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Data Gap Analysis Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place, Sidney, BC

May 2016
SLR Project No.: 201.02016.00001

DATA GAP ANALYSIS - REAY CREEK POND
CANORA ROAD BETWEEN NORTHBROOK DRIVE AND BOWCOTT PLACE
SIDNEY, BC

SLR Project No.: 201.02016.00001

Prepared by
SLR Consulting (Canada) Ltd.
200 - 1620 West 8th Avenue
Vancouver, BC V6J 1V4

For
Town of Sidney
2440 Sidney Avenue
Sidney, BC V8L 1Y7

30 May 2016

Prepared by:	Reviewed by:
	J. G. Malick
Jackie Smith, M.A.Sc., R.P.Bio., P.Ag., CSAP Project Manager	**J. G. Malick, Ph.D., R.P.Bio., P.Ag., CSAP** Senior Ecologist and Regulatory Specialist

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EXECUTIVE SUMMARY

The Reay Creek Technical Working Group and the Town of Sidney required a review and interpretation of sediment investigation results collected since 2010, with a view to examine the need for, and feasibility of, future remediation and/or restoration of Reay Creek Pond.

This report provides the document review and data gap analysis portion of this work. Since the metals in sediments are the predominant contaminant and are likely the most toxic to aquatic organisms, the focus on the review has been related to these parameters. In addition, from a potential sediment disposal perspective, these parameters would likely dictate disposal options and costs.

In general the analytical results for metals were relatively uniform throughout the sediments, and it was concluded that all samples were from one population and that the entire accumulated sediment mass is contaminated.

SLR Consulting (Canada) Ltd. (SLR) understands the metals source (Victoria Airport Authority (VAA) industrial lands) has been somewhat controlled via the creek diversion and wetland development. Other sources (neighborhood roadways and runoff) will remain unchanged, although these are likely less significant sources of contaminants, especially metals.

The remedial options for the Pond are somewhat limited given it is in a well-established residential neighbourhood, with much of adjoining land is private property. Also, anecdotal information indicates the general public wish to retain the pond environment (as opposed to reinstating it as a creek, with dam removal). The disruption of the pond environment and riparian area as well as to local residents should also be considered.

Based on our review of the existing data, SLR recommends additional investigation to fill data gaps and allow a full evaluation of remedial options as follows:

Additional Sediment Analyses:

- Chromium speciation (there are two main forms of chromium, Cr III and Cr VI, the latter being the more toxic); and
- Metals SEM/AVS analyses to determine the bioavailability of the sediment metals to aquatic organisms.

Additional Water Analyses:

- Dissolved oxygen concentration near sediment surface;
- Porewater - from sediments in the top 10 centimetres - metals analyses;
- Dissolved and total metals content in pond waters;
- Petroleum hydrocarbon analyses in pond waters; and
- Chromium speciation (if significant chromium present in water).

Ecology:

- Plant identification and distribution survey (aquatic species);
- Zooplankton presence, relative abundance and identification; and
- Benthic invertebrate population analysis - this will be important in determining how diverse or not the benthic invertebrate species are which in turn indicates the relative health of the system.

Tissue Analyses:

- Fish and/or invertebrates for metals content; and
- Plants (aquatic species) tissue analysis for metals content.

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GLOSSARY

As	Arsenic
CCME	Canadian Council of Ministers of the Environment
Cd	Cadmium
cm	centimetre
Cr	Chromium
CSR	Contaminated Sites Regulation
CSR SD_{ft}	Contaminated Sites Regulation freshwater sediment typical standards
CSR SD_{fs}	Contaminated Sites Regulation freshwater sediment sensitive standards
Cu	Copper
DDT	Dichloro-diphenyl-trichloroethane
ISGQ	Interim Sediment Quality Guideline
km	kilometre
L	Litre
m	metre
MOE	Ministry of Environment
ng/g	nanogram/gram
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PBDE	Polybrominated diphenyl ethers
PCB	Polychlorinated Biphenyls
PCDD	Polychlorinated Dibenzodioxins
PCDF	Polychlorinated Dibenzofurans
PEL	Probable Effect Level
PFOS	Perfluorooctane Sulfonate
pg/g	picogram/gram
SedQC	Generic Numerical Sediment Criteria
SLR	SLR Consulting (Canada) Ltd.
TEL	Threshold Effect Level
µg/g	micrograms per gram
VAA	Victoria Airport Authority
YYJ	Victoria International Airport
Zn	Zinc

1.0 INTRODUCTION

1.1 Background

The Reay Creek Technical Working Group and the Town of Sidney required a review and interpretation of sediment investigation results collected since 2010, with a view to examine the need for, and feasibility of, future remediation and/or restoration of Reay Creek Pond.

This report provides the document review and data gap analysis portion of this work.

1.2 Objectives

The scope of work included two main tasks: Document Review and Reporting. The tasks are detailed below:

- Review all investigation reports available with Reay Creek Pond sediment analytical results in regards to:
    - Methods of sampling and information provided;
    - Laboratory analyses conducted;
    - Location of the samples collected and ongoing land uses/activities that have occurred that may affect results; and
    - Assess sediment quality with respect to the applicable BC sediment standards.
- Review previously reported sediment data and evaluate in relation to:
    - Depth of samples and volume of sediment represented;
    - Reported water quality data, if any, associated with the sediment analytical data;
    - Land uses/activities, alteration works within the drainage area; and
    - Identify any data gaps that would assist in determining potential future remedial options.
- Prepare a report presenting the information, data, evaluations, and recommendations for additional investigations.

2.0 REGULATORY REQUIREMENTS AND REFERENCE VALUES

The following sections provide a summary of BC Sediment Quality Criteria and national Sediment Quality Guidelines.

2.1 Provincial Sediment Quality Criteria

The Contaminated Sites Regulation (CSR), Schedule 9, Generic Numerical Sediment Criteria (SedQC) provides reference values for assessing sediment quality. Concentration criteria for substances of potential concern are provided for freshwater and marine sediments. These criteria are for aquatic life use and are intended to protect sediment-dwelling species from unacceptable effects that may be associated with exposure to contaminated sediments at typical and sensitive sites. The designated use of the aquatic, estuarine, or marine ecosystem portion of a site is used to classify the site as either typical or sensitive (i.e., for Freshwater, or

Marine and Estuarine: Sensitive SedQC_{SS} and Typical SedQC_{TS}). “Sensitive sediment use” and “Typical sediment use” are defined in a Ministry of Environment (MOE) procedure document.[1]

"Sensitive sediment use" means the use as habitat for sensitive components of freshwater, marine, or estuarine aquatic ecosystems of a site containing sediment, which sensitive components include, but are not limited to:

(a) Phytoplankton, zooplankton, benthos, macrophytes, and fish;
(b) Habitats used by endangered or threatened species or species of special concern under the Species at Risk Act (Canada);
(c) Watercourses, wetlands, forested riparian areas, mudflats, and intertidal zones that are important to the preservation of fish or wildlife;
(d) Reaches of aquatic habitats that are important to fish spawning or serve as important rearing habitat for fish;
(e) Reaches of aquatic environments that encompass or border habitat compensation or restoration sites or other areas that are intended or designed to create, restore or enhance biological or habitat features; and
(f) Areas and aquatic habitat included in wild life management areas designated under the *Wildlife Act*.

"Typical sediment use" means the use of a site containing sediment for a use that is not a sensitive sediment use.

As implied by the terms sensitive and typical, the sensitive criteria are more stringent (i.e., have lower concentration thresholds) and typical criteria are less stringent (i.e., have higher concentration thresholds).

Criteria are provided in Schedule 9 for a number of substance/contaminant groups including:

- Metals (7 substances);
- Chlorinated hydrocarbons (3 substance groups, including: polychlorinated biphenyls (PCB), polychlorinated dibenzodioxins (PCDD), and polychlorinated dibenzofurans (PCDF);
- Phenolic substances (1 substance, pentachlorophenol);
- Polycyclic aromatic hydrocarbons (PAH) (13 substances and total PAH); and
- Pesticides (8 substances).

Provision also is included in the CSR (Section 11[3]) for considering background concentration standards for sediments; however, requirements for determining background sediment quality have not been specified in an approved Protocol so using alternate numerical standards to those prescribed in Schedule 11 of the CSR is not currently possible.

2.2 National Sediment Quality Guidelines

Canadian Council of Ministers of the Environment (CCME) guidelines for sediment quality are derived from the available toxicological information according to the formal protocol established

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[1] *Definitions and Acronyms for Contaminated Sites*. Procedure 8. January 14, 2014. Effective January 14, 2014. BC Ministry of Environment.

by CCME. The lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely. The upper value, referred to as the probable effect level (PEL), defines the level above which adverse effects are expected to occur frequently. The definition of the TEL is consistent with the definition of a Canadian sediment quality guideline and is also referred to as the Interim Sediment Quality Guideline (ISQG). The PEL is recommended as an additional sediment quality assessment tool that can be useful in identifying sediments in which adverse biological effects are more likely to occur.

Guidelines (i.e., TEL and PEL) are provided by CCME for essentially the same substance/ contaminant groups as in the CSR for BC, namely:

- Metals (7 substances);
- Chlorinated hydrocarbons (3 substance groups, including: PCB, PCDD, and PCDF;
- Phenolic substances (1 substance, pentachlorophenol);
- PAH (13 substances, and total PAH); and
- Pesticides (8 substances).

As implied by the explanations for the CCME guideline terms TEL/ISQG and PEL, the TEL/ ISQG guidelines are more stringent (i.e., have lower concentration thresholds) and PEL guidelines are less stringent (i.e., have higher concentration thresholds).

2.3 Applicable Criteria/Guidelines

Both the CSR criteria for BC and the CCME guidelines include substance concentrations for protection of marine and freshwater aquatic systems. Reay Creek Pond and Reay Creek in the area of the Reay Creek Pond is a freshwater system. The criteria and guideline concentrations for freshwater are considered applicable. Sediment chemistry data tables in this report therefore include only the concentrations for freshwater.

From the definitions for “sensitive sediment use” in the CSR, some elements would apply. Other aspects of the definition for “sensitive” would clearly not apply. Sediment chemistry data tables at the end of the text of this report therefore include the concentrations for both “sensitive” and “typical”.

From the explanation of the TEL and PEL threshold levels used in the CCME guidelines the objectives for use of, and reference to, both the TEL and PEL levels could apply. Sediment chemistry data tables at the end of the text of this report therefore include the concentrations for both TEL and PEL.

2.4 Alternate Criteria - Risk-Based

It should be noted that contaminated sites legislation and the CSR in BC define two general types of standards (in the case of sediment, standards are referred to as criteria):

- *Numerical standards* are acceptable concentrations of substances in soil, surface water, groundwater, vapour, and sediments; and
- *Risk-based standards* are acceptable risk levels from exposure to substances at sites.

At sites under BC jurisdiction, either numerical concentration or risk-based standards or criteria may be applied when considering remediation requirements and options. One option for remediation is to remove contaminants so no sediments exceeding reference concentrations remain. An alternate is to conduct risk assessment to confirm that contaminants managed in-place would not pose unacceptable risks to human health or the environment, or if required, risk management/risk control measures could be implemented so risk would be reduced to acceptable levels.

Despite the options for remediation, numerical concentration standards/criteria must be used to determine whether or not contamination is present at a site and if the site is classified as a contaminated site. The CSR Section 11 states:

> “(1) Subject to section 12 and subsections (2), (3) and (4) of this section, the following substances, standards and conditions are prescribed for the purposes of the definition of "contaminated site" in section 39 of the Act: (a)…; (b)…; (c) the concentration of any substance in sediment at the site is greater than the applicable generic numerical sediment criterion; (d)…;”.

3.0 SITE INFORMATION

3.1 Location

Reay Creek Pond is part of Reay Creek Park, to the southeast of Victoria International Airport (see Figure A), just east of Canora Road and between Northbrook and Westbrook Drive on the north and Bowcott Place on the south. Reay Creek Park is within the boundaries of the Town of Sidney in its southwest corner. The Patricia (Pat) Bay Hwy is located about 0.5 kilometres (km) east of the south end of the pond and about 0.6 km in the downstream direction (i.e., southeast) of the south end of the Reay Creek Pond.

The Victoria International Airport (YYJ) is located to the west and mainly northwest of Reay Creek Pond and is the headwaters of the creek. The length of the pond is about 200 metres (m) between Canora Road and the dam.

Reay Creek originates on YYJ property just to the south of the industrial properties and control tower, flows across non-YYJ property within North Saanich, under Canora Road, through the Reay Creek Pond portion of Reay Creek Park (Town of Sidney), through Peter Grant Park (Town of Sidney), and then south, again into North Saanich, under the Pat Bay Hwy and thence east-southeast under Lochside Drive to its discharge location into Bazan Bay portion of Haro Strait. Figure A illustrates the location of Reay Creek, Reay Creek Park and Pond, as well as YYJ, the Pat Bay Hwy and Haro Strait.

The airport was operated by Transport Canada until about 1997, when the Victoria Airport Authority took over the operations of the airport.

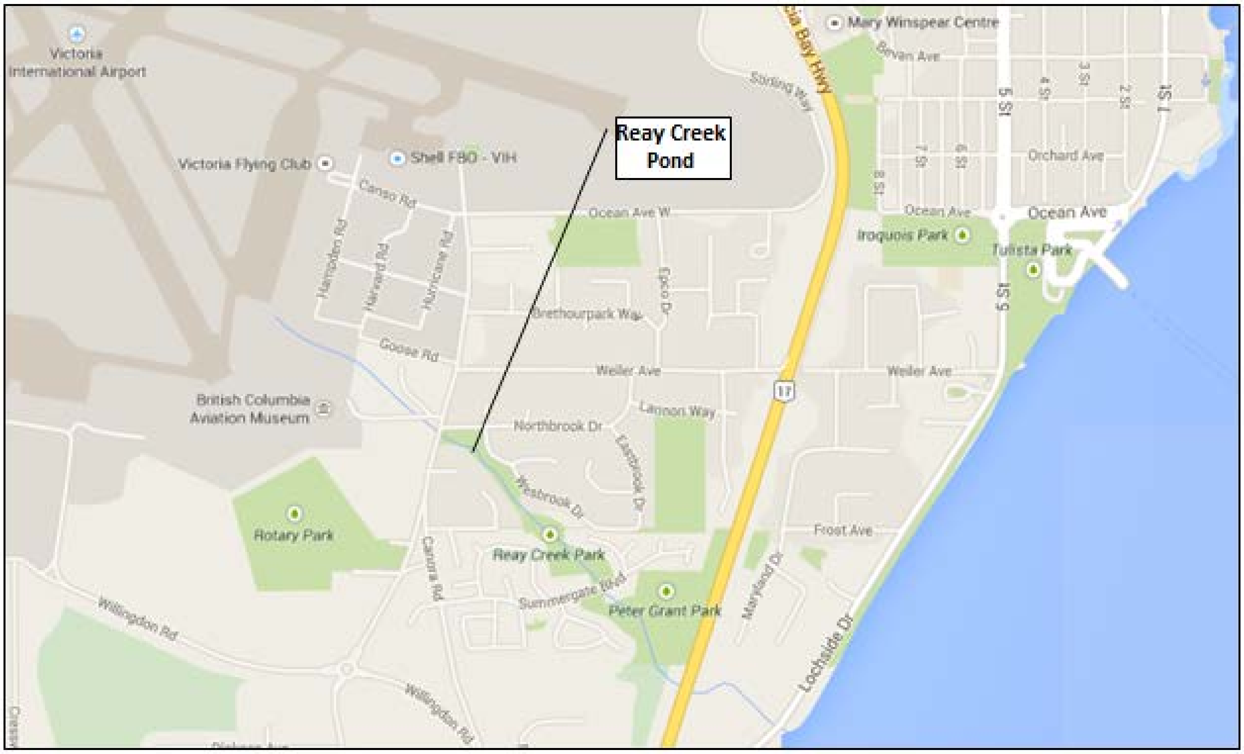

Figure A: Reay Creek Pond Site Location

3.2 Reay Creek Pond

Historically, lands adjacent to Reay Creek in the area of the pond were owned by many different property owners. SLR Consulting (Canada) Ltd. (SLR) understands that a duck farm owner adjacent to the creek constructed an earthen/mud dam to control water flow and levels. A pond was created above the dam.

The dam was reconstructed by the Town of Sidney in 1997 to prevent failure and better control the flow. This occurred after an overflow event in 1996.

A number of stream restoration efforts have been undertaken to restore Reay Creek Pond and have involved many different stakeholders, volunteers, Association and Society members, the Airport, and several levels of government.

3.3 Ministry of Environment Points of Diversion

SLR searched the MOE's iMapBC web site (http://maps.gov.bc.ca/ess/sv/imapbc/) for points of diversion (including drinking water) from Reay Creek. The only point of diversion found was the dam at the site. There does not appear to be any registered drinking water uses/extraction from Reay Creek. Information from the iMapBC web site is included in Appendix A.

3.4 Upstream on Airport Property

SLR contacted Mr. James Bogusz, Vice-President Operations & Development, and Mr. Stacey Lee at the VAA on March 21, 2016. They informed SLR the following:

- Historically, sediment contamination in the upper reaches of Reay Creek (i.e., on airport property) contained various contaminants of concern, mostly metals;
- An individual source was not identified. Storm drains were checked and high metals concentrations were found in many locations;
- Chromium in surface water in the system is sampled regularly by VAA (see Appendix B);
- The entire VAA storm system was cleaned out (McRae's Environmental Services);
- The older clay pipe system has been removed from service and the area is acting as a wetland/settling system. This area will be cleaned out on an on-going (1 to 2 years) basis;
- A new "by pass channel" was created for the main water flow to Reay Creek Pond; and
- Most recent reported spill was of the contents of a chromium plating tank at Viking Air. The spill was contained and cleaned up at the source.

Since 2012, remedial and restoration activities have been undertaken along the upper sections of Reay Creek to address historic contamination of the creek sediment and water presumed to be the result of industrial inputs to the creek via storm water outfalls (Appendix C). The upper section of Reay Creek (on VAA property) was diverted to a newly created channel while the historic alignment was retained as a side channel and water quality improvement linear wetland/retention pond. Diversion berms were constructed at the upstream and downstream ends of the side channel with culverts to allow water flow into and from the side channel to the main flow of the realigned Reay Creek channel. Spillway valves were also fitted to the culverts to allow for control of flows in the event of a spill from the adjacent industrial area and/or airport lands to allow for appropriate spill response activities. This was deemed desirable to reduce potential impacts to downstream areas of Reay Creek in the event of a spill, such that cleanup of unanticipated releases from adjacent activities could be performed in isolation of the main flow of Reay Creek.

4.0 PREVIOUS INVESTIGATIONS

4.1 Camosun College (2010)

The Environmental Technology Program at Camosun College conducted studies and prepared a report for the Reay Creek Pond in June 2010 (Appendix D).

A number of characteristics and aspects of the pond were investigated and reported on in the Camosun College report, including:

- Water and sediment depth transects (11 transect locations);
- Water quality sample analyses (3 samples, in-house analyses; ammonia-N; nitrite-N; nitrate-N; phosphate-P);
- Water parameter measurements (Field measurements for dissolved oxygen, electrical conductivity, pH, temperature);
- Sediments sample analyses (4 locations; surface grab samples):
  - Extracted pore water (4 samples, in-house analyses; ammonia-N; nitrite-N; nitrate-N; phosphate-P),
  - Sediment 5-day BOD tests ([BOD_5] 5 samples; in-house analyses), and
  - Sediment metals (2 samples; Maxxam Analytics Inc. analyses);

- Invertebrates (2 locations, water and surface sediment); and
- Fish observations (4 locations).

From the information collected in the field and calculations carried out, the Camosun College report provided information regarding:

- Pond water depths;
- Sediment thicknesses;
- Estimated total volumes of sediment; and
- Observations and summaries pertaining to general water conditions, habitat suitability, water quality, flora, and fauna.

The main information in this report is as follows:

- Water depth is greatest in front of the dam (almost 2 m);
- Sediment thickness is greatest in the central portion (about 1.5 m);
- Two dominant aquatic plants observed: Elodea Canadensis and Potamogeton robbinsii;
- Only aquatic vertebrate found was three-spined stickleback (4 captured);
- Water - ammonia and nitrite-N were highest at the inflow (culvert) end;
- Water - nitrate-N and phosphate highest 20 m from dam;
- In general middle sediments had slightly higher metals than sediments closer to the dam;
- Total Organic Carbon (TOC) in one sample was reported as 62 g/kg;
- Ammonia and nitrite testing was not reliable due to poor condition and age of the reagents used and condition of the colourimeter equipment;
- BOD data was not reliable; and
- Authors noted in general a lack of amphibious life in the pond.

4.2 SLR Consulting (Canada) Ltd. (2015)

SLR was retained by the Town of Sidney to conduct sediment sampling and determine if the sediments are considered contaminated when compared to the BC CSR and the CCME guidelines (Appendix E):

- Sediment sampling was carried out using either petite ponar or wildco stainless steel corer;
- Locations were selected to represent sediments over full length of the Pond;
- Used lab-supplied sampling jars and cross-contamination prevention measures;
- Some organics (twigs, decomposed leaves, etc.) limited sample collection to 10 centimetres (cm) in some areas;
- Ponar samples represented top 10 cm of sediment;
- Core samples represented surface (0-8 cm or 0-10 cm); mid-core (8-30 cm); deeper (25-40 cm);
- Samples were analyzed for PAH and metals content;

- Other parameters were not analyzed for (PCB, dioxins, etc.) because concentrations are typically very low (less than lab method detection), costs of analyses are high, and often no guidelines or standards have been developed);
- Samples collected at 10 locations at multiple depths at each location. Total samples collected were 25;
- Three of these were grab samples with the ponar (samples 1G, 5G, and 8G);
- Remaining samples were collected from different depths at seven locations (2C-C,B, A; 3C- C,B, A; 4C- C,B, A; 5C- C,B, A; 6C- C,B, A; 7C- C,B, A; 8C- C,B, A);
- Arsenic, cadmium, chromium, lead, and zinc exceeded CSR SDfs in various core samples:
    - 0-8 cm or 0-10 cm depths - cadmium, chromium, lead, zinc,
    - 10-20 cm mid-range - cadmium, chromium, lead, zinc, and
    - 30-40 cm range - arsenic, cadmium, chromium;
- Three samples were analyzed for PAH content - one collected at 10-20 cm contained benzo(a)anthracene, phenanthrene, and pyrene concentrations exceeding the CSR SDfs. The other two samples had PAH exceedances of CCME ISQG; and
- Report confirmed that sediments are considered to be contaminated.

4.3 R. Macdonald Presentation (2015)

SLR was provided with the slides from a power point presentation by R. Macdonald from 2015 (Appendix F). The following information was provided in the presentation:

- An estimated 3,107 m^3 of sediments are in the pond;
- Sedimentation rate of the upper 24 cm uniform mud layer was estimated at 0.33 cm/yr, and has accumulated since about 1930s/1940s;
- Sediments are underlain by a base layer of mud of mixed materials (course material, wood chips, etc.);
- The author investigated contaminants such as PCB, pesticides, Perfluorooctane sulfonate (PFOS), Polybrominated diphenyl ethers (PBDE), and PAH;
- Lead dating was used to calculate sedimentation rates;
- Metals data from two sediment cores, at two depths (0-24 cm and 24-62 cm) were presented. Shallower sediments had higher concentrations of all metals except chromium (Cr), lead (Pb), and arsenic (As) where reverse was true;
- Cadmium (Cd), Cr, copper (Cu), Pb, and zinc (Zn) exceeded one or more standard/ guideline;
- PCB were measured in shallow (0-24 cm) and deeper (24-62 cm) depths. Total PCB in the shallow sample met both CSR SD_{fs} and CSR SD_{ft} criteria. Total PCB in the deeper sediments met the CSR SD_{ft} but exceeded the CSR_{fs} criteria of 0.17 micrograms per gram (µg/g) (0.213 µg/g measured is sediments from 24-62 cm);
- PAH were also measured and were higher in top samples. Only total PAH were reported;

- Dichloro-diphenyl-trichloroethane (DDT) was measured in both shallow (0-24 cm) and deeper (24-62 cm) sediments. Total DDT in the shallow samples met the CSR SD_{fs} and SD_{ft} criteria. Total DDT in the deeper sediments exceeded both the CSR SD_{fs} and SD_{ft} criteria;
- Traces of other pesticides noted, higher in bottom samples; and
- PFOS higher in the top sediment samples. There are no current CSR or CCME criteria for PFOS.

4.4 Macdonald and Bruce (2015)

This report presents some history of the Reay Creek Pond, including dates of dam construction, and anecdotal information about fish kills and some information on the airport activities (Appendix G). The data presented is similar to that found in the above presentation:

- Estimate of contaminated sediments was 2,144 tonnes dry wt;
- Analyses of samples was conducted by Axys Analytical Ltd. of Sydney, BC;
- Implied sedimentation rate of 0.125 g cm^{-2} yr^{-1};
- Taking into account the water content of the sediment, average sediment velocity is 0.32 cm/yr;
- PCB reported in the nanogram/gram (ng/g) range, and the sum of PCB exceeds CCME ISGQ guidelines;
- PBDE reported in pictogram/gram (pg/g), and were found at detectable concentrations in shallow sediments (0-24 cm);
- PAH also reported in ng/g concentrations, and were greater in shallow sediments (0-24 cm), correlating to increased vehicle traffic, as well as other common sources of PAH;
- Pesticides were also measured in ng/g concentrations, and were higher in deeper sediments (24-64 cm), correlating to their decreased use in recent times, as well as change in land use from farming to residential;
- PFOS data were not provided, but was reported as being more prevalent in the top sediments;
- Identified Cd, Cr, and Zn as of most concern due to highest toxicity and concentrations; and
- Summarized previous reports.

5.0 SEDIMENT RESULTS

5.1 General Comments

A log of all samples collected, sampling depths, and analyses conducted is provided in Table 1. Sediment analytical results from all three studies are compared to numerical criteria/guidelines. Sampling locations are shown on Drawing 1. Drawing 2 shows the thickness of the sediments in the Pond. Sediment contamination is shown on Drawing 3. Cross-sections of the Pond sediments at specific transects are shown provided in the Camosun report, attached as Appendix D of this report.

Sampling methods used include Eckman sampler (Camosun work), Ponar sampler and the Wildco Core sampler (SLR work), and a plastic corer (Macdonald and Bruce). The Eckman and Ponar samplers typically collect samples of the top 10 cm, and these types of samplers include collection of detritus, roots, and aquatic plants. Core samplers allow for sampling at greater depths, although they may become blocked, limiting the depth of the sample. All types of samplers used are appropriate for the collection of sediment samples.

5.2 Laboratory Analytical Results

The analytical data from all three previous studies have been summarized in Tables 2 through 4 attached. Data have been compared to the CSR and CCME criteria and guidelines, respectively.

5.2.1 Metals

Table 2 presents metals analysis results in relation to both CSR criteria and CCME guidelines. In general, metals concentrations in sediments were about twice the CSR sensitive criteria and CCME PEL concentrations and over five times the CCME ISQG guidelines.

Except for one sample at 30-40 cm depth, all samples analysed (15), including grab samples, exceeded one or more criterion/guideline for Cd and Zn. Nine of the 15 samples exceeded one or more criterion/guideline for Pb and 13 of the 15 samples for Zn. Eleven of the 15 samples exceed the CCME (but not CSR) guidelines for Cu. One sample (30-40 cm depth) contained As exceeding the CSR SD_{fs} and three exceeded the CCME ISQG guideline but not the CSR SD_{ft} or SD_{fs} criteria. These data indicate that the accumulated sediments above the native material are all contaminated.

5.2.2 Polycyclic Aromatic Hydrocarbons

Table 3 presents PAH analysis results for the three samples collected. In summary, the results indicate:

- Five or more PAH parameters exceed the CCME and/or CSR guidelines/criteria in each sample analysed. In each case where the sediment PAH exceeded the CSR SDfs criteria, it exceeded by a small amount of <20%. The only exception was pyrene which exceeded by the CSR SDfs by about 25%; and
- Not enough samples were analyzed for PAH to allow observations regarding variability or trends in concentrations, if any. However, the concentrations of PAHs were relatively low compared to the guidelines, and the high TOC value indicates a low toxicity for these compounds.

5.2.3 Other Parameters

One sample was analyzed for total organic carbon (62 g/kg), one sample for orthophosphate (Table 4), and one sample for grain size analysis. One sample was analyzed for each parameter to indicate conditions that are typical of the area.

The grain size distribution results are included with the laboratory reports in the SLR 2015 report. The sample has 95% “fines” less than 0.075 mm and would be classified as a “silt loam”.

Since the previously-analysed samples for PCB, DDT, and other parameters (Macdonald and Bruce, 2015) are present in very low concentrations, the toxicity of the sediments is, for the most part, likely to come from the high metals contamination, there will be no further discussion of these other parameters, and the focus will be on the metals contamination.

5.2.4 Statistics

Sediment sampling has been carried out at a number of different depths in the pond. As can be seen from Table 5 the sediment is generally contaminated with metals at all depths and at similar concentrations. Only metals which contained concentrations exceeding the applicable criteria/guidelines were included (As, Cd, Cr, Cu, Pb, and Zn). For the purpose of the statistical analyses of the data, since analytical results for metals were relatively uniform throughout the sediments it was concluded that all samples were from one population and that the entire accumulated sediment mass is contaminated.

The results of the statistical analyses are summarized below:

- The sediment pH is consistent across the Pond;
- The greatest variability is in the Zn concentrations;
- The median and arithmetic mean concentrations for As and Cu are below the CSR freshwater sensitive criteria. The Pb median concentration exceeds the criteria and Pb arithmetic mean meets the criterion; and
- The median and arithmetic mean concentrations for the other metals above exceed the CSR freshwater sensitive criteria.

6.0 DISCUSSION

As previously discussed, since the metals are the predominant and highest relative to standards contaminant and are likely to cause the greatest toxicity/effect to aquatic organisms, the focus on the remediation planning should be related to these parameters. In addition, from a potential sediment disposal perspective, it is likely these parameters would dictate sediment disposal options and costs.

Since, to SLR’s knowledge, the pond has not been previously dredged, and since contamination is found throughout the depth of the accumulated sediments, it can be considered that the sediment contamination has been accumulating in the pond since the pond/dam was first constructed and since the Pat Bay Highway, the airport, and the associated industrial businesses were developed. In addition, the accumulation of sediment has been estimated at 0.33 cm per year and the average depth of sediment in approximately 88 cm above native material, while the pond is not as old as this rate of accumulation and average depth would indicate it is clear that the timeline extends beyond 1997.

SLR understands the source (VAA industrial lands) has been somewhat controlled via the creek diversion, wetland operation and periodic cleaning of their system. Other sources (neighborhood roadways and runoff) will remain unchanged, although these are likely less significant sources of contaminants.

The remedial options for the Pond are somewhat limited given it is in a well-established residential neighbourhood, with much of the upland access on private property. There also appears to be a relatively well established riparian zone around the pond. Anecdotal information indicates the general public wish to keep the pond environment (as opposed to reinstating it as a creek, with dam removal).

The additional work recommended in Section 7.0 will further determine whether toxicity/effect to aquatic organisms from the in-situ sediments are a factor to be considered in the evaluation of remedial options, and/or whether the water or other factors are having a significant influence on the pond environment.

Remedial alternatives that SLR currently considers may be available are:

- partial or complete removal of sediments;
- capping sediments in place; and
- risk assessment if the effects of existing contamination is low.

A more complete evaluation of remedial options can be completed after the recommended work is completed and may include the above alternatives, other alternatives that become apparent or some combination of these alternatives. Future assessment of alternatives would include a range of factors associated with acceptability, cost, regulatory and other factors.

7.0 DATA GAPS IDENTIFIED

Based on SLR's review of the existing data, SLR recommends additional work as follows:

Additional Sediment analyses:

- Chromium speciation (there are two main forms of chromium, Cr III and Cr VI, the latter being the more toxic); and
- Metals SEM/AVS analyses to determine the bioavailability of the sediment metals to aquatic organisms.

Additional water analyses:

- Dissolved oxygen concentration near sediment surface;
- Porewater - from sediments in top 10 to 50 cm - metals analyses;
- Surface water dissolved and total metals content;
- Surface water petroleum hydrocarbon analyses; and
- Chromium speciation (if significant chromium present in water).

Ecology:

- Plant identification and distribution survey (aquatic species);
- Zooplankton presence, relative abundance and identification; and
- Benthic invertebrate population analysis - this will be important in determining how diverse or not the benthic invertebrate species are which in turn indicates the relative health of the system.

Tissue analyses:

- Fish and/or invertebrates for metals content; and
- Plants (aquatic species) tissue analysis for metals content.

8.0 PROFESSIONAL STATEMENT

This data gap analysis report, prepared by SLR for the above-referenced site, was prepared by Ms. Jackie Smith, M.A.Sc., R.P.Bio., P.Ag. and Dr. James Malick, R.P.Bio., P.Ag. The authors of the report have over 65 years of combined experience in ecological investigations and the assessment and remediation of similar sites and are familiar with the work carried out for the subject site.

9.0 STATEMENT OF LIMITATIONS

This report has been prepared and the work referred to in this report has been undertaken by SLR for the Town of Sidney, hereafter referred to as the "Client". It is intended for the sole and exclusive use of the Client. Other than by the Client and as set out herein, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted without the express written permission of SLR.

This report has been prepared for specific application to this site and site conditions existing at the time work for the report was completed. Any conclusions or recommendations made in this report reflect SLR's professional opinion based on limited investigations including: visual observation of the site, surface and subsurface investigation at discrete locations and depths, and laboratory analysis of specific chemical parameters. The results cannot be extended to previous or future site conditions, portions of the site that were unavailable for direct investigation, subsurface locations which were not investigated directly, or chemical parameters and materials that were not addressed. Substances other than those addressed by the investigation may exist within the site; and substances addressed by the investigation may exist in areas of the site not investigated in concentrations that differ from those reported. SLR does not warranty information from third party sources used in the development of investigations and subsequent reporting.

Nothing in this report is intended to constitute or provide a legal opinion. SLR expresses no warranty to the accuracy of laboratory methodologies and analytical results. SLR makes no representation as to the requirements of compliance with environmental laws, rules, regulations, or policies established by federal, provincial, or local government bodies. Revisions to the regulatory standards referred to in this report may be expected over time. As a result, modifications to the findings, conclusions, and recommendations in this report may be necessary.

10.0 REFERENCES

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JAS/ijk

N:\Vancouver\Projects\Clients\201.02016.01 Sidney Reay Cr Pond Review\Reporting\
1. Reay Cr Pond Sediments Data Gap.2016-05-30.docx

TABLES

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001

TABLE 1: SEDIMENT SAMPLE LOG AND RECORD OF ANALYSIS

Sample Location ID	Sample ID	Sampler	Sample Depth (cm)	Metals Analysis	PAH Analysis	TOC Analysis	Grain Size Analysis
Core 1	Core 1	Macdonald and Bruce	0-24	1	0	0	0
Core 2	Core 2	Macdonald and Bruce	24-62	1	0	0	0
Middle Sediment	Middle Sediment	Camosun	0-10*	1	0	0	0
Dam Sediment	Dam Sediment	Camosun	0-10*	1	0	0	0
1G	1G	SLR	0-10	1	0	0	0
2C	-C	SLR	0-8	0	0	0	0
	-B	SLR	8-25	1	0	0	0
	-A	SLR	25-35	0	0	0	0
3C	-C	SLR	0-8	1	0	0	0
	-B	SLR	8-25	0	0	0	0
	-A	SLR	25-35	0	0	0	0
4C	-D	SLR	0-10	0	0	0	0
	-C	SLR	10-20	1	1	0	0
	-B	SLR	20-30	0	0	0	0
	-A	SLR	30-40	1	1	0	0
5G	5G	SLR	0-10	0	0	0	0
5C	-C	SLR	0-10	1	0	0	0
	-B	SLR	10-20	0	0	0	0
	-A	SLR	20-32	0	0	0	0
6C	-C	SLR	0-10	1	0	0	0
	-B	SLR	10-20	1	1	1	1
	-A	SLR	20-30	0	0	0	0
7C	-C	SLR	0-10	1	0	0	0
	-B	SLR	10-20	0	0	0	0
	-A	SLR	20-30	1	0	0	0
8G	8G	SLR	0-10	0	0	0	0
8C	-C	SLR	0-9	1	0	0	0
	-B	SLR	9-16	0	0	0	0
	-A	SLR	16-25	0	0	0	0
			Totals	**11**	**3**	**1**	**1**

Notes:

G - Grab Sample (Petite Ponar)
C - Core Sample (Wildco Corer)
PAH - polycyclic aromatic hydrocarbons
TOC - total organic carbon
Sample Depth - From Top of Sediment
* - samples collected with Eckman Grabber, assumed depth of collection noted here

TABLE 2: SEDIMENT CHEMISTRY RESULTS - METALS PARAMETERS (mg/kg)

Sample ID	Middle Sediment	Dam Sediment	Core 1 0 to 24 cm	Core 1 24-62 cm	1G	2C-B	3C-C	4C-A	4C-C	5C-C	6C-B	6C-C	7C-A	7C-C	8C-C	National - CCME Sediment		Provincial - CSR Sediment	
Date (dd-mmm-yyyy)	09-Jun-2010	09-Jun-2010	19-Sep-2013	19-Sep-2013	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	CCME ISQG FW	CCME PEL FW	CSR SDft	CSR SDfs
Sampler	Camosun	Camosun	Macdonald and Bruce	Macdonald and Bruce	SLR	SLR	SLR	SLR	SLR	SLR	SLR	SLR	SLR	SLR	SLR				
Depth (cm)	0-10	0-10	0-24	24-62	0-10	8-25	0-8	30-40	10--20	0-10	10-20	0-10	20-30	0-10	0-9	n/a	n/a	n/a	n/a.
pH	6.76	6.71	---	---	6.44	6.53	7.07	7.16	6.76	6.47	6.63	6.49	7.21	6.17	6.41	ns	ns	ns	ns
Aluminum	20600	23700	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Antimony	1.2	1.4	---	---	1.19	0.29	0.47	0.40	0.58	1.30	0.61	1.21	0.39	0.76	1.25	ns	ns	ns	ns
Arsenic	4.6	5.3	5.4	6.2	5.18	4.85	7.32	11.2	4.55	5.11	5.35	4.71	6.17	4.51	5.53	5.9	17	20	11
Barium	114	138	---	---	105	105	59.7	79.4	86.6	123	126	118	105	119	133	ns	ns	ns	ns
Beryllium	0.5	0.5	---	---	0.45	0.33	0.29	0.33	0.33	0.49	0.50	0.56	0.38	0.52	0.51	ns	ns	ns	ns
Bismuth	0.1	0.2	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Boron	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Cadmium	***21.5***	***18***	***27.9***	***34.2***	***22.1***	***19.8***	***26.0***	0.448	***17.3***	***24.7***	***42.1***	***21.4***	***14.1***	***35.3***	***19.7***	0.6	3.5	4.2	2.2
Chromium (+3)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Chromium (+6)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Chromium (total)	***115***	***107***	***148***	***190***	***146***	***90.6***	***144***	31.2	***130***	***134***	***153***	***119***	***141***	***153***	***111***	37.3	90	110	56
Cobalt	15	15.5	---	---	14.1	12.0	9.43	11.4	11.1	15.6	13.4	14.8	10.6	14.0	15.2	ns	ns	ns	ns
Copper	88.8	103	98.2	43.7	75.9	31.3	22.5	30.5	37.3	*99.8*	64.1	*93.9*	34.7	74.6	88.4	35.7	197	240	120
Iron	29300	34400	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Lead	*65.7*	*65*	*78.6*	37	53.9	16.5	13.9	16.1	25.3	63.4	58.6	60.7	19.7	64.6	68.2	35	91.3	110	57
Lithium	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Magnesium	7130	8180	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Manganese	474	783	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Mercury	0.09	0.12	0.06	0.066	0.100	< 0.05	< 0.05	< 0.05	0.056	0.128	0.098	0.129	0.055	0.112	0.124	0.17	0.486	0.58	0.3
Molybdenum	1.6	2.2	---	---	1.78	1.16	0.40	0.57	0.91	2.05	1.49	1.98	0.70	1.30	1.94	ns	ns	ns	ns
Nickel	34.5	38	---	---	33.3	19.9	18.5	23.4	22.7	38.5	34.1	38.2	23.9	36.0	37.3	ns	ns	ns	ns
Selenium	<0.5	<0.5	---	---	0.67	0.55	< 0.2	0.27	0.43	0.82	0.51	0.79	0.40	0.61	0.69	ns	ns	ns	ns
Silver	0.16	0.18	0.4	0.2	0.25	< 0.1	0.11	0.13	0.10	0.34	0.25	0.32	< 0.1	0.33	0.35	ns	ns	ns	ns
Strontium	51.4	52.5	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Thallium	0.08	0.1	---	---	0.085	0.064	0.097	0.053	0.065	0.102	0.089	0.106	0.071	0.103	0.097	ns	ns	ns	ns
Tin	1.4	1.5	1.8	1.1	2.2	< 2	< 2	< 2	< 2	< 2	2.2	< 2	< 2	3.0	*7.3*	ns	ns	ns	ns
Titanium	788	685	---	---	---	---	---	---	---	---	---	---	---	---	---	ns	ns	ns	ns
Uranium	---	---	---	---	1.09	0.822	0.534	0.648	0.810	1.17	1.02	1.12	0.972	0.961	1.34	ns	ns	ns	ns
Vanadium	69	77	---	---	76.4	56.0	50.1	65.9	55.2	77.7	81.8	78.5	62.2	76.3	80.3	ns	ns	ns	ns
Zinc	***701***	***741***	***741***	*234*	**519**	181	90.7	97.5	*218*	***700***	***347***	***639***	146	***480***	***603***	123	315	380	200

Notes:
mg/kg - milligrams per dry kilogram
cm - centimetres
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
n/a - not applicable

Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG).

Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL).

Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical.

Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive.

TABLE 3: SEDIMENT CHEMISTRY RESULTS - PAH PARAMETERS (mg/kg)

Sample ID	**4C-A**	**4C-C**	**6C-B**	**National - CCME Sediment**		**Provincial - CSR Sediment**	
Date (dd-mmm-yyyy)	**15-Jan-2015**	**15-Jan-2015**	**15-Jan-2015**	**CCME ISQG FW**	**CCME PEL FW**	**CSR SDft**	**CSR SDfs**
Depth (cm)	30-40	10-20	10-20	**n/a**	**n/a**	**n/a**	**n/a**
Acenaphthene	< 0.05	< 0.05	< 0.05	**0.00671**	**0.0889**	**0.11**	**0.055**
Acenaphthylene	< 0.05	< 0.05	< 0.05	**0.00587**	**0.128**	**0.15**	**0.08**
Acridine	---	---	---	**ns**	**ns**	**ns**	**ns**
Anthracene	< 0.05	< 0.05	< 0.05	**0.0469**	**0.245**	**0.29**	**0.15**
Benz(a)anthracene	0.051	< 0.05	0.252	**0.0317**	**0.385**	**0.46**	**0.24**
Benzo(a)pyrene	0.064	0.051	*0.440*	**0.0319**	**0.782**	**0.94**	**0.48**
Benzo(b)fluoranthene	0.117	*0.106*	*0.832*	**ns**	**ns**	**ns**	**ns**
Benzo(g,h,i)perylene	0.051	< 0.05	0.355	**ns**	**ns**	**ns**	**ns**
Benzo(k)fluoranthene	< 0.05	< 0.05	*0.264*	**ns**	**ns**	**ns**	**ns**
Chrysene	0.087	0.075	0.507	**0.0571**	**0.862**	**1**	**0.53**
Dibenz(a,h)anthracene	< 0.05	< 0.05	0.056	**0.00622**	**0.135**	**0.16**	**0.084**
Fluoranthene	0.106	0.133	0.806	**0.111**	**2.355**	**2.8**	**1.5**
Fluorene	< 0.05	< 0.05	< 0.05	**0.0212**	**0.144**	**0.17**	**0.089**
Indeno(1,2,3-c,d)pyrene	0.053	0.052	*0.398*	**ns**	**ns**	**ns**	**ns**
1-Methylnaphthalene	---	---	---	**ns**	**ns**	**ns**	**ns**
2-Methylnaphthalene	< 0.05	< 0.05	< 0.05	**0.0202**	**0.201**	**0.24**	**0.12**
Naphthalene	< 0.05	< 0.05	< 0.05	**0.0346**	**0.391**	**0.47**	**0.24**
Phenanthrene	0.067	0.099	0.352	**0.0419**	**0.515**	**0.62**	**0.32**
Pyrene	0.101	0.116	0.728	**0.053**	**0.875**	**1.1**	**0.54**
PAHs, Total	---	---	---	**ns**	**ns**	**20**	**10**

Notes:
PAH - polycyclic aromatic hydrocarbons
mg/kg - milligrams per dry kilogram
cm - centimetres
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard/guideline listed
n/a - not applicable

Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG).

Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL).

Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical.

Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive.

TABLE 4: SEDIMENT CHEMISTRY RESULTS - OTHER PARAMETERS (mg/kg)

Sample ID	Middle Sediment	6C-B	National - CCME Sediment		Provincial - CSR Sediment	
Sampler	**Camosun**	**SLR**				
Date (dd-mmm-yyyy)	**09-Jun-2010**	**15-Jan-2015**	**CCME ISQG FW**	**CCME PEL FW**	**CSR SDft**	**CSR SDfs**
Depth (cm)	0-10	10-20	**n/a**	**n/a**	**n/a**	**n/a**
Orthophosphate	60.5	---	**ns**	**ns**	**ns**	**ns**
Organic Carbon, Total	---	5.33	**ns**	**ns**	**ns**	**ns**

Notes:

mg/kg - milligrams per kilogram
'---' - sample not analyzed for parameter indicated
CCME - Canadian Council of Ministers of the Environment
CSR - Contaminated Sites Regulation
ISQG FW - Interim Sediment Quality Guidelines Freshwater
PEL FW - Freshwater Probable Effect Levels
CSR SD_{ft} - Contaminated Sites Regulation freshwater typical standards
CSR SD_{fs} - Contaminated Sites Regulation freshwater sensitive standards
ns - no standard listed
n/a - not applicable

TABLE 5: STATISTICAL ANALYSES - METALS PARAMETERS (mg/kg)

Sample ID	Core 1 0-24 cm	Core 1 24-62 cm	Middle Sediment	Dam Sediment	1G	2C-B	3C-C	4C-A	4C-C	5C-C	6C-B	6C-C	7C-A	7C-C	8C-C	Minimum	Maximum	Median	Arithmetic Mean	90th Percentile	Standard Deviation	CSR SDfs
Depth (cm)	0-24	24-62	0-10	0-10	0-10	8-25	0-8	30-40	10--20	0-10	10-20	0-10	20-30	0-10	0-9	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
pH	---	---	6.76	6.71	6.44	6.53	7.07	7.16	6.76	6.47	6.63	6.49	7.21	6.17	6.41	6.17	7.21	6.63	6.678	7.142	0.313	**N/A**
Arsenic	5.4	6.2	4.6	5.3	5.18	4.85	7.32	11.2	4.55	5.11	5.35	4.71	6.17	4.51	5.53	4.51	11.2	5.3	5.732	6.872	1.690	**11**
Cadmium	***27.9***	***34.2***	***21.5***	***18***	***22.1***	***19.8***	***26***	0.448	***17.3***	***24.7***	***42.1***	***21.4***	***14.1***	***35.3***	***19.7***	0.448	42.1	21.5	22.970	34.86	9.818	**2**
Chromium (total)	***148***	***190***	***115***	***107***	***146***	***90.6***	***144***	31.2	***130***	***134***	***153***	***119***	***141***	***153***	***111***	31.2	153	134	127.520	153	35.885	**56**
Copper	98.2	43.7	88.8	103	75.9	31.3	22.5	30.5	37.3	*99.8*	64.1	*93.9*	34.7	74.6	88.4	22.5	103	74.6	65.780	99.16	29.496	**120**
Lead	*78.6*	37	*65.7*	*65*	53.9	16.5	13.9	16.1	25.3	63.4	58.6	60.7	19.7	64.6	68.2	13.9	68.2	58.6	47.147	67.2	22.939	**57**
Zinc	***741***	*234*	***701***	***741***	**519**	181	90.7	97.5	*218*	***700***	***347***	***639***	146	***480***	***603***	90.7	741	480	429.213	725	251.054	**200**

Notes:

mg/kg - milligrams per dry kilogram
cm - centimetres
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
n/a - not applicable

Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG).

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Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical.

Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive.

DRAWINGS

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001

NOTES:
REFERENCED FROM: CAPITAL REGIONAL DISTRICT, REGIONAL COMMUNITY ATLAS

LEGAL DESCRIPTION:
SECTION 8, RANGE 3 EAST, NORTH SAANICH DISTRICT
PID: 000-213-365

LEGEND:

●C	CORE SAMPLE LOCATION (2015, SLR)
◉C	CORE SAMPLE LOCATION (2013, MACDONALD & BRUCE)
◆G	GRAB SAMPLE LOCATION (2015, SLR)
X	SEDIMENT SAMPLE LOCATION (2010, ROBINSON AND SARRAZIN)
- - -	APPROXIMATE LOCATION OF 2010 CAMOSUM COLLEGE STUDY TRANSECT (*REAY CREEK POND REMEDIATION STUDY*. ENVIRONMENTAL TECHNOLOGY PROGRAM. , JUSTIN ROBINSON & RACHELLE SARRAZIN. JUNE 2010)

0 5 10 20 30 40 m

SCALE 1:750
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 10N

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

TOWN OF SIDNEY
REAY CREEK POND, REAY CREEK PARK - CANORA ROAD BETWEEN NORTHBROOK DRIVE AND BOWCOTT PLACE SIDNEY, BC

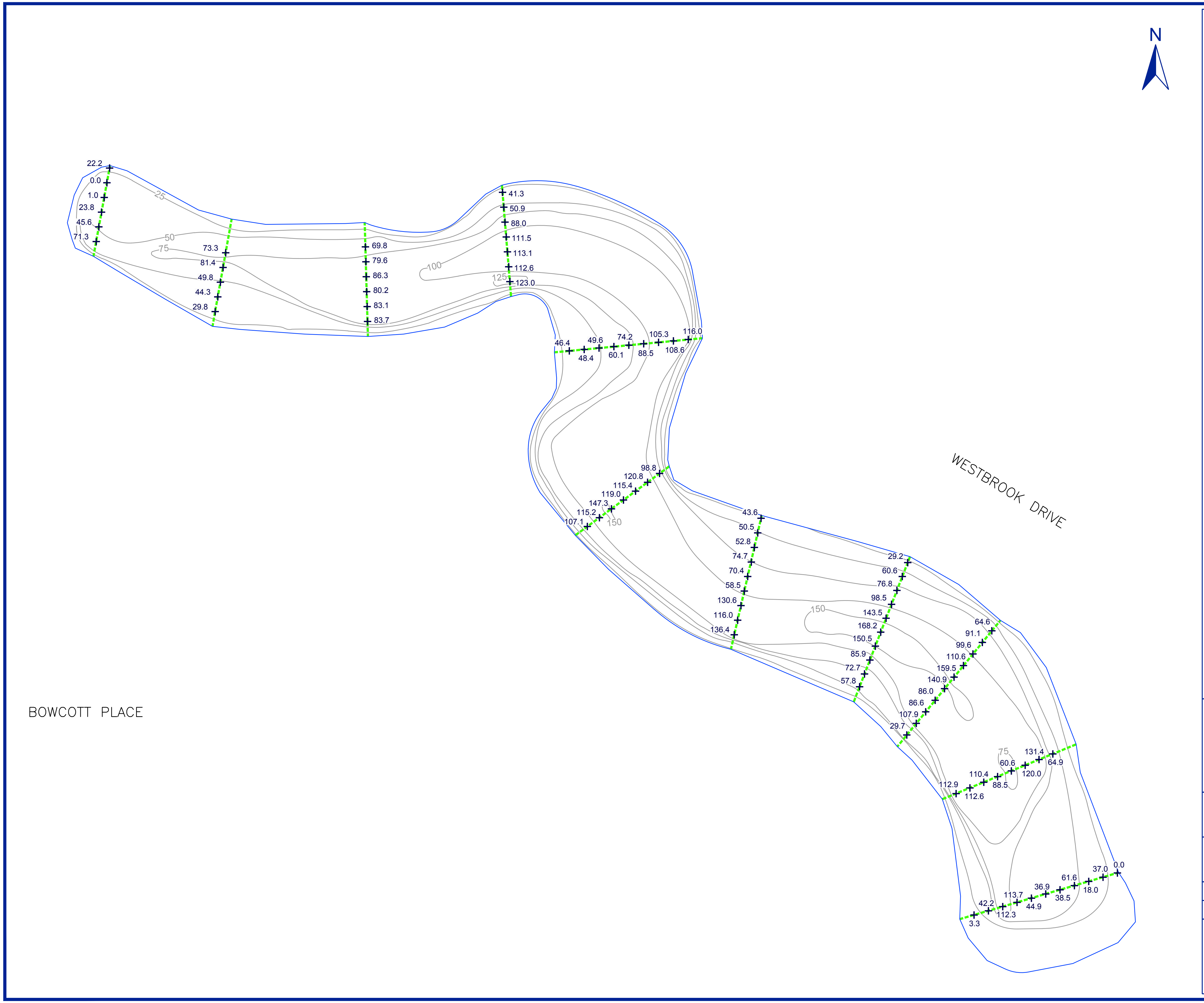
DATA GAP ANALYSIS

SEDIMENT SAMPLING LOCATIONS

Date:	March 23, 2016	Drawing No. 1
Project No.	201.02016.00001	

SLR
global environmental solutions

Cadfile name: S_201-02016-00001-A1.dwg



Cadfile name: S_201-02016-00001-A1.dwg

NOTES:
REFERENCED FROM: CAPITAL REGIONAL DISTRICT, REGIONAL COMMUNITY ATLAS

LEGAL DESCRIPTION:
SECTION 8, RANGE 3 EAST, NORTH SAANICH DISTRICT
PID: 000-213-365

LEGEND:

APPROXIMATE LOCATION OF 2010 CAMOSUM COLLEGE STUDY TRANSECT (*REAY CREEK POND REMEDIATION STUDY*. ENVIRONMENTAL TECHNOLOGY PROGRAM. , MACDONALINSON & RACHELLE SARRAZIN. JUNE 2010)

25 CONTOUR (25cm INTERVAL)

+83.7 SEDIMENT DEPTH (cm)

0 5 10 20 30 m

SCALE 1:500
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 10N

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

TOWN OF SIDNEY
REAY CREEK POND, REAY CREEK PARK - CANORA ROAD BETWEEN NORTHBROOK DRIVE AND BOWCOTT PLACE
SIDNEY, BC

DATA GAP ANALYSIS

THICKNESS OF SEDIMENT – CONTOURS

Date: March 23, 2016	Drawing No.
Project No. 201.02016.00001	2

SLR
global environmental solutions

NOTES:
REFERENCED FROM: CAPITAL REGIONAL DISTRICT, REGIONAL COMMUNITY ATLAS

LEGAL DESCRIPTION:
SECTION 8, RANGE 3 EAST, NORTH SAANICH DISTRICT
PID: 000-213-365

LEGEND:

●C	CORE SAMPLE LOCATION (2015, SLR)
◉C	CORE SAMPLE LOCATION (2013, MACDONALD & BRUCE)
◆G	GRAB SAMPLE LOCATION (2015, SLR)
X	SEDIMENT SAMPLE LOCATION (2010, ROBINSON AND SARRAZIN)
- - -	APPROXIMATE LOCATION OF 2010 CAMOSUM COLLEGE STUDY TRANSECT (*REAY CREEK POND REMEDIATION STUDY*. ENVIRONMENTAL TECHNOLOGY PROGRAM. , JUSTIN ROBINSON & RACHELLE SARRAZIN. JUNE 2010)
	SEDIMENT LABORATORY ANALYSIS RESULTS
○	CONCENTRATION(S) GREATER THAN APPLICABLE SDfs STANDARD(S)
○	CONCENTRATION(S) GREATER THAN APPLICABLE SDft STANDARD(S)
0-10cm	DEPTH OF SAMPLE COLLECTED (cm)

0 5 10 20 30 40 m
SCALE 1:750
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 10N

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

TOWN OF SIDNEY
REAY CREEK POND, REAY CREEK PARK - CANORA ROAD BETWEEN NORTHBROOK DRIVE AND BOWCOTT PLACE SIDNEY, BC

DATA GAP ANALYSIS

ANALYTICAL RESTULS (0-24CM)

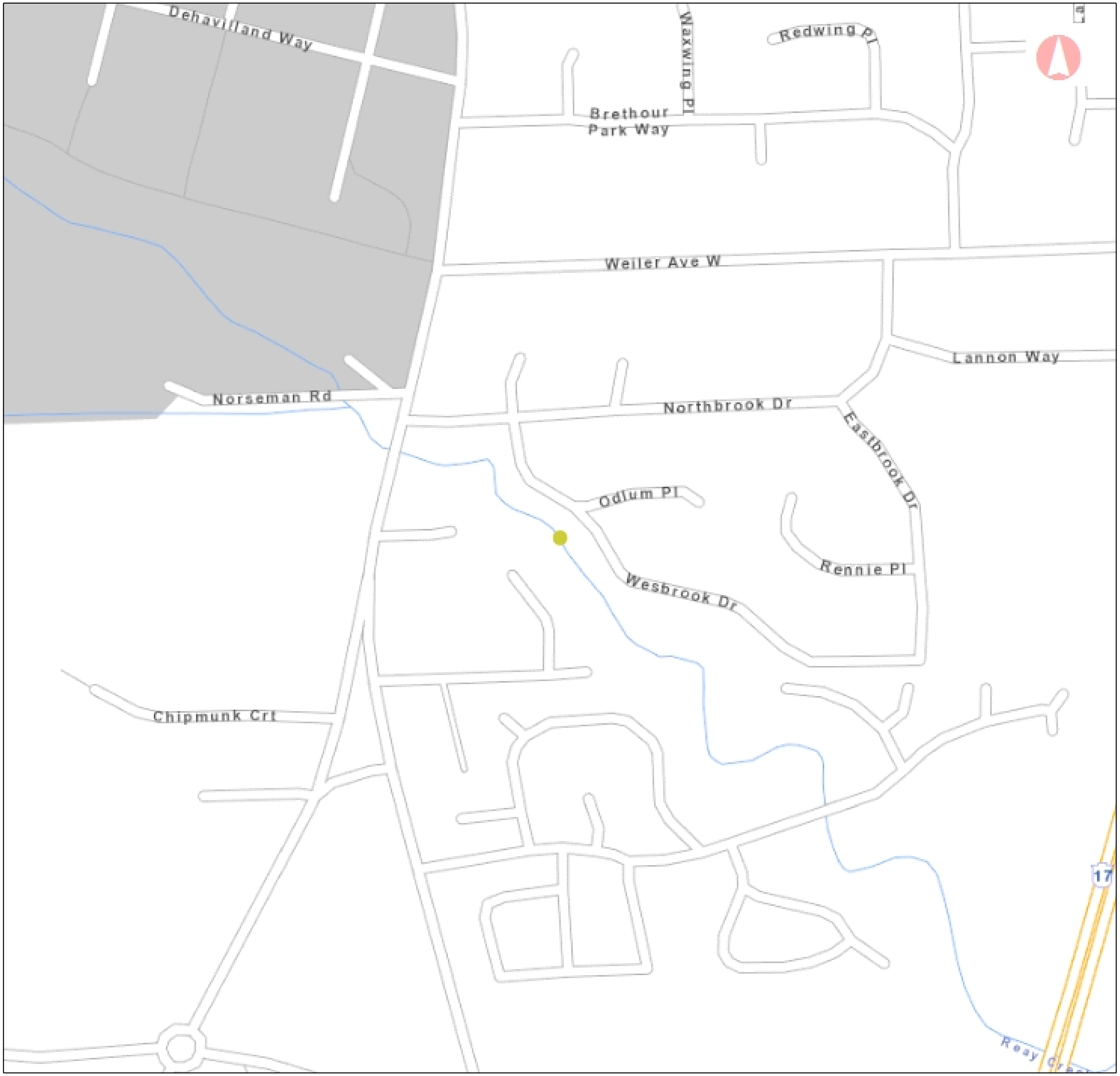
Date: March 23, 2016
Project No. 201.02016.00001
Drawing No. 3

SLR
global environmental solutions

Cadfile name: S_201-02016-00001-A1.dwg

APPENDIX A
Point of Diversion

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001



BRITISH COLUMBIA

iMapBC Mapping

Legend

Water Licence Points of Dive
Water Sources

STATUS

● Active Application

● Active Application and Licence

● Active Licence

Water Licence Points of Dive

STATUS

● Active Application

● Active Application and Licence

● Active Licence

● Inactive

Water Licence Points of Dive
Utilities

STATUS

0 0.10 0.20 km

1: 5,000

Copyright/Disclaimer

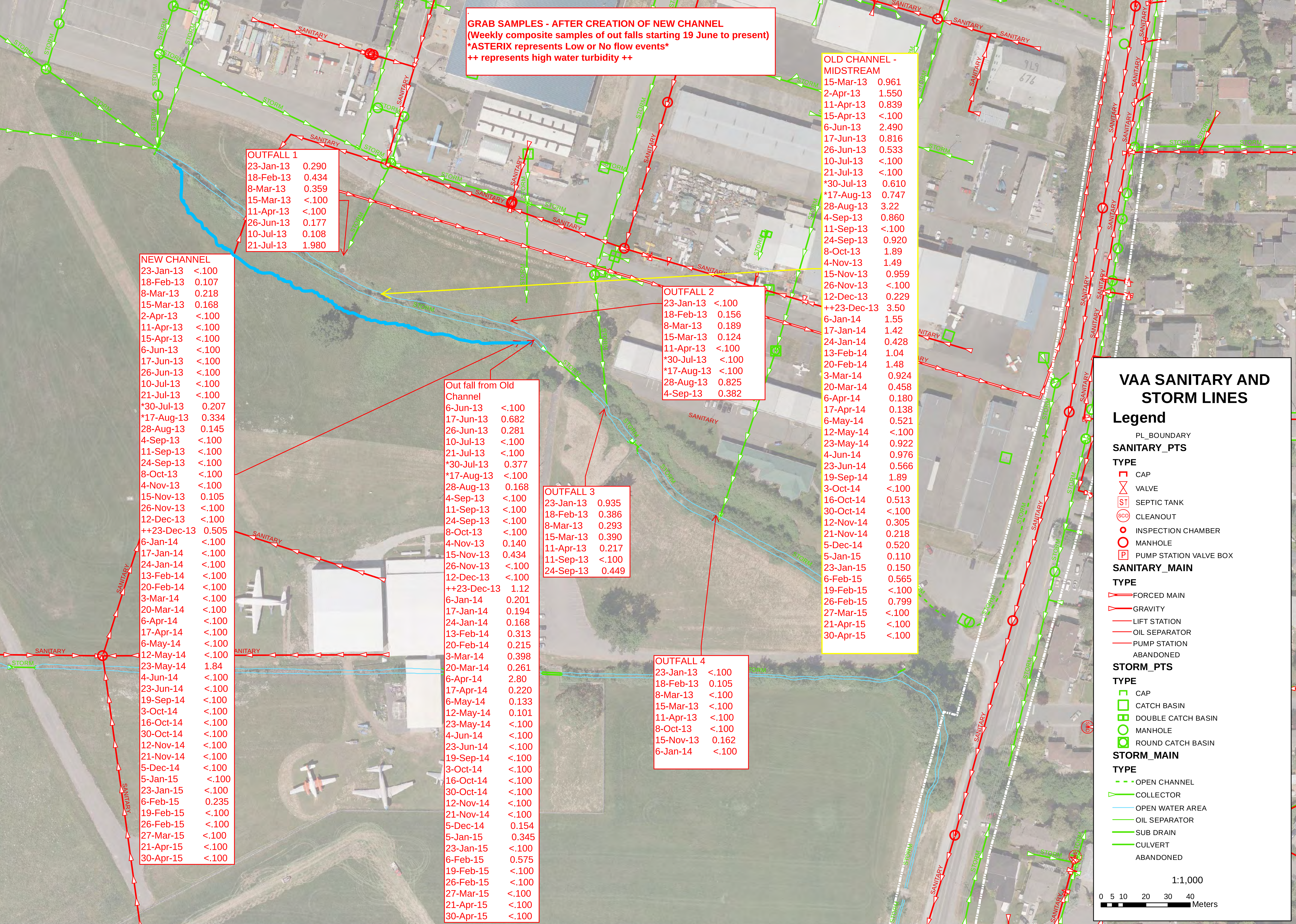
Datum: NAD83
Projection: NAD_1983_BC_Environment_Albers

Key Map of British Columbia

Field Name	Field Value
UNITS	MY
STREAM_NAME	Reay Creek
STATUS L	
REDIV_FLAG	N
QUANTITY	3700.43994140625
QTY_FLAG	T
PURPOSE	CONSERVATION: CONSTRUCT W
PROC_STATUS	N/A
PRIORITY_DATE	19870120
POSTAL_CODE	V8L1Y7
PNTS_CODE	PD33776
PCL_NO	
OBJECTID	67756
MAPSHEET_POD	8793A N4 (PD33776)
LICENSEE	TOWN OF SIDNEY
LICENCE_NO	C064092
LIC_STATUS	CURRENT
LIC_STAT_DATE	19910125
LIC_APPL_FLAG L	
GEOMETRY	Point
FLAG_DESC	Total demand one POD
FILE_NO	1000682
FEATURE_CODE	
EXPIRY_DATE	
DIST_PREC_NAME	VIC - VICTORIA
COUNTRY	
ADDRESS_LINE4	
ADDRESS_LINE3	
ADDRESS_LINE2	SIDNEY BC
ADDRESS_LINE1	2440 SIDNEY AVE

APPENDIX B
VAA Site Plan and Chromium Data (2015)

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001



VAA SANITARY AND STORM LINES

GRAB SAMPLES - AFTER CREATION OF NEW CHANNEL
(Weekly composite samples of out falls starting 19 June to present)
ASTERIX represents Low or No flow events
++ represents high water turbidity ++

OUTFALL 1	
23-Jan-13	0.290
18-Feb-13	0.434
8-Mar-13	0.359
15-Mar-13	<.100
11-Apr-13	<.100
26-Jun-13	0.177
10-Jul-13	0.108
21-Jul-13	1.980

NEW CHANNEL	
23-Jan-13	<.100
18-Feb-13	0.107
8-Mar-13	0.218
15-Mar-13	0.168
2-Apr-13	<.100
11-Apr-13	<.100
15-Apr-13	<.100
6-Jun-13	<.100
17-Jun-13	<.100
26-Jun-13	<.100
10-Jul-13	<.100
21-Jul-13	<.100
*30-Jul-13	0.207
*17-Aug-13	0.334
28-Aug-13	0.145
4-Sep-13	<.100
11-Sep-13	<.100
24-Sep-13	<.100
8-Oct-13	<.100
4-Nov-13	<.100
15-Nov-13	0.105
26-Nov-13	<.100
12-Dec-13	<.100
++23-Dec-13	0.505
6-Jan-14	<.100
17-Jan-14	<.100
24-Jan-14	<.100
13-Feb-14	<.100
20-Feb-14	<.100
3-Mar-14	<.100
20-Mar-14	<.100
6-Apr-14	<.100
17-Apr-14	<.100
6-May-14	<.100
12-May-14	<.100
23-May-14	1.84
4-Jun-14	<.100
23-Jun-14	<.100
19-Sep-14	<.100
3-Oct-14	<.100
16-Oct-14	<.100
30-Oct-14	<.100
12-Nov-14	<.100
21-Nov-14	<.100
5-Dec-14	<.100
5-Jan-15	<.100
23-Jan-15	<.100
6-Feb-15	0.235
19-Feb-15	<.100
26-Feb-15	<.100
27-Mar-15	<.100
21-Apr-15	<.100
30-Apr-15	<.100

Out fall from Old Channel	
6-Jun-13	<.100
17-Jun-13	0.682
26-Jun-13	0.281
10-Jul-13	<.100
21-Jul-13	<.100
*30-Jul-13	0.377
*17-Aug-13	<.100
28-Aug-13	0.168
4-Sep-13	<.100
11-Sep-13	<.100
24-Sep-13	<.100
8-Oct-13	<.100
4-Nov-13	0.140
15-Nov-13	0.434
26-Nov-13	<.100
12-Dec-13	<.100
++23-Dec-13	1.12
6-Jan-14	0.201
17-Jan-14	0.194
24-Jan-14	0.168
13-Feb-14	0.313
20-Feb-14	0.215
3-Mar-14	0.398
20-Mar-14	0.261
6-Apr-14	2.80
17-Apr-14	0.220
6-May-14	0.133
12-May-14	0.101
23-May-14	<.100
4-Jun-14	<.100
23-Jun-14	<.100
19-Sep-14	<.100
3-Oct-14	<.100
16-Oct-14	<.100
30-Oct-14	<.100
12-Nov-14	<.100
21-Nov-14	<.100
5-Dec-14	0.154
5-Jan-15	0.345
23-Jan-15	<.100
6-Feb-15	0.575
19-Feb-15	<.100
26-Feb-15	<.100
27-Mar-15	<.100
21-Apr-15	<.100
30-Apr-15	<.100

OUTFALL 3	
23-Jan-13	0.935
18-Feb-13	0.386
8-Mar-13	0.293
15-Mar-13	0.390
11-Apr-13	0.217
11-Sep-13	<.100
24-Sep-13	0.449

OUTFALL 2	
23-Jan-13	<.100
18-Feb-13	0.156
8-Mar-13	0.189
15-Mar-13	0.124
11-Apr-13	<.100
*30-Jul-13	<.100
*17-Aug-13	<.100
28-Aug-13	0.825
4-Sep-13	0.382

OUTFALL 4	
23-Jan-13	<.100
18-Feb-13	0.105
8-Mar-13	<.100
15-Mar-13	<.100
11-Apr-13	<.100
8-Oct-13	<.100
15-Nov-13	0.162
6-Jan-14	<.100

OLD CHANNEL - MIDSTREAM	
15-Mar-13	0.961
2-Apr-13	1.550
11-Apr-13	0.839
15-Apr-13	<.100
6-Jun-13	2.490
17-Jun-13	0.816
26-Jun-13	0.533
10-Jul-13	<.100
21-Jul-13	<.100
*30-Jul-13	0.610
*17-Aug-13	0.747
28-Aug-13	3.22
4-Sep-13	0.860
11-Sep-13	<.100
24-Sep-13	0.920
8-Oct-13	1.89
4-Nov-13	1.49
15-Nov-13	0.959
26-Nov-13	<.100
12-Dec-13	0.229
++23-Dec-13	3.50
6-Jan-14	1.55
17-Jan-14	1.42
24-Jan-14	0.428
13-Feb-14	1.04
20-Feb-14	1.48
3-Mar-14	0.924
20-Mar-14	0.458
6-Apr-14	0.180
17-Apr-14	0.138
6-May-14	0.521
12-May-14	<.100
23-May-14	0.922
4-Jun-14	0.976
23-Jun-14	0.566
19-Sep-14	1.89
3-Oct-14	<.100
16-Oct-14	0.513
30-Oct-14	<.100
12-Nov-14	0.305
21-Nov-14	0.218
5-Dec-14	0.520
5-Jan-15	0.110
23-Jan-15	0.150
6-Feb-15	0.565
19-Feb-15	<.100
26-Feb-15	0.799
27-Mar-15	<.100
21-Apr-15	<.100
30-Apr-15	<.100

Legend

PL_BOUNDARY

SANITARY_PTS

TYPE

- CAP
- VALVE
- ST SEPTIC TANK
- SCO CLEANOUT
- INSPECTION CHAMBER
- MANHOLE
- P PUMP STATION VALVE BOX

SANITARY_MAIN

TYPE

- FORCED MAIN
- GRAVITY
- LIFT STATION
- OIL SEPARATOR
- PUMP STATION
- ABANDONED

STORM_PTS

TYPE

- CAP
- CATCH BASIN
- DOUBLE CATCH BASIN
- MANHOLE
- ROUND CATCH BASIN

STORM_MAIN

TYPE

- OPEN CHANNEL
- COLLECTOR
- OPEN WATER AREA
- OIL SEPARATOR
- SUB DRAIN
- CULVERT
- ABANDONED

1:1,000

0 5 10 20 30 40 Meters

APPENDIX C
SLR VAA Property Reports (2012)

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001

SLR Consulting (Canada) Ltd.
6-40 Cadillac Avenue
Victoria, BC V8Z 1T2

Tel: (250) 475-9595
Fax: (250) 475-9596

Memorandum

To:	Michelle Bigg	**From:**	David McKeown
Company:	Fisheries and Oceans Canada		
cc:	James Bogusz (VAA)	**Date:**	June 21, 2012
Subject:	***REAY CREEK CHANNEL REHABILITATION – INFORMATION FOR FISHERIES AND OCEANS CANADA PRELIMINARY REVIEW***		

Dear Ms. Bigg,

On behalf of the Victoria Airport Authority (VAA), the consulting team[1] has included a brief overview of the proposed Reay Creek channel mitigation work. Please find below a summary of the proposed work program and initial concept plan for review by Fisheries and Oceans Canada (FOC). Several letters of support for the project are also included with this submission. We are eager to work closely with FOC to facilitate this restoration project and would appreciate a response at your earliest convenience with respect to approval process requirements.

Project Rationale:

The Reay Creek Channel Rehabilitation project is being conducted to aid in mitigation of historic heavy metal contamination entering Reay Creek from stormwater drainage of adjacent airport lands.

Objectives:

The primary project objectives include the following:

- Develop remediation measures to reduce heavy metal and other pollutant concentrations in stormwater runoff from the East Industrial Area (located north of the existing channel) and the eastern half of the airport property;

---

[1] Consulting team consists of Kerr Wood Leidal Associates Ltd., SLR Consulting (Canada) Ltd., and Murdoch DeGreeff Inc.

- Construct 210 m of new channel to bypass the existing channel that receives potentially contaminated stormwater from the East Industrial Area;
- Prevent fish access to the wetland treatment cell in the old channel but incorporate fish and riparian habitat features in the bypass channel for potential fish habitat;
- Incorporate bio-remediation techniques into the old channel remediation design to provide water quality treatment while limiting bird and wildlife conflicts with airport operations;
- Incorporate and/or plan for hydraulic control structures which could be used to limit the impact of spills or other emergent events;
- Conduct and implement the project utilizing appropriate best management practices and mitigation measures to ensure protection of fish and fish habitat during construction activities; and
- Develop an on-going monitoring plan to measure the effectiveness of the remediation project and consider an adaptive management plan to provide strategies to improve overall effectiveness of the remediation approach.

Reay Creek Watershed:

The Reay Creek watershed drains an area of approximately 119 ha. The eastern half of the Victoria Airport property, including runways, aprons and the East Camp Industrial Area (see Figure 1). A small tributary enters Reay Creek immediately upstream of the airport property boundary. The tributary drains the northern slopes of Mount Newton and the south-eastern part of the VAA property. Downstream of the VAA property, Reay Creek flows through several constructed ponds and a wetland before flowing into Bazan Bay. The project area is located in the upper reach of the creek.

