Deep Panuke

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2016 Offshore Environmental Effects Monitoring Annual Report

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Executive Summary

The objective of the Environmental Effects Monitoring (EEM) program for the Deep Panuke natural gas field is to address all production operations-related EEM commitments made during the Deep Panuke regulatory process as outlined in the 2007 Comprehensive Study Report (CSR) and environmental effects predictions made during the 2006 Environmental Assessments (EAs). The Deep Panuke EEM Plan (EEMP) builds on results and lessons learned from the Sable Offshore Energy Project (SOEP) EEM program which has been carried out on Sable Island Bank since 1997. The Deep Panuke EEM program is an adaptive process which incorporates learnings from the previous years of monitoring.

The Deep Panuke offshore EEM program was designed to address the following objectives:

- identify and quantify environmental effects;
- verify predictions made during the EA processes;
- evaluate the effectiveness of mitigation and identify the need for improved or altered mitigation;
- provide an early warning of undesirable change in the environment; and,
- assist in identifying research and development needs.

This documents details 2016 findings for the following EEM components:

- Produced water chemistry and toxicity (section 6.1 of the EEMP)
- Marine water quality monitoring (section 6.2 of the EEMP)
- Sediment chemistry and toxicity (section 6.3 of the EEMP)
- Fish habitat alteration on the subsea production structures (section 6.4 of the EEMP)
- Fish health assessment (mussels and fish) (section 6.5 of the EEMP)
- Marine wildlife observations (section 6.6 of the EEMP)
    - marine mammal and sea turtle observations;
    - stranded-bird observations; and
    - beached bird observation on Sable Island
- Air quality monitoring (section 6.7 of EEMP)

- air quality monitoring on Sable Island; and
- flare plume observations on Deep Panuke.

The results of the 2016 EEM program include the following:

Produced water chemistry and toxicity:

March and November 2016 produced water chemistry:

- Except for elevated naphthalene (PAH), benzene, toluene and ethylbenzene (March only) levels, all metal, non-metal, hydrocarbon and nutrient concentrations in the produced water were found to fall below threshold levels as defined by the Canadian EQG (CCME Guidelines) where available.
- 4-Nonylphenols (24.7 ng/L), 4-Nonylphenol monoethoxylates (226 ng/L) and 4-n-Octylphenol (2.3 ng/L) were detected in the November produced water sample. (No APs were detected in the March produced water sample.) No CCME guidelines are available.

March 2016 produced water toxicity:

- The IC50 for the Microtox test was 1.02%.
- The IC25 for the sea urchin fertilization test was 1.86%.
- The LC50 for the Threespine Stickleback toxicity test was 12.5%.

Marine water quality:

- All nutrients, major ions and organic aids detected were either slightly above or below the reportable detection limit (RDL)
- and did not exceed CCME guidelines where available.
- Metal, non-metal, hydrocarbon and nutrient concentrations were all found to fall below threshold levels as defined by the Canadian EQG (Environmental Quality Guidelines) where available, except for cadmium, which was slightly above CCME guidelines at the three stations where it was detected, and mercury, which was above CCME guidelines at all stations and depths sampled and at higher levels than measured in 2015.

- PAH and Total Petroleum Hydrocarbons including BTEX-TPH were all below laboratory RDLs.
- 4-Nonylphenols (which were not detected in 2015) were detected at all water stations and depths sampled with levels between 10.6 and 64.1 ng/L.
- 2016 detection patterns for tested parameters were similar to 2015 results except for the differences mentioned above. The data does not show any pattern of impact from production discharges on marine water chemistry.
- Dispersion rates for hydrocarbons and sulphides detected in produced water and water samples are within the levels predicted by the model (2006 and 2015 re-modeling). In fact, PAH / hydrocarbons and sulphide were not detected at any water sample from any of the seven stations.
- Temperature was similar across all stations sampled and ranged between 3.11 °C and 3.23 °C.
- pH was consistent across all stations sampled and had a narrow range of 7.38 to 7.88.
- Salinity followed similar trends across stations sampled, increasing slightly with depth. Salinity values ranged from 31.70 PSU to 32.82 PSU.
- Dissolved oxygen generally decreased with depth, and ranged from 79.11% to 99.34%.

Sediment Chemistry and Toxicity:

- The sediment type found at all stations consisted of fine to medium sand.
- Barium, strontium, thallium and zinc were not present at detectable levels across any stations, which is consistent with 2011 and 2015 results and a decrease from the baseline study results from 2008.
- Mercury, antimony, beryllium, bismuth, boron, cadmium, cobalt, copper, lithium, molybdenum, nickel, rubidium, selenium, silver and tin concentrations remain below detectable levels across all stations as was the case in all years tested.
- Aluminum, arsenic, iron, lead manganese, vanadium, chromium and uranium were detected at similar levels and followed generally similar trends across stations as in 2011 and 2015.

- Sulphide levels are consistent since 2011 at levels around/below 0.5 µg/g across all stations.
- PAH and BTEX-TPH parameters remain at non-detectable levels.
- Only one alkylated phenol parameter was detected, i.e. 4-Nonylphenol (NP) at the 250m station (0.686 ng/g).
- The comparison of post production data (2015 and 2016) with pre-production data (2008 and 2011) shows no sign of sediment contamination from production activities.
- All samples and control sediment as tested were found to be non-toxic to the amphipod *Eohaustorius estuaries*, except for the 500 m DS sample.
- The mean survival rate for the 500 m DS sediment was 54%, i.e. 45% lower than the control sediment. This sediment was much coarser than the other sediments tested with many shell fragments found at termination. It should be noted that the chemistry testing did not show any spike in any of the tested parameters for this sample.

Fish habitat alteration:

- Epifauna colonization of WHPS at all well site locations observed varied in numbers for some species from the 2015 survey. Several sections of the WHPS were cleaned one month prior to the 2016 survey, which accounted for the lower abundance observations. Species composition was relatively homogenous across all wellhead sites.
- Zonation of the PFC legs was similar to the 2015 survey results. Marine growth was sparse (<10% coverage) near the base of the legs with some hydroids, sea cucumbers, frilled anemone and sea stars. Cunner were also seen swimming around the base of all four legs. Five metres from the base of the legs, dense mussels were observed over the entire legs. *Asterias* sp. and *Henricia* sp. were more common around the midpoint of the legs. Metridium and hydroids were present on the legs, and increased with decreasing water depth.
- Wellheads and protective structures appear to continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures, as predicted in the 2006 EA. The structures are attracting fish from the surrounding areas and providing shelter in an otherwise relatively featureless seafloor.

- In addition to the WHPS video clips analyzed, incidental species sightings by the ROV operator in 2016 included eight lobsters and an Atlantic torpedo ray.
- The GEP continues to act as an artificial reef to provide shelter and protection for many species of fish (*i.e.,* redfish and Atlantic wolffish) and invertebrates.
- Commercial fish species recorded from the video analysis included Atlantic cod, pollock, haddock, redfish and Atlantic hagfish (*Myxine glutinosa*). Abundance of these commercial species increased starting around KP 52.
- Commercial crustaceans observed in the analyzed video were snow crabs and Jonah crabs. Jonah crabs were the most abundant crustacean in the eight videos analyzed, which is consistent with the same video sections in 2014.
- Other commercial invertebrates observed include the orange-footed sea cucumber, which were often observed on top of the GEP.
- SARA-listed Atlantic wolffish were observed near the GEP, beginning at KP 63 and appear to be using the pipeline as a refuge burrow.
- Garbage and debris continue to collect at the GEP, due to it being a physical barrier. The most common items were soft debris, rope and netting.
- Habitat/substrate types along buried sections of the GEP and flowlines were consistent with previous years. Sand buried sections showed no difference to the adjacent sand seafloor with very little marine life/growth and periodic starfish and shells. Rock berms and rock filter units installed were predominately covered with sea cucumbers with some starfish.

Fish Health Assessment:

Mussel sampling

- As in 2015, no PAH parameters tested for were detected in the mussels collected from the PFC or the commercial control mussels.
- Deep Panuke and control mussels had similar levels of 4-NP and NP2EO. NP1EO was not detected in the Deep Panuke sample or the control. 4n-OP was only detected in the control sample.

Fish sampling

- The fish health assessment found no significant abnormalities in either the caught cod or the caught sculpin.

- PAHs were non-detectable in the caught cod and the commercial cod. 4-NP, 4n-OP and NP2EO were detected in the caught cod, but they were all also detected in higher concentrations in the commercial cod.

Marine wildlife observations:

- Nine bird strandings were reported in 2016. All birds were found dead on the PFC. No birds were found to have oil on them. Two were sent for necropsies, the others were either inaccessible or disposed of at sea.
- Both the supply vessels, the M/V Atlantic Condor and the M/V Atlantic Tern, reported wildlife sightings in 2016, including a variety of seabirds as well as seals, dolphins, sunfish, and Minke and large whales.
- Monitoring of oiling rates in beached birds on Sable Island was conducted over the course of eight surveys carried out between January and November 2016, where 149 beached seabird corpses were collected. Alcids accounted for 28.9% of the total corpses recovered. Of the 149 corpses, 98 (65.8%) were complete (>70% of body intact). The overall oiling rate for all species combined (based on complete corpses) was 0.0% (compared with 0.5% in 2015 and 3.2% in 2014).

Air Quality Monitoring:

- Sable Island air emissions monitoring
  - 2016 had reasonable environmental effects monitoring coverage thanks to new instruments installed on Sable Island in Q1 of 2016.
  - 2016 data completeness for temperature, wind direction and wind speed was excellent.
  - There were no operational spike threshold or air quality standard breaches for O_3 or NOx in 2016. However, there was an H_2S spike of 6.01 ppbv on July 17, 2016, which was well below the 1-hr Nova Scotia air quality objective of 30 ppbv. An elevated SO_2 level of 3.04 ppbv was recorded at the same time, though it was well below the operational spike threshold of 6.0 ppbv and the 1-hr Canada Ambient Air Quality Objectives threshold of 344 ppbv. Back trajectory modeling shows that air flow passed over both the Deep Panuke and Thebaud platforms. The spike might be due to an issue with flaring of

H_2S on the Deep Panuke platform at the time (abnormally low ratio of dilution gas).

- The Ringelmann smoke chart was used to monitor the flare twice daily on the PFC. On a scale from zero to five, the flare was a “0” (no smoke) 22% of the time that the plant was in production, a "1" 69% of the time, a "2" 8% of the time and a “3” 0.4% of the time. Flare tip replacement in April-May 2016 had no obvious effect on flare smoke quality.

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All appendices follow the main body of the report

LIST OF DIGITAL APPENDICES

Digital appendices are submitted separately.

GLOSSARY OF TERMS

APs	Alkyl Phenols
BC	Black Carbon
BC	British Columbia
BTEX	Benzene, Toluene, Ethylbenzene, Xylene(s)
C	Celsius
CCME	Canadian Council of Ministers of the Environment
CEQG	Canadian Environmental Quality Guidelines
CH_4	Methane
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COPAN	Cohasset and Panuke
CSR	Comprehensive Study Report
CWS	Canadian Wildlife Service
DIC	Dissolved Inorganic Carbon
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DS	Downstream
EA	Environmental Assessment
EEM	Environmental Effects Monitoring
EEMP	Environmental Effects Monitoring Plan
EPCMP	Environment Protection and Compliance Monitoring Plan
EQG	Environmental Quality Guidelines
ESRF	Environmental Studies Research Fund
GC	Gas Chromatography
GEP	Gas Export Pipeline
GHG	Greenhouse Gases
GVI	General Visual Inspection
H_2S	Hydrogen Sulphide
IC	Ion Chromatography
ICP	Inductively Coupled Plasma

ISE	Ion Selective Electrode
KP	Kilometre Point
LC49	Bioassay Acute Toxicity Analysis
LAT	Lowest Astronomical Tide
LRMS	Low Resolution Mass Spectrometry
MOPU	Mobile Offshore Production Unit
M&NP	Maritimes & Northeast Pipeline
MS	Mass Spectrometry
MV	Motor Vessel
NB	New Brunswick
ND	Not Detected
NEB	National Energy Board
NMHC	Non-methane hydrocarbons
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Nitrogen Oxides
OES	Optical Emission Spectroscopy
O&G	Oil and Gas
O_3	Ozone
OWTG	Offshore Waste Treatment Guidelines
PAH	Polynuclear Aromatic Hydrocarbons
PFC	Production Field Centre
pH	Power of Hydrogen
$PM_{2.5}$	Fine airborne particulate matter with a median aerodynamic diameter ≤ 2.5 microns
ppb	Parts per billion
PPMW	Parts per million by weight
PSU	Practical Salinity Units
PTGC	Programmed Temperature Gas Chromatography
ROV	Remotely Operated Vehicle
QA	Quality Assurance
QC	Quality Control
RDL	Reportable Detection Limit
S^{2-}	Sulphide

SACFOR	Abundance Scale; S-superabundant, A-abundant, C-common, F-frequent, O-occasional, R-rare
SBM	Single Buoy Moorings Inc.
SO_2	Sulphur Dioxide
SOEP	Sable Offshore Energy Project
SSIV	Subsea Isolation Valve
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
US	United States
US	Upstream
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VECs	Valued Environmental Components
VOCs	Volatile Organic Compounds
WBM	Water-based Mud
WGS84	World Geodetic System 1984
WHPS	Wellhead Protection Structure

1 INTRODUCTION

The environmental effects monitoring (EEM) program for the Deep Panuke natural gas field started in 2011 (post drilling and pre-production activities). This 2016 report represents the sixth yearly EEM report submitted by Encana as per the approved Deep Panuke Offshore Production EEM Plan (Encana, 2011: DMEN-X00-RP-EH-90-0003).

The 2016 EEMP project team consisted of the following:

- McGregor GeoScience Ltd. for field sampling operations and lab testing coordination;
- Lab services from Maxxam Analytics (produced water, marine water, sediment, mussel and fish chemistry, including subcontract to AXYS Analytical Services Ltd for alkylphenol testing); Harris Industrial Testing Service (produced water and sediment toxicity, including subcontract to Aquatox for Microtox and sea urchin fertilization testing) and the Atlantic Veterinary College (fish health assessment);
- Stantec for subsea video data analysis;
- SBM/Encana personnel from the production field centre (PFC) and support vessels, MV Atlantic Condor and MV Atlantic Tern, for sampling operations, bird monitoring, wildlife observations and flare plume monitoring;
- Zoe Lucas Consulting for Sable Island beached bird surveys;
- Kingfisher Environmental Health Consultants for Sable Island air quality monitoring; and
- Encana for project reporting.

Table 1.1 below provides an overview of the 2016 EEM program including relevant EEM components and survey timing.

Table 1.1 - Overview of 2016 EEM Program

EEM Component(s)	*2015 EEM Program*	*Survey Timing*
Produced water chemistry and toxicity Section 6.1 of EEMP	Produced water collected on Deep Panuke for chemical characterization and toxicity testing.	Mar and Nov 2016
Marine water quality monitoring Section 6.2 of EEMP	Chemical and oceanographic characterization of water at 3 depths at 7 tide-dependent sites around the PFC.	Mar 2016
Sediment chemistry and toxicity Section 6.3 of EEMP	Chemical characterization and toxicity of sediments at 6 field and reference stations.	Mar 2016

EEM Component(s)	2015 EEM Program	Survey Timing
Fish health assessment Section 6.5 of EEMP	Collection of mussels and fish for body burden and fish health analysis.	Mar 2016
Fish Habitat Alteration Section 6.4 of EEMP	Inspection of ROV video data to determine development of benthic communities at the wellheads, PFC legs and pipelines.	Feb to Dec 2016
PFC Marine Wildlife Observations Section 6.6 of EEMP	Summarize PFC and vessels wildlife observations, including stranded birds.	Continuous
Oiled Bird Study on Sable Island Section 6.6 of EEMP	Beached bird surveys on Sable Island. Species identification, corpse condition and extent of oiling.	Throughout 2016
Air Quality Section 6.7 of EEMP	Monitoring of air emissions with air quality monitoring instruments deployed on Sable Island	Throughout 2016
Flare Plume observations Section 6.7 of EEMP	Systematic flare smoke monitoring (twice a day) using the Ringelmann smoke chart.	Throughout 2016

1.1 DEEP PANUKE BACKGROUND

The Deep Panuke natural gas field is located offshore, 250 km southeast of Halifax, Nova Scotia, approximately 45 km to the west of Sable Island in water depths ranging from 42 m to 50 m (Figure 1.1).

The project involves offshore production, processing and transport via a nominal 559 mm (22 inch) pipeline to an interconnection with the Maritimes & Northeast Pipeline (M&NP) facilities near Goldboro, Nova Scotia. The M&NP main transmission pipeline delivers to markets in Canada and the Northeast United States. The condensate produced offshore is treated and used as fuel on the PFC. The Deep Panuke facilities consist of a PFC which includes a hull and topsides facilities, four subsea production wells (H-08, M-79A, F-70, and D-41) (Figures 1.2 and 1.3), a disposal well (E-70) and associated subsea flowlines and control umbilicals, and a gas export pipeline to shore.

Deep Panuke is a sour gas reserve with raw gas containing approximately 0.18 mol % hydrogen sulphide (H2S). The offshore processing system consists of separation, compression (inlet and export), gas sweetening, gas dehydration, gas dewpointing (via Joule-Thompson), condensate sweetening and stabilization, and produced water treatment and disposal. Once H2S and carbon dioxide (acid gas) have been removed from the raw gas stream to acceptable levels, the acid gas is injected into a dedicated underground disposal well.

In November 2007, Encana entered into an agreement with Single Buoy Moorings Inc. (SBM) for the engineering, procurement, fabrication, installation and commissioning of the Deep Panuke PFC. During the production operations, Encana remains the Operator of Record but SBM owns and operates the production facility and oversees day-to-day field operations, as directed by Encana, including production, marine, helicopter and onshore logistics.

Significant project's milestones achieved in 2016 are as follows:

- 2016 was the fourth year of production operations at Deep Panuke (the field started producing in August 2013 and "First Gas", or start of steady state production, was announced on December 17, 2013). Depending on operational status, production rate varied, with maximum production capability reaching approximately 148 million cubic feet per day in January. Produced water volumes varied greatly depending on wells producing and peaked at 4,808 m^3/day in January.
- There were several extended shutdown periods in 2016 (Jan 15-26; Mar 20-May 26; May 29-Jun 16; Oct 14-25 and Nov 1-8).
- The annual ROV subsea survey took place over the flowlines, wellheads and export pipeline to shore from February to December.
- D-41 started producing formation water in October. (H-08, F-70 and M-79A have been making formation water since 2014.)
- An acid treatment was conducted on M-79A on January 30 (though the well did not re-start until March 17).
- A foam-assisted lift trial was conducted on H-08 between January 10-29 and March 2-5.

The general project location of the Deep Panuke EEMP is shown in **Figure 1.1**. Rendering of the production platform and the wellheads are shown in **Figure 1.2** and schematic of the Deep Panuke subsea production structures referenced in this report can be seen on **Figure 1.3**.

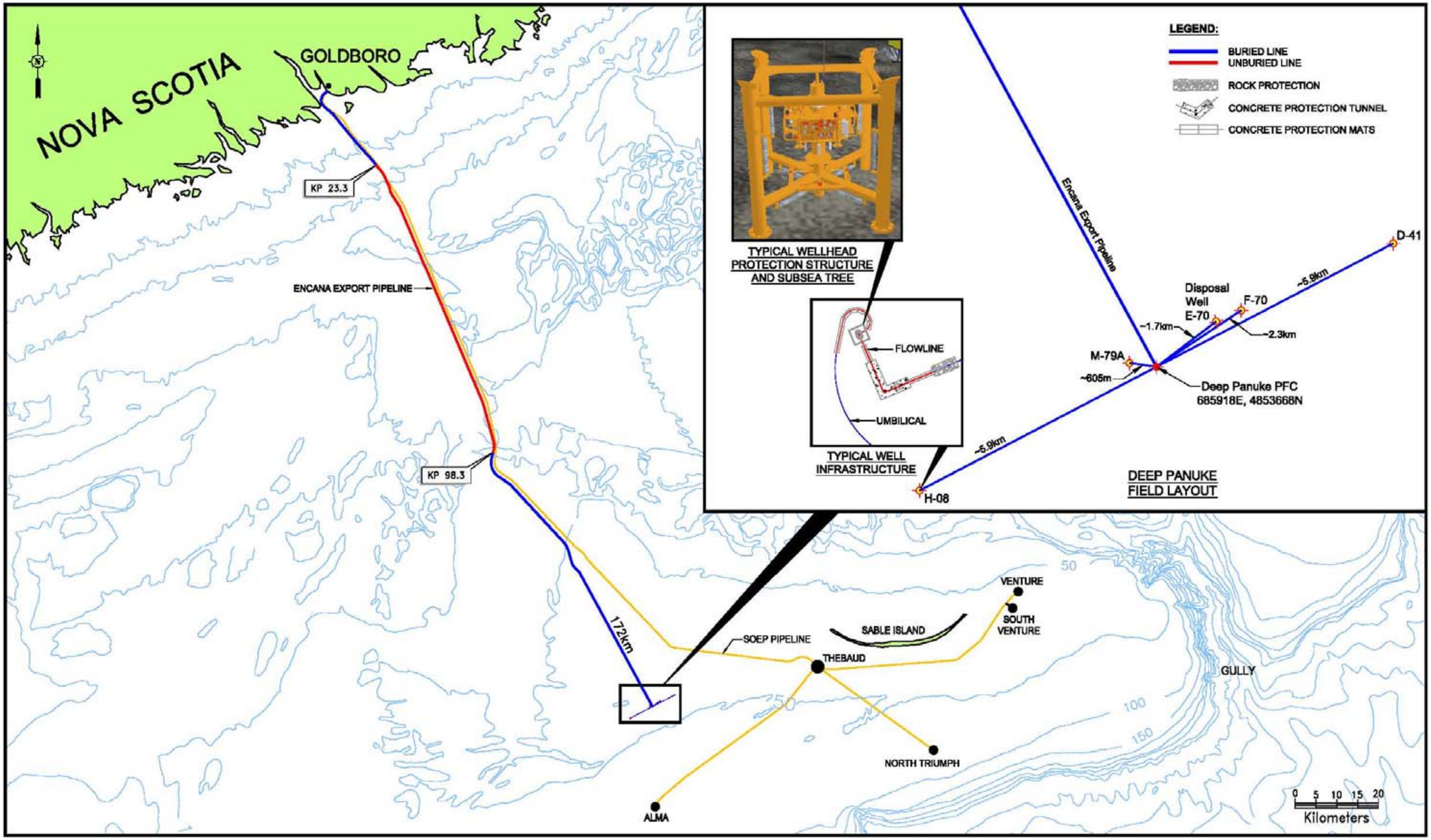

Figure 1.1 Deep Panuke Subsea Production Structures - General Overview (From Offshore Production EEMP - May 21, 2011)

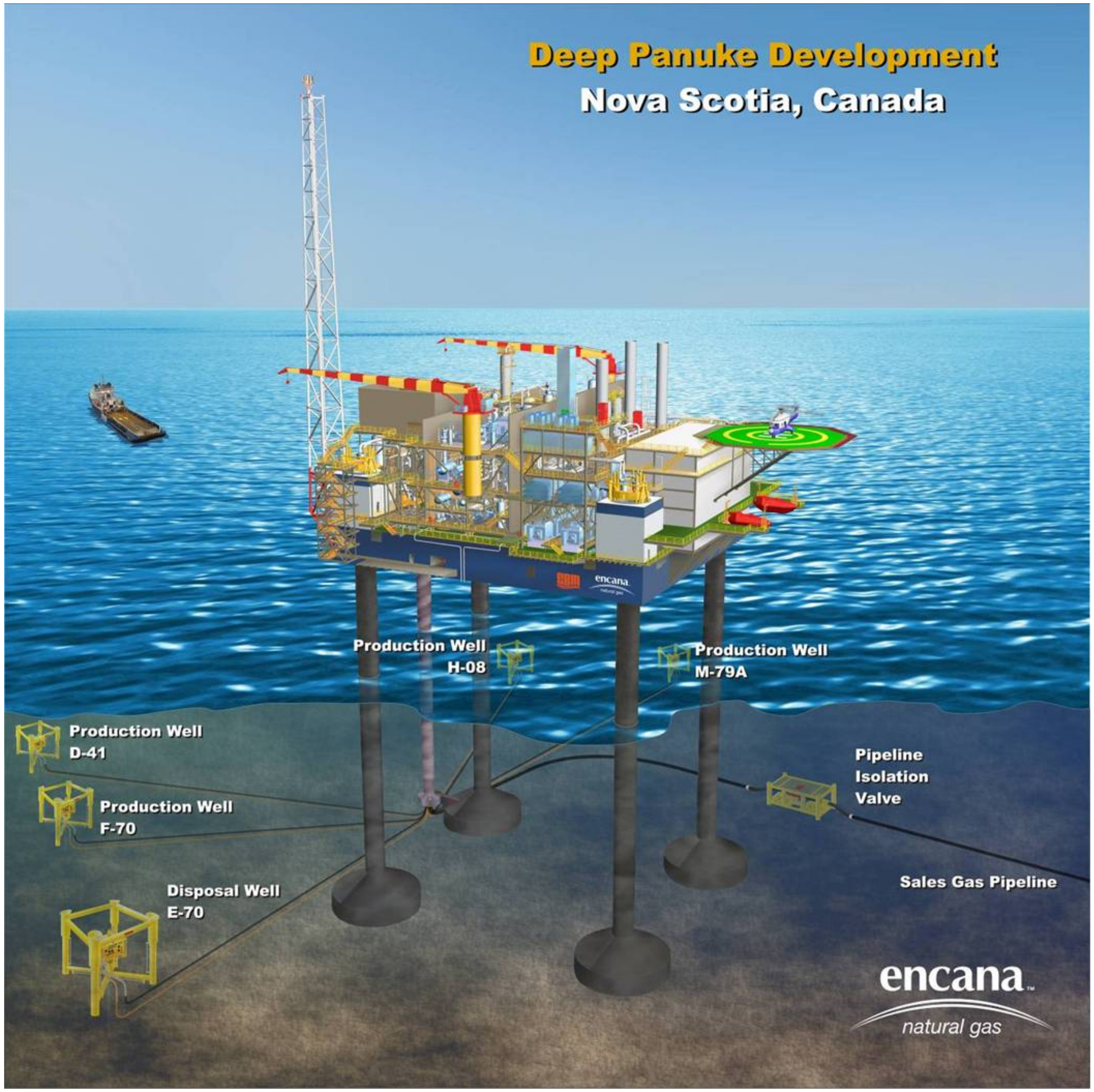

Figure 1.2 Deep Panuke Production Field Centre Rendering (From Offshore Production EEMP - May 21, 2011)

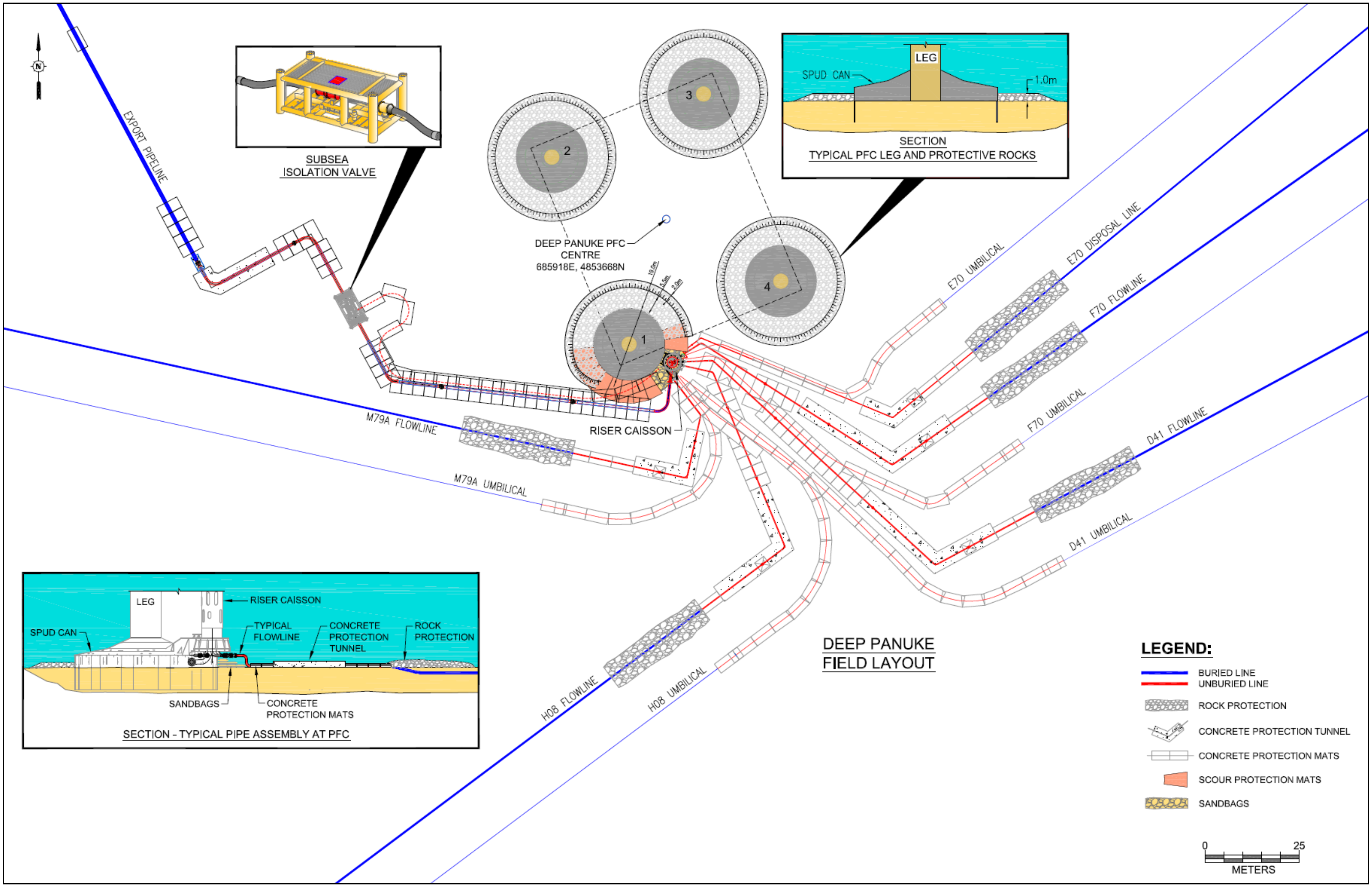

Figure 1.3 Deep Panuke Subsea Production Structures - PFC Area (From Offshore Production EEMP, May 21 2011)

2 EEM COMPONENTS

2.1 PRODUCED WATER CHEMISTRY AND TOXICITY

2.1.1 Background

Produced waters, which are generated during the production of oil and gas, represent a complex mixture of dissolved and particulate organic and inorganic chemicals varying in salinity from freshwater to concentrated saline brine (Lee & Neff, 2011). The physical and chemical properties of produced water vary widely depending on the geological age, depth, geochemistry of the hydrogen-bearing formation as well as the chemical composition of the oil and gas phases in the reservoir and processes added during production. On most offshore platforms, these waters represent the largest volume waste stream in oil and gas exploration and production operations (Stephenson, 1992).

There is concern about ocean disposal of produced water because of the potential for chronic ecological impact. In particular, aromatic hydrocarbons, some alkylated phenols and some metals, if present in high enough concentrations, can lead to bioaccumulation and toxicity in marine organisms.

The Deep Panuke produced water compliance monitoring program is designed to meet testing and reporting requirements from the *Offshore Waste Treatment Guidelines* (*OWTG*) (CNSOPB, C-NLOPB, NEB, December 2010) and is outlined in the Deep Panuke Production Environment Protection and Compliance Monitoring Plan (EPCMP) (DMEN-X00-RP-EH-90-0002). Produced water chemistry and toxicity testing are considered environmental compliance monitoring since they are a requirement under the *OWTG*. They are included together in the EEMP report as they assess the potential impact of contaminants discharged in the marine environment.

The *OWTG* specify a maximum limit of 30 mg/L (30-day volume-weighted average) and 44 mg/L (24-hour volume-weighted average) of oil in produced water discharged to the marine environment. Encana's design target for Deep Panuke is 25 mg/L (30-day volume-weighted average). The concentration of oil in produced water is measured at least every 12 hours and rolling 24-hr and 30-day volume-averages are calculated for each sample.

The chemical composition of produced water is analyzed twice yearly for the following parameters (see **Table 2.3** for details):

- hydrocarbons: total petroleum hydrocarbons (TPH), BTEX, poly-aromatic hydrocarbons (PAHs) and alkyl phenols (APs);
- metals;
- non-metals (nitrogen, phosphorus, sulphur, oxygen);
- nutrients (nitrate, phosphate, ammonia, organic acids);
- sulphide;
- salinity;
- pH; and
- temperature.

This list of chemical parameters to test for in produced water has been developed to be consistent with the EEM marine water quality sampling program in order to allow for comparisons between concentrations of the same parameters prior to and after discharge of produced water to the marine environment. As such, the list is expected to evolve based on the results from the marine water quality monitoring program.

Produced water is tested for toxicity annually. The marine toxicity testing typically includes the sea urchin fertilization test and at least two other bioassay tests (e.g., early life stage of fish, bacteria, algal species, etc.). The tests are conducted contemporaneously with one of the twice-yearly chemical characterization tests. Besides the Sea Urchin Fertilization test, Dr. Ken Doe of the Environment Canada Toxicology Laboratory in Moncton, NB recommended the Threespine Stickleback Test for the SOEP EEM Program as an indicator of fish toxicity and the Microtox test as an indicator of toxicity at the cellular level.

2.1.2 EEMP Goal

The potential toxicity of produced water from the Deep Panuke PFC will be examined using indicator species and to perform chemical characterization test as per the Deep Panuke Production EPCMP (DMEN-X00-RP-EH-90-0002) [Deep Panuke EA predictions #1, 3, 4, 5 & 6 in **Table 3.1**].

2.1.3 Objectives

Produced water collected on the Deep Panuke PFC will be analyzed for marine toxicity testing and chemical composition as per the Deep Panuke Production EPCMP (DMEN-X00-RP-EH-90-0002, refer to Section 6.1.1).

Produced water samples are taken on the PFC (i.e., prior to mixing with seawater system discharge before overboard discharge) to be analyzed for chemistry (twice yearly) and toxicity (annually). If feasible, one of the twice-yearly produced water chemistry samples is collected the same day as the EEM water quality samples to allow for comparison between concentrations of the tested parameters prior to and after discharge of produced water to the marine environment. If feasible, this sampling is scheduled during steady state of production operations such that the samples are representative of average conditions. Production data and produced water equipment performance are recorded at the time of sampling.

2.1.4 Sampling

Produced water was collected in March and November 2016 for chemical characterization (See **Table 2.1** and **Table 2.2** for details) and in March 2016, toxicity tests were performed (See **Table 2.2**).

Table 2.1 - Produced Water Sampling Details - March

<table>
<tr><td>Sample Date:</td><td>March 12, 2016 at 07:30 (local time)</td></tr>
<tr><td>Type of Sample:</td><td>Produced water samples</td></tr>
<tr><td>Test Sample Locations:</td><td>
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<tr><th>Station</th><th>Water Depth(m)</th><th>Easting</th><th>Northing</th></tr>
<tr><td>PFC, produced water discharge line sampling point</td><td>NA</td><td>685918</td><td>4853668</td></tr>
<tr><td colspan="4">WGS84 UTM Zone 20N</td></tr>
</table>
</td></tr>
<tr><td>Number of Samples/Locations:</td><td>Water was collected on the platform by PFC laboratory personnel.</td></tr>
<tr><td>Equipment:</td><td>Water was collected directly from a produced water outlet located on the PFC and transferred to sampling containers. Containers were put on ice in a cooler and shipped to Halifax via the MV Atlantic Condor.</td></tr>
<tr><td>Sample Preparation:</td><td>
<table>
<tr><th>Parameter</th><th>Preservative</th></tr>
<tr><td>Organic acids</td><td>no preservative</td></tr>
<tr><td>Mercury</td><td>Potassium dichromate</td></tr>
<tr><td>BTEX/TPH</td><td>Sodium Bisulphate</td></tr>
<tr><td>Metal scan and Sulphur</td><td>Nitric acid</td></tr>
<tr><td>BTEX/TPH - volatile</td><td>Sodium Bisulphate</td></tr>
<tr><td>Alkylated Phenols</td><td>no preservative</td></tr>
<tr><td>PAHs</td><td>no preservative</td></tr>
<tr><td>Nitrate/ortho-P/Total Nitrogen</td><td>no preservative</td></tr>
<tr><td>Sulphide</td><td>Zn Acetate + NaOH</td></tr>
<tr><td>Total P/Ammonia</td><td>Sulphuric Acid</td></tr>
<tr><td>Microtox</td><td>no preservative</td></tr>
<tr><td>Sea Urchin Fertilization Test</td><td>no preservative</td></tr>
<tr><td>Threespine Stickleback LC50</td><td>no preservative</td></tr>
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</td></tr>
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Table 2.2 - Produced Water Sampling Details - November

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<tr><td>Sample Date:</td><td>November 29, 2016 at 10:10 am local time</td></tr>
<tr><td>Type of Sample:</td><td>Produced water samples</td></tr>
<tr><td>Test Sample Locations:</td><td>
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<tr><td>PFC, produced water discharge line sampling point</td><td>10:10</td><td>NA</td><td>685918</td><td>4853668</td></tr>
<tr><td colspan="5">WGS84 UTM Zone 20N</td></tr>
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<tr><td>Metal scan and Sulphur</td><td>Nitric acid</td></tr>
<tr><td>BTEX/TPH - volatile</td><td>Sodium Bisulphate</td></tr>
<tr><td>Alkylated Phenols</td><td>no preservative</td></tr>
<tr><td>PAHs</td><td>no preservative</td></tr>
<tr><td>Nitrate/ortho-P/Total Nitrogen</td><td>no preservative</td></tr>
<tr><td>Sulphide</td><td>Zn Acetate + NaOH</td></tr>
<tr><td>Total P/Ammonia</td><td>Sulphuric Acid</td></tr>
</table>
</td></tr>
</table>

2.1.5 Analyses

2.1.5.1 Produced Water Chemistry Analysis

Produced water was analyzed for parameters summarized in **Table 2.3**. Major ions were determined using Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES), while trace elements were determined using Inductively Coupled Plasma – Mass

Spectrometry (ICP-MS) was used, except for mercury, which was analyzed using Cold Vapour AA method. Nutrients were determined by a variety of instruments including chromatographs, colorimeters, and spectrophotometers. DIC was measured on an Elemental Analyzer. DOC was measured with a carbon analyzer after high temperature catalytic oxidation.

Water samples were also analyzed for total petroleum hydrocarbons (TPH) including benzene, toluene, ethylbenzene, and xylene(s) (BTEX), gasoline range organics (C6 to C10), and analysis of extractable hydrocarbons – fuel oil (>C10 to C16), fuel oil (>C16 to C21) and lube oil (>C21 to C32) range organics. BTEX and gasoline range organics were analyzed by purge and trap-gas chromatography/ mass spectrometry or headspace – gas chromatography (MS/flame ionization detectors). Extractible hydrocarbons, including diesel and lube range organics were analyzed using capillary column gas chromatography (flame ionization detector).

Alkylated phenols were analyzed by AXYS Analytical Services Ltd. for Maxxam Analytics. AXYS method MLA-004 describes the determination of 4-n-octylphenol, nonylphenol and nonylphenol ethoxylates in aqueous samples, and in extracts from water sampling columns (XAD-2 columns). Concentrations in XAD-2 resin and filters are reported on a per sample basis or a per volume basis.

Sulphides in water were analyzed using the ion selective Electrode (ISE). The sulphide may be in the form of S^{2-}, HS- or H_2S.

Produced water chemistry analysis QA/QC parameters are described in the labs reports found in **Digital Appendices A1 and A2**.

Table 2.3 - Produced Water Chemistry Parameters Measured

Parameter	Units	RDL March	RDL November	CCME Guidelines	Analysis Method
Nutrients					
Nitrate + Nitrite	mg/L	0.050	0.050	N/A	colorimetry
Nitrate (N)	mg/L	0.050	0.050	1500	colorimetry
Nitrite (N)	mg/L	0.010	0.010	N/A	colorimetry
Nitrogen (Ammonia)	mg/L	0.25	2.5	N/A	colorimetry
Orthophosphate (P)	mg/L	0.050	0.010	N/A	colorimetry
Major Ions					

Parameter	Units	RDL March	RDL November	CCME Guidelines	Analysis Method
Phosphorus	mg/L	0.020	0.020	N/A	AC
Salinity	N/A	2.0	10	N/A	
Sulphide	mg/L	0.020	0.020	N/A	ISE
Organic Acids					
Formic Acid	mg/L	10	10	N/A	IC
Acetic Acid	mg/L	20	20	N/A	IC
Propionic Acid	mg/L	20	20	N/A	IC
Butyric Acid	mg/L	40	40	N/A	IC
Trace Metals					
Aluminum (Al)	µg/L	5.0	500	N/A	ICP-MS
Antimony (Sb)	µg/L	1.0	100	N/A	ICP-MS
Arsenic (As)	µg/L	1.0	100	12.5	ICP-MS
Barium (Ba)	µg/L	0.1	100	N/A	ICP-MS
Beryllium (Be)	µg/L	0.1	100	N/A	ICP-MS
Bismuth (Bi)	µg/L	2.0	200	N/A	ICP-MS
Boron (B)	µg/L	500	5000	N/A	ICP-MS
Cadmium (Cd)	µg/L	0.010	1.0	0.12	ICP-MS
Calcium (Ca)	µg/L	100	10000	N/A	ICP-MS
Chromium (Cr)	µg/L	1.0	100	Hex = 1.5, Tri = 56	ICP-MS
Cobalt (Co)	µg/L	0.40	40	N/A	ICP-MS
Copper (Cu)	µg/L	2.0	200	N/A	ICP-MS
Iron (Fe)	µg/L	50	5000	N/A	ICP-MS
Lead (Pb)	µg/L	0.50	50	N/A	ICP-MS
Magnesium (Mg)	µg/L	100	10000	N/A	ICP-MS
Manganese (Mn)	µg/L	2.0	200	N/A	ICP-MS
Mercury (Hg)	µg/L	0.13	0.13	0.016	Cold Vapour AA
Molybdenum (Mo)	µg/L	2.0	200	N/A	ICP-MS
Nickel (Ni)	µg/L	2.0	200	N/A	ICP-MS
Phosphorus (P)	µg/L	100	10000		
Potassium (K)	µg/L	100	10000	N/A	ICP-MS
Selenium (Se)	µg/L	1.0	100	N/A	ICP-MS
Silver (Ag)	µg/L	0.10	10	N/A	ICP-MS
Sodium (Na)	µg/L	1000	10000	N/A	ICP-MS
Strontium (Sr)	µg/L	20	2000	N/A	ICP-MS
Thallium (Tl)	µg/L	0.10	10	N/A	ICP-MS
Tin (Sn)	µg/L	2.0	200	N/A	ICP-MS
Titanium (Ti)	µg/L	2.0	200	N/A	ICP-MS
Uranium (U)	µg/L	0.10	10	NRG	ICP-MS
Vanadium (V)	µg/L	2.0	200	N/A	ICP-MS
Zinc (Zn)	µg/L	5.0	500	N/A	ICP-MS
PAH					
1-Methylnaphthalene	µg/L	0.50	0.050	N/A	GC/MS
2-Methylnaphthalene	µg/L	0.50	0.050	N/A	GC/MS
Acenaphthene	µg/L	3.0	0.010	N/A	GC/MS
Acenaphthylene	µg/L	5.0	0.060	N/A	GC/MS
Anthracene	µg/L	0.60	0.87	N/A	GC/MS
Benzo(a)anthracene	µg/L	0.010	0.044	N/A	GC/MS
Benzo(a)pyrene	µg/L	0.010	0.010	N/A	GC/MS

Parameter	Units	RDL March	RDL November	CCME Guidelines	Analysis Method
Benzo(b)fluoranthene	µg/L	0.010	0.010	N/A	GC/MS
Benzo(g,h,i)perylene	µg/L	0.010	0.010	N/A	GC/MS
Benzo(j)fluoranthene	µg/L	0.010	0.010	N/A	GC/MS
Benzo(k)fluoranthene	µg/L	0.010	0.010	N/A	GC/MS
Chrysene	µg/L	0.010	0.010	N/A	GC/MS
Dibenz(a,h)anthracene	µg/L	0.010	0.010	N/A	GC/MS
Fluoranthene	µg/L	0.010	0.010	N/A	GC/MS
Fluorene	µg/L	0.010	0.010	N/A	GC/MS
Indeno(1,2,3-cd)pyrene	µg/L	0.010	0.010	N/A	GC/MS
Naphthalene	µg/L	2.0	2.0	1.4	GC/MS
Perylene	µg/L	0.010	0.010	N/A	GC/MS
Phenanthrene	µg/L	0.010	0.010	N/A	GC/MS
Pyrene	µg/L	0.010	0.010	N/A	GC/MS
Petroleum Hydrocarbons					
Benzene	mg/L	0.10	0.025	110	PTGC
Toluene	mg/L	0.050	0.010	215	PTGC
Ethylbenzene	mg/L	0.050	0.010	25	PTGC
Xylene (Total)	mg/L	0.10	0.020	N/A	PTGC
C_6 - C_{10} (less BTEX)	mg/L	1.0	0.25	N/A	PTGC
$>C_{10}$-C_{16} Hydrocarbons	mg/L	0.050	0.050	N/A	PTGC
$>C_{16}$-C_{21} Hydrocarbons	mg/L	0.050	0.050	N/A	PTGC
$>C_{21}$-$<C_{32}$ Hydrocarbons	mg/L	0.10	0.10	N/A	PTGC
Modified TPH (Tier1)	mg/L	1.0	0.25	N/A	PTGC
Reached Baseline at C_{32}	mg/L	N/A	N/A	N/A	PTGC
Alkylated Phenols					
4-Nonylphenols (NP)	ng/L	10	11.5	700	LR GC/MS
4-Nonylphenol monoethoxylates	ng/L	50	3.77	700	LR GC/MS
4-Nonylphenol diethoxylates (NP2EO)	ng/L	50	8.05	700	LR GC/MS
4-n-Octylphenol (OP)	ng/L	50	1.21	N/A	LR GC/MS
Field Measurements					
pH (field)	pH units	-	-	7.0-8.7	PFC lab data
Temperature	˚C	-	-	N/A	Field meter
Salinity	mg/L	-	-	N/A	PFC lab data

2.1.5.2 Produced Water Toxicity Analysis

Toxicity test for produced water were coordinated by Harris Industrial Testing Service (HITS) and completed as follows:

- Sea Urchin Fertilization Test by Aquatox;
- Microtox Test by Aquatox; and
- Threespine Stickleback LC50 Test by HITS.

