risks.

in potentially contaminated areas. Areas near the CRD's outfalls are closed to commercial and recreational shellfish harvesting,[5] and some anecdotal evidence suggests that windsurfers and others involved in recreation stay away from the vicinity of the outfalls (Golder Associates and Archipelago Marine Research 2002). The Panel concludes, however, that such effects are minimal, because there are other areas in which to recreate.[6]

As with most other aspects of sewage treatment in Victoria, however, the larger problem is with estimating the likelihood of events that have not yet, and might never, occur. Again, only a rough guess could be made of the likelihood of such an event.

Commercial and recreational fisheries

Contaminants have had little demonstrable effect on marine life beyond the vicinity of the outfalls, based on Golder (2005) and the Panel's review (Section 4.2).They might, however, have several impacts on fisheries in the Victoria area. First, an area of some 60 square kilometres in the vicinity of the outfalls is closed to shellfish harvesting. Second, monitoring data suggest that benthic invertebrate communities are more abundant because of the presence of nutrients from the outfalls. Third, there is also evidence that chemical contaminants are more common in the area of the outfall. It is possible, albeit not demonstrated, that these contaminants may impact commercial or recreational species. Fourth, contaminants might also have effects far away from the outfalls, either through transport or through being ingested by species with ranges beyond the outfalls. Finally, by virtue of the harvesting closure, the vicinity of the outfalls might, in effect, be a "marine protected area" whose net effects could be to enhance the abundance of commercial or recreational species.

Possible "far-field" effects will be discussed below in the consideration of ecological consequences. Otherwise, the Panel concludes that effects on commercial fisheries are minimal**.** While the CRD has received inquiries about the effects of treatment on closures (Taylor 2005), the Panel believes only a very small increase in total landings could be expected if areas affected by Victoria's wastewater were open to fishing. The Panel has not seen evidence that the sites of the outfalls, in deep water and not far from navigational routes, would attract significant fishing effort.[7]

Recreational fisheries can, in some instances, be more valuable than commercial fisheries. In British Columbia, sport fishing revenues, and their contribution to gross domestic product and employment, are all roughly comparable to those of commercial fishing and aquaculture.[8] However, the Panel also has no reason to suppose that any effects on sport fishing in the vicinity of the closures would be of any major consequence, given the many other areas open for fishing in the Province.

Amenity values

Some of the benefits of environmental improvement cannot be linked to easily measurable conditions. What is it "worth" to the citizens of Victoria to enjoy the beautiful vistas, wildlife, and pleasant ambiance of the city? How much of the growth in the CRD economy and population in recent years can be credited to its natural environment, and how much of its economy might be jeopardized by damage to that environment?

These are difficult questions, and the Panel cannot provide definitive answers. However, some relevant evidence can be brought to bear. One source estimates that some 33,500 jobs in the Victoria area involve tourism, and that tourism contributes in excess of a billion dollars to the local economy every year (City of

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[5] Department of Fisheries and Ocean, Shellfish Contamination–Pacific Region: Sanitary Closures, Area 19

[6] This may strike the reader as morally objectionable. Why should people be precluded from the free exercise of their "right" to the use of all areas? It is hard to support such a "right" as a general principle, however. Would one apply the same argument to airport runways? National defense installations? Private property in general?

[7] There seems to be some question as to "whether the shellfish resource could sustain a fishery" in the area now closed (CRD 2000). This Fact Sheet also suggests that shellfish are sustained by nutrients from the outfalls.

[8] BCStats, op. cit.

Victoria 2006a). It can be difficult to infer the contribution of an industry to the economy, or how an unpriced input (such as "the environment") contributes to an industry. Still, the obvious importance of tourism to Victoria leads the Panel to wonder what impact an actual or even perceived decline in environmental quality might have on the local economy. Boycotts have been attempted against the city in the past, and there could be more in the future.

One way in which economists infer the value of environmental amenities is through property prices. The price of property reflects the attributes of its location, and among those attributes is its environmental condition. If that condition is degraded, the value of the property is likely to fall.

Using some rough data, in 2003 the average house in the CRD sold for about $361,000, the average townhouse for $321,000, and the average condominium unit for $204,000 (City of Victoria 2006b). CRD estimates of the per-household costs of primary and secondary treatment are based on assessed property values of about $40 billion.[9] These figures beg several questions:

- How much of this housing stock value is at risk from sewage-related mishaps, including, perhaps, bad publicity?
- How do the values of other potential risks compare to the value of housing?
- Would an investment of several hundred million dollars—perhaps on the order of a percent or so of the value all property in the area—represent a reasonable "insurance premium" against sewage-related risks?

These questions are intended to frame the issue, not resolve it. No one can tell Victoria residents how much they *should* be willing to pay to avoid the risk of a sewage disaster. Some would choose to pay their share for peace of mind. On the other hand, a hundred or more dollars per household per year is not a trivial amount, especially to a family on a limited budget.

A final observation: different policy choices affect different households in different ways. One argument for paying more for sewage treatment is that doing so will insure property owners against risks that might otherwise decrease the value of their property. Homeowners might then find that improved sewage treatment would increase their property values, partly offsetting the burden of increased taxes. However, renters could be less pleased by such effects: they could pay higher rents for more valuable properties. In short, benefits and costs may not be distributed equitably. It would take a detailed analysis to determine all distributional impacts, but the CRD should factor these in when evaluating how to pay for treatment.

Ecological values

Some of the most important reasons for concern with the environment are also among the least quantifiable. While no ecological effects of Victoria's sewage have been identified beyond the vicinity of the outfalls (Golder 2005; also Section 4.2), there is still concern that pollutants released from the outfalls may affect marine life and ecosystems much farther away.

Ecological values are a concern both of local residents and of people who live far from the area where sewage is released. This may be particularly true of contaminants that get concentrated in the food chain (for example, PCBs, with potential effects far from their source. By the same token, the incremental effects of Victoria's release of such compounds will depend on the combined contamination from other sources. For this reason, elsewhere in this report, the Panel has encouraged the CRD to take a watershed or ecosystem context for management of liquid wastes.

While the ecological benefits of sewage treatment are important to the debate, in the Panel's view, those benefits are presently unknown and beyond understanding.

[9] This figure is derived by dividing the total annualized cost for different treatment options by the report's figure for the assessment per $100,000 of value (CRD 2005). Similar estimates have been derived by other means.

The Question of Cost Effectiveness

It is very difficult to know what value to assign to the environmental improvements that would result from treatment of Victoria's sewage. This is largely because such benefits are uncertain and poorly understood. It is easier to see that the treatment of the city's sewage would result in fewer pathogens, toxins, and other chemicals discharged into the marine environment than to know precisely what this might mean in terms of human well-being and ecological function.

If the goal is to reduce pathogens, toxins, and other chemicals, it is only prudent to ask whether the CRD could achieve the same result with a less costly option than sewage treatment, estimated at roughly half a billion dollars. Asked another way, will that half billion dollars achieve the desired result? The Panel has considered 3 issues:

1) Could source control provide similar benefits to sewage treatment, at less cost?
2) Similarly, could other policies such as storm sewer improvements or alternative environmental programs produce equivalent benefits less expensively?
3) If treatment is instituted, will the additional biosolids generated be disposed of more safely than at present?

Source control

The CRD has initiated source control programs to intercept and isolate certain contaminants before they enter the sewers. Examples include metals from dentists' offices and photo shops; lubricants and other materials from auto repair businesses; fat, oil, and grease from restaurants; and several other types of materials .The Panel is impressed by the coverage and effectiveness of the CRD's source control programs, and agrees with the wisdom of preventing some materials from entering into wastewater so they never need to be taken out of it. However, the effectiveness and adequacy of source control programs are limited by several factors:

- Many potentially dangerous contaminants come from human waste and other materials introduced into the sewer system by households. Controlling industrial or commercial sources will help, but household sources will continue to be a major concern.
- While compliance with the CRD's source control programs has generally been good (Smyth 2000–2004; Gartner Lee 2005), such programs are only effective with adequate monitoring and enforcement. Continued monitoring and enforcement will be required to assure continued good performance.
- The source control programs impose costs on the businesses that comply with them, as well as on the authorities that must oversee them. While existing costs are relatively modest, expanding the programs would impose additional costs. Some of these costs might be easily measured (for example, the enforcement budget), others not (for example, investment, operating, and opportunity costs of affected businesses).

As discussed in Section 4.1, the Panel concludes that

- the source control program is an important part of the CRD's overall liquid waste management plan, but
- source control has already achieved many of the benefits that can be expected of it, and
- source control is not an effective alternative to treatment.

Stormwater Management

Storm sewers in the CRD are a matter of particular concern for several reasons:

- Various contaminants (bacterial and chemicals) are entering the harbours and nearshore environments through the CRD's stormwater drainage system. The bacteria data suggest that direct contact by humans has the potential to adversely affect human health of exposed individuals. The chemical contaminant data in storm water drainage sediments indicate that the storm water has the potential to adversely affect ecological health in nearshore and harbour environments.

- Storm water discharges are periodic and enter marine waters in much closer proximity to nearshore environments and areas of human use than the two sewage outfalls. Therefore, stormwater effects are felt at different times, locations, and intensity than those of the sewer discharges (with the exception of overflows, which are also discussed in Section 4.1 as an issue of concern).
- Because the storm and sanitary sewers share pipes in some areas, and opportunities exist for cross-flows from one to the other, storm events can result in sewage escaping through storm sewer outfalls and/or storm water overwhelming the Macaulay and Clover Point pumping stations.

These are important concerns, and merit further study. In Section 4.1, the panel concludes that

- storm water management should be coordinated across jurisdictions and should be considered within the context of other stressors to the local marine environment and
- stormwater monitoring programs need re-evaluation and some specific modifications.

Based on their analysis, the Panel concludes better understanding and management of storm water, while desirable and recommended by the Panel, is not an adequate substitute for action on sewage treatment.

Alternatives for reducing effects far away from outfalls

Some of the more compelling arguments for treating the CRD's sewage concern potential effects on the distant environment. While there are no clearly demonstrated or substantial effects on human health or aquatic life beyond a short distance from the outfalls, this might become a greater problem. This is especially true with emerging concerns about chemicals which scientists are just beginning to understand (for example, endocrine-disrupting compounds [EDCs], pharmaceutical and personal care products [PPCPs]) and is clearly an issue for persistent organic pollutants (POPs).

Part of the reason for uncertainty regarding the effects of such compounds is that they come from many difficult-to-trace sources. Because traces of such compounds are everywhere, two questions arise:

- Does the CRD's release of compounds of emerging concern materially affect their concentration in distant waters and organisms?
- Would the CRD's decision to intercept more of such compounds in treatment influence other jurisdictions to do the same?

The latter question raises some subtle issues of politics and social psychology. Certainly part of the reason some CRD citizens favour sewage treatment in Victoria is the sense that this is a reasonable expectation of cities in advanced industrial nations. While some have argued with the wisdom of investments in treatment in Vancouver, Seattle, and other jurisdictions in British Columbia, Washington State, and elsewhere, the fact is that such cities have adopted more advanced treatment. It is possible that Victoria's decision to treat its sewage might reinforce similar expectations in cities elsewhere in the world. While some have dismissed the notion as mere "optics",[10] it is not unreasonable for residents of Victoria and the CRD to regard sewage treatment as evidence of their global citizenship and a benefit of treatment.

However, if citizens' chief concern is with contaminants with distant effects, and especially with their impacts on endangered species and ecosystems, it can be argued that other policies would provide a greater return per dollar of

[10] Robin Adair, Chair of the Victoria Chamber of Commerce, articulates the "optics" view: "It's the optics. If our visitors are not happy with a lot of raw sewage in our strait and a lot of people in Victoria are not happy about it then we have to do something about it" (Harnett 2006).

expenditure. To take the point to an extreme, if the public's wish is broadly to reduce the human impact on natural systems, expenditures to combat global warming or slow deforestation might be more cost-effective.[11]

Such extreme examples make a general point. The search for "better" environmental policy alternatives could range over extremely broad alternatives and, consequently, never reach a conclusion.