Existing Habitat Condition:

The existing upper section of Reay Creek consists of a very low gradient channel (0.7% gradient) approximately 2 to 3 m in width (at high water mark). The area of focus is the open channel which runs parallel to the south of Goose Road from the stormwater sewer outfall at the upstream end to the service road crossing at the downstream end. Flows within the creek are considerably variable depending on precipitation events (~2.0 m^3/s for peak flow events) and may become dry during prolonged periods of drought. The majority of flow is derived from runoff from the airport runway landscape and is delivered to the stream via 600 mm, 750 mm, and 1,350 mm diameter stormdrains. This small stream also receives runoff from four smaller stormdrains that service the Eastern Industrial lands of the airport property.

Several blockages to fish passage, such as culverts and dams as identified through the BC Conservation Data Centre mapping resource, exist downstream of the project area. However, coho spawners have been observed to enter the upper sections of Reay Creek only once (2001).

The existing channel is considered to be in poor ecological condition. The stream habitat is classified as 100% glide habitat with no riffles or deep pools. The channel is confined with little or no flood plain. Substrates consist of silt and mud sediments with varying organic components. There is no spawning habitat and very limited rearing habitat present within this section of the creek. Overstream cover is generally good but is comprised of a mix of native and invasive plant species. Riparian habitat is limited to approximately 5 m wide zones adjacent to the stream and consists of a mix of Nootka Rose, Snowberry and invasive Himalayan Blackberry. There is no large woody debris (LWD) within the channel nor is there the potential for recruitment from the existing riparian plan community. One large mature oak tree exists south of the existing channel. This tree will be retained as per the concept design.

The most significant issue with this section of Reay Creek is that it has been impacted by heavy metal contamination as a result of stormwater discharges from the adjacent industrial lands. In the past several years, the Victoria Airport Authority (VAA) has undertaken numerous studies and actions to identify and remove the source of the metals contamination, worked with industrial lease holders to implement source controls for contaminants, and cleaned the suspect stormdrains to remove contamination from within the pipe system. However, elevated metals concentrations still exist within the existing creek sediments and occasional exceedances of various parameters, including dissolved metals, have been noted historically within Reay Creek. Sediment contamination in the channel varies, but metal concentrations, primarily cadmium, have been noted in excess of CCME Sediment Quality Guidelines for the Protection of Aquatic Life (CCME SQG AW). The existing channel in its current state may be a continued source of metals contamination for downstream habitat and fish populations. The VAA is proposing to build a new channel adjacent to the impacted existing channel. Construction of the new channel will isolate the old contaminated channel from major stream flows and provide for treatment opportunities. Considerations for including a diverter system will also be included in the design phase of the project in order to provide storage capacity within the existing channel in the event of a spill within the creek’s upper catchment area or the East Camp Industrial Area. The intent is to enhance the remnant channel and develop it into a bioremediation wetland. The following table compares existing and proposed habitat values for the site. Much of the riparian area surrounding the existing channel will remain in-tact as disturbance to these areas is not anticipated to be required. New habitat will be created through construction of the diversion channel and additional seeding and planting. Existing degraded habitat will continue to function as it will be retained and converted into a bioremediation wetland which will provide water quality improvement opportunities.

Table 1: Existing and proposed additional habitat areas for Reay Creek channel enhancement work.

HABITAT TYPE	EXISTING	PROPOSED
Open Channel Water	423 sq m	430 sq m
Bioremediation Wetland	0	490 sq m
Total Aquatic Area	*423 sq m*	*920 sq m*
Riparian Area	1,471 sq m	1,766 sq m
Trees	1 Garry Oak	1 Garry Oak (retained)
	0	20 Red Alder

Concept Design:

A concept design has been developed for the completion of the creek realignment project and is appended to this document (see Figure 2). The new channel is constrained by the elevation of the existing stormdrain at the upstream end of the site and the 1,800 mm diameter culvert under a service road at the downstream end of the reach. The channel gradient will remain the same at 0.7% gradient, incorporating two or three riffle structures to reduce potential channel erosion and perhaps provide support for future spawning beds. New riparian plantings will provide both ecological (wildlife habitat, riparian cover, and shade) and bank stabilizing benefits. The goal is to shade the new channel as quickly as possible after construction to help keep water temperatures cool for downstream fish populations. Areas outside of the planted areas would be seeded with suitable meadow grass seed mix. Most importantly, a potential source of pollution for the remainder of the watershed will be isolated for treatment in the bioremediation wetland.

Opportunities for partnerships with local groups such as Peninsula Streams Society and local school programs will be sought to aid in providing additional plantings and educational opportunities.

The design team will also work proactively to incorporate any modifications suggested by FOC to the extent possible in order to better accommodate potential habitat considerations or to decrease any potential for impact to existing habitat resources within the watershed.

Methods, Equipment and Materials:

The new channel will be constructed with the use of appropriate excavating machinery. A test pitting program has been conducted within the general alignment of the new channel to determine soil conditions associated with construction of the diversion channel. Construction of the new channel will be conducted in isolation of the existing creek flow until such time as it is ready to receive inputs from the main upstream stormwater outfall.

The new channel will be designed to control flow velocities through addition of floodplain benches and riffle structures. The new channel will also provide stormwater management capacity and will include erosion control measures such as biodegradable erosion control matting and riparian plantings to provide bank stability and riparian cover.

All appropriate mitigation measures and best management practices associated with the construction of the new channel and the bioremediation wetland will be employed including those set forth in DFO's Land Development Guidelines for the Protection of Aquatic Habitat. Prior to initiation of construction works, a Spill Contingency and Response Plan and a Sediment and Erosion Control Plan will be developed and implemented.

Timing and Sequencing:

The Reay Creek Realignment project has recently been initiated. The consulting team is currently working towards preparing a preliminary design for the project, which is anticipated to be completed by late July.

Construction of the new channel is planned to commence on August 15 and all works are anticipated to be completed by September 15 within the reduced risk work window to capitalize on this lowered period of sensitivity to in-stream environmental resources.

Monitoring:

A Qualified Environmental Monitor will conduct monitoring of construction activities throughout the project. A Sediment and Erosion Control Plan will be prepared prior to initiation of the construction works as well as a Spill Contingency and Control Plan. All pertinent Best Management Practices and mitigation measures identified in applicable Operational Statements and the DFO Land Development Guidelines for the Protection of Aquatic Habitat will be implemented for this project. The Environmental Monitor will conduct periodic site inspections to verify that these measures are properly placed and maintained.

A follow-up monitoring plan will also be prepared as part of this project that will include assessments of water quality, vegetation establishment, and fisheries resources following construction of the newly created channel.

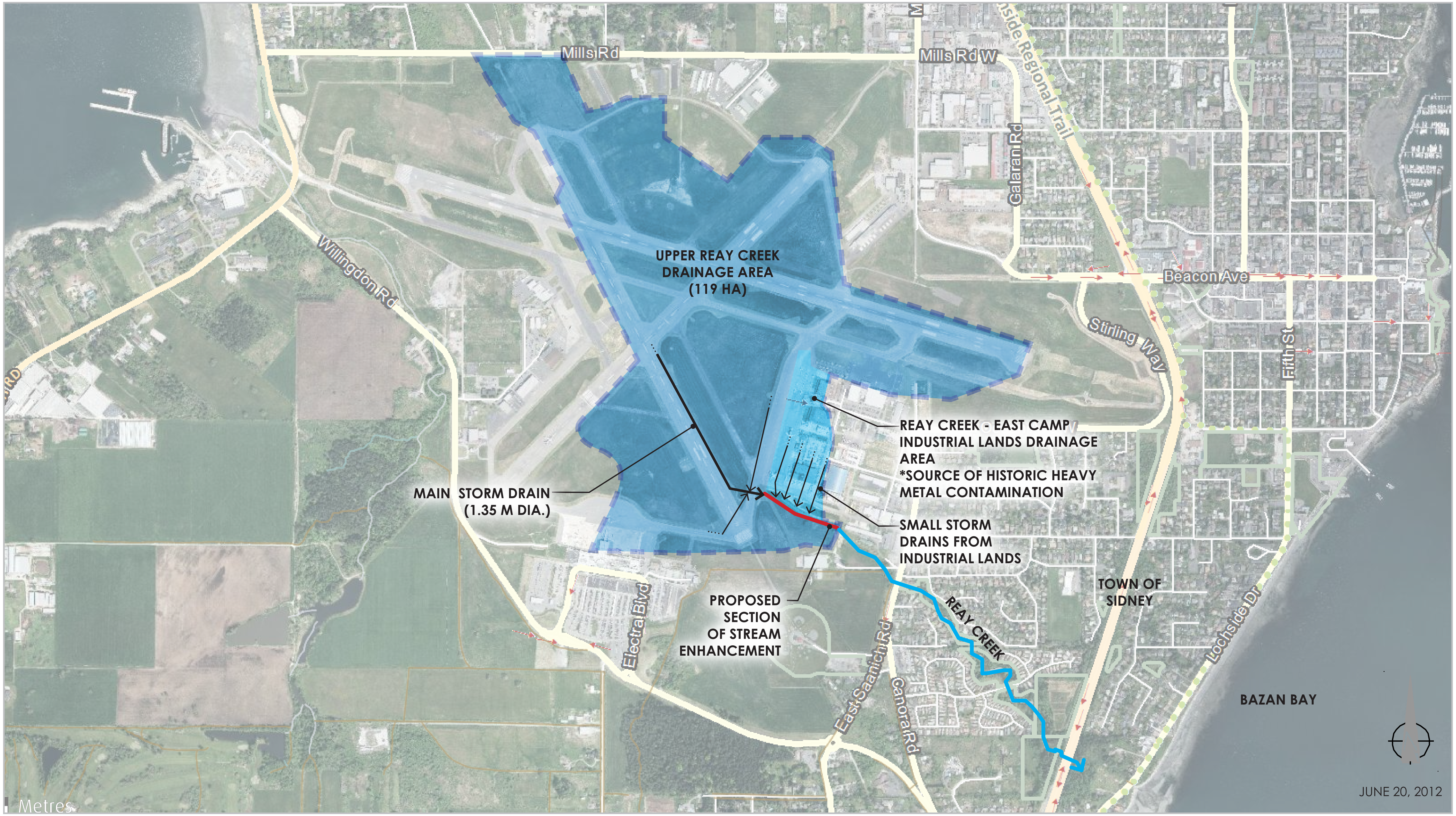
Regards,

David McKeown, R.P.Bio.
SLR Consulting (Canada) Ltd.
Project Manager

Email: dmckeown@slrconsulting.com
Office: 250.475.9595 Ext. 238
Cell: 250.661.2220
Fax: 250.475.9596
#6 – 40 Cadillac Avenue
Victoria, BC V8Z 1T2

Enc Reay Creek Concept Plan

Existing Channel Photographs



JUNE 20, 2012

REAY CREEK WATERSHED (NORTH CATCHMENT AREAS)

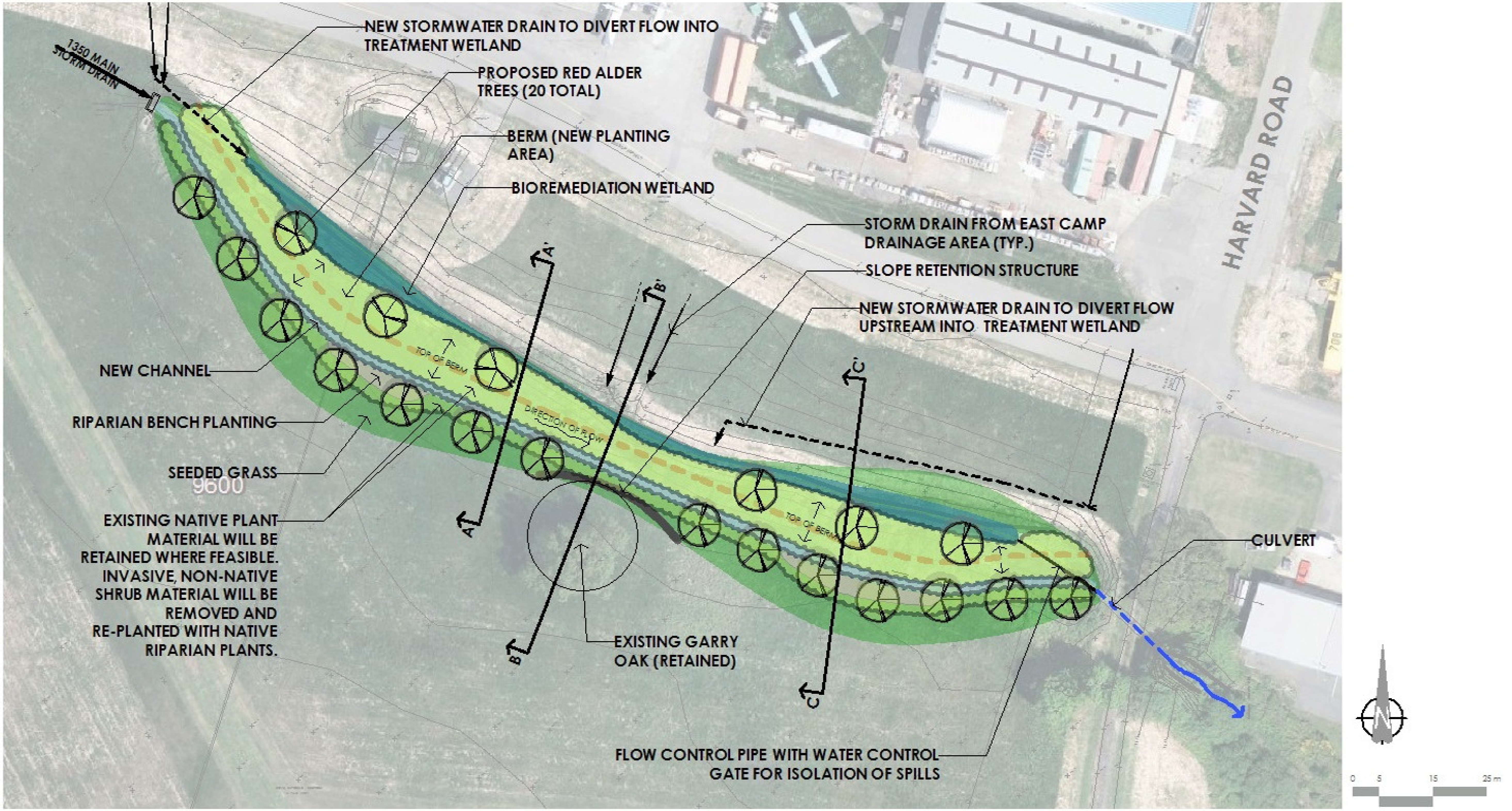
REAY CREEK REHABILITATION

FIGURE 1

KERR WOOD LEIDAL
consulting engineers

SLR
global environmental solutions

Murdoch deGreeff INC
Landscape Planning & Design



JUNE 20, 2012

CONCEPT PLAN

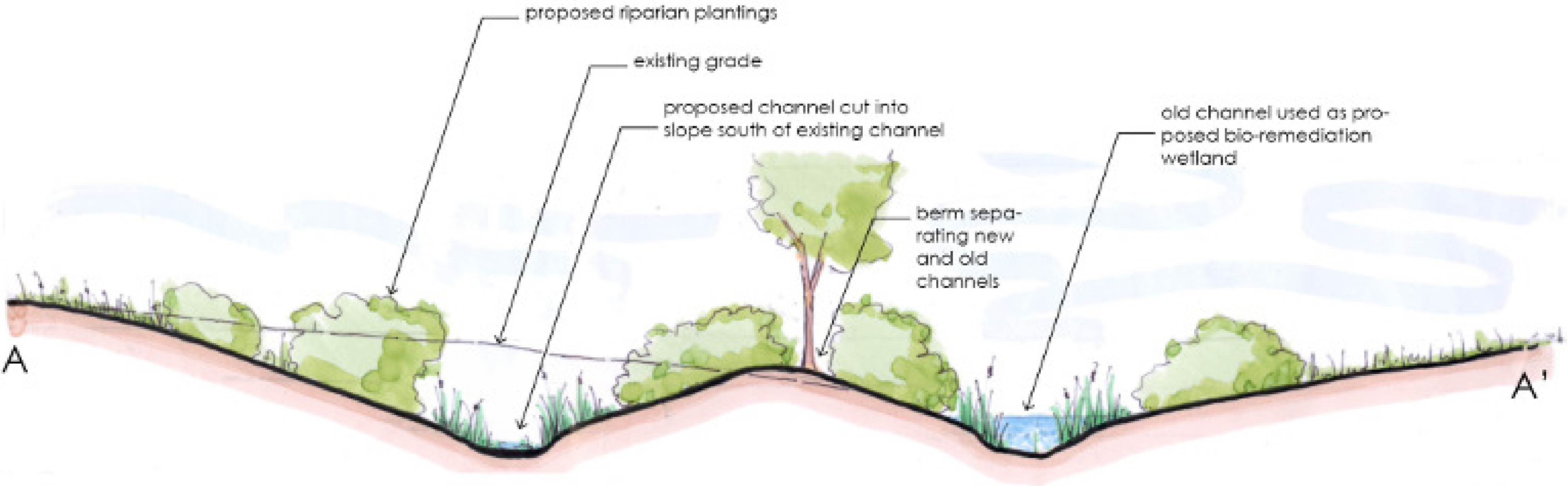
REAY CREEK REHABILITATION

FIGURE 2

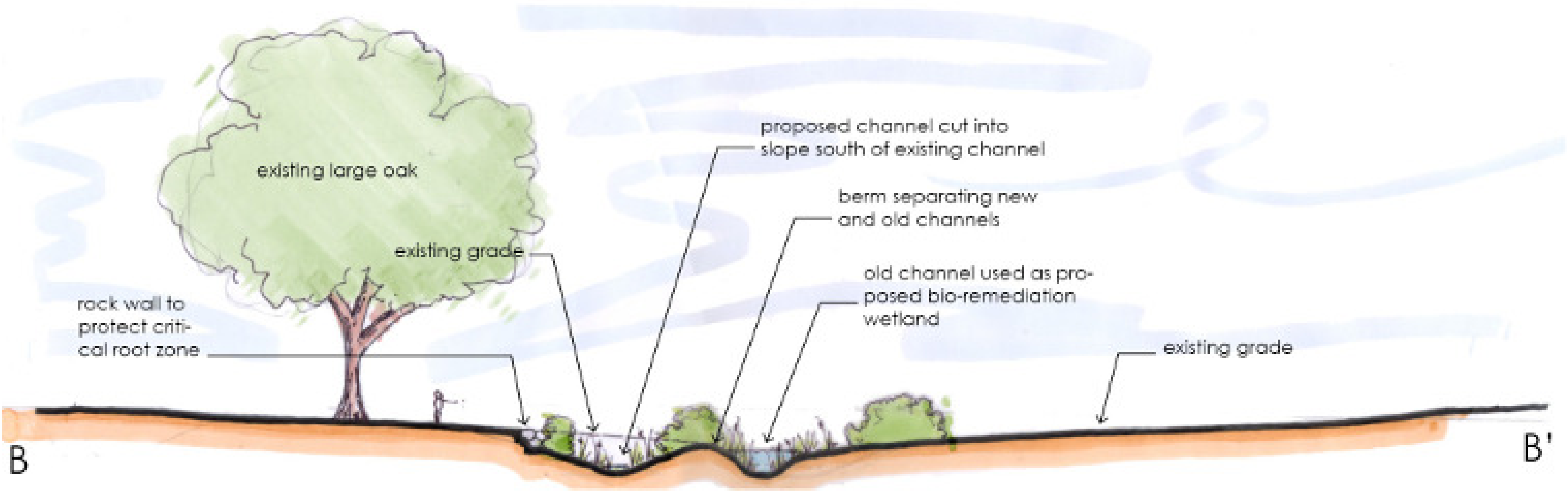
KERR WOOD LEIDAL consulting engineers

SLR global environmental solutions

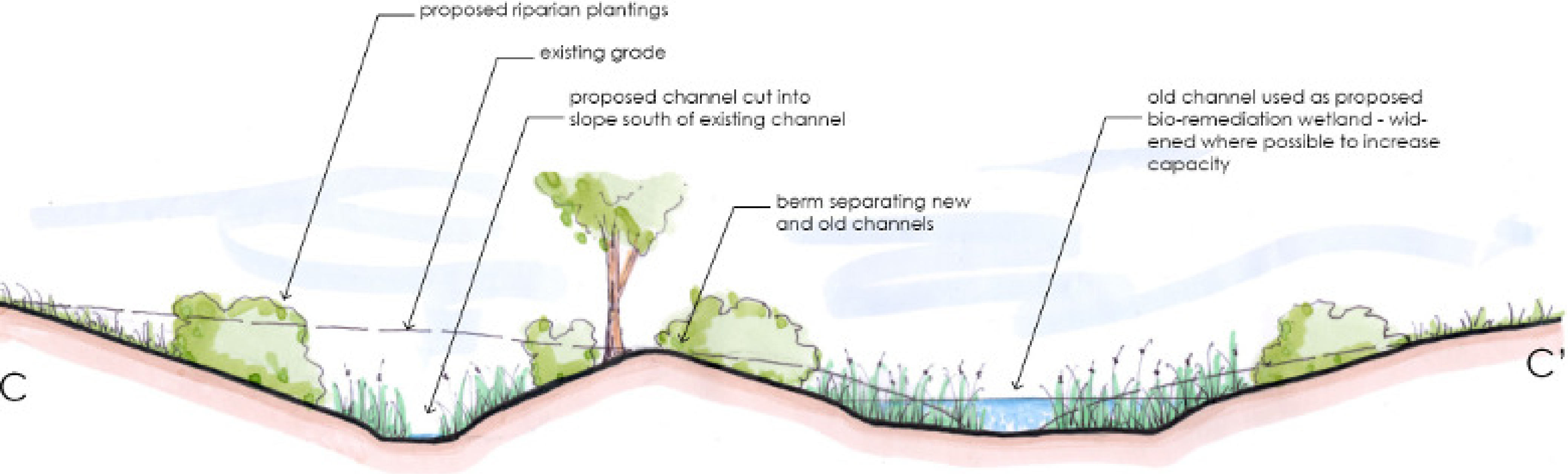
Murdoch de Greeff INC Landscape Planning & Design



Section A-A' - Typical Channel Cut



Section B-B' - Context Section (w/ Large Oak)



Section C-C' - Widened Bio-remediation Wetland

Photograph 1: Existing Reay Creek channel immediately downstream of stormwater outfall at the eastern-most (upstream) end of the creek (June 13, 2012).

Photograph 2: Minimal flow further downstream of stormwater outfall with grassy riparian vegetation (June 13, 2012).

SLR	Reay Creek Channel Mitigation Victoria International Airport North Saanich, BC
SITE PHOTOGRAPHS	

Photograph 3: Sparse shrub and grassy riparian vegetation along mid-section of proposed project area (June 13, 2012).

Photograph 4: Riparian vegetation slightly more pronounced at downstream end of project area. Thick mats of in-stream vegetation present due to stagnant flow (June 13, 2012).

Photograph 5: Typical substrates consisting of fine-grained silty sediments and organic debris (June 13, 2012).

Photograph 6: View of Reay Creek channel looking west from downstream end of project area (April 27, 2012).

Photograph 7: View of Reay Creek channel looking east from mid-section of project area (June 13, 2012). Large trees in background are beyond project limits.

27 November 2012

James Bogusz, Director – Airside Operations, Technology and Environment
Victoria Airport Authority
201 – 1640 Electra Boulevard
Sidney, BC   V8L 5V4

SLR Project No.:   205.03609.00000

Dear Mr. Bogusz,

RE: SEDIMENT AND WATER SAMPLING RESULTS, REAY CREEK HYDRAULIC OIL SPILL

SLR Consulting (Canada) Ltd. (SLR) was contracted by the Victoria Airport Authority (VAA) to conduct sediment and water sampling within the newly constructed section of Reay Creek, located at the Victoria International Airport, near Sidney, BC (the “site”) following a spill of hydraulic oil that entered the creek.

BACKGROUND

A spill of hydraulic oil occurred on approximately October 25, 2012 from a piece of machinery operated by Purolator along the east apron area of the VAA lands. Spilled material entered storm drains adjacent to the spill site and was conveyed into Reay Creek. The spill was detected the following morning and was subsequently reported to the Provincial Emergency Program (PEP) and cleanup activities followed. It is estimated that approximately 80 L of hydraulic fluid was spilled from the equipment, most of which subsequently entered Reay Creek.

Absorbent spill booms and padding were deployed at the site to contain the spilled material; however, some residual material was visible along the banks of the newly created Reay Creek diversion channel following the spill. SLR conducted a site visit on November 2, 2012 and a subsequent sampling event on November 15, 2012 to assess whether residual hydrocarbon contamination was present in sediment and water as a result of the spill event.

APPLICABLE GUIDELINES AND STANDARDS

The site is crown-owned land, under the custodianship of Transport Canada and leased to the VAA, and therefore falls under federal regulatory jurisdiction. The prime regulatory framework considered is that of the Canadian Council of Ministers of the Environment (CCME). The current and envisioned future land uses are commercial; therefore, sediment and water analytical results are compared to CCME guidelines.

CCME Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life were used to screen sediments collected below the high water line.

CCME Water Quality Guidelines for the Protection of Freshwater Aquatic Life were used for comparison of water results. Provincial water quality guidelines were also used for comparison purposes, given that water within Reay Creek ultimately leaves the site and is conveyed to areas downstream that are under provincial jurisdiction. The following standards were applied to the analytical results:

- CCME Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life;
- CCME Water Quality Guidelines for the Protection of Freshwater Aquatic Life;
- BC Approved Water Quality Guidelines for the Protection of Freshwater Aquatic Life; and
- BC Working Water Quality Guidelines for the Protection of Freshwater Aquatic Life.

NOVEMBER 15, 2012 INVESTIGATION

SLR collected sediment samples from the water – creek bank interface at four locations within the newly constructed Reay Creek channel (sampling stations 3609 S12-01 to S12-04). At each sediment sampling location samples were collected from surface sediment layers (0 – 10 cm depth) using cleaned stainless steel spoons and bowls from immediately below, at, and above the existing water line along the margins of the creek. All samples were collected from below the high water line. Sediments were placed in a clean stainless steel bowl and mixed prior to being placed in laboratory prepared 125 mL glass jars, which were labelled and stored in an insulated, ice-chilled cooler until they were shipped to ALS Environmental Laboratories (ALS) for analysis. Sampling equipment was washed with Alconox detergent between sampling stations to avoid cross contamination. One blind field duplicate was collected for quality assurance/quality control purposes.

One sediment sample (sampling station 3609 SED12-01) was also collected from the bottom of the creek channel to a maximum depth of 10 cm to assess whether elevated levels of hydrocarbons were present.

In addition to the sediment samples, surface water samples were collected from one upstream (3609 SWS12-02) and one downstream (3609 SWS12-01) location.

Sampling locations are provided in Drawing 1 attached.

Sediments generally consisted of fine-grained silts with varying clay components. Organic material was present in all sediment samples. No odour or visual evidence of hydrocarbons was detected within the sediment samples during the field sampling program.

QUALITY ASSURANCE / QUALITY CONTROL

Field Procedures

- Quality assurance (QA) and quality control (QC) procedures used during sediment and water sample collection, handling, identification and shipping procedures included the following:
    - Sediment sample containers used were supplied by the laboratory to minimize sample container contamination;

- Sediment samples collected were placed directly in the laboratory supplied containers in the field;
- Sediment samples were stored in coolers in the field at approximately 4 oC until delivery to the laboratory;
- All samples were submitted to and analyzed by the laboratory within hold times specified by the laboratory to obtain reliable results;
- One blind field duplicate (BFD) was collected to verify analytical results;
- Equipment and materials that contacted sediment (i.e., spoons, bowls) were decontaminated between sample collection to minimize the possibility for cross contamination; and
- New nitrile gloves were used for each sample to minimize the potential for cross contamination.

Laboratory QA/QC Program

All samples were analysed by ALS, which is accredited by the Canadian Association for Laboratory Accreditation Inc. for the parameters analyzed during this project, and uses CCME and MOE recognized methods to conduct laboratory analyses. As conveyed by the laboratory, method blanks, control standards samples, certified reference material standards, method spikes, replicates, duplicates, surrogates and instrument blanks are routinely analyzed as part of the QA/QC programs.

ALS conducts routine internal laboratory QA/QC analyses to validate the reliability of the analytical results. The internal laboratory analysis indicated the replicates were within the acceptable limits for samples analyzed at this site. The results of laboratory internal QC replicates can be found within the attached laboratory analysis report.

ANALYTICAL RESULTS

Sediment

During the sampling program, six samples were collected for analysis of hydrocarbon parameters in sediment, including one BDF. All samples were submitted to ALS and were analyzed for the following parameters:

- Three samples were analyzed for polycyclic aromatic hydrocarbons (PAH);
- Six samples, including one BFD, were analyzed for Canada Wide Standards (CWS) petroleum hydrocarbon fractions F1 to F4; and
- Six samples, including one BFD, were analyzed for benzene, ethylbenzene, toluene, xylene (BETX) and methyl tert-butyl ether (MTBE).

Analytical results are included in attached Tables 1 through 3.

A copy of the laboratory analytical report is attached following the tables.

PAH

Analytical results for all samples analyzed for PAH were below the applicable CCME Interim Sediment Quality Guidelines (ISQG).

CWS Hydrocarbon Fractions F1 – F4

Hydrocarbon fractions F3 and F4 at Station 3609 S12-04 were detected at concentrations slightly above laboratory detection limits (97 and 93 mg/kg, respectively). There are no CCME sediment quality guidelines for these parameters; however, the concentrations are considerably below CCME soil guidelines for ecological soil contact in commercial land uses (2,500 and 6,600 mg/kg, respectively) and are unlikely to represent adverse conditions in creek sediments.

All other parameters were below the laboratory detection limits for the samples analyzed.

BETX and MTBE

All the BETX and MTBE parameters were below the laboratory detection limits for the samples analyzed.

Water

Two water samples were collected during the sampling program and were analyzed for the following parameters:

- PAH;
- CWS petroleum hydrocarbon fractions F1 to F4; and
- BETX) and MTBE.

Benzo(g,h,i)perylene at station 3609 SWS12-02 was detected at a concentration slightly above the laboratory detection limit; however, no water quality guideline is available for this parameter. All other parameters were below laboratory detection limits.

Analytical results for water samples are provided in Tables 4 through 6 attached.

QA/QC

One BFD sample was analyzed for CWS petroleum hydrocarbon fractions, BETX and MTBE. Relative percent difference calculations could not be performed since all parameters were less than the laboratory detection limit in both the original and BFD sample.

CONCLUSIONS

Analytical results of sediment and water samples collected on November 15, 2012 from the Reay Creek channel were below laboratory detection limits and/or below applicable CCME guidelines for the protection of freshwater aquatic life.

Yours sincerely,
SLR Consulting (Canada) Ltd.

DRAFT

David McKeown, R.P.Bio.
Project Manager

Enc Table 1: Sediment Chemistry Results – PAH Parameters (mg/kg)
Table 2: Sediment Chemistry Results – Petroleum Hydrocarbon Fractions (mg/kg)
Table 3: Sediment Chemistry Results – Petroleum Hydrocarbon Constituents and MTBE (mg/kg)
Table 4: Water Chemistry Results – PAH Parameters (ug/L)
Table 5: Water Chemistry Results – Petroleum Hydrocarbon Fractions (mg/L)
Table 6: Water Chemistry Results – Petroleum Hydrocarbon Constituents and MTBE (ug/L)
Drawing 1: Sediment and Water Sampling Locations
ALS Certificate of Analysis L1238343

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TABLE 1: SEDIMENT CHEMISTRY RESULTS - PAH PARAMETERS (mg/kg)

Sample ID	**3609 S12-01**	**3609 S12-04**	**3609 SED12-01**	**CCME ISQG FW**	**CCME PEL FW**
Date	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**		
Depth (m)	---	---	---	ns	ns
Acenaphthene	< 0.005	< 0.005	< 0.005	0.00671	0.0889
Acenaphthylene	< 0.005	< 0.005	< 0.005	0.00587	0.128
Acridine	---	---	---	ns	ns
Anthracene	< 0.004	0.0082	< 0.004	0.0469	0.245
Benzo(a)anthracene	< 0.01	0.014	< 0.01	0.0317	0.385
Benzo(a)pyrene	< 0.01	0.012	< 0.01	0.0319	0.782
Benzo(b)fluoranthene	0.012	0.022	0.010	ns	ns
Benzo(g,h,i)perylene	< 0.01	0.019	< 0.01	ns	ns
Benzo(k)fluoranthene	< 0.01	< 0.01	< 0.01	ns	ns
Chrysene	< 0.01	0.030	< 0.01	0.0571	0.862
Dibenzo(a,h)anthracene	< 0.005	< 0.005	< 0.005	0.00622	0.135
Fluoranthene	0.013	0.020	0.012	0.111	2.355
Fluorene	< 0.01	< 0.01	< 0.01	0.0212	0.144
Indeno(1,2,3-c,d)pyrene	< 0.01	0.014	< 0.01	ns	ns
1-Methylnaphthalene	---	---	---	ns	ns
2-Methylnaphthalene	< 0.01	< 0.01	< 0.01	0.0202	0.201
Naphthalene	< 0.01	< 0.01	< 0.01	0.0346	0.391
Phenanthrene	< 0.01	0.013	< 0.01	0.0419	0.515
Pyrene	0.010	0.016	< 0.01	0.053	0.875
Quinoline	---	---	---	ns	ns
PAHs, Total	---	---	---	ns	ns
Benzo(a)pyrene Equivalency	< 0.02	0.020	< 0.02	ns	ns

Notes:
m - metres
PAH - polycyclic aromatic hydrocarbons
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard/guideline listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)

TABLE 2: SEDIMENT CHEMISTRY RESULTS - PETROLEUM HYDROCARBON FRACTIONS (mg/kg)

Sample ID	**3609 S12-01**	**3609 S12-02**	**3609 S12-03**	**3609 S12-A (Duplicate of 3609 S12-03)**	**3609 S12-04**	**3609 SED12-01**	**CCME ISQG FW**	**CCME PEL FW**
Date	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**		
Depth	---	---	---	---	---	---	ns	ns
F1 (C6-10)	< 10	< 10	< 10	< 10	< 10	< 10	ns	ns
F2 (C10-16)	< 30	< 30	< 30	< 30	< 30	< 30	ns	ns
F3 (C16-34)	< 50	< 50	< 50	< 50	97	< 50	ns	ns
F4 (C34-50+)	< 50	< 50	< 50	< 50	93	< 50	ns	ns

Notes:
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)

TABLE 3: SEDIMENT CHEMISTRY RESULTS - PETROLEUM HYDROCARBON CONSTITUENTS AND MTBE (mg/kg)

Sample ID	**3609 S12-01**	**3609 S12-02**	**3609 S12-03**	**3609 S12-A (Duplicate of 3609 S12-03)**	**3609 S12-04**	**3609 SED12-01**	**CCME ISQG FW**	**CCME PEL FW**
Date	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**	**15-Nov-2012**		
Depth (m)	---	---	---	---	---	---	ns	ns
HSVL (ppmv)	---	---	---	---	---	---	ns	ns
Benzene	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	ns	ns
Ethylbenzene	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	ns	ns
Toluene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	ns	ns
Xylenes	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	ns	ns
MTBE	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	ns	ns
VPHs	---	---	---	---	---	---	ns	ns
EPHs (C10-19)	---	---	---	---	---	---	ns	ns
EPHs (C19-32)	---	---	---	---	---	---	ns	ns
LEPHs	---	---	---	---	---	---	ns	ns
HEPHs	---	---	---	---	---	---	ns	ns

Notes:
m - metres
mg/kg - milligrams per kilogram
HSVL (ppmv) - headspace vapour level (parts per million by volume)
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
EPH(C10-19) standard is the CSR standard for LEPH. MOE advised (June 06, 10) that EPH(C10-19) and LEPH are equivalent for screening purposes but EPH cannot be used to demonstrate legal compliance with CSR standards
EPH(C19-32) standard is the CSR standard for HEPH. MOE advised (June 06, 10) that EPH(C19-32) and HEPH are equivalent for screening purposes but EPH cannot be used to demonstrate legal compliance with CSR standards
MTBE - methyl tert-butyl ether
VPHs - volatile petroleum hydrocarbons (C6-10), excluding benzene, ethylbenzene, toluene, xylenes
EPHs - extractable petroleum hydrocarbons
LEPHs - light extractable petroleum hydrocarbons (C10-19), excluding specific polycyclic aromatic hydrocarbon parameters
HEPHs - heavy extractable petroleum hydrocarbons (C19-32), excluding specific polycyclic aromatic hydrocarbon parameters
ns - no standard listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)

TABLE 4: WATER CHEMISTRY RESULTS - PAH PARAMETERS (ug/L)

Sample ID	**3609 SWS12-01**	**3609 SWS12-02**	**CCME AFW**	**BCWWQfw**	**BCWQ AFWm**	**BCWQ AFW**
Date	**15-Nov-2012**	**15-Nov-2012**				
Acenaphthene	< 0.01	< 0.01	5.8	ns	6	ns
Acenaphthylene	< 0.01	< 0.01	ns	ns	ns	ns
Acridine	< 0.01	< 0.01	4.4	ns	3	0.05
Anthracene	< 0.01	< 0.01	0.012	ns	0.4	ns
Benzo(a)anthracene	< 0.01	< 0.01	0.018	ns	0.1	ns
Benzo(a)pyrene	< 0.01	< 0.01	0.015	ns	0.01	ns
Benzo(b)fluoranthene	< 0.01	< 0.01	ns	ns	ns	ns
Benzo(g,h,i)perylene	< 0.01	0.035	ns	ns	ns	ns
Benzo(k)fluoranthene	< 0.01	< 0.01	ns	ns	ns	ns
Chrysene	< 0.01	< 0.01	ns	ns	ns	ns
Dibenzo(a,h)anthracene	< 0.01	< 0.01	ns	ns	ns	ns
Fluoranthene	< 0.01	< 0.01	0.04	ns	4	0.2
Fluorene	< 0.01	< 0.01	3	ns	12	ns
Indeno(1,2,3-c,d)pyrene	< 0.01	< 0.01	ns	ns	ns	ns
1-Methylnaphthalene	---	---	ns	ns	ns	ns
2-Methylnaphthalene	---	---	ns	ns	ns	ns
Naphthalene	< 0.05	< 0.05	1.1	ns	1	ns
Phenanthrene	< 0.02	< 0.02	0.4	ns	0.3	ns
Pyrene	< 0.01	< 0.01	0.025	ns	0.02	ns
Quinoline	< 0.01	< 0.01	3.4	3.4	ns	ns

Notes:
ug/L - micrograms per litre
PAH - polycyclic aromatic hydrocarbons
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard/guideline listed
Exceeds CCME AFW: CCME Canadian Environmental Quality Guidelines, Canadian Water Quality Guidelines for the Protection of Aquatic Water, Freshwater Aquatic Life
Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
Exceeds BCWQ AFWm: BC Approved Water Quality Guidelines - Aquatic Life Freshwater (maximum concentration)
Exceeds BCWQ AFW: BC Approved Water Quality Guidelines - Aquatic Life Freshwater (30-day averages)

TABLE 5: WATER CHEMISTRY RESULTS - PETROLEUM HYDROCARBON FRACTIONS (mg/L)

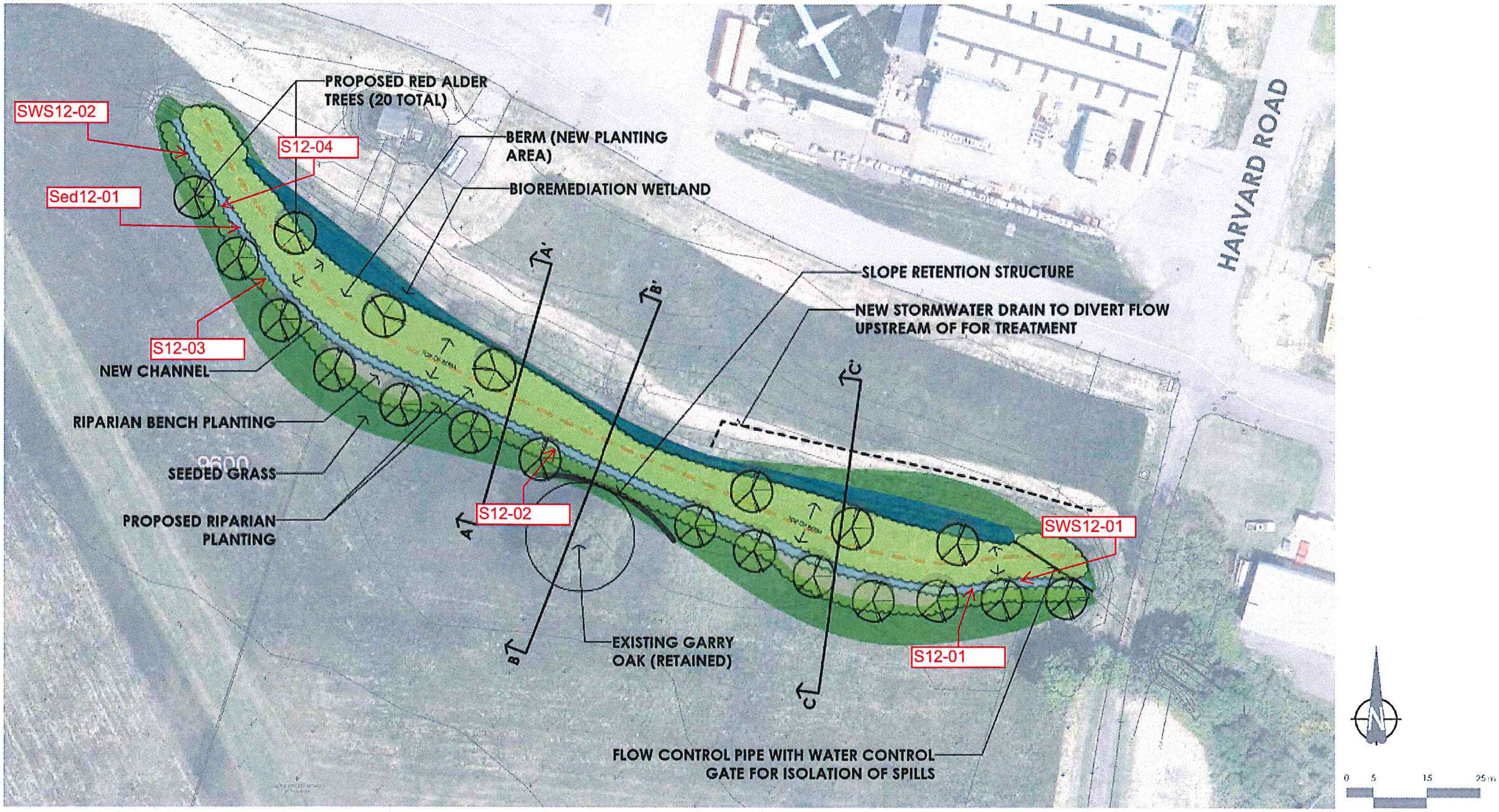
Sample ID	**3609 SWS12-01**	**3609 SWS12-02**	**CCME AFW**	**BCWWQfw**	**BCWQ AFWm**	**BCWQ AFW**
Date	**15-Nov-2012**	**15-Nov-2012**				
F1 (C6-10)	< 0.1	< 0.1	ns	ns	ns	ns
F2 (C10-16)	< 0.3	< 0.3	ns	ns	ns	ns
F3 (C16-34)	< 0.3	< 0.3	ns	ns	ns	ns
F4 (C34-50+)	< 0.3	< 0.3	ns	ns	ns	ns

Notes:
mg/L - milligrams per liters
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CCME AFW: CCME Canadian Environmental Quality Guidelines, Canadian Water Quality Guidelines for the Protection of Aquatic Water, Freshwater Aquatic Life
Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
Exceeds BCWQ AFWm: BC Approved Water Quality Guidelines - Aquatic Life Freshwater (maximum concentration)
Exceeds BCWQ AFW: BC Approved Water Quality Guidelines - Aquatic Life Freshwater (30-day averages)

TABLE 6: WATER CHEMISTRY RESULTS - PETROLEUM HYDROCARBON CONSTITUENTS AND MTBE (ug/L)

Sample ID	**3609 SWS12-01**	**3609 SWS12-02**	**CCME AFW**	**BCWWQfw**	**BCWQ AFWm**	**BCWQ AFW**
Date	**15-Nov-2012**	**15-Nov-2012**				
Benzene	< 0.5	< 0.5	370	370	40	ns
Ethylbenzene	< 0.5	< 0.5	90	ns	200	ns
Toluene	< 0.5	< 0.5	2	ns	0.5	ns
Xylenes	< 0.75	< 0.75	ns	ns	30	ns
MTBE	< 0.5	< 0.5	10000	ns	3400	ns
VPHw	---	---	ns	ns	ns	ns
VHw	---	---	ns	ns	ns	ns
EPHw (C10-19)	---	---	ns	ns	ns	ns
LEPHw	---	---	ns	ns	ns	ns
EPHw (C19-32)	---	---	ns	ns	ns	ns
HEPHw	---	---	ns	ns	ns	ns

Notes:
ug/L - micrograms per litre
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
MTBE - methyl tertiary-butyl ether
VPHw - volatile petroleum hydrocarbons (C6-10), excluding benzene, ethylbenzene, toluene and xylenes
VHw - volatile petroleum hydrocarbons (C6-10), including benzene, ethylbenzene, toluene and xylenes
EPHw - extractable petroleum hydrocarbons in water
LEPHw - light extractable petroleum hydrocarbons (C10 -19), excluding specific polycyclic aromatic hydrocarbon parameters
HEPHw - heavy extractable petroleum hydrocarbons (C19-32), excluding specific polycyclic aromatic hydrocarbon parameters
ns - no standard listed
Exceeds CCME AFW: CCME Canadian Environmental Quality Guidelines, Canadian Water Quality Guidelines for the Protection of Aquatic Water, Freshwater Aquatic Life
Exceeds BCWWQfw: BC Working Water Quality Guidelines - Table 1: Working Guidelines for the Water Column - Freshwater Aquatic Life
Exceeds BCWQ AFWm: BC Approved Water Quality Guidelines - Aquatic Life Freshwater (maximum concentration)
Exceeds BCWQ AFW: BC Approved Water Quality Guidelines - Aquatic Life Freshwater (30-day averages)



Drawing 1: Sediment and Water Sampling Locations

Reay Creek Spill Environmental Sampling 205.03609.00000

SLR
global environmental solutions

SLR CONSULTING (CANADA) LTD.
ATTN: Dave McKeown
6 - 40 Cadillac Avenue
Victoria BC V8Z 1T2

Date Received:	16-NOV-12
Report Date:	22-NOV-12 16:53 (MT)
Version:	FINAL

Client Phone: 250-475-9595

Certificate of Analysis

Lab Work Order #:	**L1238343**
Project P.O. #:	VIC1206
Job Reference:	REAY CREEK / 205.03609.00000
C of C Numbers:	
Legal Site Desc:	

Elle D

Elle Diniz
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1238343-1	L1238343-2	L1238343-3	L1238343-4	L1238343-5
	Description	SED./SOIL	SED./SOIL	SED./SOIL	SED./SOIL	SED./SOIL
	Sampled Date	15-NOV-12	15-NOV-12	15-NOV-12	15-NOV-12	15-NOV-12
	Sampled Time					
	Client ID	3609 S12-01	3609 S12-02	3609 S12-03	3609 S12-04	3609 S12-A
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	28.2	35.2	28.0	32.1	32.1
	pH (1:2 soil:water) (pH)	6.96	6.52	6.40	7.66	6.43
Volatile Organic Compounds	Benzene (mg/kg)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Ethylbenzene (mg/kg)	<0.015	<0.015	<0.015	<0.015	<0.015
	Methyl t-butyl ether (MTBE) (mg/kg)	<0.20	<0.20	<0.20	<0.20	<0.20
	Toluene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	ortho-Xylene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	meta- & para-Xylene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Xylenes (mg/kg)	<0.075	<0.075	<0.075	<0.075	<0.075
	Surrogate: 4-Bromofluorobenzene (SS) (%)	81.1	83.8	78.5	79.9	75.3
	Surrogate: 1,4-Difluorobenzene (SS) (%)	83.4	85.2	82.5	83.8	79.9
Hydrocarbons	F1 (C6-C10) (mg/kg)	<10	<10	<10	<10	<10
	F1-BTEX (mg/kg)	<10	<10	<10	<10	<10
	F2 (C10-C16) (mg/kg)	<30	<30	<30	<30	<30
	F2-Naphth (mg/kg)	<30			<30	
	F3 (C16-C34) (mg/kg)	<50	<50	<50	97	<50
	F3-PAH (mg/kg)	<50			97	
	F4 (C34-C50) (mg/kg)	<50	<50	<50	93	<50
	F4G-SG (mg/kg)				<500	
	Chrom. to baseline at nC50	YES	YES	YES	NO	YES
	Surrogate: 3,4-Dichlorotoluene (SS) (%)	111.5	95.3	120.6	111.6	101.0
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)	<0.0050			<0.0050	
	Acenaphthylene (mg/kg)	<0.0050			<0.0050	
	Anthracene (mg/kg)	<0.0040			0.0082	
	Benz(a)anthracene (mg/kg)	<0.010			0.014	
	Benzo(a)pyrene (mg/kg)	<0.010			0.012	
	Benzo(b)fluoranthene (mg/kg)	0.012			0.022	
	Benzo(b+j+k)fluoranthene (mg/kg)	<0.015			0.022	
	Benzo(g,h,i)perylene (mg/kg)	<0.010			0.019	
	Benzo(k)fluoranthene (mg/kg)	<0.010			<0.010	
	Chrysene (mg/kg)	<0.010			0.030	
	Dibenz(a,h)anthracene (mg/kg)	<0.0050			<0.0050	
	Fluoranthene (mg/kg)	0.013			0.020	
	Fluorene (mg/kg)	<0.010			<0.010	
	Indeno(1,2,3-c,d)pyrene (mg/kg)	<0.010			0.014	
	2-Methylnaphthalene (mg/kg)	<0.010			<0.010	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

	Sample ID	L1238343-6				
	Description	SED./SOIL				
	Sampled Date	15-NOV-12				
	Sampled Time					
	Client ID	3609 SED12-01				
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	31.8				
	pH (1:2 soil:water) (pH)	7.51				
Volatile Organic Compounds	Benzene (mg/kg)	<0.0050				
	Ethylbenzene (mg/kg)	<0.015				
	Methyl t-butyl ether (MTBE) (mg/kg)	<0.20				
	Toluene (mg/kg)	<0.050				
	ortho-Xylene (mg/kg)	<0.050				
	meta- & para-Xylene (mg/kg)	<0.050				
	Xylenes (mg/kg)	<0.075				
	Surrogate: 4-Bromofluorobenzene (SS) (%)	77.0				
	Surrogate: 1,4-Difluorobenzene (SS) (%)	82.1				
Hydrocarbons	F1 (C6-C10) (mg/kg)	<10				
	F1-BTEX (mg/kg)	<10				
	F2 (C10-C16) (mg/kg)	<30				
	F2-Naphth (mg/kg)	<30				
	F3 (C16-C34) (mg/kg)	<50				
	F3-PAH (mg/kg)	<50				
	F4 (C34-C50) (mg/kg)	<50				
	F4G-SG (mg/kg)					
	Chrom. to baseline at nC50	YES				
	Surrogate: 3,4-Dichlorotoluene (SS) (%)	112.4				
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)	<0.0050				
	Acenaphthylene (mg/kg)	<0.0050				
	Anthracene (mg/kg)	<0.0040				
	Benz(a)anthracene (mg/kg)	<0.010				
	Benzo(a)pyrene (mg/kg)	<0.010				
	Benzo(b)fluoranthene (mg/kg)	0.010				
	Benzo(b+j+k)fluoranthene (mg/kg)	<0.015				
	Benzo(g,h,i)perylene (mg/kg)	<0.010				
	Benzo(k)fluoranthene (mg/kg)	<0.010				
	Chrysene (mg/kg)	<0.010				
	Dibenz(a,h)anthracene (mg/kg)	<0.0050				
	Fluoranthene (mg/kg)	0.012				
	Fluorene (mg/kg)	<0.010				
	Indeno(1,2,3-c,d)pyrene (mg/kg)	<0.010				
	2-Methylnaphthalene (mg/kg)	<0.010				

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1238343-1	L1238343-2	L1238343-3	L1238343-4	L1238343-5
	Description	SED./SOIL	SED./SOIL	SED./SOIL	SED./SOIL	SED./SOIL
	Sampled Date	15-NOV-12	15-NOV-12	15-NOV-12	15-NOV-12	15-NOV-12
	Sampled Time					
	Client ID	3609 S12-01	3609 S12-02	3609 S12-03	3609 S12-04	3609 S12-A
Grouping	**Analyte**					
SOIL						
Polycyclic Aromatic Hydrocarbons	Naphthalene (mg/kg)	<0.010			<0.010	
	Phenanthrene (mg/kg)	<0.010			0.013	
	Pyrene (mg/kg)	0.010			0.016	
	Surrogate: Acenaphthene d10 (%)	84.3			86.9	
	Surrogate: Chrysene d12 (%)	102.3			102.1	
	Surrogate: Naphthalene d8 (%)	84.3			83.0	
	Surrogate: Phenanthrene d10 (%)	93.3			95.2	
	B(a)P Total Potency Equivalent (mg/kg)	<0.020			0.020	
	IACR (CCME) (mg/kg)	<0.15			0.28	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1238343-6				
	Description	SED./SOIL				
	Sampled Date	15-NOV-12				
	Sampled Time					
	Client ID	3609 SED12-01				
Grouping	**Analyte**					
SOIL						
Polycyclic Aromatic Hydrocarbons	Naphthalene (mg/kg)	<0.010				
	Phenanthrene (mg/kg)	<0.010				
	Pyrene (mg/kg)	<0.010				
	Surrogate: Acenaphthene d10 (%)	82.3				
	Surrogate: Chrysene d12 (%)	102.2				
	Surrogate: Naphthalene d8 (%)	80.4				
	Surrogate: Phenanthrene d10 (%)	86.1				
	B(a)P Total Potency Equivalent (mg/kg)	<0.020				
	IACR (CCME) (mg/kg)	<0.15				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1238343-7	L1238343-8			
	Description	WATER	WATER			
	Sampled Date	15-NOV-12	15-NOV-12			
	Sampled Time					
	Client ID	3609 SWS12-01	3609 SWS12-02			
Grouping	**Analyte**					
WATER						
Volatile Organic Compounds	Benzene (mg/L)	<0.00050	<0.00050			
	Ethylbenzene (mg/L)	<0.00050	<0.00050			
	Methyl t-butyl ether (MTBE) (mg/L)	<0.00050	<0.00050			
	Toluene (mg/L)	<0.00050	<0.00050			
	ortho-Xylene (mg/L)	<0.00050	<0.00050			
	meta- & para-Xylene (mg/L)	<0.00050	<0.00050			
	Xylenes (mg/L)	<0.00075	<0.00075			
	F1 (C6-C10) (mg/L)	<0.10	<0.10			
	Surrogate: 4-Bromofluorobenzene (SS) (%)	81.9	82.3			
	Surrogate: 1,4-Difluorobenzene (SS) (%)	84.2	84.5			
Hydrocarbons	F1-BTEX (mg/L)	<0.10	<0.10			
	F2 (C10-C16) (mg/L)	<0.30	<0.30			
	F3 (C16-C34) (mg/L)	<0.30	<0.30			
	F4 (C34-C50) (mg/L)	<0.30	<0.30			
	Surrogate: 3,4-Dichlorotoluene (SS) (%)	82.4	83.4			
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/L)	<0.000010	<0.000010			
	Acenaphthylene (mg/L)	<0.000010	<0.000010			
	Acridine (mg/L)	<0.000010	<0.000010			
	Anthracene (mg/L)	<0.000010	<0.000010			
	Benz(a)anthracene (mg/L)	<0.000010	<0.000010			
	Benzo(a)pyrene (mg/L)	<0.000010	<0.000010			
	Benzo(b)fluoranthene (mg/L)	<0.000010	<0.000010			
	Benzo(g,h,i)perylene (mg/L)	<0.000010	0.000035			
	Benzo(k)fluoranthene (mg/L)	<0.000010	<0.000010			
	Chrysene (mg/L)	<0.000010	<0.000010			
	Dibenz(a,h)anthracene (mg/L)	<0.000010	<0.000010			
	Fluoranthene (mg/L)	<0.000010	<0.000010			
	Fluorene (mg/L)	<0.000010	<0.000010			
	Indeno(1,2,3-c,d)pyrene (mg/L)	<0.000010	<0.000010			
	Naphthalene (mg/L)	<0.000050	<0.000050			
	Phenanthrene (mg/L)	<0.000020	<0.000020			
	Pyrene (mg/L)	<0.000010	<0.000010			
	Quinoline (mg/L)	<0.000010	<0.000010			
	Surrogate: Acenaphthene d10 (%)	80.1	80.7			
	Surrogate: Acridine d9 (%)	108.0	110.8			
	Surrogate: Chrysene d12 (%)	92.7	95.4			

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1238343-7	L1238343-8			
	Description	WATER	WATER			
	Sampled Date	15-NOV-12	15-NOV-12			
	Sampled Time					
	Client ID	3609 SWS12-01	3609 SWS12-02			
Grouping	**Analyte**					
WATER						
Polycyclic Aromatic Hydrocarbons	Surrogate: Naphthalene d8 (%)	78.3	79.1			
	Surrogate: Phenanthrene d10 (%)	93.1	96.0			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	F2 (C10-C16)	DUP-H	L1238343-1, -2, -3, -4, -5, -6
Duplicate	F3 (C16-C34)	DUP-H	L1238343-1, -2, -3, -4, -5, -6
Duplicate	F4 (C34-C50)	DUP-H	L1238343-1, -2, -3, -4, -5, -6
Laboratory Control Sample	F1 (C6-C10)	LCS-ND	L1238343-4, -5, -6

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DUP-H	Duplicate results outside ALS DQO, due to sample heterogeneity.
LCS-ND	Lab Control Sample recovery was slightly outside ALS DQO. Reported non-detect results for associated samples were unaffected.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
F1-BTX-CALC-VA	Water	F1-Total BTX	CCME CWS PHC TIER 1 (2001)

This analysis is based on the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." For F1 (C6-C10), the sample undergoes a purge and trap extraction prior to analysis by GC/FID. The F1-BTEX result is calculated as follows:

F1-BTEX: F1 (C6-C10) minus benzene, toluene, ethylbenzene and xylenes (BTEX).

F1-BTX-CALC-VA	Soil	F1-Total BTX	CCME CWS PHC TIER 1 (2001)

This analysis is carried out in accordance with the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." For F1 (C6-C10) and F1-BTEX, a subsample of the sediment/soil is extracted with methanol and analysed by purge & trap GC/FID. The F1-BTEX result is then calculated as follows:

F1-BTEX: F1 (C6-C10) minus benzene, toluene, ethylbenzene and xylenes (BTEX).

F1-HSFID-VA	Water	CCME F1 By Headspace with GCFID	CCME PHC TIER 1

This analysis is based on the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." For F1 (C6-C10), the sample undergoes a headspace purge prior to analysis by GC/FID.

F1 (C6-C10): Sum of all hydrocarbons that elute between nC6 and nC10.

F1-HSFID-VA	Soil	CCME F1 by headspace GCMS	EPA SW846, CCME CWS PHC TIER 1

The soil methanol extract is added to water and reagents, then heated in a sealed vial to equilibrium. The headspace from the vial is transferred into a gas chromatograph. The F1 fraction concentration is measured using flame ionization detection.

F2-4-SF-FID-VA	Water	Extractable Hydrocarbons in water GCFID	CWS (CCME)

Petroleum Hydrocarbons (F2-F4) in Water

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, published by the United States Environmental Protection Agency (EPA) and the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." The procedure involves a liquid-liquid extraction of the entire water sample using dichloromethane prior to capillary column gas chromatography with flame ionization detection (GC/FID).

A silica gel cleanup procedure is applied before GC analysis, which is intended to selectively remove most naturally occurring organics.

F2F3-PAH-CALC-VA	Soil	F2&F3-PAH	CCME CWS PHC TIER 1 (2001)

This analysis is carried out in accordance with the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." For F2 (C10-C16) and F3 (C16-C34), a subsample of the sediment/soil is extracted with 1:1 hexane:acetone using a rotary extractor. The extract undergoes a silica-gel clean-up to remove polar compounds prior to analysis by on-column GC/FID. The F2-Napth and F3-PAH results are then calculated as follows:

1. F2-Napth: F2 (C10-C16) minus naphthalene.
2. F3-PAH: F3 (C16-C34) minus selected PAHs (phenanthrene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene and pyrene).

F2F4-TUMB-H/A-FID-VA	Soil	Petroleum Hydrocarbon by Tumbler GCFID	CCME PETROLEUM HYDROCARBONS

This analysis is carried out in accordance with the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." For C10 to C50 hydrocarbons (F2, F3, F4) and gravimetric heavy hydrocarbons (F4G-sg), a subsample of the sediment/soil is extracted with 1:1 hexane:acetone using a rotary extractor. The extract undergoes a silica-gel clean-up to remove polar compounds. F2, F3 & F4 are analyzed by on-column GC/FID, and F4G-sg is analyzed gravimetrically.

Notes:
1. F2 (C10-C16): Sum of all hydrocarbons that elute between nC10 and nC16.
2. F3 (C16-C34): Sum of all hydrocarbons that elute between nC16 and nC34.
3. F4 (C34-C50): Sum of all hydrocarbons that elute between nC34 and nC50.
4. F4G: Gravimetric Heavy Hydrocarbons
5. F4G-sg: Gravimetric Heavy Hydrocarbons (F4G) after silica gel treatment.

Reference Information

6. Where F4 (C34-C50) and F4G-sg results are reported for a sample, the larger of the reported values is used for comparison against the relevant CCME standard for F4.
7. The gravimetric heavy hydrocarbon results (F4G-sg), cannot be added to the C6 to C50 hydrocarbon results.
8. This method is validated for use.
9. Data from analysis of quality control samples is available upon request.
10. Reported results are expressed as milligrams per dry kilogram.

MOISTURE-VA	Soil	Moisture content	ASTM D2974-00 Method A

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

OGG-F4G-TUMB-SG-VA	Soil	CWS F4G with Silica Gel	CCME PETROLEUM HYDROCARBONS-GRAVIMETRIC

This analysis is carried out in accordance with the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." For gravimetric heavy hydrocarbons (F4G-sg), a subsample of the sediment/soil is extracted with 1:1 hexane:acetone using a rotary extractor. The extract undergoes a silica-gel clean-up to remove polar compounds prior to gravimetric analysis.

Notes:
1. F4G-sg: Gravimetric Heavy Hydrocarbons (F4G) after silica gel treatment.
3. Where F4 (C34-C50) and F4G-sg results are reported for a sample, the larger of the reported values is used for comparison against the relevant CCME standard for F4.
4. The gravimetric heavy hydrocarbon (F4G-sg) result cannot be added to the C6 to C50 hydrocarbons results.
5. This method is validated for use.
6. Data from analysis of quality control samples is available upon request.
7. Reported results are expressed as milligrams per dry kilogram.

PAH-LL-SF-MS-VA	Water	PAH-Low Level in Water by GCMS	EPA 3510, 8270

The entire water sample is extracted with dichloromethane, prior to analysis by gas chromatography with mass spectrometric detection (GC/MS). Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

PAH-SURR-MS-VA	Water	PAH Surrogates for Waters	EPA 3510, 8270

Analysed as per the corresponding PAH test method. Known quantities of surrogate compounds are added prior to analysis to each sample to demonstrate analytical accuracy.

PAH-TMB-H/A-MS-VA	Soil	PAH - Rotary Extraction (Hexane/Acetone)	EPA 3570/8270

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, Methods 3545 & 8270, published by the United States Environmental Protection Agency (EPA). The procedure uses a mechanical shaking technique to extract a subsample of the sediment/soil with a 1:1 mixture of hexane and acetone. The extract is then solvent exchanged to toluene. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection (GC/MS). Surrogate recoveries may not be reported in cases where interferences from the sample matrix prevent accurate quantitation. Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

PH-1:2-VA	Soil	pH in Soil (1:2 Soil:Water Extraction)	BC WLAP METHOD: PH, ELECTROMETRIC, SOIL

This analysis is carried out in accordance with procedures described in the pH, Electrometric in Soil and Sediment method - Section B Physical/Inorganic and Misc. Constituents, BC Environmental Laboratory Manual 2007. The procedure involves mixing the dried (at <60°C) and sieved (No. 10 / 2mm) sample with deionized/distilled water at a 1:2 ratio of sediment to water. The pH of the solution is then measured using a standard pH probe.

VH-SURR-FID-VA	Water	VH Surrogates for Waters	B.C. MIN. OF ENV. LAB. MAN. (2009)
VH-SURR-FID-VA	Soil	VH Surrogates for Soils	BCMELP CSR ANALYTICAL METHOD 2
VOC7-HSMS-VA	Water	BTEX/MTBE/Styrene by Headspace GCMS	EPA8260B, 5021

The water sample, with added reagents, is heated in a sealed vial to equilibrium. The headspace from the vial is transfered into a gas chromatograph. Target compound concentrations are measured using mass spectrometry detection.

VOC7-L-HSMS-VA	Soil	VOCs in soil by Headspace GCMS	EPA8260B, 5021, 5035, BC MOE

The soil methanol extract is added to water and reagents, then heated in a sealed vial to equilibrium. The headspace from the vial is transferred into a gas chromatograph. Target compound concentrations are measured using mass spectrometry detection.

VOC7/VOC-SURR-MS-VA	Water	VOC7 and/or VOC Surrogates for Waters	EPA8260B, 5021
VOC7/VOC-SURR-MS-VA	Soil	VOC7 and/or VOC Surrogates for Soils	EPA METHODS 8260B & 524.2
XYLENES-CALC-VA	Water	Sum of Xylene Isomer Concentrations	CALCULATION

Calculation of Total Xylenes

Total Xylenes is the sum of the concentrations of the ortho, meta, and para Xylene isomers. Results below detection limit (DL) are treated as zero. The DL for Total Xylenes is set to a value no less than the square root of the sum of the squares of the DLs of the individual Xylenes.

XYLENES-CALC-VA	Soil	Sum of Xylene Isomer Concentrations	EPA 8260B & 524.2

Calculation of Total Xylenes

Total Xylenes is the sum of the concentrations of the ortho, meta, and para Xylene isomers. Results below detection limit (DL) are treated as zero.