2.1.6 Results

2.1.6.1 Produced Water Chemical Characterization Results

Produced water was collected twice in 2016. Results for nutrients, major ions, organic acids, trace metals, PAHs, BTEX-TPH and alkylated phenols carried out by Maxxam and Axys laboratories are summarized in the tables below. CEQG for marine water quality are included in **Appendix A** and reported in **Table 2.4** below for all detectable chemical parameters. The labs produced water chemistry reports can be found in **Digital Appendices A1 and A2**. Results from all tested produced water parameters from 2014 to 2016 are compiled in **Table 2.4** and results from the 2016 March and November testing are summarized below.

- Nitrogen, orthophosphate and total phosphorus were all well above the RDL, and nitrite was slightly above RDL. The pH of the produced water was 7.21 (Mar) and 7.17 (Nov), which is within the CCME guidelines of 7.0-8.7. The organic acids analyzed were not detected. All results were compared with CCME guidelines where available. It should be noted that CCME guidelines are for marine water quality and are not available for outfalls.
- No metals were found in concentrations above CCME guidelines where available. Barium, boron, calcium, magnesium, potassium, sodium and strontium were all detected well above RDL, and no CCME guidelines were available for these elements. All other metals were found to be in significantly smaller concentrations or not detected.
- Toluene, ethylbenzene (March only) and benzene results were found to be above CCME guidelines. All other BTEX-TPH results except C6-C10 less BTEX (which was not detected) were found to be well above RDLs, but no CCME guidelines were available.
- Naphthalene was found to have elevated levels of 83 (Mar) and 79 (Nov) μg/L, which is well above the CCME guideline of 1.4 μg/L. All other PAH parameters measured were not detected or did not have CCME guidelines to be compared to.
- 4-Nonylphenols (24.7 ng/L), 4-Nonylphenol monoethoxylates (226 ng/L) and 4-n-Octylphenol (2.3 ng/L) were detected in the November produced water sample (no APs were detected in the March produced water sample). No CCME guidelines are available.

Table 2.4 - Produced Water Quality Results Summary (2014 to 2016)

Parameter	Units	10-Jun-2014 07:00 M-79A, F-70, D-41, H-08 wells Formation water	24-Mar-2015 07:00 M-79A, F-70, D-41, H-08 wells Formation water	30-Dec-2015 08:15 M-79A, D-41 wells Formation water	12-Mar-2016 07:30 D-41 well Condensed water	29-Nov-2016 10:10 D-41 well 90% formation / 10% condensed	CCME Guidelines*
Nutrients, Major Ions and Organic Acids							
Nitrate (N)	mg/L	ND	ND	ND	0.22	ND	200
Nitrate + Nitrite	mg/L	ND	ND (1)	ND (2)	0.23	ND	No data
Nitrite (N)	mg/L	ND	0.11 (2)	ND (2)	0.012	0.012	-
Nitrogen (Ammonia Nitrogen)	mg/L	46	73	74	7.9	68	No data
Orthophosphate (P)	mg/L	1.4	0.31 (2)	0.49 (2)	0.52	0.099	No data
pH	pH	6.95	6.79	7.10	7.21	7.17	7.0-8.7
Total Phosphorus	mg/L	4.3	1.2	0.73	0.81	0.56	No data
Salinity	PSU	71	160	150	7.0	93	-
Sulphide	mg/L	2.6	0.63	1.5	4.6	0.27	No data
Formic Acid	mg/L	ND	ND	ND	ND	ND	-
Acetic Acid	mg/L	ND	ND	ND	ND	ND	-
Propionic Acid	mg/L	ND	ND	ND	ND	ND	-
Butyric Acid	mg/L	ND	ND	ND	ND	ND	-
Metals							
Total Aluminum (Al)	µg/L	210	ND	690	320	ND	No data
Total Antimony (Sb)	µg/L	ND	ND	ND	ND	ND	No data
Total Arsenic (As)	µg/L	ND	ND	ND	ND	ND	12.5
Total Barium (Ba)	µg/L	3800	19000	25000	690	12000	No data
Total Beryllium (Be)	µg/L	ND	ND	ND	ND	ND	No data
Total Bismuth (Bi)	µg/L	ND	ND	ND	ND	ND	-
Total Boron (B)	µg/L	49000	89000	87000	5500	76000	NRG
Total Cadmium (Cd)	µg/L	ND	ND	**4.4**	0.014	ND	0.12
Total Calcium (Ca)	µg/L	4200000	8000000	7100000	450000	5900000	No data
Total Chromium (Cr)	µg/L	ND	ND	**320**	33	ND	Hex=1.5, Tri=56
Total Cobalt (Co)	µg/L	ND	ND	ND	ND	ND	No data
Total Copper (Cu)	µg/L	ND	ND	ND	ND	ND	No data
Total Iron (Fe)	µg/L	ND	ND	ND	1000	ND	No data
Total Lead (Pb)	µg/L	ND	ND	220	ND	ND	No data
Total Magnesium (Mg)	µg/L	510000	850000	790000	68000	660000	-

Parameter	Units	10-Jun-2014 07:00	24-Mar-2015 07:00	30-Dec-2015 08:15	12-Mar-2016 07:30	29-Nov-2016 10:10	CCME Guidelines*
		M-79A, F-70, D-41, H-08 wells	M-79A, F-70, D-41, H-08 wells	M-79A, D-41 wells	D-41 well	D-41 well	
		Formation water	Formation water	Formation water	Condensed water	90% formation / 10% condensed	
Total Manganese (Mn)	µg/L	510	270	730	150	490	No data
Total Mercury (Hg)	µg/L	Not tested	ND	ND	ND (1)	ND (1)	0.016
Total Molybdenum (Mo)	µg/L	ND	ND	ND	ND	ND	No data
Total Nickel (Ni)	µg/L	ND	ND	ND	ND	ND	No data
Total Phosphorus (P)	µg/L	5000	ND	ND	1000	ND	No data
Total Potassium (K)	µg/L	280000	380000	360000	38000	350000	-
Total Selenium (Se)	µg/L	ND	ND	ND	ND	ND	No data
Total Silver (Ag)	µg/L	ND	ND	ND	ND	ND	No data
Total Sodium (Na)	µg/L	18000000	31000000	28000000	1900000	24000000	No data
Total Strontium (Sr)	µg/L	310000	730000	600000	37000	540000	-
Total Thallium (Tl)	µg/L	2.0	14	ND	ND	ND	No data
Total Tin (Sn)	µg/L	ND	ND	ND	ND	ND	No data
Total Titanium (Ti)	µg/L	ND	ND	ND	ND	ND	-
Total Uranium (U)	µg/L	ND	ND	ND	ND	ND	NRG
Total Vanadium (V)	µg/L	ND	ND	ND	ND	ND	No data
Total Zinc (Zn)	µg/L	170	ND	590	590	1100	No data
Polyaromatic Hydrocarbons							
1-Methylnaphthalene	µg/L	200 (3)	410 (3)	220 (3)	100 (3)	28	-
2-Methylnaphthalene	µg/L	230 (3)	470 (3)	300 (3)	120 (3)	34	No data
Acenaphthene	µg/L	3.3	3.0	2.5	ND (4)	0.39	Insufficient data
Acenaphthylene	µg/L	ND (4)	4.1	ND (4)	ND (4)	ND (4)	No data
Anthracene	µg/L	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)	Insufficient data
Benzo(a)anthracene	µg/L	ND (4)	1.0	0.073	0.036	ND (4)	Insufficient data
Benzo(a)pyrene	µg/L	0.012	0.014	ND	ND	ND	Insufficient data
Benzo(b)fluoranthene	µg/L	0.17	0.080	0.048	0.042	0.069	No data
Benzo(g,h,i)perylene	µg/L	0.022	ND	ND	ND	ND	-
Benzo(j)fluoranthene	µg/L	0.015	0.017	ND	ND	0.010	-
Benzo(k)fluoranthene	µg/L	ND	ND	ND	ND	ND	No data
Chrysene	µg/L	1.7	0.93	0.63	0.49	0.82	Insufficient data
Dibenz(a,h)anthracene	µg/L	ND	ND	ND	ND	ND	No data
Fluoranthene	µg/L	2.7	2.0	1.6	0.67	1.4	Insufficient data
Fluorene	µg/L	55 (3)	76 (3)	55 (3)	28	13	Insufficient data

Parameter	Units	10-Jun-2014 07:00 M-79A, F-70, D-41, H-08 wells Formation water	24-Mar-2015 07:00 M-79A, F-70, D-41, H-08 wells Formation water	30-Dec-2015 08:15 M-79A, D-41 wells Formation water	12-Mar-2016 07:30 D-41 well Condensed water	29-Nov-2016 10:10 D-41 well 90% formation / 10% condensed	CCME Guidelines*
Indeno(1,2,3-cd)pyrene	µg/L	ND	ND	ND	ND	ND	No data
Naphthalene	µg/L	**310** (3)	**660** (3)	**470** (3)	**83** (3)	**79** (3)	1.4
Perylene	µg/L	0.036	0.023	ND	0.015	0.033	-
Phenanthrene	µg/L	56 (3)	48 (3)	38	25	22	Insufficient data
Pyrene	µg/L	1.5	0.97	0.86	0.55	1.1	Insufficient data
Petroleum Hydrocarbons							
Benzene	mg/L	**3.2**	**3.5**	**3.6**	**8.0**	**1.4**	0.110
Toluene	mg/L	**1.3**	**1.6**	**1.7**	**2.9**	**0.52**	0.215
Ethylbenzene	mg/L	**0.049**	**0.058**	**0.069**	**0.084**	0.023	0.025
Total Xylenes	mg/L	0.39	0.53	0.57	0.55	0.18	No data
C6 - C10 (less BTEX)	mg/L		ND	ND	ND	ND	-
>C10-C16 Hydrocarbons	mg/L	5.9	15 (5)	6.5 (5)	6.4	1.0	-
>C16-C21 Hydrocarbons	mg/L	8.3	7.6	3.3 (5)	4.2	3.2	-
>C21-<C32 Hydrocarbons	mg/L	5.3	4.5	1.8 (5)	2.9	2.2	-
Modified TPH (Tier1)	mg/L	20	27	12	14	6.4	-
Reached Baseline at C32	mg/L	Yes	Yes	Yes	Yes	No	-
Alkylphenols							
4-Nonylphenols	ng/L	122	ND	ND	ND	24.7	700
4-Nonylphenols monoethoxylates	ng/L	ND	ND	ND	ND	226	700
4-Nonylphenols diethoxylates	ng/L	ND	ND	ND	ND	ND	700
4-n-Octylphenol	ng/L	ND	145	ND	ND	2.3	N/A
Field Measurements							
pH (field)	pH units	3-4	3-4	3-4	3-4	3-4	7.0-8.7
Temperature	˚C	75	90	81	~70	71	N/A
Salinity (Cl)	mg/L	>70,000	>70,000	>70,000	<1,000	59,400	N/A

*CCME Guidelines only for detected parameters only using Water Quality Guidelines for the Protection of Aquatic Life.
RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
ND = Not detected
N/A = Not Applicable
NRG = No Recommended Guideline
(1) Elevated RDL due to sample matrix
(2) Elevated reporting limit due to sample matrix
(3) Elevated PAH RDL(s) due to sample dilution
(4) Elevated PAH RDL(s) due to matrix / co-extractive interference
(5) Elevated TEH RDL(s) due to sample dilution / limited sample

Table 2.5 - Produced Water Quality Results: Produced Water Compared to Marine Water Quality Sampling Stations

Parameters	Units	Produced Water 12-Mar 2016	Marine Water Stations 12-Mar 2016
Calculated Parameters			
Nitrate (N)	mg/L	0.22	ND
Inorganics			
Nitrate + Nitrite	mg/L	0.23	ND – 0.055
Nitrite (N)	mg/L	0.012	ND - 0.014
Nitrogen (Ammonia Nitrogen)	mg/L	7.9	ND – 0.46
Orthophosphate (P)	mg/L	0.52	0.011 - 0.016
pH	pH	7.21	7.38 - 7.88
Total Phosphorus	mg/L	0.81	0.024 - 0.058
Salinity	PSU	7.0	31.70 – 31.82
Sulphide	mg/L	4.6	ND
Miscellaneous Parameters			
Formic Acid	mg/L	ND	ND
Acetic Acid	mg/L	ND	ND
Propionic Acid	mg/L	ND	ND
Butyric Acid	mg/L	ND	ND
Metals			
Total Aluminum (Al)	µg/L	320	ND
Total Antimony (Sb)	µg/L	ND	ND
Total Arsenic (As)	µg/L	ND	ND
Total Barium (Ba)	µg/L	690	ND
Total Beryllium (Be)	µg/L	ND	ND
Total Bismuth (Bi)	µg/L	ND	ND
Total Boron (B)	µg/L	5500	3900-4400
Total Cadmium (Cd)	µg/L	0.014	ND - 0.3
Total Calcium (Ca)	µg/L	450000	350000 - 380000
Total Chromium (Cr)	µg/L	33	ND
Total Cobalt (Co)	µg/L	ND	ND
Total Copper (Cu)	µg/L	ND	ND
Total Iron (Fe)	µg/L	1000	ND
Total Lead (Pb)	µg/L	ND	ND
Total Magnesium (Mg)	µg/L	68000	1100000 - 1200000
Total Manganese (Mn)	µg/L	150	ND
Total Mercury (Hg)	µg/L	ND (1)	0.15 - 0.18
Total Molybdenum (Mo)	µg/L	ND	ND
Total Nickel (Ni)	µg/L	ND	ND
Total Phosphorus (P)	µg/L	1000	N/A
Total Potassium (K)	µg/L	38000	340000 - 360000
Total Selenium (Se)	µg/L	ND	ND
Total Silver (Ag)	µg/L	ND	ND
Total Sodium (Na)	µg/L	1900000	9300000 - 9800000
Total Strontium (Sr)	µg/L	37000	6600 - 7200
Total Thallium (Tl)	µg/L	ND	ND

Parameters	Units	Produced Water 12-Mar 2016	Marine Water Stations 12-Mar 2016
Total Tin (Sn)	µg/L	ND	ND
Total Titanium (Ti)	µg/L	ND	ND
Total Uranium (U)	µg/L	ND	2.7 - 3.2
Total Vanadium (V)	µg/L	ND	ND
Total Zinc (Zn)	µg/L	590	ND - 1800
Polyaromatic Hydrocarbons			
1-Methylnaphthalene	µg/L	100 (2)	ND
2-Methylnaphthalene	µg/L	120 (2)	ND
Acenaphthene	µg/L	ND (3)	ND
Acenaphthylene	µg/L	ND (3)	ND
Anthracene	µg/L	ND (3)	ND
Benzo(a)anthracene	µg/L	0.036	ND
Benzo(a)pyrene	µg/L	ND	ND
Benzo(b)fluoranthene	µg/L	0.042	ND
Benzo(g,h,i)perylene	µg/L	ND	ND
Benzo(j)fluoranthene	µg/L	ND	ND
Benzo(k)fluoranthene	µg/L	ND	ND
Chrysene	µg/L	0.49	ND
Dibenz(a,h)anthracene	µg/L	ND	ND
Fluoranthene	µg/L	0.67	ND
Fluorene	µg/L	28	ND
Indeno(1,2,3-cd) pyrene	µg/L	ND	ND
Naphthalene	µg/L	83 (2)	ND
Perylene	µg/L	0.015	ND
Phenanthrene	µg/L	25	ND
Pyrene	µg/L	0.55	ND
Petroleum Hydrocarbons			
Benzene	mg/L	8.0	ND
Toluene	mg/L	2.9	ND
Ethylbenzene	mg/L	0.084	ND
Total Xylenes	mg/L	0.55	ND
C6 - C10 (less BTEX)	mg/L	ND	ND
>C10-C16 Hydrocarbons	mg/L	6.4	ND
>C16-C21 Hydrocarbons	mg/L	4.2	ND
>C21-<C32 Hydrocarbons	mg/L	2.9	ND
Modified TPH (Tier1)	mg/L	14	ND
Reached Baseline at C32	mg/L	Yes	N/A
Alkylphenols			
4-Nonylphenols	ng/L	ND	10.6 – 64.1
4-Nonylphenols monoethoxylates	ng/L	ND	ND
4-Nonylphenols diethoxylates	ng/L	ND	ND
4-n-Octylphenol	ng/L	ND	ND

1 - Elevated RDL due to sample matrix
2- Elevated PAH RDLs due to sample dilution
3- Elevated PAH RDLs due to matrix/co-extractive interference

2.1.6.2 Produced Water Toxicity Test Results

To assess the toxicity of the produced water, a Microtox test, a sea urchin fertilization test and a Threespine Stickleback toxicity test were performed on water collected at the PFC on March 12, 2016.

2.1.6.2.1 Microtox Toxicity Results

The Microtox test consists in exposing and measuring light levels of bioluminescent bacteria *Vibrio fischeri* at various concentrations of the sampled produced water. The toxicity of the sample is presumed to have an effect on the metabolic processes of the bacteria, and the measured bioluminescence is inhibited in proportion to the metabolic effect. Inhibition is measured after a set amount of exposure time and expressed as the IC50 (Inhibitory Concentration 50%), *i.e.* the concentration that causes 50% inhibition (Environment Canada, Biological Test Method EPS 1/RM/24, 1992). The IC50 for the produced water was 1.02% (**Table 2.6).** Complete results can be found in **Appendix D**.

Table 2.6 - Produced Water Microtox Results

Substance	Data Collected	Date Tested	Species/Test	15 Minute IC50	95% Confidence Limits
Deep Panuke Produced Water	12/03/2016	14/03/2016	Microtox IC50	1.02%	0.93-1.12

2.1.6.2.2 Sea Urchin Fertilization Test Results

The sea urchin fertilization test is a sub-lethal marine toxicity test that uses sea urchin gametes. Sperm is first exposed to the substance being tested, and then eggs are added. The test is conducted at various concentrations. The endpoint of the test is decreased fertilization success (in this case, a reduction of 25% from the control), and the concentration at which it occurs is calculated using the various concentrations tested and linear interpolation. The fertilization process and cells at the gamete stage are highly sensitive, so this test is one of the most sensitive marine sub-lethal toxicity tests. The test also has a quick turnaround time (Environment Canada, 2011).

The IC25 (Fertilization) test was conducted on the sea urchin *Lytechinus pictus*. At a concentration of 1.86% produced water, 25% of the eggs are inhibited from being fertilized. See **Table 2.7** and **Table 2.8** for a summary of results, and **Appendix D** for full results.

Table 2.7 - Produced Water Sea Urchin Fertilization Results

Effect	Value	95% Confidence Limits	Statistical Method
IC25 (Fertilization)	1.86%	1.82-1.91	Linear Interpolation

Table 2.8 - Produced Water Sea Urchin Fertilization Data

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
Control	A	91	9	91	90.5	1.29
	B	90	10	90		
	C	89	11	89		
	D	92	8	92		
Blank	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
1.56	A	81	19	81	83	1.63
	B	83	17	83		
	C	83	17	83		
	D	85	15	85		
3.13	A	20	80	20	18.5	1.91
	B	16	84	16		
	C	20	80	20		
	D	18	82	18		
6.25	A	2	98	2	0.75	0.96
	B	0	100	0		
	C	0	100	0		
	D	1	99	1		
12.5	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
25	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
50	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
100	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		

2.1.6.2.3 Threespine Stickleback Toxicity Test Results

The 96-hour LC50 results for the produced water with the Threespine Stickleback toxicity test was 12.5% (**Table 2.6).** Complete results can be found in **Appendix D**.

Table 2.9 - Produced Water Threespine Stickleback Toxicity Test Results

Substance	Data Collected	Date Tested	Species/Test	96 Hour LC50	95% Confidence Limits
Deep Panuke Produced Water	12/03/2016	18/03/2016	Threespine Stickleback	12.5%	10.0-15.6

2.1.7 Summary and Conclusions

March and November 2016 produced water chemistry:

- Except for elevated naphthalene (PAH), benzene, toluene and ethylbenzene (March only) levels, all metal, non-metal, hydrocarbon and nutrient concentrations in the produced water were found to fall below threshold levels as defined by the Canadian EQG (CCME Guidelines) where available.
- 4-Nonylphenols (24.7 ng/L), 4-Nonylphenol monoethoxylates (226 ng/L) and 4-n-Octylphenol (2.3 ng/L) were detected in the November produced water sample (no APs were detected in the March produced water sample). No CCME guidelines are available.

March 2016 produced water toxicity:

- The IC50 for the Microtox test was 1.02%.
- The IC25 for the sea urchin fertilization test was 1.86%.
- The LC50 for the Threespine Stickleback toxicity test was 12.5%.

2.2 MARINE WATER QUALITY MONITORING

2.2.1 Background

The 2006 Deep Panuke Environmental Assessment (EA) (p. 8-38) made the following specific predictions with respect to water quality dispersion:

- the maximum discharge rate of produced water will be 6,400 m^3/day (266.7 m^3/hr) and 2,400 m^3/hr for cooling water giving a dilution rate of 9:1;
- the project's produced water treatment facilities are expected to treat produced water so that H_2S concentration prior to mixing with cooling water does not exceed 1 to 2 ppmw; and
- produced water will be mixed with cooling water prior to discharge. Upon being released to the marine environment, discharged water will be rapidly diluted by ambient currents and background oceanic mixing as per **Table 2.10** below (Table 8.18 from the 2006 Deep Panuke EA).

Table 2.10 – Summary of 2006 Discharged Water Far-Field Dispersion Modelling Results

Distance from Discharge Site	Dilution (Discharge/Background Waters)	Temperature Anomaly (°C)	Salinity Anomaly (PSU)	Hydrocarbon Concentration (mg/L)	H_2S Concentration (PPMW)	Oxygen Concentration Relative to Background (%)
End of Pipe*	No dilution	25	6.25	.8	0.2	0
Site (seafloor)	10:1	2.5	0.6	0.28	0.02	90
500m	70:1	0.4	0.1	0.04	0.003	98
1km	100:1	0.25	0.06	0.03	0.002	99
2km	400:1	0.06	0.02	0.007	0.0005	100
End of discharge caisson at a depth of 10m						

Note: discharge water consists of produced water mixed with cooling water (9:1 mixing ration)

The Deep Panuke Production EPCMP (DMEN-X00-RP-EH-90-0002) provides more recent information on the design of the PFC produced water system. The current system is designed for a produced water rate of 6,400 m^3/d (266.7 m^3/hr). After treatment and sampling, the treated produced water goes down the seawater discharge caisson located in the PFC SE leg and is mixed with the spent 3,340 m^3/hr cooling water inside the leg prior to discharge into the ocean environment at a depth of approximately 26 m below Lowest Astronomical Tide (LAT). Therefore, the dilution ratio for a maximum produced water rate has increased from 1:9 to 1:13, with the discharge depth changed from 10 m to 26 m below LAT.

In July 2015, the produced water dispersion modeling completed in the 2006 EA was revised with updated parameters (e.g. lower dilution of produced water in cooling water prior to discharge and increased produced water temperature, hydrocarbon concentration and H_2S concentration). The re-modelling demonstrated similar plume behaviour to that described in the 2006 modelling with respect to plume buoyancy and interaction with the sea floor. Slight differences were observed in the anomaly in temperature and salinity, hydrocarbon concentration, and dissolved oxygen concentration (see **Table 2.11**). A greater difference was observed between the 2006 and 2015 results for H_2S concentrations. However, analysis of the modeling results concluded that the environmental effect assessment and significance determinations presented in the 2006 EA report remain valid for the updated 2015 cooling water and produced water discharge data. No significant adverse environmental effects are predicted to occur as a result of routine operational discharges with the updated parameters.

Table 2.11 - Summary of 2015 Discharged Water Far-Field Dispersion Modeling Results

From Discharge Site	Centerline Dilution (Background/ Discharge Waters)		Temperature Anomaly (°C)		Salinity Anomaly (PSU)		Hydrocarbon Concentration (mg/L)		H_2S Concentration (ppm)		Oxygen Concentration Relative to Background (%)	
	2006	2015	2006	2015	2006	2015	2006	2015	2006	2015	2006	2015
End of Pipe	1:1	1:1	25	38	6.25	7	2.8	6.67	0.2	2.22	0	0
Site (seabed)	10:1	8:1	2.5	4.75	0.6	0.88	0.28	0.83	0.02	0.28	90	87.5
500m	70:1	56:1	0.4	0.68	0.1	0.12	0.04	0.12	0.003	0.04	98	98
1km	100:1	80:1	0.25	0.48	0.08	0.09	0.03	0.08	0.002	0.03	99	99
2km	400:1	320:1	0.06	0.12	0.02	0.02	0.007	0.02	0.0005	0.007	100	100

Represents worst case scenario: cooling water flow rate = 1500 m^3/hr in winter; cooling water temp = 25°C

2.2.2 EEMP Goal

Predictions regarding water quality dispersion made in the 2006 Deep Panuke EA [EA predictions #1, 3, 4, 5, 6, 11 & 13 in **Table 3.1**] are to be validated and 2015 produced water dispersion modeling updated.

2.2.3 Objectives

Key water quality parameters in seawater samples collected on the PFC (i.e. prior to mixing with cooling water and discharge to marine environment) and at several locations away from the Deep Panuke PFC are to be analyzed along with key water quality parameters via conductivity, temperature and depth (CTD) in seawater samples collected at sites in the vicinity of the PFC.

2.2.4 Sampling

Water was collected on March 11-12, 2016 for chemical characterization, at seven stations. See **Table 2.12** below and **Appendix C** (Daily Progress Reports (DPRs)) for details.

Table 2.12 - Marine Water Sampling Details - March

<table>
<tr><td>Survey Date:</td><td>March 11-12, 2016</td></tr>
<tr><td>Platform:</td><td>M/V Atlantic Condor</td></tr>
<tr><td>Type of Sample:</td><td>Water samples, Water column sampling</td></tr>
<tr><td>Test Sample Locations:</td><td>
<table>
<tr><th>#</th><th>Station</th><th>Time UTC</th><th>Water Depth(m)</th><th>Easting</th><th>Northing</th></tr>
<tr><td>1</td><td>2000m US</td><td>March 11, 23:35</td><td>40m</td><td>686774</td><td>4851909</td></tr>
<tr><td>2</td><td>250m US</td><td>March 12, 01:10</td><td>48m</td><td>685843</td><td>4853437</td></tr>
<tr><td>3</td><td>PFC (20m)</td><td>08:05</td><td>46m</td><td>685860</td><td>4853605</td></tr>
<tr><td>4</td><td>250m DS</td><td>06:44</td><td>46m</td><td>685906</td><td>4853394</td></tr>
<tr><td>5</td><td>500m DS</td><td>05:47</td><td>44m</td><td>686079</td><td>853164</td></tr>
<tr><td>6</td><td>1000m DS</td><td>04:25</td><td>45m</td><td>686790</td><td>4853201</td></tr>
<tr><td>7</td><td>2000m DS</td><td>02:49</td><td>47m</td><td>687560</td><td>4854915</td></tr>
<tr><td colspan="6">WGS84 UTM Zone 20N</td></tr>
</table>
</td></tr>
<tr><td>Number of Samples/Locations:</td><td>Tri-level seawater samples were collected from the surface, mid-water column and near-bottom depths at the PFC location; 250m, 500m, 1,000m and 2,000m from the PFC downstream along the tide direction at the time of sampling activities. Tide and current predictions for the water sampling day are in Digital Appendix B. Two stations upstream of the PFC were also collected at 250m and 2,000m. Water sampling locations are shown in Figure 2.1.</td></tr>
<tr><td>Equipment:</td><td>Water column properties were collected via a single profile at each station via a multi-parameter CTD (RBR XR-620 Multi-channel Logger) which measured conductivity (salinity derived), temperature, pressure, pH and dissolved oxygen.

Physical water samples were collected with 5L Niskin bottles (at the surface, mid-water and near-bottom at each station. All three bottles were deployed in tandem via an onboard winch and crane at each station location from the starboard side of the ATLANTIC CONDOR. Logs are available in Appendix E.</td></tr>
<tr><td>Sample Preparation:</td><td>Each 5L Niskin was sub-sampled into the following for subsequent analysis:
<table>
<tr><th>Parameter</th><th>Preservative</th></tr>
<tr><td>Organic acids</td><td>no preservative</td></tr>
<tr><td>Mercury</td><td>Potassium Dichromate</td></tr>
<tr><td>Metal scan and Sulphur</td><td>Nitric acid</td></tr>
<tr><td>BTEX/TPH</td><td>Sodium Bisulphate</td></tr>
<tr><td>BTEX/TPH - volatile</td><td>Sodium Bisulphate</td></tr>
<tr><td>Alkylated Phenols</td><td>no preservative</td></tr>
<tr><td>PAHs</td><td>no preservative</td></tr>
<tr><td>Nitrate/ortho-P/Total Nitrogen</td><td>no preservative</td></tr>
<tr><td>Sulphide</td><td>Zn Acetate + NaOH</td></tr>
<tr><td>Total P/Ammonia</td><td>Sulphuric Acid</td></tr>
</table>
</td></tr>
</table>

2.2.5 Analysis

Water samples collected were analyzed by Maxxam Analytics for parameters summarized in **Table 2.13.** Major ions were determined using Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES), while trace elements were determined using Inductively Coupled Plasma – Mass Spectrometry (ICP-MS). Nutrients were determined by a variety of instruments including chromatographs, colorimeters, and spectrophotometers. DIC was measured on an Elemental Analyzer. DOC was measured with a carbon analyzer after high temperature catalytic oxidation.

Water samples were also analyzed for TPH including benzene, toluene, ethylbenzene, and xylene(s) (BTEX), gasoline range organics (C6 to C10), and analysis of extractable hydrocarbons – fuel oil (>C10 to C16), fuel oil (>C16 to C21) and lube oil (>C21 to C32) range organics. BTEX and gasoline range organics were analyzed by purge and trap-gas chromatography/ mass spectrometry or headspace – gas chromatography (MS/flame ionization detectors). Extractible hydrocarbons, including diesel and lube range organics were analyzed using capillary column gas chromatography (flame ionization detector).

Alkylated phenols were analyzed by AXYS Analytical Services Ltd. for Maxxam Analytics. AXYS method MLA-004 describes the determination of 4-n-octylphenol, nonylphenol and nonylphenol ethoxylates in aqueous samples, and in extracts from water sampling columns (XAD-2 columns). Concentrations in XAD-2 resin and filters are reported on a per sample basis or a per volume basis.

Sulphides in water were analyzed using the ion selective Electrode (ISE). The sulphide may be in the form of S2-, HS- or H_2S. Temperature, salinity and DO affect the amount of H_2S found in undissociated form. Sulphide H_2S was determined using SM 4500-S2-G.

2.2.5.1 Parameters Analyzed

Table 2.13 - Marine Water Quality Parameters Measured

Parameter	Units	RDL	CEQG Threshold	Analysis Method
Nutrients				
Nitrate + Nitrite	mg/L	0.05	N/A	colourimetry
Nitrate (N)	mg/L	0.05	200	colourimetry
Nitrite (N)	mg/L	0.01	N/A	colourimetry

Parameter	Units	RDL	CEQG Threshold	Analysis Method
Nitrogen (Ammonia)	mg/L	0.05	2.33	colourimetry
Orthophosphate (P)	mg/L	0.01	N/A	colourimetry
Major Ions				
Phosphorus	mg/L	0.02	N/A	AC
Sulphide	mg/L	0.02	N/A	ISE
Organic Acids				
Formic Acid	mg/L	10	N/A	IC
Acetic Acid	mg/L	20	N/A	IC
Propionic Acid	mg/L	20	N/A	IC
Butyric Acid	mg/L	40	N/A	IC
Trace Metals				
Aluminum (Al)	µg/L	50	N/A	ICP-MS
Antimony (Sb)	µg/L	10	N/A	ICP-MS
Arsenic (As)	µg/L	10	12.5	ICP-MS
Barium (Ba)	µg/L	10	N/A	ICP-MS
Beryllium (Be)	µg/L	10	N/A	ICP-MS
Bismuth (Bi)	µg/L	20	N/A	ICP-MS
Boron (B)	µg/L	500	NRG	ICP-MS
Cadmium (Cd)	µg/L	0.10	0.12	ICP-MS
Calcium (Ca)	µg/L	1000	N/A	ICP-MS
Chromium (Cr)	µg/L	10	Hex = 1.5, Tri = 56	ICP-MS
Cobalt (Co)	µg/L	4.0	N/A	ICP-MS
Copper (Cu)	µg/L	20	N/A	ICP-MS
Iron (Fe)	µg/L	500	N/A	ICP-MS
Lead (Pb)	µg/L	5.0	N/A	ICP-MS
Magnesium (Mg)	µg/L	1000	N/A	ICP-MS
Manganese (Mn)	µg/L	20	N/A	ICP-MS
Mercury (Hg)	µg/L	0.013	0.016	Cold Vapour AA
Molybdenum (Mo)	µg/L	20	N/A	ICP-MS
Nickel (Ni)	µg/L	20	N/A	ICP-MS
Phosphorus (P)	µg/L	1000		
Potassium (K)	µg/L	1000	N/A	ICP-MS
Selenium (Se)	µg/L	10	N/A	ICP-MS
Silver (Ag)	µg/L	1.0	N/A	ICP-MS
Sodium (Na)	µg/L	1000	N/A	ICP-MS
Strontium (Sr)	µg/L	20	N/A	ICP-MS
Thallium (Tl)	µg/L	1.0	N/A	ICP-MS
Tin (Sn)	µg/L	20	N/A	ICP-MS
Titanium (Ti)	µg/L	20	N/A	ICP-MS
Uranium (U)	µg/L	1.0	NRG	ICP-MS
Vanadium (V)	µg/L	20	N/A	ICP-MS
Zinc (Zn)	µg/L	50	N/A	ICP-MS
PAH				
Naphthalene	µg/L	0.20	1.4	GC/MS
Benzo(j)fluoranthene	µg/L	0.01	N/A	GC/MS
Chrysene	µg/L	0.01	N/A	GC/MS
Benzo(b)fluoranthene	µg/L	0.01	N/A	GC/MS
Benzo(k)fluoranthene	µg/L	0.01	N/A	GC/MS
Benzo(a)pyrene	µg/L	0.01	N/A	GC/MS
Perylene	µg/L	0.01	N/A	GC/MS
Acenaphthylene	µg/L	0.01	N/A	GC/MS
Indeno(1,2,3-cd)pyrene	µg/L	0.01	N/A	GC/MS
Dibenz(a,h)anthracene	µg/L	0.01	N/A	GC/MS
Benzo(g,h,i)perylene	µg/L	0.01	N/A	GC/MS
2-Methylnaphthalene	µg/L	0.05	N/A	GC/MS

Parameter	Units	RDL	CEQG Threshold	Analysis Method
Acenaphthene	µg/L	0.01	N/A	GC/MS
Fluorene	µg/L	0.01	N/A	GC/MS
1-Methylnaphthalene	µg/L	0.05	N/A	GC/MS
Benzo(a)anthracene	µg/L	0.01	N/A	GC/MS
Phenanthrene	µg/L	0.01	N/A	GC/MS
Anthracene	µg/L	0.01	N/A	GC/MS
Fluoranthene	µg/L	0.01	N/A	GC/MS
Pyrene	µg/L	0.01	N/A	GC/MS
BTEX-TPH				
Benzene	µg/L	0.001	110	PTGC
Toluene	µg/L	0.001	215	PTGC
Ethylbenzene	µg/L	0.001	25	PTGC
Xylene (Total)	µg/L	0.002	N/A	PTGC
C_6 - C_{10} (less BTEX)	µg/L	0.01	N/A	PTGC
>C_{10}-C_{16} Hydrocarbons	µg/L	0.05	N/A	PTGC
>C_{16}-C_{21} Hydrocarbons	µg/L	0.05	N/A	PTGC
>C_{21}-<C_{32} Hydrocarbons	µg/L	0.1	N/A	PTGC
Modified TPH (Tier1)	µg/L	0.1	N/A	PTGC
Reached Baseline at C_{32}	µg/L	N/A	N/A	PTGC
Alkylated Phenols				
4-Nonylphenol (NP)	ng/L	varies (see lab report)	0.7	LR GC-MS
4-Nonylphenol monoethoxylate (NP1EO)	ng/L	varies (see lab report)	0.7	LR GC-MS
4-Nonylphenol diethoxylate (NP2EO)	ng/L	varies (see lab report)	0.7	LR GC-MS
4-n-Octylphenol (OP)	ng/L	varies (see lab report)	N/A	LR GC-MS
Field Measurements				
pH (field)	pH units		7.0-8.7	Field meter
Temperature	˚C		N/A	Field meter
Dissolved oxygen	mg/L, % sat.		8	Field meter
Salinity	PSU		N/A	Conductivity meter

2.2.6 Results

2.2.6.1 Marine Water Chemical Characterization

- 2016 Maxxam marine water quality data is included in **Digital Appendix C.**
- 2016 CTD Data is presented in **Digital Appendix D** and **Figures 2.2 to 2.8** including: salinity, temperature and pH results.
- CEQG for marine water quality are included in **Appendix A.**
- Nutrients, major ions and organic acid results are shown below in **Table 2.15 and Figure 2.9.** Nitrate + nitrite, nitrate, nitrite, orthophosphate, phosphorus and ammonia were detected at all stations sampled at some water level (either surface, mid depth, or bottom) with results below or slightly above laboratory RDL, not exceeding any CCME guidelines that were available.

- Trace metals, hydrocarbons and alkylated phenol results are shown in **Table 2.15 to Table 2.18** and **Figures 2.10 and 2.11**.
- Boron, calcium, magnesium, mercury, potassium, sodium, strontium and uranium were found at all water stations at all depths sampled.
- Mercury was found to be above CCME guidelines (0.016 µg/L) and consistent at all depths at all stations. Mercury levels ranged from 0.15 to 0.18 µg/L which is higher than 2015 (0.035 to 0.062 µg/L).
- Cadmium was detected at the 2000 m US middle station (0.23 µg/L), at the 20 m bottom station (0.3 µg/L) and at the 2000 m surface station (0.19 µg/L). CCME guidelines for cadmium are 0.12 µg/L, so all three levels were above guidelines.
- Zinc was detected at the 2000 m US surface station (1,800 µg/L), 500 m surface station (660 µg/L) and 1000 m middle station (64 µg/L).
- PAH and TPH including BTEX-TPH were all below laboratory RDLs.
- 4-Nonylphenols (which were not detected in 2015) were detected at all water stations and all depths sampled with levels between 10.6 and 64.1 ng/L.
- 2016 detection patterns were similar to 2015 results except for the differences mentioned above. The data does not show any pattern of impact from production discharges on marine water chemistry.

2.2.6.2 Comparison of Produced Water to Marine Water Quality Sampling Stations

A comparison of parameters tested at water stations (a range of levels is listed from the seven stations sampled) and in the produced water samples collected the same day (12 March 2016) is provided in **Table 2.5**.

- The following parameters were detected in produced water samples but were not found at detectable levels at any water stations and sampling depths:
  - nitrate
  - sulphide
  - aluminum
  - barium
  - chromium
  - iron
  - manganese
  - 1-Methylnaphthalene
  - 2-Methylnaphthalene
  - benzo(a)anthracene
  - benzo(b)fluoranthene
  - chrysene
  - fluoranthene

- fluorene
- naphthalene
- perylene
- phenanthrene
- pyrene
- benzene
- toluene
- ethylbenzene
- Total Xylenes
- >C10-C16 Hydrocarbons
- >C16-C21 Hydrocarbons
- >C21-<C32 Hydrocarbons
- Modified TPH (Tier1)

• The following parameters were detected in produced water samples and were detected in similar or lower quantities in at least some water stations:
  - nitrite
  - nitrate + nitrite
  - nitrogen (ammonia)
  - orthophosphate (P)
  - phosphorus
  - boron
  - calcium
  - strontium

• The following parameters were detected in produced water samples and were detected in higher quantities in at least some water stations:
  - cadmium (four stations)
  - magnesium (all stations)
  - potassium (all stations)
  - sodium (all stations)
  - zinc (two stations)

• Mercury, uranium and 4-Nonylphenols were found at all water stations, but not in the produced water.

• Salinity of the produced water at the time of sampling was lower than marine water salinity; however, only condensed water was being discharged at the time; actual formation water is more saline than marine water.

• pH from the produced water was slightly lower than marine water pH (7.21 versus 7.38 - 7.88).

2.2.6.3 CTD

Water quality sampling was conducted on March 12, 2016, at seven stations: 2000 m, 1000 m, 500 m, 250 m, and 20 m downstream, and 2000 m and 250 m upstream of the

PFC. **Table 2.14** shows minimum and maximum values recorded for temperature, pH, salinity and dissolved oxygen and **Figures 2.2 to 2.8** show graphs for all parameters.

Table 2.14 – Min and Max Measured Marine Water Temp, pH, Salinity and DO (Mar 12, 2016)

	Temp (°C)		pH (pH units)		Salinity (PSU)		Dissolved O2 (sat %)	
	Min	Max	Min	Max	Min	Max	Min	Max
2000 m US	3.15	3.17	7.84	7.88	31.78	31.81	98.71	98.80
250 m US	3.13	3.17	7.60	7.67	31.77	31.82	79.97	82.45
20 m	3.11	3.13	7.38	7.47	31.74	31.79	79.11	80.43
250 m	3.12	3.23	7.76	7.81	31.70	31.82	98.27	99.34
500 m	3.13	3.16	7.81	7.84	31.76	31.80	98.31	98.80
1000 m	3.15	3.21	7.83	7.87	31.73	31.81	98.04	98.87
2000 m	3.15	3.21	7.59	7.65	31.72	31.80	79.10	79.46

2.2.7 Summary and Conclusions

2.2.7.1 Marine Water Chemical Characterization

- All nutrients, major ions and organic aids detected were either slightly above or below RDL and did not exceed CCME guidelines where available.
- Metal, non-metal, hydrocarbon and nutrient concentrations were all found to fall below threshold levels as defined by the Canadian EQG (Environmental Quality Guidelines) where available, except for cadmium, which was slightly above CCME guidelines at the three stations where it was detected, and mercury, which was above CCME guidelines at all stations and depths sampled and at higher levels than measured in 2015.
- PAH and TPH including BTEX-TPH were all below laboratory RDLs.
- 4-Nonylphenols (which were not detected in 2015) were detected at all water stations and depths sampled with levels between 10.6 and 64.1 ng/L.
- 2016 detection patterns for tested parameters were similar to 2015 results except for the differences mentioned above. The data does not show any pattern of impact from production discharges on marine water chemistry.

2.2.7.2 Comparison of Produced Water to Marine Water Quality Sampling Stations

Dispersion rates for hydrocarbons and sulphides detected in produced water and water samples are within the levels predicted by the model (2006 and 2015 re-modeling). In fact, PAH/hydrocarbons and sulphide were not detected at any water sample from any of the seven stations.

2.2.7.3 CTD summary:

- Temperature was similar across all stations sampled and ranged between 3.11 °C and 3.23 °C.
- pH was consistent across all stations sampled, and had a narrow range of 7.38 to 7.88.
- Salinity followed similar trends across stations sampled, increasing slightly with depth. Salinity values ranged from 31.70 PSU to 32.82 PSU.
- Dissolved oxygen generally decreased with depth, and ranged from 79.11% to 99.34%.