Disposal of biosolids

The goal of treatment is to remove potentially dangerous pollutants from the wastewater stream so they do not enter the marine environment. However, whatever is removed from the wastewater (as biosolids) must be disposed of elsewhere.

Additional levels of treatment would substantially increase the volume of solids for treatment and disposal. This raises some additional concerns:

- Such wastes must be handled carefully, so as to avoid accidental spillage or release before disposal or safe reuse.
- Permanent disposal facilities must be constructed to prevent the leaching or other release of the substances that treatment was intended to eliminate.
- A solution to the liquid waste management problem must be sustainable. Simply storing dangerous pollutants until "later" is not a solution.

In Section 4.7, the Panel concluded the following:

- The costs of managing, transporting, and disposing of biosolids from treatment are considerable, and must be factored into decisions among options.
- However, these costs are not prohibitive (as evidenced by other communities), nor are the environmental consequences of alternative disposal more troubling than the present uncontrolled dispersal of contaminants in the Straits of Juan de Fuca.
- Ecologically and economically feasible options exist for rendering biosolids safe and returning them to the environment.

Additional "Non-science" Factors in the "Treat or Not Treat" Decision

While a BCA can bring valuable and important information to decision making, it cannot quantify the benefits citizens perceive from alternative policy choices. Additionally, people may view benefits and costs quite differently.

After years of debate, many Victoria citizens have formed and expressed firm views on sewage treatment (see Section 2). While the Panel cannot identify the "right" choice for the CRD, it provides scientific expertise—one of several important factors to be considered. Additionally, the Panel can offer some perspective from the social and decision sciences on how that choice might be made.

Public values

Not surprisingly, there is a reasonably broad consensus that Winston Churchill was right in declaring that "democracy is the worst form of government except all the others that have been tried". Elections have a number of drawbacks. The principle of "one-person, one-vote" does not account for the intensity of preferences, and some people may assign their own small benefits a greater weight than others' large costs. Also, electoral participation is often relatively low. A person might vote only when she or he thinks her or his ballot will make a difference (this becomes unlikely when turnout is high). It would also be expensive and unwieldy to have literally *all* social decisions decided at the ballot box. Most jurisdictions discourage too-frequent referenda in order to keep special interests from proposing an unending string of measures for which only they would have the time and patience to vote.

[11] Chapman 2006 considers several alternative investments that might achieve social and/or environmental goals more cost-effectively than would spending hundreds of millions of dollars to treat Victoria's sewage.

Elections also have virtues, however. Perhaps most importantly, they give people a chance to choose for themselves the option they believe gives them the greatest benefits (net of its costs) to them. Moreover, in referenda, people must "put their money where their mouth is", and will vote only for something they are really willing to pay for. Majority rule is perceived as an equitable principle, and the results of elections are generally accepted as legitimate expressions of public preferences.

For all these reasons, the expression of public values is a crucial input to the decision about sewage treatment. We review below three pieces of information: the proposed division of the expense of treatment, the referendum of 1992, and a more recent survey on public preferences.

Support from various levels of government

Recent senior government policy announcements suggest that the CRD's sewage treatment decisions concern not only Victoria residents but also people in British Columbia and Canada more generally—despite the absence of compelling evidence of harmful health and environmental effects from current practices. The Prime Minister has recently reaffirmed his party's electoral promise that the Federal Government would provide financial support for treatment in the CRD (Shaw 2006). It is expected that Provincial Government will contribute as well (Shaw 2006).

At the local level, 6 out of the 8 recently elected Victoria Councillors (in addition to the Mayor), and 4 of the 8 elected Saanich Councillors are now on record as favouring secondary sewage treatment.

A number of jurisdictions around the world endorse the "polluter pays" principle: whoever produces pollution must bear the cost of either cleaning it up or compensating those injured by it. While a case might be made by others in Canada that Victoria should bear the cost of treatment, imposing this burden in the absence of stronger evidence of actual damage might constitute a "tyranny of the majority". By the same token, the Provincial and Federal Governments' apparent recent willingness to share in the costs of treatment seem to suggest that Canadians more generally regard the benefits of treatment in Victoria as warranting at least their share of the costs.

The Referendum of 1992

In 1992, the communities of Victoria, Esquimalt, Oak Bay, Colwood, Langford, Saanich, and View Royal were asked if they would be willing to pay for primary or secondary sewage treatment, or if they would prefer to continue the *status quo*.[12] The results of that referendum are summarized in Table 4.9-1.

A majority voted in favour of the *status quo* at the time. Electoral participation was low, however. Only about 24% of eligible voters voted.

While the referendum of 1992 did not pass, a couple of aspects of that effort are worth noting. First, the annual costs of the two treatment options were estimated at $231 and $336 per $100,000 of assessed value for primary and secondary treatment, respectively. The average assessed value of a residential property in 1992 was $165,304 (CH2M Hill 1991). Thus the average cost per household for primary and secondary treatment would have been 1.653 × $231 = $381 for primary treatment and 1.653 × $336 = $555 for secondary treatment. Second, these figures were based on a 50% capital cost share from the Provincial government.

The 1992 referendum, then, was based on rather high estimates of the costs of treatment. Of course, incomes have gone up and public sentiments may well have changed over the past 14 years. It seems reasonable to suppose that the referendum would command greater support if offered for a vote again today.

The Ipsos-Read Survey of 2004

A recent public opinion poll raised questions similar to those posed in the 1992 referendum

[12] The status quo option also included institution of 5 source control programs at modest levels of expenditure (Moore 1992).

Table 4.9-1 Results of the 1992 Referendum

Option	Cost: Capital (million $)	Cost: Annual (million $)	Cost: Annual cost per $100,000 assessed value ($)	Cost: Annual cost per house-hold ($)	Vote in favor	Percent in favor
Status quo	0	0.65	4	7	19,181	56.7
Primary treatment	379	37	231	381	7,186	21.2
Secondary treatment	518	54	336	555	7,481	22.1

Source: Moore 1992.
Note: Turnout 24%.

(Ipsos-Read 2004b). The results of this poll will be discussed in a moment. Before doing so, it is appropriate to raise caveats and qualifications. No survey can be regarded as a completely trustworthy instrument for gauging public sentiment:

- There is always some risk of selection bias. Surveyors attempt to assemble representative samples, but one can never know if those who declined to participate would have answered in the same way as those who were questioned.
- Surveyors may have their own agenda, and this agenda may be reflected in the form of the questions or, more subtly, in other cues.
- A survey, in contrast to an actual referendum, asks hypothetical questions. People may be more apt to state noble intentions, such as supporting environmental protection, when it costs them nothing to do so.

The Ipsos-Read Survey may, then, be an inadequate and flawed guide to the sentiments of the CRD electorate, but it is one of the few guides available. Moreover, it approximates in many ways the "stated preference" approach often employed by environmental economists to measure the public's willingness to pay for environmental improvement (see, for example, Mitchell and Carson 1989; Bateman and Willis 1999). While it is extremely controversial (see, for example, Hausman 1993) many such surveys have been conducted in environmental valuation.

It is, then, worth considering the Ipsos-Read Survey results in some greater detail. One question on the survey is of particular interest because it comes close to replicating the 1992 referendum. Respondents were asked if they preferred to

1) maintain the *status quo* at no incremental cost;
2) be assessed $70 per household per year on average for an enhanced source control program;
3) be assessed $230 per household for a new primary treatment plant; or
4) be assessed $490 per household for a new primary and secondary treatment plant. Answers to this question are summarized in Table 4.9-2.

The impression given in Table 4.9-2 is that a small majority favored either the *status quo* or the least costly option, enhanced source control. However, the Panel offers the following observations:

- While this survey is subject to the same criticisms as any would be, comparison of Tables 4.9-1 and 4.9-2 suggests that the *hypothetical* survey tracks the *actual* referendum results reasonably well.
- The survey is reasonably thorough in setting the context for respondents. In addition to asking respondents their views regarding important issues facing the region in general and environmental issues in particular, it describes for them the basics of liquid waste disposal in the CRD. Then it asks 8 questions designed to ac-

Table 4.9-2: Results of the 2004 Ipsos-Read Survey

Option	Additional annual cost per household ($)	Percentage of respondents in favor
Status quo	—	15.6
Enhanced source control	70	34.5
Primary treatment	230	23.0
Secondary treatment	490	23.9
Don't know/no opinion	—	3.0

Source: Ipsos-Read 2004a.
Note: Sample size = 1515.

quaint respondents with the details of the program. Each of the questions appears to be intended to strengthen the case that treatment is not necessary. While it might still be supposed that respondents would not take answers to a survey as seriously as they would votes in a referendum, it does not appear that the survey itself is biased toward treatment. All in all, then, the results of the survey as presented seem credible: a majority of respondents would not pay $230 or more per household per year for treatment.

- The dollar figures presented in the survey seem excessive, however. In 2005, the CRD again estimated costs of primary treatment. The estimate in 2005 was $237 million in capital costs and $5.8 million per year in operating costs. The corresponding costs for secondary treatment were $447 million and $16.7 million per year, respectively (cost estimates). These figures were converted to average annual costs per household of $277.24 and $573.02, for primary and secondary treatment respectively. Let us begin with these figures, which are somewhat higher than the estimated costs per household of $230 and $490, respectively, employed in the Ipsos-Read Survey. If the Provincial and Federal governments are willing to contribute to the expenses of sewage treatment, it would be appropriate to reduce the 2005 figures by the amounts contributed by senior governments.[13] The results of this amendment are shown in the middle column of numbers in Table 4.9-3. The per-household expense would be reduced to $126 and $288 per year for primary and secondary treatment, respectively.
- The Panel has some question about how cost estimates were presented to respondents. In the 2005, CRD cost estimates capital costs were amortized over 15 years at a 6% interest rate to derive an annual debt service payment of $226.76 per household for primary treatment and $427.68 per household for secondary treatment. When a loan is amortized, payments include both interest and principal repayment. In a 15-year loan at 6% interest, principal repayment is substantial even in early periods. In the survey, however, respondents are asked if they would accept an increase in taxes, *presumably in perpetuity*, rather than for only a limited time. A more appropriate comparison might be to calculate the yearly opportunity cost of capital as the interest rate, 6%, times the total capital investment, and reduce the capital portion of the per-household payments accordingly. Alternative figures derived under these assumptions are $91.73 and $223.14, for primary and secondary treatment, respectively.[14]

[13] This was done as follows. The figure of $277.24 is comprised of $226.76 per household per year in capital costs and $50.48 in operating cost. If we assume households in the CRD need only pay one-third of capital costs, while covering all operating costs, the average yearly assessment per CRD household per year would be $226.76/3 + 50.48 = $126.07. The figure of $573.02 for the average yearly household assessment for secondary treatment is comprised of $427.68 per household per year for capital costs and $145.34 per household per year for operating costs. If CRD residents were also only to pay a third of all capital costs for secondary treatment and all operating costs, the average assessment per CRD household per year would be $287.90.

Table 4.9-3: Cost estimates of alternative treatment technologies under alternative assumptions on capital financing

	Cost per household per year ($)		
Level of treatment	CRD cost estimate (Appendix A and other CRD sources)	Cost if senior governments underwrite 2/3 of capital expenditure	Cost if senior governments underwrite 2/3 of capital expenditure and opportunity cost of capital calculated
Primary	277	126	92
Secondary	573	288	223

- The Survey asks respondents if they would be willing to pay rather large amounts in increased taxes for various treatment options. Implicitly, the alternative is maintaining the *status quo* indefinitely. In fact, however, there is some unknown but probably not trivial likelihood that CRD will be forced to institute more advanced treatment, either because the trigger process is tripped or because of action from Senior Government. The cost savings of acting *sooner* could, then, be considerably greater than those represented in the survey.