Reference Information

The DL for Total Xylenes is set to a value no less than the square root of the sum of the squares of the DLs of the individual Xylenes.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L1238343 Report Date: 22-NOV-12

Client: SLR CONSULTING (CANADA) LTD.
6 - 40 Cadillac Avenue
Victoria BC V8Z 1T2

Contact: Dave McKeown

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
F1-HSFID-VA	**Water**							
Batch R2479618								
WG1588504-2 LCS								
F1 (C6-C10)			112.8		%		50-150	21-NOV-12
WG1588504-1 MB								
F1 (C6-C10)			<0.10		mg/L		0.1	21-NOV-12
F2-4-SF-FID-VA	**Water**							
Batch R2475403								
WG1587714-1 MB								
F2 (C10-C16)			<0.30		mg/L		0.3	20-NOV-12
F3 (C16-C34)			<0.30		mg/L		0.3	20-NOV-12
F4 (C34-C50)			<0.30		mg/L		0.3	20-NOV-12
PAH-LL-SF-MS-VA	**Water**							
Batch R2476594								
WG1587714-2 LCS								
Acenaphthene			113.4		%		60-130	19-NOV-12
Acenaphthylene			110.4		%		60-130	19-NOV-12
Acridine			106.8		%		60-130	19-NOV-12
Anthracene			110.7		%		60-130	19-NOV-12
Benz(a)anthracene			102.3		%		60-130	19-NOV-12
Benzo(a)pyrene			92.7		%		60-130	19-NOV-12
Benzo(b)fluoranthene			100.0		%		60-130	19-NOV-12
Benzo(g,h,i)perylene			112.3		%		60-130	19-NOV-12
Benzo(k)fluoranthene			106.6		%		60-130	19-NOV-12
Chrysene			115.3		%		60-130	19-NOV-12
Dibenz(a,h)anthracene			106.8		%		60-130	19-NOV-12
Fluoranthene			105.0		%		60-130	19-NOV-12
Fluorene			109.1		%		60-130	19-NOV-12
Indeno(1,2,3-c,d)pyrene			106.3		%		60-130	19-NOV-12
Naphthalene			111.6		%		50-130	19-NOV-12
Phenanthrene			114.1		%		60-130	19-NOV-12
Pyrene			100.1		%		60-130	19-NOV-12
Quinoline			109.6		%		60-130	19-NOV-12
WG1587714-1 MB								
Acenaphthene			<0.000010		mg/L		0.00001	19-NOV-12
Acenaphthylene			<0.000010		mg/L		0.00001	19-NOV-12
Acridine			<0.000010		mg/L		0.00001	19-NOV-12
Anthracene			<0.000010		mg/L		0.00001	19-NOV-12

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-LL-SF-MS-VA	**Water**							
Batch R2476594								
WG1587714-1 MB								
Benz(a)anthracene			<0.000010		mg/L		0.00001	19-NOV-12
Benzo(a)pyrene			<0.000010		mg/L		0.00001	19-NOV-12
Benzo(b)fluoranthene			<0.000010		mg/L		0.00001	19-NOV-12
Benzo(g,h,i)perylene			<0.000010		mg/L		0.00001	19-NOV-12
Benzo(k)fluoranthene			<0.000010		mg/L		0.00001	19-NOV-12
Chrysene			<0.000010		mg/L		0.00001	19-NOV-12
Dibenz(a,h)anthracene			<0.000010		mg/L		0.00001	19-NOV-12
Fluoranthene			<0.000010		mg/L		0.00001	19-NOV-12
Fluorene			<0.000010		mg/L		0.00001	19-NOV-12
Indeno(1,2,3-c,d)pyrene			<0.000010		mg/L		0.00001	19-NOV-12
Naphthalene			<0.000050		mg/L		0.00005	19-NOV-12
Phenanthrene			<0.000020		mg/L		0.00002	19-NOV-12
Pyrene			<0.000010		mg/L		0.00001	19-NOV-12
Quinoline			<0.000010		mg/L		0.00001	19-NOV-12
VOC7-HSMS-VA	**Water**							
Batch R2478804								
WG1588504-2 LCS								
Benzene			96.1		%		70-130	21-NOV-12
Ethylbenzene			101.6		%		70-130	21-NOV-12
Methyl t-butyl ether (MTBE)			101.7		%		70-130	21-NOV-12
Toluene			95.8		%		70-130	21-NOV-12
meta- & para-Xylene			99.6		%		70-130	21-NOV-12
ortho-Xylene			100.9		%		70-130	21-NOV-12
WG1588504-1 MB								
Benzene			<0.00050		mg/L		0.0005	21-NOV-12
Ethylbenzene			<0.00050		mg/L		0.0005	21-NOV-12
Methyl t-butyl ether (MTBE)			<0.00050		mg/L		0.0005	21-NOV-12
Toluene			<0.00050		mg/L		0.0005	21-NOV-12
meta- & para-Xylene			<0.00050		mg/L		0.0005	21-NOV-12
ortho-Xylene			<0.00050		mg/L		0.0005	21-NOV-12
F1-HSFID-VA	**Soil**							
Batch R2479547								
WG1587834-1 MB								
F1 (C6-C10)			<10		mg/kg		10	21-NOV-12

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
F1-HSFID-VA	**Soil**							
Batch R2479618								
WG1587493-2 LCS								
F1 (C6-C10)			117.8		%		70-130	21-NOV-12
WG1587834-2 LCS								
F1 (C6-C10)			131.3	LCS-ND	%		70-130	21-NOV-12
WG1587493-1 MB								
F1 (C6-C10)			<10		mg/kg		10	21-NOV-12
F2F4-TUMB-H/A-FID-VA	**Soil**							
Batch R2481511								
WG1587741-4 DUP		**L1238343-4**						
F2 (C10-C16)		<30	<30	DUP-H	mg/kg	N/A	40	22-NOV-12
F3 (C16-C34)		97	<50	DUP-H	mg/kg	N/A	40	22-NOV-12
F4 (C34-C50)		93	<50	DUP-H	mg/kg	N/A	50	22-NOV-12
WG1587741-3 IRM		**ALS PHC1 RM**						
F2 (C10-C16)			70.3		%		70-130	22-NOV-12
F3 (C16-C34)			84.3		%		70-130	22-NOV-12
F4 (C34-C50)			82.6		%		70-130	22-NOV-12
WG1587741-2 LCS								
F2 (C10-C16)			88.4		%		80-120	22-NOV-12
F3 (C16-C34)			85.8		%		80-120	22-NOV-12
F4 (C34-C50)			84.2		%		80-120	22-NOV-12
WG1587741-1 MB								
F2 (C10-C16)			<30		mg/kg		30	22-NOV-12
F3 (C16-C34)			<50		mg/kg		50	22-NOV-12
F4 (C34-C50)			<50		mg/kg		50	22-NOV-12
MOISTURE-VA	**Soil**							
Batch R2475679								
WG1587740-2 LCS								
Moisture			99.8		%		90-110	18-NOV-12
WG1587740-1 MB								
Moisture			<0.25		%		0.25	18-NOV-12
Batch R2475806								
WG1587828-2 LCS								
Moisture			100.2		%		90-110	19-NOV-12
WG1587828-1 MB								
Moisture			<0.25		%		0.25	19-NOV-12
OGG-F4G-TUMB-SG-VA	**Soil**							

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
OGG-F4G-TUMB-SG-VA	**Soil**							
Batch R2481584								
WG1587741-3 IRM		**ALS PHC1 RM**						
F4G-SG			114.7		%		70-130	21-NOV-12
WG1587741-1 MB								
F4G-SG			<500		mg/kg		500	21-NOV-12
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R2477829								
WG1587739-4 IRM		**ALS PAH1 RM**						
Acenaphthene			92.7		%		60-130	20-NOV-12
Acenaphthylene			109.4		%		60-130	20-NOV-12
Anthracene			100.5		%		60-130	20-NOV-12
Benz(a)anthracene			115.7		%		60-130	20-NOV-12
Benzo(a)pyrene			113.7		%		60-130	20-NOV-12
Benzo(b)fluoranthene			114.0		%		60-130	20-NOV-12
Benzo(g,h,i)perylene			118.8		%		60-130	20-NOV-12
Benzo(k)fluoranthene			108.2		%		60-130	20-NOV-12
Chrysene			124.5		%		60-130	20-NOV-12
Dibenz(a,h)anthracene			127.2		%		60-130	20-NOV-12
Fluoranthene			125.8		%		60-130	20-NOV-12
Fluorene			90.6		%		60-130	20-NOV-12
Indeno(1,2,3-c,d)pyrene			115.0		%		60-130	20-NOV-12
2-Methylnaphthalene			98.1		%		60-130	20-NOV-12
Naphthalene			99.9		%		50-130	20-NOV-12
Phenanthrene			126.8		%		60-130	20-NOV-12
Pyrene			126.8		%		60-130	20-NOV-12
WG1587835-4 IRM		**ALS PAH1 RM**						
Acenaphthene			92.7		%		60-130	20-NOV-12
Acenaphthylene			109.4		%		60-130	20-NOV-12
Anthracene			100.5		%		60-130	20-NOV-12
Benz(a)anthracene			115.7		%		60-130	20-NOV-12
Benzo(a)pyrene			113.7		%		60-130	20-NOV-12
Benzo(b)fluoranthene			114.0		%		60-130	20-NOV-12
Benzo(g,h,i)perylene			118.8		%		60-130	20-NOV-12
Benzo(k)fluoranthene			108.2		%		60-130	20-NOV-12
Chrysene			124.5		%		60-130	20-NOV-12
Dibenz(a,h)anthracene			127.2		%		60-130	20-NOV-12
Fluoranthene			125.8		%		60-130	20-NOV-12

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R2477829								
WG1587835-4 IRM		**ALS PAH1 RM**						
Fluorene			90.6		%		60-130	20-NOV-12
Indeno(1,2,3-c,d)pyrene			115.0		%		60-130	20-NOV-12
2-Methylnaphthalene			98.1		%		60-130	20-NOV-12
Naphthalene			99.9		%		50-130	20-NOV-12
Phenanthrene			126.8		%		60-130	20-NOV-12
Pyrene			126.8		%		60-130	20-NOV-12
WG1587739-1 MB								
Acenaphthene			<0.0050		mg/kg		0.005	20-NOV-12
Acenaphthylene			<0.0050		mg/kg		0.005	20-NOV-12
Anthracene			<0.0040		mg/kg		0.004	20-NOV-12
Benz(a)anthracene			<0.010		mg/kg		0.01	20-NOV-12
Benzo(a)pyrene			<0.010		mg/kg		0.01	20-NOV-12
Benzo(b)fluoranthene			<0.010		mg/kg		0.01	20-NOV-12
Benzo(g,h,i)perylene			<0.010		mg/kg		0.01	20-NOV-12
Benzo(k)fluoranthene			<0.010		mg/kg		0.01	20-NOV-12
Chrysene			<0.010		mg/kg		0.01	20-NOV-12
Dibenz(a,h)anthracene			<0.0050		mg/kg		0.005	20-NOV-12
Fluoranthene			<0.010		mg/kg		0.01	20-NOV-12
Fluorene			<0.010		mg/kg		0.01	20-NOV-12
Indeno(1,2,3-c,d)pyrene			<0.010		mg/kg		0.01	20-NOV-12
2-Methylnaphthalene			<0.010		mg/kg		0.01	20-NOV-12
Naphthalene			<0.010		mg/kg		0.01	20-NOV-12
Phenanthrene			<0.010		mg/kg		0.01	20-NOV-12
Pyrene			<0.010		mg/kg		0.01	20-NOV-12
Surrogate: Naphthalene d8			105.2		%		50-130	20-NOV-12
Surrogate: Acenaphthene d10			104.7		%		60-130	20-NOV-12
Surrogate: Phenanthrene d10			107.3		%		60-130	20-NOV-12
Surrogate: Chrysene d12			122.2		%		60-130	20-NOV-12
WG1587835-1 MB								
Acenaphthene			<0.0050		mg/kg		0.005	20-NOV-12
Acenaphthylene			<0.0050		mg/kg		0.005	20-NOV-12
Anthracene			<0.0040		mg/kg		0.004	20-NOV-12
Benz(a)anthracene			<0.010		mg/kg		0.01	20-NOV-12
Benzo(a)pyrene			<0.010		mg/kg		0.01	20-NOV-12
Benzo(b)fluoranthene			<0.010		mg/kg		0.01	20-NOV-12

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R2477829								
WG1587835-1 MB								
Benzo(g,h,i)perylene			<0.010		mg/kg		0.01	20-NOV-12
Benzo(k)fluoranthene			<0.010		mg/kg		0.01	20-NOV-12
Chrysene			<0.010		mg/kg		0.01	20-NOV-12
Dibenz(a,h)anthracene			<0.0050		mg/kg		0.005	20-NOV-12
Fluoranthene			<0.010		mg/kg		0.01	20-NOV-12
Fluorene			<0.010		mg/kg		0.01	20-NOV-12
Indeno(1,2,3-c,d)pyrene			<0.010		mg/kg		0.01	20-NOV-12
2-Methylnaphthalene			<0.010		mg/kg		0.01	20-NOV-12
Naphthalene			<0.010		mg/kg		0.01	20-NOV-12
Phenanthrene			<0.010		mg/kg		0.01	20-NOV-12
Pyrene			<0.010		mg/kg		0.01	20-NOV-12
Surrogate: Naphthalene d8			105.2		%		50-130	20-NOV-12
Surrogate: Acenaphthene d10			104.7		%		60-130	20-NOV-12
Surrogate: Phenanthrene d10			107.3		%		60-130	20-NOV-12
Surrogate: Chrysene d12			122.2		%		60-130	20-NOV-12
VOC7-L-HSMS-VA	**Soil**							
Batch R2473716								
WG1587493-2 LCS								
Benzene			87.9		%		70-130	21-NOV-12
Ethylbenzene			96.2		%		70-130	21-NOV-12
Methyl t-butyl ether (MTBE)			82.4		%		70-130	21-NOV-12
Toluene			93.9		%		70-130	21-NOV-12
meta- & para-Xylene			97.9		%		70-130	21-NOV-12
ortho-Xylene			98.3		%		70-130	21-NOV-12
WG1587493-1 MB								
Benzene			<0.0050		mg/kg		0.005	21-NOV-12
Ethylbenzene			<0.015		mg/kg		0.015	21-NOV-12
Methyl t-butyl ether (MTBE)			<0.20		mg/kg		0.2	21-NOV-12
Toluene			<0.050		mg/kg		0.05	21-NOV-12
meta- & para-Xylene			<0.050		mg/kg		0.05	21-NOV-12
ortho-Xylene			<0.050		mg/kg		0.05	21-NOV-12
Batch R2477261								
WG1587834-2 LCS								
Benzene			99.9		%		70-130	20-NOV-12
Ethylbenzene			101.0		%		70-130	20-NOV-12

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
VOC7-L-HSMS-VA	**Soil**							
Batch R2477261								
WG1587834-2 LCS								
Methyl t-butyl ether (MTBE)			99.0		%		70-130	20-NOV-12
Toluene			97.1		%		70-130	20-NOV-12
meta- & para-Xylene			106.9		%		70-130	20-NOV-12
ortho-Xylene			105.5		%		70-130	20-NOV-12
WG1587834-1 MB								
Benzene			<0.0050		mg/kg		0.005	20-NOV-12
Ethylbenzene			<0.015		mg/kg		0.015	20-NOV-12
Methyl t-butyl ether (MTBE)			<0.20		mg/kg		0.2	20-NOV-12
Toluene			<0.050		mg/kg		0.05	20-NOV-12
meta- & para-Xylene			<0.050		mg/kg		0.05	20-NOV-12
ortho-Xylene			<0.050		mg/kg		0.05	20-NOV-12

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
DUP-H	Duplicate results outside ALS DQO, due to sample heterogeneity.
LCS-ND	Lab Control Sample recovery was slightly outside ALS DQO. Reported non-detect results for associated samples were unaffected.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

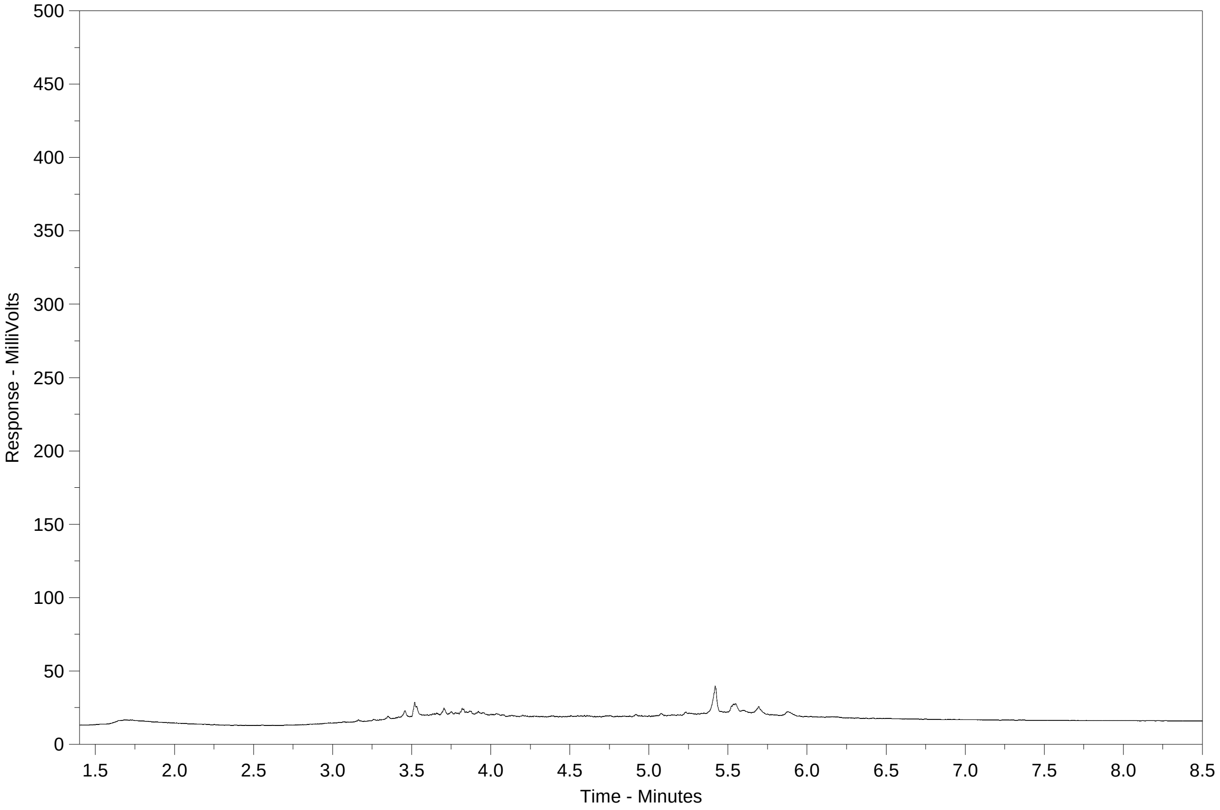
ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

CCME F2F4 Hydrocarbon Distribution Report

ALS Sample ID: L1238343-C-1
Client Sample ID: 3609 S12-01



nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F

← Gasoline → ← Motor Oils / Lube Oils / Grease →
← Diesel / Jet Fuels →

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

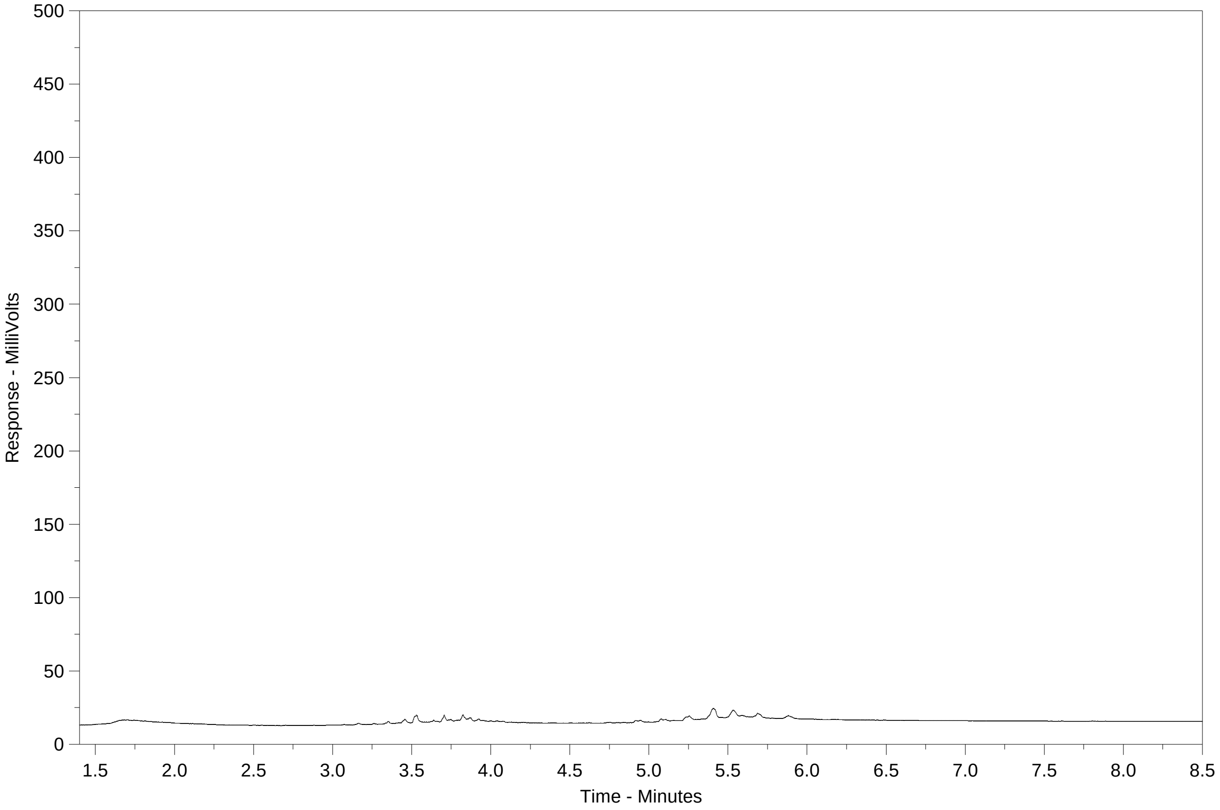
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at left.

Note: This chromatogram was produced using GC conditions that are specific to the CCME F2-F4 method (December 2007 version). Chromatograms generated using this method will resemble those found in the ALS-Vancouver HDR library, though they will appear compressed as the F2-F4 analysis covers a broader range of boiling points. The HDR library can be found at www.alsglobal.com.

CCME F2F4 Hydrocarbon Distribution Report

ALS Sample ID: L1238343-C-2
Client Sample ID: 3609 S12-02



nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F

← Gasoline →
← Motor Oils / Lube Oils / Grease →
← Diesel / Jet Fuels →

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

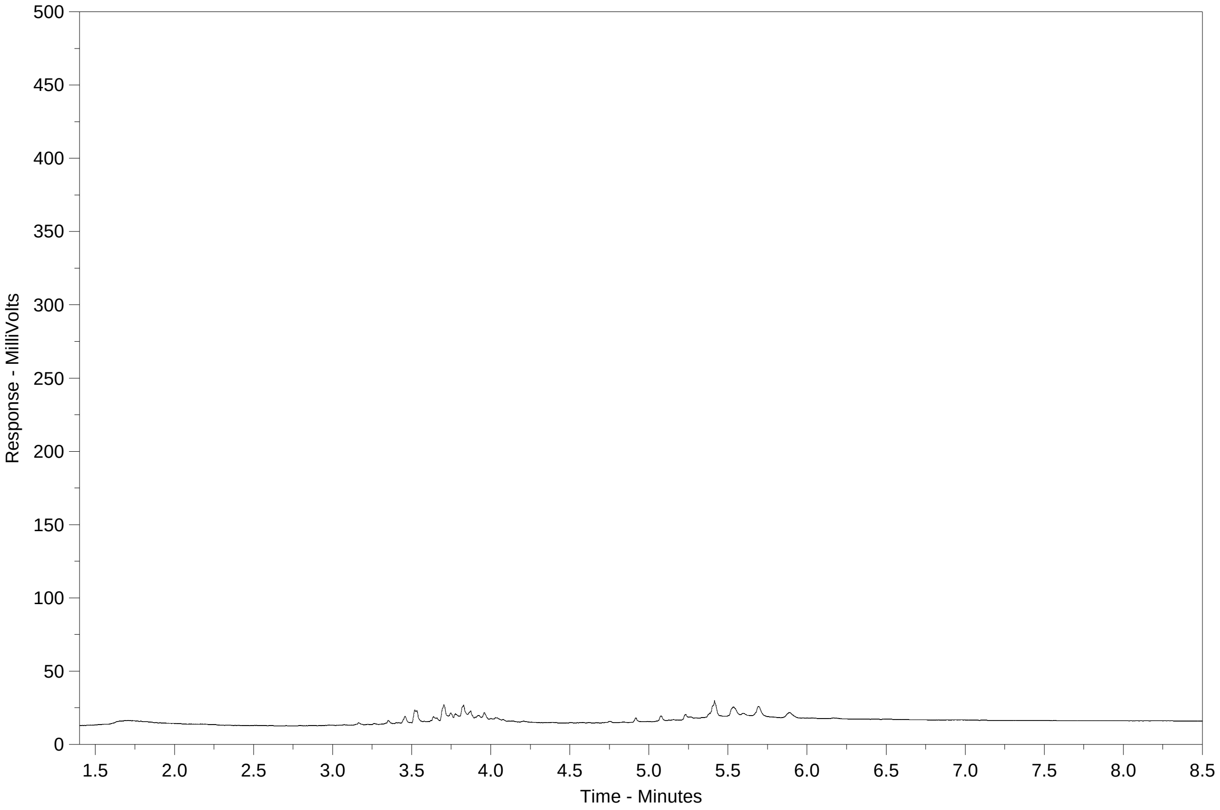
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at left.

Note: This chromatogram was produced using GC conditions that are specific to the CCME F2-F4 method (December 2007 version). Chromatograms generated using this method will resemble those found in the ALS-Vancouver HDR library, though they will appear compressed as the F2-F4 analysis covers a broader range of boiling points. The HDR library can be found at www.alsglobal.com.

CCME F2F4 Hydrocarbon Distribution Report

ALS Sample ID: L1238343-C-3
Client Sample ID: 3609 S12-03



nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F

← Gasoline →
← Diesel / Jet Fuels →
← Motor Oils / Lube Oils / Grease →

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

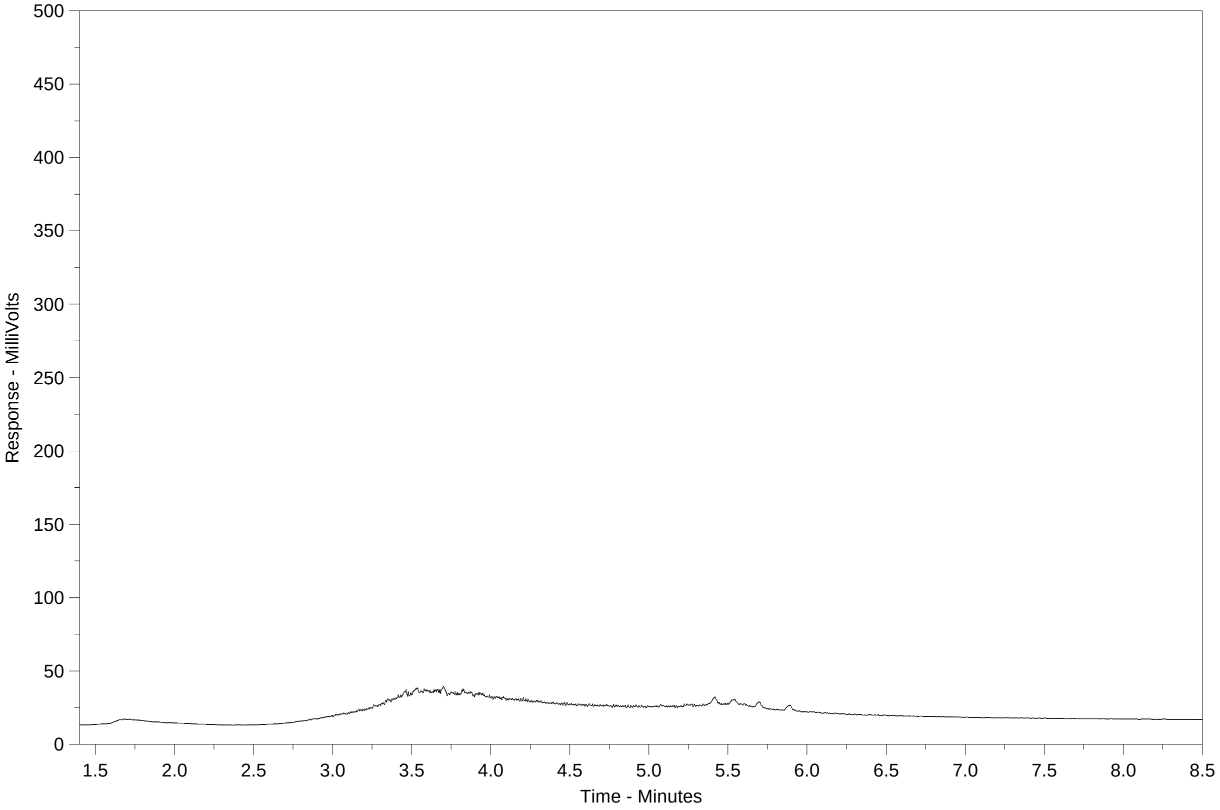
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at left.

Note: This chromatogram was produced using GC conditions that are specific to the CCME F2-F4 method (December 2007 version). Chromatograms generated using this method will resemble those found in the ALS-Vancouver HDR library, though they will appear compressed as the F2-F4 analysis covers a broader range of boiling points. The HDR library can be found at www.alsglobal.com.

CCME F2F4 Hydrocarbon Distribution Report

ALS Sample ID: L1238343-C-4
Client Sample ID: 3609 S12-04



nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F

← Gasoline →

← Diesel / Jet Fuels →

← Motor Oils / Lube Oils / Grease →

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

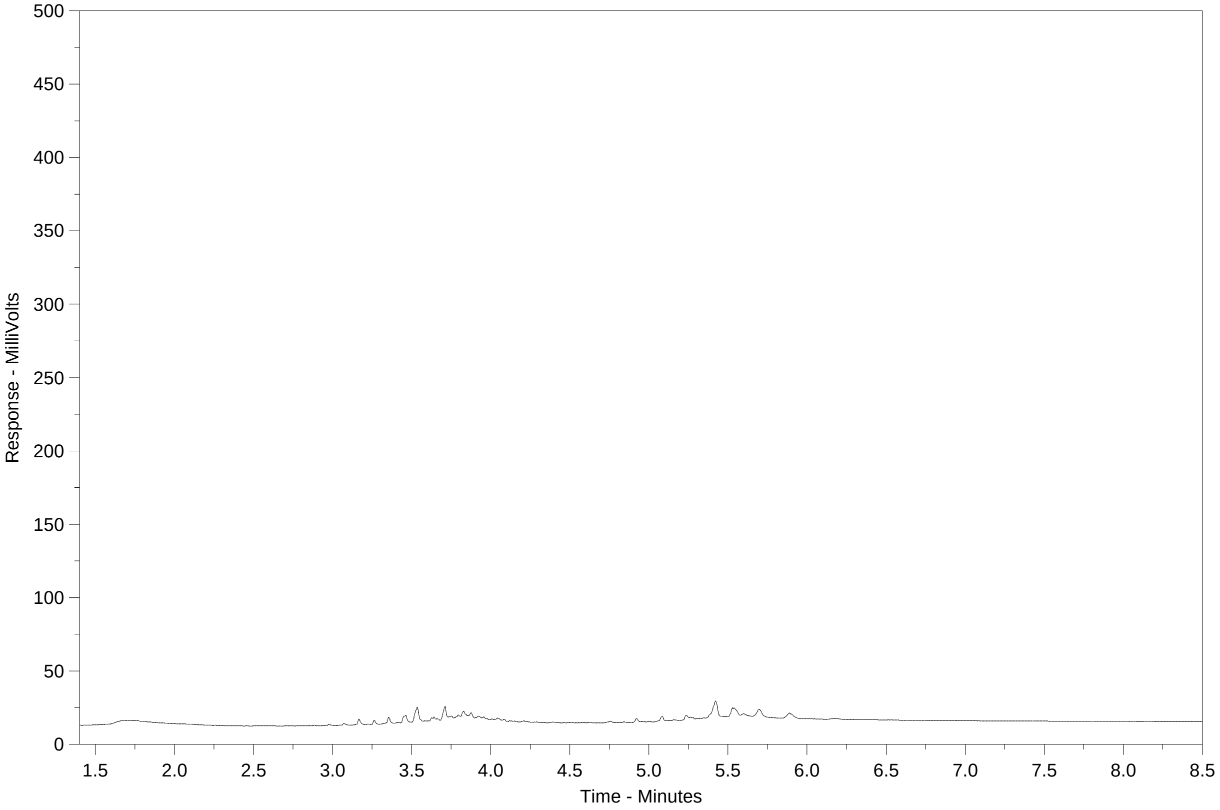
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at left.

Note: This chromatogram was produced using GC conditions that are specific to the CCME F2-F4 method (December 2007 version). Chromatograms generated using this method will resemble those found in the ALS-Vancouver HDR library, though they will appear compressed as the F2-F4 analysis covers a broader range of boiling points. The HDR library can be found at www.alsglobal.com.

CCME F2F4 Hydrocarbon Distribution Report

ALS Sample ID: L1238343-C-5
Client Sample ID: 3609 S12-A



nC10	nC16	nC34	nC50
174°C	287°C	481°C	575°C
346°F	549°F	898°F	1067°F

← Gasoline →
← Diesel / Jet Fuels →
← Motor Oils / Lube Oils / Grease →

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

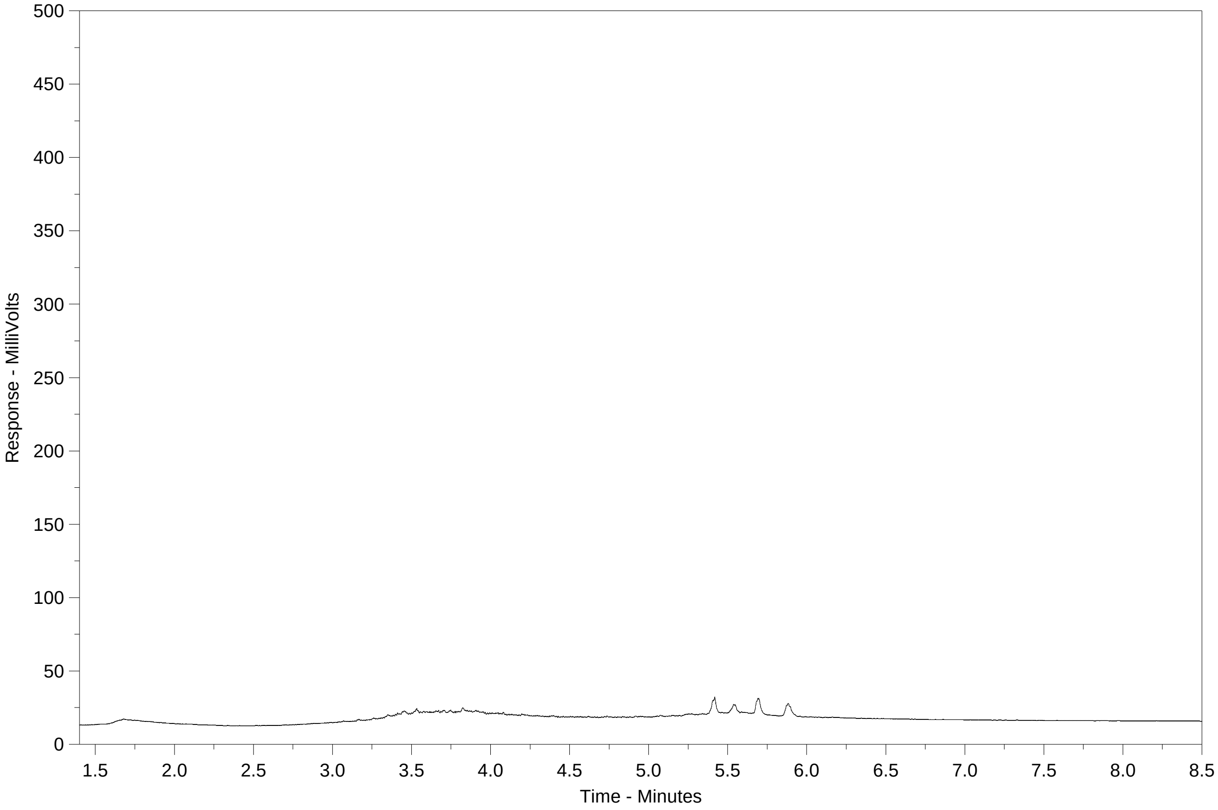
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at left.

Note: This chromatogram was produced using GC conditions that are specific to the CCME F2-F4 method (December 2007 version). Chromatograms generated using this method will resemble those found in the ALS-Vancouver HDR library, though they will appear compressed as the F2-F4 analysis covers a broader range of boiling points. The HDR library can be found at www.alsglobal.com.

CCME F2F4 Hydrocarbon Distribution Report

ALS Sample ID: L1238343-C-6
Client Sample ID: 3609 SED12-01



nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F

← Gasoline → ← Motor Oils / Lube Oils / Grease →
← Diesel / Jet Fuels →

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

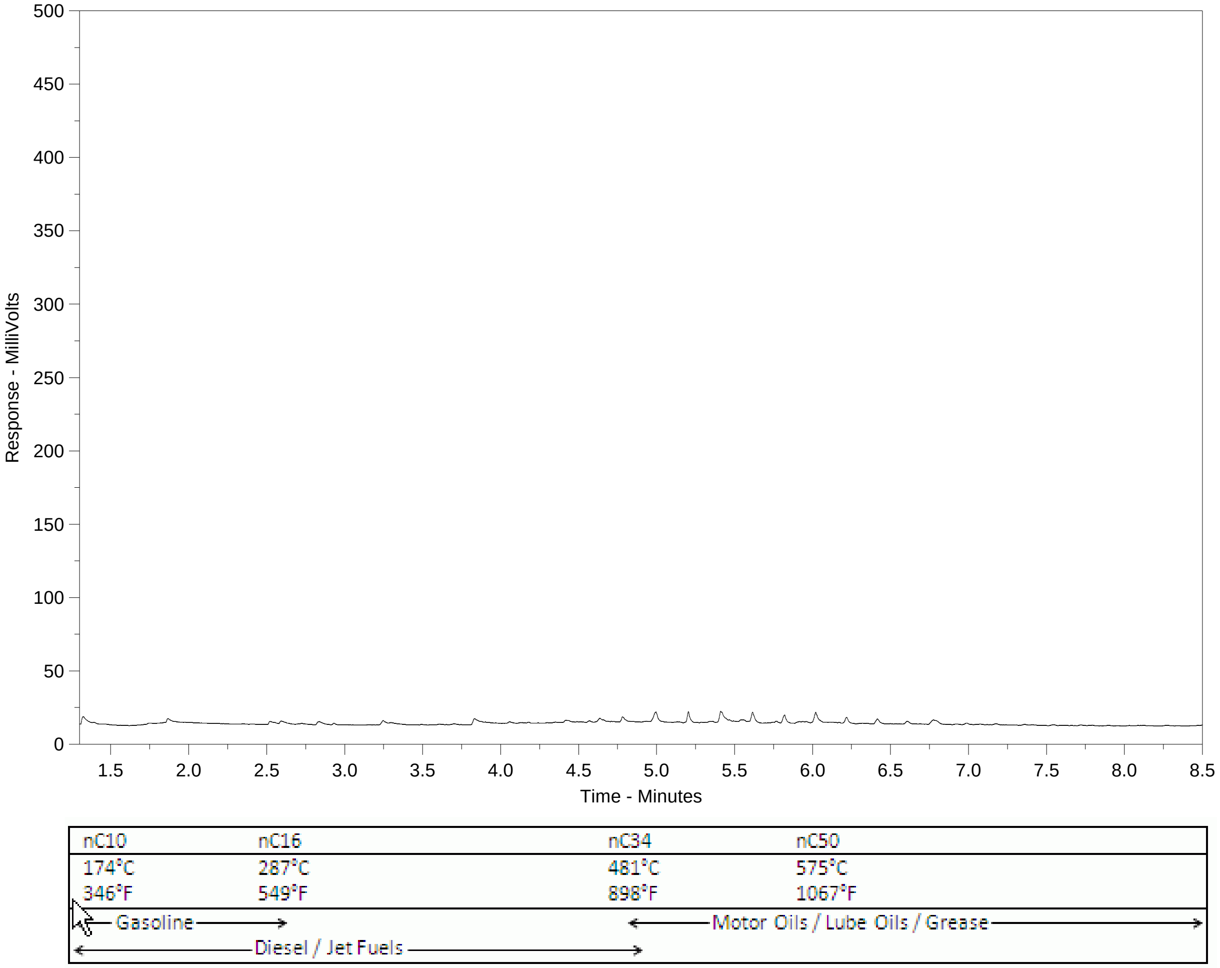
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at left.

Note: This chromatogram was produced using GC conditions that are specific to the CCME F2-F4 method (December 2007 version). Chromatograms generated using this method will resemble those found in the ALS-Vancouver HDR library, though they will appear compressed as the F2-F4 analysis covers a broader range of boiling points. The HDR library can be found at www.alsglobal.com.

CCME F2F4 Hydrocarbon Distribution Report

ALS Sample ID: L1238343-7
Client Sample ID: 3609 SWS12-01



The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

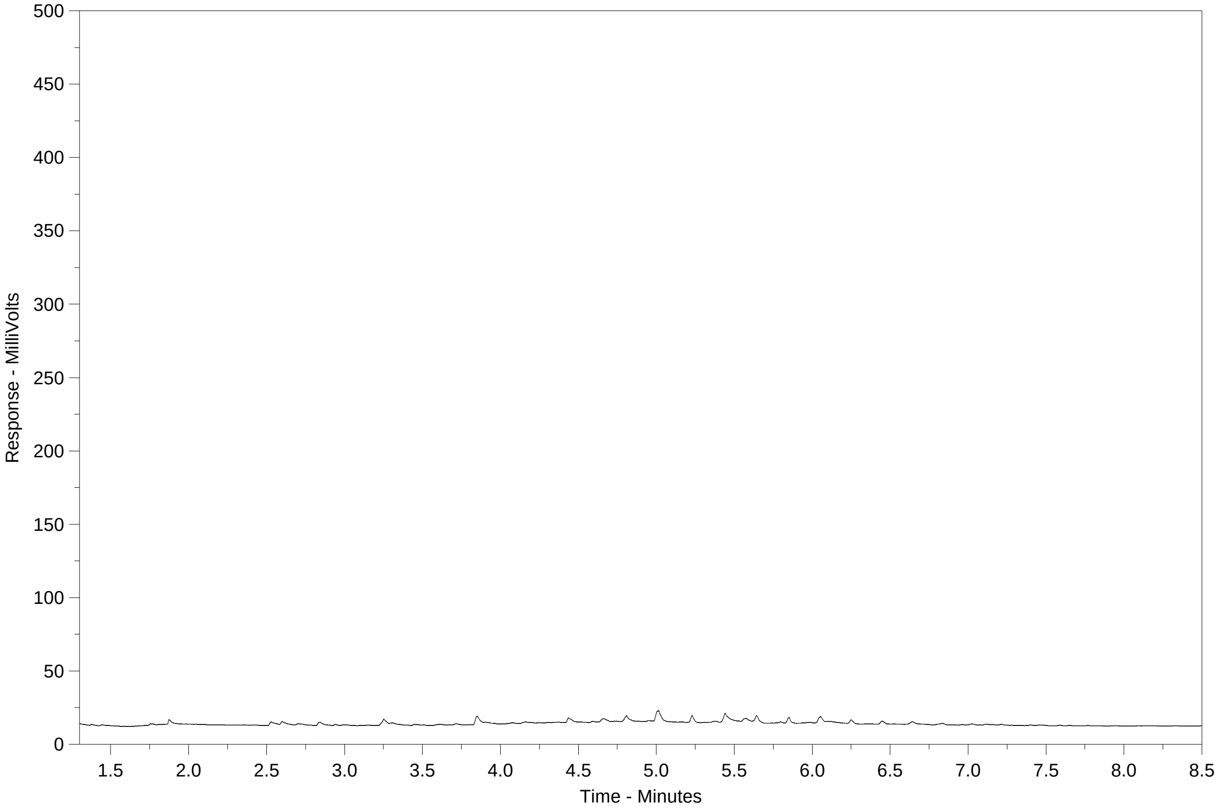
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

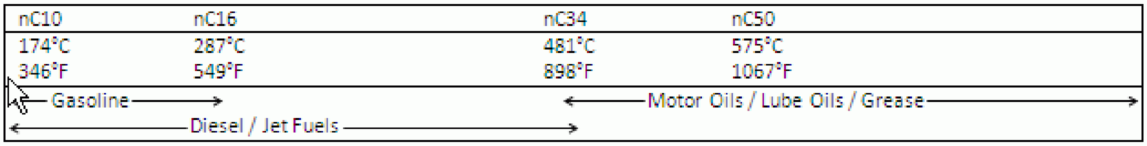
Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at left.

Note: This chromatogram was produced using GC conditions that are specific to the CCME F2-F4 method (December 2007 version). Chromatograms generated using this method will resemble those found in the ALS-Vancouver HDR library, though they will appear compressed as the F2-F4 analysis covers a broader range of boiling points. The HDR library can be found at www.alsglobal.com.

CCME F2F4 Hydrocarbon Distribution Report

ALS Sample ID: L1238343-8
Client Sample ID: 3609 SWS12-02





The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at left.

Note: This chromatogram was produced using GC conditions that are specific to the CCME F2-F4 method (December 2007 version). Chromatograms generated using this method will resemble those found in the ALS-Vancouver HDR library, though they will appear compressed as the F2-F4 analysis covers a broader range of boiling points. The HDR library can be found at www.alsglobal.com.

L1238343

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L1238343-COFC

CHAIN OF CUSTODY / ANALYTICAL REQU

PAGE 1 OF 1

SEND REPORT TO:

COMPANY: SLR Consulting
ADDRESS: 6-40 Cadillac Ave
CITY: Victoria PROV: BC POSTAL CODE: V8Z 1T2
CONTACT: David McKeown TELEPHONE: 250-475-9595
PROJECT NAME/#: Reay Creek / 205.03609.00000 SAMPLER: David McKeown
ALSE QUOTE #: SLR Pricing ALSE CONTACT: Elle Diniz

REPORT FORMAT:
○ Hardcopy ○ Fax #:
● E-mail Specify file type:
E-mail Address: msloan@slrconsulting.com

INVOICE FORMAT:
● Hardcopy ○ Fax #:
○ E-mail (pdf format)
E-mail Address:

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○ Rush (Surcharges May Apply) Specify Due Date: Time:

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:opy of Report? ☑ Yes ☐ No
COMPANY: SLR Consulting Ltd ivid McKeown
ADDRESS: #6 - 40 Cadillac Ave P.O. #: VIC1206
CITY: Victoria PROV: BC POSTAL CODE: V8Z 1T2 TEL:

ANALYSIS REQUESTED:

SAMPLE IDENTIFICATION	DATE / TIME COLLECTED YY-MM-DD	Time	MATRIX	CWS BETX/F1	CWS F2 - F4	CCME PAH (low level)	pH			HOLD for possible leachate test	NOTES (sample specific comments, due dates, etc.)
3609 S12-01	12-11-15		sed./soil	X	X	X	X			X	3 jars
3609 S12-02	12-11-15		sed./soil	X	X		X			X	3 jars
3609 S12-03	12-11-15		sed./soil	X	X		X			X	3 jars
3609 S12-04	12-11-15		sed./soil	X	X	X	X			X	3 jars
3609 S12-A	12-11-15		sed./soil	X	X		X			X	3 jars
3609 Sed12-01	12-11-15		sed./soil	X	X	X	X			X	3 jars
3609 SWS12-01	12-11-15		water	X	X	X					2 x 500mL; 3 x BETX vials
3609 SWS12-02	12-11-15		water	X	X	X					2 x 500mL; 3 x BETX vials

FOR LAB USE ONLY

RELINQUISHED BY:				RECEIVED BY:			
NAME:	David McKeown	DATE:	15-Nov-12	NAME:		DATE:	
OF:	SLR Consulting	TIME:	4:00 PM	OF:		TIME:	
NAME:		DATE:		NAME:	Brittany	DATE:	Nov.16
OF:		TIME:		OF:	ALS Environmental	TIME:	9:00

Special Instructions / Comments (billing details, QC reporting, etc.): Hold samples for possible leachate tests in future.

FOR LAB USE ONLY Cooler Seal Intact? Yes X No__ N/A__ Sample Temperature: 5.1 °C Frozen? Yes__ No X Cooling Method? Icepacks X Ice__ None__

APPENDIX D
Camosun College Report (2010)

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001

Reay Creek Pond Remediation Study

Produced for Camosun College
Environmental Technology Program

By Justin Robinson
& Rachelle Sarrazin

June 2010

Executive Summary

Reay Creek is one of the few urban streams in Victoria that supports an established run of Coho Salmon. However, problems upstream have put this run at risk. Reay Creek Pond is a potential contributor to these problems. The pond is situated on the Saanich Peninsula on the border of Sidney, North Saanich and the Victoria International Airport. This anthropogenically created pond, formed by an earthen dam first installed in the early half of the 20th century, has become an overactive sediment deposition zone. These sediments contain the cumulative effect of decades of agricultural use, historic and current run-off from Victoria International Airport and now runoff from residential areas. These factors have caused Reay Creek Pond to contain a build-up of organic sedimentation, agricultural nutrients and heavy metal contamination.

This study aims to determine water quality, with emphasis on eutrophication factors; sediment depth and pond topography; and recommendations for remediation for the Reay Creek Pond.

Reay Creek Pond was divided into 11 transects every 20 m, each transect then had water and total depth measurements taken at 2 m intervals. The difference between these two measurements was the sediment depth. The results were then mapped using ESRI ArcGIS.

Water quality was determined from three points in the pond: near the dam, at the approximate centre and near the inflow culvert. These samples were tested for nitrogen, nitrite-nitrogen, nitrate-nitrogen and phosphate. Additionally, at each sampling location conductivity, dissolved oxygen, temperature and pH were measured.

Sediment samples were collected at the same 3 locations as water quality tests and one additional location 20 m from the dam. The samples were then separated, homogenised and placed in a centrifuge to extract the sediment pore water. The resulting pore water was then tested for the same parameters as surface water. Samples were also collected for lab analysis at Maxxam Analytics. These samples were taken from the 20 m from dam point and the approximate middle of the pond.

Sedimentation levels in Reay Creek Pond are high, with an average water depth of 38.8 cm and a sediment depth of 129.4 cm. Over the entire pond there is an approximate total volume of 2569 m^3 of non-compacted sediment.

The temperature throughout Reay Creek Pond is very variable (ranging from 12.5 to 21.5 °C) an indicator of poor water quality. The pH was found to fluctuate between 7.22 and 8.46, causing potential stress on fish health. Phosphate was determined to be a limiting nutrient and identified Reay Creek Pond's trophic level to be oligotrophic to meso-eutrophic.

Ammonia concentrations in sediment pore water were exceed testable limits of 2 ppm. Reay Creek Pond sediment displayed relatively normal conditions for freshwater systems. Total phosphorus levels in the sediment were high, potentially causing a eutrophic event if disturbed.

Maxxam laboratory analysis of heavy metals determined that both cadmium and chromium were higher than probable effect levels (PEL) determined by the Canadian Environmental Quality Guidelines[1]. The tested sediments contained 21.5 ppm and 18 ppm of cadmium in the middle and dam sediment respectively, with a PEL guideline of 3.5 ppm. These sediments also contained 115 ppm (middle sediment) and 107 ppm (dam sediment) of chromium, with a PEL guideline of 90.0 ppm).

Based on these results it is recommended that the sediment from Reay Creek Pond be removed. Remediation is also an option however less attractive considering the pond size, metal contamination, sediment loads and neighbourhood desire of a publicly usable pond.

Sediment removal can be accomplished either through draining and excavation of sediments or suction dredging.

Draining and excavation is a laboriously complex solution, requiring a bypass pipe to be installed to drain the pond before excavation can begin. The process will also require large machinery to gain access to the pond, possibly resulting in destruction of shoreline vegetation.

Suction dredging may be a better solution, utilising a smaller suction raft to remove sediment without requiring heavy machinery or draining the pond. The primary concern with suction dredging will be acquiring the machinery.

Mitigation and remediation of sediments to reduce metal contamination and possible eutrophic events is conceivable, however undesirable as the sediments would continue to build up in the pond.

Acknowledgements

Special thanks to those who were able to provide assistance for this project: Ian Bruce was an immense help, providing contacts, materials, ideas and a pillar of support; Reg Kirkham for use of his property and local knowledge of Reay Creek Pond; Cindy Wright for her insight and knowledge with sediments and sediment coring; Audrey Dallimore for providing tools for sediment coring; Tony Dorling for providing equipment on short notice; Neil Meanwell for chemistry insight; Steve Gormican for his experience with aquatic environments; Leslie Glover for her assistance with lab work and passionate drive; Dave Thomas for biology technical support; David Wade and Robin Robinson for guest field day appearances and alternative points of view.

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Introduction

Reay Creek is one of the few urban streams in Victoria that supports an established run of Coho Salmon. Each year Coho return to Reay Creek to spawn and produce another run of ocean going fish. However, there have been events in the past that have caused this run to fail.

Reay Creek is situated in both North Saanich and Sidney, British Columbia in a Costal Douglas-fir Biogeoclimatic zone. The creek begins at two tributaries located at the southern end of the Victoria Airport and empties into the Saanich Inlet. One tributary runs along the southern property boundary of the Victoria Airport and the other tributary runs 460 m beside many of the Victoria Airport commercial facilities. Situated in the middle of Reay Creek, the Reay Creek Pond stretches 255 m from East Saanich Road to Frost Avenue. The extent of Reay Creek's watershed includes the south-eastern half of the Victoria Airport to Mayneview Terrance near the northern boundary of Central Saanich. The total area of the Reay Creek Watershed is 3,540,784 m_2. Over 80% of Reay Creek Watershed is either within the Victoria Airport Property or Residential Land Use Zones. Slightly less than half of the Reay Creek watershed is within the Victoria Airport property, where industrial and institutional aircraft facilities are located. There are several agricultural properties located in the Reay Creek Watershed, but they only represent a fraction of total watershed area[2]. Other commercial, industrial and institutional land uses in Reay Creek Watershed include a car repair shop, school, flight school, airport museum, and restaurant.

Figure 1 – Reay Creek Watershed (shown in in red) and Reay Creek Location on the Saanich Peninsula[2]

History

In the last one hundred years, land use in North Saanich and Sidney has changed dramatically. During early settlement, the Hudson Bay Company purchased North and South Saanich from the First Nations people living in the region. In 1958, John Trutch from the Hudson Bay Company declared that 18,000 acres of the purchased land will be marked off into 100 acre allotments[3]. North and South Saanich settles were then able to own either 100 or 200 acres depending on their marital status. The fertility of Saanich land was far greater than that of Victoria's, causing agriculture to boom in the region[3]. Gain was the first crop to be used on a large scale in North Saanich, then dairying, sheep raising, poultry and hogs followed in quick succession. In the very early days of settlement, fruit trees were introduced successfully followed by other fruit varieties later on. In 1953, nearly 40,000 crates of strawberries, 8,000 crates of Logan berries, 200 crates of strawberries, and almost 200 crates of blackberries were shipped to the Prairies from Saanich[3]. The Victoria Airport started as a military airfield in March of 1939[4]. In 2000, the Airport Authority began the process of renovating and expanding its terminal to meet passenger needs[5]. By 2005, the new Departures and Arrival areas were completed, and the airport terminal had changed dramatically from how it was 100 years ago[6].

Overtime the housing density of Saanich has increased significantly, changing from an agricultural to residential land use zone. In 1984, the North Saanich council declared that its residential density will increase from one residential unit per two hectares to twelve residential units per hectare. In the past, Reay Creek was owned by many different property owners bordering the shoreline of the creek. One property owner used the creek as a duck farm, installing a mud dam and several wooden fences to control water and duck movement in Reay Creek. Once the dam was created, water levels of the creek rose causing a large pond to be created above the dam. Overtime the Reay Creek Pond became exposed to large levels of sediment accumulation and duck excrement[7].

In 1998 the dam was reconstructed by the municipality of Sidney. This was required as the previous dam was beginning to fail. The new dam was engineered of stronger material and provided a better outflow.

Restoration of Reay Creek has been ongoing since 1982 and has involved the participation of many different stakeholders. From 1982 to 1996, restoration efforts were geared towards establishing viable populations of Coho Salmon in a 300 m section of Reay Creek, directly below the pond[8]. Fry from Goldstream Park were transported and released at Reay Creek and spawning and rearing habitats within the creek were improved. With funding from the Department of Fisheries and Oceans and Sidney Anglers Association, the Sidney Anglers and a group of local volunteers were able to install gravel bedding and construct pool/riffle morphology along the 300 m section of the creek. During the period of 1982 to 1996, the Municipality of North Saanich and the Town of Sidney were able to divert unused well water into the Creek with the help of funding assistance from the Provincial Capital Commission[8]. Additionally, the Victoria Airport Authority installed a water quality monitoring station and spill control dam at the southern edge of their property.

From 1997 to 2001, $25,000 in large stream restoration projects were completed on Reay Creek. Restoration projects completed by ex-fisherman and Sidney Anglers Association volunteers included: bank stabilization, stream bed improvement, placement of large woody debris, streamside planting, and construction of spawning beds[8]. Funding for these projects was provided by Fish Renewal BC, the Sidney Anglers Association, Port of Sidney Marina, and the Vitoria Airport Authority.

Metal Contamination

Reay Creek has experienced two heavy metal pollution events, one in 2003 and again 2004, that killed Coho Salmon and Cutthroat Trout populations[9]. Of the 600 Coho fry and 80 cutthroat trout that were killed, many contained lethal doses of cadmium[10]. Cadmium has continued to be a major concern for the fish population and aquatic health of Reay Creek. Contaminated soil located on Airport property and along the upper reaches of the creek was removed by the Victoria Airport Authority during the summer of 2009[11].

In order to rehabilitate the Reay Creek run, the Sidney Anglers and Friends of Reay Creek released one thousand Coho fry in March 2006 to rebuild its salmon population[9]. Current local school programs also contribute each year towards restoration by rearing and releasing Coho Salmon fry and qualitatively monitoring creek health.

Eutrophication

Eutrophication is the naturally occurring process by which a nutrient poor body of water becomes nutrient rich. This process can be sped up by cultural eutrophication, where excess nutrients from agriculture leach into the water body increasing the productivity at a rate far exceeding natural processes. This causes mass blooms of algae, which will eventually die. Bacteria then use oxygen to decompose the dead algae releasing phosphates, further feeding algae growth. Eventually this cyclic process decreases the dissolved oxygen levels in the water body to anoxic levels. This process can either continue long-term through multiple seasons, devastating a water body for an extended period, or can be a single event. In the case of a single event the water body is able to recover and halt the cycle.

The impounding of the upper portion of Reay Creek to create a duck pond provided an excellent reservoir for sediment accumulation. In addition, duck excrement and feed provided an increased nutrient load directly to the water body and its sediments. This pond is an anthropogenic creation, resulting in an unnatural change in habitat for Reay Creek.

In 2005 an engineer and his team from the Municipality of North Saanich entered the Reay Creek Pond to retrieve a fallen tree branch. After the branch removal, the water colour of the pond shifted from clear to bright orange, growing large colonies of algae on its surface. This event occurred a day after the disruption and continued for a week. This eutrophication event caused a decrease in dissolved oxygen in the stream resulting in an aquatic life disruption downstream (i.e. fish kills, however not on the same level as experienced in 2003 and 2004 from cadmium contamination)[7]. This event likely occurred due to sediment disruption, re-suspending stored organic matter and nutrients.

Objectives

Due to the history and level of anthropogenic pollution in Reay Creek Pond, the objectives of this study include:

- Determination of water quality of the pond, including possible eutrophication parameters and heavy metal contamination to prevent future fish kills downstream.
- Mapping sediment depth and pond topography for possible remediation preparation.
- Providing recommendations for remediation and further sampling projects and analysis.

Methodology

Sediment and Water Depth Measurements

Reay Creek Pond was divided into 11 transects every 20 meters. The first transect started 5 m away from the dam, as poor sediment levels were found close to the dam. The location of the second transect was determined by measuring 20 m away from the first transect on both shores. Transects 3 and 4 were measured 10 meters away from the last transect on one shore and 20 m away on the opposing shore in order to compensate for a sharp turn. After Transect 4, each transect was measured by connecting a 50 m measuring tape to the center of the previous transect and measuring 20 m while following the contours of the pond. The location of the next transect was visually defined by features on both shores and the addition of red flagging tape. Transect locations can be seen in Figure 2.

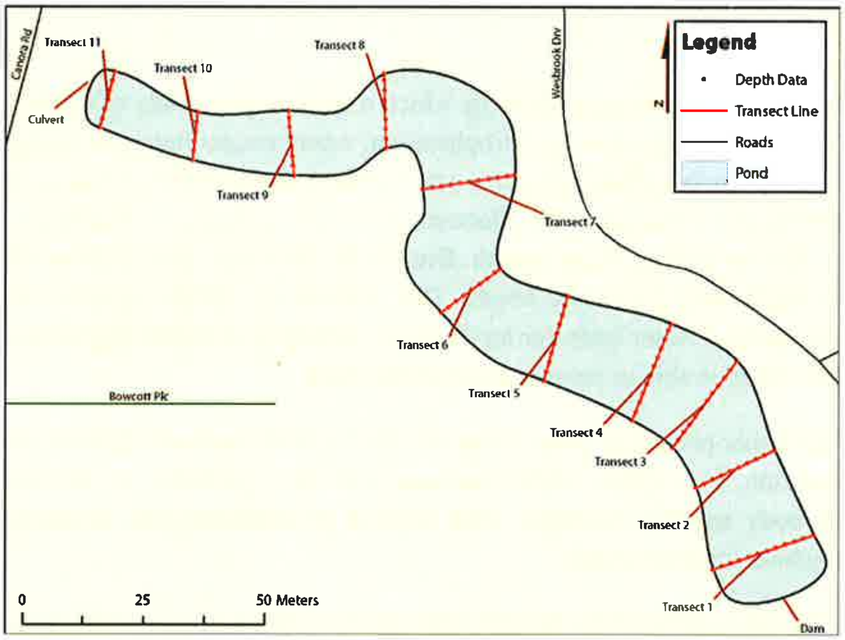

Figure 2 – Map showing transect locations and data collection points for Reay Creek Pond study, June 2010

For each transect, rebar was hammered into opposing shores and rope with flagged 2 m intervals was stretched tightly between both rebar locations. In order to maintain accuracy, the distance between each 2 m marked intervals was measured and corrected for each transect. For correct referencing, the same shore was used for the zero meter mark of each transect. The distance, bearing, and GPS location of each transects start and end points were collected in order to be referenced in Arc Map GIS software.

Sediment and water depth measurements were taken from a boat using several thin bamboo rods at different lengths. The bamboo rods were inserted in the water body until there was a slight resistance, at which time the measurer would mark the water level in regards to the bamboo rod with his or her index and thumb. A 50 m measure tape was pulled tight across the bottom of the bamboo stick to the measurer's index finger where the water to sediment depth is recorded in cm to one decimal place of precision. In order to compensate for increased bending in the bamboo sticks, the measuring tape was stretched tightly across the stick without following its contour. Water to sediment depth measurements were collected simultaneously by both measurers at a selected sample location. The discrepancy between the two measurements were noted and adjusted to maintain accuracy.

The bamboo stick was then inserted into the water at a new location close to the original sampling site location to collect total depth measurements. Strong force was used on the bamboo stick in order to be certain that a hard substrate was reached and was applied multiple times to ensure correct measurement. The measurer then marked the water level on the bamboo stick using his or her index finger and thumb and then gently pulled up the stick while maintaining their grasp location on the stick. The stick was cleaned and then measured using the same 50 m measuring tape. Measurements were recorded in centimetres to one decimal place of precision. Sediment depth was calculated by subtracting the total depth of the sample site by the water to sediment depth.

Water Quality Sampling

Water samples were collected at the beginning, middle, and end of the pond using 1 litre plastic bottles. Bottles were cleaned three times with pond water and inserted into the pond for several minutes to allow for water flow. Water samples were collected at a depth of one foot in order to prevent contamination of surface water. Bottles were shaken and capped in the water to prevent any bubbles from being collected. Two water samples were collected at the end of pond in order to match the location of sediment samples collected at 20 meters and 5 meters away from the dam.

Water samples were refrigerated between 4 and 6°C for 24 hours following collection. LaMotte's Water Quality Testing Products were used in conjunction with a LaMotte SMART 2 Colorimeter to test for Ammonia Nitrogen (Low Range), Nitrite Nitrogen (Low Range), Nitrate Nitrogen (Low Range), and Phosphate (Low Range). The colorimeter was pre-calibrated by LaMotte for proper use all of their water quality testing kits. Before testing, all tubes, flasks, and graduated cylinders were rinsed with tap water. Testing methods followed LaMotte's Procedure sheets provided with each kit. In order to assess errors associated with sample heterogeneity and sample testing techniques, two replicates were created for each test using the same water sample. Colorimeter results were collected until values were stable. In some cases an average of many colorimeter results was recorded due to fluctuations caused by tube orientation in the colorimeter.

Water parameters were also collected using a Model 85 YSI meter. These parameters included conductivity and dissolved oxygen. A pHTestr 30 was used to collect pH information. Temperature was also recorded using a glass thermometer. These parameters were collected at the same sites as above: beginning, middle, and end.

Sediment Sample Collection and Pore Water Analysis

Sediment samples were collected at four different sampling locations along Reay Creek using an metal Ekman Grab. Sediment sampling sites were located at the beginning, middle and end of the pond as close to water sampling sites as possible. At the end of the pond, sediment samples were collected at two locations 20 and 5 meters away from the dam. Sediment samples were collected following the RISC protocol for sampling lake sediment on a boat[12]. Once collected, samples were released from the Ekman Grabber into a large plastic container and scooped into a labelled Tupperware container using the container itself. Large organic content was manually removed as the sample was scooped into the Tupperware container. Each sample container was quickly moved to shore and placed into the pond in order to maintain a constant temperature. To prevent contamination of surface water, the lids of the containers were closed tightly and never allowed to be submerged. Sediment samples were refrigerated between 4 and 6°C for 42 hours, following the RISC Preservation and Hold Times for Sediments and Tissues Guidelines[12]. The temperature of the refrigerator was checked twice and adjusted to maintain a constant temperature.

Sediment samples were brought to Camosun College's Microbiology Lab in order to undergo pore water extraction through the use of their centrifuge. A non-analytical balance scale was balanced and tared with an empty 10 ml glass test tube and a test tube holder in order to hold the tubes upright when being weighed. For each sediment sample the sediment was transferred into thirty-two 10 ml glass test tubes using small metal scoopers and 20ml plastic pipettes. Each test tube was weighed to a weight of 10.50 g with a standard deviation of 30mg in order to properly balance the centrifuge. Eight test tubes were placed evenly over each of the four test tube holding blocks in the centrifuge and caped tightly with plastic lids. To determine the highest pore water yield speed for the centrifuge, we used the equation found in *Comparison of techniques for the isolation of sediment pore water for toxicity testing*[13]. This was then used in conjunction with a table, provided by the centrifuge manufacture, to determine the correct speed for the centrifuge. Test tubes were spun at 3500 revolutions per minute for 15 minutes with the use of speed brake to slow down the centrifuge afterwards. All four sediment samples were spun individually in separate batches. All equipment that came into contact with sediment was rinsed with tap water after each batch. To prevent phosphorous contamination, soap was not used to clean any of the equipment.

Pore water was decanted from the glass test tubes with a new 20 ml pipette and transferred into a labelled flask. Pore water from each sediment sample batch was combined into one flask. Pore water quality of each sediment sample was assessed using the same methods used for surface water quality (see Water Quality Analysis). For Phosphorous (Low Range) and Ammonia Nitrogen (Low Range) tests, we were able to use new reagents that replaced several old to expired kits.

Sediment Biochemical Oxygen Demand Sample Collection and Analysis

Sediment for Biochemical Oxygen Demand (BOD) analysis was collected 20 m away from the dam where sediment deposition was high. An Ekman Grab was used to collect several allotments of sediment into a large bucket. Sediment from the bucket was then poured into a large plastic container with a lid.

The collected sediment was transported directly to Camosun College's Microbiology Lab in order to undergo a BOD five day test (BOD5). Large organic matter was removed from the sediment sample before being poured into a large, glass graduated cylinder where it was mechanically mixed by a plastic stirring rod. A mixing bead was added to each 300 ml BOD bottle with sediment and deionised water. The dilution ratio of sediment to water was chosen based on the U.S. Geological Society's guidelines at 1:5, 1:14, 1:29, 1:59, and 1:149[14] . Following the Puget Sound Water Quality Guidelines for sediment BOD testing, dilution water was aerated by capping and shaking each volume of dilution water for 30 seconds before being added to the BOD bottles[15]. As a precautionary measure, one 5 ml buffer pillow was added to the dilution water in order to prevent the effects of oxygen consumption by heavy metal ions. Ingredients in the buffer pillow matched the requirements set out in the Puget Sound Water Quality Authority's sediment BOD test methodology[15].

The top of each bottle and the bottom rim of each rubber insert were greased with stop cock grease. In order to prevent the contamination of Lithium Hydroxide in the solution, the chemical was slowly added to the rubber insert outside of the bottle with a plastic funnel. One blank was created by filling a BOD bottle with 300 ml of aerated, deionised water used as dilution water for all other bottles. All six bottles were placed onto a manometric BOD machine and attached. The machine was set to detect a BOD range of 0-700 mg/L for all bottles for a duration of five days while constantly stirring. The BOD machine was placed into a incubator with a set temperature of 20°C, as outlines in the Puget Sound Water Quality Authority's sediment BOD test methodology[15]. The temperature of the incubator was set at 20°C four hours before the test and maintained 20°C for five days with a maximum deviation of 0.5°C. After three and five days the BOD results were checked.

Invertebrate and Aquatic Wildlife Identification

Fish were collected selectively along Reay Creek Pond at four different locations where fish were present. A D-net was used to scoop fish into a small Tupperware container filled with pond water. Invertebrates were collected at the beginning and end of the pond after spending 2 minutes inspecting each site. A clear plastic water bottle filled with pond water was used to contain all identifiable invertebrates. In order to collect a sample of smaller invertebrates, another clear plastic bottle was used to scoop a 3cm x 1cm area of surface sediment at a depth of 2 centimetres.

The main aquatic vegetation species in Reay Creek Pond were identified using the Identification Keys to the Aquatic Plants of British Columbia[16]. Fish species were identified using the Field Key to the Freshwater Fishes of British Columbia[17].

GIS Map of Pond and Sediment Features

After differentially correcting the raw data from the GPS, the points were imported into ESRI ArcMap. The points were added to a base map and satellite image of the area obtained from the CRD's Natural Areas Atlas[2]. From this set of data the perimeter of the pond was approximated.

To form a representation of the transects, the two start and end GPS points were joined by polylines. These polylines were then divided into two meter increments and the division points were plotted. To this new point layer (Transect Depths) the required fields were populated from measurements taken in the field (transect numbers, water depth, sediment depth, and other observations). A final field was added that calculated the difference between the sediment depth and water depth to show the depth of just the sediment.

A digital elevation model (DEM) was created for both the sediment depth and water depth. This was achieved by utilising the Topo to Raster function. This function is specially designed with the creation of hydrologically correct DEMs[18], interpolating elevation (in this case depth) values based on a connected drainage structure and correct representation of ridges and valleys. Topo to Raster allows for interpolation based on a much smaller quantity of data than other interpolation tools available (inverse distance weighted interpolation, kriging and spline). Of the interpolation tools available in ArcMap Topo to Raster provided the most logical, natural, and accurate modeling.

The transect depths shapefile was used for interpolation to DEM. Depending on the required depth measurement (sediment bottom or water bottom) a field was selected from this layer in the Topo to Raster function box. The result was then contained by the Pond polygon selected as boundary in the same box. The resulting DEM had its symbology modified to show a colour ramp and had contour lines generated by the Spatial Analyst at 0.25 m intervals.

Using the interpolated DEM a triangulated irregular network (TIN) was created in ArcScene. This allowed for a 3 dimensional representation of the pond bottom and sediment bottom for easier sediment depth visualisation. This was achieved by using the 3D Analyst's convert raster to TIN function, the default 0.13 m z-tolerance was used.

Results

Sediment Depth Transects & Mapping

From the depths recorded in the field the depth of sediment was determined. The results of this can be found in Table 1 of Appendix A. Transect Locations can be seen in Figure 5. Figure A-1 to Figure A-11 shows the cross-sectional depths of the water and sediment based on this data.

Two maps were produced using the collected depth data (Table 1 of Appendix A). Figure 3 shows the depth of water and Figure 4 shows the depth of sediment in Reay Creek Pond. A third map (Figure 5) was produced to show the thickness of sediment.

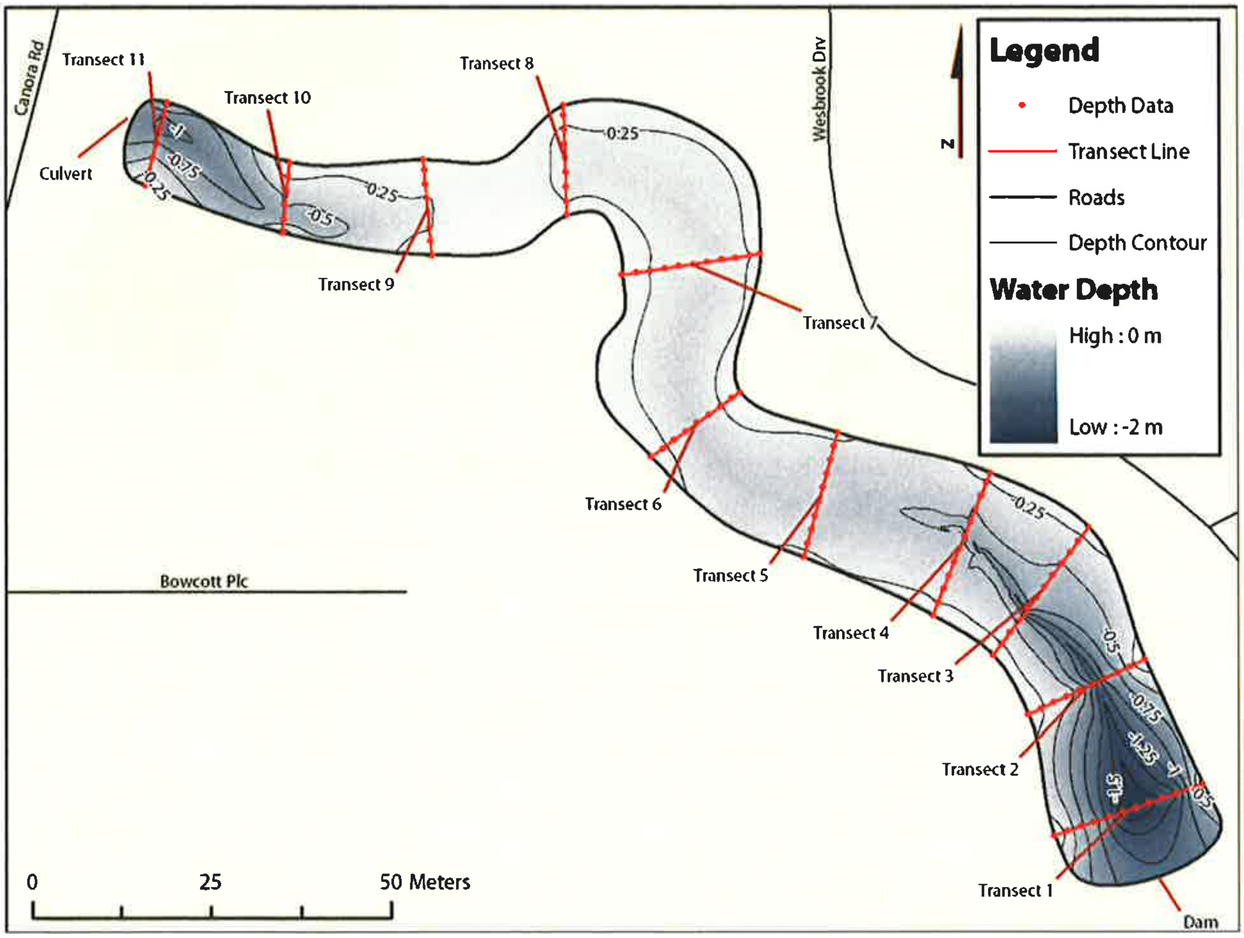

Figure 3 – Water Depth Contour Map of Reay Creek Pond, June 2010

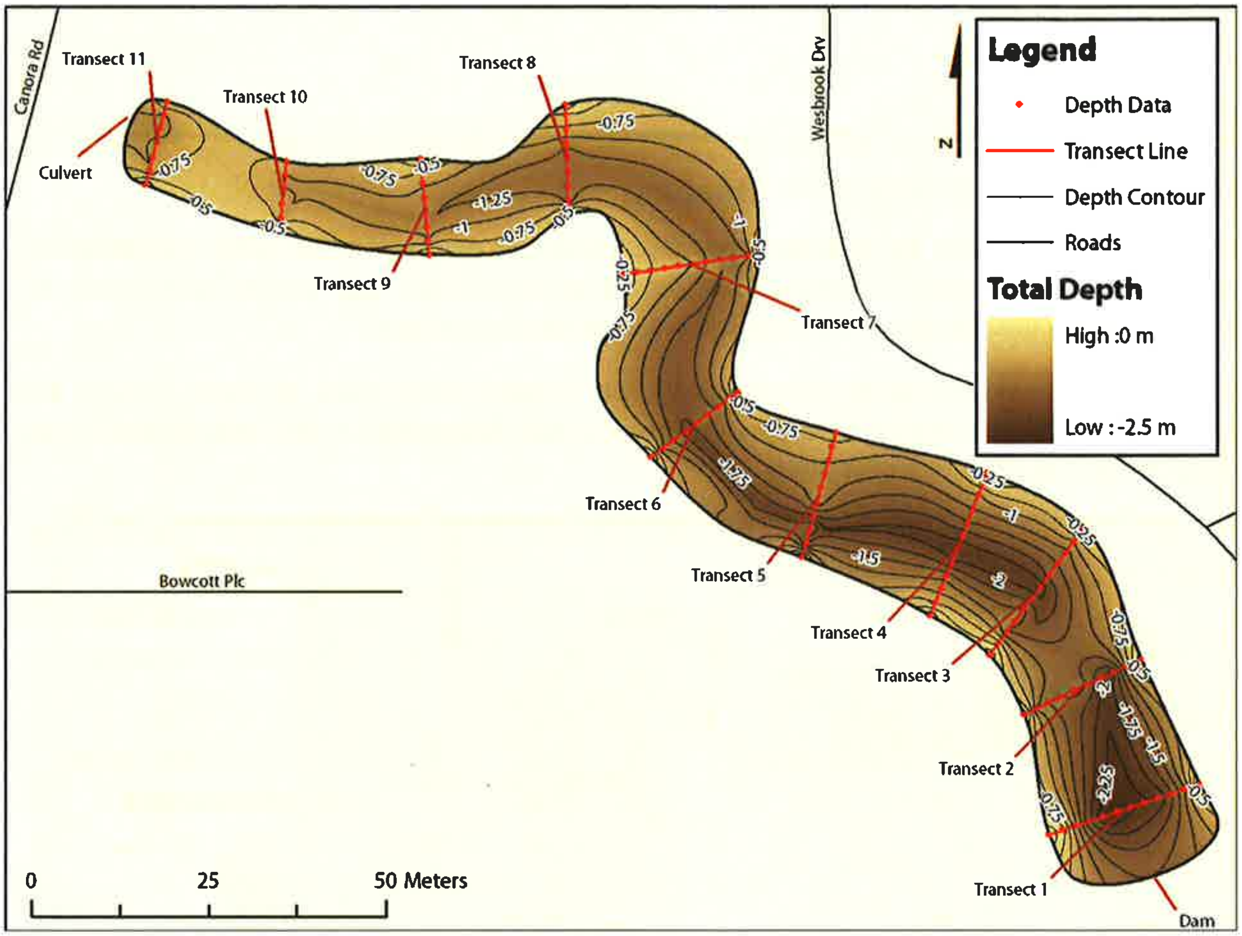

Figure 4 – Total Depth Contour Map of Reay Creek Pond, June 2010

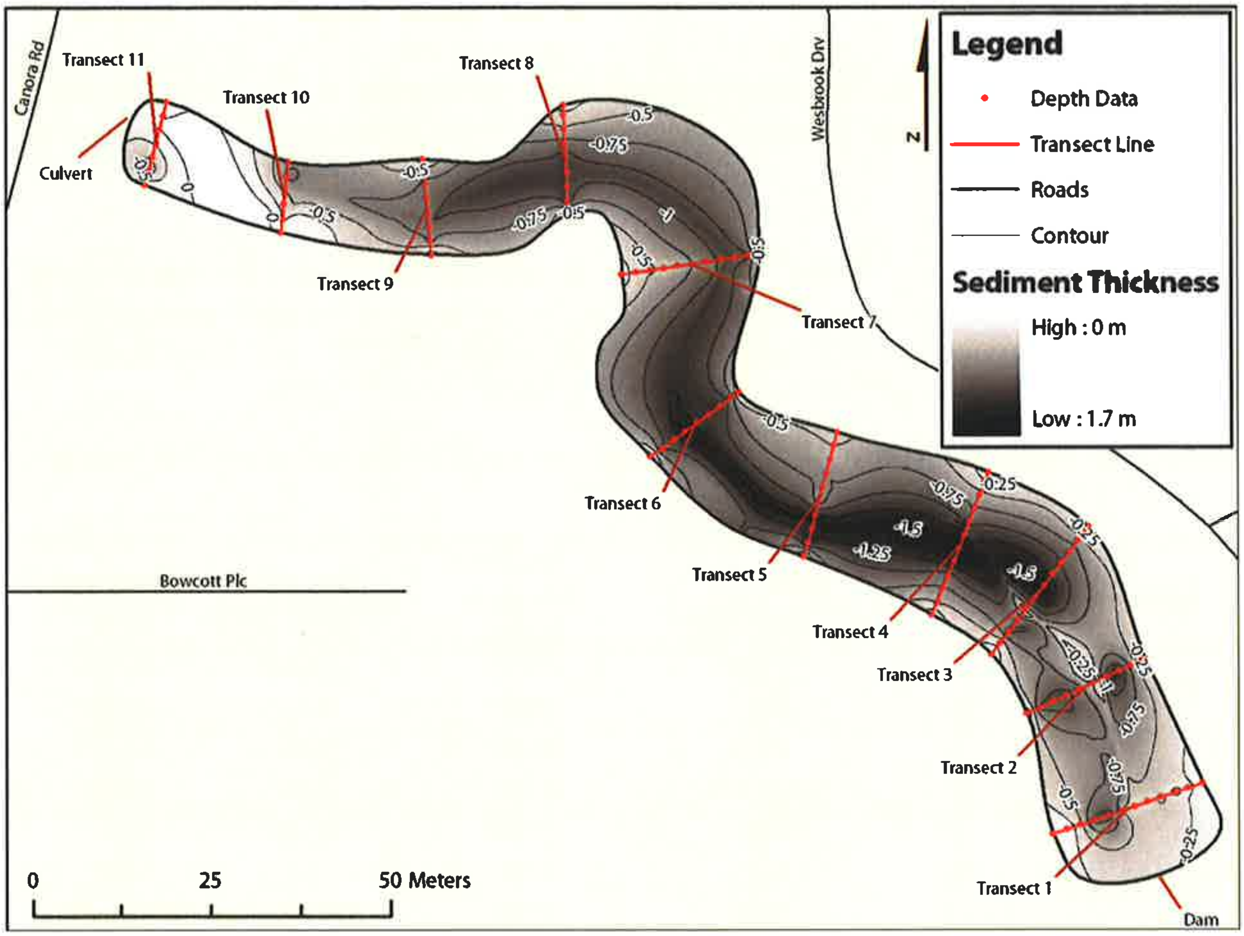

Figure 5 – Thickness of Sediment and Contours Map of Reay Creek Pond, June 2010

Three dimensional analysis was conducted on the sediment and water depth layers, this resulted in a 3 dimensional TIN (triangulated irregular network). Due to the constraints of displaying 3D media in reports the ArcScene files can be found on the accompanying CD-ROM in Appendix B. From the 3D model it was determined that the volume of sediment in the pond is approximately 2569 m^3.