Table 2.15 – Marine Water Chemistry Results Comparison: Nutrients, Major Ions and Organic Acids

Parameters (mg/L)	2000m US 2011	2000m US 2015	2000 m US 2016	250m US 2011	250m US 2015	250m US 2016	20m DS 2011	20m DS 2015	20m DS 2016	250m DS 2011	250m DS 2015	250m DS 2016	500m DS 2011	500m DS 2015	500m DS 2016	1000m DS 2011	1000m DS 2015	1000m DS 2016	2000m DS 2011	2000m DS 2015	2000m DS 2016
SURFACE																					
Nutrients																					
Nitrate + Nitrite	ND	0.13	ND	ND	0.12	ND	ND	0.12	ND	ND	0.13	ND	ND	0.11	ND	ND	0.11	ND	ND	0.14	0.055
Nitrate (N)	ND	0.12	ND	ND	0.11	ND	ND	0.12	ND	ND	0.13	ND	ND	0.1	ND	ND	0.097	ND	ND	0.13	ND
Nitrite (N)	ND	0.012	0.012	ND	0.01	ND	ND	ND	0.014	ND	ND	ND	ND	0.011	0.011	ND	0.017	0.012	ND	0.01	0.012
Nitrogen (Ammonia)	ND	0.097	ND	0.08	0.29	0.21	0.19	2.2	0.19	0.05	0.63	ND	0.08	ND	0.069	ND	0.46	ND	ND	ND	0.32
Orthophosphate (P)	0.01	0.026	0.014	0.01	0.023	0.013	0.01	0.023	0.011	0.01	0.022	0.012	0.01	0.024	0.012	0.01	0.023	0.013	0.01	0.025	0.014
Major Ions																					
Phosphorus	ND	0.031	0.025	0.02	0.029	0.027	0.02	0.03	0.026	0.02	0.027	0.027	ND	0.034	0.024	ND	0.033	0.058	ND	0.031	0.026
Sulphide	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Organic Acids																					
Formic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acetic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propionic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Butyric Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MIDDLE																					
Parameters (mg/L)	**2000m US 2011**	**2000m US 2015**	**2000 m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
Nutrients																					
Nitrate + Nitrite	ND	0.13	ND	ND	0.11	ND	ND	0.14	ND	ND	0.11	ND	ND	0.14	ND	ND	0.12	ND	ND	0.12	ND
Nitrate (N)	ND	0.12	ND	ND	0.099	ND	ND	0.14	ND	ND	0.097	ND	ND	0.13	ND	ND	0.11	ND	ND	0.12	ND
Nitrite (N)	ND	0.012	0.010	ND	0.013	0.010	ND	ND	0.012	ND	0.012	ND	ND	0.01	0.010	ND	0.01	0.012	ND	ND	ND
Nitrogen (Ammonia)	ND	0.36	0.22	0.12	ND	0.27	ND	ND	0.057	ND	0.31	ND	ND	0.06	0.064	ND	0.49	ND	0.05	0.39	0.066
Orthophosphate (P)	0.01	0.024	0.015	0.01	0.025	0.012	0.01	0.022	0.012	0.01	0.023	0.012	0.01	0.024	0.012	0.01	0.026	0.013	0.01	0.023	0.013
Major Ions																					
Phosphorus	ND	0.031	0.028	ND	0.029	0.027	0.02	0.03	0.027	0.02	0.03	0.024	ND	0.031	0.027	0.02	0.032	0.058	ND	0.031	0.024
Sulphide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Organic Acids																					
Formic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acetic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propionic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Butyric Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BOTTOM																					
Parameters (mg/L)	**2000m US 2011**	**2000m US 2015**	**2000 m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
Nutrients																					
Nitrate + Nitrite	ND	0.13	ND	ND	0.12	ND	ND	0.12	ND	ND	0.28	ND	ND	0.12	ND	ND	0.12	ND	ND	0.12	ND
Nitrate (N)	ND	0.12	ND	ND	0.11	ND	ND	0.12	ND	ND	0.26	ND	ND	0.11	ND	ND	0.11	ND	ND	0.12	ND
Nitrite (N)	ND	0.01	0.013	ND	0.012	ND	ND	ND	0.011	ND	0.01	0.010	ND	0.011	0.011	ND	0.01	0.012	ND	ND	ND
Nitrogen (Ammonia)	0.01	ND	0.12	0.05	ND	ND	0.05	1	0.46	0.06	ND	ND	ND	0.21	0.099	ND	0.22	0.19	ND	ND	0.18
Orthophosphate (P)	ND	0.025	0.016	0.01	0.024	0.013	0.01	0.023	0.011	0.01	0.025	0.012	0.01	0.024	0.012	0.01	0.024	0.013	0.01	0.024	0.012
Major ions																					
Phosphorus	ND	0.029	0.049	0.02	0.029	0.027	0.02	0.031	0.026	0.02	0.03	0.024	ND	0.028	0.026	0.03	0.028	0.027	ND	0.029	0.025
Sulphide	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Organic Acids																					
Formic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acetic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Propionic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Butyric Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND – Not detectable

Table 2.16 - Marine Water Chemistry Results Comparison: Trace Metals

	SURFACE																				
Metals (µg/L)	**2000m US 2011**	**2000m US 2015**	**2000m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
ICP/MS Method																					
Total Aluminum (Al)	ND	ND	ND	ND	ND	ND	ND	ND	ND	318	ND	ND	105	ND	ND	ND	ND	ND	ND	ND	ND
Total Antimony (Sb)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Arsenic (As)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Barium (Ba)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Beryllium (Be)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Bismuth (Bi)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Boron (B)	4410	4100	4200	4530	4200	4100	4670	4400	4000	4610	4300	4000	4510	4400	4200	4490	4300	4000	4530	4200	4000
Total Cadmium (Cd)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.19	ND	ND	0.12	0.19
Total Calcium (Ca)	363000	390000	370000	363000	400000	370000	375000	380000	370000	380000	370000	360000	372000	390000	380000	365000	390000	360000	371000	390000	370000
Total Chromium (Cr)	ND	ND	ND	ND	ND	ND	ND	ND	ND	39	ND	ND	151	ND	ND	ND	ND	ND	ND	ND	ND
Total Cobalt (Co)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Copper (Cu)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Iron (Fe)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Lead (Pb)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Magnesium (Mg)	1240000	1100000	1200000	1250000	1200000	1100000	1290000	1200000	1200000	1310000	1200000	1100000	1280000	1200000	1200000	1260000	1200000	1200000	1270000	1200000	1100000
Total Manganese (Mn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Molybdenum (Mo)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Nickel (Ni)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Potassium (K)	340000	360000	350000	342000	360000	350000	354000	350000	350000	352000	340000	340000	348000	350000	350000	340000	360000	340000	343000	360000	350000
Total Selenium (Se)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Silver (Ag)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Sodium (Na)	9560000	9300000	9800000	9660000	9500000	9500000	10100000	9900000	9500000	10100000	9700000	9400000	10100000	9900000	9700000	9520000	9600000	9400000	9720000	9700000	9500000
Total Strontium (Sr)	6860	7300	7000	6850	7300	6900	7110	7400	6800	7040	7300	6800	7020	7400	7100	6870	7300	6800	6840	7300	6800
Total Thallium (Tl)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Tin (Sn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Titanium (Ti)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Uranium (U)	3.0	3.3	2.8	2.8	3.5	2.8	3.1	2.8	2.8	3.3	3.1	2.9	2.7	3.1	2.9	3.0	3.2	2.8	2.7	3.2	3.0
Total Vanadium (V)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Zinc (Zn)	ND	ND	1800	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	660	ND	ND	ND	ND	ND	ND
Cold Vapour AA Method																					
Total Mercury (Hg)	ND	0.057	0.18	ND	0.058	0.17	ND	0.035	0.18	ND	0.053	0.17	ND	0.062	0.16	ND	0.062	0.15	ND	0.055	0.18

ND – Not detectable

Metals (µg/L)	MIDDLE																				
	2000m US 2011	2000m US 2015	2000m US 2016	250m US 2011	250m US 2015	250m US 2016	20m DS 2011	20m DS 2015	20m DS 2016	250m DS 2011	250m DS 2015	250m DS 2016	500m DS 2011	500m DS 2015	500m DS 2016	1000m DS 2011	1000m DS 2015	1000m DS 2016	2000m DS 2011	2000m DS 2015	2000m DS 2016
ICP/MS Method																					
Total Aluminum (Al)	66	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Antimony (Sb)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Arsenic (As)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Barium (Ba)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Beryllium (Be)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Bismuth (Bi)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Boron (B)	4660	4200	4400	4750	4200	4000	4650	4300	4100	4710	4300	3900	4780	4400	4000	4790	4300	4100	4820	4200	4000
Total Cadmium (Cd)	ND	ND	0.23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.18	ND	ND	0.12	ND
Total Calcium (Ca)	375000	400000	380000	382000	390000	360000	375000	380000	370000	386000	380000	360000	388000	380000	370000	385000	390000	370000	391000	390000	360000
Total Chromium (Cr)	ND	21	ND	84	ND	ND	313	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	38	ND	ND
Total Cobalt (Co)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Copper (Cu)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Iron (Fe)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Lead (Pb)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Magnesium (Mg)	1190000	1200000	1200000	1230000	1200000	1100000	1200000	1200000	1200000	1240000	1200000	1100000	1220000	1200000	1200000	1230000	1200000	1200000	1250000	1200000	1100000
Total Manganese (Mn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Molybdenum (Mo)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Nickel (Ni)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Potassium (K)	354000	360000	360000	358000	360000	340000	356000	350000	350000	363000	350000	340000	365000	350000	350000	361000	360000	350000	369000	360000	340000
Total Selenium (Se)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Silver (Ag)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Sodium (Na)	10100000	9600000	9800000	10300000	9600000	9400000	10200000	9800000	9500000	10500000	10000000	9500000	10500000	9900000	9500000	10400000	9600000	9400000	10700000	9600000	9300000
Total Strontium (Sr)	7020	7600	7200	7020	7500	6700	6900	7400	6900	7110	7600	6800	7220	7500	6900	7080	7400	6800	7230	7400	6800
Total Thallium (Tl)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Tin (Sn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Titanium (Ti)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Uranium (U)	3.1	3.2	3.1	2.8	3.6	3.0	2.7	2.7	2.9	3.0	3	2.8	3.1	2.7	3.2	3.0	3.2	2.7	2.9	3.3	2.9
Total Vanadium (V)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Zinc (Zn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	390	64	ND	ND	ND
Cold Vapour AA Method																					
Total Mercury (Hg)	ND	0.053	0.17	ND	0.057	0.17	ND	0.038	0.17	ND	0.06	0.17	ND	0.06	0.16	ND	0.058	0.18	ND	0.053	0.18

ND – Not detectable

	BOTTOM																				
Metals (µg/L)	**2000m US 2011**	**2000m US 2015**	**2000m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
ICP/MS Method																					
Total Aluminum (Al)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Antimony (Sb)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Arsenic (As)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Barium (Ba)	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Beryllium (Be)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Bismuth (Bi)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Boron (B)	4760	4100	4200	4660	4300	4200	4810	4400	4000	4700	4300	4200	4700	4200	4000	4710	4200	4200	4690	4200	4000
Total Cadmium (Cd)	ND	0.11	ND	ND	ND	ND	ND	ND	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Calcium (Ca)	387000	390000	370000	386000	390000	370000	389000	380000	370000	385000	380000	380000	382000	380000	360000	383000	390000	380000	378000	400000	350000
Total Chromium (Cr)	116	ND	ND	194	ND	ND	519	ND	ND	ND	ND	ND	538	ND	ND	ND	ND	ND	ND	ND	ND
Total Cobalt (Co)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Copper (Cu)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Iron (Fe)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Lead (Pb)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Magnesium (Mg)	1220000	1100000	1200000	1240000	1200000	1200000	1240000	1200000	1100000	1230000	1200000	1200000	1210000	1200000	1100000	1240000	1200000	1200000	1220000	1200000	1100000
Total Manganese (Mn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Molybdenum (Mo)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Nickel (Ni)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Potassium (K)	362000	360000	350000	363000	370000	350000	369000	350000	350000	361000	350000	360000	357000	350000	340000	362000	360000	360000	355000	360000	340000
Total Selenium (Se)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Silver (Ag)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Sodium (Na)	10500000	9400000	9600000	10300000	9700000	9700000	10600000	10000000	9600000	10500000	9800000	9800000	10300000	9900000	9300000	10400000	9600000	9700000	10300000	9600000	9300000
Total Strontium (Sr)	7100	7300	7000	6990	7500	6900	7190	7700	6900	7130	7400	7100	7010	7500	6800	7140	7400	7100	7040	7500	6600
Total Thallium (Tl)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Tin (Sn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Titanium (Ti)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Uranium (U)	3.2	3.2	2.8	2.8	3.2	2.9	2.9	3	3.1	2.9	3.1	3.1	2.9	3.1	2.9	2.8	3.2	3.1	2.6	3.3	2.7
Total Vanadium (V)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Zinc (Zn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cold Vapour AA Method																					
Total Mercury (Hg)	ND	0.057	0.17	ND	0.057	0.18	ND	0.047	0.17	ND	0.057	0.18	ND	0.06	0.15	ND	0.053	0.17	ND	0.053	0.18

ND – Not detectable

Table 2.17 - Marine Water Chemistry Results Comparison: PAH and Petroleum Hydrocarbons

	SURFACE																				
Parameter	**2000m US 2011**	**2000m US 2015**	**2000m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
Polyaromatic Hydrocarbons (µg/L)																					
1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	0.012	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	0.012	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(j)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons (mg/L)																					
Benzene	ND	ND	ND	0.001	ND	ND	ND	ND	ND	0.001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	0.004	ND	ND	0.001	ND	ND	0.023	ND	ND	0.001	ND	ND	0.016	ND	ND	0.005	ND	ND	0.016	ND	ND
Ethylbenzene	ND	ND	ND	0.001	ND	ND	ND	ND	ND	0.001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylene (Total)	ND	ND	ND	0.002	ND	ND	ND	ND	ND	0.003	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C6 - C10 (less BTEX)	ND	ND	ND	0.01	ND	ND	ND	ND	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C10-C16 Hydrocarbons	ND	ND	ND	0.05	ND	ND	ND	ND	ND	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C16-C21 Hydrocarbons	ND	ND	ND	0.05	ND	ND	ND	ND	ND	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C21-<C32 Hydrocarbons	ND	ND	ND	0.1	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Modified TPH (Tier1)	ND	ND	ND	0.1	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Reached Baseline at C32	N/A	NA	NA	N/A	N/A	NA	N/A	NA	NA	N/A	N/A	NA	N/A	NA	NA	N/A	NA	NA	N/A	NA	NA
Hydrocarbon Resemblance	NA	NA	NA	N/A	N/A	NA	N/A	NA	NA	N/A	N/A	NA	N/A	NA	NA	N/A	NA	NA	N/A	NA	NA

ND – Not detectable, NA – Not applicable

	MIDDLE																				
Parameter	**2000m US 2011**	**2000m US 2015**	**2000m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
Polyaromatic Hydrocarbons (µg/L)																					
1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(j)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons (mg/L)																					
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	0.009	ND	ND	0.021	ND	ND	0.018	ND	ND	0.009	ND	ND	0.04	ND	ND	0.004	ND	ND	0.038	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylene (Total)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C6 - C10 (less BTEX)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND	ND
>C10-C16 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C16-C21 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C21-<C32 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Modified TPH (Tier1)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Reached Baseline at C32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocarbon Resemblance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ND – Not detectable, NA – Not applicable

	BOTTOM																				
Parameter	2000m US 2011	2000m US 2015	2000m US 2016	250m US 2011	250m US 2015	250m US 2016	20m DS 2011	20m DS 2015	20m DS 2016	250m DS 2011	250m DS 2015	250m DS 2016	500m DS 2011	500m DS 2015	500m DS 2016	1000m DS 2011	1000m DS 2015	1000m DS 2016	2000m DS 2011	2000m DS 2015	2000m DS 2016
Polyaromatic Hydrocarbons (µg/L)																					
1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	0.083	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	0.098	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(j)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons (mg/L)																					
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	0.014	ND	ND	0.013	ND	ND	0.003	ND	ND	0.002	ND	ND	0.024	ND	ND	0.009	ND	ND	0.012	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylene (Total)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C6 - C10 (less BTEX)	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C10-C16 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C16-C21 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>C21-<C32 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Modified TPH (Tier1)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Reached Baseline at C32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocarbon Resemblance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ND – Not detectable, NA – Not applicable

Table 2.18 - Marine Water Chemistry Results Comparison: Alkylated Phenols

											SURFACE											
Alkylated Phenols	**Units**	**2000m US 2011**	**2000m US 2015**	**2000m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
4-Nonylphenols	ng/L	ND	ND	46.1	ND	ND	61.7	ND	ND	60.7	ND	ND	10.6	ND	ND	42.5	ND	ND	33.7	ND	ND	39.4
4-Nonylphenol monoethoxylates	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nonylphenol diethoxylates	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-n-Octylphenol	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
											MIDDLE											
Alkylated Phenols	**Units**	**2000m US 2011**	**2000m US 2015**	**2000m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
4-Nonylphenols	ng/L	ND	ND	59.1	ND	ND	30.3	ND	ND	31.0	ND	ND	40.4	ND	ND	46.0	ND	ND	35.8	ND	ND	64.1
4-Nonylphenol monoethoxylates	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nonylphenol diethoxylates	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-n-Octylphenol	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
											BOTTOM											
Alkylated Phenols	**Units**	**2000m US 2011**	**2000m US 2015**	**2000m US 2016**	**250m US 2011**	**250m US 2015**	**250m US 2016**	**20m DS 2011**	**20m DS 2015**	**20m DS 2016**	**250m DS 2011**	**250m DS 2015**	**250m DS 2016**	**500m DS 2011**	**500m DS 2015**	**500m DS 2016**	**1000m DS 2011**	**1000m DS 2015**	**1000m DS 2016**	**2000m DS 2011**	**2000m DS 2015**	**2000m DS 2016**
4-Nonylphenols	ng/L	ND	ND	54.9	ND	ND	42.1	ND	ND	30.8	ND	ND	40.2	ND	ND	39.2	ND	ND	35.0	5.35	ND	51.9
4-Nonylphenol monoethoxylates	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nonylphenol diethoxylates	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-n-Octylphenol	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND – Not detectable

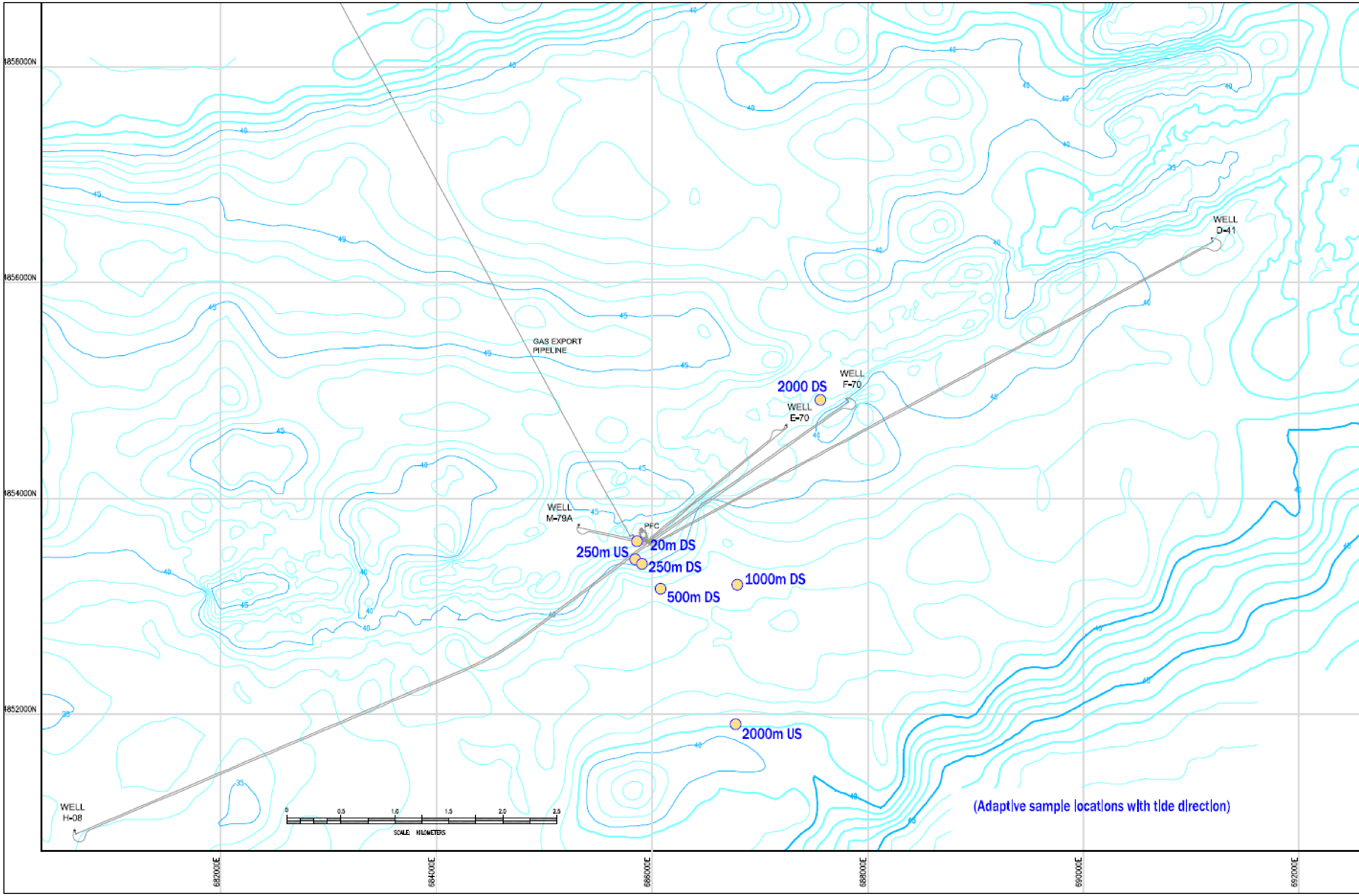


Figure 2.1 2016 Water Sample Locations

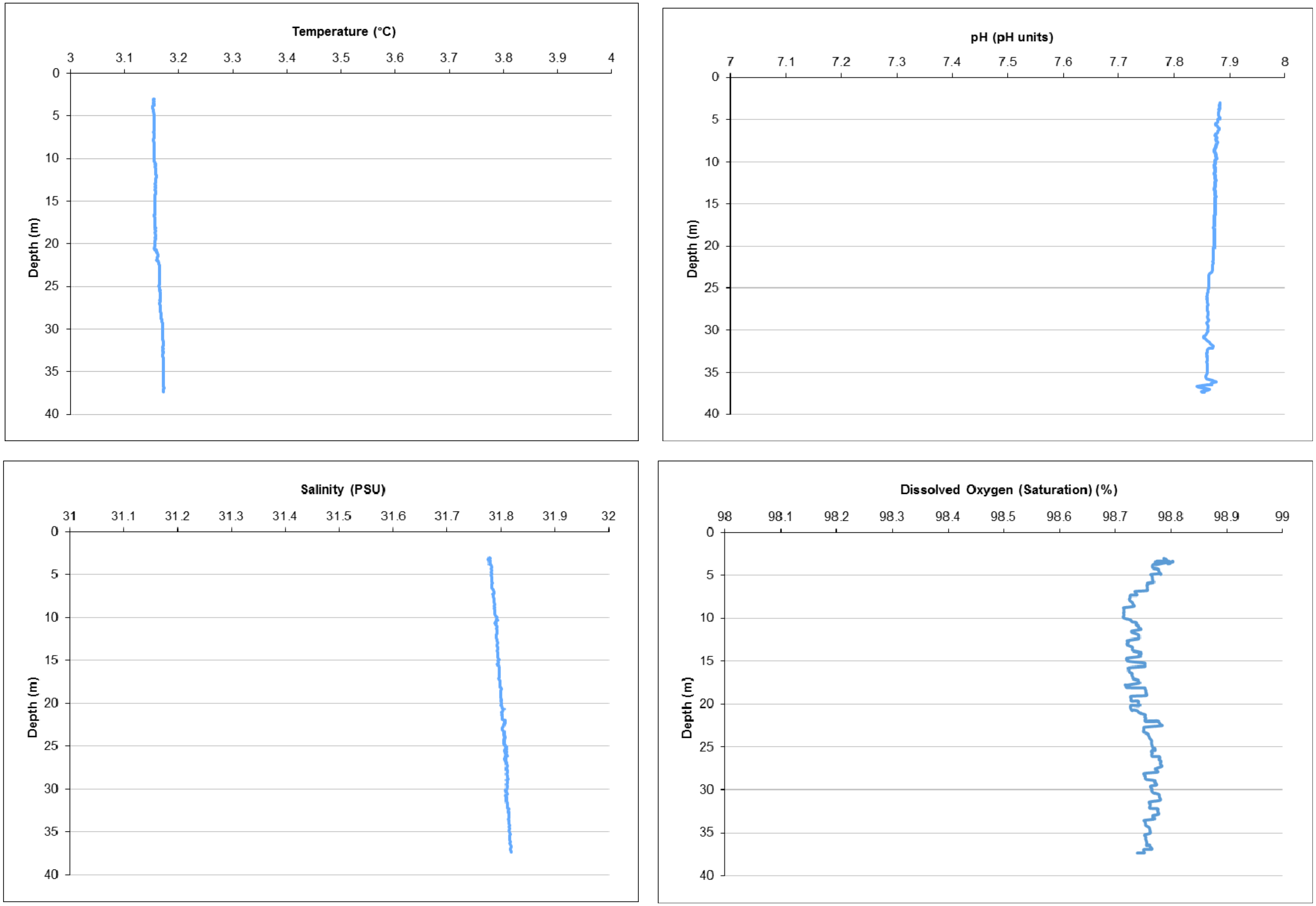


Figure 2.2 Salinity, Temperature and pH Results at the 2000m US station in 2016

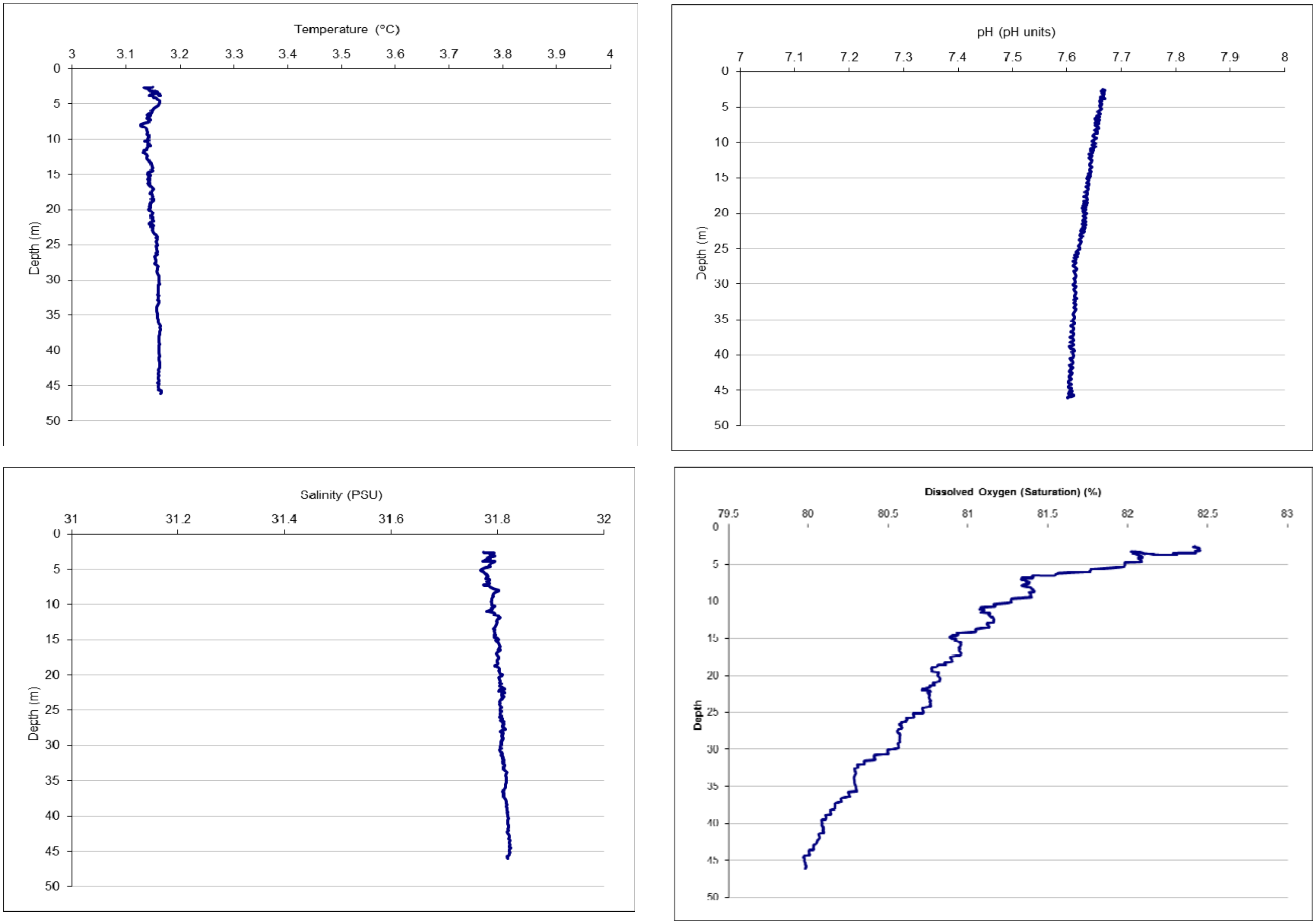


Figure 2.3 Salinity, Temperature and pH Results at the 250m US Station in 2016

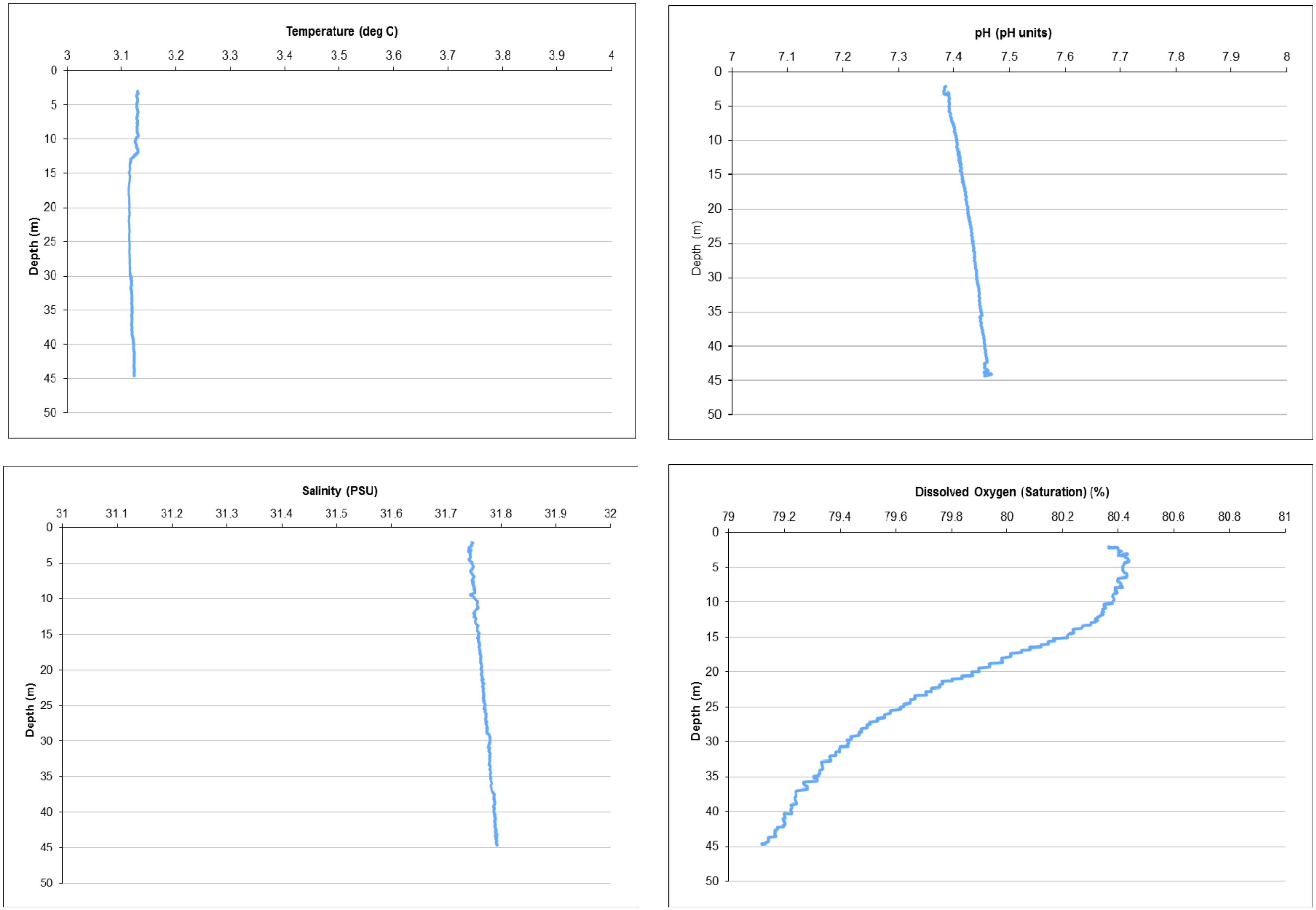


Figure 2.4 Salinity, Temperature and pH Results at the 20m DS Station in 2016

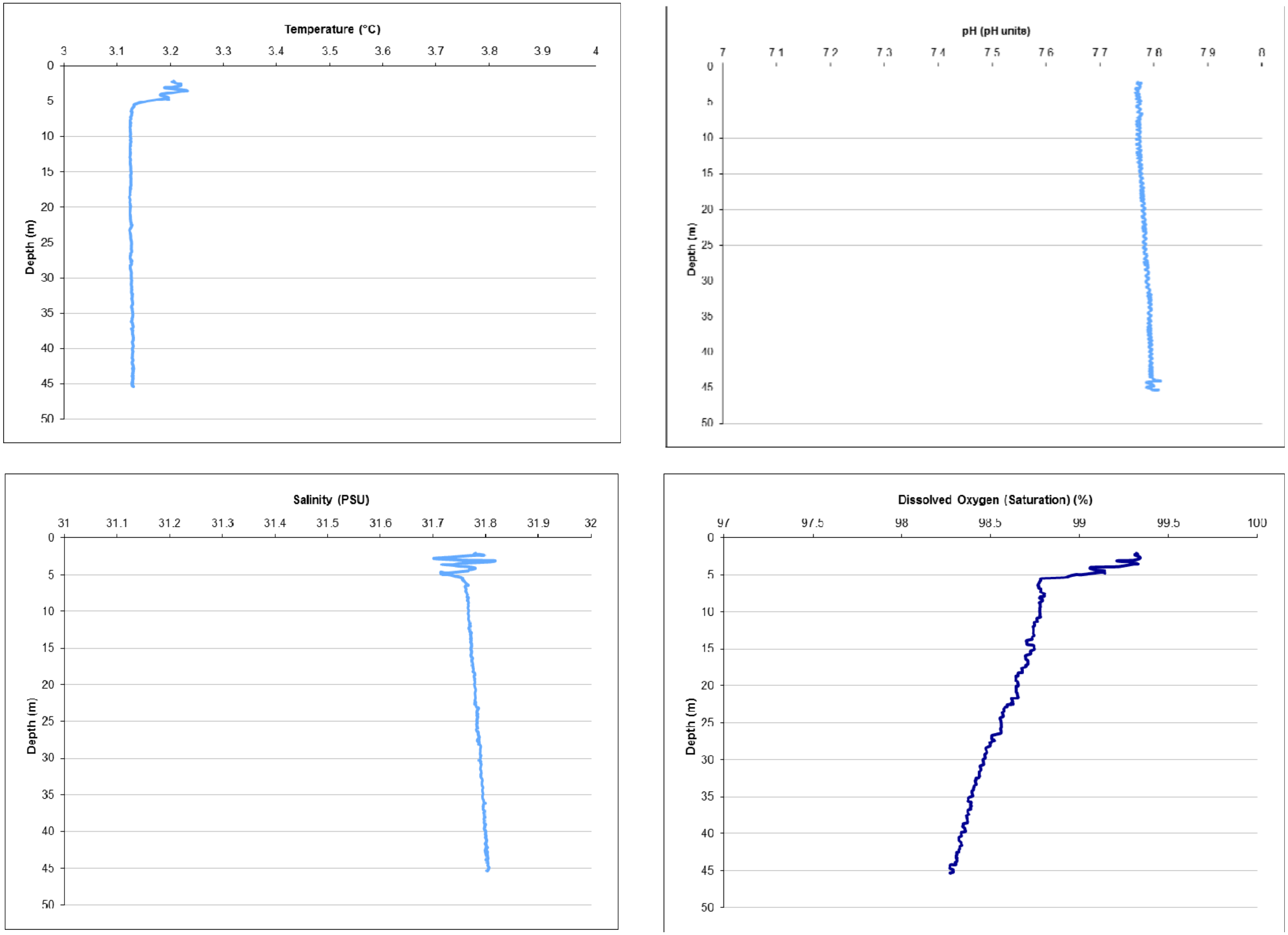


Figure 2.5 Salinity, Temperature and pH Results at the 250m DS Station in 2016

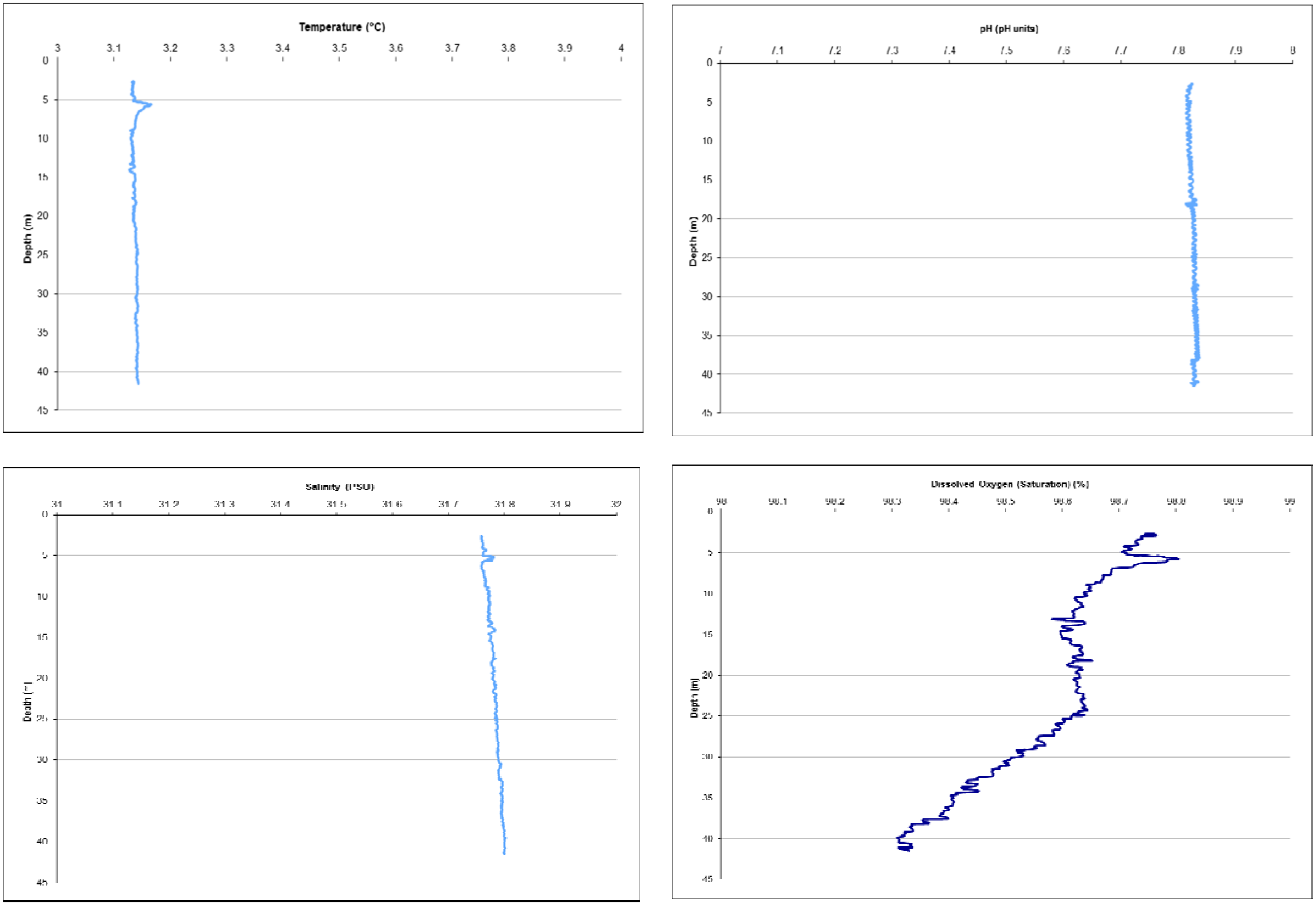


Figure 2.6 Salinity, Temperature and pH Results at the 500m DS Station in 2016

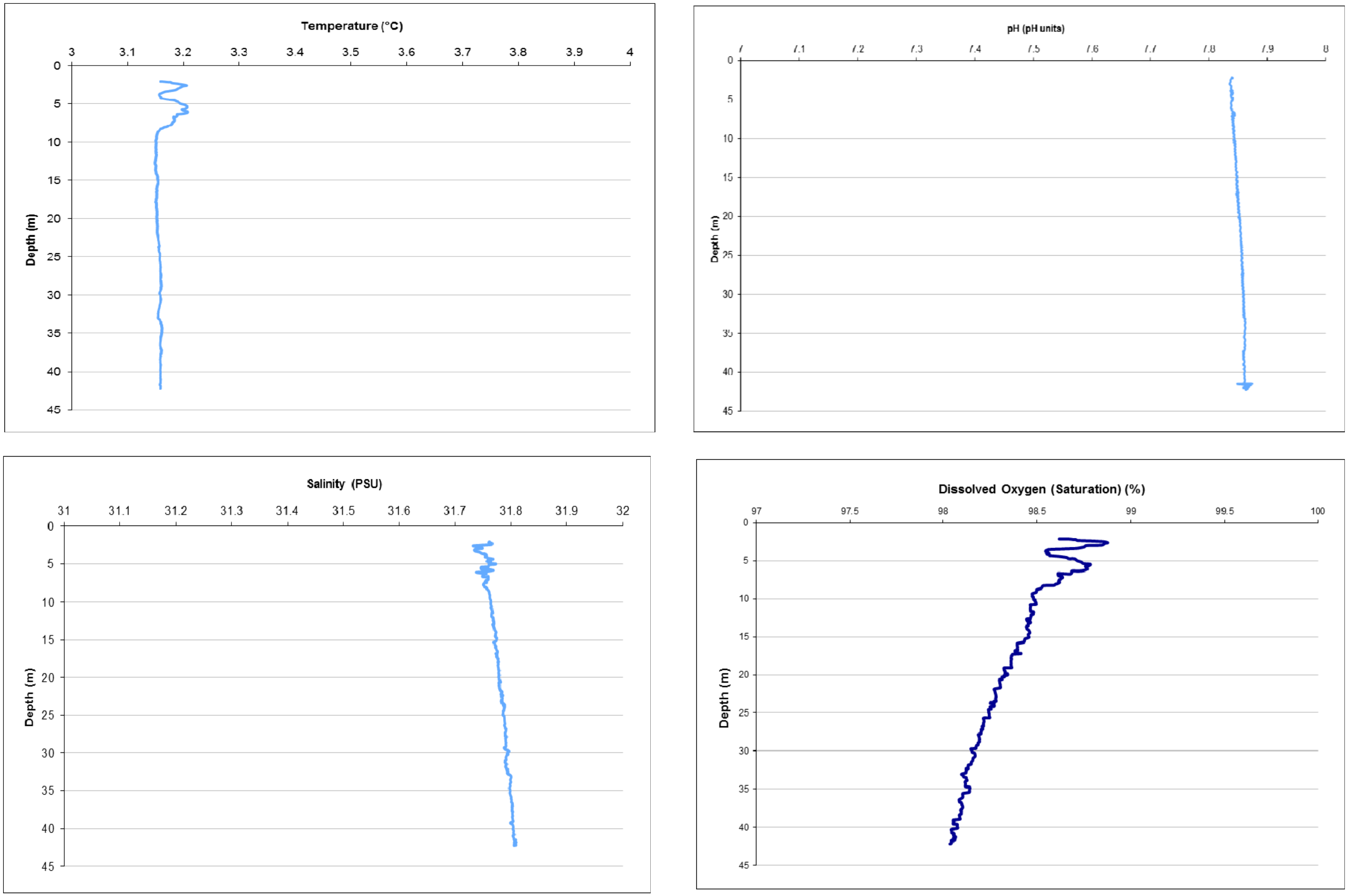


Figure 2.7 Salinity, Temperature and pH Results at the 1000m US Station in 2016

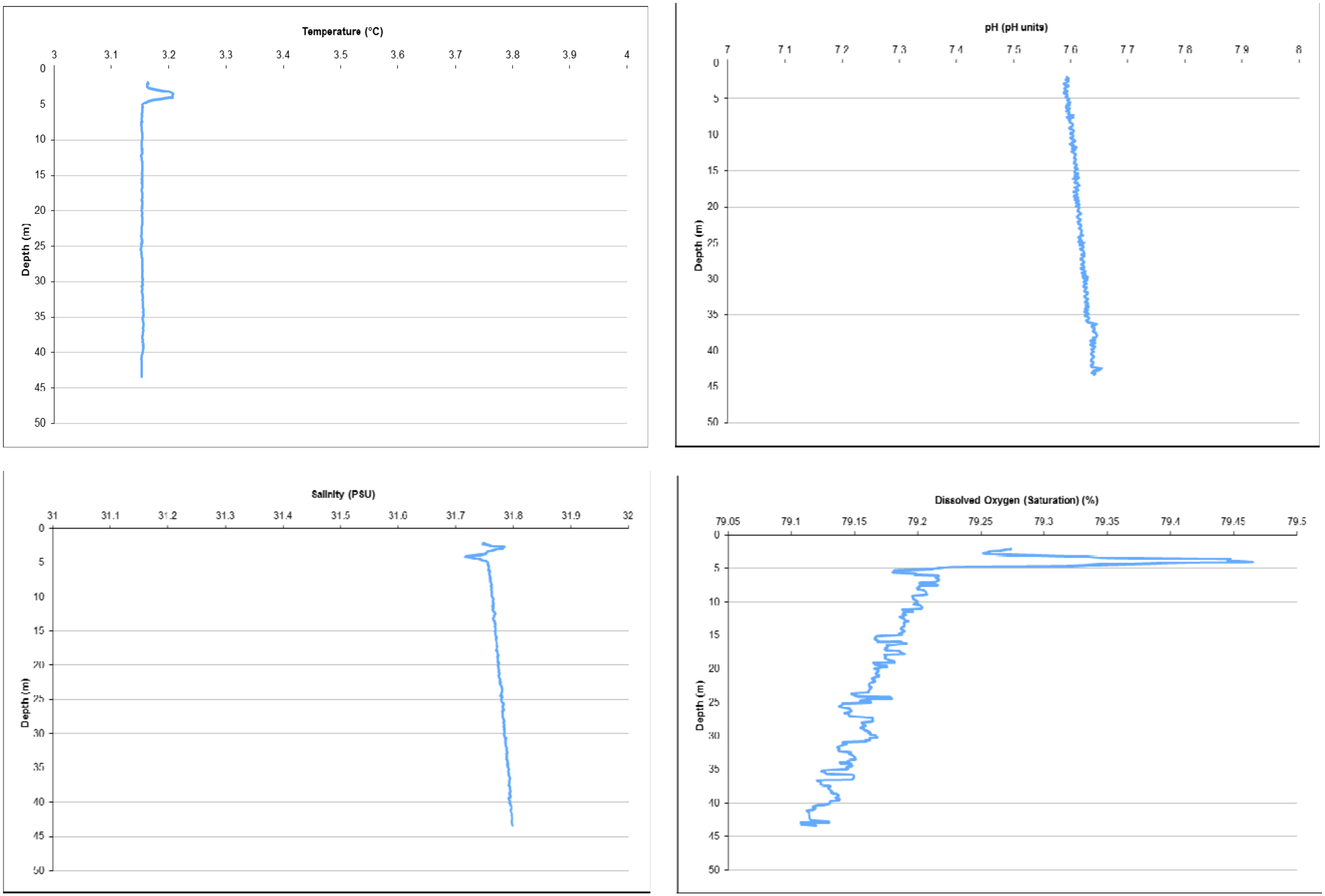


Figure 2.8 Salinity, Temperature and pH Results at the 2000m DS Station in 2016

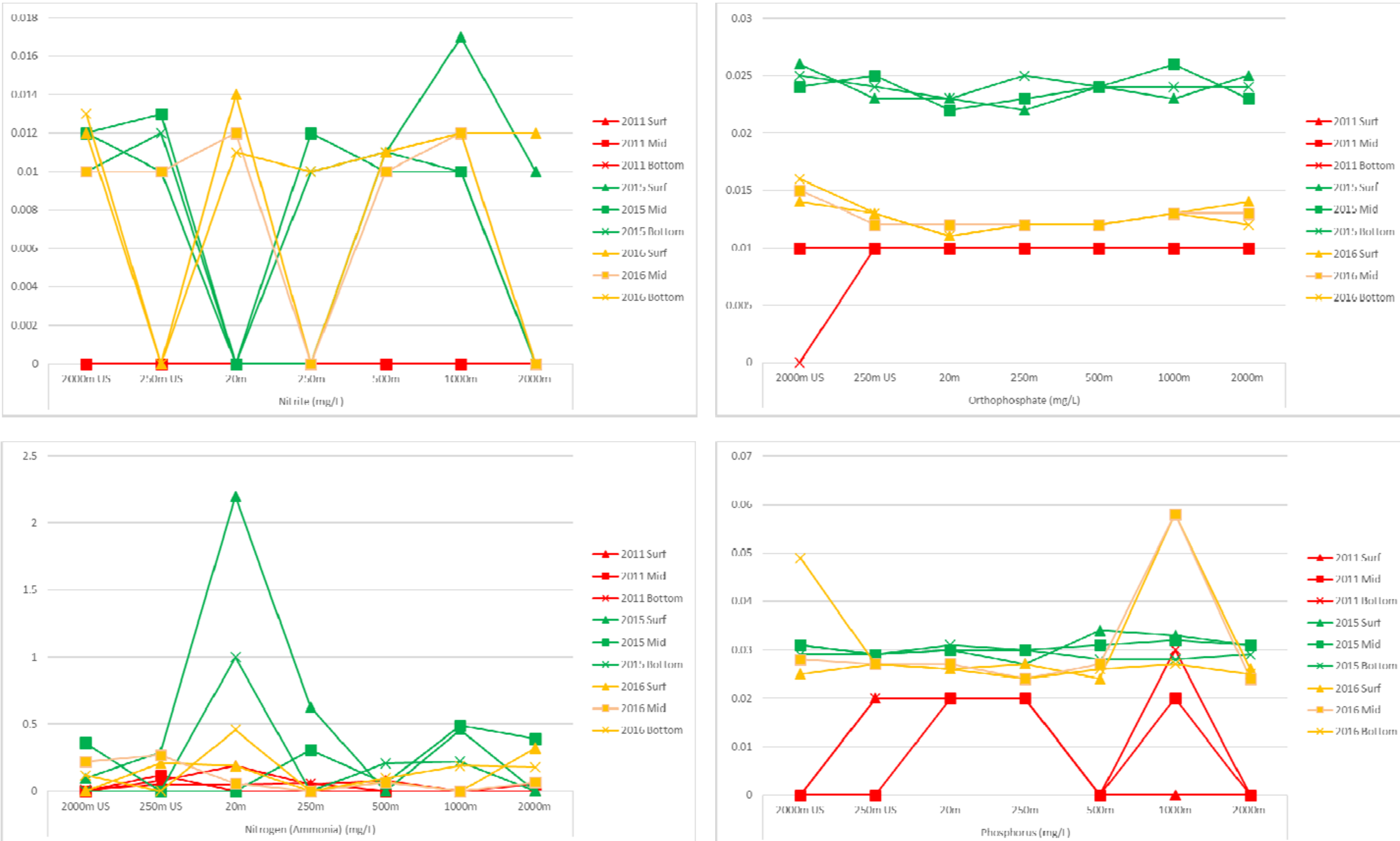


Figure 2.9 Comparison of nutrients and major ions tested for in water in 2011, 2015 and 2016