Conclusions

To conclude this section on sewage treatment as a risk management decision, the Panel finds the following:

- While there is a tremendous volume of scientific data, the benefits of treatment cannot be described or calculated with any precision. This observation does not mean that the benefits of treatment would be insignificant.
- The costs of treatment are more certain, and they are significant.
- People can reach different conclusions based on their own interpretation of the available evidence; no outcome will please everyone.
- In such circumstances, great deference is due to the expressed will of the electorate.
- Senior governments demonstrate a willingness on the part of the Province and the Nation as a whole to support the expense of wastewater treatment in Victoria.
- Residents of the CRD indicated through a referendum 14 years ago that the benefits of treatment did not outweigh its considerable costs. Due to changed circumstances, decision-makers should assume that this may no longer be the case.

The Panel believes it is likely that, if a BCA could be conducted to state-of-the art standards, it would find that treatment is justified. This conclusion rests on the Panel's perception that the electorate would now support treatment, that is, that the benefits perceived by a majority would exceed the costs they perceive.[15] Put in very simple terms, if a referendum *almost* passed when the costs of treatment were represented as being very high, it likely *would* pass if costs were much lower. Costs to CRD residents should be reduced, reflecting the contributions of senior governments and, possibly, other factors that have changed over time.

This argument begs the question of whether a new referendum should be held. This is a possibility, but the Panel's sense is that the outcome is not in great doubt. Advocates of the *status quo* have argued eloquently and con-

[14] The Panel advises that this calculation be regarded with some caution, however. These calculations might differ depending on the treatment of depreciation and eventual replacement investment, which the Panel did not attempt to determine in the limited time it had available.

[15] There are two closely related issues: First, do aggregate benefits exceed aggregate costs? Second, would a majority vote in favor? The latter would imply the former if, as might be expected, the distribution of net benefits is skewed.

vincingly, that treatment is unnecessary and even wasteful. However, the fact remains that, after many years of discourse, many people would decide the issue on grounds other than an absence of currently demonstrated health and ecological effects. The Panel cannot refute sentiments based on willingness to bear risks, ethics, esthetics, or other factors that cannot be resolved on purely "scientific" grounds.

Under these circumstances, the CRD might consider steps to

- **confirm the contributions from senior governments,**
- **identify sites for enhancement of waste treatment and sludge management, and**
- **refine its estimates of the costs of different treatment options.**

The latter activity would be a proactive step toward identifying the treatment option that, if selected, would best meet the long-term needs of the community and the anticipated future regulatory environment. Benefit–cost prescriptions have been suggested for such choices: the best choice among options is that for which the last dollar spent on treatment costs is just balanced by an equal gain in benefits. Given the difficulty in estimating benefits, however, a potential approach might be to **install treatment comparable to that now employed in the similar cities surveyed in Section 4.8 of this report.**

References

Allaby M. 2004. Oxford dictionary of ecology. Oxford (UK): Oxford Univ Pr. 440 p. [Glossary]

[APHA] American Public Health Association. 2005. Standard methods for the examination of water and wastewater. 21st edition. Washington (DC): APHA. [Glossary]

[APHA, AWWA, WEF] American Public Health Association. 2005. Standard methods for the examination of water and wastewater. Washington (DC): APHA. [Section 4.1]

[ASL and EVS] Analytical Service Laboratories Ltd, Environment Consultants. 1994. Characterisation and possible environmental effects of oil and grease in wastewater discharged through the Clover and Macaulay Point outfalls. [Section 4.2]

Auriol M, Filali-Meknassi Y, Tyagi RD, Adams CD, Surampalli RY. 2006. Endocrine disrupting compounds removal from wastewater, a new challenge. Process Biochemistry 41:525–539. [Section 4.6]

Bateman IJ, Willis KG, editors. 1999. Valuing environmental preferences: theory and practice of the contingent valuation method in the U. S., E. U., and developing countries. Oxford: Oxford Univ Pr. [Section 4.9]

BC/Washington Marine Science Panel. 1994. The shared marine waters of BC and Washington. Report to BC/Washington Environmental Cooperation Council. [Section 4.2]

Beanlands GE, Duinker PN. 1983. An ecological framework for environmental impact assessment in Canada. Halifax (NS): Institute for Resource and Environmental Studies, Dalhousie Univ. 132 p. [Glossary]

Beauchemin PA, Rahman M. 2003. Review of the regulations related to trucked liquid wastes in the Capital Regional District (CRD). Victoria (BC): Capital Regional District. 43 p plus attachments. [Section 4.1]

Bennie D, Sullivan C, Lee H-B, Maguire R. 1998. Alkylphenol polyethoxylate metabolites in Canadian sewage treatment plant effluent streams. Water Quality Research Journal of Canada 33:231–252. [Section 4.6]

Bennie DT. 1999. Review of the environmental occurrence of alkylphenols and alkylphenol ethoxylates. Water Quality Research Journal of Canada 34:79–122.

Birkett JW, Lester JN, editors. 2003. Endocrine disrupters in wastewater and sludge treatment processes. Boca Raton (FL): Lewis/CRC Pr. 295 p. [Glossary]

Birkett JW, Lester JN. 2003. Endocrine disruptors in wastewater and sludge treatment processes. London: Lewis. 295 p. [Section 4.6]

Burd, van Roodeslaar, Bertold, 2005. Application of cautions, warnings and triggers to benthos for the GVRD marine WWTP outfalls. Proceedings of the 2005 Puget Sound Georgia Basin Research Conference. [Section 4.8]

Busch DE, Trexler JC. 2003. Monitoring ecosystems. Washington (DC): Island Pr.

Cairns Jr J, Mount DI. 1990. Aquatic toxicology. Environ Sci and Technol 24:154–161. [Glossary]

Calderon RL, Mood EW, Dufour AP. 1991. Health effects of swimmers in nonpoint sources of contaminated water. International Journal of Environmental Health Research 1:21–31. [Section 4.2]

Cameron RLN, Green D. 2004. Stormwater quality annual report Core Area-2004. Capital Regional District, Environmental Programs, Victoria (BC): Capital Regional District. June 2005. [Section 4.2]

Cameron RLN, Green D. 2005. Stormwater quality annual report, Core Area – 2004. Victoria (BC): Capital Regional District, Environmental Programs. 90 p plus attachments. [Section 4.1]

CH2M Hill. 1991. Memo to CRD, dated 4 June 1991. [Section 4.9]

Chapman P. 2006. Emerging issues – emerging problems. Environmental Toxicology and Chemistry 25(6):1445–1447. [Section 4.9]

City of San Diego. 2004. Annual receiving waters monitoring report for the Point Loma Ocean Outfall 2004. p 10. [Section 4.8]

City of Victoria. 2006a. Economic profile. Available at: http://www.victoria.ca/common/pdfs/profiles_city_ecnomic.pdf. Accessed 20 April 2006. [Section 4.9]

City of Victoria. 2006b. Housing profile. Available at: http://www.victoria.ca/common/pdfs/profiles_city_hsing.pdf. Accessed 20 April 2006. [Section 4.9]

Clark BD. 1983. EIA manuals: general objectives and the PADL manual. In: PADL, EIA and Planning Unit, editors. Environmental impact assessment. The Hague (NL): Martinus Nijhoff. p 149–164. [Glossary]

[CRD] Capital Regional District Core Area Liquid Waste Management Plan. 2000. Fact Sheet Number 7. March 2000. [Section 4.9]

[CRD] Capital Regional District Environmental Services Group. 2000. The Trigger Process: An early warning of adverse environmental effects for the Clover and Macaulay Point Outfalls, May 2000. [in the CRD (2000), as an appendix to the LWMP] [Glossary]

[CRD] Capital Regional District. 2000. Core Area Liquid Waste Management Plan, Stage 3. Victoria (BC): CRD. [Section 4.1]

[CRD] Capital Regional District. 2000. Core area liquid waste management plan. Victoria (BC): CRD Environmental Services Department. [Glossary]

[CRD] Capital Regional District. 2000. Core area liquid waste management plan. July 12, 2000. Victoria, (BC): CRD Environmental Services Department. [Section 4.2]

[CRD] Capital Regional District. 2002. Comments on the report “A Comparative Review of the CRD’s Environmental Monitoring Program for the Clover Point and Macaulay Point Wastewater Outfalls”. 2WE Associates Consulting Ltd. Capitol Regional District, Environmental Services Department. [Section 4.2]

[CRD] Capital Regional District. 2003. Macaulay and Clover Point Wastewater and Marine Environment Program. 2002 Annual Report. Marine Programs Environmental Programs, October 2003. Victoria, BC. [Section 4.2]

[CRD] Capital Regional District. 2004. Macaulay and Clover Point Wastewater and Marine Environment Program. 2003 Annual Report. Marine Programs Environmental Programs, October 2004. Victoria, BC. [Section 4.2]

[CRD] Capital Regional District. 2005. Core Area Liquid Waste Management Committee Environmental Services Department Information Report #EHQ – 05 86. 6 July 2005. [Section 4.9]

[CRD] Capital Regional District. 2005. Macaulay and Clover Point Wastewater and Marine Environment Program. 2004 Annual Report. Marine Programs Scientific Programs Division, October 2005. Victoria, BC. [Section 4.2]

[CRD] Capital Regional District. 2005. Seafloor triggers for Clover and Macaulay outfalls and the Early Indication Process. [Section 4.3]

[CRD] Capital Regional District. 2006. Macaulay and Clover Point surface fecal coliform monitoring data, program changes, and diffuser maintenance history. Prepared by the Capital Regional District, Environmental Services Department, Scientific Programs Division, Marine Programs. March 2006. [Section 4.2]

Cullon DL, Jefferies SJ, Ross PS. 2005. Persistent organic pollutants in the diet of Harbour seals (Phoca vitulina) inhabiting Puget Sound, Washington (USA), and the Strait of Georgia, British Columbia (Canada): a food basket approach. Enivronmental Toxicology and Chemistry 24(10):2562–2572. [Section 4.6]

Daughton CG, Ternes TA. 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? Environmental Health Perspectives [Section 4.6]

[DFO] Department of Fisheries and Oceans. 1997. Canada’s Oceans Act. Ottawa (ON): DFO. [Glossary]

Drinnan RW. 1997. Stormwater discharge rating system for the Capital Regional District. Victoria (BC); Capital Regional District, Environmental Services Group. 17 p. [Section 4.1]

Duffus JH. 2001. Risk assessment terminology. Chemistry International 23(2), March 2001. [Glossary]

Dussault ÈB, Sherry JP, Lee H-B, Burnison BK, Bennie DT, Servos MR. 2005. In Vivo estrogenicity of nonylphenol and its ethoxylates in the Canadian environment. Human and Ecological Risk Assessment 11(2):353–364. [Section 4.6]

Earth Tech (Canada) Inc. 2002. Inventory of trucked liquid waste generated in the core area of the Capital Regional District – Part 1. Victoria (BC): Capital Regional District, Environmental Services. 31 p plus attachments. [Section 4.1]

Earth Tech Inc. 2002. Review of management practices for catchbasin and oil-water separator wastes. Victoria (BC): Capital Regional District, Environmental Services. 31 p plus attachments. [Section 4.1]

Environmental Services. 2005. Core area inflow and infiltration program, I&I analysis results: 2001–2004 flow monitoring sites. Final report. Victoria (BC): Capital Regional District. 40 p. [Section 4.1]

EVS Consultants Ltd. 1992. Effluent toxicity testing programs. Prepared for the Capital Regional District. (Abstract only, in CRDMP 2005). [Section 4.2]

Exxon-Mobil. 2001. Discussion of recovery from oil spills. Exxon-Mobil Newsletter, 2001. [Glossary]

Fattal B, Peleg-Olevsky Agurshy T, Shuval HI. 1987. The association between sea-water pollution as measured by bacterial indicators and morbidity of bathers at Mediterranean beaches in Israel. Chemosphere 16:565–570. [Section 4.2]

Fattal B, Vasl RJ, Katzenelson E, Shuval HI. 1983. Survival of bacteria indicator organisms and enteric viruses in the Mediterranean coastal waters off Tel-Aviv. Water Research 17:397–402. [Section 4.2]