Flora & Fauna

A cursory identification of the dominant aquatic vegetation occurred during depth analysis. It was found the two dominant aquatic plants were *Elodea canadensis* and *Potamogeton robbinsii.*

The only aquatic vertebrate found during the period of study was the three-spined stickleback *(Gasterosteus aculeatus).* Four were captured for identification, one was found floating on the surface already deceased (the largest of the four, approximately 3.5 inches long, with puncture marks near pectoral fin).

Testing Results

The following sections describe the results obtained from water quality testing "in-house" using individual quality sets as described in the methodology and the results obtained from Maxxam Analytical Laboratories.

In-House Experiments

In the following tables (Table 1 – Table 3) the results of the individual test packages for water quality is presented. Table 1 shows the water quality of surface water where over the entire pond ammonia concentration ranged from 0.03 to 1.02 ppm, nitrite-nitrogen ranged from 0.0025 to 1.775 ppm, nitrate-nitrogen ranged from 0.002 to 1.69 ppm and phosphate ranged from 0.03 to 0.23 ppm.

Table 1 – Water Quality results of Water Samples from Reay Creek Pond collected June 5 2010, analysed June 6 2010

Location	Rep	Ammonia-Nitrogen (ppm)	Nitrite-Nitrogen (ppm)	Nitrate-Nitrogen (ppm)	Phosphate (ppm)
Culvert	1	0.165	1.775	0.0045	0.09
	2	N/A*	0.0025	1.69	0.03
Middle	1	1.02	0.007	0.76	0.09
	2	0.915**	0.009	0.76	0.09
20m From Dam	1	0.03	0.052	0.315	0.07
	2	0.31	0.005	0.4	0.15
	3	MAX	0.005	0.33	0.155
3m From Dam	1	0.25	0.31	0.005	0.23
	2	0.41	0.43	0.002	0.115

*Reagents exhausted

**New reagents used

Table 2 shows the results of testing water quality from pore water extracted from sediments. In the pore water ammonia concentration was higher than measureable values except for in one case where the concentration was 0.98 ppm; both nitrite-nitrogen and nitrate-nitrogen measured 0 ppm in all tests; phosphate ranged from 1.3 to 2.13 ppm.

Table 2 – Water Quality results of Pore Water Samples from Reay Creek Pond Sediment collected June 5 2010, analysed June 7 2010

Location	Rep	Ammonia-Nitrogen (ppm)	Nitrite-Nitrogen (ppm)	Nitrate-Nitrogen (ppm)	Phosphate (ppm)
Culvert	1	0.98	0	0	1.3
	2	>2	0	0	1.31
Middle	1	>2	0	0	2.13
	2	>2	0	0	2.06
20m From Dam	1	>2	0	0	1.91
	2	>2	0	0	1.9
3m From Dam	1	>2	0	0	1.42
	2	>2	0	0	1.48

Table 3 shows water parameters (dissolved oxygen, conductivity, pH and temperature) taken while in the field. Dissolved oxygen ranged from 6.84 to 16.5 mg/L; conductivity ranged from 266.5 to 302 µS; pH ranged from 7.22 to 8.46 and temperature ranged from 12.5 to 21.5 °C. Surface water alkalinity was later determined to be 160 ppm.

Table 3 – Water Parameters Collected in-field from Reay Creek Pond on June 5 2010

Location	DO (mg/L)	Conductivity (µS)	pH	Temp (°C)	Time
Culvert	7.65	270.8	7.22	12.5	12:05
Middle	17.5	302	8.46	21.5	16:32
3 m From Dam	6.84	266.5	7.22	16.5	16:10

Biochemical Oxygen Demand

After three days, the biochemical oxygen demand (BOD) in five of the six BOD bottles was 0 mg/L. At day two the BOD spiked to about 30mg/L for the five BOD bottles, but dropped to zero shortly thereafter. BOD in the third bottle, at a sediment to water dilution ratio of 1:29, continuously increased to 50 mg/L by the third day. After five days the BOD in all bottles was at zero, with the BOD in the third bottle decreasing rapidly after day three. These results are tabulated in Table 4.

Table 4 – Results of Biochemical Oxygen Demand tests for Reay Creek Pond, Analysed June 2 2010

Sample	Day 1	Day 2	Day 3	Day 4	Day 5
BOD Sample 1	0	30	0	0	0
BOD Sample 2	0	28	0	0	0
BOD Sample 3	0	29	50	0	0
BOD Sample 4	0	24	0	0	0
BOD Sample 5	0	27	0	0	0

Metal Analysis Results

The following tables show results requested from Maxxam Analytics. Table 5 shows heavy metal results from sediment sampled from the middle and near the dam (approximately 3 m in front of dam) of Reay Creek Pond. Of interest are the concentrations of chromium, with 115 ppm in middle sediment and 107 in dam sediment, and cadmium, with 21.5 ppm in middle sediment and 18 ppm in dam sediment. In addition to total metals, available orthophosphate and total organic carbon (TOC) were also requested. Maxxam reported 60.5 µg/g available orthophosphate and 62 g/kg of TOC.

Table 5 – Total Metal Results from Maxxam Lab for Middle and Near-Dam Sediments

Metal	Middle Sediment (ppm)	Dam Sediment (ppm)
Total Aluminum (Al)	20600	23700
Total Antimony (Sb)	1.2	1.4
Total Arsenic (As)	4.6	5.3
Total Barium (Ba)	114	138
Total Beryllium (Be)	0.5	0.5
Total Bismuth (Bi)	0.1	0.2
Total Cadmium (Cd)	21.5	18
Total Calcium (Ca)	7560	8070
Total Chromium (Cr)	115	107
Total Cobalt (Co)	15	15.5
Total Copper (Cu)	88.8	103
Total Iron (Fe)	29300	34400
Total Lead (Pb)	65.7	65
Total Magnesium (Mg)	7130	8180
Total Manganese (Mn)	474	783
Total Mercury (Hg)	0.09	0.12
Total Molybdenum (Mo)	1.6	2.2
Total Nickel (Ni)	34.5	38
Total Phosphorus (P)	882	1320
Total Potassium (K)	947	1180
Total Selenium (Se)	<0.5	<0.5
Total Silver (Ag)	0.16	0.18

Metal	**Middle Sediment (ppm)**	**Dam Sediment (ppm)**
Total Sodium (Na)	453	603
Total Strontium (Sr)	51.4	52.5
Total Thallium (Tl)	0.08	0.1
Total Tin (Sn)	1.4	1.5
Total Titanium (Ti)	788	685
Total Vanadium (V)	69	77
Total Zinc (Zn)	701	741
Total Zirconium (Zr)	3.3	2.9

Discussion

Sediment Transects

Based on the results, the deepest sedimentation was found around the middle sections of the pond (between transects 3 and 6, see Figure 5). This was expected as the inflow has larger sediment particles. As the flow slows along the middle fines begin to drop out— being the majority of suspended particles— and reconstruction in the dam, vicinity would have removed or redistributed large amounts of sediment. As well, flow patterns at the dam would promote less deposition and more scouring of sediments.

The resulting interpolation of the water depth was relatively accurate to what was observed in the field, with only a few concerns. Based on visual inspection there is a larger sink or depression after transect 10 that is not accounted for in the interpolation. There is also a shallower mound at the south end of transect 11. The accuracy of this interpolation is still subject to scrutiny. With limited data points a fully accurate bathymetric analysis is suspect. Due to this possible inaccuracy the sediment volume stated is purely an estimate.

Water Quality Analysis

Temperature

The temperature at the Reay Creek Pond varied widely depending on location (see Table 3). The high temperature in the middle of the pond could have been caused by the lack of vegetation cover and intense solar radiation during testing. Due to the short duration temperature was recorded; we were not able to compare the results with RISC's weekly temperature criteria. Based on the Optimum Temperature Ranges of Specific Life History Stages of Salmonids by the BC Ministry of the Environment, the temperature at several locations in Reay Creek exceeded temperature requirements for many of the Coho Salmon and Cutthroat Trout life stages[19]. Water temperature at the culvert did not exceed any of the optimum temperatures for Coho Salmon life stages, but did reach the maximum for incubation and spawning of Cutthroat Trout. Conversely, the water temperature in the middle of Reay Creek Pond exceeded all optimum temperatures for incubation, rearing, migration, and spawning life stages for both Coho Salmon and Cutthroat Trout[19]. At the dam, water temperature had decreased to the maximum range for all Coho Salmon life cycles but exceeded incubation and spawning temperatures for Cutthroat Trout.

Due to the shallow depth of water and lack of vegetative cover in many areas along Reay Creek Pond, it can be expected that temperatures could reach dangerous spikes during summer. This combined with our temperature results suggests that Reay Creek Pond would not be able to support or sustain populations of Coho Salmon and Cutthroat Trout.

Dissolved Oxygen

The dissolved oxygen (DO) concentrations in at the culvert and dam deviated by 0.81mg/L, but levels in the middle of Reay Creek Pond spiked by over 10 mg/L (see Table 3). In shallow waters, such as Reay Creek, the majority of oxygen loss can be attributed to oxidation occurring at the sediment-water interface[1]. Oxygen is depleted by bacteria as they consume organic material in the sediment-water interface, which could explain the overall decrease of DO from the beginning of Reay Creek Pond to its end. Although organic decomposition is a large factor in the depletion of DO, the presence of a storm water outflow inside the culvert could also be source for its larger DO value. The large spike of DO in the middle of Reay Creek Pond could have been caused by photosynthesis by aquatic vegetation, which is one the most common sources of DO[1]. While dissolved oxygen readings were being recorded in the middle of Reay Creek Pond, hundreds of bubbles were being created on the leaves of aquatic vegetation. The large presence of bubbles, accompanied by high levels of solar radiation, is a strong indication that the high dissolved oxygen readings were caused by photosynthesis of pond vegetation. The DO spike in the middle of Reay Creek Pond is an outlier due its consequential high temperature reading. With high summer temperatures, the DO concentration and solubility in the circulating epilimnion should decrease[1]. Unfortunately, due to a lack of temporal data, both hypotheses cannot be tested. Additionally, respiration from populations of juvenile stickleback may have an impact on dissolved oxygen depletion in Reay Creek Pond, although this is thought to be slight.

All three testing locations at Reay Creek Pond contained DO concentrations that were greater than the lowest acceptable dissolved oxygen concentrations for aquatic life in warm water[1]. Dissolved Oxygen at the dam was very close to the lowest acceptable concentration of 6.5mg/L, based on a safety margin of 0.5 mg/L set out by the Canadian Environmental Quality Guidelines[1] (see Table 3). Based on RISC's criteria for dissolved oxygen, concentrations found in Reay Creek Pond exceed criteria for sustaining embryo and alevin stages of fish in the water column. Both guidelines suggest, that based on DO concentration, Reay Creek Pond provides an environment suitable for freshwater aquatic life but currently cannot act as a spawning ground[1 20]. Also, it is important to note that the dissolved oxygen concentrations at the culvert and dam were at a concentration that decreased the survival of the emergence life stage of *Ephemera* and *Leptophlebia* (two genus of Mayfly)[1]. Mayfly nymphs are important in freshwater systems because their grazing activities play an important role in preventing the build-up of a large biomass of aquatic algae and detritus[21]. By removing aquatic algae and detritus, Mayfly nymphs might be able to limit the effects of eutrophication events by removing several carbon sources for bacteria.

Conductivity

Overall, the conductivity stayed relatively constant at all three locations along Reay Creek Pond. At the middle of Reay Creek Pond, the conductivity was 30μS/cm greater than the other sampling stations (see Table 3). The spike in conductivity could be caused by the high water temperature at the middle of Reay Creek Pond, which affects the degree to which water will carry an electrical current[22]. Due to the large variation of conductivity results in natural waters, we were not able to find any criteria or guidelines.

Total dissolved solids can cause toxicity through changes in ionic composition of water, toxicity of individual ions, and increase in salinity[23]. High concentrations of total dissolved solids have been shown to cause shifts in biotic communities, limited biodiversity, remove less-tolerant species and cause chronic and acute effects at various life stages. The estimated total dissolved solids values at Reay Creek Pond were way below the values required for high mortality rates of Coho Salmon fry (between 1875 and 2500ppm) and the toxic effects listed above[23].

pH and Alkalinity

The pH stayed neutral over the extent of Reay Creek at 7.22, with a large increase of 1.24 at its middle (see Table 3). As organic matter decays, carbon dioxide is released which in turn combines with water molecules to create carbonic acid, a weak acid[24]. It is unlikely that organic decomposition in the sediment-water boundary is a dominate process in the pond, due to its neutral pH. The general trend of lake acidification as organic matter accumulates over time was not found in the Reay Creek Pond[24]. The high pH in the middle of Reay Creek Pond could be explained by high levels of photosynthesis observed in this region (shown by the high density of bubbles being created on leaves). Photosynthesis by aquatic vegetation creates the opposite effect of organic decomposition, absorbing carbon dioxide and sunlight to convert carbon dioxide into organic compounds before it can become carbonic acid[25]. By removing carbon dioxide, photosynthesis increases the alkalinity of the surrounding water. Unfortunately, we do not have the correct temporal data to test that respiration and photosynthesis of aquatic vegetation is the dominate factor effecting pH in Reay Creek Pond. It is important to note that if Reay Creek Pond is poorly buffered and its pH is largely in impacted by aquatic vegetation processes, diurnal changes in pH can be stressful and damaging to fish health even if they are within acceptable ranges[25]. Respiration by populations of stickleback in the pond may also slightly effect pH by releasing carbon dioxide into the water. Based on the pH and alkalinity data provided, Reay Creek Pond meets all Provincial and Federal criteria for sustaining sensitive populations of aquatic wildlife[20] [19].

The measured alkalinity value of 160 ppm was considerably higher than expected. Coastal BC lakes and ponds tend to range between 0-10ppm with only interior waters reaching levels greater than 100ppm[20]. If the result is accurate it infers that the water is excessively hard. The accuracy of the testing equipment is suspect for this result. The age of reagents is unknown and the method of titration is relatively simplistic for precision results.

Ammonia

Due the poor condition and age of the reagents used for ammonia testing, many of the replicates varied dramatically between each other (see Table 1). An example of testing error can be seen by the different ammonia concentrations in each of the three dam sample replicates (see Table 1). Additionally, the variability of ammonia concentrations could have been caused by poor readings from the colorimeter. The internal chamber of the colorimeter was quite dirty and it seemed that the laser lens was not clean. As tubes were rotated in the colorimeter's chamber, concentration results would change by up to 0.30 ppm. The cause of value changes in the colorimeter may have been caused by differences in the reflective index of glass, or settling of fine particulate matter that would have interfered with laser readings.

The only valid results came from the middle of Reay Creek Pond, where results from the old reagents were correlated by results from a new set of reagents. The difference in ammonia concentration between new and old reagents in water samples was 0.105ppm (see Table 1). The ammonia concentration at the middle of Reay Creek is a source of concern, due to the fact that most natural waters commonly have an ammonia concentration less than 0.1mg/L[20]. Based on the assumption that pure water weights one gram, we can convert the ammonia concentration in the middle of the creek to 0.915mg/L-1.02mg/L. Based on the temperature and pH conditions at the middle of Reay Creek pond, the ammonia concentration does not exceed the maximum of 0.171 mg/L set out the Canadian Water Quality Guidelines for the Protection of Aquatic Wildlife[1]. Unfortunately, due to the large variability of our results, we cannot discuss the effect ammonia concentrations in the surface water could have on eutrophication events.

Nitrite

The variability is also very large between replicates from culvert and dam water samples, which was most likely caused by the condition of reagents and poor colorimeter accuracy. The variation makes it difficult to make assumptions about Reay Creek Pond as a whole. Based on a nitrite concentration increase of 0.36 ppm from the middle of the pond to 3 m away from the dam, there might be a trend of increasing concentrations over the distance of the pond (See Table 1). Unfortunately, our limited number of replicates and variability of results restricts our ability to validate the assumption of increasing nitrite over the distance of Reay Creek Pond. Although Reay Creek was anthropogenically formed, it is questionable if its nitrite concentration should be greater than the minute concentrations found in natural surface waters (0.001mg/L)[20]. However, nitrite levels were too low to be considered significant.

Nitrate

Replicates from the culvert water sample were far too variable to be used for analysis (see Table 1). Nitrate concentrations seem to be decreasing by 0.76 ppm from the middle of Reay Creek to 3 meters away from the dam (see Table 1). The largest decrease in nitrate concentration was between the middle of the pond and 20 meters away from the dam (see Table 1). Nitrate concentrations in the middle of the pond and 20 meters away from the dam exceeded the guideline of 13mg/L from the Canadian Water Quality Guidelines for Aquatic Wildlife[1].

The source of high nitrate concentrations in Reay Creek Pond could be from the leaching of nitrogen fertilizers from agricultural land uses into the Reay Creek Watershed. In 2000, a study of the components of nitrogen fertilizer used by the agricultural industry found that 18% of fertilizer was composed of nitrate compounds[1]. It is unlikely that nitrate levels in Reay Creek are caused by nitrogen fertilizer leaching, based on the fact that in the United States nitrate concentrations exceeding 2.4 mg/L are normally considered the result of anthropogenic input[1]. Also, the US Geological Association considers nitrate concentrations above 4 mg/L in freshwater bodies are often associated with eutrophic conditions[1]. The nitrate concentrations in Reay Creek do not exceed the 4 mg/L standard; therefore it is improbable that the pond is currently eutrophic. Additionally the nitrate concentrations in Reay Creek Pond are lower than the 40 mg/L average nitrate concentration guideline for water bodies supporting aquatic life; therefore, they are not issue[20].

Phosphate

In comparing phosphate concentrations with nitrate concentrations, it is apparent that phosphate is a limiting nutrient in Reay Creek Pond (see Table 1). Without correct ammonia and nitrite concentrations, the assumption that phosphorous is a limited nutrient cannot be properly supported, although this is the case for most freshwater systems[1]. The phosphate concentration in Reay Creek Pond shows an increasing trend from the beginning of the pond to its end (see Table 1). The total increase of phosphate from one end of the pond to the other is 0.20 ppm (see Table 1). An increase of phosphate levels may have been caused by the organic decomposition of plant and animal matter located in Reay Creek Pond sediment. When vegetative matter decomposes, organic phosphate bound in the plant tissue is converted to orthophosphate which makes up 90% of phosphate concentrations[19]. Currently there are no phosphate guidelines for sustaining aquatic wildlife[20] [1]. It is also important to note that another major source of phosphate could be the leaching of phosphorous fertilizers and nutrients from manure into Reay Creek Watershed, although the presence of agriculture in the watershed is small (see Figure 1). The concentration of orthophosphate (inorganic phosphate) found in Reay Creek Pond does not reflect the large amount of organic phosphate that could be introduced from soil entering the pond by erosion.

In natural freshwater systems, phosphate normally accounts for 95% of the total phosphorous levels[1]. Based on this assumption and total phosphorous standards from Canadian Water Quality Guidelines, the phosphate concentrations in Reay Creek Pond identify its tropic status as oligotrophic to meso-eutrophic. Consequently phosphate is a poor indicator of total phosphorous, due to its quick turnover rate in phosphorus limiting environments and proportionality decline as phosphorous levels increase[1].

Sediment Pore Water Quality

Ammonia

The majority of pore water replicates from Reay Creek Pond contained ammonia concentrations greater than 2 ppm (see Table 2). By reaching the maximum detectable concentration, it is possible that the accuracy of all ammonia measurements were poor. We were not able to mitigate, or quantify accuracy errors caused by the colorimeter because Maxxam Analytics ammonia testing results were late and not completed by the time this report was composed. If all of the ammonia located in Reay Creek's sediment was released into the surface water, concentrations would be greater than the total ammonia nitrogen concentrations required for the protection of aquatic life of 1.66 mg/L[20]. This assumes that the colorimeter readings were correct and the surface water temperature will be equal to the mean temperature recorded (16.3°C). Both of these assumptions are poor, due to the fact that water temperature in the pond is likely to fluctuate and ammonia readings are inaccurate. Also the maximum concentration of 1.66 mg/L is a 30 day average, whereas out data is only on a snapshot of ammonia concentrations in Reay Creek Pond[1]. Alternatively, based on the Canadian Environmental Quality Guidelines, the maximum ammonia concentration for the protection of aquatic life is 2.22 mg/L which might be greater than the ammonia concentration in the sediment[1]. High concentrations of ammonia in the sediment can be partially explained by its ability to be absorbed onto suspended and bed sediments, and colloidal particles[1]. Large values of ammonia in Reay Creek Pond sediment could signify that decomposition is occurring rapidly, due to the fact that organic decomposition is a large contributor of ammonia in sediment [26]. Unfortunately, without specific ammonia concentration values, we cannot discuss the effect it would have on eutrophication events.

Nitrite and Nitrate

The low levels of nitrite and nitrate found in Reay Creek Pond sediment pore water samples is reflective of normal conditions in sediment (see Table 2). As both nitrate and nitrite do not participate in any absorption complex in sediments, they will most often be converted to N_2 through the process of denitrification[26]. Denitrification occurs very rapidly in environments where oxygen concentrations approach zero[26]. Due to very low levels of nitrate and nitrite in the pond sediment, it can be assumed that anoxic conditions occur even at shallow depths of the sediment. Due to the low levels of nitrate and nitrite in the Reay Creek Pond sediment, there would be no adverse effects if it were to be mixed into surface waters.

Phosphorous and Phosphate

If the concentration of phosphorous in Reay Creek Pond sediment was transferred into the surface water through a large disruption event, it would trigger a trophic status change to hyper-eutrophic[1]. With a total phosphorous concentration between 882 ppm and 1320 ppm, the pond sediment is over 8000 times greater than the minimum total phosphorous concentration range observed in the surface waters hyper-eutrophic lakes[1] (see Table 5). Due to the fact that inorganic phosphate readily absorbs onto small particulate matter, only a fraction of total phosphorous would be available to mix with surface waters[26]. Although much of the organic phosphate is mineralized within the sediment column into useable inorganic phosphate, much of it would also become absorbed either onto surrounding sediment particles or onto suspended particulates in the water after being stirred[22]. Both the sedimentation and mineralization of organic and inorganic phosphorous would prevent all of the sediment phosphorous from entering the surface waters of Reay Creek Pond during disruption. Unfortunately, the amount of phosphorous tied to particulate matter depends strongly on the concentration of Fe(OOH) and $CaCO_3$, which is unknown in Reay Creek Pond[26]. Even though we do not know how much phosphorous is tied up in sediment, it can be inferred based on the high concentrations of total phosphorous found in our results that only a small fraction of the sediment column would need to be disturbed in order to cause a eutrophication event in the pond[26].

Phosphate levels in the sediment pore water varied little over the extent of the pond. A spike of 0.70 ppm from the culvert to the middle of Reay Creek Pond may have been caused by the increased biotic activity and presence in the area (shown by high levels of photosynthesis) (see Table 2). High biotic activity could result in high decomposition rates where large quantities of inorganic phosphate would be released[26]. The released inorganic phosphate would be transported downward into the sediment by absorbing onto suspended matter entering the pond as a result of erosion[26]. The large difference between phosphate and phosphorous concentrations could be explained by the fact that phosphate decreases as total phosphorous increases[1]. Additionally, the difference between total phosphorous and phosphate values reinforces the fact that phosphate is a poor indicator of phosphorous.

Flora & Fauna

The two main species of aquatic vegetation in Reay Creek Pond, *Elodea canadensis* and *Potamogeton robbinsii,* form monoculture mats. This is expected as that is the primary life strategy of these two species[27]. However, this does not account for the observed lack of aquatic plant diversity throughout the pond.

There was a resounding lack of amphibious life in this pond, both adult and pre-adult stages. During the time of study amphibious reproduction should have been occurring. This could either be attributed to toxic metal contamination or the possibility that amphibious life has not colonised this anthropogenically created pond.

Metal Analysis

Due to the proximity to Victoria International Airport one of the primary concerns for this study was the concentration of cadmium and other heavy metals in sediments. When comparing the results of metal analysis (Table 5) to the Canadian Environmental Quality Guidelines produced by the Canadian Council of Ministers of the Environment[1], it was found that both cadmium and chromium were above both Canadian interim sediment quality guidelines (ISQG) and probable effect levels (PEL) established for sediments (for cadmium the ISQG is 0.6 and PEL is 3.5, for chromium the ISQG is 37.3 and PEL is

90.0). Cadmium concentration in the middle sediments was seven times the recommended value (PEL) with 21.5 mg/kg (ppm).

These results indicate that adverse biological effects may occur due to higher than PEL concentrations, especially for benthic organisms. This would reduce mortality, diversity abundance and would result in behavioural changes in aquatic organisms[1]. This would partially explain the lack of aquatic diversity quantitatively observed in the field.

Biochemical Oxygen Demand

The BOD examination used in this study was ineffective (see Table 4). The methodology used for examining sediments was adopted from a dilution method and did not take into consideration the manometric measuring device used. Incorrect dilutions caused the noticeable crash, even if a value had been reported after 5 days—due to incorrect dilutions—the result would have not been accurate. Measurements from a manometric BOD device are correlated to the volume within each container, and do not require dilution.

Conclusion

Sedimentation levels in Reay Creek Pond are high, with an average water depth of 38.8 cm and a sediment depth of 129.4 cm. Over the entire pond there is an approximate total volume of 2569 m^3 of non-compacted sediment.

Water temperature was too high to sustain many of the various life stages of Cutthroat Trout and Coho Salmon. The temperature throughout Reay Creek Pond is very variable which is a poor indicator of water quality. The dissolved oxygen levels were high enough to sustain aquatic wildlife but were too low to accommodate spawning activities and healthy populations of mayfly. Conductivity was too low to cause toxic effects on aquatic life, specifically Coho Salmon. The pH was found to be under heavy influence of respiration of aquatic vegetation, due to the large growth area provided by shallow conditions. This causes large fluctuations of pH which can stress and damage to fish health, even though overall the pH remains an acceptable neutral value. Ammonia levels fall within the prescribed guidelines set out by the Canadian Council of Ministers of the Environment (CCME) for sustaining aquatic life. Nitrate exceed the same guidelines at two sampling sites but was able to meet Environment Canada's guidelines for freshwater aquatic life. Phosphate was determined to be a limiting nutrient and identified Reay Creek Pond's trophic level to be oligotrophic to meso-eutrophic.

Ammonia concentrations in sediment pore water were found to be very high, exceeding testable limits of 2 ppm. Low levels of nitrate and nitrite were found in the sediment pore water, reflecting normal sediment conditions in a freshwater system. Total phosphorus levels in the sediment were very high. Even though we were unable to measure the amount of phosphorus tied up in the sediment, if the sediments were to be mixed into the water column the resulting phosphorus concentration would not be able to sustain aquatic life. Additionally, if a small fraction of sediment was disrupted, an eutrophication event could occur.

Both cadmium and chromium were higher than probable effect levels (PEL) determined by the Canadian Environmental Quality Guidelines[1]. The tested sediments contained 21.5 ppm and 18 ppm of cadmium in the middle and dam sediment respectively, with a PEL guideline of 3.5 ppm. These sediments also contained 115 ppm (middle sediment) and 107 ppm (dam sediment) of chromium, with a PEL guideline of 90.0 ppm).

Overall the surface water quality of Reay Creek Pond is capable of supporting a low diversity of aquatic life. However, for life to thrive within this system, sediment remediation—in some form—must occur. The water quality of Reay Creek Pond directly affects the downstream ecosystem and the aquatic life residing within. Based on the results of this study, there is a possibility of an eutrophication event disrupting sensitive creek habitat.

Recommendations

Based on the study findings there are many remediation options, the ultimate goal being removal or neutralization of the sedimentation from Reay Creek Pond a decrease the possibilities of contamination downstream. The anthropogenic creation and management of the pond means this is already an altered habitat and has never been a natural occurrence.

There is a possibility of in-situ remediation of heavy metals however this would not alleviate the problem of sedimentation and is therefore not recommended as a final solution. As well, considering the pH of the pond (between 7.22 and 8.46) the probability of the heavy metals being released to the surface water is low, as acidification increases the solubility of metals.

Further study will be required to determine levels of metal contamination and to better examine eutrophication status and future eutrophication event possibilities.

Removal of Sediment

There are two main solutions for removing sediment from Reay Creek Pond: excavation and suction dredging. Both will improve pond health, provide rearing options for fish and are attractive options for local residents who desire a more usable and visually appealing pond.

Excavation

This is an invasive process requiring the pond to be dewatered by rerouting creek flow through a bypass network of piping. This is likely the most cost effective procedure. Access to the pond will be difficult requiring permission from municipal bodies for access through park lands and road right of ways. Excavation will remove sediments to the firmer clay layer; this is so the machinery is able to access locations further from shore. The intrusive nature of this option may be unappealing to local residents.

Suction Dredging

An alternative to excavation is suction dredging. This would allow removal of sediments without draining the pond, will allow removal of sediments from specific layers with low disruption of organics and avoids damage to adjacent landscapes (shoreline)[28]. This method has also been shown to be cheaper in medium scale operations (fish ponds 1km in length), however, at the scale of Reay Creek Pond a cost benefit analysis should be conducted.

Remediation & Mitigation

Remediation and mitigation is either a short term or low impact solution. Options for metal remediation include an electrokinetic process (passing a current through the sediment in order to cause a migration of heavy metals. This is been used in Europe for medium sized pond remediation)[29] and phytoremediation (plant based absorption of metals using plants such as *Thlaspi*, *Urtica*, *Chenopodium*, *Polygonum sachalase* and *Alyssim)*[29]. However, this still leaves the problem of sediment loading, continuing the possibility of a eutrophic event.

Eutrophic events could possibly be mitigated by filtration at the dam spillway. Carbon filter pads could be installed to mitigate toxic events and re-oxygenation of the outflow could be possible, however there is little supporting literature for this.

Further Study

Further study is recommended for analysis of metal contaminants. Sediment coring was attempted for this study, however, due to time constraints and budget limitations, was delayed until a future date. From core sampling a determination of location of metal contamination could be analyzed allowing for a thorough remediation and removal of contaminants.

Further sediment and water sampling and analysis would allow a new study to correctly determine the relative eutrophication level of the pond and internal sediment loading; the parameters collected in this study we were unable to relate to an accepted eutrophication scales.

To create a more accurate interpolation of depth it is suggested that more depth data be collected. This could either continue with the same procedure used, or by more technologically advanced methods which were not used in this study given budget constraints.

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Appendix A– Depth Data

The following appendix contains depth results for field work and transect figures for visualisation.

Table A-1 – Collected depth measurements and sediment depth calculation for Reay Creek Pond, collected May 7 2010 to June 12 2010

Transect	Distance (m)	Water to Sediment Depth (cm)	Total Depth (cm)	Sediment Depth (cm)	Comments
1	2	31.9	35.2	3.3	
1	4	74.5	116.7	42.2	
1	6	86.8	199.1	112.3	
1	8	138.1	251.8	113.7	
1	10	199.7	244.6	44.9	
1	12	190.3	227.2	36.9	
1	14	184.7	223.2	38.5	
1	16	158.9	220.5	61.6	
1	18	159.8	177.8	18.0	Gray clay
1	20	92.7	129.7	37.0	Hit rock substrate
1	22	0.0	0.0	0.0	Shoreline
2	2	22.2	135.1	112.9	
2	4	39.3	151.9	112.6	
2	6	38.6	149.0	110.4	Possible log
2	8	51.1	139.6	88.5	Possible log
2	10	87.6	148.2	60.6	
2	12	79.5	199.5	120.0	
2	14	79.8	211.2	131.4	
2	16	28.0	92.9	64.9	
3	2	25.9	55.6	29.7	A lot of coarse organic debris
3	4	41.9	149.8	107.9	
3	6	52.8	139.4	86.6	
3	8	56.5	142.5	86.0	
3	10	46.7	187.6	140.9	
3	12	55.0	214.5	159.5	
3	14	53.9	164.5	110.6	
3	16	50.2	149.8	99.6	
3	18	45.1	136.2	91.1	
3	20	35.6	100.2	64.6	
3	22.38				Shore
4	2	27.8	85.6	57.8	
4	4	35	107.7	72.7	
4	6	45.6	131.5	85.9	
4	8	47.2	197.7	150.5	

Transect	Distance (m)	Water to Sediment Depth (cm)	Total Depth (cm)	Sediment Depth (cm)	Comments
4	10	46.9	215.1	168.2	
4	12	47.4	190.9	143.5	
4	14	50.2	148.7	98.5	
4	16	47.1	123.9	76.8	
4	18	45.6	106.2	60.6	
4	20	30.5	59.7	29.2	Woody Debris
4	21.5				Shore
5	2	46.6	183.0	136.4	
5	4	40.6	156.6	116.0	Strong Stratification
5	6	43.2	173.8	130.6	Strong Stratification
5	8	44.0	102.5	58.5	
5	10	36.6	107.0	70.4	
5	12	37.7	112.4	74.7	
5	14	44.2	97.0	52.8	
5	16	38.3	88.8	50.5	
5	18	11.3	54.9	43.6	Shore
6	2	19.5	126.6	107.1	
6	4	36.5	151.7	115.2	
6	6	37.2	184.5	147.3	Strong Stratification
6	8	46.0	165.0	119.0	
6	10	34.7	150.1	115.4	
6	12	26.9	147.7	120.8	
6	14	6.9	105.7	98.8	
6	15.345				Shore
7	2	20.6	67.0	46.4	Sand (~2cm)
7	4	26.1	74.5	48.4	Sand (~3cm)
7	6	27.8	77.4	49.6	Sand (~3cm)
7	8	30.7	90.8	60.1	Sand (~2 cm)
7	10	25.0	99.2	74.2	Sand (~2cm)
7	12	36.9	125.4	88.5	Sand (~1.5 cm)
7	14	37.7	143.0	105.3	Sand (~4 cm)
7	16	38.6	147.2	108.6	Sand (~2.5 cm)
7	18	25.4	141.4	116.0	Sand (~1 cm)
7	19.45				Shore
8	2	26.7	149.7	123.0	Sand (~15cm)
8	4	32.3	144.9	112.6	Sand (~15cm)
8	6	28.3	141.4	113.1	Sand
8	8	27.5	139.0	111.5	Firm sand
8	10	30.6	118.6	88.0	no sand (limted)
8	12	28.8	79.7	50.9	no sand (limted)

Transect	Distance (m)	Water to Sediment Depth (cm)	Total Depth (cm)	Sediment Depth (cm)	Comments
8	14	17.5	58.8	41.3	Dense Layer (2cm)
8	15.4				Shore
9	2	18.8	102.5	83.7	rocks (holding fence post)
9	4	26.8	109.9	83.1	Partial sand
9	6	26.3	106.5	80.2	Partial sand
9	8	26.8	113.1	86.3	Partial sand
9	10	16.6	96.2	79.6	Stirred sediment
9	12	12.4	82.2	69.8	
9	13.5				Shore
10	2	68.2	98.0	29.8	
10	4	43.7	88.0	44.3	
10	6	48.1	97.9	49.8	Sand (1 cm)
10	8	21.4	102.8	81.4	Sand
10	10	1.0	74.3	73.3	Shore
11	2	29.0	100.3	71.3	Sand
11	4	48.2	93.8	45.6	Sand
11	6	67.1	90.9	23.8	Sand
11	8	112.5	113.5	1.0	Sand (1 cm)
11	10	106.3	106.3	0.0	Dense gravel
11	12	27.2	49.4	22.2	Shore

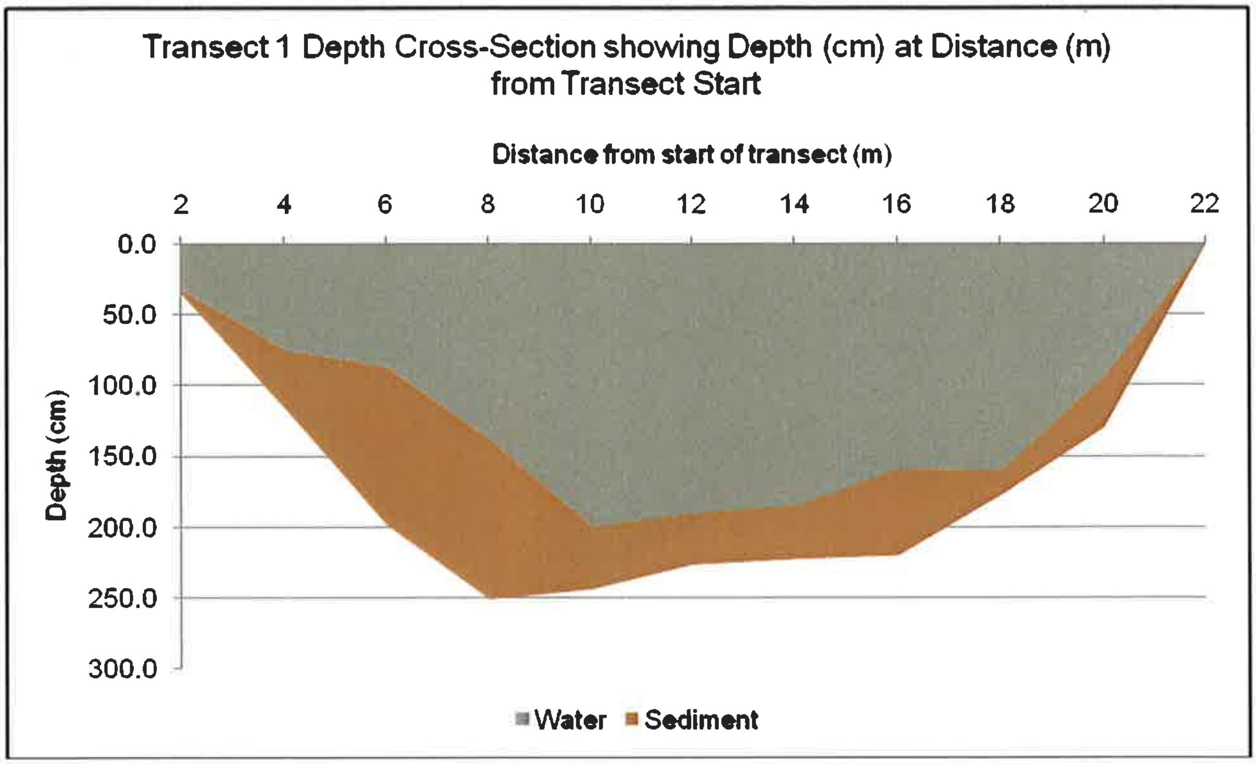

Figure A-1 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 1

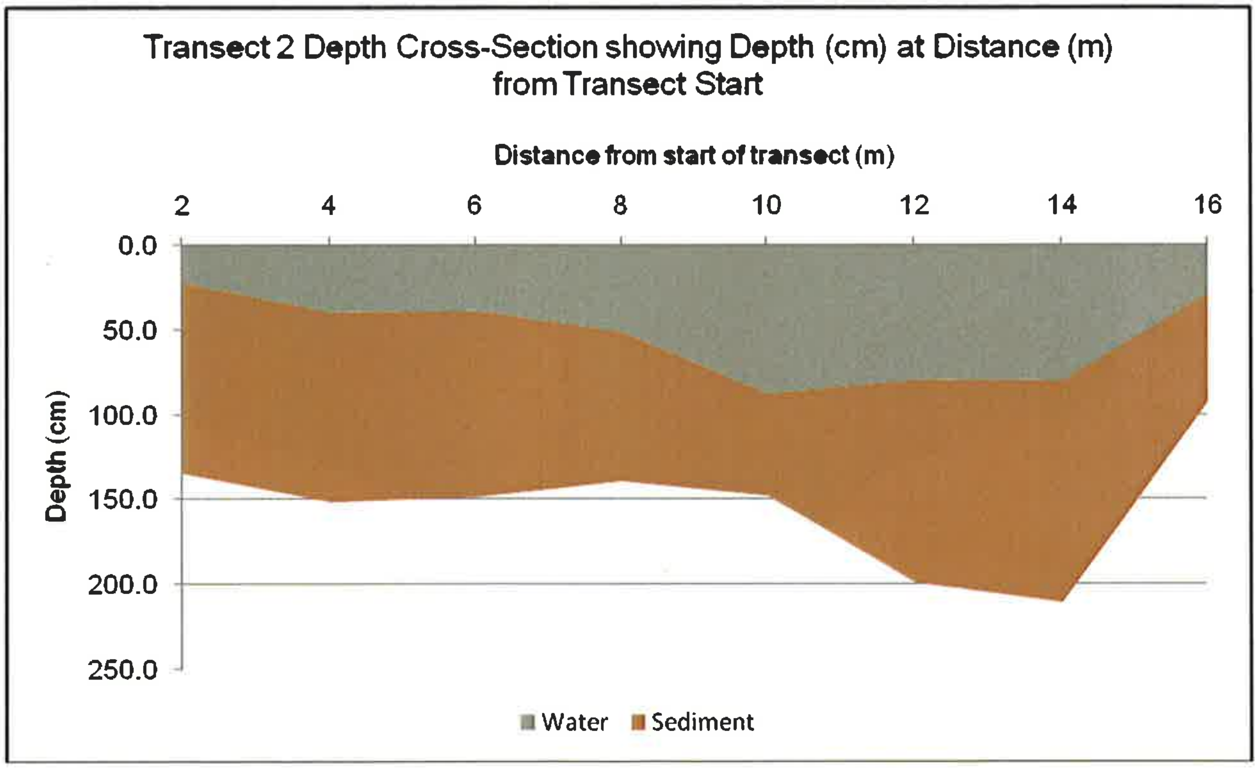

Figure A-2 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 2

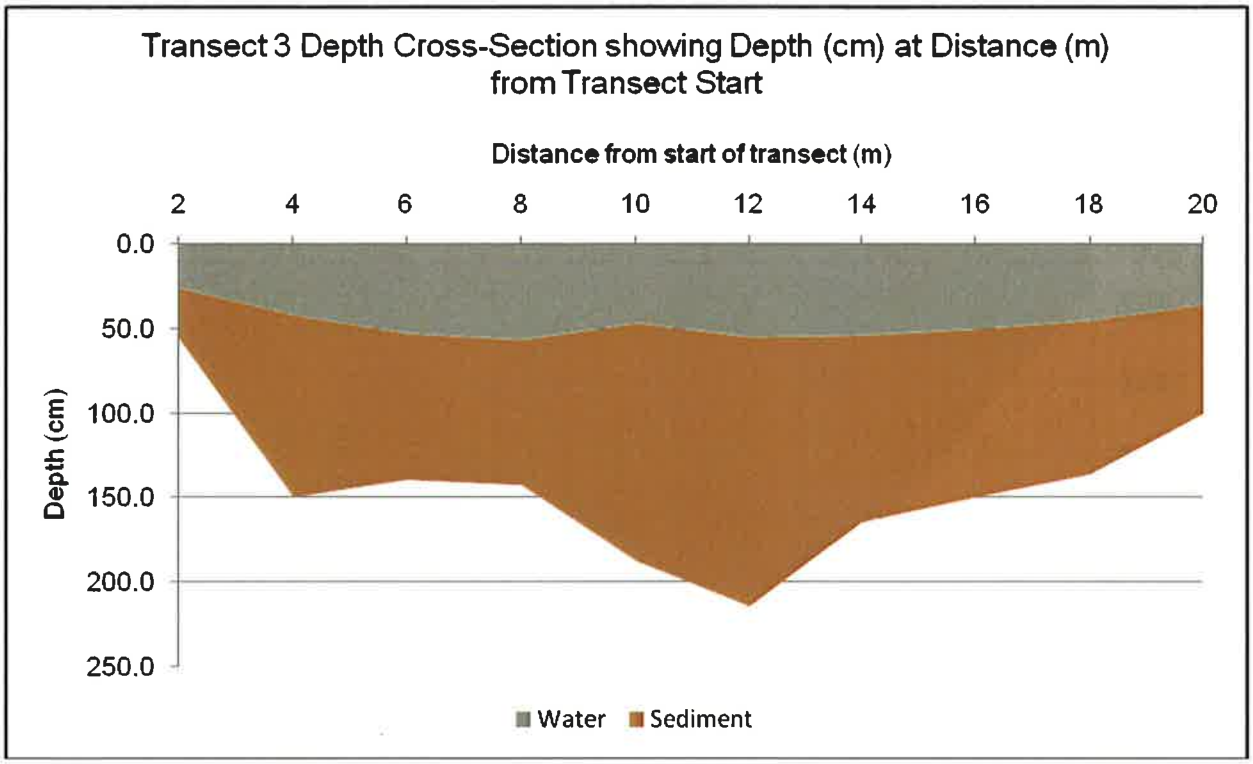

Figure A-3 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 3

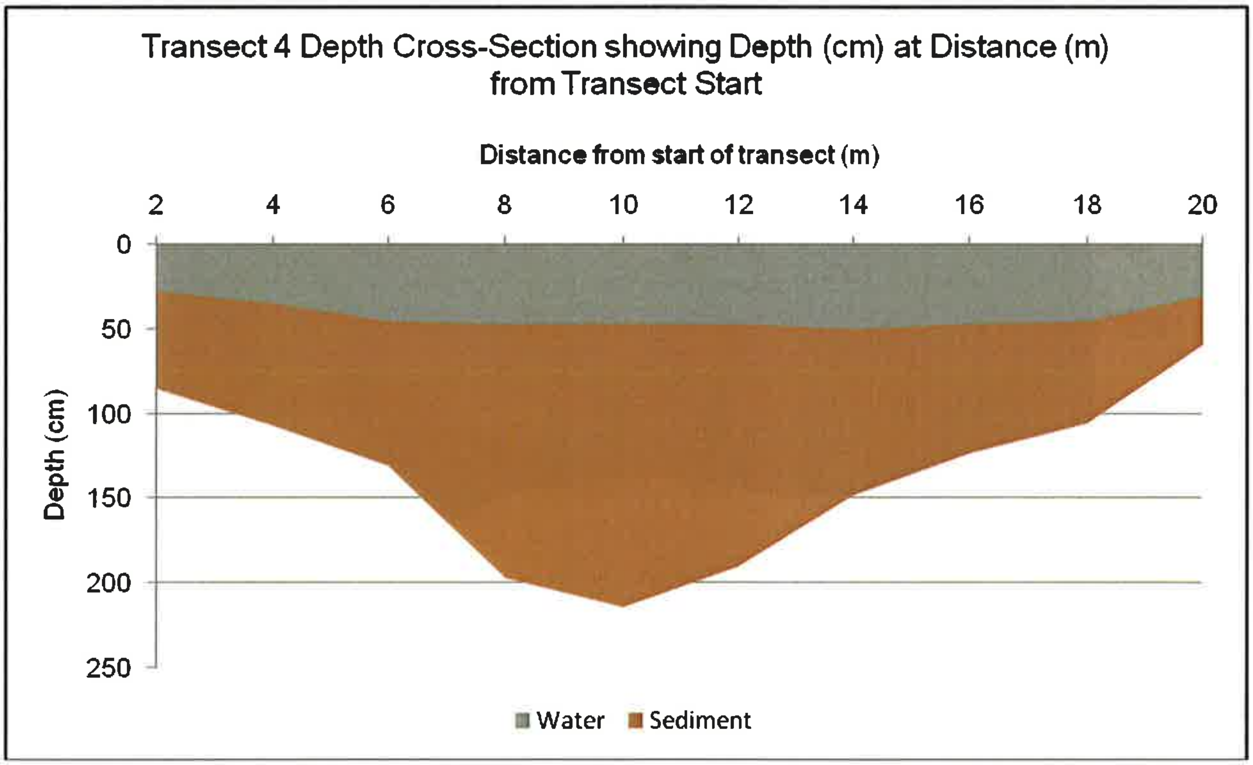

Figure A-4 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 4

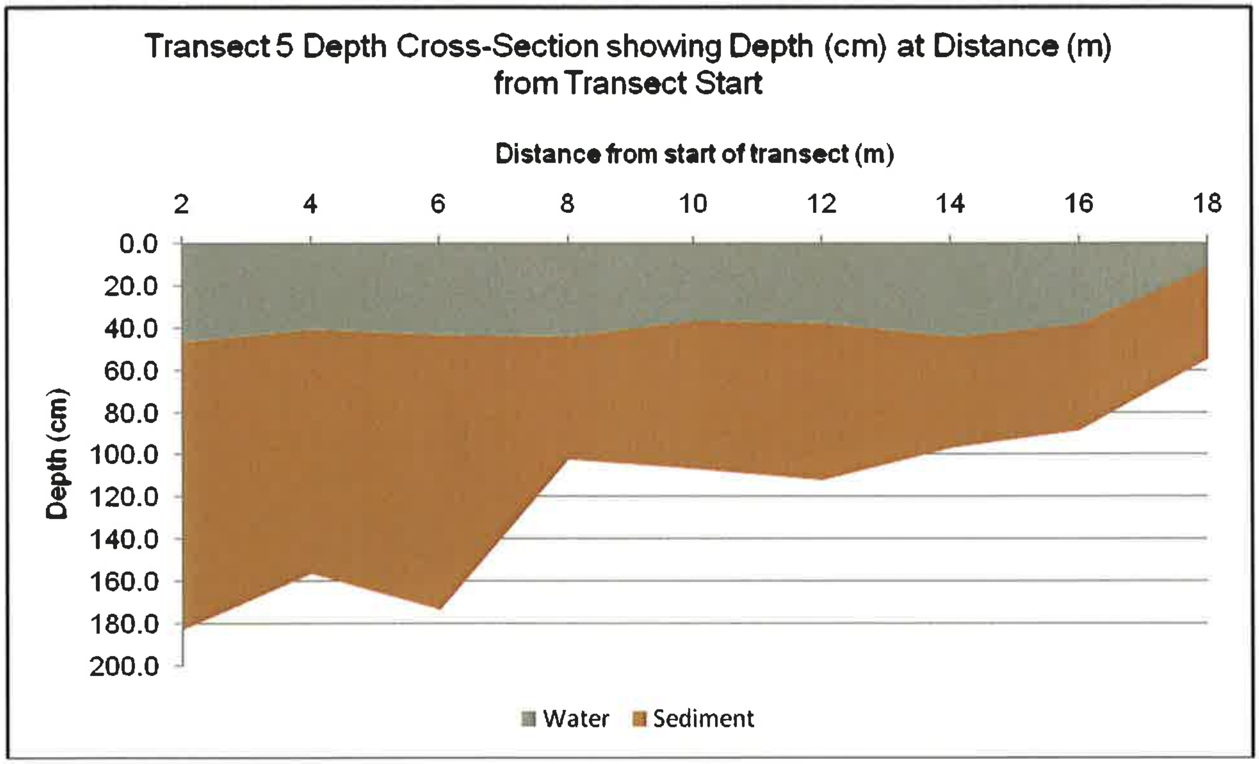

Figure A-5 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 5

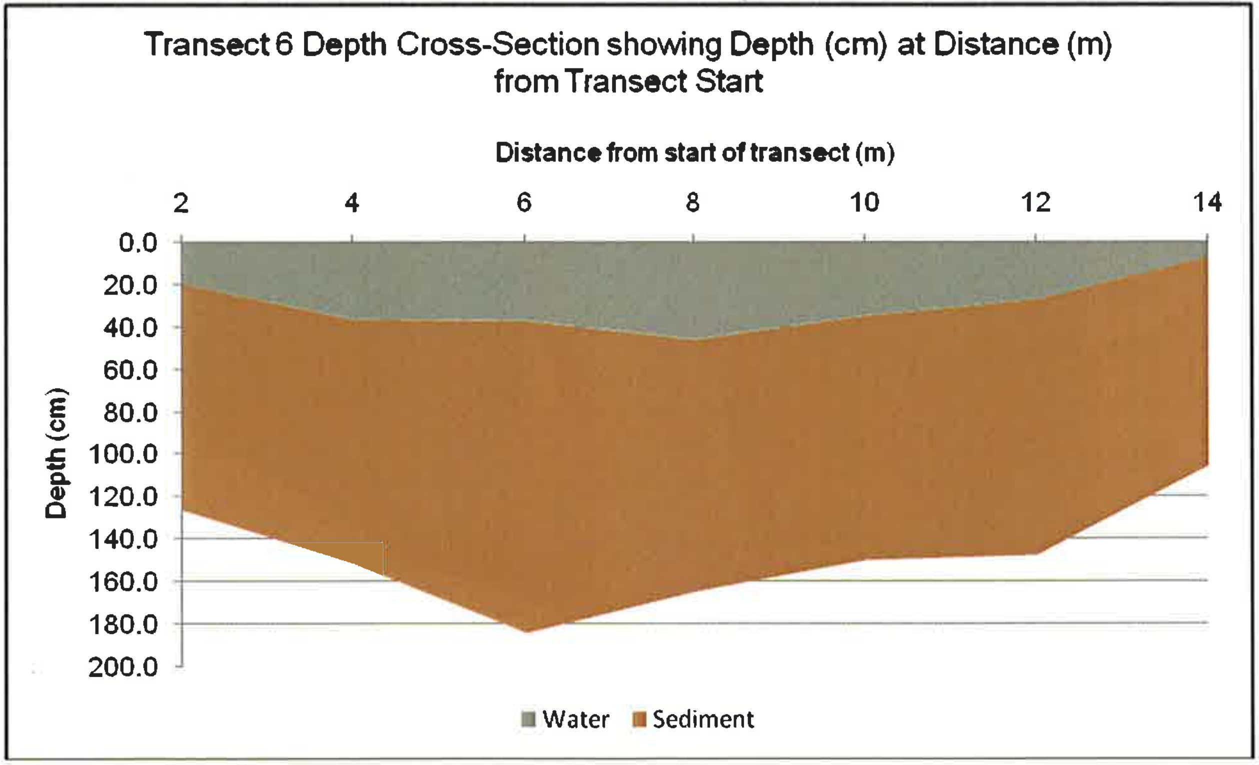

Figure A-6 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 6

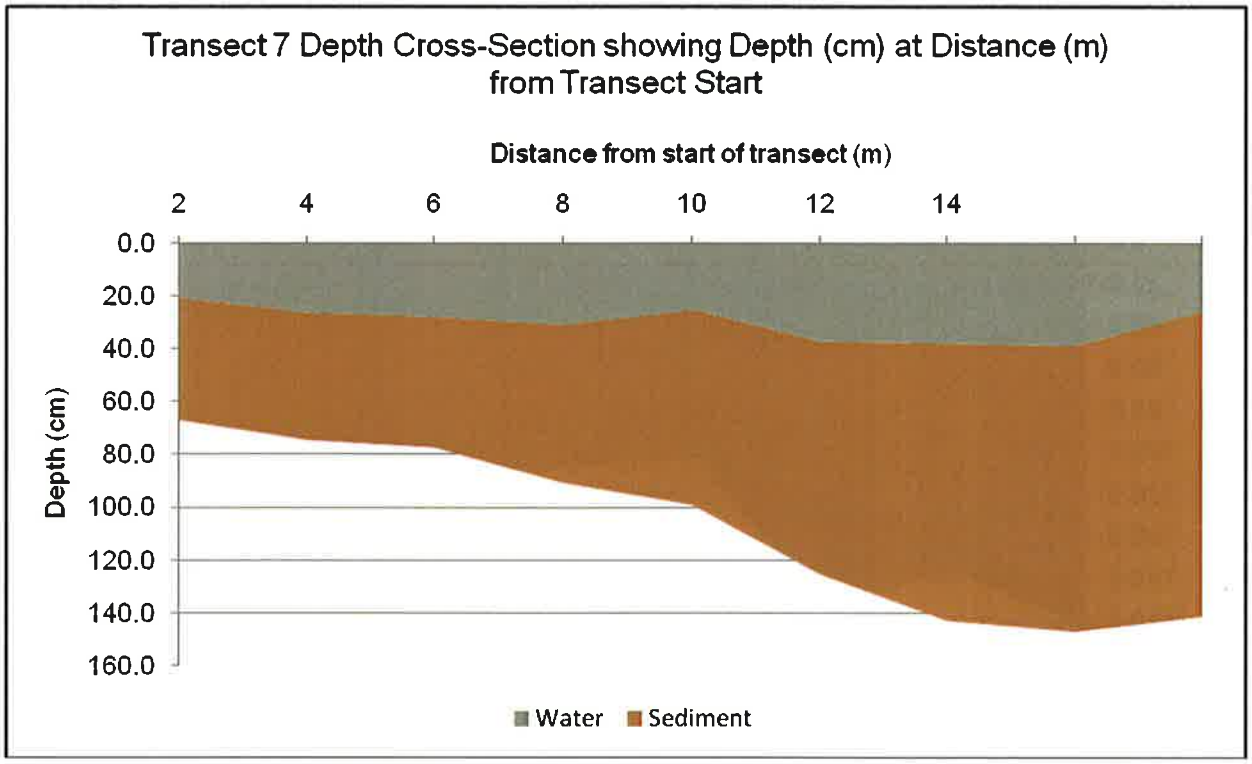

Figure A-7 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 7

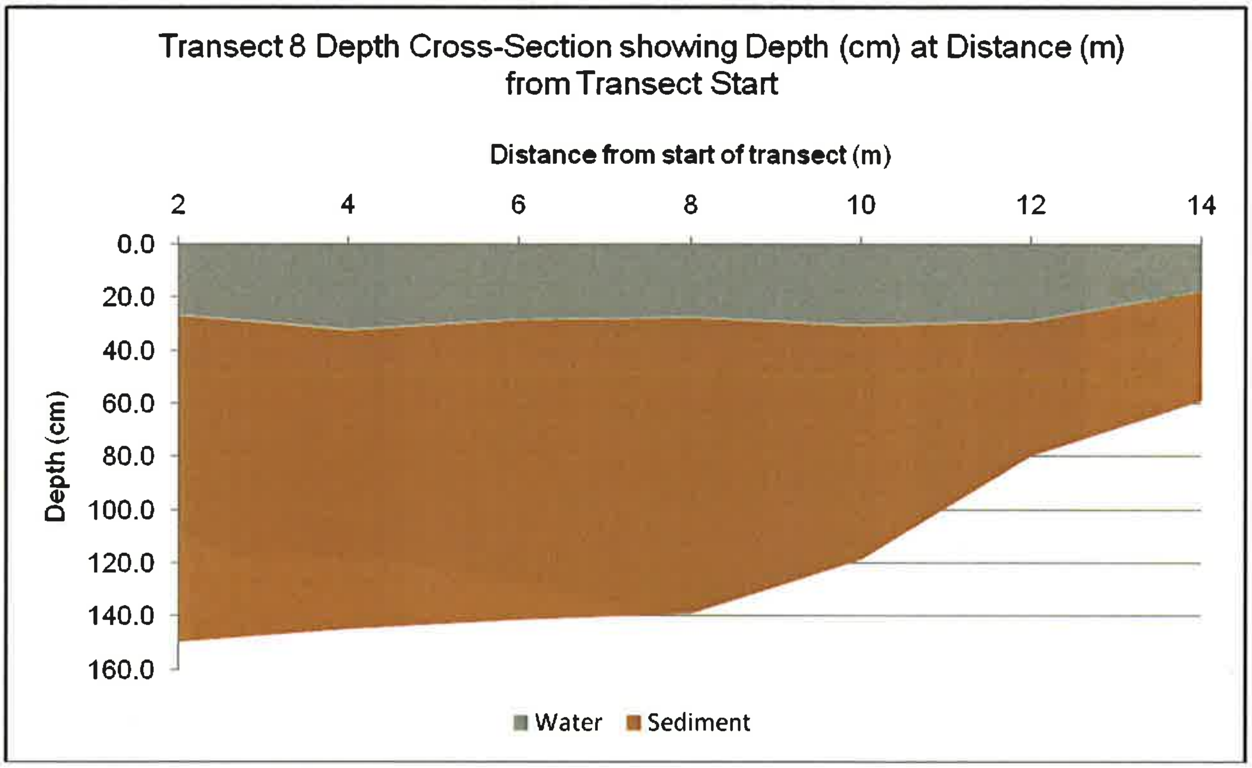

Figure A-8 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 8

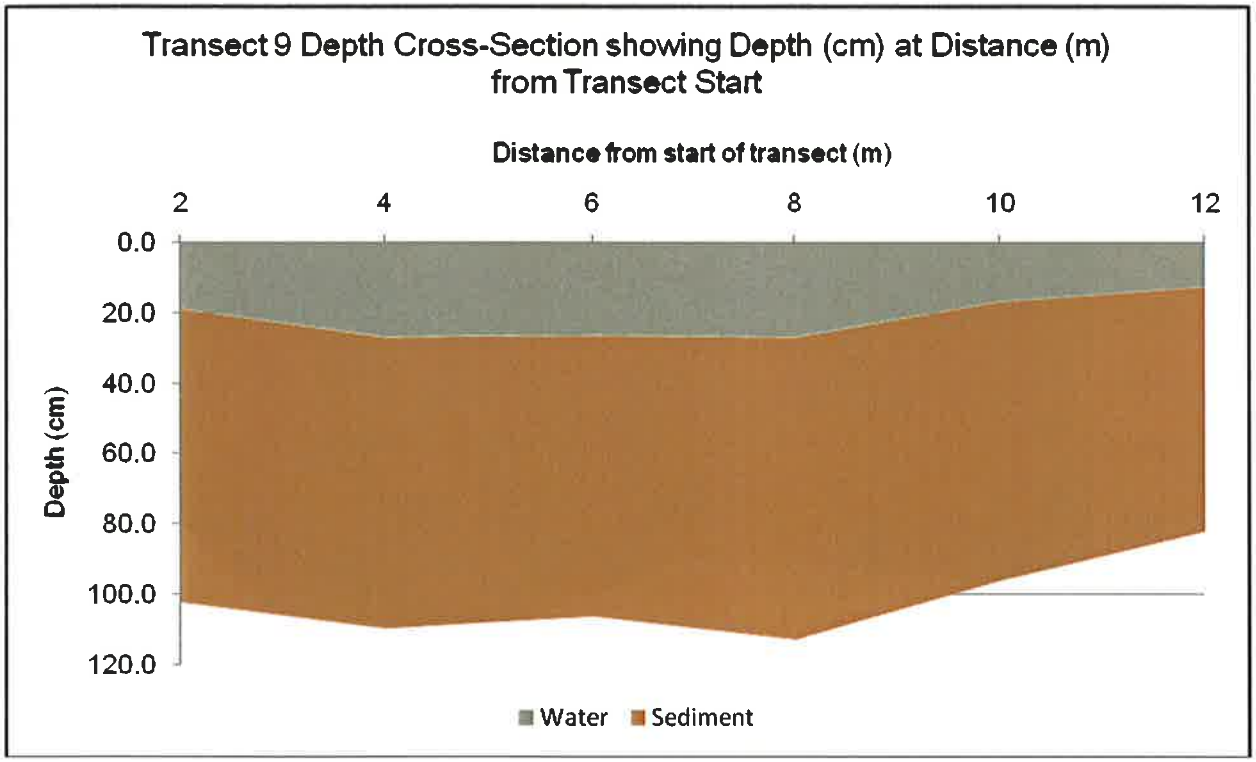

Figure A-9 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 9

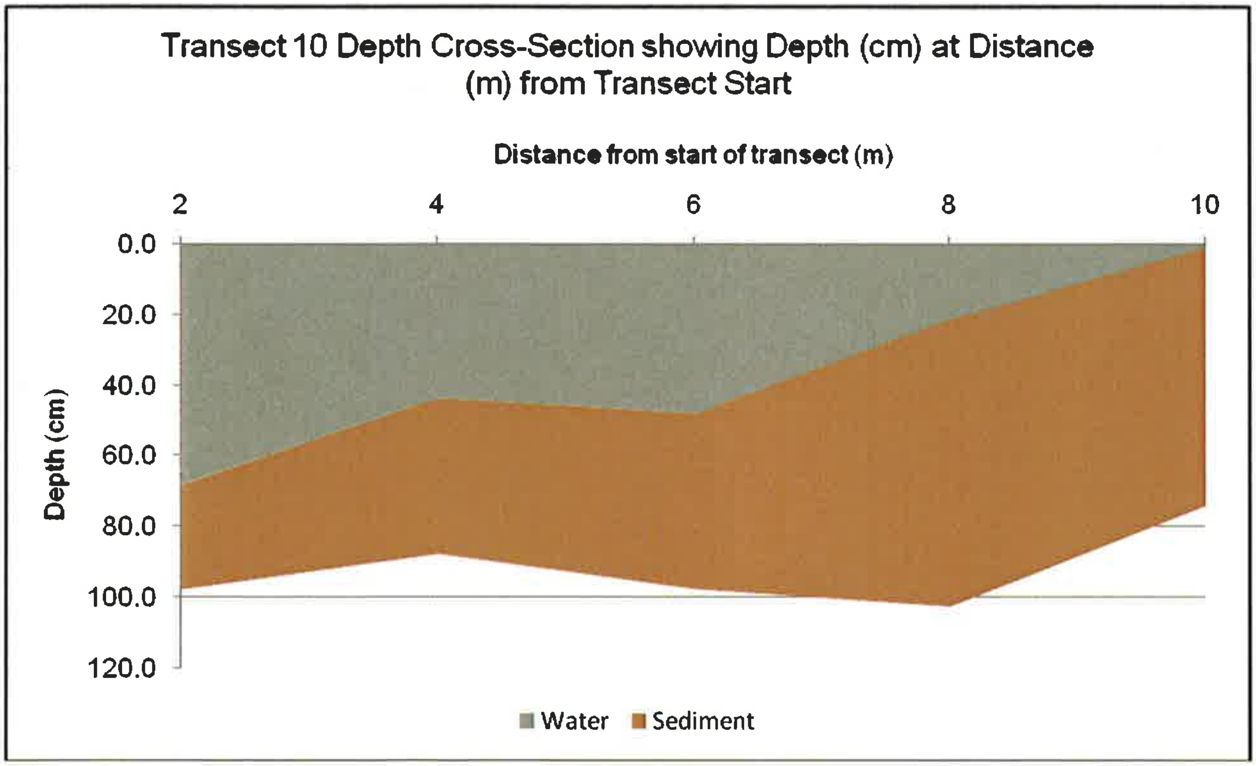

Figure A-10 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 10

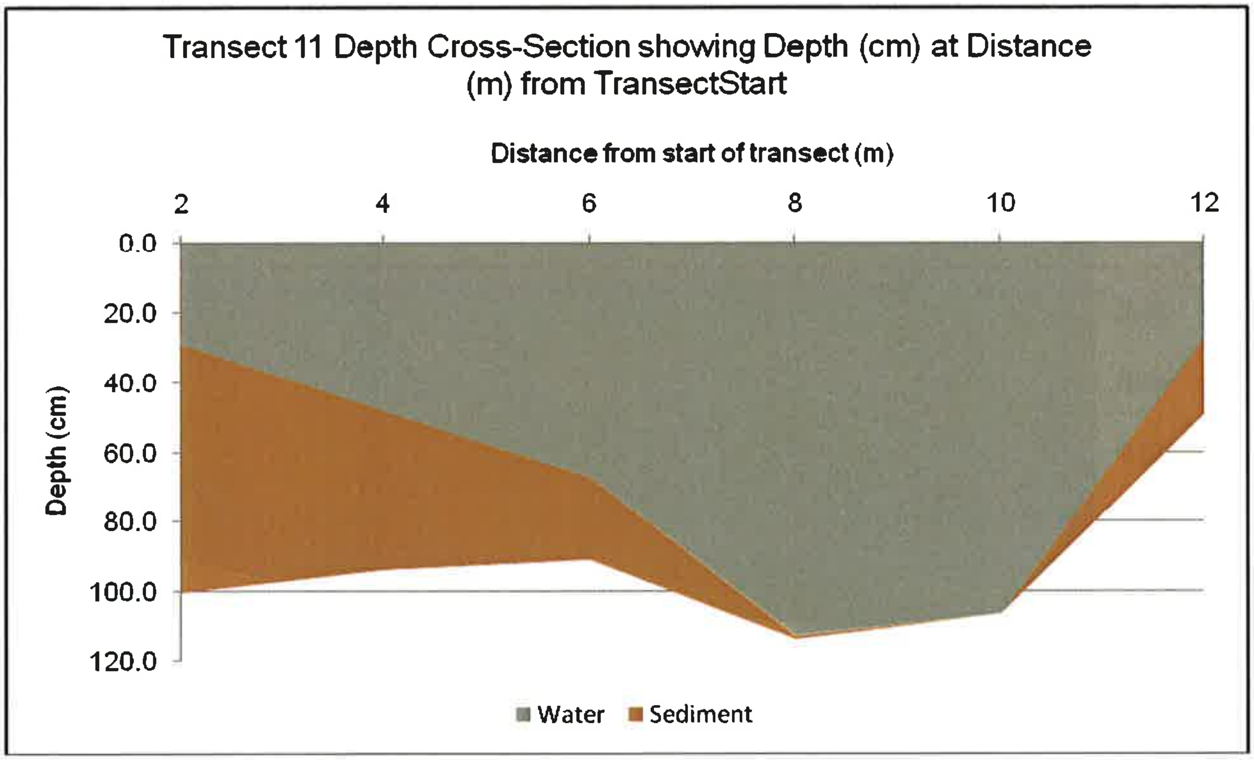

Figure A-11 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 10

APPENDIX E
SLR Sediment Sampling Report (Reay Creek Pond) (2015)

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001

global environmental solutions

Reay Creek Pond Sediment Investigations
Canora Road Between Northbrook Drive and Bowcott Place

Sampling and Analysis of Reay Creek Pond Sediments

May 2015
SLR Project No.: 205.03696.00000

SAMPLING AND ANALYSIS OF REAY CREEK POND SEDIMENTS

CANORA ROAD BETWEEN NORTHBROOK DRIVE AND BOWCOTT PLACE

SLR Project No.: 205.03696.00000

Prepared by
SLR Consulting (Canada) Ltd.
6-40 Cadillac Avenue
Victoria, BC V8Z 1T2

for

TOWN OF SIDNEY
2440 SIDNEY AVENUE
SIDNEY BC V8L 1Y7

May 2015

Prepared by:

for **Benjamin McKinnon, B.Sc., B.I.T.**
Environmental Scientist

Reviewed by:

May 15 15

John H. Wiens, Ph.D., P.Ag.
Technical Director

BRITISH COLUMBIA INSTITUTE OF AGROLOGISTS
B.C.I.A
John H. Wiens, Ph.D. P.Ag

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EXECUTIVE SUMMARY

Samples of sediments were collected and analysed to assess sediment quality at eight locations and from several depths in the Reay Creek Pond. The locations were selected to represent the areas of the pond between the Canora Rd. end and the dam. The locations were considered representative of Reay Creek Pond sediments. Better understanding of the variation and range of concentrations over the length of the Pond could benefit from more samples, but the current results address the purpose of the investigations.

The specific purpose was to compare analytical results to established regulatory reference values to determine if the sediments would be classified as contaminated. Reference values (i.e., substance concentrations) in the Contaminated Sites Regulation (BC CSR) and national Canadian Council of Minister of the Environment (CCME) guidelines were used.

Sediments were analyzed for two chemical substance groups, metals and polycyclic aromatic hydrocarbons (PAHs). Provincial and national criteria or guidelines have been established and published for metals and PAHs (i.e., BC CSR; and CCME), so comparison of analytical concentrations of these substances with the criteria and guidelines determines whether the sediments should be classified as contaminated. Metals and PAHs commonly occur in sediments and elevated concentrations can reflect impacts from the drainage areas to the water bodies that the sediments underlie.

Review of remediation requirements and options are not included in the purpose of the current investigations and this report. While either numerical concentration criteria or risk-based criteria can be used to determine acceptable remediation according to the CSR in BC, concentration criteria are used to determine if contamination is present.

Metals concentrations in Reay Creek Pond exceeded CSR and CCME reference criteria / guidelines. In summary regarding metal concentrations in the sediments:

- Six of the 7 metals with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Four of the metals, cadmium (Cd), chromium (Cr), lead (Pb) and zinc (Zn) exceeded the criteria / guidelines to the greatest degree, with Cd exceeding criteria / guidelines by the greatest margin and lead by the lowest margin; and
- Arsenic and copper in at least one sample also exceeded a criterion / guideline but to a lesser degree than the four other metals noted.

PAH concentrations in Reay Creek Pond exceeded CSR and CCME reference criteria / guidelines. In summary regarding PAH concentrations in the sediments:

- Seven of the 13 PAH substances with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines and six had concentrations below all applicable criteria / guidelines; and
- Two of the 3 samples for which PAH analyses were carried out had relatively low concentrations of PAHs exceeding criteria / guidelines close to the most stringent of the criteria / guidelines, (i.e., TEL / ISQG guidelines) but below the CSR “sensitive” criteria.

Sediments in the Reay Creek Pond would be classified as “contaminated” on account of both metals and PAH concentrations when referenced to both national (CCME) guidelines and BC (CSR) sediment quality criteria.

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APPENDICES

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1.0 INTRODUCTION

1.1 Background

The Town of Sidney requires data for sediment quality in the Reay Creek Pond located within the Reay Creek Park. New accounting standards are applicable to the Town of Sidney according to Public Sector Accounting Standards (PSAS). Liability for contamination is an aspect to be considered in accounting by public sector entities. The question of whether sediments in the Reay Creek Pond were contaminated and therefore whether remediation costs should be allowed for was an issue to be addressed.

At about the same time that the need for sediment quality confirmation and potential remediation cost was being considered by the Town of Sidney, others were also investigating sediments and indicating that results had showed concentrations of several substances exceeding national and provincial guidelines.

1.2 Objectives

The objectives of the sediment sampling and analysis project carried out by SLR on behalf of the Town of Sidney were to:

- Obtain representative, albeit limited, samples of sediments from the floor of the Reay Creek Pond;
- Describe the methods, procedures used to collect sediment samples and document the locations so any further sampling or sampling by others could be compared and supplemented as appropriate;
- Obtain laboratory analyses of the samples for substances / contaminants of potential concern; and
- Compare the laboratory analysis results to established guidelines, criteria or standards (i.e., National; Provincial) so it could be determined if Reay Creek Pond sediment concentrations exceed these reference values and the sediments would be classified as contaminated, thereby addressing the first two of five PSAS questions.

2.0 PREVIOUS INVESTIGATIONS

2.1 Camosun College

The Environmental Technology Program at Camosun College conducted studies and prepared a report for the Reay Creek Pond in June 2010.[1] The report prepared by Camosun College was provided to and reviewed by SLR so that sampling and analysis could account for and supplement the information in the Camosun College report.

A number of characteristics and aspects of the pond were investigated and reported on in the Camosun College report, including:

- Water and sediment depth transects (11 transect locations);

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[1] *Reay Creek Pond Study.* Camosun College Environmental Technology Study. Justin Robinson and Rachelle Sarrazin. June 2010.

- Water quality sample analyses (3 samples, in-house analyses; ammonia-N; nitrite-N; nitrate-N; phosphate-P);
- Water parameter measurements (Field measurements for dissolved oxygen [DO], electrical conductivity [EC], pH, temperature);
- Sediments sample analyses (4 locations; surface grab samples):
  - Extracted pore water (4 samples, in-house analyses; ammonia-N; nitrite-N; nitrate-N; phosphate-P).
  - Sediment five day BOD tests ([BOD5] 5 samples; in-house analyses).
  - Sediment metals (2 samples; Maxxam Analytics Inc. analyses).
- Invertebrates (2 locations, water and surface sediment); and
- Fish (4 locations).