Figure 2.10 Comparison of metals tested for in water in 2011, 2015 and 2016

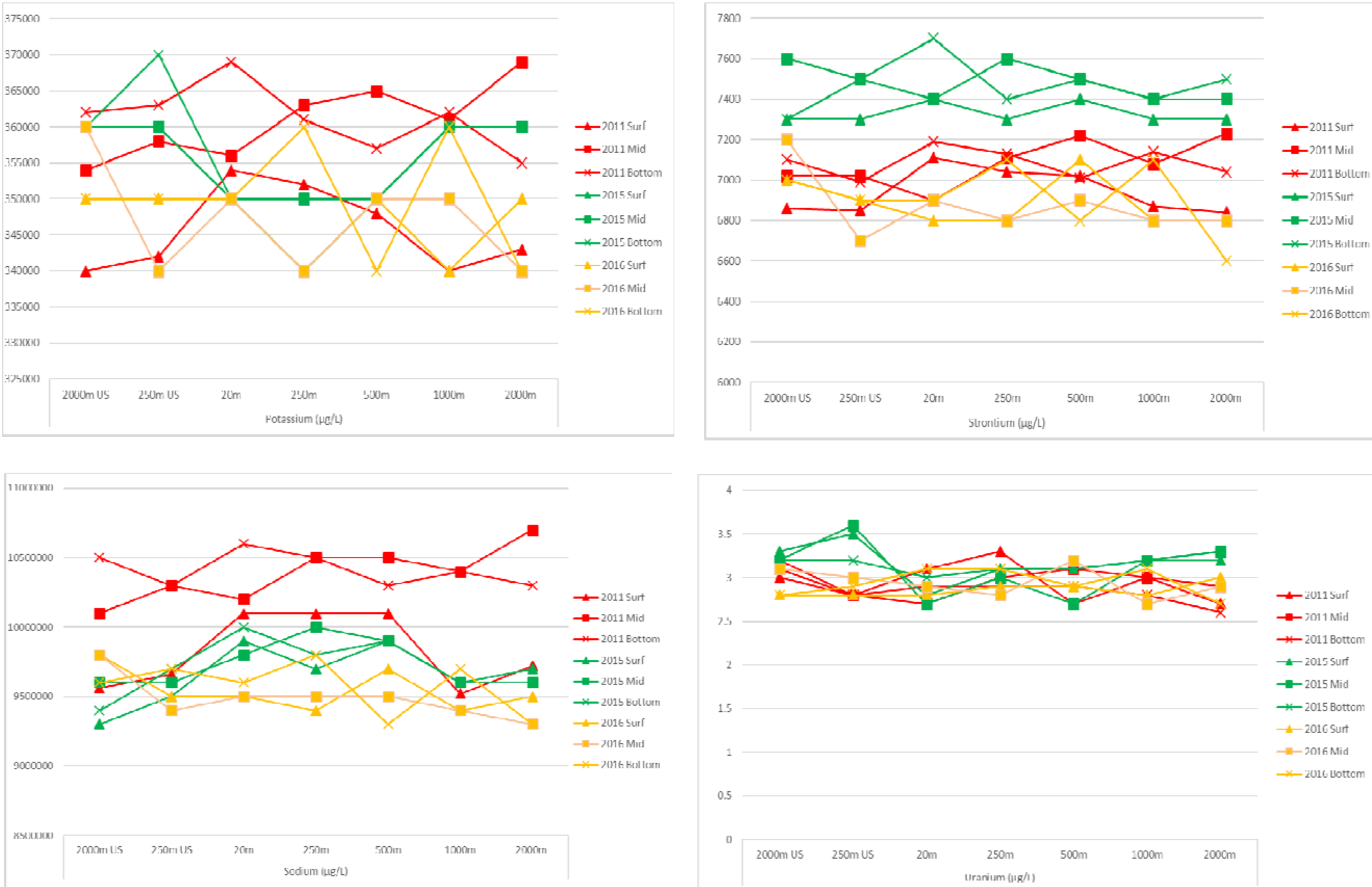


Figure 2.10 Comparison of metals tested for in water in 2011, 2015 and 2016

Figure 2.10 Comparison of metals tested for in water in 2011, 2015 and 2016

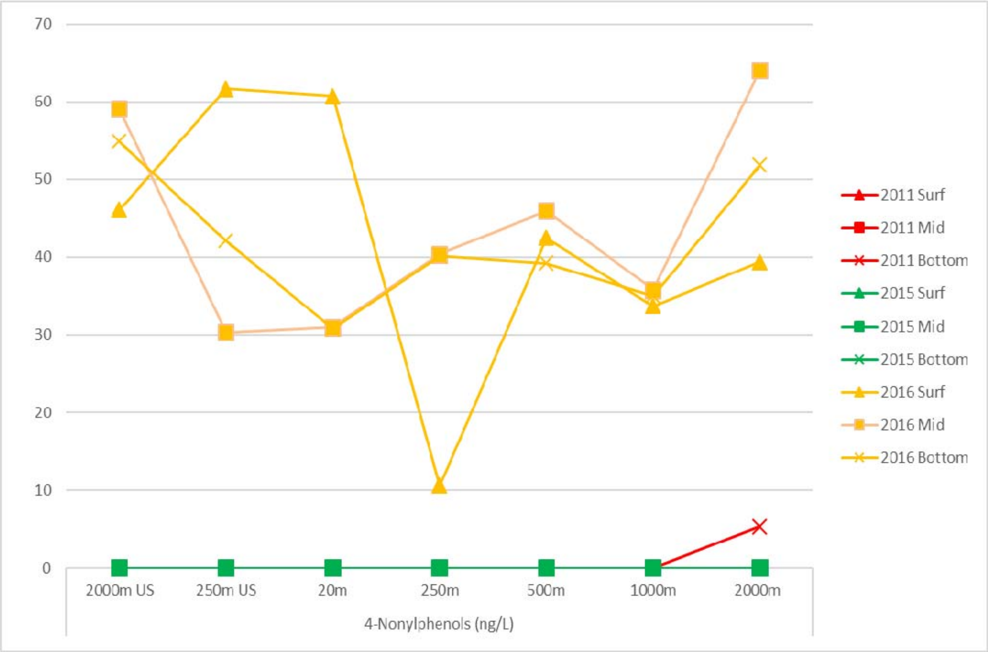


Figure 2.11 Comparison of alkylated phenols tested for in water in 2011, 2015 and 2016

2.3 SEDIMENT CHEMISTRY

2.3.1 Background

Chemical contamination of sediments in the vicinity of offshore gas platforms can be the result of discharges of mud/cuttings during drilling and completion, produced water during production operations and/or accidental releases (*i.e.*, spills). While effects are anticipated to be localized, such contamination can be potentially toxic, especially to bottom-dwelling fauna. Bioassay analysis using a suitable indicator species is a useful technique for evaluation of the toxicology of sediments collected at various distances from the source of contamination.

Analytical parameters for sediment chemistry initially used in the SOEP EEM program were the following: full metal (24 parameters) scan, grain size analysis, C6-C32 hydrocarbon scan, benzene, ethylbenzene, toluene, xylene, polycyclic aromatic hydrocarbons, organic and inorganic carbon, ammonia and sulphide. With the exception of barium and TPH concentrations in the near-field area (within 1,000 m of a discharge site) along the direction of the prevailing current, all other parameters showed no significant differences from levels measured during baseline surveys and from other near-field and far-field reference stations. Consequently, the number of stations and parameters for recent sediment samples taken for the SOEP EEM program was first reduced to three near-field stations (at 250 m, 500 m and 1,000 m) downstream of the main production platform at Thebaud and a few key parameters and finally discontinued from the program because of non-detectable/background levels for measured parameters.

A variety of laboratory-based sediment toxicity bioassays were originally used in the SOEP EEM program to evaluate potential lethal and sublethal effects on organisms representing several different trophic levels - amphipod (*Rhepoxynius abronius*) survival, echinoderm (*Lytechinus pictus*) fertilization and bacterial luminescence of *Vibrio fischeri* (Microtox). Within a relatively short period (two to three years of sampling), the echinoderm fertilization and Microtox tests were discontinued as the results did not correlate with trends in sediment chemistry results. However, the marine amphipod survival test has proved to be the most reliable indicator of sediment contamination and was a valuable monitoring parameter in the SOEP EEM program until this EEM component was discontinued after 2007.

At the Deep Panuke site, produced water and hydrocarbon spills are the only potential sources of TPH in sediments since only water-based mud (WBM) was used during drilling and completion activities. While barium was a component of WBM used to drill the production wells in 2000 (M-79A and H-08) and 2003 (F-70 and D-41), it was not a component of WBM used for the 2010 drilling and completion program (drilling of the new E-70 disposal well and recompletion of the four production wells), which instead used brine as a weighting agent.

The 2008 Baseline Benthic Study provided comparative data on sediment quality for the 2011 EEM program. Results from the 2008 Baseline Benthic Study indicated that the concentrations of metals in offshore sediments collected at the Deep Panuke site (pipeline route and PFC area) in 2008 (before the 2010 drilling and completion program but post drilling of the four production wells) were within background ranges found in other offshore studies on Scotian Shelf sediments. (In particular, mercury levels were non-detectable.)

The Deep Panuke 2011 sediment chemistry and toxicity testing (after the 2010 drilling and completion program) confirmed that all metal, non-metal, hydrocarbon and nutrient concentrations were below Canadian EQG threshold levels and that all collected sediments were non-toxic. Therefore, sediment sampling at the wellsites was discontinued and sediment sampling was focused downstream of the PFC to monitor potential impact from production discharges.

2.3.2 EEMP Goal

Predictions regarding sediment toxicity made in the 2006 Deep Panuke EA [EA predictions #1, 2, 3, 4, 5, 6, 7 & 8 in **Table 3.1**] are to be validated.

2.3.3 Objectives

The dispersion of key production chemical parameters at the production site is to be determined.

2.3.4 Sampling

Sediments were collected on March 8, 2016, at six stations for physical and chemical characterization. See **Table 2.19** below for sampling details.

Table 2.19 - 2016 Sediment Sampling Details

<table>
<tr><td>Survey Date:</td><td>March 8, 2016</td></tr>
<tr><td>Platform:</td><td>M/V Atlantic Condor</td></tr>
<tr><td>Type of Sample:</td><td>Sediment Physico-Chemistry</td></tr>
<tr><td>Test Sample Locations – Field Stations:</td><td>
<table>
<tr><th>Station</th><th>Time UTC</th><th>Water Depth(m)</th><th>Easting</th><th>Northing</th></tr>
<tr><td>250m DS</td><td>01:18</td><td>47</td><td>0685731</td><td>4853510</td></tr>
<tr><td>500m DS</td><td>01:57</td><td>46</td><td>0685655</td><td>4853225</td></tr>
<tr><td>1000m DS</td><td>02:35</td><td>42</td><td>0685219</td><td>4852959</td></tr>
<tr><td>2000m DS</td><td>03:20</td><td>40</td><td>0684489</td><td>4852283</td></tr>
<tr><td colspan="5">WGS84 UTM Zone 20N</td></tr>
</table>
</td></tr>
<tr><td>Test Sample Locations – Reference Stations:</td><td>
<table>
<tr><th>Station:</th><th>Time UTC</th><th>Water Depth(m)</th><th>Easting</th><th>Northing</th></tr>
<tr><td>5000m US NE</td><td>06:05</td><td>38</td><td>0689460</td><td>4857167</td></tr>
<tr><td>5000m DS SW</td><td>05:28</td><td>37</td><td>0682333</td><td>4850162</td></tr>
<tr><td colspan="5">WGS84 UTM Zone 20N</td></tr>
</table>
</td></tr>
<tr><td>Number of Samples/Locations:</td><td>Sediment samples were collected from the seafloor surface from 6 stations both upstream and downstream from the PFC. Sediment sampling locations are available in Figure 2.12. Logs and photos are available in Appendix F.

Field stations:
• 250m downstream of PFC (2008 station #12);
• 500m downstream of PFC (2008 station #13);
• 1,000m downstream of PFC (2008 station #14);
• 2,000m downstream of PFC (not surveyed in 2008);

Reference stations:
• 5,000m upstream (NE) of the PFC area
• 5,000m downstream (SW, towards the Haddock Box) of the PFC area</td></tr>
<tr><td>Equipment:</td><td>A stainless steel Van Veen grab was deployed as the ATLANTIC CONDOR held position via dynamic positioning (DP). The onboard winch and crane were used to deploy the Van Veen over the side of the vessel at each sample location to capture physical samples of the surficial sediments.

Following touchdown the Van Veen grab was raised to the surface and recovered via crane onboard the vessel. Retrieved samples</td></tr>
</table>

	were visually inspected, digitally photographed (**Appendix F)**, fully described and sub-sampled and logged.
Sample Preparation:	Samples were collected and subsampled into the following for subsequent analysis:

Parameter	Preservative
PSA and TOC	no preservative
Metal scan (incl. Hg)	no preservative
BTEX/TPH/PAHs	no preservative
Sulphide	Zinc Acetate
Alkylated Phenols	no preservative

2.3.5 Analysis

Maxxam Analytics undertook analysis of the physico-chemical composition of sediment samples. Parameters analyzed in sediment samples are listed in **Table 2.20**, including analysis methods and reportable detection limits. Major ions were determined by inductively coupled atomic photometry (ICAP). Metals were determined via Inductively Coupled Plasma Mass Spectrometry (ICP-MS), except mercury, which was determined using cold vapour atomic absorption (CVAA). Gas range hydrocarbons (TPH) were determined by P/T mass spectrophotometry (P/T MS) and diesel range hydrocarbons by gas chromatography (GC/MS or headspace-GC-PID/FID). Total organic carbon (TOC) was determined using LECO furnace methods. Moisture, as %, was determined by the difference between the wet and dry weight of a sample.

Sediment samples were also analyzed for TPH including benzene, toluene, ethylbenzene, and xylene(s) (BTEX), gasoline range organics (C6 to C10), and analysis of extractable hydrocarbons - diesel (>C10 to C16), diesel (>C16 to C21) and lube (>C21 to C32) range organics. BTEX and gasoline range organics were analyzed by purge and trap-gas chromatography/mass spectrometry or headspace – gas chromatography (MS/flame ionization detectors). Polyaromatic Hydrocarbons were determined by GC-MS. Extractable hydrocarbons, including diesel and lube range organics were analyzed using capillary column gas chromatography (flame ionization detector). Samples were also analyzed for alkylated phenols (APs). AXYS method MLA-004 describes the determination of 4-n-octylphenol, nonylphenol and nonylphenol ethoxylates (mono- and di-) in solids (sediment, soil, biosolids).

Physical characteristics of sediment samples were analyzed by classifying the proportion (%) of sample based on the Wentworth (1922) substrate scale, as well as a detailed particle size analysis (PSA) of the silt/clay fraction. To determine the proportion of sample as gravel, sand, silt and clay, organic matter and carbonates were destroyed by treating the sample with hydrogen peroxide.

As was done in 2015, raw data was presented in the results for comparison with previous years. A reference element that is naturally occurring in the earth's crust such as aluminum or iron can be used to normalize the data, as there is a relationship between levels of aluminum and other metals, causing increased levels (Carvalho & Schropp, 2002). In 2015 and 2016, the data was not normalized to aluminum as it was in 2011 for the 2008 and 2011 data, as increased levels of aluminum are associated with fine-grained aluminosilicate minerals that are most commonly associated with clays. This reference method is often used in estuarine studies to compensate for varying sediment types. In this case, all of the sediment at all stations across years is very consistent with the majority being comprised of fine to medium grained sand and little to no clay content.

2.3.5.1 Parameters Analyzed

Table 2.20 - Sediment Quality Parameters Measured

Parameter	Units	RDL	Analysis Method
Trace Elements			
Aluminum (Al)	mg/kg	10	ICP-MS
Antimony (Sb)	mg/kg	2	ICP-MS
Arsenic (As)	mg/kg	2	ICP-MS
Barium (Ba)	mg/kg	5	ICP-MS
Beryllium (Be)	mg/kg	2	ICP-MS
Bismuth (Bi)	mg/kg	2	ICP-MS
Boron (B)	mg/kg	50	ICP-MS
Cadmium (Cd)	mg/kg	0.30	ICP-MS
Chromium (Cr)	mg/kg	2	ICP-MS
Cobalt (Co)	mg/kg	1	ICP-MS
Copper (Cu)	mg/kg	2	ICP-MS
Iron (Fe)	mg/kg	50	ICP-MS
Lead (Pb)	mg/kg	0.50	ICP-MS
Lithium (Li)	mg/kg	2	ICP-MS
Manganese (Mn)	mg/kg	2	ICP-MS
Mercury (Hg)	mg/kg	0.010	CVAA
Molybdenum (Mo)	mg/kg	2	ICP-MS
Nickel (Ni)	mg/kg	2	ICP-MS
Rubidium (Rb)	mg/kg	2	ICP-MS

Parameter	Units	RDL	Analysis Method
Selenium (Se)	mg/kg	1	ICP-MS
Silver (Ag)	mg/kg	0.50	ICP-MS
Strontium (Sr)	mg/kg	5	ICP-MS
Thallium (Tl)	mg/kg	0.10	ICP-MS
Tin (Sn)	mg/kg	2	ICP-MS
Uranium (U)	mg/kg	0.10	ICP-MS
Vanadium (V)	mg/kg	2	ICP-MS
Zinc (Zn)	mg/kg	5	ICP-MS
PAH			
Naphthalene	mg/kg	0.01	GC-MS
Benzo(j)fluoranthene	mg/kg	0.01	GC-MS
Chrysene	mg/kg	0.01	GC-MS
Benzo(b)fluoranthene	mg/kg	0.01	GC-MS
Benzo(k)fluoranthene	mg/kg	0.01	GC-MS
Benzo(a)pyrene	mg/kg	0.01	GC-MS
Perylene	mg/kg	0.01	GC-MS
Acenaphthylene	mg/kg	0.01	GC-MS
Indeno(1,2,3-cd)pyrene	mg/kg	0.01	GC-MS
Dibenz(a,h)anthracene	mg/kg	0.01	GC-MS
Benzo(g,h,i)perylene	mg/kg	0.01	GC-MS
2-Methylnaphthalene	mg/kg	0.01	GC-MS
Acenaphthene	mg/kg	0.01	GC-MS
Fluorene	mg/kg	0.01	GC-MS
1-Methylnaphthalene	mg/kg	0.01	GC-MS
Benzo(a)anthracene	mg/kg	0.01	GC-MS
Phenanthrene	mg/kg	0.01	GC-MS
Anthracene	mg/kg	0.01	GC-MS
Fluoranthene	mg/kg	0.01	GC-MS
Pyrene	mg/kg	0.01	GC-MS
BTEX-TPH			
Benzene	mg/kg	0.025	PTGC
Toluene	mg/kg	0.025	PTGC
Ethylbenzene	mg/kg	0.025	PTGC
Xylene (Total)	mg/kg	0.05	PTGC
C6 - C10 (less BTEX)	mg/kg	2.50	PTGC
>C10-C16 Hydrocarbons	mg/kg	10	PTGC
>C16-C21 Hydrocarbons	mg/kg	10	PTGC
>C21-<C32 Hydrocarbons	mg/kg	15	PTGC
Reached Baseline at C32	mg/kg	N/A	PTGC
Modified TPH (Tier1)	mg/kg	15	PTGC
Sulphide	µg/g	0.50	ISE
Alkylated Phenols			
4-Nonylphenol (NP)	ng/g	varies (see lab report)	LRMS
4-Nonylphenol monoethoxylate (NP1EO)	ng/g	varies (see lab report)	LRMS
4-Nonylphenol diethoxylate (NP2EO)	ng/g	varies (see lab report)	LRMS
4-n-Octylphenol (OP)	ng/g	varies (see lab report)	LRMS
Physical Measures			
Particle Size	%, Phi	0.1	Sieves, hydrometer
Total Organic Carbon (TOC)	g/kg	0.2	LECO furnace
Moisture	%	1	Wet and dry weights

2.3.6 Results

- Sediment quality results including particle size analysis, metals, PAH and petroleum hydrocarbons, sulphides, alkylated phenols and total organic carbon results are presented in **Table 2.21** through **Table 2.25,** respectively, and in **Figure 2.13** and the full labs reports are included in **Digital Appendix E**.
- CEQG for sediment quality are included in **Appendix B.**
- The sediment type at all stations consisted of fine to medium grained sand.
- Aluminum levels in 2015 were similar at all stations than in 2011 and 2015 and significantly lower than in 2008.
- As in 2015, arsenic was only detected at the 5000m downstream station at 2.4 g/kg. Arsenic was found at the 250m station in 2008 and at none of the stations in 2011. Arsenic was present at 2.7 mg/kg (above the RDL of 2.0 mg/kg) at the 5000m downstream sediment station in 2015.
- Iron followed similar trends to the distribution across stations as in 2011 and 2015. Iron levels were highest at the 250m station and similar or lower than the 5000m upstream reference station at all other stations.
- Lead followed similar trends in detected levels across sites as in 2011 and 2015, where the highest detection was at the 250m site, and all other sites had similar or lower lead levels than 5000m upstream reference site. Lead levels are well below CCME guidelines.
- Manganese followed similar trends in detection levels across stations as in 2011 and 2015, with the highest levels found at the 250m station and all other stations with similar values to the 5000m upstream reference station. Manganese levels ranged from 12 to 28 mg/kg in 2016.
- Vanadium followed similar trends in detected levels across sites as in 2011 and 2015, where the highest detection was at the 250m site, and all other sites had similar levels as the 5000m upstream reference site. Levels of vanadium ranged from 3.0 - 6.4 mg/kg in 2016.
- Chromium was found at the 5000m upstream, 250m, 1000m and 5000m downstream stations at levels of 2.4, 4.1, 2.2 and 2.2 mg/kg, respectively. Trends in chromium detection and distribution over the sites sampled were similar to 2011 and 2015, other than the detected levels at the 1000m downstream site this year. These values are well below CCME guidelines.

- Uranium was found at the 5000m upstream, 250m and 2000m stations at levels of 0.12, 0.16 and 0.11 mg/kg, respectively. Uranium was only detected at the 250m station in 2011 and 2015 (at 0.10 and 0.15 mg/kg, respectively).
- Barium, strontium, thallium and zinc were not present at detectable levels across any stations, which is consistent with 2011 and 2015 results and a decrease from the baseline study results from 2008.
- Mercury, antimony, beryllium, bismuth, boron, cadmium, cobalt, copper, lithium, molybdenum, nickel, rubidium, selenium, silver and tin concentrations remain below detectable levels for all benthic stations as was the case in all years tested.
- PAH and BTEX-TPH remain below laboratory detection levels for all benthic stations.
- TOC concentrations were not detectable at any stations, except for the 250m station (0.59 g/kg), which is consistent with the 2011 and 2015 surveys.
- The only alkylated phenols detected were 4-Nonylphenol (NP) at the 250m station (0.686 ng/g). No alkylated phenols were detected at any stations in 2011 or 2015.
- Sulphide levels were below the reportable detection limit of 0.50 µg/g at all stations except for the 250m station (sulphide measured at 0.51 µg/g). This is consistent with 2011 and 2015 results. In 2011 sulphide was measured at 5 out of 6 stations at levels between 0.21 and 0.46 µg/g (reportable detection limit for that testing was 0.25 µg/g). In 2015, sulphide levels were below the reportable detection limits of 0.50 and 0.55 µg/g at all stations.

Table 2.21 - Sediment Quality: 2016 Particle Size Analysis Results

Parameter	Units	SED 250 M	SED 500 M	SED 1000 M	SED 2000 M	SED 5000 MUP	SED 5000 MDO
Moisture	%	18	14	15	16	17	17
< -1 Phi (2 mm)	100	99	100	100	100	100	100
< 0 Phi (1 mm)	100	92	100	100	100	100	100
< +1 Phi (0.5 mm)	99	61	89	97	90	87	99
< +2 Phi (0.25 mm)	83	11	22	28	13	9.3	83
< +3 Phi (0.12 mm)	4.9	0.82	1.2	1.2	0.90	0.88	4.9
< +4 Phi (0.062 mm)	1.0	0.65	0.87	0.90	0.74	0.76	1.0
< +5 Phi (0.031 mm)	1.0	0.58	0.87	0.89	0.69	0.75	1.0
< +6 Phi (0.016 mm)	1.0	0.65	0.80	0.85	0.71	0.79	1.0
< +7 Phi (0.0078 mm)	1.0	0.72	0.81	0.92	0.59	0.75	1.0
< +8 Phi (0.0039 mm)	1.0	0.68	0.98	0.86	0.64	0.78	1.0
< +9 Phi (0.0020 mm)	1.1	0.62	0.96	0.92	0.64	0.76	1.1
Gravel	ND	0.78	ND	ND	ND	ND	ND
Sand	99	99	99	99	99	99	99
Silt	ND	ND	ND	ND	0.10	ND	ND
Clay	1.0	0.68	0.98	0.86	0.64	0.78	1.0

ND – not detected

Table 2.22 - Sediment Chemistry Results Comparison: Trace Metals

Parameter	5000 US (NE) 2011	5000 US (NE) 2015	5000 US (NE) 2016	250 DS 2008	250 DS 2011	250 DS 2015	250 DS 2016	500 DS 2008	500 DS 2011	500 DS 2015	500 DS 2016	1000 DS 2008	1000 DS 2011	1000 DS 2015	1000 DS 2016	2000 DS 2011	2000 DS 2015	2000 DS 2016	5000 DS (SW) 2011	5000 DS (SW) 2015	5000 DS (SW) 2016	CCME Guidelines mg/kg	
																						ISQG	PEL
Inorganics (g/kg)																							
Moisture	15	16	17	13	18	19	18	12	15	16	14	17	14	15	15	14	17	16	17	17	17	-	-
TOC	ND	ND	ND	ND	0.5	0.49	0.59	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Metals (mg/kg)																							
Aluminum (Al)	460	450	390	11000	810	740	690	13000	450	450	350	12000	380	350	470	390	400	470	400	400	400	-	-
Antimony (Sb)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Arsenic (As)	ND	ND	ND	2.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.7	2.4	7.24	41.6
Barium (Ba)	ND	ND	ND	190	ND	ND	ND	200	ND	ND	ND	190	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	-
Beryllium (Be)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	-
Bismuth (Bi)	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Boron (B)	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	-
Cadmium (Cd)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.7	4.2
Chromium (Cr)	2	2.6	2.4	3.1	5	4.4	4.1	4.5	ND	ND	ND	3.6	ND	ND	2.2	ND	ND	ND	ND	2.1	2.2	52.3	160
Cobalt (Co)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	No data
Copper (Cu)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18.7	108
Iron (Fe)	2000	2000	1900	2400	3300	3500	3200	2800	1800	2000	1400	2100	1500	1500	1900	1500	1900	1800	2200	2400	2100	No data	No data
Lead (Pb)	0.7	0.74	0.67	4.4	1.1	1.2	1.1	4.8	ND	0.52	ND	4.7	ND	0.5	0.54	0.5	0.65	0.61	0.6	0.64	0.56	30.2	112
Lithium (Li)	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	No data
Manganese (Mn)	11	12	12	29	30	32	28	63	16	17	14	37	12	10	17	12	18	14	18	28	17	No data	No data
Mercury (Hg)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.13	0.7
Molybdenum (Mo)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	No data
Nickel (Ni)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	No data
Rubidium (Rb)	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Selenium (Se)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	No data
Silver (Ag)	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	N/A	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	No data
Strontium (Sr)	ND	ND	ND	45	ND	ND	ND	50	ND	ND	ND	46	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Thallium (Tl)	ND	ND	ND	0.16	ND	ND	ND	0.17	ND	ND	ND	0.16	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	No data
Tin (Sn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	No data	No data
Uranium (U)	ND	ND	0.12	0.19	0.1	0.15	0.16	0.35	ND	ND	ND	0.20	ND	ND	ND	ND	ND	0.11	ND	ND	ND	No data	No data
Vanadium (V)	5	4.6	4.0	6.2	7	6.7	6.4	7.6	5	3.8	3.0	5.9	4	3	4.1	3	3.7	3.7	5	5	5.2	No data	No data
Zinc (Zn)	ND	ND	ND	6.1	ND	ND	ND	6.9	ND	ND	ND	6.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	124	271

ND – not detected
NA – not tested
ISQG -Interim Sediment Quality Guidelines
PEL - Probable Effect Level

Table 2.23 - Sediment Chemistry Results Comparison: Petroleum Hydrocarbons and PAH

Parameter	5000 US (NE) 2011	5000 US (NE) 2015	5000 US (NE) 2016	250 DS 2011	250 DS 2015	250 DS 2016	500 DS 2011	500 DS 2015	500 DS 2016	1000 DS 2011	1000 DS 2015	1000 DS 2016	2000 DS 2011	2000 DS 2015	2000 DS 2016	5000 DS (SW) 2011	5000 DS (SW) 2015	5000 DS (SW) 2016	CCME Guidelines ISQG	CCME Guidelines PEL
Total Petroleum Hydrocarbons (mg/kg)																				
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Xylene (Total)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
C6 - C10 (less BTEX)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
>C10-C16 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
>C16-C21 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
>C21-<C32 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Modified TPH (Tier1)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Reached Baseline at C32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-	-
Hydrocarbon Resemblance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-	-
Polyaromatic Hydrocarbons (mg/kg)																				
1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
2-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0202	0.201
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00671	0.0889
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00587	0.128
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0469	0.245
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0888	0.763
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Benzo(j)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.108	0.846
Dibenz(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.113	1.494
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0212	0.144
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0346	0.391
Perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0867	0.544
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.153	1.398

N/A - Not Applicable
ND – not detected
ISQG - Interim Sediment Quality Guidelines
PEL - Probable Effect Level

Table 2.24 - Sediment Chemistry Results Comparison: Sulphide

Parameter	5000 US (NE) 2011	5000 US (NE) 2015	5000 US (NE) 2016	250 DS 2011	250 DS 2015	250 DS 2016	500 DS 2011	500 DS 2015	500 DS 2016	1000 DS 2011	1000 DS 2015	1000 DS 2016	2000 DS 2011	2000 DS 2015	2000 DS 2016	5000 DS (SW) 2011	5000 DS (SW) 2015	5000 DS (SW) 2016	CCME Guidelines	
																			ISQG	PEL
Sulphide (µg/g)																				
H_2S	0.46(1)	<0.50	<0.50(2)	0.22(1)	<0.50	<0.50(2)	0.25(1)	<0.50	0.51(3)	0.21(1)	<0.55	<0.50(3)	<0.20(1)	<0.50	<0.50(2)	0.25(1)	<0.50	<0.50(2)	-	-

1 - RDL in 2011 was 0.20 µg/g as opposed to 0.50 µg/g in 2015 and 2016.
2 - RDL raised due to high sample moisture content. Matrix spike exceeds acceptance limits due to matrix interference. Re-analysis yields similar results. Sample arrived to laboratory past recommended hold time.
3 - Sample arrived to laboratory past recommended hold time.
ISQG - Interim Sediment Quality Guidelines
PEL - Probable Effect Level

Table 2.25 - Sediment Chemistry Results Comparison: Alkylated Phenols

Parameter	5000 US (NE) 2011	5000 US (NE) 2015	5000 US (NE) 2016	250 DS 2011	250 DS 2015	250 DS 2016	500 DS 2011	500 DS 2015	500 DS 2016	1000 DS 2011	1000 DS 2015	1000 DS 2016	2000 DS 2011	2000 DS 2015	2000 DS 2016	5000 DS (SW) 2011	5000 DS (SW) 2015	5000 DS (SW) 2016	CCME Guidelines	
																			ISQG	PEL
Alkylated Phenol (ng/g)																				
4-Nonylphenol (NP)	ND	ND	ND	ND	ND	0.686	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1 mg/kg	No data
4-Nonylphenol monoethoxylates (NP1EO)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1 mg/kg	No Data
4-Nonylphenol diethoxylates (NP2EO)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1 mg/kg	No Data
4-n-Octylphenol (OP)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	No Data
% Moisture	16.9	15.9	15.5	20.1	18.6	19	23.2	14.7	11.8	18.9	18.3	16.4	21.4	14.9	15.7	18.8	12.2	15.9	-	-

ISQG - Interim Sediment Quality Guidelines
PEL - Probable Effect Level

2.3.7 Summary and Conclusions

- The sediment type found at all stations consisted of fine to medium sand.
- Barium, strontium, thallium and zinc were not present at detectable levels across any stations, which is consistent with 2011 and 2015 results and a decrease from the baseline study results from 2008.
- Mercury, antimony, beryllium, bismuth, boron, cadmium, cobalt, copper, lithium, molybdenum, nickel, rubidium, selenium, silver and tin concentrations remain below detectable levels across all stations as was the case in all years tested.
- Aluminum, arsenic, iron, lead manganese, vanadium, chromium and uranium were detected at similar levels and followed generally similar trends across stations as in 2011 and 2015.
- Sulphide levels are consistent since 2011 at levels around/below 0.5 µg/g across all stations.
- PAH and BTEX-TPH parameters remain at non-detectable levels.
- Only one alkylated phenol parameter was detected, i.e. 4-Nonylphenol (NP) at the 250m station (0.686 ng/g).
- The comparison of post production data (2015 and 2016) with pre-production data (2008 and 2011) shows no sign of sediment contamination from production activities.

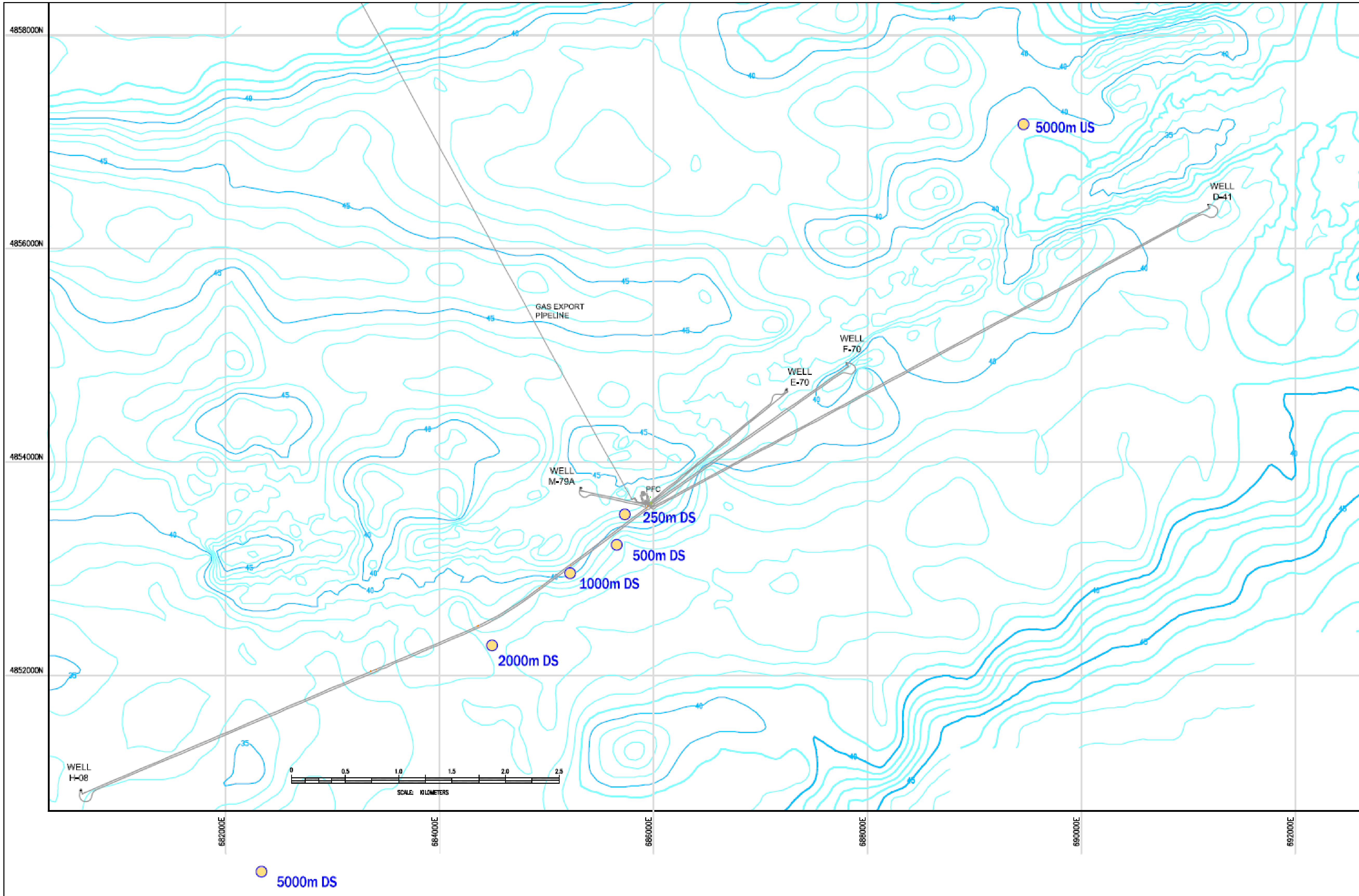


Figure 2.12 2016 Sediment Sample Locations

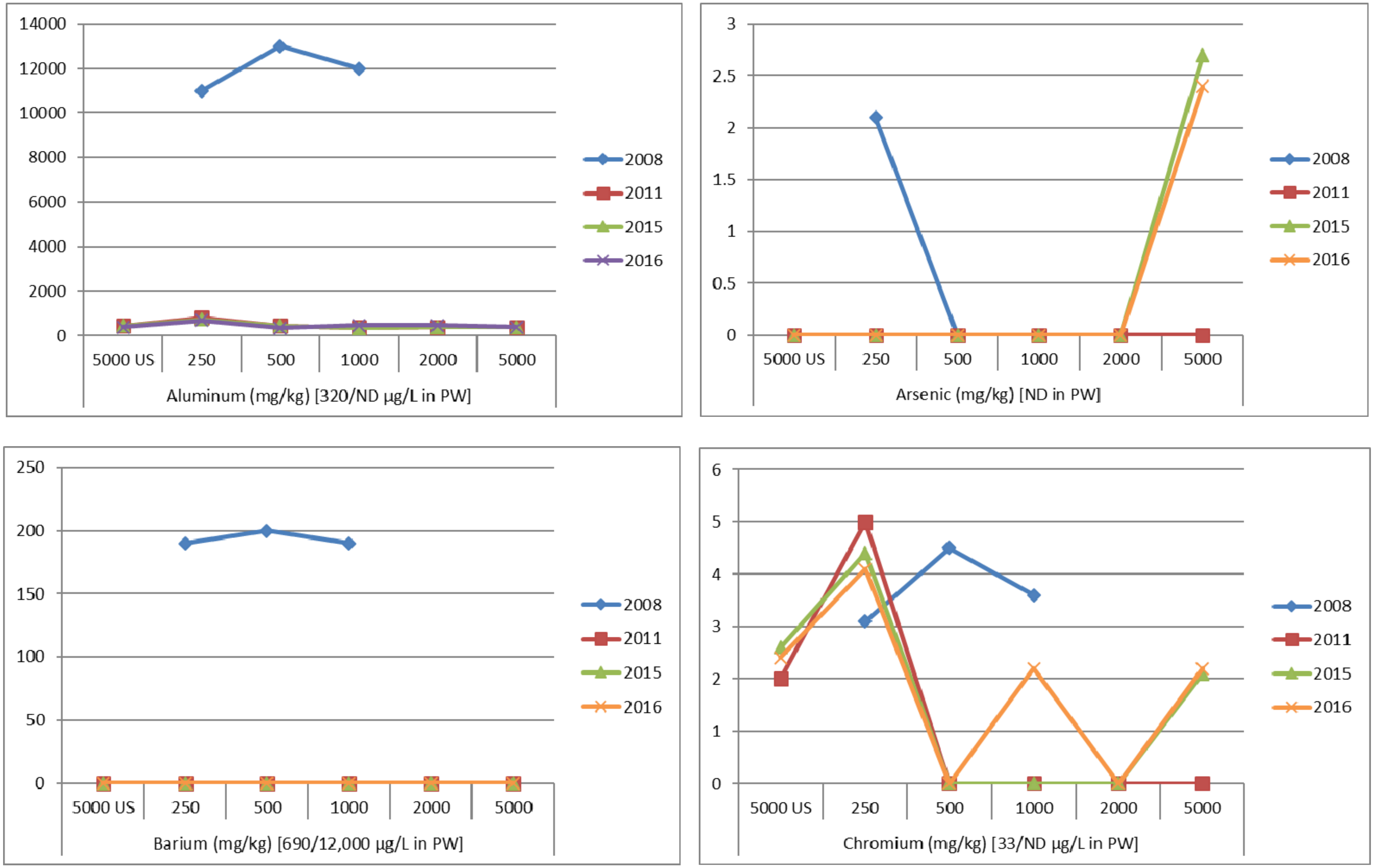


Figure 2.13 Comparisons of parameters tested for in sediment in 2008, 2011, 2015 and 2016

[values in brackets indicate the concentration of the parameter found in produced water in March / November 2016]

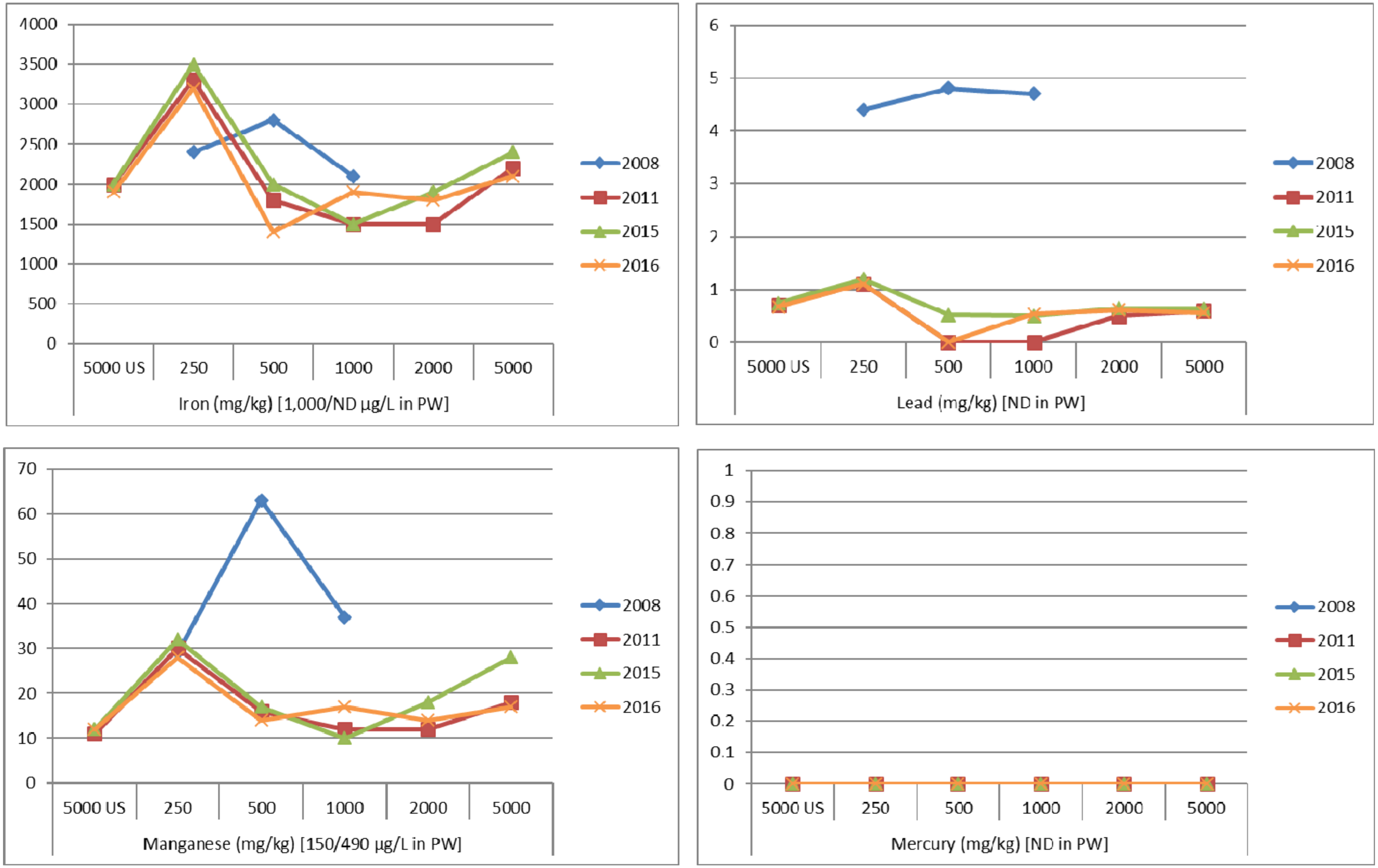


Figure 2.13 Comparisons of parameters tested for in sediment in 2008, 2011, 2015 and 2016

