DELTAPORT THIRD BERTH
ADAPTIVE MANAGEMENT STRATEGY
2007 ANNUAL REPORT

Prepared for:
VANCOUVER FRASER PORT AUTHORITY
100 The Pointe
999 Canada Place
Vancouver, BC V6C 3T4

Prepared by:
HEMMERA
250 – 1380 Burrard Street
Vancouver, BC V6Z 2H3

and

NORTHWEST HYDRAULIC CONSULTANTS
30 Gostick Place
North Vancouver, BC V7M 3G3

and

PRECISION IDENTIFICATION BIOLOGICAL CONSULTANTS
3622 West 3rd Avenue
Vancouver, BC V6R 1L9

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EXECUTIVE SUMMARY

At the request of the Vancouver Fraser Port Authority, Hemmera, Northwest Hydraulics (NHC) and Precision Identification (Precision) are pleased to provide the 2007 Adaptive Management Strategy (AMS) Annual Report for the Deltaport Third Berth (DP3) construction project. This report documents the first year of the AMS. The objective of the annual report is to provide a summary of the information attained in the first year along with interpretation of these results, and recommendations for adapting the program for the second year of monitoring.

The main components of the AMS monitoring program include: monitoring of coastal geomorphology, surface water and sediment quality, eelgrass distribution, benthic community structure, and coastal seabird/shorebird composition. As summarized below, to date, the findings from these components have not shown compelling evidence to suggest that the DP3 construction activities are contributing to significant widespread adverse effects within the inter-causeway area.

COASTAL GEOMORPHOLOGY

The coastal geomorphology portion of the AMS includes the following activities:

- Monitoring of the area around the Crest Protection Structure;
- Automated monitoring of turbidity in the water column on the tidal flats;
- Monitoring of erosion and deposition on the tidal flats in the immediate vicinity of the new terminal;
- Collection and analysis of sediment samples for changes in grains size and organic carbon content;
- Interpretation of orthophotographs for the purpose of detecting large-scale geomorphic adjustments to the study area; and
- Coastal geomorphology mapping, consisting of hydrographic and topographic surveys.

The results of the first year of geomorphology monitoring indicated that the magnitude of sediment deposition and erosion within the study area was low, typically less than 10 cm. Similarly, suspended sediment concentrations were low. The most dynamic areas within the study area, the system of dendritic channels draining into the turning basin, were related to pre-existing processes and were not related to DP3 construction activities. The exception was the formation of new drainage channels in response to the short-term drainage of water from behind the perimeter dyke prior to filling. These channels have begun to stabilize but it is not clear, at this time, if tidal drainage within the channels will persist into the future.

Recommended changes to the coastal geomorphology program include:

- An additional six DoD rods to provide increased resolution about sedimentation and erosion trends in the area of the new drainage channels,
- Quarterly crest protection monitoring be reduced to twice yearly during (Q1 and Q3) and that photographs be taken during only one of these monitoring periods (Q3); and
- The automated turbidity monitoring program be discontinued after collection of the Q4-2008 monitoring data.

SURFACE WATER AND SEDIMENT QUALITY

Seven surface water and sediment quality monitoring stations were established: one in a ditch that drains into the inter-causeway area near the base of the BC Ferries Causeway; four inter-causeway stations; and two reference stations (intertidal and subtidal). The quarterly monitoring events took place on the following dates:

- Q1-2007: March 22 to 24, 2007
- Q2-2007: June 20 to 21, 2007
- Q3-2007: October 1 and 2, 2007
- Q4-2007: December 10, 2007

In addition to comparison to regulatory guidelines, a 20% difference both spatially and/or temporally was used to gauge the potential for surface water and sediment impacts from DP3 construction.

Copper and zinc were the only two surface water metals guideline exceedances that were significant. Upland drainage from the DP01 ditch may be a source for copper and zinc levels in surface water but is not related to the construction of DP3. Arsenic and cadmium concentrations in the inter-causeway area were generally higher (by more than 20%) than the reference station but barium, copper, lead and zinc were lower than the reference stations. There was no consistent temporal pattern in metals concentrations. If no trends specifically related to DP3 construction are observed at the end of 2008, then it is recommended that metals parameters be dropped from the AMS surface water quality program.

Nutrients were generally higher in the inter-causeway area than at the reference stations but there is insufficient data given only one year (4 seasons) of sampling to establish trends with respect to eutrophication. The difference between the inter-causeway stations and the reference stations may be a function of the sheltered environment created by the two causeways, rather than eutrophication.

There were no metals exceedances of the BC Contaminated Sites Regulation sediment guidelines; however, the results of a lithium geonormalizing technique (to distinguish between external metals inputs and natural variations) suggested potential minor upland metals impacts (copper and zinc) from DP01, consistent with the surface water data. Metals concentrations in inter-causeway sediments were consistently lower that those of the reference stations. There is no current evidence of metals impacts from DP3. If no metals trends related to DP3 are observed by the end of 2008, it is recommended that these parameters be dropped from the AMS sediment quality program.

For all nutrient parameters except phosphate, inter-causeway sediment concentrations were consistently higher than the reference stations. Phosphorus concentrations were lower. There was no clear spatial or temporal trend in redox values which were generally between–100 mV and –200 mV except for DP06 which ranged from –20 mV to –60 mV. Although there were elevated nutrients in the inter-causeway area, there is currently insufficient data to determine a trend towards eutrophication.

EELGRASS

The epiphyte load, *Z. marina* and *Z. japonica* distribution, and the absence of *Beggiatoa* sp. indicate that the eelgrass habitat was in good condition. A reduction in shoot length was recorded for most of the inter-causeway and the reference stations, although this was not always statistically significant. Mean widths were less at all six of the Roberts Bank sites, although the decrease was not significant at two of the inter-causeway sites. These trends are likely due to a large-scale environmental factor, and not related to DP3.

The Leaf Area Index (LAI) values for the 2007 survey of the inter-causeway areas were not significantly different than the 2003 estimates, indicating that the inter-causeway eelgrass population had not been negatively impacted at any of the stations. Comparison of the 2007 and 2003 eelgrass habitat maps revealed that eelgrass habitat loss has occurred near the dendritic channels. This is likely due to the evolution of these systems and not caused by DP3 construction.

The *Z. marina* distribution in the new drainage channel area adjacent to the DP3 footprint was reduced relative to 2003; however it is likely that the surviving shoots will naturally restore many of these areas. The extent to which *Z. marina* will be able to naturally recolonize will depend mainly on the final elevation of the substrate (once the area has stabilized) and the velocity of water within the channels. An area between the crest protection and the Deltaport causeway that was unvegetated in 2003 has since been colonized by *Z. japonica*.

No changes to the eelgrass survey program are recommended.

BENTHIC INVERTEBRATE COMMUNITY

The benthic invertebrate populations in both the inter-causeway area and the reference area appeared diverse, healthy and well established. Variations in total abundance and the number of taxa did not appear to be directly influenced by substrate type or sulphide concentrations. One intertidal station (DP08) has been added to the benthic community sampling for 2008. Surface water and sediment at this station will be sampled only during benthic invertebrate sampling events.

COASTAL SEABIRDS/SHOREBIRD COMPOSITION

During the spring and summer, great blue heron are dependent upon the tidally exposed eelgrass within the inter-causeway area for foraging. Brant geese used the inter-causeway area for feeding on eelgrass, obtaining gravel, and resting. Flocks of up to several hundred brant were observed offshore along the TFN transect during November and December 2007. Between March and May, brant were recorded in large flocks in deeper water. Brant were essentially absent between June and October. Shorebirds forage on exposed mudflat and roost along the perimeter of the inter-causeway area and Dunlin were observed roosting on the newly constructed perimeter dyke during both high and low tides. Dabbling ducks were recorded in mixed flocks throughout the inter-causeway area with the greatest densities along the TFN transect between October and December. Diving ducks and other coastal waterbirds were recorded offshore along the Deltaport and BC Ferries causeways.

Impacts to coastal seabirds and waterfowl appear limited to direct habitat loss associated with the DP3 footprint as predicted by the environmental assessment. Observations during the 2007 survey period indicate that, in response, birds used alternative habitat available within the inter-causeway area.

Recommended adaptations to the AMS bird monitoring program include:

1. Change the categories for all point counts to 0 – 250 m, 250 - 500m, and 500m - 1km.
2. Discontinue point counts along the BC Ferries Causeway transect.
3. Retain the TFN transect but reduce the number of point counts from 5 to 3.
4. Reduce the frequency of survey events from bi-weekly to once every four weeks with the exception of a six-week window during spring western sandpiper migration (April – May).
5. Reduce the winter surveys from December to February to one tidal event per survey.
6. Complete seasonal species-specific “windshield” surveys during the regular monthly sampling events for brant and great blue heron when these species are most abundant in the survey area.

ACKNOWLEDGEMENTS

Hemmera gratefully acknowledges the contributions of additional project team members including:

Coastal Geomorphology: Northwest Hydraulic Consultants Ltd.
30 Gostick Place
North Vancouver, BC V7M 3G2

Eelgrass Assessment: Precision Identification
3622 West 3rd Avenue
Vancouver, BC V6R 1L9

Vessel Services: Ross Wetzel
18341 72nd Avenue
Surrey, BC V4N 3G6

Analytical Laboratory: ALS Environmental
1988 Triumph Street
Vancouver, BC V5L 1K5

Biological Laboratory: Biologica Environmental Services Ltd.
Suite H50 Nootka Ct.
634 Humboldt Street
Victoria, BC V8W 1A4

In addition, Hemmera would also like to acknowledge the effort and contributions of the following individuals:

Vancouver Fraser Port Authority

Darrell Desjardin, Director of Environment

Carolina Eliasson, Environmental Specialist

Scientific Advisory Committee

Rowland Atkins, M.Sc. P.Geo.
Senior Geomorphologist, Golder Associates Ltd.

Terri Sutherland, Ph.D.
Research Scientist, Science Branch, Department of Fisheries and Oceans

Ron Ydenberg, Ph.D.
Dept of Biological Sciences, Simon Fraser University

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1.0 INTRODUCTION

At the request of the Vancouver Fraser Port Authority (VFPA), Hemmera, Northwest Hydraulics (NHC) and Precision Identification (Precision) are pleased to provide the Deltaport Third Berth (DP3) construction project 2007 Annual Report for the Adaptive Management Strategy (AMS). This report documents the first year of implementation of the AMS. The objective of the report is to provide a summary and interpretation of the results of quarterly monitoring programs completed in 2007 at Deltaport.

1.1 BACKGROUND

1.1.1 DP3 Project Description

Deltaport is a marine container terminal located on Roberts Bank in Delta, BC (**Figure 1**). The DP3 project consists of construction to accommodate an additional ship berth along with approximately twenty hectares of land for an expanded container storage yard. It will also include dredging to deepen the existing ship channel and creation of an adjacent tug moorage area. Rail and road improvements will also be required along the Deltaport causeway to minimize project impacts on existing traffic flow.

The major construction activities and their schedule at Deltaport during 2007 included the following:

Mobilization	January 2007
Perimeter Dyke Construction	January 2007 - May 2007
Dredging (disposal) - Approach Channel (Phase 1)	March 2007 - April 2007
Dredging (disposal) - Tug Basin	April 2007
Tug Basin Construction	March 2007 - August 2008
Dredging (disposal & fill) - Caisson Trench	April 2007 - February 2008
Caisson Fabrication	June 2007 - November 2007
Caisson Mattress Construction	June 2007 - May 2008
Marine Densification	August 2007 - June 2008
Terminal In-fill	September 2007 - August 2009
Site Pre-loading	October 2007 - December 2008
Tug Basin Construction	March 2007 - August 2008

The DP3 project was subject to both the provincial *British Columbia Environmental Assessment Act* and the federal *Canadian Environmental Assessment Act*. The environmental assessment involved a large number of studies including coastal geomorphology, water quality, sediment quality, marine resources, coastal seabirds and waterfowl, vegetation and wildlife, archaeology, socio-economics, noise, visual and lighting, air quality, and road, rail and ship traffic. This report is available from the BC Environmental Assessment Office (EAO) website (http://www.eao.gov.bc.ca/). As part of the acceptance of the environmental assessment by the BC Environmental Assessment Office were recommendations by Environment Canada - Canadian Wildlife Service (CWS) that an AMS be developed to provide practical advance warning of potential emerging negative ecosystem trends during project construction and operation. The AMS program is being implemented by a project team led by Hemmera with subcontractors NHC and Precision.

1.1.2 AMS Project Objectives

The objectives of the AMS project are to undertake a science based systematic approach to Roberts Bank inter-causeway ecosystem to reduce uncertainty and assess the potential for negative trends in the ecosystem from marine eutrophication and dendritic channelization. This approach should:

1. provide practical advance warning of potential emerging negative ecosystem trends during DP3 construction and operation, and
2. establish actions that VFPA would undertake to prevent or mitigate negative trends that are linked to the DP3 project and found to exceed applicable thresholds.

The AMS includes monitoring methods to specifically identify and mitigate potential environmental effects in the following areas of concern (the AMS project team member completing the work is shown in brackets):

- Coastal geomorphology (NHC)
- Surface water quality (Hemmera)
- Sediment quality (Hemmera)
- Eelgrass distribution (Precision)
- Benthic community structure (Hemmera)
- Coastal seabird / shorebird composition (Hemmera)

1.2 SCOPE OF WORK

The AMS support program has been implemented to address concerns and meet requirements of stakeholders such as Environment Canada (EC), the Department of Fisheries and Oceans (DFO) and the CWS as well as other legislation, guidelines, and best management practices applicable to the work. The AMS involves the identification, management, prevention, and mitigation of environmental effects that may result from DP3 construction. The AMS program also undergoes an independent peer review by a Scientific Advisory Committee (SAC), comprised of scientists with expertise in the various study areas of the AMS, appointed by VFPA and EC.

The scope-of-work for the annual report involved completion of the following tasks:

- Analysis of quarterly data from coastal geomorphology/oceanography monitoring and crest protection monitoring.
- Analysis of quarterly data from surface water quality monitoring
- Analysis of quarterly data from sediment quality monitoring
- Analysis of eelgrass data collected in September 2007
- Analysis of benthic invertebrate community data collected in March 2007
- Analysis of quarterly data from bi-weekly coastal seabird / shorebird composition surveys to monitor brant geese, great blue heron, coastal seabirds, waterfowl, and other birds
- Summarizing the quarterly monitoring data collected over the year
- Evaluating the data relative to the objectives of the AMS program. Data evaluation included looking at both temporal and spatial trends in the data observed during the year as well as comparison to data collected from previous years, where applicable.
- Providing recommendations for adaptations to the AMS program based on the findings to date.

1.3 FIELD METHODOLOGIES

The detailed field methodologies for the various survey and sampling methods are included in the Detailed Workplan document prepared for the VFPA by Hemmera (2007a) and a summary is also attached in **Appendix A**. The following sections provide some of the basic methodology along with any methodological variations that were necessary for completion of the work.

1.3.1 Coastal Geomorphology

Relevant data on conditions prior to the commencement of DP3 construction (without project condition) includes the following:

- Orthophoto mapping from 2005 and 2002;
- Bathymetric charts covering portions of the area from 2006, 2002 and earlier;
- Current velocity transects carried out in 2004 by NHC;
- Sediment samples at portions of the tidal flats collected in 2004 and in previous studies.

This information was collected in support of other ongoing projects or studies such as the Coastal Geomorphology Study (NHC, 2004). These data provide very important background information on pre-project conditions in the study area but were not collected as part of a systematic long-term monitoring program. Due to timing constraints, the AMS monitoring activities commenced in April 2007, shortly after the start of DP3 construction. Therefore, the 2007 monitoring program captures conditions during the initial construction phase. It is expected that any long-term effects of DP3 would take several years to develop and evolve. Therefore, the available historic data and 2007 AMS monitoring is considered adequate to detect and define long-term effects.

The AMS coastal geomorphology monitoring program includes six primary activities:

- Monitoring of the area around the Crest Protection Structure.
- Monitoring of turbidity in the water column on the tidal flats.
- Automated monitoring of erosion and deposition on the tidal flats in the vicinity of the new terminal.
- Collection and analysis of sediment samples for changes in grain size.
- Interpretation of orthophotographs for the purpose of detecting large-scale geomorphic adjustments in the study area.
- Coastal geomorphology mapping, consisting of hydrographic and topographic surveys.

Monitoring of the Coastal Geomorphology activities began in April 2007. The following sub-sections provide a summary of the methodology and timing for each monitoring activity. A detailed description of the methodology is presented in **Appendix A**.

1.3.1.1 Crest Protection Monitoring

Monitoring of the Crest Protection Structure is a quarterly activity conducted by NHC and consists of a field reconnaissance during very low tide conditions. Crest Protection Monitoring activities involved collection of cross-section surveys as well as photographs that are taken at previously established sites. **Figure 2** shows the locations of the monitoring cross-sections as well as the monitoring points on the Crest Protection Structure and **Table 1** shows the coordinates of the monitoring points. A Real-Time Kinematic Global Positioning System (RTK GPS) is used to navigate to monitoring cross-sections for repeat measurements. Very low tides occur only at night during the winter months from late September to mid-February. Cross-section surveys were carried out as part of the monitoring but effective photography of the Crest Protection Structure is not possible at night, and as a result, visual inspection of the crest protection structure was not supplemented with a photographic record during the winter monitoring periods (Q3-2007 and Q4-2007).

1.3.1.2 Automated Turbidity Monitoring

Water turbidity is monitored continuously at two fixed locations in order to provide a proxy record of sediment transport across the tidal flats. Turbidity provides only a proxy for sediment concentrations because it is affected by a number of factors such as grain size, material type, and organic content. Therefore, a location-specific curve needed to be derived in order to relate the measured turbidity to the concentration of total suspended solids (TSS). To address this requirement, the AMS Detailed Workplan included a task for periodic collection of water samples during a tidal cycle. Preliminary field data collection showed that this method would not be successful, mainly due to the low turbidity levels in the inter-causeway portion of Roberts Bank. Capturing the rare occurrence of higher turbidity levels would require extensive field time, and without measuring these higher turbidity levels, extension of the curve would not be valid. NHC's memo of November 2007 (NHC, 2007b), which was presented in the Q3-2007 report, offers a rationale for revising this methodology. The revised methodology was reviewed and approved by the SAC and the VFPA. With the development of a TSS-Turbidity relationship using laboratory measurements (**Figure 3**), the collection of water samples was discontinued. Turbidity monitoring stations provide a continuous record of measured turbidity from which TSS can be computed using the expression x=y/0.5123 (where x=TSS and y=turbidity)

Two Analite NEP495 Turbidity Logging Probes have been installed in their present location since July 12, 2007 (shown in **Figure 4**). The elevation at each instrument is approximately 0.5 m Chart Datum (CD). The sensors are located 20 cm above the bed level in order to document near-bed sediment transport characteristics. The turbidity values (in NTU units) are recorded at 15 minute intervals. Data were successfully downloaded from Sensor 2 during each quarterly monitoring visit. On two occasions, inspection of Sensor 1 revealed that water had penetrated the instrument, resulting in loss of data over certain periods of the 2007 monitoring program. Data was not retrievable from this sensor for the period between August 23 and September 6, 2007 and after October 3, 2007.

Tidal flow is thought to be one of the most important processes affecting the physical environment at Roberts Bank. A local tide gauge was installed on a berth caisson at Deltaport on June 14, 2007 to provide information to supplement interpretation of the turbidity data. The instrument was placed inside a white plastic pipe and attached to a rope that extends to the top of the caisson for retrieval during high tides. Human tampering with the tide gauge has occurred on two occasions and has been documented in the quarterly monitoring reports. The result is missing data for the periods from August 23 to September 6, 2007, and October 24 to October 28, 2007. Modifications made to the gauge installation should prevent further tampering and loss of data, however, retrieval at high tide is no longer possible.

1.3.1.3 Monitoring of Erosion and Deposition

The pattern of erosion and deposition over the portion of Roberts Bank adjacent to DP3 terminal is monitored using an array of depth of disturbance (DoD) rods. These consist of a smooth rod with a washer placed over the rod resting at the sediment surface. Burial or scour of the washer is measured relative to the top of the rod. The bottom of the rod is buried well below the maximum expected depth of disturbance. The rods are inspected on a quarterly basis to record the rate of scour and/or fill and to clear any vegetation that may build up on the rod.

Twenty-six DoD rods were installed in April 2007 **(Figure 5)**. An RTK GPS was used to navigate to the DoD rods during low tides. Monitoring consists of measuring the depth of scour or burial relative to the top of the rod using a steel tape. At locations where the washer is buried, the surrounding sediment is excavated by hand to expose the washer and then subsequently re-graded to the level of the surrounding surface to reset the washer height. Any significant amount of eelgrass or weed accumulation is recorded. A comparison with previous measurements taken at the DoD rods indicates the magnitude of deposition or erosion, if any, at each site. A photograph is taken at each installation site to record the general site conditions as well as the specific condition of the DoD rod.

1.3.1.4 Sediment Samples

Collection of sediment samples is included as part of the AMS geomorphology monitoring to characterize changes to the grain size of near-surface sediments. Samples are collected twice a year, once in the early spring and again in late August to be representative of conditions during the lower-energy, post-Fraser River freshet season. Initial sampling was conducted in April and then in October 2007 in conjunction with monitoring of the DoD rods. The first set of samples was collected at a distance of 5 m to the north of the DoD rods, while the second sampling took place at a distance of 5 m to the south of each rod. Subsequent sampling will rotate about the rods to avoid re-sampling in the same location. Samples were photographed, stored in containers, and brief sedimentological descriptions were noted. Samples were sent to a commercial lab to be analyzed for particle size as well as organic content.

1.3.1.5 Interpretation of Ortho Photographs

Aerial photographs of the study area are scheduled to be taken on a yearly basis during summer low tides. The 2007 photos were flown in July. These photos are evaluated annually to assess trends and patterns of erosion and/or accretion on the tidal flats. The methodology consists of overlaying successive ortho-rectified photographs using GIS mapping techniques to delineate and identify morphological changes on the tidal flats. A set of systematic mapping protocols was developed to map geomorphic features on the 2007 orthophotos. These mapping protocols are similar to those that were used in previous mapping exercises conducted as part of the DP3 environmental assessment for the VFPA, which assists in making a comparison to previous conditions. Mapping was completed by a geomorphologist who is familiar with the physical environment of Roberts Bank.

1.3.1.6 Coastal Geomorphology Mapping

Coastal geomorphology mapping is included as part of the AMS geomorphology monitoring to assess topographic changes due to long-term erosion or accretion of the inter-causeway tidal flats in the general vicinity of DP3. A combined bathymetric and topographic survey of the tidal flats using RTK GPS positioning began on July 8, 2007, taking advantage of a tide cycle that included reasonably high tides for several days followed by several days of low tides. The hydrographic survey portion of the project was not completed due to very high winds and the resulting large waves. Between July 10 and July 13, 2007, ground surveys were conducted using two RTK GPS units to survey in areas where bathymetric survey quality would be low due to high eelgrass densities. A hydrographic survey was scheduled to be conducted on October 1 to capture the remaining areas but high winds and waves persisting for several days prevented completion of the survey. A subsequent bathymetric survey was conducted on November 7, 2007 to complete the remaining areas. Additional survey data was collected in the area of the new drainage channels by the VFPA Engineering Department on June 25, July 3, and July 12, 2007. This information was not required for the analysis in this report as this area was surveyed in detail by NHC. Based on a detailed review of the DoD rods, crest protection surveys and previous surveys carried out in 2006 and 2007 it was found that topographic changes on the tidal flats have been very small. Therefore, the gap in the surveys between July and October should not affect the interpretation of the survey results.

1.3.1.7 Wave and Current Monitoring

The wave and current meter (AWAC) was destroyed during the fall 2007 and as a result, no data was received. NHC has issued a memo proposing an alternative wave and current monitoring program in the Q3-2007 report. The alternate program has been reviewed and approved by VFPA and the SAC and is discussed further in **Section 4.1.4**.

1.3.2 Surface Water Quality

Surface water samples were collected by Hemmera at the seven fixed surface water and sediment monitoring stations illustrated on **Figure 6** on the following dates:

- Q1: March 22 to 24, 2007
- Q2: June 20 to 21, 2007
- Q3: October 1 and 2, 2007
- Q4: December 10, 2007

A representative surface water sample was collected one metre below the surface at each sampling station using a Van Dorn sampler. At the subtidal sampling stations, a second surface water sample was collected two metres above the seafloor. At DP01, located in a tidally influenced drainage ditch discharging to the inter-causeway area, samples were collected from 0.5 m below surface from under the dyke bridge (**Figure 7**). Samples were collected as outlined in the methodology presented in **Appendix A**.

The parameters analyzed for each surface water sample included:

- Temperature
- pH
- Hardness
- Salinity
- Metals
- Chlorine[1]
- Turbidity and total suspended solids (TSS)
- Nutrients (Phosphate, Phosphorus, Ortho-phosphorus, Total Kjeldahl Nitrogen [TKN], Total Nitrogen, Ammonia, Nitrate, Nitrite and Organic Nitrogen)
- Clarity (via secchi disc)
- Chlorophyll *α*

Polycyclic aromatic hydrocarbons (PAHs) were also analyzed in Q1-2007. The detailed methodology and the field and laboratory quality assurance and quality control (QA/QC) measures are as outlined in **Appendix A**.

The area station nearest the DP3 construction area (DP04), was also monitored continuously for a number of water quality parameters (pH, temperature, conductivity, dissolved oxygen, and turbidity) using a YSI 6600V2 buoy-mounted sonde operated in conjunction with the DP3 construction environmental monitoring program. This sonde was lost in September 2007. Therefore, limited data was available for Q3-2007 and no data was available during the Q4-2007. A replacement sonde was ordered and has since been deployed at the site. Data will be available starting with the Q2-2008 event.

[1] Chlorine was analyzed only in the sample collected at station DP01. The purpose of this parameter relates to the presence of an immediately up-gradient recreational water park and concerns of discharge to the inter-causeway area.

1.3.3 Sediment Quality

Quarterly sediment sampling was completed by Hemmera at the same time as the surface water sampling at the stations illustrated on **Figure 6**. A representative sediment grab sample was collected from each of the seven stations using a Ponar sampler. Sediment samples were analyzed for the following parameters:

- Metals
- Total nitrogen
- Ammonia
- Nutrients
- Redox (Eh)
- Hydrogen sulphide (H_2S)

The detailed methodology and the field and laboratory quality assurance and quality control (QA/QC) measures are as outlined in **Appendix A**.

1.3.4 Eelgrass

1.3.4.1 Distribution and Mapping

Digital orthophotos of the Deltaport area were flown in July but did not become available until late August. Therefore, it was not possible for Precision to interpret the photos prior to the lowest tides of the season. The preliminary orthophoto interpretation was completed during the week of August 27, 2007 and a preliminary base map created. A field survey, to ground truth the photos and base map, was conducted on September 7 and 8, 2007.

1.3.4.2 Monitoring Eelgrass Vigour & Health at the Established Stations

The first annual eelgrass survey was conducted by Precision between July 12 and 16, 2007. Nine stations were sampled; four in the inter-causeway, two west of the Deltaport causeway (**Figure 8**), and three reference stations in Boundary Bay (**Figure 9**). Previous surveys, completed prior to the AMS, included two additional stations west of the Deltaport causeway (5 and 6); these stations were eliminated from the 2007 survey following discussions with the VFPA. The decision was based on the fact that two stations (3 and 4) would be sufficient to monitor local variability outside of the inner causeway, and that the morphology of the eelgrass in the vicinity the two remaining stations was similar to that of the eelgrass in the inter-causeway area.

The inter-causeway stations located near the ferry causeway were assigned the numbers 7 and 8 in the 2003 survey. These two sites were re-assigned the numbers 5 and 6 in the 2007 survey, to reflect the reduction in the total number of sites at Roberts Bank.

Eelgrass density and shoot size varies with elevation. Shoot length and width increase from the intertidal through the subtidal. The smallest shoots within a bed are usually found at the upper intertidal limit, and the largest at the lower subtidal limit. The shoot density tends to be the greatest at locations where the shoots are the smallest (intertidal) and usually decreases with depth as the mean shoot size increases (subtidal).

The three reference stations in Boundary Bay were selected in 2003 to represent eelgrass habitat within the range of the 2003 Roberts Bank study area. Reference Site WR1 is located near the upper limit of the eelgrass bed and provides habitat similar to one of the 2003 reference sites that was not included in the 2007 survey. The reference site WR1 was surveyed in 2007 while waiting for the tide to ebb, providing access to WR2 and WR3. Reference Site WR2 is slightly lower and therefore supports larger plants, while Reference Site WR3 is the deepest and supports the largest plants of the three reference sites in Boundary Bay.

The detailed methodology for the surveys is included in **Appendix A**.

1.3.5 Benthic Community

Hemmera collected and prepared sediment samples for benthic community analysis at six of seven sampling stations on March 22 to 24, 2007 (**Figure 6**). Rough conditions (high winds and waves) during sampling resulted in poor sample recovery at several sampling stations. Benthic invertebrate sediment samples were not collected from station DP01 (**Figure 7**), a tidally influenced freshwater drainage ditch distinct from the other sampling stations. To capture inherent variability potentially present at the stations, three replicates were collected per station for the benthic community sampling. Benthic invertebrate samples were shipped to Biologica Environmental Services (Biologica) for taxonomic identification. The detailed methodology for the benthic invertebrate sampling is included in **Appendix A**.

1.3.6 Birds

The Fraser River delta provides habitat that is international in its significance for a wide variety of birds including waterfowl, shorebirds, coastal seabirds, great blue herons, and raptors. Annually, approximately half a million birds depend on this delta with approximately 1.4 million birds utilizing the delta during the peak of migration (Butler and Campbell, 1987). The Fraser River Estuary, of which Roberts Bank and the inter-causeway area between the Deltaport Causeway and the BC Ferries Causeway are a part, provide critical habitat for the largest wintering concentrations of waterbirds and raptors in Canada (BC Waterfowl

Society 2006). In addition, the Fraser delta has been designated part the Western Hemispheric Shorebird Reserve Network (WHSRN) due to its status as a key stopover point used by shorebirds during migration. The entire worldwide population of western sandpipers (estimated 3.6 million birds) are believed to migrate along the coast of British Columbia (Environment Canada, 2001). Of these birds, between 500,000 – 1,000,000 stage along the Fraser delta during peak spring migration to forage along tidal mudflats where they build up energy reserves needed to reach breeding grounds in the Yukon-Kuskokwim Delta (Butler et al. 2002 and Butler and Lemon 2001). Peak spring migration numbers have declined steadily between 1994 (1,125,000) and 2001 (126,000) as indicated by Butler and Lemon (2001). Due to the potential for disturbance to this habitat, a detailed study of waterfowl and coastal seabirds was conducted as part of the Deltaport Third Berth environmental assessment (VPA, 2005). This document indicated the following potential impacts to waterfowl and coastal seabirds:

- Approximately 6% of the resting/roosting and/or foraging habitat available to waterfowl and coastal seabirds would be lost under the project footprint. Compensation has been planned for this loss of habitat.
- Temporary displacement of resting/roosting and/or foraging habitat for birds using the inter-causeway area during construction. These impacts were not deemed significant given the availability of alternative habitat throughout the remainder of the study area.
- Dredging operations may cause a reduction in prey items for foraging birds near the dredge areas and increased turbidity associated with dredging could affect visibility for foraging birds.
- No significant auditory impacts from construction were expected to waterfowl and coastal seabirds due to acclimation to existing noise levels and the expectation that noise levels resulting from construction would not exceed existing conditions.
- No significant impacts from additional lighting were expected as birds have become acclimated to existing lighting at the port facility.

1.3.6.1 Bird Survey Objectives

The main objectives of this bird study are to provide complementary data towards answering the concern regarding potential marine eutrophication and changes to coastal erosion processes and the distribution and composition of local biota, including shorebirds and coastal seabirds in the inter-causeway area. The bird study data are considered as one indicator of ecosystem structure and function on a relatively broad spatial-temporal scale. Ecosystem changes leading to adverse ecosystem effects (e.g., eutrophication and erosion) that may be attributable to DP3 would likely be first detected through monitoring at a finer scale (e.g., water quality, benthic community, and eelgrass monitoring). However, construction activities can potentially alter bird feeding and/or resting behaviours and bioenergetics, and as such, monitoring bird relative abundance and behaviours in the context of the DP3 construction activity is an important indicator of construction-related effects to a valued component of the ecosystem (birds).

Due to the possibility that changes to the ecosystem over time can be linked to key species such as great blue heron, brant, western sandpiper, and dunlin, monitoring of bird usage within the inter-causeway area is part of the overall strategy to monitor ecosystem structure and function in the inter-causeway area.

To this end, the following study objectives were identified:

1. Determine whether there are impacts to brant geese and great blue heron usage of the inter-causeway area during critical periods of construction and operation.
2. Determine whether there are impacts on coastal seabird and shorebird usage of the inter-causeway area during construction.

1.3.6.2 Methodology

Hemmera conducted 20 bi-weekly surveys (07-01 to 07-20) for waterfowl and coastal seabirds between March and December 2007 on the dates listed in **Table 2**. Each survey consisted of point counts (PCs) of 20 minutes in duration along three transects: South Roberts Bank Transect, herein labelled Deltaport Causeway (DP), Tsawwassen First Nation (TFN) Reserve Lands Transect, and the Tsawwassen Ferry Causeway Transect, herein labelled BC Ferry Causeway Transect (BCF). **Figure 10** outlines the study area and PC stations. Both high and low tide surveys were conducted at each PC during survey events 07-01 to 07-18. As fluctuations between daytime high and low tides became minimal due to the winter tidal regime (essentially high tide all day), Hemmera proposed a temporary change in methodology, from two survey events to a single survey event at each PC as daytime low tides shifted from minimal to negligible. This change was initiated during surveys 07-19 and 07-20 following discussion with the BC Ministry of Environment (MOE) and CWS, with the stipulation that we recognize that several species of shorebirds (primarily dunlin and black-bellied plover) will be underestimated in the survey results (R. Butler and B. Elner pers. comm., 2007). This adaptation is consistent with survey methods used by CWS during 2004 surveys conducted along the Brunswick Marsh Transect, north of the Deltaport Causeway. The original low and high-tide survey schedule was resumed after tidal conditions were more favourable.

Surveys were generally conducted over a one to three-day period, which is consistent with the methodology presented in **Appendix A**; however, this approach was not possible for survey events 07-16 and 07-17 due to weather, daylight, and tidal constraints. During those two events, the surveys were conducted over a five-day period.

2.0 RESULTS

The following sections provide a summary of key findings for the AMS quarterly monitoring events during 2007.

2.1 BACKGROUND INFORMATION

2.1.1 Weather, Tides and Fraser River

Winds, waves, tidal currents and discharge from the Fraser River provide the main driving forces for the physical processes occurring at Roberts Bank. This section provides a brief overview of these parameters over the 2007 monitoring period. Statistical comparisons were made with historic conditions to provide an assessment of the overall frequency and magnitude of these driving forces.

2.1.2 Winds and Waves

Waves in deep water are governed by the wind speed, duration of strong winds and fetch[2] length. Deltaport is exposed to waves from the northwest, west, south west, south and south east. **Figure 11** shows the fetch lengths measured at 10 degree intervals from a point near the offshore end of the terminal. There are no continuous long-term wave or wind measurements at Deltaport. However, hourly wind data for the period April to December 2007 were obtained from Vancouver International Airport. Wave heights and wave periods have been recorded at Halibut Bank by Fisheries and Oceans Canada through the Marine Environmental Data Service (MEDS) program. The Halibut Bank station is located in Georgia Strait approximately mid-way between Nanaimo and Sechelt and 45 km northwest of Deltaport. The combination of wind and wave measurements provides a reasonable basis for characterizing the deepwater wave climate near Deltaport in 2007. The wind speed and direction data were used to hindcast the deepwater wave conditions at the site while the measurements at Halibut Bank provided an independent check on the predictions.

Wind speed and wind direction were tabulated for three periods- April-June (**Table 3**), July-September (**Table 4**) and October-December (**Table 5**). The values in these tables represent the number of observations in each speed class and direction range. The time series of wind measurements was also reviewed to identify specific storm events over the monitoring period. In this case, a storm event was defined as having a wind speed greater than 30 km/hour. **Table 6** summarizes each event in terms of the time period, corresponding tide levels and estimated significant wave height (H_s) and wave period (T_p).

The strongest winds in April-June were from the northwest and west, with seven observations exceeding 40 km/hour (**Table 3**). Strong winds on May 8, May 12 and June 5 were of sufficient duration and intensity to generate waves greater than 1 m (H_s). The strongest winds in July-September were also from west and northwest, with five observations exceeding 40 km/hr. Strong winds on July 9, July 10, September 8,

2 Fetch: the distance that the wind blows across open water

September 22 and September 27 generated waves greater than 1 m in height. The strongest winds in October-December were from the southeast, south, west and northwest. South-easterly winds exceeded 40 km/hour on 10 observations and reached a maximum value of 61 km/hour on November 12th (**Table 6**). Strong winds also occurred from the west, with values exceeding 40 km/hr on 12 occasions, with the maximum value reaching 46 km/hour (on October 24).

The most severe storm event of the year occurred on November 11 and 12 due to sustained southeasterly winds, which exceeded 30 km/hour for 24 hours and exceeded 50 km/hour for over five hours. The highest reported significant wave height (H_s) at Halibut Banks was 2.4 m and the corresponding period (T_p) was 6.4 seconds. The hindcast wave height at Deltaport was (2.5 m). This event had a return period of approximately 4 years (based on the previous hindcasting studies). The storm caused considerable damage to some low-lying coastal areas in part due to the occurrence of a relatively high tide (4.4 m) at 08:00 hr. The storm on November 26 was from the northwest direction with sustained winds reaching to 52 km/hour and exceeding 30 km/hour for a period of eight hours. The station at Halibut Bank recorded only small waves (0.8 m) during this event, while hindcast wave heights at Roberts Bank were estimated to be 2.2 m. Another strong storm event occurred on December 19th and 20th with winds veering between the south, west and northwest. The significant wave height (H_s) was estimated to reach 2.0 m during this event.

A frequency analysis was carried out on the wind and wave data to assess whether 2007 was representative of long-term conditions. Estimates of long-term frequency and durations of winds and wave conditions were summarized in NHC (2004). **Figure 12** shows cumulative frequency distribution (percent exceedance) plots of wind speed for the three seasons. **Figure 13** shows similar plots for wave heights recorded at Halibut Banks. The two sets of measurements show approximately similar results with wind speeds and wave heights being lower than the long-term conditions in April-June 2007 and October-December 2007. The lower intensity winds and waves were most noticeable for moderate conditions (wave heights in the range of 0.5 to 1.5 m). 2007 began to approach the long-term pattern in terms of more severe storm events (for example, wave heights greater than 2.0 m). However, in spite of the major storm event on November 12, the year 2007 was subject to less frequent high winds and waves than the long-term.

2.1.3 Tides

Tide levels are predicted by the Canadian Hydrographic Service at Tsawwassen using observed levels at Point Atkinson as a reference station. Tide levels have also been measured by NHC at Deltaport since June 14, 2007 using a pressure transducer and data logger. **Figures 14** to **16** show observed tide levels for 2007. The tides are mixed, mainly semi-diurnal in nature. Consequently, there are differences in elevation between successive high waters and successive low waters. The sequence of the tides always follows the pattern of Higher High Water, Higher Low Water, Lower High Water and Lower Low Water. Lower Low Water occurs in daylight hours between March and September. During the fall and winter season Lower Low Water occurs during the night time, which imposes a great constraint on carrying out field investigations at the site. The tide range undergoes a biweekly variation due to the influence of the moon. Spring tides, having the largest range, occur 15 days apart, 26 hours after a new or full moon. The maximum tidal ranges occur near the time of the summer and winter solstices. The minimum tidal range occurs around the time of the spring and autumn equinoxes.

The highest tide of the year occurred during the major south-easterly storm on November 12. The predicted High Water at Tsawwassen was 4.4 m CD at 08:00 hr. **Figure 17** shows the actual observed tide at Deltaport. The storm reached its peak intensity at the time of High Tide, with sustained winds exceeding 50 km/hr for over four hours. The highest observed level reached 5.36 m CD at 08:00 hr, indicating a storm surge temporarily super-elevated the water level by nearly 1 m. Super-elevation was also recorded at Point Atkinson, although the total amount was somewhat lower in magnitude (0.53 m).

A second large storm-induced tide occurred on December 3, again due to a south-easterly storm event. In this case the predicted High Water at Tsawwassen was 4.2 m CD at 12:00. The highest observed water level at Deltaport reached 5.27 m CD at 12:30 hr. For comparison, the highest observed tide level at Point Atkinson was reported to by 5.21 m CD at 13:00 hr.

2.1.4 Fraser River Discharge and Sediment Inflow

Figure 18 shows the 2007 Fraser River hydrograph, based on preliminary data from Water Survey of Canada. Flows began to rise in April in response to rising temperatures in the basin, peaked in early June and then receded through July and August as the snowpack depleted. The 2007 freshet was larger than average, reaching a maximum discharge of 11,000 m^3/s at Hope (WSC gauge 08MF005) and 12,300 m^3/s at Mission (WSC gauge 08MH024) during the first week of June. This flood had a return period of approximately 10 years. By mid-July the discharge decreased to 6,000 m^3/s and by September the flow decreased further to 2,000 m^3/s at Hope. Between October and December the discharge remained between 2,000 to 3,000 m^3/s, fluctuating in response to local rainstorms.

Water Survey of Canada has carried out sediment transport measurements on the Fraser River for many years. However, no measurements were made in 2007. Therefore, a simple rating curve method was used to estimate concentrations in 2007 using regression relations described previously (McLean and Church, 1986). **Figure 18** also shows the estimated suspended sediment concentrations. It is expected that the highest sediment concentrations would have risen from approximately 200 mg/L in early April up to 900 mg/L in late May in response to the increasing runoff and sediment production in the basin. The sediment concentrations would have then declined throughout June and July in response to reduced sediment supply and reduced flow, decreasing to a few hundred mg/L by mid-August. The total sediment load in 2007 was estimated to be approximately 24 million tonnes, of which approximately 15 million tonnes was sand. Most of this sediment would have been deposited in the steep submarine canyon at the head of the delta near Sandheads Lighthouse.

2.2 COASTAL GEOMORPHOLOGY

One of the primary objectives of the AMS monitoring program is to make an assessment of the possible effects of the DP3 project on the surrounding physical environment of the Roberts Bank tidal flats. The following sections outline the results of the monitoring activities under the Coastal Geomorphology portion of the AMS Monitoring Program.

2.2.1 Crest Protection Monitoring

The primary purpose for monitoring of the crest protection structure, as outlined in the *Detailed AMS Workplan* (Hemmera, 2007a) is to “detect channel incision, headcutting or dendritic channel formation around perimeter crest protection.” Tidal flows interact with the crest protection structure at a range of tidal stages during both the flood and the ebb tide. Water flows over the structure during high tidal stages and is diverted laterally by the structure during lower tidal stages. The result is a complex, dynamic system resulting in channels and flow paths of various sizes at different orientations relative to the crest protection structure.

The main data collection tools used in the crest protection monitoring program are visual inspection and repeat topographic surveys of established cross-sections. Repeat photography from established photo points during daytime low tides supplements the visual inspection. Additional information about the physical processes affecting the area in the vicinity of the crest protection structure is provided from the other monitoring activities such as interpretation of orthophotos and monitoring of the DoD rods which are discussed in the following sections.

Monitoring of the crest protection structure has demonstrated that the structure itself remains stable, with no detectable change over the 2007 monitoring period. The area of tidal flats and tidal channels in the vicinity of the structure was stable, with minor changes in elevation in the tidal channels near the structure.

Figure 19 shows the plotted cross-section data from July and October 2007 as well as January 2008 (January 2008 is included for comparison despite that this data falls outside of the 2007 monitoring period) and **Appendix B** shows selected photos (**Photo 1** to **Photo 5**) taken during the April and July, 2007 monitoring. These surveys show very minor elevation changes at all cross-sections. The accuracy of the surveys is explored in the Discussion (Section 3.1.1). Cross-section 3 shows that the shoreward channel running parallel to the structure experienced some minor scour and fill on the order of 20 cm to 30 cm over the monitoring period. Cross-section 5 shows a similar pattern with up to 0.5 m of fill followed by 20 cm to 30 cm of scour on the seaward side of the structure.

2.2.2 Automated Turbidity Monitoring

The time series from the two sensors was reviewed carefully to identify and screen out anomalous readings. Turbidity values from both sensors were found to drift upwards during the period September 14 to October 2, and then dropped after maintenance was carried out on the wiper mechanisms on October 3. Therefore, it was decided to not rely on the data for this period. Sensor T1 was damaged after October 3 and was sent to the manufacturer to try to recover the data. The instrument was repaired; however, no data could be recovered.

Daily average turbidity and sediment concentration were computed from the 15 minute values. **Table 7** and **Table 8** summarize these results. **Figures 20 and 21** show the variation in daily turbidity and suspended sediment concentration over time. During the period of time when both instruments were operating, the values were very similar. The daily average values were typically low - in the order of 10 mg/L to 20 mg/L. These values are 5% of the values typically measured in the main channel of the Fraser River during low flow season and 1% of the typical freshet concentrations. The minimum values observed each day ranged between 2 to 10 mg/l and showed no systematic trend over the period of observations.

Several spikes in daily concentrations were observed, particularly on August 16, October 7, October 20, November 12, December 3 and December 15. These spikes coincide with storm events that occurred in 2007. Comparable values have been measured as part of the construction monitoring activities during intense dredging operations or while placing large amounts of material at the site (**Section 1.1.1**). However, a review of the construction field monitoring reports showed the extent of any turbidity plumes generated during dredging operations was very localized and turbidity levels returned to near-background conditions within approximately 100 m from the operations. The two automated turbidity sensors were located away from the dredging operations. These sensors were intended for monitoring sediment transport on the tidal flats, not for water quality monitoring purposes.

Figure 22 shows the pattern of sediment concentration and tide level on November 12 and December 15. The storm of November 12 was a south-easterly, with the greatest winds occurring in the morning, close to the time of highest tide. Sediment concentration rose to 100 mg/L near the start of the storm when the water level was near mid-tide (elevation 3 m CD) level. The concentration then dropped when the tide level reached its maximum value around 07:00 hr and then rose again to 80 to 140 mg/L after High Water when the tide level was 3.0 to 4.0 m CD.

Strong northwest winds occurred during the evening of November 26 and early morning of November 27 (**Table 5**). However, this time the peak of the storm coincided with low tide, so that waves would have been breaking on the seaward side of the crest protection. In this event the peak sediment concentration reached 40 mg/l at 01:00 hr and rose to 70 mg/l at 03:00 hr. Four hours later at High Tide (4.7 m CD), sediment concentrations had returned back to 5 mg/l.

Conditions during December 15 were similar to the November 12 event, with the highest suspended sediment concentrations occurring around mid-tide levels and low concentrations occurring at the time of High Water. The sediment concentrations on December 15 reached up to 150 mg/L, which is comparable to November 12. Therefore, the highest intensity of sediment transport at these sites is strongly affected by the tide level at the time of the storm. At the two sensor locations, the highest sediment mobility occurs when storms coincide with tide levels in the range of 2.5 to 3.5 m CD (near mid-tide).

The above represents analysis of the higher turbidity events that correspond strongly with the recorded high wind events. While all of the significant turbidity events occur in conjunction with high wind events, the exact timing does not generally correspond well because the wind data is collected at a significant distance from the site. Without local wind or wave data it is not possible to provide detailed analysis of the remaining turbidity events. The installation of wave monitoring equipment that is scheduled for spring of 2008 to replace the destroyed AWAC should address this deficiency.

2.2.3 Monitoring of Erosion and Deposition

The array of DoD rods (**Figure 5**) that was installed on the tidal flats is capable of capturing very small changes in bed levels due to erosion and deposition. The main limitations are:

- The resolution of these changes is limited by the frequency with which the rods are monitored;
- The rods cannot detect deposition and subsequent erosion; and
- The rods each collect information at a single point only.

It is also important to distinguish between the erosion data, which represent maximum scour, and the deposition data, which represent net accretion within the quarter. For the purpose of long-term monitoring of erosion and deposition processes and the specific objectives of the AMS study, these limitations are not considered to reduce the usefulness of the data. Long-term changes to the tidal flats that occur over months and years are more important than the short-term transient variations in sediment movement that might occur due to individual storms or the passage of a sand wave.

The DoD rod array covers an area approximately 750 m by 600 m, not including the DoD rods that extend southward along the perimeter of the turning basin. Therefore, large scale changes to the tidal flats are inferred from individual point measurements. Since field time during low tide is limited, a trade-off must be made between covering a larger area with the rod array versus covering a smaller area with a more dense coverage of rods. Observations made during the first year of monitoring indicate that the magnitude of changes to the pattern of erosion and deposition over small distances may outweigh the conclusions that can be made about changes over larger distances.

Table 9 summarizes the bed elevation changes recorded for each monitoring period. Many of the DoD rods experience both erosion and deposition during each quarterly monitoring period. A series of figures have been prepared to display the monitoring results graphically. **Figure 23** shows a plot of erosion and deposition during each monitoring quarter as a series of bar charts for each site. The net change is represented with shaded dots in **Figure 24** to **Figure 26**.

2.2.4 Sediment Samples

The primary purpose of collecting sediment samples was to allow a comparison of the grain size distribution over time (**Table 10**). Significant changes in hydraulic conditions (such as a reduction in wave heights or tidal current velocities) due to DP3 could potentially cause changes to the size distribution of the sediments being deposited. Sampling depth was limited to the top 10 cm of the sediments, which is a reasonable sampling depth considering the typical depth of disturbance that has been observed in the DoD rod results. The sediments consist primarily of medium to fine sand (median size typically 0.1 to 0.2 mm) with minor amounts of silt. The percentage of silt (less than 0.063 mm) in the samples was used as an indicator of fine sediment inputs to the site. **Figure 27** and **Figure 28** graphically represent the percent silt content of the sediment samples collected during the Q1-2007 and Q3-2007 monitoring periods. The silt content of the sediment samples is classified into four categories, each with a range of 16 percentage points. The majority of samples contain very low amounts of silt (16% or less), and silt proportions in the majority of these samples do not change from May to October. The most obvious exceptions are the samples taken from sites E01 and E02, which are within the area of new drainage channels which contained up to 39% silt in the May sampling program.

Carbon content in the samples was primarily included in the analysis as a means of removing it from the sample to ensure that the fine particulate matter did not skew the grain size analysis. The purpose of presenting the results of the carbon content analysis (**Table 11**) is to demonstrate the overall very low carbon content in the samples. The majority of the samples collected in both May and November have very low carbon content. Percent carbon for all of the sample sites on the seaward side of the crest protection structure is between 0.1% and 0.3% for both sampling periods (**Figure 29** and **Figure 30)**.

Most of the sample sites on the landward side of the structure are in either the 0.1% to 0.3% range or the 0.4% to 0.6% range. The main anomalies to this pattern include the May sample at A03, which also had much higher silt content during this sampling period, as well as the sampling sites in the vicinity of the new drainage channels. It is likely that the large amounts of fine sediments in this area have also slightly increased the percent carbon in these samples.

2.2.5 Interpretation of Ortho Photographs

The study area for this monitoring activity includes the entire area of Roberts Bank within the inter-causeway tidal flats. **Figure 31** shows the results of the orthophotographic interpretation, which was completed using GIS mapping techniques under the direction of the project geomorphologist. The main features of interest shown in **Figure 31** include:

1. New drainage channels that have formed at the north-eastern margin of the perimeter dyke.
2. Formation of sand bars on the tidal flats on the seaward side of the crest protection structure.
3. The large system of dendritic channels draining into the turning basin.
4. The tidal channels adjacent to the BC Ferries causeway.

Items 2 through 4 are historic features that pre-date the DP3 project and have been identified and described previously (NHC 2004).

Figure 32 shows a comparison of the area of new drainage channels from May 2006, when there were no channels, and July 2007, after the new channels had formed. **Photo 6 to Photo 12 in Appendix B** show oblique aerial photographs as well as photographs taken from the ground on March 12, 2008 of the new channels.

Figure 33 shows the outline of the large dendritic channels that were digitised from the 2006 and 2007 orthophotos while **Figure 34** shows a comparison of the channels using orthophotos from 2002, 2006, and 2007 and includes fixed control points for comparison.

2.2.6 Coastal Geomorphology Mapping

Figure 35 shows the bathymetry of the study area based on the hydrographic surveys conducted between July 8, 2007 and November 7, 2007. This represents the first comprehensive survey of the tidal flats for more than a decade. Based on the DoD rod results and comparison with previous localized surveys, the present survey can be considered to represent the pre-project baseline condition for the purposes of the AMS monitoring program. The next comprehensive survey for the coastal geomorphology mapping activity is due to be completed within three to four years based on the *AMS Detailed Workplan (*Hemmera, 2007a).

2.3 SURFACE WATER QUALITY

2.3.1 Quality Assurance/Quality Control

For surface water metals, the data quality objective (DQO) for precision was to obtain a relative percent difference (RPD) of less than 20% or a difference factor (DF) of less than 2. The DQO for completeness was 100%. For the organic parameters the DQO for precision was RPD of less than 50%. As RPDs/DFs for most parameters met the DQOs, it was concluded that the data was, on the whole, reliable and met project requirements for laboratory and field duplicate quality assurance/quality control (QA/QC) evaluation. Detailed QA/QC evaluations are presented in the quarterly reports. A summary of issues encountered is presented in **Table 12** and discussed below.

In Q1-2007, the elevated RPDs for copper, lead, nickel, and zinc are believed to be linked to the difference in TSS in the samples (with 33.6 mg/L measured in SWDP07A-1 and 15.6 mg/L measured in SWDP19-1). Due to rough weather conditions, the containers for the duplicates were filled one after the other from the Van Dorn to minimize the risk of spillage. The discrepancy is therefore not considered to be indicative of low precision, but does highlight the variability introduced by field conditions at that time. Similarly, TSS was the suspected source of discrepancy between uranium concentrations in Q2-2007 and arsenic concentrations in Q3-2007.

In Q2-2007, elevated DFs were encountered for three of six nitrogen parameters. Similar elevated RPDs were noted in sediment so it may be reflective of natural variability in these parameters. There was a large variability in the conductivity and salinity between the sample and its duplicate. Sample re-analysis was requested but the lab indicated that the samples had already been discarded.

In Q3-2007, the chlorophyll α RPD was 80.7%. Due to hold time limitations, re-analysis was not possible. However, chlorophyll α results from Q1-2007 and Q2-2007 suggest that this degree of variability is anomalous. The elevated RPD for TSS is not considered to be indicative of low precision, but highlights the variability associated with suspended particulate matter. Although multiple Van Dorn deployments were required (a 2.0 litre Van Dorn was used during repairs of the larger unit), each sample was generally comprised of an equal volume of water from each deployment.

2.3.2 Chemistry

The parameters collected as indicators of potential toxicity to marine organisms were compared against the BC Water Quality Guidelines (WQG) for the Protection of Marine Aquatic Life (MAL) and the Canadian Council of Ministers of the Environment (CCME) MAL WQG presented in **Table 13**. There were no exceedances of the CCME guidelines. Total boron, iron, copper, and zinc concentrations exceeding the BC WQG were measured. However, the PAH concentrations met the BC WQG and, with the exception of fluoranthene, phenanthrene, and pyrene at station DP01 and phenanthrene at station DP03, all PAH concentrations were less than the reported detection limit (RDL). Given these results, surface water samples were not analyzed for PAHs after Q1-2007. Results for metals exceeding the BC WQG are reviewed below.

Total boron concentrations measured during 2007 ranged from 129 to 4,000 µg/L. This is compatible with boron concentrations in coastal marine water in Canada (typically ranges from 3,700 to 4,300 µg/L) (Moss and Nagpal, 2003). The only stations where boron concentrations did not consistently exceed the BC WQG were DP01 (a drainage ditch) and DP06 (adjacent to the Fraser River), where there is greatest freshwater influence.

Dissolved iron was added to the program after total iron concentrations in excess of the BC WQG were measured in Q1-2007. Given that total iron includes iron associated with suspended sediments, dissolved iron is considered more relevant to the assessment of water quality for the AMS. The dissolved iron concentrations were less than the BC WQG, except during Q3-2007 where dissolved iron concentrations were less than the RDL, but the RDL was greater than the BC WQG. The RDL issue was discussed with the project laboratory (ALS of Vancouver, BC), and measures were taken to avoid this during future monitoring events. The dissolved iron results suggest that suspended particulate matter was responsible for the elevated total iron concentration measured.

In addition, there were five copper exceedances (**Table 13**). Two of these were noted at the drainage ditch DP01 (Q1-2007 and Q2-2007), one at the deepwater station DP05 (Q1-2007), and two at the intertidal reference station DP06 (Q1-2007 and Q3-2007). The three zinc exceedances were encountered at two of the stations with copper exceedances: DP01 during Q1-2007 and Q2-2007 and DP05 during Q1-2007.

The RDL for vanadium was greater than the BC WQG during all four quarterly monitoring events due to the dilution required to avoid sodium interference during analysis. However, all vanadium concentrations were below the RDL. For cadmium, cobalt, copper, iron, lead, manganese, nickel, uranium, and zinc, a chelation procedure can be used to remove the sodium; however, this procedure cannot be used for vanadium.

Nitrate concentrations met the CCME MAL. There are no other regulatory criteria applicable to nutrients in seawater. Other parameters will be discussed in the context of potential eutrophication in **Section 3.2.**

Data from the YSI Sonde, located near DP04 (**Figure 6**) was available to September 18, 2007. The sonde was destroyed sometime in September 2007. The sonde data for the period of May 2007 to September 2007 was presented in the Q3-2007 quarterly report (Hemmera, 2008 b) and included in the Annual Report as **Appendix C**. Analysis of the data indicated the following trends:

- DO, pH and turbidity variation mirrors the tidal cycle with peaks at low tide and dips at high tide
- DO has decreased from 12-14% in May & June down to below 8% in September
- pH was in the low 8's in spring but dropped abruptly down to 7 for August and September
- Highest turbidity averaged about 4 NTU in May and it dropped down to below 2 NTU for rest of summer

The information most relevant to the issue of potential eutrophication in the inter-causeway area is the decline in DO and pH. The DO decline is likely seasonal but is difficult to determine without a year's worth of data. DO fluctuations, on a daily basis, are quite large so discrete spot sampling will not give data of sufficient quality to determine a trend. The drop in measured pH, with steady readings after that is believed to be a calibration issue; however, this cannot be determined with the instrument no longer available to check calibration. If the pH drop was related to increased CO_2 production in the inter-causeway area, the drop would be anticipated to be more gradual.

Although not in the same location, NHC have turbidity sondes installed nearby (**Figure 4**) that will be used to provide the future turbidity monitoring data. A replacement sonde was installed at the site in spring 2008.

2.4 SEDIMENT QUALITY

2.4.1 Quality Assurance/Quality Control

For sediment, the DQOs were a RPD of less than 20% or a Difference Factor (DF) of less than 2. The sediment data set was considered complete and accurate based on the results of the field and laboratory QA/QC. Detailed QA/QC evaluations are presented in the quarterly reports. A summary of issues encountered is discussed below.

In Q1-2007, the RPDs between characterization and blind duplicate samples exceeded the DQO for ammonia, sulphide, and chromium. In Q2-2007, nitrate and sulphide concentrations exceeded the DQO, while in Q3-2007, total organic carbon (TOC) was the only parameter to exceed the DQO. Given that the vast majority of the parameters within these same samples met the DQO, the elevated RPDs for ammonia, sulphide, and chromium appear to reflect above average variability in these parameters, rather than low precision associated with insufficient sample homogenization or laboratory sample handling errors. No issues were encountered in Q4-2007.

2.4.2 Sediment Chemistry

The sediment toxicity parameters (metals) were compared against the BC Contaminated Sites Regulation, Schedule 9 Generic Numerical Sediment Criteria for sensitive marine and estuarine sediments ($SedQC_{ss}$) (**Table 14**). No exceedances of the $SedQC_{ss}$ were measured during the four quarterly monitoring events.

There are no regulatory criteria applicable to nutrients in sediment. Nutrient concentrations will be discussed in the context of potential eutrophication in **Section 3.2.**

2.4.3 Grain Size

Grain size samples were collected during the Q1-2007 monitoring event (**Table 15**). The sediment consisted of sand with a trace to some silt and clay, except at DP05 where the sediment was finer grained, consisting of sand and silt with some clay. This is consistent with the grain size results from NHC (**Section 2.2.4**).

2.5 EELGRASS

2.5.1 Distribution and Mapping

The 2007 eelgrass habitat classification map prepared for this study is provided in **Figure 36**. The figure also includes a similar map based on data collected in 2003 for the Deltaport Third Berth Project Marine Resources Impact Assessment.

Reflection and glare from water over the eelgrass complicated interpretation of the digital orthophotos at some locations. Site photographs that were recorded during July 2007 for the monitoring portion of the eelgrass study, and by NHC were cross-referenced to provide data for of these areas.

The low tides during September 2007 were not as low as those that occurred during July and August; this limited the extent of the ground truthing. A sample of the light coloured areas that appeared devoid of eelgrass on the orthophoto was visited to determine whether these areas were in fact unvegetated or whether the 'signal' was merely a reflection. Reflection was found to be the cause of the large light coloured areas east of the crest protection; these areas supported dense eelgrass. The smaller light coloured areas adjacent to the large dendritic channels that drain into the turning basin were unvegetated sand. The areas of unvegetated sand were often adjacent to areas where *Z. japonica* has replaced *Z. marina* since 2003. It is likely that the elevation in these areas currently exceeds that where *Z. marina* can survive.

The area classified as Zostera-mixed represents the transition zone between *Z. marina* and *Z. japonica* habitat where the two species co-exist; it is located above the optimal elevation for *Z. marina*[3]. The extent of this zone has varied inter-annually for decades, often reflecting large-scale environmental conditions such as the duration of exposure during summer low tides, summer weather, and likely the effect of the Pacific Decadal Oscillation which has been shown to affect sea level in the region. The transition zone in 2007 extended into an area previously classified as *Z. marina*, west of the main dendritic channel complex and adjacent to an area of patchy *Z. japonica.* Given the extent of sediment accretion in this area since 2003, it is likely that this change is not due large-scale environmental change but rather due to localized sediment accretion.

3 Wetland plants of the Pacific Northwest. 1984. US Army Corps of Engineers, Seattle District.

The areas that appeared light and mottled between the large dendritic channels and the Deltaport Causeway supported a low density of *Z. marina* (1% to 10%) and *Z. japonica* (0% to 10%). These areas were classified as *Z. marina*-patchy. Examination of *Z. marina* rhizomes in these areas revealed vertical growth ranging from 4 cm to 8 cm. Vertical rhizome growth is indicative of sediment accretion.

The evolution of these dendritic channels and sand accretion in the vicinity of the channels has been studied in detail by NHC (**Section 3.1.5.3**). NHC concluded, "it is considered unlikely that that these large channels, which are removed from the assumed area of influence of the new DP3, are being influenced by, or have influence on the present project." The areas devoid of vegetation, and those where *Z. marina* has declined or been replaced by *Z. japonica* are likely the result of sediment movement or accretion caused by the continued evolution of the dendritic channels, and not related to the development of DP3.

Sediment deposition in the vicinity of the dendritic channels near the ferry causeway has lead to additional decreases in *Z. marina* habitat; these losses are likely due to the continued evolution of these channels, and not related to the development of DP3. The distribution of eelgrass in this area was based on orthophoto interpretation and a review of the figures produced by NHC for this study.

A comparison between the 2007 orthophotos and the 2003 eelgrass distribution map revealed that sediment deposition adjacent to the perimeter dyke in the inter-causeway had altered the eelgrass distribution in that area (**Photo 7, Appendix B**). Eelgrass shoots are very slow to decompose and therefore it is usually not possible to distinguish between live and recently dead eelgrass shoots. A field survey of this area in September 2007 would not have been able to distinguish between shoots that were senescing and those that would survive. In response, one of the field survey days originally scheduled for 2007 was reserved for a spring low tide cycle on May 6, 2008, to accurately document the distribution of eelgrass in this area.

The May 2008 survey determined that the survival of eelgrass in the area where sediment was deposited and new drainage channels formed far exceeded that indicated on the 2007 orthophoto. Areas that appeared devoid of vegetation on the orthophoto often supported remnant patches of *Z. marina* **(Figure 36**, *Z. marina* – patchy). These areas may be able to recover as the surviving shoots branch to produce additional shoots.

A large area between the crest protection and the Deltaport Causeway that was classified as mud in 2003 has since been colonized by *Z. japonica*.

2.5.2 Monitoring Eelgrass Vigour & Health at the Established Stations

The epiphyte load at all stations was ranked as typical. Photographs were taken at each station to document the epiphytic cover for future reference. *Beggiatoa sp.* was not present at any of the sites, nor was it observed when travelling to or from the sites.

The distribution of *Zostera marina* was continuous at all sampling stations. *Z. japonica* was absent from all of the sampling stations.

The parameters that were quantified at each of the stations included total shoot density, reproductive shoot density, shoot length, and shoot width. Means were calculated from 20 replicate samples at each station.

The relative productivity at each station was calculated using a Leaf Area Index (LAI) formula. The LAI is calculated as follows:

$$\text{LAI} = \text{mean density } (\#/m^2) \times \text{mean shoot length (m)} \times \text{mean shoot width (m)}$$

The data collected in 2003 and in 2007 are summarized in **Table 2.5-1**.

Table 2.5-1: Mean eelgrass *(Z. marina*) shoot density (total and reproductive), length, and width at each reference station in 2003 and 2007

Site (#)	Total Density (#/0.25m^2)		Length (cm)		Width (mm)		LAI		Reproductive Shoot Density (#/0.25m^2)	
	2003	2007	2003	2007	2003	2007	2003	2007	2003	2007
Inter-causeway near Deltaport Causeway										
1	24	25.8	140.0	115.8	8.5	8.2	1.18	0.99	1.2	1.4
2	23.9	26.5	137.6	146.7	8.5	7.8	1.12	1.19	1.2	2.1
Inter-causeway near Ferry Causeway										
5	14.5	17.4	163.5	130.7	9.3	7.8	0.88	0.71	0.4	0.4
6	16.8	20.6	132.4	127.3	7.5	7.2	0.66	0.76	0.6	0.8
West of Deltaport Causeway										
3	17.3	16.0	141.1	121.8	9.7	7.9	0.95	0.61	0.6	1.9
4	15.7	14.7	188.8	164.0	9.5	8.2	1.12	0.79	0.8	1.1
Boundary Bay										
WR1	33	60.6	44.4	48.4	4.5	4.9	0.29	0.56	28.7	0.7
WR2	14	29.4	137.4	122.7	7.0	7.3	0.54	1.04	0.5	1.4
WR3	21	19.9	215.2	167.4	7.3	7.7	1.33	1.04	0.8	1.3

Note: Means were calculated from 20 samples at each station, and were reduced to one decimal place. Leaf Area Index values were calculated using two decimal places for each parameter in the equation. WR1 is not currently included in the eelgrass assessment for the AMS as the habitat at this location is not comparable to other sites within the study area at this time.

Student's t-tests are commonly used in seagrass research to test for differences between sets of data. The data that was collected at each site in 2007 was compared with that collected in 2003 using a paired two-sample, 2-tailed t-test (**Table 2.5-2**).

The Student's t-test assumes a normal distribution; this is not always a valid assumption. The non-parametric Wilcoxon's signed ranks test does not assume a normal distribution and provides an alternative analysis to test for significant differences. The data was also analysed using Wilcoxon's signed ranks test, the results of which matched that of the t-test. (**Table 2.5-3**).

The t-tests were repeated using the Bonferroni correction adjustment, this lead to a reduction in the number of significant differences. The comparisons that were not significant using the Bonferroni correction are highlighted in Table 2.5-2. No additional significant differences were obtained.

The actual p-values for each test are provided in **Appendix D**.

Table 2.5-2: Summary of results from paired two-sample, 2-tailed t-tests (Values of p <0.05 were considered significant. Comparisons that were not significant once the Bonferroni adjustment was applied are in italics.)

Site #	Total density	Length	Width	LAI	Reproductive Density
Inter-causeway near Deltaport Causeway					
1	no difference	**significantly less**	no difference	no difference	no difference
2	no difference	no difference	**significantly less**	no difference	no difference
Inter-causeway near Ferry Causeway					
5	no difference	**significantly less**	**significantly less**	no difference	no difference
6	***significantly greater***	no difference	no difference	no difference	no difference
West of Deltaport Causeway					
3	no difference	**significantly less**	**significantly less**	**significantly less**	***significantly greater***
4	no difference	no difference	**significantly less**	***significantly less***	no difference
Boundary Bay					
WR1	**significantly greater**	no difference	no difference	**significantly greater**	**significantly less**
WR2	**significantly greater**	no difference	***significantly greater***	**significantly greater**	***significantly greater***
WR3	no difference	**significantly less**	***significantly greater***	***significantly less***	no difference

Note: WR1 is not currently included in the eelgrass assessment for the AMS as the habitat at this location is not comparable to other sites within the study area at this time.

Table 2.5-3: Summary of results using a Wilcoxon's signed ranks test (95.2% confidence interval for difference between population medians)

Site #	Total density	Length	Width	LAI	Reproductive Shoot Density
Inter-causeway near Deltaport Causeway					
1	no difference	**significantly less**	no difference	no difference	no difference
2	no difference	no difference	**significantly less**	no difference	no difference
Inter-causeway near Ferry Causeway					
5	no difference	**significantly less**	**significantly less**	no difference	no difference
6	**significantly greater**	no difference	no difference	no difference	no difference
West of Deltaport Causeway					
3	no difference	**significantly less**	**significantly less**	**significantly less**	**significantly greater**
4	no difference	no difference	**significantly less**	**significantly less**	no difference
Boundary Bay					
WR1	**significantly greater**	no difference	no difference	**significantly greater**	**significantly less**
WR2	**significantly greater**	no difference	**significantly greater**	**significantly greater**	no difference
WR3	no difference	**significantly less**	**significantly greater**	**significantly less**	no difference

Note: WR1 is not currently included in the eelgrass assessment for the AMS as the habitat at this location is not comparable to other sites within the study area at this time.

All of the results from the Student's t-tests were confirmed by Wilcoxon's tests.

2.6 BENTHIC COMMUNITY

Due to a limited time window, the first quarterly benthic community sampling event was conducted during a period of high winds and rough seas. The associated wave action complicated access to and Ponar deployment at sampling stations in the intertidal zone, particularly at DP06. Sediment recovery was low relative to subsequent sampling events (Q1-2008). In Q1-2007, recovery volumes for each station and replicate were not recorded but estimated to average 3.0L, with the exception of DP05 where sample recovery was approximately 8.0L.

Core indicators used to evaluate the baseline benthic invertebrate community data included total species abundance, taxa richness and diversity. Benthic species abundance and richness were further compared to grain size and sulphide concentration to determine if correlations existed. To evaluate core indicators, sampling stations (DP02 to DP07) were assessed as a composite of the replicate numbers (A, B & C). Intermediate and junior stages and only 1.0 mm sieve samples were included in evaluating benthic invertebrate data at each of the stations. As indicated in **Appendix A**, no sample was collected at DP01, a tidally influenced freshwater drainage ditch distinct from the other sampling stations. Benthic invertebrate data evaluated for the baseline sampling program are presented in **Table 16**.

The greatest abundance of benthic invertebrates was observed at DP04, the site closest to the Third Berth construction; however taxa richness was observed to be greater at DP07 and DP05, the subtidal stations (**Figure 6**). The lowest abundance of benthic invertebrates and number of taxa was observed at DP06 (**Figure 37**).

The largest proportion of species belonged to the class Bivalvia followed by Polychaeta (**Figure 37**). Over 83% of station DP06 was composed of species in the class Bivalvia. Station DP02 contained over 50% of its species from the Polychaeta class. The remaining stations were more species rich as demonstrated by the Shannon's Index of Diversity (H) and Equitability (E_H) calculations (**Figure 2.6-1**). The most diversity was present at DP07 followed by DP05 and DP04 with the greatest evenness, as calculated by E_H, also found at DP07.

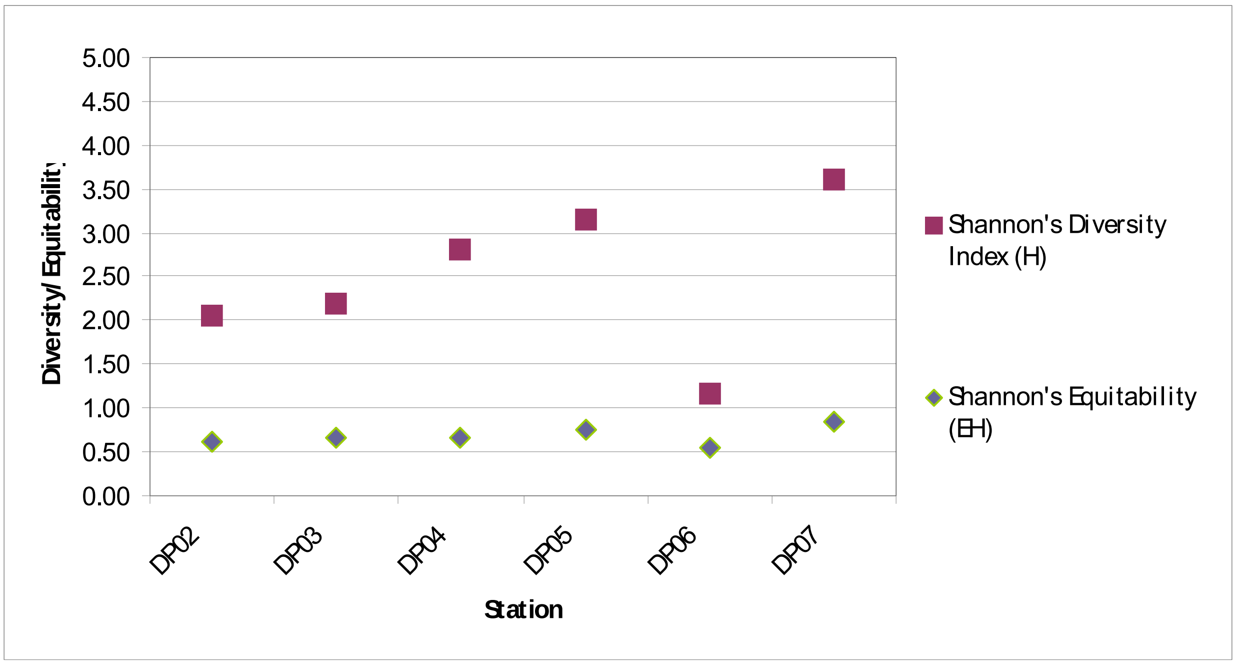

Figure 2.6-1: Shannon's diversity and Shannon's equitability (evenness) index

The majority of the stations, with the exception of DP05, were composed of over 70% sand (0.063mm – 2.0mm). DP05 contained relatively equal portions of sand and silt, 44% and 41% respectively. No observable correlations between grain size and species abundance or taxa richness were noted (**Figures 2.6-2 and 2.6-3**). Similarly, no positive correlations were observed between sulphide concentrations and species abundance or taxa richness (**Figures 2.6-4 and 2.6-5**). The sulphide samples collected during Q1-2007 and Q2-2007 were analyzed within 7 days. However, due to concern regarding degradation of the sample, sulphide samples during Q3-2007 and subsequent quarters were analyzed within 24 hours (**Appendix A**). Therefore, the Q1-2007 (when the benthic community samples were collected) and Q2-2007 sulphide data is considered less reliable.