From the information collected in the field and calculations carried out, the Camosun College report provided information regarding:

- Pond water depths;
- Sediment thicknesses;
- Estimated total volumes of sediment; and
- Observations and summaries pertaining to general water conditions, habitat suitability, water quality, flora and fauna, etc.

2.2 Peninsula Streams Association

The Peninsula Streams Society collected sediments in the Reay Creek Pond Area in 2013 and following SLR's sampling and analysis of sediments. Additionally, surface sediment grab samples within Reay Creek downstream of the Reay Creek Pond were collected on January 22, 2015. The 2013 sample analytical results have not been provided to SLR. The results of analyses of the January 22, 2015 samples below the Reay Creek Pond have been provided to the Town of Sidney and to SLR. General comments about methods and findings have been indicated to both the Town of Sidney and to SLR.

3.0 SITE INFORMATION

3.1 Location

Reay Creek Pond is part of the Reay Creek Park, located to the southeast of the Victoria International Airport, just east of Canora Road and between Northbrook and Westbrook Drive on the north and Bowcott Place on the south. Reay Creek Park is within the boundaries of the Town of Sidney in its southwest corner. The Patricia (Pat) Bay Hwy is located about 0.5 km east of the south end of the pond and about 0.6 km in the downstream direction (i.e., southeast) of the south end of the Reay Creek Pond. The Victoria International Airport (YYJ) is located to the west, but mainly to the northwest of the Reay Creek Pond. The length of the pond is about 200 m between Canora Road and the dam.

Reay Creek originates on YYJ property just to the south of the commercial properties in the area of the control tower, flows across non-YYJ property within North Saanich, under Canora Road, through the Reay Creek Pond portion of the Reay Creek Park (Town of Sidney), through Peter Grant Park (Town of Sidney) and then south, again into North Saanich, under the Pat Bay Hwy and thence east-southeast under Lochside Drive to its discharge location into the Bazan Bay portion of Haro Strait. Figure A illustrates the location of Reay Creek, the Reay Creek Park and Pond, as well as YYJ, the Pat Bay Hwy and Haro Strait.

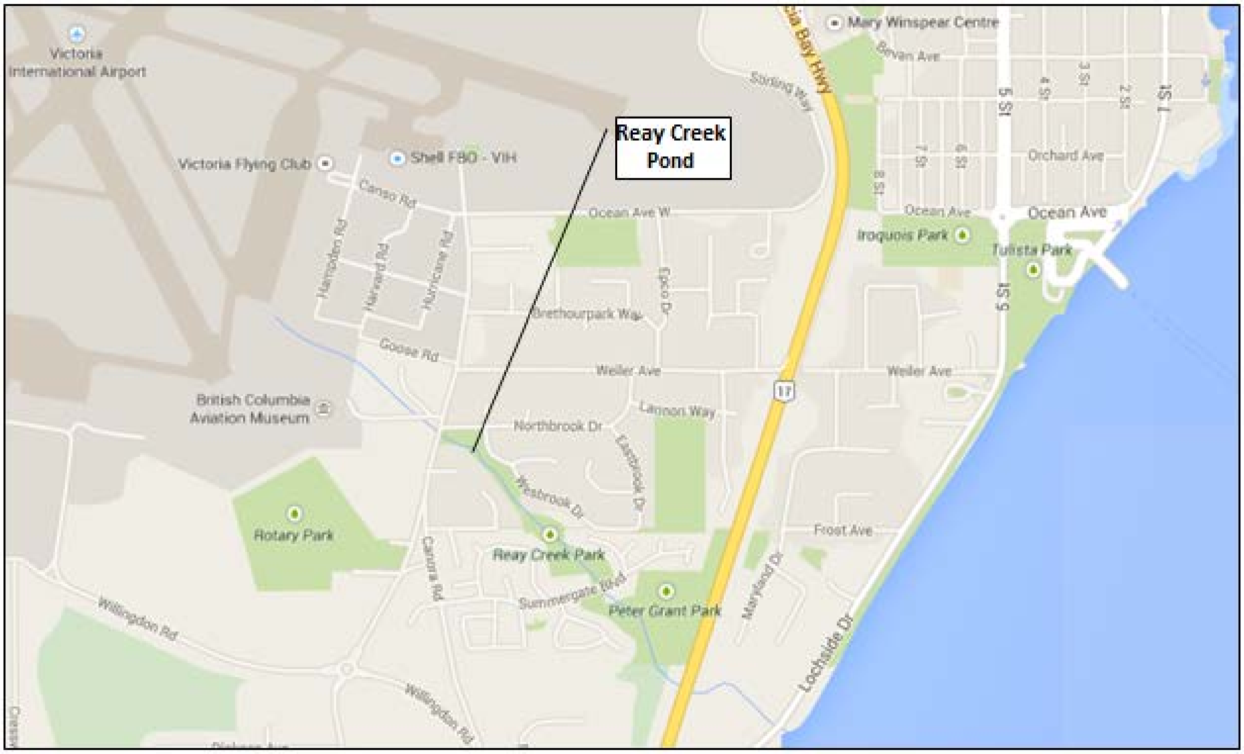

Figure A
Reay Creek Pond Site Location

3.2 Reay Creek Pond

In the past, lands adjacent to Reay Creek in the area of the Pond were owned by many different property owners. SLR understands that a duck farm owner adjacent to the Creek constructed an earthen / mud dam to control water flow and levels. A pond was created above the dam.

In 1998 the dam was reconstructed by the Town of Sidney to prevent failure and better control the flow.

Much effort to restore Reay Creek and a number of stream restoration components have involved many different stakeholders, volunteers, Association and Society members, the Airport and several levels of government.

4.0 SEDIMENT SAMPLING AND ANALYTICAL METHODS

Sampling was conducted on Thursday January 15, 2015 and samples were submitted to the laboratory the next day. Sampling locations, methods and procedures, and quality assurance / quality control procedures are outlined in the following sections.

Prior to sampling, SLR prepared a site / project specific Health & Safety Plan (HASP) with attached copies of SLR's:

- Standard Safety Procedure – Working Around Water (SSP 019); and
- Safety Guidance Document – Working Around Water (SGD 09).

The HASP was reviewed prior to the start of work and a copy was on-hand during sampling.

4.1 Sampling Locations

Sample locations were selected to represent sediments over the full length of Reay Creek Pond, limited by the numbers of samples proposed and budgeted for. Areas of accumulation of sediments as indicated by cross-sections and sediments depth reported in the previous Camosun College report were considered when selecting locations.

Locations were distributed from near the top (Canora Rd end) of the Pond to near the dam, with depth samples in the areas of greatest sediment deposit as indicated by the Camosun College report. Camosun College transects as reported were located by overlay and plotted on orthophotos that included the Reay Creek Pond area. It was considered that future reference and comparison of results could benefit from sample location selection that could also reference the previous sampling. Drawing 1 illustrates the selected sample locations and also the previous transects for reference.

4.2 Sampling Methods and Equipment

Sampling was carried out from a small boat, moved between locations and stabilised at each location with oars. Depth of water at the time of sampling was shallow so no anchors or longer poles were needed. Sampling was completed with assistance of Town of Sidney personnel.

Both surface grab samples and core samples were collected depending on location and expected depth of sediment. Core samples collected so that both shallow (i.e., more recently deposited) and deeper (i.e., older deposit) sediments could be represented. Surface grab samples were collected using a stainless steel Petite Ponar Sampler that is widely used in both fresh and salt water for sediment sampling including from hard bottoms such as sand, gravel, consolidated marl or clay. Core samples were collected using a Wildco stainless steel corer with enclosed ~5 cm (~2 in) sleeve inside the stainless steel sheath attached to the threaded head assembly. Both Petite Ponar and Wildco core sampler were dropped for sampling and retrieved manually using a rope securely attached to each. Figure B illustrates the samplers.

Petite Ponar Grab Sampler

Wildco Stainless Steel Core Sampler

Figure B
Samplers Used for Sediment Sample Collection

4.3 Sample Handling

A portion of the grab samples collected with the Petite Ponar were transferred by hand with single use disposable gloves, to laboratory supplied 120 ml glass jars with Teflon lined lids. Two sample jars were filled where sufficiently large grab samples had been collected. Jars were labelled at the time of sampling. The sampler was cleaned between samples firstly with pond water and then rinsed thoroughly with distilled water between samples.

Cores samples in the sleeves / tubes collected in the Wildco core sampler were removed from the sampler and capped on both ends in the field to fully retain the samples and prevent contamination. Tubes were labelled, the sampler cleaned with pond water and rinsed with distilled water and then a new, clean sleeve re-inserted into the sampler for collecting the next sample.

Grab samples were placed in glass jars in the field and capped sleeves with core samples were stored and transported from the field in coolers.

Sampling of the cores was completed indoors at SLR facilities in Victoria. To allow transferring core samples, caps from corer sleeves were removed and cores were extruded in increments into cleaned stainless steel bowls using a clean, plastic sample container with the same outside diameter as the inside diameter of the sleeves and a stainless steel rod to move the container through the sleeve. Core samples were collected in depth increments either from the stainless steel bowl or directly from the core extruded but suspended from the sleeve.

4.4 Sampling Depths and Sub-Samples

Grab samples (3 locations) collected with the Pettite Ponar collected samples from approximately the top 10 cm of sediment. Detritus and organic materials (e.g., twigs, largely undecomposed leaves and grass, or rooted grass) at this site limited the depth of samples to 10 cm and may have limited the depth to even less than 10 cm at one or two of the locations.

Core samples were collected to depths ranging from 25 to 40 cm below the surface of the sediments. Three depth increments (6 locations), or four depth increments (1 location) were segregated for sub-sampling of the cores. Core segments ranged in lengths from 8 cm to 17 cm, depending on the overall core length, but also on the consistency of the materials and feasibility of controlling core extrusion rates. Depth increments obtained were considered suitable as sub-samples.

Grab samples and core sub-samples were selected for analyses. Not all samples and sub-samples could be selected for laboratory analyses. Numbers of samples were limited by budget allowances. As well, a number of samples could be expected to have similar analytical results (e.g., ~10 cm surface increments of core samples and nearby grab samples). Table A summarizes the sample depths selected for one or more laboratory analyses as well as the overall number of samples collected.

Table A
Numbers of Samples Selected for Analysis and Sampled - by Depth Increment

Depth	Samples Selected for Analysis	Number of Samples Collected
Grab (~10 cm)	1	3
Surface (0-8cm; 0-10 cm)	6	7

Depth	Samples Selected for Analysis	Number of Samples Collected
Mid-core (range, 8-30 cm)	4	7
Deeper (range, 25-40 cm)	5	7

4.5 Parameters for Analyses

Two groups of substances were selected for analyses, metals and polycyclic aromatic hydrocarbons (PAHs). Additionally, one sample was selected for total organic carbon (TOC) and one for grain size analyses.

Metals and PAH groups are each comprised of numerous individual substances. Typically, about 30 metals (including sub-species of several) and about 20 PAH substances are included in analyses. Metals and PAHs were the focus of analyses because both national and provincial guidelines and criteria have been developed and published for these groups of substances. Also, these groups of substances are most likely to reflect elevated concentrations due to land uses and activities, particularly commercial or industrial, in upland drainage areas contributing to sediment deposited in receiving water bodies.

A number of other groups of substances could be analyzed for and may be present in sediments (e.g., pesticides; polychlorinated biphenyls (PCBs); dioxins and furans) but were not selected for this preliminary sediment characterization project for several reasons, for example:

- Analytical results are often below detection levels or detectable concentrations are very low;
- Costs of analyses of single or small numbers of samples are very high; or
- Guidelines or criteria may not have been developed and published.

4.6 Quality Assurance / Quality Control

Field procedures and sample handling methods were implemented to minimize opportunity for contamination and to confirm tracking of samples. Procedures included:

- Using laboratory cleaned and sealed sampling containers;
- Using single use, disposal gloves for each new sample;
- Cleaning and rinsing reusable sampling equipment (e.g., Ponar Sampler; Wildco Core Sampler);
- Labelling all samples in the field to ensure correct tracking;
- Accompanying samples submitted to the laboratory with a completed Chain of Custody document;

All samples were analyzed by ALS Environmental (ALS) of Burnaby, BC, which is accredited by the Canadian Association for Laboratory Accreditation (CALA) for the parameters analyzed and uses MOE recognized methods to conduct analyses. As conveyed by the laboratory, method blanks, control standards samples, certified reference material standards, method spikes, replicates, duplicates, surrogates and instrument blanks are routinely analyzed as part of their QA/QC programs. ALS conducts routine internal laboratory QA/QC analyses to validate the reliability of the analytical results. The results of laboratory internal quality control replicates can be found within the chemical analysis reports included in Appendix C.

5.0 REGULATORY REQUIREMENTS AND REFERENCE VALUES

As noted above in Section 1.2, one of the objectives of this project was compare laboratory analysis results for sediment samples to established guidelines, criteria or standards (i.e., National; Provincial) so it could be determined if Reay Creek Pond sediment concentrations exceed these reference values and the sediments would be classified as contaminated, thereby addressing the first two of five PSAS questions.

The sections below provide a summary of Sediment Quality Criteria and National Sediment Quality Guidelines.

5.1 Provincial Sediment Quality Criteria

The Contaminated Sites Regulation (CSR), Schedule 9, Generic Numerical Sediment Criteria (SedQC) provides reference values for assessing sediment quality. Concentration criteria for substances of potential concern are provided for freshwater and marine sediments. These criteria are for aquatic life use and are intended to protect sediment-dwelling species from unacceptable effects that may be associated with exposure to contaminated sediments at typical and sensitive sites. The designated use of the aquatic, estuarine, or marine ecosystem portion of a site is used to classify the site as either typical or sensitive (i.e., for Freshwater, or Marine and Estuarine: Sensitive $SedQC_{SS}$ and Typical $SedQC_{TS}$). “Sensitive sediment use” and “Typical sediment use” are defined in a MOE procedure document.[2]

"Sensitive sediment use" means the use as habitat for sensitive components of freshwater, marine or estuarine aquatic ecosystems of a site containing sediment, which sensitive components include, but are not limited to,

(a) phytoplankton, zooplankton, benthos, macrophytes and fish,
(b) habitats used by endangered or threatened species or species of special concern under the Species at Risk Act (Canada),
(c) watercourses, wetlands, forested riparian areas, mudflats and intertidal zones that are important to the preservation of fish or wildlife,
(d) reaches of aquatic habitats that are important to fish spawning or serve as important rearing habitat for fish,
(e) reaches of aquatic environments that encompass or border habitat compensation or restoration sites or other areas that are intended or designed to create, restore or enhance biological or habitat features, and
(f) areas and aquatic habitat included in wild life management areas designated under the *Wildlife Act*; and

"Typical sediment use" means the use of a site containing sediment for a use that is not a sensitive sediment use.

As implied by the terms sensitive and typical, the sensitive criteria are more stringent (i.e., have lower concentration thresholds) and typical criteria are less stringent (i.e., have higher concentration thresholds).

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[2] *Definitions and Acronyms for Contaminated Sites*. Procedure 8. January 14, 2014. Effective January 14, 2014. BC Ministry of Environment.

Criteria are provided in Schedule 9 for a number of substance / contaminant groups including:

- Metals (7 substances);
- Chlorinated hydrocarbons (3 substance groups, including: PCBs, PCDDs (dioxins), and PCDFs (furans);
- Phenolic substances (1 substance, pentachlorophenol);
- Polycyclic aromatic hydrocarbons (PAHs) (13 substances, and total PAHs); and
- Pesticides (8 substances).

Provision also is included in the CSR (Section 11(3)) for considering background concentration standards for sediments; however, requirements for determining background sediment quality have not been specified in an approved Protocol so using alternate numerical standards to those prescribed in Schedule 11 of the CSR is not currently possible.

5.2 National Sediment Quality Guidelines

Canadian Council of Ministers of the Environment (CCME) guidelines for sediment quality are derived from the available toxicological information according to the formal protocol established by CCME. The lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely. The upper value, referred to as the probable effect level (PEL), defines the level above which adverse effects are expected to occur frequently. The definition of the TEL is consistent with the definition of a Canadian sediment quality guideline and is also referred to as the Interim Sediment Quality Guideline (ISQG). The PEL is recommended as an additional sediment quality assessment tool that can be useful in identifying sediments in which adverse biological effects are more likely to occur.

Guidelines (i.e., TEL & PEL) are provided by CCME for essentially the same substance / contaminant groups as in the CSR for BC, namely:

- Metals (7 substances);
- Chlorinated hydrocarbons (3 substance groups, including: PCBs, PCDDs (dioxins), and PCDFs (furans);
- Phenolic substances (1 substance, pentachlorophenol);
- Polycyclic aromatic hydrocarbons (PAHs) (13 substances, and total PAHs); and
- Pesticides (8 substances).

As implied by the explanations for the CCME guideline terms TEL / ISQG and PEL, the TEL / ISQG guidelines are more stringent (i.e., have lower concentration thresholds) and PEL guidelines are less stringent (i.e., have higher concentration thresholds).

5.3 Applicable Criteria / Guidelines

Both the CSR criteria for BC and the National CCME guidelines include substance concentrations for protection of marine and freshwater aquatic systems. Reay Creek Pond and Reay Creek in the area of the Reay Creek Pond is a freshwater system. The criteria and guideline concentrations for freshwater are considered applicable. Sediment chemistry data tables at the end of the text of this report therefore include only the concentrations for freshwater.

From the definitions for “sensitive sediment use” in then CSR, some elements would apply. Other aspects of the definition for “sensitive” would clearly not apply. Sediment chemistry data tables at the end of the text of this report therefore include the concentrations for both “sensitive” and “typical”.

From the explanation of the TEL and PEL threshold levels used in the CCME guidelines the objectives for use of, and reference to both the TEL and PEL levels could apply. Sediment chemistry data tables at the end of the text of this report therefore include the concentrations for both TEL and PEL.

5.4 Alternate Criteria - Risk-Based

It should be noted that contaminated sites legislation and the Contaminated Sites Regulation in BC define two general types of standards (in the case of sediment, standards are referred to as criteria):

- *Numerical standards* are acceptable concentrations of substances in soil, surface water, groundwater, vapour and sediments.
- *Risk-based standards* are acceptable risk levels from exposure to substances at sites.

At sites under BC jurisdiction, either numerical concentration or risk-based standards or criteria may be applied when considering remediation requirements and options. One option for remediation is to remove contaminants so no sediments exceeding reference concentrations remain. An alternate is to conduct risk assessment to confirm that contaminants managed in-place would not pose unacceptable risks to human health or the environment, or if required, risk management / risk control measures could be implemented so risk would be reduced to acceptable levels.

Despite the options for remediation, numerical concentration standards/criteria must be used to determine whether or not contamination is present at a site and if the site is classified as a contaminated site. The Contaminated Site Regulation. Section 11 states:

> “(1) Subject to section 12 and subsections (2), (3) and (4) of this section, the following substances, standards and conditions are prescribed for the purposes of the definition of "contaminated site" in section 39 of the Act: (a)…; (b)…; (c) the concentration of any substance in sediment at the site is greater than the applicable generic numerical sediment criterion; (d)…;”

6.0 SEDIMENT RESULTS

Sediment analytical results are compared below to numerical concentrations criteria / guidelines. Risk assessment has not been carried out so risk-based concentrations as might be considered for remediation, are not discussed.

6.1 Field Observations

At the time of sampling in mid-January 2015, SLR noted that Reay Creek Pond water was relatively shallow and exposed grasses, brush and several overhanging trees reduced the area of open water, generally confirming the views from aerial photos. Overflow via the spillway at the dam was relatively low.

Sediment sampling via both the Ponar sampler and the Wildco Core sampler collected in the open water areas, encountered a surface layer of grasses, roots of grasses, some detritus (e.g., leaves, twigs). These materials were included in the Ponar grab samples and limited sediment sample recovery somewhat. Due to these materials, the flexible plastic fluted core catcher in the leading edge of the sleeve / tube inside the sampler, intended to maintain the collected sample inside of the core tube, tended to become blocked, limiting the depth of sampling. This resulted in use of the core catcher being abandoned.

6.2 Laboratory Analytical Results

Laboratory analyses reports for sediment samples submitted are included in Appendix C. Summary Tables of the analytical results along with CSR and CCME criteria and guidelines as discussed in Section 5 above are included at the end of the text of this report and are discussed in the following sections.

6.2.1 Metals

Table 2 presents metals analysis results in relation to both CSR criteria and CCME guidelines. Seven of the metal substances for which analyses were completed had published CSR criteria and CCME guidelines. In summary regarding metal concentrations in the sediments:

- Six of the 7 metals with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Four of the metals, cadmium (Cd), chromium (Cr), lead (Pb) and zinc (Zn) exceeded the criteria / guidelines to the greatest degree, with Cd exceeding criteria / guidelines by the greatest margin and lead by the lowest margin; and
- Arsenic and copper also exceed at least one criterion / guideline but to a lesser.

Figure C below illustrates the range of concentrations of the four metals noted above and the criteria / guidelines.

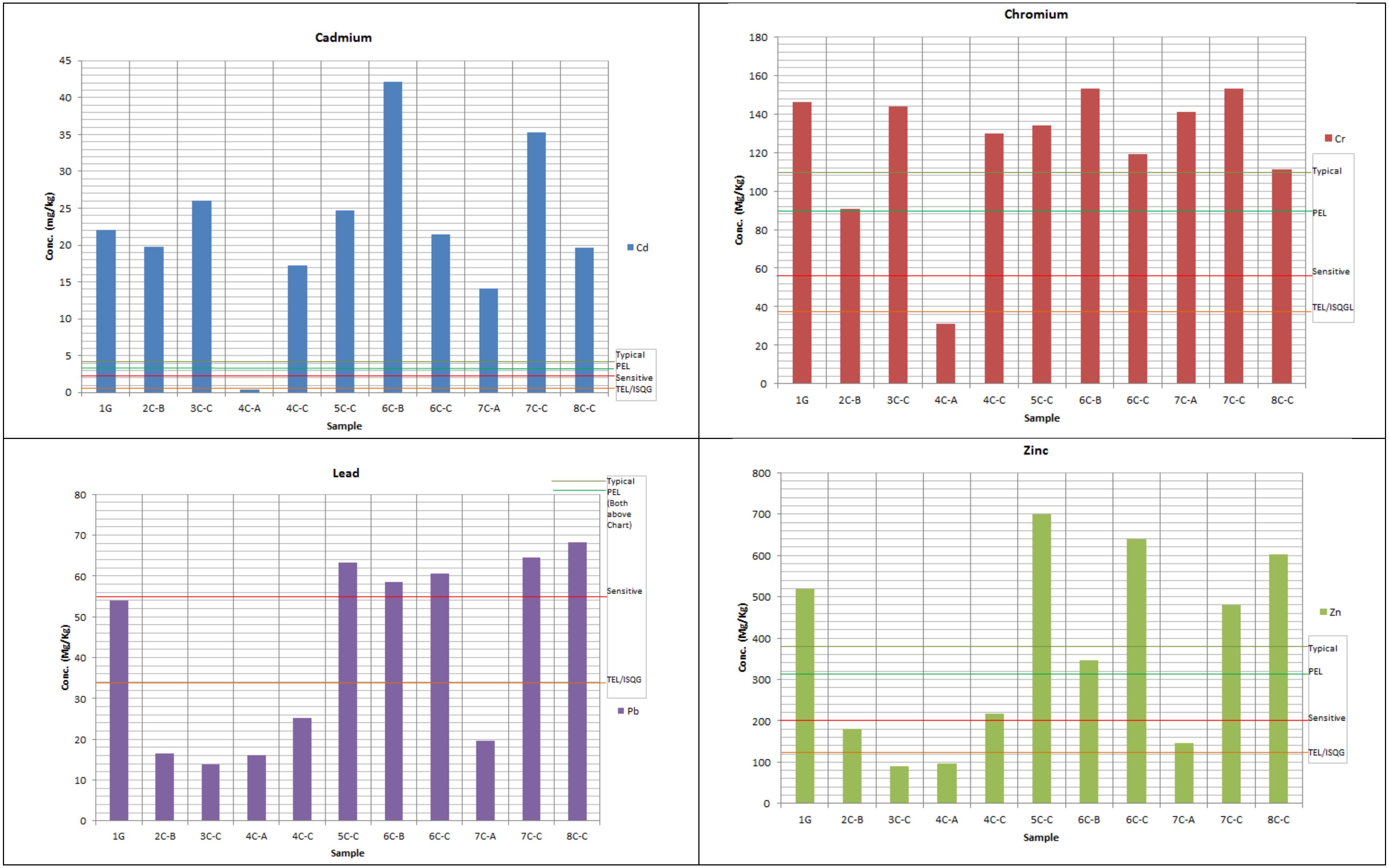

Figure C
Metal Concentrations (Cd, Cr, Pb & Zn) in Relation to CSR Criteria & CCME Guidelines

Additionally, regarding concentrations of metals, the charts in Figure C indicate:

- Very low threshold concentrations for cadmium and significant exceedances of criteria / guideline for all samples except one deeper sample (4C-A);
- Considerable variability of concentrations between samples, but generally the highest concentrations for surface sediment samples (i.e., samples with labels XC-C (core samples) and XG (surface grab)); and
- No apparent clear trend of higher concentration of the metals at the Canora Rd. end or the end nearest the dam, though slightly higher concentrations for several metals may be suggested closer to the end of the Pond nearest the dam.

6.2.2 Polycylic Aromatic Hydrocarbons (PAHs)

Table 3 presents PAH analysis results for 3 samples in relation to both CSR criteria and CCME guidelines. Thirteen of the 20 PAH substances for which analyses were completed had published CSR criteria and CCME guidelines. In summary regarding PAH concentrations in the sediments:

- Seven of the 13 PAHs with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Six of the 13 PAHs with published criteria / guidelines had concentrations below all applicable criteria / guidelines;
- Two of the 3 samples that had concentrations of PAHs exceeding criteria / guidelines close to the most stringent of the criteria / guidelines, the TEL / ISQG guidelines but below the provincial “sensitive” criteria; and
- Not enough samples were analyzed for PAHs to allow observations regarding variability or trends in concentrations, if any near the Canora Rd. end of the Pond and the end nearest the dam.

Figure D below illustrates the concentrations of four selected PAH substances that had concentrations exceeding one or more published criteria / guidelines. This sample with the highest concentration of a number of the PAHs was for a mid-depth sample (i.e., indicated by the XX-B label vs. the surface sample (XX-C) or the deeper (XX-A) sample).

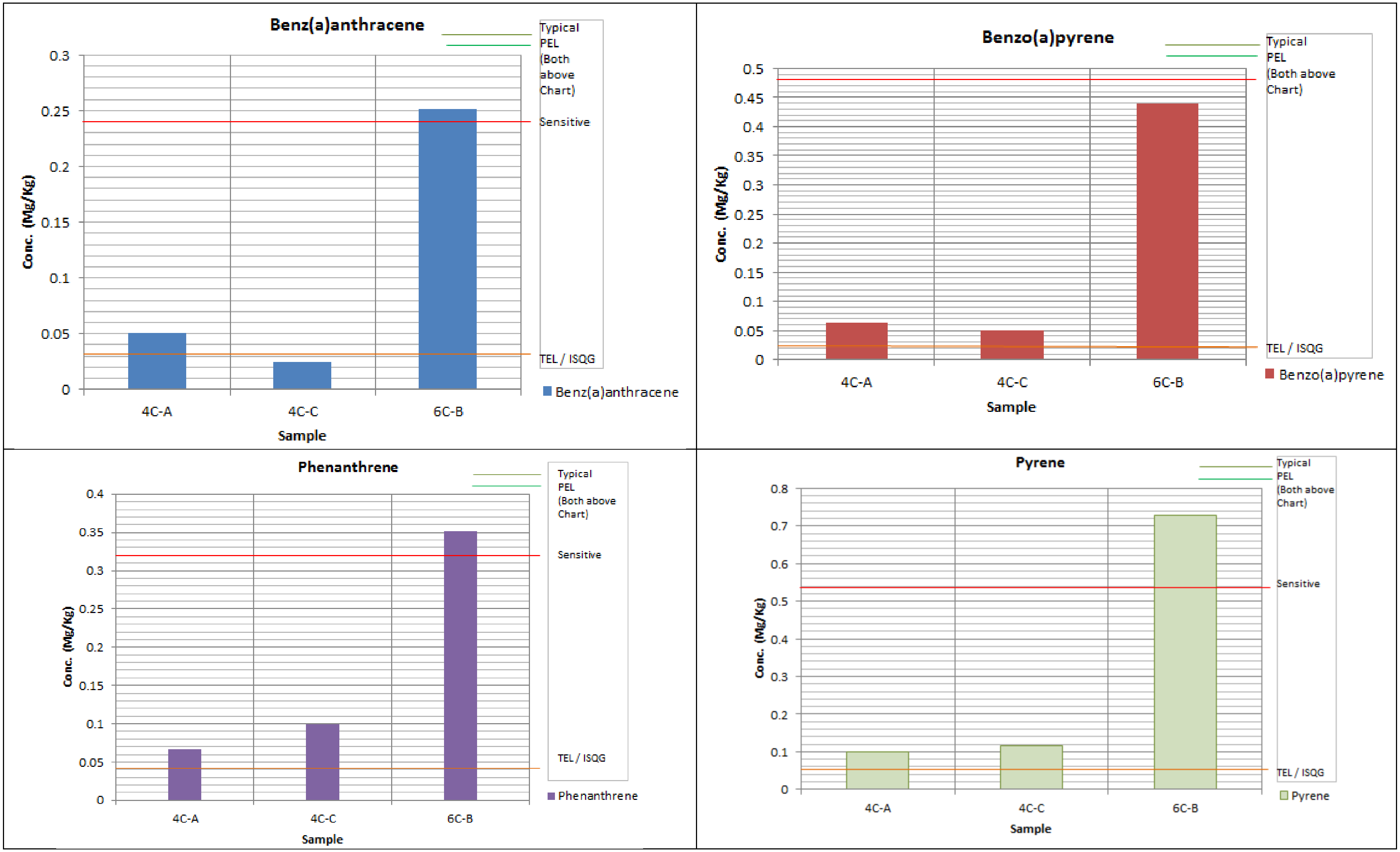

Figure D
Concentrations of Selected PAHs in Relation to CSR Criteria & CCME Guidelines

6.2.3 Representative Characterization Results – TOC and Grain Size

One sample was analyzed for total organic carbon and one sample for grain size analysis. One sample was analyzed for each to indicate the conditions generally considered representative, from field observations. While considered representative, one sample cannot be indicated as the "average"; however, it does indicate that conditions that are typical of the area and do not represent an unusual or extreme condition. Table 4 includes the results for total organic carbon and the laboratory report with the analytical result is included in Appendix C.

The grain size distribution results are included with the laboratory reports (i.e., near end) in Appendix C. The sample has 95% "fines" less than 0.075 mm and would be classified as a "silt loam".

7.0 DISCUSSION

7.1 Current Investigation

Samples of sediments at eight locations and several depths in the Reay Creek Pond were collected and submitted to a laboratory for chemical analyses to assess sediment quality. The locations were selected to represent all areas of the pond. The locations were also selected with reference to eleven previous transects across the pond, used by the Environmental Technology Program, Camosun College, to characterize Reay Creek Pond water and sediment depths. The locations were considered representative of Rey Creek Pond sediments. Better understanding of the variation and range of concentrations over the length of the Pond would benefit from more samples, but the results for current samples address the purpose of the investigations.

The specific purpose was to compare analytical results to established regulatory reference values to determine if the sediments would be classified as contaminated. Reference values (i.e., substance concentrations) in the CSR (BC) and CCME Guidelines (National) were used.

Sediments were analyzed for two chemical substance groups, metals and polycyclic aromatic hydrocarbons (PAHs). Provincial and national criteria or guidelines have been established and published for metals and PAHs (i.e., BC CSR; and CCME), so comparison of analytical concentrations of these substances with the criteria and guidelines determines whether the sediments should be classified as contaminated. Metals and PAHs commonly occur in sediments and elevated concentrations typically reflect impacts from the drainage areas, but also direct deposits, if any, to the water bodies that the sediments underlie.

Review of remediation requirements and options are not included in the purpose of the current investigations and this report. As outlined in Section 5.4 above, while either numerical concentration criteria or risk-based criteria can be used to determine acceptable remediation according to the CSR in BC, concentration criteria must be used to determine if contamination is present in sediments (i.e., at this site; or if applicable, in soils, groundwater, surface water or site vapour at a site).

7.2 Comparison to Previous Camosun College Results

The Camosun College study included laboratory analyses of metals for two locations, one sample from near the middle of the pond and one sample from near the dam. Chromium and cadmium analytical results were noted in the report discussion as elevated, exceeding CCME

“Probable Effect Levels” (PEL) guidelines at both locations. Reference was not made to zinc concentrations at both locations also exceeding PEL guidelines. Results were not compared to the more stringent TEL / ISQG reference values.

Regarding cadmium and the Camosun College results compared to the SLR concentrations:

- The two cadmium concentrations were within the range of the larger number of SLR concentrations, with the SLR average slightly above the Camosun College average (i.e., 21.5 vs. 19.75mg/kg); and
- If only the surface and mid-depth SLR samples were considered, the SLR sample average cadmium was higher that the Camosun College surface (grab) sample cadmium by slightly more (22.86 vs. 19.75 mg/kg).

Regarding chromium and the Camosun College results compared to the SLR concentrations:

- The two chromium concentrations were also within the range of the larger number of SLR concentrations, with the SLR average slightly above the Camosun College average (i.e., 112.73 vs. 111 mg/kg); and
- If only the surface and mid-depth SLR samples were considered, the SLR sample average cadmium was higher that the Camosun College surface (grab) sample cadmium by slightly more (118.06 vs. 111 mg/kg).

Regarding lead and the Camosun College results compared to the SLR concentrations:

- The two lead concentrations were also within the range of the larger number of SLR concentrations, but the SLR average was well below the Camosun College average (i.e., 38.41 vs. 65.35 mg/kg); and
- If only the surface and mid-depth SLR samples were considered, the SLR sample average lead was still well below the Camosun College surface (grab) sample (42.51 vs. 65.35 mg/kg).

Regarding zinc and the Camosun College results compared to the SLR concentrations:

- The two zinc concentrations were above the range of the larger number of SLR concentrations, and the SLR average was well below the Camosun College average (i.e., 335.1 vs. 721 mg/kg); and
- If only the surface and mid-depth SLR samples were considered, the SLR sample average lead was still well below the Camosun College surface (grab) sample average (337.77 vs. 721 mg/kg).

In summary, cadmium and chromium results are considered to be very similar for the 2010 Camosun College samples as for the SLR samples. The lead and particularly the zinc concentrations were somewhat different, however, and would need to be examined more closely in regard to sample characteristics or analytical method differences, if information is available. Nonetheless, the conclusions regarding classification of the sediments as contaminated would be the same.

8.0 CONCLUSIONS AND SUMMARY

Metals concentrations in Reay Creek Pond exceeded CSC and CCME reference criteria / guidelines. In summary regarding metal concentrations in the sediments:

- Six of the 7 metals with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Four of the metals, cadmium (Cd), chromium (Cr), lead (Pb) and zinc (Zn) exceeded the criteria / guidelines to the greatest degree, with Cd exceeding criteria / guidelines by the greatest margin and lead by the lowest margin; and
- Arsenic and copper also exceed at least one criterion / guideline but to a lesser.

PAH concentrations in Reay Creek Pond exceeded CSC and CCME reference criteria / guidelines. In summary regarding PAH concentrations in the sediments:

- Seven of the 13 PAHs with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Six of the 13 PAHs with published criteria / guidelines had concentrations below all applicable criteria / guidelines;
- Two of the 3 samples that had concentrations of PAHs exceeding criteria / guidelines close to the most stringent of the criteria / guidelines, the TEL / ISQG guidelines but below the provincial “sensitive” criteria; and
- Not enough samples were analyzed for PAHs to allow observations regarding variability or trends in concentrations, if any, near the Canora Rd. end of the Pond and the end nearest the dam.

Sediments in the Reay Creek Pond would be classified as “contaminated” on account of both metals and PAH concentrations when referenced to both national (CCME) guidelines and BC (CSR) sediment quality criteria.

9.0 PROFESSIONAL STATEMENT

This sediment sampling and analysis report, prepared by SLR for the above-referenced site, was prepared by Benjamin McKinnon, B.I.T. and John Wiens, Ph.D., P.Ag. The authors of the report have over 25 years of combined experience in the assessment and remediation of similar sites and are familiar with the work carried out for the subject site.

10.0 STATEMENT OF LIMITATIONS

This report has been prepared and the work referred to in this report has been undertaken by SLR Consulting (Canada) Ltd. (SLR) for the Town of Sidney, hereafter referred to as the “Client”. It is intended for the sole and exclusive use of the Town of Sidney. Other than by the Client and as set out herein, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted without the express written permission of SLR.

This report has been prepared for specific application to this site and site conditions existing at the time work for the report was completed. Any conclusions or recommendations made in this report reflect SLR’s professional opinion based on limited investigations including: visual observation of the site, surface and subsurface investigation at discrete locations and depths, and laboratory analysis of specific chemical parameters. The results cannot be extended to previous or future site conditions, portions of the site that were unavailable for direct investigation, subsurface locations which were not investigated directly, or chemical parameters and materials that were not addressed. Substances other than those addressed by the investigation may exist within the site; and substances addressed by the investigation may exist in areas of the site not investigated in concentrations that differ from those reported. SLR does not warranty information from third party sources used in the development of investigations and subsequent reporting.

Nothing in this report is intended to constitute or provide a legal opinion. SLR expresses no warranty to the accuracy of laboratory methodologies and analytical results. SLR makes no representation as to the requirements of compliance with environmental laws, rules, regulations or policies established by federal, provincial or local government bodies. Revisions to the regulatory standards referred to in this report may be expected over time. As a result, modifications to the findings, conclusions and recommendations in this report may be necessary.

11.0 REFERENCES

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TABLES

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

TABLE 1: SEDIMENT SAMPLE LOG AND RECORD OF ANALYSIS

Sample Location ID	Sample ID	Sample Depth (cm)	Metals Analysis	PAH Analysis	TOC Analysis	Grain Size Analsis
1G	1G	0-10	1	0	0	0
2C	-C	0-8	0	0	0	0
	-B	8-25	1	0	0	0
	-A	25-35	0	0	0	0
3C	-C	0-8	1	0	0	0
	-B	8-25	0	0	0	0
	-A	25-35	0	0	0	0
4C	-D	0-10	0	0	0	0
	-C	10-20	1	1	0	0
	-B	20-30	0	0	0	0
	-A	30-40	1	1	0	0
5G	5G	0-10	0	0	0	0
5C	-C	0-10	1	0	0	0
	-B	10-20	0	0	0	0
	-A	20-32	0	0	0	0
6C	-C	0-10	1	0	0	0
	-B	10-20	1	1	1	1
	-A	20-30	0	0	0	0
7C	-C	0-10	1	0	0	0
	-B	10-20	0	0	0	0
	-A	20-30	1	0	0	0
8G	8G	0-10	0	0	0	0
8C	-C	0-9	1	0	0	0
	-B	9-16	0	0	0	0
	-A	16-25	0	0	0	0
Totals			11	3	1	1

Notes:
G - Grab Sample (Petite Ponar)
C - Core Sample (Wildco Corer)
Sample Depth - From Top of Sediment

TABLE 2: SEDIMENT CHEMISTRY RESULTS - METALS PARAMETERS (mg/kg) [1 of 3]

Sample ID	**1G**	**2C-B**	**3C-C**	**4C-A**	**National - CCME Sediment**		**Provincial - CSR Sediment**	
Date	**15-Jan-2015**	**15-Jan-2015**	**15-Jan-2015**	**15-Jan-2015**	**CCME ISQG FW**	**CCME PEL FW**	**CSR SDft**	**CSR SDfs**
Depth (cm)	0-10	8-25	0-8	30-40	ns	ns	ns	ns
pH	6.44	6.53	7.07	7.16	ns	ns	ns	ns
Aluminum	---	---	---	---	ns	ns	ns	ns
Antimony	1.19	0.29	0.47	0.40	ns	ns	ns	ns
Arsenic	5.18	4.85	7.32	11.2	5.9	17	20	11
Barium	105	105	59.7	79.4	ns	ns	ns	ns
Beryllium	0.45	0.33	0.29	0.33	ns	ns	ns	ns
Bismuth	---	---	---	---	ns	ns	ns	ns
Boron	---	---	---	---	ns	ns	ns	ns
Cadmium	***22.1***	***19.8***	***26.0***	0.448	0.6	3.5	4.2	2.2
Chromium (+3)	---	---	---	---	ns	ns	ns	ns
Chromium (+6)	---	---	---	---	ns	ns	ns	ns
Chromium (total)	***146***	***90.6***	***144***	31.2	37.3	90	110	56
Cobalt	14.1	12.0	9.43	11.4	ns	ns	ns	ns
Copper	75.9	31.3	22.5	30.5	35.7	197	240	120
Iron	---	---	---	---	ns	ns	ns	ns
Lead	53.9	16.5	13.9	16.1	35	91.3	110	57
Lithium	---	---	---	---	ns	ns	ns	ns
Magnesium	---	---	---	---	ns	ns	ns	ns
Manganese	---	---	---	---	ns	ns	ns	ns
Mercury	0.100	< 0.05	< 0.05	< 0.05	0.17	0.486	0.58	0.3
Molybdenum	1.78	1.16	0.40	0.57	ns	ns	ns	ns
Nickel	33.3	19.9	18.5	23.4	ns	ns	ns	ns
Selenium	0.67	0.55	< 0.2	0.27	ns	ns	ns	ns
Silver	0.25	< 0.1	0.11	0.13	ns	ns	ns	ns
Strontium	---	---	---	---	ns	ns	ns	ns
Thallium	0.085	0.064	0.097	0.053	ns	ns	ns	ns
Tin	2.2	< 2	< 2	< 2	ns	ns	ns	ns
Titanium	---	---	---	---	ns	ns	ns	ns
Uranium	1.09	0.822	0.534	0.648	ns	ns	ns	ns
Vanadium	76.4	56.0	50.1	65.9	ns	ns	ns	ns
Zinc	519	181	90.7	97.5	123	315	380	200

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

TABLE 2: SEDIMENT CHEMISTRY RESULTS - METALS PARAMETERS (mg/kg) [2 of 3]

Sample ID	4C-C	5C-C	6C-B	6C-C	National - CCME Sediment		Provincial - CSR Sediment	
Date	15-Jan-2015	15-Jan-2015	15-Jan-2015	15-Jan-2015	CCME ISQG FW	CCME PEL FW	CSR SDft	CSR SDfs
Depth (cm)	10--20	0-10	10-20	0-10	ns	ns	ns	ns
pH	6.76	6.47	6.63	6.49	ns	ns	ns	ns
Aluminum	---	---	---	---	ns	ns	ns	ns
Antimony	0.58	1.30	0.61	1.21	ns	ns	ns	ns
Arsenic	4.55	5.11	5.35	4.71	5.9	17	20	11
Barium	86.6	123	126	118	ns	ns	ns	ns
Beryllium	0.33	0.49	0.50	0.56	ns	ns	ns	ns
Bismuth	---	---	---	---	ns	ns	ns	ns
Boron	---	---	---	---	ns	ns	ns	ns
Cadmium	**17.3**	**24.7**	**42.1**	**21.4**	0.6	3.5	4.2	2.2
Chromium (+3)	---	---	---	---	ns	ns	ns	ns
Chromium (+6)	---	---	---	---	ns	ns	ns	ns
Chromium (total)	**130**	**134**	**153**	**119**	37.3	90	110	56
Cobalt	11.1	15.6	13.4	14.8	ns	ns	ns	ns
Copper	37.3	99.8	64.1	93.9	35.7	197	240	120
Iron	---	---	---	---	ns	ns	ns	ns
Lead	25.3	63.4	58.6	60.7	35	91.3	110	57
Lithium	---	---	---	---	ns	ns	ns	ns
Magnesium	---	---	---	---	ns	ns	ns	ns
Manganese	---	---	---	---	ns	ns	ns	ns
Mercury	0.056	0.128	0.098	0.129	0.17	0.486	0.58	0.3
Molybdenum	0.91	2.05	1.49	1.98	ns	ns	ns	ns
Nickel	22.7	38.5	34.1	38.2	ns	ns	ns	ns
Selenium	0.43	0.82	0.51	0.79	ns	ns	ns	ns
Silver	0.10	0.34	0.25	0.32	ns	ns	ns	ns
Strontium	---	---	---	---	ns	ns	ns	ns
Thallium	0.065	0.102	0.089	0.106	ns	ns	ns	ns
Tin	< 2	< 2	2.2	< 2	ns	ns	ns	ns
Titanium	---	---	---	---	ns	ns	ns	ns
Uranium	0.810	1.17	1.02	1.12	ns	ns	ns	ns
Vanadium	55.2	77.7	81.8	78.5	ns	ns	ns	ns
Zinc	218	**700**	**347**	**639**	123	315	380	200

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

TABLE 2: SEDIMENT CHEMISTRY RESULTS - METALS PARAMETERS (mg/kg) [3 of 3]

Sample ID	7C-A	7C-C	8C-C	National - CCME Sediment		Provincial - CSR Sediment	
Date	**15-Jan-2015**	**15-Jan-2015**	**15-Jan-2015**	**CCME ISQG FW**	**CCME PEL FW**	**CSR SDft**	**CSR SDfs**
Depth (cm)	20-30	0-10	0-9	ns	ns	ns	ns
pH	7.21	6.17	6.41	ns	ns	ns	ns
Aluminum	---	---	---	ns	ns	ns	ns
Antimony	0.39	0.76	1.25	ns	ns	ns	ns
Arsenic	6.17	4.51	5.53	5.9	17	20	11
Barium	105	119	133	ns	ns	ns	ns
Beryllium	0.38	0.52	0.51	ns	ns	ns	ns
Bismuth	---	---	---	ns	ns	ns	ns
Boron	---	---	---	ns	ns	ns	ns
Cadmium	***14.1***	***35.3***	***19.7***	0.6	3.5	4.2	2.2
Chromium (+3)	---	---	---	ns	ns	ns	ns
Chromium (+6)	---	---	---	ns	ns	ns	ns
Chromium (total)	***141***	***153***	***111***	37.3	90	110	56
Cobalt	10.6	14.0	15.2	ns	ns	ns	ns
Copper	34.7	74.6	88.4	35.7	197	240	120
Iron	---	---	---	ns	ns	ns	ns
Lead	19.7	64.6	68.2	35	91.3	110	57
Lithium	---	---	---	ns	ns	ns	ns
Magnesium	---	---	---	ns	ns	ns	ns
Manganese	---	---	---	ns	ns	ns	ns
Mercury	0.055	0.112	0.124	0.17	0.486	0.58	0.3
Molybdenum	0.70	1.30	1.94	ns	ns	ns	ns
Nickel	23.9	36.0	37.3	ns	ns	ns	ns
Selenium	0.40	0.61	0.69	ns	ns	ns	ns
Silver	< 0.1	0.33	0.35	ns	ns	ns	ns
Strontium	---	---	---	ns	ns	ns	ns
Thallium	0.071	0.103	0.097	ns	ns	ns	ns
Tin	< 2	3.0	*7.3*	ns	ns	ns	ns
Titanium	---	---	---	ns	ns	ns	ns
Uranium	0.972	0.961	1.34	ns	ns	ns	ns
Vanadium	62.2	76.3	80.3	ns	ns	ns	ns
Zinc	146	***480***	***603***	123	315	380	200

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

TABLE 3: SEDIMENT CHEMISTRY RESULTS - PAH PARAMETERS (mg/kg)

Sample ID	**4C-A**	**4C-C**	**6C-B**	**National - CCME Sediment**		**Provincial - CSR Sediment**	
Date	**15-Jan-2015**	**15-Jan-2015**	**15-Jan-2015**	**CCME ISQG FW**	**CCME PEL FW**	**CSR SDft**	**CSR SDfs**
Depth (cm)	30-40	10-20	10-20	ns	ns	ns	ns
Acenaphthene	< 0.05	< 0.05	< 0.05	0.00671	0.0889	0.11	0.055
Acenaphthylene	< 0.05	< 0.05	< 0.05	0.00587	0.128	0.15	0.08
Acridine	---	---	---	ns	ns	ns	ns
Anthracene	< 0.05	< 0.05	< 0.05	0.0469	0.245	0.29	0.15
Benz(a)anthracene	0.051	< 0.05	0.252	0.0317	0.385	0.46	0.24
Benzo(a)pyrene	0.064	0.051	*0.440*	0.0319	0.782	0.94	0.48
Benzo(b)fluoranthene	0.117	*0.106*	*0.832*	ns	ns	ns	ns
Benzo(g,h,i)perylene	0.051	< 0.05	0.355	ns	ns	ns	ns
Benzo(k)fluoranthene	< 0.05	< 0.05	*0.264*	ns	ns	ns	ns
Chrysene	0.087	0.075	0.507	0.0571	0.862	1	0.53
Dibenz(a,h)anthracene	< 0.05	< 0.05	0.056	0.00622	0.135	0.16	0.084
Fluoranthene	0.106	0.133	0.806	0.111	2.355	2.8	1.5
Fluorene	< 0.05	< 0.05	< 0.05	0.0212	0.144	0.17	0.089
Indeno(1,2,3-c,d)pyrene	0.053	0.052	*0.398*	ns	ns	ns	ns
1-Methylnaphthalene	---	---	---	ns	ns	ns	ns
2-Methylnaphthalene	< 0.05	< 0.05	< 0.05	0.0202	0.201	0.24	0.12
Naphthalene	< 0.05	< 0.05	< 0.05	0.0346	0.391	0.47	0.24
Phenanthrene	0.067	0.099	0.352	0.0419	0.515	0.62	0.32
Pyrene	0.101	0.116	0.728	0.053	0.875	1.1	0.54
Quinoline	---	---	---	ns	ns	ns	ns
Benzo(a)pyrene Equivalency	---	---	---	ns	ns	ns	ns
PAHs, Total	---	---	---	ns	ns	20	10

Notes:
m - metres
PAH - polycyclic aromatic hydrocarbons
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard/guideline listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

TABLE 4: SEDIMENT CHEMISTRY RESULTS - OTHER PARAMETERS (mg/kg)

Sample ID	6C-B	National - CCME Sediment		Provincial - CSR Sediment	
Date	**15-Jan-2015**	**CCME ISQG FW**	**CCME PEL FW**	**CSR SDft**	**CSR SDfs**
Depth (cm)					
Calculated Chloride	---	ns	ns	ns	ns
Calculated Sodium	---	ns	ns	ns	ns
Organic Carbon, Total	5.33	ns	ns	ns	ns

Notes:
mg/kg - milligrams per kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed

DRAWINGS

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

NOTES:
REFERENCED FROM: CAPITAL REGIONAL DISTRICT, REGIONAL COMMUNITY ATLAS

LEGAL DESCRIPTION:
SECTION 8, RANGE 3 EAST, NORTH SAANICH DISTRICT
PID: 000-213-365

LEGEND:

— — —	PROPERTY BOUNDARY
● C	CORE SAMPLE LOCATION
◆ G	GRAB SAMPLE LOCATION
- - - -	APPROXIMATE LOCATION OF 2010 CAMOSUM COLLEGE STUDY TRANSECT (*REAY CREEK POND REMEDIATION STUDY*. ENVIRONMENTAL TECHNOLOGY PROGRAM. JUSTIN ROBINSON & RACHELLE SARRAZIN. JUNE 2010)

0 5 10 20 30 40 m

SCALE 1:750
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 10N

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

TOWN OF SIDNEY
REAY CREEK POND, REAY CREEK PARK - CANORA ROAD BETWEEN NORTHBROOK DRIVE AND BOWCOTT PLACE SIDNEY, BC

SAMPLING AND ANALYSIS OF REAY CREEK POND SEDIMENTS

SEDIMENT SAMPLING LOCATIONS

Date: Ma□5, 2015
Project No. 205.03696.00000
Drawing No. 1

SLR
global environmental solutions

Cadfile name: S_205-03696-00000-A1.dwg

PHOTOGRAPHS

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

Photo 1: Reay Cr. Pond viewed to the southeast towards the area of the dam, from approximate mid-pond area, Oct. 22, 2014

Photo 2: Pond area viewed north from approximately mid-pond area, Oct. 2014

SLR	Sampling and Analysis of Reay Creek Pond Sediments Canora Rd. Between Northbrook Dr. & Bowcott Pl. Sidney, BC
SITE PHOTOGRAPHS	SLR Project No: 205.03696.00000

Photo 3: Pond area east of Canora Rd. end of Pond, Oct. 2014

Photo 4: Pond discharge over dam spillway (left & top of right photo) and valve controlled discharge pipe at dam

Photo 5: Open water area of Pond viewed north from about mid-pond area on January 15, 2015

Photo 6: Pond area narrowed by vegetation, viewed northeast from approximate mid-pond

Photo 7: Petite Ponar (top) sampler used for surface sediment grab sampling

Photo 8: Sediment core samples in capped tubes ready for extruding and sampling

APPENDIX A
Previous Report Information – Camosun College

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

Reay Creek Pond Remediation Study

Produced for Camosun College
Environmental Technology Program

By Justin Robinson
& Rachelle Sarrazin

June 2010

Executive Summary

Reay Creek is one of the few urban streams in Victoria that supports an established run of Coho Salmon. However, problems upstream have put this run at risk. Reay Creek Pond is a potential contributor to these problems. The pond is situated on the Saanich Peninsula on the border of Sidney, North Saanich and the Victoria International Airport. This anthropogenically created pond, formed by an earthen dam first installed in the early half of the 20th century, has become an overactive sediment deposition zone. These sediments contain the cumulative effect of decades of agricultural use, historic and current run-off from Victoria International Airport and now runoff from residential areas. These factors have caused Reay Creek Pond to contain a build-up of organic sedimentation, agricultural nutrients and heavy metal contamination.

This study aims to determine water quality, with emphasis on eutrophication factors; sediment depth and pond topography; and recommendations for remediation for the Reay Creek Pond.

Reay Creek Pond was divided into 11 transects every 20 m, each transect then had water and total depth measurements taken at 2 m intervals. The difference between these two measurements was the sediment depth. The results were then mapped using ESRI ArcGIS.

Water quality was determined from three points in the pond: near the dam, at the approximate centre and near the inflow culvert. These samples were tested for nitrogen, nitrite-nitrogen, nitrate-nitrogen and phosphate. Additionally, at each sampling location conductivity, dissolved oxygen, temperature and pH were measured.

Sediment samples were collected at the same 3 locations as water quality tests and one additional location 20 m from the dam. The samples were then separated, homogenised and placed in a centrifuge to extract the sediment pore water. The resulting pore water was then tested for the same parameters as surface water. Samples were also collected for lab analysis at Maxxam Analytics. These samples were taken from the 20 m from dam point and the approximate middle of the pond.

Sedimentation levels in Reay Creek Pond are high, with an average water depth of 38.8 cm and a sediment depth of 129.4 cm. Over the entire pond there is an approximate total volume of 2569 m^3 of non-compacted sediment.

The temperature throughout Reay Creek Pond is very variable (ranging from 12.5 to 21.5 °C) an indicator of poor water quality. The pH was found to fluctuate between 7.22 and 8.46, causing potential stress on fish health. Phosphate was determined to be a limiting nutrient and identified Reay Creek Pond's trophic level to be oligotrophic to meso-eutrophic.

Ammonia concentrations in sediment pore water were exceed testable limits of 2 ppm. Reay Creek Pond sediment displayed relatively normal conditions for freshwater systems. Total phosphorus levels in the sediment were high, potentially causing a eutrophic event if disturbed.

Maxxam laboratory analysis of heavy metals determined that both cadmium and chromium were higher than probable effect levels (PEL) determined by the Canadian Environmental Quality Guidelines[1]. The tested sediments contained 21.5 ppm and 18 ppm of cadmium in the middle and dam sediment respectively, with a PEL guideline of 3.5 ppm. These sediments also contained 115 ppm (middle sediment) and 107 ppm (dam sediment) of chromium, with a PEL guideline of 90.0 ppm).

Based on these results it is recommended that the sediment from Reay Creek Pond be removed. Remediation is also an option however less attractive considering the pond size, metal contamination, sediment loads and neighbourhood desire of a publicly usable pond.

Sediment removal can be accomplished either through draining and excavation of sediments or suction dredging.

Draining and excavation is a laboriously complex solution, requiring a bypass pipe to be installed to drain the pond before excavation can begin. The process will also require large machinery to gain access to the pond, possibly resulting in destruction of shoreline vegetation.

Suction dredging may be a better solution, utilising a smaller suction raft to remove sediment without requiring heavy machinery or draining the pond. The primary concern with suction dredging will be acquiring the machinery.

Mitigation and remediation of sediments to reduce metal contamination and possible eutrophic events is conceivable, however undesirable as the sediments would continue to build up in the pond.

Acknowledgements

Special thanks to those who were able to provide assistance for this project: Ian Bruce was an immense help, providing contacts, materials, ideas and a pillar of support; Reg Kirkham for use of his property and local knowledge of Reay Creek Pond; Cindy Wright for her insight and knowledge with sediments and sediment coring; Audrey Dallimore for providing tools for sediment coring; Tony Dorling for providing equipment on short notice; Neil Meanwell for chemistry insight; Steve Gormican for his experience with aquatic environments; Leslie Glover for her assistance with lab work and passionate drive; Dave Thomas for biology technical support; David Wade and Robin Robinson for guest field day appearances and alternative points of view.

Contents

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Methodology

Sediment and Water Depth Measurements

Reay Creek Pond was divided into 11 transects every 20 meters. The first transect started 5 m away from the dam, as poor sediment levels were found close to the dam. The location of the second transect was determined by measuring 20 m away from the first transect on both shores. Transects 3 and 4 were measured 10 meters away from the last transect on one shore and 20 m away on the opposing shore in order to compensate for a sharp turn. After Transect 4, each transect was measured by connecting a 50 m measuring tape to the center of the previous transect and measuring 20 m while following the contours of the pond. The location of the next transect was visually defined by features on both shores and the addition of red flagging tape. Transect locations can be seen in Figure 2.

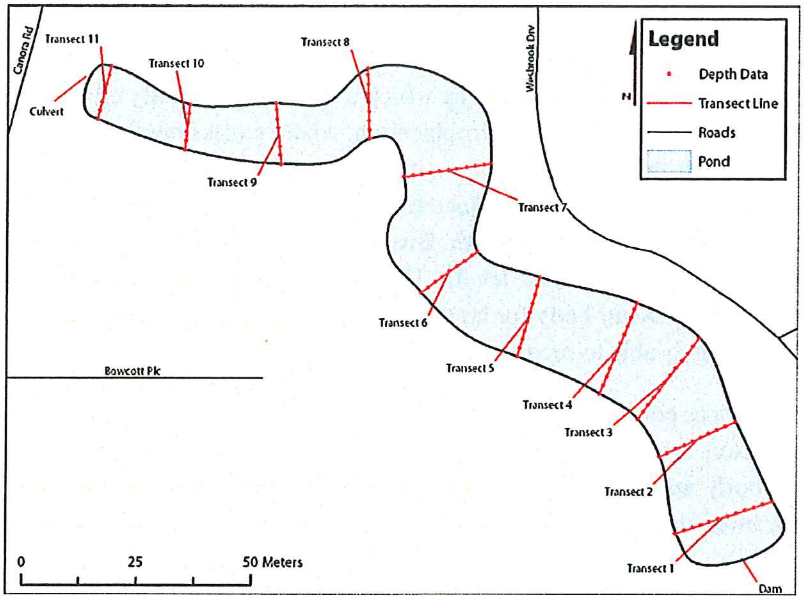

Figure 2 – Map showing transect locations and data collection points for Reay Creek Pond study, June 2010

For each transect, rebar was hammered into opposing shores and rope with flagged 2 m intervals was stretched tightly between both rebar locations. In order to maintain accuracy, the distance between each 2 m marked intervals was measured and corrected for each transect. For correct referencing, the same shore was used for the zero meter mark of each transect. The distance, bearing, and GPS location of each transects start and end points were collected in order to be referenced in Arc Map GIS software.

Sediment and water depth measurements were taken from a boat using several thin bamboo rods at different lengths. The bamboo rods were inserted in the water body until there was a slight resistance, at which time the measurer would mark the water level in regards to the bamboo rod with his or her index and thumb. A 50 m measure tape was pulled tight across the bottom of the bamboo stick to the measurer's index finger where the water to sediment depth is recorded in cm to one decimal place of precision. In order to compensate for increased bending in the bamboo sticks, the measuring tape was stretched tightly across the stick without following its contour. Water to sediment depth measurements were collected simultaneously by both measurers at a selected sample location. The discrepancy between the two measurements were noted and adjusted to maintain accuracy.

The bamboo stick was then inserted into the water at a new location close to the original sampling site location to collect total depth measurements. Strong force was used on the bamboo stick in order to be certain that a hard substrate was reached and was applied multiple times to ensure correct measurement. The measurer then marked the water level on the bamboo stick using his or her index finger and thumb and then gently pulled up the stick while maintaining their grasp location on the stick. The stick was cleaned and then measured using the same 50 m measuring tape. Measurements were recorded in centimetres to one decimal place of precision. Sediment depth was calculated by subtracting the total depth of the sample site by the water to sediment depth.

Water Quality Sampling

Water samples were collected at the beginning, middle, and end of the pond using 1 litre plastic bottles. Bottles were cleaned three times with pond water and inserted into the pond for several minutes to allow for water flow. Water samples were collected at a depth of one foot in order to prevent contamination of surface water. Bottles were shaken and capped in the water to prevent any bubbles from being collected. Two water samples were collected at the end of pond in order to match the location of sediment samples collected at 20 meters and 5 meters away from the dam.

Water samples were refrigerated between 4 and 6°C for 24 hours following collection. LaMotte's Water Quality Testing Products were used in conjunction with a LaMotte SMART 2 Colorimeter to test for Ammonia Nitrogen (Low Range), Nitrite Nitrogen (Low Range), Nitrate Nitrogen (Low Range), and Phosphate (Low Range). The colorimeter was pre-calibrated by LaMotte for proper use all of their water quality testing kits. Before testing, all tubes, flasks, and graduated cylinders were rinsed with tap water. Testing methods followed LaMotte's Procedure sheets provided with each kit. In order to assess errors associated with sample heterogeneity and sample testing techniques, two replicates were created for each test using the same water sample. Colorimeter results were collected until values were stable. In some cases an average of many colorimeter results was recorded due to fluctuations caused by tube orientation in the colorimeter.

Water parameters were also collected using a Model 85 YSI meter. These parameters included conductivity and dissolved oxygen. A pHTestr 30 was used to collect pH information. Temperature was also recorded using a glass thermometer. These parameters were collected at the same sites as above: beginning, middle, and end.

Sediment Sample Collection and Pore Water Analysis

Sediment samples were collected at four different sampling locations along Reay Creek using an metal Ekman Grab. Sediment sampling sites were located at the beginning, middle and end of the pond as close to water sampling sites as possible. At the end of the pond, sediment samples were collected at two locations 20 and 5 meters away from the dam. Sediment samples were collected following the RISC protocol for sampling lake sediment on a boat[12]. Once collected, samples were released from the Ekman Grabber into a large plastic container and scooped into a labelled Tupperware container using the container itself. Large organic content was manually removed as the sample was scooped into the Tupperware container. Each sample container was quickly moved to shore and placed into the pond in order to maintain a constant temperature. To prevent contamination of surface water, the lids of the containers were closed tightly and never allowed to be submerged. Sediment samples were refrigerated between 4 and 6°C for 42 hours, following the RISC Preservation and Hold Times for Sediments and Tissues Guidelines[12]. The temperature of the refrigerator was checked twice and adjusted to maintain a constant temperature.

Sediment samples were brought to Camosun College's Microbiology Lab in order to undergo pore water extraction through the use of their centrifuge. A non-analytical balance scale was balanced and tared with an empty 10 ml glass test tube and a test tube holder in order to hold the tubes upright when being weighed. For each sediment sample the sediment was transferred into thirty-two 10 ml glass test tubes using small metal scoopers and 20ml plastic pipettes. Each test tube was weighed to a weight of 10.50 g

Results

Sediment Depth Transects & Mapping

From the depths recorded in the field the depth of sediment was determined. The results of this can be found in Table 1 of Appendix A. Transect Locations can be seen in Figure 5. Figure A-1 to Figure A-11 shows the cross-sectional depths of the water and sediment based on this data.

Two maps were produced using the collected depth data (Table 1 of Appendix A). Figure 3 shows the depth of water and Figure 4 shows the depth of sediment in Reay Creek Pond. A third map (Figure 5) was produced to show the thickness of sediment.

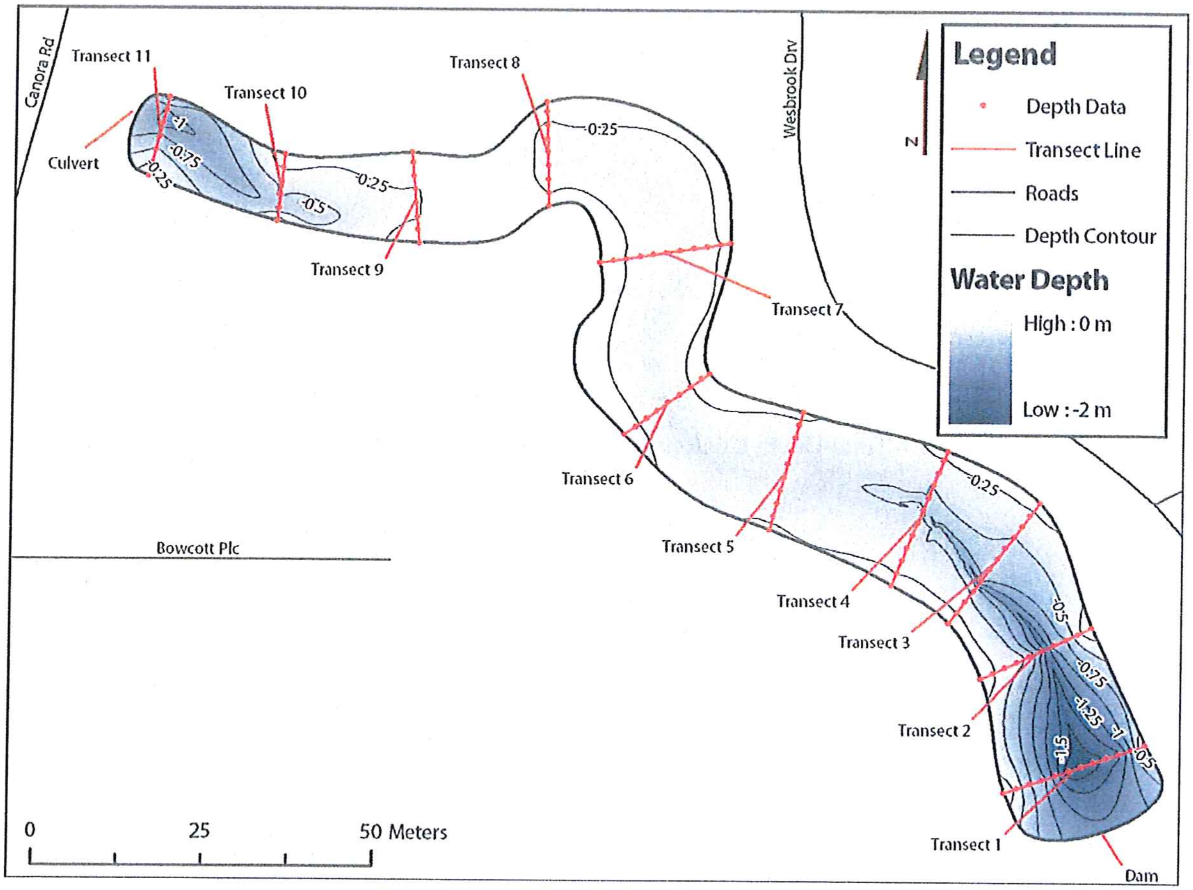

Figure 3 – Water Depth Contour Map of Reay Creek Pond, June 2010

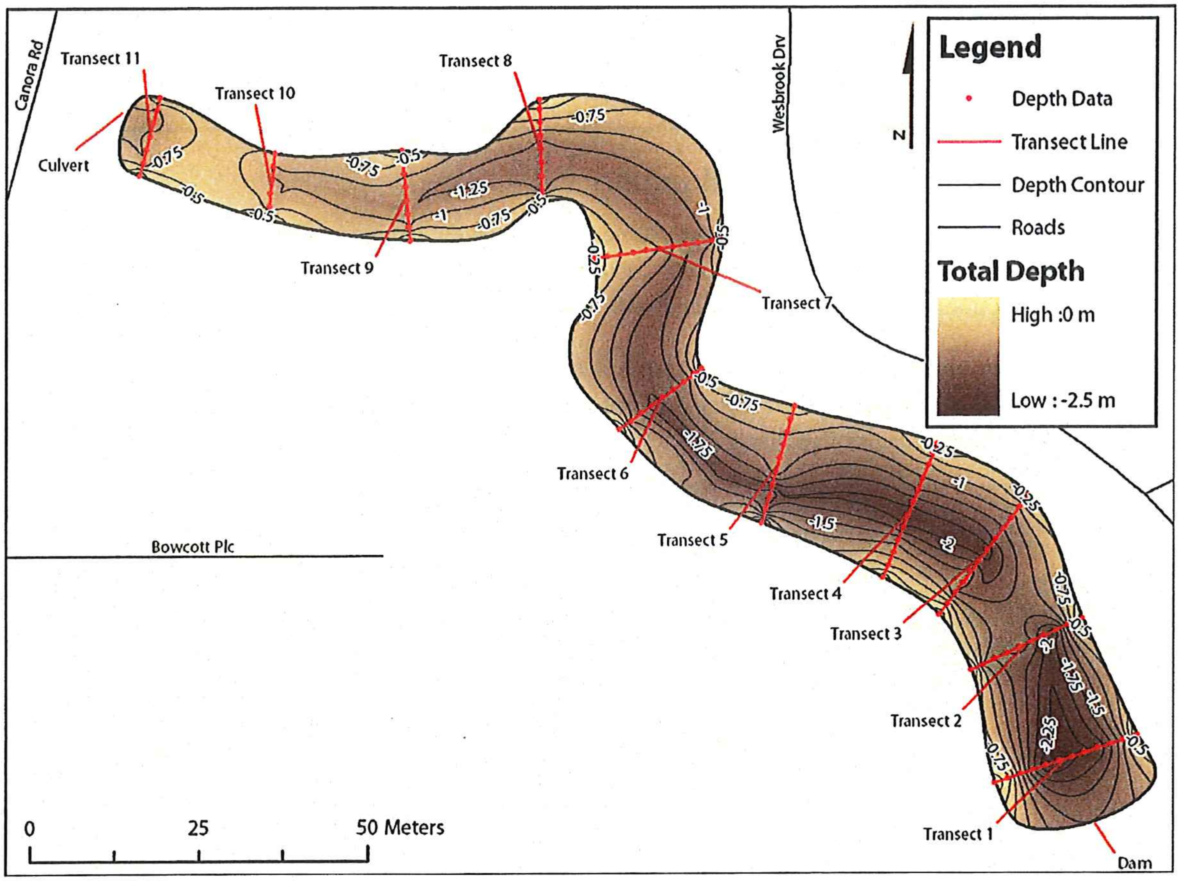

Figure 4 – Total Depth Contour Map of Reay Creek Pond, June 2010

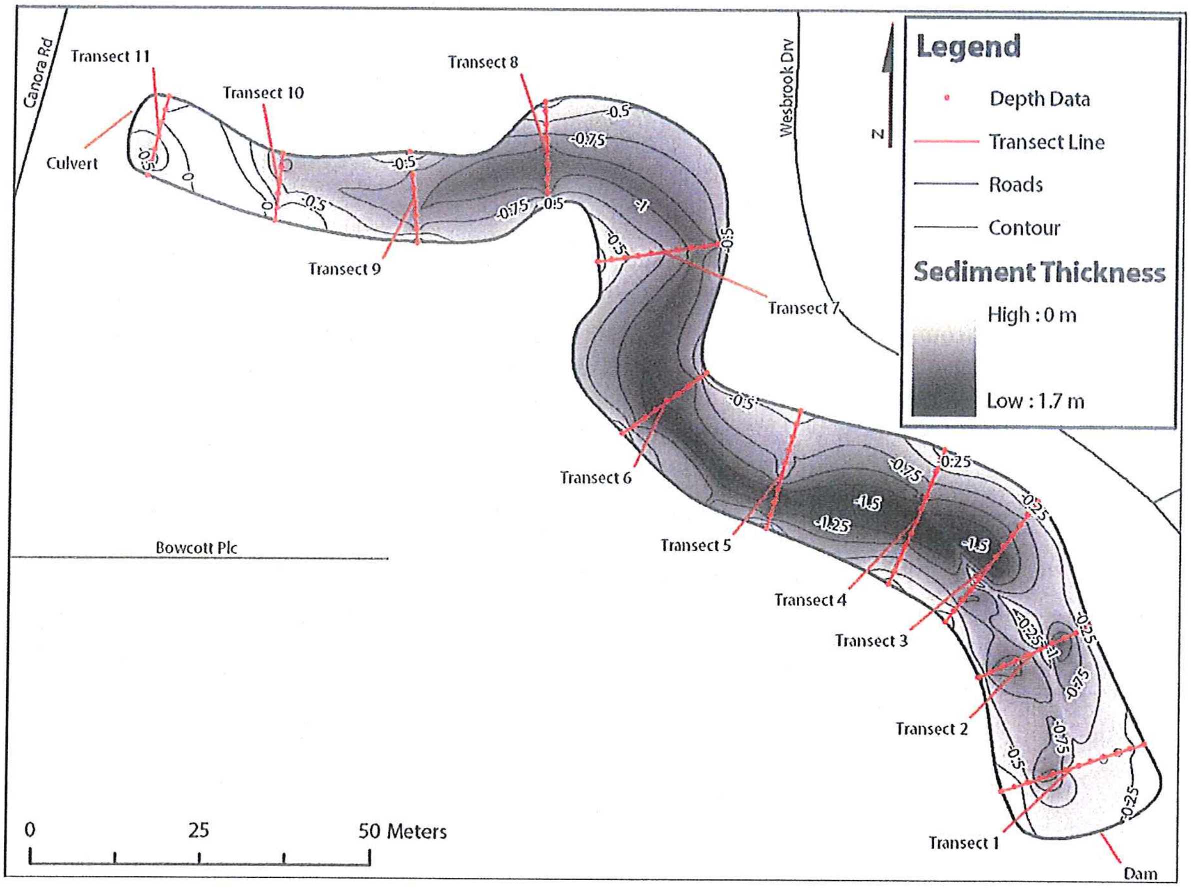

Figure 5 – Thickness of Sediment and Contours Map of Reay Creek Pond, June 2010

Three dimensional analysis was conducted on the sediment and water depth layers, this resulted in a 3 dimensional TIN (triangulated irregular network). Due to the constraints of displaying 3D media in reports the ArcScene files can be found on the accompanying CD-ROM in Appendix B. From the 3D model it was determined that the volume of sediment in the pond is approximately 2569 m^3.

Flora & Fauna

A cursory identification of the dominant aquatic vegetation occurred during depth analysis. It was found the two dominant aquatic plants were *Elodea canadensis* and *Potamogeton robbinsii.*

The only aquatic vertebrate found during the period of study was the three-spined stickleback *(Gasterosteus aculeatus).* Four were captured for identification, one was found floating on the surface already deceased (the largest of the four, approximately 3.5 inches long, with puncture marks near pectoral fin).