[values in brackets indicate the concentration of the parameter found in produced water in March / November 2016]

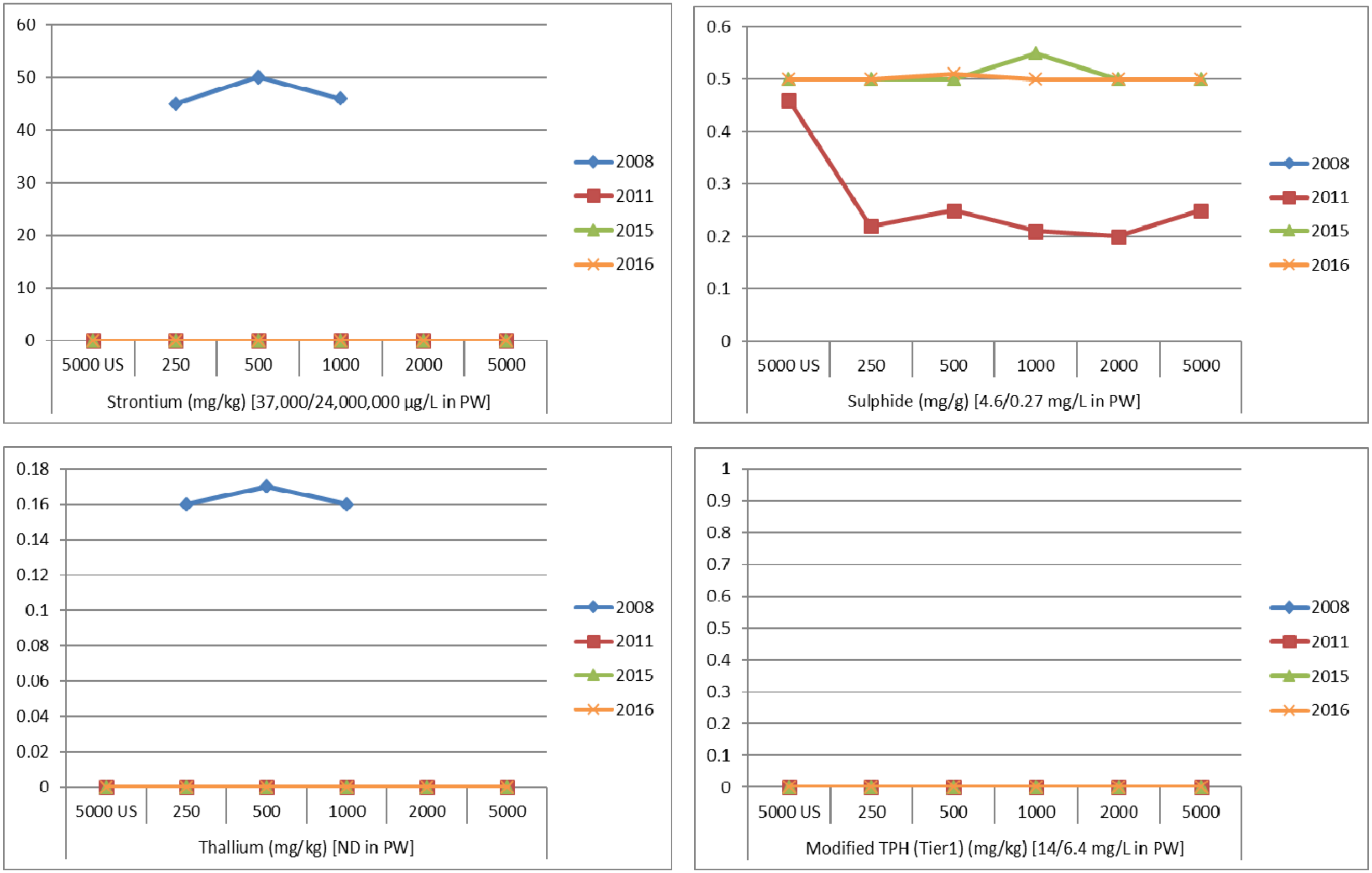
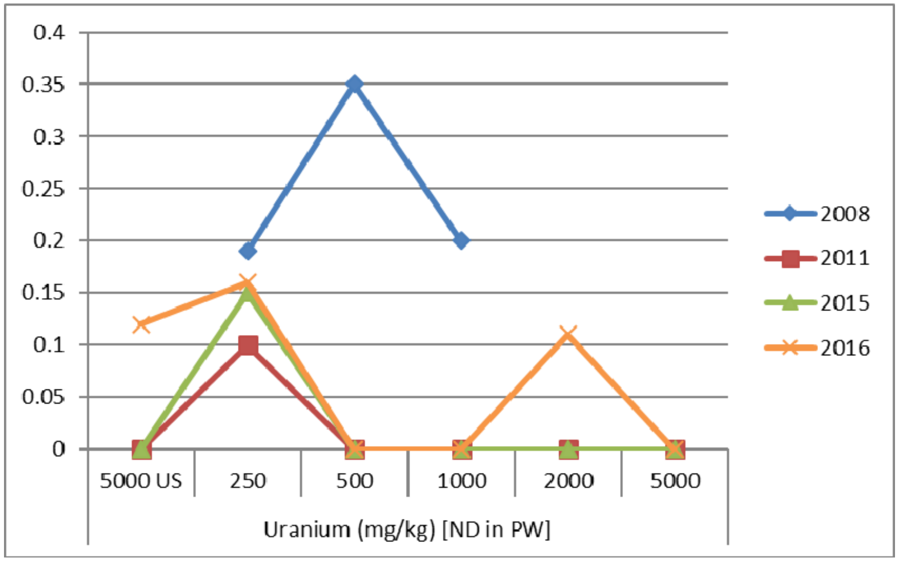
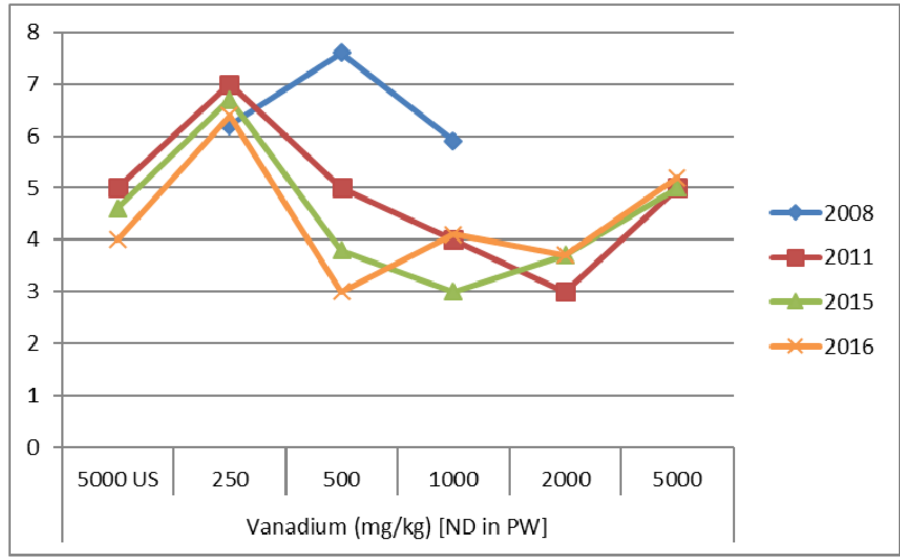


Figure 2.13 Comparisons of parameters tested for in sediment in 2008, 2011, 2015 and 2016

[values in brackets indicate the concentration of the parameter found in produced water in March / November 2016]





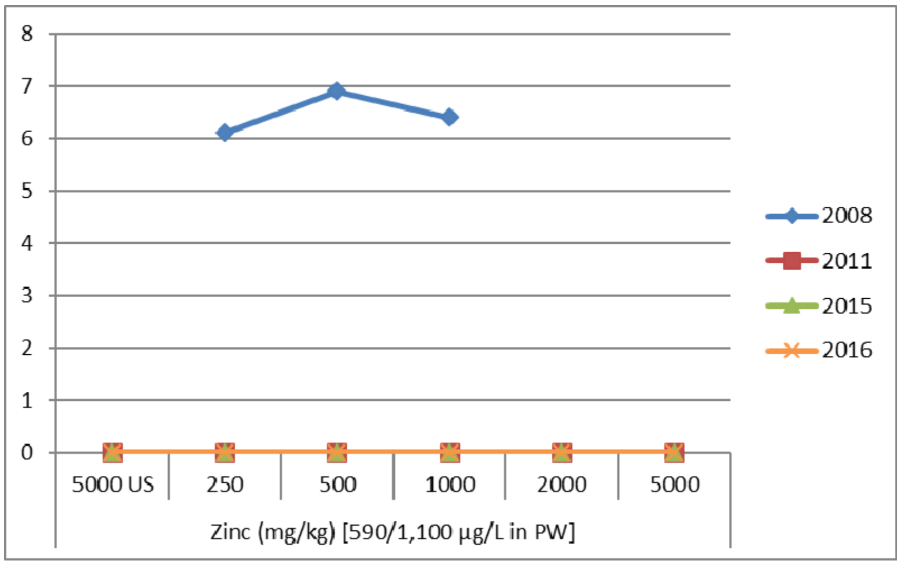


Figure 2.13 Comparisons of parameters tested for in sediment in 2008, 2011, 2015 and 2016

[values in brackets indicate the concentration of the parameter found in produced water in March / November 2016]

2.4 SEDIMENT TOXICITY

2.4.1 Background

A variety of laboratory-based sediment toxicity bioassays were originally used in the SOEP EEM program to evaluate potential lethal and sublethal effects on organisms representing several different trophic levels - amphipod (*Rhepoxynius abronius*) survival, echinoderm (*Lytechinus pictus*) fertilization and bacterial luminescence of *Vibrio fischeri* (Microtox). Within a relatively short period (two to three years of sampling), the echinoderm fertilization and Microtox tests were discontinued as the results did not correlate with trends in sediment chemistry results. However, the marine amphipod survival test has proved to be the most reliable indicator of sediment contamination in the SOEP EEM program.

In 2011 and in 2015, laboratory-based toxicity bioassays were conducted with Deep Panuke sediments samples in accordance with Environment Canada's "Biological Test Method: Reference Method for Determining Acute Lethality of Sediment to Marine or Estuarine Amphipods", EPS 1/RM/35, December 1998, using *Eohaustorius estuarius* as the test species. All sediments were found to be non-toxic.

Sediment samples at the drill sites were discontinued after the 2011 sediment chemistry and toxicity program confirmed that chemical parameters were below Canadian EQG threshold levels and that all collected sediments were non-toxic (see Section 2.3.1). Sediment sampling was focused downstream of the PFC to monitor potential impact from production discharges.

2.4.2 EEMP Goal

Predictions regarding sediment toxicity made in the 2006 Deep Panuke EA [EA predictions #1, 2, 3, 4, 5, 6, 7 & 8 in **Table 3.1** from the Offshore EEMP] are to be validated.

2.4.3 Objectives

A suitable indicator species to evaluate acute toxicity of sediments collected at the production site is to be used.

2.4.4 Sampling

Sampling of six sediment stations took place in March 2016 (**Table 2.26**), as well as laboratory-based sediment toxicity bioassays tests.

Table 2.26 - Sediment Sampling details - March 2016

<table>
<tr><td>Survey Date:</td><td>March 8, 2016</td></tr>
<tr><td>Platform:</td><td>M/V Atlantic Condor</td></tr>
<tr><td>Type of Sample:</td><td>Sediment Toxicity</td></tr>
<tr><td>Test Sample Locations – Field Stations:</td><td>
<table>
<tr><th>Station</th><th>Time UTC</th><th>Water Depth(m)</th><th>Easting</th><th>Northing</th></tr>
<tr><td>250m DS</td><td>01:18</td><td>47</td><td>0685731</td><td>4853510</td></tr>
<tr><td>500m DS</td><td>01:57</td><td>46</td><td>0685655</td><td>4853225</td></tr>
<tr><td>1000m DS</td><td>02:35</td><td>42</td><td>0685219</td><td>4852959</td></tr>
<tr><td>2000m DS</td><td>03:20</td><td>40</td><td>0684489</td><td>4852283</td></tr>
<tr><td colspan="5">WGS84 UTM Zone 20N</td></tr>
</table>
</td></tr>
<tr><td>Test Sample Locations – Reference Stations:</td><td>
<table>
<tr><th>Station:</th><th>Time UTC</th><th>Water Depth(m)</th><th>Easting</th><th>Northing</th></tr>
<tr><td>5000m US NE</td><td>06:05</td><td>38</td><td>0689460</td><td>4857167</td></tr>
<tr><td>5000m DS SW</td><td>05:28</td><td>37</td><td>0682333</td><td>4850162</td></tr>
<tr><td colspan="5">WGS84 UTM Zone 20N</td></tr>
</table>
</td></tr>
<tr><td>Number of Samples/Locations:</td><td>
Sediment samples were collected from the seafloor surface from 6 stations both upstream and downstream from the PFC. Sediment sampling locations are shown in Figure 2.12. Logs and photos are available in Appendix F.

Field stations:

250m downstream of PFC (2008 station #12);
500m downstream of PFC (2008 station #13);
1000m downstream of PFC (2008 station #14);
2000m downstream of PFC (not surveyed in 2008);

Reference stations:

5000 m upstream (NE) of the PFC area
5000 m downstream (SW, towards the Haddock Box) of the PFC area

</td></tr>
<tr><td>Equipment:</td><td>
A stainless steel van Veen grab was deployed as the ATLANTIC CONDOR held position via DP. The onboard winch and crane were used to deploy the van Veen over the starboard side of the vessel at each sample location to capture physical samples of the surficial sediments.

Following touchdown the van Veen grab was raised to the surface and recovered via crane onboard the vessel. Retrieved samples were visually inspected, digitally photographed, fully described and logged.
</td></tr>
<tr><td>Sample Preparation:</td><td>
<table>
<tr><th>Parameter</th><th>Preservative</th></tr>
<tr><td>Lab-based sediment bioassay</td><td>no preservative</td></tr>
</table>
</td></tr>
</table>

2.4.5 Analysis

Analysis was conducted by Harris Industries in accordance with Environment Canada's "Biological Test Method: Reference Method for Determining Acute Lethality of Sediment to Marine or Estuarine Amphipods", EPS 1/RM/35, December 1998.

Lab method "Tox 49" was used for the bioassay. Sediment samples were kept in the dark at 4 $\pm$ 2 °C until use. Pre-sieved, control sediment was received in sealed polyethylene bags with the amphipods and was kept in the dark at 4 $\pm$ 2 °C until use.

The organism of choice for these tests was *E. estuarius* purchased from NW Seacology, North Vancouver, BC. Collection took place on March 16, 2016. Organisms were received in Dartmouth, NS on March 24, 2016 and held at the lab in site sediment covered with aerating seawater at test temperature (15 $\pm$ 2 °C) in continuous light for 5 days prior to commencement of testing. Organism health during the acclimation period met the validity criteria.

Testing procedure details are outlined in Harris Industrial's full report provided in **Appendix G**.

2.4.5.1 Parameters Analyzed

Survival of amphipods in the replicate samples from each sampling station after a 10-day period were compared against survival of organisms exposed to control (clean) sediments.

2.4.6 Results

- All test validity criteria for the sediment test method were satisfied.
- No organisms exhibiting unusual appearance or undergoing unusual treatment were used in the test.
- Statistically, there was no significant difference between the survival in the control sediment and the survival in the test sediments except for the 500m DS sample. The mean survival rate for this sediment was 54%, i.e. 45% lower than the control sediment (**Table 2.27**). The sediment in this sample was much coarser than the other sediments tested. Many shell fragments were found at termination.

- All samples and control sediment as tested were found to be non-toxic to the amphipod *Eohaustorius estuaries*, except for the 500m DS sample.
- It should be noted that the chemistry testing did not show any spike in any of the tested parameters for the 500m DS sample (see Section 2.3).

Table 2.27 - Toxicity Results of *E. estuarius* Exposed to Sediments

Sample Location	Lab ID	Survival (±SD)%
BLIND	16-134-A	96% ± 0.84
250 DS	16-134-B	96% ± 0.84
500 DS	16-134-C	54% ± 1.48
1000 DS	16-134-D	95% ± 0.71
2000 DS	16-134-E	97% ± 0.56
5000 DS (SW)	16-134-F	96% ± 1.30
5000 US (NE)	16-134-G	98% ± 0.55
Control Sediment	16-134-Ctl	99% ± 0.45

2.4.7 Summary and Conclusions

- All samples and control sediment as tested were found to be non-toxic to the amphipod *Eohaustorius estuaries*, except for the 500 m DS sample.
- The mean survival rate for the 500 m DS sediment was 54%, i.e. 45% lower than the control sediment. This sediment was much coarser than the other sediments tested with many shell fragments found at termination. It should be noted that the chemistry testing did not show any spike in any of the tested parameters for this sample.

2.5 FISH HABITAT ALTERATION

2.5.1 Background

Fish habitat is predicted to be enhanced to a minor extent from a “reef” effect due to additional habitat created by the Deep Panuke subsea production structures (*i.e.* PFC legs, spool pieces, protective mattresses, SSIV valve, subsea wellheads and exposed sections of the subsea export pipeline to shore) and possibly a “refuge” effect associated with the creation of a safety (no fishing) zone around PFC facilities.

Underwater ROV video camera surveys at the SOEP and COPAN platform areas have shown that exposed subsea structures on Sable Bank were colonized predominantly by blue mussels, starfish, sea cucumbers, sea anemones and some fish species (most likely cunners), and occasionally by crustaceans (*e.g.* Jonah crabs). Sea stars, sea anemones and hydroids were also commonly observed on subsea platform/wellhead structures in association of mussel aggregations. It is well known that mussels are a preferred prey species of sea stars. Concentrations of small redfish have been observed at most span locations along the SOEP subsea pipeline to shore and snow crabs are frequently encountered on many exposed sections of the pipeline.

It is highly unlikely that the proposed subsea pipeline, where unburied, would constitute a significant concern as a physical barrier to the migration of most crustacean species (Martec Ltd. *et al*. 2004). Snow crab is the main commercial-sized crustacean species commonly observed near/on exposed sections of the SOEP subsea pipeline to shore. Cunners and pollock were the most commonly observed fish species at SOEP platforms. Hurley and Ellis (2004), in their review of EEM results of drilling, concluded that the spatial and temporal extent of discharged drill wastes appears to be related to mud type, differences in the number of wells/volume of discharges, oceanic and environmental conditions such as current speed and direction, water depth or sediment mobility at the drilling location.

Changes in the diversity and abundance of benthic organisms were detected within 1,000 m of drill sites, most commonly within the 50 m to 500 m range of drill sites. Benthic impacts in the Deep Panuke production field are anticipated to be negligible given the low biological diversity and highly mobile sand bottom characteristic of shallower areas of Sable Island Bank.

Based on the results of dispersion modeling carried out for the 2006 Deep Panuke EA, discharged mud/cuttings were predicted to have smothering effects over a relatively small area (cone with a base radius of 20 m from the drill site for subsea release of cuttings and with a base radius of between 30-160 m depending on the particle settling rate for surface release of cuttings). Such effects (if any) are likely to be relatively transient (less than one year) with the marine benthic community rapidly colonizing affected areas (*i.e.*, returning them to baseline conditions). One new well (disposal well E-70) was drilled as part of the 2010 drilling and completion program; the other Deep Panuke wells were drilled in 2000 (M-79A and H-08) and 2003 (F-70 and D-41) and were re-completed in 2010 (*i.e.* no cuttings piles involved) so no cuttings piles remain at these locations. The 2011 EEM work confirmed that there was no cutting pile at the E-70 location or any of the other well sites. The 2008 Baseline Benthic Study provides comparative data on benthic mega-faunal diversity as a basis for assessing potential impacts on fish habitat from the 2010 drilling and completion program and the Deep Panuke production subsea structures.

2.5.2 EEMP Goal

Predictions made in the 2006 Deep Panuke EA re fish habitat alteration from subsea production structures [EA predictions #1, 2, 3, 4, 5, 6, 7, 8, 9 & 10 in **Table 3.1**] are to be validated**.**

2.5.3 Objectives

The extent of fish habitat created by new hard substrate provided by subsea production structures installed for the Deep Panuke natural gas field are to be assessed. Species found and coverage of structures to previous years are to be compared.

2.5.4 Sampling

2.5.4.1 Subsea Structures

Annual remotely-operated vehicle (ROV) video-camera imagery of epibenthic community near subsea production structures (*i.e.* PFC legs, spool pieces, protective rocks and mattresses, subsea wellheads and exposed sections of the export pipeline to shore) were collected during planned activities such as routine inspection surveys, storm scour surveys, etc.

2.5.5 Analysis

2.5.5.1 Subsea Structures

Subsea inspection videos of the wellhead areas (September 2016) and of the PFC area (July 2016) were provided on an external hard drive and viewed with Visual Review video software. After initial viewing, inspection tasks, length and subsea structure were recorded for each video segment. A marine biologist analyzed the general visual inspection (GVI) with the aid of the commentary and inspection drawings to identify all mega-fauna associated with each structure. Detailed notes were kept on the colonization for parts of each structure, and abundance values (SACFOR scale; Joint Nature Conservation Committee, 2011) calculated for all epifauna encountered.

Fish abundance was calculated for the subsea structures. Each species encountered was identified and given approximate estimates for abundance. Data from 2016 were compared to the 2015 video data.

Analysis of Cuprotect-coated areas was not conducted for the 2016 data, since previous monitoring requirements from the *Pest Control Protection Act* have been met, and no need for this specific analysis was identified. In addition, all Cuprotect-coated structures were cleaned from marine growth in summer 2016.

2.5.5.2 GEP and Flowlines

Videos of the GEP subsea inspection survey (May 2016) were provided on external hard drive and viewed with Visual Review video software. A marine biologist analyzed the video with the aid of the commentary and inspection drawings to identify all fish and mega-fauna associated with each section. The GEP is exposed from KP 13.5 to KP 98.3. Video clips for eight representative segments of the exposed pipeline, each 250 to

800 m in length and spaced out at approximately 10-km intervals, were analyzed. Quantitative values were recorded for all fish and epifauna encountered and compared with data obtained from the 2014 and 2015 surveys. The eight representative segments in 2016 were approximately the same segments as surveyed in previous years (the main exception was the first segment which began at KP 17.209 as compared to KP 23.222 in past years surveyed). It should be noted that not all the GEP from KP 23 to KP 98 was inspected in 2015; therefore, not all sections in 2016 could be compared to the 2015 data. Small organisms, (i.e., shrimp) were given abundance values due to their sometimes large numbers and small size. Colonial species were also given abundance values (e.g., encrusting algae and encrusting sponges) as they are not easily quantifiable.

A qualitative review of the buried GEP and flowline areas was also performed.

2.5.6 Results

2.5.6.1 Subsea Structures

- Species present were analogous to those observed during the 2015 survey of the WHPS at each location. The WHPS structure legs were cleaned of marine growth in August 2016 thereby making comparisons of species abundance to the 2015 results less conclusive. Seasonal differences could also account for a difference in numbers for the WHPS survey as the 2016 survey was conducted in September while the 2015 survey was conducted in either March, April, or June, depending on the structure. Similar to that noted in 2015, the common species observed include the dominant blue mussel *Mytilus edulis*, the hydroid *Tubularia* spp., brittle stars (Ophiuroidea), the frilled anemone *Metridium senile*, and the sea star *Asterias vulgaris*.
- Zonation was observed on each WHPS in different locations in 2016, which was consistent with the results from the 2015 survey. The bottom zone was mainly colonized by mussels, with crabs (*Cancer* spp.) and sea stars (*Asterias vulgaris*) on the surrounding seafloor. The top zone was colonized mainly by mussels, frilled anemones and hydroids (*Tubularia* spp.) (**Table 2-28 to Table 2.32; Figure 2.14**). Dense mussels extended from 0.5 to 4.0 metres above the seafloor to the top of the structure. Total fouling of the WHPS was estimated to

be between 50% to 65% for all structures (**Figure 2.15**). Percentage of marine growth coverage was 100% in some areas of the WHPS, except for areas that were cleaned in August, a month before the survey, such as the base of legs and the subsea tree panel.

- Zonation of the PFC legs was consistent to past survey results. Marine growth was sparse (<10% coverage) near the base of the legs with some hydroids, sea cucumbers, frilled anemone, and sea stars. Cunner were also seen swimming around the base of all four legs. Five metres from the base of the legs, dense mussels were observed over the entire legs. *Asterias sp.* and *Henricia sp.* were more common around the midpoint of the legs. Metridium and hydroids were present on the legs, and increased with decreasing water depth (**Table 2.33; Figure 2.16**). A lion's mane jellyfish (*Cyanea capillata*) (**Figure 2.16**) was observed swimming near PFC Leg 2 and Leg 3.
- In addition to the WHPS video clips analyzed, there were several incidental species sightings by the ROV operator in 2016. An Atlantic torpedo ray (*Tetranarce nobiliana*) (**Figure 2.17**) was sighted at H-08 in September and again in October; this species was also observed during the subsea surveys in 2012, 2013 and 2014. Eight lobsters were observed in total as follows (**Figure 2.17**):
    - (1) under the edge of a D-41 umbilical mat at the PFC;
    - (1) walking over a concrete tunnel at D-41 wellsite;
    - (1) taking shelter under a flowline concrete mat at the E-70 wellsite;
    - (1) taking shelter under a concrete mat on the abandoned Panuke export oil line where it had been cut to allow the H-08 flowline to be laid; it appears that the lobster has been digging out the sand to keep his shelter available;
    - (2) at H-08, at the end of a concrete tunnel and under the flowline/mat closest to the tree;
    - (2) at the abandoned Cohasset PLEM; the lobsters take shelter under the corner of the PLEM; it is the only visible part of the PLEM and the lobsters appear to keep the sand dug out to maintain access. One lobster only had 1 claw and tried to chase the ROV away.

Table 2.28 - September 2016 Survey of E-70 WHPS compared to April 2015 Survey

<table>
<tr><th>Wellhead Site</th><th>Structure</th><th>Fauna</th><th>April 2015 Abundance</th><th>Sept 2016 Abundance</th><th>Sept 2016 Number</th><th>Description</th></tr>
<tr><td rowspan="14">E-70</td><td rowspan="7">WHPS</td><td>Metridium senile</td><td>A</td><td>C</td><td>-</td><td rowspan="7">Less marine growth on legs which were cleaned in August 2016. Most of the growth was on horizontal brackets.

Some mussel growth and hydroids on legs.

Metridium dense in patches.

Cunner swimming around all sections of structure.</td></tr>
<tr><td>Tubularia? spp.</td><td>S</td><td>C</td><td>-</td></tr>
<tr><td>Mytilus edulis</td><td>S</td><td>F</td><td>-</td></tr>
<tr><td>Cucumaria frondosa</td><td>C/O</td><td>O</td><td>-</td></tr>
<tr><td>Asterias vulgaris</td><td>A</td><td>-</td><td>-</td></tr>
<tr><td>Henricia sp.</td><td>A</td><td>-</td><td>-</td></tr>
<tr><td>Tautogolabrus adspersus</td><td>-</td><td>A</td><td>-</td></tr>
<tr><td rowspan="7">Subsea Tree</td><td>Metridium senile</td><td>C</td><td>C</td><td>-</td><td rowspan="7">Less marine growth on the tree panel, appears to have been Porifera (encrusting sponge) that was cleaned.

Metridium on the top of the tree.</td></tr>
<tr><td>Tubularia? spp.</td><td>S</td><td>C</td><td>-</td></tr>
<tr><td>Mytilus edulis</td><td>S</td><td>O</td><td>-</td></tr>
<tr><td>Asterias vulgaris</td><td>C</td><td>-</td><td>-</td></tr>
<tr><td>Henricia sp.</td><td>C</td><td>-</td><td>-</td></tr>
<tr><td>Tautogolabrus adspersus</td><td>-</td><td>C</td><td>-</td></tr>
<tr><td>Porifera (encrusting)</td><td>O</td><td>O</td><td>-</td></tr>
</table>

***** Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table 2.29 - September 2016 Survey of F-70 WHPS Compared to March 2015 Survey

Wellhead Site	Structure	Fauna	March 2015 Abundance	Sept 2016 Abundance	Sept 2016 Number	Description
F-70	WHPS	Porifera (encrusting)	-		-	Mussels more evident on lower brackets. Minimal marine growth on legs which were recently cleaned. 100% marine coverage in areas on horizontal cross where area was not recently cleaned. Cunner swimming around all sections of structure.
		Metridium senile	S/A	O	-	
		Tubularia? spp.	S	O	-	
		Hydroids	S	O	-	
		Mytilus edulis	S/A	A	-	
		Cancer sp.	-		-	
		Cucumaria frondosa	-		-	
		Asterias vulgaris	C		-	
		Henricia sp.	C		-	
		Hemitripterus sp.	-		-	
		Pollachius sp.	-	O	-	
		Tautogolabrus adspersus	-	C	-	
		Unidentified fish	-	-	-	
	Subsea Tree	Porifera (encrusting)	-	C	-	100% marine growth coverage on most areas (that were not previously cleaned).
		Metridium senile	-	C	-	
		Tubularia? spp.	-	A	-	
		Mytilus edulis	-	A	-	
		Cancer sp.	-	R	1	
		Cucumaria frondosa	-	R	-	
		Pollachius sp.	-	O	-	
		Tautogolabrus adspersus	-	C	-	

***** Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table 2.30 - September 2016 Survey of M-79A WHPS Compared to April 2015 Survey

Wellhead Site	Structure	Fauna	April 2015 Abundance	Sept 2016 Abundance	Sept 2016 Number	Description
M-79A	WHPS	*Metridium senile*	A	A	-	Minimal to no marine growth on middle section of legs due to recent cleaning. *Metridium* observed on horizontal cross sections or at the top of the leg (dense in some areas). Cunner swimming around all sections of structure.
		Tubularia? spp.	S	A	-	
		Campanulariidae? sp.	-	-	-	
		Ctenophora	-	-	-	
		Mytilus edulis	C	C	-	
		Cucumaria frondosa	F	O	-	
		Asterias vulgaris	C	O	-	
		Henricia sp.	C	-	-	
		Ophiuroidea	-	-	-	
		Myoxocephalus sp.	-	-	-	
		Pollachius sp.	-	O	<10	
		Tautogolabrus adspersus	-	O	-	
		Unidentified fish			-	
	Subsea Tree	*Tubularia? spp.*	S	C	-	Recent cleaning of subsea tree. In some sections, however, there was coverage in some areas around the base of *Mytilus edulis* and *Tubularia spp.*; *Asterias* on hard substrate marine growth.
		Mytilus edulis	A	C	-	
		Asterias vulgaris	C	O	-	
		Henricia sp.	O	-	-	
		Metridium senile	C	C	-	
		Pollachius sp.	-	R	-	
		Tautogolabrus adspersus	-	O	-	
	Concrete mats	*Cucumaria frondosa*	S	-	-	Difficult to see in video.
		Metridium senile	C	-	-	
		Cancer sp	-	-	-	

***** Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table 2.31 - September 2016 Survey of D-41 WHPS Compared to June 2015 Survey

Wellhead Site	Structure	Fauna	June 2015 Abundance	Sept 2016 Abundance	Sept 2016 Number	Description
D-41	WHPS	Porifera	-	R	-	Mussels abundant and underneath soft growth species such as *Metridium* (appear to be growing on top of mussels). Recent cleaning in September accounts for minimal marine growth (most coverage is on horizontal brackets). Cunner swimming around all sections of structure.
		Metridium senile	S	A	-	
		Tubularia? spp.	S	A	-	
		Mytilus edulis	C	A	-	
		Cancer sp.	-	R	-	
		Cucumaria frondosa	-	O	<10	
		Asterias vulgaris	C	-	-	
		Ophiuroidea	O	-	-	
		Myoxocephalus sp.	-	-	-	
		Tautogolabrus adspersus	-	C	>50	
	Subsea Tree and Closing Spools	*Metridium senile*	S/A	C	-	Minimal marine growth on panel for ROV manipulation due to recent cleaning in September.
		Tubularia? spp.	S/A	C	-	
		Hydoids	S/A	-	-	
		Mytilus edulis	A	R	-	
		Henricia sp.	C	-	-	
		Asterias vulagaris	C	R	-	
		Tautogolabrus adspersus	-	C	-	
		Cucumaria frondosa	-	O	5	
	Concrete Mats	*Cucumaria frondosa*	S	-	-	Difficult to see in video.
		Tautogolabrus adspersus	-	-	-	
		Metridium senile	C	-	-	
		Asterias vulagaris	C	-	-	
	Concrete Protection Tunnel	*Cucumaria frondosa*	A	-	-	Incidental sighting by the ROV operator of an American lobster
		Tautogolabrus adspersus	10	-	-	
		Metridium senile	C	-	-	
		Asterias vulgaris	C	-	-	
		Myoxocephalus sp.	-	-	-	
		Homarus americanus	-	R	1	
	Closing spool	Hydroid	A	-	-	Difficult to see in video.
		Metridium senile	A	-	-	

***** Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table 2.32 - September 2016 Survey of H-08 WHPS Compared to June 2015 Survey

Wellhead Site	Structure	Fauna	June 2015 Abundance	Sept 2016 Abundance	Sept 2016 Number	Description
H-08	WHPS	*Metridium senile*	C	C	-	Sea cucumbers around base of legs Soft growth on top of hard growth (mussels). Some sections have been recently cleaned so minimal marine growth. Cunner swimming around all sections of structure.
		Tubularia? spp.	A	S/A	-	
		Mytilus edulis	S	S/A	-	
		Cucumaria frondosa	O	O	-	
		Asterias vulgaris	C	O	-	
		Myoxocephalus sp.	O	-	-	
		Pollachius sp.	-	R	1	
		Tautogolabrus adspersus	F	O	-	
		Urophysis sp.	-	-	-	
		Cancer so.	O	R	1	
		Ophiuroidea	O	O	-	
		Henricia sp.	C	-	-	
		Gadus morhua	-	R	-	
	Subsea tree	*Mytilus edulis*	S	A	-	Dense mussel in some areas, other areas have been recently cleaned with minimal marine growth.
		Tubularia? spp.	S	C	-	
		Henricia sp.	C	-	-	
		Asterias vulgaris	C	O	-	
		Metridium senile	C	C	-	
		Tautogolabrus adspersus	-	O	-	
		Asterias vulgaris	-	O	-	
		Ophiuroidea	-	R	1	
		Metridium senile	-	C	-	
		Pollachius sp.	-	R	-	
	Concrete Mats	*Myoxocephalus sp.*	C	-	-	
		Cucumaria frondosa	S	F	-	
		Asterias sp.	C	C	-	
		Euspira heros	O	-	-	
		Mytilus edulis	-	O	-	
		Cancer sp.	O	-	-	
		Unknown fish	O	-	-	
	Concrete Protection Tunnel	*Cucumaria frondosa*	S	O	-	Incidental sighting by the ROV operator of an unidentified flatfish observed on the flowline concrete tunnel.
		Myoxocephalus sp.	F	-	-	
		Asterias vulgaris	C	-	-	
		Unknown flatfish (Pleuronectidae)	-	R	1	
	Closing spools	*Mytilus edulis*	A	C	-	
		Hydroids	C	C	-	
		Asterias vulgaris	C	O	-	
		Henricia sp.	C	-	-	
		Tautogolabrus adspersus	-	F	>50	

***** Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table 2.33 - Summer 2016 Survey of PFC legs Compared to Summer 2015 Survey

Wellhead site	Structure	Fauna	Summer 2015 Abundance	Summer 2016 Abundance	Summer 2016 Number	Description
PFC	PFC Leg 1 (July)	*Metridium senile*	C	A	-	Few marine organisms at the base of the leg, around 10% coverage with some *Asterias*, and *Metridium*. Dense mussels start around 5 m up, increasing in number as the legs get closer to the surface. Sea stars are present where mussels start on the leg, but do not continue towards the surface. Hydroids become more prominent 20 m and up. Some *Metridium* is present closer to the surface (25 m and up). Cunner were present at the base of all legs of the PFC.
		Tubularia? spp.	A		-	
		Mytilus edulis	S	S	-	
		Asterias vulgaris	A	C	-	
		Ophiuroidea	O	O	-	
		Cancer sp.	2	-	-	
		Tautogolabrus adspersus	A	-	-	
		Pollachius sp.	-	C	-	
		Unidentified fish	-	-	-	
		Henricia sp.	C	-	-	
	PFC Leg 2 (July)	*Metridium senile*	C	A	-	
		Tautogolabrus adspersus	-	O	-	
		Tubularia? spp.	A	C	-	
		Mytilus edulis	S	S	-	
		Ophiuroidea	O	O	-	
		Cucumaria frondosa	O	-	-	
		Asterias vulgaris	C	O	-	
		Henricia sp.	O		-	
		Ctenophora	-	R	-	
		Cyanea capillata	-	R	1	
	PFC Leg 3 (July)	*Metridium senile*	C	A	-	
		Tautogolabrus adspersus	-	-	-	
		Ophiuroidea	O	O	-	
		Tubularia? spp.	C	-	-	
		Henricia sp.	O	-	-	
		Mytilus edulis	S	S	-	
		Solaster endeca	R	-	-	
		Asterias vulgaris	-	A	-	
		Pollachius sp.	-	O	-	
		Cyanea capillata	-	R	2	
	PFC Leg 4 (July)	*Metridium senile*	F	A	-	
		Tubularia? spp.	F		-	
		Mytilus edulis	S	S	-	
		Ophiuroidea	O	C	-	
		Asterias vulgaris	C	C	-	
		Tautogolabrus adspersus	-	-	-	
		Pollachius sp.	-	O	-	
		Cucumaria frondosa	-	R	-	

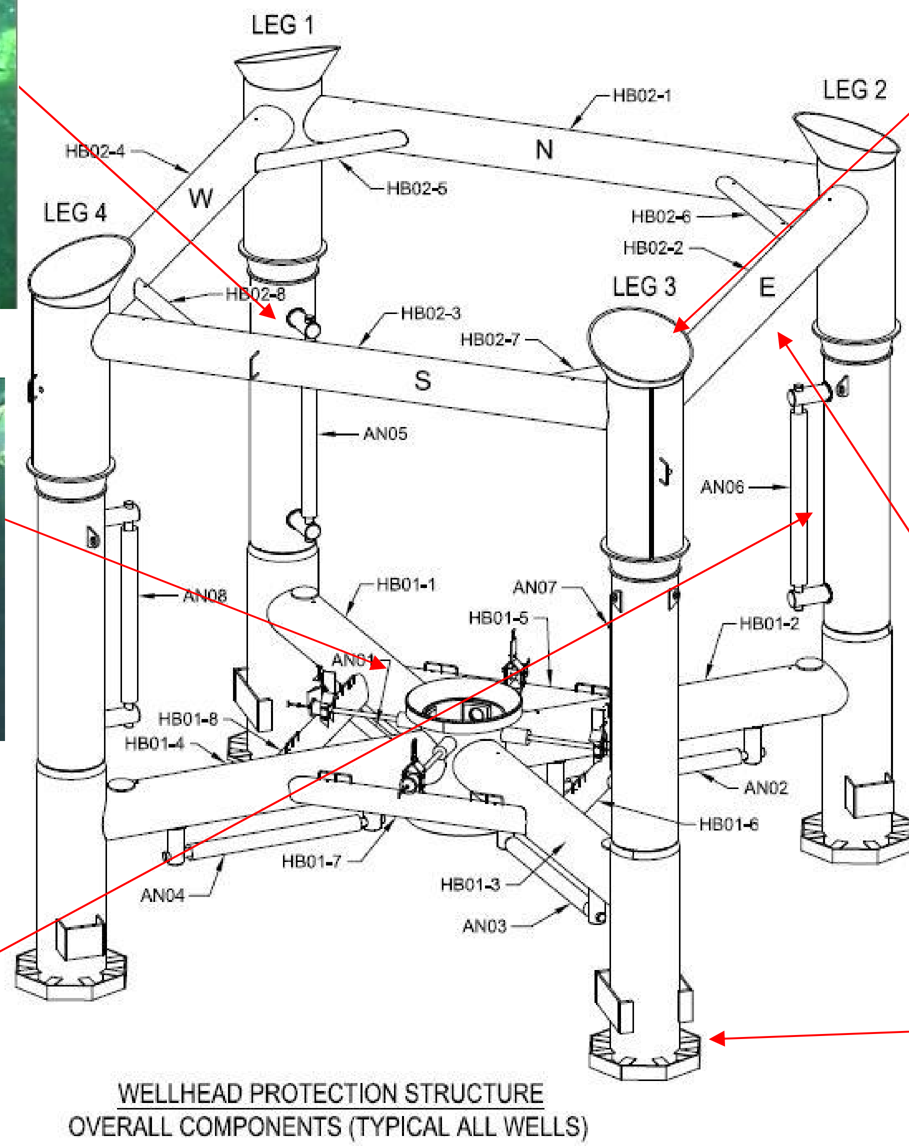
Wellhead site	Structure	Fauna	Summer 2015 Abundance	Summer 2016 Abundance	Summer 2016 Number	Description
	Protection Tunnel (M79A)	*Cucumaria frondosa*	S	-	-	
		Metridium senile	O	-	-	
		Asterias vulgaris	O	-	-	
		Hemitripterus americanus	-	-	-	
		Henricia sp.	R	-	-	

***** Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Dense mussels and hydroids at MG-02.

Hydroids and frilled anemone on the subsea tree. Area was cleaned August 2016. Pollock also present.

Mussels, sea stars and cunner at the base of the Leg (not specified).



Minimal marine growth at the top of Leg 3 where area was cleaned in August 2016.

Hydroids and frilled anemone on the MG-18 horizontal bracket. Area was cleaned in August 2016.

Dense hydroids, frilled anemone, sea star and cunner at MG-05.

Figure 2.14 Wellhead Protection Structure and Associated Fauna at H-08

2011

Moderate marine growth on East horizontal brackets at WHPS M-79A in the 2011 survey.

2012

Significant growth of marine fauna on East horizontal bracket at WHPS M-79A in 2012.

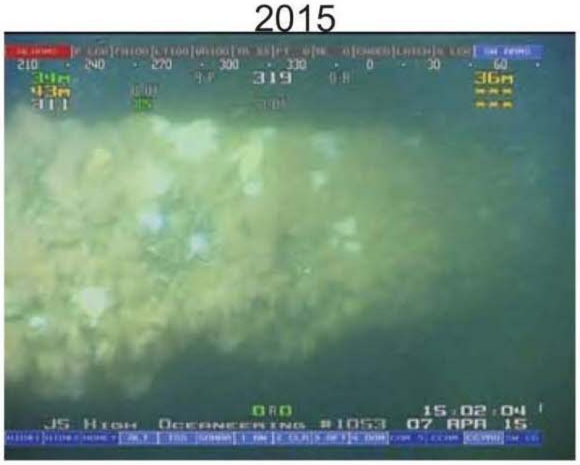
2013

Significant growth, and 100% coverage of marine fauna on the East horizontal bracket at WHPS M-79A in 2013.

2014

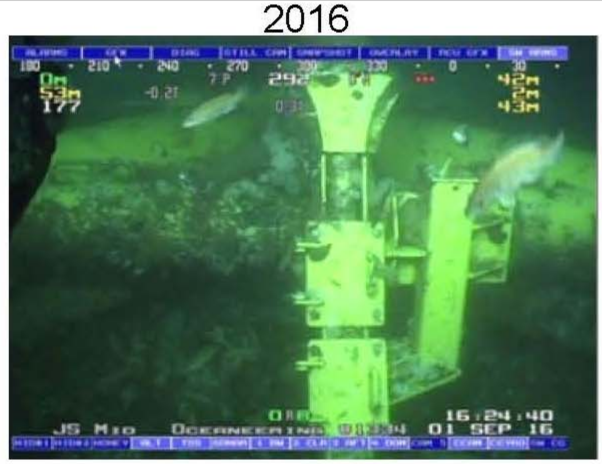
100% coverage of marine fauna on the East horizontal bracket at WHPS M-79A in 2014. Appears to have changed little since the 2013 survey.

2015



100% coverage of marine fauna. Hydroids appear to have colonized on top of blue mussel since 2014.

2016



Minimal marine growth at MG-14 between Legs 2 and 3 which were cleaned in August 2016. Cunner are present.

Figure 2.15 Comparison of benthic fauna between 2011 to 2016 surveys at WHPS M-79A

2013 Survey **2014 Survey** **2015 Survey** **2016 Survey**

D

Dense mussel patches near the top of the leg, with some possible *Metridium senile*.

Increased mussel coverage (almost 100%) near the top of the leg with some possible *Metridium senile*.

Similar mussel coverage to 2014 near the top of the leg with some possible *Metridium senile*.

Mussel coverage near the top of the leg with sea stars.

Some mussel and sea star coverage mid leg, similar to the base of the leg.

Dense mussel colonization mid leg, with dense patches of sea stars.

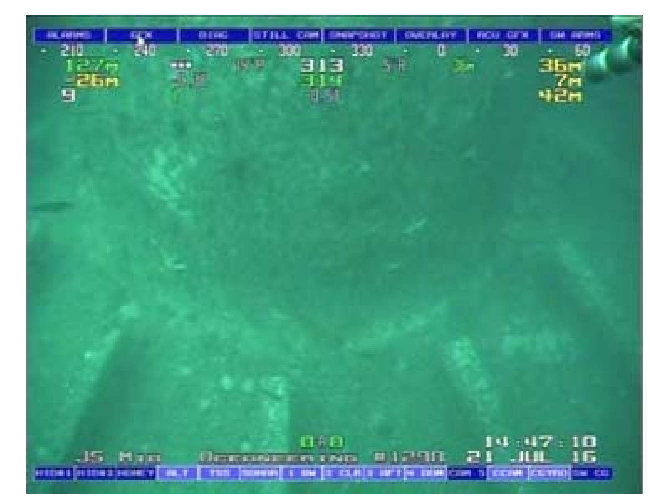
Dense mussel colonization mid leg, with dense patches of sea stars.