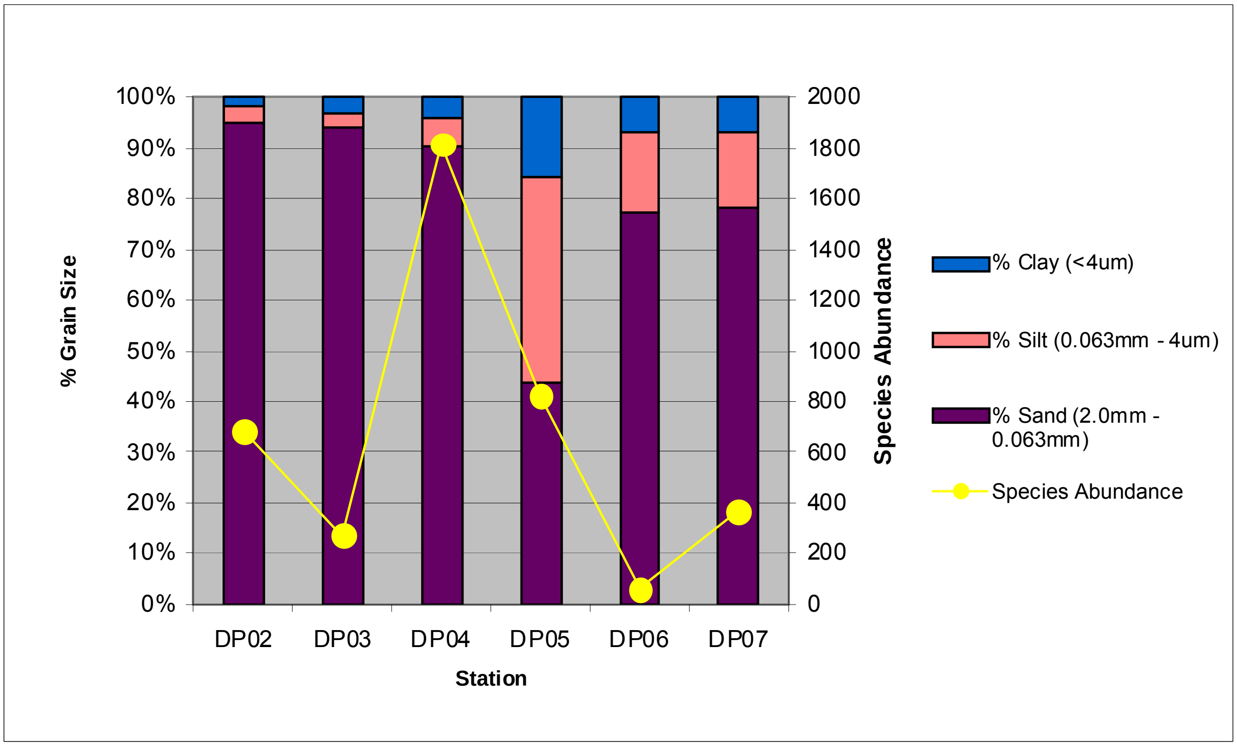

Figure 2.6-2: Species abundance versus percentage of grain size at each station

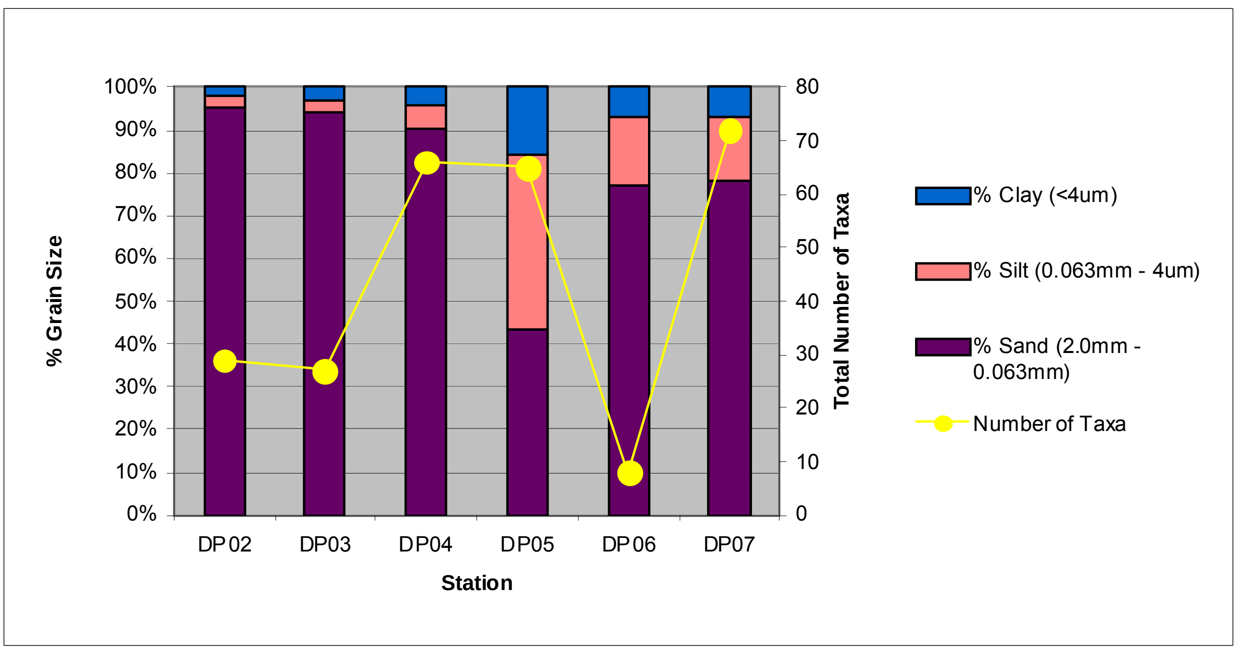

Figure 2.6-3: Total number of taxa observed (frequency) versus percentage of grain size at each station

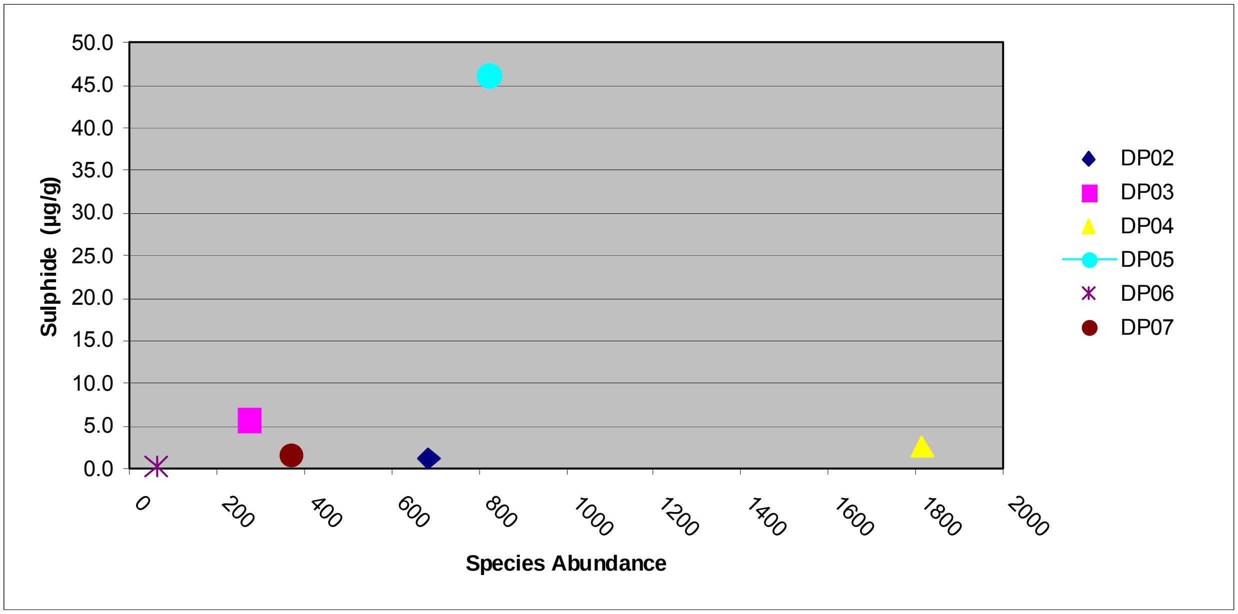

Figure 2.6-4: Species abundance versus sulphide concentration (µg/g) at each station

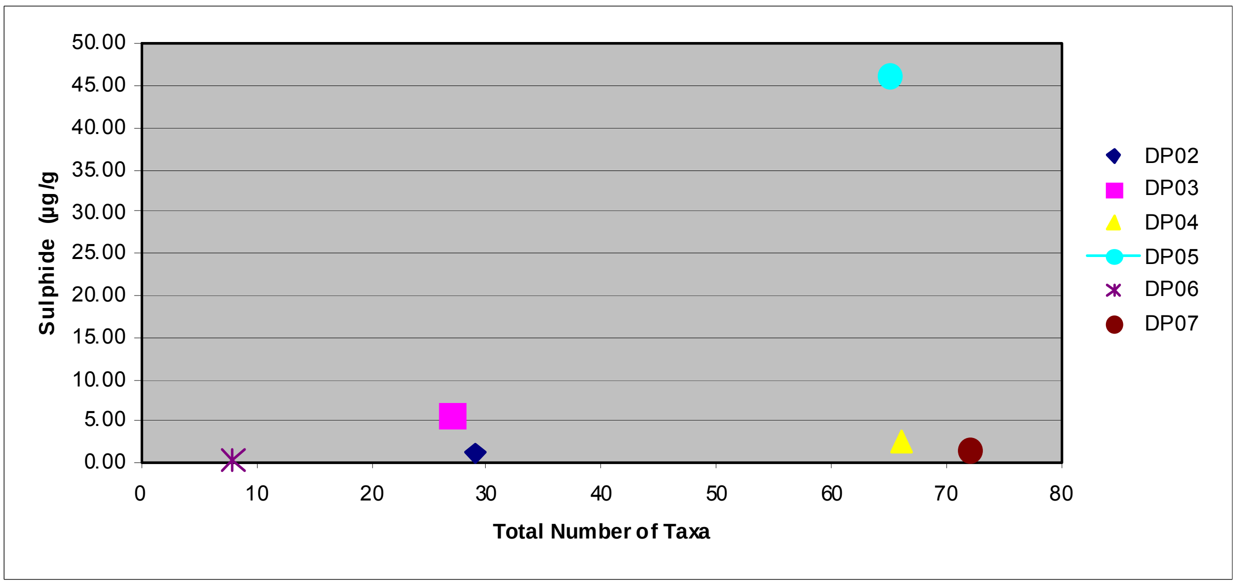

Figure 2.6-5: Total number of taxa observed (frequency) versus sulphide concentration (µg/g) at each station

2.7 BIRDS

Complete results of the bi-weekly surveys are presented in **Table 17.** The data are intended to provide an indication of the number, composition, and distribution of species using the inter-causeway area during low and high tides on a bi-weekly basis between March 25 and December 28, 2007.

The birds observed at Roberts Bank have been organized into six categories: great blue herons; brant; shorebirds; coastal waterbirds; raptors; and other birds to facilitate a clear presentation of the report's findings and conclusions. Categories consisting of a large number of species, such as coastal waterbirds, have been further separated into dabbling ducks, diving ducks, 'other' waterbirds, and gulls and terns to provide meaningful presentation of the data collected. Point count survey locations are provided in **Figure 10**.

The following sections summarize data collected for the bird species/categories described above.

2.7.1.1 Great Blue Heron

Assessing and monitoring potential impacts to great blue heron was identified as a primary objective of the AMS (Hemmera, 2007a). The great blue heron is listed federally by COSEWIC and SARA in Schedule 3 as a species of 'Special Concern', meaning that it is particularly sensitive to human disturbance. Provincially, the coastal *fannini* subspecies is blue-listed due to declining populations attributed primarily to human development and in part to increasing disturbance from eagle populations (Gebauer and Moul, 2001).

Great blue herons were recorded in the study area throughout the report period (March – December 2007); however, distribution and abundance changed seasonally within the inter-causeway area as indicated in **Figure 2.7.1.**

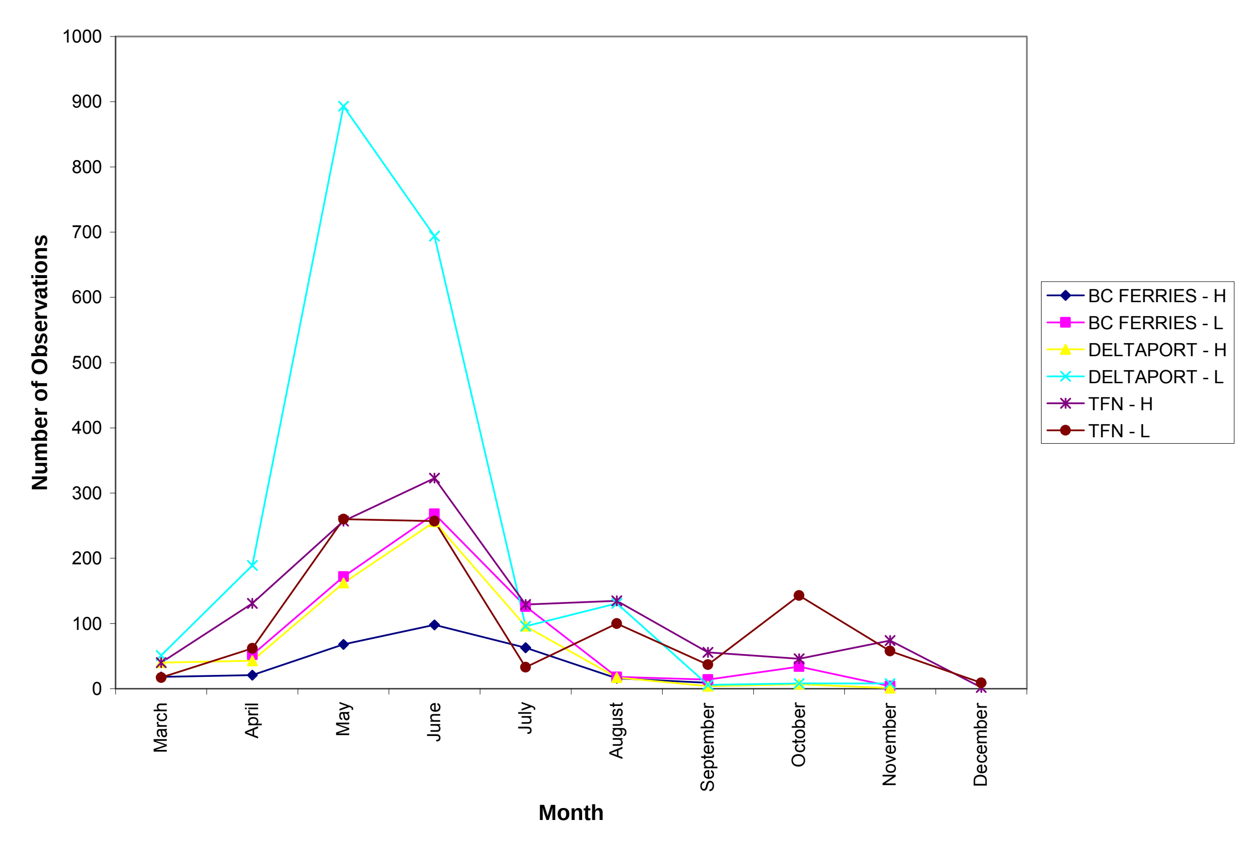

Figure 2.7-1: Seasonal abundance of great blue herons using the inter-causeway area separated by tide and transect

Great blue herons were recorded in the study area 5,856 times between March 25, 2007 and December 28, 2008. **Figure 2.7.1** includes all great blue herons observed either flying over or using the inter-causeway area for foraging and resting. Of these observations, 17% were recorded along the BCF transect, 46% along the DP transect, and 37% along the TFN transect. **Figure 2.7-1** shows changes in great blue heron distribution within the study area on a seasonal basis, as indicated by relative abundance on each of the three transects. Heron density peaked during May and June 2007, as indicated in **Figure 2.7-2**, at which time herons exploited long hours of daytime low tides to forage on exposed eelgrass beds primarily along the DP transect during low tide. Usage of the remaining study area over the summer is consistent between transects with the exception of the BCF transect during high tide, which received the lowest summer use by great blue herons.

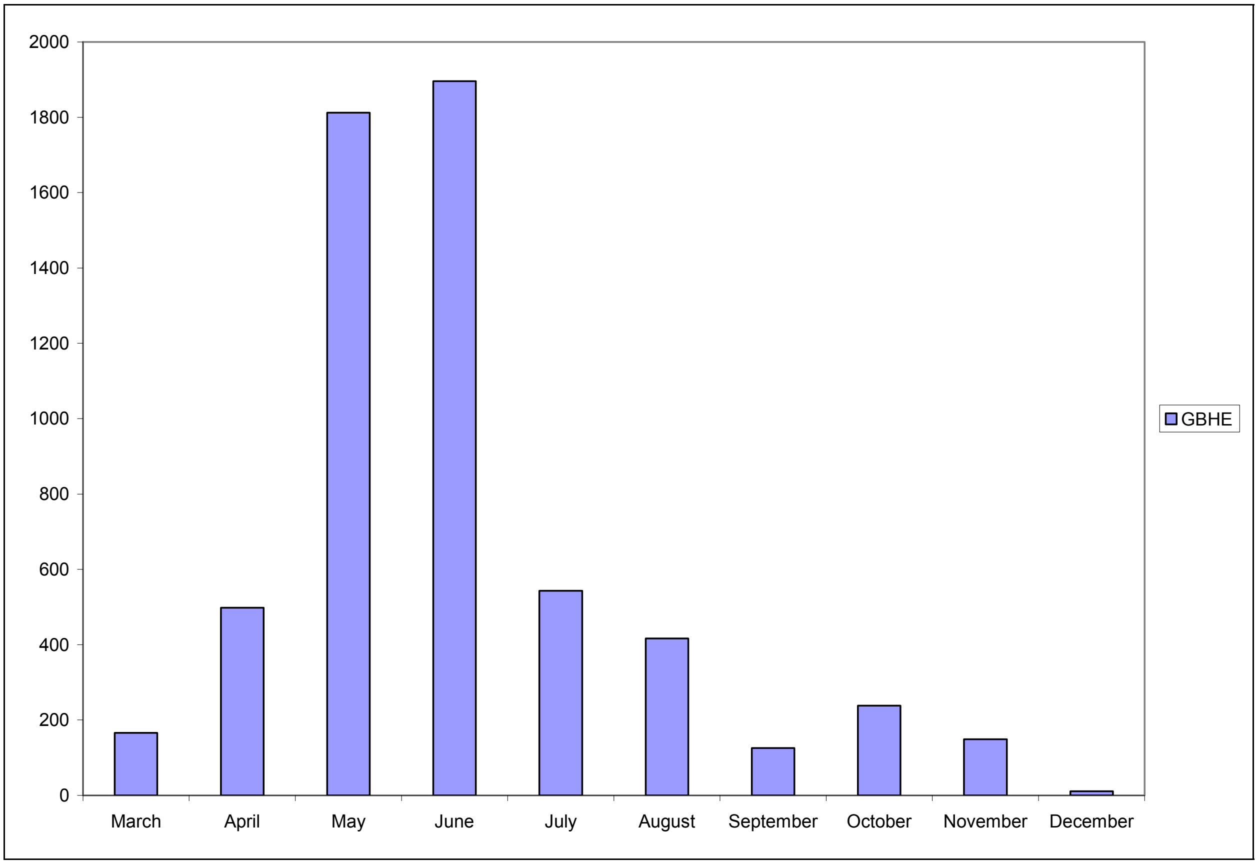

Figure 2.7-2: Seasonal relative abundance of great blue herons within the inter-causeway area

During the spring and summer, great blue heron are dependent upon the eelgrass meadows within the inter-causeway area for foraging. Heron foraging in the inter-causeway area is tidally influenced because the lower tides expose the extensive eelgrass meadows which provide shelter for a variety of prey during the summer months. Fish species present within the inter-causeway area include sculpins, sticklebacks, herring, tube snout, starry flounder, gunnels, and surf perch.

The heron counts between March and December 2007 (**Appendix C2** and **Figures 2.7-3 and 2.7-4)** demonstrate the dependence of great blue heron usage of the inter-causeway area on tidal levels. During low tides, herons were found throughout much of the inter-causeway area, following the tide line as eelgrass beds were exposed. Key areas included PCs 14 and 15 inside of the crest protection. Daytime low tides exposed extensive inter-tidal areas and eelgrass meadows during May and June, corresponding to peak heron densities indicated in **Figure 2.7-1** and **2.7-2.** The duration and extent of these seasonally low daytime tides gradually waned into the late summer and fall at which point daily low tides were short lived and exposed less of the eelgrass meadows. At this point, a decrease in heron density within the inter-causeway area was observed, corresponding to an increase in heron usage of the salt marsh 100 m inland along the TFN transect in late July. By November, the majority of heron using the study area were recorded inland as the tidal regime no longer exposed sufficient patches of eelgrass (**Figure 2.7-3**). Fish continued to remain in the eelgrass meadows; however, they were larger and harder for the herons to catch at this time (Butler 1997). Butler (1997) provides an excellent overview of the seasonal behaviour of coastal great blue herons, and patterns elucidated in his work are consistent with the observations collected during the survey period addressed in this report.

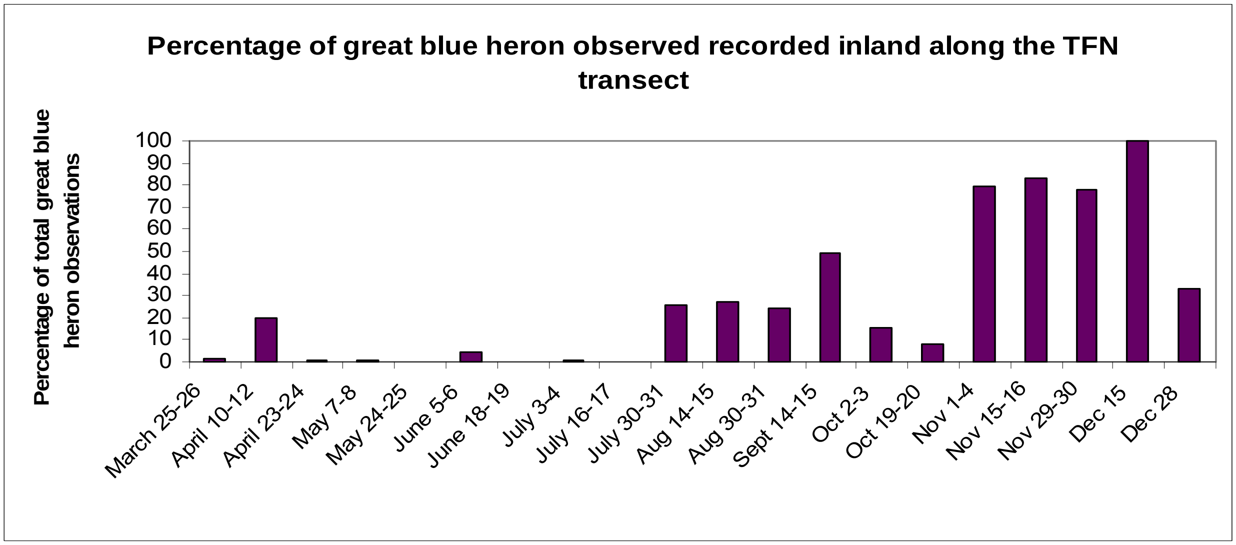

Figure 2.7-3: Percentage of great blue heron observations recorded inland along the TFN transect on a seasonal basis

The greatest heron density during the fall and winter months occurs inland along the TFN transect. **Figure 2.7-3** highlights the seasonal switch in foraging pattern as indicated by the percentage of total heron observations recorded inland along the TFN transect. This seasonal change in foraging is also described in Butler (1997). Heron distribution within the inter-causeway area during high and low tide events is provided in **Figure 38**.

2.7.1.2 Brant Geese

Brant density in the study area fluctuated between approximately 500 and 1,000 birds during November and December 2007, at which time only over-wintering black-bellied brant are present in the study area (see **Figure 2.7-4**). We estimate the maximum value of over-wintering black-bellied brant at 1,400 based on low tide observations recorded during survey event 07-17. Observations for this survey event were collected between November 15, 16, and 19. Subsequent winter surveys recorded closer to 1,000 brant through the rest of November and December 2007. Brant distribution within the inter-causeway area during high and low tide events is provided in **Figure 39**.

Increasing numbers of brant observed during late April are attributed to migrants staging in the inter-causeway on their way to summer breeding grounds in Alaska. This is evidenced by an influx of grey-bellied brant that do not over-winter in the Lower Mainland as well as an increase in numbers of black-bellied brant. Migrating brant staging in the inter-causeway area winter primarily in Baja, California, and Mexico's mainland coast (Moore *et al*., 2004).

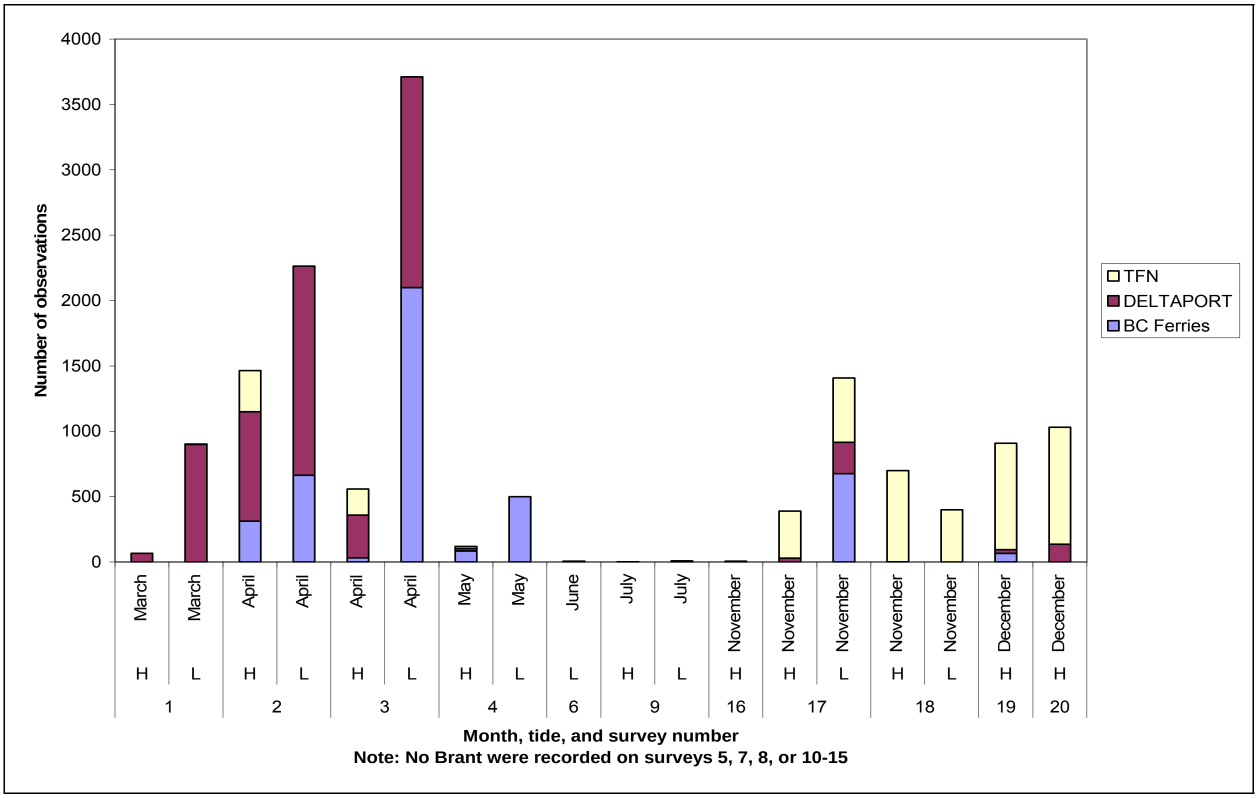

Figure 2.7-4: Total brant observations as recorded by tidal level throughout the study period

Peak estimates of 3,560 brant (unpublished data cited in Moore *et al*., 2004) using Roberts Bank as spring staging habitat are also consistent with peak brant numbers (3,710 brant) observed during late April 2007 surveys completed during this study. Additionally, estimates of 1,000 over-wintering brant in the inter-causeway area reported in Butler and Cannings (1989) are consistent with typical over-wintering brant numbers observed during this report period.

Interestingly, Moore and others (2004) found that both Boundary Bay (peak estimate of 1,660 brant during spring migration) and Roberts Bank (peak estimate of 3,170 during spring migration) received lower usage than expected by spring staging brant along the Pacific Flyway based on the amount of eelgrass habitat available and in the context of isolation from other staging sites. Moore and others (2004) concluded that there is sufficient eelgrass habitat to support more brant in both the inter-causeway area and at Boundary Bay, than are currently supported. Additionally, both of these staging areas were among the least isolated of the sites examined. In this same study, isolation from other staging areas was shown to influence brant usage, as isolated eelgrass habitats are implied to be more critical for staging brant than those in close proximity to other staging areas. Central Vancouver Island (along the east coast) hosts an estimated 6,160 brant during the peak of spring migration (Moore *et al*., 2004).

During this report period, brant were observed to use the inter-causeway area to feed on eelgrass fronds, obtain gravel (generally along exposed shoreline along the TFN transect), and loaf, rest, or preen. Previous descriptions of brant usage of the inter-causeway area (e.g., ECL Envirowest, 2004) are consistent with patterns observed during this reporting period.

Flocks of up to several hundred brant were observed offshore along the TFN transect during November and December 2007. Between March and May, with numbers peaking in April due to migration, brant were recorded in large flocks in deeper water, 500 - 1,000 m offshore, in PCs 12-15 on the DP transect and PCs 126-122 along the BCF transect. Brant were essentially absent from the study area between June and October; however, between one and nine brant were recorded during surveys in both June and July. **Table 2** provides on overview of brant distribution and relative abundance within the study area.

2.7.1.3 Shorebirds

Fourteen species of shorebirds were observed during the survey period as indicated in **Figure 2.7-5**. A list of all bird codes used in this report is included as **Appendix E**. Of the 14 species, dunlin was by far the most frequently recorded species comprising 83% of the total observations. Western sandpiper comprised an additional 11%, while unknown *Caldris* species made up 4%, and black-bellied plover comprised approximately 1% of the total observations. Western sandpipers comprised the majority of shorebird detections during July and early August 2007 (fall migration), and were abundant during spring migration (April and early May). Peak daily counts of western sandpiper during spring migration were 6,055 (April 24) and 1,315 during fall migration (July 17); however, the fall migration was more protracted than spring migration.

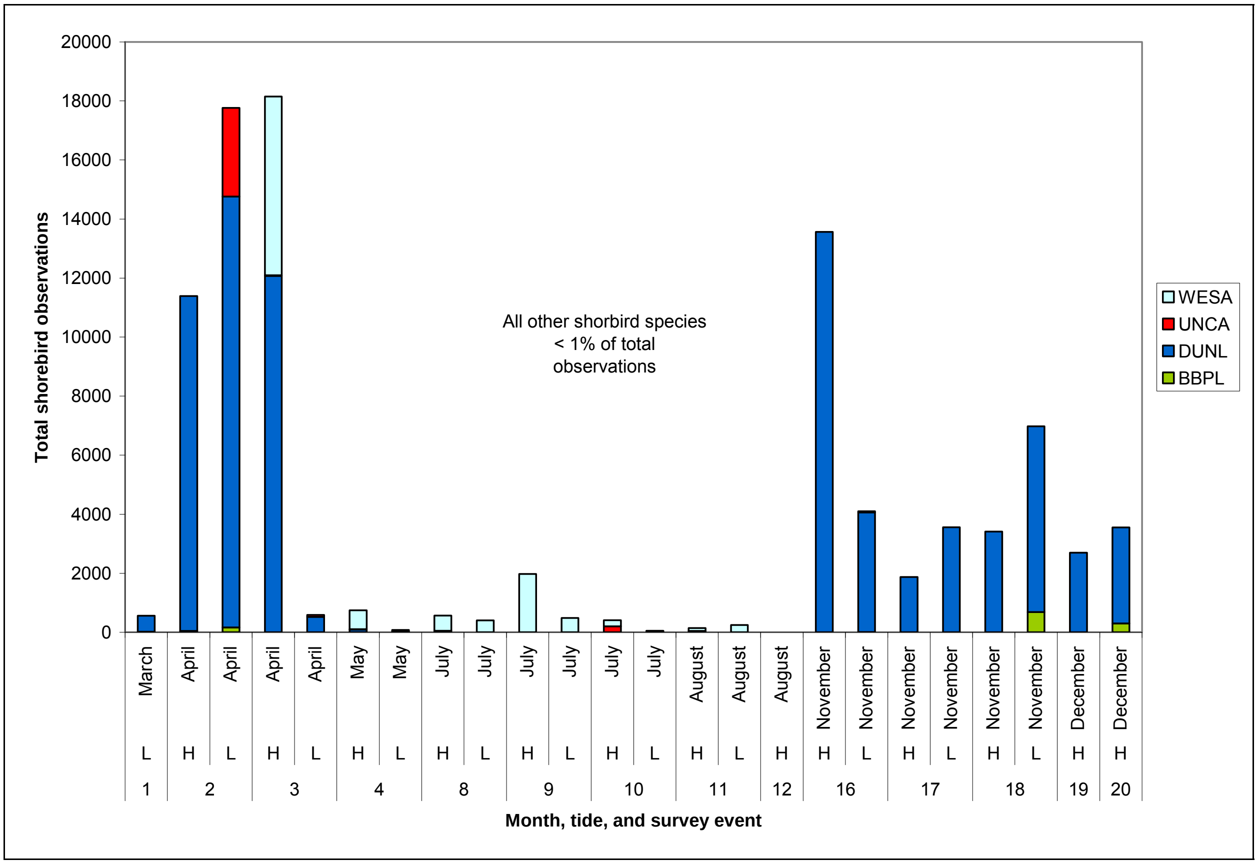

Figure 2.7-5: Total number and composition of shorebird species observed in the study area

Shorebirds were observed along the TFN transect during high tide (where there is usually some mudflat exposed); however, surveys conducted in November detected large flocks of dunlin using the newly constructed perimeter dyke for roosting during both high and low tides (minimal daily low tides at this point). At low tides, shorebirds distribute themselves along exposed mudflat often following the tide line, and as such, shorebirds were more frequently observed along the DP and BCF transects during low tide events as indicated in **Figure 2.7-6**.

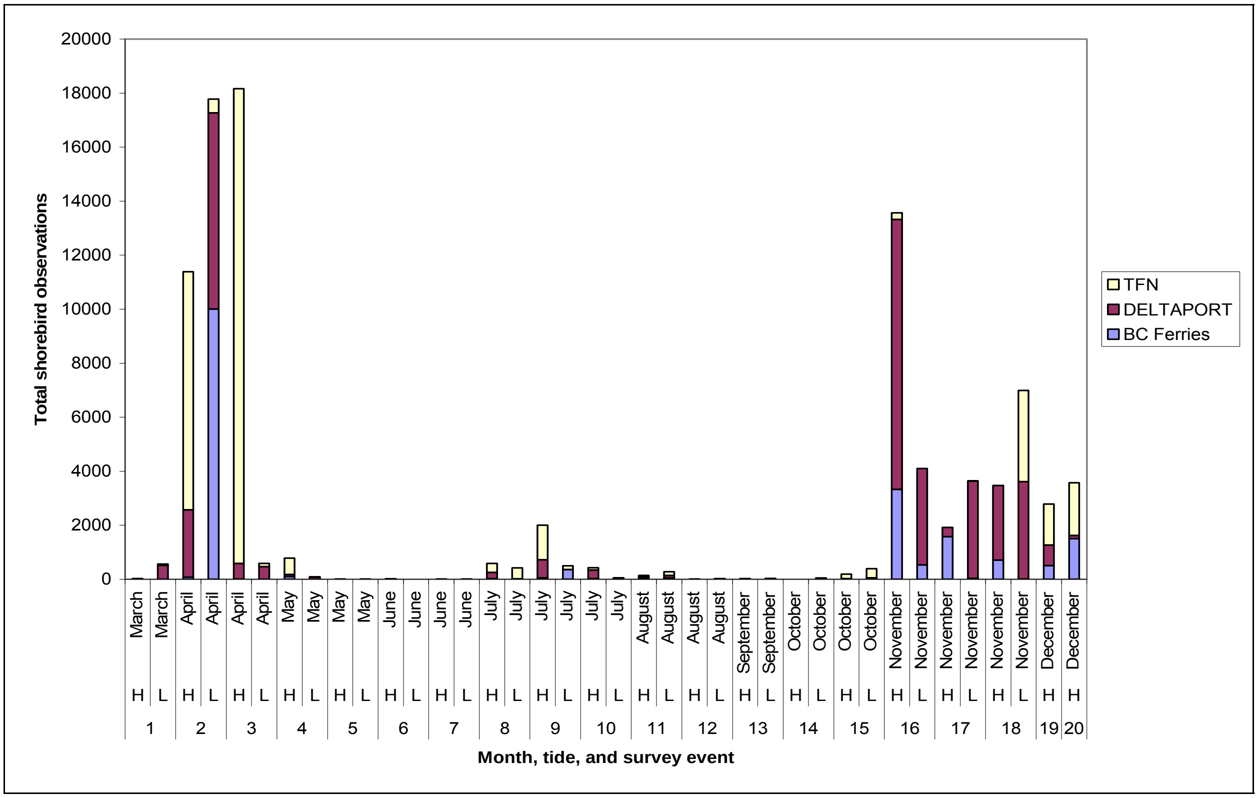

Figure 2.7-6: Total shorebird observations as recorded by transect and separated by tidal level and survey event

2.7.1.4 Coastal Waterbirds

For the purposes of this annual report, birds that are categorized as coastal waterbirds include ducks, cormorants, grebes, swans, geese (other than brant; see **Section 1.1.4.2**), gulls, terns, jaegers, coots, and alcids. The following discussion provides details of the distribution and relative abundance of dabbling ducks, diving ducks, and other coastal waterbirds including cormorants, grebes, gulls and terns.

Dabbling Ducks

Eight dabbling duck species observed during this reporting period include American widgeon, Eurasian widgeon, gadwall, cinnamon teal, green-winged teal, mallard, northern pintail, northern shoveler. American widgeon were the most commonly observed dabbling duck followed by northern pintail, mallard, and green-winged teal as indicated on **Figure 2.7-7**.

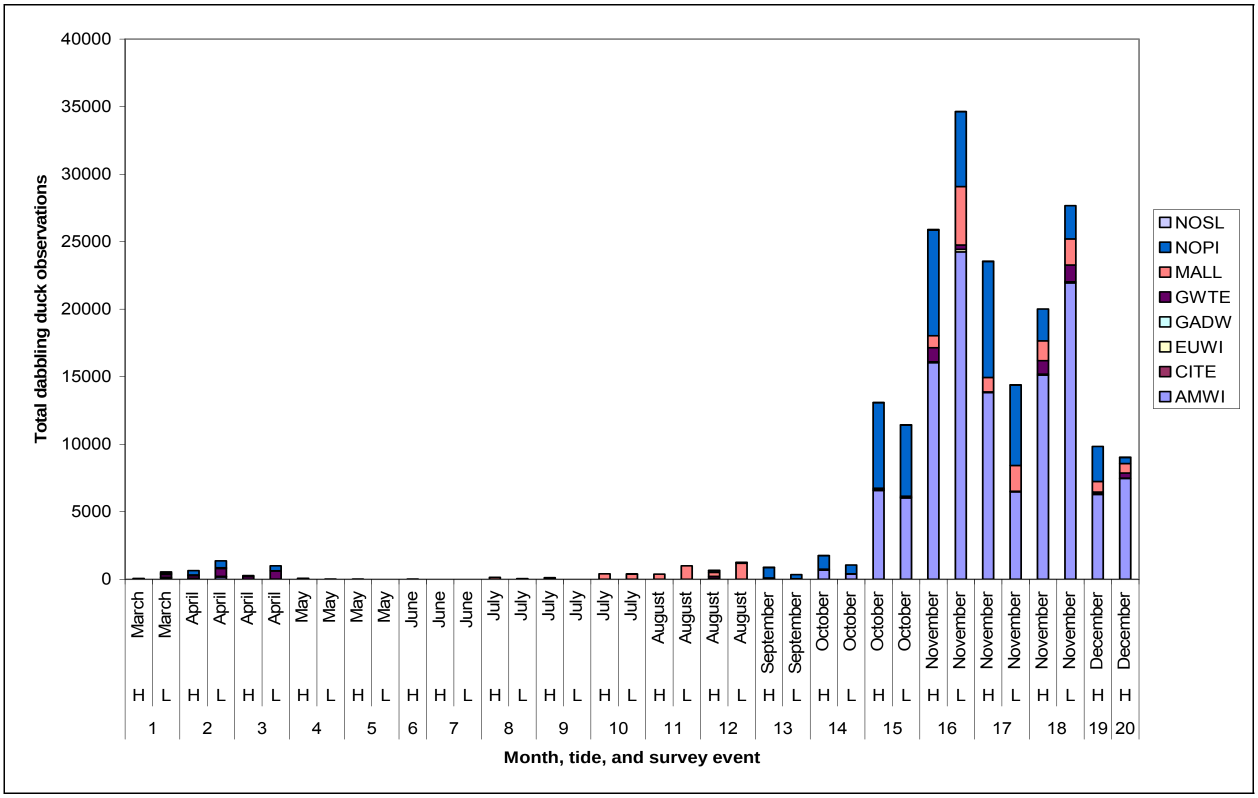

Figure 2.7-7: Total number and composition of dabbling duck species observed in the study area

Dabbling ducks were consistently recorded in mixed flocks throughout the inter-causeway area; however, densities were greatest along the TFN transect between October and December. This is consistent with peak numbers of dabbling ducks (approximately 25,000 in December 1988) using the inter-causeway area as reported in Butler and Cannings (1989). Dabbling ducks were also consistently recorded along the DP transect and to a lesser extent, along the BCF transect (primarily the compensation lagoon). Mallard and American widgeon were consistently recorded swimming and resting around the newly constructed perimeter dyke at PC 13. Green-winged teal were found almost exclusively within 250 m offshore along the TFN transect, although they were also recorded using the compensation lagoon. Northern pintail were found in the greatest densities along the TFN transect but were common throughout the study area. American widgeon and mallard were the most widely distributed dabblers and were frequently found further offshore than the other species. **Figure 2.7-8** represents dabbling duck usage of the inter-causeway area by transect as separated by tide and survey event.

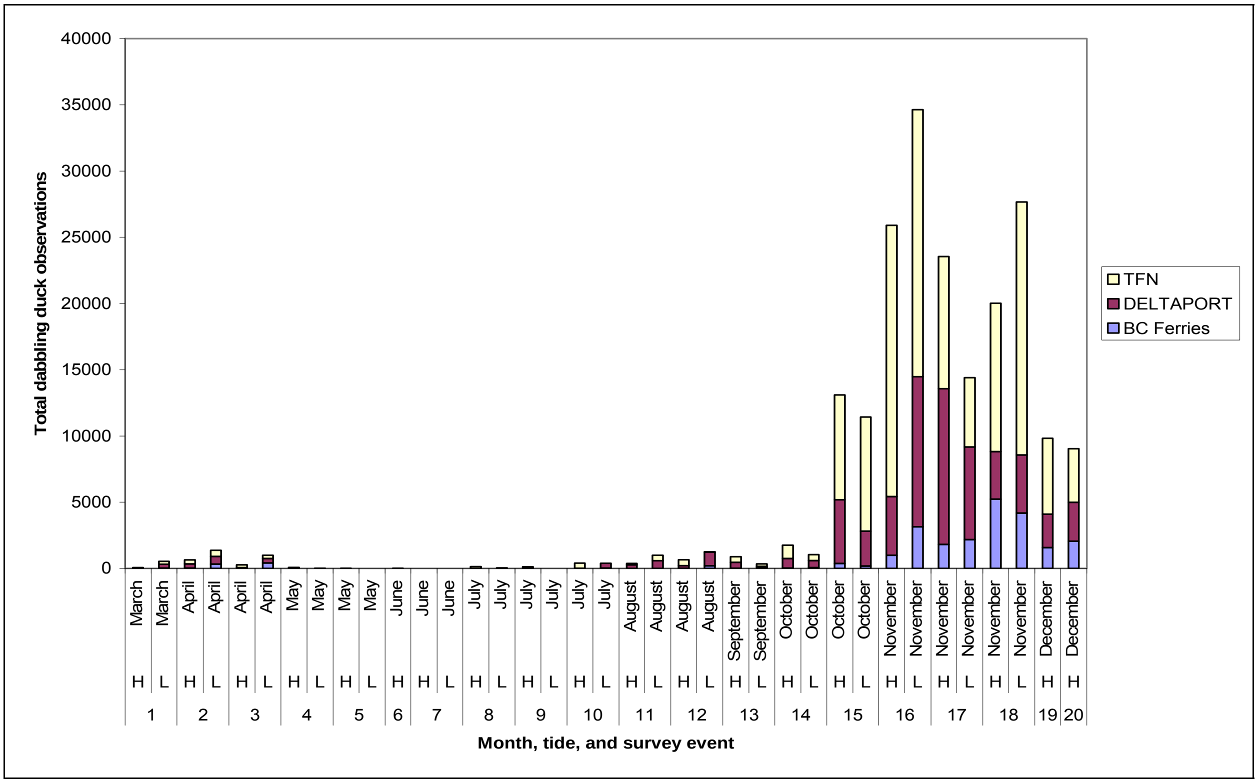

Figure 2.7-8: Total dabbling duck observations as recorded by transect and separated by tidal level and survey event

Diving Ducks

Eleven species of diving ducks were recorded during the study period. Of these eleven species, four species comprised 97% of the total observations: greater scaup (34%), surf scoter (25%), white-winged scoter (20%), and bufflehead (18%). In general, diving ducks are considerably less abundant than dabblers. The maximum count of diving ducks during a single tidal event was approximately 1,000 birds, while up to 35,000 dabblers were recorded on a single tidal event. Additionally, numbers of diving ducks observed during survey events remained consistent between October - December and March - April 2007 (**Figure 2.7-9**) while numbers of dabbling ducks were much higher during the October – December survey period than the March – April period.

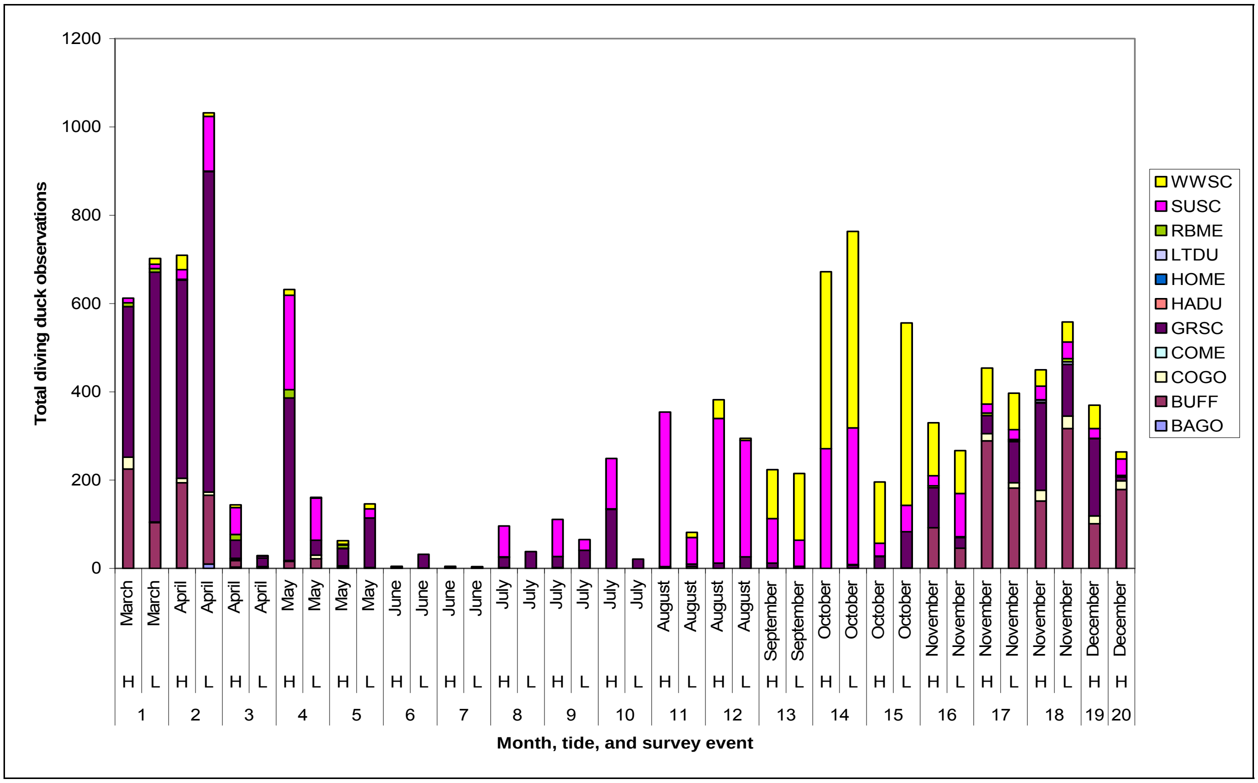

Figure 2.7-9: Total number and composition of diving duck species observed in the study area

The majority of diving ducks were recorded offshore along the DP and BCF transects (**Figure 2.7-10**). Diving ducks were infrequently recorded along the TFN transect and were observed between 500 – 1,000 m offshore.

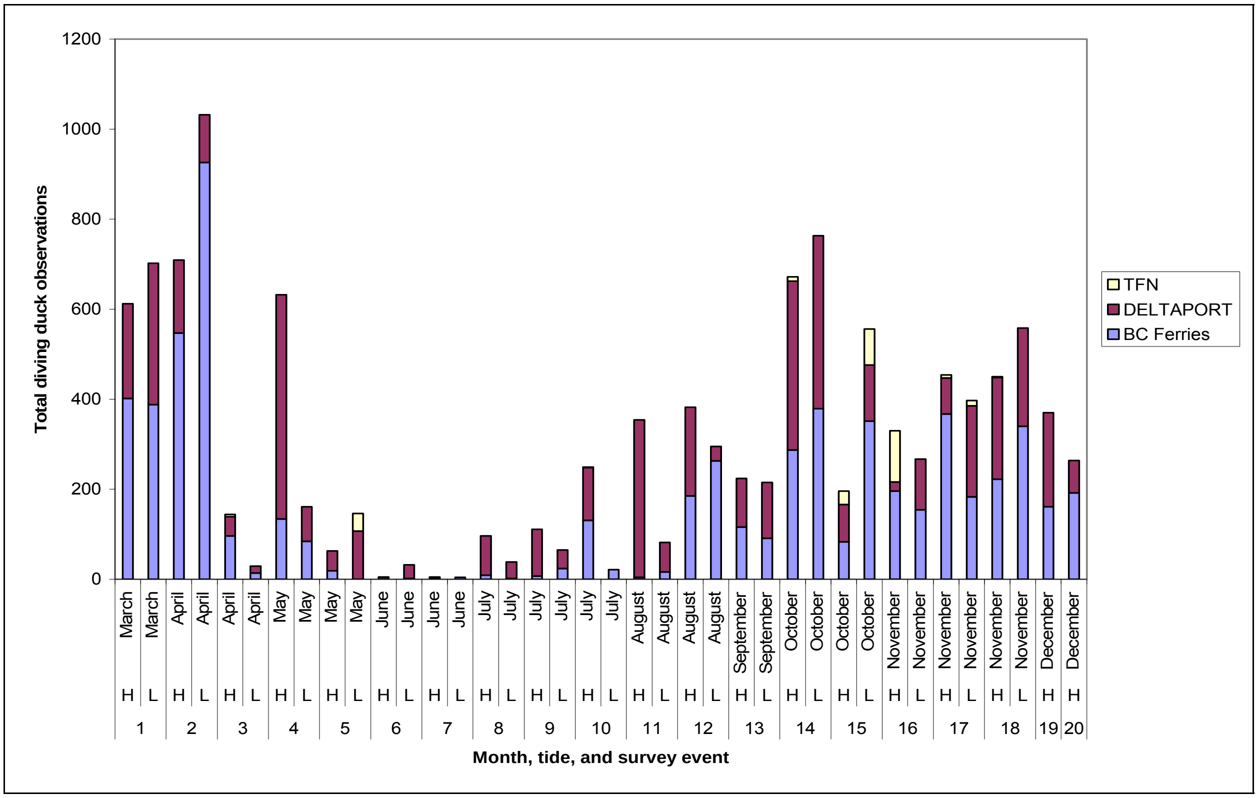

Figure 2.7-10: Total diving duck observations as recorded by transect and separated by tidal level and survey event

<u>'Other' Coastal Waterbirds</u>

Other relatively common coastal waterbirds included western and horned grebe, double-crested and pelagic cormorant, and common loon. These birds comprised approximately 99% of all 'other' coastal waterbird observations: double-crested cormorant (44%), western grebe (32%), horned grebe (10%), common loon (8%), and pelagic cormorant (5%). Less common species included red-throated and Pacific loon, red-necked grebe, Brandt's cormorant, common murre, pigeon guillemot, rhinocerous auklet, Canada goose, and trumpeter swan. **Figure 2.7-11** indicates the number and composition of these waterbirds by survey, separated by tidal level.

Similar to diving ducks, the majority of waterbird observations were recorded offshore along the DP and BCF transects with infrequent observations along the TFN transect (**Figure 2.7-12**).

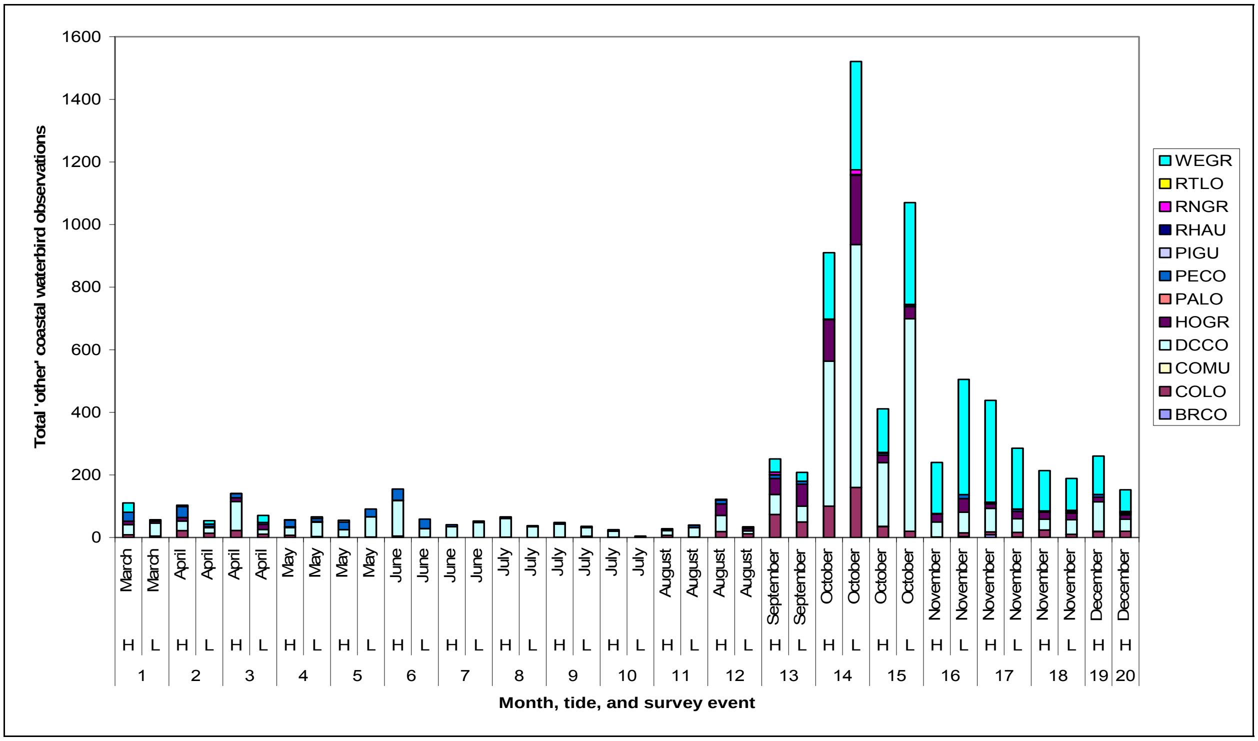

Figure 2.7-11: Total number and composition of coastal waterbird species observed in the study area

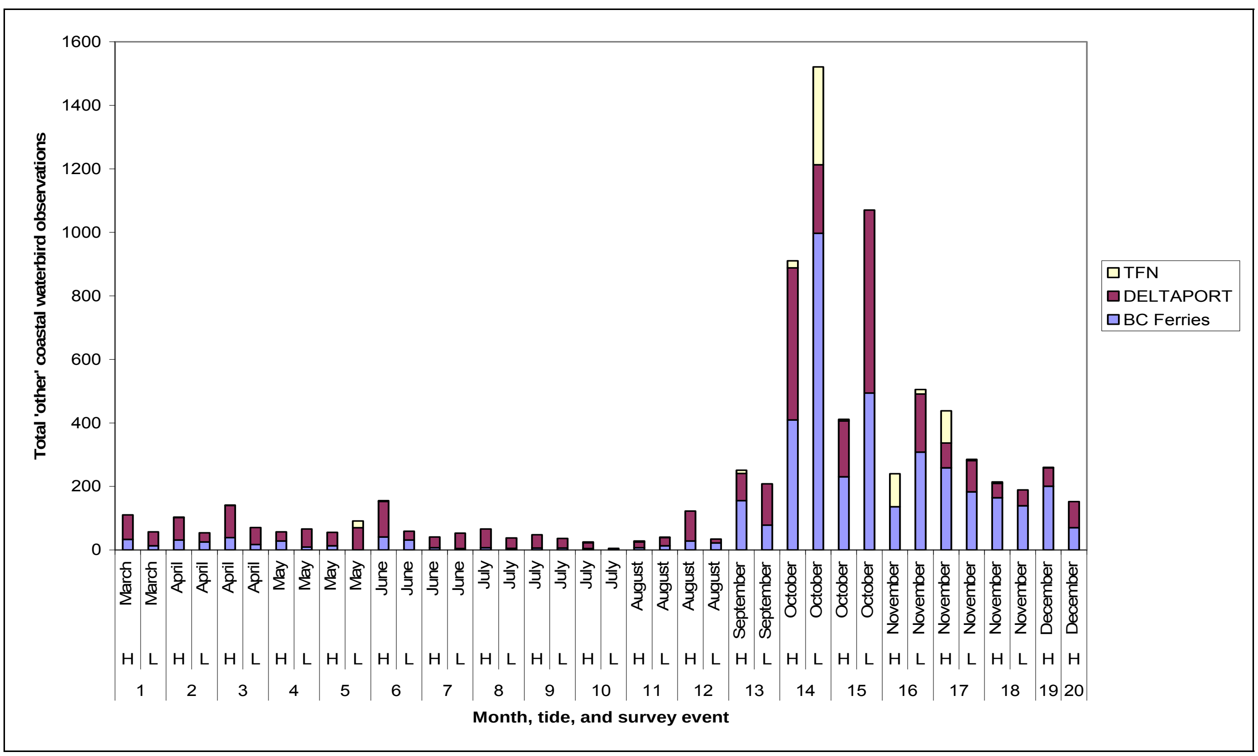

Figure 2.7-12: Total 'other' waterbirds observations as recorded by transect and separated by tidal level and survey event

Gulls and Caspian Tern

Five species of gulls comprised 99% of the gulls observed: ring-billed gull (43%), glaucous-winged gull (37%), mew gull (9%), unknown gull (8%), and California gull (2%). Other species of gulls observed include Bonaparte's, herring gull, Thayer's gull, western gull, and assumed hybrid gulls. Potential hybrid gulls (assumed to contain part glaucous-winged gull) were classified during the study as glaucous-winged and potential hybridization was noted. Based on our observations of larger white-headed gulls, we suggest that a relatively large proportion of the local population of glaucous-winged gulls may have undergone some degree of hybridization (e.g., glaucous-winged gull x western gull, and to a lesser extent glaucous-winged x either herring or Thayer's gull). Attempts were made to distinguish hybrids but accurate classification was often not possible in the field (8% of total observations were 'unknown gulls'). The seasonal distribution and relative abundance of gulls in the study area is presented in **Figures 2.7-13 and 2.7-14**. Caspian terns are also included in these figures.

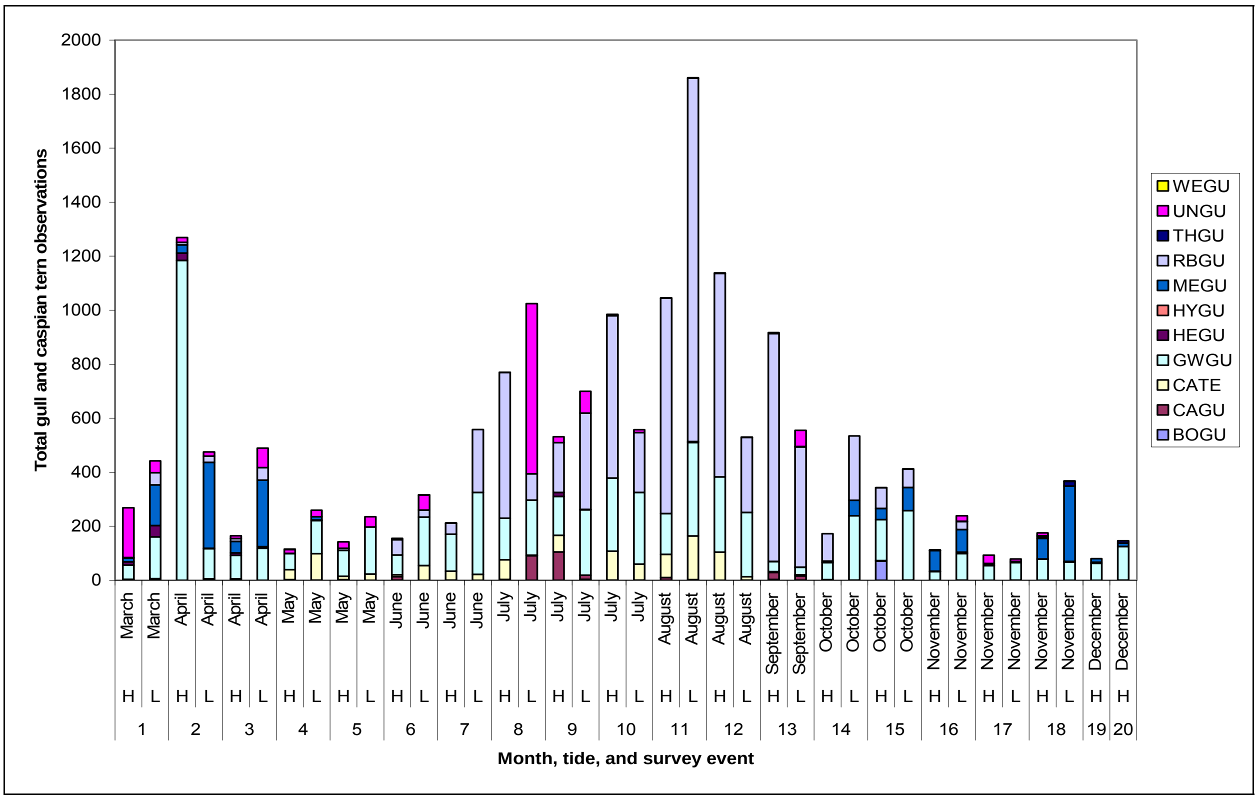

Figure 2.7-13: Total number and composition of gull species observed in the study area (Caspian tern are also included in this figure.)

Gulls were distributed primarily along the DP transect but were common throughout the inter-causeway area, as indicated in **Figure 2.7-14**.

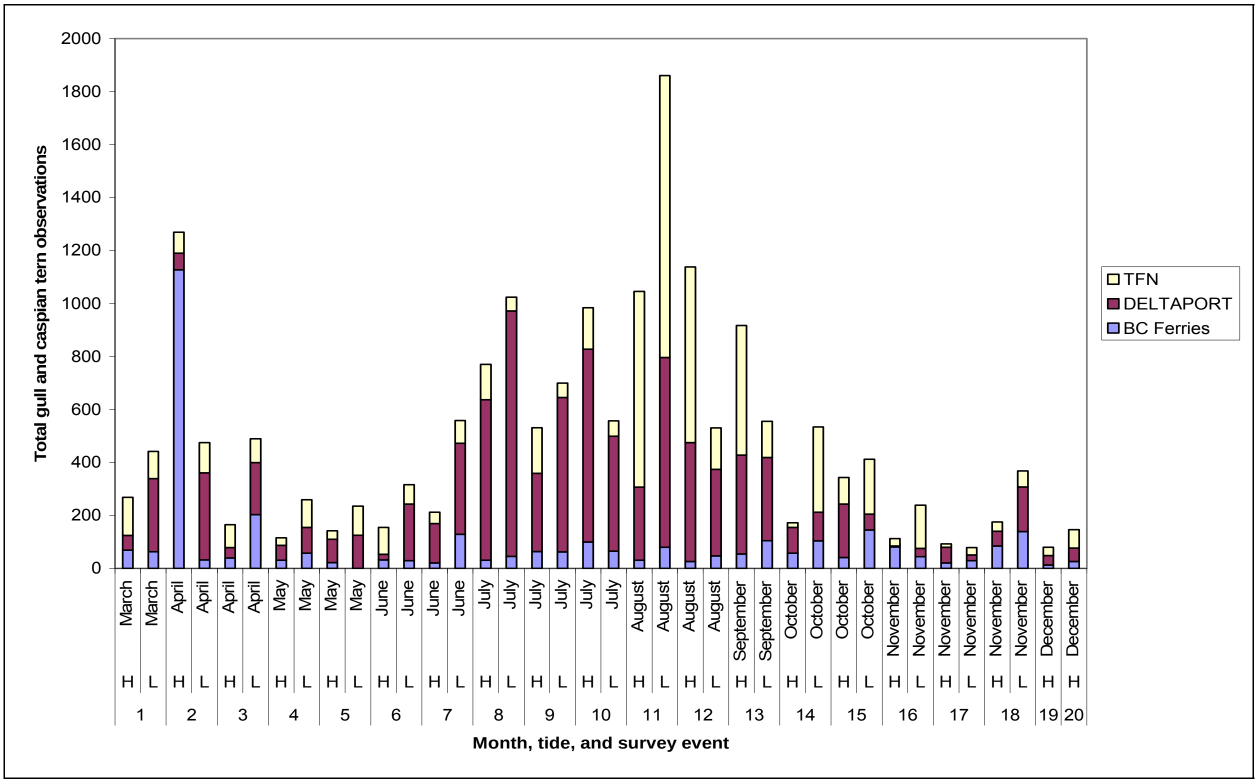

Figure 2.7-14: Total gull observations as recorded by transect and separated by tidal level and survey event (Caspian terns are also included in this figure.)

2.7.1.5 Raptors

Nine species of raptors were identified in and around the inter-causeway area. Bald eagles were by far the most abundant comprising 74% of 381 total observations, followed by northern harrier (14%), and osprey (6%). Other, less frequently observed raptors include American kestrel, peregrine falcon, rough-legged hawk, red-tailed hawk, short-eared owl, and sharp-shinned hawk. Bald eagles have several nests in areas surrounding the study area, including two nests in the heron rookery at Tsatsu Bluffs, one (which blew down in October and has not been rebuilt) in a hydro tower just north of the overpass crossing the railway along the Deltaport Causeway, one, and possibly two nests inland along the Brunswick Marsh dyke, and another further along the Deltaport Causeway near the Highway 17 interchange.

Eagles were observed as flyovers throughout much of the survey area and were the major cause of disturbance to resting and feeding duck species. Northern harrier and red-tailed hawk were commonly seen around the TFN marshlands. Peregrine falcons were observed on several occasions along the Ferry Causeway and the TFN transects.

A pair of osprey was previously observed nesting in a navigational aid situated within the DP3 footprint (ECL Envirowest, 2004). Hemmera and VPA relocated this nest on March 12 and 13, 2007, under MOE permit SU07-31495 granted under provisions of the *Wildlife Act*, prior to the arrival of the osprey pair to the inter-causeway area in the spring. While the navigation marker and the remnant nest structure were successfully relocated and a pair of osprey returned to the inter-causeway area, no nesting was observed either on the relocated platform or elsewhere in the vicinity of the study area. Bald eagles were observed perching on the relocated nest on several occasions and may have deterred osprey from using this as a nesting location. No juvenile ospreys were observed during the survey period, and a maximum of two birds were recorded at any given time. Assuming the osprey return this April, greater effort will be required to determine if an alternate nesting location is being used.

2.7.1.6 Other Birds

Other birds observed regularly during the survey period include: northwestern crow, Brewer's blackbird, red-winged blackbird, savannah sparrow, song sparrow, white-crowned sparrow, house finch, rock pigeon, European starling, barn and tree swallows, and American robin among others. These birds were observed along the perimeter of the study area, often perched in surrounding trees and shrubs, as flyovers, or heard singing/calling.

3.0 DISCUSSION

3.1 COASTAL GEOMORPHOLOGY

3.1.1 Crest Protection Monitoring

The crest protection structure was installed on the tidal flats, in the inter-causeway area, as an erosion mitigation measure between 1982 and 1984 in conjunction with expansion of the ship turning basin at Deltaport. As drainage channels had formed around the perimeter of the initial excavated sediment borrow pit, the turning basin was installed in part to mitigate the formation of new channels. Since 1984, an extensive and complex system of channels has formed on the tidal flats, which are driven by tidal flow.

The crest protection structure is not perfectly level. Therefore, water flowing over the structure at higher tide stages is concentrated into the areas where the crest is lower. Channels running perpendicular to the structure on both the seaward and landward sides are found in these areas. At tide stages near to the elevation of the crest, tidal flow is diverted laterally along the structure, and this flow has created significantly-sized channels running parallel to the shoreward side of the structure. These features are visible on the historic air photos and were observed during earlier site inspections in 2004 and 2006. The features are not related to DP3 construction activities.

Figure 19 shows the plotted cross-section data from July and October 2007 as well as January 2008 (January 2008 is included for comparison despite this data falling outside of the 2007 monitoring period). These surveys show very minor elevation changes (up to 10 cm to 15 cm) at all cross-sections as well as some more significant elevation changes at cross-sections 3 and 5. Cross-section 3 shows that the shoreward channel running parallel to the structure experienced scour and fill on the order of 20 cm to 30 cm over the monitoring period. Cross-section 5 shows a similar pattern with up to 0.5 m of fill followed by 20 cm to 30 cm of scour on the seaward side of the structure.

Prior to discussing these apparent changes, it is useful to consider the accuracy of the survey data. Sources of error in the plotted cross-sections arise from random error in the equipment as well as random error introduced by the instrument operator. The real-time kinematic global positioning system (RTK GPS) that is used to collect the survey data relies on a real-time correction for accurate positions. The user-specified software thresholds are set to a minimum of 5 cm accuracy in both the horizontal and vertical measurements. This prevents data collection during periods when data quality may be degraded, for example because of poor signal strength, and ensures good relative accuracy. Repeat measurements of local benchmarks during quarterly monitoring activities have shown that the absolute accuracy of the GPS data remains within these bounds.

Random error introduced by the equipment operator represents a much greater source of error in the surveys. The survey data are collected during a range of tide, weather, and light conditions. Lateral variation in the position of the collected points, both parallel and perpendicular to the cross-section can result in significant variation in elevation. For example, on the crest protection structure, horizontal variation in elevation is largely due to the presence or absence of large pieces of rock. Review of the survey data shows that during the initial survey there was up to 4.5 m of lateral drift from the survey line (with the lines established, subsequent re-surveys typically vary by less than 0.4 m laterally). During the Q3-2007 monitoring, a less dense survey was completed because of night-time conditions and the rapidly rising tide. Interpolation between points that were not collected in precisely the same location is another source of uncertainty. Although it is not possible to precisely evaluate the magnitude of these errors, it is reasonable to expect that apparent differences in the plotted cross-sections of 10 cm to 20 cm may not be significant.

Cross-sections 3 and 5 show areas where elevation changes exceed the estimated error of the surveys. The scour and fill in the channel on the shoreward side of the crest protection structure at cross-section 3 occurs in an area where the channel has been observed to be fairly active. It is highly unlikely that these changes are related to the DP3 project. Future quarterly monitoring will continue to observe this area.

The changes at cross-section 5, amounting to up to 50 cm of fill and between 20 cm to 30 cm of scour, occur on the seaward side of the crest protection structure in an area that is affected by wave action and mobile sandy sediments. The DoD rod at E06, which is nearby, has shown a similar amount of scour and fill during the same period. These elevation changes appear to be related to movement of sandy sediments that may originate from the large dendritic channels but are definitely being reworked by tidal flow over the structure as well as wave action affecting the area seaward of the structure. Past observations suggest that the sandbars that have formed around the edge of the turning basin migrate through a process of longshore drift.

A brief examination of orthophotos collected in 2002, 2006, and 2007 shows that the small channels on the seaward side of the crest protection structure appear to be stable. Any apparent change in the location of the channels over time is within the error limits of the photos, particularly introduced by slight changes in tide levels. The elevation changes shown in cross-sections 3 and 5 are small and suggesting cyclical variation, possibly related to winter storms, rather than a long-term trend. These processes were actively occurring prior to the DP3 project and the changes noted should not be attributed to DP3.

The *AMS Detailed Workplan (*Hemmera, 2007a) includes a methodology for evaluating change within the study area. For those monitoring parameters that do not have national, provincial or regional objectives or standards, a 20% effect level or percent change over background has been selected as the AMS threshold. The 20% effect level is derived from standard toxicity testing and as a result, does not necessarily have wide application to monitoring of geomorphic parameters. Many natural physical processes vary within a very large range of values. For example, the mean discharge in the Fraser River at Hope for the period March 1 to March 14, 2008 was approximately 820 m^3/s while the peak discharge during the spring freshet of 2007 was over 10,000 m^3/s (Water Survey of Canada), representing a change of over 1100%. A further complication to applying this method for evaluating change at the crest protection structure is that the survey data are not in an absolute scale and there is no record of typical background variation at the site. At this time it is necessary to rely on qualitative interpretation of the monitoring data to evaluate acceptable thresholds for change.

3.1.2 Automated Turbidity Monitoring

The sensors showed suspended sediment concentrations that were generally very low in comparison to Fraser River concentrations, which is in agreement with previous studies on the Fraser River plume and Roberts Bank Causeway. Sediment concentrations increased in a relatively complex fashion in response to storm events due to the effect of tide levels on near bed velocities and wave breaking conditions. Sediment concentrations at the two sensors reached a maximum when storm activity coincided with a near mid-tide level (approximately 2.5 to 3.5 m CD). When storms coincided with low tide, the waves were breaking seaward of the crest protection, which limited wave conditions on the tidal flats. When storms coincided with high tides, the near bed velocities were reduced, which also reduced sediment entrainment and transport.

Sediment mobility under wave action was characterized previously on Roberts Bank using the sediment transport equations developed by van Rijn (1989). The method is based on relating sediment mobility to the applied bed shear stress using the following parameters:

$$D_* = [\frac{(s-1)g}{\nu^2}]^{1/3} D_{50}$$ Dimensionless grain diameter

$$T = \frac{\tau - \tau_c}{\tau_c}$$ Excess shear parameter T

Where, D_{50} is the median grain size, (s – 1) is the submerged specific gravity of the sediment, ν is the kinematic viscosity, t is the bed shear stress and t_c is the critical shear stress to initiate sediment movement

The maximum bed shear stress (τ) due to waves was computed as follows:

$$\tau = 1/2 \rho f_w U_0^2$$

Where, f_w is the wave friction factor, U_0 is the maximum orbital velocity due to waves, and ρ is the density of seawater. These parameters were computed for selected wind and wave frequencies using the SWAN numerical wave model output for existing conditions (NHC, 2004). These computations represent the effect of waves entraining the sediment into suspension, essentially by "stirring-up" the sediments. Tidal currents or other longshore-generated currents may then advect the sediment across the tidal flats. Tidal current velocities on most of the tidal flats (outside of defined channels) were found to be too low to entrain the sandy sediments.