Testing Results

The following sections describe the results obtained from water quality testing "in-house" using individual quality sets as described in the methodology and the results obtained from Maxxam Analytical Laboratories.

In-House Experiments

In the following tables (Table 1 – Table 3) the results of the individual test packages for water quality is presented. Table 1 shows the water quality of surface water where over the entire pond ammonia concentration ranged from 0.03 to 1.02 ppm, nitrite-nitrogen ranged from 0.0025 to 1.775 ppm, nitrate-nitrogen ranged from 0.002 to 1.69 ppm and phosphate ranged from 0.03 to 0.23 ppm.

Table 1 – Water Quality results of Water Samples from Reay Creek Pond collected June 5 2010, analysed June 6 2010

Location	Rep	Ammonia-Nitrogen (ppm)	Nitrite-Nitrogen (ppm)	Nitrate-Nitrogen (ppm)	Phosphate (ppm)
Culvert	1	0.165	1.775	0.0045	0.09
	2	N/A*	0.0025	1.69	0.03
Middle	1	1.02	0.007	0.76	0.09
	2	0.915**	0.009	0.76	0.09
20m From Dam	1	0.03	0.052	0.315	0.07
	2	0.31	0.005	0.4	0.15
	3	MAX	0.005	0.33	0.155
3m From Dam	1	0.25	0.31	0.005	0.23
	2	0.41	0.43	0.002	0.115

*Reagents exhausted

**New reagents used

Table 2 shows the results of testing water quality from pore water extracted from sediments. In the pore water ammonia concentration was higher than measureable values except for in one case where the concentration was 0.98 ppm; both nitrite-nitrogen and nitrate-nitrogen measured 0 ppm in all tests; phosphate ranged from 1.3 to 2.13 ppm.

Table 2 – Water Quality results of Pore Water Samples from Reay Creek Pond Sediment collected June 5 2010, analysed June 7 2010

Location	Rep	Ammonia-Nitrogen (ppm)	Nitrite-Nitrogen (ppm)	Nitrate-Nitrogen (ppm)	Phosphate (ppm)
Culvert	1	0.98	0	0	1.3
	2	>2	0	0	1.31
Middle	1	>2	0	0	2.13
	2	>2	0	0	2.06
20m From Dam	1	>2	0	0	1.91
	2	>2	0	0	1.9
3m From Dam	1	>2	0	0	1.42
	2	>2	0	0	1.48

Table 3 shows water parameters (dissolved oxygen, conductivity, pH and temperature) taken while in the field. Dissolved oxygen ranged from 6.84 to 16.5 mg/L; conductivity ranged from 266.5 to 302 µS; pH ranged from 7.22 to 8.46 and temperature ranged from 12.5 to 21.5 °C. Surface water alkalinity was later determined to be 160 ppm.

Table 3 – Water Parameters Collected in-field from Reay Creek Pond on June 5 2010

Location	DO (mg/L)	Conductivity (µS)	pH	Temp (°C)	Time
Culvert	7.65	270.8	7.22	12.5	12:05
Middle	17.5	302	8.46	21.5	16:32
3 m From Dam	6.84	266.5	7.22	16.5	16:10

Biochemical Oxygen Demand

After three days, the biochemical oxygen demand (BOD) in five of the six BOD bottles was 0 mg/L. At day two the BOD spiked to about 30mg/L for the five BOD bottles, but dropped to zero shortly thereafter. BOD in the third bottle, at a sediment to water dilution ratio of 1:29, continuously increased to 50 mg/L by the third day. After five days the BOD in all bottles was at zero, with the BOD in the third bottle decreasing rapidly after day three. These results are tabulated in Table 4.

Table 4 – Results of Biochemical Oxygen Demand tests for Reay Creek Pond, Analysed June 2 2010

Sample	Day 1	Day 2	Day 3	Day 4	Day 5
BOD Sample 1	0	30	0	0	0
BOD Sample 2	0	28	0	0	0
BOD Sample 3	0	29	50	0	0
BOD Sample 4	0	24	0	0	0
BOD Sample 5	0	27	0	0	0

Metal Analysis Results

The following tables show results requested from Maxxam Analytics. Table 5 shows heavy metal results from sediment sampled from the middle and near the dam (approximately 3 m in front of dam) of Reay Creek Pond. Of interest are the concentrations of chromium, with 115 ppm in middle sediment and 107 in dam sediment, and cadmium, with 21.5 ppm in middle sediment and 18 ppm in dam sediment. In addition to total metals, available orthophosphate and total organic carbon (TOC) were also requested. Maxxam reported 60.5 µg/g available orthophosphate and 62 g/kg of TOC.

Table 5 – Total Metal Results from Maxxam Lab for Middle and Near-Dam Sediments

Metal	Middle Sediment (ppm)	Dam Sediment (ppm)
Total Aluminum (Al)	20600	23700
Total Antimony (Sb)	1.2	1.4
Total Arsenic (As)	4.6	5.3
Total Barium (Ba)	114	138
Total Beryllium (Be)	0.5	0.5
Total Bismuth (Bi)	0.1	0.2
Total Cadmium (Cd)	21.5	18
Total Calcium (Ca)	7560	8070
Total Chromium (Cr)	115	107
Total Cobalt (Co)	15	15.5
Total Copper (Cu)	88.8	103
Total Iron (Fe)	29300	34400
Total Lead (Pb)	65.7	65
Total Magnesium (Mg)	7130	8180
Total Manganese (Mn)	474	783
Total Mercury (Hg)	0.09	0.12
Total Molybdenum (Mo)	1.6	2.2
Total Nickel (Ni)	34.5	38
Total Phosphorus (P)	882	1320
Total Potassium (K)	947	1180
Total Selenium (Se)	<0.5	<0.5
Total Silver (Ag)	0.16	0.18

Metal	Middle Sediment (ppm)	Dam Sediment (ppm)
Total Sodium (Na)	453	603
Total Strontium (Sr)	51.4	52.5
Total Thallium (Tl)	0.08	0.1
Total Tin (Sn)	1.4	1.5
Total Titanium (Ti)	788	685
Total Vanadium (V)	69	77
Total Zinc (Zn)	701	741
Total Zirconium (Zr)	3.3	2.9

phosphorous concentration between 882 ppm and 1320 ppm, the pond sediment is over 8000 times greater than the minimum total phosphorous concentration range observed in the surface waters hyper-eutrophic lakes[1] (see Table 5). Due to the fact that inorganic phosphate readily absorbs onto small particulate matter, only a fraction of total phosphorous would be available to mix with surface waters[26]. Although much of the organic phosphate is mineralized within the sediment column into useable inorganic phosphate, much of it would also become absorbed either onto surrounding sediment particles or onto suspended particulates in the water after being stirred[22]. Both the sedimentation and mineralization of organic and inorganic phosphorous would prevent all of the sediment phosphorous from entering the surface waters of Reay Creek Pond during disruption. Unfortunately, the amount of phosphorous tied to particulate matter depends strongly on the concentration of Fe(OOH) and $CaCO_3$, which is unknown in Reay Creek Pond[26]. Even though we do not know how much phosphorous is tied up in sediment, it can be inferred based on the high concentrations of total phosphorous found in our results that only a small fraction of the sediment column would need to be disturbed in order to cause a eutrophication event in the pond[26].

Phosphate levels in the sediment pore water varied little over the extent of the pond. A spike of 0.70 ppm from the culvert to the middle of Reay Creek Pond may have been caused by the increased biotic activity and presence in the area (shown by high levels of photosynthesis) (see Table 2). High biotic activity could result in high decomposition rates where large quantities of inorganic phosphate would be released[26]. The released inorganic phosphate would be transported downward into the sediment by absorbing onto suspended matter entering the pond as a result of erosion[26]. The large difference between phosphate and phosphorous concentrations could be explained by the fact that phosphate decreases as total phosphorous increases[1]. Additionally, the difference between total phosphorous and phosphate values reinforces the fact that phosphate is a poor indicator of phosphorous.

Flora & Fauna

The two main species of aquatic vegetation in Reay Creek Pond, *Elodea canadensis* and *Potamogeton robbinsii,* form monoculture mats. This is expected as that is the primary life strategy of these two species[27]. However, this does not account for the observed lack of aquatic plant diversity throughout the pond.

There was a resounding lack of amphibious life in this pond, both adult and pre-adult stages. During the time of study amphibious reproduction should have been occurring. This could either be attributed to toxic metal contamination or the possibility that amphibious life has not colonised this anthropogenically created pond.

Metal Analysis

Due to the proximity to Victoria International Airport one of the primary concerns for this study was the concentration of cadmium and other heavy metals in sediments. When comparing the results of metal analysis (Table 5) to the Canadian Environmental Quality Guidelines produced by the Canadian Council of Ministers of the Environment[1], it was found that both cadmium and chromium were above both Canadian interim sediment quality guidelines (ISQG) and probable effect levels (PEL) established for sediments (for cadmium the ISQG is 0.6 and PEL is 3.5, for chromium the ISQG is 37.3 and PEL is

90.0). Cadmium concentration in the middle sediments was seven times the recommended value (PEL) with 21.5 mg/kg (ppm).

These results indicate that adverse biological effects may occur due to higher than PEL concentrations, especially for benthic organisms. This would reduce mortality, diversity abundance and would result in behavioural changes in aquatic organisms[1]. This would partially explain the lack of aquatic diversity quantitatively observed in the field.

Biochemical Oxygen Demand

The BOD examination used in this study was ineffective (see Table 4). The methodology used for examining sediments was adopted from a dilution method and did not take into consideration the manometric measuring device used. Incorrect dilutions caused the noticeable crash, even if a value had been reported after 5 days—due to incorrect dilutions—the result would have not been accurate. Measurements from a manometric BOD device are correlated to the volume within each container, and do not require dilution.

Conclusion

Sedimentation levels in Reay Creek Pond are high, with an average water depth of 38.8 cm and a sediment depth of 129.4 cm. Over the entire pond there is an approximate total volume of 2569 m^3 of non-compacted sediment.

Water temperature was too high to sustain many of the various life stages of Cutthroat Trout and Coho Salmon. The temperature throughout Reay Creek Pond is very variable which is a poor indicator of water quality. The dissolved oxygen levels were high enough to sustain aquatic wildlife but were too low to accommodate spawning activities and healthy populations of mayfly. Conductivity was too low to cause toxic effects on aquatic life, specifically Coho Salmon. The pH was found to be under heavy influence of respiration of aquatic vegetation, due to the large growth area provided by shallow conditions. This causes large fluctuations of pH which can stress and damage to fish health, even though overall the pH remains an acceptable neutral value. Ammonia levels fall within the prescribed guidelines set out by the Canadian Council of Ministers of the Environment (CCME) for sustaining aquatic life. Nitrate exceed the same guidelines at two sampling sites but was able to meet Environment Canada's guidelines for freshwater aquatic life. Phosphate was determined to be a limiting nutrient and identified Reay Creek Pond's trophic level to be oligotrophic to meso-eutrophic.

Ammonia concentrations in sediment pore water were found to be very high, exceeding testable limits of 2 ppm. Low levels of nitrate and nitrite were found in the sediment pore water, reflecting normal sediment conditions in a freshwater system. Total phosphorus levels in the sediment were very high. Even though we were unable to measure the amount of phosphorus tied up in the sediment, if the sediments were to be mixed into the water column the resulting phosphorus concentration would not be able to sustain aquatic life. Additionally, if a small fraction of sediment was disrupted, an eutrophication event could occur.

Both cadmium and chromium were higher than probable effect levels (PEL) determined by the Canadian Environmental Quality Guidelines[1]. The tested sediments contained 21.5 ppm and 18 ppm of cadmium in the middle and dam sediment respectively, with a PEL guideline of 3.5 ppm. These sediments also contained 115 ppm (middle sediment) and 107 ppm (dam sediment) of chromium, with a PEL guideline of 90.0 ppm).

Overall the surface water quality of Reay Creek Pond is capable of supporting a low diversity of aquatic life. However, for life to thrive within this system, sediment remediation—in some form—must occur. The water quality of Reay Creek Pond directly affects the downstream ecosystem and the aquatic life residing within. Based on the results of this study, there is a possibility of an eutrophication event disrupting sensitive creek habitat.

Appendix A– Depth Data

The following appendix contains depth results for field work and transect figures for visualisation.

Table A-1 – Collected depth measurements and sediment depth calculation for Reay Creek Pond, collected May 7 2010 to June 12 2010

Transect	Distance (m)	Water to Sediment Depth (cm)	Total Depth (cm)	Sediment Depth (cm)	Comments
1	2	31.9	35.2	3.3	
1	4	74.5	116.7	42.2	
1	6	86.8	199.1	112.3	
1	8	138.1	251.8	113.7	
1	10	199.7	244.6	44.9	
1	12	190.3	227.2	36.9	
1	14	184.7	223.2	38.5	
1	16	158.9	220.5	61.6	
1	18	159.8	177.8	18.0	Gray clay
1	20	92.7	129.7	37.0	Hit rock substrate
1	22	0.0	0.0	0.0	Shoreline
2	2	22.2	135.1	112.9	
2	4	39.3	151.9	112.6	
2	6	38.6	149.0	110.4	Possible log
2	8	51.1	139.6	88.5	Possible log
2	10	87.6	148.2	60.6	
2	12	79.5	199.5	120.0	
2	14	79.8	211.2	131.4	
2	16	28.0	92.9	64.9	
3	2	25.9	55.6	29.7	A lot of coarse organic debris
3	4	41.9	149.8	107.9	
3	6	52.8	139.4	86.6	
3	8	56.5	142.5	86.0	
3	10	46.7	187.6	140.9	
3	12	55.0	214.5	159.5	
3	14	53.9	164.5	110.6	
3	16	50.2	149.8	99.6	
3	18	45.1	136.2	91.1	
3	20	35.6	100.2	64.6	
3	22.38				Shore
4	2	27.8	85.6	57.8	
4	4	35	107.7	72.7	
4	6	45.6	131.5	85.9	
4	8	47.2	197.7	150.5	

Transect	Distance (m)	Water to Sediment Depth (cm)	Total Depth (cm)	Sediment Depth (cm)	Comments
4	10	46.9	215.1	168.2	
4	12	47.4	190.9	143.5	
4	14	50.2	148.7	98.5	
4	16	47.1	123.9	76.8	
4	18	45.6	106.2	60.6	
4	20	30.5	59.7	29.2	Woody Debris
4	21.5				Shore
5	2	46.6	183.0	136.4	
5	4	40.6	156.6	116.0	Strong Stratification
5	6	43.2	173.8	130.6	Strong Stratification
5	8	44.0	102.5	58.5	
5	10	36.6	107.0	70.4	
5	12	37.7	112.4	74.7	
5	14	44.2	97.0	52.8	
5	16	38.3	88.8	50.5	
5	18	11.3	54.9	43.6	Shore
6	2	19.5	126.6	107.1	
6	4	36.5	151.7	115.2	
6	6	37.2	184.5	147.3	Strong Stratification
6	8	46.0	165.0	119.0	
6	10	34.7	150.1	115.4	
6	12	26.9	147.7	120.8	
6	14	6.9	105.7	98.8	
6	15.345				Shore
7	2	20.6	67.0	46.4	Sand (~2cm)
7	4	26.1	74.5	48.4	Sand (~3cm)
7	6	27.8	77.4	49.6	Sand (~3cm)
7	8	30.7	90.8	60.1	Sand (~2 cm)
7	10	25.0	99.2	74.2	Sand (~2cm)
7	12	36.9	125.4	88.5	Sand (~1.5 cm)
7	14	37.7	143.0	105.3	Sand (~4 cm)
7	16	38.6	147.2	108.6	Sand (~2.5 cm)
7	18	25.4	141.4	116.0	Sand (~1 cm)
7	19.45				Shore
8	2	26.7	149.7	123.0	Sand (~15cm)
8	4	32.3	144.9	112.6	Sand (~15cm)
8	6	28.3	141.4	113.1	Sand
8	8	27.5	139.0	111.5	Firm sand
8	10	30.6	118.6	88.0	no sand (limted)
8	12	28.8	79.7	50.9	no sand (limted)

Transect	Distance (m)	Water to Sediment Depth (cm)	Total Depth (cm)	Sediment Depth (cm)	Comments
8	14	17.5	58.8	41.3	Dense Layer (2cm)
8	15.4				Shore
9	2	18.8	102.5	83.7	rocks (holding fence post)
9	4	26.8	109.9	83.1	Partial sand
9	6	26.3	106.5	80.2	Partial sand
9	8	26.8	113.1	86.3	Partial sand
9	10	16.6	96.2	79.6	Stirred sediment
9	12	12.4	82.2	69.8	
9	13.5				Shore
10	2	68.2	98.0	29.8	
10	4	43.7	88.0	44.3	
10	6	48.1	97.9	49.8	Sand (1 cm)
10	8	21.4	102.8	81.4	Sand
10	10	1.0	74.3	73.3	Shore
11	2	29.0	100.3	71.3	Sand
11	4	48.2	93.8	45.6	Sand
11	6	67.1	90.9	23.8	Sand
11	8	112.5	113.5	1.0	Sand (1 cm)
11	10	106.3	106.3	0.0	Dense gravel
11	12	27.2	49.4	22.2	Shore

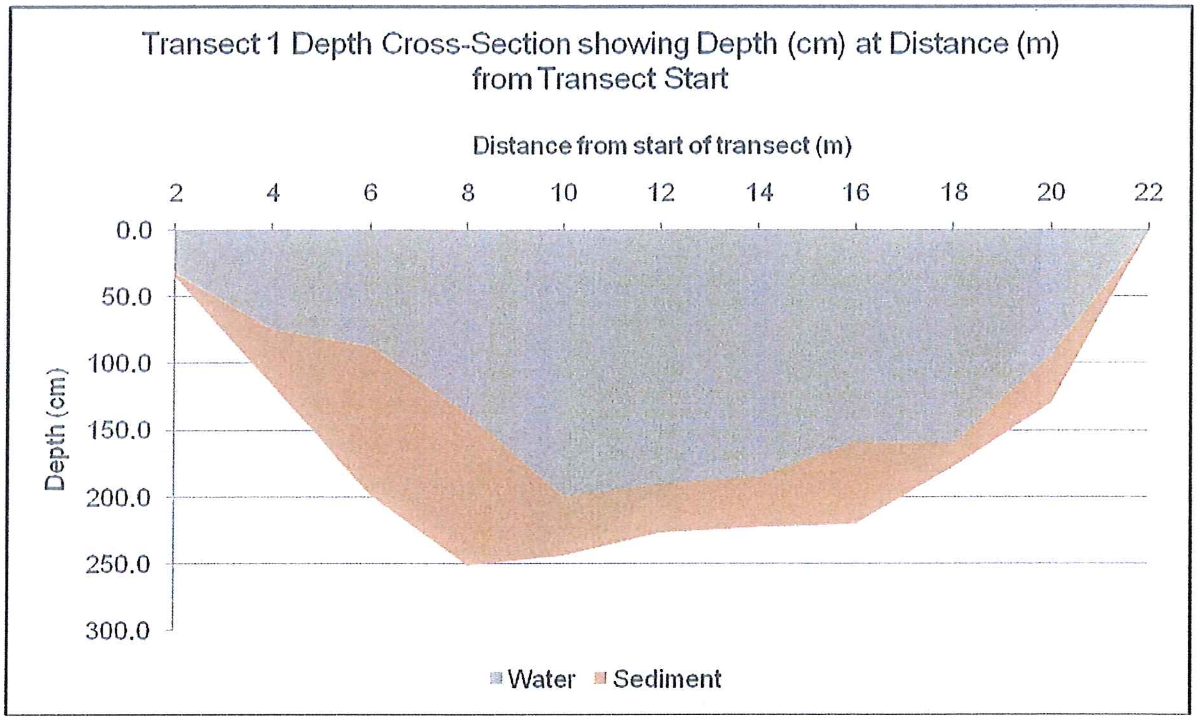

Figure A-1 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 1

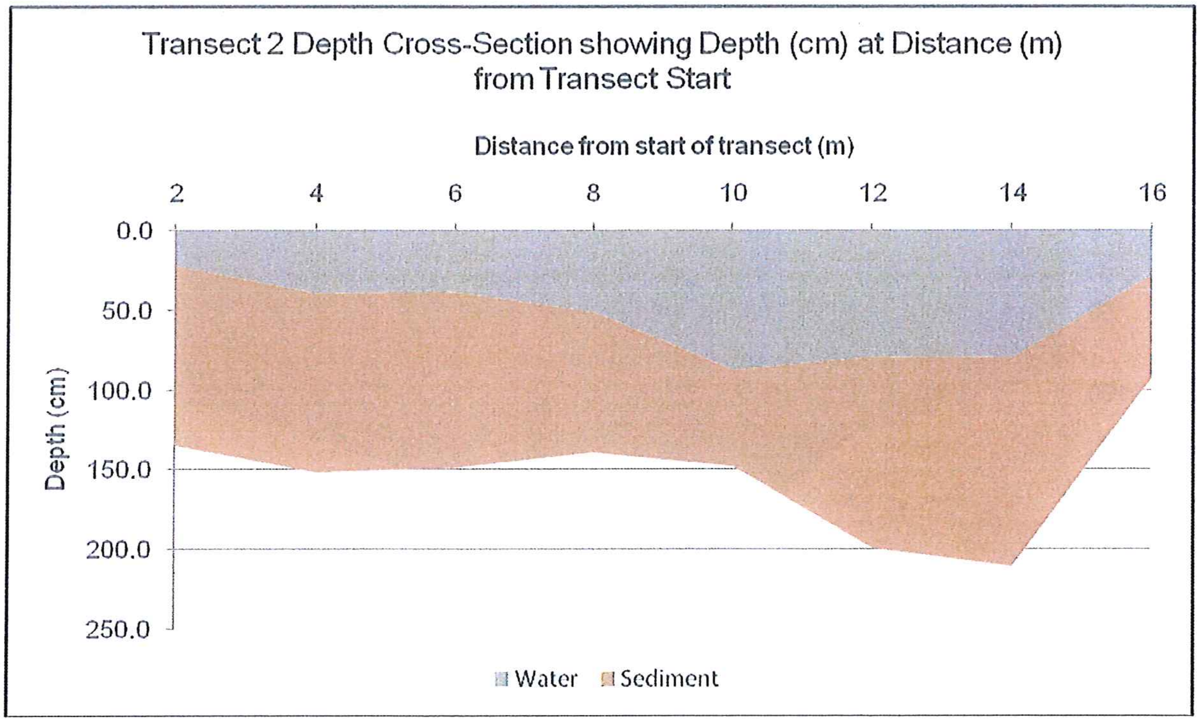

Figure A-2 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 2

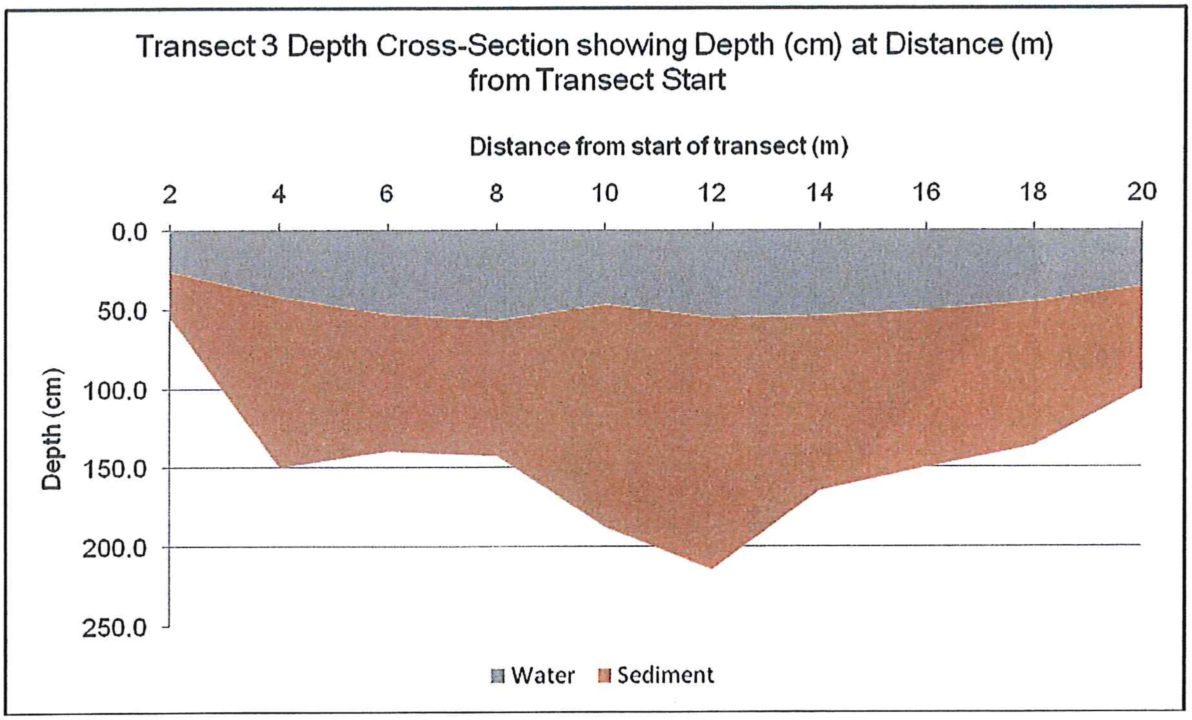

Figure A-3 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 3

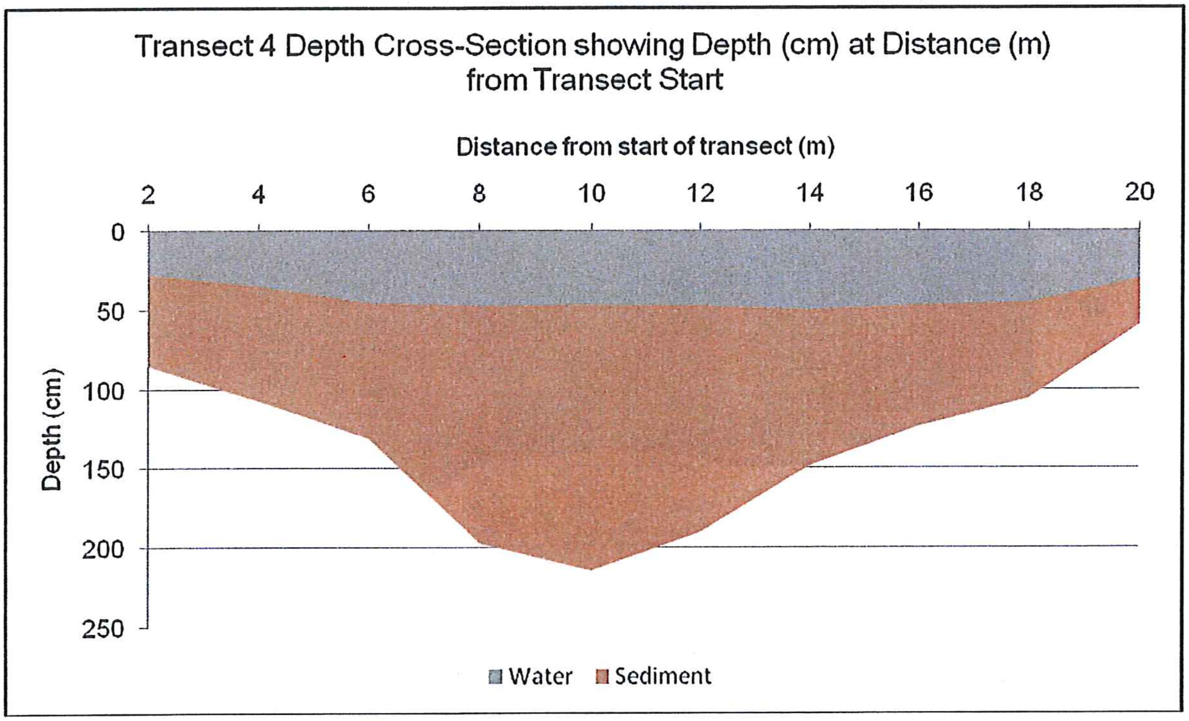

Figure A-4 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 4

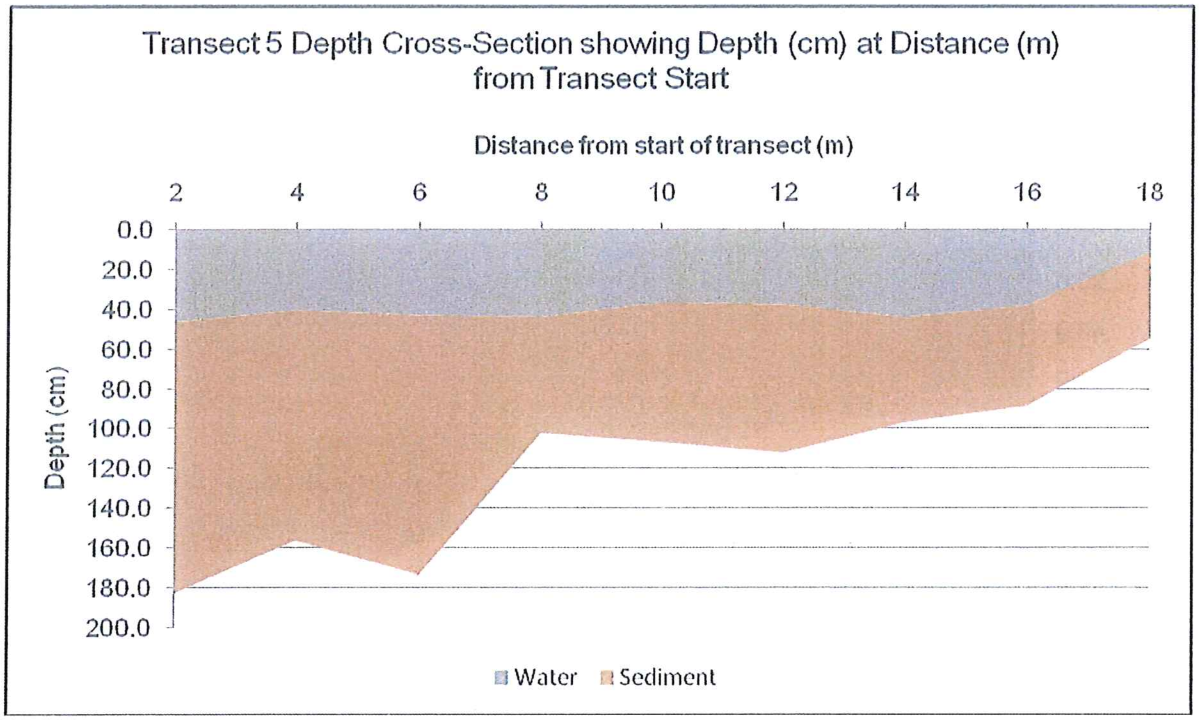

Figure A-5 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 5

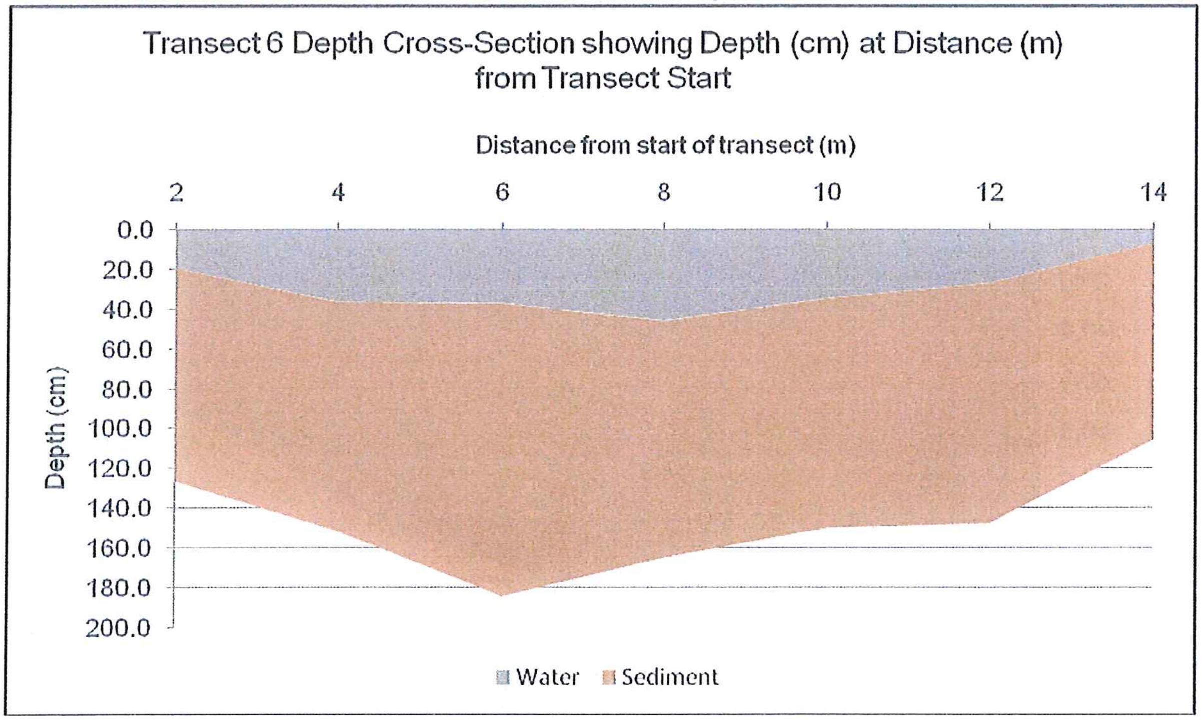

Figure A-6 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 6

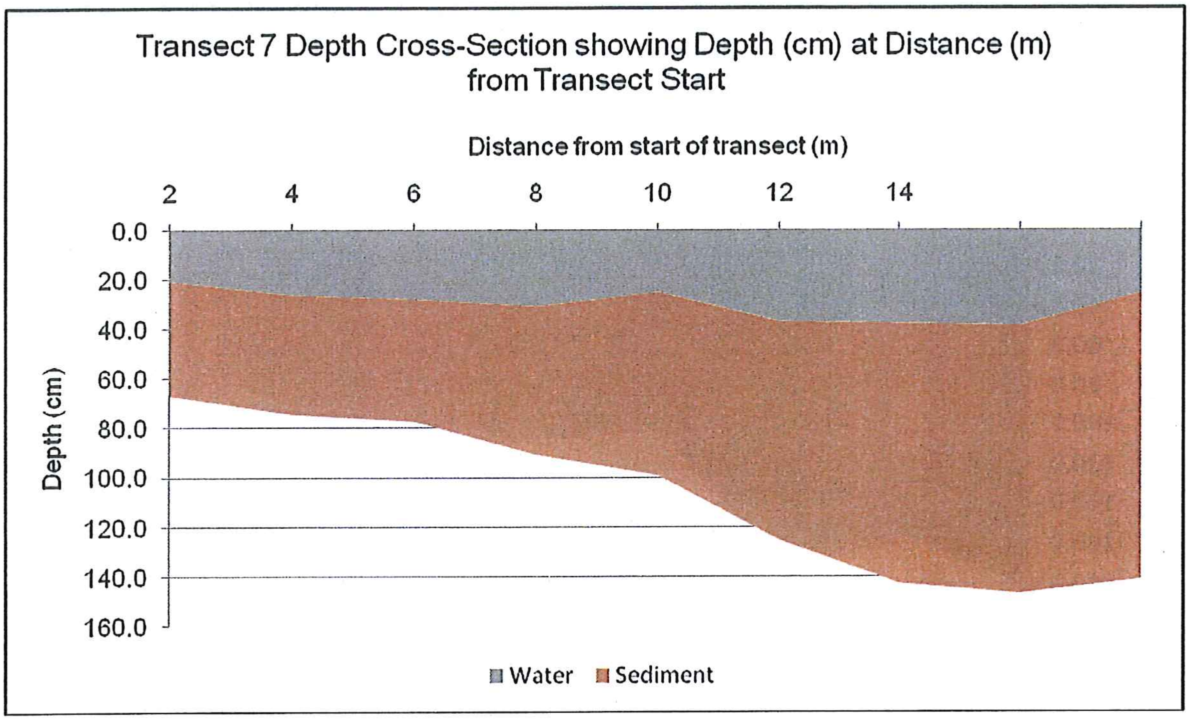

Figure A-7 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 7

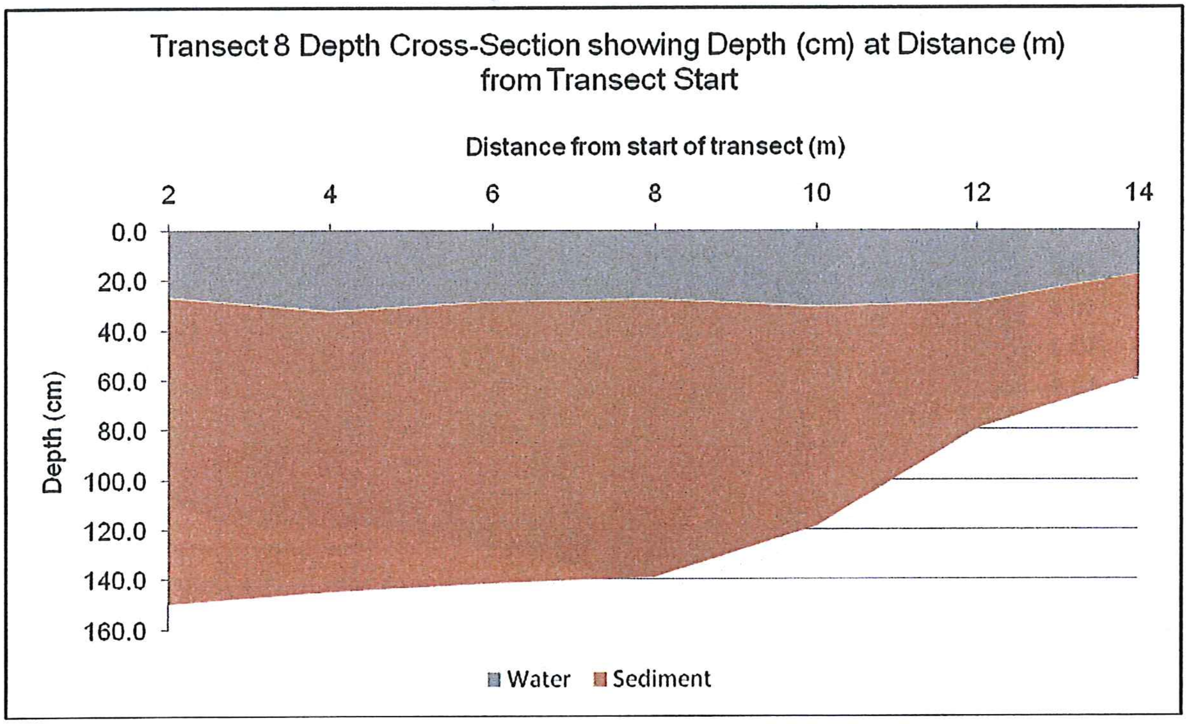

Figure A-8 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 8

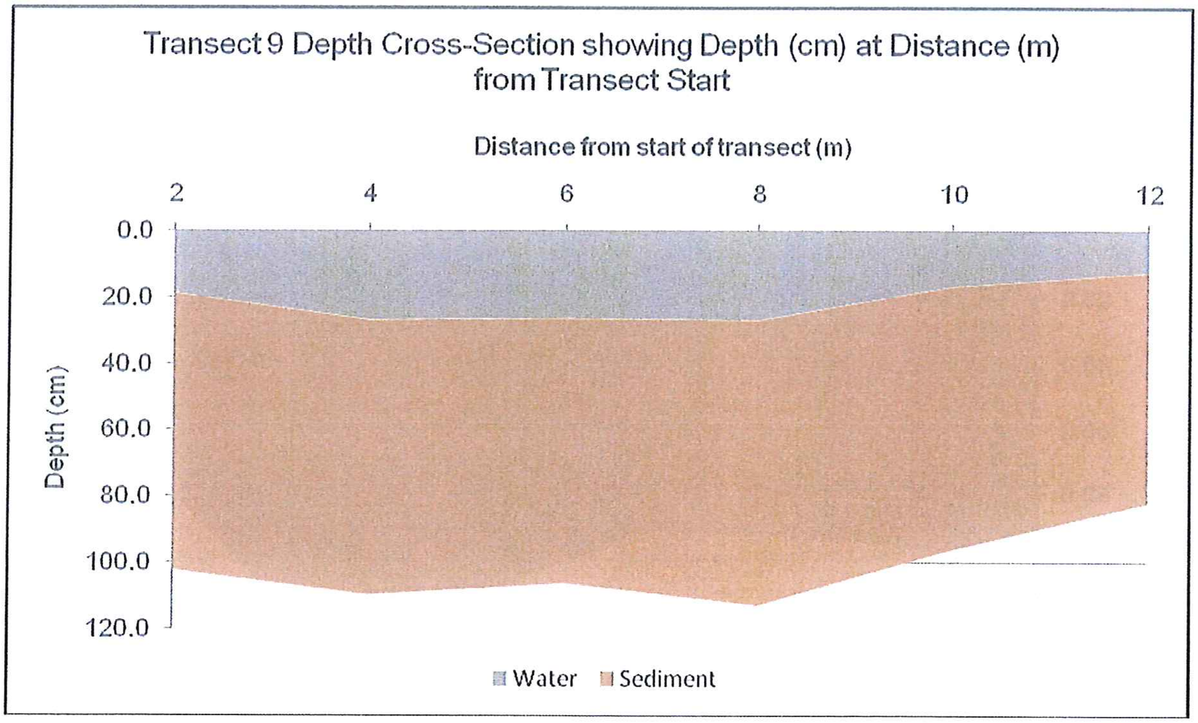

Figure A-9 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 9

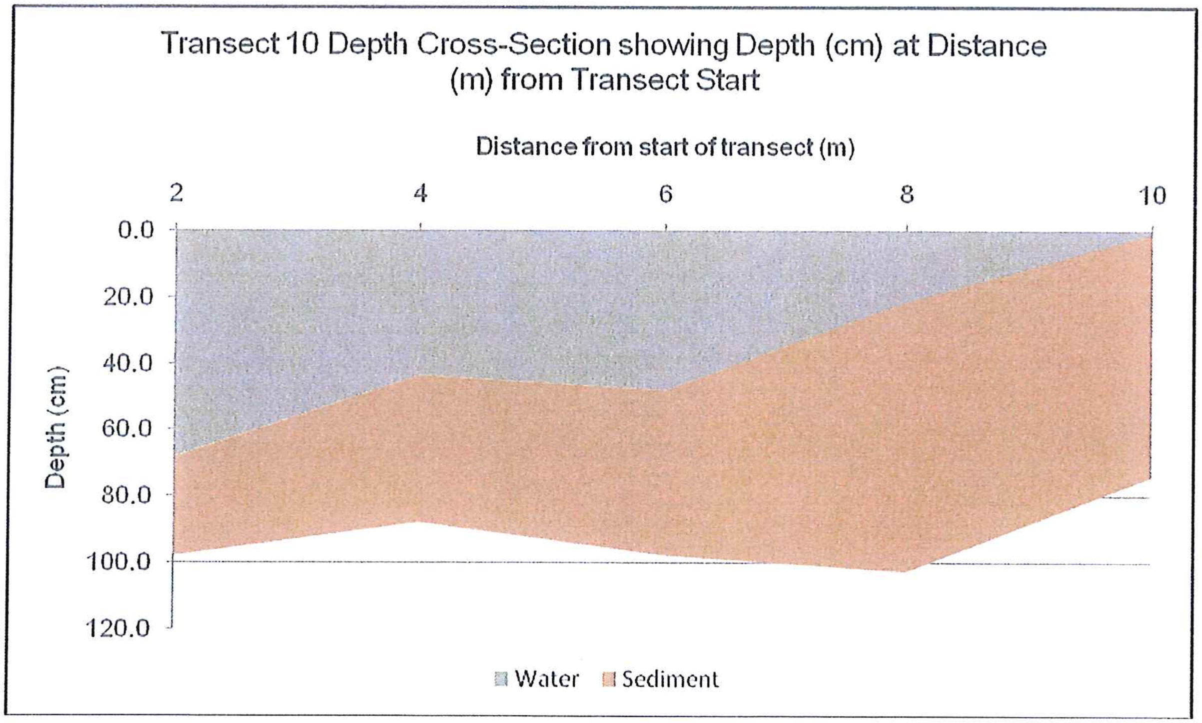

Figure A-10 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 10

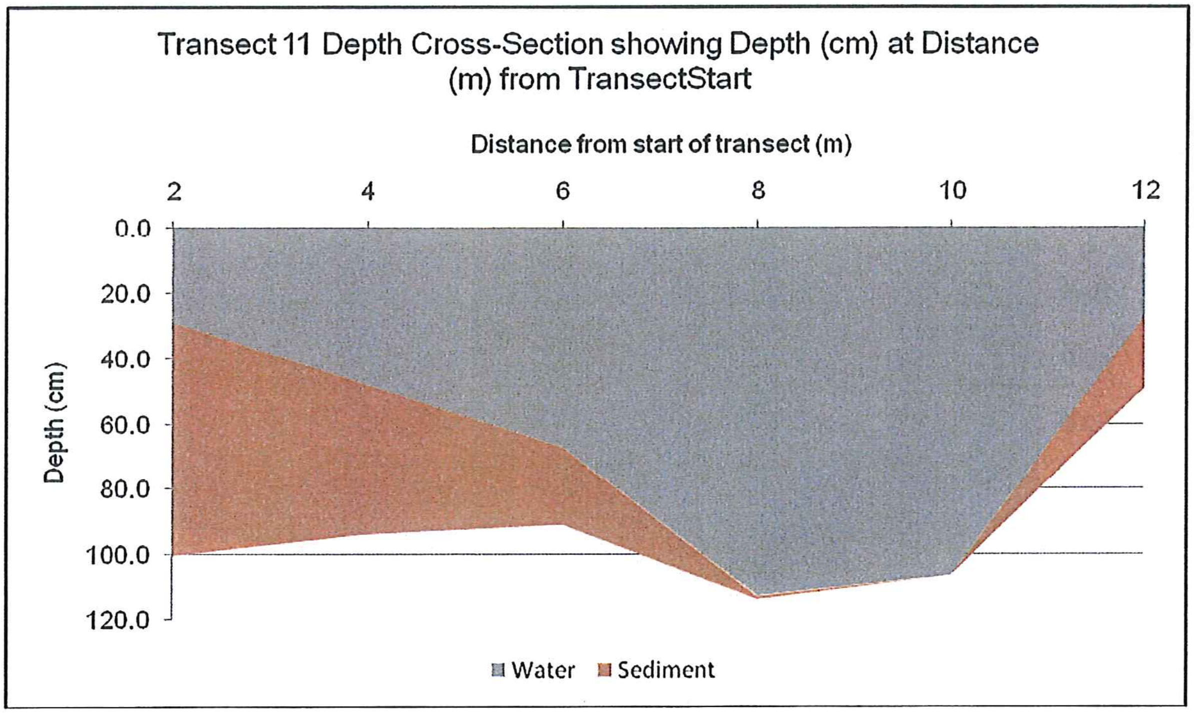

Figure A-11 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 10

APPENDIX B
Regulatory Criteria & Guidelines Information

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

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B.C. Reg. 375/96
O.C. 1480/96 and M271/2004

Deposited December 16, 1996
effective April 1, 1997

Environmental Management Act

CONTAMINATED SITES REGULATION

Note: Check the Cumulative Regulation Bulletin 2014 and 2015
for any non-consolidated amendments to this regulation that may be in effect.

[includes amendments up to B.C. Reg. 4/2014, January 31, 2014]

Point in Time

Schedule 9

[en. B.C. Reg. 324/2004, s. 70; am. B.C. Regs. 239/2007, s. 9; 343/2008, s. 18.]

Generic Numerical Sediment Criteria[1]

COLUMN I Substance	COLUMN II Freshwater Sediment[2]	COLUMN III Freshwater Sediment[2]	COLUMN IV Marine and Estuarine Sediment[3]	COLUMN V Marine and Estuarine Sediment[3]
	Sensitive[4] ($SedQC_{SS}$)	Typical[5] ($SedQC_{TS}$)	Sensitive[4] ($SedQC_{SS}$)	Typical[5] ($SedQC_{TS}$)
Inorganic Substances				
arsenic	11.0	20.0	26.0	50.0[6]
cadmium	2.2	4.2	2.6	5.0
chromium (total)	56.0[6]	110.0	99.0	190.0
copper	120.0	240.0	67.0	130.0
lead	57.0	110.0	69.0	130.0
mercury	0.3	0.58	0.43	0.84
zinc	200.0	380.0	170.0	330.0
Organic Substances **Chlorinated Hydrocarbons** *chlorinated aliphatics*				
hexachlorocyclohexane[7]	0.00086[6]	0.0017[6]	0.00061	0.0012[6]
miscellaneous chlorinated hydrocarbons				

PCBs[9](total)	0.17	0.33	0.12	0.23
PCDDs and PCDFs[8]	0.00013[6]	0.00026[6]	0.00013	0.00026[6]
Phenolic Substances				
chlorinated phenols				
pentachlorophenol	0.4[10]	0.8[10]	0.36[11]	0.69[11]
Polycyclic Aromatic Hydrocarbons (PAHs)				
alkylated low molecular weight PAHs 2-methylnaphthalene	0.12	0.24	0.12	0.24
low molecular weight PAHs				
acenaphthene	0.055	0.11	0.055	0.11
acenaphthylene	0.08	0.15	0.079	0.15
anthracene	0.15	0.29	0.15	0.29
fluorene	0.089	0.17	0.089	0.17
naphthalene	0.24	0.47	0.24	0.47
phenanthrene	0.32	0.62	0.34	0.65
high molecular weight PAHs				
benz[a]anthracene	0.24	0.46	0.43	0.83
benzo[a]pyrene	0.48	0.94	0.47	0.92
chrysene	0.53	1.0	0.52	1.0
dibenz[a,h]anthracene	0.084	0.16	0.084	0.16
fluoranthene	1.5	2.8	0.93	1.8
pyrene	0.54	1.1	0.87	1.7
Total PAHs				
PAHs (total) [12]	10.0	20.0	10.0	20.0
Pesticides				
chlordane	0.0055	0.011	0.003	0.0057
DDD (total) [13]	0.0053	0.01	0.0048	0.0094
DDE (total) [14]	0.0042	0.0081	0.23	0.45
DDT (total) [15]	0.003	0.0057	0.003	0.0057
dieldrin	0.0041	0.008	0.0027	0.0052
endrin	0.039	0.075[6]	0.039	0.075[6]
heptachlor and heptachlor epoxide	0.0017	0.0033[6]	0.0017	0.0033
lindane [7]	0.00086[6]	0.0017[6]	0.00061	0.0012[6]

Footnotes

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

2. Criteria to protect freshwater aquatic life.
3. Criteria to protect marine and/or estuarine aquatic life.
4. Sensitive sediment means sediment at a site with sensitive aquatic habitat and for which sensitive sediment management objectives apply. Consult director for further advice.
5. Typical sediment means sediment that is not sensitive sediment. Consult director for further advice.
6. Denotes a sediment quality criteria which is considered less reliable or that could not be fully evaluated.
7. Criteria is specific to gamma isomer.
8. Calculated using data for PCDDs, PCDFs, PCBs and associated PCDD, PCDF and PCB toxicity equivalency factors.
9. Total PCBs includes either the sum of four to seven Arochlor mixtures (i.e. Arochlor 1016, 1221, 1232, 1242, 1248, 1254 and/or 1260) or the sum of ≥ 20 individual PCB congeners. No discrete criterion for Arochlor 1254 was derived, since the existing Canadian Council of Ministers of the Environment interim Probable Effects Level (PEL) for that substance was inconsistent with the PEL provided for total PCBs and the Probable Effects Level (PEL) for Arochlor 1254 was derived using methods different from those used to derive the criterion for total PCBs listed in this schedule.
10. Criterion is set equal to the State of New York, Department of Environmental Conservation, 1994 criterion for the substance.
11. Criterion is set equal to the Washington State, Department of Ecology, 1991 criterion for the substance.
12. Total PAHs includes:
    2-methylnaphthalene,
    acenaphthalene,
    acenaphthene,
    anthracene,
    benz[a]anthracene,
    benzo[a]pyrene,
    chrysene,
    dibenz[a,h]anthracene,
    fluorene,
    fluoranthene,
    naphthalene,
    phenanthrene, and
    pyrene.
13. DDD is 2,2-bis(p-chlorophenyl)-1,1-dichloroethane
14. DDE is 2,2-bis(p-chlorophenyl)-1,1-dichloroethylene
15. DDT is 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane

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Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

INTRODUCTION

As chemicals or substances are released into the environment through natural processes or human activities, they may enter aquatic ecosystems and partition into the particulate phase. These particles may be deposited into the bed sediments where the contaminants may accumulate over time. Sediments may therefore act as long-term reservoirs of chemicals to the aquatic environment and to organisms living in or having direct contact with sediments. Because sediments comprise an important component of aquatic ecosystems, providing habitat for a wide range of benthic and epibenthic organisms, exposure to certain substances in sediments represents a potentially significant hazard to the health of the organisms. Effective assessment of this hazard requires an understanding of relationships between concentrations of sediment-associated chemicals and the occurrence of adverse biological effects. Sediment quality guidelines are scientific tools that synthesize information regarding the relationships between the sediment concentrations of chemicals and any adverse biological effects resulting from exposure to these chemicals.

This chapter provides information regarding the derivation and implementation of Canadian sediment quality guidelines. In addition, detailed chemical-specific fact sheets have been developed for those chemicals for which national guidelines have been derived.

Sediment quality guidelines provide scientific benchmarks, or reference points, for evaluating the potential for observing adverse biological effects in aquatic systems. The guidelines are derived from the available toxicological information according to the formal protocol established by the Canadian Council of Ministers of the Environment (CCME 1995). The protocol, reprinted in this chapter for reference, includes general guidance on the implementation of sediment quality guidelines, in conjunction with other relevant information, in order to prioritize and focus sediment quality assessments. The formal protocol used to derive sediment quality guidelines relies on both a modification of the National Status and Trends Program (modified NSTP) approach and the spiked-sediment toxicity test (SSTT) approach.

To derive sediment quality assessment values, the modified NSTP approach uses data from North American field-collected sediments that contain chemical mixtures (Long and Morgan 1990; Long 1992; Long and MacDonald 1992; MacDonald 1994; CCME 1995; Long et al. 1995). Synoptically collected chemical and biological data ("co-occurrence data") are evaluated from numerous individual studies to establish an association between the concentration of each chemical measured in the sediment and any adverse biological effect observed.

The co-occurrence data are compiled in a database referred to as the Biological Effects Database for Sediments (BEDS) in order to calculate two assessment values. The lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely. The upper value, referred to as the probable effect level (PEL), defines the level above which adverse effects are expected to occur frequently. By calculating TELs and PELs according to a standard formula, three ranges of chemical concentrations are consistently defined: (1) the minimal effect range within which adverse effects rarely occur (i.e., fewer than 25% adverse effects occur below the TEL), (2) the possible effect range within which adverse effect occasionally occur (i.e., the range between the TEL and PEL), and (3) the probable effect range within which adverse biological effects frequently occur (i.e., more than 50% adverse effects occur above the PEL). The definitions of these ranges are based on the assumption that the potential for observing toxicity resulting from exposure to a chemical increases with increasing concentration of the chemical in the sediment (Long et al. 1995). The definition of the TEL is consistent with the definition of a Canadian sediment quality guideline. The PEL is recommended as an additional sediment quality assessment tool that can be useful in identifying sediments in which adverse biological effects are more likely to occur.

The SSTT approach involves an independent evaluation of information from spiked-sediment toxicity tests for estimating the concentration of a chemical below which adverse effects are not expected to occur. In this approach, an SSTT value is derived using data from controlled laboratory tests in which organisms are exposed to sediments spiked with known concentrations of a chemical or specific mixture of chemicals. Such studies provide quantifiable cause-and-effect relationships between the concentration of a chemical in sediments and the observed biological response (e.g., survival, reproductive success, or growth). Spiked-sediment toxicity tests may also be used to determine the extent to which environmental conditions modify the bioavailability of a chemical, and ultimately the response of organisms exposed to the spiked sediments.

Minimum toxicological data requirements have been set for the SSTT approach to ensure that the derived SSTT values provide adequate protection to aquatic organisms. Spiked-sediment toxicity tests that meet the minimum data requirements are currently available only for cadmium in marine (and estuarine) sediments. In addition, concerns regarding spiked-sediment toxicity testing methodology limit the degree to which these values may be used as the scientific basis for recommending sediment quality guidelines at this time.

Subsequent to an evaluation of the toxicological information, Canadian sediment quality guidelines are recommended if information exists to support both the modified NSTP and the SSTT approaches. (These are referred to as *full* sediment quality guidelines.) Generally, the lower of the two values derived using either approach is recommended as the Canadian sediment quality guideline. Interim sediment quality guidelines (ISQGs) are recommended if information is available to support only one approach.

The guidelines may also be derived to reflect predictive relationships that have been established between the concentration of the chemical in sediments, and any environmental factor or condition that may influence the toxicity of a specific chemical (e.g., sediment characteristics, such as total organic carbon content [TOC] or acid volatile sulphides [AVS]; or water column characteristics, such as hardness). Consideration of these relationships will increase the applicability of guidelines to a wide variety of sediments throughout Canada.

If insufficient information exists to derive interim guidelines using either the modified NSTP approach or the SSTT approach, guidelines from other jurisdictions are evaluated and may be provisionally adopted in the short term as ISGQs. Further details on the derivation and evaluation of Canadian ISQGs and PELs for both freshwater and marine sediments are outlined in the protocol (CCME 1995, reprinted in this chapter).

Canadian ISQGs are recommended for total concentrations of chemicals in freshwater and marine surficial sediments (i.e., top 5 cm), as quantified by standardized analytical protocols for each chemical. For the analytical quantification of metals in sediments, the choice of digestion method is dependent on the intended use of the results (e.g., for quantification of the bioavailable fraction or for geochemical evaluation). Because ISQGs are intended to be used for evaluating the potential for biological effects, "near-total" trace metal extraction methods that remove the biologically available fraction of metals and not residual metals (i.e., those metals held within the lattice framework of the sediment) are recommended for determining sediment metal concentrations. A strong extraction method using hydrofluoric acid would remove both the bioavailable and residual fractions of metals in the sediment. Therefore in this chapter, the concentration of "total" metal refers to the concentration of metal recovered using a near-total (mild digestion; e.g., aqua regia, nitric acid, or hydrochloric acid) method.

To date, spiked-sediment toxicity data are limited; therefore, ISQGs, which are derived using only the modified NSTP approach (i.e., the TEL), are reported instead of full sediment quality guidelines. Currently, ISQGs and PELs are recommended for 31 chemicals or substances (7 metals, 13 PAHs, and 11 organochlorine compounds). Tables 1 and 2 list the chemicals and corresponding ISQGs and PELs that are recommended for freshwater and marine (including estuarine) sediments as well as the percentages of adverse biological effects found within concentration ranges surrounding the ISQGs and PELs. Although these sediment quality guidelines are considered interim at this time, they should not be used differently than if they were full sediment quality guidelines. During their application, it should however be recognized that these values reflect associative information only because insufficient reliable spiked-sediment toxicity data currently exist to evaluate cause-and-effect relationships.

Sediment quality guidelines have a broad range of potential applications, as do other environmental quality guidelines. They can serve as goals or interim targets for national and regional toxic chemical management programs, as benchmarks or targets in the assessment and remediation of contaminated sites, or as the basis for the development of site-specific objectives. They may also be used as environmental benchmarks for international discussions on emission reductions, as environmental guidelines on trade agreements, in reports on the state of regional or national sediment quality, in the assessment of the efficacy of environmental regulations, in evaluations of potential impacts of developmental activities, and in the design, implementation, and evaluation of sediment quality monitoring programs. Despite the variety of potential uses, sediment quality guidelines are likely to be routinely applied as screening tools in the site-specific assessment of the potential risk of exposure to chemicals in sediment and in formulating initial management decisions (e.g., acceptability for open-water disposal, required remediation, further site investigation, and prioritization of sites).

In the application of the existing framework for assessing sediment quality, it is important to recognize that

Canadian ISQGs are intended to be used in conjunction with other supporting information. Such information includes site-specific background concentrations and concentrations of other naturally occurring substances, biological assessments, environmental quality guidelines for other media (e.g., water, tissue, and soil), and Canadian ISQGs and PELs (or other relevant sediment quality assessment values) for other chemicals. It should also be noted that the ISQGs and PELs are developed using scientific information only. Socioeconomic (e.g., cost) or technological (e.g., remedial technology) factors that may influence their application are not considered in the development process, but may play a varying role in their application (and/or in the development of site-specific sediment quality objectives) within the decision-making framework of different jurisdictions and programs.

It is widely recognized that no single sediment quality assessment tool should be used to predict whether adverse biological effects will occur as a result of exposure to chemicals in sediments. Rather, the appropriate use of different tools will provide the most useful information (Luoma and Carter 1993; Chapman 1995). The use of ISQGs to the exclusion of other supporting information can lead to erroneous conclusions or predictions about sediment quality. Decisions are more defensible if they are administered in a manner that acknowledges scientific uncertainties and allows for management modifications as scientific knowledge improves (Luoma and Carter 1993). In the framework discussed above, Canadian ISQGs and PELs provide nationally consistent benchmarks with which to evaluate the ecological significance of concentrations of sediment-associated chemicals and determine the relative priority of sediment quality concerns. Canadian ISQGs should be used along with all other relevant information in making practical and informed decisions regarding sediment quality. These considerations are equally important whether the focus is to maintain, protect, or improve sediment quality conditions at a particular site in Canada.

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Reference listing:

Canadian Council of Ministers of the Environment. 2001. Canadian sediment quality guidelines for the protection of aquatic life: Introduction. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

For further scientific information, contact:

Environment Canada
Guidelines and Standards Division
351 St. Joseph Blvd.
Hull, QC K1A 0H3
Phone: (819) 953-1550
Facsimile: (819) 953-0461
E-mail: ceqg-rcqe@ec.gc.ca
Internet: http://www.ec.gc.ca

For additional copies, contact:

CCME Documents
c/o Manitoba Statutory Publications
200 Vaughan St.
Winnipeg, MB R3C 1T5
Phone: (204) 945-4664
Facsimile: (204) 945-7172
E-mail: spccme@chc.gov.mb.ca

Excerpt from Publication No. 1299; ISBN 1-896997-34-1

Aussi disponible en français.

Canadian Council
of Ministers
of the Environment
CCME

Le Conseil canadien
des ministres
de l'environnement

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	**Chemical groups**	ISQG	PEL		ISQG	PEL	
2-Methylnaphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	20.2	201	1998	20.2	201	1998
Acenaphthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	6.71	88.9	1998	6.71	88.9	1998
Acenaphthylene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	5.87	128	1998	5.87	128	1998

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	**Chemical groups**	ISQG	PEL		ISQG	PEL	
Anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	46.9	245	1998	46.9	245	1998
Aroclor 1254 PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	60	340	2001	63.3	709	2001
Arsenic CASRN none	Inorganic	5900	17 000	1998	7240	41 600	1998
Benz(a)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	31.7	385	1998	74.8	693	1998

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
Benzo(a)pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	31.9	782	1998	88.8	763	1998
Beryllium	Inorganic	No data	No data	2015-02-23	No data	No data	2015-02-23
Cadmium CASRN 7440439	Inorganic	600	3500	1997	700	4200	1997
Chlordane	Organic Pesticides Organochlorine compounds	4.5	8.87	1998	2.26	4.79	1998
Chromium (total) CASRN 7440-47-3	Inorganic	37 300	90 000	1998	52 300	160 000	1998
Chrysene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	57.1	862	1998	108	846	1998

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
Copper	Inorganic	35 700	197 000	1998	18 700	108 000	1998
Dibenz(a,h)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	6.22	135	1998	6.22	135	1998
Dichloro diphenyl dichloroethane, 2,2-Bis (p-chlorophenyl)-1,1-dichloroethane DDD	Organic Pesticides Organochlorine compounds	3.54	8.51	1998	1.22	7.81	1998
Dichloro diphenyl ethylene, 1,1-Dichloro-2,2-bis(p-chlorophenyl)-ethene DDE	Organic Pesticides Organochlorine compounds	1.42	6.75	1998	2.07	374	1998
Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane DDT (total)	Organic Pesticides Organochlorine compounds	1.19	4.77	1998	1.19	4.77	1998
Dieldrin	Organic Pesticides Organochlorine compounds	2.85	6.67	1998	0.71	4.3	1998

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
Endrin	Organic Pesticides Organochlorine compounds	2.67	62.4	1998	2.67	62.4	1998

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
Fluoranthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	111	2355	1998	113	1494	1998
Fluorene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	21.2	144	1998	21.2	144	1998

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
Heptachlor Heptachlor epoxide	Organic Pesticides Organochlorine compounds	0.6	2.74	1998	0.6	2.74	1998
Hexachlorocyclohexane Lindane	Organic Pesticides Organochlorine compounds	0.94	1.38	1998	0.32	0.99	1998
Lead	Inorganic	35 000	91 300	1998	30 200	112 000	1998
Mercury CASRN 7439976	Inorganic	170	486	1997	130	700	1997
Naphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	34.6	391	1998	34.6	391	1998

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	**Chemical groups**	ISQG	PEL		ISQG	PEL	
Nonylphenol and its ethoxylates CASRN 84852153	Organic Nonylphenol and its ethoxylates	1400	*No data*	2002	1000	*No data*	2002
Phenanthrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	41.9	515	1998	86.7	544	1998
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	34.1	277	2001	21.5	189	2001
Polychlorinated dibenzo-p-dioxins/dibenzo furans PCDDs, PCDFs	Organic Polyaromatic compounds Polychlorinated dioxins and furans	0.85 ng TEQ/kg dry weight	21.5 ng TEQ/kg dry weight	2001	0.85 ng TEQ/kg dry weight	21.5 ng TEQ/kg dry weight	2001
Pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	53	875	1998	153	1398	1998

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	**Chemical groups**	ISQG	PEL		ISQG	PEL	
		Concentration	Concentration	Date	Concentration	Concentration	Date
Chemical name	**Chemical groups**	ISQG	PEL		ISQG	PEL	
Sodium adsorption ratio SAR		*No data*	*No data*	*No data*	*No data*	*No data*	*No data*
		Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date	Concentration (µg/kg dry weight)	Concentration (µg/kg dry weight)	Date
Chemical name	**Chemical groups**	ISQG	PEL		ISQG	PEL	
Toxaphene	Organic Pesticides Organochlorine compounds	0.1	No PEL derived	2002	0.1	No PEL derived	2002
Zinc	Inorganic	123 000	315 000	1998	124 000	271 000	1998

Chemical name	Chemical groups

Chemical name	Chemical groups
Sodium adsorption ratio SAR	

APPENDIX C
Laboratory Analytical Report

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

SLR CONSULTING (CANADA) LTD.
ATTN: John Wiens
6 - 40 Cadillac Avenue
Victoria BC V8Z 1T2

Date Received: 17-JAN-15
Report Date: 27-JAN-15 10:44 (MT)
Version: FINAL

Client Phone: 250-475-9595

Certificate of Analysis

Lab Work Order #: **L1568180**
Project P.O. #: NOT SUBMITTED
Job Reference: 205.03696.00000
C of C Numbers: 10-192650, 10-192652
Legal Site Desc:

Comments: Please note that the pH ratio was changed to 1:4 for samples L1568180-12,18.

Erin Bolster, B.Sc.
Account Manager

ADDRESS: 8081 Lougheed Hwy, Suite 100, Burnaby, BC V5A 1W9 Canada | Phone: +1 604 253 4188 | Fax: +1 604 253 6700
ALS CANADA LTD Part of the ALS Group A Campbell Brothers Limited Company

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID **Description** **Sampled Date** **Sampled Time** **Client ID**	L1568180-1 SEDIMENT 15-JAN-15 1G	L1568180-3 SEDIMENT 15-JAN-15 2C-B	L1568180-5 SEDIMENT 15-JAN-15 3C-C	L1568180-7 SEDIMENT 15-JAN-15 4C-C	L1568180-9 SEDIMENT 15-JAN-15 4C-A
Grouping	**Analyte**					
SOIL						
Physical Tests	Grain Size Curve					
	Moisture (%)				48.8	39.5
	pH (1:2 soil:water) (pH)	6.44	6.53	7.07	6.76	7.16
Organic / Inorganic Carbon	Total Organic Carbon (%)					
Metals	Antimony (Sb) (mg/kg)	1.19	0.29	0.47	0.58	0.40
	Arsenic (As) (mg/kg)	5.18	4.85	7.32	4.55	11.2
	Barium (Ba) (mg/kg)	105	105	59.7	86.6	79.4
	Beryllium (Be) (mg/kg)	0.45	0.33	0.29	0.33	0.33
	Cadmium (Cd) (mg/kg)	22.1	19.8	26.0	17.3	0.448
	Chromium (Cr) (mg/kg)	146	90.6	144	130	31.2
	Cobalt (Co) (mg/kg)	14.1	12.0	9.43	11.1	11.4
	Copper (Cu) (mg/kg)	75.9	31.3	22.5	37.3	30.5
	Lead (Pb) (mg/kg)	53.9	16.5	13.9	25.3	16.1
	Mercury (Hg) (mg/kg)	0.100	<0.050	<0.050	0.056	<0.050
	Molybdenum (Mo) (mg/kg)	1.78	1.16	0.40	0.91	0.57
	Nickel (Ni) (mg/kg)	33.3	19.9	18.5	22.7	23.4
	Selenium (Se) (mg/kg)	0.67	0.55	<0.20	0.43	0.27
	Silver (Ag) (mg/kg)	0.25	<0.10	0.11	0.10	0.13
	Thallium (Tl) (mg/kg)	0.085	0.064	0.097	0.065	0.053
	Tin (Sn) (mg/kg)	2.2	<2.0	<2.0	<2.0	<2.0
	Uranium (U) (mg/kg)	1.09	0.822	0.534	0.810	0.648
	Vanadium (V) (mg/kg)	76.4	56.0	50.1	55.2	65.9
	Zinc (Zn) (mg/kg)	519	181	90.7	218	97.5
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)				<0.050	<0.050
	Acenaphthylene (mg/kg)				<0.050	<0.050
	Anthracene (mg/kg)				<0.050	<0.050
	Benz(a)anthracene (mg/kg)				<0.050	0.051
	Benzo(a)pyrene (mg/kg)				0.051	0.064
	Benzo(b)fluoranthene (mg/kg)				0.106	0.117
	Benzo(g,h,i)perylene (mg/kg)				<0.050	0.051
	Benzo(k)fluoranthene (mg/kg)				<0.050	<0.050
	Chrysene (mg/kg)				0.075	0.087
	Dibenz(a,h)anthracene (mg/kg)				<0.050	<0.050
	Fluoranthene (mg/kg)				0.133	0.106
	Fluorene (mg/kg)				<0.050	<0.050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

	Sample ID	L1568180-10	L1568180-12	L1568180-13	L1568180-15	L1568180-16
	Description	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
	Sampled Date	15-JAN-15	15-JAN-15	15-JAN-15	15-JAN-15	15-JAN-15
	Sampled Time					
	Client ID	5C-C	6C-C	6C-B	7C-C	7C-A
Grouping	**Analyte**					
SOIL						
Physical Tests	Grain Size Curve			SEE ATTACHED		
	Moisture (%)			63.3		
	pH (1:2 soil:water) (pH)	6.47	6.49	6.63	6.17	7.21
Organic / Inorganic Carbon	Total Organic Carbon (%)			5.33		
Metals	Antimony (Sb) (mg/kg)	1.30	1.21	0.61	0.76	0.39
	Arsenic (As) (mg/kg)	5.11	4.71	5.35	4.51	6.17
	Barium (Ba) (mg/kg)	123	118	126	119	105
	Beryllium (Be) (mg/kg)	0.49	0.56	0.50	0.52	0.38
	Cadmium (Cd) (mg/kg)	24.7	21.4	42.1	35.3	14.1
	Chromium (Cr) (mg/kg)	134	119	153	153	141
	Cobalt (Co) (mg/kg)	15.6	14.8	13.4	14.0	10.6
	Copper (Cu) (mg/kg)	99.8	93.9	64.1	74.6	34.7
	Lead (Pb) (mg/kg)	63.4	60.7	58.6	64.6	19.7
	Mercury (Hg) (mg/kg)	0.128	0.129	0.098	0.112	0.055
	Molybdenum (Mo) (mg/kg)	2.05	1.98	1.49	1.30	0.70
	Nickel (Ni) (mg/kg)	38.5	38.2	34.1	36.0	23.9
	Selenium (Se) (mg/kg)	0.82	0.79	0.51	0.61	0.40
	Silver (Ag) (mg/kg)	0.34	0.32	0.25	0.33	<0.10
	Thallium (Tl) (mg/kg)	0.102	0.106	0.089	0.103	0.071
	Tin (Sn) (mg/kg)	<2.0	<2.0	2.2	3.0	<2.0
	Uranium (U) (mg/kg)	1.17	1.12	1.02	0.961	0.972
	Vanadium (V) (mg/kg)	77.7	78.5	81.8	76.3	62.2
	Zinc (Zn) (mg/kg)	700	639	347	480	146
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)			<0.050		
	Acenaphthylene (mg/kg)			<0.050		
	Anthracene (mg/kg)			<0.050		
	Benz(a)anthracene (mg/kg)			0.252		
	Benzo(a)pyrene (mg/kg)			0.440		
	Benzo(b)fluoranthene (mg/kg)			0.832		
	Benzo(g,h,i)perylene (mg/kg)			0.355		
	Benzo(k)fluoranthene (mg/kg)			0.264		
	Chrysene (mg/kg)			0.507		
	Dibenz(a,h)anthracene (mg/kg)			0.056		
	Fluoranthene (mg/kg)			0.806		
	Fluorene (mg/kg)			<0.050		

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

	Sample ID	L1568180-18				
	Description	SEDIMENT				
	Sampled Date	15-JAN-15				
	Sampled Time					
	Client ID	8C-C				
Grouping	**Analyte**					
SOIL						
Physical Tests	Grain Size Curve					
	Moisture (%)					
	pH (1:2 soil:water) (pH)	6.41				
Organic / Inorganic Carbon	Total Organic Carbon (%)					
Metals	Antimony (Sb) (mg/kg)	1.25				
	Arsenic (As) (mg/kg)	5.53				
	Barium (Ba) (mg/kg)	133				
	Beryllium (Be) (mg/kg)	0.51				
	Cadmium (Cd) (mg/kg)	19.7				
	Chromium (Cr) (mg/kg)	111				
	Cobalt (Co) (mg/kg)	15.2				
	Copper (Cu) (mg/kg)	88.4				
	Lead (Pb) (mg/kg)	68.2				
	Mercury (Hg) (mg/kg)	0.124				
	Molybdenum (Mo) (mg/kg)	1.94				
	Nickel (Ni) (mg/kg)	37.3				
	Selenium (Se) (mg/kg)	0.69				
	Silver (Ag) (mg/kg)	0.35				
	Thallium (Tl) (mg/kg)	0.097				
	Tin (Sn) (mg/kg)	7.3				
	Uranium (U) (mg/kg)	1.34				
	Vanadium (V) (mg/kg)	80.3				
	Zinc (Zn) (mg/kg)	603				
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)					
	Acenaphthylene (mg/kg)					
	Anthracene (mg/kg)					
	Benz(a)anthracene (mg/kg)					
	Benzo(a)pyrene (mg/kg)					
	Benzo(b)fluoranthene (mg/kg)					
	Benzo(g,h,i)perylene (mg/kg)					
	Benzo(k)fluoranthene (mg/kg)					
	Chrysene (mg/kg)					
	Dibenz(a,h)anthracene (mg/kg)					
	Fluoranthene (mg/kg)					
	Fluorene (mg/kg)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1568180-1	L1568180-3	L1568180-5	L1568180-7	L1568180-9
	Description	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
	Sampled Date	15-JAN-15	15-JAN-15	15-JAN-15	15-JAN-15	15-JAN-15
	Sampled Time					
	Client ID	1G	2C-B	3C-C	4C-C	4C-A
Grouping	**Analyte**					
SOIL						
Polycyclic Aromatic Hydrocarbons	Indeno(1,2,3-c,d)pyrene (mg/kg)				0.052	0.053
	2-Methylnaphthalene (mg/kg)				<0.050	<0.050
	Naphthalene (mg/kg)				<0.050	<0.050
	Phenanthrene (mg/kg)				0.099	0.067
	Pyrene (mg/kg)				0.116	0.101
	Surrogate: Acenaphthene d10 (%)				92.7	95.0
	Surrogate: Chrysene d12 (%)				107.5	111.7
	Surrogate: Naphthalene d8 (%)				85.2	88.9
	Surrogate: Phenanthrene d10 (%)				109.0	107.8

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID **Description** **Sampled Date** **Sampled Time** **Client ID**	L1568180-10 SEDIMENT 15-JAN-15 5C-C	L1568180-12 SEDIMENT 15-JAN-15 6C-C	L1568180-13 SEDIMENT 15-JAN-15 6C-B	L1568180-15 SEDIMENT 15-JAN-15 7C-C	L1568180-16 SEDIMENT 15-JAN-15 7C-A
Grouping	**Analyte**					
SOIL						
Polycyclic Aromatic Hydrocarbons	Indeno(1,2,3-c,d)pyrene (mg/kg)			0.398		
	2-Methylnaphthalene (mg/kg)			<0.050		
	Naphthalene (mg/kg)			<0.050		
	Phenanthrene (mg/kg)			0.352		
	Pyrene (mg/kg)			0.728		
	Surrogate: Acenaphthene d10 (%)			92.8		
	Surrogate: Chrysene d12 (%)			105.4		
	Surrogate: Naphthalene d8 (%)			85.0		
	Surrogate: Phenanthrene d10 (%)			103.7		

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1568180-18				
	Description	SEDIMENT				
	Sampled Date	15-JAN-15				
	Sampled Time					
	Client ID	8C-C				
Grouping	**Analyte**					
SOIL						
Polycyclic Aromatic Hydrocarbons	Indeno(1,2,3-c,d)pyrene (mg/kg)					
	2-Methylnaphthalene (mg/kg)					
	Naphthalene (mg/kg)					
	Phenanthrene (mg/kg)					
	Pyrene (mg/kg)					
	Surrogate: Acenaphthene d10 (%)					
	Surrogate: Chrysene d12 (%)					
	Surrogate: Naphthalene d8 (%)					
	Surrogate: Phenanthrene d10 (%)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Chromium (Cr)	DUP-H	L1568180-18

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DUP-H	Duplicate results outside ALS DQO, due to sample heterogeneity.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
C-TOT-ORG-LECO-SK	Soil	Organic Carbon by combustion method	SSSA (1996) p. 973

Total Organic Carbon (C-TOT-ORG-LECO-SK, C-TOT-ORG-SK)

Total C and inorganic C are determined on separate samples. The total C is determined by combustion and thermal conductivity detection, while inorganic C is determined by weight lass after addition of hydrochloric acid. Organic C is calculated by the difference between these two determinations.