Dense mussel colonization mid leg, with occasional sea stars. A *Cyanea capillata* is swimming away from the leg (right).

Base of PFC leg 1 with some mussel and sea star coverage.

Less marine growth than 2013, possibly due to cleaning.

Similar marine growth to 2014, with cunner swimming around the base.



Similar marine growth to 2015, including sea stars and cunner swimming around the base.

Figure 2.16 Comparison of PFC Legs from 2013, 2014, 2015 and 2016 Surveys

Lobster (*Homarus americanus*) backing under flowline concrete mat at E-70

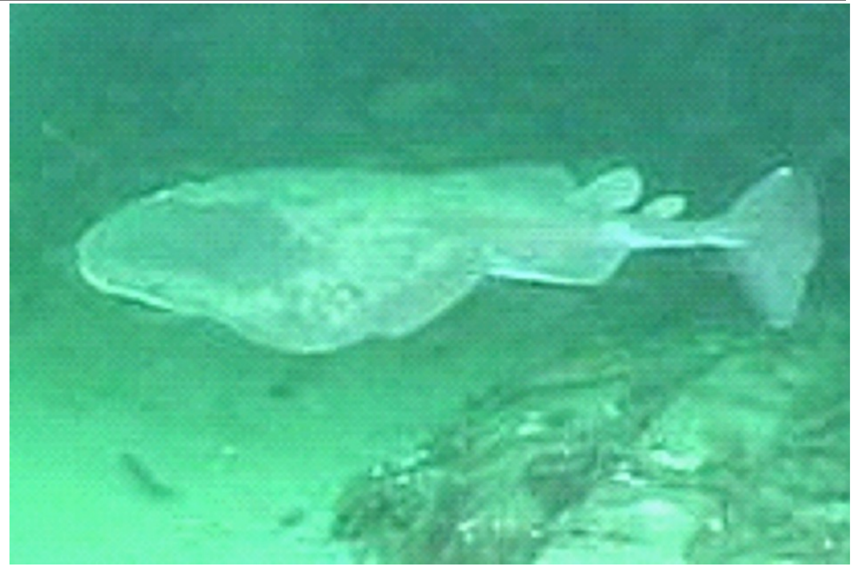
Lobster (*Homarus americanus*) under the edge of D-41 umbilical mat at PFC

Lobster (*Homarus americanus*) walking over concrete tunnel at D-41

Lobster (*Homarus americanus*) hiding under the flowline/mat closest to tree at H-08

Figure 2.17 Incidental Faunal Observations at Subsea Structures in 2016

Lobster (*Homarus americanus*) taking shelter under concrete mat on abandoned Panuke export oil line where it had been cut to allow H-08 flowline to be laid; it appears the lobster has been digging out the sand to keep his shelter available



Atlantic torpedo ray (*Tetranarce nobiliana*) observed at H-08 on 2016-09-24 (40m water depth)

Lobster (*Homarus americanus*) under corner of abandoned Cohasset PLEM; it is the only visible part of the PLEM and lobsters appear to keep sand dug out to maintain access. One lobster had only 1 claw and tried to chase ROV away.

Atlantic torpedo ray (*Tetranarce nobiliana*) (likely same individual) observed at H-08 on 2016-10-06

Figure 2.17 Incidental Faunal Observations at Subsea Structures in 2016

2.5.6.2 GEP and Flowlines

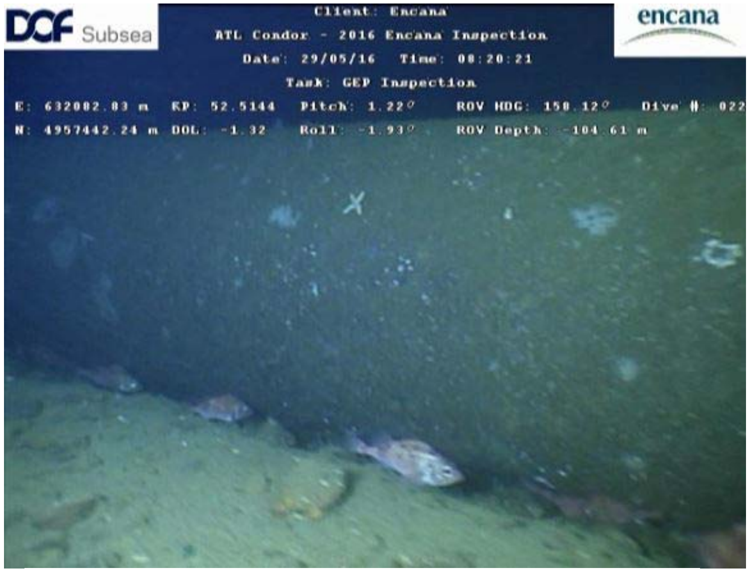
- In all videos analyzed, marine life continues to be abundant and diverse around the GEP in relation to the surrounding ocean floor (see **Table A-1 from Appendix H** for raw 2016 data; and **Figures 2.18 and 2.19**).
- The pipeline is exposed from KP 13.5 to 98.3 (85 km). Eight representative video clips were analyzed in 2016, starting at approximately KP 17. The similar eight segments were also reviewed in 2014 and therefore abundance comparisons in this report were made between those two sampling years. Of the eight clips captured in 2016, only four similar segments of video were surveyed/analyzed in 2015. Where relevant, 2015 results are discussed for particular segments.
- Comparison of faunal diversity by major group among the 2014, 2015 and 2016 surveys is presented in **Table A-2 from Appendix H**. Some species were categorized based on the SACFOR scale and therefore could not be quantified. Generally, for each of the categorized groups (Pisces, Crustacea, Echinodermata, Anthozoa, Mollusca, and Porifera) the highest observations were noted in 2014 for each of the KP segments. The exception was for Pisces, which generally had similar or greater numbers observed in 2016 starting at KP 42.787. The species below are discussed in greater detail based on their commercial value, higher number of observations, or because they are listed under the *Species at Risk Act* (SARA).
- Approximately 5500 redfish (*Sebastes sp.*) were observed in the eight videos analyzed in 2016. In 2014, there were a total of 4655 redfish observed for the same segments of the GEP. This species was commonly found wherever the pipeline created a shallow excavation in the seafloor (**Figure 2.18**). It should also be noted that redfish numbers are likely higher than reported, as they are primarily found at the base of the pipe where a shadow is often created. Depending on how the lights are adjusted on the ROV, the base of the pipe is not always visible on video, making fish and other species difficult to see and identify.
- Four Atlantic cod (*Gadus morhua*) were observed in the eight videos analyzed in 2016. This was lower than the 51 individuals observed in 2014 over the same segments of the GEP. In comparison, of the four segments from 2015 that were

analyzed for the same segments as in 2016, only six Atlantic cod were observed. Similar to redfish, cod are primarily found at the base of the pipe, and the same lighting issues may be a factor in the number observed.

- It is also notable that it is often difficult to distinguish gadoids (the family Gadidae which includes cod, haddock and pollock) on video. There were 10 gadoids (in addition to Atlantic cod) observed in the eight videos analyzed in 2016. In 2014, there were approximately 50 pollock observed in addition to Atlantic cod. In comparison, five haddock were observed in 2015 in the four representative segments and none were observed in 2014.
- Seven flatfish (Pleuronectidae) were observed in the eight video clips in 2016. There were 10 flatfish observed along the same segments in 2014. No flatfish were observed in 2015 video clips. As flatfish typically cover themselves with sand to blend in with the surrounding substrate, video quality could be a factor in reported numbers from year to year (**Figure 2.18**).
- The number of observed Atlantic wolffish (*Anarhichas lupus*) increased from 2014 to 2016. A total of 17 Atlantic wolffish were noted in the eight video clips in 2016, compared to seven individuals observed in 2014 along the same eight segments of the GEP. In 2015 there were a total of eight Atlantic wolfish observed in only four segments analyzed. The Atlantic wolffish is notable, as it is considered a species of special concern under SARA. In many of the Atlantic wolffish video sightings they appeared to have a burrow at the base of the pipe, or to be swimming along the protected area at the base of the pipe (**Figure 2.18**).
- Approximately 848 commonly observed sea stars (*Asterias* sp. and *Henricia* sp.) were present in the eight video clips analyzed in 2016 (**Figure 2.18**). This number was much lower than the 8877 observed in 2014. The small size of many of the sea stars inhabiting the pipeline makes it difficult to obtain exact numbers. Video quality has varied between years, making comparison between the annual surveys difficult to interpret.
- Sea anemones, including tube anemones (*Cerianthus* sp.) (**Figure 2.18**) were observed in all eight videos analyzed in 2016, totalling approximately 211 individuals sighted. The number of sightings appeared to increase the further along the GEP, with the highest number recorded at the mid-point along the KP segments analyzed. In 2014, 1102 sea anemones were reported in the same video clips for the same eight KP segments.

- Snow crab (*Chionoecetes opilio*) (**Figure 2.19**) were observed in three of the eight videos analyzed in 2016, totalling 42 individuals sighted. In 2014, snow crab was observed in all eight segments analyzed, totalling 261 individuals. In comparison, in 2015 there were 31 snow crabs observed in the four representative GEP segments.
- In 2016, over 177 Jonah crabs (*Cancer borealis*) were observed in the eight videos analyzed (**Figure 2.18**). In 2014 of the same eight video clips analyzed, 340 Jonah crabs were observed. No hermit crabs (*Pagurus sp*.) were observed in 2016 or 2015 videos analyzed. This may be due to video quality, as many hermit crabs are small in size, compared to other macrofauna present. In 2014 there was only one hermit crab observed. Ten northern stone crabs (*Lithodes maja*) (**Figure 2.19**) were observed in 2016, which was the same number of individuals observed in 2014 for the same eight segments.
- One American lobster (*Homarus americanus*) (**Figure 2.19**) was observed on rocky substrate at KP 17.4 in 2016. There were no observations of lobster along the same segments of the GEP in 2014 or 2015.
- Dead crabs or crab exoskeletons from molting were observed near the GEP. In 2016, only three dead crabs or exoskeletons were observed in total for all eight video clips observed. In comparison, 39 dead or exoskeletons were observed in 2014.
- Buried sections of the GEP and flowlines were covered by sand, rock, or a mixture of the two. The sand buried sections of flowlines and GEP show no difference to the adjacent sand seafloor, with very little marine life/growth and periodic starfish and shells observed. The flowline rock berms are predominately covered with sea cucumbers with some starfish. The rock filter units installed in 2015 over some areas of the flowlines and GEP are covered entirely with sea cucumbers, with some starfish (see **Figure 2.20**).
- In addition to the video clips analyzed, there were several incidental sightings by the ROV operator in 2016. A lion’s mane jellyfish was observed swimming at the D-41 flowline at KP 2.3 (**Figure 2.21**) at a water depth of approximately 36 m.
- 82 debris items were located at the GEP during the 2016 subsea survey. The most common item found were soft debris (e.g. cloth, plastic tarp) (28), rope (18), netting (8) and rubber fishing gloves (7) (**Figure 2.22**). The most significant debris item observed was a large section of netting approximately 2m in length at

KP28.7 (see **Figure 2.22**). It is believed, based on its position, that the netting drifted to the pipeline location versus became entangled in the pipeline and cut free from the fishing vessel.



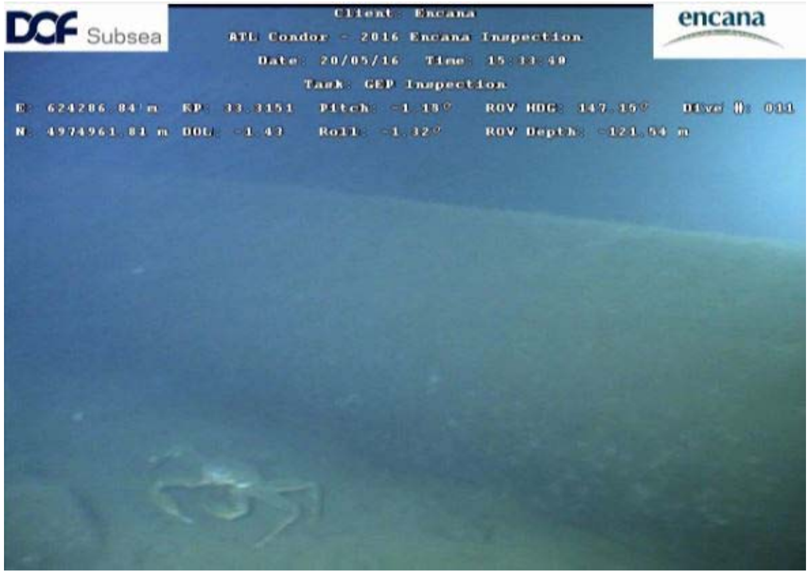
Redfish (*Sebastes sp.*) and sea star (*Asterias* sp.) at KP 52.14.

Flatfish (Pleuronectidae) in soft sediment at KP 93.05.

Wolffish (*Anarhichas lupus*) at KP 64.51.

Tube anemone (*Cerianthus* sp.) and sea stars (*Asterias* sp.) at KP 83.38.

Figure 2.18 Some Marine Fauna Observed along the GEP in 2016



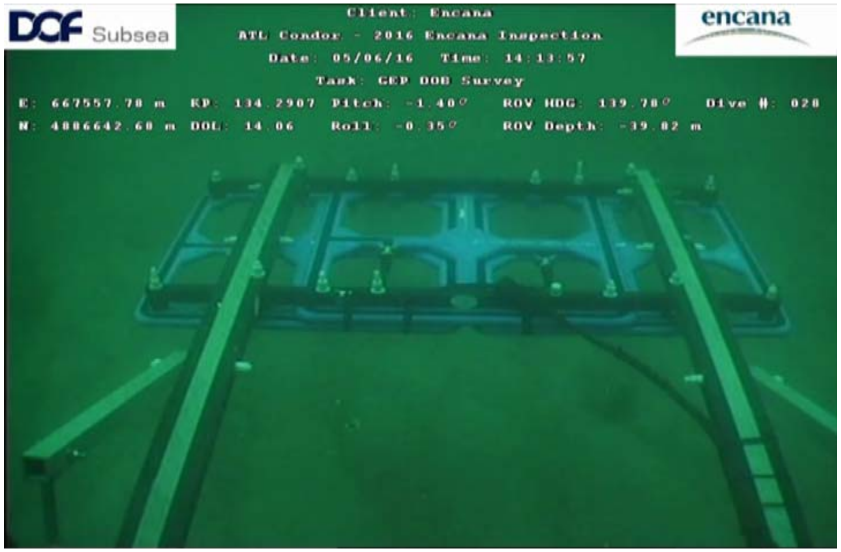
Snow crab (*Chionoecetes opilio*) at KP 33.31.

Jonah crabs (*Cancer borealis*) at KP 93.03.

Northern stone crab (*Lithodes maja*) at KP 73.58.

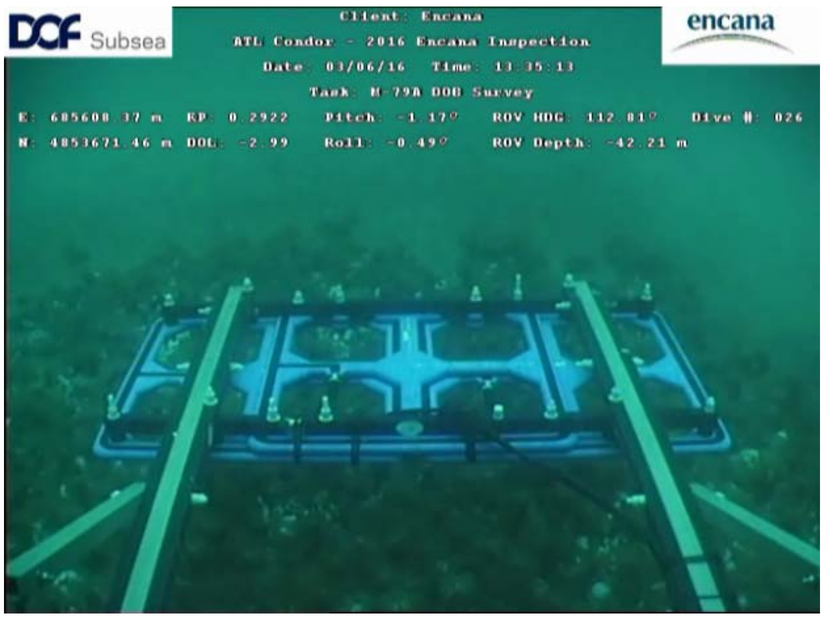
American lobster (*Homarus americanus*) at KP 17.40.

Figure 2.19 Crustaceans Observed along the GEP in 2016



Buried GEP section [KP 134.3] (very little marine life, periodic starfish and shells observed)

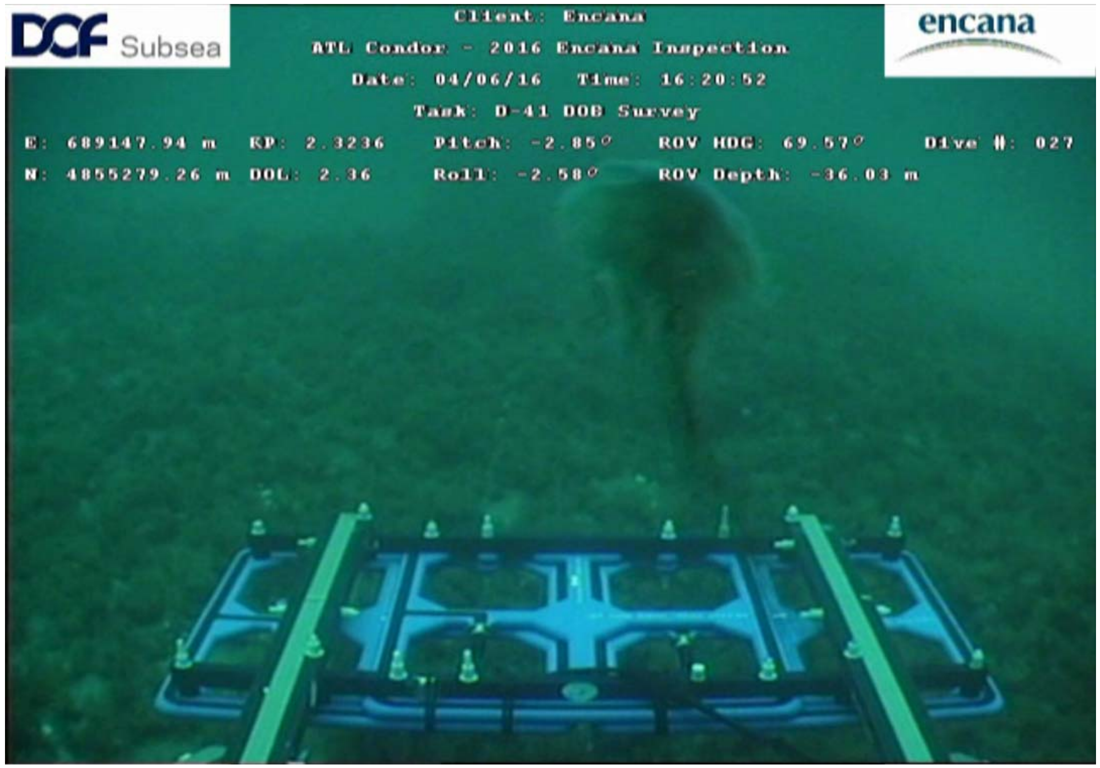
Flowline/GEP rock filter units: as installed in June/July 2015



M-79A flowline rock berm (predominant sea cucumbers with some starfish)

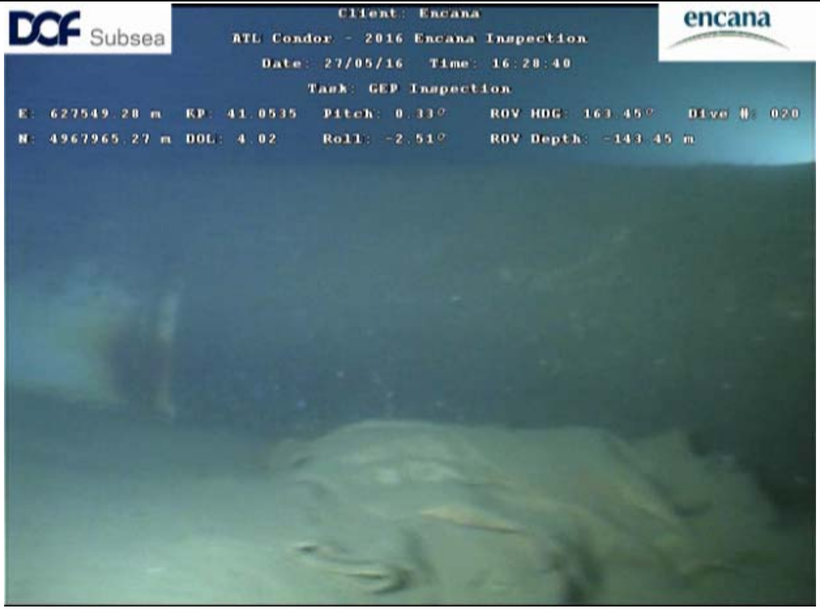
Flowline/GEP rock filter units: as surveyed in May 2016 (fully covered with sea cucumbers, some starfish)

Figure 2.20 Representative Photos of Buried GEP / Flowline Sections during the 2016 Survey



Lion's mane jellyfish (Cyanea capillata) on the D41 flowline at KP 2.3

Figure 2.21 Incidental Faunal Observations along the Flowlines in 2016



Soft debris at KP 41.047

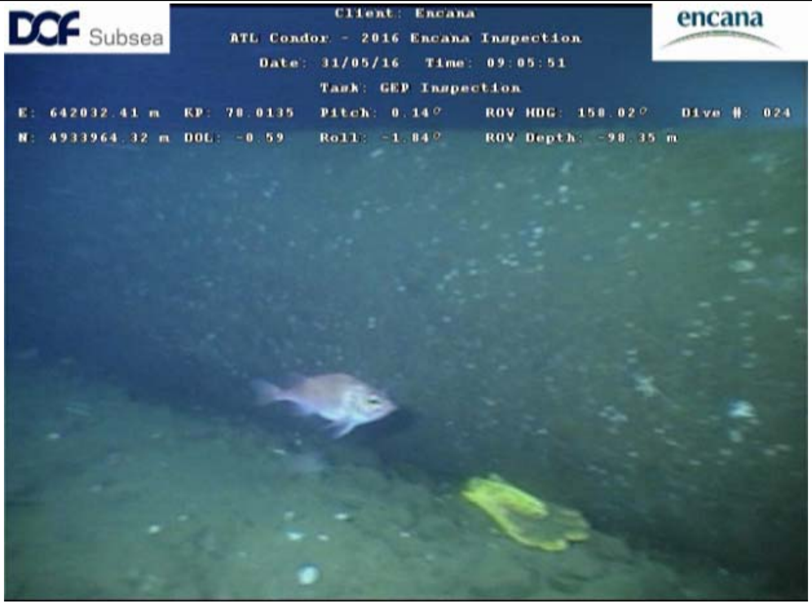
Rope at KP 95.455

Soft debris at KP 83.515

Netting at KP 28.717

Figure 2.22 Debris at the GEP during the 2016 Survey

Netting at KP 54.355



Rubber glove at KP 78.014

Hard debris at PK 86.062

Plastic container at KP 97.333

Figure 2.22 Debris at the GEP during the 2016 Survey

2.5.7 Summary and Conclusions

2.5.7.1 Subsea Structures

- Epifauna colonization of WHPS at all well site locations observed varied in numbers for some species from the 2015 survey. Several sections of the WHPS were cleaned one month prior to the 2016 survey, which accounted for the lower abundance observations. Species composition was relatively homogenous across all wellhead sites.
- Seasonal differences in the timing or surveys could account for differences in fish species at the WHPS. For example, at WHPS F-70 pollock were present in the 2016 fall video survey compared to the spring 2015 video survey, where no pollock were present.
- Zonation of the PFC legs was similar to the 2015 survey results. Marine growth was sparse (<10% coverage) near the base of the legs with some hydroids, sea cucumbers, frilled anemone and sea stars. Cunner were also seen swimming around the base of all four legs. Five metres from the base of the legs, dense mussels were observed over the entire legs. *Asterias* sp. and *Henricia* sp. were more common around the midpoint of the legs. Metridium and hydroids were present on the legs, and increased with decreasing water depth.
- Wellheads and protective structures appear to continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures, as predicted in the 2006 Environmental Assessment (EA). The structures are attracting fish from the surrounding areas and providing shelter in an otherwise relatively featureless seafloor.
- Video quality and the distance between the ROV to PFC legs made identification difficult at times. The ROV operator switched from colour to the black and white camera in some sections of the survey to improve the clarity.
- In addition to the WHPS video clips analyzed, incidental species sightings by the ROV operator in 2016 included eight lobsters and an Atlantic torpedo ray.

2.5.7.2 GEP and Flowlines

- The GEP continues to act as an artificial reef to provide shelter and protection for many species of fish (*i.e.,* redfish and Atlantic wolffish) and invertebrates.

- Commercial fish species recorded from the video analysis included Atlantic cod, pollock, haddock, redfish and Atlantic hagfish (*Myxine glutinosa*). Abundance of these commercial species increased starting around KP 52.
- Commercial crustaceans observed in the analyzed video were snow crabs and Jonah crabs. Jonah crabs were the most abundant crustacean in the eight videos analyzed, which is consistent with the same video sections in 2014.
- One American lobster was observed in 2016 (in the eight video clips analyzed).
- Other commercial invertebrates observed include the orange-footed sea cucumber, which were often observed on top of the GEP.
- Compared to 2014 and 2015, new species were observed in 2016 near the GEP in the video clips analyzed, included American lobster and comb jellies (Ctenophore).
- SARA-listed Atlantic wolffish were observed near the GEP, beginning at KP 63 and appear to be using the pipeline as a refuge burrow.
- As in past survey years, crustaceans were observed on video sitting on top of the pipe and climbing on it. Lobsters have not been observed climbing the pipeline or sitting on top of it in this project; however, as the GEP is not a physical barrier for other crustaceans, it is unlikely that it is a physical barrier for lobsters. Studies have also shown that lobsters are capable of climbing over a pipeline (Martec 2004).
- As in 2014 and 2015, dead crustaceans or possible exoskeletons from molting were found along the GEP in 2016.
- Garbage and debris continue to collect at the GEP, due to it being a physical barrier. The most common items were soft debris, rope and netting.
- Habitat/substrate types along buried sections of the GEP and flowlines were consistent with previous years. Sand buried sections showed no difference to the adjacent sand seafloor with very little marine life/growth and periodic starfish and shells. Rock berms and rock filter units installed were predominately covered with sea cucumbers with some starfish.

2.6 FISH HEALTH ASSESSMENT

2.6.1 Background

The effects of environmental contamination can be viewed at different levels of biological organization, extending from the molecular or biochemical level to effects on organ physiology and histology at the individual animal level and ultimately to the population or community level. Over the past few years, there has been increasing emphasis on the use of individual-level indicators of chemical stress to obtain an appreciation of the degree, extent and severity of potential health effects in populations. These indicators are commonly referred to as bio-indicators or health effect indicators. Use of such indicators at the individual level has the potential to identify adverse conditions in advance of responses at the population level and as such can provide an early warning of potential problems and adverse health effects. Thus, they are of special value for use in EEM programs around development sites in the open ocean where population level effects or for instance any site-induced changes in various condition indices could be very difficult to detect in the absence of major impacts since exposure levels are typically well below those that would pose a health risk (Lee and Neff, 2009, in press).

It is important to have background knowledge on selected bio-indicators for selected adult fish and shellfish species in order to provide perspective on any future changes which may arise over the life of the Deep Panuke project. In this regard it is also important to note that bio-indicators can be a powerful tool for "disproving" as well as "proving" whether or to what extent effects may be occurring. The typical bio-indicators used in EEM programs, including the SOEP EEM program, have been shellfish (taint and body burden) and fish (body burden and health parameters). The shellfish monitoring program was initiated at Deep Panuke in 2015 and the fish program started in 2016.

The low concentrations of hydrocarbons in produced water stipulated by relevant offshore guidelines, the rapid dilution of hydrocarbon fractions and the physiological ability of marine organisms to depurate hydrocarbons mitigate the potential for significant effects of hydrocarbon fractions in produced water on marine benthos. In the case of Deep Panuke, treating the produced water at several levels (including polishing) prior to discharge and the rapid dilution of the plume implies that marine organisms will be exposed to very low concentrations of contaminants that are unlikely to elicit measurable effects. The trace amounts of toxic contaminants likely to be in the discharged produced water, the rapid dilution of produced water, and the transient exposure of organisms mitigates against measurable, long-lasting effects. Of the organic constituents, PAH and alkylated phenols (APs) often contribute significantly to the environmental risk, exhibiting both toxic and sub-lethal effects. Experimental data pertinent to the toxicity of H_2S on invertebrates suggest that the concentrations of H_2S that benthic organisms will likely be exposed to are less than the concentrations required to cause chronic or acute effects. However, the potential for taint exists particularly in filter-feeders, such as mussels which can concentrate contaminants in body tissues. Potential H_2S contamination is not an issue at SOEP facilities since the gas/condensate is considered sweet.

Summary of Lessons Learned from SOEP EEM Program

- Hydrocarbons found in blue mussels collected from Thebaud jacket legs were shown to be non-petrogenic (i.e., derived from phytoplankton);

- Aliphatic hydrocarbons in mussels collected from platform legs (and in suspended cages as close as 250 m from the platform) have consistently been shown to have a biogenic origin (i.e., derived from natural sources).

2.6.2 EEMP Goal

Predictions made in the 2006 Deep Panuke EA re fish health [EA predictions #1, 3, 4, 5, 6, and 7] in **Table 3.1** are to be validated**.**

2.6.3 Objectives

The tissues of shellfish species collected on PFC legs (i.e., blue mussels) are to be examined for possible body burden due to petroleum contamination. Fish health is to be assessed using suitable bio-indicators for selected fish species collected near the Deep Panuke PFC.

2.6.4 Sampling

2.6.4.1 Mussel Sampling

Mussels are collected annually using an ROV attachment to scrape the SW leg of the PFC (which is downstream from the SE leg discharge caisson for the various waste streams) during planned water quality field surveys. Mussels were sampled for the first time in 2015 during the field survey in May. An ROV scraping attachment and collection bag and basket were used to collect mussels attached to the SW leg of the PFC.

Commercial mussels were purchased at Sobeys on March 14, 2016 to be compared to those collected at the PFC.

See **Figure 2.23** for mussel sampling location, and **Appendix I** for mussel sampling logs and photos.

2.6.4.2 Fish Sampling

The goal was to have professional fishing specialists hired by McGregor capture fish by angling using rod and reel fishing methods at two stations; i.e. in the immediate vicinity of the PFC and from a far-field reference site (5,000 m NE from the PFC). A scientific fishing license was obtained from DFO for this activity. Up to 50 fish were to be collected at each station. However, despite sustained efforts from the fishing crew over several days, only two fish were captured during the sampling program, one cod and one sculpin. See **Figure 2.24** for fish sampling location, and **Appendix J** for fish sampling logs and photos.

2.6.5 Analysis

2.6.5.1 Mussel Testing

Mussel tissues were tested for PAHs and alkylphenols by Maxxam Analytics (AP subcontracted to AXYS Analytical Services Ltd), as listed in the **Table 2.34** below. Although testing of sulphide in mussel tissues was initially mentioned in the EEMP, in October 2014, the CNSOPB agreed to forgo that test because of the inability to find a lab that could conduct the testing; the fact that concentration of H_2S in mussel tissues is expected to be nil/very low due the very low H_2S concentration in discharged produced water; and the low likelihood of uptake of H_2S derived from PW by mussels because of rapid oxidization to elemental sulphur.

Table 2.34 - Parameters Analysed in Mussel Tissue

Parameter	Units	RDL	Analysis Method
Polyaromatic Hydrocarbons			
1-Methylnaphthalene	mg/kg	0.050	GC-MS
2-Methylnaphthalene	mg/kg	0.050	GC-MS
Acenaphthene	mg/kg	0.050	GC-MS
Acenaphthylene	mg/kg	0.050	GC-MS
Anthracene	mg/kg	0.050	GC-MS
Benzo(a)anthracene	mg/kg	0.050	GC-MS
Benzo(a)pyrene	mg/kg	0.050	GC-MS
Benzo(b)fluoranthene	mg/kg	0.050	GC-MS
Benzo(g,h,i)perylene	mg/kg	0.050	GC-MS
Benzo(j)fluoranthene	mg/kg	0.050	GC-MS
Benzo(k)fluoranthene	mg/kg	0.050	GC-MS
Chrysene	mg/kg	0.050	GC-MS
Dibenz(a,h)anthracene	mg/kg	0.050	GC-MS
Fluoranthene	mg/kg	0.050	GC-MS
Fluorene	mg/kg	0.050	GC-MS
Indeno(1,2,3-cd)pyrene	mg/kg	0.050	GC-MS
Naphthalene	mg/kg	0.050	GC-MS
Perylene	mg/kg	0.050	GC-MS
Phenanthrene	mg/kg	0.050	GC-MS
Pyrene	mg/kg	0.050	GC-MS
Alkylated Phenols			
4-Nonylphenol (4-NP)	ng/g	0.461-0.476	LC-MS
4-n-Octylphenol (4n-OP)	ng/g	2.13-0.581	LC-MS
4-Nonylphenol monoethoxylate (NP1EO)	ng/g	0.598-1.93	LC-MS
4-Nonylphenol diethoxylate (NP2EO)	ng/g	0.461-0.476	LC-MS

2.6.5.2 Fish Testing

The parameters that fish were tested for are listed in **Table 2.35** below.

Some of the processing and health testing was conducted offshore by the McGregor offshore fishing crew, and the more advanced health testing was conducted by the Atlantic Veterinary College (AVC) laboratory in PEI. Health testing was conducted on both fish caught (cod and sculpin).

Body burden analysis (PAH and AP) was conducted by Maxxam Analytics (AP subcontracted to AXYS Analytical Services Ltd) on the cod specimen caught in the field as well as on a reference (commercial) cod.

Table 2.35 – Fish Health Analyses

Analyses	Details	Company to perform testing
Fish ID	Species	McGregor offshore field crew
Length	cm	McGregor offshore field crew
Weight	g	McGregor offshore field crew
Sex	M/F	McGregor offshore field crew
Gross Pathology	Lesions, tumours, inflammation, necrosis/acresia, atrophy, vacuolation, cysts, neoplasia, parasites	McGregor offshore field crew to pre-process - AVC to do lab analysis
Tissue Histopathology - Liver	Presence of cellular damage (lesions and tumours)	McGregor offshore field crew to pre-process - AVC to do lab analysis
Tissue Histopathology - Gills	Presence of cellular damage (lesions and tumours)	McGregor offshore field crew to pre-process - AVC to do lab analysis
Tissue Histopathology - Kidney	Presence of cellular damage (lesions and tumours)	McGregor offshore field crew to pre-process - AVC to do lab analysis
Tissue Histopathology - Gonads	Presence of cellular damage (lesions and tumours)	McGregor offshore field crew to pre-process - AVC to do lab analysis
HPLC Analysis – Gall Bladder	Extract bile from gall bladder in field	McGregor offshore field crew to pre-process - AVC to do lab analysis
Body Burden Contamination (PAH and alkylphenol)	Take fillet and remaining liver sample in field	McGregor offshore field crew to pre-process; Maxxam to do lab analysis

2.6.6 Results

2.6.6.1 Mussel Testing

As in 2015, all PAH's tested for were not detectable in either of the mussel samples (control site and the PFC). See **Table 2.36** for results and **Digital Appendix F** for the full report by Maxxam Analytics. Mussels collected were also tested for alkylated phenols (**Table 2.36).** Mussels collected from the Deep Panuke site had detectable levels of 4-NP and NP2EO. However, the control tissue had similar levels of 4-NP and NP2EO as the Deep Panuke mussels. NP1EO was not detected in the Deep Panuke sample or the control. 4n-OP was only detected in the control sample.

Table 2.36 - Comparison of PAH Levels in Mussels from Deep Panuke and Control Site

Parameter	Units	2015 PFC	2015 Control	2016 PFC	2016 Control
Polyaromatic Hydrocarbons					
1-Methylnaphthalene	mg/kg	ND	ND	ND	ND
2-Methylnaphthalene	mg/kg	ND	ND	ND	ND
Acenaphthene	mg/kg	ND	ND	ND	ND
Acenaphthylene	mg/kg	ND	ND	ND	ND
Anthracene	mg/kg	ND	ND	ND	ND
Benzo(a)anthracene	mg/kg	ND	ND	ND	ND
Benzo(a)pyrene	mg/kg	ND	ND	ND	ND
Benzo(b)fluoranthene	mg/kg	ND	ND	ND	ND
Benzo(g,h,i)perylene	mg/kg	ND	ND	ND	ND
Benzo(j)fluoranthene	mg/kg	ND	ND	ND	ND
Benzo(k)fluoranthene	mg/kg	ND	ND	ND	ND
Chrysene	mg/kg	ND	ND	ND	ND
Dibenz(a,h)anthracene	mg/kg	ND	ND	ND	ND
Fluoranthene	mg/kg	ND	ND	ND	ND
Fluorene	mg/kg	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	mg/kg	ND	ND	ND	ND
Naphthalene	mg/kg	ND	ND	ND	ND
Perylene	mg/kg	ND	ND	ND	ND
Phenanthrene	mg/kg	ND	ND	ND	ND
Pyrene	mg/kg	ND	ND	ND	ND

ND = Not Detected

Table 2.37 - Comparison of AP Levels in Mussels from Deep Panuke and Control Site

Parameter	Units	2015 PFC	2015 Control	2016 PFC	2016 Control
4-NP	ng/g	17.5	16.3	17.0	16.1
4n-OP	ng/g	0.59	1.1	ND	1.25
NP1EO	ng/g	1.28	ND	ND	ND
NP2EO	ng/g	ND	ND	1.41	1.55

ND = Not Detected

2.6.6.2 Fish Testing

The fish health assessment found no significant abnormalities in either the caught cod or the caught sculpin. Detailed results from health testing conducted on both fish by the McGregor offshore crew and by the AVC lab are provided in **Table 2.38**. The full health assessment reports are provided in **Appendix K**.

All PAHs tested for in the caught cod and the commercial cod were non-detectable. Alkylphenols 4-NP, 4n-OP and NP2EO were detected in the caught cod but they were all also detected in higher concentrations in the commercial cod. Results from the body burden contamination analysis are included in **Tables 2.39 and 2.40**. The full report by Maxxam Analytics is provided in **Digital Appendix G**.

Table 2.38 - Fish Health Assessment Results

Analyses	Fish Sample	Fish Sample
ID Number	PFC-001	PFC-002
Capture date	8-Mar-2016, 15:15 UTC	10-Mar-2016; 21:15 UTC
Capture coordinates	E 0685589, N 4853236	E 0686024 N 4853635
Species	Atlantic Cod (*Gadus morhua*)	Longhorn Sculpin (*Myoxocephalus octodecemspinosus*)
Length	45 cm	23 cm
Weight	740 g	149 g
Sex	Immature	Male
Gross pathology	**External examination:** In the left side at the level of the pectoral fin there are 2 approximately 2 mm wide and 3 cm long linear and circular skin pale white and smooth lines (interpret as scars) **Internal examination:** There is minimal amount of adipose tissue surrounding the abdominal viscera. • Gall Bladder: The gall bladder contains approximately 0.05 mL of bile. • Liver: Liver is small. In the subserosa there is a (thin 0.5 mm) and coiled elevation (interpret as a nematode) • Stomach: Contains abundant 2-3 cm long crustaceans (photo taken) and a 4 cm long and flat orange organism (unidentified) • Intestine is full and contains similar crustaceans as observed in the stomach. • Swim bladder: a patch approximately 2 cm long, star shape and orange and slightly granular is observed in the internal aspect at the level of the trunk kidney (possibly a normal anatomic structure, sample taken for confirmation). No additional comments.	**External examination:** Not significant findings, good body condition. **Internal examination:** Spleen: In the caudal apex there is a 2 mm white and round focal nodule. A similar area is also observed in the peritoneal serosa (possibly a parasite). Gall Bladder: empty. No additional comments.
Histopathology	Slide/tissue (1) Gills, Liver, head kidney (2) Heart, trunk kidney, head kidney, intesine (3) Brain, piloric caeca, pancreas. Gills: Multifocally there are up to 150 microns xenomas, oval shape and laden with hundreds of 3-4 microns acorn shape spore with a dense polar area and overall slighly refractile	Slide/tissue (1): Gills, Kidney, testis, spinal cord, stomach. (2): Head kidney, skeletal muscle. (3): Heart, liver, stomach, intestine, pancreas, serosa, brain, heart. Multiple tissues: Multifocally and more prominently in gills, kidney and heart, there are numerous oval to round 10 to 50 microns

	(Interpret as Microsporidian). Head kidney: Numerous xenomas randomly distribute. Liver: Multifocally and within the large bile ducts there are few coiled metazoan larvae (likely a Trematode) Trunk kidney: Multifocally there are numerous xenomas as abovely described. In addition and within the ureter there is an unidentified protozoan. Intestine: Within the lumina there is a 700 microns cross section of a metazoan featuring a body cavity, a prominent and striated muscular layer, a thick scaloped cuticule layer (most likely a Acanthocephalan) Heart: Multifocally there are numerous microsporidian xenomas as abovely described Piloric caeca: Multifocally there are numerous metazoans featuring oral suckers, absence of cavity, and a digestive tract (most likely a tremadode) Brain: Within the saccus dorsalis there are few large up to 250 microns microsporidian xenomas. Peritoneum: Multifocally, there are few cross sections up to 200 microns wide of a metazoan featuring cuticle, a pseudocoelomic cavity, a simple digestive tract, platymiryan muscular layer) likely a nematode. No other significant abnormalities Morphologic Diagnosis Multiple tissues: Microsporidian xenomas Liver: Bile ducts, metazoan (likely trematode) Piloric caecae: multiple metazoan (likely trematode) Intestine: Metazoan (likely acanthocephala) Abdominal cavity: Metazoan (likely a nematode) **Comments**: No significant abnormalities have been found in this specimen. The large number of parasites observed is a common finding present on wild life fish.	structures with a 2-3 microns refractile capsule and commonly surrounded by thin rim of fibroblast. (structures most likely represent various developmental stages of a trematode eggs) All other tissues: Non Significant abnormalities detected. Morphologic Diagnosis Multiple tissues: Variably encapsulated metazoan eggs (most likely trematode) **Comments:** All tissues within the normal range. The presence of parasites is common in wild life populations.

Table 2.39 - Fish Body Burden PAH Levels

Parameter	Units	PFC-001 (Cod)	Commercial Control
Polyaromatic Hydrocarbons			
1-Methylnaphthalene	mg/kg	ND	ND
2-Methylnaphthalene	mg/kg	ND	ND
Acenaphthene	mg/kg	ND	ND
Acenaphthylene	mg/kg	ND	ND
Anthracene	mg/kg	ND	ND
Benzo(a)anthracene	mg/kg	ND	ND
Benzo(a)pyrene	mg/kg	ND	ND
Benzo(b)fluoranthene	mg/kg	ND	ND
Benzo(g,h,i)perylene	mg/kg	ND	ND
Benzo(j)fluoranthene	mg/kg	ND	ND
Benzo(k)fluoranthene	mg/kg	ND	ND
Chrysene	mg/kg	ND	ND
Dibenz(a,h)anthracene	mg/kg	ND	ND
Fluoranthene	mg/kg	ND	ND
Fluorene	mg/kg	ND	ND
Indeno(1,2,3-cd)pyrene	mg/kg	ND	ND
Naphthalene	mg/kg	ND	ND
Perylene	mg/kg	ND	ND
Phenanthrene	mg/kg	ND	ND
Pyrene	mg/kg	ND	ND

ND = Not Detected

Table 2.40 - Fish Body Burden AP Levels

Parameter	Units	PFC-001 (Cod)	Commercial Control
4-NP	ng/g	11.6	92
4n-OP	ng/g	ND	ND
NP1EO	ng/g	3.12	67.8
NP2EO	ng/g	2.44	387

ND = Not Detected

2.6.7 Summary and Conclusions

2.6.7.1 Mussel Sampling

- As in 2015, no PAH parameters tested for were detected in the mussels collected from the PFC or the commercial control mussels.
- Deep Panuke and control mussels had similar levels of 4-NP and NP2EO. NP1EO was not detected in the Deep Panuke sample or the control. 4n-OP was only detected in the control sample.

2.6.7.2 Fish Sampling

- The fish health assessment found no significant abnormalities in either the caught cod or the caught sculpin.
- PAHs were non-detectable in the caught cod and the commercial cod. 4-NP, 4n-OP and NP2EO were detected in the caught cod but they were all also detected in higher concentrations in the commercial cod.