The wave computations were made for a SE wave having a deep water wave height of 2.4 m and a wave period of 7.3 seconds, which is similar to conditions experienced on November 12, 2007. **Figure 40** shows the spatial distribution of sediment mobility for SE waves at High Tide and Mean Tide (from NHC, 2004). In deep water where the bed velocities were virtually zero, conditions were below the threshold for sediment movement. Initiation of motion occurred at depths of approximately 7 to 10 m for incident wave heights greater than 1.5 m. Transport intensities peaked in depths of 3-4 m, then decreased shoreward due to the reduction in wave heights due to refraction, shoaling and attenuation. The computed sediment mobility at the locations of the two turbidity sensors showed sediment transport intensity was greatest at mid-tide level and decreased at higher tide due to the increased water depth and reduction in velocities. The peak sediment concentration was estimated to reach up to a maximum of 200 mg/L for these particular conditions, and is consistent with the measured values shown in **Figure 22,** which presents measurements from storm events on November 12 and December 15, 2007.

The results from the monitoring program to-date generally confirm that the analytical methods and models used in (NHC, 2004) were appropriate for predicting sediment transport conditions under waves.

3.1.3 Monitoring of Erosion and Deposition

The rates of erosion and deposition on the tidal flats were low, typically less than 10 cm. **Figure 23** shows that the DoD rods located on the seaward side of the crest protection structure have experienced the greatest change, with a net deposition of 11.1 cm and 19 cm at F06 and G06 respectively and total erosion in one quarter (Q2-2007) of 14.9 cm at G06. These changes in bed elevation appear to be related to migration of sand bars. The area around the new drainage channels has also experienced high amounts of deposition, particularly between the first two monitoring periods when water was still draining from the perimeter dyke. Deposited material was observed to be composed of fine cohesive sediments overlying the sandier pre-existing material.

The large amount of erosion and deposition that was measured at C02 between the Q1-2007 to Q2-2007 period is somewhat anomalous as it is caused by a small drainage channel that formed adjacent to the DoD rod. This channel has since migrated away from the rod and has stabilized to some degree. The large amount of erosion that has occurred at B02, amounting to 5.2 cm between Q1-2007 and Q2-2007, and 4.2 cm between Q3-2007 and Q4-2007, with 5.4 cm of deposition during the final period, cannot be explained so readily. A shallow depression has been observed shoreward of B02, and this may be related to the trend at the DoD rod.

The DoD rods at B05 and C05 both show anomalously high rates of erosion between the Q3-2007 to Q4-2007 period, on the order of 6.5 cm and 4.5 cm respectively. Although the occurrence is anomalous in the context of the magnitude of erosion and deposition that occurred at the surrounding DoD rods, the absolute value of the erosion is not very large. **Figure 31** shows the results of interpretation of the ortho-photographs taken in 2007, which is discussed below. DoD rods B05 and C05 correspond to an area of channel that has been mapped on the ortho-photo because it appears to be a shallow depression that remains partially wetted at low tide. The anomalously high rates of erosion measured at these DoD rod sites may be related to slightly higher rates of tidal flow within this depression. There does not appear to be an active channel forming in this depression at present. The area contains a dense coverage of eelgrass and there are no bare channels visible. Continued monitoring in 2008 may improve our understanding of these results as well as ensure that any signs of channel formation are detected. It is unlikely that additional DoD rods in this area would significantly improve our understanding of the sediment transport dynamics, nor is the allocation of additional field time warranted given that the processes acting at the site are not significantly affected by the presence of the DP3 project.

As discussed above in **Section 3.1.1**, the *AMS Detailed Workplan* (Hemmera, 2007a) stipulates that changes in the monitoring parameters in the study be evaluated based on a 20% exceedance threshold. Similar to the elevation data collected during crest protection structure monitoring, it is not possible to make a simple percentage calculation for a threshold of change because the values collected refer to relative, not absolute, change. Also, as described above, the magnitude of change to geomorphic parameters in a natural system can exceed one or more orders of magnitude.

A methodology has been developed to evaluate the DoD rod data objectively, meeting the commitments of the AMS Workplan. It is necessary to use the existing DoD rod data as a basis for evaluating the normal range of values for erosion and deposition because pre-project data are not available. For the purposes of the analysis, the DoD rods are separated into three areas having similar geomorphic characteristics: rods outside the crest protection structure (n=5), rods within the area of new drainage channels (n=3), and the remaining rods on the tidal flats behind the crest protection structure (n=18). Most DoD rods were sampled four times during 2007, resulting in three measurements of relative change. The quarterly measurements for each subset of rods were lumped together to provide a grouping of measurements describing change in elevation on the tidal flats throughout one year. The rods were assigned to the three groups as follows:

- Group 1 (area seaward of the crest protection structure): D04, D05, E06, F06, G06;
- Group 2 (area of new drainage channels): D01, E01, E02;
- Group 3 (remainder of tidal flats): A03, A04, A05, A06, B02, B03, B04, B05, B06, C01, C02, C03, C04, C05, C06, D02, D03, and D06.

Table 18 shows the summary statistics for each geomorphic area (group) by quarter and for the year, as well as the summary statistics for the combined erosion and deposition data for each group. Group 1 and Group 3 show almost zero net change in elevation for the year, while Group 2 shows a net change for the area of less than 1 cm. Group 1 experienced the greatest range in erosion and deposition with a standard deviation of 6.57 cm, while Group 2 and Group 3 experienced a much smaller range in erosion and deposition with a standard deviation of 3.22 cm and 2.15 cm respectively.

The summary statistics provide a measure of variability and from these it is possible to set a reasonable threshold of change for consideration under the AMS. For normally distributed data, one standard deviation (1s) on either side of the mean accounts for 68.3% of the variance, while two standard deviations (2s) account for 95.5% of the variance. Given that there is a considerable amount of natural variability in most geomorphic systems, 1s seems too low of a threshold but 2s captures too much of the variability and does not provide enough conservatism for monitoring a sensitive environment such as the Roberts Bank tidal flats. A reasonable limit therefore, would be to consider that 80% of the variability is acceptable and that values falling outside of the 1.282s bear further investigation. **Table 18** provides a calculation of the 1.282s threshold.

For Group 1, DoD rods F06 and G06 exceeded the threshold for deposition in Q2 and G06 exceeded the threshold for deposition in Q3. All other values were within the threshold and there does not appear to be any issues of concern in the area outside the crest protection structure.

In Group 2, DoD rods E01 and E02 exceeded the threshold for deposition in Q2 and E02 exceeded the threshold in Q3. All other values were within the threshold. We know from observations, that following the initial disturbance of erosion and deposition that occurred when water and sediment were leaking from the perimeter dyke, that leakage ceased and the site has begun to stabilise. The values of deposition that exceeded the threshold are no longer of concern in terms of immediate action.

In Group 3, the threshold for erosion and deposition was exceeded at a number of DoD rods during each quarter. High values for C02, as well as for B05 and C05 have been discussed above. For the remainder of the instances of exceedence, the values are generally one-off during a single quarterly monitoring period and are not repeated and therefore do not point to a negative or positive trend.

3.1.4 Sediment Samples

Most samples (23 out of 26) showed only very minor changes in grain size or silt fraction between May and October 2007 (**Table 10**). The samples taken from sites E01 and E02, which are within the area of new drainage channels, showed the sediment composition was notably finer in October. These samples also showed an increase in silt content. The May samples contained 17% silt and 8% silt respectively.

Samples from E01 and E02 in October contained 36% to 39% silt. Based on supplementary field observations, this change is due primarily to the large amount of fine sediment that was introduced to this area by leakage of water and sediment from the DP3 footprint through the perimeter dyke.

The May sample collected at A03 had a silt content of 34%, which is consistent with its location higher on the tidal flats. The second sample collected from this location showed a slight decrease to 28% silt content. Although this does not represent a significant change, the map shows it as such because the samples fall into different Silt % classes (from the 33% to 48% class down to the 17% to 32% class). The very high silt concentration in the May sample at site D02 was not replicated in the November sample, which had a silt content below 17%. This could be attributed to localized sediment erosion/deposition or to shifting of the drainage channels or slight differences in sampling location. At D02, fine material initially deposited may have been remobilized during the much lower summer tides in June and July to result in an October sediment grain-size distribution that is more similar to the rest of the tidal flats.

Organic carbon content (**Table 11**) was determined as part of the grain-size distribution analysis by measuring loss on ignition. This parameter is sensitive to the presence or absence of pieces of eelgrass within the sample because root fragments or blades of eelgrass can have a marked effect on the results of the carbon analysis. Also, unlike changes in the grain size that occur in only the near-surface sediments, carbon content would be expected to change at greater depths in the sediment due to bioturbation and other natural processes. Carbon content is primarily analysed in order to remove it from the sample (during loss on ignition) so that the fine organic matter cannot skew the results of the grain size analysis. The organic carbon content is presented here to demonstrate that it is very small in all samples. Local variation in the samples due to micro site sampling selection appears to have a greater influence on the returned value than any expected temporal or geographic trend.

3.1.5 Interpretation of Orthophotographs

Four main areas of geomorphic change have been identified from the interpretation and mapping of the orthophotos:

1. New drainage channels that have formed at the north-eastern margin of the perimeter dyke
2. Formation of sand bars on the tidal flats on the seaward side of the crest protection structure
3. The large system of dendritic channels draining into the turning basin
4. The tidal channels adjacent to the BC Ferries causeway

These features are shown in **Figure 31.**

3.1.5.1 New Drainage Channels

The new drainage channels visible in the July 2007 orthophoto (**Figure 31**) were initially formed by seawater, and later by both seawater and fine sediment from the dredgate, leaking from the perimeter dyke enclosing the DP3 footprint. **Figure 32** shows a comparison of the same area from May 2006, when there were no channels, and July 2007, after the channels had formed. Following construction of the perimeter dyke, the area inside the dyke filled with water during high tide and then the water flowed out onto the tidal flats during the dropping tide. The channels were observed during quarterly monitoring on April 18, 2007 and documented in the environmental monitoring reports for construction activities as early as April 20, 2007 (Hemmera, 2007c). A seal, comprised of a layer of dredged sand several metres thick placed against the inside face of the perimeter dyke, was installed along the south side of the perimeter dyke on July 9, 2007 and the environmental monitoring report noted decreased flow from the perimeter dyke the following day. Some leakage of sediment-laden waters was reported within this period but it is not known if this resulted in deposition of significant amounts of sediment onto the tidal flats or if this material consisted of small amounts of fine material only. The area within the footprint has been filled with sediment from dredging activities to a level above the highest tide and water drainage from behind the dyke has ceased.

A large system of dendritic channels that formed in the centre portion of the inter-causeway area, and continues to evolve, was documented in the *Coastal Geomorphology Study* (NHC, 2004). These channels formed in response to the dredging of the ship turning basin and continue to evolve through a complex interaction between the eelgrass and tidally-driven flow. In contrast, the drainage channels adjacent to the DP3 perimeter dyke have formed in response to leakage of retained water and sediment through the perimeter dyke after the tide level has receded from the mud flats. Leakage of water ceased once the footprint was backfilled with sand and the channels appear to be inactive. The strategies proposed for mitigation of dendritic channels that are outlined in the AMS base document (Hemmera 2005), such as construction of additional crest protection structures, are not required.

The channels have affected an area of approximately 3.4 ha, which can be roughly divided between a zone of erosion and a zone of deposition. The channels on the upper mud flats (above approximately 1.5 m (CD) elevation), which were mostly free of vegetation, initially incised into the soft sediments and carried a significant amount of material into the lower tidal flats immediately shoreward of the crest protection structure. The deposition zone resembles that of an alluvial fan and coincides with an area of medium to dense eelgrass beds. Areas within the eelgrass were observed to be buried under the soft sediments within the deposition zone (**Photo 6, Appendix B**). In some areas the sediment is deposited as a prograding 'sheet' (**Photo 7, Appendix B**). Observations made during the Q2-2007 data collection at the DoD rods located in the vicinity of the new drainage channels reported deposition of 6.5 cm to 8.5 cm of soft sediments (Hemmera, 2008a).

The new drainage channels were inspected from a fixed-wing airplane as well as on the ground on March 12, 2007. Initially the channel cross-section displayed a sharp-sided channel shape that is characteristic of newly incised channels (**Photo 8, Appendix B**). Recent inspections show that the channels have evolved to have gently-sloping channel edges that are more characteristic of a stable channel (**Photo 9, Appendix B**). The channels, therefore, appear to no longer be very active, though water continues to flow within them.

Photo 10 (Appendix B) is an oblique view of the new channels taken during the March 12 over flight with the zones of erosion and deposition clearly visible. **Photo 11** and **Photo 12 (Appendix B)** show a slight depression running parallel to the causeway and draining water at low tide into the new drainage channels. Future monitoring will pay particular attention to this feature.

3.1.5.2 Sand Bars Seaward of the Crest Protection Structure

The portion of the tidal flats on the seaward side of the crest protection structure has a much higher level of exposure to wave action than the areas inside the structure. Breaking waves have often been observed in this area but never on the landward side of the structure. Extensive bar forms are visible in the orthophotos taken in 2007 but appear smaller than those on the 2006 orthophoto, which was taken prior to the initiation of DP3 construction activities. This apparent difference is likely partly due to slight differences in the tide level between the photos, but it appears that at some locations the amount of eelgrass between the sand bars and the crest protection structure has decreased.

Constant modification of the sand bars in this area will continue, with wave action and tidal flow moving the existing sediment along the edge of the turning basin, with some new sediment coming from the existing tidal channels. Some of the sand bars have been observed to be burying the existing eelgrass beds but it is apparent that eelgrass will re-colonise areas between the sand bars that are not experiencing rapid deposition. The DoD rods in this area have captured some of the greatest amounts of erosion and deposition, which is discussed above, and the crest protection monitoring cross-sections have captured some of the elevation changes.

Future monitoring activities will continue to make note of changes to this area.

3.1.5.3 Large System of Dendritic Channels

The large system of dendritic channels shown in **Figure 31** was the focus of detailed analysis as part of the *Coastal Geomorphology Study* (NHC, 2004). These channels have been observed to be evolving since 1984, which is the first year of available aerial photographs that were taken following expansion of the turning basin and construction of the crest protection structure in 1982. The system of channels has evolved to cover a very large area of the tidal flats and continues to evolve and expand shoreward. The main trunk channel is approximately 90 m in width and at low tide is over 2 m deep. These channels lie outside the zone of potential influence from DP3 construction activities and are not being affected by, or have any direct effect on the present project.

The main features of interest in the large dendritic channels include the main trunk channel, a very large sand deposit at the shoreward end of the trunk channel, and a system of smaller 'tributary' channels extending from the trunk channel shoreward across the tidal flats. **Figure 34** shows a comparison of the channels using orthophotos from 2002, 2006, and 2007 and includes fixed control points for comparison. **Figure 33** shows the outline of the channels that were digitised from the 2006 and 2007 orthophotos. Shoreward extension of the tributary channels occurred at several locations since 2002 as well as some lateral migration of these channels while the trunk channel appears to have remained stable. Apparent changes to the landward end of the trunk channel are most likely related to slight differences in tide level but could be related to an elevation difference on the large sand bar.

3.1.5.4 Channel Development along the BC Ferries Causeway

The tidal channels that have formed adjacent to the BC Ferries causeway are not related to any of the activities of the Vancouver Fraser Port Authority, however, the channels fall within the study area for the AMS monitoring program. These channels likely formed initially in response to expansion of the ferry terminal. An attempt to block flow within the channel by constructing a rock berm across the channels was unsuccessful and the channels have continued to extend shoreward. A much smaller channel has formed on the upper tidal flats because of overland drainage from the agricultural lands inside the dykes and has been extending seaward. It is expected that at some point in the future these channels may join and it is possible that the larger channel will expand more rapidly once this has occurred.

3.1.6 Coastal Geomorphology Mapping

Figure 35 shows the results of bathymetric surveys that were conducted in 2007 to provide baseline topographic data of the study area.

Figure 41 shows a detailed view of the area around the new drainage channels. This area was surveyed after the new drainage channels had been initiated so for this area the coastal geomorphology mapping does not represent a baseline condition. VFPA conducted additional detailed ground surveys around the perimeter of the channels on June 25 and July 12, 2007 which provide additional resolution on the channel extent. It is very difficult to conduct ground surveys in the channels due to the soft nature of the sediments. It would be useful to carry out a local bathymetric survey (using a boat) in 2008 to estimate the depth of incision of the channels.

3.1.7 General Coastal Geomorphology Discussion

Two important processes have affected the distribution of sediment within the study area during the 2007 monitoring period. The most important process was the formation of new drainage channels near the northeastern edge of the new DP3 footprint, in the vicinity of DoD rods C01, C02, D01, D02, E01 and E02. The formation of these channels was initiated by water filling the DP3 footprint area behind the perimeter dyke and subsequently draining through the porous perimeter dyke material during low ebb tide. A complete discussion of these channels is included with the interpretation of the orthophotographs in **Section 3.1.5.1**. This process has resulted in erosion of material from the upper tidal flats, which was deposited on the lower tidal flats. Additional material also originated from inside the DP3 footprint from leakage of sediment during filling of the perimeter dyke (dredged sediment was pumped into the perimeter dyke using a suction cutter dredge). This impact is related specifically to construction activities and was not anticipated during the previous impact assessment studies (NHC, 2004).

The second major process is movement of sand bars along the seaward side of the crest protection structure. Sediment movement in this area appears to be caused by the combined processes of tidal flow moving material perpendicular to the crest protection structure and wave action moving material along the low-tide shoreline. It is not possible to determine if the sandy sediments are simply being re-distributed from the material already present on this part of the tidal flats or if new sediment is introduced from the erosion of the upper tidal flats and transport by the large dendritic channels.

Changes to the physical environment at Roberts Bank have been ongoing since the initiation of construction activities for the BC Ferries Tsawwassen causeway and terminal in 1958. These changes have been extensively documented in the Coastal Geomorphology Study (NHC, 2004) and include formation of large systems of dendritic channels, lateral expansion of eelgrass beds, and dredging for expansion of the ship turning basin.

Although these large-scale changes are directly related to development at Roberts Bank, there was no cumulative effect predicted from the construction of the new DP3 terminal. The effects that have occurred, such as the formation of new drainage channels at the north-eastern boundary of the perimeter dyke, are specifically related to construction activities.

The data analysed in this report represent almost one full year of quarterly monitoring. The existing AMS monitoring program was designed to monitor the potential effects of the DP3 project on the surrounding environment of the Roberts Bank tidal flats. To date, the measured effects have resulted from short-term unanticipated construction activities and not from the project itself. These effects have been captured by the monitoring program nonetheless, providing useful data from which to continue monitoring in the future. These short-term effects of construction activities have resulted in localized channel formation on the adjacent mud flats.

The AMS monitoring program has collected a significant amount of data that describes the ongoing processes at Roberts Bank. The data indicate that there has been minimal change on the tidal flats. As expected, sedimentation and erosion rates were small (generally less than 10 cm) and sediment transport rates were low. There were relatively few storms in 2007 and the larger storms that did occur, had no apparent significant effects on the processes that were being monitored.

3.2 SURFACE WATER QUALITY

The discussion of surface water quality monitoring results considered both spatial and temporal trends, with particular attention given to parameters associated with eutrophication. A brief description of the parameters included in the trend analysis is provided below.

Results from DP02, DP03, and DP04, intertidal stations in the inter-causeway area, were compared to results from DP06, the intertidal reference station. The results from DP05, the subtidal station in the inter-causeway area were compared to those from the subtidal reference station (DP07).The A level and B level subtidal results were considered separately. DP01 was not included in this comparison as it has no associated reference station.

Copper and zinc were the only two metals that exceeded the BC WQG. As indicated in **Section 2.2**, the five copper exceedances (**Table 13**) were encountered at DP01 (in Q1-2007 and Q2-2007), DP05 (in Q1-2007), and two at DP06 (Q1-2007 and Q3-2007). The zinc exceedances were encountered at DP01 (during Q1-2007 and Q2-2007) and DP05 (during Q1-2007). Although boron, iron, and vanadium exceedances were measured, these exceedances are not considered significant for the reasons discussed in **Section 2.3**

During the Q1-2007 and Q2-2007 sampling events, DP01 was sampled during seasonal daytime low tides where freshwater flow from the ditch was predominant. This can be seen in the lower sodium and chloride concentrations of these two samples (**Table 13**). In contrast, DP01 was sampled at seasonal daytime high tides during Q3-2007 and Q4-2007 as low tides occurred only at night.. The copper and zinc exceedances measured during Q1-2007 and Q2-2007 at DP01 suggest potential upland inputs of metals from the ditch waters. This influence can also be seen during Q4-2007 where copper and zinc concentrations are elevated (three times higher) relative to DP02. This input appears to be limited, as copper and zinc concentrations at the next nearest station, DP02, met the BC WQG. The source(s) of the copper and zinc exceedances at DP06 and DP05 are not known.

Phosphorus and nitrogen are two key nutrients associated with plant growth. Increasing concentrations of either may signal an increased risk of algal blooms or eutrophication. Orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, is the form taken up by plants. For nitrogen, nitrate is the primary source for aquatic plants; however, both nitrite and ammonia have the potential to undergo nitrification to nitrate. TKN is the sum of organic nitrogen and ammonia. Elevated TKN concentrations are usually the result of sewage and manure discharges to water bodies. Nitrate accounted for the bulk of total nitrogen in the water samples (**Table 13**) and the highest concentrations were observed at DP01. Nitrite concentrations were in a similar range across all stations, while TKN concentrations were also greatest at DP01, reflecting potential upland input to the inter-causeway area from adjacent agricultural land.

Other parameters that may act as warning indicators for eutrophication include chlorophyll *α,* TSS, and dissolved oxygen. Chlorophyll *α* concentrations provide a direct measure for an increase in algal biomass. An increase in TSS can signal an increase in phytoplankton or detritus associated with eutrophication although inorganic particulate matter may account for a significant portion of TSS and confound any trends. For this reason TSS was not graphed. Algal blooms associated with eutrophication may initially be linked to a diurnal increase in dissolved oxygen concentrations; however, as eutrophication progresses, an increase in bacterial populations feeding on the algae would be expected to increase biological oxygen demand and decrease dissolved oxygen concentrations.

3.2.1 Spatial Trends between Inter-causeway and Reference Stations

The data collected within the inter-causeway area were tabulated, graphed, and statistically compared with the results from the relevant reference stations elsewhere along Robert's Bank. A 20% difference between the measured parameter inter-causeway and reference station results was used to gauge the potential for impacts.

Figure 42 shows a comparison of metal concentrations between each intertidal station and its associated reference station for each quarterly monitoring period. For example DP02-1/DP06-1 compares the Q1-2007 metals results from DP02 with those of DP06. DP05A-2/DP07A-2 compares the Q2-2007 metals results from the surface sample at DP05 with those of the surface sample at DP07. In addition to the two metals with BC WQG exceedances (copper and zinc), the trend comparison also included arsenic, barium, lead and cadmium as these are metals with regulatory guidelines with detected concentrations generally greater than the RDL. Other regulated metals parameters, including beryllium, chromium, mercury, selenium and silver, were not compared as most values were less than the RDL. Uranium was not compared as concentrations were typically less than 2% of the BC WQG.

The comparison indicates that arsenic and cadmium concentrations in the intertidal stations are generally greater than 20% higher. The difference in arsenic concentrations showed a positive peak (i.e. greater concentration in the inter-causeway stations relative to the reference station) of approximately 80% to 100% during Q2-2007 and Q4-2007 and the difference for cadmium concentrations showed a positive peak in Q2-2007 for DP02 and in Q3-2007 for DP03 and DP04. In contrast, for the subtidal stations, arsenic showed contrasting pattern with a negative peak (i.e. lower concentration in the inter-causeway stations relative to the reference station) at or near 20% during Q3-2007 and Q3-2007. Cadmium differences were also negative but were less than 20%.

There was no common pattern for copper concentrations other than negative peaks ranging from approximately -60% to -140%. The exceptions were Q4-2007 for DP05B where the concentration was 25% greater than the reference station and the Q1-2007 copper exceedance at DP05A which was 100% greater than the reference station.

The percent difference for barium at the intertidal stations was consistently negative relative to the reference station ranging from -10% to -70%. Generally, the percentage difference dropped sharply in Q2-2007 then climbed again to peak in Q4-2007 although there was no Q2-2007 drop for DP04. Barium concentrations in subtidal samples showed a much lower range of difference, but still negative except for DP05B during Q2-2007. Lead concentrations at the intertidal stations were also consistently negative relative to the reference station ranging from -40% to -160% but were variable for the subtidal stations.

The percent difference for zinc was generally negative relative to the reference stations for both intertidal and subtidal stations. Differences typically ranged from -30% to -105%. Positive differences of 10% to 50% were noted for Q1-2007 and Q3-2007 for DP02, Q2-2007 for DP04, Q3-2007 for DP05A and Q2-2007 and Q4-2007 for DP05B and a positive difference of approximately 115% was noted for the Q1-2007 zinc exceedance at DP05A.

In summary, arsenic and cadmium were typically at greater concentrations than the reference stations in the inter-causeway intertidal area and barium, copper, lead and zinc were lower. The reasons for this are not currently known but may reflect the sheltered nature of the inter-causeway area or different sequestration mechanisms at work. Additional data from 2008 is required to confirm these observed patterns and/or determine the cause.

Figure 42 also shows a comparison of concentrations of eutrophication-related parameters. The percent difference for phosphate was generally positive in both the inter-causeway intertidal and subtidal stations than in the reference stations. Phosphate differences range from approximately 60% to 150% and generally peaked in Q3-2007 for all intertidal stations but was generally less than 20% in the subtidal stations with the exception of an 80% positive difference at DP05 during Q2-2007. The chlorophyll α percent difference is similarly generally positive for the intertidal stations peaking during Q2-2007 and Q3-2007. However it becomes variable in the subtidal stations **Figure 42**.

At the intertidal stations, the percent difference for nitrate was positive during Q1, Q2 and Q3, peaking at up to 155% in Q2-2007 and then dropping to near zero percent difference in Q3-2007 and - 40% to -50% difference in Q4-2007. Nitrite percent difference ranged from positive 200% in Q2-2007 down to 140% in

Q3-2007 then declined to near zero in Q4-2007. TKN was generally -20% to 40% in Q1-2007 and Q2-2007, increasing as much as positive 60% in Q3-2007 before declining to positive 15% to 40% in Q4-2007. Total nitrogen started off negative in Q1-2007 (except for DP04), peaked positive in Q3-2007, and dropped back to negative in Q3-2007. Ammonia was, with only one exception, negative in the inter-causeway stations, generally reaching the greatest negative percent difference in Q3-2007 and Q4-2007. Dissolved oxygen remained generally less than -20% throughout the year (**Figure 42)**.

Concentrations in the subtidal stations were generally less variable than for the intertidal stations. Given that DP05 and DP07 are both subtidal, water at these stations is likely to be well mixed with water from Georgia Straight throughout the day. In contrast, water at stations in the intertidal zone is in closer contact with the sediment. With the exception of Q2-2007 phosphate and dissolved oxygen concentrations were relatively consistent. Chlorophyll α, nitrate, nitrite, TKN and total nitrogen all show a similar pattern to the intertidal stations. However, for nitrate and total nitrogen the Q3-2007 drop is more pronounced (greater than -100%) (**Figure 42)**.

In summary, for the intertidal inter-causeway stations chlorophyll α, phosphate and nitrate were generally higher in concentration than at the intertidal reference station. This may be due to the sheltered nature of the inter-causeway area. Similar concentration ranges were present at all three stations. In contrast, ammonia was generally at a lower concentration in the inter-causeway stations relative to the reference station. However, these trends were not present for the subtidal station. The remaining parameters were variable. As with the metals parameters, additional data is required to confirm these observed patterns and/or determine the cause.

3.2.2 Temporal Trends between Quarters

Arsenic, barium, copper and zinc showed a similar pattern at DP1 of decreasing concentration through to Q3-2007 and then increasing slightly in Q4-2007 (**Figure 43**). For DP02, DP03 and DP04 there is no clear temporal trend in metals concentrations although the pattern in DP03 most closely resembles the intertidal reference stations DP06. DP05A and its reference station DP07A show a weak similarity as does DP05B and DP07B. In summary, apart from DP01 where there are apparent metals loadings from the ditch at DP01 (**Section 3.2**), there are no apparent temporal trends in metals concentrations.

Dissolved oxygen concentrations were lowest during Q2-2007, except at DP05 and DP07, where the lowest concentrations were measured in Q3-2007 (**Figure 44**). This is in general agreement with the pattern seen in the sonde data (**Section 2.3.2**), which is located in the subtidal portion of the inter-causeway area.

Oxygen uptake by biota likely accounts for this seasonal decrease. Chlorophyll *α* concentrations showed a steady decline at DP01, but peaked in Q2-2007 at DP03, DP04, DP05A, and DP07A and peaked in Q3-2007 at DP02, DP05B, DP06, and DP07B (**Figure 44**).

The total nitrogen and nitrate concentrations showed a sharp increase from Q3-2007 to Q4-2007 at all stations except DP07A and DP07B, where a steady increase in total nitrogen and nitrate concentrations from Q1-2007 through Q4-2007 was observed. Noting that the bulk of total nitrogen was accounted for by nitrate, focus of this discussion was on the latter. Increases in nitrate concentrations are typically linked to anthropogenic inputs in the form of fertilizers, rather than to biological nutrient cycling. Data from 2008 will need to be evaluated to determine if this trend is seasonal in nature. The nitrite, TKN, phosphorus and ammonia concentrations did not exhibit a clear temporal trend (**Figure 44**).

3.3 SEDIMENT QUALITY

As for surface water, the discussion of sediment quality results considered both spatial and temporal trends, with particular attention given to parameters associated with eutrophication.

A lithium geonormalizing technique was applied to distinguish between external metals inputs and natural variations in hydrographic and bathymetric conditions and sediment grain size. Lithium occurs predominantly in several common silicate minerals where it substitutes for K, Na and Mg and has been shown to be an effective means to normalize metals concentrations to background (Sutherland et. al. 2007).

Figure 45 shows sediment metals parameters normalized to lithium. For most parameters the normalized metal parameters lay close to the regression line suggesting natural background concentrations. Outliers representing potential external enrichment for aluminum, barium, copper, chromium, manganese and zinc are noted for the Q1-2007 and Q4-2007 data from DP01 and DP02 suggesting potential upland inputs from the ditch located at DP01 (**Figures 6 and 7**). During Q1-2007 and Q4-2007, winter and fall rains are anticipated to increase water flows from the ditch into the inter-causeway area. Some nickel depletion was noted for Q3-2007 (DP01) and Q4-2007 (DP01and DP02). Outliers were also noted at DP06 (the intertidal reference station) for mercury during Q4-2007 and manganese during Q3-2008.

3.3.1 Spatial Trends between Inter-causeway and Reference Stations

Figure 46 shows a comparison of the relative variation of sediment metals and nutrient parameters between the intertidal inter-causeway stations (DP02 to DP04) and their associated reference samples (DP06) and the subtidal inter-causeway station (DP06) and its associated reference samples DP07).

As shown by the negative percent difference, metals concentrations for the CSR sediment metals parameters[4] (arsenic, chromium, copper, mercury and zinc) in inter-causeway sediments are consistently lower that those of the reference stations for all metals parameters. Arsenic, zinc and chromium were generally less than -40% and were consistent between quarters. Mercury and copper were generally more than -50% and tended to increase from Q1-2007 through to Q2-2007. Subtidal samples showed the opposite trend. Subtidal samples from the inter-causeway station (DP05) generally had positive percent differences with respect to the reference station (DP07). As with the subtidal stations, arsenic copper and zinc had percent differences less than 40% while mercury and copper were more than 50%.

For all the nutrient parameters except phosphate (**Figure 46**), concentrations in inter-causeway stations were consistently greater than positive 20% with respect to the reference stations for both intertidal and subtidal stations. Ammonia ranged from positive 50% to 150% and sulphide from 80% to almost 200%. Concentrations of Total Nitrogen and TKN were greatest (110% to 150%) in the subtidal station (DP05). Concentrations of phosphate generally had negative percent differences of less than -20% (not considered significant) in the intertidal stations, but had significant positive percent differences of up to 20% to 40% in the subtidal station (DP05), likely reflecting the uptake of phosphorus by primary producers in the inter-causeway area (eelgrass and algae).

Redox values were generally between–100 mV and –200 mV. Exceptions to this included redox values measured at DP06 in Q1, Q2, and Q3, which ranged from –20 mV to –60 mV, and an anomalous redox value of +50 mV measured at DP01 in Q2. Other than the relatively high redox values at DP06, there was no clear spatial or temporal trend in redox values (**Table 14**).

In summary, metals concentrations in the inter-causeway area are consistently lower than for the reference station for the intertidal stations but not for the subtidal station. This suggests that at this time, metal loading of sediments in the inter-causeway area from DP3 construction is not occurring. However, some minor localized metal loading of the sediment at DP01 and DP02 appears to be associated with the surface water metal loadings (**noted in Section 3.2**) from the ditch at DP01. However, additional data is required to confirm this conclusion.

3.3.2 Temporal Trends between Quarters

Temporal variation in metal concentrations of the intertidal sediments can also be seen in **Figure 46**. Arsenic, chromium, and zinc showed little temporal variation between quarters with generally less than a 20% difference. Copper concentrations decreased gradually through Q1-2007 to Q3-2007 (with over -80% difference) but then increased in Q4-2007. Mercury concentrations decreased between Q1-2007 and Q2-2007, increased slightly in Q3-2007 and then decreased sharply (greater than -100% difference)

4 Cadmium and lead were not included as concentrations were less than the RDL for all samples.

in Q4-2007. For the subtidal samples, arsenic, chromium, and zinc also showed little temporal variation between quarters. Copper increased through Q1-2007 to Q2-2007, decreased in Q3-2007 and then increased again in Q4-2007. Subtidal mercury concentrations increased through to Q3-2007 and then declined in Q4-2007.

For nutrient parameters, a general trend of increasing concentration from Q1-2007 to Q3-2007 followed by a drop in Q4-2007 is evident at all stations for sulphide and ammonia (although less pronounced in DP04) (**Figure 46**). There was little temporal variation for phosphate with percent differences generally less than $\pm$20% (percent differences were slightly higher than $\pm$20% in the subtidal samples. TKN had the greatest positive percent difference in Q1-2007 and decreased through to Q4-2007 to less than 20% in Q4-2007. Total nitrogen showed no observable trend.

Figure 47 shows temporal trends for each station including DP01. Copper concentrations in sediment at DP01 were relatively consistent for Q1-2007 and Q2-2007, decreased slightly in Q3-2007 but rose sharply (three times) in Q4-2007. Zinc and chromium showed a similar pattern although the Q4-2007 rise was much less pronounced. The drop in Q3-2007 is consistent with anticipated consistent flows during the winter and spring (Q1-2007 and Q2-2007) followed by lower flows in the ditch during the drier summer months (Q3-2007) followed by increased flows from the fall rains in Q4-2007. In the subtidal inter-causeway stations (DP02, DP03 and DP04) chromium, copper and zinc concentrations were relatively consistent except for DP02 where chromium decreased by half in Q4-2007. Concentrations in the intertidal reference station, DP06 show a similar temporal trend but concentrations were higher, potentially reflecting metals inputs from the Fraser River. Concentrations of these metals in DP05 show a similar temporal pattern to DP01, however this pattern is not repeated in the reference subtidal station. Arsenic concentrations varied little between quarters and between stations. Mercury shows a Q4-2007 rise the four intertidal stations, a steady decline through Q3-2007 and Q4-2007 in DP01 and shows an inconsistent pattern for the two subtidal stations.

The sulphide concentration decreased by two orders of magnitude at DP01 and DP05 between Q2-2007 and Q3-2007. Less marked decreases (a single order of magnitude) were noted for DP02 and DP03. Sulphide concentrations in DP04 and DP07 peaked in Q3-2007 and then dropped back down in Q4-2007. Sulphide concentrations in DP06 were negligible and showed no trend **(Figure 48**). While ammonia concentrations showed a consistent trend for the two reference stations, there was no consistent trend in the inter-causeway stations. The TKN and total nitrogen concentrations showed a similar range and showed similar temporal variation across stations (**Figure 48**). Phosphate concentrations show a similar pattern for the inter-causeway stations with a Q2-2007 peak and a Q3-2007 dip. There was little variation in the two reference stations. Concentrations of TKN and Total Nitrogen tend to be higher in Q1-2007 and Q2-2007 and decline in Q3-2007 and Q4-2007.

3.4 EELGRASS

Research has shown that eutrophication is one of the factors that may lead to an elevated epiphyte load on eelgrass. The epiphyte load on the eelgrass all stations on Roberts Bank and at the reference stations at Boundary Bay in 2007 was comparable to previous years at the time these beds were surveyed.

Beggiatoa sp is often used an indicator species to identify degraded marine habitats. The filamentous preteobacteria forms visible whitish mats in many polluted marine environments, especially those with sediments rich in hydrogen sulphate. *Beggiatoa* sp. was not noted at either Roberts Bank or Boundary Bay during the 2007 eelgrass surveys.

The distribution of *Zostera marina* and absence of *Z. japonica* at all sampling stations was consistent with records from previous years.

The eelgrass density, shoot morphology, and relative productivity are assessed by location in **Sections 3.4.1** through **3.4.2**. The data from the inter-causeway sites are compared to those from the reference sites in **Section 3.4.4**.

3.4.1 Inter-causeway Area

The analysis shows that although shoot length and/or width decreased at several of the inter-causeway stations relative to 2003, the productivity (LAI) in 2007 was not significantly different from 2003. The decrease in shoot size was offset by the increase in density. The mean density was greater at all stations in 2007, although the difference was only significant at Station 6 according to the t-test and Wilcoxon's test; the difference was not significant once the Bonferroni adjustment was applied.

The reproductive shoot density was not significantly different at any of in the inter-causeway stations.

3.4.2 West of Deltaport Causeway

The sampling sites located west of the Deltaport Causeway (**Figure 8**) serve as local reference sites for the inter-causeway sites; they are located outside of the assumed area of influence of DP3.

The trend of reduced shoot size continued to the west of the causeway; in most cases the decreases were significant. The mean density of shoots was also less, and although this decrease was not significant, it contributed to significant decline in productivity (LAI) at Site 3. The decline was only significant at Site 4 using the t-test and Wilcoxon's test; the difference was not significant once the Bonferroni adjustment was applied.

The reproductive shoot density was greater at both stations; however the increase was only significant at Site 3 according to the t-test and Wilcoxon's test.

3.4.3 Boundary Bay (White Rock)

The station near the upper limit for eelgrass in Boundary Bay (**Figure 9**), WR1, was almost twice as productive in 2007 when compared with data from 2003. The shoots were larger and denser. Reproductive shoot density was significantly less than in 2003.

The productivity at the mid station WR2 in 2007 was also almost double the 2003 value. The shoots were significantly wider (t-test and Wilcoxon's test) and the density significantly greater, and although the mean shoot length was less the decrease was not significant. The density of reproductive shoots was significantly greater in 2007 compared to 2003 according to the t-test and Wilcoxon's test.

The mean shoot length at the deepest station, WR3, was significantly less than in 2003, although the mean width (t-test and Wilcoxon's test) was significantly greater. The mean density was not significantly different. The relative productivity was significantly less in 2007 compared with 2003 (t-test and Wilcoxon's test). The density of reproductive shoots was slightly greater although the difference was not significant.

3.4.4 Site Comparison

The productivity (LAI) of eelgrass at the inter-causeway sites in 2007 was comparable to the productivity at these sites in 2003. The productivity of eelgrass at the reference stations located west of the Deltaport Causeway was significantly less in 2007 than that recorded in 2003. These reference sites are strongly influenced by the Fraser River plume. The Deltaport causeway deflects the Fraser River plume from the inter-causeway area. It is possible that the reference sites demonstrated reduced productivity in response to variations in the water quality of the Fraser River plume. These stations are located outside of the assumed area of influence of the new DP3, and are not considered as being influenced by, or having influence on the present project.

The eelgrass at the mid reference site in Boundary Bay (WR2) was significantly more productive in 2007 than in 2003. The eelgrass at this station is similar to Sites 1, 2, 3, and 6 at Roberts Bank. However, the relative productivity at WR2 in 2003 was much lower than at the comparable Roberts Bank stations. The productivity at site WR2 was within the range of the Roberts Bank sites in 2007. The eelgrass bed in Boundary Bay has suffered from the intense public use of this area. The Friends of Semiahmoo Bay have been actively promoting eelgrass conservation and education in Boundary Bay for several years; it is possible that their efforts have enabled the eelgrass at Site WR2 to reach a level of productivity comparable to that of Roberts Bank.

WR3 is the deepest of the Boundary Bay reference sites; the eelgrass at this location is comparable to Sites 4 and 5 at Roberts Bank. The productivity at WR3 decreased relative to 2003; however it remains much greater than Sites 4 and 5 at Roberts Bank.

WR1 is not currently included in the eelgrass assessment for the AMS as the habitat at this location is not comparable to other sites within the study area at this time.

3.5 BENTHIC COMMUNITY

The rough weather conditions experienced during the Q1-2007 baseline sampling event had a significant effect on sediment grab recovery. Only at station DP05, where an estimated 8 litres of sediment was recovered, was the sample considered optimal. At the remaining sample locations, sample recovery ranged from 2 to 3 litres. Due to the poor recovery, life stages were not separated out in the Q1-2007 baseline data set. A qualitative and a simplified quantitative approach was used to interpret the benthic invertebrate data.

Adult, intermediate, and juvenile benthic invertebrates were observed at all stations. The diversity in taxa observed in the samples suggests that benthic invertebrate populations in both the inter-causeway area and the reference area were healthy and growing (Val MacDonald, pers. comm.) before construction activity began. This is substantiated further by Shannon's Index, which shows that all stations with the exception of DP06 are relatively diverse and individual species are also distributed fairly evenly among the stations.

The baseline benthic invertebrate data also demonstrated that there were no observable positive correlations between either grain size or sulphide concentrations and species abundance or taxa richness. This may be attributable to the low recovery of sediment samples at each of the stations. Additional data from future sampling events will provide a more extensive data set for separating out, for example, life stages or polychaete feeding habits and comparing it to grain size and sulphide concentrations and for looking at indices such as opportunistic polychaete – amphipod ratios, nematode – harpaticoid copepod ratios. In addition, data from subsequent sampling events are required to use these additional tools to make comparisons of the year to year changes in the benthic community structure that are part of the objectives of this AMS.

3.6 BIRDS

3.6.1 Disturbance Assessment

As indicated in **Section 1.3.6**, the following objectives were identified as key elements of the bird component of the AMS:

1. Determine whether there are impacts to Brant geese and great blue heron usage of the inter-causeway area during critical periods of construction and operation.
2. Determine whether there are impacts on coastal seabird and shorebird usage of the inter-causeway area during construction.

Disturbance to great blue herons, brant, and coastal seabirds and shorebirds is discussed in the following sections.

3.6.1.1 Great Blue Heron

Based on observations during the survey period, impacts to great blue herons from construction of DP3 are limited to the loss of foraging habitat within the DP3 footprint as anticipated from the EA work that was conducted for DP3.

Results from surveys conducted in 2004 (Envirowest, 2004) indicate that great blue herons used the PC13 (primary PC station associated with direct footprint impacts) area primarily between March and October, during both low and high tide. The extent of this usage cannot be directly compared to results from this survey period due to the unavailability of raw data from the 2004 surveys. Habitat loss associated with the DP3 footprint has precluded heron usage of approximately 5% of the total resting/roosting and foraging habitat available in the study area associated with infilling the embayment area in PC13 for DP3 construction. Based on the availability of alternative habitat and the extensive confirmed use of this alternative habitat by great blue herons during the surveys conducted in 2007, it is concluded that construction impacts have not had a detrimental effect on heron foraging in the inter-causeway area.

Observations recorded during the survey period also indicate that herons can be quite opportunistic and acclimatize to certain types of disturbance. Specific examples include high densities of herons congregating within Fill Area 1 between the perimeter dyke and containment dyke (**Figure 38**) during infilling (pumping dredgate from caisson trench) and herons resting on the perimeter dyke despite repeated disturbance. Herons congregating in Fill Area 1 appeared to be foraging on invertebrates and other prey items carried in with the dredgate. Large flocks of gulls also exploited this opportunistic food source. While infilling provides some temporary foraging habitat, the availability of food items is limited to periods of infilling and the use of this area for foraging ceases once infilling is discontinued. Further construction of DP3 is expected to preclude heron usage of most of this footprint with the possible exception of the riprap perimeter dyke.

Additionally, herons appear habituated to traffic from the both Deltaport Causeway and the Ferry Causeway; however, less common, "acute disturbances" such as surveyors or recreational walkers and cyclists sometimes caused herons to abandon a resting or hunting locations if they were approached too closely.

Eagles appear to pose the greatest threat to herons nesting at the base of Tsatsu Bluffs, and in one instance, an eagle reportedly attacked and killed a full-grown heron (Westshore Terminals employee pers. comm. 2007).

3.6.1.2 Brant

During the survey period, observations of acute disturbances resulting in brant displacement were limited to bald eagles flying over, surveyors, cyclists, and walkers (sometimes with dogs), disturbing resting and feeding birds near the shoreline, and a Coast Guard hovercraft parking in the compensation lagoon on a single occasion. In all of these situations, brant and other waterfowl took off and circled for a short period of time before settling down on or close to the same location. It is likely that the birds using the inter-causeway area are habituated to a degree of disturbance as a result of fairly constant ship, truck, and train traffic, as well as recreational users including people walking along the TFN dyke, and cars and trucks pulling off along the Deltaport Causeway. Brant were typically observed offshore (**Figure 39**) and did not react to regular traffic such as vehicles moving along the Deltaport Causeway or the Ferry Causeway or surveyors, cyclists, and walkers using the edges of the study area.

Negative impacts to brant from the DP3 construction were not observed; however, VFPA is continuing to try and access raw data from earlier work conducted for the DP3 EA which could be used at a later time to compare distribution and usage patterns. It is assumed that the main impact to brant is exclusion from the embayment area lost to the DP3 footprint. This was a known resting site and a location where loose eelgrass fronds would wash up providing an easy foraging opportunity for brant.

With respect to diet, brant are adaptable to changes in the composition of eelgrass meadows from the native Z*ostera marina* to the introduced *Z. japonica*. Dietary studies conducted on brant feeding in nearby Boundary Bay indicate consumption of both *Z. japonica* (57% dry mass) and *Z. marina* (41% dry mass) based on examination of esophageal contents (Baldwin and Lovvorn, 1994).

3.6.1.3 Shorebirds

While no direct impacts to shorebirds were observed, the main potential impact to shorebird species such as western sandpipers and dunlin that rely on mudflat for feeding could potentially occur as a result of changes to inter-causeway topography, water elevations, and distribution of eelgrass. *Z. japonica* is able to grow in slightly more exposed locations than the native *Z. marina* and as such, there is a potential for loss of critical mudflat habitat if these changes were to occur. Monitoring of sedimentation and eelgrass distribution as part of this AMS will help to track the reality of this potential impact.

3.6.1.4 Coastal Waterbirds

Coastal waterbirds observed in PC12 appeared quite habituated to disturbance from DP3 construction activities, likely due to the extent of disturbance that already occurs in this area from operation of the existing two berths at Deltaport and the Seaspan tug facilities located in the embayment area. Diving birds including cormorants, grebes, loons, mergansers, and other diving ducks were regularly seen swimming, diving, and feeding in close proximity to active dredging and densification work.

Dabbling ducks, primarily American widgeon and mallard, were frequently observed resting/roosting along the newly constructed perimeter dyke, likely due to the protection from wind and wave action that it provides. Based on observed foraging patterns for dabbling ducks (observed closer to the head of the bay following the tide line), DP3 related construction impacts are considered negligible. However, non-routine disturbance, such as an observer setting up to survey along the TFN transect when large flocks of dabbling ducks are present during high tide often caused birds closest to the shoreline to take flight. Disturbed birds would settle either slightly further out within the same PC, or move further along the transect staying at approximately the same tidal line. Recreational users (cyclists, walkers) had the same effect on birds resting or feeding close to the dyke or walkway.

3.6.2 Summary of Construction Impacts on Birds

In an attempt to determine patterns in bird disturbance relating to DP3 construction activities, several sources were considered including notes taken during surveys while in the vicinity of DP3 construction, daily environmental monitoring logs (compiled by Hemmera for VFPA), and daily engineer's reports summarizing site activity (compiled by Klohn Crippen Berger for VFPA). Based on analysis of these sources, a rating scheme (**Table 3.6-1**) was developed to rank disturbance severity from DP3 construction activity.

Table 3.6.1: Disturbance severity ratings

0 = No disturbance
1 = Low – minimal noise being generated, and/or minimal in water (or near water) activities that would disturb birds
2 = Moderate – some construction noise generated and/or activities in project area that may disturb birds
3 = High – activities producing loud noises (i.e., pile driving), and/or many activities going on in water.

Figure 3.6-1 plots disturbance severity against the total bird observations recorded daily in PCs 12 and 13 as a percentage of total bird observations recorded throughout the entire study area on the survey date. This method was selected as it is thought that if disturbance from construction was affecting bird counts, then the greatest impact would be seen in PCs 12 and 13, which are in the DP3 footprint. Further, by using the number of birds recorded in PCs 12 and 13 as a percentage of the total bird observations recorded on a given day, there is some consideration to the overall presence / absence of birds in the inter-causeway area unrelated to construction activity.

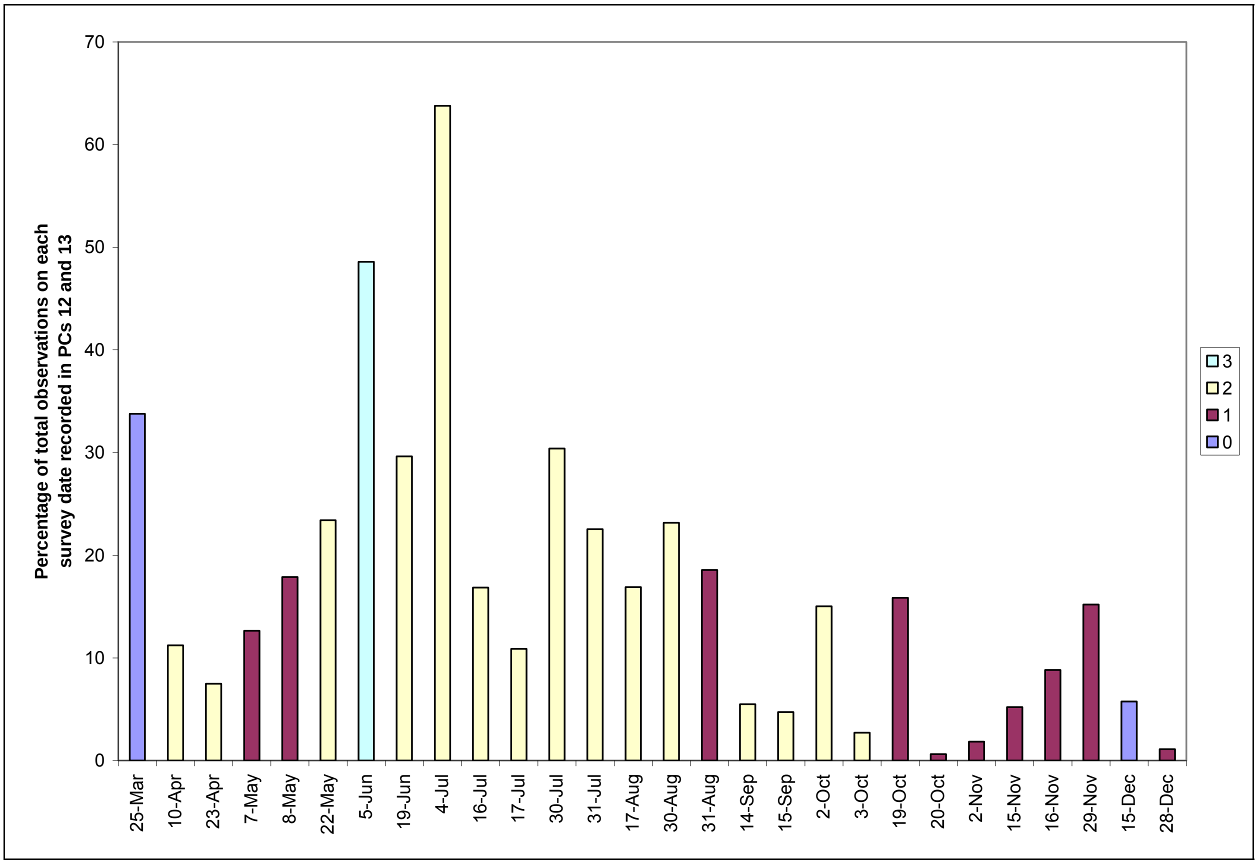

Figure 3.6-1: Number of birds observed in PCs 12 and 13 as a percentage of total bird observations recorded during the survey date (Coloured columns indicate disturbance severity as rated using the criteria in Table 3.6-1.)

For comparison, the total number of bird observations during each survey event is provided in **Figure 3.6-2**. Visual inspection of the two graphs does not indicate any obvious relationship between disturbance severity and the number of birds observed in PCs 12 and 13 as a percentage of total bird observations by survey date. This disturbance assessment method is limited in its utility, as it does not consider weather variables (although these were kept within acceptable standards for waterfowl and coastal seabird studies), and there is the potential that there could be changes to bird energy budgets due to displacements that are not detectable by the methods used in this study. However, based on the observations of bird activity in the inter-causeway area, it is concluded that bird species using the study area have not been significantly impacted by DP3 related construction activities to date. Rather, it is habitat loss (estimated at 6% of total resting/roosting and foraging habitat available) that will likely have the greater impact. Based on the availability of alternative habitat within the study area, and the observed usage of alternative habitat by bird species in the inter-causeway area, this habitat loss does not appear to be significant as is consistent with the predicted impacts assessed in the EA.

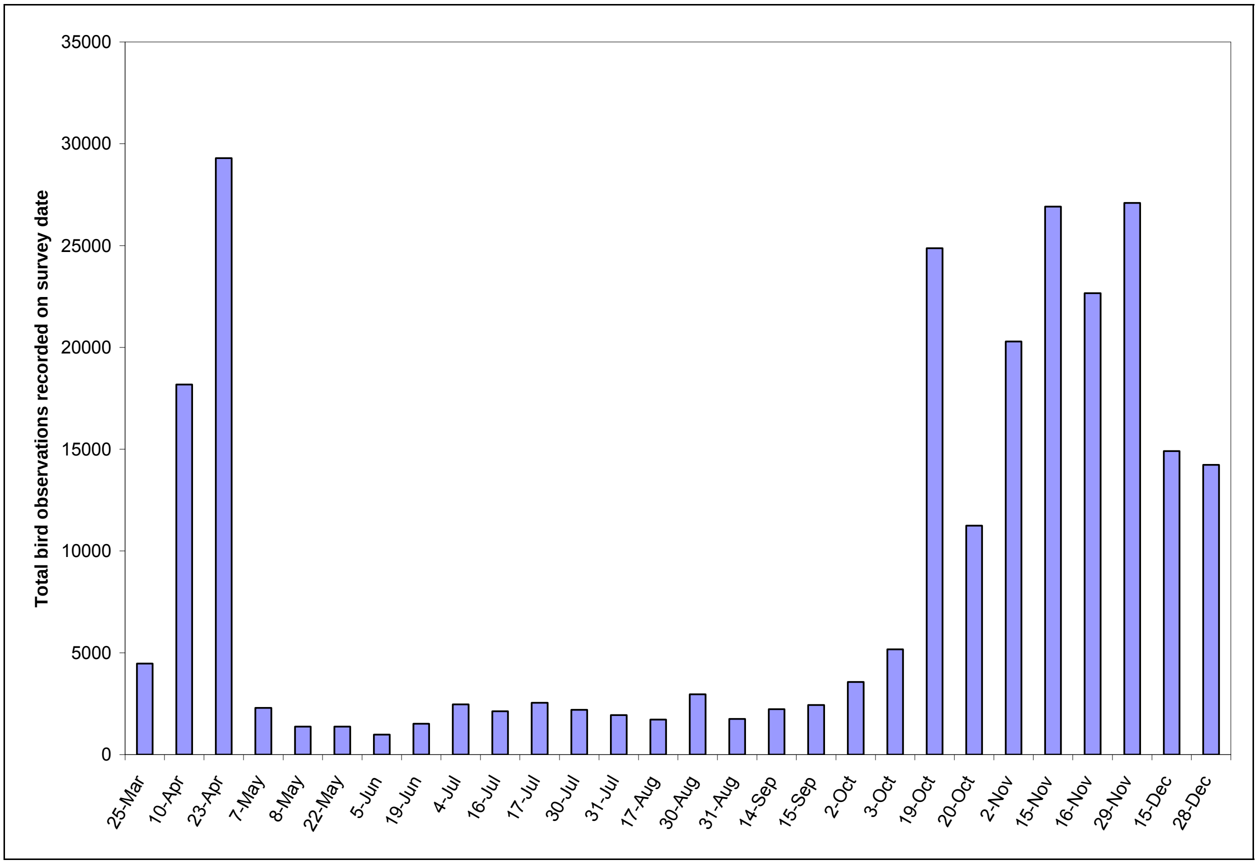

Figure 3.6-2: Total bird observations recorded on each survey date

3.6.3 Ecosystem Health and Function

No inference to ecosystem structure and function, specifically with respect to eutrophication and erosion, can be inferred from the survey results presented herein. Indications of eutrophication and erosion would be detected by other studies included as part of this AMS long before they would be detected in bird populations as there a significant number of climatic and environmental variables would act to confound trends in population numbers. At a minimum, baseline data collected by Envirowest and CWS (2004) would be required to compare with the data presented in this report to provide an initial assessment of trends in bird usage of the inter-causeway area.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 COASTAL GEOMORPHOLOGY

The first year of monitoring has indicated that sedimentation and erosion rates on the tidal flats were small (generally less than 10 cm). Suspended sediment concentrations at the two monitoring sites also remained low. Short-term storm events mobilized sediment on the tidal flats, raising sediment concentrations to approximately 50 to 100 mg/L, with peaks of up to 190 mg/L, which was in accordance with predictions using van Rijn's sediment transport theory. Net sediment movement on the tidal flats appeared to be very limited, which is also in general agreement with previous findings (NHC 2004).

Three of the most dynamic areas within the study area include the large system of dendritic channels that has formed since the ship turning basin was dredged in 1982, the tidal channels adjacent to the BC Ferries Causeway and the sand bars on the seaward side of the crest protection structure. These processes continue to evolve slowly and are quite separate from the DP3 project and influence from the project was not detectable.

The other area of significant change is the area of new drainage channels to the northeast of the DP3 perimeter dyke. The channels were formed by the short-term effects of construction activities and have resulted in fairly significant but localized effects to the mud flats in the area where new drainage channels have formed, as well as to the eelgrass beds where these channels have deposited sediment. Although the initial mechanism that triggered their formation has ceased, the channels themselves have persisted and are continuing to evolve.

The AMS monitoring program is adaptive in that the specific monitoring activities can be modified or expanded to provide data in areas where change is occurring. Because the low-tide window for fieldwork lasts only for three to four hours within a two to three day period, it is important to ensure that the total of all monitoring activities can be completed within this time. The following outlines some recommendations for modifications to the Coastal Geomorphology portion of the AMS program.

4.1.1 New Drainage Channels

The area of new drainage channels has been captured by some of the existing monitoring activities. DoD rods and sediment sampling at four sites within this area have provided some information as well as the orthophotographic interpretation and surveying for the coastal geomorphology mapping. The official monitoring tasks were supplemented by observations made by field staff. Considering the magnitude of the impacts that these channels have had, it would be appropriate to develop specific monitoring activities to determine if these channels continue to be active or are in the process of stabilising. Recommended modifications and/or additions to the monitoring program include:

- Additional DoD rods – **Figure 49** shows the proposed location of additional DoD rods that would provide increased resolution about sedimentation and erosion trends in the area of the new drainage channels. Sediment samples would also be collected at these locations to provide additional resolution about changes to the near-surface sediments. In addition, we would also propose to install an additional rod in the small pond area adjacent to the causeway but not to collect a sediment sample at this location.
- The area of new drainage channels has been captured by some of the existing monitoring activities. DoD rods and sediment sampling at four sites within this area have provided some information as well as the orthophotographic interpretation and surveying for the coastal geomorphology mapping. In addition to the official monitoring tasks, casual observations have been carried out by field staff during regular monitoring activities. Considering the magnitude of the impacts that these channels have had, it would be appropriate to increase the resolution of the monitoring program in this area. We therefore recommend that six additional DoD rods be installed in the area of new drainage channels as shown in **Figure 43.** Sediment samples would also be collected at these locations to provide additional resolution about changes to the near-surface sediments.

4.1.2 Crest Protection Structure Monitoring

The results of the crest protection structure monitoring have demonstrated that there has been generally very little change measured at the structure or in most of the areas adjacent to the structure. Two areas show noticeable change. One is related to movement of sand bars on the seaward side of the structure while the other is related to changes to the back channel on the shoreward side of the structure. Changes to the sand bars are also detected in the DoD rods. Photography was not possible during two of the four monitoring periods because low tides in winter expose the structure only at night. Based on the results of the 2007 monitoring, we recommend that the quarterly monitoring be reduced to twice yearly (Q1 and Q3) and that photographs be taken during only one of these monitoring periods (Q3). There would be no significant degradation in the value of the data collected for this activity.

4.1.3 Automated Turbidity Monitoring

At present the automated turbidity monitoring stations are collecting data, but the average turbidity levels are not particularly high. Given the harsh operating conditions and the expense of making repairs to the instruments, we recommend that unless analysis of the 2008 data detects a departure from the trends shown in the 2007 data, that the program be discontinued after collection of the Q4-2008 monitoring data. If, prior to Q4-2008, the instrumentation ceases to function and significant maintenance or repairs would be required, we recommend that data collection be discontinued at that time.

4.1.4 Current and Wave Monitoring

Current and wave monitoring was originally planned as part of the AMS monitoring program using an Acoustic Wave and Current Profiler (AWAC) deployed off Deltaport by ASL. The AWAC was dragged and then subsequently destroyed. NHC provided a memo to the VFPA on January 30, 2008 (NHC, 2008) outlining an alternative program for monitoring waves and currents which has since been reviewed and approved by the VFPA and the SAC. The equipment has been ordered and will be deployed once received. The proposed location of the wave sensors is shown in **Figure 50**. Implementation of this program represents an expansion to the original scope of work as outlined in the *AMS Detailed Workplan* (Hemmera, 2007a).

4.2 SURFACE WATER QUALITY

Of the entire suite of metals analyzed, the only two that exceeded the British Columbia Water Quality Guidelines that were considered significant were copper and zinc. While boron, iron, and vanadium exceedances were measured, as discussed in **Section 2.3.2**, these exceedances were not considered significant. The copper exceedances were encountered at DP01 (Q1-2007 and Q2-2007), DP05 (Q1-2007), and DP06 (Q1-2007 and Q3-2007). The zinc exceedances were encountered at DP01 (Q1-2007 and Q2-2007) and DP05 (Q1-2007).

To help gauge the potential for DP3 construction-specific impacts, a 20% difference between the metals concentrations was used when comparing the inter-causeway samples with those from the reference stations (spatial variability) and when comparing the quarterly sampling events at each station (temporal variability). The results revealed that arsenic and cadmium in the inter-causeway intertidal area were typically present at greater concentrations than at the reference station; while barium, copper, lead and zinc were typically present at lower concentrations. The reasons for this are not conclusive based on the sampling completed to date. Additional data are required to evaluate these patterns to determine if there may be seasonal factors contributing to the levels observed (e.g., comparison of Q1-2007 results for given stations with Q1-2008 results). There were no consistent temporal patterns in the metals concentrations.

With the exception of ammonia, concentrations of nutrient parameters were higher in the inter-causeway area than at the reference stations. Nitrate accounted for the bulk of total nitrogen in the water samples. The highest concentrations of nitrate and Total Kjeldahl Nitrogen were observed at DP01 reflecting upland input to the inter-causeway area from adjacent agricultural land. Ortho-phosphate concentrations in surface water samples were also lower during Q2-2007. Elevated chlorophyll *α* concentrations in Q2-2007 indicated increased photosynthesis during this period, which likely accounts for the decline in phosphate in the same time period. The nitrate concentration showed an increase from Q3-2007 to Q4-2007 at all stations except the subtidal reference station. This is likely due to decreased biotic uptake of nitrate due to declining photosynthesis as evidenced in the decline in chlorophyll *α* concentrations over the same period.

Dissolved oxygen concentrations were consistent between the inter-causeway and reference stations. Dissolved oxygen concentrations at the two subtidal stations were even more closely correlated. The dissolved oxygen concentrations were lowest during Q2-2007, except at DP05B and DP07B, where the lowest concentrations were measured in Q3-2007. Increased water temperature and oxygen uptake by biota likely accounts for this seasonal decrease. It will be possible to begin assessing seasonal factors once there is data available for the second and third years of the AMS program.

Although there are elevated nutrient levels present within the inter-causeway area there have been no observations of unacceptable adverse effects to the valued ecosystem components (e.g., eelgrass density and distribution, benthic invertebrate community, bird usage) in the first year of the AMS program or indication that there is a trend towards increased levels of nutrients. Again, subsequent years will allow for evaluation of seasonal trends which will be valuable with respect to parameters such as nutrient levels.

In the first year, there was no evidence of metals loading as a result of the construction activities at Deltaport. Metals input to the inter-causeway area appears to be primarily related to the ditch located immediately up-gradient of sampling station DP01. Copper and zinc exceedances at stations DP05 and DP06 have no obvious source, but may simply represent ambient levels from Fraser River outflow. Continued monitoring of the nutrient and metals concentrations in surface water is recommended for 2008. However, should no adverse metal trends related to DP3 construction be observed at the end of 2008, then it will be recommended that these parameters be dropped from the AMS program.

At the request of the SAC, one intertidal station (DP08) has been added to the surface water sampling program for 2008 (**Figure 6**). Surface water samples will only be collected at this station during events including benthic invertebrate sampling.

4.3 SEDIMENT QUALITY

There were no metals exceedances of the BC Contaminated Sites Regulation, sediment quality standards. In addition to comparing to the CSR standards, the sediment results, as with the surface water results, were also considered using a 20% difference threshold between the metals parameters both spatially and temporally. The results were also reviewed considering lithium geonormalization to attempt to further distinguish between anthropogenic and natural metals variation.

Outliers to the lithium normalized regression line represent potential external enrichment for aluminum, barium, copper, chromium and manganese (Q1-2007 and Q4-2007 data from DP01 and DP02) suggesting that there is some input from upland areas originating from the ditch at DP01. During Q1-2007 and Q4-2007, winter and fall rains are anticipated to increase water discharge volumes from the ditch transporting metals into the inter-causeway area. This hypothesis is consistent with the noted metals loading to surface waters from the ditch at DP01.

Metal concentrations in inter-causeway sediments were consistently 40% to 50% lower that those of the reference stations while concentrations in the subtidal inter-causeway station (DP05) were 40% to 50% higher than the reference station. These results suggest that the DP3 construction activities were not significantly contributing to metals loading at the site.

For all the nutrient parameters except phosphate, concentrations at the inter-causeway stations were consistently more than 20% higher than the reference stations for both intertidal and subtidal stations. Ammonia was up to 150% higher and sulphide up to 200%. Concentrations of Total Nitrogen and TKN were greatest (up to 150%) in the subtidal station (DP05). Concentrations of phosphate tended to be consistently lower in the inter-causeway stations but generally varied less than the 20% threshold likely reflecting the uptake of phosphorus by primary producers in the inter-causeway area (eelgrass and algae).

While ammonia concentrations showed a consistent trend for the two reference stations, there was no consistent trend in the inter-causeway stations. The TKN and total nitrogen concentrations showed a similar range and showed similar temporal variation across stations. Phosphate concentrations show a similar pattern for the inter-causeway stations with a Q2-2007 peak and a Q3-2007 dip. There was little variation in the two reference stations. Concentrations of TKN and Total Nitrogen tended to be higher in Q1-2007 and Q2-2007 and declined in Q3-2007 and Q4-2007. Given anticipated seasonal fluctuations, it will be relevant to review the corresponding 2008 results with the 2007 results for comparison and consideration of seasonal trends.

Redox values were generally between – 100 mV and – 200 mV. Other than the relatively high values at DP06 (–20 mV to –60 mV) , there was no consistent spatial or temporal trends in redox values. The value of 50 mV at DP01 during Q2-2007 was considered to be anomalous as values in other quarters ranged from -100 mV to -150 mV.

As with the surface water results, there were elevated nutrients present in the inter-causeway sediments. It is unclear based on the monitoring completed to date, whether theses levels are increasing or whether they may result in unacceptable adverse effects on valued ecosystem components. There is no evidence, at this time, of metals contamination as a result of the construction activities at Deltaport. As with the surface water data, metals inputs to the inter-causeway area appear to be primarily related to the ditch at DP01. Continued monitoring of the nutrient and metals concentrations in sediments is recommended for 2008. However, should no metals trends related to DP3 construction be observed at the end of 2008, it will be recommended that these parameters be dropped from the AMS program.

At the request of the SAC, one intertidal station has been added to the benthic community sampling program for Q1-2008. This station will be sampled only during the benthic invertebrate sampling event in 2008 and 2009.

4.4 EELGRASS

The assessment of epiphyte load, *Z. marina* and *Z. japonica* distribution at the sampling sites, and absence of *Beggiatoa* sp. indicate that the eelgrass habitat was in good condition.

A reduction in shoot length was recorded at all but one of the inter-causeway stations, although the reduction was not always significant. This trend was also documented at the stations west of the Deltaport causeway and the mid and low reference sites in Boundary Bay. Mean widths were less at all six of the Roberts Bank sites, although the decrease was not significant at two of the sites in the inter-causeway area. These trends are likely due to a large-scale environmental factor, and not related to DP3.

The sites located within the inter-causeway area are the most likely to be affected by DP3 development due to their proximity. Estimates of relative productivity (LAI) are the best measure by which to evaluate change since the estimate integrates three parameters (density, shoot length, shoot width). The LAI values for the 2007 survey of the inter-causeway areas were not significantly different from the estimates based on the 2003 data for this area. The LAI values for the 2007 survey of the inter-causeway areas were not significantly different from the estimates based on the 2003 values for this area, indicating that the inter-causeway eelgrass population had not been negatively impacted at any of the stations.

Comparison of the 2007 and 2003 eelgrass habitat maps revealed that eelgrass habitat loss has occurred near the dendritic channels; this is likely due to the evolution of these systems and not the development of DP3.

The *Z. marina* distribution in the new drainage channel area adjacent to the DP3 footprint was reduced relative to 2003; however it is likely that the surviving shoots will multiply and naturally restore many of these areas. The extent to which *Z. marina* will be able to naturally recolonize will depend mainly on the final elevation of the substrate once the area has stabilized.

An area between the crest protection and the Deltaport causeway that was unvegetated in 2003 has since been colonized by *Z. japonica*.

No changes to the eelgrass survey program are recommended.

4.5 BENTHIC COMMUNITY

The results indicate that the benthic invertebrate populations in both the inter-causeway area and the reference area appeared diverse, healthy and well established. Variations in total abundance and the number of taxa were not directly influenced by substrate type or sulphide concentrations but this could be due to the limited data set. Due to the variability in the benthic invertebrate baseline data set, opportunistic polychaete – amphipod ratios, nematode – harpaticoid copepod ratios or grain size and life stages was not assessed in this report; however, it will be included in the 2008 Annual Report when two years worth of data will be available. It is therefore recommended that subsequent data be further broken out into life stages and species grouping such as opportunistic polychaetes or polychaetes that like organic enriched environments, to better understand any relationships with potential anthropogenic disturbances and benthic community distribution at DP3.

The *AMS Detailed Workplan* (Hemmera, 2007a) indicated two benthic community sampling events were planned for the AMS program: one event during Q1-2007 and a second event when construction of DP3 was complete. At the request of the SAC, a third benthic community sampling event has been added to the program for Q1-2008. During that sampling event and the subsequent event(s), one additional intertidal station has been added (**see Section 4.2**). Other modifications to the benthic community sampling program include greater weighting of the Ponar sampler to improve penetration into eelgrass covered substrates and better recovery of sediments overall.

4.6 BIRDS

The first year of the AMS implementation has identified several opportunities for adaptation of the bird monitoring program These recommended changes include the following:

1. The distance categories for all point counts will be changed to **0 – 250 m**, **250 – 500 m**, **and 500 m – 1 km** as used by the Canadian Wildlife Service during surveys conducted in 2004.
2. Point counts along the BC Ferries Causeway transect will be discontinued as we have seen no evidence of impacts from the Deltaport work except as outlined in recommendation #7.
3. The TFN transect will be retained but the number of point counts will be reduced from 5 to 3 (we propose to merge PCs 113 and 115, keep 109, and merge PCs 105 and 107). **Figure 51** outlines the proposed sampling design.
4. The frequency of survey events will be reduced from bi-weekly to once every four weeks beginning the week of **June, 2008** (survey event 31) with the exception of a six-week period during spring western sandpiper migration (April – May).
5. The winter surveys during December, January, and February be reduced to one tidal event per survey for a period of three months as per CWS methodology.
6. Seasonal species-specific “windshield” surveys in conjunction with regularly scheduled (monthly) survey events to provide absolute abundance counts of brant (i.e., November – May) and great blue heron (i.e., May – August) are recommended when these species are most abundant in the survey area. The proposed sampling design (**Figure 51**) will utilize a subset of current PC locations (PCs 12, 15, 18, 109, 120, and 124) to provide coverage of the inter-causeway in a

repeatable manner. These surveys will insure that focal species of the AMS (brant and great blue heron), are represented along the BC Ferries Causeway (which has been otherwise removed from the survey scope) and will provide an improved estimate (absolute abundance) of the total number of brant and great blue heron using the study area. No time limit is proposed for these windshield surveys; rather, the objective of the survey is to count all the brant and great blue heron using the inter-causeway area at a given time. These “windshield” surveys will be included as part of the existing monthly survey events.

Obtaining the baseline data collected by Envirowest and CWS (2004) in support of the DP3 EA Application (2005), which had been anticipated as being available to compare to the 2007 survey data is recommended to advance decision-making with regards to monitoring adaptations.

4.7 SUMMARY

In conclusion, to date, the AMS monitoring program has not shown compelling evidence to suggest that the DP3 construction activities are contributing to significant widespread adverse effects within the inter-causeway area.

Based on the findings to date, the following adaptations to the AMS program have been recommended:

- Install additional DoD rods and complete surveys at the new drainage channels.
- Reduce the Crest Protection Monitoring Program frequency.
- Discontinue the automated turbidity monitoring at the end of 2008.
- Implement an alternate wave and current monitoring program 2008 to replace the destroyed AWAC.
- Continue the surface water and sediment quality monitoring programs but delete metals from the program if no adverse trends seen by the end of 2008.
- No change in the eelgrass monitoring program.
- Add and extra benthic community sampling station and an extra benthic community sampling event in Q1-2008.
- Reduce the frequency and extent of the bird surveys but add short term windshield surveys of species of concern (brant geese, great blue heron and western sandpiper) species during key windows.