Fleisher JM, Kay D, Salmon RL, Jones F, Wyer MD, Godfree AF. 1996. Marine waters contaminated with domestic sewage: nonenteric illnesses associated with bather exposure in the United Kingdom. American Journal of Public Health 86:1228–1234. [Section 4.2]

Freeman III AM. 2003. the measurement of environmental and resource values: theory and methods. 2nd edition. Washington (DC): Resources for the Future. [Section 4.9]

Gartner Lee, Ltd. 2005. CRD Regional Source control program – five-year review (1999–2003). April 2005. [Section 4.9]

GESAMP. 1990. The state of the marine environment. London: Blackwell Scientific. 146 p. [Glossary]

GESAMP. 2001. A sea of troubles. GESAMP Reports and Studies No. 70. UNEP and IMO. 35 p. [Section 4.2]

Golder Associates and Archipelago Marine Research. 2002. Qualitative risk assessment of marine-based public activities in the vicinity of the Macaulay Point and Clover Point marine outfalls. Report to Capital Regional District. [Section 4.9]

Golder Associates Ltd. 2002. Report on qualitative risk assessment of marine-based public activities in the vicinity of Macaulay Point and Clover Point wastewater outfalls, CRD, BC. Submitted to Capital Regional District, Environmental Programs, Victoria, BC. [Section 4.2]

Golder. 2004. Benthic macroinvertebrate analysis for Macaulay Point outfall. (Report 69). [Section 4.2]

Golder Associates Ltd. 2005. Potential environmental effects from the Macaulay and Clover Point outfalls and review of the wastewater and marine environment program (Draft). [Sections 4.2, 4.9]

Golder Associates Ltd. 2006. Macaulay and Clover Point additional investigations-high resolution chemical analyses (Draft). [Section 4.2]

Goyette DM, Thomas M, Kay B. 1979. Marine environmental assessment of the Macaulay Point sewage outfall, Victoria, BC. [Section 4.2]

Griffin DW, Donaldson KA, Paqul JH, Rose JB. 2003. Pathogenic human viruses in coastal waters. Clinical Microbiological Reviews 16:129–143. [Section 4.2]

Halifax Regional Municipality, Water Quality Sampling Program. Available at: http://www.halifax.ca/harboursol/waterqualitydata.html. [Section 4.8]

Harnett CE. 2006. PM to help fund sewage plant. Victoria Times-Colonist. 27 May 2006. [Section 4.9]

Harrison PJ, Mackas DL, Frost BW, MacDonald RW, Crecelius EA. 1994. An assessment of nutrients, plankton and some pollutants in the water column of Juan de Fuca Strait, Strait of Georgia and Puget Sound and their transboundary transport. In: Wilson RC et al., editors. Review of the marine environment and Biota of the Strait of Georgia, Puget Sound and Juan de Fuca Strait. Can Tech Rept Fish Aquat Sci No. 1948. [Section 4.2]

Haskell BD, Norton BG, Costanza R. 1992. Introduction. What is ecosystem health and why should we worry about it? In: Costanza R, et al. Ecosystem Health. New Goals for Environmental Management. Washington (DC): Island Pr. p 3–20. [Glossary]

Hausman J, editor. 1993. Contingent valuation: a critical assessment. Amsterdam (NL): Elsevier. [Section 4.9]

Health and Welfare of Canada. 1992. Guidelines for Canadian Recreational Water Quality. Ottawa (ON): Federal-Provincial Working Group on Recreational Water Quality of the Federal-Provincial Advisory Committee on Environmental and Occupational Health. Canadian Government Publishing Centre. [Section 4.2]

Hodgins DO. 2006. Assessment of plume trapping and dilution at the Clover Point outfall and Macaulay Point outfall. Techical Memorandum. Prepared for Capital Regional District, Victoria, BC. [Section 4.2]

Hodgins DO. 2006. Technical Memorandum, submitted to the SETAC CRD Panel. March 2006. [Section 4.2]

Hodgins DO, Hodgins SLM. 2000. East Coast interceptor sewer overflow analysis. Victoria (BC): Capital Regional District, 32 p plus attachments. [Section 4.1]

Hodgson E, Mailman RB, Chambers JE, editors. 1998. Dictionary of toxicology. 2nd edition. New York (NY): Groves Dictionaries. 504 p. [Glossary]

Ipsos-Read. 2004a. Capital Region District Liquid Waste Management Plan survey, 8 March 2004. [Section 4.9]

Ipsos-Read. 2004b. CRD liquid waste management: survey of opinions and attitudes. Draft Report, 28 March (slides to accompany presentation). [Section 4.9]

Ishiguru E. 2005. Presentation to workshop on Victoria sewage: separating myth from fact. 26 September 2005. Transcript available at: http://www.bucksuzuki.org/publications/Transcript%20Sewage%20Forum%20Final.pdf. Accessed 14 June 2006. [Section 4.9]

Jiang S, Noble R, Chu W. 2001. Human adenoviruses and coliphages in urban runoff-impacted coastal waters of Southern California. Applied Environmental Microbiology 67:179–184. [Section 4.2]

Jones OAH, Voulvoulis N, Lester JN. 2005. Human pharmaceuticals in wastewater treatment processes. Critical Reviews in Environmental Science and Technology 35:401–427. [Section 4.6]

King County Department of Natural Resources and Parks, Wastewater Management Division, King County Combined Sewer Overflow Program. weblink: http://dnr.metrokc.gov/wlr/waterres/marine/monitor.htm. [Section 4.8]

Kirchner TB. 1998. Time, space, variability, and uncertainty. Chapter 13. In: Newman MC, Strojan CL, editors. Risk assessment. Logic and measurement. Chelsea (MI): Ann Arbor Pr. p 303–323. [Glossary]

Kolpin D, Furlong E, Meyer M, Thurman E, Zaugg S, Barber L, Buxton H. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance. Environmental Science and Technology 36:1201–1211. [Section 4.6]

Krümmmerer K. 2004. Pharmaceuticals in the environment: sources fate and risks. 2nd edition. Berlin: Springer. 527 p. [Section 4.6]

Lee H, Peart TE, Sarafin K. 2004. Occurrence of polycyclic and nitro musk compounds in Canadian sludge and wastewater samples. Water Quality Research Journal of Canada 38(4):683–702. [Section 4.6]

Lee H-B, Peart T. 2000. Determination of bisphenol A in sewage and sludge by solid-phase and supercritical fluid extraction and gas chromatography/mass spectrometry. Journal of AOAC International 83:290–297. [Section 4.6]

Lee H-B, Peart TE, Svoboda ML. 2005. Determination of endocrine-disrupting phenols, acidic pharmaceuticals, and personal-care products in sewage by solid-phase extraction and gas chromatography-mass spectrometry. Journal of Chromatography A 1094:122–129. [Section 4.6]

Lewis RA. 1998. Lewis' dictionary of toxicology. Boca Raton (FL): Lewis. 1127 p. [Glossary]

Lishman L, Smyth SA, Sarafin K, Kleywegt S, Toito J, Peart T, Lee B, Servos M, Beland M, Seto P. 2006. Occurrence and reductions of pharmaceuticals and personal care products and estrogens by municipal wastewater treatment plants in Ontario, Canada. Science of the Total Environment, forthcoming. [Section 4.6]

Lister A, Van Der Kraak G. 2001. Endocrine disruption: why is it so complicated? Water Quality Research Journal of Canada 36:175–190. [Section 4.6]

Lorax Environmental. 2006. The Lorax Environmental CRD C3 Hydrodynamic Simulation for IDZ. Submission to Panel of January 12, 2006, on behalf of CRD. [Section 4.2]

Mackas DL, Harrison PJ. 1997. Nitrogenous nutrient sources and sinks in the Juan de Fuca Strait/Strait of Georgia/Puget Sound estuarine system: assessing the potential for eutrophication. Estuarine, Coastal and Shelf Science 44:1–21. [Section 4.2]

Makepease DK, Smith DW, Stanley SJ. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Control 25(2):93–139. [Section 4.1]

McKinney RE. 1962. Microbiology for sanitary engineers. New York (NY): McGraw-Hill. 293 p. [Glossary]

Metcalfe C, Metcalfe T, Kiparissis Y, Koenig B, Khan C, Hughes R, Croley T, March R, Potter T. 2001. Estrogenic potency of chemical detected in sewage treatment plant effluents as determined by in vivo assays with Japanese Medaka (Oryzias latipes). Environmental Toxicology and Chemistry 20:297-308. [Section 4.6]

Metcalfe C, Miao X-S, Hua W, Letche R, Servos M. 2004. Pharmaceuticals in the Canadian Environment. In: Krummer K, editor. Pharmaceuticals in the environment: sources, fate, effects and risks. Springer. p 528. [Section 4.6]

Metcalfe CD, Koenig BG, Bennie DT, Servos M, Ternes TA, Hirsch R. 2003. Occurrence of neutral and acidic drugs in the effluents of Canadian sewage treatment plants. Environmental Toxicology and Chemistry 22:2872–2880. [Section 4.6]

Mills LJ, Chichester C. 2005. Review of evidence: Are endocrine-disrupting chemicals in the aquatic environment impacting fish populations? Science of the Total Environment 343:1–34. [Section 4.6]

Mitchell RC, Carson RT. 1989. Using surveys to value the environment: the contingent valuation method. Washington (DC): Resources for the Future. [Section 4.9]

MOE. Undated. Guidelines for developing a liquid waste management plan. Environmental Management Branch. Available at: http://www.env.gov.bc.ca/epd/epdpa/mpp/gfdalowmp.html@A11. [Section 4.1]

Moore TF. 1992. Proclamation of poll results. 23 November 1992. [Section 4.9]

Munn RE, editor. 1985. Environmental impact assessment: principles and procedures. SCOPE Report 5. Toronto (ON): UNEP, Environment Canada, and UNESCO. [Glossary]

[NAS] National Academy of Science. 1999. Hormonally active agents in the environment. Sciences NAo, editor. Washington (DC): National Academy Pr. 430 p. [Section 4.6]

Newman MC, Unger MA, editors. 2003. Fundamentals of ecotoxicology. 2nd edition. Boca Raton (FL): Lewis/CRC Pr. 458 p. [Glossary]

Newman MC. 1998. Fundamentals of ecotoxicology. Chelsea (MI): Ann Arbor Pr. 402 p. [Glossary]

Nielsen NO. 1999. The meaning of health. Ecosystem Health 5(2):65–66. [Glossary]

Noble RT, Fuhrman JA. 2001. Enteroviruses detected by reverse transcriptase polymerase chain reaction from coastal waters of Santa Monica Bay, California:

low correlation to bacterial indicator levels. Hydrobiologia 460:175–184. [Section 4.2]

Novotny V. 2003. Water quality, diffuse pollution and watershed management. New York (NY): J Wiley. 864 p. [Section 4.1]

Odum EP. 1959. Fundamentals of ecology. Philadelphia (PA): W.B. Saunders. 546 p. [Glossary]

Oxford. 2005. Oxford dictionary of English. 2nd edition revised. Oxford (UK): Oxford Univ Pr. 2088 p. [Glossary]

Paine, Ledge and Associates. 2004. Trend analysis of selected substances in the Clover and McCaulay Point effluents: 1996–2003. Victoria (BC): Capital Regional District. 8 p plus attachments. [Section 4.1]

Paine MD. 2004. Trend analysis of Macauley Point invertebrate community data: 1994-2002. Report prepared for the Capital Regional District, Victoria BC by Paine, Ledge and Associates, North Vancouver, BC. July 2004. [Section 4.2]

Pauly D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10:430. [Glossary]

Pearson TH, Rosenberg R. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr Mar Biol Ann Rev 16:229–311. [Section 4.3]

Peck S. 2006. The public health perspective on the current two deep-sea outfalls and potential need for increased treatment. Letter to the Chair, CRD Scientific and technical Review Panel. [Glossary]

Pesch GG, Wells PG, editors. 2004. Tides of change across the gulf. An environmental report on the Gulf of Maine and Bay of Fundy. Augusta (ME) and Concord (NH): Gulf of Maine Council on the Marine Environment. 81 p. [Section 4.2, Glossary]