Reference for Total C:
Nelson, D.W. and Sommers, L.E. 1996. Total Carbon, organic carbon and organic matter. P. 961-1010 In: J.M. Bartels et al. (ed.) Methods of soil analysis: Part 3 Chemical methods. (3rd ed.) ASA and SSSA, Madison, WI. Book series no. 5

Reference for Inorganic C:
Loeppert, R.H. and Suarez, D.L. 1996. Gravimetric Method for Loss of Carbon Dioxide. P. 455-456 In: J.M. Bartels et al. (ed.) Methods of soil analysis: Part 3 Chemical methods. (3rd ed.) ASA and SSSA, Madison, WI. Book series no. 5

GRAIN SIZE-SK	Soil	Grain Size Analysis	SSIR-51 METHOD 3.2.1

Particle size distribution is determined by a combination of techniques. Dry sieving is performed for coarse particles, wet sieving for sand particles and the pipette sedimentation method for clay particles.

Reference:

Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.

HG-200.2-CVAF-VA	Soil	Mercury in Soil by CVAFS	EPA 200.2/1631E (mod)

Soil samples are digested with nitric and hydrochloric acids, followed by analysis by CVAFS.

MET-200.2-CCMS-VA	Soil	Metals in Soil by CRC ICPMS	EPA 200.2/6020A (mod)

Soil samples are digested with nitric and hydrochloric acids, followed by analysis by CRC ICPMS.

Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may be environmentally available. This method does not dissolve all silicate materials and may result in a partial extraction. depending on the sample matrix, for some metals, including, but not limited to Al, Ba, Be, Cr, Sr, Ti, Tl, and V.

MOISTURE-VA	Soil	Moisture content	ASTM D2974-00 Method A

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

PAH-TMB-H/A-MS-VA	Soil	PAH - Rotary Extraction (Hexane/Acetone)	EPA 3570/8270

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, Methods 3570 & 8270, published by the United States Environmental Protection Agency (EPA). The procedure uses a mechanical shaking technique to extract a subsample of the sediment/soil with a 1:1 mixture of hexane and acetone. The extract is then solvent exchanged to toluene. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection (GC/MS). Surrogate recoveries may not be reported in cases where interferences from the sample matrix prevent accurate quantitation. Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

PH-1:2-VA	Soil	pH in Soil (1:2 Soil:Water Extraction)	BC WLAP METHOD: PH, ELECTROMETRIC, SOIL

This analysis is carried out in accordance with procedures described in the pH, Electrometric in Soil and Sediment method - Section B Physical/Inorganic and Misc. Constituents, BC Environmental Laboratory Manual 2007. The procedure involves mixing the dried (at <60°C) and sieved (No. 10 / 2mm) sample with deionized/distilled water at a 1:2 ratio of sediment to water. The pH of the solution is then measured using a standard pH probe.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Reference Information

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

10-192650 10-192652

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L1568180 Report Date: 27-JAN-15

Client: SLR CONSULTING (CANADA) LTD.
6 - 40 Cadillac Avenue
Victoria BC V8Z 1T2
Contact: John Wiens

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
C-TOT-ORG-LECO-SK	**Soil**							
Batch R3137083								
WG2029212-2	**IRM**	**08-109_SOIL**						
Total Organic Carbon			0.98		%		0.77-1.43	22-JAN-15
WG2029212-3	**MB**							
Total Organic Carbon			<0.10		%		0.1	22-JAN-15
HG-200.2-CVAF-VA	**Soil**							
Batch R3138207								
WG2030529-4	**CRM**	**VA-NRC-STSD1**						
Mercury (Hg)			104.0		%		70-130	24-JAN-15
WG2030529-5	**CRM**	**VA-CANMET-TILL1**						
Mercury (Hg)			102.6		%		70-130	24-JAN-15
WG2030529-3	**LCS**							
Mercury (Hg)			98.2		%		70-130	24-JAN-15
WG2030529-1	**MB**							
Mercury (Hg)			<0.0050		mg/kg		0.005	24-JAN-15
Batch R3138336								
WG2030545-4	**CRM**	**VA-NRC-STSD1**						
Mercury (Hg)			102.3		%		70-130	25-JAN-15
WG2030545-5	**CRM**	**VA-CANMET-TILL1**						
Mercury (Hg)			101.1		%		70-130	25-JAN-15
WG2030545-3	**LCS**							
Mercury (Hg)			96.2		%		70-130	25-JAN-15
WG2030545-1	**MB**							
Mercury (Hg)			<0.0050		mg/kg		0.005	25-JAN-15
MET-200.2-CCMS-VA	**Soil**							
Batch R3138038								
WG2030529-4	**CRM**	**VA-NRC-STSD1**						
Antimony (Sb)			99.0		%		70-130	23-JAN-15
Arsenic (As)			99.9		%		70-130	23-JAN-15
Barium (Ba)			93.0		%		70-130	23-JAN-15
Beryllium (Be)			103.0		%		70-130	23-JAN-15
Cadmium (Cd)			101.0		%		70-130	23-JAN-15
Chromium (Cr)			101.1		%		70-130	23-JAN-15
Cobalt (Co)			99.3		%		70-130	23-JAN-15
Copper (Cu)			99.4		%		70-130	23-JAN-15
Lead (Pb)			101.9		%		70-130	23-JAN-15
Molybdenum (Mo)			97.1		%		70-130	23-JAN-15
Nickel (Ni)			99.1		%		70-130	23-JAN-15

Quality Control Report

Workorder: L1568180 Report Date: 27-JAN-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-VA	**Soil**							
Batch R3138038								
WG2030529-4 CRM		**VA-NRC-STSD1**						
Selenium (Se)			96.2		%		70-130	23-JAN-15
Silver (Ag)			94.6		%		70-130	23-JAN-15
Thallium (Tl)			107.9		%		70-130	23-JAN-15
Tin (Sn)			95.4		%		70-130	23-JAN-15
Vanadium (V)			102.2		%		70-130	23-JAN-15
Zinc (Zn)			98.5		%		70-130	23-JAN-15
WG2030529-5 CRM		**VA-CANMET-TILL1**						
Antimony (Sb)			102.0		%		70-130	23-JAN-15
Arsenic (As)			106.8		%		70-130	23-JAN-15
Barium (Ba)			101.6		%		70-130	23-JAN-15
Beryllium (Be)			0.52		mg/kg		0.34-0.74	23-JAN-15
Cadmium (Cd)			102.0		%		70-130	23-JAN-15
Chromium (Cr)			110.7		%		70-130	23-JAN-15
Cobalt (Co)			105.4		%		70-130	23-JAN-15
Copper (Cu)			100.9		%		70-130	23-JAN-15
Lead (Pb)			95.3		%		70-130	23-JAN-15
Molybdenum (Mo)			0.70		mg/kg		0.24-1.24	23-JAN-15
Nickel (Ni)			105.2		%		70-130	23-JAN-15
Selenium (Se)			0.30		mg/kg		0.12-0.52	23-JAN-15
Silver (Ag)			0.22		mg/kg		0.12-0.32	23-JAN-15
Thallium (Tl)			0.137		mg/kg		0.075-0.175	23-JAN-15
Tin (Sn)			1.1		mg/kg		0-3	23-JAN-15
Uranium (U)			111.4		%		70-130	23-JAN-15
Vanadium (V)			111.2		%		70-130	23-JAN-15
Zinc (Zn)			103.4		%		70-130	23-JAN-15
WG2030529-3 LCS								
Antimony (Sb)			98.2		%		70-130	23-JAN-15
Arsenic (As)			98.8		%		70-130	23-JAN-15
Barium (Ba)			94.9		%		70-130	23-JAN-15
Beryllium (Be)			96.0		%		70-130	23-JAN-15
Cadmium (Cd)			97.9		%		70-130	23-JAN-15
Chromium (Cr)			96.8		%		70-130	23-JAN-15
Cobalt (Co)			96.1		%		70-130	23-JAN-15
Copper (Cu)			94.6		%		70-130	23-JAN-15
Lead (Pb)			99.1		%		70-130	23-JAN-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-VA	**Soil**							
Batch R3138038								
WG2030529-3 LCS								
Molybdenum (Mo)			94.8		%		70-130	23-JAN-15
Nickel (Ni)			97.4		%		70-130	23-JAN-15
Selenium (Se)			100.1		%		70-130	23-JAN-15
Silver (Ag)			95.7		%		70-130	23-JAN-15
Thallium (Tl)			98.7		%		70-130	23-JAN-15
Tin (Sn)			97.1		%		70-130	23-JAN-15
Uranium (U)			100.1		%		70-130	23-JAN-15
Vanadium (V)			97.4		%		70-130	23-JAN-15
Zinc (Zn)			93.7		%		70-130	23-JAN-15
WG2030529-1 MB								
Antimony (Sb)			<0.10		mg/kg		0.1	23-JAN-15
Arsenic (As)			<0.10		mg/kg		0.1	23-JAN-15
Barium (Ba)			<0.50		mg/kg		0.5	23-JAN-15
Beryllium (Be)			<0.10		mg/kg		0.1	23-JAN-15
Cadmium (Cd)			<0.020		mg/kg		0.02	23-JAN-15
Chromium (Cr)			<0.50		mg/kg		0.5	23-JAN-15
Cobalt (Co)			<0.10		mg/kg		0.1	23-JAN-15
Copper (Cu)			<0.50		mg/kg		0.5	23-JAN-15
Lead (Pb)			<0.50		mg/kg		0.5	23-JAN-15
Molybdenum (Mo)			<0.10		mg/kg		0.1	23-JAN-15
Nickel (Ni)			<0.50		mg/kg		0.5	23-JAN-15
Selenium (Se)			<0.20		mg/kg		0.2	23-JAN-15
Silver (Ag)			<0.10		mg/kg		0.1	23-JAN-15
Thallium (Tl)			<0.050		mg/kg		0.05	23-JAN-15
Tin (Sn)			<2.0		mg/kg		2	23-JAN-15
Uranium (U)			<0.050		mg/kg		0.05	23-JAN-15
Vanadium (V)			<0.20		mg/kg		0.2	23-JAN-15
Zinc (Zn)			<2.0		mg/kg		2	23-JAN-15
Batch R3138770								
WG2030545-4 CRM		**VA-NRC-STSD1**						
Antimony (Sb)			102.3		%		70-130	25-JAN-15
Arsenic (As)			99.7		%		70-130	25-JAN-15
Barium (Ba)			98.3		%		70-130	25-JAN-15
Beryllium (Be)			102.8		%		70-130	25-JAN-15
Cadmium (Cd)			93.6		%		70-130	25-JAN-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-VA	**Soil**							
Batch R3138770								
WG2030545-4 CRM		**VA-NRC-STSD1**						
Chromium (Cr)			99.0		%		70-130	25-JAN-15
Cobalt (Co)			99.0		%		70-130	25-JAN-15
Copper (Cu)			98.0		%		70-130	25-JAN-15
Lead (Pb)			99.1		%		70-130	25-JAN-15
Molybdenum (Mo)			94.8		%		70-130	25-JAN-15
Nickel (Ni)			98.2		%		70-130	25-JAN-15
Selenium (Se)			99.0		%		70-130	25-JAN-15
Silver (Ag)			98.1		%		70-130	25-JAN-15
Thallium (Tl)			98.4		%		70-130	25-JAN-15
Tin (Sn)			98.6		%		70-130	25-JAN-15
Vanadium (V)			101.7		%		70-130	25-JAN-15
Zinc (Zn)			98.9		%		70-130	25-JAN-15
WG2030545-5 CRM		**VA-CANMET-TILL1**						
Antimony (Sb)			99.6		%		70-130	25-JAN-15
Arsenic (As)			102.2		%		70-130	25-JAN-15
Barium (Ba)			100.5		%		70-130	25-JAN-15
Beryllium (Be)			0.51		mg/kg		0.34-0.74	25-JAN-15
Cadmium (Cd)			93.3		%		70-130	25-JAN-15
Chromium (Cr)			98.0		%		70-130	25-JAN-15
Cobalt (Co)			97.4		%		70-130	25-JAN-15
Copper (Cu)			95.4		%		70-130	25-JAN-15
Lead (Pb)			87.4		%		70-130	25-JAN-15
Molybdenum (Mo)			0.64		mg/kg		0.24-1.24	25-JAN-15
Nickel (Ni)			99.3		%		70-130	25-JAN-15
Selenium (Se)			0.29		mg/kg		0.12-0.52	25-JAN-15
Silver (Ag)			0.23		mg/kg		0.12-0.32	25-JAN-15
Thallium (Tl)			0.111		mg/kg		0.075-0.175	25-JAN-15
Tin (Sn)			1.0		mg/kg		0-3	25-JAN-15
Uranium (U)			107.8		%		70-130	25-JAN-15
Vanadium (V)			98.9		%		70-130	25-JAN-15
Zinc (Zn)			95.4		%		70-130	25-JAN-15
WG2030545-1 MB								
Antimony (Sb)			<0.10		mg/kg		0.1	25-JAN-15
Arsenic (As)			<0.10		mg/kg		0.1	25-JAN-15
Barium (Ba)			<0.50		mg/kg		0.5	25-JAN-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-VA	**Soil**							
Batch R3138770								
WG2030545-1 MB								
Beryllium (Be)			<0.10		mg/kg		0.1	25-JAN-15
Cadmium (Cd)			<0.020		mg/kg		0.02	25-JAN-15
Chromium (Cr)			<0.50		mg/kg		0.5	25-JAN-15
Cobalt (Co)			<0.10		mg/kg		0.1	25-JAN-15
Copper (Cu)			<0.50		mg/kg		0.5	25-JAN-15
Lead (Pb)			<0.50		mg/kg		0.5	25-JAN-15
Molybdenum (Mo)			<0.10		mg/kg		0.1	25-JAN-15
Nickel (Ni)			<0.50		mg/kg		0.5	25-JAN-15
Selenium (Se)			<0.20		mg/kg		0.2	25-JAN-15
Silver (Ag)			<0.10		mg/kg		0.1	25-JAN-15
Thallium (Tl)			<0.050		mg/kg		0.05	25-JAN-15
Tin (Sn)			<2.0		mg/kg		2	25-JAN-15
Uranium (U)			<0.050		mg/kg		0.05	25-JAN-15
Vanadium (V)			<0.20		mg/kg		0.2	25-JAN-15
Zinc (Zn)			<2.0		mg/kg		2	25-JAN-15
Batch R3138832								
WG2030545-3 LCS								
Antimony (Sb)			96.9		%		70-130	26-JAN-15
Arsenic (As)			100.1		%		70-130	26-JAN-15
Barium (Ba)			106.1		%		70-130	26-JAN-15
Beryllium (Be)			93.5		%		70-130	26-JAN-15
Cadmium (Cd)			97.7		%		70-130	26-JAN-15
Chromium (Cr)			95.1		%		70-130	26-JAN-15
Cobalt (Co)			99.2		%		70-130	26-JAN-15
Copper (Cu)			97.9		%		70-130	26-JAN-15
Lead (Pb)			97.0		%		70-130	26-JAN-15
Molybdenum (Mo)			94.1		%		70-130	26-JAN-15
Nickel (Ni)			99.1		%		70-130	26-JAN-15
Selenium (Se)			99.8		%		70-130	26-JAN-15
Silver (Ag)			102.2		%		70-130	26-JAN-15
Thallium (Tl)			90.0		%		70-130	26-JAN-15
Tin (Sn)			96.8		%		70-130	26-JAN-15
Uranium (U)			90.1		%		70-130	26-JAN-15
Vanadium (V)			100.8		%		70-130	26-JAN-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-VA	**Soil**							
Batch R3138832								
WG2030545-3 LCS								
Zinc (Zn)			91.2		%		70-130	26-JAN-15
MOISTURE-VA	**Soil**							
Batch R3137528								
WG2030532-2 LCS								
Moisture			100.0		%		90-110	22-JAN-15
WG2030532-1 MB								
Moisture			<0.25		%		0.25	22-JAN-15
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R3138053								
WG2030531-4 IRM		**ALS PAH1 RM**						
Acenaphthene			95.3		%		60-130	24-JAN-15
Acenaphthylene			100.3		%		60-130	24-JAN-15
Anthracene			98.4		%		60-130	24-JAN-15
Benz(a)anthracene			95.4		%		60-130	24-JAN-15
Benzo(a)pyrene			96.2		%		60-130	24-JAN-15
Benzo(b)fluoranthene			103.0		%		60-130	24-JAN-15
Benzo(g,h,i)perylene			108.4		%		60-130	24-JAN-15
Benzo(k)fluoranthene			103.2		%		60-130	24-JAN-15
Chrysene			107.9		%		60-130	24-JAN-15
Dibenz(a,h)anthracene			97.8		%		60-130	24-JAN-15
Fluoranthene			99.3		%		60-130	24-JAN-15
Fluorene			89.3		%		60-130	24-JAN-15
Indeno(1,2,3-c,d)pyrene			102.5		%		60-130	24-JAN-15
2-Methylnaphthalene			96.4		%		60-130	24-JAN-15
Naphthalene			94.2		%		50-130	24-JAN-15
Phenanthrene			103.5		%		60-130	24-JAN-15
Pyrene			98.4		%		60-130	24-JAN-15
WG2030531-1 MB								
Acenaphthene			<0.0050		mg/kg		0.005	24-JAN-15
Acenaphthylene			<0.0050		mg/kg		0.005	24-JAN-15
Anthracene			<0.0040		mg/kg		0.004	24-JAN-15
Benz(a)anthracene			<0.010		mg/kg		0.01	24-JAN-15
Benzo(a)pyrene			<0.010		mg/kg		0.01	24-JAN-15
Benzo(b)fluoranthene			<0.010		mg/kg		0.01	24-JAN-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R3138053								
WG2030531-1 MB								
Benzo(g,h,i)perylene			<0.010		mg/kg		0.01	24-JAN-15
Benzo(k)fluoranthene			<0.010		mg/kg		0.01	24-JAN-15
Chrysene			<0.010		mg/kg		0.01	24-JAN-15
Dibenz(a,h)anthracene			<0.0050		mg/kg		0.005	24-JAN-15
Fluoranthene			<0.010		mg/kg		0.01	24-JAN-15
Fluorene			<0.010		mg/kg		0.01	24-JAN-15
Indeno(1,2,3-c,d)pyrene			<0.010		mg/kg		0.01	24-JAN-15
2-Methylnaphthalene			<0.010		mg/kg		0.01	24-JAN-15
Naphthalene			<0.010		mg/kg		0.01	24-JAN-15
Phenanthrene			<0.010		mg/kg		0.01	24-JAN-15
Pyrene			<0.010		mg/kg		0.01	24-JAN-15
Surrogate: Naphthalene d8			94.7		%		50-130	24-JAN-15
Surrogate: Acenaphthene d10			94.3		%		60-130	24-JAN-15
Surrogate: Phenanthrene d10			96.5		%		60-130	24-JAN-15
Surrogate: Chrysene d12			93.3		%		60-130	24-JAN-15

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
DUP-H	Duplicate results outside ALS DQO, due to sample heterogeneity.
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

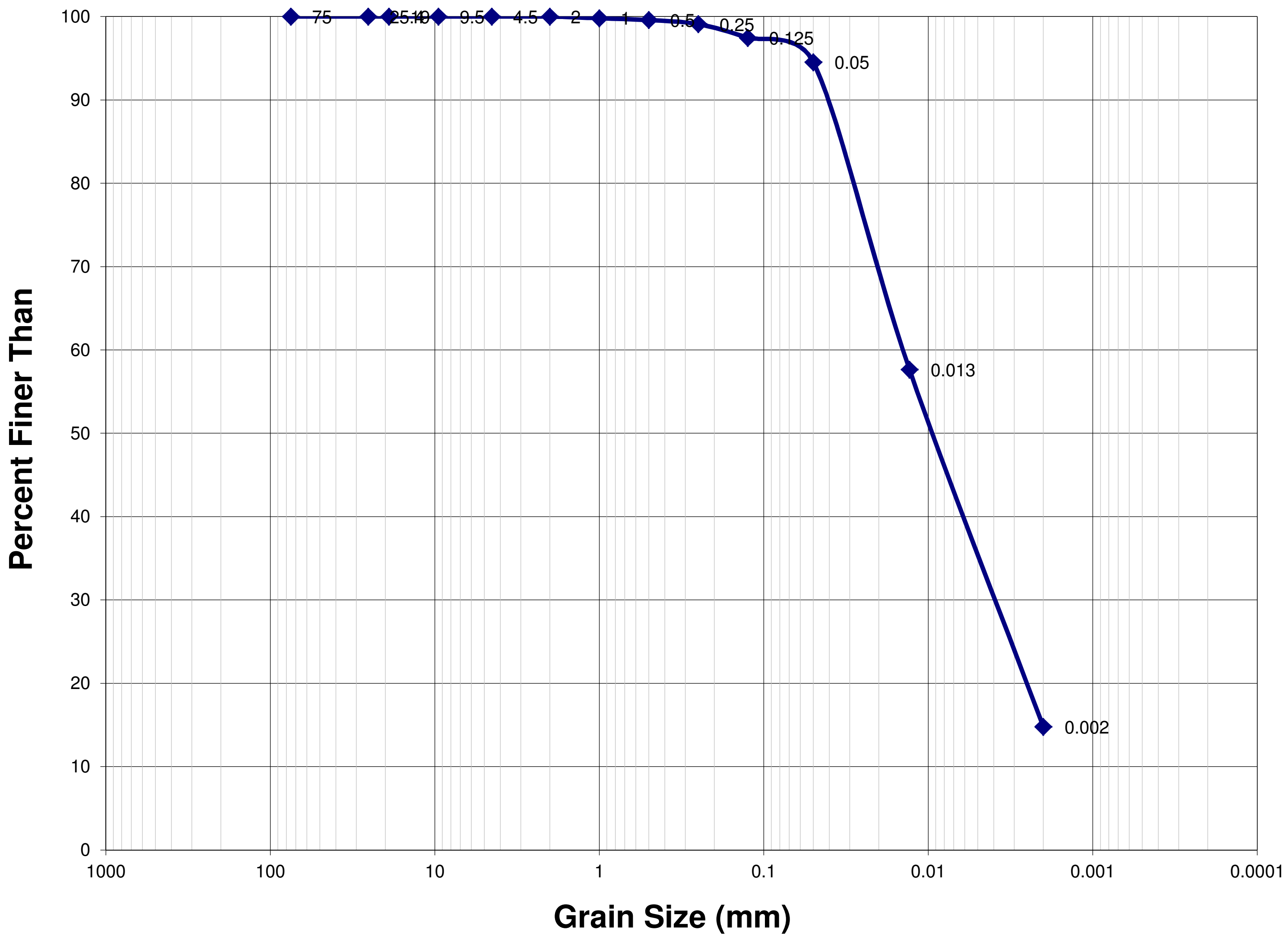
ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Client Name: SLR CONSULTING (CANAD
Project:
Sample ID: 6C-B
Lab ID: L1568180-13

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	0
Coarse Sand	2.0mm - 4.75mm	0
Medium Sand	0.425mm - 2.0mm	0
Fine Sand	0.075mm - 0.425mm	4
Fines	< 0.075mm	95

Canadian Soil Survey Committee (CSSC)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	0
Sand	0.05mm - 2mm	5
Silt	0.002mm - 0.05mm	80
Clay	< 0.002mm	15

Texture Silt loam

Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

10-192650

ALS Environmental

Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878
www.alsglobal.com

Page 1 of 2

Report To John Wiens
Company: SLR Consulting (Canada) Ltd
Contact: John Wiens
Address: 6-40 Cadillac Ave, Victoria, B.C. V8Z1T2, CANADA
Phone: 250-475-9595 Fax: 250-475-9596

Invoice To Same as Report ? (circle) [✓ Yes] or No (if No, provide details)
Copy of Invoice with Report? (circle) [✓ Yes] or No
Company:
Contact:
Address:
Phone:
Lab Work Ord

L1568180-COFC

Report Format / Distribution
Standard: X Other (specify):
Select: PDF X Excel X Digital Fax
Email 1: jwiens@slrconsulting.com
Email 2: bmckinnon@slrconsulting.com

Client / Project Information
Job #: 205.03696.00000
PO / AFE:
LSD:
Quote #:
ALS Contact: Erin Bolster **Sampler:** BAM

Service Request:(Rush subject to availability - Contact ALS to confirm TAT)
☒ Regular (Standard Turnaround Times - Business Days)
☐ Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
☐ Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
☐ Same Day or Weekend Emergency - Contact ALS to confirm TAT

Analysis Request
(Indicate Filtered or Preserved, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Metals	PAH	Total Organic Carbon (TOC)	Grain Size (GS)	HOLD								Number of Containers
	1G	15-Jan-15	—	Sediment	X												3
	2C-C		—						X								2
	2C-B		—		X												2
	2C-A		—						X								2
	3C-C		—		X												2
	3C-~~B~~A		—						X								2
	4C-C		—		X	X											1
	4C-B		—						X								2
	4C-A		—		X	X											2
	5C-C		—		X												2
	5C-A		—						X								2
	6C-C		—		X												2

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Ben McKinnon	Date: 16-01-15	Time: 1600	Received by:	Date: Jan 17	Time: 1155	Temperature: 4 °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

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10-192652

ALS Environmental

Chain of Custody / Analytical Request Form
Canada Toll Free: 1 800 668 9878
www.alsglobal.com

Page 2 of 2

Report To John wiens	**Report Format / Distribution**
Company: SLR Consulting (Canada) Ltd	Standard: X Other (specify):
Contact: John wiens	Select: PDF X Excel X Digital Fax
Address: 6-40 Cadillac Ave, Victoria, BC.	Email 1: jwiens@slrconsulting.com
V8Z 1T2, CANADA	Email 2: bmckinnon@slrconsulting.com
Phone: 250-475-9595 Fax: 250-475-9596	
Invoice To Same as Report ? (circle) [✓ Yes] or No (if No, provide details)	**Client / Project Information**
Copy of Invoice with Report? (circle) [✓ Yes] or No	Job #: 205.03696.00000
Company:	PO / AFE:
Contact:	LSD:
Address:	
Phone:	Quote #:
Lab Work Orde L1568180-COFC	**ALS Contact:** Erin Bokster **Sampler:** BAM

Service Request:(Rush subject to availability - Contact ALS to confirm TAT)

☒ Regular (Standard Turnaround Times - Business Days)
☐ Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
☐ Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
☐ Same Day or Weekend Emergency - Contact ALS to confirm TAT

Analysis Request

(Indicate Filtered or Preserved, F/P)

Sample #	**Sample Identification** (This description will appear on the report)	**Date** (dd-mmm-yy)	**Time** (hh:mm)	**Sample Type**	Metals	PAH	Total Organic Carbon (TOC)	Grain Size (GS)	Hold								Number of Containers
	6C-B	15-Jan-15	—	Sediment.	X	X	X	X									2
	6C-A		—						X								2
	7C-C		—		X												2
	7C-A		—		X												2
	8G		—						X								4
	8C-C		—		X												2
	8C-B		—						X								2

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Ben McKinnon	Date: 16-01-15	Time: 1600	Received by: Doren	Date: Jan17	Time: 1155	Temperature: 4° °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

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global environmental solutions

Calgary, AB
134-12143 40 Street SE
Calgary, AB T2Z 4E6
Canada
Tel: (403) 266-2030
Fax: (403) 263-7906

Calgary, AB
1140-10201 Southport Rd SW
Calgary, AB T2W 4X9
Canada
Tel: (403) 259-6600
Fax: (403) 259-6611

Edmonton, AB
6940 Roper Road
Edmonton, AB T6B 3H9
Canada
Tel: (780) 490-7893
Fax: (780) 490-7819

Fort St. John, BC
9943 100 Avenue
Fort St. John, BC V1J 1Y4
Canada
Tel: (250) 785-0969
Fax: (250) 785-0928

Grande Prairie, AB
10015 102 Street
Grande Prairie, AB T8V 2V5
Canada
Tel: (780) 513-6819
Fax: (780) 513-6821

Halifax, NS
115 Joseph Zatzman Drive
Dartmouth, NS B3B 1N3
Canada
Tel: (902) 420-0040
Fax: (902) 420-9703

Kamloops, BC
8 West St. Paul Street
Kamloops, BC V2C 1G1
Canada
Tel: (250) 374-8749
Fax: (250) 374-8656

Kelowna, BC
200-1475 Ellis Street
Kelowna, BC V1Y 2A3
Canada
Tel: (250) 762-7202
Fax: (250) 763-7303

Markham, ON
101-260 Town Centre Blvd
Markham, ON L3R 8H8
Canada
Tel: (905) 415-7248
Fax: (905) 415-1019

Nanaimo, BC
9-6421 Applecross Road
Nanaimo, BC V9V 1N1
Canada
Tel: (250) 390-5050
Fax: (250) 390-5042

Prince George, BC
1586 Ogilvie Street
Prince George, BC V2N 1W9
Canada
Tel: (250) 562-4452
Fax: (250) 562-4458

Regina, SK
1048 Winnipeg Street
Regina, SK S4R 8P8
Canada
Tel: (306) 525-4690
Fax   (306) 525-4691

Saskatoon, SK
620-3530 Millar Avenue
Saskatoon, SK S7P 0B6
Canada
Tel: (306) 374-6800
Fax: (306) 374-6077

Sydney, NS
PO Box 791, Station A
122-45 Wabana Court
Sydney, NS B1P 6J1
Canada
Tel: (902) 564-7911
Fax: (902) 564-7910

Vancouver, BC (Head Office)
200-1620 West 8 Avenue
Vancouver, BC V6J 1V4
Canada
Tel: (604) 738-2500
Fax: (604) 738-2508

Victoria, BC
6-40 Cadillac Avenue
Victoria, BC V8Z 1T2
Canada
Tel: (250) 475-9595
Fax: (250) 475-9596

Winnipeg, MB
Unit D, 1420 Clarence Avenue
Winnipeg, MB R3T 1T6
Canada
Tel: (204) 477-1848
Fax: (204) 475-1649

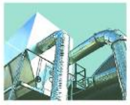
Whitehorse, YT
6131 6 Avenue
Whitehorse, YT Y1A 1N2
Canada
Tel: (867) 689-2021

Yellowknife, NT
Unit 44, 5022 49 Street
Yellowknife, NT X1A 3R8
Canada
Tel: (867) 765-5695


Energy


Waste Management


Planning & Development


Industry


Mining & Minerals


Infrastructure

APPENDIX F
R. Macdonald Presentation (2015)

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001

Figure 1 a. The location of Reay Creek and Reay Creek Pond on northern Saanich Peninsula

Figure 1 b. Reay Creek & Pond showing Core Locations

Figure 2. Plan view of Reay Creek Pond showing locations of Cores (2013), Original Dam (~1935) and transects and sampling points at which water and sediment depth were determined in 2010 (Robinson and Sarrazin, 2010).

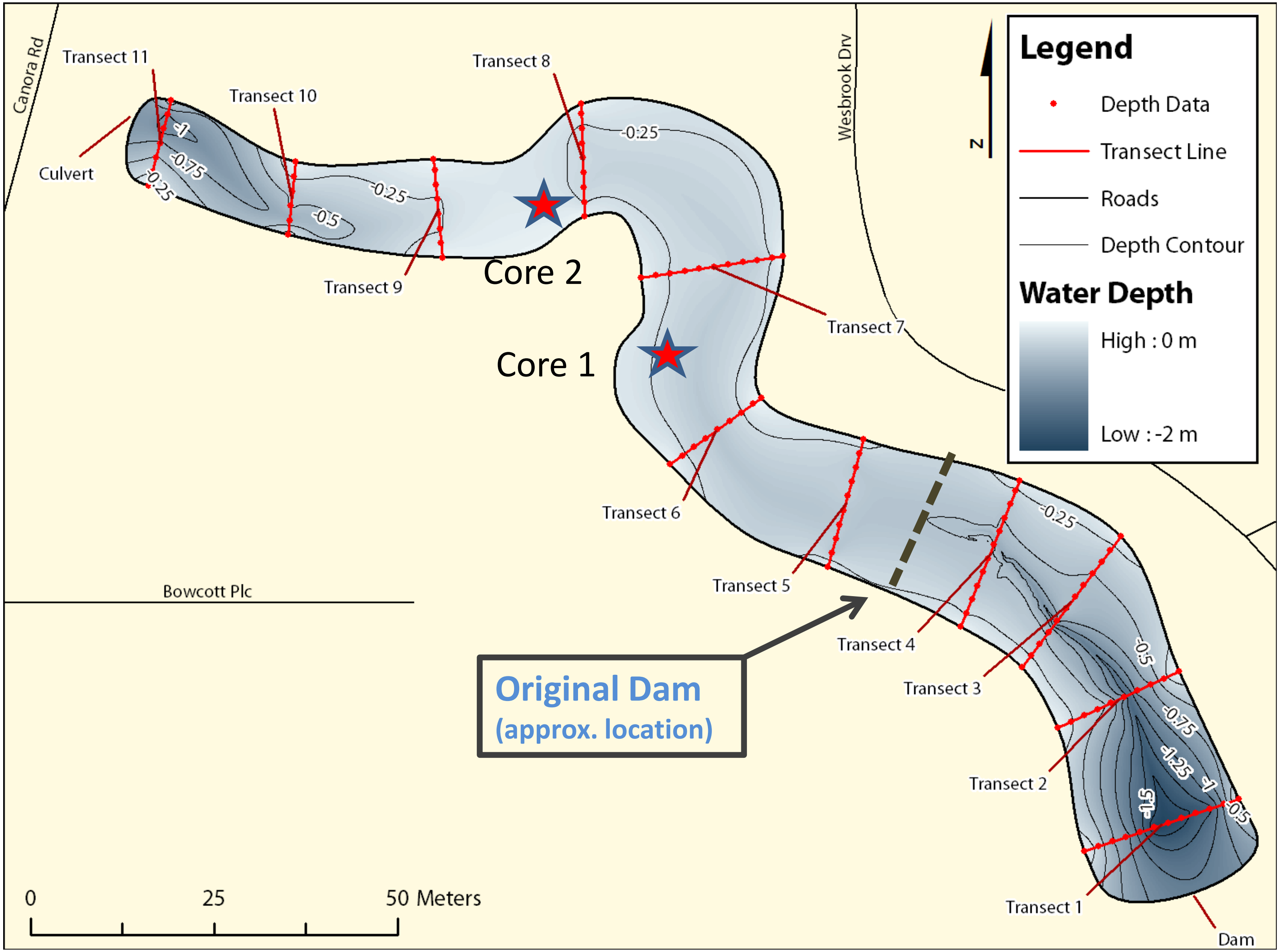


Figure 3. Histogram of sediment depths in Reay Creek Pond

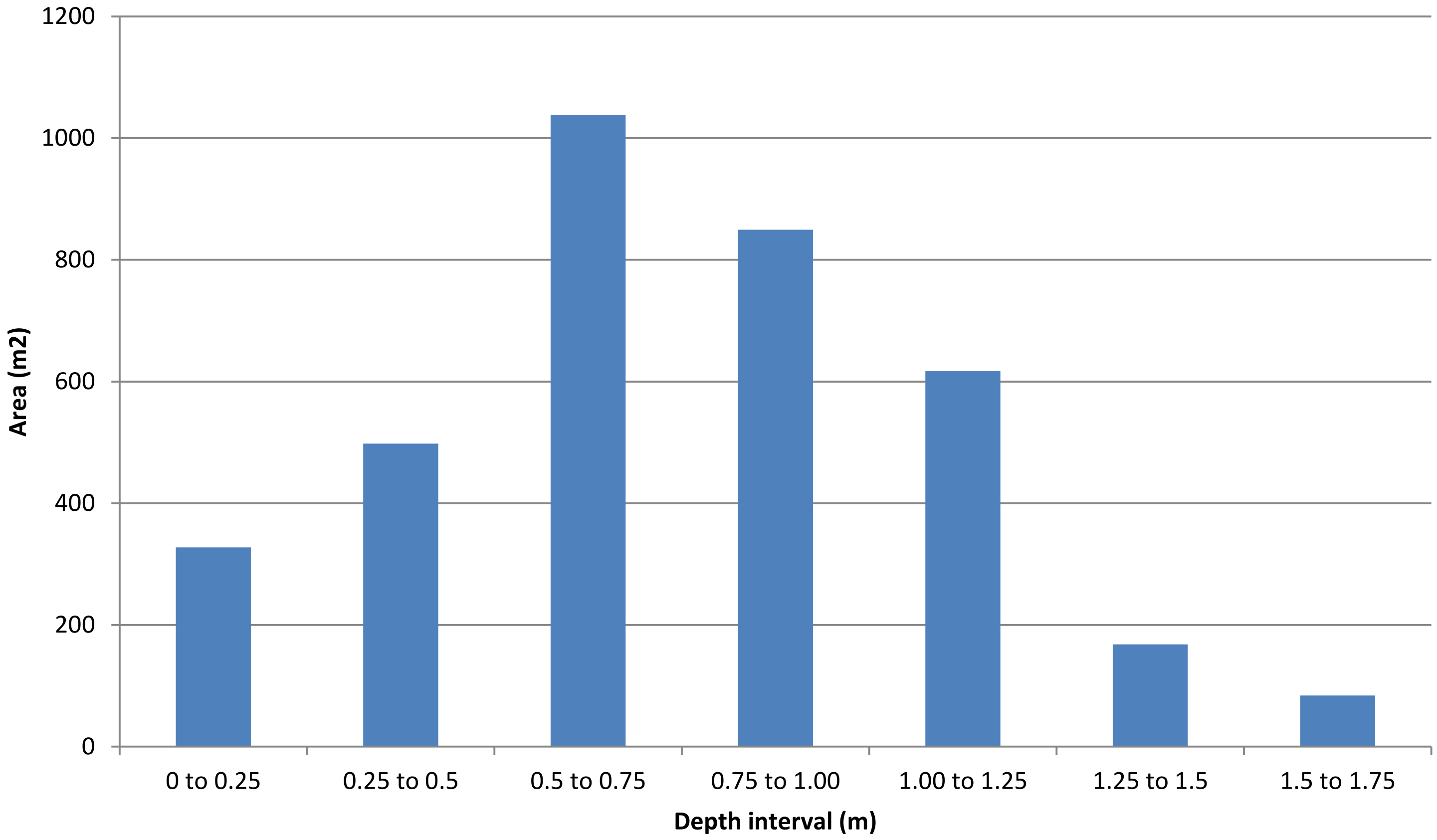


Table 2: Reay Pond area and sediment dimensions

Surface Area	3583 m^2
Total volume of accumulated sediment	3107 m^3
Total wet weight mass of sediments	4400 tonnes
Total dry weight mass of sediments	2144 tonnes
Mean depth of sediments	0.87 m

Sediment Dating

Dating based on ^{210}Pb, ^{137}Cs and physical examination of the core

Top ~24 cm was uniform mud. This layer appears to have been accumulating since about 1935-40, indicating a recent sedimentation rate of 0.117 g cm^{2} yr^{-1} (~0.33 cm yr^{-1})

Below this is a basement layer of mud that appears to have been physically disturbed and contains visible signs of development (i.e., coarse material, wood chips, etc.)

Accordingly, we have examined both layers for contaminants. For economy, we have done pooled analyses for expensive items like:

PCBs – classic contaminants phased out in the 70s – were used for heat transfer fluids, in paints, in electronic boards etc.

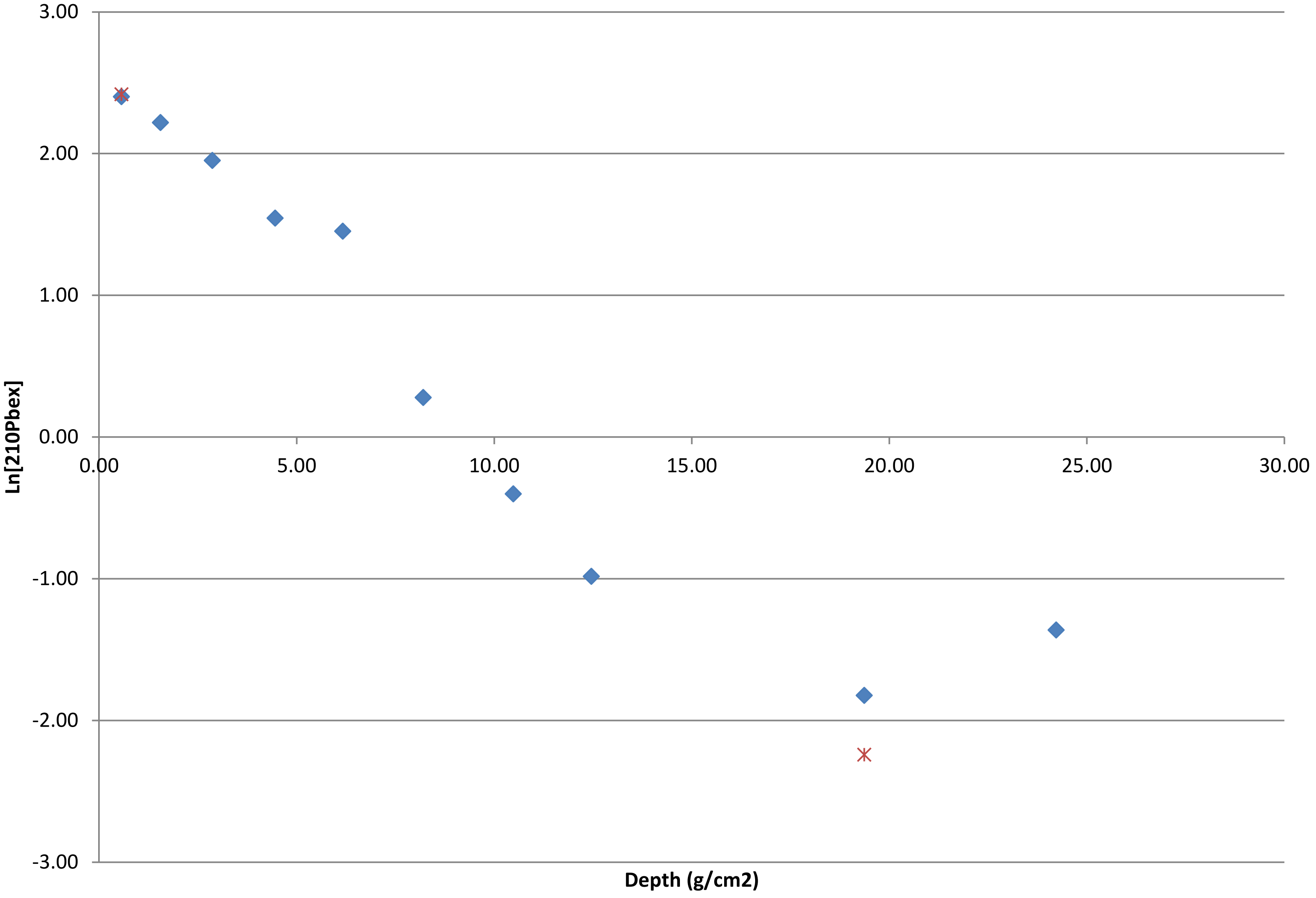
Pesticides – these include DDT, Chlordanes, Toxaphene, Lindane etc. Many of these have been phased out as early as in the 1960s.

PFOS – these perfluoro compounds have been used as textile protective coatings like Scotchguard

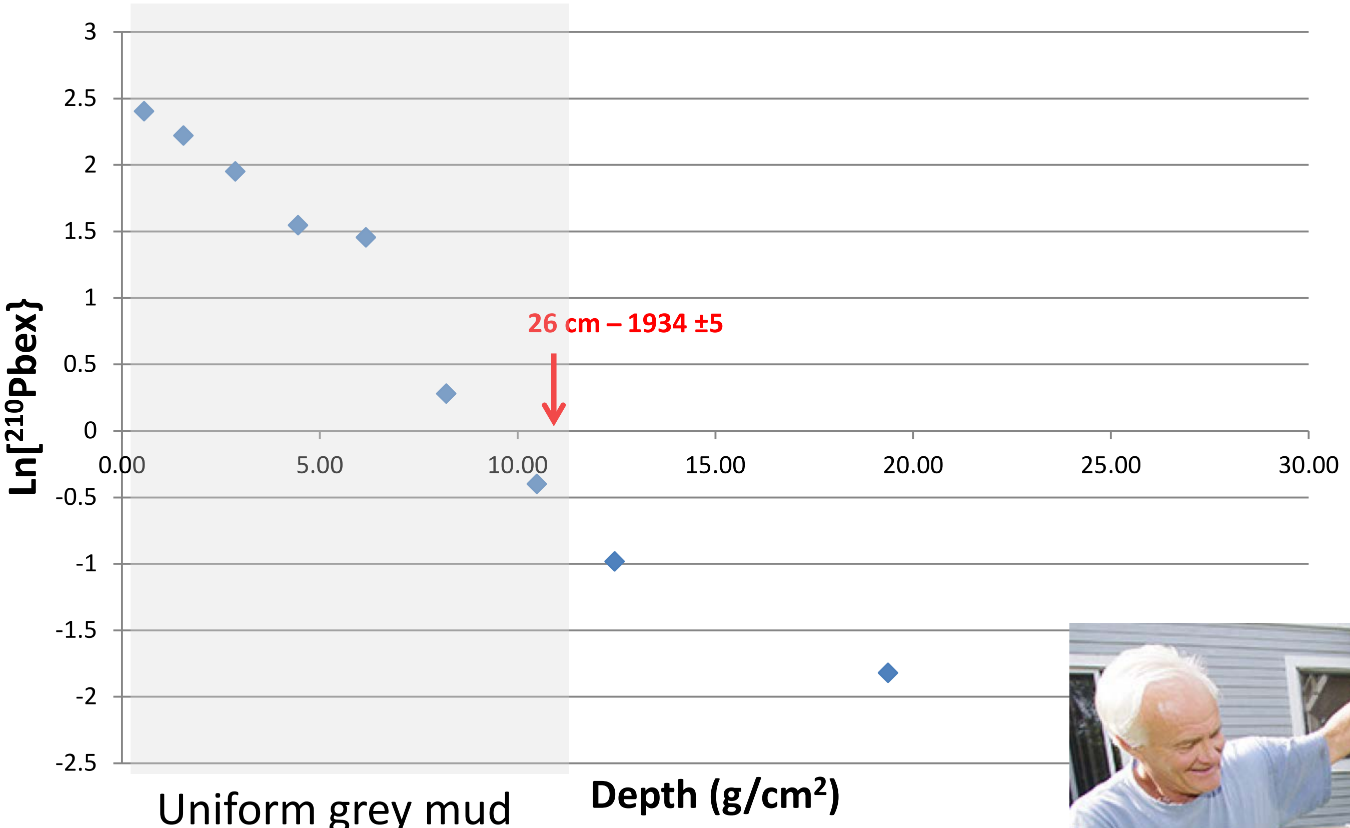
PBDE – polybrominated diphenyl ethers, or flame retardants, applied to textiles (rugs, curtains, cushions) and electronic circuit boards

PAHs – hydrocarbon ring compounds; products of combustion and contained naturally in oils, shales, soils. Parent compounds contain no methyl groups and have been the focus of screening tests for toxicity (EPA list, e.g.). Methylated PAHs also have toxicity associated.

Figure 4. A plot of Ln[$^{210}Pb_{ex}$] versus sediment depth for Core 1 . Also shown are the approximate dates associated with depth in the core.



^{210}Pb dating results



Sedimentation rate ~ 0.117 g cm^2 yr^{-1}

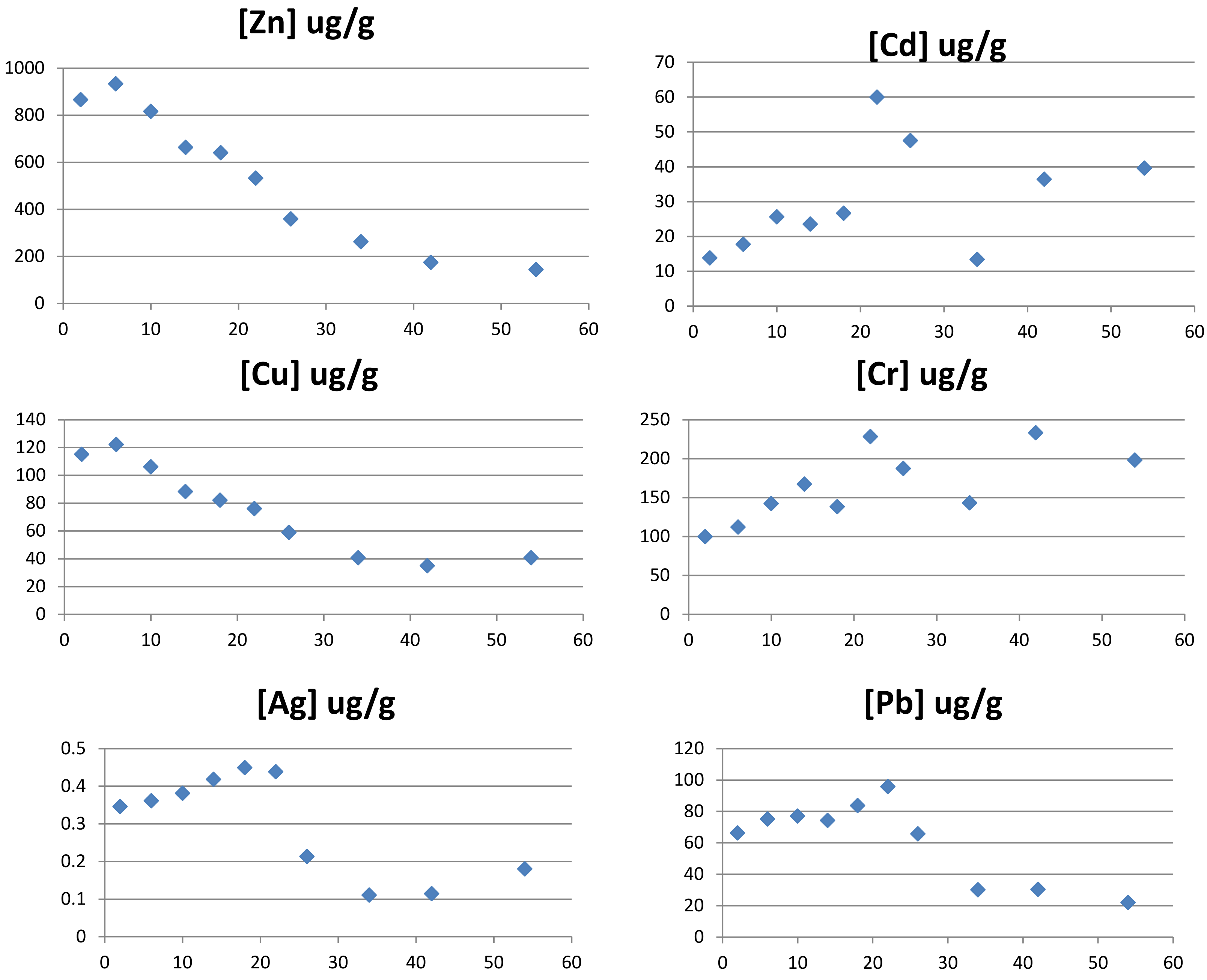
~0.33 cm yr^{-1}

Table 3a Metals data for Core 1 (all units in μg/g)

Element			Reay Pond 0 to 24 cm		Reay Pond 24-62 cm	
μg/g	Crustal Value[1,2]	BC Lakes[3]	Average	SD (n=6)	Average	SD (n=4)
Pb	12.5 – 15	8 – 30	78.6	10.1	37	19.5
Cd	0.1 – 0.2		27.9	16.5	34.2	14.6
Cu	25 – 55	35 – 105	98.2	18.8	43.7	10.4
Zn	65 – 70	85 – 180	741	154	234	97
Hg	0.08	0.012 – 0.35	0.06	0.006	0.066	0.011
Cr	100 – 200	80 – 150	148	46	190	37
Ag	0.07 – 0.1		0.4	0.04	0.2	0.1
Sn	2		1.8	0.3	1.1	0.2
As	1.8		5.4	0.14	6.2	2.3

[1] Taylor, 1964. [2] Turekian and Wedepohl, 1961. [3] Gallagher et al., 2004.

Figure 5. Plots of metal concentrations as a function of depth in the sediments.



[Zn] ug/g

[Cd] ug/g

[Cu] ug/g

[Cr] ug/g

[Ag] ug/g

[Pb] ug/g

Table 3b Reay Creek Pond sediment averages for metals and sediment guideline values (all units are µg/g)

Element	Sample Concentration Mean	SD (n=10)	BC FW Sediment[1]		CCME FW Sediment[2]	
			SedQCscs[3]	SedQtcs[3]	ISQC[4]	PEL[5]
arsenic	5.7	1.5	11	20	5.9	17
cadmium	30.4	15.5	2.2	4.2	0.6	3.5
chromium	164.8	44.6	56	110	37.3	90
copper	76.4	29.4	120	240	35.7	197
lead	62	26.5	57	110	35	91.3
mercury	0.043	0.008	0.3	0.58	0.17	0.486
zinc	538	271.6	200	380	123	315

[1] Criteria for Managing Contaminated Sediments in British Columbia- Technical Appendix

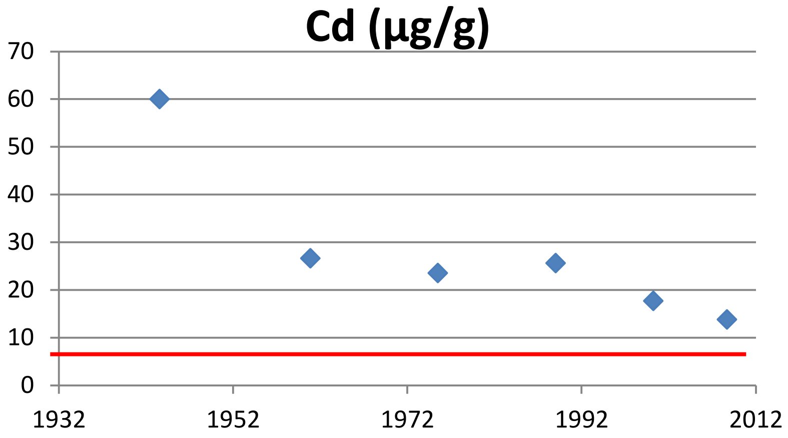
[2] CCME Fresh Water Sediment Guidelines

[3] Sediment Quality Criteria: scs – sensitive contaminated sites; tcs – typical contaminated sites

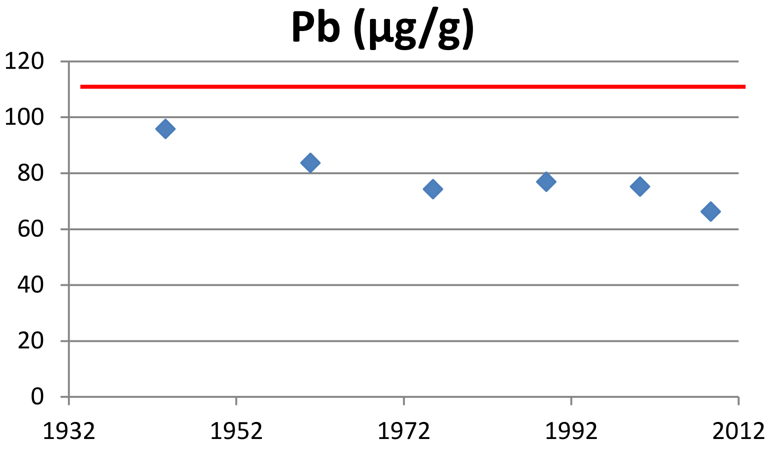
[4] Interim Sediment Quality Guideline

[5] Probable Effects Limit

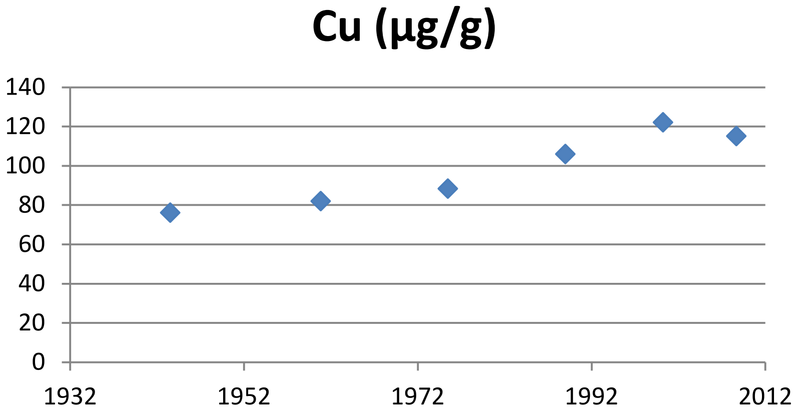
A Few Timelines - Total Metal Concentrations



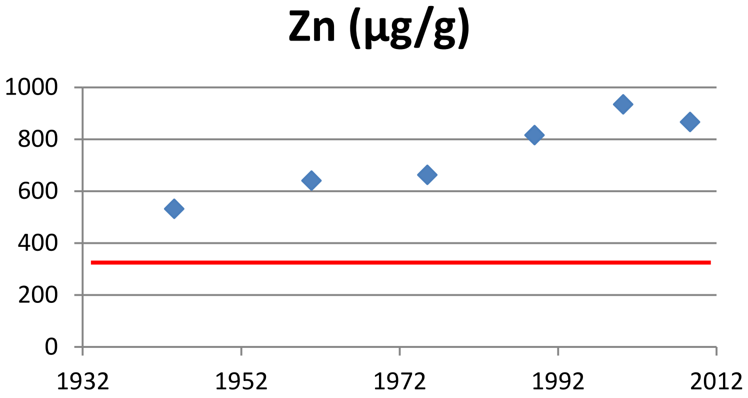
4.2 ug/g = BC FW TCS Contaminated Sediment Guideline



110 ug/g = BC FW TCS Contaminated Sediment Guideline

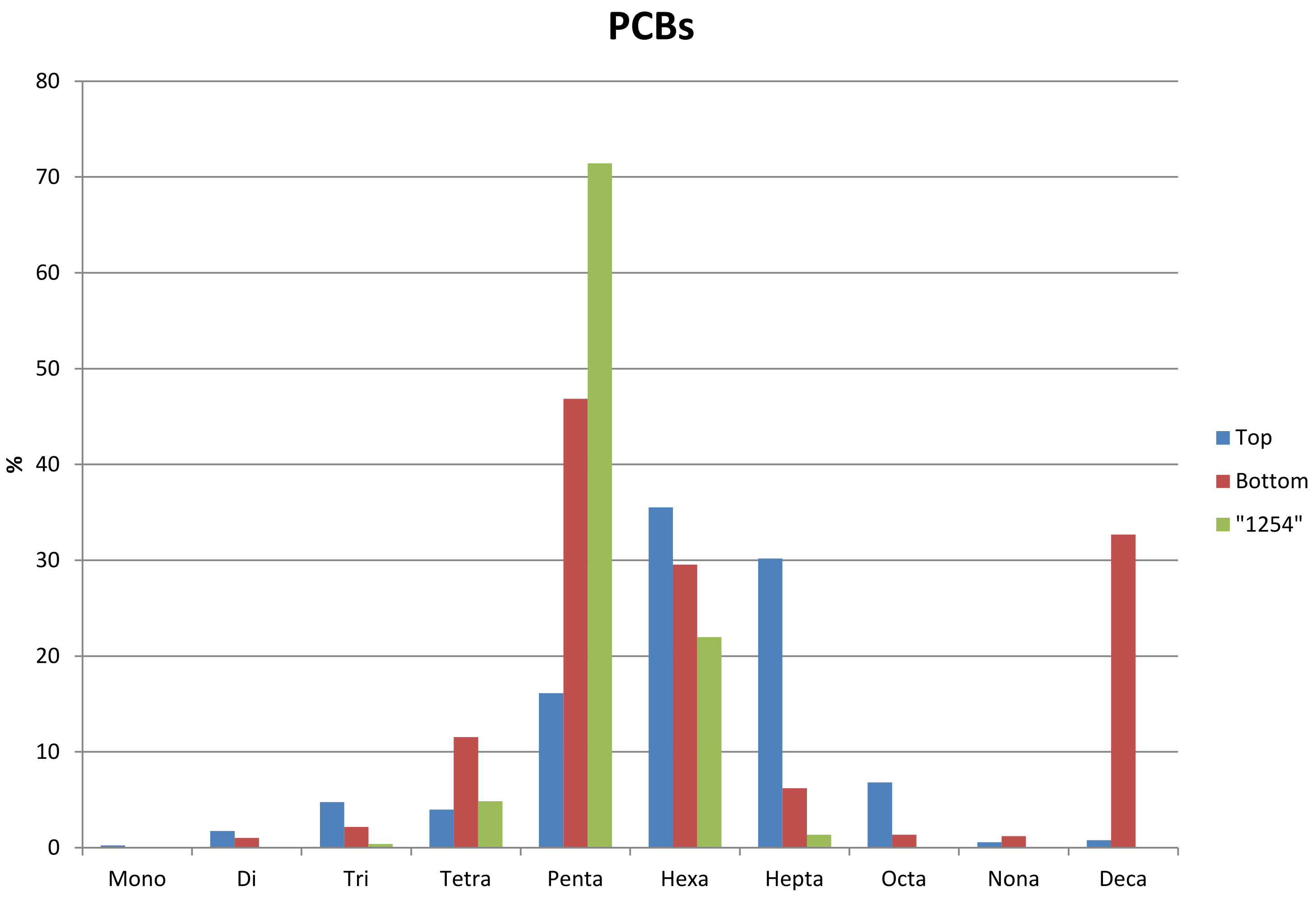


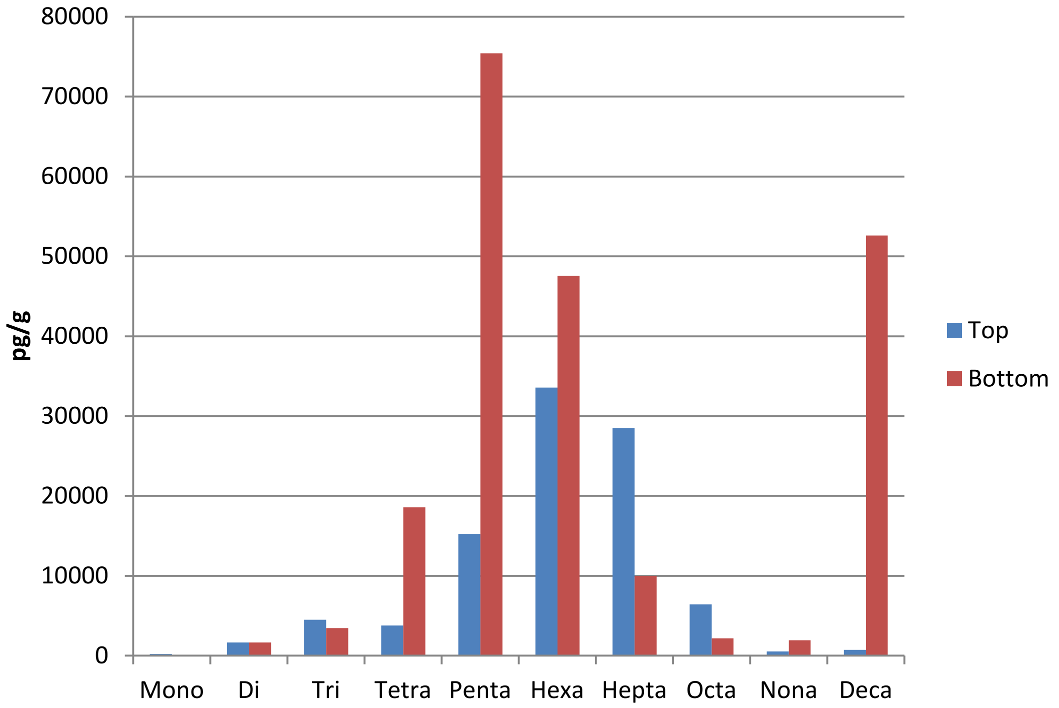
240 ug/g -= BC FW TCS Contaminated Sediment Guideline



380 ug/g = BC FW TCS Contaminated Sediment Guideline

Figure 6. A histogram of PCB congener data organized by chlorine number for the pooled sediment samples (top and bottom) and the commercial PCB mixture 1254.





PCBs by Chlorine groups for top and bottom of sediment core

Total PCBs are lower in the upper sediments (~100 ng/g) than deep sediments (~200 ng/g). The distribution among congeners suggests a fairly heavy formulation (Arochlor 1254 to 1260), which indicates local sources and not long range atmos transport. A strange occurrence is the very high decachloro PCB in the bottom sample. I'm not sure where that comes from.

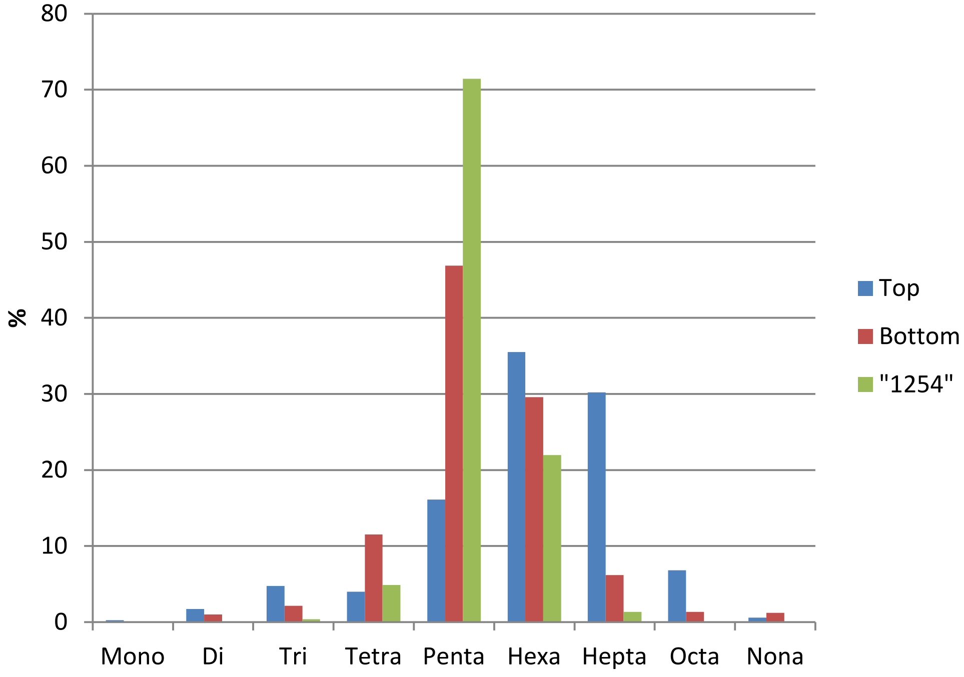


Figure 7. A bar diagram showing PBDE congener concentrations for the pooled sediment samples (top and bottom).