Report prepared by:
HEMMERA

Michael Geraghty, M.Sc., P.Geo.
Project Manager

Christine Lussier, M.A.Sc.
Environmental Scientist

Steve Clark, M.Sc., R.P.Bio.
Senior Ecologist

Geoff Wickstrom, M.A.Sc., R.P.Bio.
Project Director

NHC

Derek Ray, M.Sc., P.Geo
Geomorphologist-Hydrologist

Dave McLean, Ph.D. P.Eng.
Principal

Charlene Menezes, B.Sc., G.I.T.
Geomorphologist-Hydrologist

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6.0 STATEMENT OF LIMITATIONS

This report was prepared by Hemmera, based on work conducted by the project team of Hemmera, Northwest Hydraulic Consultants (NHC) and Precision Identification (the Project Team) for the sole benefit and exclusive use of the Vancouver Fraser Port Authority. The material in it reflects the Project Team's best judgment in light of the information available to it at the time of preparing this Report. Any use that a third party makes of this Report, or any reliance on or decision made based on it, is the responsibility of such third parties. The members of the Project Team accept no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this Report.

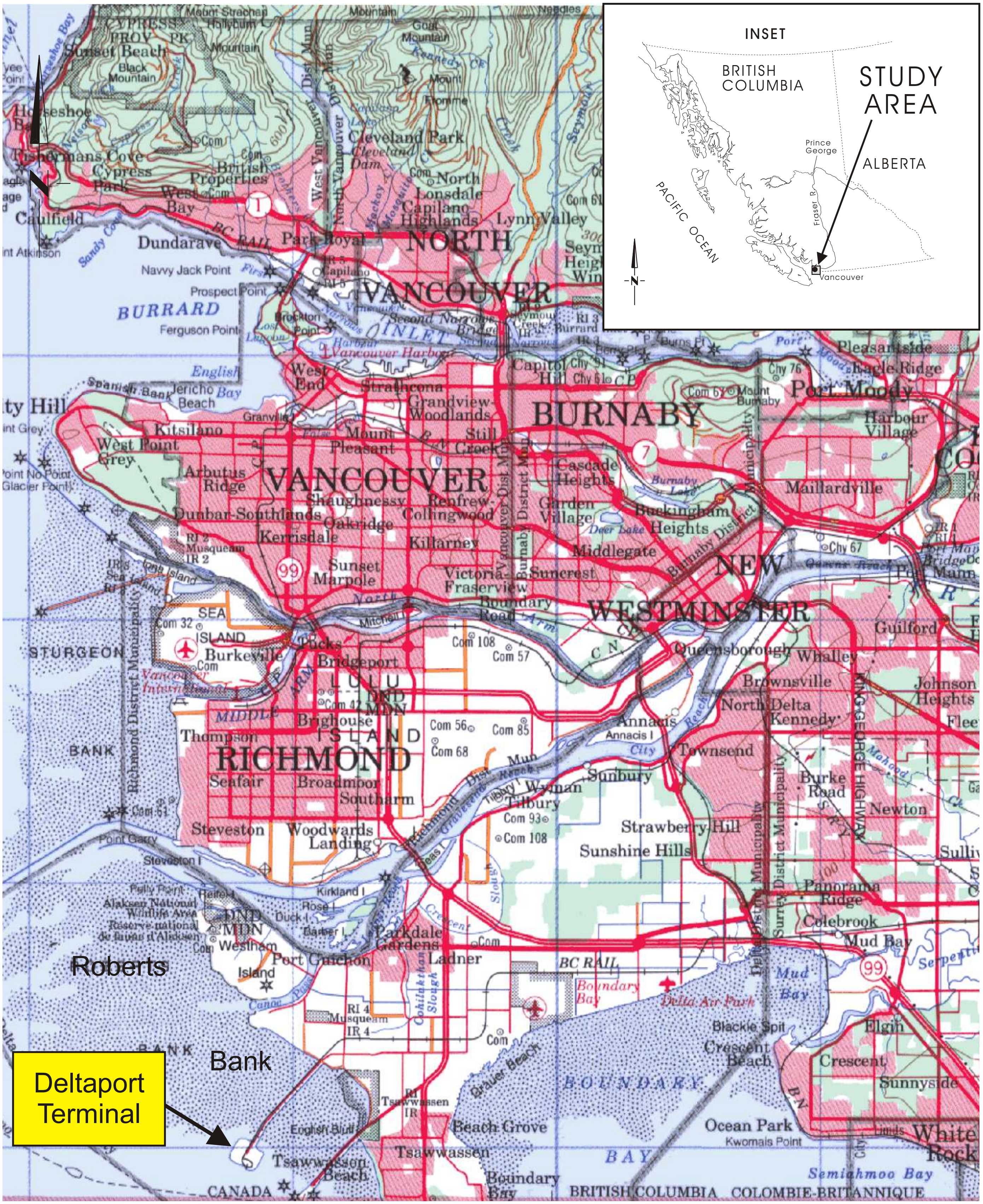
The Project Team has performed the work as described above and made the findings and conclusions set out in this Report in a manner consistent with the level of care and skill normally exercised by members of the environmental science profession practicing under similar conditions at the time the work was performed.

This Report represents a reasonable review of the information available to the Project Team within the established Scope, work schedule and budgetary constraints. It is possible that the levels of contamination or hazardous materials may vary across the Site, and hence currently unrecognised contamination or potentially hazardous materials may exist at the Site. No warranty, expressed or implied, is given concerning the presence or level of contamination on the Site, except as specifically noted in this Report. The conclusions and recommendations contained in this Report are based upon applicable legislation existing at the time the Report was drafted. Any changes in the legislation may alter the conclusions and/or recommendations contained in the Report. Regulatory implications discussed in this Report were based on the applicable legislation existing at the time this Report was written.

In preparing this Report, the Project Team have relied in good faith on information provided by others as noted in this Report, and has assumed that the information provided by those individuals is both factual and accurate. The members of the Project Team accept no responsibility for any deficiency, mis-statement or inaccuracy in this Report resulting from the information provided by those individuals.

The liability of the members of the Project Team to the Vancouver Fraser Port Authority shall be limited to injury or loss caused by the negligent acts of the Project Team. The total aggregate liability of Hemmera and the members of the Project Team related to this agreement shall not exceed the lesser of the actual damages incurred, or the total fee of the members of the Project Team for services rendered on this project.

FIGURES



HEMMERA

CLIENT:

PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2007 ANNUAL REPORT

SITE LOCATION

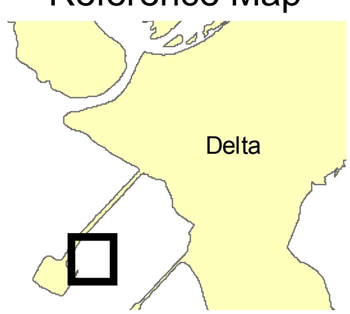
PROJECT No.		
499-002.11	July 2008	FIGURE 1

Legend

- Monitoring Sites
- Topographic Sections

Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Crest Protection Monitoring Site Location Map

Scale - 1:7,500

100 50 0 100 200 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

MSN, 34648 Deltaport Monitoring\GIS\Fig_CrestProtectionSites.mxd

Figure 2

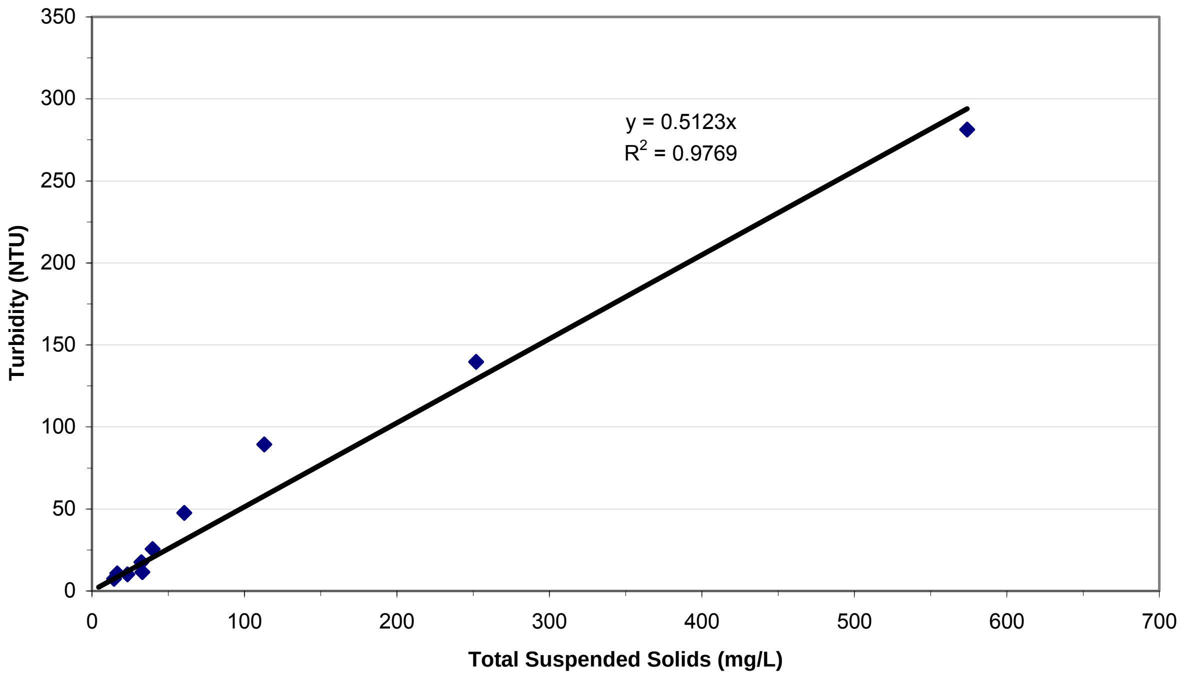


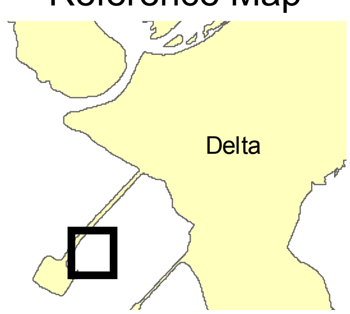
Figure 3 Relation Between Turbidity and Total Suspended Sediment Concentration

Legend

- Tide Gauge
- Turbidity Sensor

Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Instrumentation
Site Location Map

Scale - 1:7,500

100 50 0 100 200 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

CM, 34648 Deltaport Monitoring\GIS\Fig_InstrumentSites.mxd

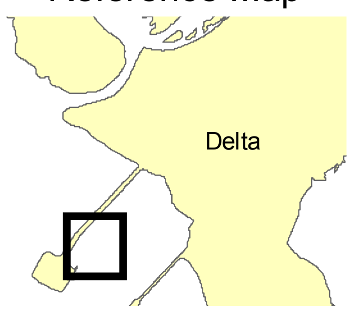
Figure 4

Legend

● DOD Rod Locations

Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Depth of Disturbance Rods Location Map

Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

MSN, 34648 Deltaport Monitoring\GIS\Fig5DepthOfDisturbanceSites.mxd

Figure 5

UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203
DP08	490760.801	5430036.675

NOTE: DP08 is a sampling station proposed for 2008.

LEGEND
- Water
- Tidal Mud & Sand
- Water Quality Sampling Station
- YSI Sonde

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CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

SURFACE WATER, SEDIMENT & BENTHIC INVERTEBRATE SAMPLING STATIONS

PROJECT No.		
499-002.11	July 2008	FIGURE 6

LEGEND

Water Quality Sampling Station

SCALE 1:5,000 (metres)

0 100 200

HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2007 ANNUAL REPORT

DETAILED LOCATION OF SAMPLE DP01

PROJECT No.		
499-002.11	July 2008	FIGURE 7

N

LEGEND

- SAMPLE LOCATION
- THIRD BIRTH FOOTPRINT

SCALE 1:30,000
metres
0 600 1200

REFERENCE DRAWINGS

- Base Map Information Provided by Triton Consultants Ltd., dated Sept 2004.
- Envirowest Environmental Consultants Figure 'Appendix A', dated Nov. 1, 2004.

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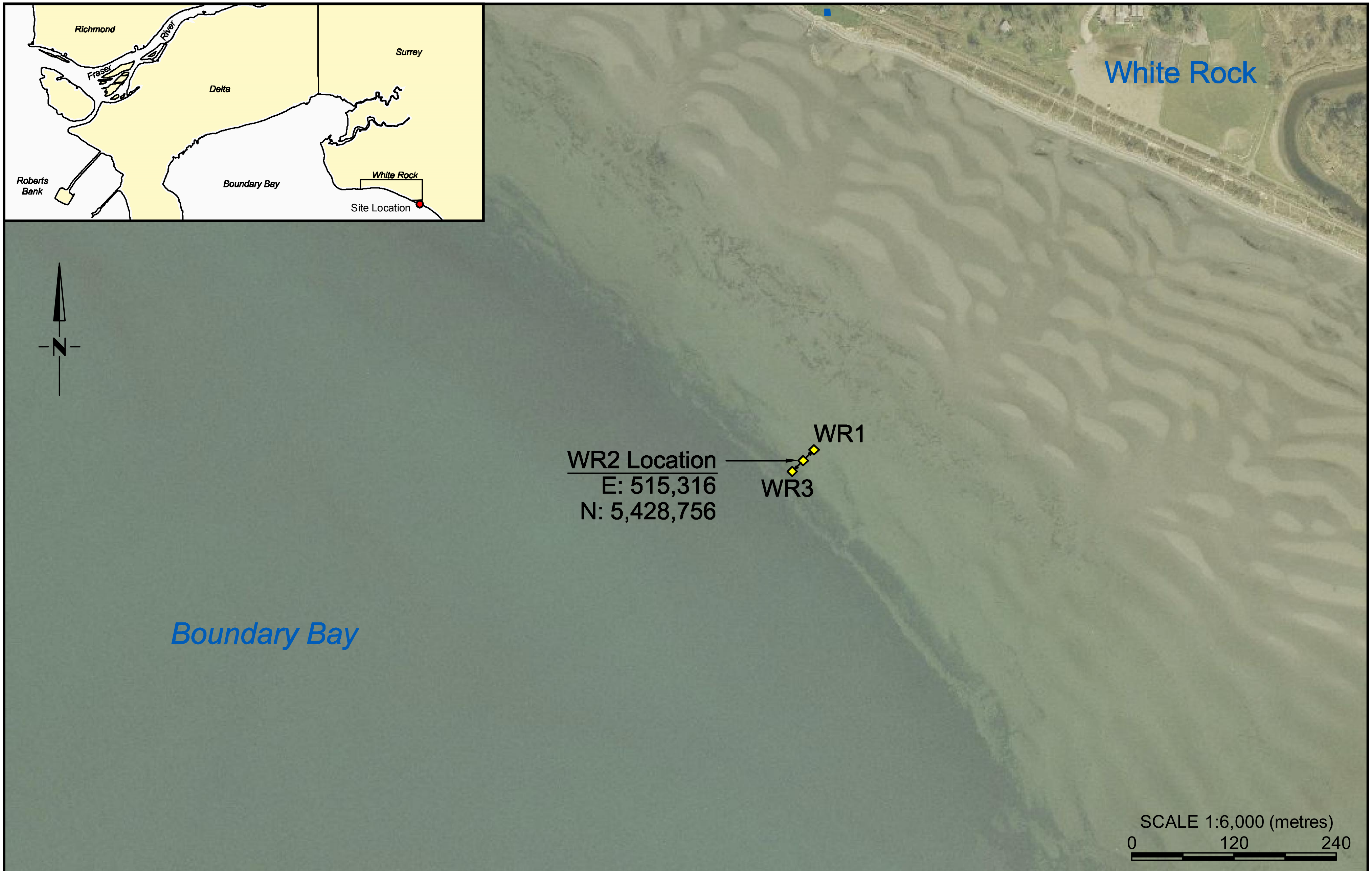
CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2007 ANNUAL REPORT

EELGRASS STATION REFERENCE LOCATIONS (DELTAPORT AREA)

PROJECT No.		
499-002.11	July 2008	FIGURE 8



LEGEND

◆ Eelgrass Sampling Station (UTM Coordinates Shown)

Note: The shallow and deep station are each approximately 10 metres away from the mid station.

HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2007 ANNUAL REPORT

EELGRASS REFERENCE STATION LOCATION (BOUNDARY BAY AREA)

PROJECT No.		
499-002.11	July 2008	FIGURE 9

N

LEGEND

● 1 POINT COUNT STATION

SAMPLE PLOT AREA

SCALE 1:30,000
metres
0 600 1200

REFERENCE DRAWINGS

- Base Map Information Provided by Triton Consultants Ltd., dated Sept 2004.
- Envirowest Environmental Consultants Figure 'Appendix A', dated Nov. 1, 2004.

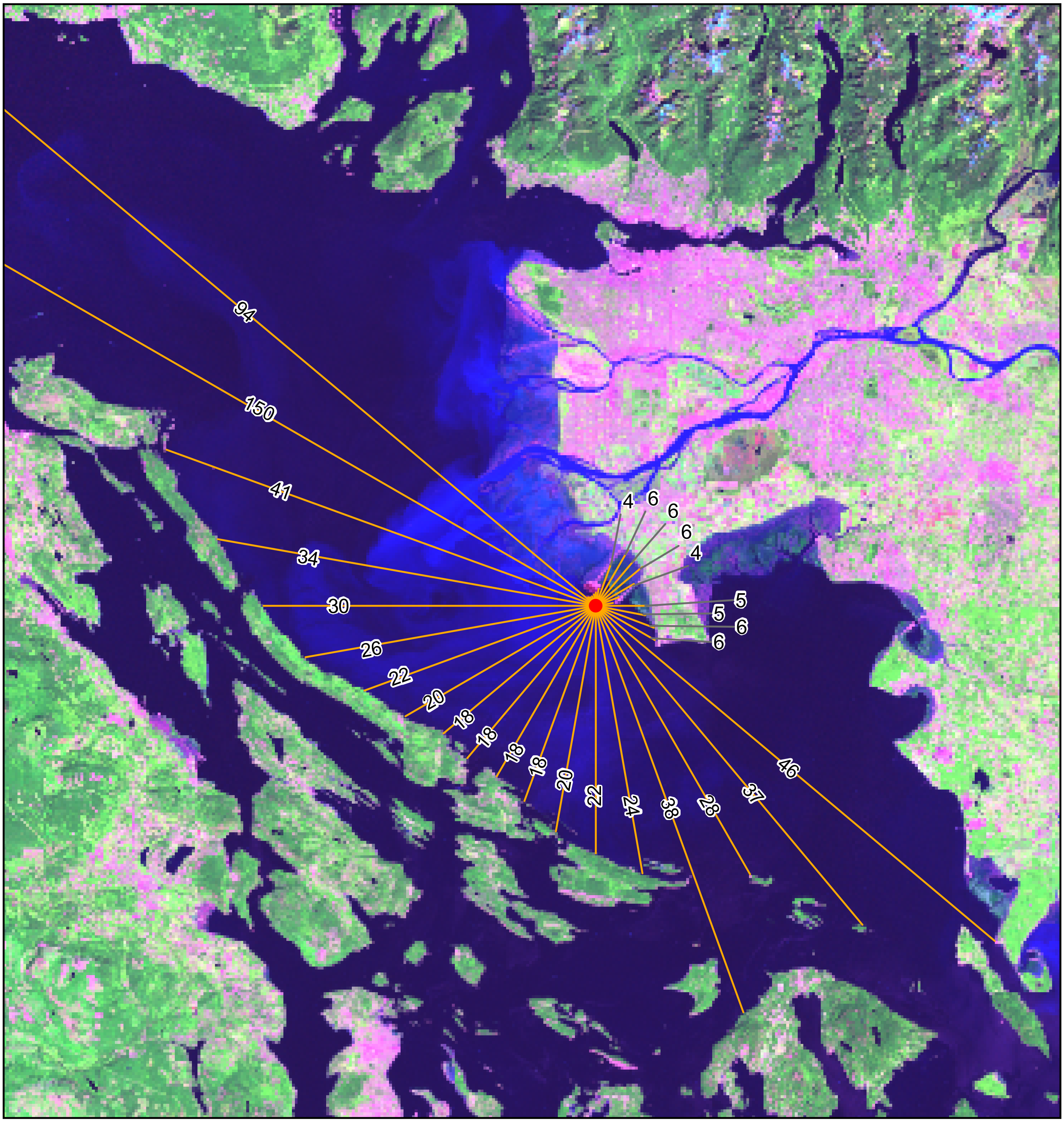
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2007 ANNUAL REPORT

BIRD SURVEY
TRANSECT LOCATIONS

PROJECT No. 499-002.11	July 2008	FIGURE 10



Legend

● Reference Point

Fetch Lengths at 10˚ intervals (km)

Note:
- July 30, 2000 Landsat composite image courtesy of Geogratis.

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Fetch Lengths at Deltaport

Scale - 1:500,000

10 5 0 10 Kilometres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

CXM/MSN, 34648 Deltaport Monitoring\GIS\Fig_FetchLength.mxd

Figure 11

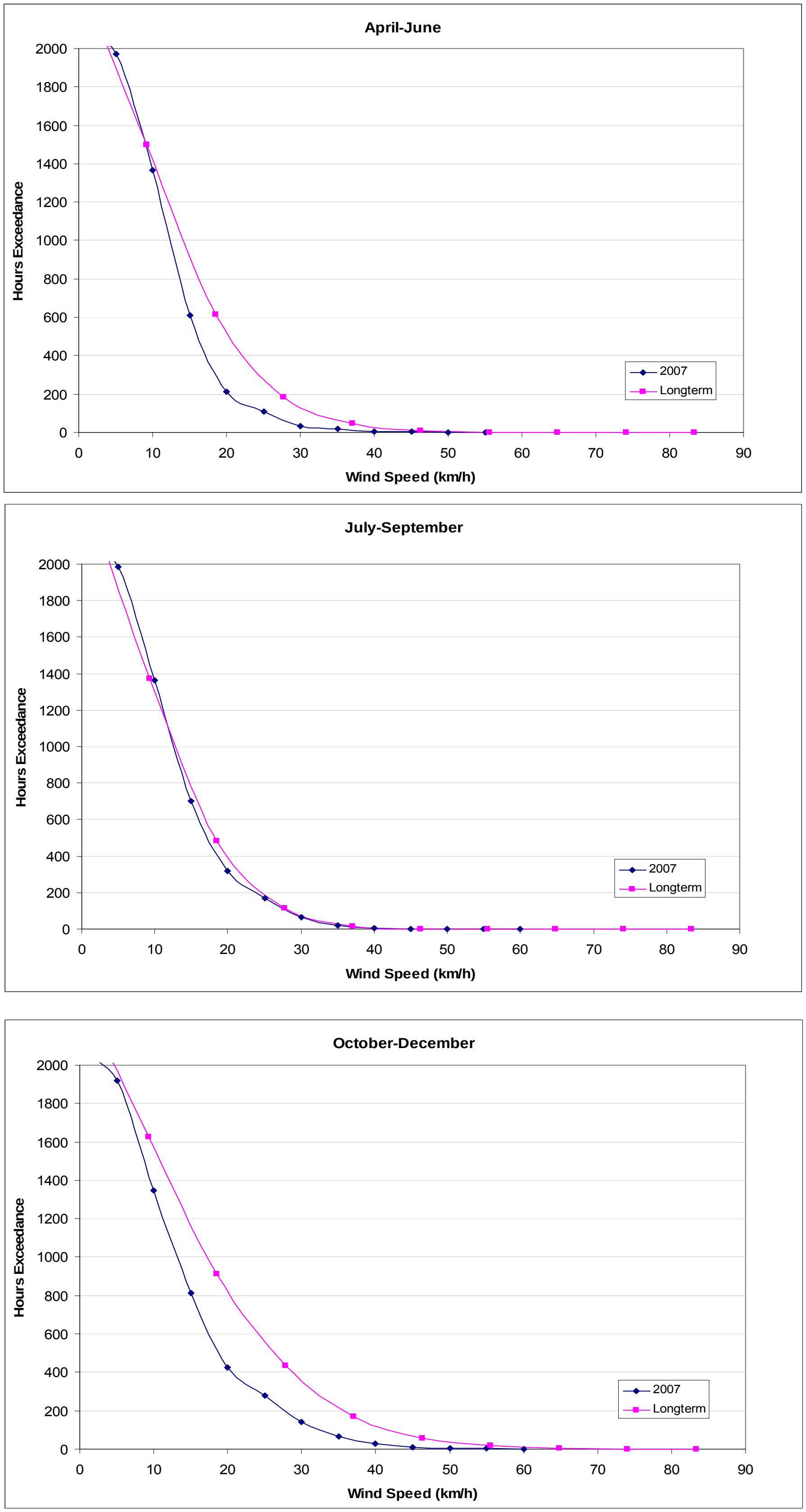


Figure 12 Percent Exceedance of Wind Speeds at Vancouver International Airport

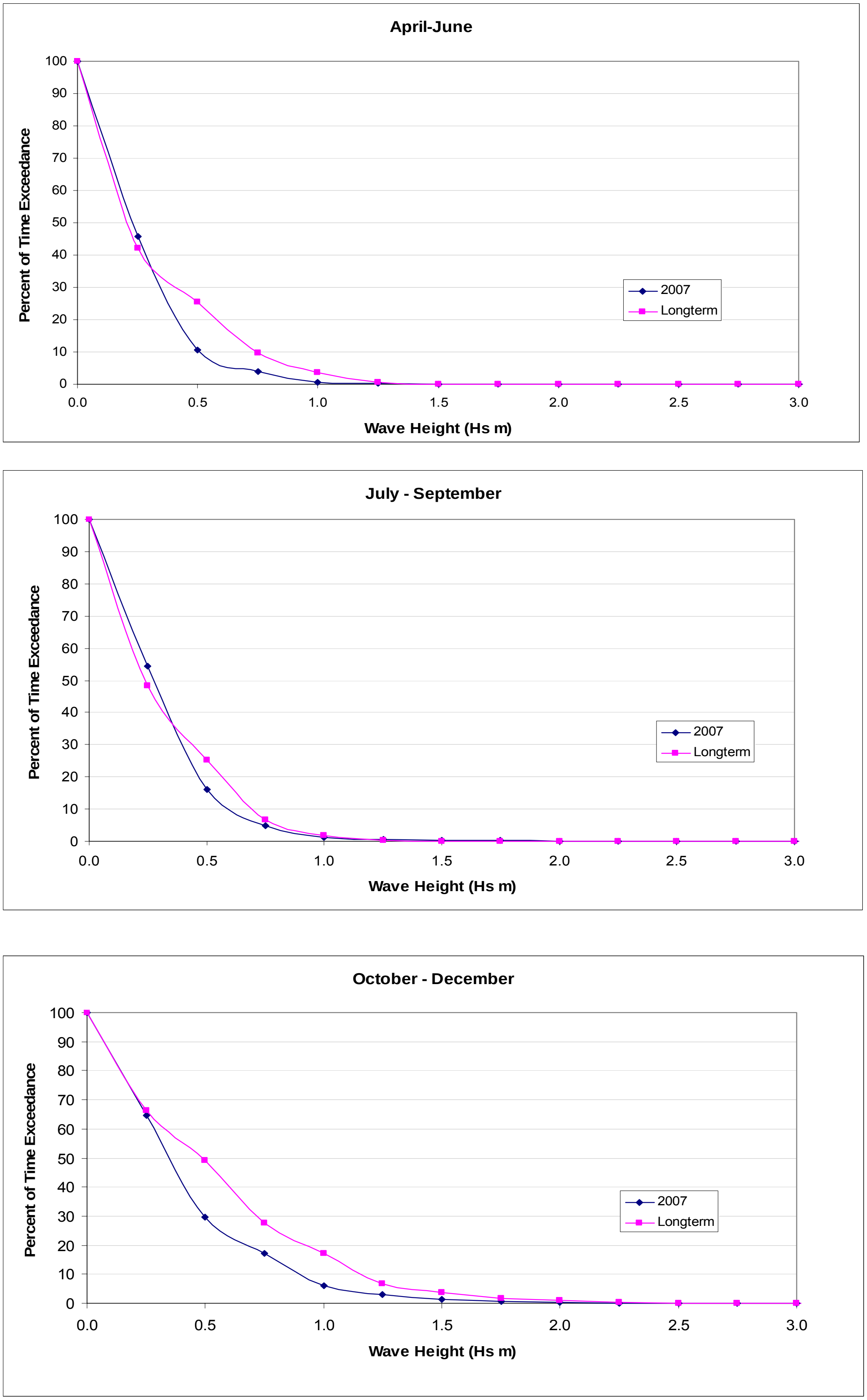


Figure 13 Percent Exceedance of Significant Wave Heights at Halibut Bank

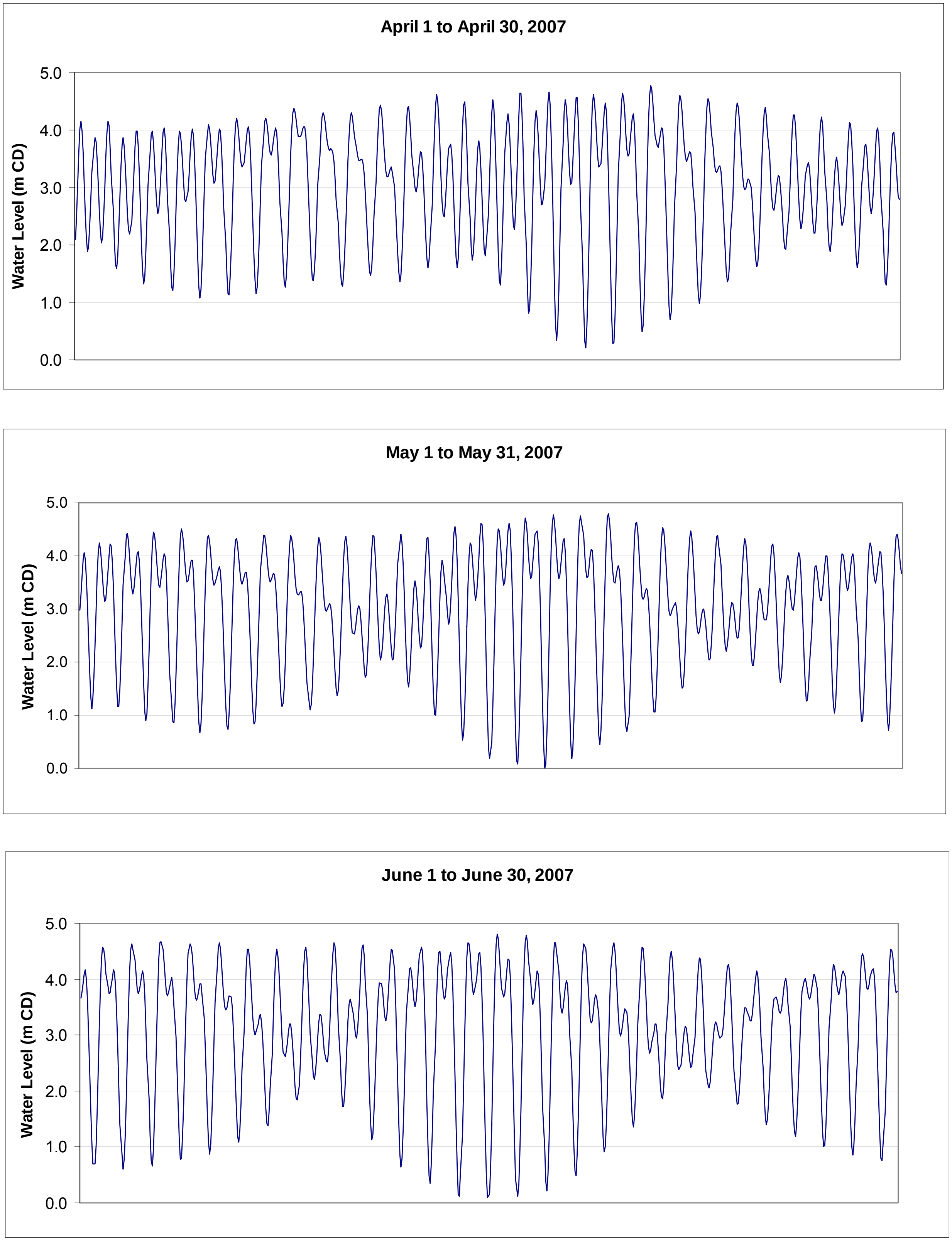


Figure 14 Observed Tide Levels April to June, 2007 at Point Atkinson

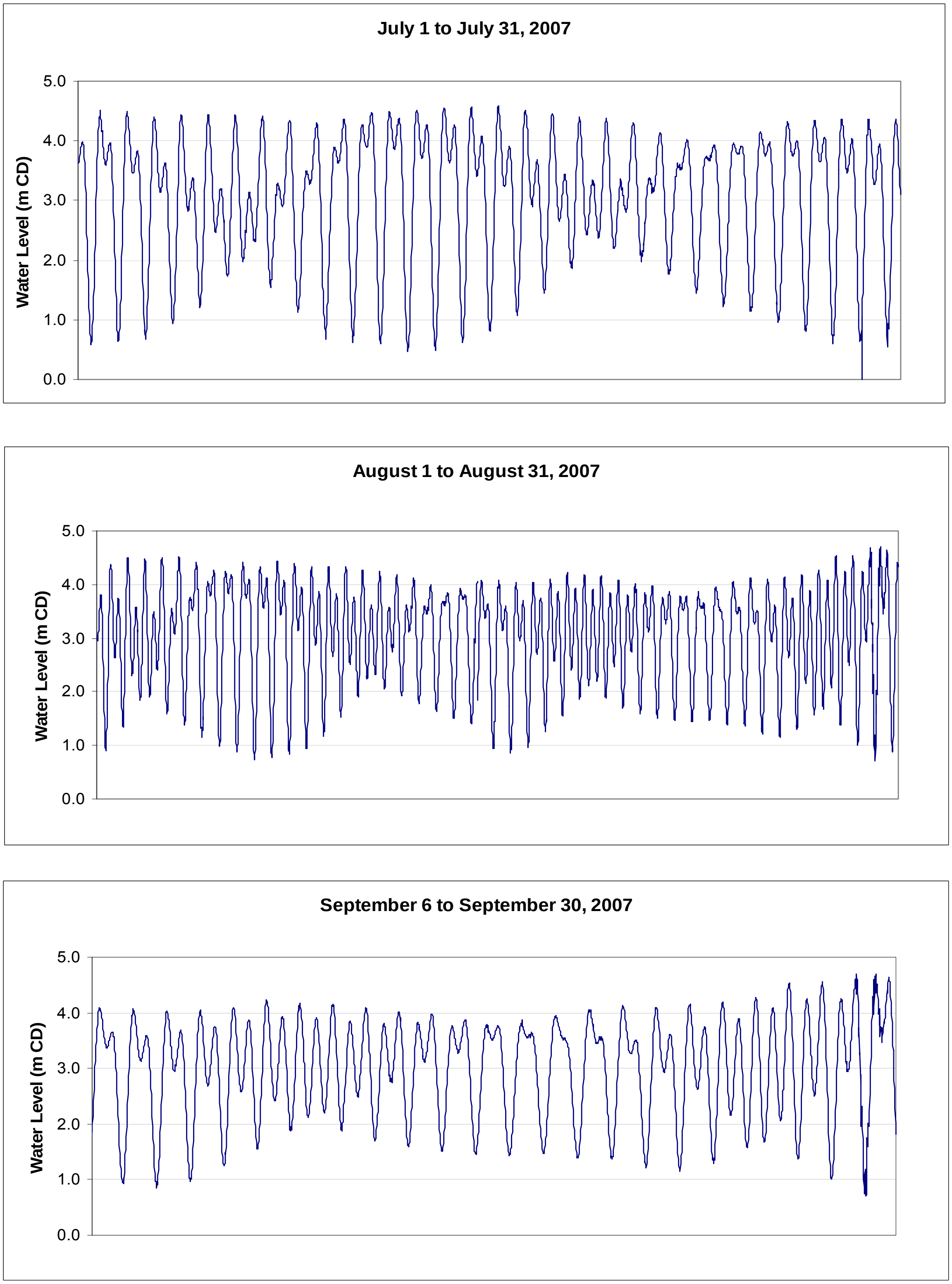


Figure 15 Observed Tide Levels July to September, 2007 at Deltaport

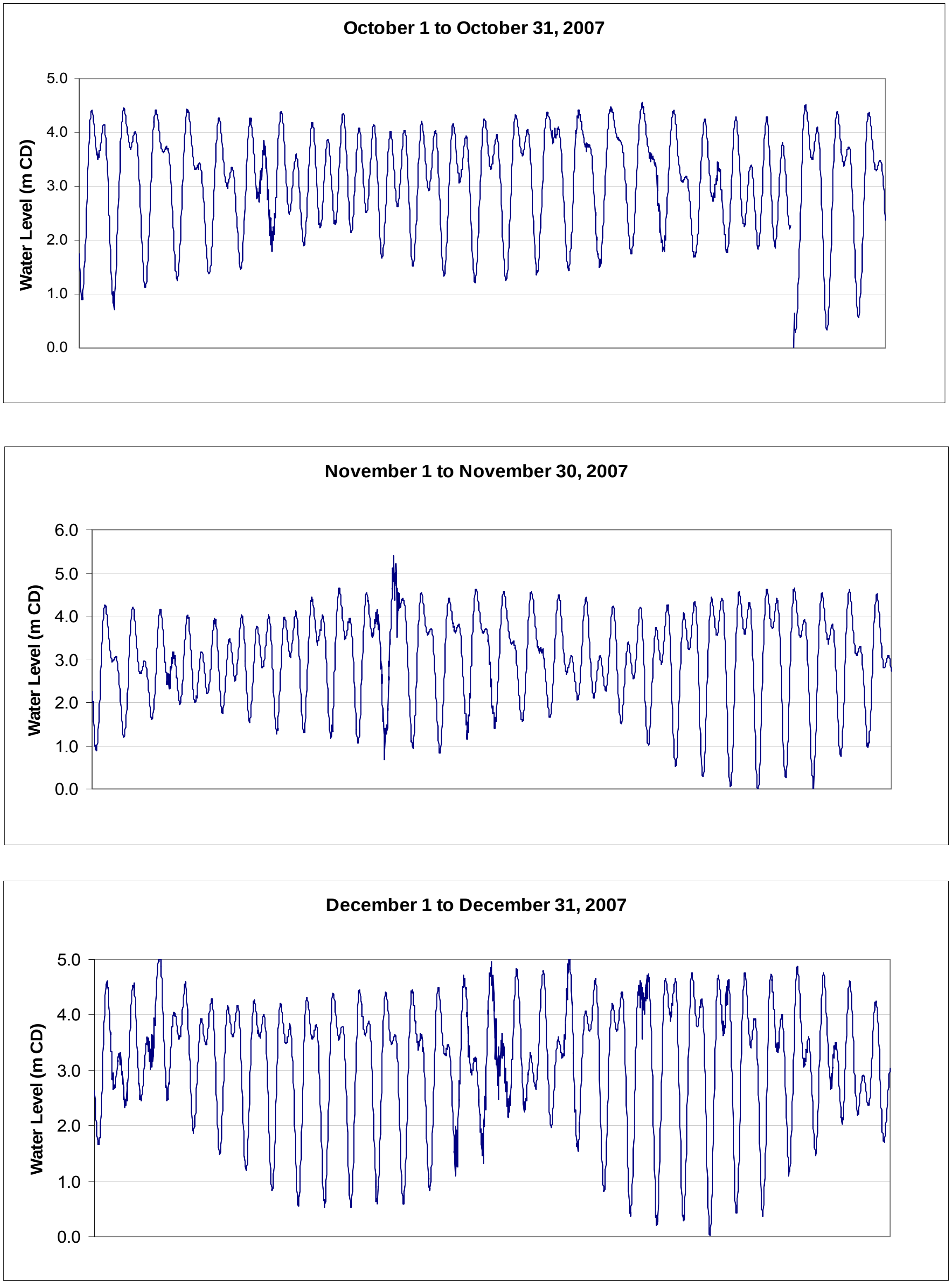


Figure 16 Observed Tide Levels October to December, 2007 at Deltaport

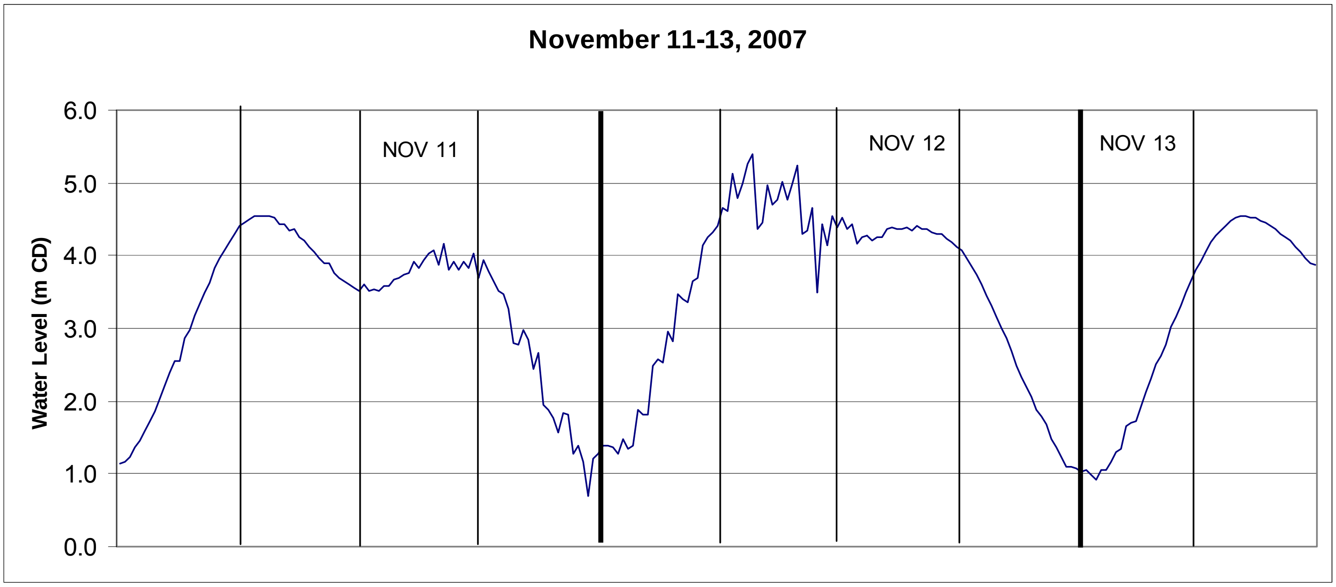


Figure 17 Observed Tide Level During November 12th, 2007 Storm Event

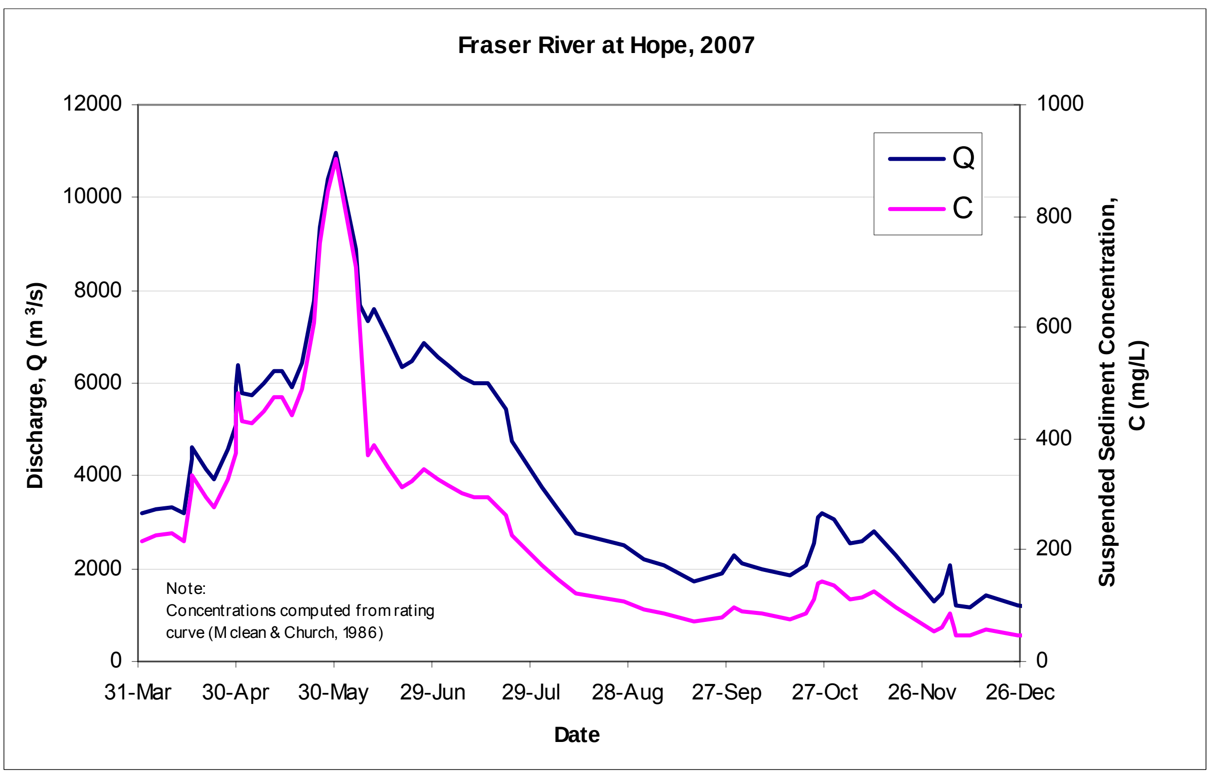


Figure 18 Fraser River at Hope (WSC gauge 08MF005), 2007

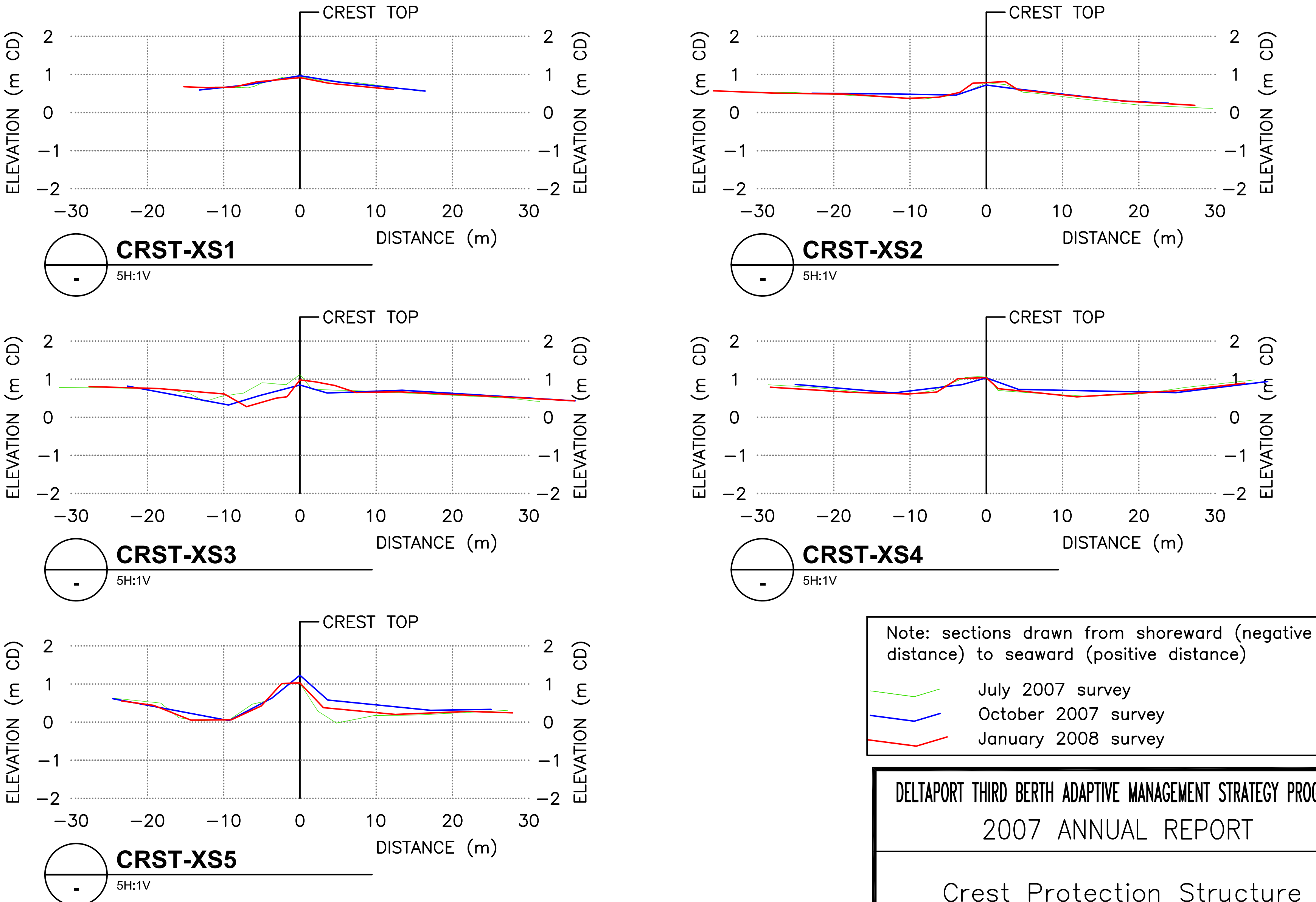


FIGURE 19

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM

2007 ANNUAL REPORT

Crest Protection Structure
Monitoring Cross Sections

northwest hydraulic consultants

DWG. NO.	REV. NO.	DATE
crstpro-08-01	00	08-02-19

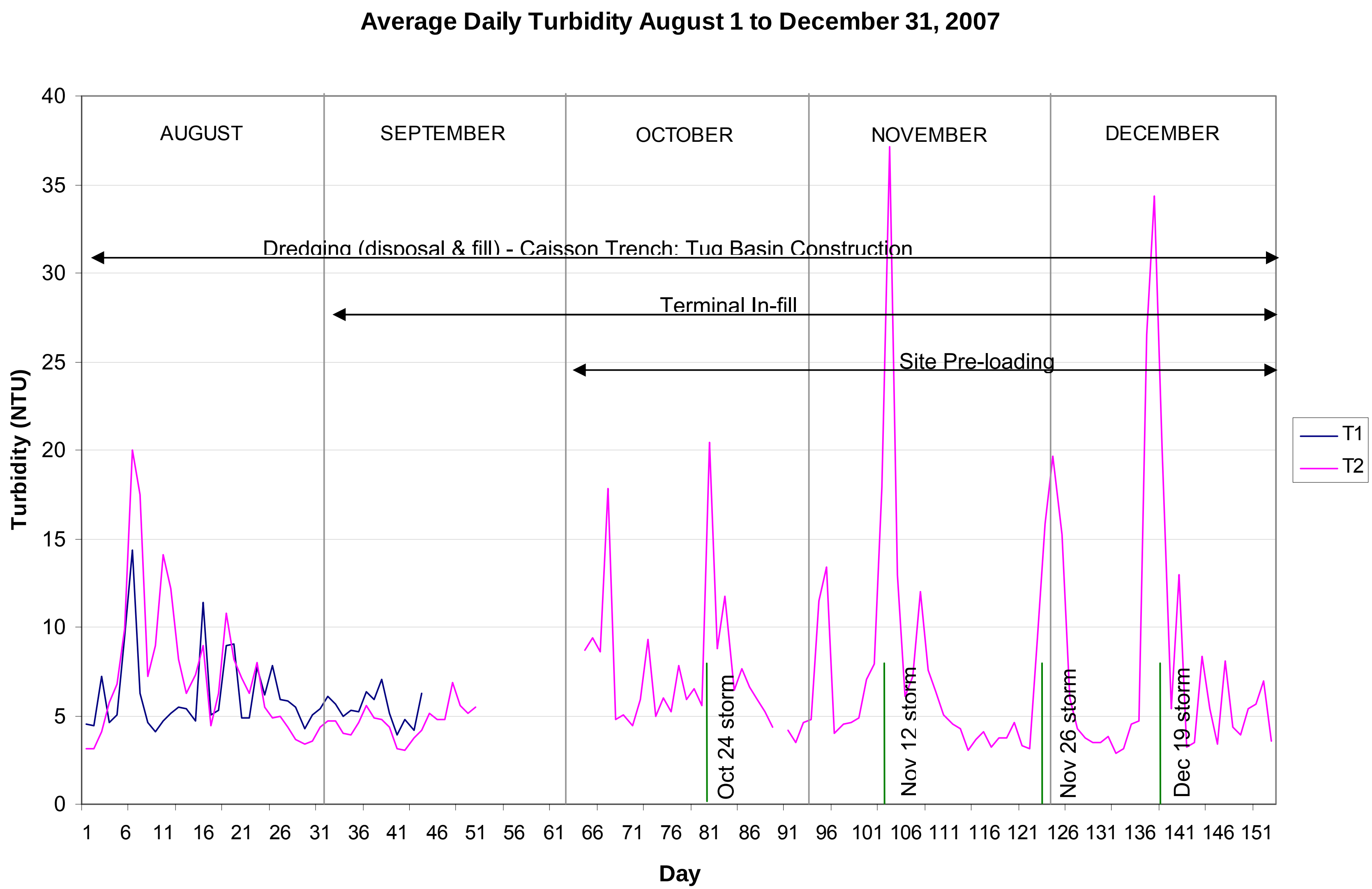


Figure 20 Average Daily Turbidity from August to December 2007

Average Daily Sediment Concentration August 1 to December 31, 2007

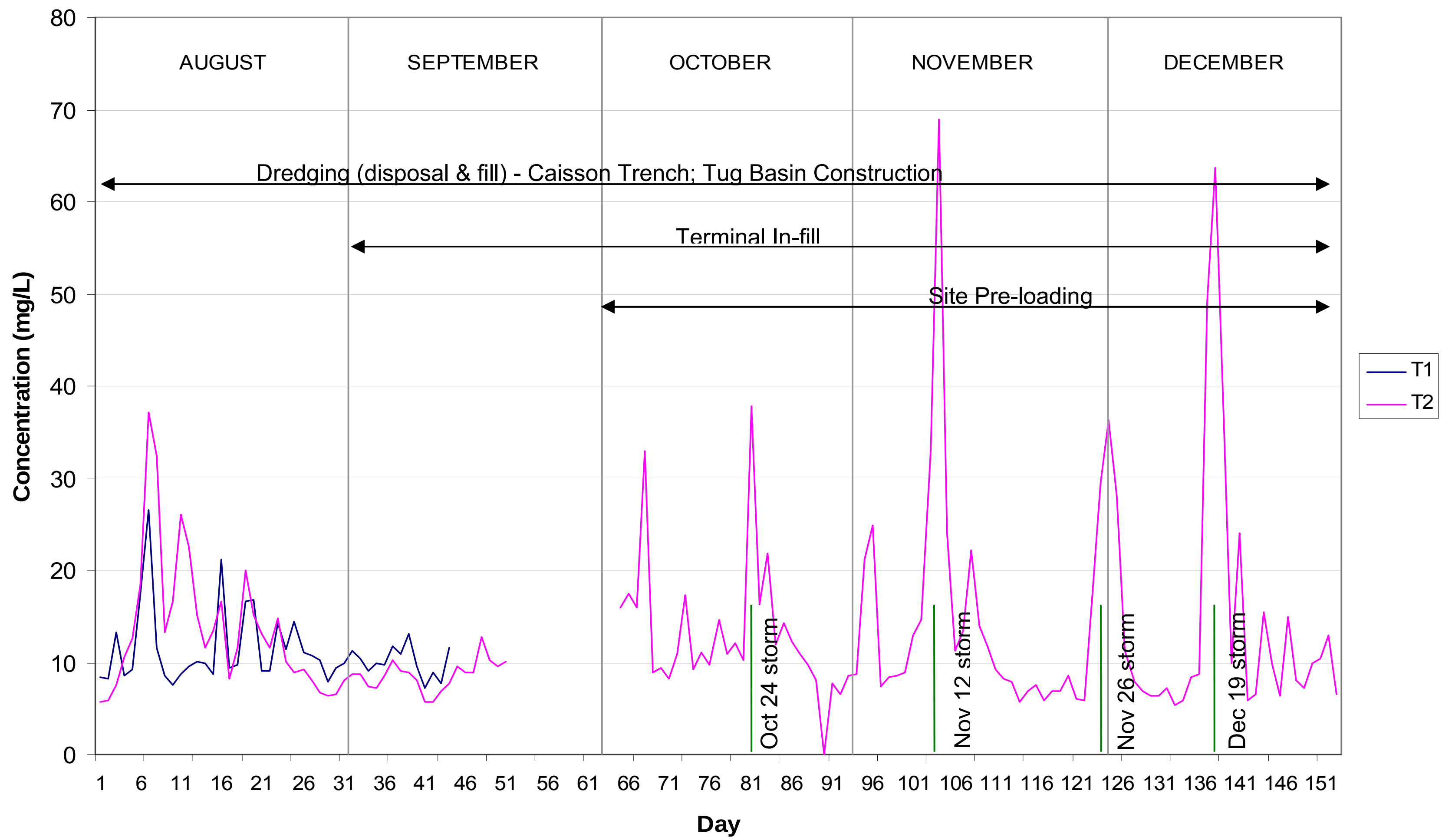
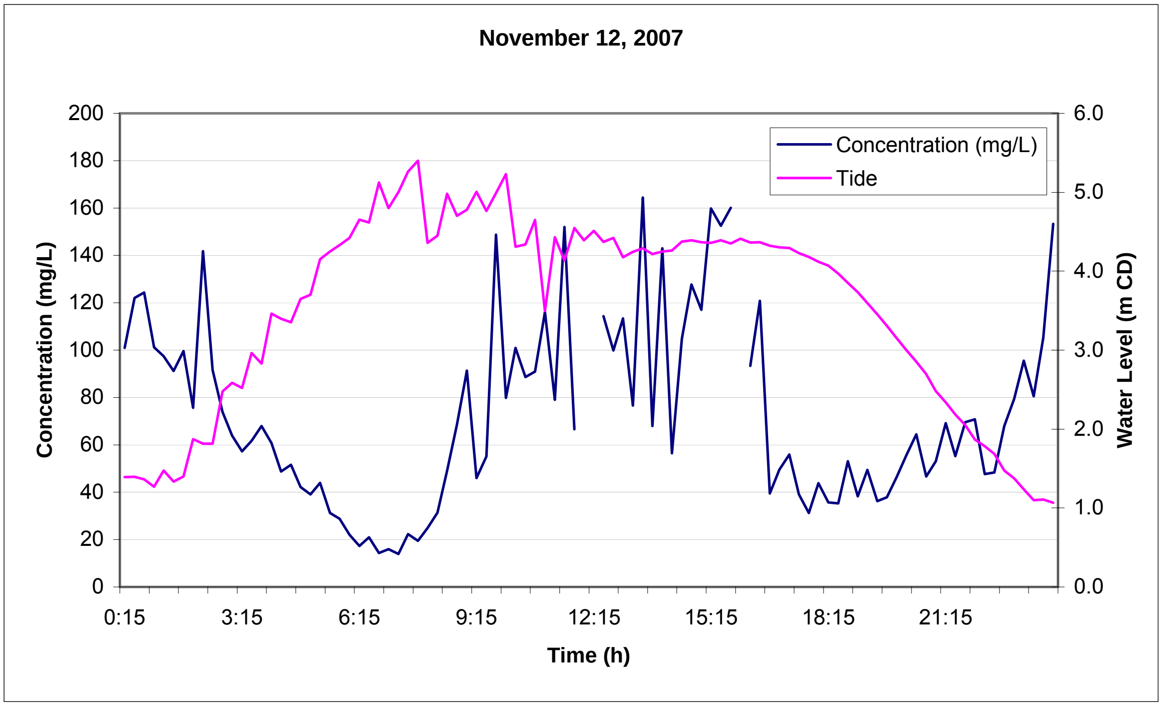


Figure 21 Average Daily Sediment Concentrations



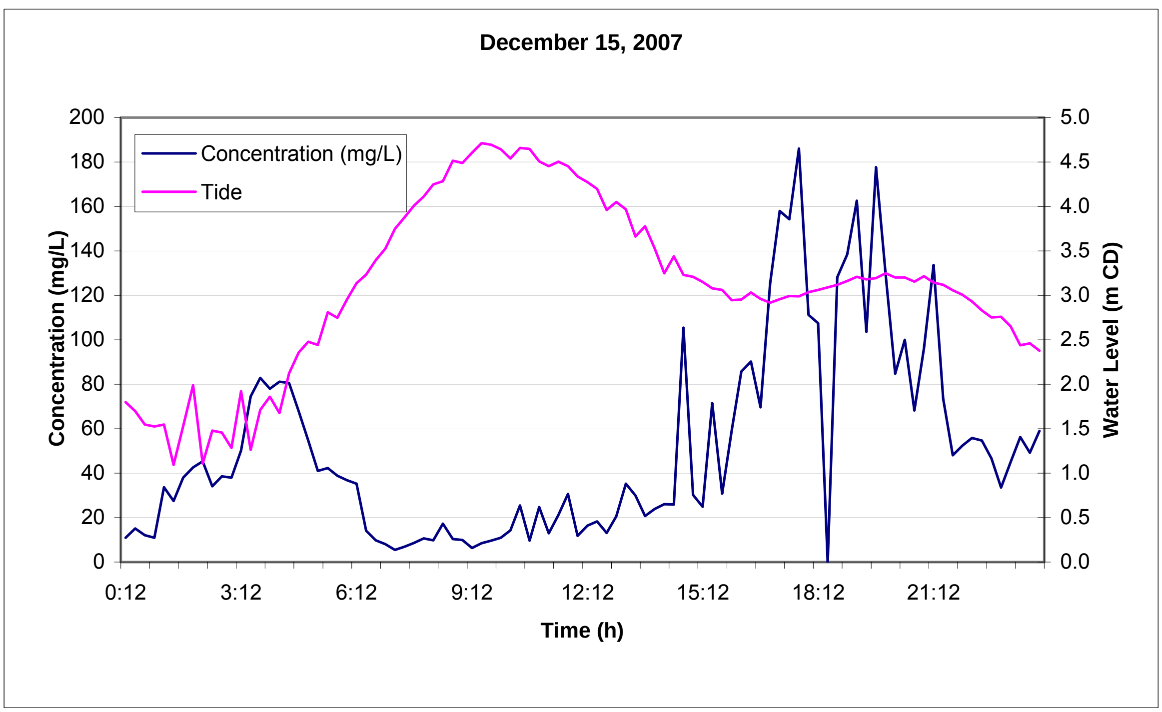
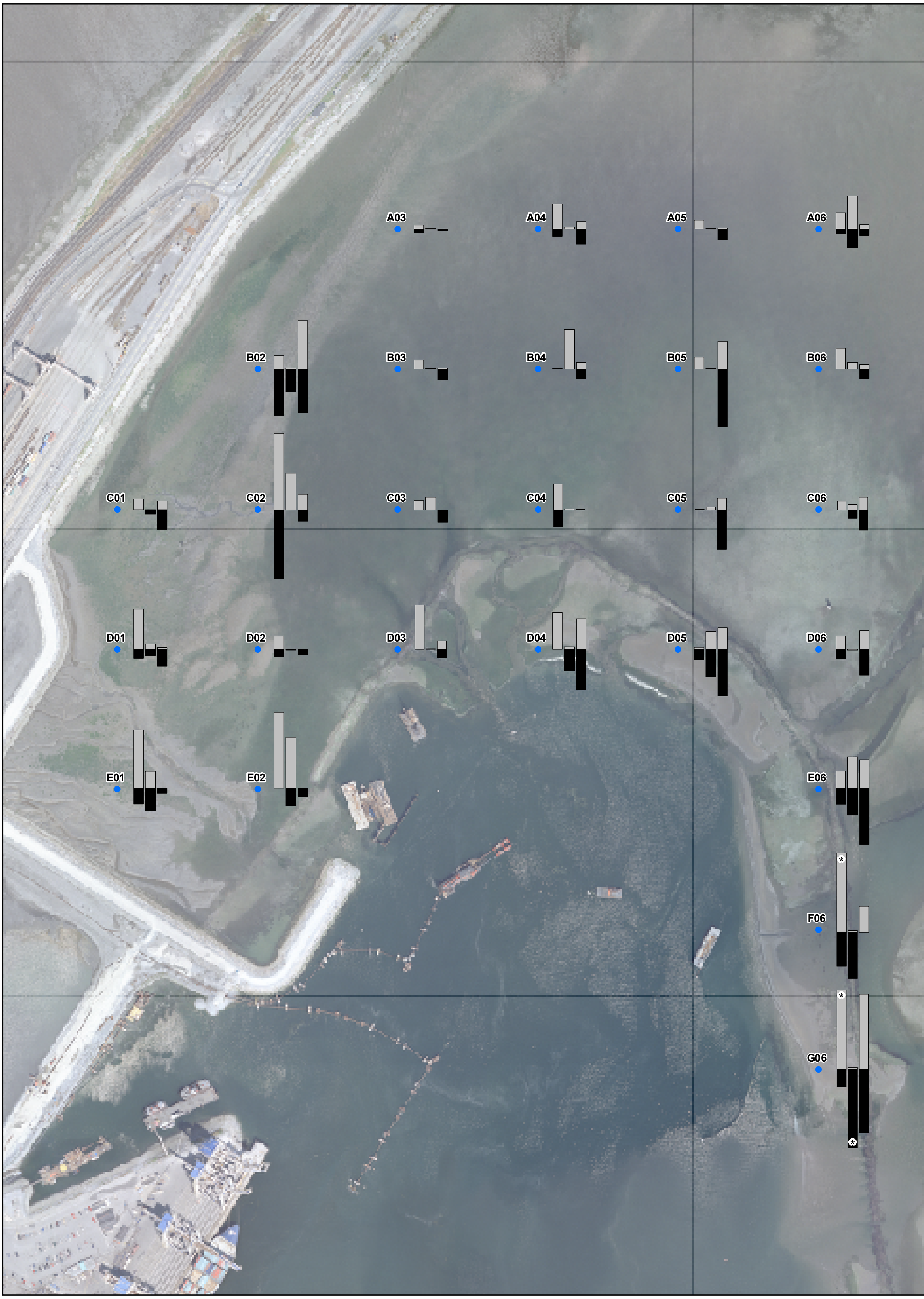


Figure 22 Sediment Concentration on November 12 and December 15, 2007 derived from hourly turbidity measurements

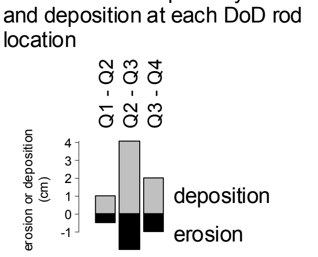


Legend

DoD Rod Locations

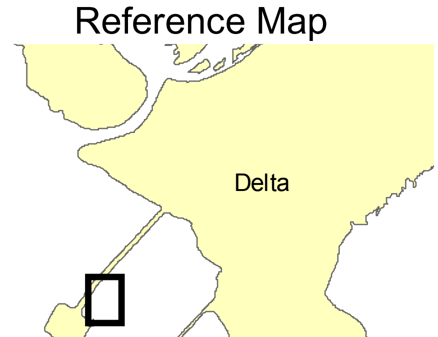
Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Bar chart shows quarterly erosion and deposition at each DoD rod location



* indicates that value extends beyond range of chart

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Bar Charts of Quarterly Erosion and Deposition at DoD Rods

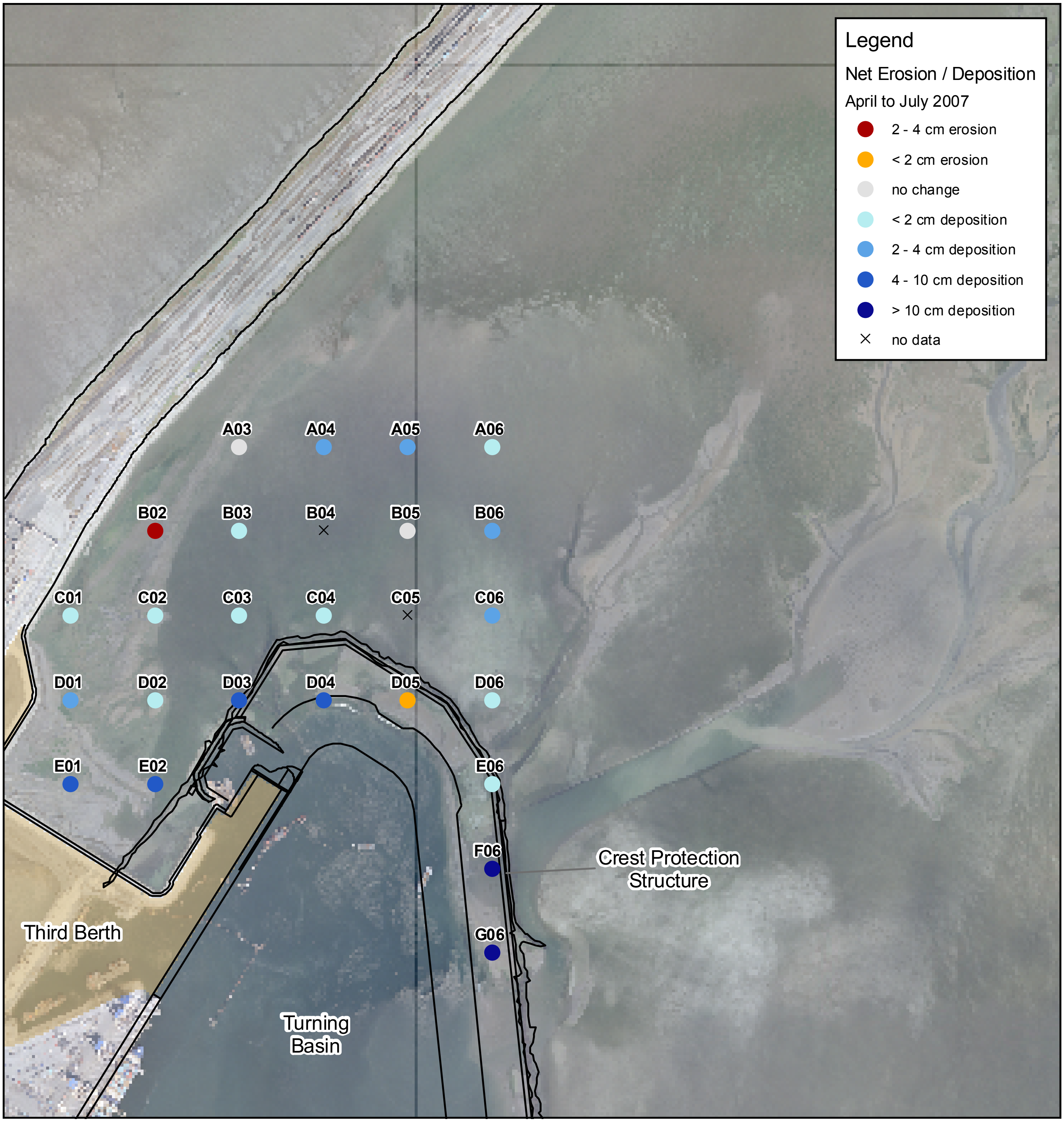
Scale - 1:4,000

100 50 0 100 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

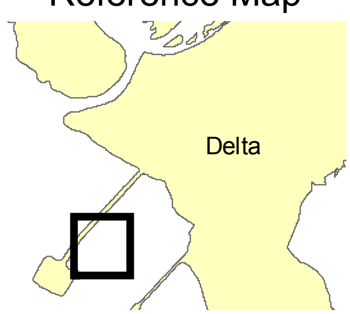
Figure 23

MSN, 34648 Deltaport Monitoring\GIS\Fig_DoDErosionDepositionCharts.mxd



Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Net Change in Erosion/Deposition at DoD Rods Q2-2007

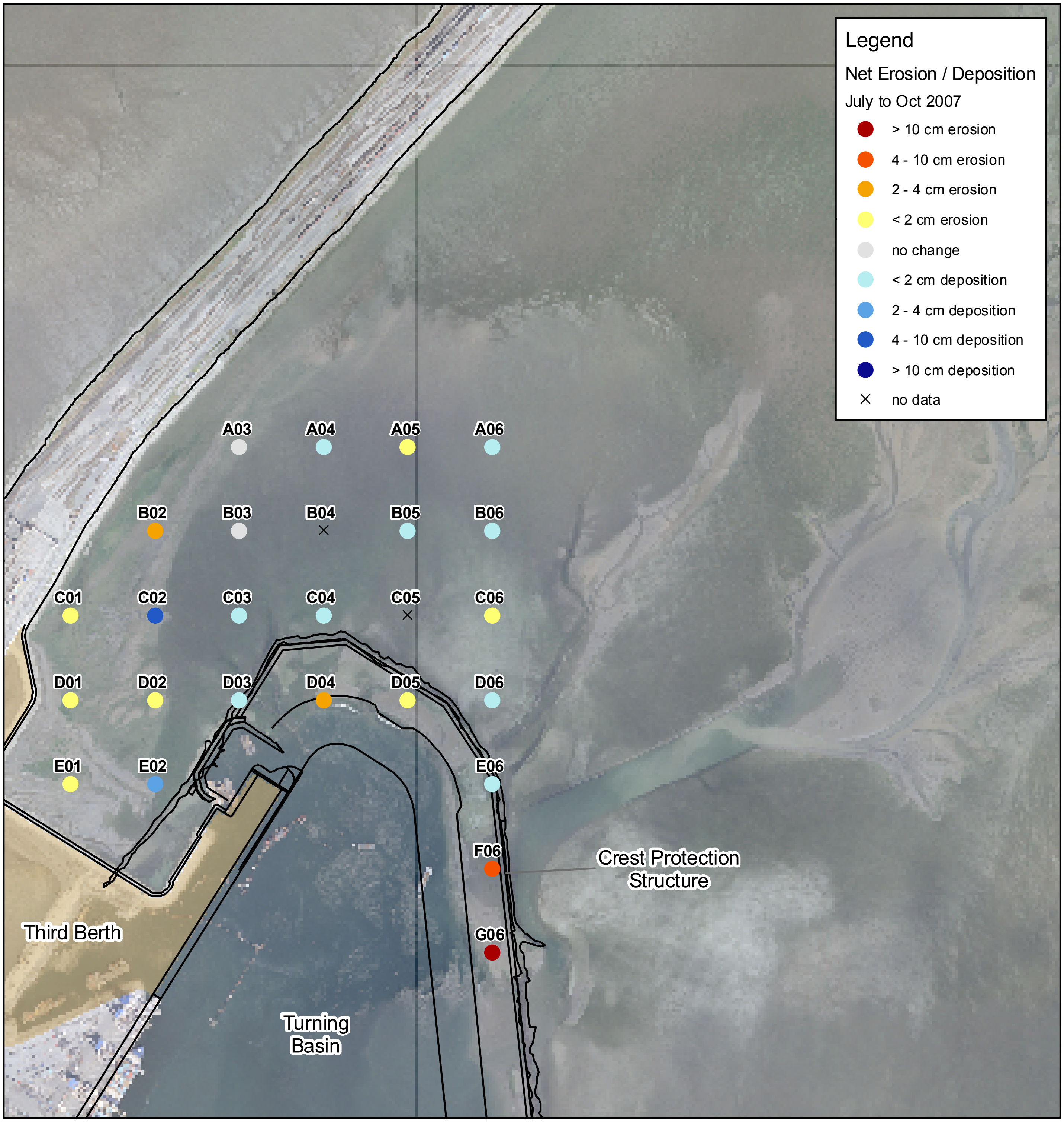
Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