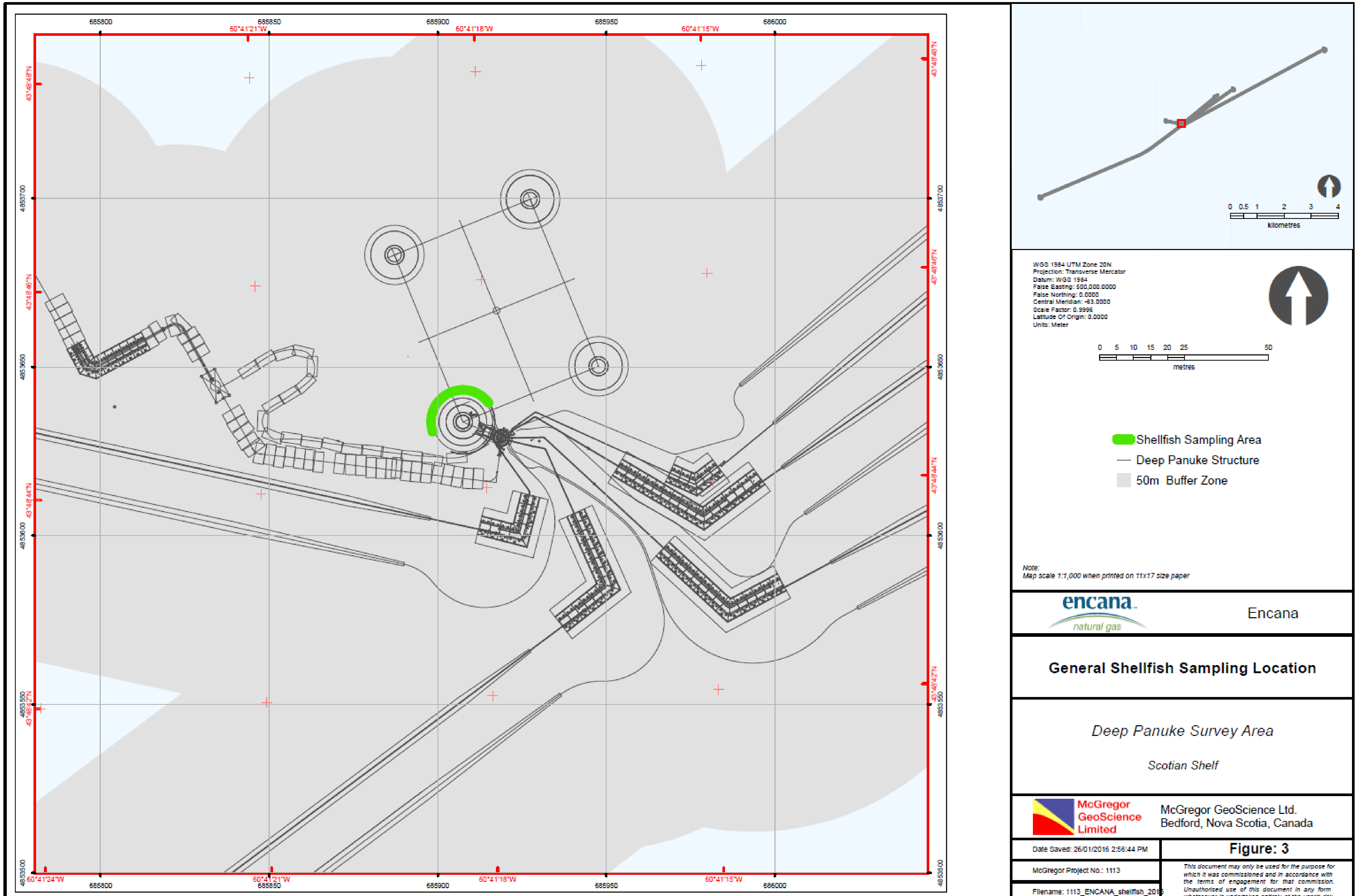


Figure 2.23 General Shellfish sampling location

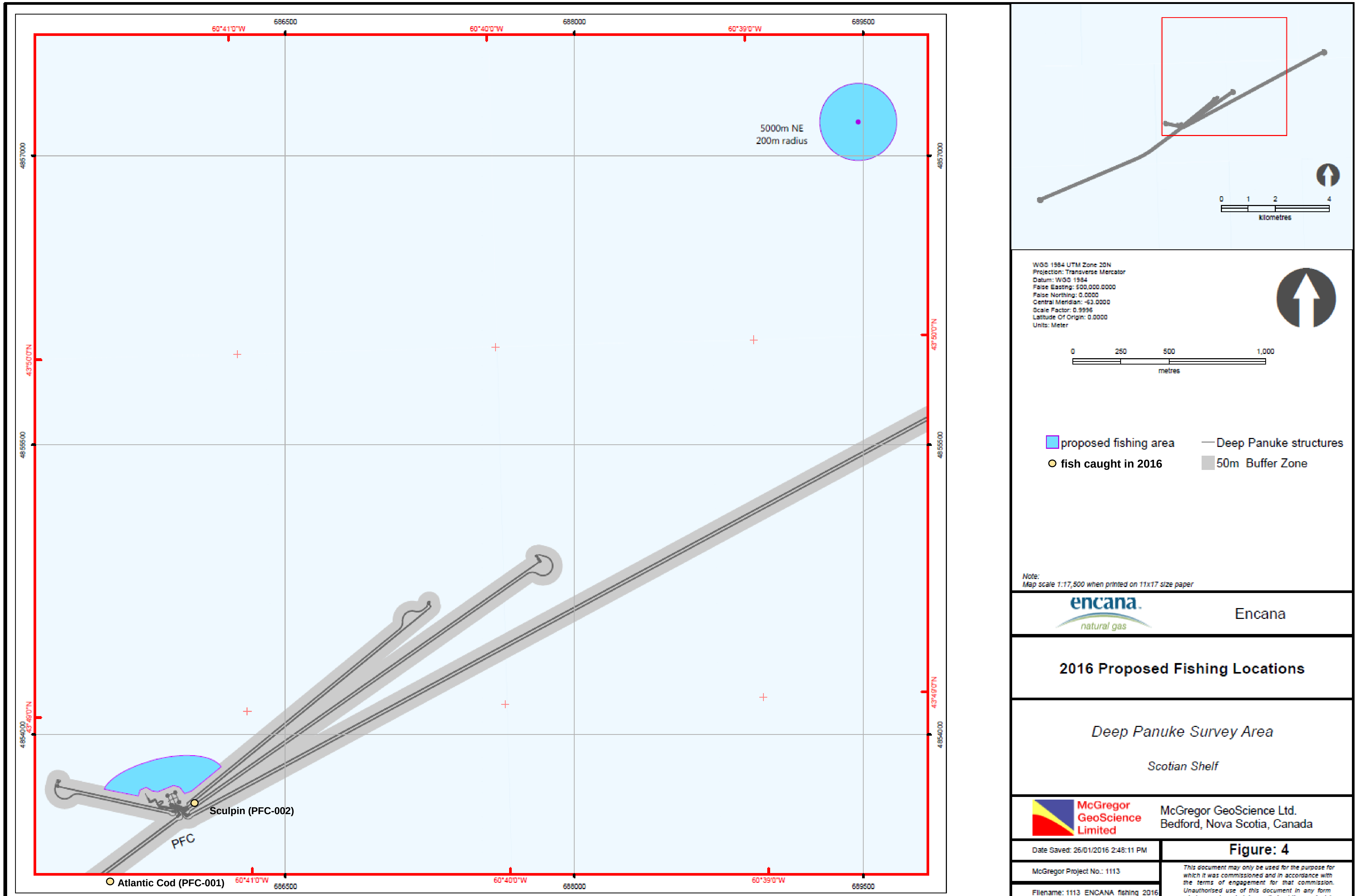


Figure 2.24 Fish Sampling Locations

2.7 MARINE WILDLIFE OBSERVATIONS

2.7.1 Background

2.7.1.1 Stranded Birds Handling

Encana's stranded bird protocol is outlined in the EPCMP and includes dedicated personnel responsible for implementing the protocol, directions on how to handle different types of stranded birds, offshore personnel awareness/training, reference material, etc. A stranded bird report Is submitted to Canadian Wildlife Service (CWS) every year.

2.7.1.2 Visual Monitoring of Wildlife around the PFC / Vessels

In recent studies, baleen whales, toothed whales, seals and sea turtles have been observed in the vicinity of production platforms and drill rigs, but the animals provided no evidence of avoidance or attraction to platform operations (Encana, 2011: DMEN-X00-RP-EH-90-0003). Cetacean species, including their young, have also been seen feeding close to platform operations.

2.7.1.3 Sable Island Beached Bird Surveys

Beached bird surveys carried out on Sable Island from January 1993 to present allowed prevalence, severity and trends of oiling, in addition to data on species composition and seasonality, and species-specific oiling rates to be monitored. Results from these surveys have shown that the composition of oil found on bird corpses suggest contaminants are a consequence of cargo tank washings and bilge discharges from large ocean-going vessels travelling along shipping routes to and from the Gulf of St. Lawrence.

2.7.2 EEMP Goal

The goal is to detect effects on marine wildlife in the in the vicinity of Deep Panuke PFC [EA predictions #11, 12 and 13 in **Table 3.1**].

2.7.3 Objectives

The following information is to be recorded/identified:

- any stranded (live or dead) birds on the Deep Panuke PFC and vessels;

- the behaviour of any birds, marine mammals and sea turtles observed in the vicinity of the Deep Panuke PFC and vessels; and
- the oil type/source on feathers of beached seabirds found on Sable Island.

2.7.4 Sampling

The following samples will be recorded/identified:

- any stranded (live or dead) birds on the Deep Panuke PFC and vessels;
- the behaviour of any birds, marine mammals and sea turtles observed in the vicinity of the Deep Panuke PFC and vessels; and
- the oil type/source on feathers of beached seabirds found on Sable Island.

2.7.5 Analysis

- Stranded birds were identified by PFC and support vessels (**Appendix M**).
- Wildlife seen from the PFC and support vessels was recorded daily.
- Oil types observed on feathers from beached seabirds collected on Sable Island were monitored (**Appendix L**);

2.7.6 Parameters Analyzed

Table 2.41 - Marine Wildlife Observations in 2016

	Sampling		Analysis	
Location	**Type/Method**	**Frequency/Duration**	**Type/Method**	**Parameters**
PFC / vessels	Implementation of Encana's EPCMP stranded bird protocol	As required	Yearly bird salvage report submitted to CWS	Species; condition; action taken; fate of bird
PFC / vessels	Visual monitoring of seabirds, marine mammals and sea turtles around PFC / vessels	Opportunistic observations from PFC / vessels	Direct observation	Species, counts and behavioural observations (*e.g.* any congregation of wildlife will be reported)
Sable Island	Beached bird surveys	Approx. 10 surveys/year	Based on CWS protocol	Oiling rate (standardized approach)

2.7.7 Results

2.7.7.1 Marine Wildlife Observations

2.7.7.1.1 Stranded Seabird Summary

- On-going monitoring for stranded birds was conducted in 2016 on the PFC and support vessels Atlantic Tern and the Atlantic Condor.
- A total of nine stranded birds were reported. Species found were a Sooty shearwater, a Sharpshinned hawk, a Baltimore oriole, a Leach's storm-petrel, two songbirds and three unidentified birds.
- All birds were found dead on the PFC. None were oiled. Two of the birds (the Sharpshinned hawk and the Baltimore oriole), which were fresh carcasses, were sent to shore for necropsy. The other birds were either inaccessible or disposed of at sea.

For complete description and photos of these stranded bird events, refer to the report "Live Seabird – 2016 Salvage Report", **Appendix M**.

2.7.7.1.2 Visual Monitoring of Wildlife around the PFC / Vessels Summary

- Both the supply vessels the Atlantic Condor and the Atlantic Tern reported wildlife sightings from January to December of 2016.
- The Atlantic Condor observed various untagged gulls throughout the year.
- The Atlantic Tern observed a variety of marine wildlife in 2016:
    - January-February: Gulls, tern, seals
    - March: Gulls, tern, seals, shearwater
    - April: Gulls, gannets, seals, sunfish
    - May: Gulls, seals, Minke whale, dolphin
    - June: Gulls, seals, dolphins, large whales (jumping)
    - July: Gulls, seals, dolphins, terns
    - August: Gulls, seals, cormorant, sunfish
    - September-October: Gulls, seals
    - November-December: Gulls

2.7.7.1.3 Sable Island Beached Bird Surveys Summary

- During 2016, eight surveys for beached seabirds were conducted on Sable Island, with no surveys done during February, March, April and December.
- During 2016, 149 beached seabird corpses were collected on Sable Island. Alcids accounted for 28.9% of total recovered. Of the 149 corpses, 98 (65.8%) were complete (i.e. with >70% of body intact).
- The overall oiling rate for all species combined (based on complete corpses) was 0.0% (compared with 0.5% in 2015 and 3.2% in 2014). In particular, the oiling rate for alcids was 0.0% (compared with 1.7% in 2015 and 7.9% in 2014).
- Although none of 98 complete corpses were oiled, of the 51 incomplete corpses, one—an Atlantic Puffin, comprised of wings, tail and feet, and found in January—showed a trace of oil on the tail. Since the oiling rate is based on complete corpses, this specimen is not represented in the reported oiling rate of 0.0% for alcids. Analysis of the oil determined it to be engine room bilge, probably from a coastal or supply vessel running on Marine Diesel, and the sample was relatively unweathered (likely <2 weeks old), indicating a nearby source. It should be noted that there was no spill hydrocarbon spill at the Deep Panuke field in 2016.

For complete details on the Sable Island Beached Seabird study, refer to **Appendix L** "2016 Beached Seabird Survey on Sable Island ".

2.7.8 Summary and Conclusions

- Nine bird strandings were reported in 2016. All birds were found dead on the PFC. No birds were found to have oil on them. Two were sent for necropsies, the others were either inaccessible or disposed of at sea.
- Both the supply vessels the M/V Atlantic Condor and the M/V Atlantic Tern reported wildlife sightings in 2016, including a variety of seabirds as well as seals, dolphins, sunfish, and Minke and large whales.
- Monitoring of oiling rates in beached birds on Sable Island was conducted over the course of eight surveys carried out between January and November 2016, where 149 beached seabird corpses were collected. Alcids accounted for 28.9% of the total corpses recovered. Of the 149 corpses, 98 (65.8%) were complete

(>70% of body intact). The overall oiling rate for all species combined (based on complete corpses) was 0.0% (compared with 0.5% in 2015 and 3.2% in 2014).

2.8 AIR QUALITY MONITORING

2.8.1 Background

Sable Island is uniquely located in the Atlantic Ocean off the east coast of North America. Despite its remote location, Sable Island receives significant trans-boundary pollutant flows from industrial and urban areas along the Great Lakes and US eastern seaboard. The local air-shed around Sable Island also receives contributions of contaminants from local sources of emissions on Sable Island itself, passing marine traffic, and from activities associated with nearby offshore hydrocarbon developments.

The Sable Island Air Monitoring Station, which has been operating since mid-2003, was installed to provide baseline information on the ambient air quality on Sable Island and to monitor trends in air quality as development of the Nova Scotia offshore oil and gas exploration expanded. Data collected serves as a basis for a comprehensive air quality management system to identify and address any potential impacts attributable to contaminant emissions from offshore activities. Monitoring is targeted at potential pollutants that could be associated with offshore oil and gas activity such as nitrogen oxides (NOx), sulphur dioxide (SO_2), fine particulate matter ($PM_{2.5}$), hydrogen sulphide (H_2S) and greenhouse gases (GHG) such as methane (CH_4), carbon monoxide (CO), and carbon dioxide (CO_2). If the station detects a pollutant spike, researchers are able to generate a back-trajectory indicating the origin of the pollutant based on flare characteristics and analysis of meteorological conditions at the time of the event.

A new study focusing on gaseous pollutants (in particular VOCs) and particulate speciation (for fine and ultra-fine particles) associated with the offshore oil and gas industry and marine emissions has been carried out by Dr. Mark Gibson, Dalhousie University, Department of Community Health and Epidemiology on Sable Island since 2011. The study is funded principally by the Environmental Studies Research Fund (ESRF) with in-kind logistical and technical support from various government agencies, stakeholder groups and offshore oil and gas companies.

Starting in 2013, Mark Gibson has been contracted by Encana and ExxonMobil through Kingfisher Environmental Health Consultants to conduct Sable Island air contaminant spike monitoring as well as data analysis of air quality and meteorological data to identify potential correlation with O&G operations.

2.8.2 EEMP Goal

The following is the goal of air quality monitoring:

- more fully understand the nature of the Sable Island air-shed;
- provide a basis for understanding environmental impacts (if any) observed on Sable Island that may be attributable to contaminant emissions from offshore petroleum production activities, and in particular the Deep Panuke natural gas field [EA predictions #14 & 15 in **Table 3.1**]; and
- provide feedback for continuous improvement in reducing flare and other emissions from the Deep Panuke natural gas field [EA prediction #14 in **Table 3.1**].

2.8.3 Objectives

Baseline information on the air quality on Sable Island will be provided. The possible relationship of anomalies (spikes of contaminants) in air quality measurements on Sable Island with flaring patterns on the PFC during production operations is to be investigated.

2.8.4 Sampling

- **Sable Island air quality:** Continuously measured Ultrafine 3031, APS 3321, O_3, H_2S, SO_2 NOx, BC (black carbon), and DRX $PM_{TSP/10/4/2.5/1}$ in 2016. For more details about Sable island air quality monitoring, refer to **Appendix N** "2016 Sable Island Air Quality Monitoring".
- **Flare smoke monitoring:** Systematic flare smoke monitoring on the PFC was conducted twice daily (morning and afternoon), assessing smoke shade using the Ringelmann chart. For more details about the flare smoke monitoring, refer to **Appendix O** "2016 Flare Plume Observations".

2.8.5 Analysis

- **Sable island air quality:** Investigation of possible relationship of air quality anomalies on Sable Island to offshore production activities by analyzing breaches of selected air emission 1-hour ‘spike’ thresholds, as well as air quality daily concentrations above background. Analysis included back-trajectory modeling.
- **Flare smoke monitoring:** Assess presence (percentage) of various flare smoke shades during the year.

2.8.6 Results

2.8.6.1 Sable Island Air Quality Monitoring:

- New instruments were installed on Sable Island in Q1 of 2016, including H_2S, SO_2, BC, O_3 and $PM_{2.5}$ (BAM 1020) analyzers. Therefore, 2016 had reasonable environmental effects monitoring coverage.
- The 2016 data completeness for temperature, wind direction and wind speed was 96%, 100% and 99% respectively, which can be considered excellent data capture for these meteorological variables. The mean (min: max) temperature and wind speed was found to be 9.04 (-11.4 : 53.8°C), 25.39 km/h (0 : 84 km/h). The maximum temperature of 53.8°C seems unlikely and suggests there might be a temperature sensor malfunction. The average wind vector for 2016 was found to be 256°, which is consistent with prevailing winds in the North West (NW) Atlantic.
- There were no operational spike threshold or air quality standard breaches for O_3 or NOx in 2016. However, there was an H_2S spike of 6.01 ppbv on July 17, 2016. This spike was above the operational spike threshold value of 3.11 ppbv. However, it was well below the 1-hr Nova Scotia air quality objective of 30 ppbv. This H_2S spike is obviously linked to the elevated SO_2 level of 3.04 ppbv that occurred on the same day. However, the SO_2 level was below the operational spike threshold of 6.0 ppbv and well below the 1-hr Canada Ambient Air Quality Objectives threshold of 344 ppbv. Scrutiny of the air mass back trajectories for this day showed that air flow passed over both the Deep Panuke and Thebaud platforms preceding and during observations on Sable Island. The spike might be due to an issue with flaring of H_2S on the Deep Panuke platform at the time (abnormally low ratio of dilution gas).

2.8.6.2 Flare Smoke Monitoring

- The Ringelmann smoke chart was used to monitor the flare twice daily on the PFC. On a scale from zero to five, the flare was a “0” (no smoke) 22% of the time that the plant was in production, a "1" 69% of the time, a "2" 8% of the time and a “3” 0.4% of the time. In comparison, during production in 2015, there was a higher frequency of days with no smoke (47% of “0”) but less light smoke (39% of “1”) and a higher frequency of darker smoke (14% of “2”) – see **Table 2.42**.
- January was the worst month in terms of presence of darker smoke; while the darkest smoke (“3”) was observed in August though for only two days (see **Figure 2.25**).
- The flare tip was replaced in April-May 2016 due to equipment failure; this had no obvious effect on flare smoke quality.

Table 2.42 - Flare Smoke Observations During Production Days in 2015 and 2016

Ringelmann Smoke Category	% Smoke Records in 2015	% Smoke Records in 2016
0	47%	22%
1	39%	69%
2	14%	8%
3	0%	0.4%
Total	100%	100%

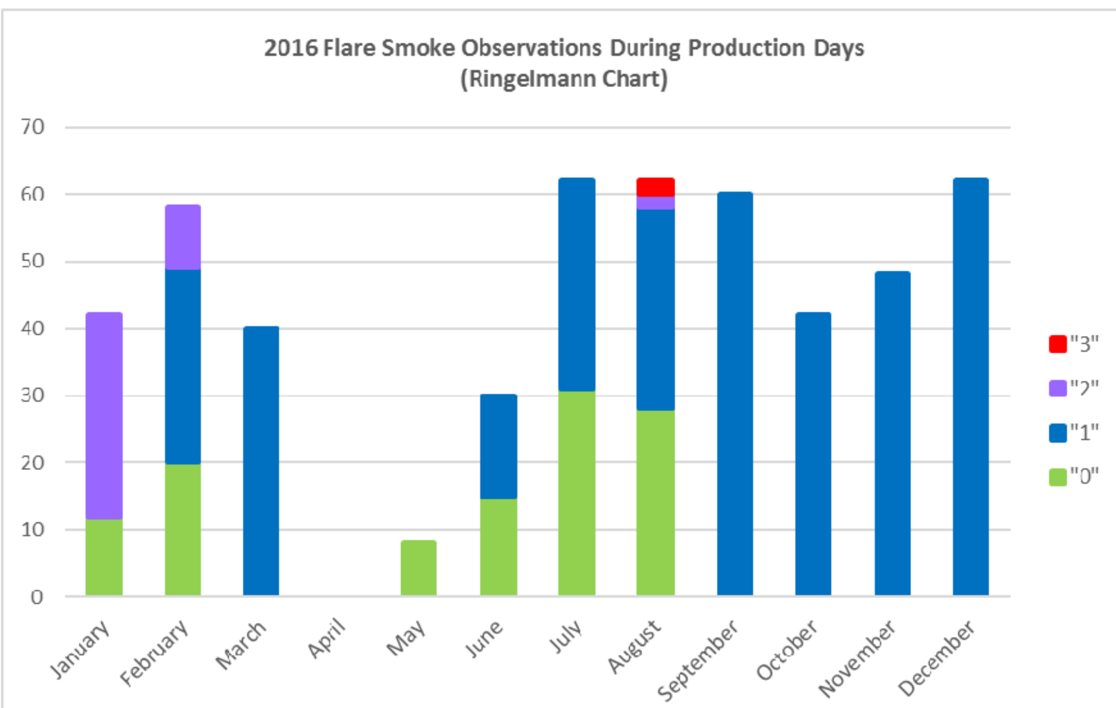


Figure 2.25 Monthly Flare Smoke Observations During Production Days in 2016

2.8.7 Summary and Conclusions

2.8.7.1 Sable Island Air Quality Monitoring

- 2016 had reasonable environmental effects monitoring coverage, thanks to new instruments installed on Sable Island in Q1 of 2016.
- 2016 data completeness for temperature, wind direction and wind speed was excellent.
- There were no operational spike threshold or air quality standard breaches for O_3 or NOx in 2016. However, there was an H2S spike of 6.01 ppbv on July 17, 2016, which was well below the 1-hr Nova Scotia air quality objective of 30 ppbv. An elevated SO2 level of 3.04 ppbv was recorded at the same time, though it was well below the operational spike threshold of 6.0 ppbv and the 1-hr Canada Ambient Air Quality Objectives threshold of 344 ppbv. Back trajectory modeling shows that air flow passed over both the Deep Panuke and Thebaud platforms. The spike might be due to an issue with flaring of H_2S on the Deep Panuke platform at the time (abnormally low ratio of dilution gas).

2.8.7.2 Flare Smoke Monitoring

The Ringelmann smoke chart was used to monitor the flare twice daily on the PFC. On a scale from zero to five, the flare was a “0” (no smoke) 22% of the time that the plant was in production, a "1" 69% of the time, a "2" 8% of the time and a “3” 0.4% of the time. Flare tip replacement in April-May 2016 had no obvious effect on flare smoke quality.

3 ENVIRONMENTAL ASSESSMENT (EA) PREDICTIONS

Table 3.1 - EEM Related Environment Assessment (EA) Predictions and 2016 Results

#	*EA Predictions*	*Relevant Section of 2006 EA*	*VEC(s)*	*EEM Component(s)*	*2016 Plan*	*2016 Results*
1	No significant adverse effects are predicted on marine receptors that are linked to water quality due to various levels of treatment of produced water on the PFC platform and rapid dilution of discharged water.	8.2.4 8.3.4 8.4.4 8.5.4	- Marine Water Quality - Marine Benthos - Marine Fish - Marine Mammals and Sea Turtles	- Produced Water Chemistry and Toxicity - Marine Water Quality - Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat. Chemistry testing of mussels collected on PFC leg.	Produced water was collected in March and November of 2016. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Some APs were detected in the November samples; no APs were detected in March. PFC and WHPS had similar species composition and growth to 2014 and 2015. Mussels were collected from the SW leg of the PFC in March of 2016. No PAH were detected in either the control mussels or those collected from the PFC. Some APs were detected in the mussel samples from Deep Panuke, however similar levels were detected in control tissues.
2	Mortality of benthic organisms due to exposure of the diluted brine plume is unlikely due to the short duration of exposure coupled with the high dilution factor. In the case of limited mortality of benthic organisms, habitat would be re-colonized from adjacent areas.	8.3.4.1	- Marine Benthos	- Sediment Chemistry and Toxicity - Fish Habitat Alteration	Discontinue E-70 cuttings pile monitoring. Continue fish habitat analysis near subsea production structures into 2015 with annual ROV footage of wellsite structures and pipeline.	Benthic communities were well developed and continue to thrive at each of the wellheads, with a dense and diverse epifaunal fouling community on the wellhead protection structures. Some fish aggregations were also observed, suggesting no negative impacts, and possible "reef" effects attracting mobile organisms into the vicinity of the subsea structures. EA prediction has been confirmed.

#	*EA Predictions*	*Relevant Section of 2006 EA*	*VEC(s)*	*EEM Component(s)*	*2016 Plan*	*2016 Results*
3	The discharged water will have a maximum "end of pipe" temperature anomaly of 25°C. The temperature anomaly will be a maximum of a 2.5°C upon contact with the seafloor. Beyond 130 m, the temperature anomaly will be less than that 1°C and will fall below 0.4°C at a distance of 500m. The temperature anomalies are not predicted to exceed temperature tolerance thresholds of fish species except in the immediate area (*i.e.*, tens of metres) from the end of pipe discharge. The benthic organisms of the study area are capable of withstanding variable temperatures and the predicted 2.5°C temperature anomaly in unlikely to exceed tolerance thresholds of benthic species present.	8.4.4.2 8.3.4.2	- Marine Fish - Marine Benthos	- Produced Water Chemistry and Toxicity - Marine Water Quality Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Marine Water Quality to be performed once a year in conjunction with produced water testing. Sediment chemistry and toxicity to be performed once a year. Mussel chemistry testing to be performed once a year and fish health testing to start in 2016. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	Produced water was collected in March and November of 2016. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Some APs were detected in the November samples; no APs were detected in March. Marine water sampling was conducted in March of 2016. Mercury levels were above CCME guidelines at all stations. Cadmium levels were also found to be above CCME guidelines at three stations. All other parameters measured were below CCME guidelines where available. 4-Nonylphenols were detected at all water stations and depths sampled. Temperature was similar across all stations sampled. Sediments were collected at six stations in March of 2016. Results show no sign of sediment contamination from production activities. Mussels were collected from the SW leg of the PFC in March of 2016. No PAH were detected in either the control mussels or those collected from the PFC. Some APs were detected in the mussel samples from Deep Panuke, however similar levels were detected in control tissues. No significant abnormalities were found in the only two fish caught by the PFC. PAHs were non-detectable in both the caught and the commercial cod. Some APs were detected in the caught cod but they were all also detected in higher concentrations in the commercial cod. PFC and WHPS had similar species composition and growth to 2014 and 2015.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2016 Plan	2016 Results
4	The maximum salinity anomaly of the plume upon contact with the seafloor will be about 0.7 PSU. Upon spreading of the plume, the maximum salinity anomaly will fall below 0.6 PSU within 100 m of the site (seafloor) and 0.1 with 500 m. Similar to the effects of the bulk discharge of completion fluid, the predicted salinity anomaly of the plume upon contact with the bottom is minor and is unlikely to exceed tolerance thresholds of benthic organisms or fish.	8.3.4.2 8.4.4.2	- Marine Benthos - Marine Fish	- Produced Water Chemistry and Toxicity - Marine Water Quality - Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Marine Water Quality to be performed once a year in conjunction with produced water testing. Sediment chemistry and toxicity to be performed once a year. Mussel chemistry testing to be performed once a year and fish health testing to start in 2016. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	Produced water was collected in March and November of 2016. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Some APs were detected in the November samples; no APs were detected in March. Marine water sampling was conducted in March of 2016. Mercury levels were above CCME guidelines at all stations. Cadmium levels were also found to be above CCME guidelines at three stations. All other parameters measured were below CCME guidelines where available. 4-Nonylphenols were detected at all water stations and depths sampled. Salinity followed similar trends across stations sampled, increasing slightly with depth. Salinity values ranged from 31.70 PSU to 32.82 PSU. Sediments were collected at six stations in March of 2016. Results show no sign of sediment contamination from production activities. Mussels were collected from the SW leg of the PFC in March of 2016. No PAH were detected in either the control mussels or those collected from the PFC. Some APs were detected in the mussel samples from Deep Panuke, however similar levels were detected in control tissues. No significant abnormalities were found in the only two fish caught by the PFC. PAHs were non-detectable in both the caught and the commercial cod. Some APs were detected in the caught cod but they were all also detected in higher concentrations in the commercial cod. PFC and WHPS had similar species composition and growth to 2014 and 2015.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2016 Plan	2016 Results
5	Treating the produced water at several levels (including continuous polishing) prior to discharge and the rapid dilution of the plume implies that benthic organisms will be exposed to very low concentrations of contaminants that are unlikely to elicit measurable effects.	8.3.4.2	- Marine Benthos	- Produced Water - Chemistry and Toxicity - Marine Water Quality Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Marine Water Quality to be performed once a year in conjunction with produced water testing. Sediment chemistry and toxicity to be performed once a year. Mussel chemistry testing to be performed once a year and fish health testing to start in 2016. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	Produced water was collected in March and November of 2016. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Some APs were detected in the November samples; no APs were detected in March. Marine water sampling was conducted in March of 2016. Mercury levels were above CCME guidelines at all stations. Cadmium levels were also found to be above CCME guidelines at three stations. All other parameters measured were below CCME guidelines where available. 4-Nonylphenols were detected at all water stations and depths sampled. Mussels were collected from the SW leg of the PFC in March of 2016. No PAH were detected in either the control mussels or those collected from the PFC. Some APs were detected in the mussel samples from Deep Panuke, however similar levels were detected in control tissues. No significant abnormalities were found in the only two fish caught by the PFC. PAHs were non-detectable in both the caught and the commercial cod. Some APs were detected in the caught cod but they were all also detected in higher concentrations in the commercial cod. PFC and WHPS had similar species composition and growth to 2014 and 2015.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2016 Plan	2016 Results
6	Experimental data pertinent to the toxicity of H2S on fish suggest that the concentrations of H2S that fish will likely be exposed to at Deep Panuke are much less than the concentrations required to cause chronic or acute effects, including at the point of discharge. The full-time "polishing" of produced water on the MOPU and the rapid dilution of the plume will result in fish being exposed to extremely low concentrations of Alkylated phenols that are unlikely to elicit measurable effects.	8.4.4.2	- Marine Fish	- Produced Water - Chemistry and - Toxicity - Marine Water Quality Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Marine Water Quality to be performed once a year in conjunction with produced water testing. Sediment chemistry and toxicity to be performed once a year. Mussel chemistry testing to be performed once a year and fish health testing to start in 2016. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	Produced water was collected in March and November of 2016. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Some APs were detected in the November samples; no APs were detected in March. Marine water sampling was conducted in March of 2016. Mercury levels were above CCME guidelines at all stations. Cadmium levels were also found to be above CCME guidelines at three stations. All other parameters measured were below CCME guidelines where available. 4-Nonylphenols were detected at all water stations and depths sampled. Sediments were collected at 6 stations in March of 2016. Results show no sign of sediment contamination from production activities. Mussels were collected from the SW leg of the PFC in March of 2016. No PAH were detected in either the control mussels or those collected from the PFC. Some APs were detected in the mussel samples from Deep Panuke, however similar levels were detected in control tissues. No significant abnormalities were found in the only two fish caught by the PFC. PAHs were non-detectable in both the caught and the commercial cod. Some APs were detected in the caught cod but they were all also detected in higher concentrations in the commercial cod. PFC and WHPS had similar species composition and growth to 2014 and 2015.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2016 Plan	2016 Results
7	The effects of cuttings and WBM are most likely to affect demersal fishes as drilling wastes will fall out of suspension and settle on the seafloor or be held in the benthic boundary layer.	4.4.4.1	- Marine Fish	- Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Sediment sampling to continue in 2013. Discontinue E-70 cuttings pile monitoring.	N/A - Sediment sampling at wellsite locations to be discontinued in 2014 based on results from 2011 chemistry and toxicity survey (no surveys conducted in 2012 and 2013) which concluded that all metal, non-metal, hydrocarbon and nutrient concentrations were below Canadian EQG threshold levels and that all collected sediments were non-toxic ("therefore, there is negligible risk to biota, their functions, or any interactions that are integral to sustaining the health of the ecosystem and the designated resource uses they support"). – EA prediction no longer applicable. The sediment chemistry and toxicity program will focus on the sampling locations downstream and upstream of the PFC site (i.e. 4 near-field and 2 far-field reference sites).
8	Overall, cuttings piles are not expected to persist for more than a year due to the dynamic and energetic environment (*i.e.* currents and storm events) of Sable Island Bank. Following dissipation of the cuttings pile, the benthic community is expected to recover within 2 to 3 years through recruitment from adjacent areas.	8.3.4 8.4.4	- Marine Benthos - Marine Fish	- Sediment Chemistry - and Toxicity - Fish Habitat Alteration	Discontinue E-70 cuttings pile monitoring.	N/A – EA prediction has been confirmed.
9	Marine life will benefit to a minor extent from a "reef" effect due to additional habitat created by PFC facilities and exposed sections of the subsea pipeline to shore and a "refuge" effect associated with the creation of a safety (no fishing) zone around PFC facilities.	8.2.4 8.3.4 8.4.4 8.5.4	- Marine Benthos - Marine Fish - Marine Mammals and Turtles	- Fish Habitat Alteration	ROV video data to be inspected in order to determine and interpret the development of benthic communities at the wellheads, wellhead protection structures, pipelines etc.	There was evidence that the PFC facility continues to cause a "reef" effect due to the habitat created by the physical sub-sea structures. Dense epifaunal colonization continued to be observed on many of the subsea structures. Presence of fish species recorded at the PFC facilities and exposed sections of the subsea pipeline to shore suggest that the structures are acting as a "refuge" for some commercial species.

#	*EA Predictions*	*Relevant Section of 2006 EA*	*VEC(s)*	*EEM Component(s)*	*2016 Plan*	*2016 Results*
10	It is highly unlikely that the proposed subsea pipeline, where unburied, would constitute a significant concern as a physical barrier to crustacean movement.	8.3.4 8.4.4	- Marine Benthos - Marine Fish	- Fish Habitat Alteration	ROV video data to be inspected in order to determine and interpret the development of benthic communities along the pipeline. Continue observation of crustaceans, particularly American lobster if present.	The subsea pipeline does not constitute a physical barrier to crustacean movement as evidenced by multiple species of crabs on top and on the sides of the exposed structure. EA prediction has been confirmed for all types of crabs found along the GEP. Lobsters have not been observed climbing the pipeline in this project; however, as the GEP is not a physical barrier for other crustaceans, it is unlikely that it is a physical barrier for lobsters. Studies have also shown that lobsters are capable of climbing over a pipeline (Martec 2004)
11	Marine Mammals and Sea Turtles may be attracted to the PFC area due to the availability of increased prey species ("reef/refuge" effects) or thermal plume (in winter).	8.2.4 8.4.4 8.5.4	- Marine Water - Quality - Marine Fish - Marine Mammals and Turtles	- Marine Water Quality - Monitoring - Marine Wildlife Observations	Marine Mammal and Sea Turtle observations to continue in 2016.	Presence of wildlife near the PFC has been observed sporadically but these observations cannot affirm the presence or nature of an attraction (*i.e.* noise, heat, food, shelter/refuge, curiosity, etc.).
12	Birds, such as gulls and tubenoses, can be attracted by macerated sewage and food waste, although this was not observed at the Cohasset Project. Overall, the potential effects of the presence of project related lighting and flares will be low.	6.3.6.4 (2002 CSR)	- Marine Related - Birds	- Marine Wildlife Observations	Bird observations from vessel and platform to continue in 2016.	Nine bird strandings were reported in 2016. All birds were found dead on the PFC. No birds were found to have oil on them. Two were sent for necropsies, the others were either inaccessible or disposed of at sea.
13	The potential for oiling of birds and/or contamination of their food sources from discharged produced water is unlikely since a sheen, if it did occur, would be very short lived and would be unlikely to produce any oiling of bird plumage.	8.2.4 8.6.4	- Marine Water - Quality - Marine Related - Birds	- Marine Water Quality - Monitoring - Marine Wildlife Observations	Summarize observations and findings from Sable Island Beach Surveys.	0.0% oiling for all species of beached birds found on Sable Island (based on complete corpses).
14	Routine operations can be conducted with sufficient mitigation to ensure that effects on air quality are not significant.	8.1.4	- Air Quality	- Air Quality Monitoring	Air quality data monitored as per proposed Sable Island air emissions monitoring plan described in 2012 EEM report.	One H_2S spike on July 17, 2016 might be due to issue with acid gas flaring on Deep Panuke PFC. However, level was well below NS air quality objective. No breaches of National Air Quality Standards, CAAQO or Canada Wide Standard for any of the air pollution metrics.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2016 Plan	2016 Results
15	Air quality modeling for accidental events indicates exposure levels to receptors on Sable Island remain not significant.	8.1.4	- Air Quality - Sable Island	- Air Quality Monitoring	Air quality data monitored as per proposed Sable Island air emissions monitoring plan described in 2012 EEM report.	One H_2S spike on July 17, 2016 might be due to issue with acid gas flaring on Deep Panuke PFC. However, level was well below NS air quality objective. No breaches of National Air Quality Standards, CAAQO or Canada Wide Standard for any of the air pollution metrics.

4 RECOMMENDED EEM PROGRAM FOR 2017

On February 3, 2017, the CNSOPB approved Encana's proposal to change the frequency of the EEM field sampling program for marine water, sediment and fish health from annual to every two years. This was supported by results from previous production EEM field sampling data (no measurable impact from production discharges on any of the receptors), decreasing produced water volumes and precedent from other local offshore projects. As a result, the next EEM field sampling program will take place in 2018.

The remaining components of the EEM program will continue to be conducted annually, including the following:

- produced water chemistry and toxicity (samples collected on the PFC);
- fish habitat alteration (ROV video-camera survey);
- marine wildlife observations (bird and marine wildlife monitoring); and
- air quality monitoring (Sable Island air quality monitoring station and PFC flare plume monitoring).

Table 4.1 provides a summary of Deep Panuke's 2016 offshore EEM sampling activities, analysis, and recommendations for the 2017 EEM program.

Table 4.1 - Summary of Deep Panuke 2016 Offshore EEMP Sampling Activities, Analysis, and 2017 Recommendations

EEMP Component	2016 Sampling			2016 Analysis		2017 Recommendations
	Location	Type/Method	Frequency/Duration	Type/Method	Parameters	
Produced Water Chemistry and Toxicity	PFC (prior to mixing with seawater system discharge)	Sampled on the PFC directly from outlet.	Twice annually after First Gas Produced water sampled in March and November 2016	Water quality composition	Trace metals; BTEX, TPH, PAHs; APs; nutrients; organic acids; major ions and physical parameters	Continue produced water sampling in 2017; to be collected and analyzed twice a year
			Annually after First Gas Conducted on produced water in March 2016	Microtox Sea urchin fertilization Threespine stickleback	15 min IC50 bioassay IC25 (Fertilization) 96-hr LC50	Continue yearly sampling in 2017
Marine Water Quality Monitoring	Tri-level seawater samples (surface, mid and bottom depths) at 5 near-field downstream sites and 2 upstream sites along tide direction	Niskin Bottle	In 2011 (prior to First Gas), then annually for the three following years Conducted in March 2016	Water quality composition	Trace metals; BTEX, TPH, PAHs; APs; nutrients; organic acids; major ions and physical parameters	Conduct marine water sampling program in 2018
Sediment Chemistry and Toxicity	4 near-field benthic sampling locations and 2 far-field reference sites (5 wellsite sampling locations discontinued in 2015)	Grab Sample - Van Veen	In 2011 (prior to First Gas and post 2010 drilling and completion activities), then annually for the following three years Conducted in March 2016	Chemical composition	Sediment grain size and TOC; suite of metals and hydrocarbons measured in 2008 Benthic Baseline Study; TPH, PAHs and APs; and sulphides	Conduct sediment sampling program in 2018
				LC49 bioassay acute toxicity analysis	Suitable marine amphipod species such as *Rhepoxynius abronius* or *Eohaustoriux estuaries*	Conduct LC49 bioassay and test in 2018

EEMP Component	2016 Sampling			2016 Analysis		2017 Recommendations
	Location	Type/Method	Frequency/Duration	Type/Method	Parameters	
Fish Habitat	Subsea production structures	ROV video- camera survey	Annually (using planned activities, *e.g.* routine inspection and storm scour surveys) Conducted in 2016 (all year)	Video analysis	Subsea production structures: evaluate the extent of marine colonization and compare to previous years.	Continue fish habitat analysis near subsea production structures into 2017 with annual ROV footage of wellsites, PFC and pipeline
Fish Health Assessment	Mussels: PFC SW leg Fish: immediate vicinity of PFC and suitable far-field reference sites	Mussels: scraping Fish: angling	Mussels: annually after First Gas Fish: every 3 years after First Gas Both mussel and fish sampling conducted in March 2016	Mussels: body burden Fish: body burden; pathology	Mussels: PAH and AP Fish: PAH and AP; standard characteristics (*e.g.* length, weight, sex, etc); gross pathology and histopathology	Conduct mussel and fish health assessment in 2018
Marine Wildlife Observations	PFC / vessels	Implementation of Williams and Chardine protocol for stranded birds	As required	Yearly bird salvage report to be submitted to CWS	Species; condition; action taken; fate of bird	Continue into 2017
		Visual monitoring of seabirds, marine mammals and sea turtles around PFC	Opportunistic observations from PFC / vessels	Direct observations	Species, counts and behavioural observations (*e.g.* any congregation of wildlife will be reported)	Continue into 2017
	Sable Island	Beached bird surveys	Approx. 10 surveys/year	Based on CWS protocol	Oiling rate (standardized approach)	Continue into 2017
Air Quality Monitoring	Sable Island Air Quality Monitoring Station	Air quality monitoring instrumentation	Continuous	Compare Sable Island air contaminant spikes with O&G production activities using meteorological records	$PM_{2.5}$; VOCs, SO_2; H_2S; NO; NO_2; NOx; O_3; CH_4; and NMHC; flare smoke shades	Continue Sable Island air quality monitoring in 2017
	PFC	Visual observations of flare plume	Continuous during walk-arounds on deck and from video camera looking at the flare			Continue twice daily visual flare plume monitoring using Ringelmann smoke chart

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APPENDIX A

CEQG for Marine Water Quality

The aquatic ecosystem is composed of the biological community (producers, consumers, and decomposers), the physical and chemical (abiotic) components, and their interactions. Within the aquatic ecosystem, a complex interaction of physical and biochemical cycles exists, and changes do not occur in isolation. Aquatic systems undergo constant change. However, an ecosystem has usually developed over a long period of time and the organisms have become adapted to their environment. In addition, ecosystems have the inherent capacity to withstand and assimilate stress based on their unique physical, chemical, and biological properties. Nonetheless, systems may become unbalanced by natural factors, which include drastic climatic variations or disease, or by factors due to human activities. Any changes, especially rapid ones, could have detrimental or disastrous effects. Adverse effects due to human activity, such as the presence of toxic chemicals in industrial effluents, may affect many components of the aquatic ecosystem, the magnitude of which will depend on both biotic and abiotic site-specific characteristics.

Canadian water quality guidelines are intended to provide protection of freshwater and marine life from anthropogenic stressors such as chemical inputs or changes to physical components (e.g., pH, temperature, and debris). Guidelines are numerical limits or narrative statements based on the most current, scientifically defensible toxicological data available for the parameter of interest. Guideline values are meant to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term. Ambient water quality guidelines developed for the protection of aquatic life provide the science-based benchmark for a nationally consistent level of protection for aquatic life in Canada.

Canadian water quality guidelines for aquatic life are not restricted to a particular (biotic) species, but species-specific information is provided in the respective fact sheets, and, more detailed, in the supporting documents, so that the water quality manager and other users may determine the appropriateness of the guideline for the protection and enhancement of local species. A consistent approach according to the nationally approved, scientifically defensible protocol for the development of water quality guidelines (freshwater and marine) for the protection of aquatic life was maintained. It is important to note that the national protocol emphasizes best scientific judgment in all cases, so the nature of the parameter and the variation in the quality and quantity of supporting information necessitates modifications to the derivation procedures from time to time.

This chapter contains (a) a summary table of the guidelines, listing the ones that either have been carried over from the original *Canadian Water Quality Guidelines* (CCREM 1987), revised since then, or newly developed; (b) the protocol (originally published in 1991); and (c) fact sheets for the respective substances and parameters of concern. These guidelines, therefore, replace the former recommendations published in CCREM (1987) and its appendixes. The fact sheets, and, more extensively, the supporting documents on which they are based, provide details for the derivation of the guidelines, physical-chemical properties, fate in the aquatic environment, use patterns, environmental concentrations, and toxicological data. Effects diagrams give a graphical summary of the relevant toxicity information, i.e., the most sensitive effects thresholds for the different taxonomic groups. The recommended guideline values are expressed to two significant figures, unless otherwise required or indicated by the original toxicity study. The guideline values apply to the total element or substance in an unfiltered sample, unless otherwise specified. It should be noted, however, that certain information about a parameter changes over time, and that the data presented in the fact sheets may not reflect current use patterns. The guidelines and their supporting documents will be reviewed and updated following national priorities and as further relevant information becomes available.

Information on the implementation of guidelines for the protection of aquatic life can be found in the Appendix IV of CCREM (1987). The CCME Task Group recognizes the importance of providing the most up-to-date scientific and technical guidance on implementing national environmental quality guidelines. For this reason, an update of Appendix IV, entitled “Scientific and Technical Guidance on Canadian Water Quality Guideline Implementation”, is currently being written and will be released shortly.

For waters of superior quality or that support valuable biological resources, the CCME nondegradation policy states that the degradation of the existing water quality should always be avoided. The natural background concentrations of parameters and their range should also be taken into account in the design of monitoring programs and the interpretation of the resulting data.

In order to apply this scientific information, for example to recommend site-specific water quality objectives, many factors such as the local water quality, resident biotic species, local water demands, and other elements have to be considered. When developing or using guidelines and site-specific objectives for aquatic life, the aquatic ecosystem should be viewed as a whole unit, not as isolated organisms affected by one or a few pollutants. The aquatic ecosystem is part of a complex system with aquatic and terrestrial components and should not be studied in isolation.

Since the release of *Canadian Water Quality Guidelines* (CCREM 1987), it has been recognized that water quality guidelines for highly persistent, bioaccumulative substances such as polychlorinated biphenyls (PCBs), toxaphene, and DDT have a high level of scientific uncertainty and limited practical management value, and are, therefore, no longer recommended. For these substances, it is more appropriate to use the respective tissue residue guidelines and/or sediment quality guidelines.