Rayne S, Ikonomou MG. 2005. Polybrominated diphenyl ethers in an advanced wastewater treatment plant. Part 1: Concentrations, patterns, and influence of treatment processes. Journal of Environmental Engineering and Science 4(5):353–367. [Section 4.6]

Rayne S, Ikonomou MG, Ross PS, Ellis GM, Barrett-Lennard LG. 2004. PBDEs, PBBs, and PCNs in three communities of free-ranging killer whales (*Orcinus orca*) from the northeastern Pacific Ocean. Environmental Science and Technology 38(16):4293–4299. [Section 4.6]

Rees G. 1993. Health implications of sewage in coastal waters – the British case. Mar Pollut Bull 26(1):14–19. [Section 4.2]

Reid Crowther & Partners Ltd. 1998. Storm sewer contaminant sampling, source tracing & reduction study in Victoria & Esquimalt Harbour. Victoria (BC): Victoria & Esquimalt Harbour Environmental Action Program. 13 p plus attachments. [Section 4.1]

Reid GK. 1961. Ecology of inland waters and estuaries. New York (NY): Van Nostrand. 375 p. [Glossary]

Ross PS, Ellis GM, Ikonomou MG, Barrett-Lennard LG, Addison RF. 2000. High PCB concentrations in free-ranging Pacific Killer Whales, Orcinus orca: Effects of age, sex and dietary preference. Mar Pollut Bull 40(6):504-515. [Section 4.2]

Schaeffer DJ, Herricks EE, Kerster HW. 1988. Ecosystem health. 1. Measuring ecosystem health. Environmental Management 12:445–455. [Glossary]

Servos M, Delorome P, Fox G, Sutcliffe R, Wade M. 2001. A Canadian perspective on endocrine disrupting substances in the environment. Water Quality Research Journal of Canada 36:331–346. [Section 4.6]

Servos MR, Bennie DT, Burnison BK, Jurkovic A, McInnis A, Neheli T, Schnell A, Seto P, Smyth SA, Ternes TA. 2005. Removal of hormones, 17β-estradiol and estrone, in Canadian municipal wastewater treatment plants. The Science of the Total Environment 336:155–170. [Section 4.6]

Servos MR, Innes E, Given J, Ostapyk K, Topp E, McInnis R, Starodub ME. 2002. Assessment and management of pharmaceuticals and personal care products in the Canadian environment. Proceedings of a Multi-Stakeholder Workshop; 2002 Feb. 24–27. Volume Environment Canada and Health Canada Special Publication (NWRI 02-334) 2002. [Section 4.6]

Servos MR, Servos MC. 2006. Emerging chemicals derived from municipal wastewater: report prepared in support of the Victoria Liquid Waste Management Expert Panel Review. [Section 4.6]

Shaw R. 2006. Ottawa ready with sewage plant funds. Victoria Times-Colonist. 25 May 2006. [Section 4.9]

Smyth T. 2000–2004. Capital Regional District regional source control program: annual reports. [Section 4.9]

Smyth T. 2005. Regional source control program. Victoria (BC): Capital Regional District. 30 p. [Section 4.1]

Stanwick et al. 2006 [Section 4.9]

Stanwick R, Fife M, Peck S. 2006. Enhanced treatment of marine outfalls: consequences, opportunity costs, and public health. Document submitted to SETAC Review Panel 7 April 2006. [Section 4.9]

Suter III GW. 1993. Ecological risk assessment. Chelsea (MI): Lewis. [Glossary]

Sydney Water. 2004. ESD indicators and environment plan report. Sydney Water Annual Report 2004. [Section 4.8]

Tarazona JV, Buzby ME, Hartmann A, Housenger JE, Olejniczak K, Sager N, Servos MR, Tolson ND. 2005. Scientific basis for aquatic environmental impact assessment of human pharmaceuticals. In: Williams R, editor. Science for assessing the impacts of human pharmaceuticals on aquatic ecosystems. Pensacola (FL): SETAC Pr. p 269–302. [Section 4.6]

Taylor L. 2005. Letter to Lisa Walls, 25 October 2005. [Section 4.9]

Ternes T, Kreckel P, Mueller J. 1999. Behaviour and occurrence of estrogens in municipal sewage treatment plants—II. Aerobic batch experiments with activated sludge. Science of the Total Environment 225:91–99. [Section 4.6]

Ternes T, Stumpf M, Kreckel P, Mueller J, Wilken R, Servos M. 1999. Behavior and occurrence of estrogens in municipal sewage treatment plants – I. investigations in Germany, Canada and Brazil. Science of the Total Environment 225:81–90. [Section 4.6]

UMA Engineering Ltd. 2002. Overflow screening investigation of seven sewer overflow locations. Victoria (BC): Capital Regional District, Environmental Services Department. 15 p plus attachments. [Section 4.1]

[USEPA] United States Environmental Protection Agency. 1986. Ambient water quality criteria for bacteria. EPA-440/5-84/002. [Section 4.2]

[USEPA] United States Environmental Protection Agency. 1998. Condition of the Mid-Atlantic estuaries. EPA 600-R-98-147. Nov. 1998. [Glossary]

[USEPA] United States Environmental Protection Agency. 2000. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2, Risk assessment and fish consumption limits. 3rd edition. Washington (DC): USEPA Office of Water. EPA/823/B-00/008. Human health risks from chemically contaminated fish and shellfish. [Section 4.2]

[VEHEAP] Victoria and Equimalt Harbours Environmental Action Program. December1999. Victoria and Esquimalt Harbours environmental management strategy. [Section 4.1]

Warman B, Kalynchuk D, Daniels K. 2006. Implementation of a management program for on-site systems. Report to Environment Committee meeting of Wednesday, 22 February 2006. Victoria (BC): Capital Regional District. Report # EES 06-09. 5 p. [Section 4.1]

Webster's third international dictionary. 1996. Springfield (MA): Merriam. [Glossary]

Wells PG, Rolston SJ, editors. 1991. Health of our oceans. A status report on Canadian marine environmental quality. Conservation and Protection, Environment Canada, Ottawa and Dartmouth. March 1991. 166 p. [Glossary]

Wells PG, Taylor MC, Davis AR. 1986. Summary – Workshop on Needs for Canadian Estuarine and Coastal Water Quality Guidelines. In: Proceedings of the 12th Annual Aquatic Toxicity Workshop; 1985 Nov 5–8; Thunder Bay, Ontario. Can Tech Rept Fish Aquat Sci No. 1462. July 1986. p 121–122. [Glossary]

Wells PG. 1991. Introduction, Chapter 1. In: Wells PG, Rolston SJ, editors. Health of our oceans. A status report on Canadian marine environmental quality. Conservation and Protection, Environment Canada, Ottawa and Dartmouth. March 1991. [Glossary]

Wells PG. 2003. Assessing health of the Bay of Fundy – concepts and framework. Mar Pollut Bull 46:1059–1077. [Glossary]

Wells PG. 2005. Assessing marine ecosystem health – concepts and indicators, with reference to the Bay of Fundy and Gulf of Maine, Northwest Atlantic. Chapter 17. In: Jorgensen, et al. Handbook of ecological indicators. Boca Raton (FL): Taylor & Francis/CRC Pr. p 395–430. [Glossary]

White ML, Maurice C. CrEAM: A method to predict ecological significance at the landscape level. Available at: www.epa.gov/Region5/osea/science/CrEAM_text.pdf. [Glossary]

[WHO] World Health Organization. 2002. Global assessment of the state-of-the-science of endocrine disruptors. Damstra T, Barlow S, Bergman A, Kevlock R, Van Der Kraak G, editors. International Programme on Chemical Safety; WHO/PCS/EDC/02.2. [Section 4.6]

Wu David. 2003. NPDES Compliance Summary Report for fiscal year 2003. Massachusetts Water Resource Authority. Technical Report 2003-11. p 34. [Section 4.8]

Glossary

Abattoir – slaughterhouse (Oxford 2005)

Absorption – the taking of molecules of one substance directly into another substance (www.answers.com)

Acceptable or acceptability – in context of changes or effects, able to be agreed upon, or suitable (Oxford 2005)

Acute toxicity – a brief exposure to a stressor or the effects associated with such an exposure; it can refer to an instantaneous exposure (oral gavage, injection, dermal application, etc.) or continuous exposures of minutes to a few days (Suter 1993)

Adsorption – adhesion of the molecules of liquids, gases, and dissolved substances to the surfaces of solids (www.answers.com)

Adverse (effects) – harmful to organisms, or to their populations and communities

Adverse effect levels – numeric chemical or biological levels that represent a high probability of actual adverse effects in the receptor (CRD 2000)

Aerobic – a descriptive term for the presence of oxygen, or an organism that can only survive in the presence of oxygen

Amphipod – small crustaceans which have a laterally compressed body with no carapace and belong to Order Amphipoda; scud, or sideswimmer, is an example of an amphipod (www.kentuckyawake.org/templates/glossary/)

Anaerobic – A descriptive term for a process, such as fermentation, which can proceed only in the absence of oxygen, or a living thing that can survive only in the absence of oxygen (www.answers.com)

Anthropogenic – processes are those that are derived from human activities, as opposed to effects or processes that occur in the natural environment without human influences (www.answers.com)

Assimilative capacity – the ability of a natural body of water to receive wastewaters or toxic materials without harmful effects and without damage to aquatic life (www.green-networld.com/facts/glossary.htm); the ability of a natural system to accept and process anthropogenic inputs or perturbations, without deleterious effect (OEF Forum www.oilandgasforum.net/oefonline/glossary.htm)

Benthic – bottom dwelling (in a water body)

Benthic invertebrates – benthos; invertebrate animals living on and in the bottom substrates and sediments of water bodies

Best management practices (BMP) – management practices (such as nutrient management, spill mitigation) or structural practices (such as terraces) designed to reduce the quantities of contaminants, such as sediment, nutrients, metals or organic compounds that enter the environment. BMPs are physical, structural, and managerial practices that, when used singly or in combination, decrease the potential for human activities to pollute the environment.

Bioaccumulation – the accumulation of a substance in a living organism as a result of its intake both in the food and also from the environment; determination of the Bioaccumulation Factor can be an important part of the risk analysis of a compound (www.eurochlor.org/tools/glossary/glossary.htm)

Bioassay – biological assay; determination of the strength, toxicity or biological activity of a substance by comparing its effects with those of a standard preparation on a test organism (www.answers.com)

Bioavailability – the fraction of a dose of a compound that reaches the systemic circulation; when a compound is administered intravenously, its bioavailability is 100%; however, when a compound is administered via other routes (such as ingestion or through the gills), its bioavailability may decreases (due to incomplete absorption and first-pass metabolism); (www.answers.com)

Biochemical (biological) oxygen demand (BOD) – the amount of oxygen required by aerobic microorganisms during the metabolism of the organic matter in water, for example, municipal wastewater; the test is conducted over a specified time period, such as 5 days, at a specific temperature, such as 20 °C (APHA 2005)

Biodegradation – the process of converting organic materials back into carbon dioxide and water through microbial action (www.answers.com)

Biodiversity – biological diversity (Lewis 1998); the variety and variability among living organisms and the ecosystems in which they occur (www.epa.gov)

Biofouling – the impairment or degradation of something, such as mechanical equipment, as a result of the growth or activity of living organisms (www.answers.com)

Biologics – biological contaminants; microorganisms, viruses and active molecules

Biomagnification – the tendency of some chemicals to accumulate to higher concentrations at higher levels in the food web through dietary accumulation (Suter 1993)

Biosolids – a mixture of active microorganisms, dead cell material, organic matter and inorganic matter, which has undergone one or more treatment steps; the major methods of separation from wastewater involve specific gravity differences (flotation and settling) and various filtration methods; note that biosolids are different from sewage sludge

Biota – the flora (plants) and fauna (animals) of a region (www.answers.com)

Bioturbation – the stirring or mixing of sediment or soil by organisms, especially by burrowing or boring (www.answers.com)