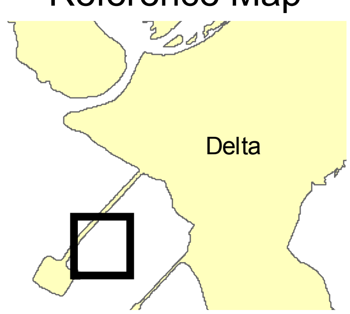
MSN, 34648 Deltaport Monitoring\GIS\Fig_DoDResultsNet.mxd

Figure 24



Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Net Change in Erosion/Deposition at DoD Rods Q3-2007

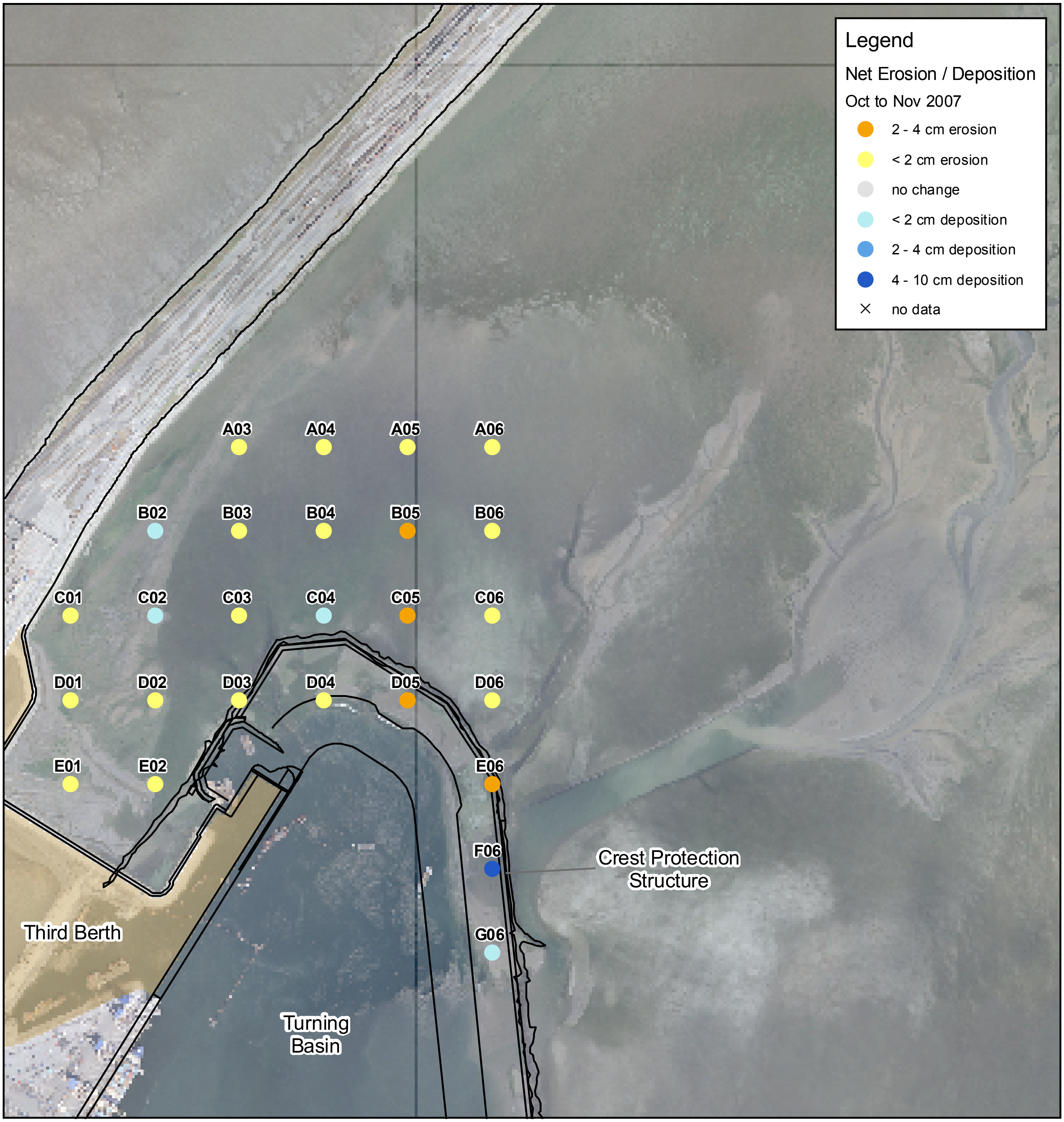
Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

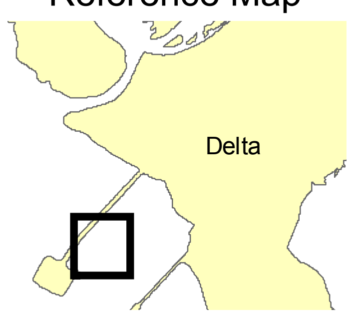
MSN, 34648 Deltaport Monitoring\GIS\Fig_DoDResultsNet.mxd

Figure 25



Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Net Change in Erosion/Deposition at DoD Rods Q4-2007

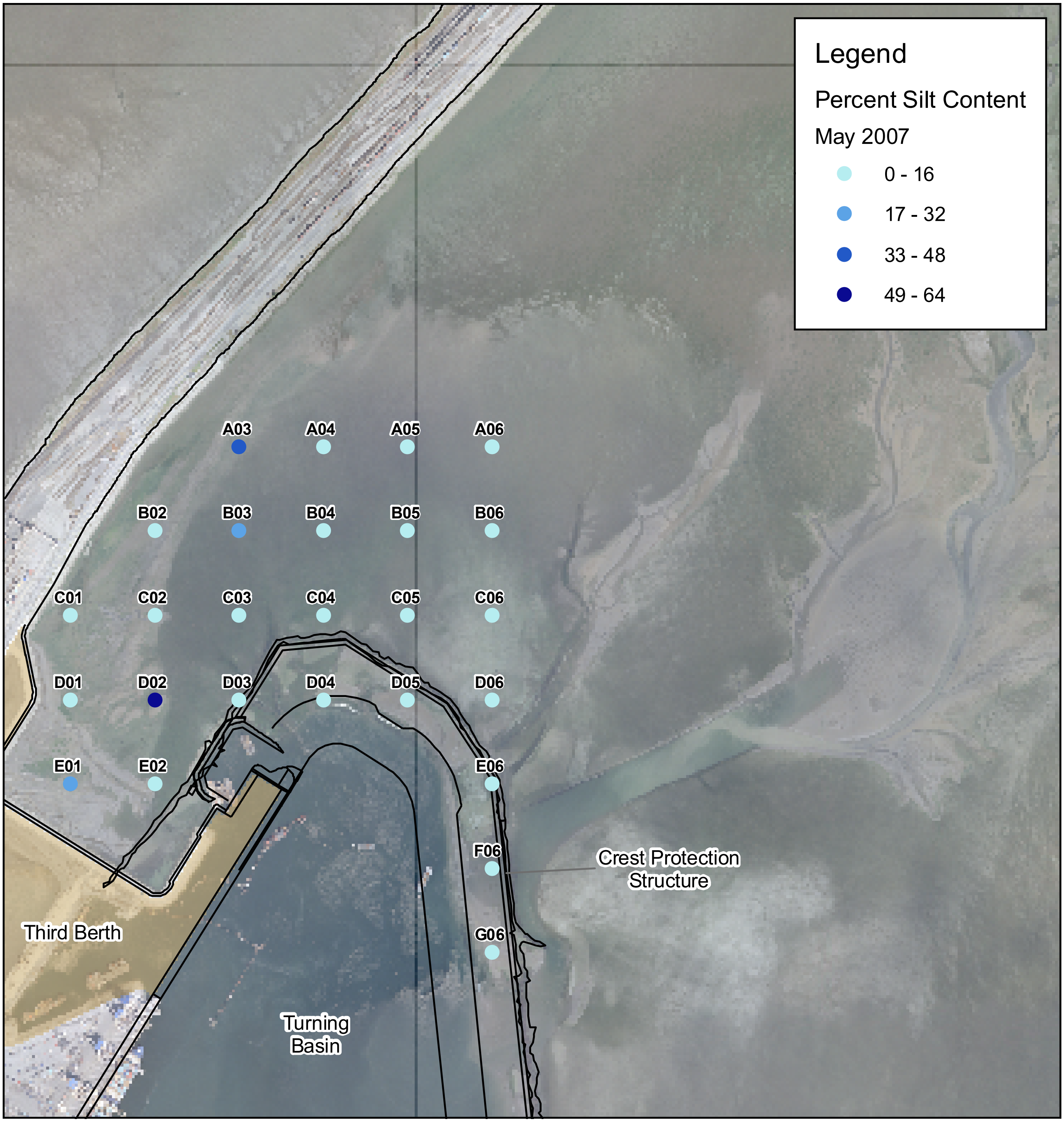
Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

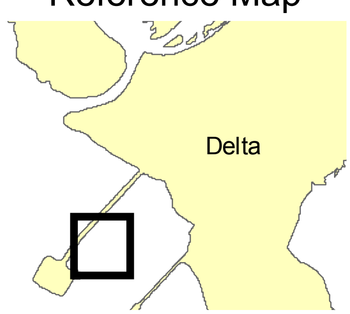
MSN, 34648 Deltaport Monitoring\GIS\Fig_DoDResultsNet.mxd

Figure 26



Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Percent Silt Content (< 0.063 mm) at DoD Rod Locations May 2007

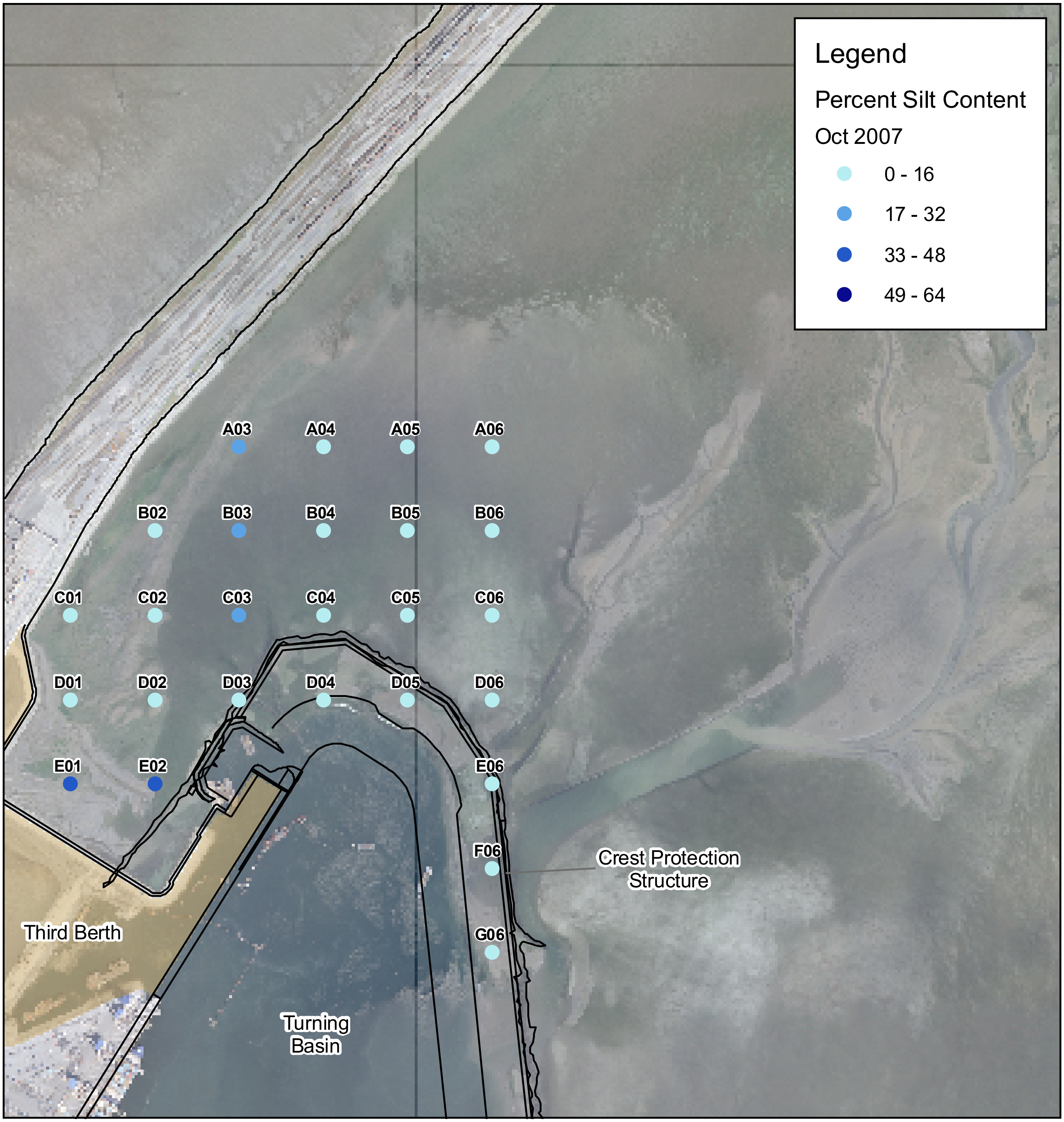
Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

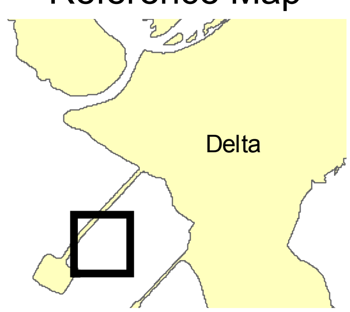
MSN, 34648 Deltaport Monitoring\GIS\Fig_SiltContent.mxd

Figure 27



Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Percent Silt Content (< 0.063 mm) at DoD Rod Locations October 2007

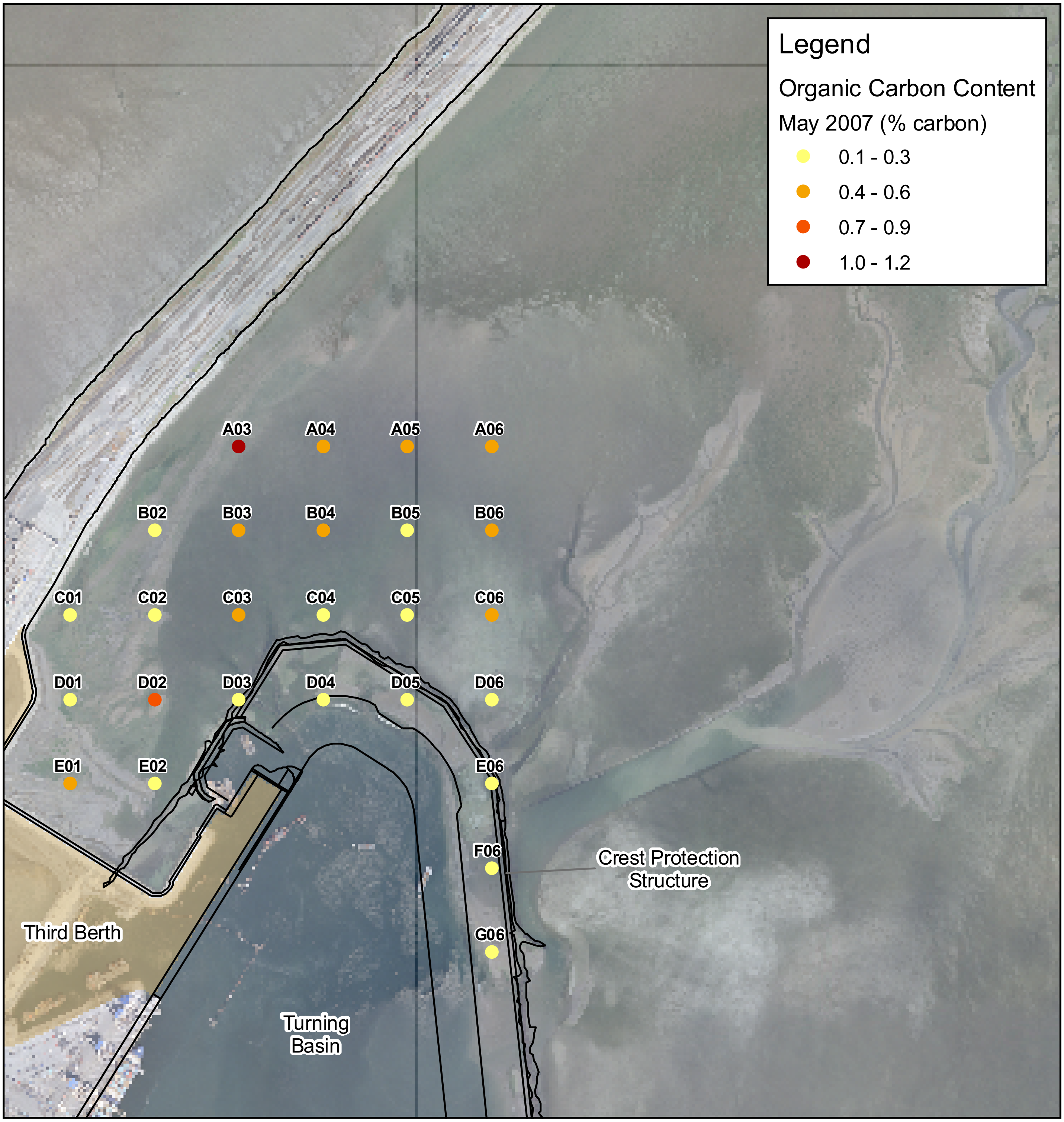
Scale - 1:10,000

100 50 0 100 200 300 Metres

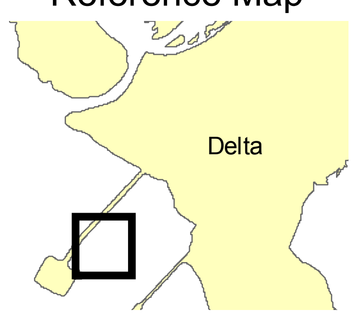
coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

MSN, 34648 Deltaport Monitoring\GIS\Fig_SiltContent.mxd

Figure 28



Note:
- July 16, 2007 orthophoto image courtesy of VPA.



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Organic Carbon Content at DoD Rod Locations May 2007

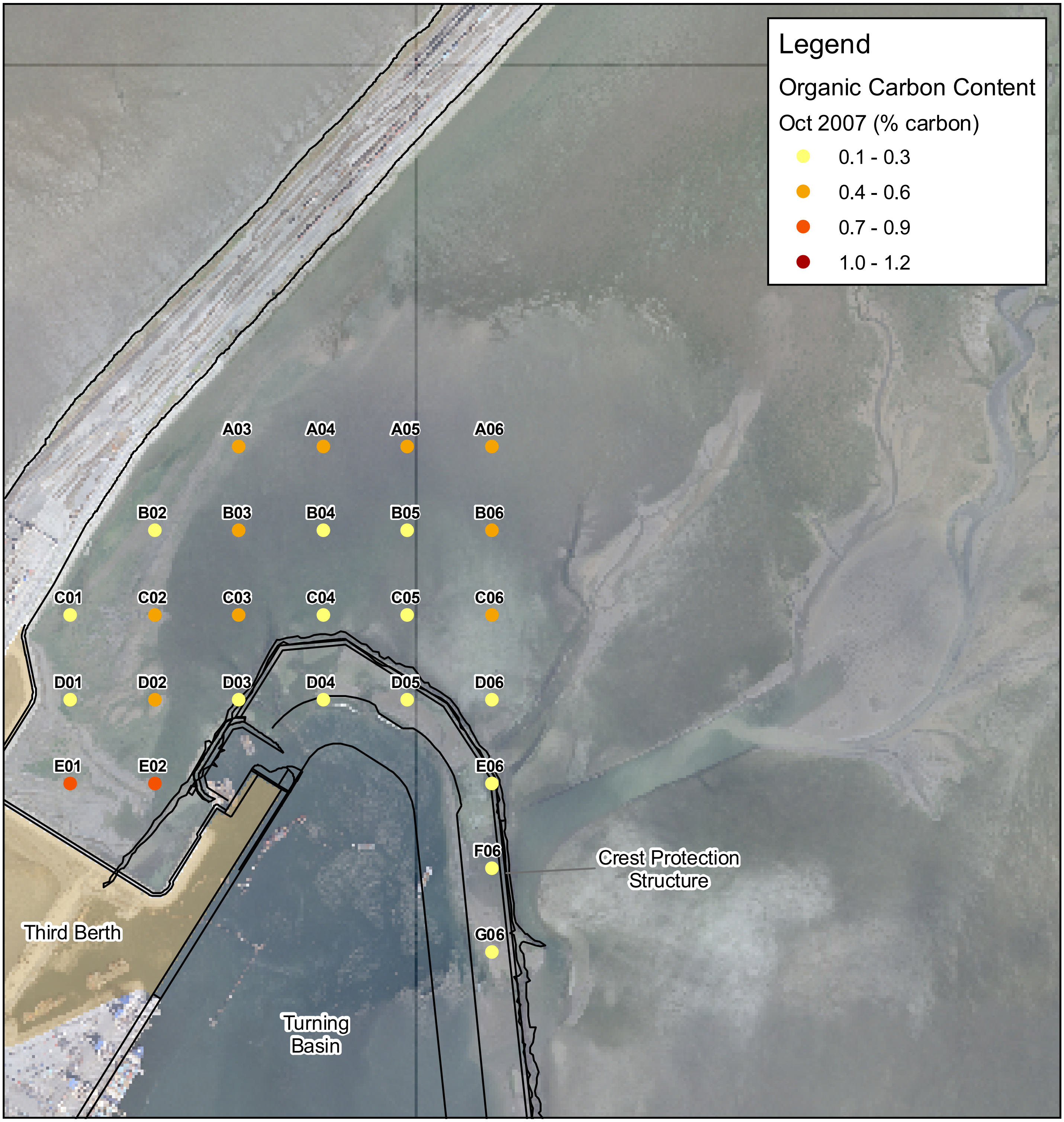
Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

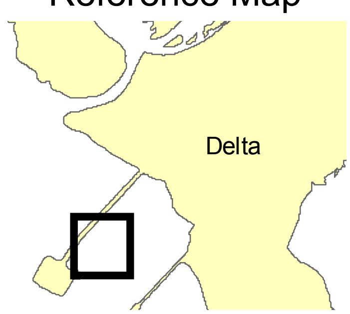
MSN, 34648 Deltaport Monitoring\GIS\Fig_OrganicCarbonContent.mxd

Figure 29



Note:
- July 16, 2007 orthophoto image courtesy of VPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Organic Carbon Content
at DoD Rod Locations October 2007

Scale - 1:10,000

100 50 0 100 200 300 Metres

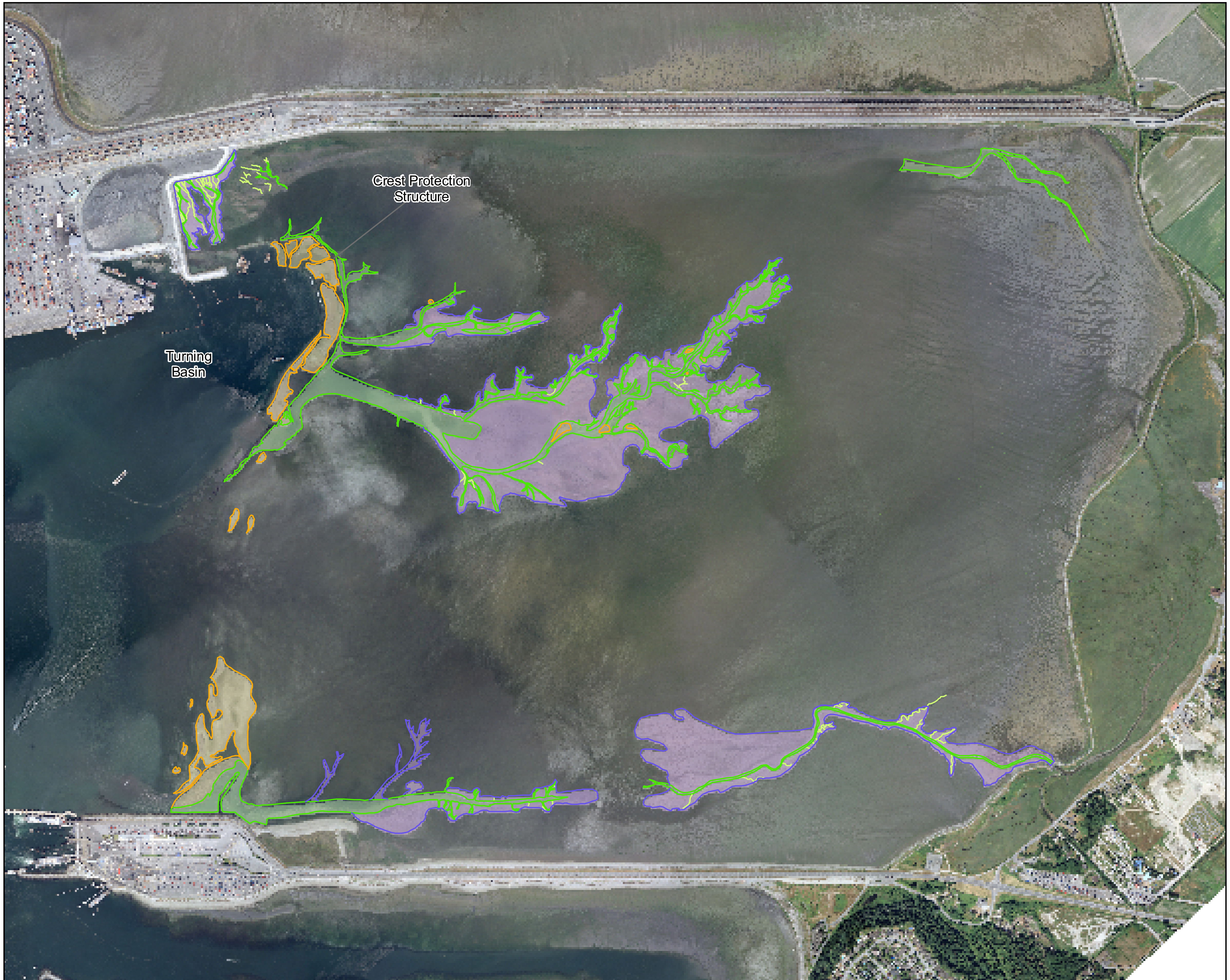
coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

MSN, 34648 Deltaport Monitoring\GIS\Fig_OrganicCarbonContent.mxd

Figure 30

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

2007 Orthophoto Interpretation

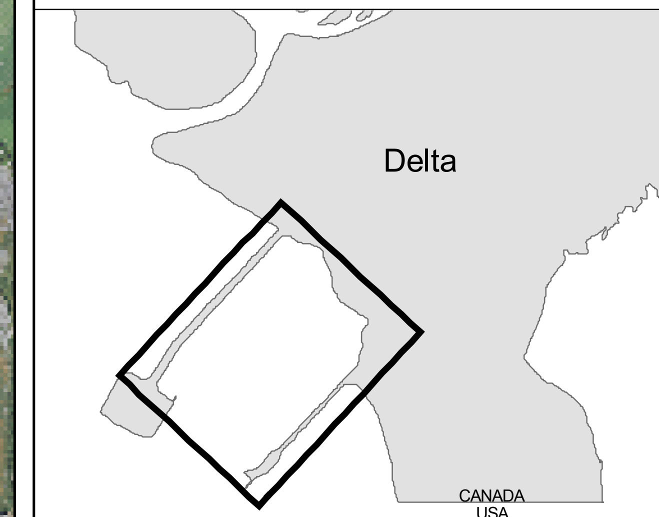


Scale - 1:15,000

400 200 0 400 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

Reference Map



Legend

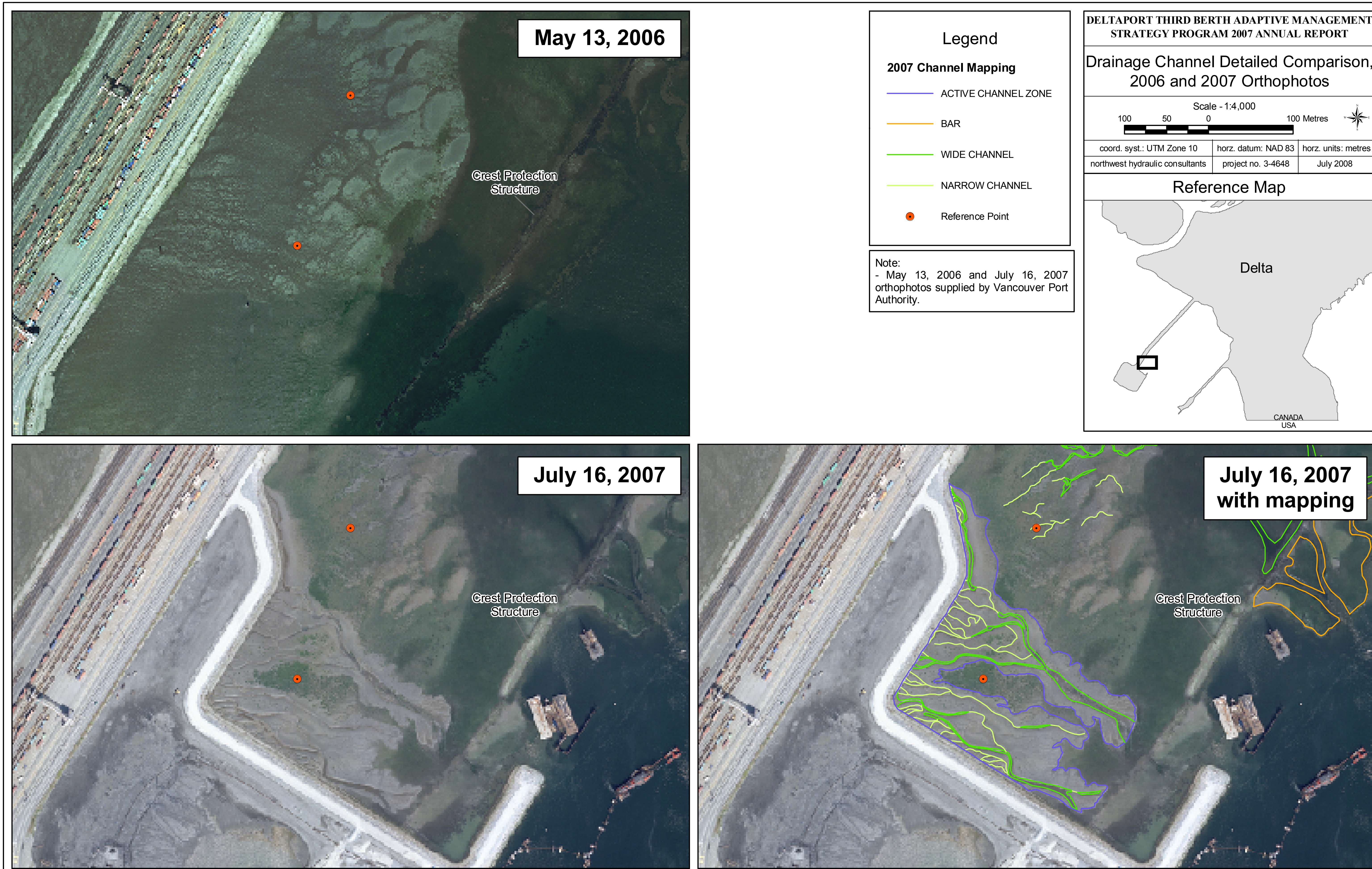
2007 Channel Mapping

- ACTIVE CHANNEL ZONE
- BAR
- WIDE CHANNEL
- NARROW CHANNEL
- ACTIVE CHANNEL ZONE
- BAR
- CHANNEL

Note:
- July 16, 2007 orthophoto supplied by Vancouver Port Authority.

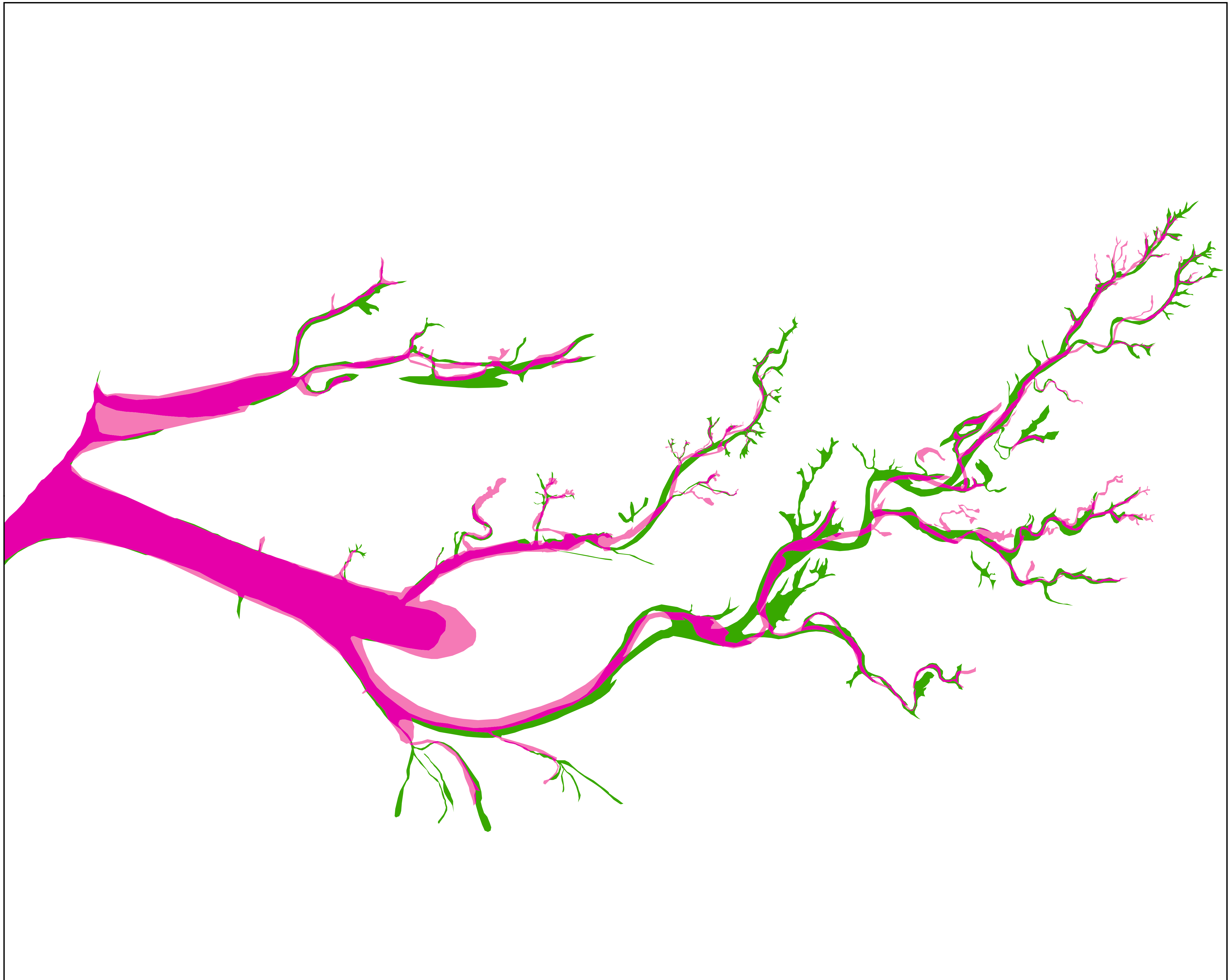
MSN_34648 Deltaport Monitoring\GIS\Fig_Mapping2007.mxd

Figure 31



May 13, 2006
Crest Protection Structure
July 16, 2007
Crest Protection Structure
July 16, 2007 with mapping
Crest Protection Structure
Legend
2007 Channel Mapping
ACTIVE CHANNEL ZONE
BAR
WIDE CHANNEL
NARROW CHANNEL
Reference Point
Note:
- May 13, 2006 and July 16, 2007 orthophotos supplied by Vancouver Port Authority.
DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT
Drainage Channel Detailed Comparison, 2006 and 2007 Orthophotos
Scale - 1:4,000
100 50 0 100 Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4648
July 2008
Reference Map
Delta
CANADA
USA
MSN_34648 Deltaport Monitoring\GIS\Fig_New2007Channels.mxd

Figure 32



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

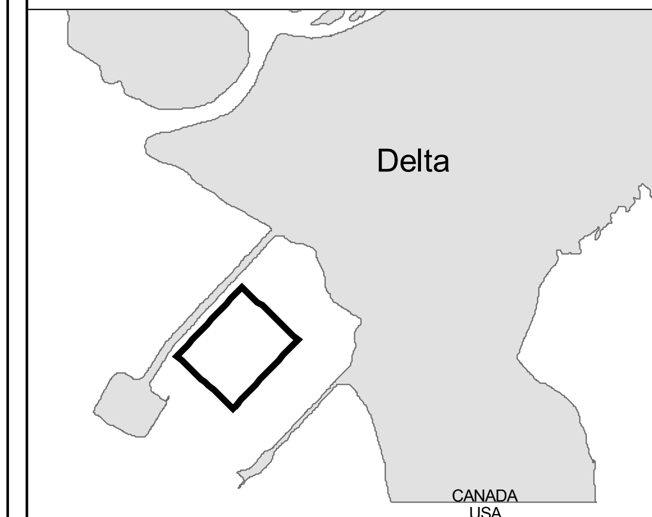
Mapped Channel Changes Based on 2006 and 2007 Orthophotos

Scale - 1:6,000

100 50 0 100 200 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

Reference Map



Legend

Channel Changes

2006 to 2007

- channel in 2006 (not in 2007)
- channel in 2006 and 2007 (no change)
- channel in 2007 (not in 2006)

Note:
- Variation in conditions such as tide level, vegetation growth and water clarity may influence the accuracy of change mapping between 2006 and 2007.

MSN_34648 Deltaport Monitoring\GIS\Fig_Mapping2007Comp2006.mxd

Figure 33

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

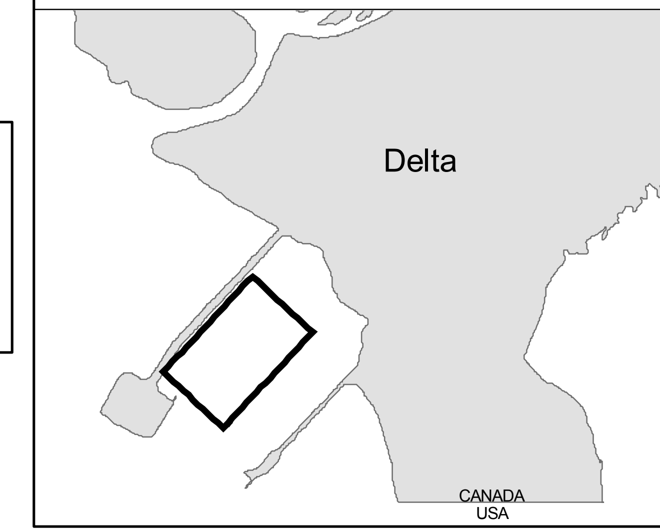
2002, 2006 and 2007 Orthophoto Comparison

Scale - 1:13,000

200 100 0 200 400 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

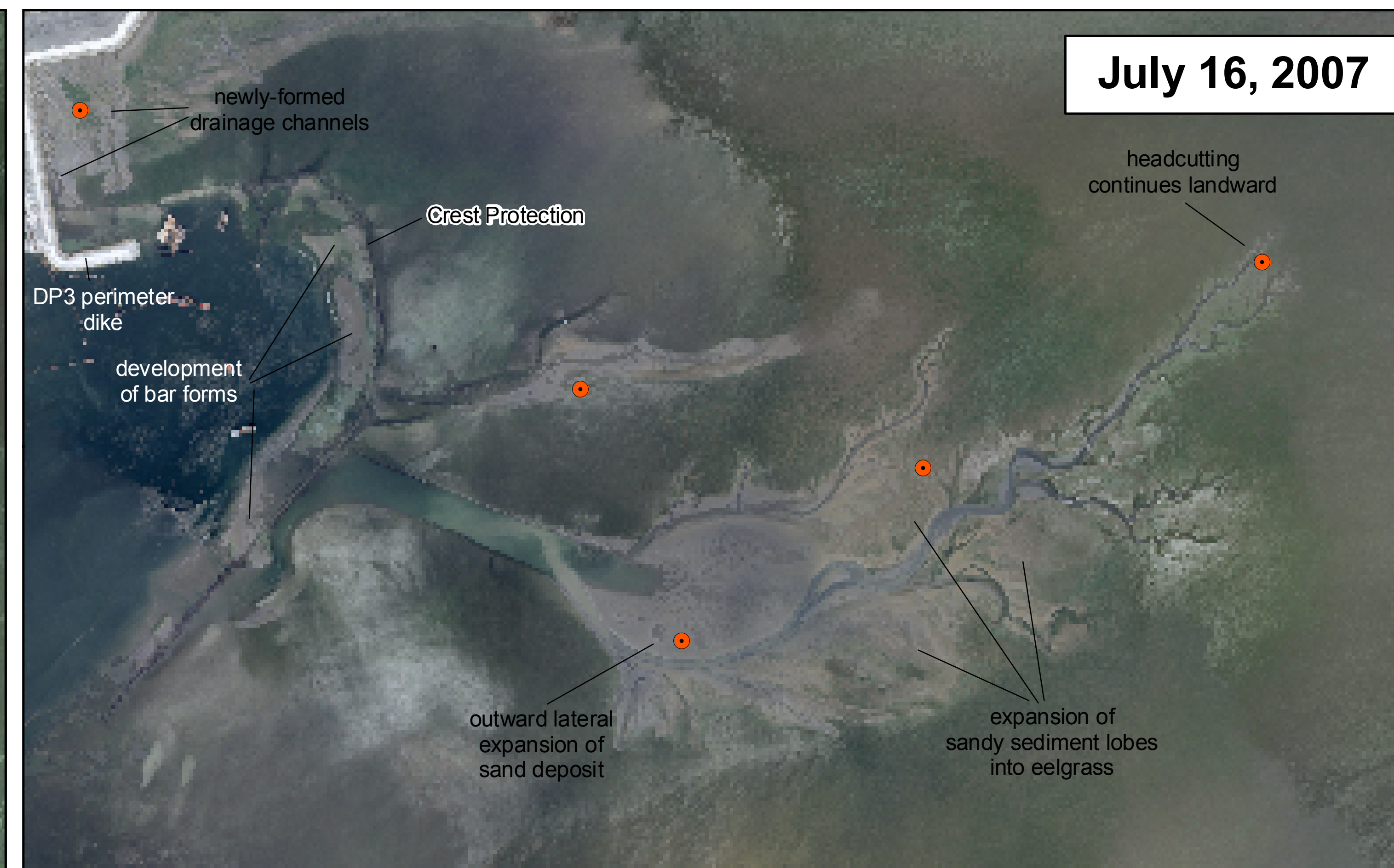
Reference Map



Legend

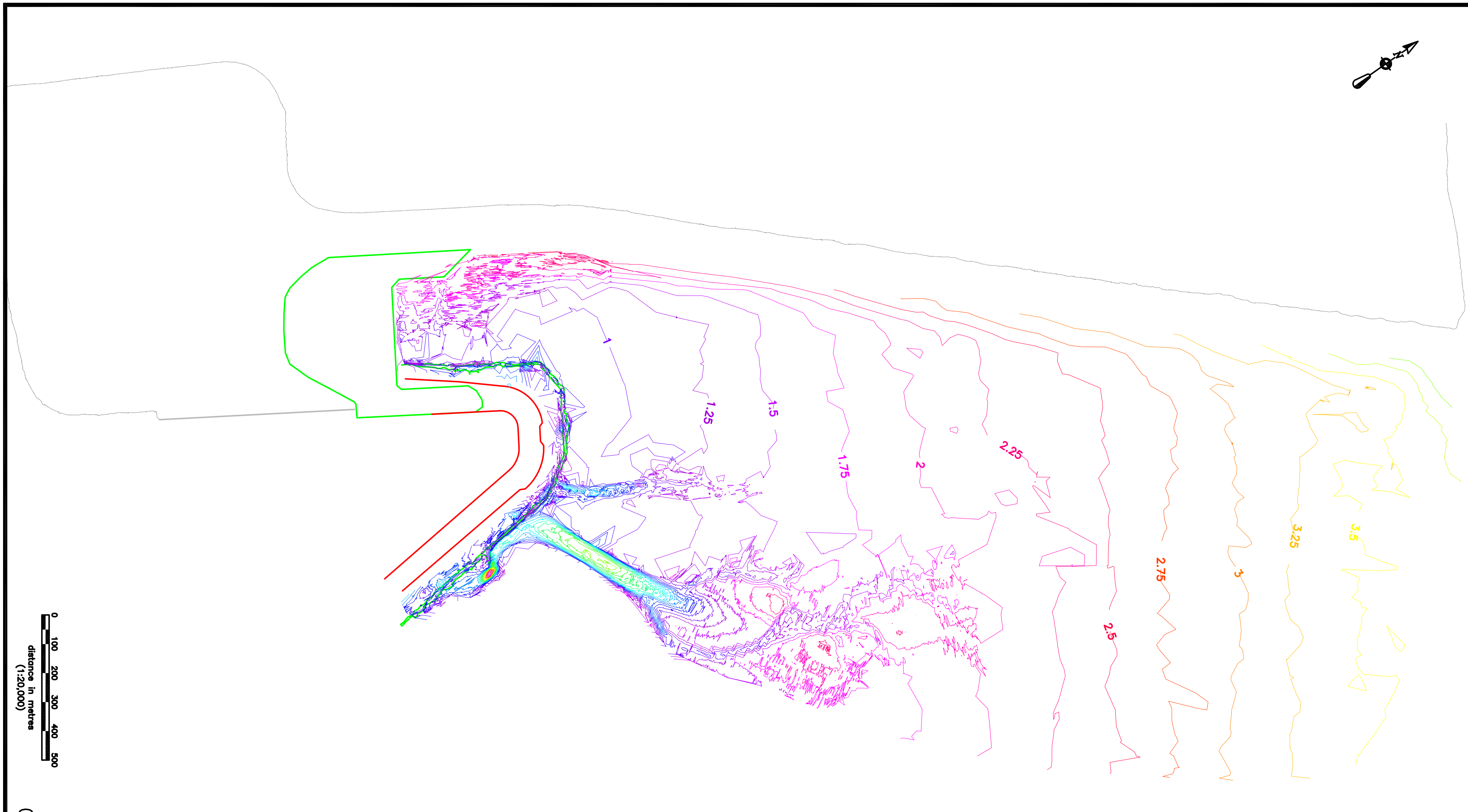
Reference Point

Note:
- May 13, 2006 and July 16, 2007 orthophotos supplied by Vancouver Port Authority.
- April 29, 2002 orthophoto supplied by the Fraser River Estuary Management Program.



MSN_34648 Deltaport Monitoring\GIS\Fig_Comparison3Yrs.mxd

Figure 34



0.25 m contour interval

FIGURE 35

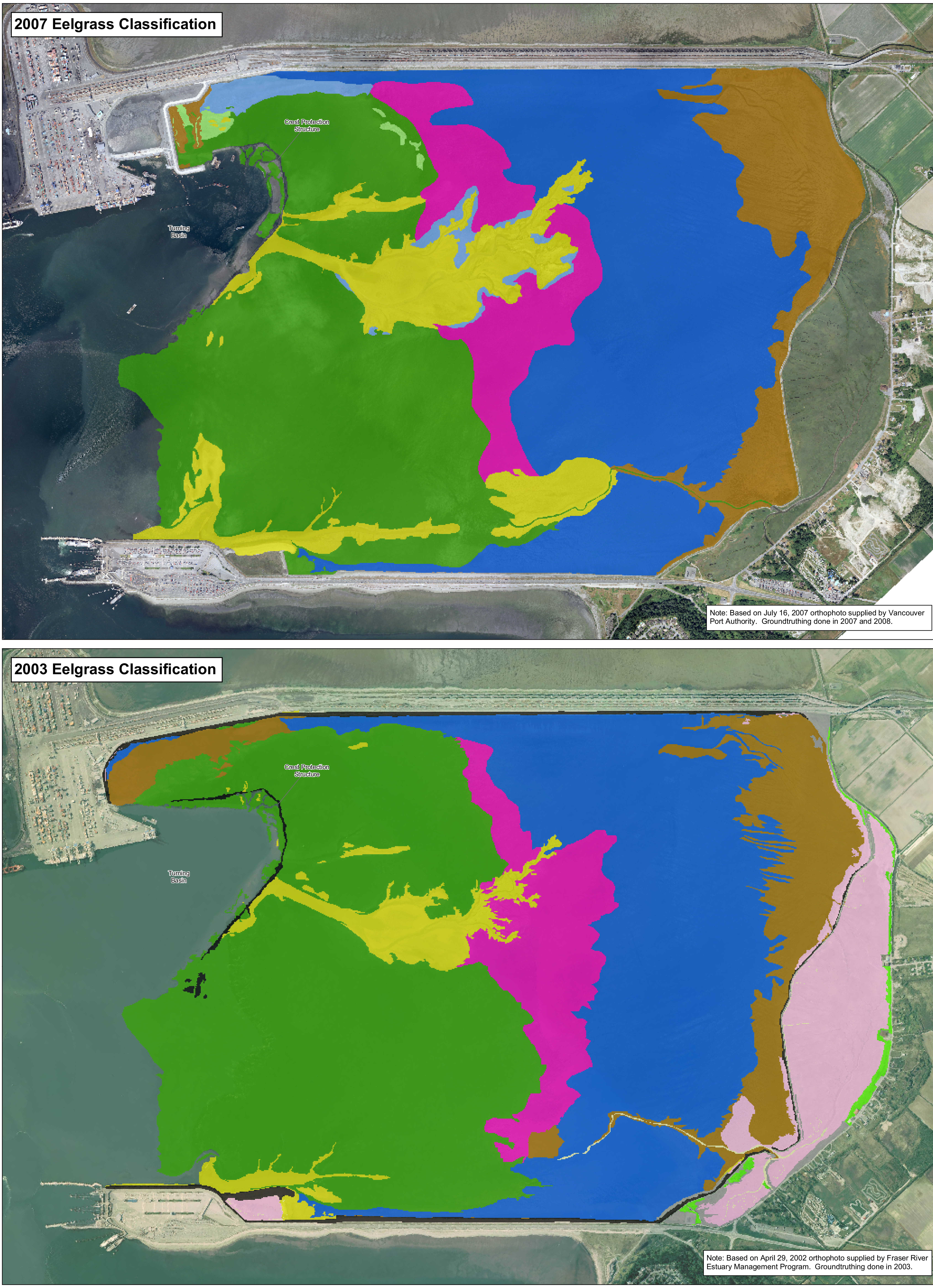
DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM

2007 ANNUAL REPORT

Coastal Geomorphology Mapping of Study Area

DWG. NO.	REV. NO.	DATE
cstmap-2007	00	08-03-24

northwest hydraulic consultants



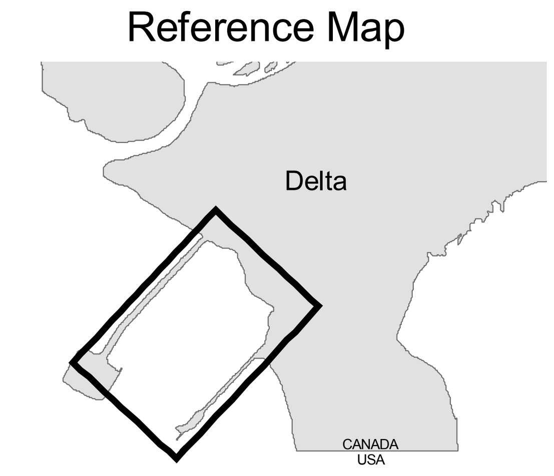
2007 Eelgrass Classification

- Z. japonica
- Z. japonica - patchy
- Z. marina
- Z. marina - patchy
- Zostera - mixed
- Mud
- Sand

2003 Eelgrass Classification

- Z. japonica
- Z. marina
- Zostera - mixed
- Channel
- Grass
- Marsh
- Mud
- Sand
- Shrubs
- Rocky Habitat

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

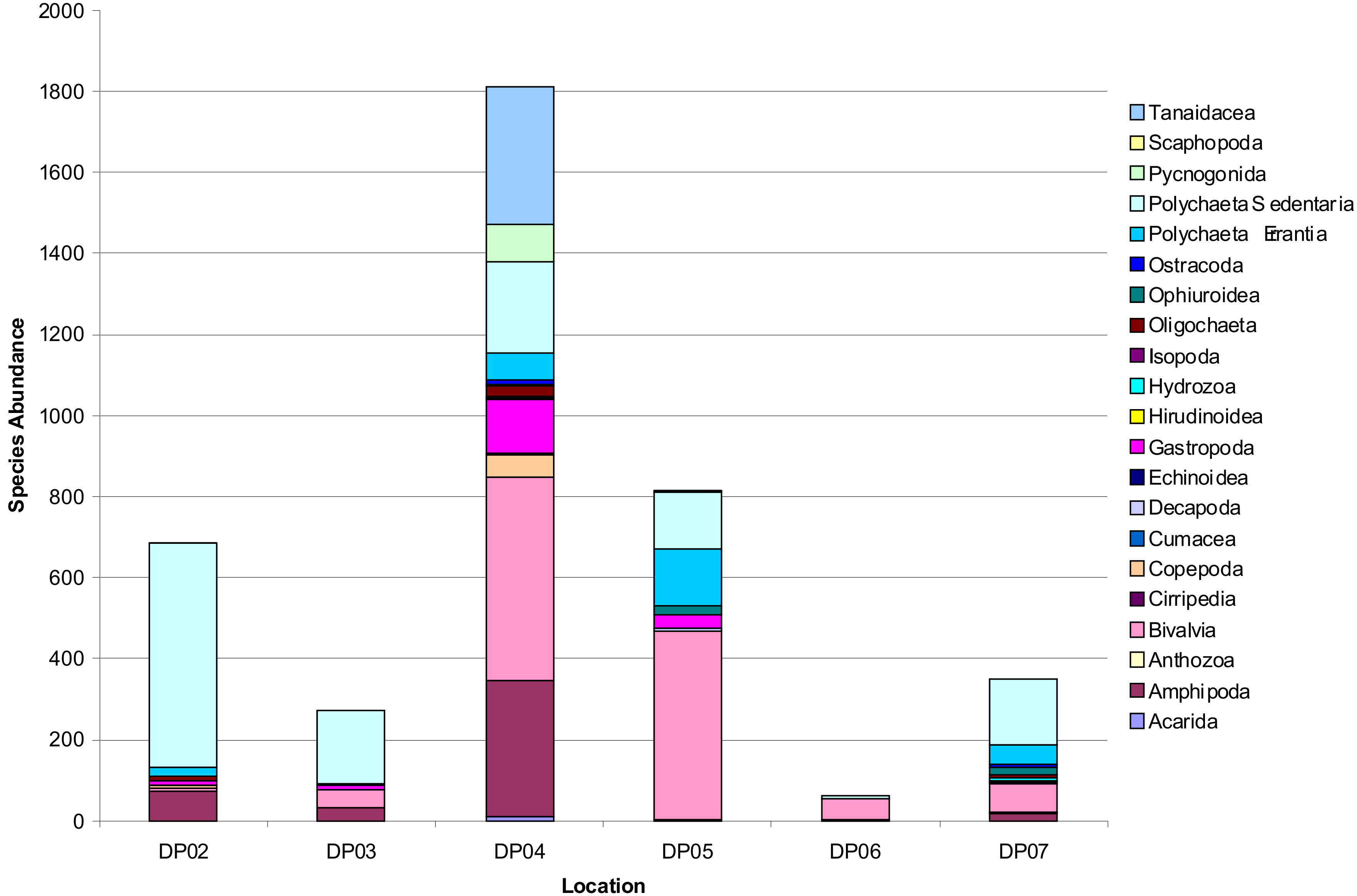
Eelgrass Classification
2003 and 2007

Scale - 1:10,000

400 200 0 400 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4935	July 2008

Figure 36



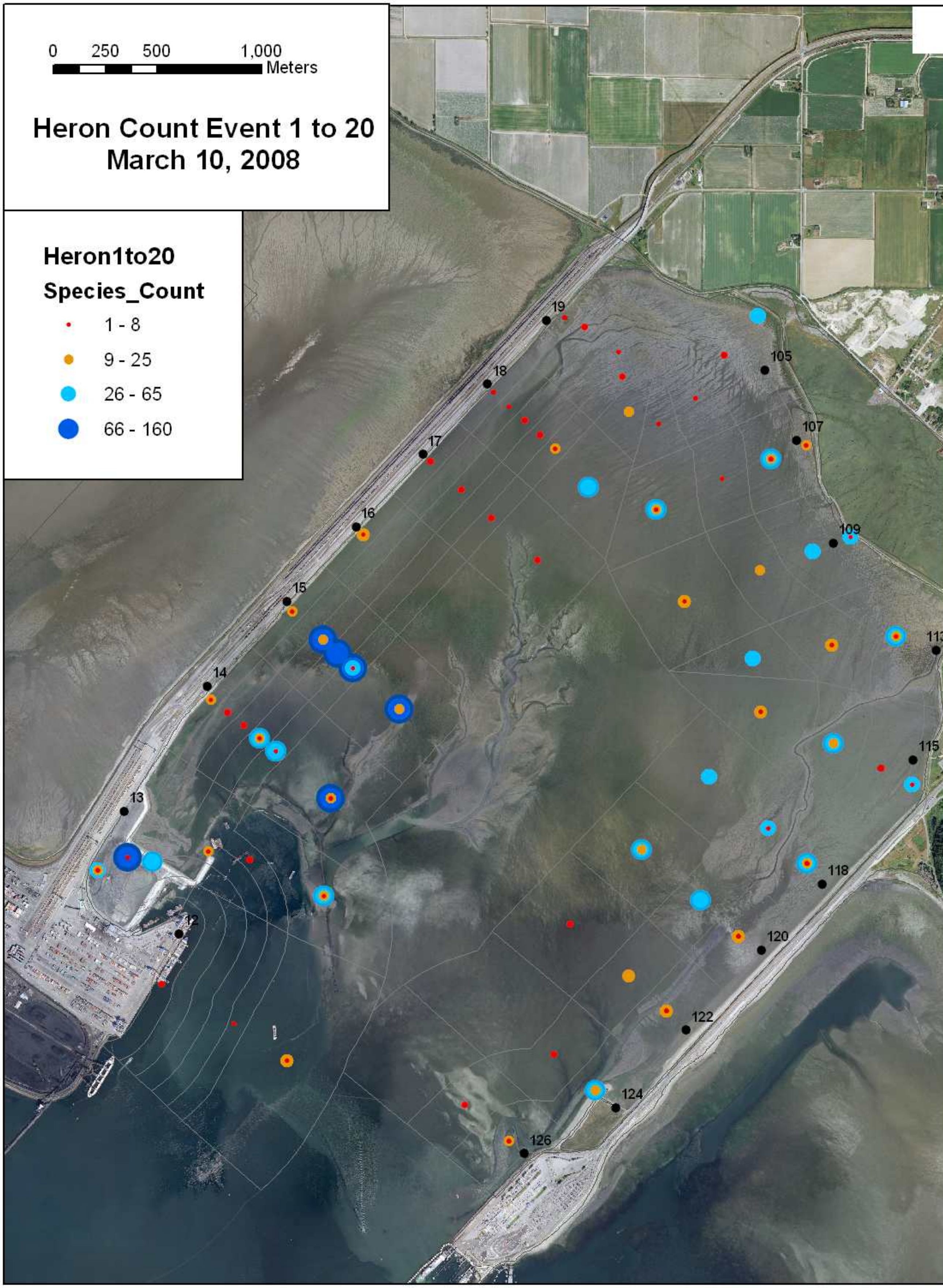
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2007 ANNUAL REPORT

BENTHIC INVERTEBRATE ABUNDANCE BY CLASS

PROJECT No. 499-002.11	July 2008	FIGURE 37



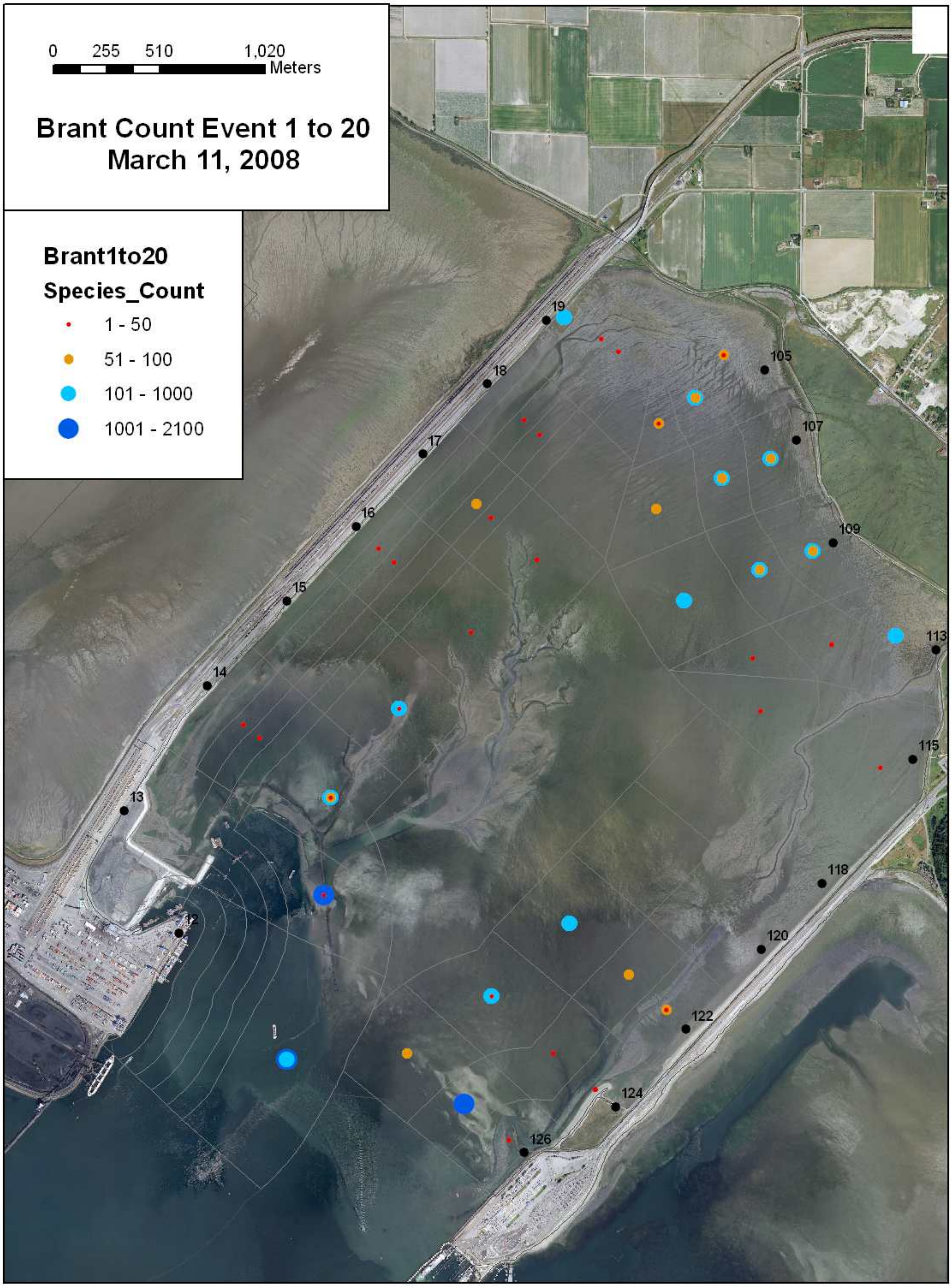
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2007 ANNUAL REPORT

HERON DISTRIBUTION WITHIN THE INTER-CAUSEWAY AREA DURING HIDE TIDE EVENTS

PROJECT No.		
499-002.11	July 2008	FIGURE 38



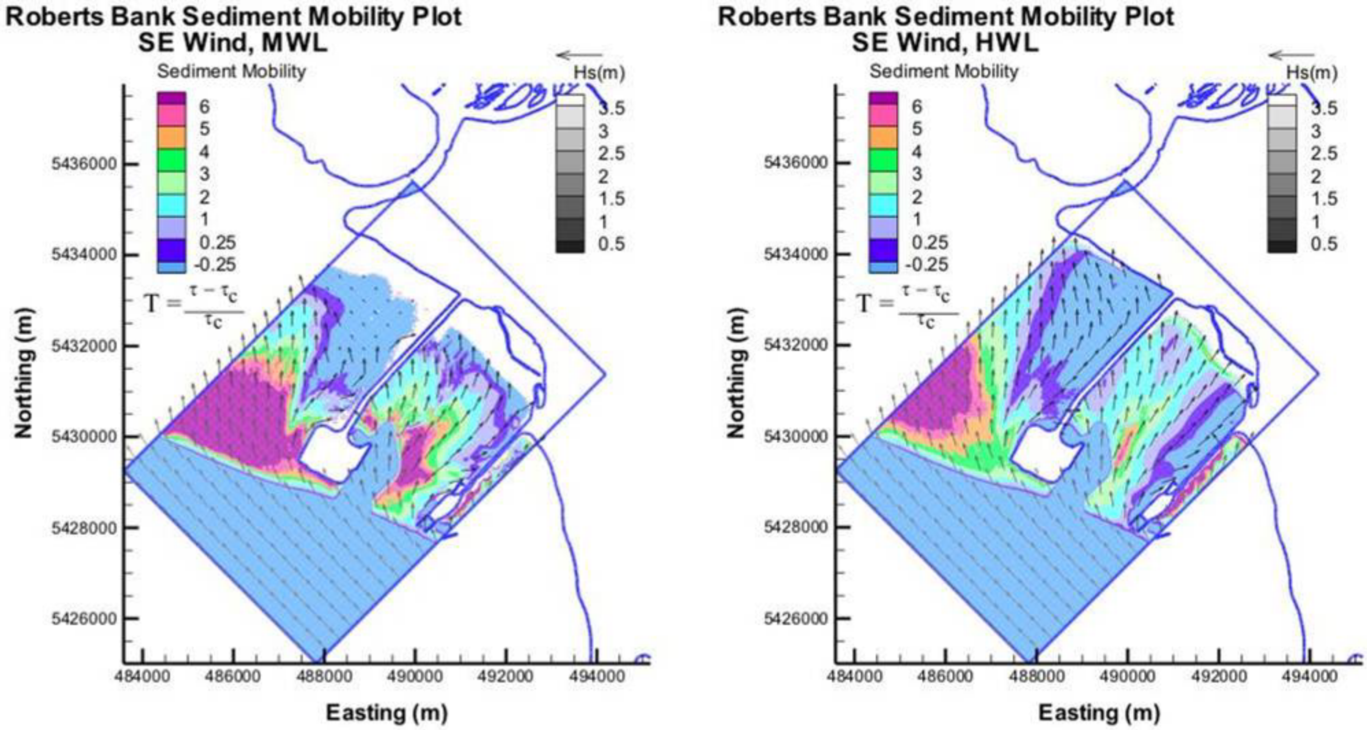
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2007 ANNUAL REPORT

BRANT DISTRIBUTION WITHIN THE INTER-CAUSEWAY AREA DURING HIDE TIDE EVENTS

PROJECT No. 499-002.11	July 2008	FIGURE 39



reproduced from NHC (2004) Figure 6-1

Figure 40 Sediment Mobility At Varying Tide Levels During South East Storms

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

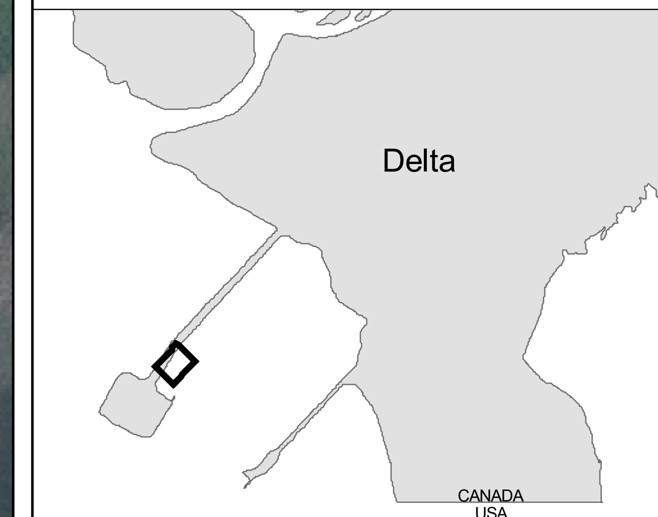
Detailed Contour Map of Newly-Formed Drainage Channels

Scale - 1:2,000

50 25 0 50 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

Reference Map



Legend

2007 Bathymetry

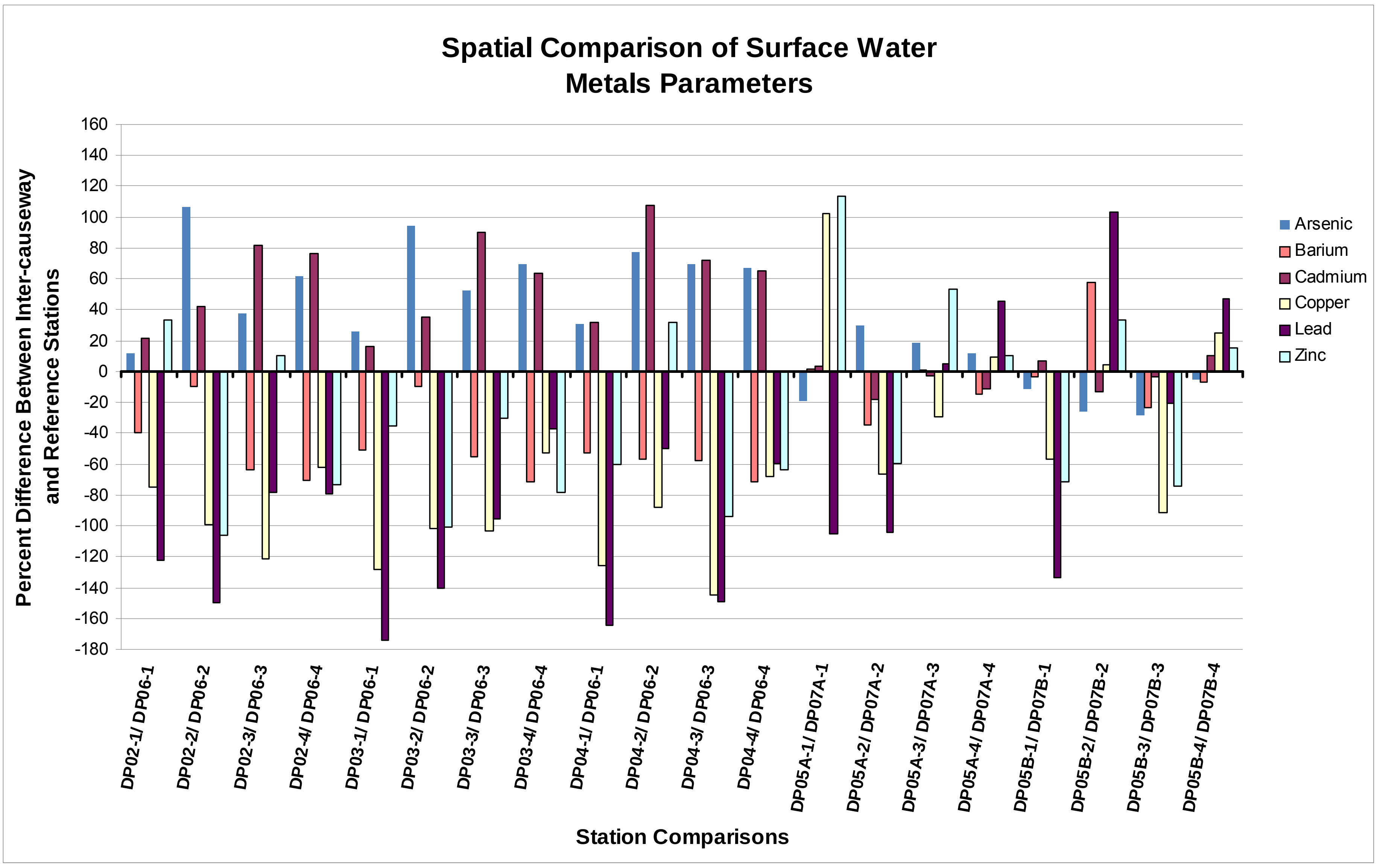
Elevation (m)

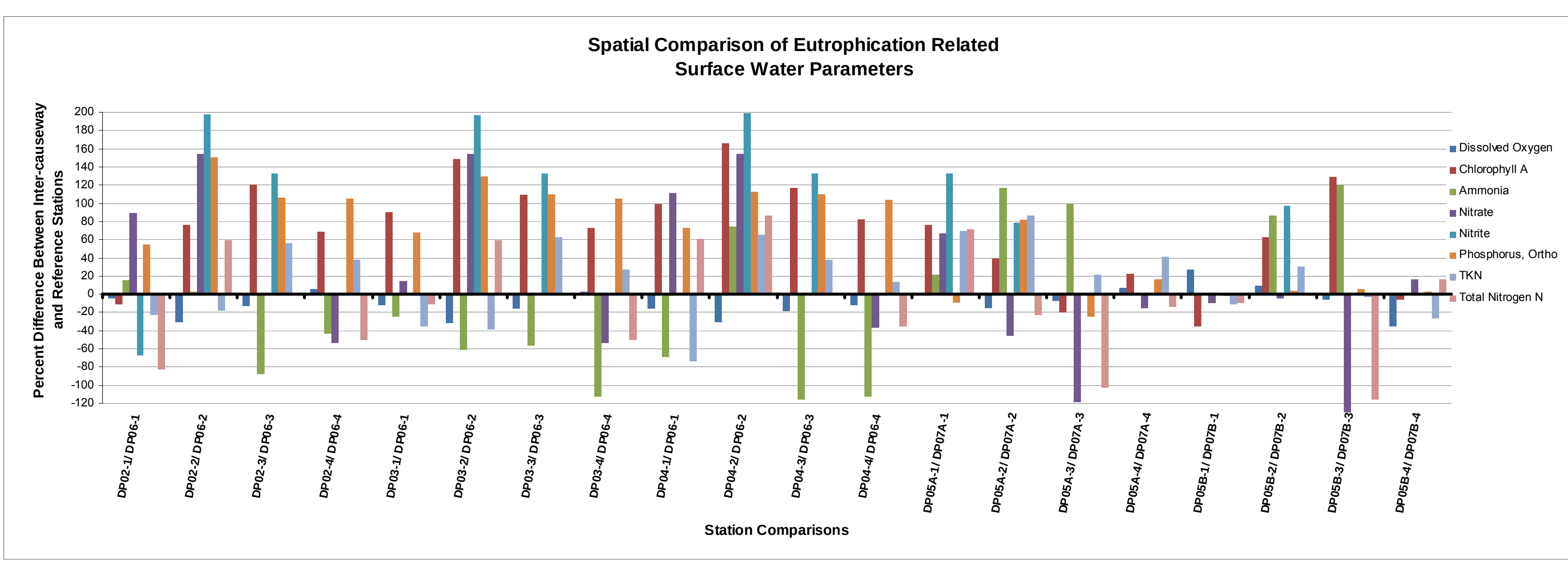
- 1.25
- 1.50
- 1.75
- 2.00
- DOD Rod Locations

Notes:
- Bathymetric survey data collected on July 8, 2007.
- July 16, 2007 orthophoto supplied by Vancouver Port Authority.