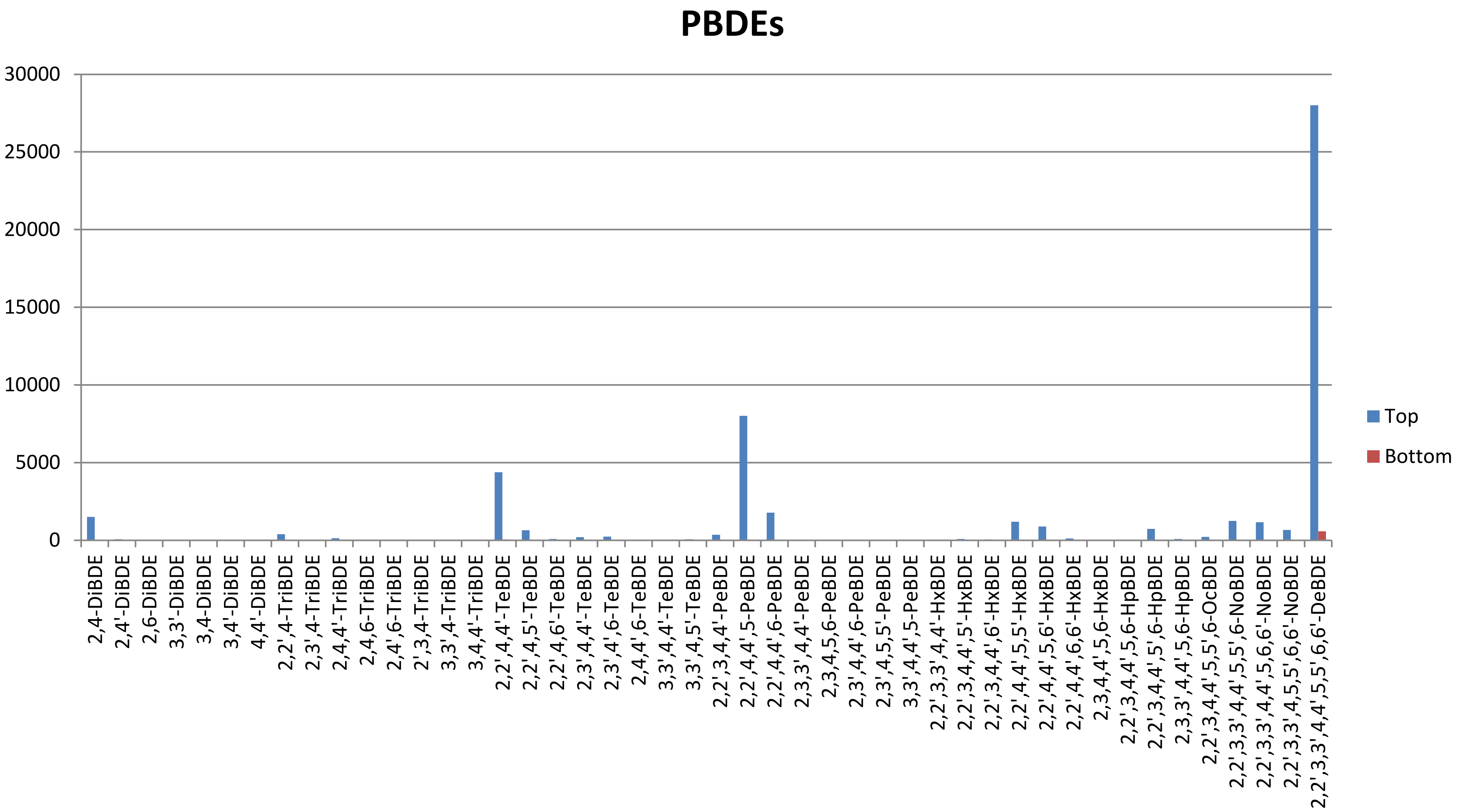
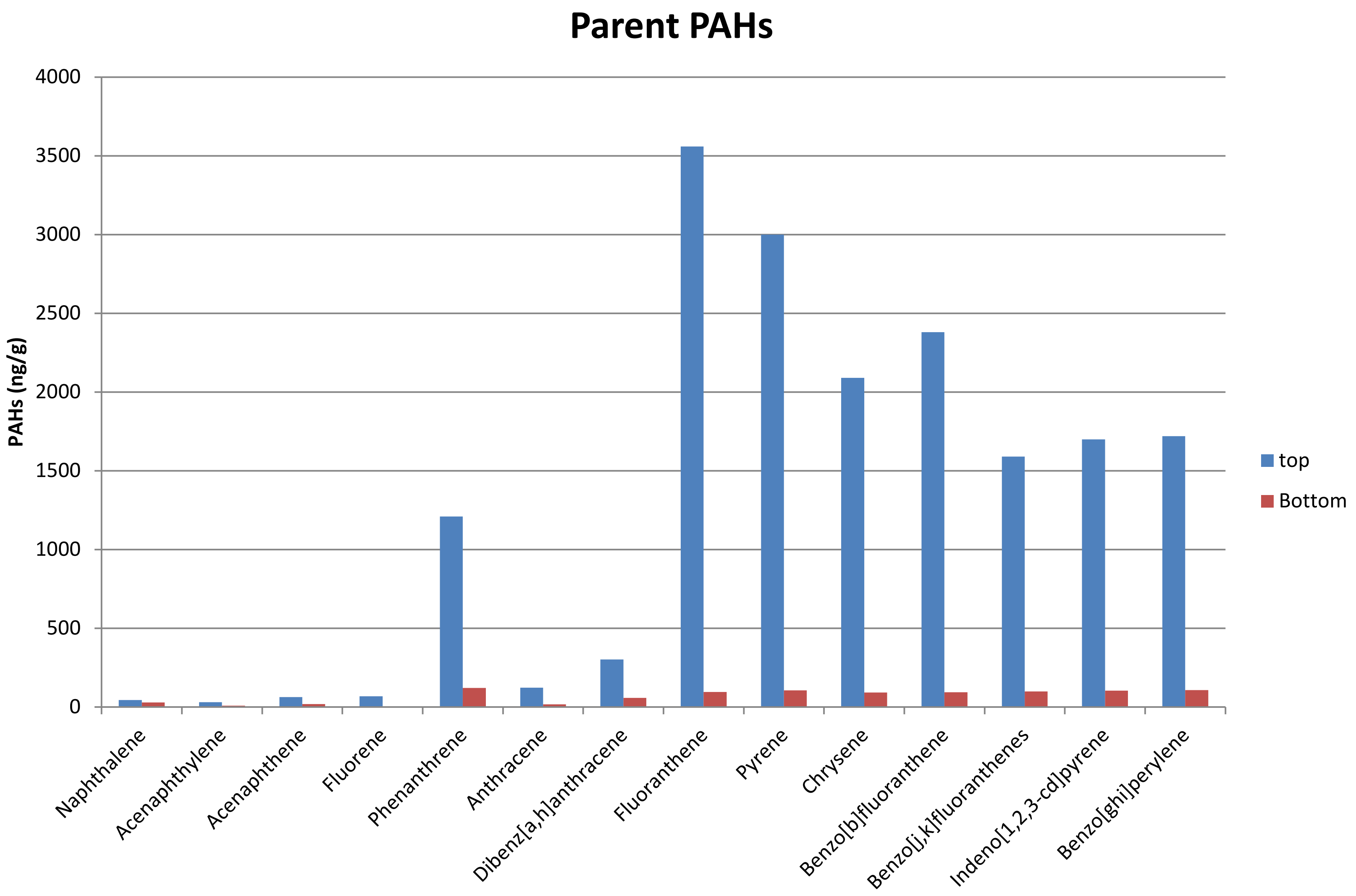
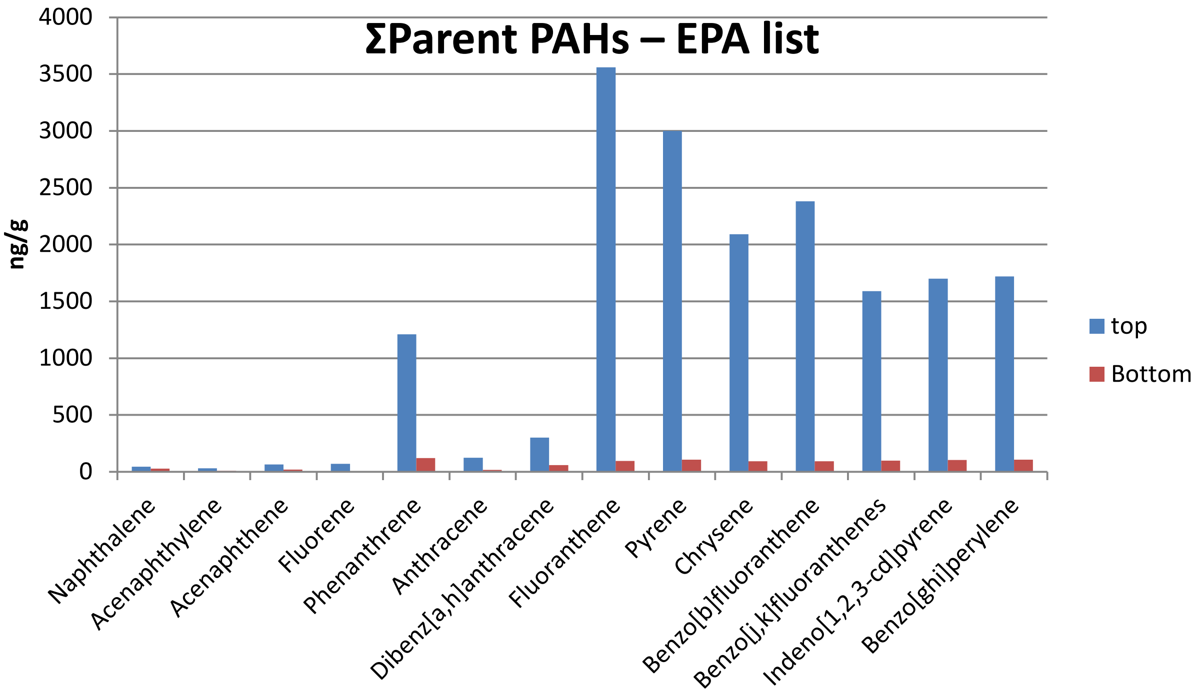
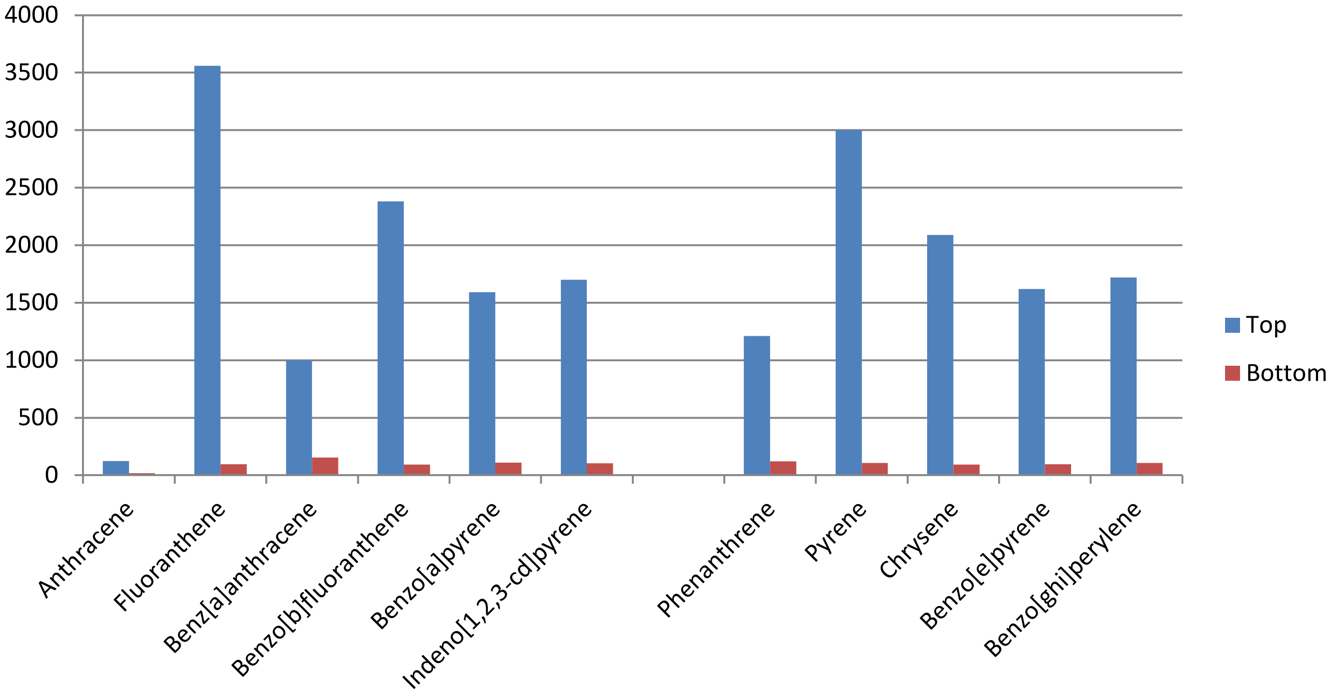


Figure 8. PAH concentrations for the 14 parent PAHs measured in the pooled sediment samples (top and bottom).



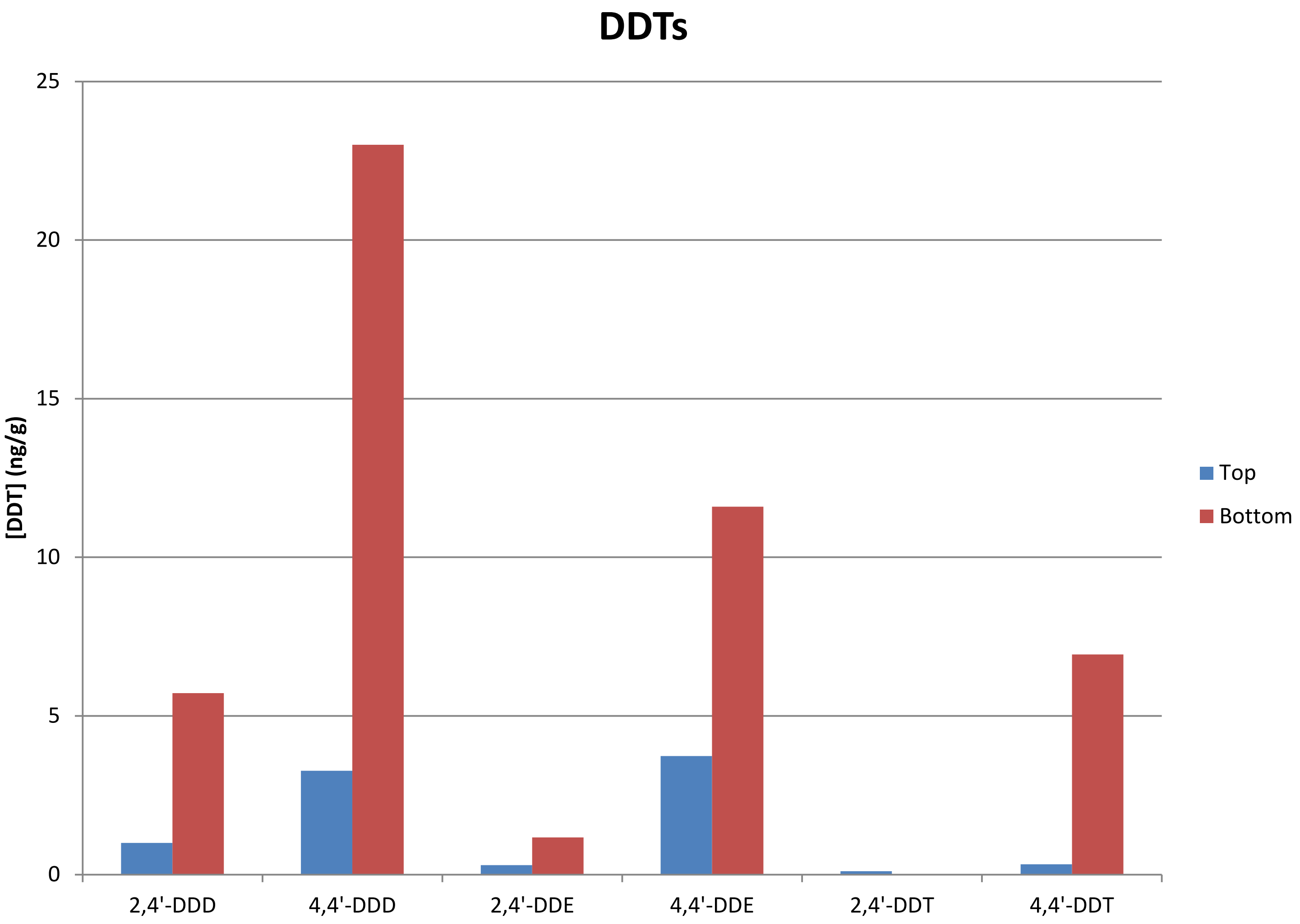


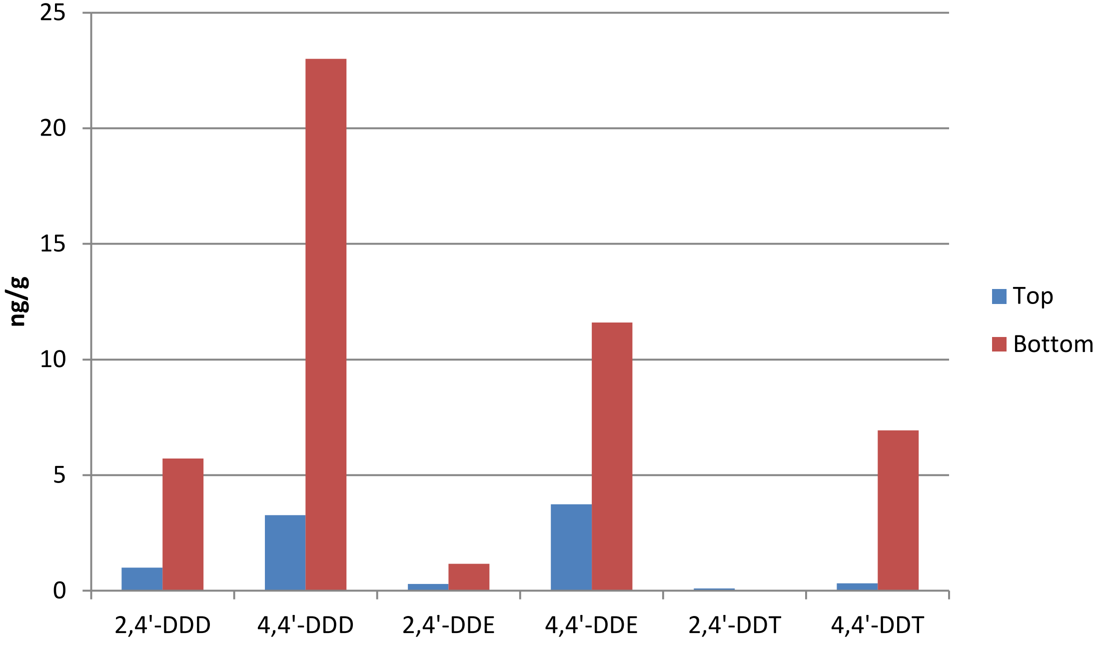
Bottom sediments have sum of Parent PAH in ranges you'd might expect for normal background. As you can see, the surface sediments contain a lot of PAH – the sum is ~ 18ug/g compared to <1 ug/g for the deep sediment. So, there has been some sort of PAH contamination associated with post 1940. My guess is that there has been the use of creosote or other strong sources of PAH, either in the subdivision or on airport land.



Less stable ones to left, more stable to right. I think we have a mix of sources including combustion and petrogenic, but more work would need to be done to sort it out. I suspect that a lot of these PAHs are coming from somewhere other than combustion – like use of creosote etc.

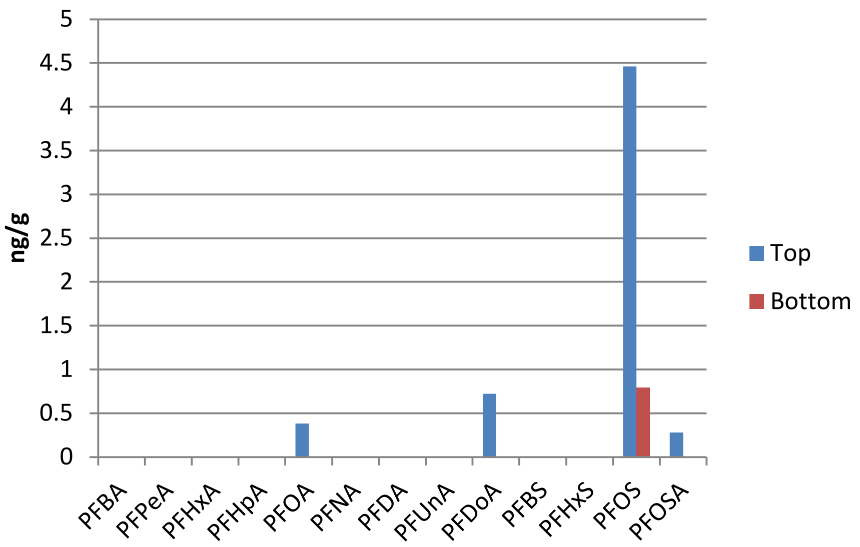
Figure 9. DDT compounds measured in the pooled sediment samples (top and bottom).





There are traces of other pesticides, but nothing unexpected. Also, there is little difference in these between deep sediment and surface sediment

DDT is interesting ; The bottom of the core (predating 1940) has higher DDT remnants as might be expected. The large amount of DDD suggests that that old buried DDT has been degraded in low oxygen sediment, so it might have been DDT when it entered these sediments, but has gradually degraded to DDD (and DDE). The top DDT also looks weathered, but more in oxic environments. It probably comes from soils and sediments washing off the fields into the creek. Values are not alarmingly high



Perfluoros: nothing alarming. As you would expect, the old material predating 1940 contains almost nothing (compounds not yet in wide use). Most of this contaminant group is PFOSA, with some PFOA and PFDoA.

Table 4. Summary of concentration data from pooled sediments (upper and lower core segments) together with some guideline values for sediments

Sediment Depth (cm)	∑PCBs ng/g	∑PBDEs ng/g	∑PAHs ng/g	∑DDTs ng/g	∑Chlordanes ng/g	∑PFOS ng/g
0 – 24	95	52	18,000	9	0.7	5.8
24 – 62	213	<1	<1,000	48	0.6	0.8
SEQCscs[1]	170		10,000	3	5.5	
ISQG[2]	34.1		n/a	n/a	4.5	
PEL[3]	277		n/a	n/a	8.87	

[1] Sediment Quality Criteria – sensitive contaminated sites, Criteria for Managing Contaminated sediments in British Columbia, Technical Appendix

[2] Interim Sediment Quality Guideline, CCME FW Sediment Guidelines

[3] Probable Effects Limit, CCME FW Sediment Guidelines

Depth in Sediments	Cd	Pb	Cu	Zn	ΣPAHs
Top 24 cm	24	41	54	512	18
Deeper sediments	44	9	3	122	1
Total	68	50	57	634	19

Burden[1] of contaminant metals and ΣPAHs in Reay Pond sediments (kg)

[1] **Burden is the net amount of contaminant, above background or "crustal" concentrations**

Depth in Sediments	ΣPBDEs	ΣPCBs	ΣDDTs	ΣPFOS
Top 24 cm	44	81	7	5
Deeper sediments	1	276	63	1
Total	45	357	70	6

Burden of organochlorine contaminants in Reay Pond sediments (g)

APPENDIX G
Macdonald and Bruce Report (2015)

Town of Sidney
Data Gap Analysis - Reay Creek Pond
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 201.02016.00001

An investigation of contamination in Reay Creek Pond sediments

R.W.Macdonald[1]

I.D Bruce[2]

[1] **Robie W. Macdonald, PhD, Research Scientist (robie.macdonald@gmail.com)**

[2] **Ian D. Bruce, BSc. R.P.Bio., Executive Coordinator, Peninsula Streams Society (www.peninsulastreams.ca; peninsulastreams@gmail.com)**

An investigation of contamination in Reay Creek Pond sediments

R.W. Macdonald and I.D. Bruce

June, 2015

Executive Summary

Reay Creek pond is a small, artificial containment produced by a dam originally constructed on Reay Creek in 1935. In its early years the pond was the site of a duck farm, but over the past several decades housing developments have taken place along the creek. Victoria Airport and associated industries have also developed in the upstream drainage basin since the dam was built. This ensemble of industries has had a number of recorded spills that led directly to fish kills, and various chemical substances of industrial origin have contaminated creek sediments. Among these, cadmium (Cd), zinc (Zn) and chromium (Cr) are of great concern due to their high sediment concentrations and known toxicities. A dated sediment core collected from Reay Creek Pond shows that contaminations have occurred from several sources, but all contaminations can be assigned to locations within the Creek's drainage basin above the pond (i.e., the industrial park-airport complex). The sediment that has accumulated within the pond after its initial construction is estimated at about 2200 tonnes (dry weight) and contains approximately 70 kg of Cd, and 630 kg of Zn. This sediment reservoir, along with sediments accumulated in the creek bed, would need to be removed and confined in a permanent containment if the creek is to be remediated to point that it can safely sustain fish. Stakeholders including the residents in the Reay Creek drainage, the Victoria Airport Authority and associated industries, and the Federal, Provincial and municipal governments need to be involved in developing a remediation plan.

Introduction

Reay Creek (~ 3 km length) is located on the east side of the Saanich Peninsula near the Town of Sidney, B.C. (Figure 1a,b). Reay Creek traverses two municipalities and the Victoria International Airport before entering salt water at Bazan Bay, which borders Haro Strait. Before extensive community involvement in stream restoration and re-introduction of coho salmon (*Onchorhyncus kisutch*), the lower reach of Reay Creek was essentially a "dead stream" with considerable garbage and debris scattered throughout (T.Davis, pers comm). Coho salmon have been successfully spawning and returning to Reay Creek almost continuously since the late 1980s and wild sea-run cutthroat trout (*Onchorhyncus clarkii clarkii*) have colonized the creek as well.

The pond on Reay Creek, 255 m in length and averaging 18 m in width, was originally created for the rearing of commercial ducks through the construction of wood stave and rubble dam in 1935 (Figure 2). In the 1950s another dam was constructed 40 m downstream of the original location to increase pond capacity to support irrigation. Housing sub-divisions have been built around the pond since the early 1970s. In 1997, following a spillway failure, the dam was reconstructed under the supervision of Fisheries and Oceans Canada (FOC) and the Sidney Anglers Association (SAA).

Figure 1a. The location of Reay Creek and Reay Creek Pond on northern Saanich Peninsula.

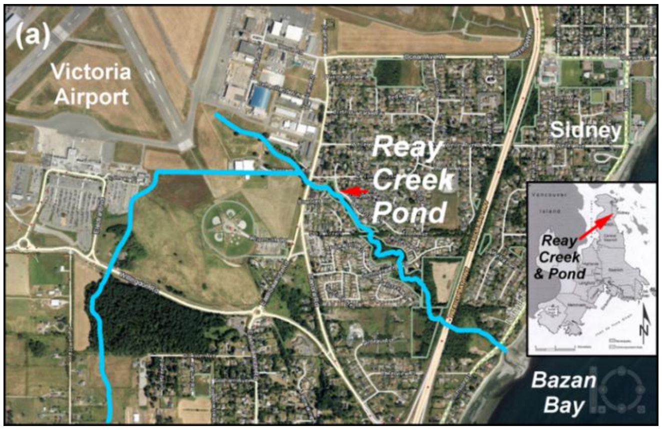
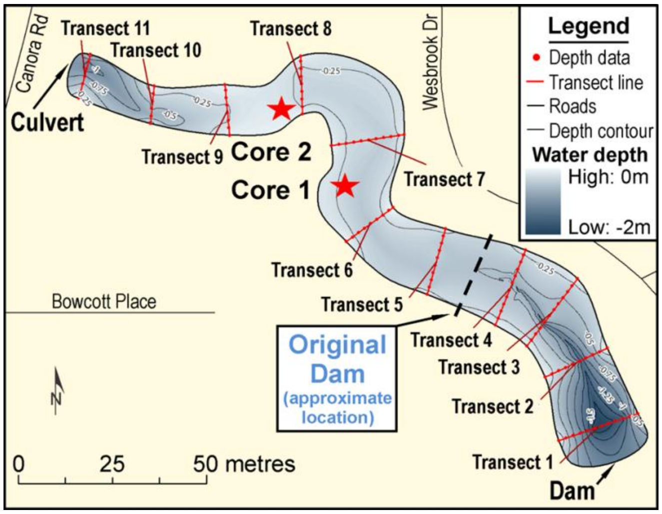


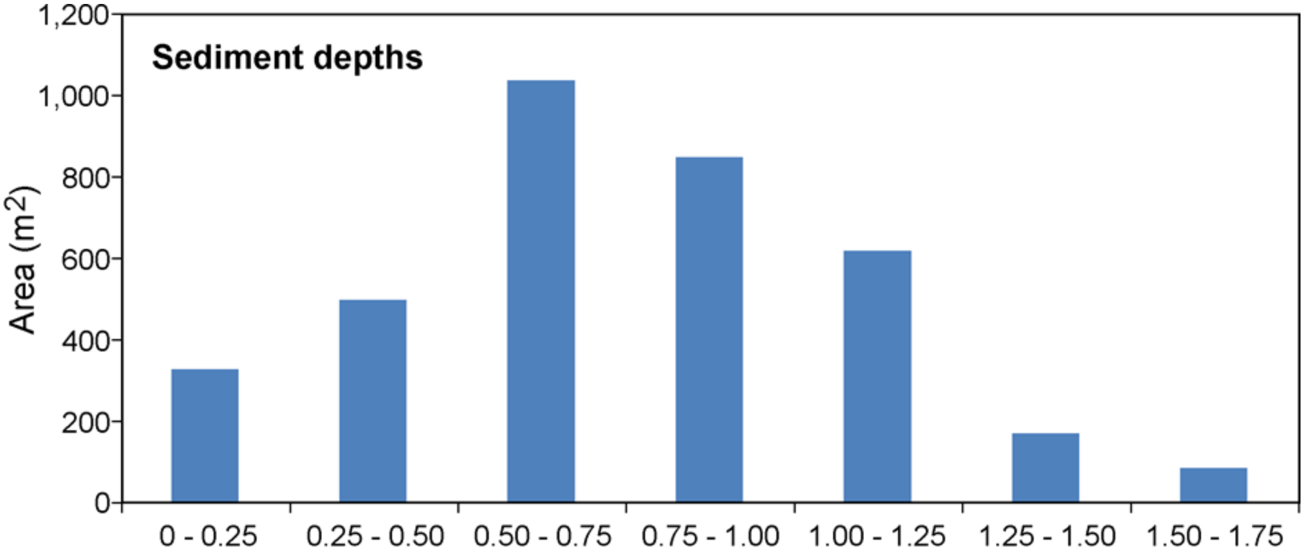
Figure 1b. Reay Creek & Pond showing Core Locations.

Figure 2. Plan view of Reay Creek Pond showing locations of Cores (2013), Original Dam (~1935) and transects and sampling points at which water and sediment depth were determined in 2010 (Robinson and Sarrazin, 2010).



Currently the pond contains significantly more accumulated sediment (Figure 3) than overlying water, reducing potential juvenile salmonid rearing habitat in the pond by an estimated 80%. Furthermore, the accumulated sediments are nutrient rich (phosphorous/nitrogen), as evidenced by the significant blue-green algal bloom consequent to sediment disturbance in the summer of 2004 when a fallen tree was removed.

Figure 3. Histogram of uncompacted sediment depths in Reay Creek Pond as determined by Robinson and Sarrazin (2010).



Six large mortality events of salmon and trout (1982, 1987, 1993, 1994, 2003, 2004) and three smaller ones have occurred in Reay Creek since the early 1980's with at least four of them (1982, 1987, 2003, 2004) associated with high levels of Cd originating from the Victoria International Airport (Table 1). Peninsula Streams Society (PSS) recently sponsored an investigation into the status of Reay Creek pond by two Camosun College students (Robinson and Sarrazin, 2010) in which they reported the accumulation of deep sediments (up to 1.5 m) exhibiting high concentrations of Cd in the near-surface sediments.

PSS and SAA would like to remediate the pond to increase its rearing capacity for coho salmon and sea-run cutthroat trout. The local community would like a pond that functions as fish habitat without the constant threat of blooms or downstream transport of contaminated sediments. The Town of Sidney is required to determine what, if any, financial liability there may be associated with the possibility that the pond qualifies as a contaminated site. The investigation reported here is meant to characterize the sedimentary environment of the pond in terms of accumulation history subsequent to the original damming, sediment contaminant concentrations, and the total inventory of contaminants. This information is sought to inform the development of strategies required to remediate the pond.

Table 1: Selected historical perspectives of Reay Creek Pond and of some of the contaminants found in its sediments

Year	Activity	Comments
1929	PCB used industrially	Erickson
1935	LG Thomas Sidney Duck Farm built	
1939	Vic Times reports 6,000 ducks at farm	
1939	Victoria Airport started as grass strip & Military Training	Wikipedia
1949	PFOS first produced commercially (3M)	
1950s &60s	Chromium plating plant (East Camp)	
1960s	DDT used in aerial spray for forestry	Gallager et al. (2004)
1965	PBDE produced industrially	Meunhor (2011)
1967	Anecdotal admission of toxic release by Viking Air/Airport	
1970	Viking Air established as aircraft modification/repair site	Wikipedia
1970s	Widespread use of PBDEs as flame retardant	Toxipedia
1972	DDT use banned	
1972	PCB sale for open uses ceased by Monsanto	Erickson & Kaley (2011)
1977	PCB production ceased by Monsanto	Erickson & Kaley (2011)
1977	PCB use banned in Canada	Ross et al. (2009)
1979	PCB use banned in USA (by EPA)	Erickson & Kaley (2011)
1982	Coho fry outplanted from Goldstream River	
1982	Fire at Viking Air; complete fish kill	Fire retardant and other toxics
1983	Oil spill at Airport; no fish kill	Spill Gate installed at airport
1985	Reg Kirkam moves to pond site	Small dam still prominent
1985	Fish kill (120 coho fry)	Hydrant flushing, Sidney
1987	Large fish kill	Possibly Cd?
1993	Coho/cutthroat killed over half stream length	Suspect municipal hydrant flushing
1993	Coho killed in top third, survived below mid-point	Cutthroat also killed
1994	Coho killed over the entire length	Sticklback hit hard in upper reaches (ballfield construction?)
1996	Earthen dam blowout (1 × 1.3 m)	Dam located to present situation
1997	Dam rebuilt in place with DFO Guidance	
2002	Fish kill – 18 cm cutthroat and suspect coho fry	Suspect chlorine/chloramine hydrant flushing
2003	Fish kill (Cd)	Complete, all species, Cd in fish tissues (DFO)
2004	Complete fish kill	Cd, Cr, Zn?
2004	PBDEs – production of octa and penta discontinued)	Toxipedia
2006	PBDEs – tetra through deca designated as	
2009	toxic under CEPA	
2008	PBDE production banned in Canada	
2009	PFOS included in Annex B, Stockholm Convention	Canada has proposed complete ban

Methods

The physical survey of Reay Creek Pond, conducted in June, 2010 (Robinson and Sarrazin, 2010), provided the foundation for selecting two sites within the pond to collect sediment cores (marked on Figure 2). In the 2010 survey of the pond, the depth of the water and of un-compacted sediments were measured along 11 transects at a total of 106 locations by pushing thin bamboo rods into the sediments at each location, which permitted the depth distribution of un-compacted sediment to be contoured as shown in Figure 2.

Volume and area calculations for the pond sediments

Using an enlarged version of Figure 2, we measured the total area of the pond and of the sediment thickness contours at 0.25 m intervals using a planimeter. The planimeter measurement of each closed contour area was repeated 3-4 times giving a precision of about 1-3% depending on size and shape of the area. The sum of all the individually measured sub-areas (3583 m^2) agreed within less than ±1% with the measurement of the total lake area (3612 m^2). This precision does not take into account errors inherent in the bamboo stick method of probing sediments and contouring the results. Un-compacted sediment depths were found to be mostly distributed between 0.5 m and 1.25 m (Figure 3), and the total amount of un-compacted sediment accumulated in the pond, based on the histogram in Figure 3 and the measurements of water content within the sediment core, is ~2144 tonnes (dry weight) (Table 2).

Table 2: Reay Pond area and sediment dimensions

Surface Area	3583 m^2
Total volume of accumulated sediment	3107 m^3
Total wet weight mass of sediments	4400 tonnes
Total dry weight mass of sediments	2144 tonnes
Mean depth of sediments	0.87 m

Sediment coring methodology

Two sediment cores were collected by hand on Sept. 19, 2013, at the locations marked on Figures 1a, 2 using a small boat. For each core, a plastic core liner (10 cm i.d.) with sharpened end was pressed into the sediment as far as possible. A cap was placed on the top end of the tube to provide a vacuum, the tube containing the core was retrieved from the sediment and, taking care to maintain the core in a vertical position, and the core was placed on a sectioning device. The cores were 62 cm (#1) and 38 cm (#2) in length. Both cores were sectioned at 2 cm intervals by extruding the sediment upward and subsampling the 2-cm plug, taking care to discard the outer material that had been in contact with the tube wall. Each sectional subsample was placed in a Whirlpak bag and frozen for later analysis. Core 1 was used for dating and contaminant analyses because it was longer, and appeared visually to be a better core. During sub-sectioning it was noticed that the top 24 cm of this core consisted of fairly uniform greyish black mud without any distinguishing features or obvious identifiable objects like wood or leaves (Appendix I Table 1). At about 25 cm, coarse woody material including a large wood chip was encountered, below which the sediment alternated between coarse woody material and finer mud, with a sandy layer at 39 cm, and mixed, coarse mud, and sand.

Sample Preparation and Analyses

Twelve 2 cm sectional sub-samples from Core 1 were frozen and sent to Flett Research Ltd. for ^{210}Pb counting (to date the core) and total mercury determination. The remaining sample from these sub-sections, along with the other nineteen 2 cm sectional sub-samples from Core 1 were delivered to Axys Analytical Ltd. in Sidney, B.C, to analyze for metals, organochlorine compounds (OCs) and poly-cyclic aromatic hydrocarbons (PAHs). Due to the cost of the OC and PAH determinations, we used only two pooled samples (shallow sediment, deep sediment) as indicated by colour coding showing how the sections were analyzed (Appendix I Table 1).

For all analyses reported here the complete methods (referenced in Appendix II) and the raw data themselves are available upon request as pdf/doc files or Excel files (Ian Bruce).

For metals analysis, ten samples were selected from Core 1 (Appendix I Table 1), corresponding sequentially to the list given in Maxxam ID # JF3164-JF3173 (Appendix II). These samples were analyzed for total metals using acid extraction and ICP-MS quantitation.

For analysis of polychlorinated biphenyls (PCBs), pesticides, PCN (polychorinated naphthalenes), PBDEs (polybrominated diphenyl ethers), PFC (perfluoro compounds), dioxins/furans and PAHs, two sample strata were created for each compound 0-24 cm and 24-62 cm (Appendix I Table 1). The analyses for these compounds were undertaken by Axys Analytical Ltd. with methodology described in the report listed in Appendix II.

^{210}Pb dating of sediments

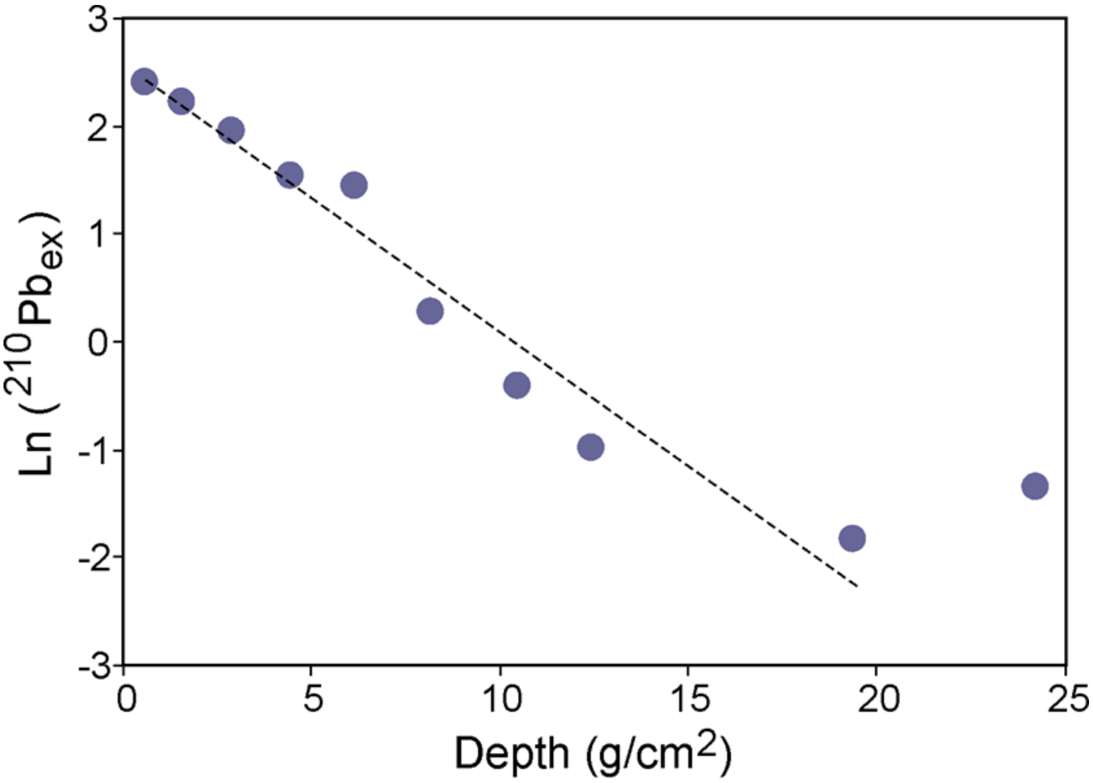
The primary dating tool for the sediments was ^{210}Pb. Briefly, this natural radionuclide enters sediments through atmospheric deposition (excess ^{210}Pb) and through the decay of naturally occurring ^{226}Ra (supported ^{210}Pb) within minerals making up the sediments. To use ^{210}Pb as a dating tool, the supported ^{210}Pb (estimated from ^{226}Ra measurements) is subtracted from the total ^{210}Pb measured, to provide an excess ^{210}Pb profile. Using the decay rate of ^{210}Pb (1/2 life of ~22 years), the vertical profile of excess ^{210}Pb can then be used to estimate sedimentation rate and assign age to various depths in the core. Sediment mixing may complicate this estimation, requiring modeling, but in the case of the Reay Creek sediments there was no evidence of surface sediment mixing. A secondary check on sedimentation rates is often provided by ^{137}Cs. This element, a product of the nuclear fission of uranium, first entered atmospheric deposition in the early 1950s, when atmospheric weapons testing was initiated. The atmospheric deposition peaked in the early 1960s and then drastically declined due to test-ban treaties. A subsequent peak in ^{137}Cs deposition at our latitude occurred in 1986 due to the Chernobyl accident.

Results

Sedimentation rates and history

The ^{210}Pb data plotted as Ln[^{210}Pb$_{ex}$] versus depth in the sediments expressed as g/cm^2 yields a reasonably good straight line with a regression coefficient of $R^2 = 0.96$ (Figure 4). The slope of the line implies a sedimentation rate of about 0.125 g cm^{-2} yr^{-1} (95% CI is 0.106 – 0.154 g cm^{-2} yr^{-1}). Taking into account the water content of the sediment, this translates into an average sediment velocity of ~0.32 cm yr^{-1}. Given the observations at the time of sectioning, this sedimentation rate probably applies only to the top 25 cm of the core, where the sediment appeared uniform in colour and texture. Below that is likely older material that had been disturbed during or shortly after the pond was first constructed. Accordingly, the ^{210}Pb data imply that the uniform sedimentation commenced in about ~ 1939, with a range of 1925 – 1954 possible (95% CI). These dates for the bottom of the uniform surface layer set against the known history of the pond (Table 1) suggest that the top 25 cm of sediment in the pond accumulated more or less uniformly after the duck pond was first constructed in 1935. The ^{137}Cs values are low and sporadic throughout the core, which is difficult to interpret in the context of ^{137}Cs deposition. ^{137}Cs data can be problematic for a number of reasons and we have therefore not relied on them here.

Figure 4. A plot of Ln[^{210}Pb$_{ex}$] versus sediment depth for Core 1 . Dashed line shows the line fit to the data to estimate sedimentation rates.



Contaminants in the pond sediments

Based on the texture and appearance of the sediments and the ^{210}Pb dating, we consider the sediments in the analyzed sediment core to consist of an overburden of fairly uniform, soft sediment that has accumulated to about 25 cm since the construction of the pond. Beneath this are disturbed, but more compact sediment, of unknown age but presumably dating before the mid 1930s.

Metals. We have analyzed a number of metals in the sediment cores, but in the context of contamination, toxicity and local metal sources, the relevant metals include cadmium (Cd), chromium (Cr), zinc (Zn), copper (Cu), tin (Sn), lead (Pb), mercury (Hg) and silver (Ag). A comparison of the metals data in the sediment cores with natural crustal values that would normally be expected in soils or values measured in uncontaminated horizons from BC lakes (Table 3a) shows that most of the metals exhibit contamination above expected backgrounds (e.g., Pb, Cu) , as would be expected given the pond's location near urban and light industrial developments. However, Cd and Zn both show gross contamination, with Cd clearly exceeding sediment toxicity guidelines (Table 3b). Fish kills in which Cd was implicated have been documented in 1982, 1987, 2003 and 2004. However, these incidents seem not to explain all of the Cd contamination given that it extends into times well before 1982.

Table 3a Metals data for Core 1 (all units in µg/g)

Element			**Reay Pond 0 to 24 cm**		**Reay Pond 24-62 cm**	
µg/g	**Crustal Value[1,2]**	**BC Lakes[3]**	**Average**	**SD (n=6)**	**Average**	**SD (n=4)**
Pb	12.5 – 15	8 – 30	78.6	10.1	37	19.5
Cd	0.1 – 0.2		27.9	16.5	34.2	14.6
Cu	25 – 55	35 – 105	98.2	18.8	43.7	10.4
Zn	65 – 70	85 – 180	741	154	234	97
Hg	0.08	0.012 – 0.35	0.06	0.006	0.066	0.011
Cr	100 – 200	80 – 150	148	46	190	37
Ag	0.07 – 0.1		0.4	0.04	0.2	0.1
Sn	2		1.8	0.3	1.1	0.2
As	1.8		5.4	0.14	6.2	2.3

[1] Taylor, 1964. [2] Turekian and Wedepohl, 1961. [3] Gallagher et al., 2004.

Table 3b Reay Creek Pond sediment averages for metals and sediment guideline values (all units are µg/g)

Element	**Sample Concentration Mean**	**SD (n=10)**	**BC FW Sediment[1]**		**CCME FW Sediment[2]**	
			SedQCscs[3]	**SedQtcs[3]**	**ISQC[4]**	**PEL[5]**
arsenic	5.7	1.5	11	20	5.9	17
cadmium	30.4	15.5	2.2	4.2	0.6	3.5
chromium	164.8	44.6	56	110	37.3	90
copper	76.4	29.4	120	240	35.7	197
lead	62	26.5	57	110	35	91.3
mercury	0.043	0.008	0.3	0.58	0.17	0.486
zinc	538	271.6	200	380	123	315

[1] Criteria for Managing Contaminated Sediments in British Columbia- Technical Appendix;
[2] CCME Fresh Water Sediment Guidelines; [3] Sediment Quality Criteria: scs – sensitive contaminated sites; tcs – typical contaminated sites; [4] Interim Sediment Quality Guideline; [5] Probable Effects Limit

Plots of the variation in metal concentrations with depth/age in sediments (Figure 5) give an indication of the time course of contamination. Together with an analysis of multiple correlations (Table 4), the profiles shown in Figure 5 reveal that metal contamination has likely occurred from three different sources. First, Cd and Cr profiles show significant similarity (R=0.84, p=0.0025),and have the deepest (longest) record of contamination. For both of these metals, the near-surface sediments (post 1964) tend to be lower than deep sediments, but in the case of Cd the values indicate gross contamination right up to the sediment surface. That is, sediments accumulating today still have Cd contents that exceed toxicity limits given in Table 3b, which suggests that suspended sediment transported by Reay Creek above the pond remains unacceptably high in Cd. Cd and Cr have contaminated the sediments in the ratio of 0.28:1 (Cd:Cr), and that contamination appears to have commenced very early in the pond's history. The second grouping of metals includes Zn, Cu and Sn. All three of these metals exhibit low values within normal crustal ranges in the deep sediments. These concentrations become markedly higher after about 1940 and have remained at more or less constant concentrations near the surface after about 1990. The correlation between Zn and Cu is particularly strong (R=0.99, p=0.0003), but correlations between these two metals (Zn, Cu) and Sn are also significant (R=0.90, p=0.0005). The contamination by these three metals is in the ratio of 563:63:1 (Zn:Cu:Sn). The final pairing, between Pb and Ag (R=0.92, p=0.002), shows background crustal values deep in the core, with contamination commencing in about 1940 where it rises sharply until about 1960 and thereafter has very gradually declined. The ratio for this contaminant pair is 175:1 (Pb:Ag). Hg, another metal that frequently poses toxic risks, appears never to have contaminated the Reay Creek Pond sediments (Table 3a) and manifests no vertical trends in the sediments.

Figure 5. Plots of selected metal concentrations as a function of depth in the sediments.

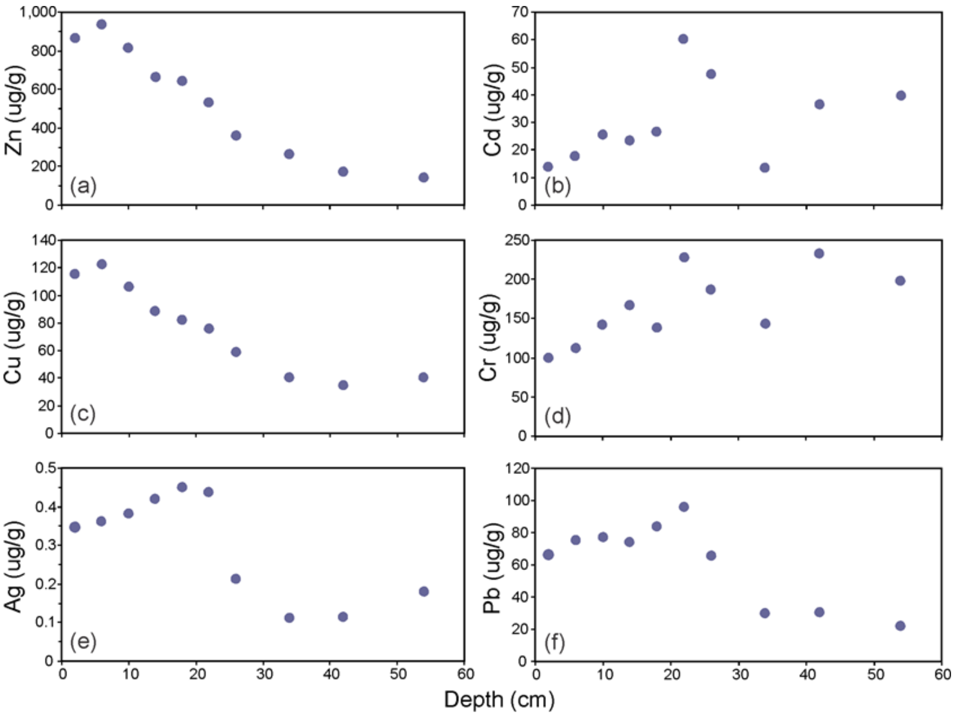


Table 4. Multiple correlations for the metals data

	Cd	Cr	Cu	Pb	Ag	Sn	Zn	As
Cd	1							
Cr	**0.84**	1						
Cu	-0.40	-0.71	1					
Pb	-0.16	-0.23	0.72	1				
Ag	0.02	-0.32	0.77	**0.92**	1			
Sn	-0.34	-0.55	**0.91**	0.61	0.68	1		
Zn	-0.43	-0.73	**0.99**	0.75	0.78	**0.90**	1	
As	0.14	0.20	-0.31	-0.51	-0.24	-0.27	-0.39	1

PCBs. Two samples were analyzed, one on a pooled sample of sediment from 0 – 24 cm in the core, the second on a pooled sample from 24 – 62 cm in the core. Based on the ^{210}Pb dating, the latter pooled sample would represent early material predating the pond construction and the former pooled sample the more recent material accumulated within the pond. The total PCB (∑PCBs) concentration, calculated by summing the congener data, was 95 ng/g and 213 ng/g for the top and bottom sediments respectively (Table 5). These concentration levels indicate contamination has been occurring in Reay Creek for a long time, which is not surprising given the multiple distributed sources of PCBs that include paint, plasticizers, electronics, lights, oils, thermal transfer fluids, hydraulic fluids, carbon copy paper, and others. Greater contamination deeper in the sediments would also be consistent with the known history of use, which commenced in 1929 and was curtailed in the early 1970s when environmental and health risks of PCBs became widely recognized (Table 2). For comparison, ∑PCBs measured in sediments of the Strait of Georgia near municipal outfalls show contamination levels that are generally <10 ng/g dry weight (Johannessen et al., 2008). However, the sites in the Strait of Georgia likely experience greater dilution of PCBs due to the nearby supply of inorganic sediment from the Fraser River, which also helps to bury the PCBs. An examination of the histogram of PCBs according to chlorine substitution (Figure 6) shows the deeper sediments to be 'lighter' (containing less chlorine) than the surface sediments (ignoring for the moment the large peak for deca-PCB) with the largest peak seen at penta CB compared to hexa and hepta CB for the top-layer sediments. Both samples,

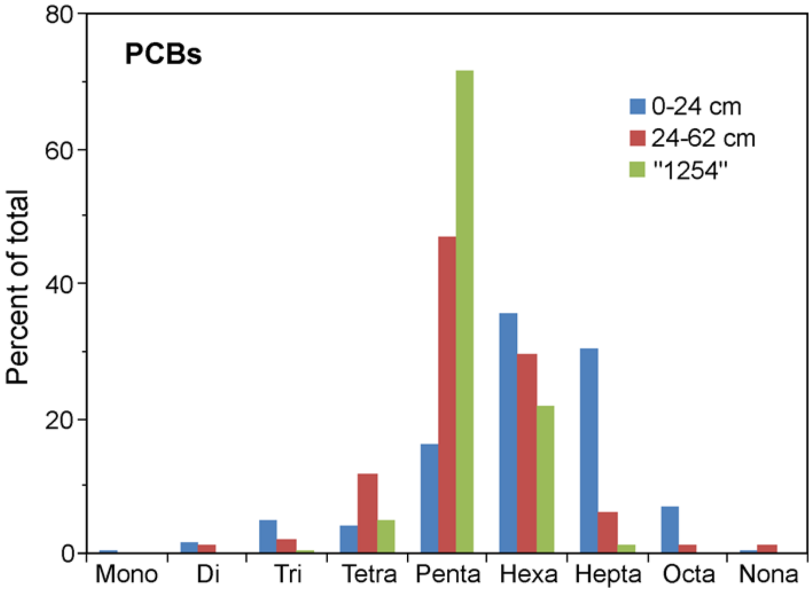
Table 5. Summary of concentration data from pooled sediments (upper and lower core segments) together with some guideline values for sediments

Sediment Depth (cm)	∑PCBs ng/g	∑PBDEs ng/g	∑PAHs ng/g	∑DDTs ng/g	∑Chlordanes ng/g	∑PFOS ng/g
0 – 24	95	52	18,000	9	0.7	5.8
24 – 62	213	<1	<1,000	48	0.6	0.8
SEQCscs[1]	170		10,000	3	5.5	
ISQG[2]	34.1		n/a	n/a	4.5	
PEL[3]	277		n/a	n/a	8.87	

[1] Sediment Quality Criteria – sensitive contaminated sites, Criteria for Managing Contaminated sediments in British Columbia, Technical Appendix
[2] Interim Sediment Quality Guideline, CCME FW Sediment Guidelines
[3] Probable Effects Limit, CCME FW Sediment Guidelines

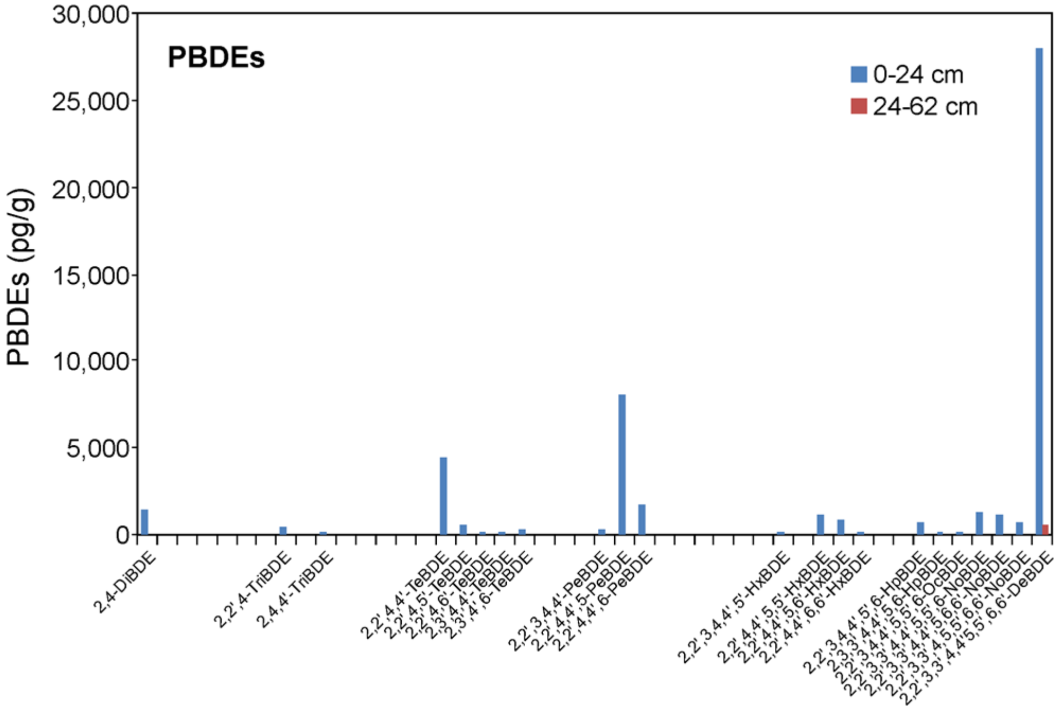
however, contain relatively heavy PCB (compare with PCB formulation 1254 (Figure 6) or the average PCB Cl-substitution histogram for Strait of Georgia sediments (see Figure 9 in Johannessen et al., 2008), indicating that the source of PCBs in Reay Creek sediments is probably local rather than distilled PCB via long-range transport. The large peak for deca-PCB in the deep sediment is clearly anomalous and cannot be explained by any of the traditional PCB formulations used such as 1254. Nor could such a heavy PCB be explained by long-range transport given its low volatility. Deca-PCB (also known as deca wax) was used in a relatively pure form for investment casting (Erickson and Kaley, 2011). Specifically, this process is used to produce precision-cast metal parts and shapes for the aircraft and other machinery manufacturing industries. Thus it seems likely that deca-wax was used locally (upper Reay Creek drainage) for aircraft-parts production in the 1950s-60s. Fortunately, this heavy PCB is not particularly toxic given that it is not taken up by biota very easily.

Figure 6. A histogram of PCB congener data organized by chlorine number for the pooled sediment samples (0-24 cm and 24-62 cm) and the commercial PCB mixture "1254".



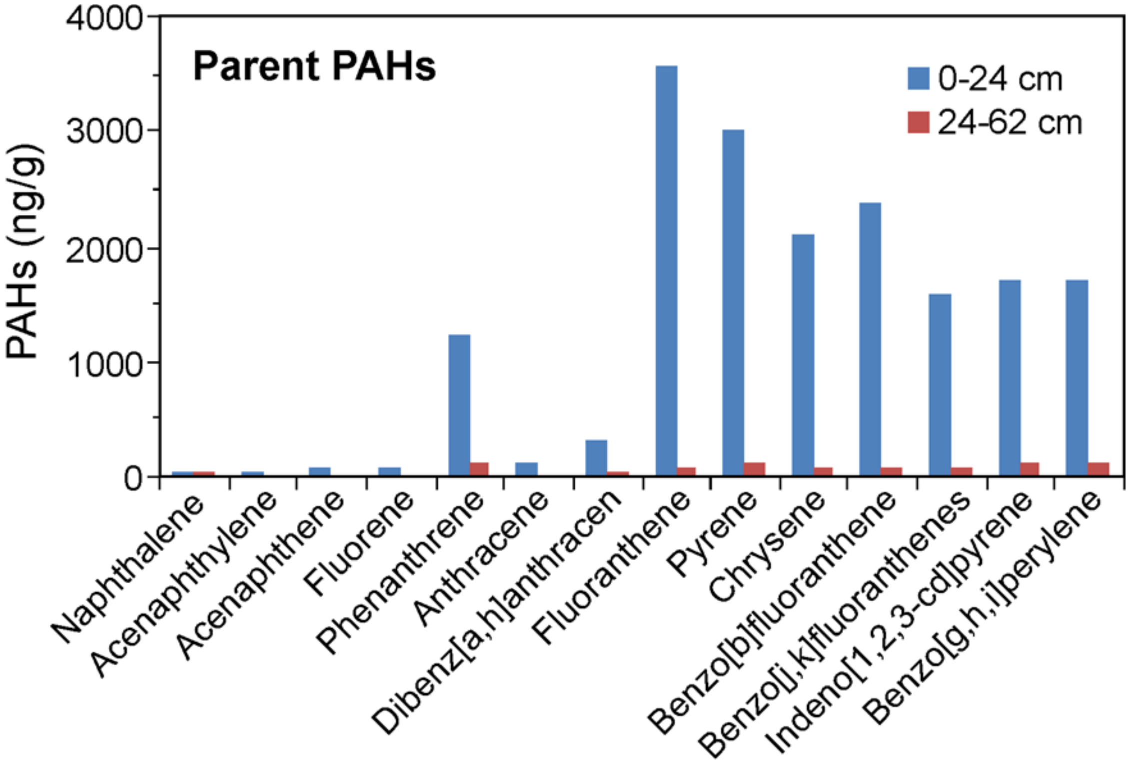
PBDEs. Like PCBs, these compounds have enjoyed wide use as flame retardants in fabrics, electronics and flame retardant fluids used to suppress fires. An important difference between these brominated compounds and PCBs is that their whole-scale use did not commence until much later, in the 1980s. Concerns about their environmental and health effects, similar to the concerns over PCBs, have led to their partial or complete banning in the 2000s (Ross et al., 2009). For the Reay Creek Pond sediments, ∑PBDEs concentrations were found to be 52 ng/g in the upper sediments and <1 ng/g in the deep sediments. Again, this depth distribution is reasonable given the much later entry of PBDEs into widespread use than the PCBs. An examination of the congener profile (Figure 7) shows that congeners 47, 99 and, especially 209, provide most of the ∑PBDE burden, which is not surprising as these are 'the usual suspects' in formulations of PBDEs some of which include mostly BDE 209 (Ross et al., 2009; De Wit, 2002). Locally, an important source of PBDEs has been marine outfalls (Dinn et al., 2012a,b), likely because they dispose of domestic wastewater containing household dust from fabrics like curtains and carpets, which frequently contain fire retardants. Near outfalls in the Strait of Georgia and Juan de Fuca, PBDE contamination of sediments, accordingly, attains concentrations of up to 20 ng/g. Thus, the upper sediments of Reay Creek Pond can be considered contaminated at relatively high levels, perhaps not surprising given the urban setting together with the known use of flame retardants to suppress a fire at Viking Air in 1982 in the drainage basin above the pond, and possibly other applications associated with the airport.

Figure 7. A bar diagram showing PBDE congener concentrations for the pooled sediment samples (0-24 cm and 24-62 cm).



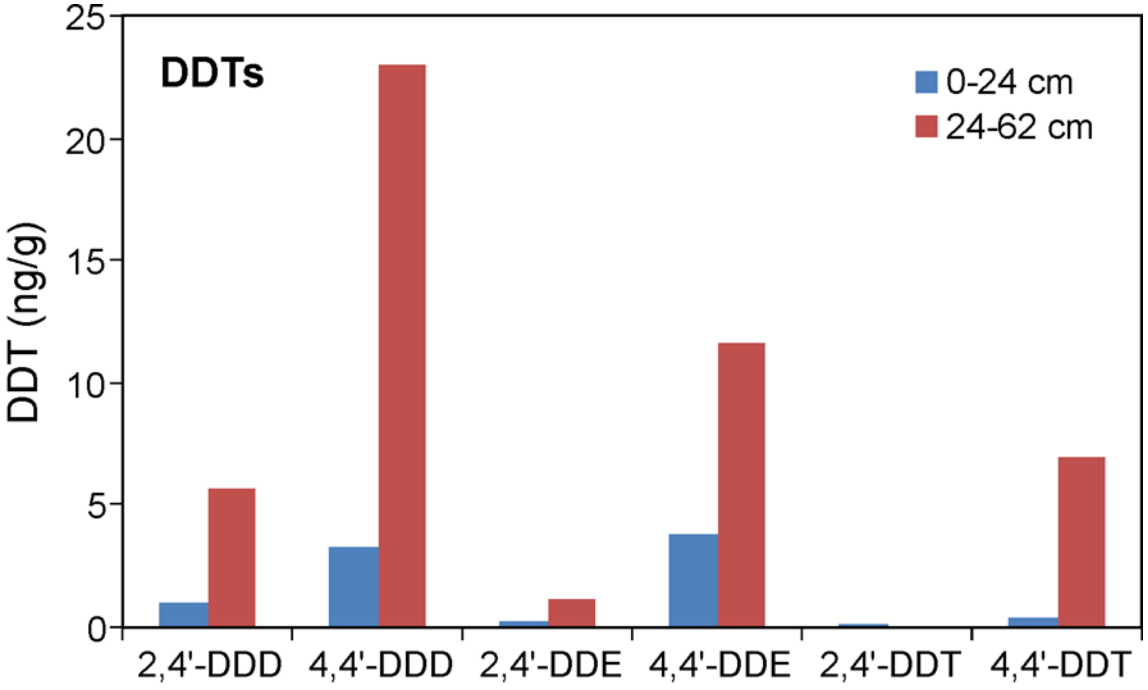
PAHs. Aromatic hydrocarbons have long been of environmental concern due to their toxicities and carcinogenicities. In the environment, these compounds come predominantly from two sources – combustion (e.g., burning of biomass, or burning of liquid and solid fuels) and petrogenic (e.g., formation in sediment and rock containing organic matter, usually involving long periods of time and elevated temperatures). Each of these processes tends to produce different compound compositions, which can be used as a way to infer source (e.g., Yunker et al., 2002). For the Reay Creek Pond sediments, the pooled sample from the top of the core had a ∑PAH of 18 µg/g compared to <1 µg/g in the deep sediments (in this case, ∑PAH refers to the sum of 14 parent PAHs included in list used by the United States' Environmental Protection Agency (USEPA) (and see Figure 8; Table 5). The source of these PAHs is probably multifold, including nearby combustion, small oil spills, crank-case oil/street runoff, and local use of creosote as a wood preservative. For comparison, a survey of lakes in the Fraser River drainage basin, some of which had adjacent roads and industry, and the Strait of Georgia, yielded ∑PAH concentrations usually much less than 1 µg/g (Yunker and Macdonald, 2003).

Figure 8. PAH concentrations for the14 parent PAHs measured in the pooled sediment samples (0-24 cm and 24-62 cm).



Pesticides. DDT is, perhaps, the classic pesticide that precipitated awareness of the danger of persistent, bioaccumulating, toxic (PBT) substances on non-target species when released broadly to the environment. DDT came into prominent use during and after the Second World War, but was banned in the USA for agricultural use in 1972, and later banned worldwide for such use under the Stockholm Convention in 2004 (Table 2). DDT was used in BC during the 1950s and 60s, both locally and by aerial spraying (e.g., Macdonald et al., 2000). The family of DDT compounds found in the environment consists of DDT itself, DDE (produced by metabolism under oxic conditions) and DDD (produced under anoxic conditions in sediments). Accordingly, the distribution of DDT/DDE/DDD compounds is often used to infer how fresh/recent the DDT is, and how the weathering of DDT has occurred after release. For Reay Creek Pond, ∑DDT concentrations were determined at 8.7 ng/g and 48 ng/g for top and bottom segments of the sediment core (Table 4). Higher concentrations in the older material at the bottom of the core are not surprising given the prevalent and sometimes casual use, commercially and privately, back in the 1940s-50s compared to post-1970. An interesting feature of the DDT profiles (Figure 9) is that the deep sediment contains DDD >> DDE > DDT, suggesting that fairly fresh DDT originally entered those sediments, but that much of the DDT then metabolized to DDD within the sediments after burial. Surface sediments contain amounts in the order DDD ≈ DDE > DDT suggesting that both oxic and anoxic metabolism have played a role in weathering the DDT before and/or after burial. Very low, but detectable, concentrations of other pesticides like the chlordanes, HCHs, and mirex were also found, but toxaphene was not detected.

Figure 9. DDT compounds measured in the pooled sediment samples (0-24 cm and 24-62 cm).



PFOS (perfluorooctanesulfonic acid or perfluorooctane sulfonate) compounds have been used widely as fluorosurfactants to protect fabrics from staining (e.g., Scotchgard). These compounds have also been used in metal plating and fire-fighting foams. First produced in 1949 (Table 2), they began to be recognized for their PBT risks in the environment in the late 1960s and were phased out of use in the USA after about 2000. These compounds were added to the Stockholm Convention Annex B in 2009. Given that history, it is not surprising that PFOS compounds are more prevalent in the top of the sediments.

Discussion

In addition to a number of physical alterations, including the removal of overburden to produce the pond in 1935, Reay Creek Pond has been the recipient of numerous industrial chemical contaminants. Many of these contaminants attain relatively high concentrations including in particular Cd and Zn, PCBs/PBDEs and parent PAHs. The contaminating sources are likely mixed, and have certainly operated on pond sediments over different periods of time. At about the time the pond was built, it is likely that it was already the recipient of Cd, PCB and DDT contamination. After construction of the pond, Zn became a dominant metal contaminant, and both PAHs and PBDEs increased to high concentration in upper parts of the sediments. In the case of PAHs, the probable effects levels occur for some of the parent PAHs at ≤1 µg/g concentrations (Yunker and Macdonald, 1995; Long and Morgan, 1990), which is well below the ∑PAHs (18 µg/g). For metals, Table 3b shows that As, Cu and Hg are not of great concern. Pb exceeds some of the quality guidelines but meets others. The prominent concern for Reay Creek, however, is Cd, which grossly exceeds all sediment guidelines. Zn and Cr also exceed guidelines.

Based on the concentration data for contaminants (Tables 3) and the estimates of sediment burden (top and bottom) presently contained in Reay Creek Pond (Table 1) we have estimated the total inventories of contaminants held in the pond sediments (background values have been subtracted from the calculation for the metals) and summarize these in Tables 6a,b. Here, we have assumed that the analyzed sediment core fairly represents the whole sediment burden accumulated within the pond. To gain better confidence in these values it would be necessary to conduct further analyses from other locations in the pond using Figure 2 to select locations containing reasonable accumulations of sediment.

Table 6a Burden of contaminants metals and ΣPAHs in Reay Pond sediments (kg)

Depth in Sediments (cm)	**Cd**	**Pb**	**Cu**	**Zn**	**ΣPAHs**
Top 24 cm	24	41	54	512	18
Deeper sediments	44	9	3	122	1
Total	68	50	57	634	19

Table 6b Burden of organochlorine contaminants in Reay Pond sediments (g)

Depth in Sediments (cm)	**ΣPBDEs**	**ΣPCBs**	**ΣDDTs**	**ΣPFOS**
Top 24 cm	44	81	7	5
Deeper sediments	1	276	63	1
Total	45	357	70	6

Recommendations

- A multi-stakeholder process should be initiated to determine the extent of contamination for the metals of greatest concern (Cd, Zn, Cr) including sediments from the creek bed upstream and downstream of the pond. Notices should also be posted informing the public of the concerns.

- Representatives of all levels of government, local residents and other agencies operating within the drainage basin (e.g., Victoria Airport Authority) should be brought together (e.g., Reay Creek Roundtable) to develop jointly strategies to complete the Reay Creek contamination assessment and recommend a remediation process. These tasks are urgent.

- The Reay Creek Roundtable should develop solutions to the problem of Reay Creek heavy metal contamination that will protect aquatic life, the health of those living nearby and their property values. Stormwater quality and quantity in Reay Creek watershed need to be brought under control as part of the long-term solution.

- Effectively, the only way to remove the threat of toxic metal release from the Reay Creek Pond sediments would be to remove them and place them into permanent containment, which would also secure the other contaminants. Additionally, strategies for removing any contaminated sediments located downstream of the dam in both the Town of Sidney and the District of North Saanich need to be developed.

- Given that the contamination, which originated in the upstream industrial setting, is located in a residential neighborhood, local citizens must be engaged in the process of investigating and remediating the contamination.

- As long as these sediments remain within the pond, activities that would disturb them should be avoided to prevent migration of contaminants and greater risk of exposure to aquatic biota.

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Appendix I

Appendix I Table 1

Reay Creek Pond Sediment Core 1 - September 19th 2013

	Observations During Sectioning			Analysis Sub-Section Groupings				
Depth (cm)	**Comments**	**^{210}Pb**	**Hg (Flynn)**	**Metals**	**PCBs**	**PCN/PBDE /PFOS**	**Dioxin/ Furans**	**PAH**
0 - 2	0-24 greyish black mud, uniform			🟩	🟧	🟦	🟪	🟨
2 - 4	0-24 greyish black mud, uniform	**x**	**x**	🟩	🟧	🟦	🟪	🟨
4 - 6	0-24 greyish black mud, uniform			🟥	🟧	🟦	🟪	🟨
6 - 8	0-24 greyish black mud, uniform	**x**	**x**	🟥	🟧	🟦	🟪	🟨
8 - 10	0-24 greyish black mud, uniform			⬛	🟧	🟦	🟪	🟨
10 - 12	0-24 greyish black mud, uniform	**x**	**x**	⬛	🟧	🟦	🟪	🟨
12 - 14	0-24 greyish black mud, uniform			🟦	🟧	🟦	🟪	🟨
14 - 16	0-24 greyish black mud, uniform	**x**	**x**	🟦	🟧	🟦	🟪	🟨
16 - 18	0-24 greyish black mud, uniform			🟧	🟧	🟦	🟪	🟨
18 - 20	0-24 greyish black mud, uniform	**x**	**x**	🟧	🟧	🟦	🟪	🟨
20 - 22	0-24 greyish black mud, uniform			🟫	🟧	🟦	🟪	🟨
22 - 24	0-24 greyish black mud, uniform	**x**	**x**	🟫	🟧	🟦	🟪	🟨
24 - 26	begin coarse woody material, big wood chip			🟪	🟩	🟧	🟥	⬛
26 - 28	sediment going back to finer material	**x**	**x**	🟪	🟩	🟧	🟥	⬛
28 - 30	fine but moving back to coarse, woody chips			🟨	🟩	🟧	🟥	⬛
30 - 32	fine but moving back to coarse, woody chips,	**x**	**x**	🟨	🟩	🟧	🟥	⬛
32 - 34	90% pure wood chips and bits			🟨	🟩	🟧	🟥	⬛
34 - 36				🟨	🟩	🟧	🟥	⬛
36 - 38				🟨	🟩	🟧	🟥	⬛
38 - 40	quite sandy			🟧	🟩	🟧	🟥	⬛
40 - 42	less wood, more sand			🟧	🟩	🟧	🟥	⬛
42 - 44	more fine material, aluminum foil	**x**	**x**	🟧	🟩	🟧	🟥	⬛
44 - 46	creosote? Separate sample taken.			🟧	🟩	🟧	🟥	⬛
46 - 48	less creosote smell, almost no chips, less sand, drier material, small white globular flecks (separate sample)			🟦	🟩	🟧	🟥	⬛
48 - 50	sandy mud, no smell, much like top of core	**x**	**x**	🟦	🟩	🟧	🟥	⬛
50 - 52	oil smell and sheen, a bit sandy/gritty			🟦	🟩	🟧	🟥	⬛
52 - 54	more oily material			🟦	🟩	🟧	🟥	⬛
54 - 56	less oily, some grit, some woody bits, but mostly dirt			🟦	🟩	🟧	🟥	⬛
56 - 58	no smell, more dirt, less sawdust, dry and firm	**x**	**x**	🟦	🟩	🟧	🟥	⬛
58 - 60				🟦	🟩	🟧	🟥	⬛
60 - 62		**x**	**x**	🟦	🟩	🟧	🟥	⬛
62 - 64	Bottom of core							

Appendix II

Analytical Methodology Sources (available on request along with Excel spreadsheets of the data (Ian Bruce))

Radionuclides (^{210}Pb, ^{226}Ra, ^{137}Cs): Summary of Pb-210, Ra-226 and Cs-137 Methods as performed at Flett Research Ltd, Winnipeg, Canada Last Modified by X. Hu on March 26, 2014

Metals:

PCBs: as described in Summary of AXYS Method MLA-010 Rev 11 Ver 03: Analytical method for the determination of 209 PCB congeners by EPA Method 1668A1, EPA METHOD 1668C2 or EPA method CBC01.23.

PBDEs: as described in Summary of AXYS method MLA-033 Rev. 06 Ver. 02: Analytical method for the determination of brominated diphenyl ethers (BDE) and other brominated flame retardants (BFR).

PAHs: as described in Summary of AXYS Method MLA-021 Rev. 12 Ver. 03: Analytical method for the determination of polycyclic aromatic hydrocarbons (PAH), alkylated polycyclic aromatic hydrocarbons, and alkanes.

Pesticides: Summary of AXYS Method MLA-028 Rev 06 Ver 07: Analytical procedures for organochlorine pesticides by isotope dilution HRGC/HRMS.

PFOS: Summary of AXYS Method MLA-041 Rev. 09 Ver. 03: Analytical Procedure for the Analysis of Perfluorinated Organic Compounds in Solid Samples by LC-MS/MS.

global environmental solutions

Calgary, AB
1185-10201 Southport Rd SW
Calgary, AB T2W 4X9
Canada
Tel: (403) 266-2030
Fax: (403) 263-7906

Edmonton, AB
6940 Roper Road
Edmonton, AB T6B 3H9
Canada
Tel: (780) 490-7893
Fax: (780) 490-7819

Grande Prairie, AB
10015 102 Street
Grande Prairie, AB T8V 2V5
Canada
Tel: (780) 513-6819
Fax: (780) 513-6821

Kamloops, BC
8 West St. Paul Street
Kamloops, BC V2C 1G1
Canada
Tel: (250) 374-8749
Fax: (250) 374-8656

Kelowna, BC
200-1475 Ellis Street
Kelowna, BC V1Y 2A3
Canada
Tel: (250) 762-7202
Fax: (250) 763-7303

Markham, ON
200 - 300 Town Centre Blvd
Markham, ON L3R 5Z6
Canada
Tel: (905) 415-7248
Fax: (905) 415-1019

Nanaimo, BC
9-6421 Applecross Road
Nanaimo, BC V9V 1N1
Canada
Tel: (250) 390-5050
Fax: (250) 390-5042

Prince George, BC
1586 Ogilvie Street
Prince George, BC V2N 1W9
Canada
Tel: (250) 562-4452
Fax: (250) 562-4458

Regina, SK
1048 Winnipeg Street
Regina, SK S4R 8P8
Canada
Tel: (306) 525-4690
Fax   (306) 525-4691

Saskatoon, SK
620-3530 Millar Avenue
Saskatoon, SK S7P 0B6
Canada
Tel: (306) 374-6800
Fax: (306) 374-6077

Vancouver, BC (Head Office)
200-1620 West 8th Avenue
Vancouver, BC V6J 1V4
Canada
Tel: (604) 738-2500
Fax: (604) 738-2508

Victoria, BC
6-40 Cadillac Avenue
Victoria, BC V8Z 1T2
Canada
Tel: (250) 475-9595
Fax: (250) 475-9596

Winnipeg, MB
1353 Kenaston Boulevard
Winnipeg, MB R3P 2P2
Canada
Tel: (204) 477-1848
Fax: (204) 475-1649

Whitehorse, YT
6131 6th Avenue
Whitehorse, YT Y1A 1N2
Canada

Yellowknife, NT
Unit 44, 5022 49 Street
Yellowknife, NT X1A 3R8
Canada
Tel: (867) 765-5695