Bivalves – a mollusk, such as an oyster or a clam, which has a shell consisting of two hinged valves (www.answers.com)

Bray-Curtis dissimilarity index – a mathematical interpretation of the biological assemblage of species between two or more sampling stations

Cetacean – any of various aquatic, chiefly marine mammals of the order Cetacea, including the whales, dolphins, and porpoises, characterized by a nearly hairless body, anterior limbs modified into broad flippers, vestigial posterior limbs, and a flat notched tail (www.answers.com)

Change/deleterious change – the action of making something different in form, quality, or state; the fact of becoming different (Webster 1996); in the context of marine ecosystems, change is harmful or deleterious if reproduction, growth and/or recruitment of individual organisms are impaired; if populations of organisms are reduced in type, number or distribution; if community structure and function are reduced or impaired; and if habitat quality declines, all of these changes being of long duration or permanent

Chronic toxicity – an extended exposure to a stressor (conventionally taken to include at least a tenth of the life span of a species) or the effects resulting from such an exposure (Suter 1993)

Coagulation – the change from a liquid to a thickened, insoluble state, not by evaporation, but by some kind of chemical reaction (www.answers.com)

Coliform bacteria – Widely distributed micro-organisms found in the intestinal tract of humans and other animals and in soils; a group of bacteria of the family Enterobacteriaceae; the genera Escherichia and Aerobacter may grow in a number of suitable environments; Escherichia coli are know to reproduce well in the guts of mammals, and particularly well in humans, with a discharge rate of about 2 x 109 per person per day; they are widely used as indicator organisms to show the potential presence of such wastes in water and the possible presence of pathogenic (disease-producing) bacteria (McKinney 1962)

Coliforms (total) – coliform bacteria are used often as an indicator of sanitary quality of foods and water; coliform bacteria are defined as rod-shaped Gram-negative organisms which ferment lactose with the production of gas when incubated at 35 °C

Colloidal – a mixture in which one substance is divided into minute particles (called colloidal particles) and dispersed throughout a second substance (www.answers.com)

Community – as in benthic community; a biotic community is any assemblage of populations living in a prescribed area or physical habitat; it has characteristics additional to its individual and population components, and is the living part of the ecosystem (Odum 1959)

Compliance zone – as defined for the CRD seafloor trigger process; the compliance zone is between 100-130 m from the diffuser section of the outfalls

Congeners – closely related chemicals with the same structure-activity relationship (Suter 1993)

Conjugation – the addition of glucuronic or sulfuric acid to certain toxic substances to terminate their biological activity and prepare them for excretion (www.answers.com)

Contamination/contaminants – any substances or agents in the natural environment that are present at concentrations above natural background levels; includes chemicals and microbial pathogens

Cross connection – the actual or potential interconnection between raw sewage and another water supply or source

Crustacean – any of various predominantly aquatic arthropods of the class Crustacea, including lobsters, crabs, shrimps, and barnacles, characteristically having a segmented body, a chitinous exoskeleton, and paired, jointed limbs (www.answers.com)

Cumulative effects/change – cumulative action; any result of repeated equivalent exposures to a biologically active agent or stimulus in which the effect of any subsequent exposure is more pronounced than that of the initial exposure (Lewis 1998)

Degradation – progressive decomposition of a chemical compound into less complex, well defined intermediary compounds (www.answers.com)

Deleterious – causing harm or damage (Oxford 2005)

Deleterious substance – under the Canadian Fisheries Act (Section 36(3)), a deleterious substance is (a) any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, or (b) any water that contains a substance in such quantity or concentration that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water

Demersal – dwelling at or near the bottom of a body of water (www.answers.com)

de minimus – without significant human health concern

Dilution capacity – the ability of a body of water to dilute materials; the larger the body of water, the larger the dilution capacity

Early indication process – numeric levels and interpretation guidelines used by CRD internally to evaluate monitoring data and the potential for the Seafloor Trigger to be exceeded in the future; the early indication process includes numeric chemical and biological levels, spatial analyses, evaluation of temporal trends, and evaluation of source control measures (CRD Environmental Services Group 2000)

Echinoderms – any of numerous radially symmetrical marine invertebrates of the phylum Echinodermata, which includes the starfishes, sea urchins, and sea cucumbers, having an internal calcareous skeleton and often covered with spines (www.answers.com)

Economics – the branch of knowledge concerned with the production, consumption, and transfer of wealth (Oxford 2005)

Ecosystem – a natural unit formed by the interaction of a community of plants and animals with their environment (physical and biological) (EPA 1998)

Ecosystem health – defined in terms of four characteristics applicable to any complex system – sustainability, activity, organization and resilience; an ecological system is healthy and free of distress syndrome if it is stable and sustainable, that is, if it is active and maintains its organization and autonomy over time, and is resilient to stress (Wells 2003, based on Schaeffer et al 1988 and Haskell et al 1992)

Ecotoxicity – the measure of causing harm, lethal or sub-lethal, to components (individuals, populations, communities) of natural ecosystems

Ecotoxicology – the branch of science that deals with the nature, effects, and interactions of substances that are harmful to the environment (Oxford 2005); the study of the fate and effects of toxic agents in ecosystems (Cairns and Mount 1990); there are a number of variations of the definition, see Newman (1998)

Effluent – any fluid discharged from a given source into the external environment; commonly refers to wastes discharged into surface waters or to wastewater (treated or untreated) that flows from a treatment plant, sewer or industrial outfall into a lake or waterway (Lewis 1998)

Emerging chemicals or contaminants – a term used by regulatory agencies to describe new or newly recognized synthetic chemical substances that are produced and used in volume, have become widely distributed in the environment, and may pose risks to human or ecosystem health; they include non-traditionally treated chemicals, and newly produced persistent organic chemicals

Empirical data – data that has been derived from observation or experiment

Endocrine disrupting compounds (EDC) – are exogenous substances that cause adverse biological effects by interfering with the endocrine system and disrupting the physiologic function of hormones (www.answers.com)

Enterococci – a usually non-pathogenic streptococcus bacteria that inhabits the intestine (www.answers.com)

Environmental effects – measures of effects, lethal or sub-lethal, on components of natural ecosystems

Environmental fate/transport – the destiny of a chemical or biological pollutant after release into the environment (www.entrix.com/resources/glossary.aspx)

Environmental quality – environmental quality is the condition of a particular environment measured in relation to its original unimpaired or "baseline" conditions, and in relation to each of its intended uses and functions; it can be described subjectively, especially if stresses impinging on the system are large and if the ecosystem or habitat is obviously degraded; however, it is usually assessed quantitatively for each environmental compartment, on temporal and spatial scales; measured using sensitive indicators of condition and change; often these measures are interpreted using objectives and limits set by environmental, health and resource agencies (adapted from Wells 1991, 2003, 2005).

Epibenthic – occurring on, but not penetrating, the substrate and submerged objects (gmbis.marinebiodiversity.ca/BayOfFundy/glossE-H.html)

Epidemiology – the branch of medicine that deals with the study of the causes, distribution, and control of disease in populations (www.answers.com)

Estrogenic (estrogenicity) – a biological response mediated through the estrogen receptor; for example, when male fish develop female characteristics such as egg development in male sex organs

Eutrophication – accelerated production of organic matter, particularly algae, in a water body causing increased oxygen demand, decreased dissolved oxygen in the water and hypoxia (lack of oxygen) in fish tissue as the organic matter decays (Pesch and Wells 2004)

Estuary – partially enclosed coastal body of water, having an open connection with the ocean, where freshwater from inland is mixed with saltwater from the sea (www.answers.com)

Fecal coliform – subgroup of total coliforms; of or relating to the bacilli that commonly inhabit the intestines of humans and other vertebrates, especially the colon bacillus

First flush – refers to the first waters released from a discharge point as a result of a storm event or runoff associated with rain and/or ice and snow melt; typically, constituent concentrations are highest in this first flush sample; first flush is operationally defined by a time-period in some jurisdictions (e.g., waters discharged within the first 15 or first 30 minutes of a discharge event); however, the "first flush" may not always contain the highest concentrations of contaminants as this depends on the rain intensity, type of contaminant, and size of the watershed; it is important to understand the watershed in order to determine if sampling of first flush in a storm event is critical; another consideration is to capture the first seasonal flush (e.g., after an extended dry period) (http://www.setac.org/wetswfaqs.pdf)

Food chain – a succession of organisms in an ecological community that constitutes a continuation of food energy from one organism to another as each consumes a lower member and in turn is preyed upon by a higher member (www.answers.com)

Gastrointestinal illness – enteric illness; gastroenteritis; inflammation of the mucous membrane of the stomach and intestines (www.answers.com)

Geochemistry – the study of the absolute and relative abundances of chemical elements in the minerals, soils, ores, rocks, water, and atmosphere of the earth and the distribution and movement of these elements from one place to another as a result of their chemical and physical properties (www.answers.com)

Geometric mean – the geometric mean of a set of positive data is defined as the nth root of the product of all the members of the set, where n is the number of members; the geometric mean is useful to determine average factors; while the arithmetic mean is relevant any time several quantities add together to produce a total, the geometric mean is relevant any time several quantities multiply together to produce a product (www.answers.com)

Guideline – a statement or other indication of policy or procedure by which to determine a course of action (www.answers.com); in Canada, environmental quality guidelines are often set at the Federal level (for example, Canadian Council of Ministers of the Environment – CCME) as numerical concentrations or narrative statements recommended to support and maintain a designated water use (Wells et al. 1986); there are differences between a criterion, a guideline, an objective and a standard.

Halocline – a vertical gradient in ocean salinity (www.answers.com)

Harmful – causing or likely to cause harm (physical injury or material damage) (Oxford 2005)

Health (ecosystem) – a systematic approach to the preventative, diagnostic, and prognostic aspects of ecosystem management, and to the understanding of relationships between ecosystem health and human health; it seeks to understand and optimize the intrinsic capacity of an ecosystem for self-renewal while meeting reasonable human goals; it encompasses the role of societal values, attitudes and goals in shaping our conception of health at human and ecosystem scales (www.med.uwo.ca/ecosystemhealth/education/glossary.htm)

Health (environmental) – the well-being of the living things in the natural and human influenced environment

Health (human) – freedom from or coping with disease on the one hand (the medical view), and the promotion of well-being and productivity on the other (the public health view); "in essence, there are two dimensions of health – the capacity for maintaining organization or renewal, and the capacity for achieving reasonable human goals or meeting needs" (Nielsen 1999).