MSN_34648 Deltaport Monitoring\GIS\Fig_2007BathyContours.mxd

Figure 41





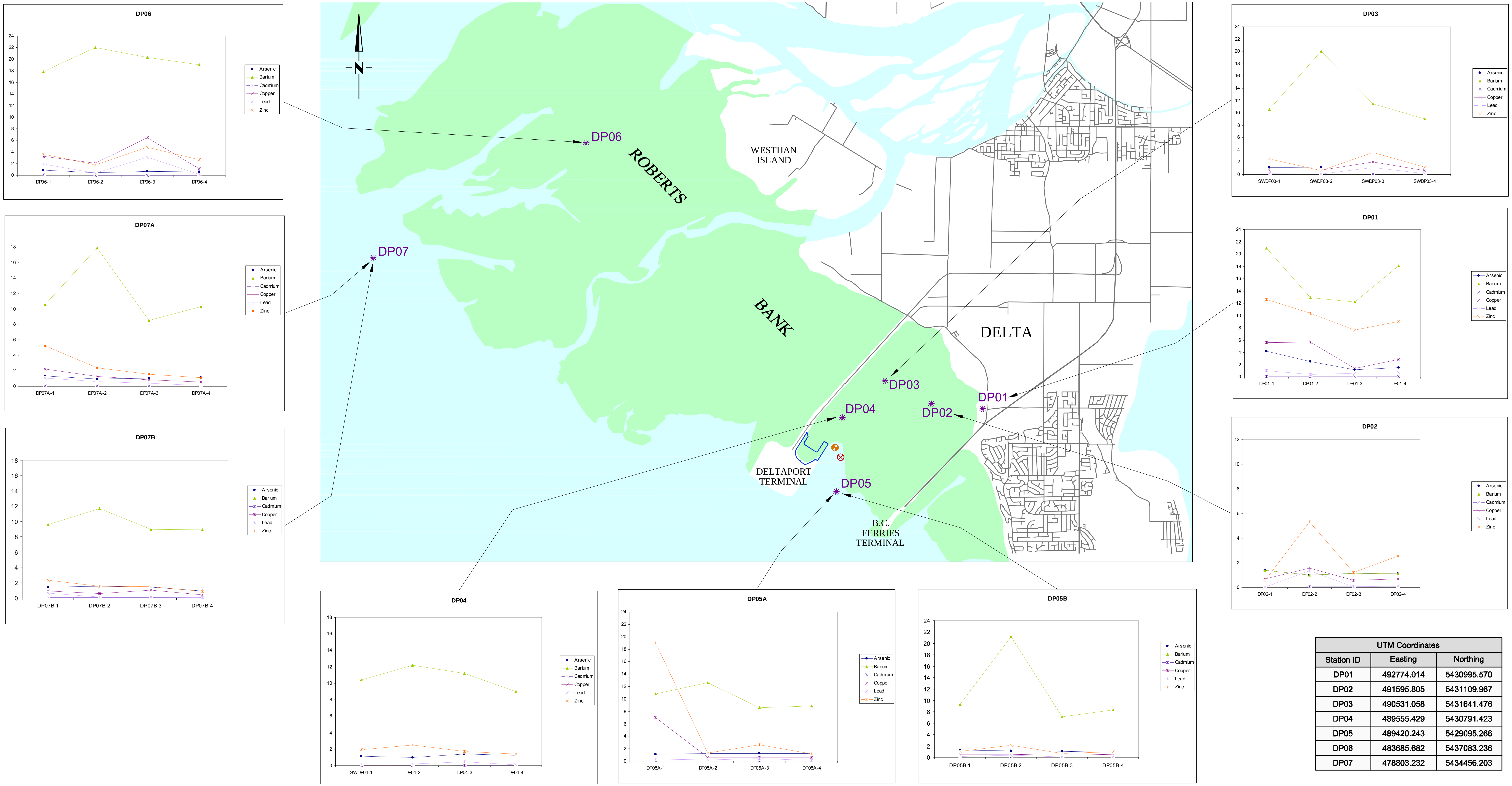
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH – ADAPTIVE MANAGEMENT STRATEGY PROGRAM – 2007 ANNUAL REPORT

SPATIAL COMPARISONS OF SURFACE WATER METAL PARAMETERS AND EUTROPHICATION-RELATED SURFACE WATER PARAMETERS

PROJECT No. 499-002.11	July 2008	FIGURE 42



UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203

LEGEND
Water
Tidal Mud & Sand
Water Quality Sampling Station
YSI Sonde

SCALE 1:75000
0 1500 3000m

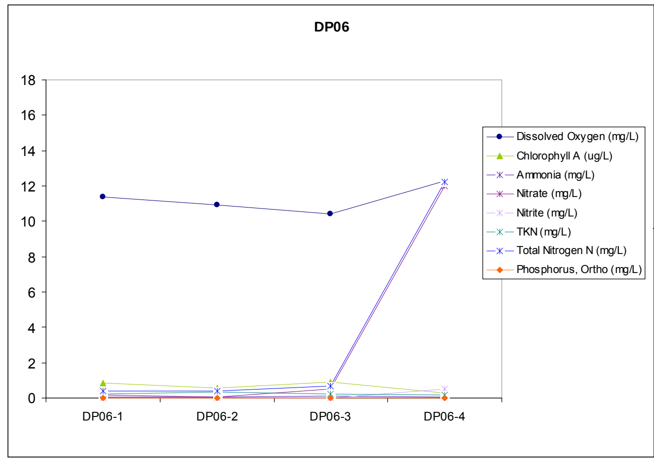
HEMMERA

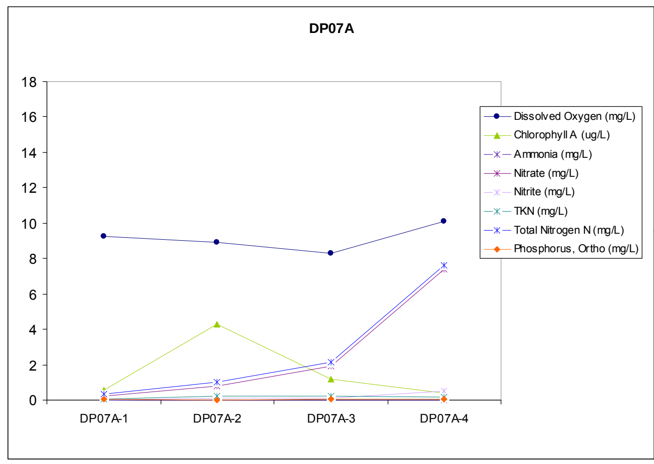
CLIENT: PORT METRO vancouver

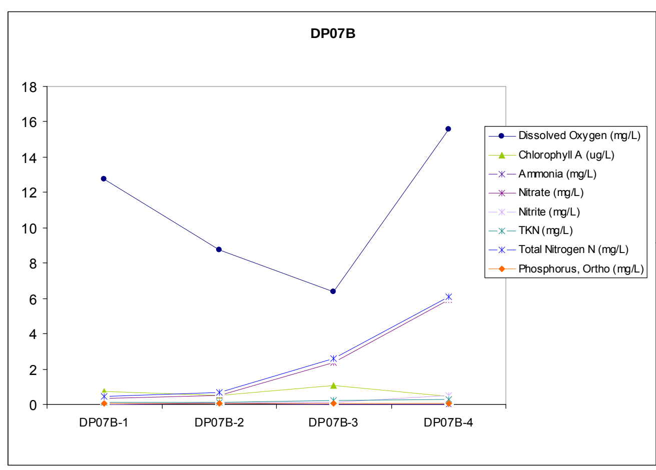
DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

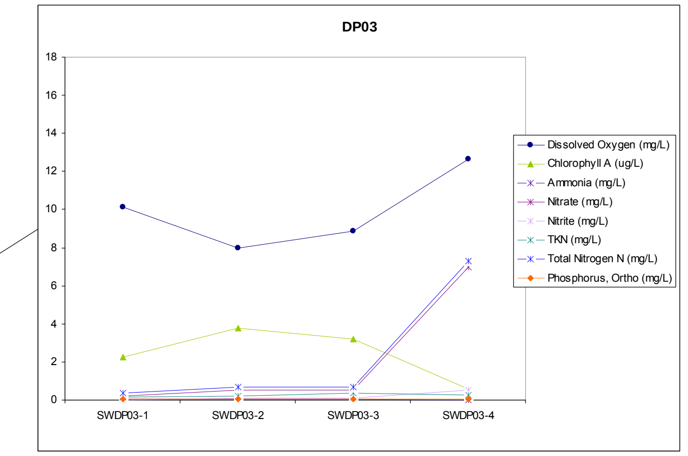
TEMPORAL TRENDS IN SURFACE WATER METALS PARAMETERS

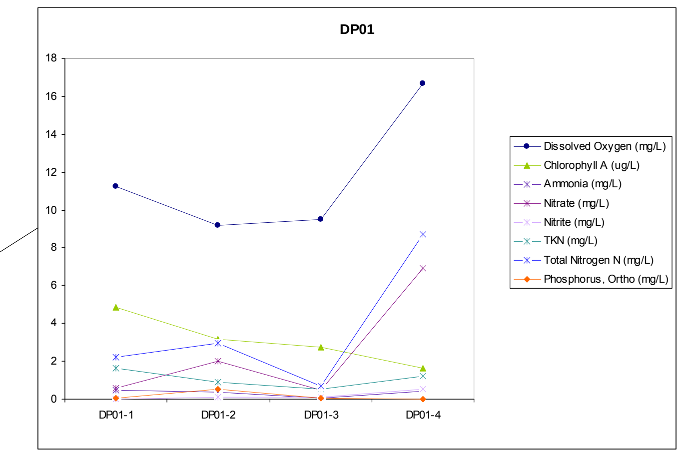
PROJECT No. 499-002.11 | July 2008 | FIGURE 43

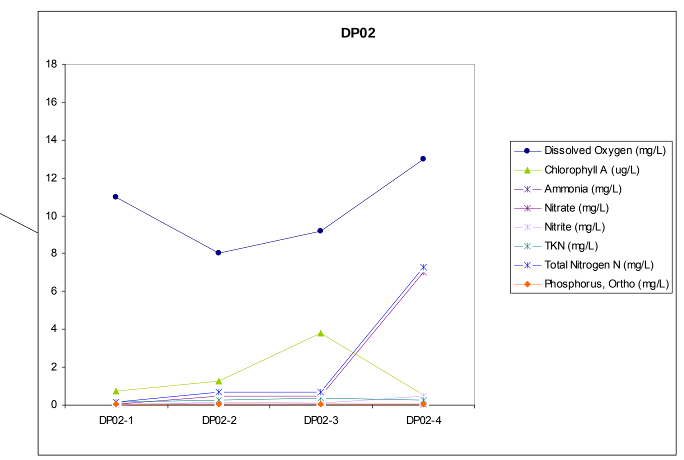


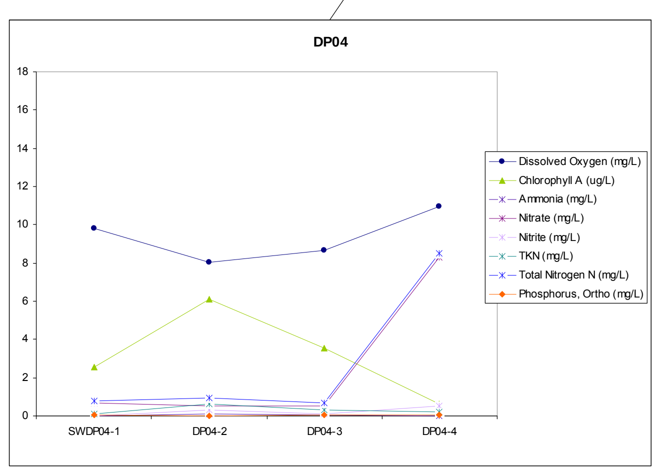


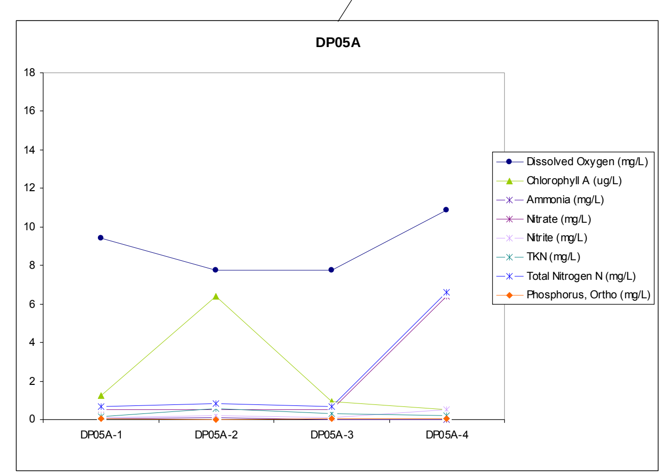


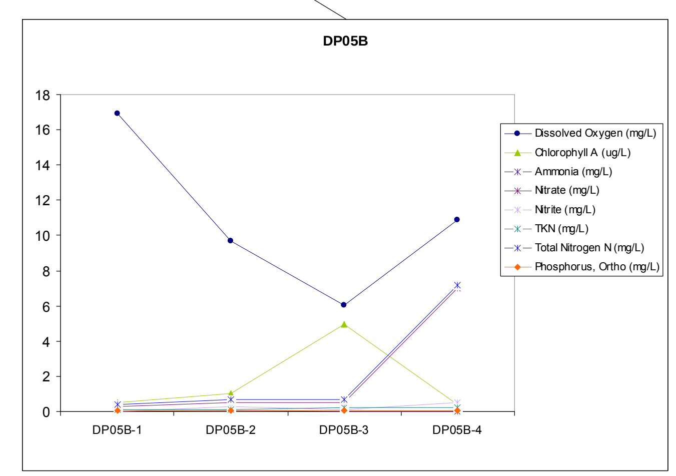












UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203

LEGEND
- Water
- Tidal Mud & Sand
- Water Quality Sampling Station
- YSI Sonde

SCALE 1:75000
0 1500 3000m

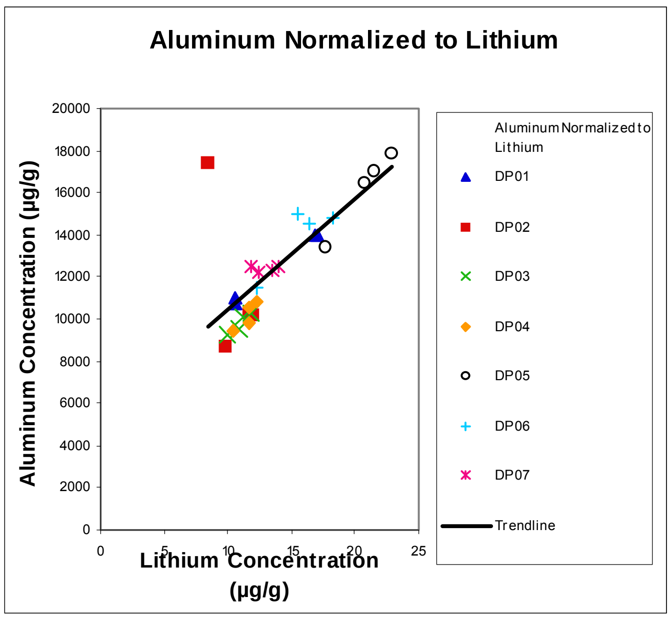
HEMMERA

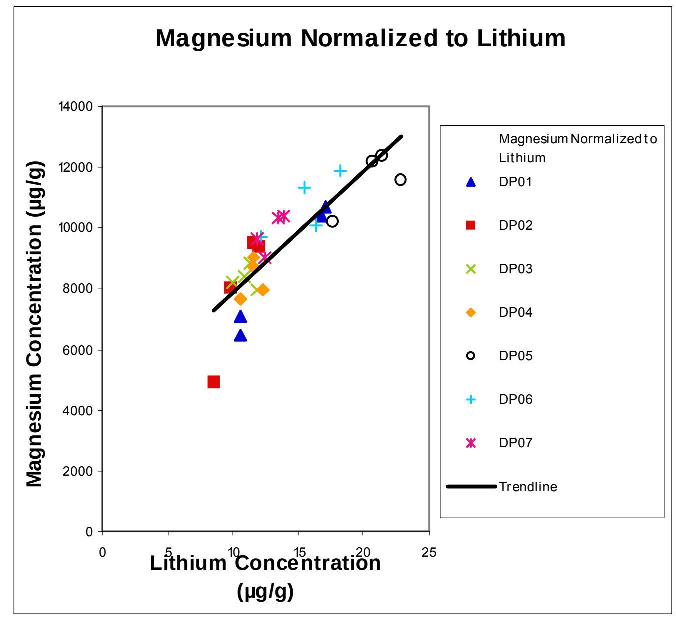
CLIENT: PORT METRO vancouver

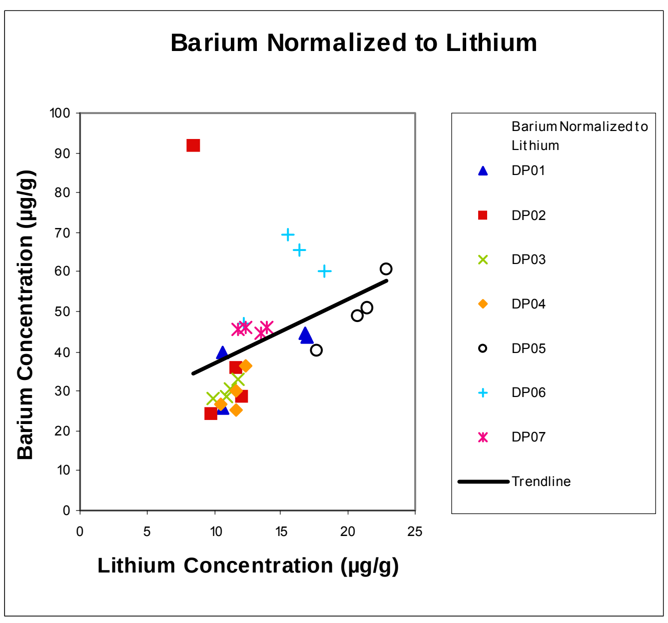
DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

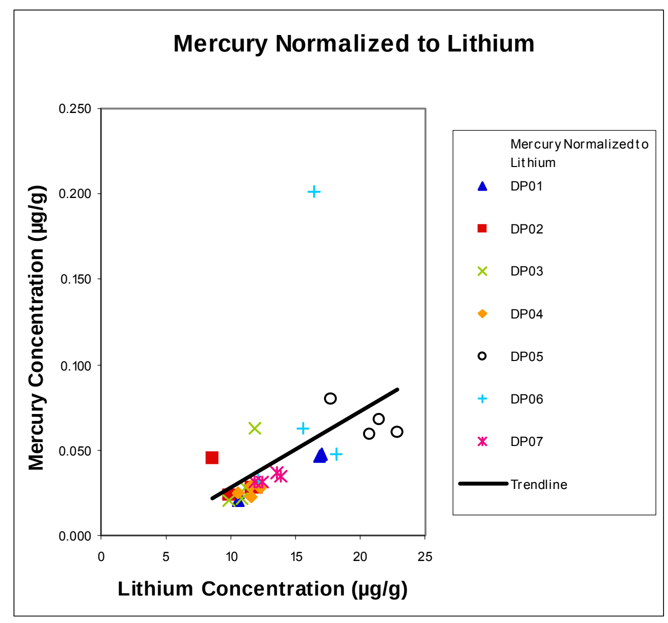
TEMPORAL TRENDS IN EUTROPHICATION-RELATED SURFACE WATER PARAMETERS

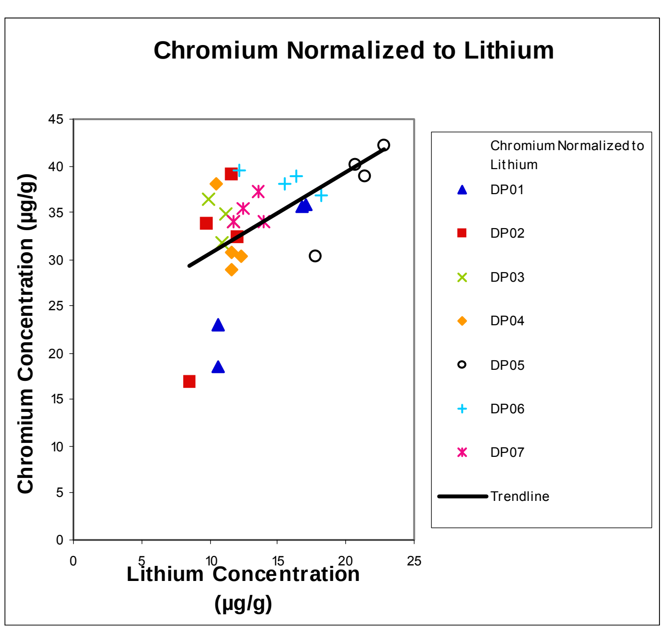
PROJECT No.		
499-002.11	July 2008	FIGURE 44

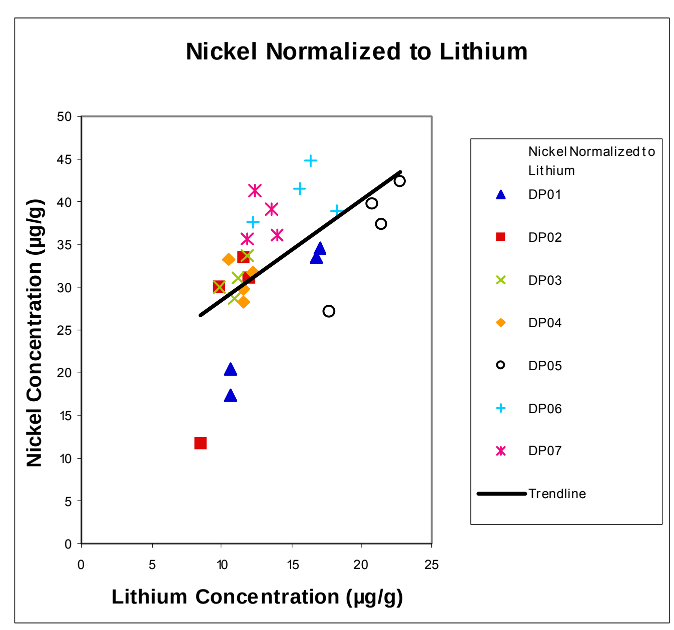


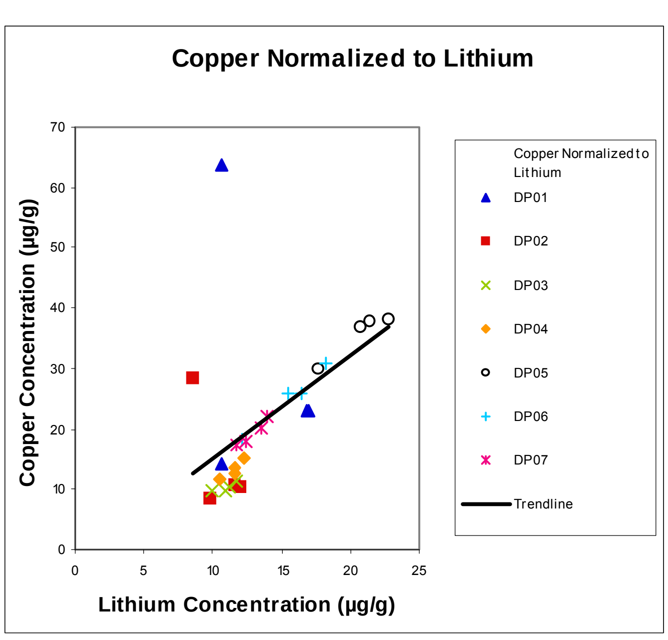


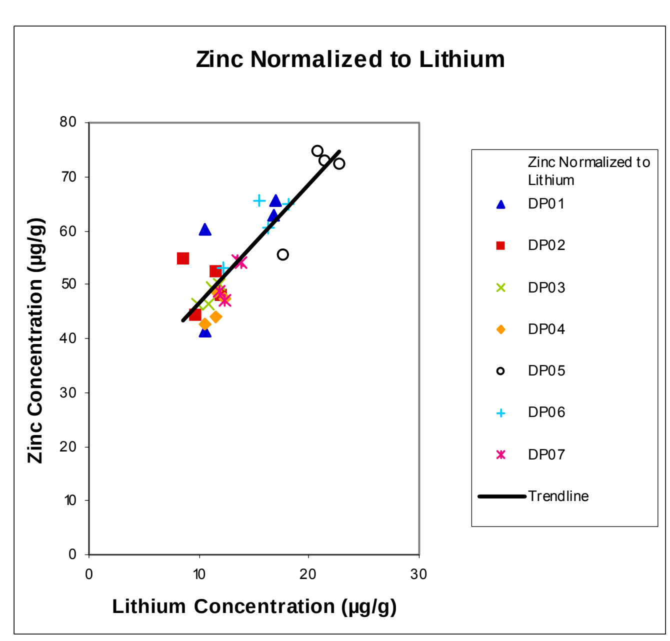












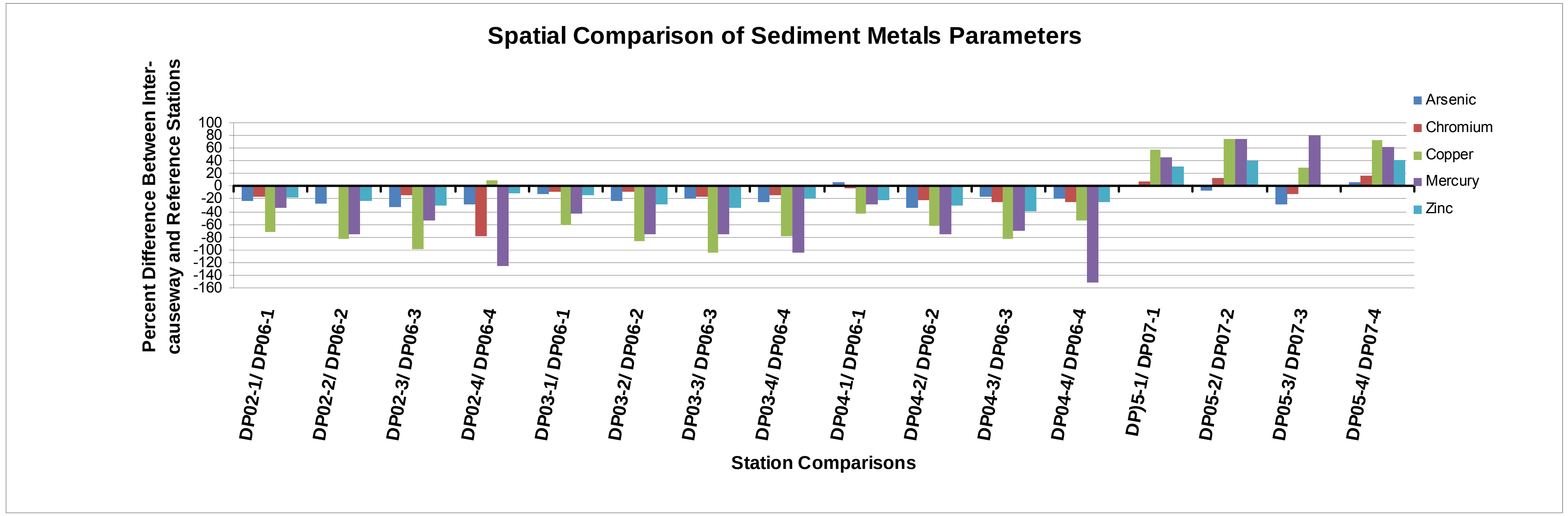
HEMMERA

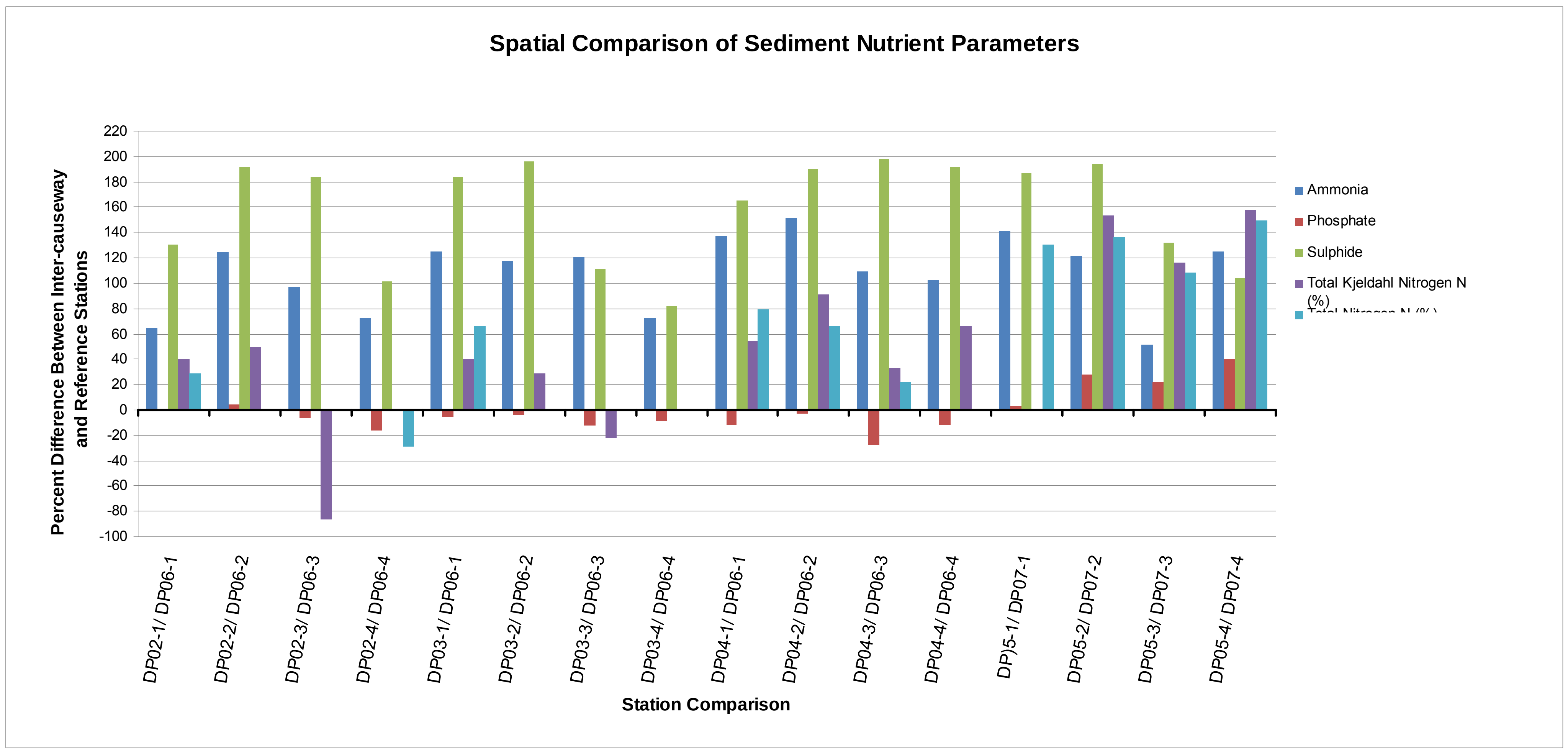
CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH – ADAPTIVE MANAGEMENT STRATEGY PROGRAM – 2007 ANNUAL REPORT

TRENDS OF METAL IN SEDIMENT NORMALIZED TO LITHIUM

PROJECT No. 499-002.11 | July 2008 | FIGURE 45





HEMMERA

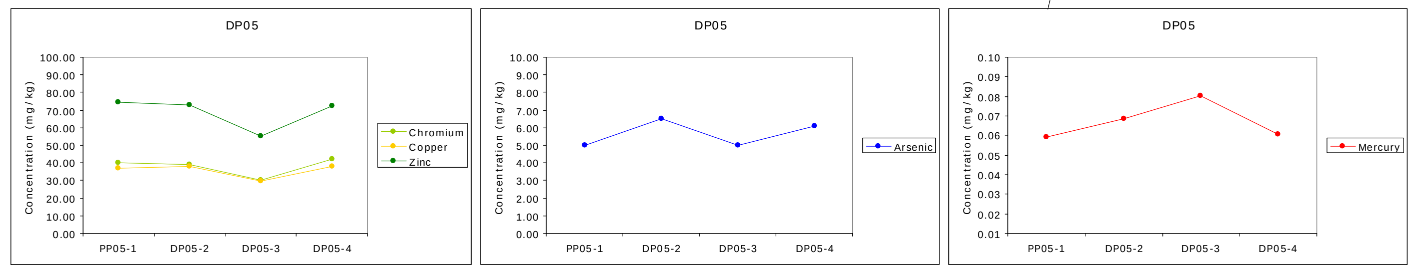
CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH – ADAPTIVE MANAGEMENT STRATEGY PROGRAM – 2007 ANNUAL REPORT

SPATIAL COMPARISON OF SEDIMENT METAL PARAMETERS AND SEDIMENT NUTRIENT PARAMETERS

PROJECT No. 499-002.11	July 2008	FIGURE 46

UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203



LEGEND
Water
Tidal Mud & Sand
Water Quality Sampling Station
YSI Sonde

SCALE 1:75000
0 1500 3000m

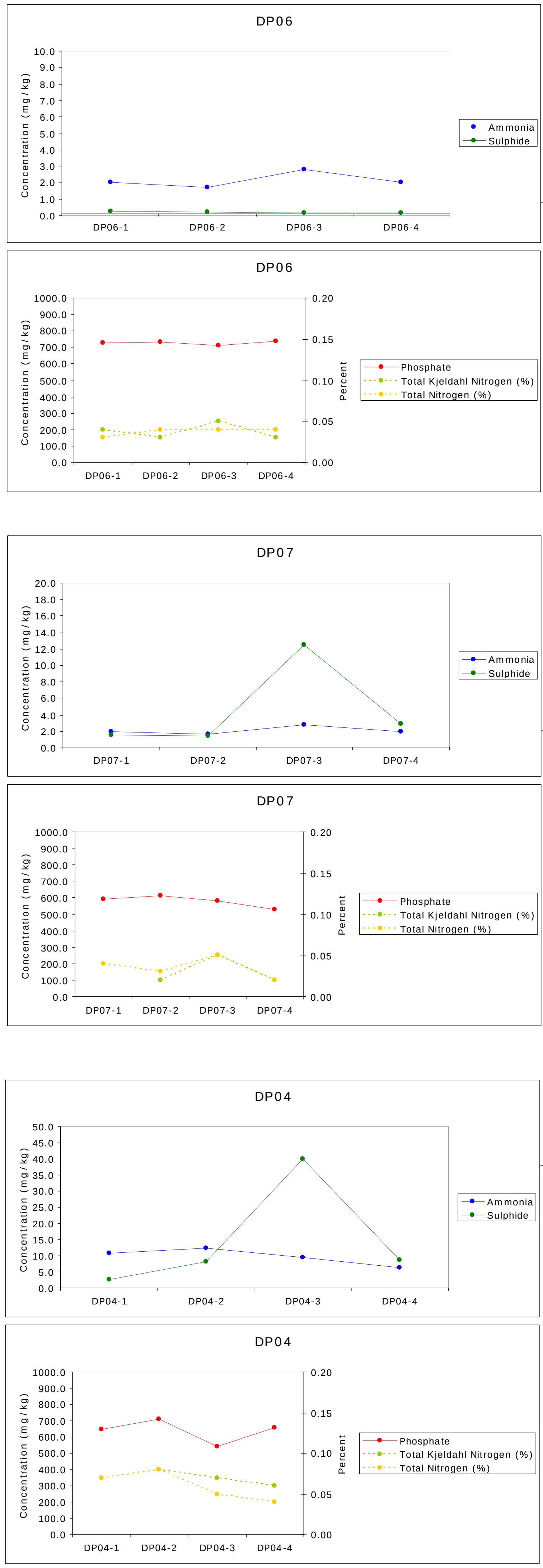
HEMMERA

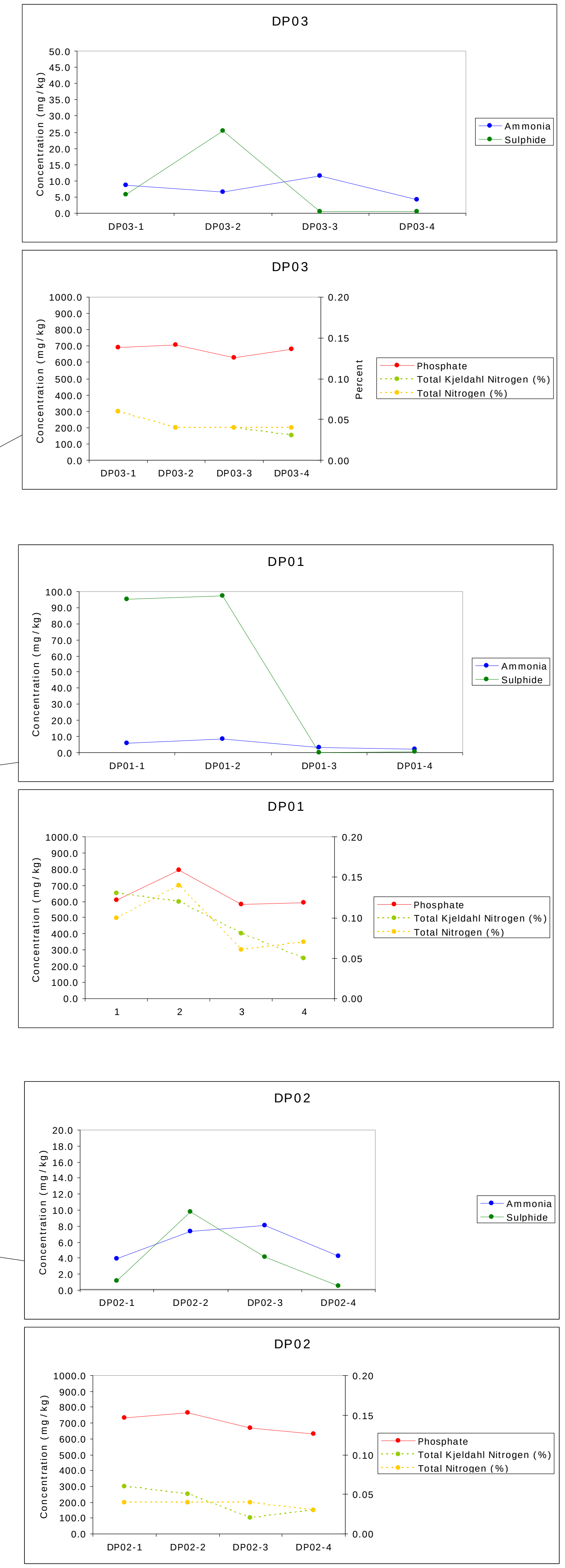
CLIENT: PORT METRO vancouver

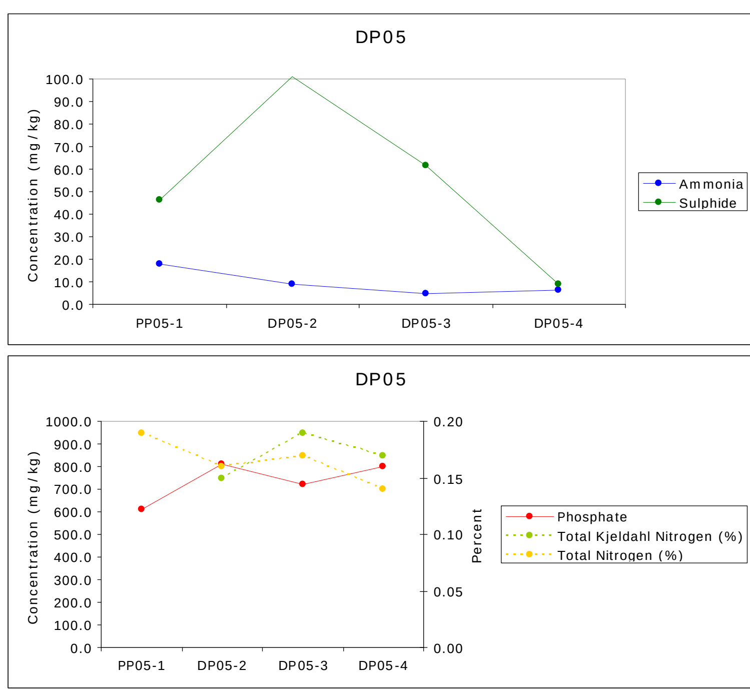
DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

TEMPORAL TRENDS OF METALS IN SEDIMENT

PROJECT No.		
499-002.11	July 2008	FIGURE 47







LEGEND
Water
Tidal Mud & Sand
Water Quality Sampling Station
YSI Sonde

UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203

SCALE 1:75000
0 1500 3000m

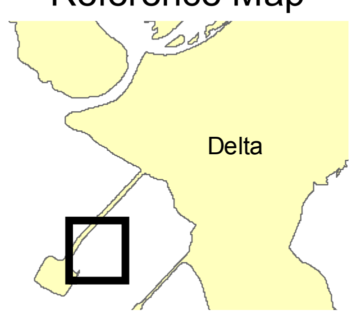
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

TEMPORAL TRENDS OF NUTRIENTS IN SEDIMENT

PROJECT No. 499-002.11 | July 2008 | FIGURE 48



Legend

- Proposed DoD Rod
- Existing DoD Rod

Note:
- July 16, 2007 orthophoto image courtesy of VPA.

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

Proposed Depth of Disturbance Rods Location Map

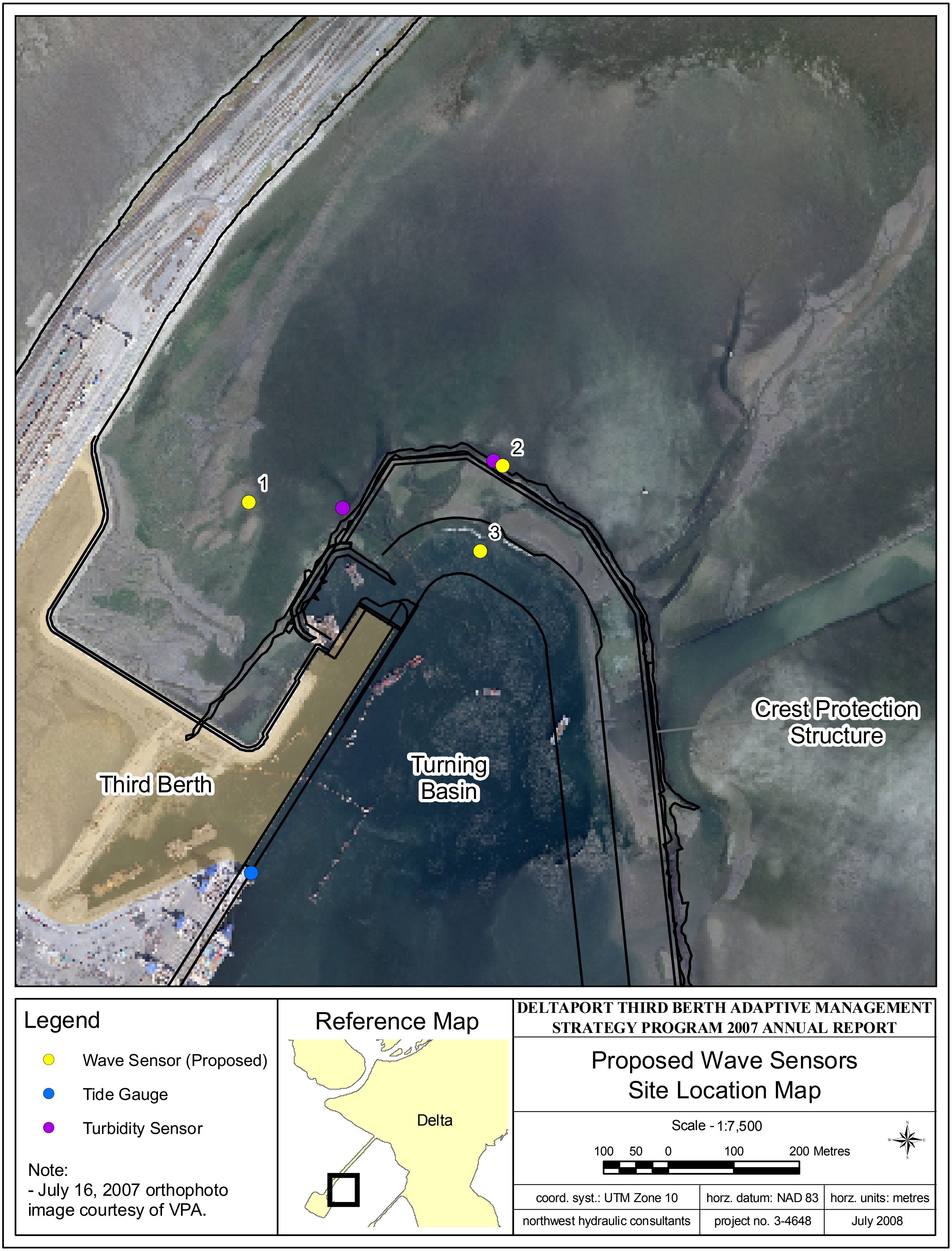
Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	July 2008

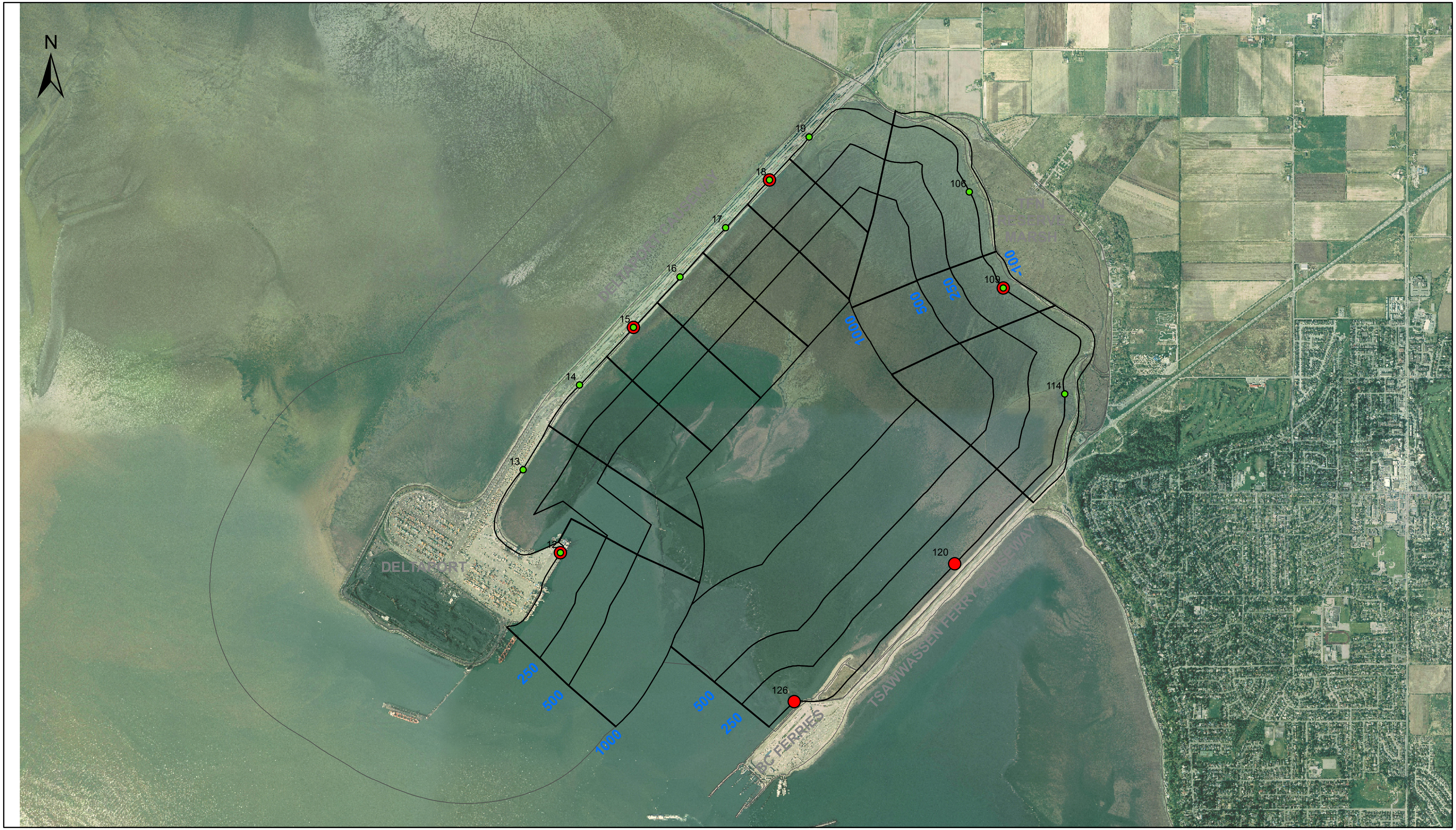
CM, 34648 Deltaport Monitoring\GIS\Fig_ProposedDoDSites.mxd

Figure 49



CM, 34648 Deltaport Monitoring\GIS\Fig_ProposedWaveSensors.mxd

Figure 50



Legend

100	Contour Line Label
12	Station ID
●	Species Specific (GBHE & BRAN) "windshield" survey locations

American Ornithological Union Code
Common Name
GBHE
Great Blue Heron
BRAN
Brant

1:25,000
750 375 0 750 Meters

HEMMERA

PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2007 ANNUAL REPORT

PROPOSED CHANGES TO THE DP3 AMS
COASTAL SEABIRD & WATERFOWL SAMPLING DESIGN

PROJECT NO: 499-002.11	JULY 2008	FIGURE 51

TABLES

Table 1
Crest Protection Monitoring Stations
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Crest Protection Monitoring Station Coordinates

Monitor Point	Northing	Easting	Elevation (m CD)
CRST-01	5430224.0	489096.7	0.899
CRST-02	5430234.8	489095.9	1.759
CRST-03	5430294.1	489130.4	1.884
CRST-04	5430338.8	489161.0	0.970
CRST-05	5430370.9	489189.9	0.540
CRST-06	5430388.6	489200.6	0.596
CRST-07	5430431.4	489229.2	0.447
CRST-08	5430471.2	489252.1	1.070
CRST-09	5430475.4	489308.0	0.564
CRST-10	5430482.1	489364.8	0.663
CRST-11	5430440.7	489434.0	1.050
CRST-12	5430410.8	489489.7	1.116
CRST-13	5430256.7	489629.8	1.229
CRST-14	5430131.6	489656.9	1.250
CRST-15	5429940.9	489678.3	1.033

Table 2
Bird Survey Dates and Times from March 25 to December 28, 2007
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Date (2007)	Event	Transect	Time	Tide (H/L)
25-Mar	1	Deltaport Way	8:15 - 12:31	H
		TFN	12:50 - 15:02	H
		BC Ferries	15:17 - 17:36	H
		Deltaport Way	17:44 -20:02	L
26-Mar	1	TFN	8:24 - 10:49	L
		BC Ferries	11:10 - 13:51	L
10-Apr	2	Deltaport Way	6:30 - 9:44	H
		BC Ferries	10:08 - 10:22	H
		TFN	12:28 - 14:25	L
		BC Ferries	14:35 - 16:58	L
		Deltaport Way	17:20 -20:23	L
12-Apr	2	TFN	6:21 – 8:13	H
23-Apr	3	Deltaport Way	6:20 - 9:24	H
		BC Ferries	9:37 - 11:57	H
		TFN	12:04 - 13:57	L
		Deltaport Way	14:10 - 16:57	L
		BC Ferries	17:35 - 19:40	L
24-Apr	3	TFN	6:14 - 8:13	H
7-May	4	TFN	6:33 - 8:37	H
		Deltaport Way	9:09 - 11:11	H
		Deltaport Way	11:11 - 12:45	L
		BC Ferries	13:10 -15:44	L
8-May	4	Deltaport Way	7:24 - 8:52	H
		BC Ferries	9:06 - 11:43	H
		TFN	11:57 - 14:00	L
		Deltaport Way	14:22 - 16:05	L
22-May	5	Deltaport Way	5:36 - 8:48	H
		TFN	8:57 - 10:53	H
		BC Ferries	11:15 - 13:34	H
		Deltaport Way	14:03 - 14:56	L
23-May	5	TFN	11:00 - 13:00	L
		BC Ferries	13:20 - 16:02	L
		Deltaport Way	16:25 - 18:35	L
5-Jun	6	TFN	5:35 - 7:42	H
		Deltaport Way	8:14 - 11:23	H
		BC Ferries	11:30 - 12:53	H
		BC Ferries	13:01 - 13:48	L
6-Jun	6	BC Ferries	10:10 - 11:24	H
		TFN	11:33 - 13:33	L
		BC Ferries	13:56 - 14:47	L
		Deltaport Way	15:19 - 18:16	L

Table 2
Bird Survey Dates and Times from March 25 to December 28, 2007
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Date (2007)	Event	Transect	Time	Tide (H/L)
18-Jun	7	TFN	6:00 - 7:55	H
		Deltaport Way	8:14 - 10:28	H
19-Jun	7	Deltaport Way	6:43 - 7:34	H
		BC Ferries	7:57 - 10:20	H
		TFN	10:32 - 12:30	L
		Deltaport Way	13:00 - 16:08	L
		BC Ferries	16:25 - 18:40	L
3-Jul	8	TFN	5:30 - 7:28	H
		BC Ferries	8:08 - 10:25	H
		TFN	10:38 - 12:35	L
4-Jul	8	Deltaport Way	7:34 - 10:53	H
		BC Ferries	11:50 - 14:03	L
		Deltaport Way	13:28 - 17:34	L
16-Jul	9	Deltaport Way	6:40 - 10:12	H
		TFN	10:43 - 12:42	L
		BC Ferries	15:33 - 17:27	L
17-Jul	9	TFN	7:40 - 9:42	H
		BC Ferries	9:50 - 12:41	H
		Deltaport Way	13:25 -16:43	L
30-Jul	10	TFN	6:17 - 8:19	H
		BC Ferries	8:35 -10:58	H
		Deltaport Way	11:40 - 14:34	L
31-Jul	10	Deltaport Way	6:15 - 9:20	H
		TFN	10:20 12:12-	L
		BC Ferries	12:28 - 14:42	L
17-Aug	11	Deltaport Way	7:07 - 10:16	H
		BC Ferries	10:20 - 12:27	H
		Deltaport Way	13:40 - 14:50	L
18-Aug	11	Deltaport Way	6:00 - 7:49	L
		TFN	7:55 - 9:42	L
		TFN	10:15 - 12:15	H
		BC Ferries	13:00 - 15:05	L
30-Aug	12	TFN	7:08 - 9:09	H
		BC Ferries	9:31 -12:03	H
		Deltaport Way	12:30 - 15:29	L
31-Aug	12	Deltaport Way	7:22 - 10:37	H
		TFN	11:49 -13:37	L
		BC Ferries	13:44 - 16:00	L
14-Sep	13	Deltaport Way	7:15 - 10:35	H
		BC Ferries	11:20 - 13:37	L
		TFN	14:00 - 15:53	L
15-Sep	13	BC Ferries	7:35 - 10:05	H
		TFN	10:13 - 12:08	H

Table 2
Bird Survey Dates and Times from March 25 to December 28, 2007
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Date (2007)	Event	Transect	Time	Tide (H/L)
		Deltaport Way	12:25 - 15:30	L
2-Oct	14	Deltaport Way	7:30 - 10:57	L
		BC Ferries	11:36 - 13:40	H
		TFN	13:55 -15:40	H
3-Oct	14	TFN	7:12 - 9:04	L
		BC Ferries	9:12 - 11:17	L
		Deltaport Way	11:40 - 14:45	H
18-Oct	15	Deltaport Way	8:08- 8:28	L
19-Oct	15	Deltaport Way	7:45 -10:23	L
		TFN	10:41 - 12:33	H
		BC Ferries	12:55 - 14:35	H
		Deltaport Way	15:23 -18:00	H
20-Oct	15	BC Ferries	7:55 - 10:08	L
		TFN	10:18 - 12:10	L
		Deltaport Way	12:56 - 13:16	H
1-Nov	16	BC Ferries	8:50 - 10:55	L
		TFN	11:08 - 13:04	H
		Deltaport Way	13:22 - 14:07	H
2-Nov	16	Deltaport Way	8:14 - 11:15	L
		BC Ferries	11:55 - 13:20	H
4-Nov	16	TFN	11:00 - 13:02	L
15-Nov	17	TFN	7:25 - 9:14	L
		BC Ferries	9:25 - 11:48	H
		Deltaport Way	12:02 - 14:58	H
16-Nov	17	Deltaport Way	7:27 - 10:25	L
		TFN	10:42 - 12:32	H
19-Nov	17	BC Ferries	7:47 - 9:55	L
29-Nov	18	TFN	8:00 - 10:00	H
		Deltaport Way	10:30 - 13:35	H
		Deltaport Way	13:48 - 16:51	L
30-Nov	18	BC Ferries	11:20 - 13:23	H
		TFN	14:35 - 15:33	L
		BC Ferries	15:50 - 16:10	L
15-Dec	19	Deltaport Way	8:00 - 10:59	H
		BC Ferries	11:12 - 13:31	H
		TFN	13:36 - 15:30	H
28-Dec	20	Deltaport Way	8:42 -11:55	H
		BC Ferries	12:10 - 14:15	H
		TFN	14:20 - 16:25	H

Table 3
Summary of Wind Speed and Direction
April to June 2007
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Summary of Wind Speed and Direction April to June, 2007

Wind Speed (km/h)	N	NE	E	SE	S	SW	W	NW
0-5	11	3	29	18	19	10	14	18
5-10	25	19	166	119	64	60	86	68
10-15	5	16	240	165	64	79	133	55
15-20	6	2	91	88	46	54	62	47
20-25			20	21	13	14	13	25
25-30			10	10	2	6	11	35
30-35			0	2	0	2	5	7
35-40			1		1		5	3
40-45							4	0
45-50								1
50-55								1
55-60								1
60-65								
Total	47	40	557	423	209	225	333	261

Note:

Total records =	2095	h
Total time winds calm =	61	h
Total observations =	2156	h

Hourly Wind Speed and Direction Recorded at Vancouver International Airport-April to June, 2007

Table 4
Summary of Wind Speed and Direction
July to September 2007
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Summary of Wind Speed and Direction July to September, 2007

Wind Speed (km/h)	N	NE	E	SE	S	SW	W	NW
0-5	27	13	25	13	14	6	6	18
5-10	36	15	187	96	63	62	88	78
10-15	1	3	189	129	51	58	147	82
15-20			108	91	10	33	54	88
20-25			33	37	1	2	16	58
25-30			25	15	0	1	11	53
30-35			7	3	1		14	20
35-40			2				6	7
40-45							3	1
45-50							1	
Total	64	31	576	384	140	162	346	405

Note:

Total records =	2108	h
Total time winds calm =	100	h
Total observations =	2208	h

Hourly Wind Speed and Direction Recorded at Vancouver International Airport-July to September, 2007

Table 5
Summary of Wind Speed and Direction
October to December 2007
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Summary of Wind Speed and Direction October to December, 2007

Wind Speed (km/h)	N	NE	E	SE	S	SW	W	NW
0-5	23	16	41	19	12	9	9	24
5-10	39	39	255	81	29	25	53	53
10-15	5	17	305	66	28	12	38	61
15-20		7	208	61	34	7	24	47
20-25			72	24	19	3	14	15
25-30			44	31	24	0	23	13
30-35			22	14	12	1	22	7
35-40			7	9	7	2	8	3
40-45				7	4		10	1
45-50				0	1		2	0
50-55				1	0			1
55-60				1	1			
60-65				1				
Total	67	79	954	315	171	59	203	225

Note:

Total records =	2073	h
Total time winds calm =	134	h
Total observations =	2207	h

Hourly Wind Speed and Direction Recorded at Vancouver International Airport-October to December 2007

Table 6
Storm Events During the
2007 Monitoring Period
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Storm Events During 2007 Monitoring Period

Start Date	Start Time	End Date	End Time	Time at Max. Speed	Tide Level at Start	Tide Level at End	Tide Level at Max.	Wind Speed Max. (km/h)	Wind Speed Average (km/h)	Wind Direction at Max	Wind Direction Average	Hs (m)	Tp (sec)
4/9/2007	18:00	4/9/2007	21:00	20:00	1.4	2.8	2.2	32	30.0	300	315	1.0	3.4
4/13/2007	8:00	4/13/2007	10:00	8:00	3.0	2.8	3.0	37	32.0	110	120	1.0	4.5
5/8/2007	14:00	5/9/2007	3:00	17:00	1.5	3.8	1.1	56	41.0	300	291	1.5	5.0
5/12/2007	1:00	5/12/2007	8:00	1:00	3.6	2.3	3.6	39	32.0	300	308	1.5	5.5
5/19/2007	12:00	5/19/2007	14:00	4:00	1.0	0.3	3.7	32	31.0	220	225	0.4	2.6
5/27/2007	4:00	5/27/2007	8:00	5:00	3.7	1.9	3.3	37	35.0	290	292	1.5	5.2
6/5/2007	21:00	6/6/2007	4:00	3:00	3.9	3.3	3.5	32	25.5	270	268	1.1	4.5
6/26/2007	16:00	6/26/2007	18:00	17:00	3.5	4.0	3.9	35	29.0	300	300	1.5	5.4
7/9/2007	8:00	7/9/2007	17:00	11:00	1.2	3.4	1.7	41	35.6	300	304	1.6	5.0
7/10/2007	8:00	7/10/2007	14:00	9:00	0.9	3.3	0.9	39	33.9	310	311	1.5	5.0
7/12/2007	5:00	7/12/2007	7:00	6:00	3.3	2.0	2.7	32	32.0	120	120	0.4	2.4
8/16/2007	8:00	8/16/2007	10:00	8:00	3.4	3.1	3.4	35	33.0	110	113	0.8	3.8
8/26/2007	2:00	8/26/2007	6:00	4:00	3.7	3.0	3.7	37	31.7	290	283	1.0	4.2
9/8/2007	9:00	9/8/2007	15:00	13:00	1.6	3.4	2.1	37	32.4	310	307	1.5	5.0
9/22/2007	0:00	9/22/2007	9:00	2:00	3.4	1.4	3.3	46	35.5	280	274	1.4	4.8
9/27/2007	22:00	9/28/2007	11:00	3:00	2.6	2.8	2.0	43	35.6	290	284	1.3	4.6
10/2/2007	1:00	10/2/2007	7:00	5:00	2.0	1.9	0.9	37	32.8	170	173	0.8	3.8
10/7/2007	3:00	10/7/2007	16:00	11:00,16:00	3.4	4.1	4.1	41	32.8	160	146	1.1	4.4
10/24/2007	17:00	10/25/2007	4:00	23:00	4.2	3.6	1.4	46	37.9	290	291	1.7	5.5
11/1/2007	5:00	11/1/2007	8:00	05:00, 06:00	1.0	2.3	1.2	33	31.8	320	174	1.5	5.0
11/4/2007	7:00	11/4/2007	9:00	8:00	2.1	2.2	2.0	37	34.3	290	300	1.5	5.5
11/10/2007	0:00	11/10/2007	6:00	5:00	1.1	4.2	3.9	44	32.1	260	179	0.9	4.0
11/11/2007	13:00	11/12/2007	13:00	6:00	3.5	3.5	3.9	61	42.2	130	150	2.5	6.0
11/26/2007	20:00	11/27/2007	3:00	0:00	2.9	1.3	0.3	52	39.5	300	300	2.2	6.0
12/1/2007	11:00	12/2/2007	1:00	17:00	4.4	2.8	2.7	39	31.4	100	99	0.4	2.4
12/3/2007	1:00	12/3/2007	19:00	13:00	3.0	1.9	4.2	37	28.0	160	123	0.9	4.0
12/15/2007	2:00	12/15/2007	15:00	3:00	1.2	3.2	1.3	41	29.0	160	175	1.2	4.4
12/16/2007	8:00	12/16/2007	22:00	19:00	3.7	3.1	2.8	39	34.9	150	144	1.1	4.0
12/19/2007	6:00	12/19/2007	15:00	10:00	2.9	3.4	4.0	41	31.5	170	130	1.1	4.2
12/20/2007	10:00	12/20/2007	20:00	15:00	3.8	0.8	3.7	44	35.2	290	295	2.0	6.0
12/24/2007	4:00	12/24/2007	15:00	11:00	2.1	2.8	4.4	39	30.4	270	285	1.2	4.7

Wind data from Vancouver International Airport
Wave hindcasting made at seaward end of Roberts Bank Causeway

Table 7
Daily Turbidity and Sediment Concentrations
August - September 2007
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Turbidity and Sediment Concentrations - August to September 2007

	August					September			
Day	T1 (NTU)	T1 (mg/L)	T2 (NTU)	T2 (mg/L)	Day	T1 (NTU)	T1 (mg/L)	T2 (NTU)	T2 (mg/L)
1	4.5	8	3.1	6	1	6.1	11	4.7	9
2	4.4	8	3.2	6	2	5.6	10	4.7	9
3	7.2	13	4.1	8	3	4.9	9	4.0	7
4	4.6	9	5.7	11	4	5.3	10	3.9	7
5	5.0	9	6.8	13	5	5.3	10	4.6	9
6	9.4	17	10.0	18	6	6.4	12	5.5	10
7	14.3	27	20.0	37	7	5.9	11	4.9	9
8	6.3	12	17.5	32	8	7.1	13	4.8	9
9	4.6	9	7.2	13	9	5.1	10	4.4	8
10	4.1	8	9.0	17	10	3.9	7	3.1	6
11	4.7	9	14.1	26	11	4.8	9	3.1	6
12	5.2	10	12.2	23	12	4.2	8	3.7	7
13	5.5	10	8.2	15	13	6.3	12	4.1	8
14	5.4	10	6.3	12	14			5.2	10
15	4.7	9	7.3	13	15			4.8	9
16	11.4	21	8.9	17	16			4.8	9
17	5.1	9	4.5	8	17			6.9	13
18	5.3	10	6.3	12	18			5.5	10
19	9.0	17	10.8	20	19			5.2	10
20	9.1	17	8.2	15	20			5.4	10
21	4.9	9	7.1	13	21				
22	4.9	9	6.3	12	22				
23	7.7	14	8.0	15	23				
24	6.2	11	5.5	10	24				
25	7.8	14	4.8	9	25				
26	6.0	11	5.0	9	26				
27	5.8	11	4.4	8	27				
28	5.5	10	3.7	7	28				
29	4.3	8	3.4	6	29				
30	5.1	9	3.5	7	30				
31	5.4	10	4.4	8	31				
Average	6.2	11.5	7.4	13.7	Average	5.5	10.1	4.7	8.6

Table 8
Daily Turbidity and Sediment Concentrations
October - December 2007
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Turbidity and Sediment Concentrations - October to December 2007

	October					November		December	
Day	T1 (NTU)	T1 (mg/L)	T2 (NTU)	T2 (mg/L)	Day	T1 (NTU)	T1 (mg/L)	T2 (NTU)	T2 (mg/L)
1					1	4.6	9	9.4	17
2					2	4.7	9	15.8	29
3					3	11.5	21	19.6	36
4			8.7	16	4	13.4	25	15.2	28
5			9.4	17	5	4.0	7	6.0	11
6			8.6	16	6	4.5	8	4.2	8
7			17.8	33	7	4.6	9	3.7	7
8			4.8	9	8	4.8	9	3.5	6
9			5.1	9	9	7.0	13	3.5	6
10			4.5	8	10	7.9	15	3.9	7
11			5.9	11	11	17.9	33	2.9	5
12			9.3	17	12	37.2	69	3.2	6
13			5.0	9	13	13.0	24	4.5	8
14			6.0	11	14	6.1	11	4.7	9
15			5.3	10	15	7.2	13	26.6	49
16			7.9	15	16	12.0	22	34.4	64
17			5.9	11	17	7.6	14	20.1	37
18			6.5	12	18	6.4	12	5.4	10
19			5.6	10	19	5.0	9	13.0	24
20			20.4	38	20	4.5	8	3.2	6
21			8.8	16	21	4.3	8	3.5	7
22			11.8	22	22	3.1	6	8.4	16
23			6.4	12	23	3.7	7	5.4	10
24			7.7	14	24	4.1	8	3.4	6
25			6.6	12	25	3.2	6	8.1	15
26			5.9	11	26	3.7	7	4.3	8
27			5.3	10	27	3.8	7	3.9	7
28			4.4	8	28	4.6	9	5.4	10
29				0	29	3.3	6	5.7	10
30			4.1	8	30	3.2	6	7.0	13
31			3.5	6	31			3.6	
Average			7.4	13.3	Average	7.4	13.6	8.4	15.9

Table 9
Quarterly Bed Elevation Changes at DoD Rods
Deltaport Third Berth
Adaptive Management Stratety
499-002.11

Depth of Disturbance Rods
Quarterly Bed Elevation Changes

Site #	Q2			Q3			Q4		
	Deposition (cm)	Erosion (cm)	Net Change (cm)	Deposition (cm)	Erosion (cm)	Net Change (cm)	Deposition (cm)	Erosion (cm)	Net Change (cm)
A03	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.2	-0.2
A04	2.8	0.8	2.0	0.2	0.0	0.8	0.8	1.7	-0.9
A05	1.5	0.0	2.5	0.3	0.5	-0.2	0.1	1.2	-1.1
A06	1.8	0.5	1.3	3.7	2.1	1.6	0.5	0.7	-0.2
B02	1.5	5.2	-3.7	0.1	2.6	-2.5	5.4	4.9	0.5
B03	1.0	0.0	1.2	0.0	0.0	0.0	0.1	1.2	-1.1
B04				4.4			0.7	1.1	-0.4
B05	1.3	0.0		0.0	0.0	1.2	3.1	6.5	-3.4
B06	2.3	0.0	2.6	0.7	0.0	0.7	0.5	1.1	-0.6
C01	1.2	0.0	1.6	0.0	0.5	-0.5	1.0	2.2	-1.2
C02	8.5	7.7	0.8	4.1	0.0	6.4	1.7	1.3	0.4
C03	1.0	0.0	1.3	1.4	0.0	1.4	0.0	1.4	-1.4
C04	2.9	1.9	1.0	0.1	0.0	1.0	0.0	0.0	0.1
C05				0.3			1.3	4.5	-3.2
C06	1.0	0.0	2.0	0.6	1.0	-0.4	1.4	2.3	-0.9
D01	4.5	1.0	3.5	0.6	0.7	-0.1	0.2	1.9	-1.7
D02	1.5	0.8	0.7	0.0	0.1	-0.1	0.0	0.6	-0.6
D03	5.0	0.0	5.5	0.0	0.0	0.5	0.9	1.0	-0.1
D04	4.1	0.0	5.5	0.3	2.4	-2.1	3.4	4.5	-1.1
D05	0.2	1.2	-1.0	2.0	3.1	-1.1	2.4	5.2	-2.8
D06	1.5	1.1	0.4	-0.1	0.0	0.5	2.1	2.9	-0.8
E01	6.5	1.8	4.7	1.9	2.5	-0.6	0.0	0.6	-0.6
E02	8.5	0.0	9.5	5.7	2.0	3.7	0.0	1.0	-1.0
E06	1.9	1.8	0.1	3.5	3.0	0.5	3.2	6.3	-3.1
F06	15.0	3.9	11.1	0.2	5.3	-5.1	3.0	0.0	5.8
G06	21.0	2.0	19.0	0.2	14.9	-14.7	8.6	7.4	1.2

Table 10
Cummulative Grain Size Distribution
of Sediment Samples
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Sediment Sample Analysis
Cumulative Grain Size Distribution (Percent Finer Than)

May 2007

	Grain Size (mm)									
Site	1.00	0.5	0.354	0.25	0.177	0.125	0.088	0.063	% Sand	% Silt/Clay
A03	100	98.3	95.2	90.9	73.9	57.6	45	34.2	65.8	34.2
A04	100	98	93	86	51	29	19	14	86	14
A05	100	98	93	86	49	26	16	11	89	11
A06	100	98	93	85	52	28	15	9	91	9
B02	100	99	90	77	54	33	17	8	92	8
B03	100	98	93	86	56	37	29	24	76	24
B04	100	97	90	81	45	24	16	12	88	12
B05	100	98	91	81	43	20	11	6	94	6
B06	100	98	90	79	44	22	12	7	93	7
C01	100	98	77	46	24	11	6	4	96	4
C02	100	99	94	87	54	29	14	7	93	7
C03	100	98	89	76	41	21	14	11	89	11
C04	100	96	81	59	27	11	7	4	96	4
C05	100	98	83	62	30	12	7	4	96	4
C06	100	93	75	50	27	14	10	7	93	7
D01	100	99	95	90	67	43	23	12	88	12
D02	100	98	93	86	75	68	64	61	39	61
D03	100	77	64	46	23	11	8	6	94	6
D04	100	99	74	37	16	6	5	4	96	4
D05	100	96	67	24	11	5	4	4	96	4
D06	100	98	76	44	23	12	8	6	94	6
E01	100	98	89	76	55	37	25	17	83	17
E02	100	93	70	38	21	12	9	8	92	8
E06	100	95	66	24	13	7	6	5	95	5
F06	100	97	72	36	19	9	5	3	97	3
G06	100	96	62	12	5	2	2	2	98	2

October 2007

	Grain Size (mm)									
Site	1.00	0.5	0.354	0.25	0.177	0.125	0.088	0.063	% Sand	% Silt/Clay
A03	100	99	96	91	68	50	38	28	72	28
A04	100	96	85	70	41	24	17	14	86	14
A05	100	97	80	56	32	19	15	14	86	14
A06	100	97	77	48	28	17	13	12	88	12
B02	100	99	83	60	42	27	16	11	89	11
B03	100	97	84	66	46	34	29	22	78	22
B04	100	98	88	74	42	23	15	12	88	12
B05	100	98	89	76	42	22	14	11	89	11
B06	100	96	82	63	35	19	13	11	89	11
C01	100	98	77	46	34	22	13	10	90	10
C02	100	99	92	82	62	41	24	17	83	17
C03	100	98	86	68	41	25	20	18	82	18
C04	100	96	80	57	30	16	12	11	89	11
C05	100	94	76	50	25	12	8	7	93	7
C06	100	95	76	50	30	19	15	14	86	14
D01	100	99	96	91	66	41	21	12	88	12
D02	100	98	80	53	30	16	11	10	90	10
D03	100	83	66	41	21	11	8	7	93	7
D04	100	99	78	47	24	13	11	11	89	11
D05	100	96	66	23	12	7	6	6	94	6
D06	100	96	77	50	29	18	15	14	86	14
E01	100	98	94	89	72	55	42	35	65	35
E02	100	97	89	78	67	55	45	40	60	40
E06	100	94	69	33	21	14	12	12	88	12
F06	100	97	70	30	15	7	5	5	95	5
G06	100	97	70	30	15	8	7	7	93	7

Table 11
Total Organic Carbon Content
of Sediment Samples
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Sediment Sample Analysis
Total Organic Carbon

Site #	May (%)	October (%)
A03	1.0	0.6
A04	0.4	0.5
A05	0.4	0.4
A06	0.5	0.4
B02	0.2	0.2
B03	0.5	0.6
B04	0.5	0.3
B05	0.3	0.3
B06	0.4	0.4
C01	0.1	0.2
C02	0.2	0.5
C03	0.4	0.4
C04	0.3	0.3
C05	0.2	0.3
C06	0.4	0.4
D01	0.2	0.2
D02	0.8	0.4
D03	0.2	0.2
D04	0.1	0.2
D05	0.2	0.1
D06	0.3	0.3
E01	0.4	0.8
E02	0.3	0.8
E06	0.2	0.3
F06	0.2	0.2
G06	0.1	0.1

Table 12
Summary of Quality Assurance/Quality Control Issues
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Surface Water	
Q1 2007	TSS, copper, lead, nickel, and zinc had RPDs in excess of the DQO. Due to rough weather conditions, the containers for the duplicates were filled one after the other from the Van Dorn to minimize the risk of spillage. Particulate matter likely accounted for the difference between the duplicates, as the RPD for TSS was 73%. The RDL for vanadium was above the WQG. The elevated RDL for vanadium was due to the dilution required to avoid sodium interference. Due to laboratory error, the chlorine sample for DP01 was not analyzed for chlorine within the sample holding time
Q2 2007	Uranium had a RPDs in excess of the DQO. Not considered to be indicative of low precision. Likely due to variability associated with suspended particulate matter. Organic nitrogen, TKN and nitrite had DFs in excess of the DQO. Potentially related to large difference in the conductivity and salinity between the sample and it's duplicate. The lab was requested to re-analyze the samples but the lab indicated that he samples had already been discarded.
Q3 2007	Chlorophyll a, TSS, and arsenic had RPDs in excess of the DQO. The chlorophyll a RPD was 80.7%. Chlorophyll a results from Q1 and Q2 suggest that this degree of variability is anomalous. Although the RPD for TSS was 50%, metals met the DQO with the exception of arsenic, for which the RPD exceeded the DQO by only 2%.
Q4 2007	TSS and zinc had RPDs in excess of the DQO. The RPDs for TSS and zinc exceeded the DQO by only 2.7% and 3.3% respectively, the data was therefore considered reliable.
Sediment	
Q1 2007	Ammonia, sulphide, and chromium had RPDs in excess of the DQO. Ammonia and chromium exceeded the DQO by 9.5 and 5.5% respectively. The sulphide RPD was 58%. The sampling methodology and laboratory handling procedure was revised to minimize loss via volatilization.
Q2 2007	Nitrate and sulphide had RPDs in excess of the DQO. The sulphide RPD exceeded the DQO by only 2.5%. The RPD for nitrate exceeded the RPD by 13%. Elevated RPDs likely reflect above average variability in these parameters, rather than low precision.
Q3 2007	The DF for TOC (3.0) exceeded the DQO of 2.0. Data quality was not considered an issue as TOC was the only parameter to exceed the DQO.
Q4 2007	All of the sediment parameters met the DQO.

Table 13
2007 Surface Water Results
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Location ID:			DP01				DP02				DP03				DP04				DP05				DP05				DP06				DP07				DP07			
Sample ID:			SWDP01-1[16]	SWDP01-2	SWDP01-3	SWDP01-4	SWDP02-1	SWDP02-2	SWDP02-3	SWDP02-4	SWDP03-1	SWDP03-2	SWDP03-3	SWDP03-4	SWDP04-1	SWDP04-2	SWDP04-3	SWDP04-4	SWDP05A-1	SWDP05A-2	SWDP05A-3	SWDP05A-4	SWDP05B-1	SWDP05B-2	SWDP05B-3	SWDP05B-4	SWDP06-1	SWDP06-2	SWDP06-3	SWDP06-4	SWDP07A-1	SWDP07A-2	SWDP07A-3	SWDP07A-4	SWDP07B-1	SWDP07B-2	SWDP07B-3	SWDP07B-4
Date Sampled:	BCWQG MAL [1,2]	CCME MAL [11,12]	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2007-03-23	2007-06-20	2007-10-02	2007-12-10	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2007-03-24	2007-06-20	2007-10-02	2007-12-10	2007-03-23	2007-06-20	2007-10-01	2007-12-10	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2007-03-24	2007-06-20	2007-10-01	2007-12-10
Sample Info																																						
Sample Depth (m)	-	-	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	10	15.0	15.0	14.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	13.0	18.0	15.0	20.0
Sample Time	-	-	15:00	14:45	11:00	18:40	9:40	10:19	12:20	16:00	8:00	10:47	13:10	15:45	9:00	11:30	13:36	14:40	11:30	12:15	14:20	13:10	10:40	12:40	14:30	13:20	10:32	8:50	10:00	9:30	8:35	9:50	11:20	11:00	9:15	10:10	11:30	11:10
Field Tests																																						
Field Conductivity (uS/cm)	-	-	6696	9810	31208	23489	32960	36600	31678	44274	10089	31300	31175	44401	42603	35800	32241	44592	43311	33000	32657	44917	45143	44700	33099	44533	20042	25500	4877	11517	43933	19590	32350	39268	45970	45000	32733	41778
Dissolved Oxygen (mg/L)	5 [11]	-	11.26	9.21	9.48	16.67	10.99	8.01	9.18	13.01	10.14	7.96	8.87	12.65	9.79	8.03	8.66	10.95	9.42	7.74	7.73	10.86	16.92	9.71	6.02	10.86	11.4	10.9	10.4	12.26	9.27	8.92	8.27	10.1	12.75	8.76	6.39	15.58
Field pH	-	7-8.7 [14]	7.31	7.38	7.60	7.79	7.89	8.38	7.68	7.67	7.80	8.55	7.66	7.73	7.89	8.47	7.67	7.75	7.77	8.3	7.68	7.62	7.76	8.07	7.53	7.58	7.81	7.65	6.5	7.45	7.80	8.29	6.87	7.64	7.73	7.95	7.63	7.61
Field Redox (mV)	-	-	121.3	136.2	207	199	248.7	231	214	274	236.1	258.6	230	252	261.2	214.7	242	239	251.9	248.3	253	230	227.2	241.1	251	221	207.0	199.2	212	176	180.3	170.1	257	172	200.2	160	255	223
Field Salinity	-	-	3.65	21.98	27.11	13.98	20.49	23.19	27.44	27.87	25.44	20.85	26.41	28.26	25.62	20.42	28.16	28.45	27.59	28.63	29.04	28.76	27.19	27.23	29.86	28.76	24.23	12.52	35.50	30.34	24.89	27.02	28.89	24.77	26.01	22.81	29.10	26.52
Field Temperature (ºC)	-	-	7.93	22.8	12.4	2.73	6.94	16.1	11.4	4.95	8.53	14.9	11.6	6.38	7.60	13.7	11.1	6.96	7.59	13.8	10.6	7.54	7.30	10.3	10.1	7.77	6.40	14.1	12.4	3.96	7.85	13.5	10.8	6.62	7.85	9.9	10.3	7.12
Field Turbidity (NTU)	-	-	46.2	220	-	15.9	10.9	1.7	-	1.79	1.20	5.2	-	1.69	0	0.53	-	1.44	3.87	1.03	-	0.88	10.2	1.2		1.46	18.9	34.0	-	8.75	1.20	7.72	-	2.21	0.09	2.6	-	1.7
Secchi Depth (m)			0.5 (bottom)	0.5 (bottom)	0.5 (bottom)	sampled in dark	0.5 (bottom)	0.7	1.2	1.0	0.60	0.6	0.7	1.6	0.9	1.4	1.7	2.0	1.5	3.4	3.6	4.3	-	-	-	-	0.5	0.7	0.6	0.9	1.1	3.9	5.2	2.0	-	-	-	-
Physical Tests																																						
Hardness, Total (CaCO3) (mg/L)	-	-	651	974	4740	2879	3550	4064	4850	5379	4750	3434	4590	5671	5060	4280	4970	5673	4370	3750	5040	5568	5350	5210	5120	5714	1950	212	6150	1126	5194	2140	5110	4618	5394	5130	5210	5430
pH	-	7-8.7 [14]	7.81	8.04	7.84	7.83	7.83	8.25	7.84	7.85	7.84	8.3	7.83	7.83	7.86	7.95	7.85	7.88	7.83	7.85	7.85	7.85	7.82	7.93	7.81	7.82	7.80	7.89	7.59	7.79	7.78	7.84	7.73	7.84	7.83	7.95	7.79	7.85
Salinity	-	-	3.7	22.3	27.3	14.3	19.9	23.1	27.7	27.9	24.4	20.8	26.4	28.3	26.1	20.3	28.2	28.6	24.0	28.7	28.1	28.4	28.5	<10	29.6	28.8	10.3	11.9	35.0	6.5	27.3	27.6	28.7	24.3	27.9	20.4	28.8	27.8
Total Suspended Solids (mg/L)	-	-	22.0	27.2	43.7	21.5	12.0	28.0	21.7	8.8	8.0	23.3	26.3	16.8	6.0	27.2	26.3	23.5	8.7	18.5	15.7	30.8	20.2	36.5	51.7	14.8	12.7	28.5	12.9	12.2	33.6	21.2	3.7	22.2	10.9	25.2	51.0	9.5
Bacteriological Tests																																						
Chlorophyll A	-	-	4.84	3.15	2.72	1.65	0.758	1.25	3.79	0.547	2.25	3.77	3.19	0.572	2.54	6.09	3.55	0.645	1.26	6.42	0.96	0.504	0.500	1	4.96	0.422	0.847	0.554	0.932	0.267	0.561	4.3	1.17	0.401	0.714	0.521	1.07	0.445
Organics																																						
Organic Nitrogen N (mg/L)	-	-	1.13	0.488	0.47	0.819	0.123	0.20	0.32	0.23	0.12	0.18	0.33	0.246	0.099	0.497	0.27	0.214	0.12	0.497	0.289	0.217	0.107	<0.070	0.22	0.201	0.17	0.256	0.10	0.115	0.05	0.207	0.23	0.143	0.119	<0.070	0.229	0.263
Inorganics																																						
Ammonia (mg/L)	-	-	0.480	0.391	0.066	0.419	0.048	0.058	0.039	0.046	0.0320	0.03	0.056	<0.020	<0.020	0.123	0.027	<0.020	0.035	0.088	<0.020	<0.020	<0.020	0.076	<0.020	<0.020	0.0410	0.056	0.1	0.071	0.028	0.023	0.0067	<0.020	<0.020	0.03	<0.005	<0.020
Nitrate (mg/L)	-	16	0.595	1.99	<0.500	6.9	<0.050	<0.500	<0.500	7	0.220	<0.500	<0.500	7	0.670	<0.500	<0.500	8.3	<0.50	<0.500	<0.500	6.4	0.30	<0.500	<0.500	7	0.190	0.0634	0.49	12	0.25	0.79	1.93	7.4	0.33	0.52	2.36	5.9
Nitrite (mg/L)	-	-	0.024	0.094	<0.100	0.54	<0.010	0.17	<0.100	<0.500	<0.020	0.13	<0.100	<0.500	<0.020	0.33	<0.100	<0.500	<0.10	0.23	<0.100	<0.500	<0.020	0.29	<0.100	<0.500	<0.020	<0.001	<0.020	<0.500	<0.020	<0.100	<0.100	<0.500	<0.020	<0.100	<0.100	<0.500
Phosphorus, Ortho (mg/L)	-	-	0.0761	0.503	0.06	0.0245	0.0420	0.0479	0.0527	0.0724	0.0482	0.0317	0.0555	0.072	0.0507	0.0241	0.0552	0.0712	0.0531	0.0217	0.0527	0.0735	0.0620	0.0634	0.0708	0.0745	0.0237	0.0067	0.016	0.0224	0.0578	0.0091	0.0672	0.0618	0.0630	0.0606	0.0665	0.0719
Dissolved Inorganics																																						
Phosphate (mg/L)	-	-	0.147	0.485	0.0569	0.0276	0.0457	0.0579	0.0515	0.0707	0.0499	0.0405	0.0551	0.0693	0.0548	0.0286	0.0493	0.0714	0.0580	0.0253	0.0527	0.0733	0.0688	0.0648	0.0683	0.067	0.0270	0.008	0.0167	0.0218	0.0618	0.0134	0.0624	0.0603	0.0656	0.0597	0.059	0.0667
Total Inorganics																																						
Chlorine			-	<200	<200	<200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate (mg/L)	-	-	0.299	0.654	0.0948	0.203	0.0568	0.0688	0.0637	0.0735	0.0589	0.0641	0.0764	0.0734	0.0612	0.0489	0.0687	0.076	0.0634	0.0418	0.0604	0.0766	0.0705	0.0716	0.0713	0.0844	0.0486	0.0477	0.0298	0.0343	0.0644	0.0352	0.0638	0.069	0.0671	0.0666	0.0678	0.0745
Phosphorus (mg/L)	-	-	<0.60	0.64	<3.000	<3.000	<3.0	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.0	<3.000	<3.000	<3.000	<3.0	<3.000	<3.000	<3.000	<3.000	<0.300	<3.000	<3.000	<3.0	<1.500	<3.000	<3.000	<3.0	<3.000	<3.000	<3.000
TKN (mg/L)	-	-	1.61	0.879	0.535	1.24	0.171	0.262	0.355	0.276	0.150	0.211	0.385	0.246	0.099	0.62	0.294	0.214	0.155	0.585	0.289	0.217	0.107	0.128	0.222	0.201	0.214	0.312	0.2	0.186	0.075	0.23	0.233	0.143	0.119	0.094	0.229	0.263
Total Nitrogen N (mg/L)	-	-	2.23	2.97	<0.700	8.7	0.17	<0.700	<0.700	7.3	0.370	<0.700	<0.700	7.3	0.770	0.95	<0.700	8.5	<0.70	0.81	<0.700	6.6	0.41	<0.700	<0.700	7.2	0.410	0.375	0.69	12.2	0.33	1.02	2.16	7.6	0.45	<0.700	2.59	6.1
Dissolved Metals																																						
Iron	50 [5]	-	-	14	<300	10	-	<10	<300	<10	-	<10	<300	<10	-	<10	<300	<10	-	<10	<300	<10	-	<10	<300	<10	-	21	-	11	-	<10	-	<10	-	<10	-	<10
Total Metals																																						
Aluminum	-	-	674	<500	<500	388	<100	<200	<100	<100	<100	<200	<200	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<300	<100	<100	226	1110	170	200	<100	<400	<100	<100	<100	<300	<100	<100
Antimony	-	-	<2.0	<2	<10	<5	<10	21	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<5	<0.5	<10	<2	<10	<5	<10	<10	<10	<10	<10	<10
Arsenic	12.5 [3]	12.5	4.22	2.52	1.22	1.54	0.97	1.41	1.01	1.16	1.11	1.2	1.18	1.26	1.17	0.97	1.42	1.23	1.11	1.24	1.28	1.25	1.26	1.16	1.05	0.88	0.860	0.43	0.69	0.61	1.34	0.92	1.06	1.11	1.41	1.51	1.4	0.93
Barium	200 [4]	-	21.0	12.9	12.2	18.1	11.9	<20	10.5	9.1	10.6	<20	11.5	9	10.4	12.2	11.2	9	10.8	12.6	8.6	8.9	9.3	21.2	7.1	8.3	17.8	22	20.3	19	10.6	17.9	8.5	10.3	9.6	11.7	9	8.9
Beryllium	100 [5]	-	<10	<10	<50	<25	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<25	<2.5	<50	<10	<50	<25	<50	<50	<50	<50	<50	<50
Bismuth	-	-	<10	<10	<50	<25	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<25	<2.5	<50	<10	<50	<25	<50	<50	<50	<50	<50	<50
Boron	1200 [6]	-	610	860	3500	2010	2700	2900	3700	3600	3500	2600	3700	3500	3500	3300	3800	3600	3300	3000	3700	3500	3800	3900	3500	3500	1310	129	<1000	740	3900	1560	4000	3000	4000	4000	4000	3400
Cadmium	0.12 [7]	0.12	0.068	0.065	0.095	0.073	0.063	0.043	0.076	0.072	0.0600	0.04	0.085	0.062	0.0700	0.093	0.068	0.063	0.069	0.055	0.066	0.051	0.064	0.064	0.054	0.062	0.0510	0.028	0.032	0.032	0.067	0.066	0.068	0.057	0.060	0.073	0.056	0.056
Calcium	-	-	65800	79800	346000	203000	236000	267000	348000	340000	305000	216000	338000	358000	322000	251000	362000	359000	285000	228000	359000	350000	345000	309000	395000	359000	133000	24500	49400	79900	332000	133000	338000	296000	346000	305000	334000	344000
Chromium	56 [7]	56 [13]	<10	<10	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<25	4.1	<50	<10	<50	<25	<50	<50	<50	<50	<50	<50
Cobalt	-	-	1.51	0.781	0.348	1.33	0.136	0.092	0.1	0.112	0.0690	0.079	0.166	0.052	<0.05	0.056	0.081	0.055	0.082	0.059	0.064	<0.05	<0.050	0.052	<0.05	<0.05	0.252	0.394	0.189	0.161	<0.050	0.123	<0.05	0.056	<0.050	0.065	<0.05	<0.05
Copper	3 [8]	-	5.59	5.71	1.4	2.9	1.49	0.696	1.58	0.591	0.709	0.672	2.06	0.652	0.743	0.804	1.04	0.552	6.99	0.636	0.615	0.617	0.496	0.562	0.389	0.507	3.27	2.07	6.45	1.12	2.25	1.27	0.825	0.563	0.887	0.539	1.04	0.396
Iron	50 [5]	-	2070	718	451	1060	116	46	111	69	55	63	186	59	21	17	72	52	68	18	47	23	29	51	22	38	300	369	161	218	36	92	<10	55	32	49	<10	32
Lead	140 [8]	-	1.08	0.437	0.637	0.687	0.469	<0.05	1.36	0.074	0.137	0.061	1.09	0.117	0.192	0.21	0.454	0.093	0.330	0.189	0.386	0.135	0.119	0.373	0.094	0.081	1.95	0.349	3.10	0.171	1.06	0.601	0.368	0.085	0.597	0.119	0.116	<0.05
Lithium	-	-	<100	<100	<500	<250	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<250	<25	<500	<100	<500	<250	<500	<500	<500	<500	<500	<500
Magnesium	-	-	118000	188000	1070000	576000	718000	825000	1100000	1100000	968000	703000	1080000	1160000	1030000	886000	1170000	1160000	887000	772000	1170000	1140000	1090000	1080000	1290000	1170000	393000	36600	119000	225000	1060000	439000	1040000	942000	1100000	1060000	1060000	1110000
Manganese	-	-	175	75	13.5	135	11.2	6.21	7.45	8.25	5.88	7.13	11.4	4.16	3.22	5.77	6.86	4.5	6.48	7.97	5.43	2.28	2.47	3.58	2.31	2.89	22.8	38.8	39.1	21.9	2.30	13.9	1.93	5.33	2.03	9.46	1.86	2.87
Mercury	2 [8]	0.016	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01
Molybdenum	-	-	2.6	5.8	8.2	6.1	5.5	12.4	9.1	9.4	7.60	7.6	9.8	8.8	7.50	9.1	9.4	9.9	6.9	7.1	9.4	9.5	8.9	9.4	8.2	10.5	2.60	1.26	<5	2.3	10.5	4.4	9.5	8.7	9.9	9.3	9.9	8.3
Nickel	-	-	8.25	5.62	1.49	5.71	0.879	0.612	0.758	0.737	0.528	0.536	1.01	0.446	0.421	0.56	0.798	0.508	0.593	0.568	0.582	0.356	0.640	0.52	0.416	0.425	1.16	1.43	0.953	0.834	0.558	0.767	0.453	0.503	0.362	0.646	0.42	0.388
Potassium	-	-	45200	64900	355000	188000	242000	271000	366000	362000	309000	226000	363000	385000	331000	264000	387000	376000	296000	239000	384000	374000	348000	329000	415000	387000	123000	12000	37000	75000	333000	137000	297000	318000	351000	321000	297000	367000
Selenium Se	2 [8]	-	<0.50	0.56	0.88	<0.5	<0.50	<0.5	<0.5	<0.5	0.510	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	0.62	<0.5	0.59	<0.50	<0.5	0.69	<0.5	<0.5	0.61	0.8	<0.5	0.70	<0.5	<0.5	<0.5	<0.50	<0.5	<0.5	<0.5
Silicon	-	-	5070	3170	2960	7370	1650	880	1540	1930	1410	1360	1890	1860	1170	1010	1420	1920	1580	1380	1380	1750	1340	1380	1560	1810	2320	3330	2250	2840	1120	1990	1350	1890	1380	1300	1330	1770
Silver	3 [9]	-	<0.20	<0.2	<1	<0.5	<1.0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1.0	<1	<1	<1	<1.0	<1	<1	<1	<0.5	<0.05	<1	<0.2	<1.0	<0.5	<1	<1	<1.0	<1	<1	<1
Sodium	-	-	1070000	1480000	7990000	4580000	6340000	7230000	8250000	8150000	7340000	5770000	8290000	8620000	7840000	6840000	8790000	8450000	7620000	6280000	8700000	8370000	8230000	8620000	9380000	8660000	3090000	257000	905000	1890000	7920000	3570000	8420000	7170000	8270000	8350000	8300000	8220000
Strontium	-	-	892	1200	6600	3270	4470	5060	7200	5820	5970	4270	6850	5960	6100	5040	7200	6250	5750	4330	7050	6170	6680	6300	6460	6290	2080	253	869	1320	6530	2520	7580	5190	6850	6130	7450	5900
Thallium	-	-	<2.0	<2	<10	<5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<5	<0.5	<10	<2	<10	<5	<10	<10	<10	<10	<10	<10
Tin	-	-	<2.0	<2	<10	<5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<5	2.22	<10	<2	<10	<5	<10	<10	<10	<10	<10	<10
Titanium	-	-	21	<20	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	25	<100	<100	<100	<50	<100	<100	<100	<100	<100	<100
Uranium	100 [5]	-	0.629	0.392	1.99	1.41	1.56	0.949	2.09	2.08	1.96	1.24	1.99	1.77	1.74	1.28	1.9	1.94	1.92	1.32	2.05	1.74	1.97	1.28	1.82	1.87	0.937	0.221	0.432	0.58	2.08	0.762	1.94	1.76	2.01	1.44	1.79	1.8
Vanadium	50 [10]	-	<20	<20	<100	<50	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<50	5	<100	<20	<100	<50	<100	<100	<100	<100	<100	<100
Zinc	10 [6]	-	12.6	10.4	7.64	9.08	5.10	0.56	5.35	1.24	2.55	0.6	3.56	1.17	1.96	2.5	1.74	1.39	19.0	1.3	2.67	1.21	1.09	2.1	0.67	1.0	3.65	1.82	4.83	2.68	5.22	2.4	1.54	1.09	2.31	1.5	1.46	0.86
PAHs																																						
Acenaphthene	6 [6]	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Acenaphthylene	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Acridine	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Anthracene	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Benzo(a)anthracene	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Benzo(a)pyrene	0.01 [6]	-	<0.010	-	-	-	<0.010	-	-	-	<0.01	-	-	-	<0.01	-	-	-	<0.010	-	-	-	<0.010	-	-	-	<0.01	-	-	-	<0.010	-	-	-	<0.010	-	-	-
Benzo(b)fluoranthene	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Benzo(g,h,i)perylene	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Benzo(k)fluoranthene	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Chrysene	0.1 [6]	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Dibenz(a,h)anthracene	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Fluoranthene	-	-	0.198	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Fluorene	12 [6]	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Naphthalene	1 [6]	1.4	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Phenanthrene	-	-	0.165	-	-	-	<0.050	-	-	-	0.059	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Pyrene	-	-	0.116	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-
Quinoline	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-	<0.05	-	-	-	<0.050	-	-	-	<0.050	-	-	-

Table 13
2007 Surface Water Quality Table Notes
Deltaport Third Berth
Adabptive Management Strategy
499-002.11

All values are reported as µg/L unless otherwise noted.

	RPD	=	Relative Percent Difference
	-	=	No standard or not analyzed
1)	BCWQG	=	British Columbia Approved Water Quality Guidelines, 1998, updated to August 2006; and A Compendium of Working Water Quality Guidelines for British Columbia, 1998, updated to Aug-06
2)	**<u>BCWQG MAL</u>**	=	Highlighted value exceeds BCWQG Marine and Estuarine Aquatic Life criteria from Approved Guidelines Tables 2 to 50 and/or Working Guidelines Table 1

3) Approved - Tables 2 to 50 - Maximum, Interim
4) Working - Table 1 - Maximum, Adverse Effects on a Bivalve
5) Working - Table 1 - Maximum, Minimal Risk
6) Approved - Tables 2 to 50 - Maximum
7) Working - Table 1 - Assumes all chromium present as Cr(III)
8) Approved - Tables 2 to 50 - Maximum
9) Approved - Tables 2 to 50 - Maximum, Open Coast and Estuaries
10) Working - Table 1 - Trigger Value for 99% Protection
11 Approved-minmum all life stages except buried embryo/alevin

12)	CCME	=	Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines, 1999, updated to January 2006
13)	**CCME MAL**	=	Highlighted value exceeds CCME Chapter 4, Canadian Water Quality Guidelines for the Protection of Aquatic Life, Summary Table, Marine, updated to July 2006

14) CCME MAL stipulates pH not < 7 and not > 8.7

	NA		Not analyzed - Due to a laboratory error, chlorine was not analyzed within the specified holding time

15) Significant figures are those reported by the laboratory

16) Station DP01 is a tidally influenced freshwater ditch discharging to the marine waters of the intercauseway area. As such, parameters have been compared to the marine criteria and not freshwater criteria.

Table 14

2007 Sediment Chemistry Results
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

	Location:	DP01				DP02				DP03			
	Sample:	SDDP01-1	SDDP01-2	SDDP01-3	SDDP01-4	SDDP02-1	SDDP02-2	SDDP02-3	SDDP02-4	SDDP03-1	SDDP03-2	SDDP03-3	SDDP03-4
	Date:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2007-03-23	2007-06-21	2007-10-02	2007-12-10
	Depth Interval Sampled:	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	**CSR SedQC$_{SS}$ [1,2]**												
Field Observation													
Odour		sulphide	sulphide	sulphide	sulphide	none	none	none	none	none	none	none	none
Physical Tests													
Moisture (%)	-	36.9	44	30.8	23.6	28.0	32.2	33	34	25.5	31.2	30.4	29.5
ORP (mV)	-	-150	50	-120	-100	-170	-	<-200	-170	-170	-	-170	-150
pH	-	8.03	7.89	8.01	7.75	7.92	7.74	8.17	8.04	7.99	7.9	8.13	7.83
Organics													
Organic Nitrogen N (%)	-	0.13	0.11	0.08	0.05	0.06	0.05	<0.02	0.03	0.06	0.04	0.04	0.03
Total Organic Carbon (%)	-	0.98	1.12	0.7	0.7	0.16	0.29	0.1	0.2	0.27	0.24	0.3	0.3
Total Inorganics													
Ammonia	-	5.9	8.7	3.1	2	3.9	7.3	8.1	4.3	8.7	6.5	11.4	4.3
Phosphate	-	610	795	580	590	730	764	670	630	690	708	630	680
Sulphide	-	95.0	97.5	<0.19	0.33	1.15	9.74	4.16	0.55	5.73	25.4	0.6	0.43
Total Kjeldahl Nitrogen N (%)	-	0.13	0.12	0.08	0.05	0.06	0.05	<0.02	0.03	0.06	0.04	0.04	0.03
Total Nitrogen N (%)	-	0.10	0.14	0.06	0.07	0.04	0.04	0.04	0.03	0.06	0.04	0.04	0.04
Total Metals													
Aluminum	-	14000	14000	10700	11000	8680	10300	10200	17400	9280	10100	9500	10300
Antimony	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	26	5.4	5.7	5.0	5.0	5	5.4	5.1	5.0	5.6	5.6	5.8	5.2
Barium	-	44.8	43.7	25.5	40	24.3	35.7	28.4	91.8	28.1	30.5	28.5	32.9
Beryllium	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Bismuth	-	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Cadmium	2.6	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Calcium	-	5960	6140	5860	6140	5020	6140	5750	5330	5000	5360	5220	5310
Chromium	99	35.7	35.9	18.5	23.1	33.9	39.1	32.4	16.8	36.5	34.8	31.8	34.0
Cobalt	-	10.6	10.7	6	6.3	9.1	10.4	9.8	8.1	9.0	8.9	8.6	9.1
Copper	67	23.1	23.1	14.2	63.7	8.6	10.8	10.4	28.4	9.8	10.3	9.7	11.2
Iron	-	27500	25800	17800	20000	23000	24200	22000	22900	24200	23400	21800	23200
Lead	69	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Lithium	-	16.8	17.0	10.6	10.6	9.8	11.6	12	8.5	9.9	11.2	10.9	11.8
Magnesium	-	10400	10700	7080	6450	8020	9520	9370	4930	8190	8810	8420	7960
Manganese	-	292	281	257	254	240	278	246	403	236	247	239	267
Mercury	0.43	0.0464	0.0476	0.0249	0.0208	0.0233	0.0284	0.0276	0.0453	0.0211	0.0283	0.0213	0.0627
Molybdenum	-	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Nickel	-	33.4	34.6	17.4	20.5	30.0	33.5	31	11.7	30.1	31.0	28.8	33.8
Potassium	-	1970	1900	1180	1060	990	1240	1320	950	1130	1270	1210	1140
Selenium	-	<2.0	<3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Silver	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sodium	-	5570	6570	4250	3640	3320	3650	5630	340	4200	4200	5440	3800
Strontium	-	42.9	41.8	28.9	38.6	28.7	32.9	28.2	41.7	29.6	30.7	27.4	31.8
Thallium	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tin	-	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Titanium	-	959	864	673	786	828	931	784	792	865	851	724	838
Vanadium	-	49.1	49.4	42.9	40.2	49.3	54.3	49.9	49	53.8	50.6	49.5	49.4
Zinc	170	62.8	65.6	41.3	60.3	44.5	52.4	48.1	54.9	46.3	49.4	46.4	50.2
Organotin	**PSSDA [3]**												
Tributyltin	0.073	<0.001	-	-	-	<0.001	-	-	-	<0.001	-	-	-
Dibutyltin	-	<0.001	-	-	-	<0.001	-	-	-	<0.001	-	-	-
Monobutyltin	-	<0.001	-	-	-	<0.001	-	-	-	<0.001	-	-	-

	Location:	DP04				DP05				DP06				DP07			
	Sample:	SDDP04-1	SDDP04-2	SDDP04-3	SDDP04-4	SDPP05-1	SDDP05-2	SDDP05-3	SDDP05-4	SDDP06-1	SDDP06-2	SDDP06-3	SDDP06-4	SDDP07-1	SDDP07-2	SDDP07-3	SDDP07-4
	Date:	2007-03-23	2007-06-20	2007-10-02	2007-12-10	2007-03-24	2007-06-20	2007-10-02	2007-12-10	2007-03-23	2007-06-20	2007-10-01	2007-12-10	2007-03-24	2007-06-20	2007-10-01	2007-12-10
	Depth Interval Sampled:	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	**CSR SedQC$_{SS}$ [1,2]**																
Field Observation																	
Odour		none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Physical Tests																	
Moisture (%)	-	36.8	41.5	33.3	33.6	46.7	54.4	51.5	52	30.4	32.6	32.4	27.2	28.5	29.4	26.1	26.3
ORP (mV)	-	-200	-220	-190	-120	-160	-200	<-200	<-200	-60	-50	-20	-140	-110	-170	<-200	-170
pH	-	7.86	8.55	8.21	7.88	8.17	7.98	8.1	7.86	7.87	7.92	7.99	7.95	8.04	8.16	8.13	8.1
Organics																	
Organic Nitrogen N (%)	-	0.07	0.08	0.05	0.06	-	0.15	0.19	0.16	0.04	0.03	0.05	0.03	-	<0.02	0.05	0.02
Total Organic Carbon (%)	-	0.39	0.58	0.4	0.5	1.72	1.66	1.9	1.8	0.32	0.46	0.5	0.4	0.55	0.25	0.4	0.2
Total Inorganics																	
Ammonia	-	10.9	12.3	9.6	6.2	17.9	9	4.9	6.1	2.0	1.7	2.8	2	3.1	2.2	2.9	1.4
Phosphate	-	650	712	540	660	610	812	720	800	730	733	710	740	590	613	580	530
Sulphide	-	2.58	8.25	39.9	8.76	46.2	101	61.6	9.1	0.24	0.21	<0.17	<0.18	1.59	1.42	12.5	2.87
Total Kjeldahl Nitrogen N (%)	-	0.07	0.08	0.07	0.06	-	0.15	0.19	0.17	0.04	0.03	0.05	0.03	-	<0.02	0.05	0.02
Total Nitrogen N (%)	-	0.07	0.08	0.05	0.04	0.19	0.16	0.17	0.14	0.03	0.04	0.04	0.04	0.04	0.03	0.05	<0.02
Total Metals																	
Aluminum	-	9420	10600	9850	10800	16500	17000	13400	17900	11500	15000	14800	14500	12300	12500	12500	12200
Antimony	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	26	6.7	5.1	6	5.5	5	6.5	5	6.1	6.3	7.1	7	6.7	<5.0	7.0	6.6	5.7
Barium	-	26.8	30	25.3	36.2	49.2	51.2	40.3	60.8	47.0	69.4	60.1	65.4	44.8	45.8	45.9	46.3
Beryllium	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Bismuth	-	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Cadmium	2.6	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Calcium	-	4530	5560	5200	6000	8070	8390	8240	9810	5660	7110	7750	7210	5760	6270	6970	6480
Chromium	99	38.1	30.7	29	30.4	40.2	38.9	30.3	42.1	39.5	38.1	36.9	38.9	37.3	34.1	34.1	35.4
Cobalt	-	8.0	8.1	7.7	7.9	10.6	10.6	7.7	10.3	11.5	12.8	12.4	11.8	10.3	10.1	10.4	9.8
Copper	67	11.8	13.6	12.7	15.1	36.8	37.8	29.8	38.2	18.3	26	30.8	25.9	20.2	17.2	22	17.9
Iron	-	20400	20400	18800	20200	30000	28700	22200	28600	27900	28500	29500	27300	25500	22600	24300	22800
Lead	69	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Lithium	-	10.5	11.6	11.6	12.3	20.7	21.4	17.7	22.8	12.2	15.5	18.2	16.4	13.5	11.8	13.9	12.4
Magnesium	-	7670	9040	8690	7940	12200	12400	10200	11600	9720	11300	11900	10100	10300	9650	10400	9010
Manganese	-	226	226	217	250	330	318	246	341	376	472	416	386	329	309	313	319
Mercury	0.43	0.0245	0.0288	0.0227	0.0281	0.0592	0.0686	0.0805	0.0608	0.0326	0.0629	0.0474	0.2010	0.0372	0.0316	0.0346	0.0317
Molybdenum	-	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Nickel	-	33.2	29.8	28.3	31.7	39.7	37.3	27.1	42.5	37.7	41.5	39	44.7	39.2	35.7	36	41.2
Potassium	-	1310	1560	1440	1420	2590	2510	2230	2600	1230	1490	1560	1490	1480	1310	1390	1160
Selenium	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Silver	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sodium	-	4240	8350	6950	6050	11300	10800	11200	11800	3110	3390	4300	3510	5080	4110	4810	3020
Strontium	-	30.4	34.8	27.4	38.5	47.7	49.5	41.8	58.7	36.7	41.6	40.4	43.9	33.8	31.4	32.3	33.9
Thallium	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tin	-	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Titanium	-	774	732	690	808	910	884	734	995	921	850	816	917	811	835	791	928
Vanadium	-	41.7	44.7	44.2	43.8	56.8	56	46.1	54.6	56.6	55.4	55.4	53	51.6	50.1	51.4	51.3
Zinc	170	42.6	48.7	44.1	47.4	74.7	72.8	55.4	72.4	53.0	65.7	64.9	60.6	54.3	48.6	54.2	47.2
Organotin	**PSSDA [3]**																
Tributyltin	0.073	<0.001	-	-	-	0.002	-	-	-	<0.001	-	-	-	<0.001	-	-	-
Dibutyltin	-	<0.001	-	-	-	<0.001	-	-	-	<0.001	-	-	-	<0.001	-	-	-
Monobutyltin	-	<0.001	-	-	-	<0.001	-	-	-	<0.001	-	-	-	<0.001	-	-	-

Table 14
2007 Sediment Chemistry Notes
Deltaport Third Berth
Adaptive Management Strategy
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All values are reported as µg/g unless otherwise noted

- = No standard or not analyzed

(1) CSR = BC Environmental Management Act, Contaminated Sites Regulation, B.C. Reg. 375/96, including amendments up to B.C. Reg. 239/2007, effective July 1, 2007

(2) CSR SedQC(SS) Marine = Schedule 9, Column IV, Marine and Estuarine Sediment, Sensitive Site

(3) PSDDA = Puget Sound Dredged Disposal Analysis

Table 15
2007 Grain Size Results
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

Location:	DP01	DP02	DP03	DP04	DP04	RPD	DP05	DP06	DP07
Sample:	SDDP01-1	SDDP02-1	SDDP03-1	SDDP04-1	SDDP19-1	(%)	SDPP05-1	SDDP06-1	SDDP07-1
Sampled:	2007-03-22	2007-03-22	2007-03-23	2007-03-23	2007-03-23		2007-03-24	2007-03-23	2007-03-24
Parameter									
Sample Info									
Field Depth From Water Surface (m)	0	1.5	1.0	3	-	-	11	8.5	14
Grain Size									
% Gravel (>2mm)	3	<1	<1	<1	<1	-	<1	<1	<1
% Sand (2.0mm - 0.063mm)	57	95	94	91	91	0.0	44	78	78
% Silt (0.063mm - 4um)	30	3	3	6	5	18.2	41	16	15
% Clay (<4um)	10	2	3	4	4	0.0	16	7	7

Table 16
2007 Benthic Community Sampling Results
Deltaport Third Berth
Adaptive Management Strategy
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Hemmera - Vancouver Port Authority Data 2007

TAXON	No. of individuals			02A-1 (1.0)			02B-1 (1.0)			02C-1 (1.0)			Proportion	03A-1 (1.0)			03B-1 (1.0)			03C-1 (1.0)			Proportion	04A-1 (1.0)			04B-1 (1.0)			04C-1 (1.0)		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	for DP02	A	Int	J	A	Int	J	A	Int	J	for DP03	A	Int	J	A	Int	J	A	Int	J
CNIDARIA																																
Hydrozoa																																
Campanularia groenlandica		8																														
Obelia dichotoma	2																										1			1		
Anthozoa																																
Edwardsiidae indet.	1		1																													
PLATYHELMINTHES																																
Pseudostylochus burchami	3																										1			2		
NEMERTEA																																
Cerebratulus californiensis	3	6	2																													
Lineus bilineatus	2		1																													
Lineidae indet.			1																													
Nemertea indet.			2																													
Paranemertes sp.			1																													
Tetrastemmidae indet.																																
Tubulanus polymorphus	3	1	1																													
ANNELIDA																																
Polychaeta Errantia																																
Diopatra ornata		1																														
Epidiopatra hupferiana monroi	1	2																														
Eteone californica	15	8		2			7	8		5			0.032	1									0.004									
Eteone spilotus	1																															
Eulalia quadrioculata	2																													2		
Glycera nana	11	7	5																													
Glycera pacifica	1																															
Glycinde armigera	5	6	1																													
Glycinde polygnatha	3	5																										1				
Glycinde spp.																																
Harmothoe spp.																																
Lumbrineris cruzensis	9																															
Micropodarke dubia	1																										1					
Nephtys caecoides	2	1																						1			1	1				
Nephtys cornuta	70	4																														
Nephtys ferruginea	3																															
Onuphis geophiliformis	1																							1								
Pholoe glabra	2	3																														
Pholoe minuta	1	3																														
Phyllodoce hartmanae	1																															
Phyllodoce williamsi	1																													1		
Phyllodoce spp.			1																													
Pilargis berkeleyae	1	3																														
Platynereis bicanaliculata	22	32	6																					7	15	3	7	8	3	8	7	
Podarkeopsis glabrus	1	6																														
Scoletoma luti	24	5	1		1								0.001																			
Sphaerosyllis ranunculus																																
Sphaerodoropsis sphaerulifer																																

Table 16
2007 Benthic Community Sampling Results
Deltaport Third Berth
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Hemmera - Vancouver Port Authority Data 2007

	No. of individuals			02A-1 (1.0)			02B-1 (1.0)			02C-1 (1.0)			Proportion	03A-1 (1.0)			03B-1 (1.0)			03C-1 (1.0)			Proportion	04A-1 (1.0)			04B-1 (1.0)			04C-1 (1.0)		
TAXON	A	Int	J	A	Int	J	A	Int	J	A	Int	J	for DP02	A	Int	J	A	Int	J	A	Int	J	for DP03	A	Int	J	A	Int	J	A	Int	J
Polychaeta Sedentaria																																
Ampharete labrops	28	8	1																					11	1	1	13	3		4	4	
Ampharete spp.			2																													
Aphelochaeta sp. 2	2	3																														
Aphelochaeta spp.																																
Arenicolidae indet.			14			1			4			5	0.015			1						3	0.015									
Aricidea wassi																																
Armandia brevis	45	31		11	7		15	11		5	4		0.077	4	3		6	1		1	4		0.069		1					3		
Barantolla nr. *americana*																																
Boccardia polybranchia		1	1																													
Capitella capitata complex	2	1			1								0.001														1			1		
Cirratulus spectabilis	2																							1						1		
Cossura pygodactylata	16																															
Decamastus nr. *gracilis*	16	2																														
Dipolydora nr. *quadrilobata*			1																1				0.004									
Dipolydora spp.		8	40																													
Euclymene nr. *zonalis*	7	3																														
Euclymeninae indet.			1																													
Galathowenia oculata	10	1																						1								
Heteromastus filobranchus	23	7	1																													
Lanassa venusta venusta																																
Laonice spp.																																
Leitoscoloplos pugettensis	36																							2			2			1		
Levinsenia gracilis	1																															
Magelona longicornis			6																													
Mediomastus ambiseta	1	2																														
Mediomastus californiensis	24	6	1																								5	1				
Monticellina spp.			1																													
Notomastus spp.		1																														
Ophelina acuminata																																
Owenia nr. collaris	3																															
Owenia nr. *johnsoni*	127									1			0.001							1			0.004	42			45			35		
Paraprionospio pinnata	16	10	6																													
Pectinaria californiensis	4																															
Pectinaria granulata	3																													1		
Polycirrus sp. I (Banse 1980)	1																															
Polydora cornuta	1						1						0.001																			
Polydora sp.			1																													
Prionospio (Prionospio) jubata		1																														
Prionospio (Minuspio) lighti	23	2	5					1					0.001														1			1		
Prionospio (Minuspio) multibranchiata	1																							1								
Prionospio (Prionospio) steenstrupi	5	1																														
Pseudopolydora kempi	23	5		5			4			14	1		0.035																			
Pseudopolydora paucibranchiata	78	7	2	9	2		12	1		23			0.069	4	2		3	1		9		1	0.073	3			10	1		5		
Pseudopolydora spp.		1																														
Pygospio elegans	132	9	111	13		3	28			71	9	108	0.338	15			2			1			0.066									
Rhynchospio glutaea	33			1									0.001	10						2			0.044	5			10			5		
Scoloplos acmeceps	7	2																										1			1	
Scoloplos armiger			1													1							0.004									
Spio cirrifera	1																															
Spionidae indet.																																
Spiophanes berkeleyorum		3	1																													
Sternaspis nr. *fossor*	2																															
Terebellides spp.																																
Tharyx parvus	231	57	4	19			98	10		23	29	4	0.267	61	18		10			18			0.391	1			1					

Table 16
2007 Benthic Community Sampling Results
Deltaport Third Berth
Adaptive Management Strategy
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Hemmera - Vancouver Port Authority Data 2007

TAXON	No. of individuals			02A-1 (1.0)			02B-1 (1.0)			02C-1 (1.0)			Proportion for DP02	03A-1 (1.0)			03B-1 (1.0)			03C-1 (1.0)			Proportion for DP03	04A-1 (1.0)			04B-1 (1.0)			04C-1 (1.0)		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J		A	Int	J	A	Int	J	A	Int	J		A	Int	J	A	Int	J	A	Int	J
Oligochaeta																																
Enchytraeidae indet.			*8*									8	0.012																			
Tubificoides brevicolus																																
Tubificidae indet. Group 5	*10*	*11*	*1*				2				1		0.004	2									0.007				5	7	1	1	1	
Limnodriloides victoriensis	*1*																															
Limnodriloides sp.																																
Tectidrilus diversus	*1*																							1								
Tectidrilus spp.		*13*	*2*																												7	2
Hirudinoidea																																
Notostomum sp.	*1*																															
ECHIURA																																
Arhynchite pugettensis			*2*																													
Echiuridae indet.			*1*																													
MOLLUSCA																																
Gastropoda																																
Aeolidacea indet.																																
Alvania compacta	*79*																							21			17			14		
Amphissa versicolor	*4*	*10*	*1*		1			4		1	2		0.012				1	1		1	2	1	0.022	1								
Amphissa sp.		*1*													1								0.004									
Astyris gausapata	*1*	*1*																														
Batillaria cumingi	*1*	*1*					1						0.001								1		0.004									
Cyclostremella concordia			*8*																							2			5			1
Cylichna culcitella		*1*			1								0.001																			
Cylichnella sp.			*1*													1							0.004									
Haminoea vesicula		*1*	*1*																		1		0.004									
Haminoea sp.																																
Lacuna vincta		*3*																							1			1			1	
Lacuna sp.			*1*																													1
Lottia parallela	*43*	*26*																						8	8		18	4		17	14	
Odostomia sp.																																
Turbonilla sp.	*1*	*1*																														
Volvulella sp.			*2*																													
Bivalvia																																
Acila castrensis		*1*																														
Axinopsida serricata	*165*	*25*																														
Bivalvia indet.																																
Cardiidae indet.			*1*																													1
Clinocardium nuttallii		*1*	*5*																						1				1			1
Clinocardium sp.			*1*																													
Compsomyax subdiaphana			*3*																													
Ennucula tenuis		*59*	*7*																													
Lucinoma annulatum			*2*																													
Lyonsia californica																																
Macoma balthica		*7*	*33*																													
Macoma carlottensis		*41*	*30*																													
Macoma elimata		*2*																														
Macoma nasuta			*76*																							8			33			10
Macoma sp.		*1*	*51*													8			6			23	0.135									
Megayoldia martyria			*1*																													
Modiolus modiolus			*118*			1							0.001			1						2	0.011			28			32			54
Mya arenaria			*16*									1	0.001			1						1	0.007									
Mytilidae indet.			*1*																													1
Nemocardium centifilosum			*1*																			1	0.004									
Nuculana hamata			*1*																													
Nuculana sp.																																
Nutricola tantilla	*5*	*37*			1								0.001														1	5		1	3	
Nutricola sp.																																
Nuttallia obscurata			*1*																													
Parvilucina tenuisculpta	*11*	*32*	*1*																													
Protothaca tenerrima			*2*																										2			
Rochefortia tumida	*316*	*55*																						89	15		86	17		91	14	
Rochefortia sp.																																
Tellina modesta	*2*	*18*	*8*																								2	1	3		3	
Tellina sp.																																
Venerupis philippinarum			*4*									3	0.004			1							0.004									
Yoldia seminuda		*2*																														
Scaphopoda																																
Pulsellum salishorum	*2*																															

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TAXON	No. of individuals			02A-1 (1.0)			02B-1 (1.0)			02C-1 (1.0)			Proportion	03A-1 (1.0)			03B-1 (1.0)			03C-1 (1.0)			Proportion	04A-1 (1.0)			04B-1 (1.0)			04C-1 (1.0)		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	for DP02	A	Int	J	A	Int	J	A	Int	J	for DP03	A	Int	J	A	Int	J	A	Int	J
ARTHROPODA																																
CHELICERATA																																
Pycnogonida																																
Anoplodactylus viridintestinalis	87	5																						43	1		20			24	3	
Acarida																																
Hydracarina indet.	8	3																						1			5	3		2		
CRUSTACEA																																
Copepoda																																
Cyclopoida indet.	2																															
Harpacticoida indet.	58	1		2	1					3			0.009														50			3		
Ostracoda																																
Bathyleberis sp.	2																															
Cyprideis sp.	12																										12					
Euphilomedes carcharodonta	4	2																														
Euphilomedes producta																																
Ostracoda indet.																																
Philomedes dentata																																
Cirripedia																																
Semibalanus balanoides		1																										1				
Cumacea																																
Cumella vulgaris	5									1			0.001	1									0.004	1								
Hemilamprops californicus	1																										1					
Eudorella pacifica																																
Leucon subnasica																																
Tanaidacea																																
Leptochelia savigyni	321	20			1								0.001											154	8		92	6		75	5	
Isopoda																																
Idotea rescata	3																							3								
Munna ubiquita	1																										1					
Synidotea nodulosa		1																										1				
Amphipoda																																
Americhelidium shoemakeri	4																										4					
Americorophium brevis	1																															
Anisogammarus pugettensis	1	2	1															2		1		1	0.015									
Caprella laeviuscula	35	18	16																					18	8	16	12	4		5	6	
Caprella sp.			52																										21			31
Chromopleustes oculatus	1																															
Eobrolgus chumashi	3						1						0.001				1						0.004	1								
Grandidierella japonica	38	23		2	2		8	6		13	7		0.055	4	1					10	7		0.080				1					
Heterophoxus affinis	1																															
Ischyrocerus anguipes	3																							3								
Monocorophium acherusicum	5	4					3	1					0.006							2	3		0.018									
Monocorophium insidiosum	26	5		2	1		17	2		7	2		0.045																			
Orchomene decipens	1																															
Pachynus barnardi	1																															
Photis brevipes	180	13	8																					71	6		63	4	8	46	3	
Photis sp.																																
Pontogeneia rostrata	2	1																						1	1		1					
Protomedeia grandimana	1																															
Protomedeia sp.			1																													
Rhepoxynius boreovariatus	11																															
Rhepoxynius fatigans																																
Rhepoxynius sp.																																
Wecomedon wecomus	2																															
Wecomedon sp.																																
Decapoda																																
Cancer gracilis		1																													1	
Pagarus sp.		1																													1	
Pinnixa schmitti	6	3																						1								
PHORONIDA																																
Phoronis muelleri																																
BRYOZOA																																
Celleporella hyalina	1																													1		
ECHINODERMATA																																
Ophiuroidea																																
Amphiodia urtica	9	11																														
Amphiodia sp.		3	10																												2	
Ophiura sp.			10																													
Echinoidea																																
Strongylocentrotus droebachiensis			1													1							0.004									
Total Number of Organisms by Stage	2575	741	713	66	19	5	197	44	4	167	55	129		102	25	15	23	5	7	46	18	33		493	66	58	490	70	109	351	76	102
Total Number of Organisms	4029			90			245			351				142			35			97				617			669			529		
Total Number of Taxa	455			18			16			17				18			9			17				34			42			39		

NOTES: Nematodes were present in most samples but because the numbers are unrealiable they were not included in the data set.

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TAXON	Proportion for DP04	05A-1 (1.0)			05B-1 (1.0)			05C-1 (1.0)			Proportion for DP05	06A-1 (1.0)			06B-1 (1.0)			06C-1 (1.0)			Proportion for DP06	07A-1 (1.0)			07B-1 (1.0)			07C-1 (1.0)			Proportion for DP07
		A	Int	J	A	Int	J	A	Int	J		A	Int	J	A	Int	J	A	Int	J		A	Int	J	A	Int	J	A	Int	J	
											0										0										0
CNIDARIA											0										0										0
Hydrozoa											0										0										0
Campanularia groenlandica											0										0								8		0.022
Obelia dichotoma	0.001										0										0										0
Anthozoa											0										0										0
Edwardsiidae indet.											0										0			1				1			0.005
											0										0										0
PLATYHELMINTHES											0										0										0
Pseudostylochus burchami	0.002										0										0										0
											0										0										0
NEMERTEA											0										0										0
Cerebratulus californiensis		1	1		1	1	1			1	0.007										0					3		1	1		0.014
Lineus bilineatus											0										0	1					1	1			0.008
Lineidae indet.											0										0									1	0.003
Nemertea indet.											0										0			1						1	0.005
Paranemertes sp.											0										0			1							0.003
Tetrastemmidae indet.											0										0										0
Tubulanus polymorphus					1			1			0.002										0	1	1	1							0.008
											0										0										0
ANNELIDA											0										0										0
Polychaeta Errantia											0										0										0
Diopatra ornata											0										0		1								0.003
Epidiopatra hupferiana monroi											0										0				1	2					0.008
Eteone californica											0										0										0
Eteone spilotus											0										0	1									0.003
Eulalia quadrioculata	0.001										0										0										0
Glycera nana		3	2		2	2			1		0.012										0	4	2				2	2		3	0.035
Glycera pacifica								1			0.001										0										0
Glycinde armigera			2		1			3	4		0.012										0				1					1	0.005
Glycinde polygnatha	0.001		3		3						0.007										0					1					0.003
Glycinde spp.											0										0										0
Harmothoe spp.											0										0										0
Lumbrineris cruzensis		2			4			3			0.011										0										0
Micropodarke dubia	0.001										0										0										0
Nephtys caecoides	0.002										0										0										0
Nephtys cornuta		11			51			5			0.081										0	1			2	4					0.019
Nephtys ferruginea					1			1			0.002										0	1									0.003
Onuphis geophiliformis	0.001										0										0										0
Pholoe glabra		1				3					0.005										0							1			0.003
Pholoe minuta						3					0.004										0							1			0.003
Phyllodoce hartmanae					1						0.001										0										0
Phyllodoce williamsi	0.001										0										0										0
Phyllodoce spp.											0										0						1				0.003
Pilargis berkeleyae						1		1	1		0.004										0								1		0.003
Platynereis bicanaliculata	0.032		2								0.002										0										0
Podarkeopsis glabrus					1	6					0.009										0										0
Scoletoma luti		6	1		5	1		3		1	0.021										0	6	2		3			1			0.033
Sphaerosyllis ranunculus											0										0										0
Sphaerodoropsis sphaerulifer											0										0										0

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	Proportion	05A-1 (1.0)			05B-1 (1.0)			05C-1 (1.0)			Proportion	06A-1 (1.0)			06B-1 (1.0)			06C-1 (1.0)			Proportion	07A-1 (1.0)			07B-1 (1.0)			07C-1 (1.0)			Proportion
TAXON	for DP04	A	Int	J	A	Int	J	A	Int	J	for DP05	A	Int	J	A	Int	J	A	Int	J	for DP06	A	Int	J	A	Int	J	A	Int	J	for DP07
Polychaeta Sedentaria											0										0										0
Ampharete labrops	0.020										0										0										0
Ampharete spp.				1						1	0.002										0										0
Aphelochaeta sp. 2			1		1	2		1			0.006										0										0
Aphelochaeta spp.											0										0										0
Arenicolidae indet.											0										0										0
Aricidea wassi											0										0										0
Armandia brevis	0.002										0										0										0
Barantolla nr. *americana*											0										0										0
Boccardia polybranchia											0										0								1	1	0.005
Capitella capitata complex	0.001										0										0										0
Cirratulus spectabilis	0.001										0										0										0
Cossura pygodactylata		1			13			2			0.019										0										0
Decamastus nr. *gracilis*											0										0	3			5	2		8			0.049
Dipolydora nr. *quadrilobata*											0										0										0
Dipolydora spp.							2				0.002										0		1	7		7	27			4	0.125
Euclymene nr. *zonalis*		1	1		5				2		0.011										0							1			0.003
Euclymeninae indet.							1				0.001										0										0
Galathowenia oculata	0.001				2						0.002										0	5			1	1		1			0.022
Heteromastus filobranchus		6			5	2		6	3		0.027										0	2	2	1				4			0.024
Lanassa venusta venusta											0										0										0
Laonice spp.											0										0										0
Leitoscoloplos pugettensis	0.003				3			1			0.005										0	16			4			7			0.073
Levinsenia gracilis					1						0.001										0										0
Magelona longicornis											0										0			1			5				0.016
Mediomastus ambiseta											0										0		2		1						0.008
Mediomastus californiensis	0.003										0										0	3	1		15	3	1	1	1		0.068
Monticellina spp.											0										0									1	0.003
Notomastus spp.						1					0.001										0										0
Ophelina acuminata											0										0										0
Owenia nr. collaris		1						2			0.004										0										0
Owenia nr. *johnsoni*	0.067				3						0.004										0										0
Paraprionospio pinnata		7	5		5		4	3	5	2	0.038										0							1			0.003
Pectinaria californiensis		1						1			0.002										0							2			0.005
Pectinaria granulata	0.001										0										0							2			0.005
Polycirrus sp. I (Banse 1980)					1						0.001										0										0
Polydora cornuta											0										0										0
Polydora sp.											0										0						1				0.003
Prionospio (Prionospio) jubata											0										0		1								0.003
Prionospio (Minuspio) lighti	0.001	1			17	1					0.023										0			5	1			2			0.022
Prionospio (Minuspio) multibranchiata	0.001										0										0										0
Prionospio (Prionospio) steenstrupi		2			1						0.004										0	2				1					0.008
Pseudopolydora kempi											0					3			1		0.065										0
Pseudopolydora paucibranchiata	0.010										0						1				0.016										0
Pseudopolydora spp.											0								1		0.016										0
Pygospio elegans											0				2						0.032										0
Rhynchospio glutaea	0.011										0										0										0
Scoloplos acmeceps	0.001	5						2			0.009										0										0
Scoloplos armiger											0										0										0
Spio cirrifera											0										0				1						0.003
Spionidae indet.											0										0										0
Spiophanes berkeleyorum			1			2	1				0.005										0										0
Sternaspis nr. *fossor*					1			1			0.002										0										0
Terebellides spp.											0										0										0
Tharyx parvus	0.001										0										0										0

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TAXON	Proportion for DP04	05A-1 (1.0)			05B-1 (1.0)			05C-1 (1.0)			Proportion for DP05	06A-1 (1.0)			06B-1 (1.0)			06C-1 (1.0)			Proportion for DP06	07A-1 (1.0)			07B-1 (1.0)			07C-1 (1.0)			Proportion for DP07
		A	Int	J	A	Int	J	A	Int	J		A	Int	J	A	Int	J	A	Int	J		A	Int	J	A	Int	J	A	Int	J	
Oligochaeta											0										0										0
Enchytraeidae indet.											0										0										0
Tubificoides brevicolus											0										0										0
Tubificidae indet. Group 5	0.008										0										0		2								0.005
Limnodriloides victoriensis											0										0	1									0.003
Limnodriloides sp.											0										0										0
Tectidrilus diversus	0.001										0										0										0
Tectidrilus spp.	0.005										0										0		6								0.016
											0										0										0
Hirudinoidea											0										0										0
Notostomum sp.											0										0				1						0.003
											0										0										0
ECHIURA											0										0										0
Arhynchite pugettensis											0										0			1			1				0.005
Echiuridae indet.											0										0						1				0.003
											0										0										0
MOLLUSCA											0										0										0
Gastropoda											0										0										0
Aeolidacea indet.											0										0										0
Alvania compacta	0.029	14			9			4			0.033										0										0
Amphissa versicolor	0.001										0										0										0
Amphissa sp.											0										0										0
Astyris gausapata											0										0	1							1		0.005
Batillaria cumingi											0										0										0
Cyclostremella concordia	0.004										0										0										0
Cylichna culcitella											0										0										0
Cylichnella sp.											0										0										0
Haminoea vesicula							1				0.001										0										0
Haminoea sp.											0										0										0
Lacuna vincta	0.002										0										0										0
Lacuna sp.	0.001										0										0										0
Lottia parallela	0.038										0										0										0
Odostomia sp.											0										0										0
Turbonilla sp.		1	1								0.002										0										0
Volvulella sp.							2				0.002										0										0
Bivalvia											0										0										0
Acila castrensis									1		0.001										0										0
Axinopsida serricata		69	10		37	8		42	6		0.209										0	12	1		3			2			0.049
Bivalvia indet.											0										0										0
Cardiidae indet.	0.001										0										0										0
Clinocardium nuttallii	0.002			1						2	0.004										0										0
Clinocardium sp.										1	0.001										0										0
Compsomyax subdiaphana										2	0.002										0			1							0.003
Ennucula tenuis			19	2		12	1		27	4	0.079										0								1		0.003
Lucinoma annulatum							2				0.002										0										0
Lyonsia californica											0										0										0
Macoma balthica											0		1	8		6	12			13	0.645										0
Macoma carlottensis			16	13		4	6		19	11	0.084										0								2		0.005
Macoma elimata						1					0.001										0								1		0.003
Macoma nasuta	0.028			4						6	0.012										0						2			13	0.041
Macoma sp.							1				0.001										0		1	3			10				0.038
Megayoldia martyria				1							0.001										0										0
Modiolus modiolus	0.063										0										0										0
Mya arenaria											0			2			3			7	0.194									1	0.003
Mytilidae indet.	0.001										0										0										0
Nemocardium centifilosum											0										0										0
Nuculana hamata										1	0.001										0										0
Nuculana sp.											0										0										0
Nutricola tantilla	0.006	1	7			7		1	4		0.024										0	1				2			8		0.030
Nutricola sp.											0										0										0
Nuttallia obscurata											0			1							0.016										0
Parvilucina tenuisculpta		4	15	1	1	10		6	7		0.053										0										0
Protothaca tenerrima	0.001										0										0										0
Rochefortia tumida	0.172	29	3		10	2		11	4		0.072										0										0
Rochefortia sp.											0										0										0
Tellina modesta	0.005		7			1	1		3	1	0.016										0		1	1					2	2	0.016
Tellina sp.											0										0										0
Venerupis philippinarum											0										0										0
Yoldia seminuda											0										0		1						1		0.005
Scaphopoda											0										0										0
Pulsellum salishorum					1			1			0.002										0										0

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TAXON	Proportion for DP04	05A-1 (1.0) A	05A-1 (1.0) Int	05A-1 (1.0) J	05B-1 (1.0) A	05B-1 (1.0) Int	05B-1 (1.0) J	05C-1 (1.0) A	05C-1 (1.0) Int	05C-1 (1.0) J	Proportion for DP05	06A-1 (1.0) A	06A-1 (1.0) Int	06A-1 (1.0) J	06B-1 (1.0) A	06B-1 (1.0) Int	06B-1 (1.0) J	06C-1 (1.0) A	06C-1 (1.0) Int	06C-1 (1.0) J	Proportion for DP06	07A-1 (1.0) A	07A-1 (1.0) Int	07A-1 (1.0) J	07B-1 (1.0) A	07B-1 (1.0) Int	07B-1 (1.0) J	07C-1 (1.0) A	07C-1 (1.0) Int	07C-1 (1.0) J	Proportion for DP07
											0										0										0
ARTHROPODA											0										0										0
CHELICERATA											0										0										0
Pycnogonida											0										0										0
Anoplodactylus viridintestinalis	0.050		1								0.001										0										0
Acarida											0										0										0
Hydracarina indet.	0.006										0										0										0
CRUSTACEA											0										0										0
Copepoda											0										0										0
Cyclopoida indet.					2						0.002										0										0
Harpacticoida indet.	0.029										0										0										0
Ostracoda											0										0										0
Bathyleberis sp.											0										0	1			1						0.005
Cyprideis sp.	0.007										0										0										0
Euphilomedes carcharodonta											0										0	1			2	1		1	1		0.016
Euphilomedes producta											0										0										0
Ostracoda indet.											0										0										0
Philomedes dentata											0										0										0
Cirripedia											0										0										0
Semibalanus balanoides	0.001										0										0										0
Cumacea											0										0										0
Cumella vulgaris	0.001										0										0				2						0.005
Hemilamprops californicus	0.001										0										0										0
Eudorella pacifica											0										0										0
Leucon subnasica											0										0										0
Tanaidacea											0										0										0
Leptochelia savigyni	0.187										0										0										0
Isopoda											0										0										0
Idotea rescata	0.002										0										0										0
Munna ubiquita	0.001										0										0										0
Synidotea nodulosa	0.001										0										0										0
Amphipoda											0										0										0
Americhelidium shoemakeri	0.002										0										0										0
Americorophium brevis											0	1									0.016										0
Anisogammarus pugettensis											0										0										0
Caprella laeviuscula	0.038										0										0										0
Caprella sp.	0.029										0										0										0
Chromopleustes oculatus											0										0							1			0.003
Eobrolgus chumashi	0.001										0										0										0
Grandidierella japonica	0.001										0										0										0
Heterophoxus affinis					1						0.001										0										0
Ischyrocerus anguipes	0.002										0										0										0
Monocorophium acherusicum											0										0										0
Monocorophium insidiosum											0										0										0
Orchomene decipens											0										0							1			0.003
Pachynus barnardi											0										0				1						0.003
Photis brevipes	0.111										0										0										0
Photis sp.											0										0										0
Pontogeneia rostrata	0.002										0										0										0
Protomedeia grandimana											0										0							1			0.003
Protomedeia sp.											0										0			1							0.003
Rhepoxynius boreovariatus											0										0	1			8			2			0.030
Rhepoxynius fatigans											0										0										0
Rhepoxynius sp.											0										0										0
Wecomedon wecomus											0										0	1			1						0.005
Wecomedon sp.											0										0										0
Decapoda											0										0										0
Cancer gracilis	0.001										0										0										0
Pagarus sp.	0.001										0										0										0
Pinnixa schmitti	0.001	4			1				2		0.009										0								1		0.003
											0										0										0
PHORONIDA											0										0										0
Phoronis muelleri											0										0										0
											0										0										0
BRYOZOA											0										0										0
Celleporella hyalina	0.001										0										0										0
											0										0										0
ECHINODERMATA											0										0										0
Ophiuroidea											0										0										0
Amphiodia urtica		2	3		4	2		1	4		0.019										0	1						1	2		0.011
Amphiodia sp.	0.001			1			6				0.009										0					1	3				0.011
Ophiura sp.											0										0			3			2			5	0.027
Echinoidea											0										0										0
Strongylocentrotus droebachiensis											0										0										0
											0										0										0
Total Number of Organisms by Stage		173	101	24	195	72	29	103	93	33		1	1	11	2	9	16		2	20		66	25	28	54	28	57	46	32	33	
Total Number of Organisms		298			296			229				13			27			22				119			139			111			
Total Number of Taxa		36			47			37				4			5			4				38			33			41			

NOTES: Nematodes were present in most sar

Table 17
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Location	FamilyGroup	Family	Species	Tide_H/L	M	A	M	J	J	A	S	O	N	D
BC FERRIES	Coastal Waterbirds	Auks, Murres, Puffins	RHAU	H							1			
		Cormorant	DCCO	H	25	14	12	10	4	6	9	259	119	105
				L	10	17		5	2	7	3	433	85	
			PECO	H	6	13	21	42	5	8	4	2	3	3
				L		5	6	34	6	8	4		4	
			UNCO	H					1		1	1		
		Geese, Ducks, Swans	AMWI	H		3						266	4945	2404
				L	2	109						42	4710	
			BAGO	H		4								
			BRAN	H		346	85		1				2	66
				L		2764	500	6					676	
			BUFF	H	89	126	14						460	235
				L	103	102	22					1	416	
			CAGO	H			14	3						
				L				10					1	
			COGO	H	16	8	2	4	2	2	1		18	20
				L	1	5	8			4	1	1	34	
			COME	H		2		2						
				L		1		2						
			EUWI	H									52	
				L		2							25	
			GADW	L		4								
			GRSC	H	292	391	68	9	134	14	9	7	125	20
				L	266	716	34	6	21	22	4	29	42	
			GWTE	H	1	30						5	130	16
				L	34	629	14						100	
			HADU	H			1							
			LTDU	H									5	2
				L									9	
			MALL	H		20				21	14	41	2061	1188
				L		9			33	190	15	37	3780	
			NOPI	H		21	37					74	841	20
				L						10	42	163	878	
			NOSH	L		10								
			NOSL	H								10	15	
				L						1				
			RBME	H		3	6	1	1				7	3
				L	1	1							5	
			SNGO	L								110		
			SUSC	H	5	71	41		1	131	25	180	36	14
				L	4	106	18		24	245	47	100	53	
			TRSW	H				5						
			TRUS	L									1	
			UNDU	H	450						1		750	
				L									40	
			UNSC	H	4									
			WWSC	H		38	21			42	81	183	134	59
				L	13	9	2			8	39	599	118	
		Grebes	HOGR	H	1	13	1				33	107	45	17
				L	2	5	1			7	11	246	31	
			RNGR	H						3	8	1		1
				L						1		16	1	
			WEGR	H	1		1			3	42	200	375	126
				L			1			1	28	641	490	
		Loon	COLO	H		30	6	3	1	15	58	70	16	16
				L	1	15	1	1	2	11	32	155	19	
			PALO	H										1
				L					1					
			RTLO	H										2
		Skuas, Gulls, Terns, Skimmers	BOGU	L					2	1	1			
			CAGU	H	2	1	2	2		10	4			
				L					5	2	15		1	
			GWGU	H	24	1130	37	48	46	29	19	23	43	24
				L	25	42	34	95	47	21	8	70	83	
			HEGU	H	4		1		11				2	1
				L	20	2	2		1				3	
			MEGU	H	14	26						32	133	12
				L		181				4		92	116	
			RBGU	H		3		27	68	10	31	43	8	
				L		3		88	65	75	78	87	4	
			THGU	H								1	1	2
				L							1		2	
			UNGU	H	25	6	1	3		1				
				L	18	7	2		1				3	
			WEGU	H			1							
		Tern	CATE	H		1	11	4	39	7	1			
				L			20	21	6	24	2			
	Heron	Herons	GBHE	H	18	21	68	98	63	16	9		4	
				L		52	172	268	126	18	14	34	4	
	Other	Crows, Jays	Nocr	H	2	82	18	18	7	2			5	1
				L	4	3	3	5	3	13		1		
		Emberizids	HOSP	H				9						
				L				5						
			SAVS	H			6	6	2		8			
				L				2				1		
			WCSP	H				1						
				L				2	1					
		Finches	HOFI	H			1							
		Kingfishers	BEKI	L							2			
		Pigeons, Doves	ROPI	H				2				18		
				L					1					
		Starlings	EUST	H			6	5						
				L			4	2		8			11	
		Swallows	BARS	H			9	17	1	2				
				L			2	2						
			VGSW	H		2	1	1						
				L			1	3						
	Raptors	Caracaras, Falcons	PEFA	H										2
		Caracaras, Falcons Total												
		Hawks, Kites, Eagles	BAEA	H		5	6	5	2	1		1	1	2
				L	4	34	1	2	3				2	
			NOHA	H		1							1	
			OSPR	H				1		1				
				L				2						
	Shorebirds	Lapwings, Plovers	BBPL	H									1	
				L									1	
			KILL	H				2	9	9	4			
				L				4	8	9	4			
			SEPL	H		3			3					
				L		2								
		Oystercatchers	BLOY	H	18	4	7	15	9	1	2	1	2	5
				L	2	2	3	12	3	4		2	15	
		Sandpipers, Phalaropes	BLTU	H							3	17	7	
				L						35	8	68	33	
			DUNL	H		70							5598	2000
				L		10000							500	
			GRYE	H								1		
			LESA	H						1				
				L				2	5	2				
			MAGO	H				1						
				L		3		1						
			UNCA	H			2	13						
				L									30	
			WESA	H			92		51	12				
				L					358	12				
			WHIM	L				3						
DELTAPORT	Coastal Waterbirds	Auks, Murres, Puffins	COMU	H								1		1
		Cormorant	BRCO	H									10	
				L									5	
			DCCO	H	7	109	36	198	57	61	53	384	33	26
				L	31	15	106	104	26	32	47	716	70	
			PECO	H	23	35	26	5	3	7	7	5	2	10
				L	5	9	13	5	2	4	6	9	21	
			UNCO	H		1		4		6	4		1	10
				L									1	
		Geese, Ducks, Swans	AMWI	H	7							2329	12906	4596
				L	100	12						1467	16003	
			BAGO	H				1						
				L		10								
			BRAN	H	67	1162	19						30	164
				L	900	3210			9				240	

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Location	FamilyGroup	Family	Species	Tide_H/L	M	A	M	J	J	A	S	O	N	D
			BUFF	H	136	82	2	2					70	45
				L	1	54							129	
			CAGO	H		1	4		34			1		
				L					10	5			2	
			COGO	H	11	5	3						20	17
				L		5		1					4	
			COME	H			3							
			EUWI	H	8	2						7	35	51
				L	30	18						2	166	
			GRSC	H	49	99	339	17	24		2	20	181	164
				L	300	30	107	65	41	10		59	188	
			GWTE	H							50	2	65	
				L								9	45	
			HADU	L								2		
			MALL	H		40	7	1	9	441	1	27	576	283
				L	53	45			346	1585	4	42	1319	
			NOPI	H	38	286	10			10	404	3171	6197	531
				L	100	834			10	35	105	1652	5179	
			NOSL	L								5	5	
			RBME	H	9	7	20					1	4	
				L	7								6	
			SNGO	H								21		
				L								954		
			SUSC	H	5	12	175	70	197	547	76	120	33	45
				L	6	22	77			79	12	269	105	
			TRUS	L									5	
			UNDU	H	231	28	11		274			15	4002	650
				L							350	800	310	
			UNSC	H							1			
			WWSC	H							30	317	18	10
				L						9	112	179	101	
		Grebes	HOGR	H	10	10	1	1		36	18	48	16	12
				L	4	15		1			59	13	52	
			RNGR	H								3	5	
				L								1	3	
			WEGR	H	28	5						151	40	65
				L		34	4					30	164	
		Loon	COLO	H	9	13	3	1	1	8	8	63	17	22
				L	4	10	3		2	2	18	23	15	
			PALO	H									1	3
				L			1						1	
			RTLO	H									1	
		Pigeons, Doves	PIGU	H			5							
		Skuas, Gulls, Terns, Skimmers	BOGU	H					1		1	70		
			CAGU	H	2			4	105		19	2		
				L			1	91	5					
			GWGU	H	25	43	90	268	289	117	15	90	58	71
				L	117	162	160	490	403	149	12	94	67	
			HEGU	H	3	35			4		1			3
				L	21	5					1			
			HYGU	L									3	
			MEGU	H		3						14	11	8
				L	121	320	12					1	138	
			RBGU	H	2	3		431	499	488	334	121	4	
				L				209	466	833	297	70	2	
			THGU	H									4	5
				L									8	
			UNGU	H	23	18	36	4	24	3	1		41	
				L	17	38	40	640	90	3	2		5	
			WEGU	L				1				1		
		Tern	CATE	H			18	68	101	117	2	2		
				L			9	53	53	58	2	2		
	Heron	Herons	GBHE	H	40	43	162	256	96	17	4	7	1	
				L	51	189	893	694	96	131	6	8	8	
	Other	Blackbirds	BRBL	H			3						30	
			RWBB	H			1							
		Crows, Jays	CORA	L		1						1		
			Nocr	H		3	5	2						
				L		2	3	2				2	1	
		Emberizids	COYE	H				1						
			SAVS	H			1	4			2	1		
				L		3	2	4						
			SOSP	H		1	1							3
			WCSP	H		1								
				L				1						
		Fringillidae	BHCO	L				1						
		Kingfishers	BEKI	L		1								
		Pigeons, Doves	ROPI	H		6	2							
				L		42	4							
		Starlings	EUST	H			1	86	97	13	31	2005	21	14
				L		10	1	16				3801	7	
		Swallows	BARS	H				14	50	3				
				L			4	1	4					
			UNSW	L		1								
		Thrushes	AMRO	H				1						
	Raptors	Caracaras, Falcons	PEFA	L		2				2		2		
		Hawks, Kites, Eagles	BAEA	H	18	4	9	18	1	2			5	5
				L	10	3	5	8	2	3	1	4	18	
			NOHA	H				1				2	1	
				L	1	1				1			2	
			OSPR	H		2	2	2	1	2				
				L		1	1	1		3				
			SSHA	L									1	
	Shorebirds	Lapwings, Plovers	BBPL	L	15	164							606	
			KILL	H			1	3						
				L				2						
			SEPL	H		1	1							
		Oystercatchers	BLOY	H	5			3	2				16	2
				L			4	1	1			1	2	
		Sandpipers, Phalaropes	BLTU	H								8	81	103
				L								30	42	
			DUNL	H		3075							13010	780
				L	500	4565							10115	
			MAGO	L			1							
			UNCA	H			18		188					
				L		3000	15		15				2	
			WESA	H			64	230	799	65				
				L			56			100				
TFN	Coastal Waterbirds	Cormorant	DCCO	H							2	23	5	1
				L			4					306	2	
			PECO	H					2					
				L			16							
			UNCO	L									1	
		Geese, Ducks, Swans	AMWI	H		71						4655	27101	6378
				L	4	59						4900	31953	
			BRAN	H		515	15						1063	1710
				L	2								892	
			BUFF	H									4	
			BWTE	L	22									
			CAGO	H					26			120		
				L	1			4		570		178		
			CITE	H			2							
			COGO	H									2	
				L			2						2	
			EUWI	H		2						2	135	54
				L								5	129	
			GADW	H				5		58				2
				L		25								
			GRSC	H					1				24	
				L			5						4	
			GWTE	H		340	16			150	2	75	1820	460
				L	194	547	2					28	1410	
			HOME	H									1	
			MALL	H		18	8	140	514	212	22	77	793	25
				L		14	1	48	4	407	4	25	3067	
			NOPI	H	8	74	23	5	2	139	380	4072	11743	2463
				L	17	49		10			170	4093	7902	
			NOSH	H					2					
				L		10								
			NOSL	H						12	12	25	48	16
				L						27	10	20	32	
			RBME	H		5								

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Location	FamilyGroup	Family	Species	Tide_H/L	M	A	M	J	J	A	S	O	N	D
			SNGO	H		25							421	
				L								325		
			SUSC	H									5	
				L			21							
			TRSW	H		1	3	14	1					
				L				5						
			UNDU	H	19			1				30	1000	
				L	4					25	400	500	3750	
			WWSC	H								40	87	
				L			11					80	6	
		Grebes	HOGR	H								2	1	
				L									4	
			WEGR	H									202	
				L									10	
		Loon	COLO	H		2		2		3	8	2	1	1
				L			1			1		2	2	
		Sandpipers, Phalaropes	RNPH	L						1				
		Skuas, Gulls, Terns, Skimmers	BOGU	H			2	2			2	1		
				L					3					
			CAGU	H		3		9			3			1
				L	6	5			5				1	
			GWGU	H	3	98	29	49	79	284	3	102	63	92
				L	12	26	103	101	57	414	8	331	79	
			HEGU	H	5	1								
				L	1								2	
			HYGU	H									1	
			MEGU	H		45						1	10	5
				L	30	65						50	109	
			RBGU	H		13	7	177	218	1052	478	13		
				L	45	66		59	48	715	70	148	26	
			THGU	L									11	2
			UNGU	H	136	5	1		3		3			
				L	9	42	20	45			58		23	
			WEGU	H									1	
		Tern	CATE	H			21	41	28	66				
				L			91	5		92				
	Heron	Herons	GBHE	H	40	131	257	323	129	135	56	46	74	11
				L	17	62	260	257	33	100	37	143	58	
	Other	Chickadee	BCCH	L				2						
			NOFL	L				1				3		
		Blackbirds	RWBB	H		4	2	7						
				L	2	2	2	4						
			RWBL	H									1	
		Bushtits	BUSH	H									2	
		Crows, Jays	CORA	H								1		
			Nocr	H	61	7	4	5	2	3	33	20	2	
				L	7	22	14	20	3	2	25	5	16	
		Emberizids	COYE	H			1	2						
				L			2							
			DEJU	L								9		
			FOSP	L								9		
			GCSP	H								3		
				L								13		
			SAVS	H		23	19	40	3	5	2	2	1	
				L	6	12	16	48	9	4	2	13		
			SOSP	H		2	1	1				2	8	1
				L	1							6	2	
			WCSP	H		23	1	7	1				1	
				L		1		6	1	3			6	
			WTSP	L								4		
		Finches	AMGO	H			15	8	5	12	3			
				L			9	7	3	12		15		
			HOFI	H			1	7	4	6	6	12	2	
				L		7		2	3	2		50		
			PUFI	L							2			
		Hummingbirds	RUHU	H				2						
				L				1						
		Kingfishers	BEKI	H				1		1				
				L					1					
		Paridae	BCCH	L					1			2		
		Pigeons, Doves	MODO	L						1				
			ROPI	H		11								
		Starlings	EUST	H	20	12	11	259	240				4	
				L	12		8	38	132	5		90		
		Swallows	BARS	H			69	90	70	60		10		
				L			32	67	25	44				
			TRES	L				4						
			TRSW	L					1					
			UNSW	H		1								
			VGSW	H		1		2						
				L				2						
		Thrushes	AMRO	H	2	7	3	6					2	
				L	6	1	3	7						
		Waxwing	CEWA	L				3						
		Waxwings	CEWA	H						2				
				L					1	2		2		
		Wood Warblers	YRWA	L								25		
		woodpeckers	DOWO	L									1	
		Wrens	BEWR	H									1	
	Raptors	Caracaras, Falcons	AMKE	H							1			
			PEFA	H			1						1	
				L								1		
		Hawks, Kites, Eagles	BAEA	H	28	5	2	11	3			2	2	4
				L	1	5	12	5	1			4	12	
			NOHA	H	4	1	4	1	1	2		2	7	4
				L	1	1	1	1		1	1	4	5	
			OSPR	H				1		1	1			
				L			1							
			RLHA	H				1						
			RTHA	H									1	
				L		2		2			1			
			UNHA	L						1				
		Owls	SEOW	H				1					1	
				L				1					1	
	Shorebirds	Lapwings, Plovers	BBPL	H		42								300
				L									81	
			KILL	H		2	10	11	2	2	15			
				L			7	9			15			
			SEPL	H			29		3					
		Oystercatchers	BLOY	H					2					
				L			3						4	
		Sandpipers, Phalaropes	BASA	L						3				
			BLTU	L						3				
			DUNL	H		20275	86						240	3170
				L	44	555							3300	
			GRYE	H		4								
				L		1								
			LBDO	L		3								
			LESA	H				5	5					
			MAGO	H					4					
			SAND	H								160		
				L								330		
			UNCA	H		21		39	14	47				
				L		64			25					
			WESA	H		6055	481	284	1332	17				
				L			5	400	135	131				

Table 18
Summary Statistics for DoD Rod Data
Deltaport Third Berth
Adaptive Management Strategy
499-002.11

		Group 1	Group 2	Group 3
Deposition	Q2 Mean	8.4	6.5	2.2
	Q3 Mean	1.2	2.7	0.9
	Q4 Mean	4.1	0.1	1.1
	Annual Mean	4.6	3.1	1.4
Erosion	Q2 Mean	-1.8	-0.9	-1.2
	Q3 Mean	-5.7	-1.7	-0.4
	Q4 Mean	-4.7	-1.2	-1.9
	Annual Mean	-4.1	-1.3	-1.2
Combined Erosion and Deposition	Min	-14.9	-2.5	-7.7
	Max	21	8.5	8.5
	Mean	0.27	0.91	0.10
	Std. Dev. (s)	6.57	3.22	2.15
	1.282 Std. Dev. (1.282s)	8.42	4.13	2.76
	Deposition Threshold	8.69	5.04	2.86
	Erosion Threshold	-8.15	-3.22	-2.65

APPENDIX A

Methodology

APPENDIX A: METHODOLOGIES

A-1 GEOMORPHOLOGY

A-1.1 INVESTIGATION METHODOLOGY

The main components of the monitoring program are based on the recommendations provided in the DP3 AMS. Based on this information and NHC's general understanding of the processes at Deltaport, the detailed geomorphological monitoring work plan is described below. The Acoustic Wave and Current Meter (AWAC) was destroyed on September 27, 2007. An alternate monitoring methodology is currently being developed.