Health (population health) – refers to the health of a population as measured by health status indicators and as influenced by social, economic and physical environments, personal health practices, individual capacity and coping skills, human biology, early childhood development, and health services (Peck 2006)

Health (public) – one of the efforts organized by society to protect, promote, and restore the people's health; the combination of sciences, skills, and beliefs directed to the maintenance and improvement of the health of all the people through collective or social actions; a social institution, a discipline, and a practice with the goal to reduce the amount of disease, premature death, and disease-produced discomfort and disability in the population (www.dph.state.ct.us/OPPE/sha99/glossary.htm)

High resolution (chemical) data – chemical data collected using analytical methods with the ability to measure at very low chemical concentrations (low detection limits) and resolve differences between different chemical constituents

Hydraulic capacity – the maximum amount of water that can go through a mechanical system

Hydraulic head – refers to the depth that water stands; energy potential stored in differential height of water

Hydrolysis – decomposition of a chemical compound by reaction with water, such as the dissociation of a dissolved salt or the catalytic conversion of starch to glucose (www.answers.com)

Hydrophilic – having an affinity for water; readily absorbing or dissolving in water (www.answers.com)

Hydrophobic – repelling, tending not to combine with, or incapable of dissolving in water (www.answers.com)

Impact – the results of any change, beneficial or not; a marked effect or influence (Oxford 2005)

Impact assessment – in the context of the environment, the practice of environmental impact assessment has been variously defined as an activity designed to identify, predict, interpret and communicate information about the impact of man's actions (legislative proposals, policies, programs, projects and operational procedures) on man's health and well-being (including the well-being of the ecosystems on which man's survival depends) (Munn 1985); a process or set of activities designed to contribute pertinent environmental information to project or program decision-making (Beanlands and Duinker 1983); a basic tool for the sound assessment of development proposals to determine the potential environmental, social and health effects of a proposed development (Clark 1983)

Immunotoxic – this refers to any substance which damages the immune system; when the immune system function is suppressed there is an increased susceptibility to infectious diseases and cancers (www.answers.com)

Indicator species – a species that is surveyed or sampled for analysis because it is believed to represent the biotic community, some functional or taxonomic group, or some population that cannot be readily sampled or surveyed (Suter 1993)

Initial dilution zone – with respect to the CRD, for each diffuser, it is the area within 100 meters of any of its discharge ports (Lorax Environmental memo to CRD, Jan. 12, 2006); from the BC Environmental Management Act, the definition is the 3 dimensional zone around the point of discharge where mixing of the effluent and the receiving water occurs; for embayed marine waters, the initial dilution zone must not extend closer to shore than the mean low water mark; the initial dilution zone must be located at least 300 m away from sensitive areas such as recreational areas, shellfish areas, domestic water intakes, agricultural water intakes, or any other sensitive area requiring protection as identified by a director

Inorganic chemicals – compounds that are not composed of organic matter and that do not contain hydrogen to carbon bonds (www.answers.com)

Landfill – the disposal of waste material by burying it (Oxford 2005)

Leachate – the liquid produced when water percolates through any permeable material. It can contain either dissolved or suspended material, or usually both. It is most commonly encountered in connection with landfills where it is produced as a result of rain percolating through the waste and reacting with the products of decomposition, chemicals and other materials in the waste (www.answers.com)

Lipids – any of a group of organic compounds, including the fats, oils, waxes, sterols, and triglycerides, that are insoluble in water but soluble in non-polar organic solvents, are oily to the touch, and together with carbohydrates and proteins constitute the principal structural material of living cells

Lipophilic – having an affinity for, tending to combine with, or capable of dissolving in lipids (fatty acids or their derivatives) (www.answers.com)

Lipophobic – avoidance of lipids

Loadings – the volume of contaminants or materials entering a body of water over a specific period of time

Macro-contaminants – materials such as suspended solids, fats, oil and grease, and nutrients such as nitrogen and phosphorus; contaminants generally found in water in higher concentrations; regulated compounds

Metabolism – sum of all biochemical processes involved in life; two subcategories of metabolism are anabolism, the building up of complex organic molecules from simpler precursors, and catabolism, the breakdown of complex substances into simpler molecules, often accompanied by the release of energy; organic molecules involved in these processes are called metabolites (www.answers.com)

Metalloid – a nonmetallic element that has some of the chemical properties of a metal and that can form an alloy with metals (www.answers.com)

Micro-contaminants – materials such as pesticides, pharmaceutical agents and endocrine disrupting compounds; generally found in water in lower concentrations; may be a regulated compound

Micro-layer – the interface between the surface of a waterbody and air

Microorganism(s) – an organism of microscopic or submicroscopic size, especially a bacterium or protozoan (www.answers.com); the grouping also includes viruses and prions

Modeling – the use of statistical analysis, computer analysis, or model organisms to predict outcomes (www.cdc.gov/genomics/gtesting/ACCE/FBR/CF/CFGlossary2.htm)

Monitoring – testing on a routine basis, with some degree of control, to ensure that the quality of water or effluent has not exceeded some prescribed criteria range (Wells and Rolston 1991); measuring, usually over time, the concentration of substances in either environmental media or living organisms (Hodgson et al. 1998); the systematic process of collecting and storing data related to particular natural and human systems at specific locations and times; determination of a system's status at various points in time yields information on trends, which is fundamental to the potential for monitoring to detect system change (also termed "status and trend detection") (Busch and Trexler 2003)

Multivariate statistical analyses – a collection of procedures which involve observation and analysis of more than one statistical variable at a time (www.answers.com)

Nanofiltration – reverse osmosis; the process of forcing a solvent from a region of high solute concentration through a membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure; the membranes used for reverse osmosis have no pores, the separation takes place in a dense polymer layer of only microscopic thickness; in most cases the membrane is designed to only allow water to pass through; the water goes into solution in the polymer of which the membrane is manufactured, and crosses it by diffusion (www.answers.com)

Nanotechnology – the science and technology of building devices, such as electronic circuits, from single atoms and molecules (www.answers.com)

Narcosis – a condition of deep stupor or unconsciousness produced by a drug or other chemical substance (www.answers.com)

Negligible – not significant or important enough to be worth considering (www.answers.com)

Non-point source pollution – comes from many unidentifiable sources with no specific solution to rectify the problem, making it difficult to regulate; e.g., urban runoff of items like oils, fertilizers, and lawn chemicals (www.answers.com); when it rains, water washes over driveways, roofs, agricultural lands, streets, lawns, construction sites, and logging operations picking up soil, garbage and toxics; the amount of pollution carried by rainwater, snowmelt and irrigation water flowing into streams and lakes, and through the soil into groundwater is much larger than pollution from industry (http://www.deq.state.or.us/wq/nonpoint/nonpoint.htm). Stormwater is an example of non-point source pollution.

Nutraceuticals – phytochemicals; natural, bioactive chemical compounds that have health promoting, disease preventing or medicinal properties (http://foodsci.rutgers.edu/nci/#what)

Nutrient(s) – essential chemicals (e.g., nitrogen, phosphorus, carbon) from the environment needed by plants and animals for maintenance and growth; excessive amounts of nutrients can lead to degradation of water quality by promoting excessive growth, accumulation, and subsequent decay of plants, especially algae (phytoplankton) (USEPA 1998)

Organic chemicals – compounds containing carbon that are typically found in living systems (www.answers.com)

Organic matter – plant and animal residues such as leaves, trimmings, and manure in various stages of decomposition (www.answers.com)

Oxidation – any chemical reaction in which a material gives up electrons, as when the material combines with oxygen; burning is an example of rapid oxidation; rusting is an example of slow oxidation (www.answers.com)

Oxidative stress – a condition of increased oxidant production in animal cells characterized by the release of free radicals and resulting in cellular degeneration (www.answers.com)

Parameter effect levels – in CRD programs, numeric chemical or biological levels that represent a high probability of actual adverse effects in the receptor; the parameter effects levels are associated with the Seafloor Trigger (CRD Environmental Services Group 2000)

Particulate – particulate matter; aerosols; tiny particles of solid or liquid suspended in a gas; they range in size from less than 10 nanometres to more than 100 micrometres in diameter, representing scales from a gathering of a few molecules to the size where the particles no longer can be carried by the gas (www.answers.com)

Partition coefficient – a measure of differential solubility of a compound in two solvents; the best known of these partition coefficients is the one based on the solvents octanol and water; the octanol-water partition coefficient is a measure of the hydrophobicity and hydrophilicity of a substance (www.answers.com)

Pathogens – organisms causing or capable of causing disease (Webster 1996)

Pelagic – refers to organisms, such as fish and swimming invertebrates, living in the water column (between the sediments and the water surface), that is, inhabiting the open water; in ornithology, applies to seabirds that come to land only to breed (Allaby 2004)

Percentile – descriptive statistics; the p'th percentile is a scale value for a data series equal to the p/100 quartile; e.g., the 1st percentile cuts off lowest 1% of data, the 98th percentile cuts off lowest 98% of data; the 25th percentile is the first quartile; the 50th percentile is the median (www.answers.com)

Persistent organic pollutants (POPs)– organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes; observed to persist in the environment, to be capable of long-range transport, bioaccumulate in human and animal tissue, and to have potential significant impacts on human health and the environment (www.answers.com)

Personal care products – products manufactured for human use; i.e. fragrances (musks) and sunscreen (UV filters)

pH – measure of degree of acidity or alkalinity; the pH is the logarithm of the reciprocal of the hydrogen ion (or more properly, the hydronium ion) activity (Reid 1961)

Pharmaceutical(s) – pharmacological agent; a compound manufactured for use as a medicinal drug; e.g., carbamazepine (Oxford 2005)

Photolysis – chemical decomposition induced by light or other radiant energy (www.answers.com)

Physico-chemical conditions – various physical and chemical parameters of a specified media or material; e.g., for a waterbody, these would include: temperature, dissolved oxygen, salinity, pH and total suspended solids

Phytoplankton – free-floating aquatic plants; most phytoplankton are too small to be individually seen with the unaided eye; however, when present in high numbers, their presence may appear as discoloration of the water (www.answers.com) pKa – in chemistry and biochemistry, acid dissociation constant, the acidity constant, or the acid-ionization constant (Ka) is a specific type of equilibrium constant that indicates the extent of dissociation of hydrogen ions from an acid; while strong acids dissociate practically completely in solution and consequently have large acidity constants, weak acids do not fully dissociate and generally have acidity constants far less than 1 (http://en.wikipedia.org/wiki/PKa)

Plankton – collection of small or microscopic organisms, including algae and protozoans, which float or drift in great numbers in fresh or salt water, especially at or near the surface, and serve as food for fish and other larger organisms (www.answers.com)

Point source pollution – discharge to aquatic environment from specific facility; i.e. sewage treatment plant or manufacturing facility; readily identifiable inputs where waste is discharged to the receiving waters from a pipe or drain

Pollutants – biological, chemical, or physical agents that cause adverse or harmful effects to organisms (plants or animals); to be distinguished from contaminants whose levels can be below those demonstrated to cause adverse effects

Pollution – the GESAMP definition, widely accepted and in legal usage, such as in the Law of the Sea Convention, is the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hindrance to marine activities, including fishing, impairment of quality for use of sea water, and reduction of amenities (GESAMP 1990); the definition is sometimes modified slightly in different conventions; pollution is distinct from contamination in that it refers to deleterious effects occurring or likely to occur as a result of the introduction of substances or energy

Precautionary principle – it is the idea that if the consequences of an action are unknown, but are judged to have some potential for major or irreversible negative consequences, then it is better to avoid that action (Peck 2006; (http://en.wilkipedia.org/wiki/precautionary_principle)

Precipitation – the process by which a solid or solid phase is separated from a solution (www.answers.com)

Preliminary Treatment – grit and solid materials are screened out of sewage before it is released into the environment

Primary Treatment – a physical process in which the sewage flow is slowed down and the solids are separated from the liquids; a large portion of the suspended solids settles naturally due to gravity; primary treatment is removal of floating and suspended solids; From the preliminary treatment, the wastewater travels to the primary treatment clarifiers, also called primary settling tanks, which removes a portion of the contaminants found in the wastewater.

Prion – a microscopic protein particle similar to a virus but lacking nucleic acid; thought to be the infectious agent responsible for scrapie and certain other degenerative diseases of the nervous system (www.answers.com)

Public health – see Health (public)

Receptor – an element of the receiving environment that could experience adverse effects as a result of exposure to contaminants, such as the benthic community, mussels, fish, birds, wildlife, or humans (CRD Environmental Services Group 2000)

Recovery (of ecosystems) – recovery means a healthy biological community has been re-established and that the plants and animals characteristic of that community are present and are functioning normally (Exxon-Mobil 2001)

Reduction – reduction is the opposite of oxidation; any process in which electrons are added to an atom or ion (as by removing oxygen or adding hydrogen) (www.answers.com)

Reference ranges – for the CRD, numeric biological ranges for benthic measurement parameters observed at reference areas used in the monitoring program; deviations from these ranges provide an early indication of the potential for parameter effects levels to be exceeded, so that source control measures can be taken to prevent the Seafloor Trigger from being exceeded in the future; reference ranges are part of the early indication process (CRD Environmental Services Group 2000)

Richness – species richness; taxonomic richness; the number of taxa per unit area

Riparian – of, on, or relating to the banks of a natural course of water (www.answers.com)

Risk – the possibility of loss, injury, disadvantage, or destruction (Webster 1996); as used in risk assessments, the probability or likelihood of some adverse consequence occurring to an exposed human or to an exposed ecological entity (Newman and Unger 2003); risk should be described in terms of probability and magnitude.

Risk assessment – ecological risk assessment; a process intended to calculate or estimate the risk for a given target system, given exposure or potential exposure to a particular stressor(s)

Risk management – decision-making process involving considerations of political, social, economic, and technical factors with relevant risk assessment information relating to a hazard so as to develop, analyze, and compare regulatory and nonregulatory options and to select and implement the optimal decisions and actions for safety from that hazard; essentially, risk management is the combination of three steps: risk evaluation, emission and exposure control, and risk monitoring (Duffus 2001)

Screening-level risk assessment (SLRA) – a streamlined risk assessment procedure; the level of detail of an SLRA will be less than a site specific, detailed risk assessment, increasing the degree of uncertainty associated with the risks; however, conservative assumptions are built into the SLRA to ensure risks to receptors are not under-estimated

Seafloor trigger – in the case of the CRD, the numeric levels and interpretation guidelines that trigger the development of treatment facilities; the trigger includes numeric biological levels along with spatial components (numbers and locations of stations) and temporal components (number of monitoring years in which the numeric levels are exceeded) (CRD Environmental Services Group 2000)

Sediment – sediment is any particulate matter that can be transported by fluid flow and which eventually is deposited as a layer of solid particles on the bed or bottom of a body of water or other liquid; sedimentation is the deposition by settling of a suspended material (http://en.wikipedia.org/wiki/Sediment)

Secondary Treatment – The second step in waste treatment systems in which bacteria consume the organic parts of the waste. Secondary treatment uses biological methods such as digestion

Septage – the mixture of solids removed from a septic tank

Sessile – permanently attached or fixed; not free-moving (www.answers.com)

Sewage – the waste and wastewater produced by residential and commercial sources and discharged into sewers (www.sbeach.navy.mil/Programs/Environmental/IR/Reading_Room/Glossary/G_S.htm)

Sewage sludge – the sludge from the wastewater treatment plant that has not been treated

Sewerage – system for the removal and disposal of chiefly liquid wastes and of rainwater, which are collectively called sewage (www.answers.com)

Shellfish – bivalve molluscs (invertebrates) that have a shell, such as scallops, quahogs, oysters, clams and mussels; the term is sometimes used popularly but incorrectly to include decapod crustaceans such as shrimp, lobsters, and crabs that have shell-like external skeletons and are the basis of lucrative fisheries

Shifting baseline (syndrome) – a shifting baseline that develops as members of the present generation (of fisheries biologists) use stock sizes and composition known during their lifetimes as reference points against which to compare the current status of fisheries (Pauly 1995); the principle can also apply to practitioners of environmental monitoring

Significance – usually used in terms of statistics; statistical significance is a mathematical tool used to determine whether the outcome of an experiment is the result of a relationship between specific factors or due to chance (http://www.wisegeek.com/what-is-statistical-significance.htm)

Slack tide – the very short period (from 1 to 3 hours generally) when the ocean is close to a balance in tidal movement (http://www.coos-bay.net/understanding-tides.html)

Sludge – wastewater treatment plants produce both primary sludges from initial separation of solids from influent streams (primary sludge), and biological sludges from the aerobic treatment of wastewater, secondary sludge, or humus sludge; sewage sludge is a complex mixture of fats, proteins, amino acids, sugars, carbohydrates, lignin, celluloses, humic material and fatty acids, with large amounts of live and dead microorganisms (Birkett and Lister 2003)

SMART – SMART refers to making goals / commitments; Specific; Measurable; Achievable; Realistic; and Time-Bound

Solvent – a substance, usually a liquid, capable of dissolving another substance (www.answers.com)

Source control – the management activity of identifying sources of harmful materials (e.g., metals, oils) and removing them from waste streams at the point of production, as an alternative to them entering wastewaters directly and relying on downstream treatment plants for their removal

Speciation – the chemical form of the compound which occurs in the natural system (e.g., chromium III, chromium VI)

Stormwater – runoff water resulting from falls of rain or snow; the majority is surface water; however, interflow, accumulated groundwater, foundation drains and building runoff contribute to the total flow; stormwater events may occur many times each year

Struvite – a chemical compound, magnesium ammonium phosphate (MgNH4PO4 x 6H2O), which is made by the body and can form crystals and stones in the urinary bladder (www.peteducation.com/dict_alpha_listing.cfm); formation of struvite at sewage treatment works can cause operational problems and decrease efficiency.

Surfactant – a substance capable of reducing the surface tension of a liquid in which it is dissolved (www.answers.com)

Surrogates – in the context of indicators, surrogates are representative biotic or abiotic measurements similar to but different from biotic or abiotic constituents or properties of an environment under study; a substitute (Oxford 2005); for example, mussels are a surrogate for the epibenthic marine community, and for the potential for bioaccumulation of chemical contaminants into marine food resources

Synchronous spawners – a group of aquatic organisms (e.g., fish, coral reefs) that all release their eggs within a short period of time

Synthetic industrial chemicals – manufactured compounds (i.e. flame retardants) for industrial or commercial use

Taxonomic richness – see species richness

Taxonomy – the classification of organisms in an ordered system that indicates natural relationships (www.answers.com)

Thermocline – a layer in a large body of water, such as a lake, that sharply separates regions differing in temperature, so that the temperature gradient across the layer is abrupt (www.answers.com)

Thresholds – in the context of chemical or physico-chemical levels in the environment, thresholds are the maximum level of concentration (of a substance) considered to be acceptable or safe (Oxford 2005); in aquatic toxicology, thresholds such as no observable effect concentrations, lowest observable effect concentrations, and maximum acceptable toxicant concentrations are estimated from toxicity tests

Tissue burden – body burden; the concentration of a contaminant in the tissue (e.g., muscle, liver) of an organism

Total organic carbon (TOC) – the amount of carbon bound in organic compounds (www.answers.com)

Total suspended solids (TSS) – the portion of total solids retained by a filter of defined pore size characteristics; total solids is the term applied to the material residue left in the vessel after evaporation of a sample and its subsequent drying in an oven at a defined temperature (APHA 2005)

Toxic (toxicity) – poisonous; relating to or caused by poisons; highly unpleasant or harmful (Oxford 2005); the adverse effects to a life form that result from being exposed to a toxic substance.

Toxicity reference value (TRV) – an ecotoxicological benchmark that reflects a chemical concentration or dose that is equivalent to the maximum acceptable exposure level for a receptor, in other words, a safe level

Treatment – in the context of sewage, there are various kinds of wastewater treatment e.g., primary, enhanced primary (chemical coagulation or ballasted flocculation) and secondary

Trigger – an event that is the cause for a particular action, process, or situation (Oxford 2005); in the context of the CRD monitoring program, see “seafloor trigger”

Trigger process – the overall process that determines when the development of treatment facilities or source control measures will be necessary to protect the receiving environment; this process consists of numeric biological and chemical warning and effects levels, monitoring, evaluation of monitoring data, and a decision framework (CRD 2000)

Uncertainty – the state of being uncertain (Oxford 2005); imperfect knowledge concerning the present of future state of the system under consideration (Suter 1993); in environmental risk assessments, there are experimentally determined uncertainties, environmental uncertainties due to natural variability, and uncertainties due to lack of knowledge about model parameters

Virus – an infective agent that typically consists of a nucleic acid molecule in a protein coat, is too small to be seen by light microscopy, and is able to multiply only within the living cells of the host (Oxford 2005)

Warning levels – in the case of the CRD, numeric chemical or biological levels below adverse effects levels that provide a margin of safety; their purpose is to provide sufficient early warning of adverse effects so that measures can be taken to prevent adverse effects levels from being exceeded in the future (CRD 2000)

Weight of evidence approach – use of multiple lines of evidence to evaluate an issue or risk; evidence can be scientific in nature or inclusive of other disciplines; e.g., socio-economic, political and legal

Wastewater treatment – chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants (www.deq.state.va.us/tmdl/glossary.html)

Zooplankton – animal constituent of plankton; mainly small crustaceans and fish larvae (www.answers.com)

Zone of impact – the area around a physical or chemical disturbance in the environment that has a significantly changed ecology or chemistry, compared to natural conditions; the changes to species, populations or communities are often considered adverse

Acronyms and Abbreviations

ADD	average daily dose
ADWF	average dry weather flow
Ag	silver
AOP	advanced oxidation process
APEO	alkylphenol polyethoxylates
As	arsenic
AVS	acid volatile sulphide
AWWF	average wet weather flow
BC	British Columbia
BCA	benefit cost analysis
BE	biotically enriched
BEHP	bis(2-ethylhexyl)phthalate
BMP	best management practice
BOD	biochemical oxygen demand
C	carbon
CB	Constance Bank
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
Cd	cadmium
CFU	colony fecal unit
COP	California Ocean Plan
CP	Clover Point
Cr	chromium
CRD	Capital Regional District
CSO	combined sewer overflow
CSR	Contaminated Sites Regulations (British Columbia)
Cu	copper
DDT	dichloro-diphenyl-trichloroethane
DO	dissolved oxygen
DUR	discharger under review
E2	17β-ethinylestradiol (natural estrogen)
EDC	endocrine-disrupting compounds
EE2	17α-ethinylestradiol (synthetic estrogen)
ESD	environmentally sustainable development (indicators)
FC	fecal coliform
ft	feet
fog	fats, oils, and grease
GESAMP	United Nations Joint Group of Experts on Scientific Aspects of Marine Environmental Protection
GI	gastrointestinal tract
GVRD	Greater Vancouver Regional District

HI	hazard index
HQ	hazard quotient
HRM	Halifax Regional Municipality
HSP	Harbour Solutions Project
I&I	inflow and infiltration control
ICI	industrial commercial institutional
IDZ	initial dilution zone
JFS	Juan de Fuca Strait
kg/d	kilograms per day
km	kilometre
L1	low impoverishment
LADD	lifetime average daily dose
LWMP	Liquid Waste Management Plan
m	metre
M1	moderate impoverishment
MBR	membrane biological reactor
MELP	Ministry of Environment, Lands and Parks (BC); now Ministry of Environment
ML	million litres
MMAG	Marine Monitoring Advisory Group
MOE	Ministry of Environment
MOR	micro-organism reduction
MOU	memorandum of understanding
MP	Macaulay Point
MWRA	Massachusetts Water Resource Authority
MWWE	municipal waste water effluent
N	nitrogen
NAS	National Academy of Sciences (USA)
Ni	nickel
NOAEL	no observable adverse effect level
NP	nonylphenol
NPDES	National Pollutant Discharge Elimination System (USA)
OE	outside effects
OECD	Organization for Economic Cooperation and Development
P	phosphorus
PAH	polycyclic aromatic hydrocarbons
Pb	lead
PBDE	polybrominated diphenyl ethers
PCA	principal components analysis
PCB	polychlorinated biphenyls
PCDD	polychlorinated dibenzo-p-dioxins
PESC	Pacific Environmental Science Centre
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonates
POP	persistent organic compounds
PPCP	pharmaceutical and personal care products
PWWF	peak waste water flow
R	reference
RSCP	Regional Source Control Program
SDI	Swartz Dominance Index
SETAC	Society of Environmental Toxicology and Chemistry (North America)
SLDF	Sierra Legal Defense Fund
SLRA	screening level risk assessment
SSO	sanitary sewer overflows
STP	sewage treatment plant

TBL	triple bottom line
TEU	toxicity equivalency units
TLW	trucked liquid wastes
TOC	total organic carbon
TOR	terms of reference
TRV	toxicity reference value
TSS	total suspended solids
USA (US)	United States of America
USEPA	Environmental Protection Agency (USA)
UV	ultraviolet
VEHEAP	Victoria and Esquimalt Harbours Environmental Action Program
WLAP	(Ministry of) Water, Lands, and Air Protection (BC) (now the Ministry of Environment)
WQG	water quality guideline
ww	wet weight
WWT	wastewater treatment
WWTP	wastewater treatment plant
Zn	zinc