A-1.1.1 Crest Protection Monitoring

The purpose of crest protection monitoring is to detect channel incision, headcutting or dendritic channel formation around perimeter crest protection. The monitoring covers the entire perimeter of the crest protection structure, with particular focus in the vicinity of the tug basin and DP3 structures. Field reconnaissance and site observations are made quarterly during low tide by a qualified geomorphologist. Fixed points were established on the ground for taking repeat photography and for conducting terrestrial surveys (**Figure 2**). Ground surveys are carried out using a Real Time Kinematic (RTK) GPS station to measure the dimensions of channels that are present or subsequently form.

A-1.1.2 Water Sampling of Suspended Solids

Periodic collection of water samples during a tidal cycle was initially proposed in order to derive a relationship between turbidity and total suspended sediment (TSS) concentration. NHC's memo of November 2007 presents the rationale for revising this methodology. With the development of a TSS-Turbidity relationship by laboratory methods, water samples will no longer be collected. Turbidity monitoring stations provide a continuous record of measured turbidity from which TSS will be computed using the expression **x=y/0.5123** (where x=TSS and y=turbidity).

A-1.1.3 Automated Turbidity Monitoring

The purpose of this monitoring activity is to measure turbidity continuously at fixed locations to provide a proxy record of sediment transport over the tidal flats. Two monitoring sites were chosen on the shoreward side of the crest protection structure (Figure 5), with Analite NEP495 Turbidity Logging Probes installed within a 2-inch PVC pipe with a flared base to protect the optics from debris. The pipe is securely attached within a stainless-steel pyramidal cage, which is weighted by 4 lb weights and marked by a small float. The instruments are programmed to record turbidity levels of up to 400 NTU every 15 minutes. A wiper assembly is programmed to clean the optics at 4-hour intervals to ensure consistent readings.

This sampling interval was selected to capture the effects of storms and other weather events with durations of several hours or more and is not designed to capture the impact of individual waves on turbidity. No cables or external power are required, which minimizes the risk of damage or loss of data. Regular maintenance of the equipment is carried out to ensure fouling or debris does not degrade the sensors. Data retrieval is performed by physically connecting the instrument to a laptop or PDA and directly downloading the data each month.

Analysis of data collected from the turbidity probes is supported by auxiliary tide level data. In order to monitor tide height, a local tide gauge was installed on a caisson at the Deltaport site. The monitoring station consists of a Solinst Levelogger, which records and stores stage (water-level) values at 15-minute intervals. The stage sensors record combined atmospheric and hydrostatic pressure. A Solinst Barologger is installed adjacent to the tide gauge in the DCL Site Office to independently record atmospheric pressure as a correction to the tide gauge. The Levelogger is housed inside a capped 2-inch PVC pipe secured to a pre-existing steel ladder on the caisson face.

A-1.1.4 Automated Monitoring of Erosion and Deposition

Measurements of the temporal variation in erosion and deposition at specified locations are collected using conventional erosion pins (depth of disturbance pins). Locations of the 26 depth of disturbance pins (DoD) are shown in **Figure 5**. The DoD pins are monitored at three-month intervals during the course of other field investigations (crest protection monitoring and bed sediment sampling). The DoD pins have been spaced at 150-m intervals and located on the tidal flats above 0.5 m chart datum in elevation. Conventional depth of disturbance rods consist of a length of rebar that is embedded into the tidal flats and a large flat disk with a central hole (similar to a washer) is placed over it, flush with the ground. The initial distance from the top of the rebar to the disk is recorded at the time of installation. If the ground is lowered as a result of scour, the distance from the top of the rebar to the disk will increase over time. If deposition occurs, the sediment buries the disk. Vegetation accumulation on the DoD pin may occur on a seasonal basis related to growth and die off of the various plant species found at Roberts Bank. The presence of vegetation is noted and photo-documented and the height of accumulated weed is recorded. Accumulated weed is carefully removed to expose the bare sediments underneath and allow measurement of washer burial or scour as described above. Quarterly observations are made, and/or observations after any significant storm events, to determine the magnitude of erosion and deposition.

A-1.1.5 Sediment Samples

Sediment samples are scheduled for collection twice yearly, once in the spring and once in the fall, post Fraser River freshet. Samples are collected at each DoD pin site using a shallow hand corer. The top 10 cm of the sample are removed from the core and stored in a freezer until analysis to ensure that biological activity does not alter the percent fines. A sampling depth of 10 cm was chosen to ensure that there is sufficient sediment to perform a robust grain size analysis and to ensure that the sample captures undisturbed sediments at depth as well as newly deposited sediments. Preliminary monitoring of the DoD pins has demonstrated that a 10 cm sampling depth is appropriate at a majority of the sites. The first set of samples was collected at a distance of 5 m to the north of each rod. To avoid re-sampling in the same hole, subsequent sampling is rotated around the rod location.

The primary purpose of the laboratory analysis is to determine the particle size distribution of the samples. Subsequent results will be compared to determine if a fining or coarsening trend is occurring. The following is a description of the methodology used to determine the organic content of the sample, analyzed by ALS Laboratories:

> The sample is introduced into a quartz tube where it undergoes combustion at 900° C in the presence of oxygen. Combustion gases are first carried through a catalyst bed in the bottom of the combustion tube, where oxidation is completed and then carried through a reducing agent (copper), where the nitrogen oxides are reduced to elemental nitrogen. This mixture of N_2, CO_2, and H_2O is then passed through an absorber column containing magnesium perchlorate to remove water. N_2 and CO_2 gases are then separated in a gas chromatographic column and detected by thermal conductivity.

The remaining sample is then put through a series of sieves and a hydrograph to provide a graph of percent finer by weight down to 0.5 mm. The following graphs and tables show the results of the analysis.

A-1.1.6 Interpretation of Ortho Photographs

Aerial photographs are evaluated to assess trends and patterns of erosion and/or accretion on the tidal flats. This evaluation is conducted annually and covers the entire inter-causeway tidal flat area. The methodology consists of overlaying successive ortho-rectified photographs using GIS mapping techniques to delineate and identify morphological changes on the tidal flats. The maps show areas of erosion or sand accretion and changes in vegetation between successive surveys.

A-1.1.7 Coastal Geomorphology Mapping

This task assesses topographic changes due to long-term erosion or accretion adjacent to the terminal. An initial baseline survey was completed at the start of the study. The surveys will be repeated every three to four years. **Figures 29 to 34** show the extent of the mapping surveys. The highest resolution surveys are made near the Deltaport 3 terminal. More limited surveys are made across the shallow inter-tidal flats where the relief is very low. Precise bathymetric surveying is performed using Real Time Kinematic GPS positioning for horizontal control and single beam digital echo sounding.

A-1.2 DATA EVALUATION

This section summarizes the geomorphological data that will be evaluated and interpreted for the monitoring components presented above. Interpretation of the DOD measurements and bathymetric survey data is straightforward, and is not included below. Results are provided only in the quarterly reports with data interpretation and discussion provided in the annual reports.

A-1.2.1 Crest Protection Monitoring

Comparisons of repeat terrestrial photographs will be performed to show seasonal and long-term changes. Comparison of ground surveys to document scour or erosion from channel formation or headcutting processes. This interpretation will be supplemented by assessment of annual air photography and periodic low-level over flights from a fixed wing aircraft, as described in **Section A-1.1.6**.

A-1.2.2 Water Sampling of Suspended Solids

Plots of suspended sediment concentration versus turbidity will be made to provide a basis for calibrating the continuous turbidity sensors. Variations in suspended sediment concentration will be related to tidal current velocities, tide levels and ambient conditions in the Lower Fraser River estuary.

A-1.2.3 Automated Turbidity Monitoring

Suspended sediment concentration will be computed from the turbidity values using correlations established from the manual sampling program. Time series plots of turbidity (NTU) and suspended sediment concentration (mg/l) will be made and compared with tide levels, tidal current magnitude and wave climate conditions (as recorded by the AWAC unit provided by others). Predicted sediment concentrations and sediment transport rates under tidal currents and waves will be compared with the observed values.

The primary objective of the automated turbidity monitoring stations is to monitor sediment concentrations and sediment transport rates to assess long-term deposition/erosion processes and long-term changes in sediment concentration that might affect habitat (such as eel-grass). However, localized higher turbidity values generated from construction activities may be reflected in the record.

A-1.2.4 Sediment Samples

Measurements of short-term accretion and erosion will be correlated with met-ocean conditions (wave and tide conditions), construction activities and changes in vegetation or eelgrass. Comparisons will also be made with surveyed topographic changes along the crest protection and results of the photographic monitoring.

A-1.2.5 Interpretation of Ortho Photographs

Overlay maps will be interpreted to assess the key factors that are controlling morphological changes on the tidal flats. Results will be compared with other long-term assessments (as documented previously in the Coastal Geomorphology Study). The results of this investigation will be integrated with other related studies on eelgrass extent and distribution in order to provide a complete understanding of any habitat changes.

A-2 SURFACE WATER

A-2.1 INVESTIGATION METHODOLOGY

Fixed sediment quality monitoring stations will be established adjacent to the Deltaport facility, within the inter-causeway area and at two reference locations along Robert's Bank. The proposed locations are shown on **Figure 6** and are described as follows:

- One station (Station 1) in the ditch near the base of the ferry terminal causeway to monitor nutrient and sediment loading from upland sources
- Two stations (Stations 2 and 3) located in the intertidal portion of the inter-causeway area within the eelgrass beds
- One station (Station 4) in the intertidal portion of the inter-causeway area at the head of the ship turning basin adjacent to DP3
- One station (Station 5) in the subtidal portion of the inter-causeway area within the ship turning basin adjacent to DP3
- One intertidal reference station (Station 6) located off Westham Island northwest of Deltaport
- One subtidal reference station (Station 7) located off Westham Island northwest of Deltaport

The surface water sampling methodology outlined below, including sample implement decontamination procedures, is based on the protocols developed for the Puget Sound Estuary Program (PSEP 1996). Representative surface water samples will be collected from each of the sampling stations (**Figure 6**).

A vessel equipped with a 5-litre Van Dorn sampler, constructed of clear lexan, will be used to collect surface water samples at each station. One water sample will be collected just below the surface and for the subtidal samples; one surface water sample will also be collected at a depth of two metres above the seafloor. As with the sediment sample, the surface water sampling stations will be located using DGPS. The vessel will be equipped with a depth sounder, however, to ensure that the sampler is triggered at an appropriate depth a two metre rope with a weight at the end will be attached to the base of the Van Dorn. To minimize the turbidity plume from disturbed sediment, the sampler will be lowered slowly and carefully as it approaches the bottom (based on depth sounder readings). Tripping the sampler is then delayed approximately one minute is used to allow currents at the site to transport turbidity generated by the weight out of the area of the sampler. Each recovered water sample will be examined to ensure acceptable sample quality, including no entrained sediment, and the water in the sampler decanted into laboratory prepared sample bottles. The five litre Van Dorn volume is sufficient to meet sample volume requirements. Similar to the sediment sampling process, field observations will be recorded at each station during sample collection. Field observations will include general information (e.g., station name, date, time), and a description of the site location, GPS coordinates, water depth and characteristics (e.g., colour, odour, turbidity).

As part of our quality assurance program, Hemmera will also undertake a number of measures including consistent use of the same field technicians, daily field reporting between field technicians and project manager, and submission of samples in laboratory supplied sterile sampling containers under chain of custody, following the directions provided by the analytical laboratory, etc. The required laboratory reported detection limits have been pre-determined with the laboratory so that the results can be compared to the appropriate regulatory screening levels. The detection limits and regulatory screening levels are provided in the AMS Detailed Workplan. One blind field duplicate sediment sample will also be collected during each sampling event to further assist in the evaluation of data quality. The data quality objective (DQO) for precision will be measured using the relative percent differences (RPD) between characterization and duplicate samples (to evaluate data precision) as well as percent completeness to evaluate the effectiveness of the sampling program with respect to the project objectives. Due to the limited number of samples, the DQO for completeness is 100%. The DQOs for precision will be 20% RPD for inorganic parameters and 50% RPD for organic parameters. Where reported concentrations of less than five times the detection limit are obtained, the DQO of a Difference Factor (DF) of < 2 will be used. The quality assurance program will also include review of the analytical laboratory's quality control results.

The samples will be stored in coolers on ice and transported directly to the laboratory at the end of the sampling day (approximately 1.5 hour travel time).

Data from Station 4, nearest the DP3 construction area, will also be monitored continuously for a number of water quality parameters (pH, temperature, conductivity, dissolved oxygen, and turbidity) using a YSI buoy-mounted sonde operated in conjunction with the DP3 construction environmental monitoring program. Data for the remaining water quality and sediment quality parameters will be collected during quarterly sampling programs.

A-2.2 SAMPLE ANALYSES

The parameters analyzed to facilitate data interpretation include:

- Temperature
- pH
- Hardness
- Salinity

The parameters being analyzed to assess the presence/absence of toxicants include:

- Metals
- Polycyclic aromatic hydrocarbon scan (PAHs)
- Chlorine[1]

Several of the water quality parameters were also selected for their use in facilitating identification of marine eutrophication and/or construction impacts. These include:

- Turbidity, TSS, Clarity (secchi disk)
- Nutrients (Phosphate, Phosphorus, Ortho-phosphorus, Total Kjeldahl Nitrogen [TKN], Total Nitrogen, Ammonia, Nitrate, Nitrite and Organic Nitrogen N)
- Chlorophyll *a*

A-2.3 DATA EVALUATION

As indicated above, a number of the monitored surface water parameters are to support data interpretation purposes and therefore do not require action levels. The other parameters collected, as indicators of potential toxicity to marine organisms, will be compared against the applicable provincial and federal water quality screening levels:

- British Columbia Approved Water Quality Guidelines (Criteria), 1998 Edition
- A Compendium of Working Water Quality Guidelines for British Columbia, 2001 Update
- CCME Water Quality Guidelines, 2006 Update

These analytical results will be provided in the quarterly reports with data interpretation and discussion of the sampling results provided only in the annual reports.

[1] Chlorine will be collected from the ditch station only. The purpose is to evaluate potential impacts from chlorine to the inter-causeway area as historical releases of water from a nearby upland water park have been documented. PAHs have been dropped from the program as no exceedances were noted during the Q1-2007 event.

The remaining results will be presented in each quarterly report with evaluation for negative trends occurring within each annual report. As with the sediment sampling program, the data collected within the inter-causeway area will be tabulated, graphed, and statistically compared with the results from the relevant reference stations elsewhere along Robert's Bank. A 20-percent difference between the eutrophication parameter inter-causeway and far-field results will be used as a preliminary indicator of a potential for eutrophication impacts and will warrant discussion within the annual report. For some parameters, such as oxygen, where critical thresholds exist and changes of less than 20% may impact biota, the absolute value of the parameter will also be evaluated.

A-3 SEDIMENT

A-3.1 INVESTIGATION METHODOLOGY

As with the surface water sampling program, representative sediment grab samples will be collected from each sampling station (**Figure 6**) on a quarterly basis (four times per year). The sampling methodology outlined below, including sample implement selection and decontamination procedures, is based on the protocols developed for the Puget Sound Estuary Program (PSEP 1996)[2]. A shallow draft vessel equipped with an 8.2 L Ponar grab sampler will be used to collect the sediment samples. Field staff will work from the ditch bank to collect samples from the sediments at Station 1. Sampling stations will be located using global positioning system (GPS) coordinates. Each recovered grab sample will be examined to ensure acceptable sample quality, the supernatant water in the sampler will be decanted and the upper 5 cm of sediment will be placed in a clean stainless steel mixing bowl. Repeated grab samples may be required to fulfill sample volume requirements. The sample will be mixed with a stainless steel spoon until homogenous in texture and colour. However, sediment for hydrogen sulphide analysis will be collected prior to mixing to minimize oxidation and volatilization. Field observations will be recorded at each station during sample collection and will include general information (e.g., station name, date, time), a description of the site location, GPS coordinates, water depth, sediment characteristics (e.g., grain size, colour, odour, debris, visual contamination), and a record of the amount of effort required for sediment collection.

Aliquots of sediment for chemical analysis will be collected in 250mL laboratory prepared glass jars with Teflon lids for submission to the project laboratory for analysis of the parameters listed in **Section A-3.2**. The sediment samples are collected and transported to the lab generally by 5:30 pm the day the samples are collected. Sediment samples are placed in jars and immediately stored in a covered cooler with ice to keep them at a cold state, at or near 4°C for delivery to the laboratory. All samples are analysed within the laboratory holding time.

2 Puget Sound Estuary Program (PSEP) 1996. Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound. Prepared by King County Environmental Laboratory for Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Sediment samples for sulphide analysis are collected prior to homogenization and are placed in jars with no headspace in order to minimize the potential for oxidation. As with the other parameters, sulphide sample jars are then placed immediately on ice. The laboratory holding time for sulphides was 7 days during Q1 and Q2; however, it was reduced to 24 hours for subsequent events, to minimize potential loss through volatilization and increase the reliability of results. Sulphide analysis is via the laboratory method is described below:

- Add 8 – 12 drops of sodium hydroxide to a centrifuge tube to 5 g (based on dry weight) of sample into the tube.
- Add water.
- Shake for 20 minutes, then centrifuge.
- Filtered supernatant through a 0.45 micro filter.
- Transfer an aliquot to a test tube containing zinc acetate.
- Bulk the sample with MQ water and analyze colourimetrically.

The field sampling equipment (i.e., Ponar, bowls and spoons, etc.) will be decontaminated prior to sample collection at each station. This involves an initial rinse with site seawater, followed by washing with Alconox soap, a second rinse with site seawater, and final rinse with distilled water in accordance with the PSEP (1996) methodology. Equipment cross-contamination (XCON) swipes will also be collected to evaluate the quality of field sampling and decontamination procedures.

Quality assurance measures (staff, sample handling, field duplicates and DQO) for the sediment sampling program will be the same as those outlined for the surface water sampling program (**Section A-2.1**) above. The detection limits and regulatory screening levels for sediment samples are provided in the AMS Detailed Workplan.

A-3.2 SAMPLE ANALYSES

Sediment samples will be analyzed for the following parameters:

1. Metals were analyzed as indicators of potential toxicity to marine organisms (Tributlytin was analyzed only during the Q1-2007 event).
2. Parameters measured to evaluate sediment eutrophication include:
    - Total nitrogen
    - Ammonia
    - Total Kjeldahl nitrogen (TKN)
    - Total organic nitrogen
    - Phosphorous
    - Redox (Eh)
    - Hydrogen sulphide (H_2S)

Sediment grain size samples are collected annually.

A-3.3 DATA EVALUATION

The toxicity parameters, when sampled, will be compared against the BC Contaminated Sites Regulation, Schedule 9 Generic Numerical Sediment Criteria for sensitive marine and estuarine sediments ($SedQC_{ss}$) and the Puget Sound Dredge Disposal Analysis (PSDDA) criteria for TBT as indicated in the AMS. These analytical results will be provided in the quarterly reports. Anomalous results will be highlighted and briefly discussed. Data interpretation and discussion of the sampling results provided only in the annual reports

The remaining sediment quality parameters will be evaluated within each annual report for observable trends. The data collected within the inter-causeway area will be tabulated, graphed, and statistically compared with the sediment results from the reference stations and with data from previous years sampling. A 20-percent difference between the eutrophication parameter inter-causeway and far-field results or between results from year to year will be used as an indicator of a potential for eutrophication impacts and will warrant discussion within the annual report.

A-4 EELGRASS

A-4.1 INVESTIGATION METHODOLOGY

A-4.1.1 Eelgrass Distribution and Mapping

Aerial photograph interpretation will be used to develop a base layer for mapping the current distribution of eelgrass in the inter-causeway area. Aerial photograph flights used for the eelgrass monitoring program are to be flown in July 2007 and at the same time in subsequent years. The amount of cloud cover, sun angle, and season at the time when the photos are flown; and the resolution of the photos, will determine whether it is possible to distinguish between areas that support a monoculture of *Z. japonica* and areas that support a monoculture of *Z. marina*. There is a ‘transition’ zone between these two habitats in the inter causeway area where the two species co-exist. It may be possible to approximate the boundaries of the transition area from the photos. Homogenous habitat types will be delineated to form polygons. We have proposed a minimum polygon size of 50 m by 50 m; however, this may be modified through discussions with VPA.

A field survey will follow the aerial photographic interpretation to confirm and/or determine the species composition of each polygon. The boundaries of the transition area will likely need to be determined on-site and mapped using a GPS. *Z. japonica* is an annual species; although a small percentage of the shoots may survive throughout the winter. To accurately map the distribution of this species the field survey should be completed between June and early September.

The data collected during the field survey would be incorporated onto the base layer by Hemmera to create a GIS map that accurately depicts the current distribution of eelgrass in the inter-causeway area.

A-4.1.2 Monitoring Eelgrass Vigour & Health at the Established Stations

The annual eelgrass vigour and health survey will be conducted during one of the low tide cycles between mid July and mid August and will assess the health and growth of eelgrass at nine of the eelgrass monitoring stations that were established for the DP3 Environmental Assessment, including four stations in the inter-causeway area, two stations west of the Westshore Coal Terminal and Deltaport Causeway and three reference stations in Boundary Bay (**see Figures 7 and 8)**.

The parameters that will be monitored at each of the stations will include those assessed for the baseline study; shoot density, shoot length, and shoot width[3]. This data will be used to calculate Leaf Area Indices (LAI) at each location.

The distribution of *Z. marina* at each station will be classified as patchy, continuous, or absent. The percent cover of *Z. japonica* will be ranked according to the following scale: <1% present; 1% to 40% sparse; 41% – 75% moderate; >75% dense.

The monitoring plan includes noting the presence or absence of epiphytes at each of the stations. It would be possible for Ms. Durance, based on her 25 experience with this population of eelgrass to further classify the presence of epiphytes in the inter-causeway area as typical, less than usual, or more than usual.

The presence or absence of *Beggiatoa* sp. will also be noted. Ms. Durance has never observed *Beggiatoa* sp. at Roberts Bank. In the unlikely event that it is noted during an annual monitoring event, a strategy would need to be developed so that increases or decreases in the area covered by this species could be assessed. The location of the *Beggiatoa* sp. would be recorded using a GPS, for future reference. If there is sufficient time available the crew will map the area covered by *Beggiatoa* sp. VPA will be notified immediately, with suggestions as to how to modify the AMS to include mapping and monitoring changes in the distribution of this species.

A-4.1.3 SIMS Survey

A Subtidal Imaging and Mapping System (SIMS) survey will be used to determine the lower limit of eelgrass in the inter-causeway during the summer of 2009. The SIMS method and equipment is only available through Archipelago Marine Research (AMR).

SIMS is a towed video system developed to carry out systematic mapping of marine vegetation, macroinvertebrates, seafloor substrates and morphology from the intertidal zone to depths of about 40m. The field of view is approximately 1 m by 2-3 m. The acquired imagery (digital video format) is geo-

[3] Quadrat sampling along transects as described in *Methods for Mapping and Monitoring Eelgrass Habitat in British Columbia* (Precision 2002).

referenced using differential GPS with positions and time "burned onto" the video imagery with one-second update intervals. Depth of the towfish is also shown on the image. The towfish is maintained at an elevation of 1-1.5 m above the seafloor. Tow speed for SIMS is about 1 knot (2 km/hr) yielding a line coverage of 12 to 15 km in a typical survey day. A seven metre vessel provided and operated by Arrawac Marine Services is used to conduct the survey. A laptop computer is used for pre-plotting the navigation lines and for showing the vessel track lines during the survey. The position, depth and video time data is stored in custom MS Access database format developed for the SIMS classification system.

The video imagery is classified (by a geologist and a biologist) for substrate, epiflora (macrophytes) and epifauna (including fish) using a standard substrate and biotic classification system initially developed for the Province of British Columbia. The SIMS database system allows data entry for each second of video imagery collected. The interpreted data are interfaced with ArcView for map production. Typically the survey product is a comprehensive portfolio of maps, developed in GIS format, showing sediment type, major vegetative features, macroinvertebrates and fish observations and an interpretation of valued and sensitive biophysical features.

A-4.2 DATA EVALUATION

An eelgrass distribution map will be produced annually, based on air photo interpretation and confirmed by ground truthing. A brief report will accompany a map that assesses changes that were observed in a local and regional context. This information will be compiled and summarized within each annual report for consideration by the SAC.

Natural eelgrass densities may vary significantly between years due to climatic changes. Although the mean density tends to be stable over time, environmental change such as El Niňo events may lead to severe changes in density. An El Niňo winter followed by a La Niňa summer once resulted in a ten-fold density increase in at least several eelgrass beds in British Columbia and Washington State. Data (vigour and epiphyte load) from the inter-causeway would be compared with many other sites in addition to Boundary Bay to ascertain whether changes subsequent to development at Roberts Bank are due to impacts attributable to the DP3 project, other non-DP3 anthropogenic causes, or natural causes.

A-5 BENTHIC COMMUNITY

A-5.1 INVESTIGATION METHODOLOGY

Benthic community health in the inter-causeway area is linked to sediment quality and water quality; and it is anticipated that if significant changes are seen in benthic community health, effects would also be observed in surface water quality and/or sediment quality (see **Sections A-2** and **A-3**). Therefore, sediment samples for benthic community analysis will be co-located with surface water and sediment samples from six of the seven sampling stations identified for the surface water and sediment quality monitoring programs (**Figure 6**). No benthic samples will be collected for station DP-01 as this station is located in a drainage ditch discharging to the inter-causeway area. The samples for benthic invertebrate analysis will be collected separately during the sediment sampling program. Samples will be preserved and packaged in the field, as required, and shipped to Biologica Environmental Services, Ltd., who will process the samples and report taxonomic results to Hemmera.

The first benthic community sampling event will be completed during the first quarterly sampling event prior to the start of dredging. The next benthic invertebrate sample collection event is scheduled to occur during the Q1-2008 sampling event in March 2008. During the March 2008 event, a fourth benthic sampling station will be sampled. The location will form the fourth corner of a rectangle created by connecting stations DP02, DP03 and DP04 and the new station. Water quality and sediment samples will be collected at this station only during the benthic community sampling event and not during subsequent quarterly monitoring events. Further benthic community sampling will be completed at the end of construction during the first post-construction quarterly sediment sampling event. To facilitate data management, a fixed naming convention will be used. For instance, DP01A-1 will denote a sample collected at DP01, with the letter distinguishing between the three benthic invertebrate samples collected at this location, and the number specifying that the sample was collected during the first benthic invertebrate sampling event.

To capture inherent variability potentially present at the stations, three replicates will be initially collected per station for the benthic community sampling (*Benthic Marine Habitats and Communities of the Southern Kaipara*, Aukland Regional Council Technical Publication 275). Should the results of statistical analysis of variance of richness and abundance in the first year’s benthic community sampling indicate acceptable variance observed between the replicates, we propose to reduce the sampling to one replicate sample per station during the second event. We have proposed an acceptable level of variance as being less than 20%.

Sampling methodology will be similar to that for the sediment sampling described in **Section A-3.1** but with some modifications. For the benthic community sample, the supernatant water is not decanted. After examination of grab quality, including consistent sample volume between stations, the sediment is placed in a plastic container (Tupperware bin) and transferred to a pre-cleaned stainless steel screening station on shore. The sample contents are gently rinsed through a 0.5 mm and 1.0 mm mesh sieve using seawater strained for zooplankton using a fine nylon mesh. The sample material remaining on 0.5 mm and 1.0 mm sieves is then transferred into a separate 1 L plastic container for each sieve size and preserved in a 10% solution of formalin buffered with marble chips. These samples are then transported to Biologica for taxonomic identification. Taxonomic identification of benthic invertebrates will be down to the species level, where practical, and include both the diversity (number of species) and abundance of individuals for adult, juvenile and intermediate life stages.

A-5.2 DATA INTERPRETATION

As stated in the AMS, infaunal and epifaunal benthic community results will be evaluated and the data collected within the inter-causeway area will be tabulated, graphed, and statistically compared with the benthic results from reference stations elsewhere along Robert's Bank. A 20-percent difference from elsewhere along Robert's Bank will be used as an indicator of a potential for benthic community impacts in the inter-causeway area requiring further discussion within the final annual report.

Benthic community health is linked to sediment quality and water quality; therefore, it is expected that if significant changes are seen in benthic community health, effects would also be observed in surface sediment quality and/or water quality.

The sampling results will also be compared to video observations made during the SIMS survey that is part of the Eelgrass program (**Section A-4.1.3**). As stated above, the video imagery will be used for epiflora (macrophytes) and epifauna (including demersal fish) classification using a standard system initially developed for the Province of British Columbia. The SIMS database system allows data entry for each second of video imagery collected. The interpreted data are interfaced with ArcView showing sediment type, major vegetative features, macroinvertebrates and fish observations and an interpretation of valued and sensitive biophysical features.

A-6 BIRDS

A-6.1 INVESTIGATION METHODOLOGY

Bird studies will be completed along the south side of the Roberts Bank causeway, north side of the Tsawwassen Ferry Causeway and the intervening shoreline at the head of the inter-causeway area. Multiple, fixed-distance point counts will be completed along the following 3 transects:

- South Roberts Bank Transect: South Roberts Bank causeway (point count stations 12 – 19)
- TFN Reserve Lands Transect: TFN Lands (point count stations 105 – 115)
- Tsawwassen Ferry Causeway Transect: Tsawwassen Ferry Jetty (point count stations 118 – 126)

The bird study transects and point count stations are shown on **Figure 9**. The sample plot associated with each point count station will be approximately 500 m^2. The coordinates of the point count stations will be determined using GPS. Point count stations will be identified with either flagging tape or paint sprayed on the ground surface. Stakes will be used along the South Roberts Bank Transects to mark the point count stations at intervals of 500 m. Point count estimates will also be made at distances ranging from greater than 500 m to approximately 1 km.

One monitoring event will be completed every two weeks. Observations will be made at a frequency of twice each day, as daylight permits, or on two consecutive days within a 3-day monitoring window. Observations will be made once during a daily high tide and once during a daily low tide. Low-tide observations along the South Roberts Bank Transect will commence approximately 30 minutes before the daily low tide, and will be made when a minimum of 500 m of mudflat is exposed. The low-tide surveys will progress from the tip of the causeway to the base. Observers will use binoculars, spotting scopes and range-finding binoculars to identify species and their distances from the point count stations. Observers will count individuals and groups of birds and document bird behaviour. Observational data will be recorded on survey forms that are consistent with those used by VPA and CWS in past bird studies.

The South Roberts Bank Causeway Transect (point count stations 12 - 19) will undergo a more intensive survey in comparison to the other observational transects. Observers will use consistent survey methodology along all transects; however, observers working along the South Roberts Bank Transect will conduct fixed-distance point counts within smaller sub-plots, according to the following scheme:

- 0 – 100 m from the shore
- 100 – 200 m from shore
- 200 – 300 m from shore
- 300 – 400 m from shore
- 400 – 500 m from shore
- > 500 m to approximately 1 km

Observers along the TFN Reserve Lands and Tsawwassen Ferry Causeway Transects will count birds within relatively larger sub-plots, according to the following scheme:

- 100 m inland to the shore
- 0 – 250 m from shore
- 250 – 500 m from the shore
- > 500 m to approximately 1 km

If large numbers of birds are observed within a sample plot, then observers will count a group of 100 individuals and then multiply the total number of groups within the sample plot. Birds observed in flight will be recorded as ‘flyovers’ and the flight direction will also be recorded; these records will be distinguished from records made for birds occurring on water or land. The duration of observation at each point count station will be 20 minutes, during which time all birds will be counted within the boundaries of the sample plot (approximately 500 m^2 and up to distance of 1 km from land, and 100 m inland).

A-6.2 DATA EVALUATION

Hemmera will document changes in species distributions that are linked to construction or post-construction activities. Hemmera's analysis of the bird monitoring data will yield: (1) total estimated counts and relative abundance of birds for a particular sample plot and/or sub-plot, and (2) the number of birds per unit area (i.e., km^2) or density. A total estimated count is indicated by the sum of the total number of birds observed in each sample plot, along a specific transect and at a given time. Species densities will be derived from the census data collected during the pre-construction (baseline) monitoring as well as the construction and post-construction monitoring conducted as part of the AMS monitoring program. Densities will be determined using the formula below.

$$D = B/A$$

Where:

D = density of birds (i.e., birds / km^2)

B = No. of birds observed

A = area surveyed

Census data collected during construction and post-construction periods will be compared to pre-construction baseline data to determine whether construction and post-construction activities result in significant changes in species populations. Hemmera will import the baseline data into its data management system to facilitate interpretation. Data interpretation will include comparisons between baseline monitoring results and construction and post-construction results, as well as spatial and temporal trend analyses using a standard statistical package (i.e., T-test, linear regression) to detect positive or negative trends occurring among the sample plots. VPA will be immediately notified if negative trends are observed during data interpretation. Additionally, Hemmera will provide VPA with recommendations, if necessary, to implement or modify mitigation measures to prevent or attenuate observed negative ecosystem trends. The data will be reported in post-survey reports, quarterly reports and annual reports.

APPENDIX B
NHC Photos

Photo 1. XS 1 looking back at Deltaport.

Photo 2. XS 2 looking northeast.

Photo 3. XS 3 looking northeast.

Photo 4. XS 4 looking southeast.

Photo 5. XS 5 looking southeast.

Photo 6. Eelgrass buried under soft sediments within the deposition zone.

Photo 7. Sediment deposited as a "prograding" sheet.


Photo 8. Dendritic channels with sharp, well-defined banks – June 2007.

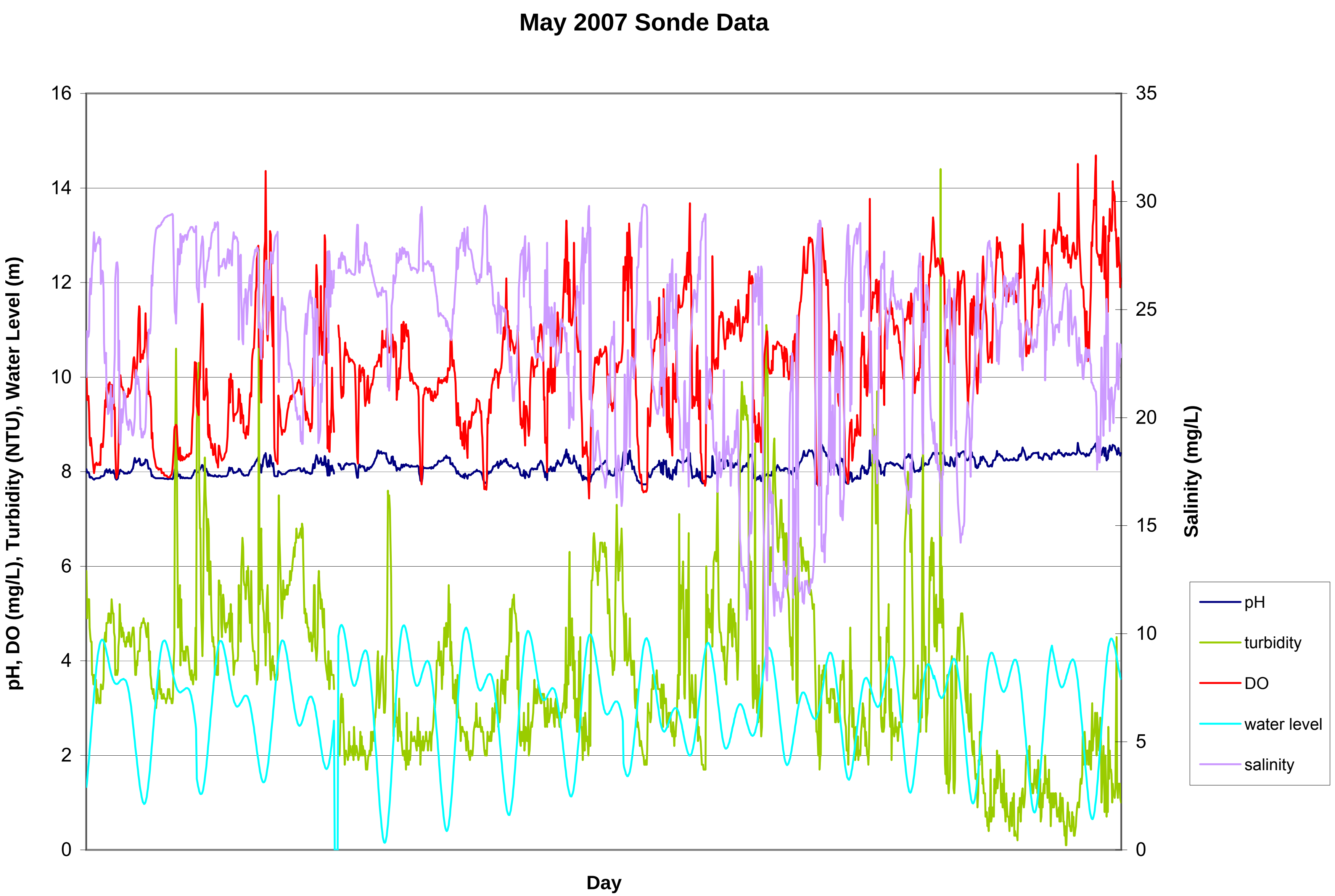

Photo 9. Dendritic channels with gently-sloping banks – March 2008.

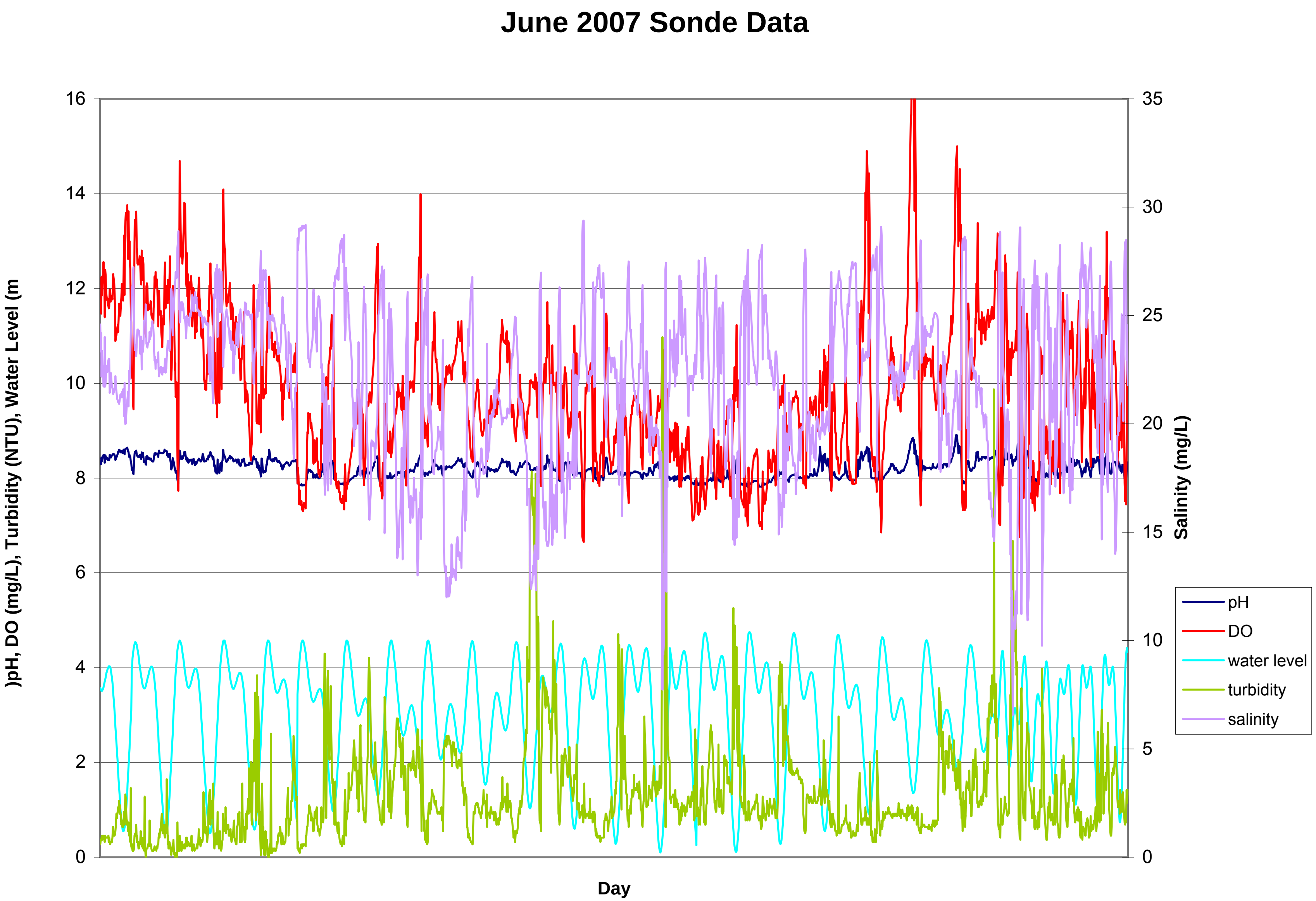
Photo 10. Newly-formed dendritic channels outside the DP3 Perimeter Dike (photo taken on March 12, 2008 overflight).

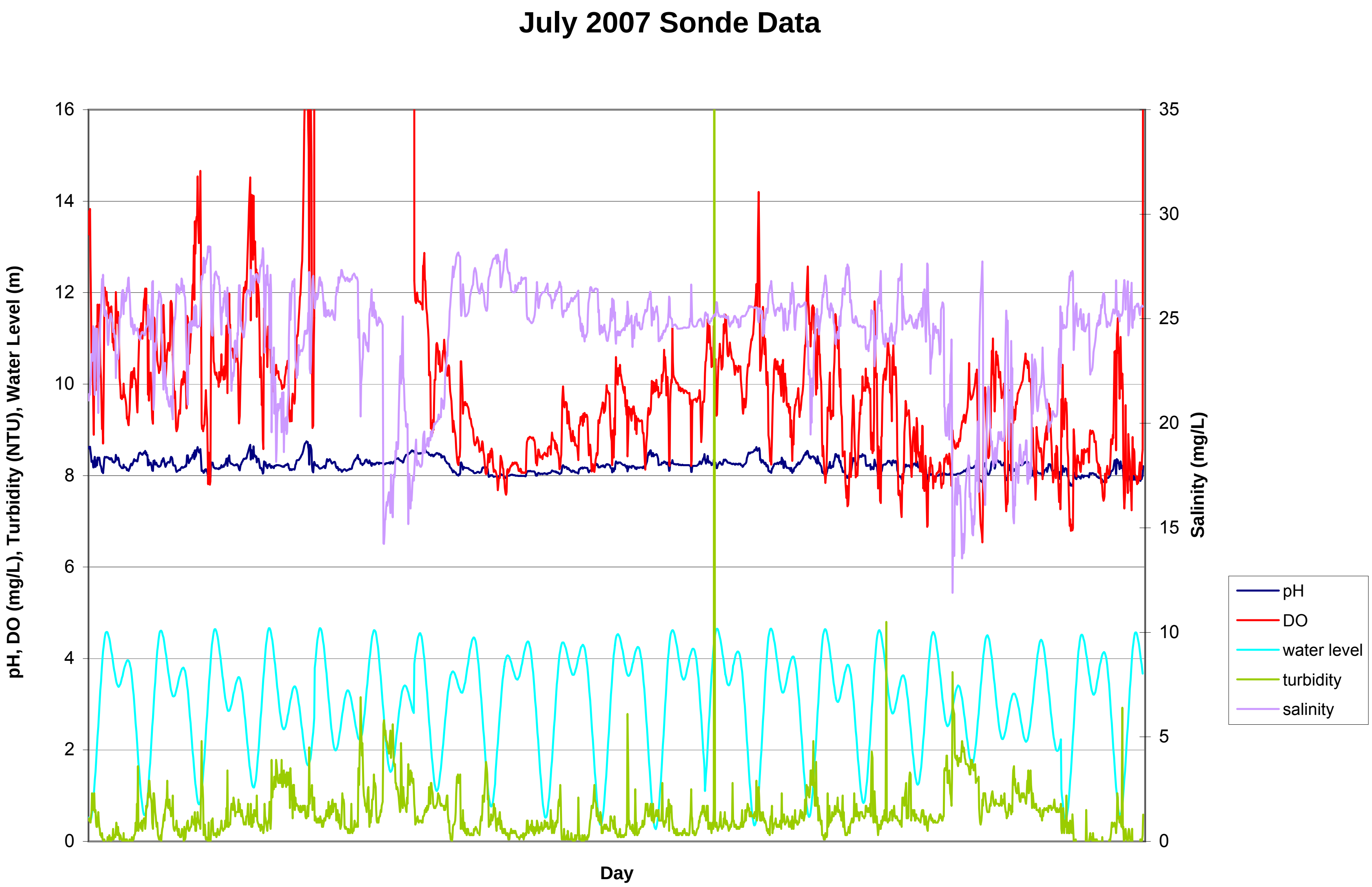
Photo 11. Hydraulic connection between water ponding along Roberts Bank causeway and with newly-formed dendritic channels.

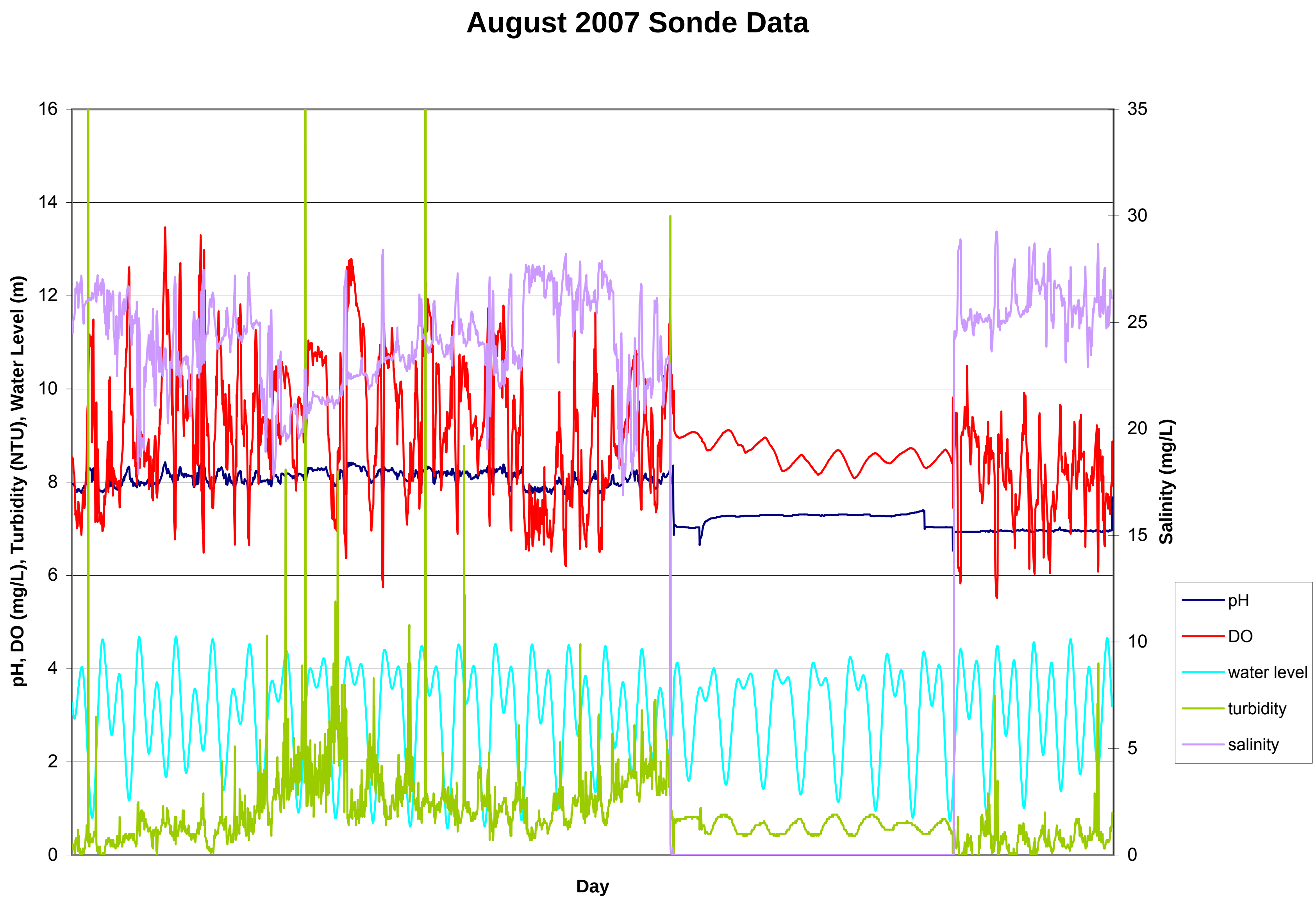
Photo 12. Drainage of ponded flow via newly-formed dendritic channels.

APPENDIX C
Sonde Data

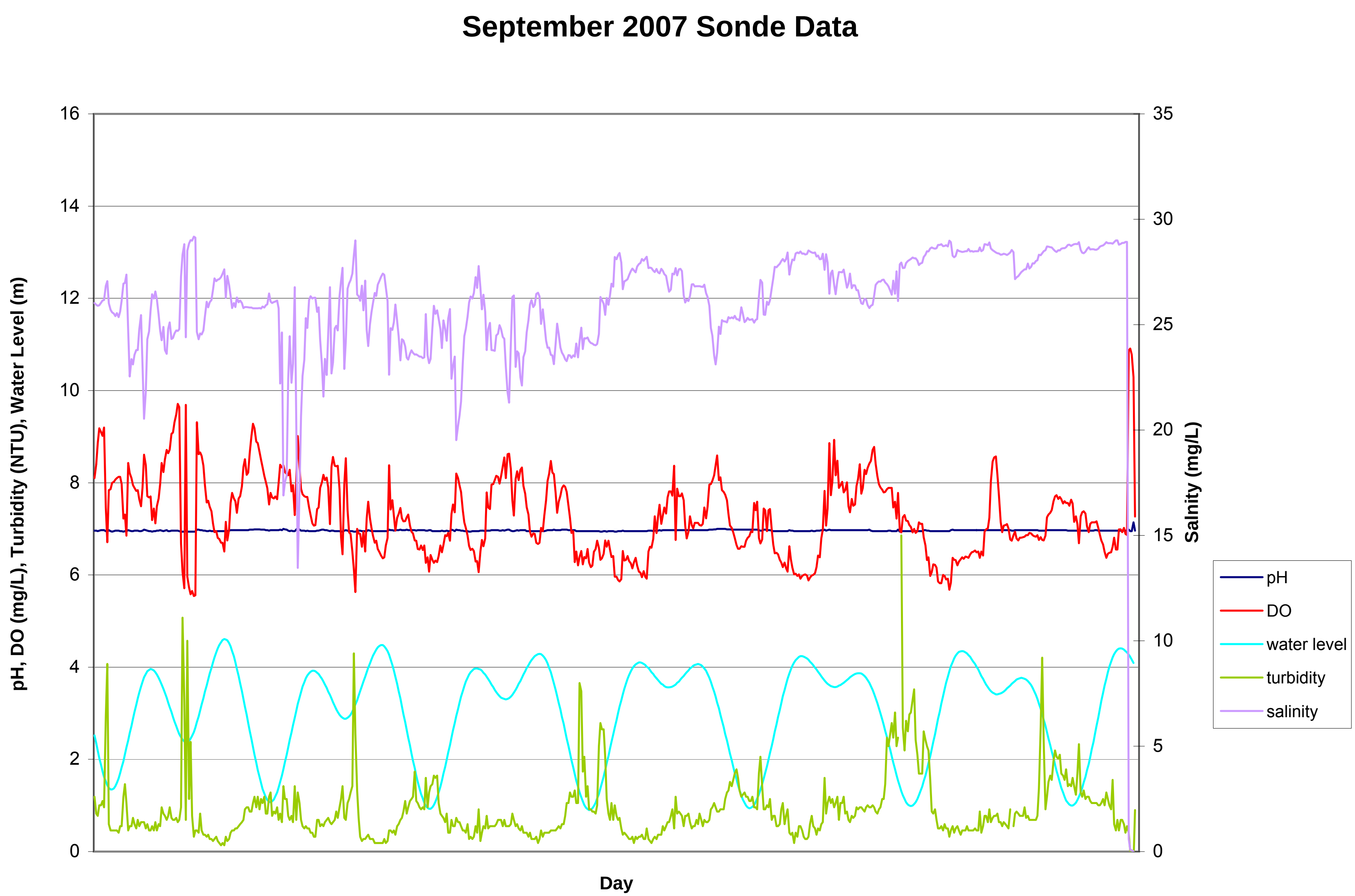

May 2007 Sonde Data
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
pH, DO (mg/L), Turbidity (NTU), Water Level (m)
Salinity (mg/L)
Day
pH
turbidity
DO
water level
salinity


June 2007 Sonde Data
)pH, DO (mg/L), Turbidity (NTU), Water Level (m
Salinity (mg/L)
Day
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
pH
DO
water level
turbidity
salinity


July 2007 Sonde Data
pH, DO (mg/L), Turbidity (NTU), Water Level (m)
Salinity (mg/L)
Day
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
pH
DO
water level
turbidity
salinity



August 2007 Sonde Data
pH, DO (mg/L), Turbidity (NTU), Water Level (m)
Salinity (mg/L)
Day
0
2
4
6
8
10
12
14
16
0
5
10
15
20
25
30
35
pH
DO
water level
turbidity
salinity


September 2007 Sonde Data
pH, DO (mg/L), Turbidity (NTU), Water Level (m)
Salnity (mg/L)
Day
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
pH
DO
water level
turbidity
salinity

APPENDIX D

Eelgrass Statistical Analysis Results

Appendix D: Results from statistical analysis comparing data from 2003 and 2007.

Results from paired two-sample, 2-tailed t-tests. Values of p <0.05 were considered significant

Site #	Total density	Length	Width	LAI	Reproductive Density
Inter-causeway near Coal Port Causeway					
1	0.389	1.797E-05	0.0692	0.061	0.639
2	0.202	0.093	0.002	0.495	0.081
Inter-causeway near Ferry Causeway					
5	0.0645	3.27E-05	7.03E-07	0.071	0.119
6	0.016	0.553	**0.206**	0.333	0.519
West of Coal Port Causeway					
3	0.169	0.012	6.140E-07	3.05E-05	0.004
4	0.268	0.077	3.486E-07	0.0007	0.419
Boundary Bay					
WR1	0.0003	0.474	0.060	0.0002	2.44E-12
WR2	1.65E-07	0.103	0.024	1.64E-05	0.007
WR3	0.441	5.834E-10	0.0001	1.33E-11	1.172

Results obtained using a Wilcoxon's signed ranks test (95.2% confidence interval) for differences between population medians.

Site #	Total density	Length	Width	LAI	Reproductive Density
Inter-causeway near Coal Port Causeway					
1	0.651	<0.0001	0.074	0.054	0.685
2	0.393	0.058	0.004	0.985	0.089
Inter-causeway near Ferry Causeway					
5	0.079	<0.0001	<0.0001	0.165	>0.999
6	0.017	0.701	0.216	0.409	0.6377
West of Coal Port Causeway					
3	0.275	0.014	<0.0001	0.0002	0.008
4	0.133	0.97	<0.0001	0.001	0.488
Boundary Bay					
WR1	0.0003	0.782	0.080	<0.0001	<0.0001
WR2	<0.0001	0.096	0.039	<0.0001	0.0078
WR3	0.368	<0.0001	0.0005	0.006	0.233

Bonferroni adjusted probability values. p-values <0.0025 were considered significant based on our understanding that p of 0.05 must be divided by the number of tests performed and that this equals the number of replicate samples (20).

Bonferroni adjusted probability values using separate variances are provided followed by the probability values calculated using pooled variance in brackets
.

Site #	Total density	Length	Width	LAI	Reproductive Density
Inter-causeway near Coal Port Causeway					
1	1.0 (1.0)	0 (0)	*	0.31 (0.30)	1 (1)
2	0.89 (0.87)	0.47 (0.43)	*	1.0 (1.0)	0.46 (0.46)
Inter-causeway near Ferry Causeway					
5	0.12 (0.12)	0 (0)	0 (0)	0.36 (0.36)	1 (1)
6	0.95 (0.94)	1 (1)	0.68 (0.65)	1 (1)	1 (1)
West of Coal Port Causeway					
3	0.94 (0.94)	0.07 (0.06)	0 (0)	0 (0)	0.009 (0.007)
4	1 (1)	0.35 (0.33)	0 (0)	0.004(0.004)	1 (1)
Boundary Bay					
WR1	0 (0)	1 (1)	0.23 (0.21)	0 (0)	0 (0)
WR2	0 (0)	0.48 (0.47)	0.09 (0.09)	0 (0)	0.13 (0.12)
WR3	1 (1)	0 (0)	0.003 (0.003)	0.07(0.07)	0.95 (0.94)

APPENDIX E

Bird Identification Codes

Code	Species	sp	su	f	w	Code	Species	sp	su	f	w
AMAV	American Avocet			ac	ac	COHA	Cooper's Hawk	u	u	u	u
ABDU	American Black Duck [I]			ca	ca	DEJU	Dark-eyed Junco	f	ca	f	f
AMCO	American Coot	u			u	DCCO	Double-crested Cormorant	f	u	f	f
AMDI	American Dipper				ac	DOWO	Downy Woodpecker	r	r	r	r
AGPL	American Golden-Plover			ca		DUNL	Dunlin	a		a	a
AMGO	American Goldfinch	f	f	f	f	EAGR	Eared Grebe				ca
AMKE	American Kestrel	r	r	r	ca	EAKI	Eastern Kingbird	r	r		
AMPI	American Pipit	u		f	ca	EMGO	Emperor Goose				ac
AMRO	American Robin	f	f	f	f	EUWI	Eurasian Wigeon	f		f	f
ATSP	American Tree Sparrow	ca			ca	EUST	European Starling [I]	c	c	c	a
AMWI	American Wigeon	a	r	a	a	EVGR	Evening Grosbeak	r		r	r
ANHU	Anna's Hummingbird		ca	ca	ca	FOSP	Fox Sparrow	u		u	u
BASA	Baird's Sandpiper	r		u		FRGU	Franklin's Gull		r	r	
BAEA	Bald Eagle	c	f	f	c	GADW	Gadwall	f	u	f	f
BTPI	Band-tailed Pigeon	r	r	r	ca	GLGU	Glaucous Gull				r
BKSW	Bank Swallow		r	r		GWGU	Glaucous-winged Gull	a	a	a	a
BNOW	Barn Owl	r	r	r	r	GOEA	Golden Eagle	ca			
BASW	Barn Swallow	f	f	c	ac	GCKI	Golden-crowned Kinglet				r
BDOW	Barred Owl				ac	GCSP	Golden-crowned Sparrow	u		u	u
BAGO	Barrow's Goldeneye	r		r	r	GCRF	Gray-crowned Rosy-Finch				ac
BEKI	Belted Kingfisher	u	u	u	u	GBHE	Great Blue Heron	c	c	c	c
BEWR	Bewick's Wren	r	ca	r	r	GREG	Great Egret		ca		
BLSC	Black Scoter	r		r	r	GHOW	Great Horned Owl		ca		
BLSW	Black Swift	f	f			GRSC	Greater Scaup	a	r	a	a
BLTU	Black Turnstone			r	r	GWFG	Greater White-fronted Goose	ca			ca
BBPL	Black-bellied Plover	a	u	a	c	GRYE	Greater Yellowlegs	f	r	f	u
BCCH	Black-capped Chickadee	f	f	f	f	GRHE	Green Heron	r	r	r	
BCNH	Black-crowned Night-Heron			ac		GWTE	Green-winged Teal	a	r	a	a
BHGR	Black-headed Grosbeak	r	r			GYRF	Gyrfalcon	ca			r
BLKI	Black-legged Kittiwake	ac				HAWO	Hairy Woodpecker				ca
BTWE	Blue-winged Teal	r	r	r		HADU	Harlequin Duck	r			r
BOGU	Bonaparte's Gull	a	c	a	r	HASP	Harris's Sparrow			ca	ca
BRCO	Brandt's Cormorant				r	HEEG	Heermann's Gull			ca	
BRAN	Brant	a	r	u	c	HETH	Hermit Thrush				ca
BRBL	Brewer's Blackbird	c	u	c	a	HEGU	Herring Gull	u		u	u
BRCR	Brown Creeper				r	HOME	Hooded Merganser			r	r
BHCO	Brown-headed Cowbird	f	u	u	r	HOGR	Horned Grebe	c		c	c
BUFF	Bufflehead	c	r	c	f	HOLA	Horned Lark			r	
BUOR	Bullock's Oriole		ca			HOFI	House Finch	f	f	f	c
BUSH	Bushtit	f	f	f	c	HOSP	House Sparrow [I]	c	c	c	c
CAGU	California Gull	c	f	c	r	HUGO	Hudsonian Godwit			ca	
CAGO	Canada Goose	a	f	c	a	HUVI	Hutton's Vireo	ca			
CANV	Canvasback	r		r	r	KILL	Killdeer	f	u	f	u
CATE	Caspian Tern	f	f	f		LZBU	Lazuli Bunting		ac		
CAVI	Cassin's Vireo	ca		ca		LESA	Least Sandpiper	a	r	a	
CEWA	Cedar Waxwing	u	f	f	ca	LESC	Lesser Scaup	f	ca	f	f
CBCH	Chestnut-backed Chickadee				r	LEYE	Lesser Yellowlegs	c	ca	c	
CHSP	Chipping Sparrow			ca		LISP	Lincoln's Sparrow	r		r	r
CITE	Cinnamon Teal	r	r	r	ca	LIST	Little Stint			ac	
CLGR	Clark's Grebe			ca		LBCU	Long-billed Curlew			ca	
CLSW	Cliff Swallow	u	u	u		LBDO	Long-billed Dowitcher	f	ca	c	u
COGO	Common Goldeneye	u	r	u	f	LEOW	Long-eared Owl				ac
COGR	Common Grackle				ac	LTDU	Long-tailed Duck (formerly Oldsquaw)		ca	r	r
COLO	Common Loon	a	u	a	c	MALL	Mallard	a	f	a	a
COME	Common Merganser			r	r	MAGO	Marbled Godwit		ca	ca	ac
COMU	Common Murre			r	r	MAMU	Marbled Murrelet				ac
CONI	Common Nighthawk		ca	ca		MAWR	Marsh Wren	u	u	u	r
CORA	Common Raven	r	r	r	r	MERL	Merlin	r	r		r
CORE	Common Redpoll				ac	MEGU	Mew Gull	a	r	a	a
COSN	Common Snipe	r	ca	r	r	MOBL	Mountain Bluebird	ca			
COTE	Common Tern	u	r	f		MODO	Mourning Dove	r	r	r	
COYE	Common Yellowthroat	u	u	u		MUSW	Mute Swan [I]	ca			ca

Code	Species	sp	su	f	w
NOFL	Northern Flicker	f	ca	f	u
NOGO	Northern Goshawk			ca	ca
NOHA	Northern Harrier	u	u	u	u
NHOW	Northern Hawk Owl				ac
NOPI	Northern Pintail	a	r	a	a
NRWS	Northern Rough-winged Swallow	r	r	r	
NOSL	Northern Shoveler	u	f	u	f
NOSH	Northern Shrike	r		r	r
NOCR	Northwestern Crow	c	f	c	c
OSFL	Olive-sided Flycatcher	ca			
OCWA	Orange-crowned Warbler	f	u	f	ac
OSPR	Osprey		ca	ca	
PALO	Pacific Loon	r		r	r
PSFL	Pacific-slope Flycatcher	r			
PAJA	Parasitic Jaeger			r	
PESA	Pectoral Sandpiper		r	f	
PECO	Pelagic Cormorant	u		u	f
PEFA	Peregrine Falcon	u	r	u	u
PBGR	Pied-billed Grebe	r		r	r
PIGU	Pigeon Guillemot				ca
PIWO	Pileated Woodpecker				ac
PISI	Pine Siskin	f	r	f	f
PRFA	Prairie Falcon				ca
PUFI	Purple Finch	r		r	r
RECR	Red Crossbill	r	r	r	r
REKN	Red Knot			ca	
RBME	Red-breasted Merganser	f	ca	f	u
RBNU	Red-breasted Nuthatch				ca
RBSA	Red-breasted Sapsucker				ac
REVI	Red-eyed Vireo	ca		ca	
REDH	Redhead				ca
RNGR	Red-necked Grebe	u		c	u
RNPL	Red-necked Phalarope	r		r	
RNST	Red-necked Stint			ac	
RTHA	Red-tailed Hawk	u	r	u	u
RTLO	Red-throated Loon	f		u	f
RWBL	Red-winged Blackbird	a	f	a	a
RBGU	Ring-billed Gull	a	a	a	f
RNPH	Ring-necked Pheasant [I]	u	u	u	u
RODO	Rock Dove [I]	f	f	f	f
ROSA	Rock Sandpiper				ca
RLHA	Rough-legged Hawk	r		r	r
RCKI	Ruby-crowned Kinglet	r		r	ca
RUDU	Ruddy Duck	r		r	r
RUTU	Ruddy Turnstone	r		r	ca
RUFF	Ruff			ca	
RUHU	Rufous Hummingbird	f	u	u	
SAND	Sanderling	c		c	c
SACR	Sandhill Crane	ca			
SAVS	Savannah Sparrow	f	f	f	f
SEPL	Semipalmated Plover	f	ca	f	ca
SESA	Semipalmated Sandpiper	ca		u	
SSHA	Sharp-shinned Hawk	r		r	r
SBDO	Short-billed Dowitcher	f		f	ca
SEOW	Short-eared Owl	r	r	r	r
SNBU	Snow Bunting			ca	
SNGO	Snow Goose	u		u	f
SNOW	Snowy Owl				ca
SOSA	Solitary Sandpiper		r	r	
SOSP	Song Sparrow	f	u	f	f

Code	Species	sp	su	f	w
SORA	Sora	r	r		
SPSA	Spotted Sandpiper	u	r	u	ca
SPTO	Spotted Towhee	u	u	u	f
STJA	Steller's Jay			ca	r
STSA	Stilt Sandpiper		r	r	
SUSC	Surf Scoter	a	r	a	a
SURF	Surfbird				ca
SWTH	Swainson's Thrush	r	r		
SWSP	Swamp Sparrow			ca	ca
THGU	Thayer's Gull	f		f	f
TOSO	Townsend's Solitaire	r			
TOWA	Townsend's Warbler				ac
TRSW	Tree Swallow	f	f	c	
TRUS	Trumpeter Swan	r		r	r
TUSW	Tundra Swan	c			c
TUVU	Turkey Vulture	r	ca	r	ca
VATH	Varied Thrush				ca
VASW	Vaux's Swift	f	f	u	
VGSW	Violet-green Swallow	f	f	c	
VIRA	Virginia Rail	ca	ca		ca
WAVI	Warbling Vireo	ca		ca	
WEGR	Western Grebe	u		c	u
WEGU	Western Gull	r		r	r
WEKI	Western Kingbird		ca		
WEME	Western Meadowlark	r	ca	r	r
WESA	Western Sandpiper	a	r	a	r
WSOW	Western Screech-Owl				ac
WETA	Western Tanager		ca		
WWPE	Western Wood-Pewee	ca			
WHIM	Whimbrel	ca	ca	ca	
WCSP	White-crowned Sparrow	f	u	f	u
WWSC	White-winged Scoter	f	r	f	f
WILL	Willet			ac	
WIFL	Willow Flycatcher	r	r	r	
WIPH	Wilson's Phalarope			r	
WIWA	Wilson's Warbler	r		r	
WIWR	Winter Wren			ca	ca
WODU	Wood Duck	ca			ca
YEWA	Yellow Warbler	f	u	f	
YHBL	Yellow-headed Blackbird	ac			
YRWA	Yellow-rumped Warbler	f	r	f	r
Other					
None					

Seasonal Occurrence
Sp = Spring (March - May; including spring migrants)
S = Summer (June - mid August; including spring arrival and fall departure)
F = Fall (mid August - November; including fall migrants)
W = Winter (November/December - February; including fall arrival and spring departures)

Relative Abundance
a = abundant [100 or more per day]
c = common [25 to 100 per day]
f = fairly common [5 to 25 per day]
u = uncommon [1 to 5 per day, with at least 10 records per year]
r = rare, but regular [1 to 10 records per year]
ca = casual [2 to 10 documented records in checklist area]
ac = accidental [only 1 documented record in checklist area during the specified season]