It has been recognized that the definition of the terms criteria, guidelines, objectives, and standards varies widely among jurisdictions and users. For the purpose of this chapter, these terms will be defined as follows:

- **Criteria:** scientific data evaluated to derive the recommended limits for water uses.
- **Water quality guideline:** numerical concentration or narrative statement recommended to support and maintain a designated water use.
- **Water quality objective:** a numerical concentration or narrative statement that has been established to support and protect the designated uses of water at a specified site.
- **Water quality standard:** an objective that is recognized in enforceable environmental control laws of a level of government.

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Reference listing:

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Canadian Council of Ministers of the Environment

CCME

Le Conseil canadien des ministres de l'environnement

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

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,1,1-Trichloroethane **CASRN** 71556	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2,2- Tetrachloroethene PCE (Tetrachloroethylene) **CASRN** 127184	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	110	1993	*No data*	Insufficient data	1993
1,1,2,2-Tetrachlorethane **CASRN** 79345	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2-Trichloroethene TCE (Trichloroethylene) **CASRN** 79-01-6	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	21	1991	*No data*	Insufficient data	1991

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,3,4-Tetrachlorobenzene **CASRN** 634662	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	1.8	1997	*No data*	Insufficient data	1997
1,2,3,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997

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

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,3-Trichlorobenzene **CASRN** 87616	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	8	1997	*No data*	Insufficient data	1997

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,4,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
1,2,4-Trichlorobenzene **CASRN** 120801	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	24	1997	*No data*	5.4	1997
1,2-Dichlorobenzene **CASRN** 95501	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	0.7	1997	*No data*	42	1997
1,2-Dichloroethane **CASRN** 1070602	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	100	1991	*No data*	Insufficient data	1991
1,3,5-Trichlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
1,3-Dichlorobenzene **CASRN** 541731	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	150	1997	*No data*	Insufficient data	1997

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,4-Dichlorobenzene **CASRN** 106467	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	26	1997	*No data*	Insufficient data	1997
1,4-Dioxane		NRG	NRG	2008	NRG	NRG	2008
3-Iodo-2-propynyl butyl carbamate IPBC **CASRN** 55406-53-6	Organic Pesticides Carbamate pesticides	*No data*	1.9	1999	*No data*	*No data*	*No data*
Acenaphthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	5.8	1999	*No data*	Insufficient data	1999

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

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Acenaphthylene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	*No data*	1999	*No data*	*No data*	1999
Acridine PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	4.4	1999	*No data*	Insufficient data	1999
Aldicarb **CASRN** 116063	Organic Pesticides Carbamate pesticides	*No data*	1	1993	*No data*	0.15	1993
Aldrin	Organic Pesticides Organochlorine compounds	*No data*	~~0.004~~	1987	*No data*	*No data*	*No data*
Aluminium	Inorganic	*No data*	Variable	1987	*No data*	*No data*	*No data*
Ammonia (total)	Inorganic Inorganic nitrogen compounds	*No data*	Table	2001	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Ammonia (un-ionized) **CASRN** 7664417	Inorganic Inorganic nitrogen compounds	*No data*	19	2001	*No data*	*No data*	*No data*
Aniline **CASRN** 62533	Organic	*No data*	2.2	1993	*No data*	Insufficient data	1993
Anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.012	1999	*No data*	Insufficient data	1999
Arsenic **CASRN** none	Inorganic	*No data*	5	1997	*No data*	12.5	1997
Atrazine **CASRN** 1912249	Organic Pesticides Triazine compounds	*No data*	1.8	1989	*No data*	*No data*	*No data*
Benz(a)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.018	1999	*No data*	Insufficient data	1999

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Benzene **CASRN** 71432	Organic Monocyclic aromatic compounds	*No data*	370	1999	*No data*	110	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Benzo(a)pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.015	1999	*No data*	Insufficient data	1999
Beryllium	Inorganic	No data	No data	2015-02-23	No data	No data	2015-02-23
Boron	Inorganic	29,000µg/L or 29mg/L	1,500µg/L or 1.5mg/L	2009	NRG	NRG	2009

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Bromacil **CASRN** 314409	Organic Pesticides	*No data*	5	1997	*No data*	Insufficient data	1997
Bromoxynil	Organic Pesticides Benzonitrile compounds	*No data*	5	1993	*No data*	Insufficient data	1993
Cadmium **CASRN** 7440439	Inorganic	1.0	0.09	2014	NRG	0.12	2014
Captan **CASRN** 133062	Organic Pesticides	*No data*	1.3	1991	*No data*	*No data*	*No data*
Carbaryl **CASRN** 63252	Organic Pesticides Carbamate pesticides	3.3	0.2	2009	5.7	0.29	2009
Carbofuran **CASRN** 1564662	Organic Pesticides Carbamate pesticides	*No data*	1.8	1989	*No data*	*No data*	*No data*
Chlordane	Organic Pesticides Organochlorine compounds	*No data*	~~0.006~~	1987	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Chloride	Inorganic	640,000 µg/L or 640 mg/L	120,000 µg/L or 120 mg/L	2011	NRG	NRG	2011
Chlorothalonil **CASRN** 1897456	Organic Pesticides	*No data*	0.18	1994	*No data*	0.36	1994
Chlorpyrifos **CASRN** 2921882	Organic Pesticides Organophosphorus compounds	0.02	0.002	2008	NRG	0.002	2008
Chromium, hexavalent (Cr(VI)) **CASRN** 7440473	Inorganic	*No data*	1	1997	*No data*	1.5	1997
Chromium, trivalent (Cr(III)) **CASRN** 7440473	Inorganic	*No data*	8.9	1997	*No data*	56	1997
Chrysene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	Insufficient data	1999	*No data*	Insufficient data	1999

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

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Colour **CASRN** N/A	Physical	*No data*	Narrative	1999	*No data*	Narrative	1999
Copper	Inorganic	*No data*	Equation	1987	*No data*	*No data*	*No data*
Cyanazine **CASRN** 2175462	Organic Pesticides Triazine compounds	*No data*	2	1990	*No data*	*No data*	*No data*
Cyanide	Inorganic	*No data*	5 (as free CN)	1987	*No data*	*No data*	*No data*
Debris **CASRN** N/A	Physical	*No data*	*No data*	*No data*	*No data*	Narrative	1996
Deltamethrin **CASRN** 52918635	Organic Pesticides	*No data*	0.0004	1997	*No data*	Insufficient data	1997
Deposited bedload sediment	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Insufficient data	1999	*No data*	Insufficient data	1999
Di(2-ethylhexyl) phthalate **CASRN** 117817	Organic Phthalate esters	*No data*	16	1993	*No data*	Insufficient data	1993

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Di-n-butyl phthalate **CASRN** 84742	Organic Phthalate esters	*No data*	19	1993	*No data*	Insufficient data	1993
Di-n-octyl phthalate **CASRN** 117840	Organic Phthalate esters	*No data*	Insufficient data	1993	*No data*	Insufficient data	1993
Dibromochloromethane	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Dicamba **CASRN** 1918009	Organic Pesticides Aromatic Carboxylic Acid	*No data*	10	1993	*No data*	*No data*	*No data*
Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane DDT (total)	Organic Pesticides Organochlorine compounds	*No data*	~~0.001~~	1987	*No data*	*No data*	*No data*
Dichlorobromomethane	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Dichloromethane Methylene chloride **CASRN** 75092	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	98.1	1992	*No data*	Insufficient data	1992

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

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Dichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	0.2	1987	*No data*	*No data*	*No data*
Diclofop-methyl **CASRN** 51338273	Organic Pesticides	*No data*	6.1	1993	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Didecyl dimethyl ammonium chloride DDAC **CASRN** 7173515	Organic Pesticides	*No data*	1.5	1999	*No data*	Insufficient data	1999
Diethylene glycol **CASRN** 111466	Organic Glycols	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
Diisopropanolamine DIPA **CASRN** 110974	Organic	*No data*	1600	2005	*No data*	Insufficient data	2005
Dimethoate **CASRN** 60515	Organic Pesticides Organophosphorus compounds	*No data*	6.2	1993	*No data*	Insufficient data	1993
Dinoseb **CASRN** 88857	Organic Pesticides	*No data*	0.05	1992	*No data*	*No data*	*No data*
Dissolved gas supersaturation **CASRN** N/A	Physical	*No data*	Narrative	1999	*No data*	Narrative	1999
Dissolved oxygen DO **CASRN** N/A	Inorganic	*No data*	Variable	1999	*No data*	>8000 & Narrative	1996

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Endosulfan	Organic Pesticides Organochlorine compounds	0.06	0.003	2010	0.09	0.002	2010
Endrin	Organic Pesticides Organochlorine compounds	*No data*	~~0.0023~~	1987	*No data*	No data	*No data*
Ethylbenzene **CASRN** 100414	Organic Monocyclic aromatic compounds	*No data*	90	1996	*No data*	25	1996
Ethylene glycol **CASRN** 107211	Organic Glycols	*No data*	192 000	1997	*No data*	Insufficient data	1997
Fluoranthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.04	1999	*No data*	Insufficient data	1999

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

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Fluorene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	3	1999	*No data*	Insufficient data	1999
Fluoride	Inorganic	*No data*	120	2002	*No data*	NRG	2002
Glyphosate **CASRN** 1071836	Organic Pesticides Organophosphorus compounds	27,000	800	2012	NRG	NRG	2012
Heptachlor Heptachlor epoxide	Organic Pesticides Organochlorine compounds	*No data*	~~0.01~~	1987	*No data*	*No data*	*No data*
Hexachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
Hexachlorobutadiene HCBD **CASRN** 87683	Organic Halogenated aliphatic compounds	*No data*	1.3	1999	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Hexachlorocyclohexane Lindane	Organic Pesticides Organochlorine compounds	*No data*	0.01	1987	*No data*	*No data*	*No data*
Imidacloprid **CASRN** 13826413		*No data*	0.23	2007	*No data*	0.65	2007
Iron	Inorganic	*No data*	300	1987	*No data*	*No data*	*No data*
Lead	Inorganic	*No data*	Equation	1987	*No data*	*No data*	*No data*
Linuron **CASRN** 41205214	Organic Pesticides	*No data*	7	1995	*No data*	*No data*	1995
Mercury **CASRN** 7439976	Inorganic	*No data*	0.026	2003	*No data*	0.016	2003
Methoprene **CASRN** 40596698		*No data*	0.09 (Target Organism Management value: 0.53)	2007	*No data*	Insufficient data	2007

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Methyl tertiary-butyl ether MTBE **CASRN** 1634044	Organic Non-halogenated aliphatic compounds Aliphatic ether	*No data*	10 000	2003	*No data*	5 000	2003

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

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Methylchlorophenoxyacetic acid (4-Chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid) MCPA **CASRN** 94746	Organic Pesticides	*No data*	2.6	1995	*No data*	4.2	1995
Methylmercury	Organic	*No data*	0.004	2003	*No data*	NRG	2003
Metolachlor **CASRN** 51218452	Organic Pesticides Organochlorine compounds	*No data*	7.8	1991	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Metribuzin **CASRN** 21087649	Organic Pesticides Triazine compounds	*No data*	1	1990	*No data*	*No data*	*No data*
Molybdenum	Inorganic	*No data*	73	1999	*No data*	*No data*	*No data*
Monobromomethane Methyl bromide	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Monochlorobenzene **CASRN** 108907	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	1.3	1997	*No data*	25	1997
Monochloromethane Methyl chloride	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Monochlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	7	1987	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Naphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	1.1	1999	*No data*	1.4	1999
Nickel	Inorganic	*No data*	Equation	1987	*No data*	*No data*	*No data*
Nitrate **CASRN** 14797-55-8	Inorganic Inorganic nitrogen compounds	550,000 µg/L or 550 mg/L	13,000 µg/L or 13 mg/L	2012	1,500,000 µg/L or 1500 mg/L	200,000 µg/L or 200 mg/L	2012

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Nitrite	Inorganic Inorganic nitrogen compounds	*No data*	60 NO_2-N	1987	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Nonylphenol and its ethoxylates **CASRN** 84852153	Organic Nonylphenol and its ethoxylates	*No data*	1	2002	*No data*	0.7	2002
Nutrients		*No data*	Guidance Framework	2004	*No data*	Guidance framework	2007
Pentachlorobenzene **CASRN** 608935	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	6	1997	*No data*	Insufficient data	1997
Pentachlorophenol PCP	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	0.5	1987	*No data*	*No data*	*No data*
Permethrin **CASRN** 52645531	Organic Pesticides Organochlorine compounds	*No data*	0.004	2006	*No data*	0.001	2006
Phenanthrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.4	1999	*No data*	Insufficient data	1999

Water Quality Guidelines for the Protection of Aquatic Life								
		Freshwater			Marine			
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Phenols (mono- & dihydric) **CASRN** 108952	Organic Aromatic hydroxy compounds	*No data*	4	1999	*No data*	*No data*	*No data*
Phenoxy herbicides 2,4 D; 2,4-Dichlorophenoxyacetic acid	Organic Pesticides	*No data*	4	1987	*No data*	*No data*	*No data*
Phosphorus	Inorganic	*No data*	Guidance Framework	2004	*No data*	Guidance Framework	2007
Picloram **CASRN** 1918021	Organic Pesticides	*No data*	29	1990	*No data*	*No data*	*No data*
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	*No data*	~~0.001~~	1987	*No data*	~~0.01~~	1991
Propylene glycol **CASRN** 57556	Organic Glycols	*No data*	500 000	1997	*No data*	Insufficient data	1997

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.025	1999	*No data*	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
pH	Inorganic Acidity, alkalinity and pH	*No data*	6.5 to 9.0	1987	*No data*	7.0 to 8.7 & Narrative	1996
Quinoline PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	3.4	1999	*No data*	Insufficient data	1999

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Reactive Chlorine Species total residual chlorine, combined residual chlorine, total available chlorine, hypochlorous acid, chloramine, combined available chlorine, free residual chlorine, free available chlorine, chlorine-produced oxidants	Inorganic Reactive chlorine compunds	*No data*	0.5	1999	*No data*	0.5	1999
Salinity	Physical	*No data*	*No data*	*No data*	*No data*	Narrative	1996
Selenium	Inorganic	*No data*	1	1987	*No data*	*No data*	*No data*
Silver	Inorganic	*No data*	0.1	1987	*No data*	*No data*	*No data*
Simazine **CASRN** 122349	Organic Pesticides Triazine compounds	*No data*	10	1991	*No data*	No data	*No data*
		Concentration	Concentration	Date	Concentration	Concentration	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Sodium adsorption ratio SAR		*No data*	*No data*	*No data*	*No data*	*No data*	*No data*
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	**Chemical groups**	**Short Term**	**Long Term**		**Short Term**	**Long Term**	
Chemical name	**Chemical groups**	**Short Term**	**Long Term**		**Short Term**	**Long Term**	
Streambed substrate	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Styrene **CASRN** 100425	Organic Monocyclic aromatic compounds	*No data*	72	1999	*No data*	*No data*	*No data*
Sulfolane Bondelane **CASRN** 126330	Organic Organic sulphur compound	*No data*	50 000	2005	*No data*	Insufficient data	2005
Suspended sediments TSS	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Tebuthiuron **CASRN** 34014181	Organic Pesticides	*No data*	1.6	1995	*No data*	Insufficient data	1995

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Temperature	Physical Temperature	*No data*	Narrative	1987	*No data*	Narrative	1996
Tetrachloromethane Carbon tetrachloride **CASRN** 56235	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	13.3	1992	*No data*	Insufficient data	1992
Tetrachlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	1	1987	*No data*	*No data*	*No data*
Thallium	Inorganic	*No data*	0.8	1999	*No data*	*No data*	*No data*
Toluene **CASRN** 108883	Organic Monocyclic aromatic compounds	*No data*	2	1996	*No data*	215	1996
Toxaphene	Organic Pesticides Organochlorine compounds	*No data*	~~0.008~~	1987	*No data*	*No data*	*No data*
Triallate **CASRN** 2303175	Organic Pesticides Carbamate pesticides	*No data*	0.24	1992	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Tribromomethane Bromoform	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Tributyltin	Organic Organotin compounds	*No data*	0.008	1992	*No data*	0.001	1992
Trichlorfon **CASRN** 52-68-6		1.1	0.009	2012	NRG	NRG	2012
Trichloromethane Chloroform **CASRN** 67663	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	1.8	1992	*No data*	Insufficient data	1992
Trichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	18	1987	*No data*	*No data*	*No data*
Tricyclohexyltin	Organic Organotin compounds	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992

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

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Trifluralin **CASRN** 1582098	Organic Pesticides Dinitroaniline pesticides	*No data*	0.2	1993	*No data*	*No data*	*No data*
Triphenyltin	Organic Organotin compounds	*No data*	0.022	1992	*No data*	*No data*	1992
Turbidity	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Uranium **CASRN** 7440-61-1	Inorganic	33	15	2011	NRG	NRG	2011
Zinc	Inorganic	*No data*	30	1987	*No data*	*No data*	*No data*

Chemical name	Chemical groups
Chemical name	Chemical groups
Sodium adsorption ratio SAR	

APPENDIX B

CEQG Sediment Quality Guidelines

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Canadian Council of Ministers of the Environment

CCME

Le Conseil canadien des ministres de l'environnement

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

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

Anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	46.9	245	1998	46.9	245	1998
Aroclor 1254 PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	60	340	2001	63.3	709	2001
Arsenic **CASRN** none	Inorganic Metals	5900	17 000	1998	7240	41 600	1998
Benz(a)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	31.7	385	1998	74.8	693	1998
Benzo(a)pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	31.9	782	1998	88.8	763	1998
Beryllium	Inorganic Metals	No data	No data	2015-02-23	No data	No data	2015-02-23
Cadmium **CASRN** 7440439	Inorganic Metals	600	3500	1997	700	4200	1997
Chlordane	Organic Pesticides Organochlorine	4.5	8.87	1998	2.26	4.79	1998

	compounds						
Chromium (total) **CASRN** 7440-47-3	Inorganic Metals	37 300	90 000	1998	52 300	160 000	1998
Chrysene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	57.1	862	1998	108	846	1998
Copper	Inorganic Metals	35 700	197 000	1998	18 700	108 000	1998
Dibenz(a,h)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	6.22	135	1998	6.22	135	1998
Dichloro diphenyl dichloroethane, 2,2-Bis (p-chlorophenyl)-1,1-dichloroethane DDD	Organic Pesticides Organochlorine compounds	3.54	8.51	1998	1.22	7.81	1998
Dichloro diphenyl ethylene, 1,1-Dichloro-2,2-bis(p-chlorophenyl)-ethene DDE	Organic Pesticides Organochlorine compounds	1.42	6.75	1998	2.07	374	1998
Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane DDT (total)	Organic Pesticides Organochlorine compounds	1.19	4.77	1998	1.19	4.77	1998
Dieldrin	Organic Pesticides Organochlorine compounds	2.85	6.67	1998	0.71	4.3	1998

Endrin	Organic Pesticides Organochlorine compounds	2.67	62.4	1998	2.67	62.4	1998
Fluoranthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	111	2355	1998	113	1494	1998
Fluorene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	21.2	144	1998	21.2	144	1998
Heptachlor Heptachlor epoxide	Organic Pesticides Organochlorine compounds	0.6	2.74	1998	0.6	2.74	1998
Hexachlorocyclohexane Lindane	Organic Pesticides Organochlorine compounds	0.94	1.38	1998	0.32	0.99	1998
Lead	Inorganic Metals	35 000	91 300	1998	30 200	112 000	1998
Mercury **CASRN** 7439976	Inorganic Metals	170	486	1997	130	700	1997
Naphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic	34.6	391	1998	34.6	391	1998

	hydrocarbons						
Nonylphenol and its ethoxylates **CASRN** 84852153	Organic Nonylphenol and its ethoxylates	1400	*No data*	2002	1000	*No data*	2002
Phenanthrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	41.9	515	1998	86.7	544	1998
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	34.1	277	2001	21.5	189	2001
Polychlorinated dibenzo-p-dioxins/dibenzo furans PCDDs, PCDFs	Organic Polyaromatic compounds Polychlorinated dioxins and furans	0.85 ng TEQ/kg dry weight	21.5 ng TEQ/kg dry weight	2001	0.85 ng TEQ/kg dry weight	21.5 ng TEQ/kg dry weight	2001
Pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	53	875	1998	153	1398	1998
Sodium adsorption ratio SAR		*No data*	*No data*	*No data*	*No data*	*No data*	*No data*
		Concentration (µg/kg dry weight)	**Concentration (µg/kg dry weight)**	**Date**	**Concentration (µg/kg dry weight)**	**Concentration (µg/kg dry weight)**	**Date**
Chemical name	**Chemical groups**	**ISQG**	**PEL**		**ISQG**	**PEL**	
	Organic						

Toxaphene	Pesticides Organochlorine compounds	0.1	No PEL derived	2002	0.1	No PEL derived	2002
Zinc	Inorganic Metals	123 000	315 000	1998	124 000	271 000	1998

Chemical name	Chemical groups
Sodium adsorption ratio SAR	

APPENDIX C

2016 Field Sampling Daily Progress Reports (McGregor)

Daily Survey Report

M/V Atlantic Condor
e-Mail gforbes@mcgregor-geoscience.com
Irridium Tel. (011) 88177702324
FBB Tel. 881-677-702-323
V-Sat (902) 702-5470
(902)-702-5471

McGregor GeoScience Limited
Project No. 1113

To: McGregor GeoScience Ltd.

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Project No. 1113 Report No. 001 Date : March 06, 2016

Encana Deep Panuke EEMP - 2015
Daily Progress Report

Location at 24:00 Local AST time: At dock - Pier 9 - Halifax

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600						
1200						
1800						
2400						

Forecast: Seas 1-3m, 8-10kts wind

Event Diary in UTC (Local Time - AST +4hr to UTC)):

	From	To	Description of Events	Code
	13:00	14:00	Loading gear and personal gear at MGS warehouse	md
	14:00	16:00	Ops meeting and HSE orientation at MGS offices	md
	16:00	16:45	Transfer oif personnel Bedford to Richmond Terminal Pier 9	md
	16:45	20:30	Arrived on site - vessel induction, loaded and set up gear - wet tested CTD	md
	20:30	23:59	Vessel drills, Crew remains on Atlantic Condor - waiting for departure	op2

Time Summary (hh:mm):

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	07:30	007:30
Transit	tr	Transit	00:00	000:00
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				
Operational	op1	Data Acq.	00:00	000:00
	op2	Standby	03:29	003:29
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	000:00
Chargeable Subtotal				
Disputed Time	dd	Downtime	00:00	000:00
	do	Other	00:00	000:00
Re-Runs	rr1	McGregor Eq.	00:00	000:00
Breakdown	be1	McGregor Eq.	00:00	000:00
	bv	Vessel	00:00	000:00
Standby	sb1		00:00	000:00
Non-Chargable Subtotal				
TOTAL			10:59	10:59

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	00	0		0
Project Total	**00**	**0**		**0**

Personnel Onboard:	Total Man Days	No. On/Off Today
McGregor:	2	2/0
Sub-Contract:	5	5/0
Client:	0	0/0
Ship:	15	15/0
Other Reps - ROV crew:	3	3/0

Safety:	Today	Cumulative
Drills :	1	1
Incidents :	0	0
Vessel Induction :	7	7
Toolbox/Safety Mtg. :	0	0

Comment
Vessel induction done for McGregor crew members.
Abandon ship vessel drill conducted.
Additionally, McGregor crew went through putting on survival suits.

Proposed Work for next 24 hours:
Transit to site, ship to load cargo on to PFC.
Start fishing at PFC station

	Seabed Sampling: VV		Water Column: CTD	Niskin Cast
Today	0		00	00
Cumulative	**0**		0	0

Party Chief Comments:

a) All gear on board and secured.
b) Fishing gear ready to go for when on site. Crew will be ready to go a few hours before starting sampling.
c) CTD wet test conducted at dock - working well.

Daily Survey Report

M/V Atlantic Condor		**McGregor GeoScience Limited**	
e-Mail	gforbes@mcgregor-geoscience.com	**Project No.**	1113
Irridium Tel.	(011) 88177702324		
FBB Tel.	881-677-702-323		
V-Sat	(902) 702-5470		
	(902)-702-5471		

To:	McGregor GeoScience Ltd.	Attn: Rick Hunter		e-Mail	rhunter@mcgregor-geoscience.com
		Attn: Tim Ryan		e-Mail	tryan@mcgregor-geoscience.com
		Attn: Marielle Thillet		e-Mail	marielle.thillet@encana.com
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Project No.	1113	Report No.	002	Date :	March 07, 2016 — Page 1 of 2

Encana Deep Panuke EEMP - 2015
Daily Progress Report

Location at 24:00 UTC: N 43º 48' 48.0", W 060° 41' 11.9"

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600	1024	Lt airs	3	-1.0		7.0
1200	1025	Lt airs	3	1.0		8.0
1800	1026	ESE/4-6	3	0.0		8
2400						

Forecast: Wind SW 10-15kts, veeering NW Tuesday morning, seas 1m.

Event Diary in UTC (Local Time AST +4hr to UTC)):

	From	To	Description of Events	Code
	00:00	05:10	At dock, waiting for departure	op2
	05:10	19:00	Transit to site	tr
	19:00	20:45	Alantic Towing Cargo loading	op2
	21:20	22:00	Tool box meeting to discuss shift operations	op1
	22:20	22:40	CTD set up	op1
	22:40	23:59	Fishing	op1

Time Summary (hh:mm): March 07, 2016 Page 2 of 2

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	007:30
Transit	tr	Transit	13:50	013:50
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	02:19	002:19
	op2	Standby	06:55	010:24
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	000:00
Chargeable Subtotal				000:00
Disputed Time	dd	Downtime	00:00	000:00
	do	Other	00:00	000:00
Re-Runs	rr1	McGregor Eq.	00:00	000:00
Breakdown	be1	McGregor Eq.	00:00	000:00
	bv	Vessel	00:00	000:00
Standby	sb1		00:00	000:00
Non-Chargable Subtotal				
TOTAL			23:04	34:03

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	00	0		0
Project Total	**00**	**0**		**0**

Personnel Onboard:

	Total Man Days	No. On/Off Today
McGregor:	4	0/0
Sub-Contract:	10	0/0
Client:	0	0/0
Ship:	30	0/0
Other Reps - ROV crew:	6	0/0

Safety:

	Today	Cumulative
Drills :	0	1
Incidents :	0	0
Vessel Induction :	0	7
Toolbox/Safety Mtg. :	2	2

Comment

Tool box and JSA done for CTD and fishing

Proposed Work for next 24 hours:

Start grabs and if finished before early morning, start fishing again.
Mussel sampling to be done after 7am local time
Fish again after mussel sampling

	Seabed Sampling: VV		Water Column: CTD	Niskin Cast
Today	0		01	00
Cumulative	**0**		1	0

Party Chief Comments:

a) fishing started early evening for a few hours, fish not biting in area, decision made to switch to sediment samples at 23:59 UTC. Will try again early tomorrow morning.
b) CTD cast done at fishing station, instrument working well.

Daily Survey Report

M/V Atlantic Condor		**McGregor GeoScience Limited**	
e-Mail	gforbes@mcgregor-geoscience.com	**Project No.**	1113
Irridium Tel.	(011) 88177702324		
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	(902)-702-5471		

To: McGregor GeoScience Ltd.	Attn: Rick Hunter		e-Mail	rhunter@mcgregor-geoscience.com
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Project No. 1113	Report No. 003	Date :	March 08, 2016	Page 1 of 2

Encana Deep Panuke EEMP - 2015
Daily Progress Report

Location at 24:00 UTC: N43°48'48.0" W060°41'11.9"

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600	1016	NW/7-10 kts	2	0.0		7.0
1200	1015	NNW/17-21kts	4	5.0		7.0
1800	1018	N/17-21kts	4	4.0		7
2400	1021	N/28-33kts	4	0.0		7.0

Forecast: Wind northwest 20 knots veering to north 10 to 15 near midnight then diminishing to light early Wednesday morning. Wind increasing to south 15 Wednesday afternoon and to southwest 25 early Wednesday evening. 1-2m seas. Chance of showers Wednesday afternoon and evening.

Event Diary in UTC (Local Time AST +4hr to UTC)):

From	To	Description of Events	Code
00:00	00:15	Cleaning up deck from fishing to start grabs	op1
00:15	01:06	Set up for grab samples	op1
01:06	01:18	Sediment sample #1 250 Meters Downstream Mark #007 0685729E 4853518N 47m WD	op1
01:18	01:57	Sediment sample #1B 250 Meters Downstream Mark #008 0685731E 4853510N 47m WD	op1
01:57	02:35	Sediment sample #2 500 Meters Downstream Mark #009 0685655E 4853225N 46m WD	op1
02:35	03:20	Sediment sample #3 1000 Meters Downstream Mark #010 0685219E 4852959N 42m WD	op1
03:20	04:10	Sediment sample #4 2000 Meters Downstream Mark #011 0684489E 4852283N 40m WD	op1
04:10	04:26	Toolbox with MGS/ship/deck crew on bridge	op1
04:26	05:28	Sediment sample #5 5000 Meters Downstream Mark #012 0682333E 4850162N 37m WD	op1
05:28	06:05	Sediment sample #6 5000 Meters Upstream Mark #013 0689460E 4857167N 38m WD	op1
06:05	06:10	Setting up for fishing	op1
06:10	08:58	Fishing - strong currents	op1
08:58	10:00	Stop fishing - VSL moving to platform for ROV/mussel recovery	op1
10:00	11:05	VSL in position at platform 500m zone - resume fishing	op1
11:05	11:36	Stop fishing for vessel move into platform	op1
11:36	12:17	VSL alongside platform, ROV in water	op1
12:17	12:25	ROV coming back on deck with mussels	op1
12:25	12:50	Mussel collection toolbox	op1
12:50	13:10	Vessel moving away from platform	op1
13:10	14:26	Resume fishing	op1
14:26	15:27	Fishing Fix - Mark #14 0685589E 4853236N	op1
15:27	16:00	1st fish caught	op1
16:00	16:05	Toolbox with MGS crew - shift change	op1
16:05	16:13	Toolbox with MGS / KDR crew - CTD cast	op1
16:13	16:26	ctd cast at fishing station	op1
16:26	18:36	Resume fishing 0685589E 4853236N	op1
18:36	19:17	Arrived at new position. Resume fishing. Water depth 40m	op1
19:17	23:25	Fishing halted. Heading to rock pile location to continue fishing.	op1
23:25	23:59	On fishing location: 0679457E 4854932N. Fishing resumes.	op1
23:59		Arrived at new position. Resume fishing. Water depth 40m	

Time Summary (hh:mm): March 08, 2016 Page 2 of 2

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	007:30
Transit	tr	Transit	00:00	013:50
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	23:59	026:18
	op2	Standby	00:00	010:24
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	000:00
Chargeable Subtotal				000:00
Disputed Time	dd	Downtime	00:00	000:00
	do	Other	00:00	000:00
Re-Runs	rr1	McGregor Eq.	00:00	000:00
Breakdown	be1	McGregor Eq.	00:00	000:00
	bv	Vessel	00:00	000:00
Standby	sb1		00:00	000:00
Non-Chargable Subtotal				

TOTAL			23:59	58:02

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	Grab	6 sediment		6
	Mussel	1 station		1
	CTD	1 station		2
Project Total		**8**		**9**

Personnel Onboard:	**Total Man Days**	**No. On/Off Today**
McGregor:	9	0/0
Sub-Contract:	3	0/0
Client:	0	0/0
Ship:	33	0/0
Other Reps - ROV crew:	9	0/0

Safety:	**Today**	**Cumulative**
Drills :	0	1
Incidents :	0	0
Vessel Induction :	0	7
Toolbox/Safety Mtg. :	2	4

Comment
Have to watch bait bag and make sure it is pulled in and confirmed before ship transits to new fishing locations

Proposed Work for next 24 hours:
Continue fishing near PFC and reference stations - trying a few sites (eg. Near pipeline and a shallower area) to see if any fish are there
Pick up 5000m ctd station
ROV crew to do work at H-08 from 7am on. Fish around H-08 after or before ROV esp. if they see fish on video

	Seabed Sampling: VV		Water Column: CTD	Niskin Cast
Today	6		01	00
Cumulative	**6**		2	0

Party Chief Comments:

a) One fish caught (cod) at station near PFC. Necropsy done.
b) Fishing is not looking promising due to time of year, but we are trying different locations and will continue fishing at all times permitted (work around ROV schedule)

Daily Survey Report

M/V Atlantic Condor		**McGregor GeoScience Limited**	
e-Mail	gforbes@mcgregor-geoscience.com	**Project No.**	1113
Irridium Tel.	(011) 88177702324		
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	(902)-702-5471		

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Project No.	1113	Report No.	004	Date :	March 09, 2016 Page 1 of 2

Encana Deep Panuke EEMP - 2016
Daily Progress Report

Location at 24:00 UTC time: 0682433E, 4851672N

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600	1024	N/7-10kts	4	-1.0		7.0
1200	1026	SSW/11-16kts	4			7.0
1800	1020	SW/11-16 kts	4	4.0		7
2400	SW	SW/28-33 kts	4	7.0		7.0

Forecast: Wind southwest 20 knots increasing to southwest 30 early this evening then diminishing to west 15 to 20 near noon Thursday. Wind diminishing to variable 10 to 15 Thursday evening. Seas 1 to 2 metres building to 2 to 3 this evening and to 3 to 4 after midnight. Seas subsiding to 2 to 3 Thursday afternoon and to 1 to 2 Thursday evening.

Event Diary in UTC (Local Time AST +4hr to UTC)):

	From	To	Description of Events	Code
		00:00	On fishing location: 0679457E 4854932N. Fishing resumes. Water depth 57m	
	00:00	02:00	Fishing paused as bridge adjusting vessel heading	op1
	02:00	02:30	Fishing resumed	op1
	02:30	03:00	Fishing halted. Moving to next location.	op1
	03:00	04:00	Shift Change	op1
	04:00	07:19	On location for fishing WD~37m, Mark #18 683945E 4857017N	op1
	07:19	08:00	VSL moving to 5000m upstream location for CTD and fishing	op1
	08:00	08:15	VSL on location, 5000m upstream, Mark #19 689279E 4857251N	op1
	08:15	08:30	CTD in water Mark #20 689483E 4857191N WD 36m	op1
	08:30	8:35	CTD finished - 018613_20160309_0823_5000UP_fish.xls	op1
	8:35	09:30	VSL heading to well for ROV work	op2
	09:30	10:00	VSL at well location for ROV work	op2
	10:00	10:52	Resuming fishing at well location, Mark #21 680706E 4850969N	op1
	10:52	15:45	Recovering fishing gear for ROV launch	op1
	15:45	16:10	Toolbox Meeting - shift change	op1
	16:10	16:20	ROV recovered onboard.	op2
	16:20	16:45	FRC launched for equipment transfer.	op2
	16:45	16:50	FRC recovered onboard.	op2
	16:50	16:55	Toolbox Meeting - fishing operations.	op1
	16:55	18:11	Fishing operations at well location, 0680593E, 4850932N. Water depth 37m	op1
	18:11	18:45	Fishing halted. Moving to next location.	op1
	18:45	19:54	Fishing resumes. Location 0681075E 4851080N. Water depth 37m	op1
	19:54	20:13	Fishing halted. Moving to next location.	op1
	20:13	21:16	Fishing resumes. Location 0681531E, 4851274N.	op1
	21:16	21:50	Fishing halted. Moving to next location.	op1
	21:50	23:00	Fishing resumes. Location 0681979E 4851436N.	op1
	23:00	23:25	Fishing halted. Moving to next location. (caught a Sea cucumber)	op1
	23:25	23:59	Fishing resumes. Location 0682433E, 4851672N. Water depth 39m	op1
	23:59	24:00	Fishing continued. Location 0682433E, 4851672N	op1

Time Summary (hh:mm): March 09, 2016 Page 2 of 2

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	007:30
Transit	tr	Transit	00:00	013:50
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	21:55	048:13
	op2	Standby	02:05	012:29
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	000:00
Chargeable Subtotal				000:00
Disputed Time	dd	Downtime	00:00	000:00
	do	Other	00:00	000:00
Re-Runs	rr1	McGregor Eq.	00:00	000:00
Breakdown	be1	McGregor Eq.	00:00	000:00
	bv	Vessel	00:00	000:00
Standby	sb1		00:00	000:00
Non-Chargable Subtotal				
TOTAL			24:00	82:02

Survey Progress

	# Stations	Daily Total # Stations	Cumulative to Date Stations

Survey Station	Grab	0		6
	Mussel	0		1
	Water	0		0
	CTD	0		2
Project Total				**9**

Personnel Onboard:	Total Man Days	No. On/Off Today
McGregor:	8	3/0
Sub-Contract:	20	1/0
Client:	0	0/0
Ship:	60	11/0
Other Reps - ROV crew:	12	3/0

Safety:	Today	Cumulative
Drills :	0	1
Incidents :	0	0
Vessel Induction :	0	7
Toolbox/Safety Mtg. :	2	6

Comment
Tool box meetings held for fishing - MGS crew.

Proposed Work for next 24 hours:
Continue fishing. Working our way into the PFC area along the H-08 flowline (hoping the structure may have fish around it) at 500m intervals. Fishing for 1 hour at each station. - continue fishing through night around PFC and work out another flowline.
ROV ops (non-environmental work) happening in the morning, Encana rep to come on board, provided good weather. If weather is too poor for ROV ops, we will continue fishing.

	Seabed Sampling: VV		**Water Column:** CTD	Niskin Cast
Today	0		00	
Cumulative	**6**		2	

Party Chief Comments:
a) Fishing continues around ROV operations. Picking stations in various areas, looking for shallower water. Also fishing around structures.
b) Attempted fishing at H-08 WHPS after ROV cleaning, hoping that marine growth cleaned from WHPS wouls attract fish although no fish observed in ROV video.
c) Following flowlines and fishing for one hour at 500m intervals. No evidence that fish are eating bait, but not getting caught.
d) Using bait bag and chumming at each station.

Daily Survey Report

M/V Atlantic Condor **McGregor GeoScience Limited**

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Project No. 1113

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Project No. 1113 Report No. 005 Date : March 10, 2016

Encana Deep Panuke EEMP - 2016
Daily Progress Report

Location at 24:00 UTC time: 0686024E 4853635N.

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600	1010	SW/W/22-27kts	6	7.0		7.0
1200	1015	NW/N/17-21kts	5	6.0		7.0
1800	1019	NNE/17-21kts	5	2.0		7
2400	1018	Easterly/17-21kts	4	2.0		7.0

Forecast: Wind northwest 10 to 15 kts, increasing to NE 15-20 near midnight (AST), then backing to N Friday afternoon. Seas 2m. Temp 0°C. Possibly snow at midnight, flurries Friday.

Event Diary in UTC (Local Time AST +4hr to UTC)):

From	To	Description of Events	Code
	00:00	Fishing continued. Location 0682433E, 4851672N	
00:00	00:24	Fishing halted, Moving to new location	op1
00:24	00:54	Fishing resumed. Location 0682897E, 4851855N. Water depth 40m.	op1
00:54	01:56	Fishing halted, Moving to new location	op1
01:56	02:24	Fishing resumed. Location 0683363E, 4852075N. Water depth 40m.	op1
02:24	03:34	Fishing halted, Moving to new location	op1
03:34	03:45	Toolbox Meeting / Shift change	op1
03:45	04:10	Resume fishing Mark #30 683833E 4852248N	op1
04:10	05:28	Fishing halted, Moving to new location	op1
05:28	5:55	Resume fishing Mark #31 684294E 4852431N	op1
5:55	07:32	Fishing halted, Moving to new location	op1
07:32	08:20	Resume fishing Mark #32 684722E 4852679N	op1
08:20	09:49	Fishing halted, Moving to new location	op1
09:49	10:42	Resume fishing Mark #33 685131E 4852995N	op1
10:42	12:11	Fishing halted, Moving to new location	op1
12:11	13:23	Resume fishing Mark #34 691207E 4856352N	op1
13:23	15:30	Fishing halted, Moving to new location	op1
15:30	15:45	Toolbox Meeting / Shift change	op1
15:45	16:00	Resume fishing Mark #35 0690762E 4856120N. Water depth 45m.	op1
16:00	16:42	Fishing paused D/T vessel changing heading	op1
16:42	16:51	Resume fishing. Same location Mark #35.	op1
16:51	17:10	Fishing halted, Moving to new location	op1
17:10	17:34	Resume fishing Mark #36 0690313E, 4855912N. Water depth 45m.	op1
17:34	18:14	Fishing halted, Moving to new location	op1
18:14	19:55	Resume fishing at PFC, Mark #37. 068608E, 4853645N. Water depth 46m.	op1
19:55	21:10	Sculpin caught.	op1
21:10	23:15	Fishing lines in for CTD cast (fish caught at this location).	op1
23:15	23:18	Toolbox meeting	op1
23:18	23:21	CTD fix position 0686024E 4853635N.	op1
23:21	23:58	CTD in water	op1
23:58	0:00	CTD on deck - bad data	op1
24:00		Troubleshooting CTD	op1

Time Summary (hh:mm): March 10, 2016

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	007:30
Transit	tr	Transit	00:00	013:50
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	24:00	072:12
	op2	Standby	00:00	012:29
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	000:00
Chargeable Subtotal				000:00
Disputed Time	dd	Downtime	00:00	000:00
	do	Other	00:00	000:00
Re-Runs	rr1	McGregor Eq.	00:00	000:00
Breakdown	be1	McGregor Eq.	00:00	000:00
	bv	Vessel	00:00	000:00
Standby	sb1		00:00	000:00
Non-Chargable Subtotal				
TOTAL			24:00	106:01

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations	
Survey Station	Grab	0		6	
	Mussel	0		1	
	Water	0		0	
	CTD	1		3	
	#fish	1		2	2 fish caught total
Project Total				**9**	

Personnel Onboard:	**Total Man Days**	**No. On/Off Today**
McGregor:	10	0/0
Sub-Contract:	25	0/0
Client:	0	0/0
Ship:	75	0/0
Other Reps - ROV crew:	15	0/0

Safety:	**Today**	**Cumulative**
Drills :	0	1
Incidents :	0	0
Vessel Induction :	0	7
Toolbox/Safety Mtg. :	3	9

Comment
Crew doing fishing tool box talks

Proposed Work for next 24 hours:
Continue fishing around ROV work. Fishing near PFC if possible, and trying D-41 flowline and WHPS.
Get water sampling equipment ready and go over procedures with crew so we are ready to water sample.
Will run a morning and afternoon tutorial and go over JSA and procedures with each shift while ROV work is happening, so we are prepared when the water sampling is to happen.

	Seabed Sampling: VV		**Water Column:** CTD	Niskin Cast
Today	0		00	
Cumulative	**6**		3	

Party Chief Comments:

a) ROV work not happening today, due to weather being beyond ROV limits.
b) Finished working our way fishing along the H-08 flowline, started working along the D-41 flowline to the WHPS on the other side - have not fished a lot over there yet.
c) One fish bite along the the H-08 flowline, but nothing caught.
d) One sculpin caught near PFC over structures - spent a lot of the day fishing over structures close to the PFC
e) Many sea cucumbers caught

Daily Survey Report

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Project No. 1113 Report No. 006 Date : March 11, 2016 Page 1 of 2

Encana Deep Panuke EEMP - 2016
Daily Progress Report

Location at 24:00 UTC time: 0686114E, 4853553N -

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600	1013	E/17-21 kts	4	1.0		6.0
1200	1010	NE/17-21kts	4	1.0		4.0
1800	1015	N/22-27kts	5	0.0		7
2400	1018	NNW/22-27kts	5	-1.0		7.0

Forecast: Wind northwest 20 to 25 knots diminishing to northwest 15 early Saturday morning then backing to southwest 15 Saturday afternoon. Wind increasing to southwest 20 to 25 early Saturday evening. Seas 1 to 2 metres building to 2 to 3 Saturday evening. Temperatures near plus 1.

Event Diary in UTC (Local Time AST +4hr to UTC)):

	From	To	Description of Events	Code
	00:00	00:20	Troubleshooting CTD	op1
	00:20	00:23	CTD in water	op1
	00:23	00:24	CTD on deck	op1
	00:24	00:45	Troubleshooting CTD	op1
	00:45	01:04	Changed batteries in CTD	op1
	01:04	01:08	CTD in water	op1
	01:08	01:50	CTD on deck.	op1
			File recorded 018613_20160311_0110.xls	
	01:50	3:45	Resume Fishing. Mark #41 0685914E, 4853529N. Water depth 45m	op1
	03:45	04:07	Toolbox Meeting / Shift Change	op1
	04:07	11:45	Resume fishing	op1
	11:45	14:15	Halt fishing for personnel transfer from PFC / ROV ops	op2
	14:15	15:45	Niskin sampling toolbox / training (ROV ops still going on)	op1
	15:45	17:00	Toolbox Meeting / Shift Change (ROV ops still going on)	op1
	17:00	17:15	Niskin sampling toolbox / training (ROV ops still going on)	op1
	17:15	22:00	ROV ops continue, transfer rep to PFC and cargo ops	op2
	22:00	22:45	Cargo operations complete, moving to niskin location	op1
	22:45	23:00	Toolbox Meeting Water Sampling	op1
	23:00	23:35	On location 2000m US. Vessel adjusting azimuth.	op1
	23:35	24:00	Start water sample 2000m up stream 0686114E, 4853553N	op1
			WD 40m, mark #42	
	24:00		midnight position 0686114E, 4853553N	

Time Summary (hh:mm): March 11, 2016 Page 2 of 2

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	007:30
Transit	tr	Transit	00:00	013:50
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	16:45	088:57
	op2	Standby	07:15	019:44
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	000:00
Chargeable Subtotal				000:00
Disputed Time	dd	Downtime	00:00	000:00
	do	Other	00:00	000:00
Re-Runs	rr1	McGregor Eq.	00:00	000:00
Breakdown	be1	McGregor Eq.	00:00	000:00
	bv	Vessel	00:00	000:00
Standby	sb1		00:00	000:00
Non-Chargable Subtotal				
TOTAL			24:00	130:01

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	Grab	0		6
	Mussel	0		1
	Water	1		1
	CTD	1		4
	#fish	0		2
Project Total				**14**

Personnel Onboard:	**Total Man Days**	**No. On/Off Today**	
McGregor:	12	0/0	
Sub-Contract:	30	0/0	
Client:	1	1/1	Rep from platform onboard for ROV ops, returned to PFC
Ship:	90	0/0	
Other Reps - ROV crew:	18	0/0	

Safety:	**Today**	**Cumulative**
Drills :	0	1
Incidents :	0	0
Vessel Induction :	0	7
Toolbox/Safety Mtg. :	3	12

Comment
Did two (one for each shift) toolbox/niskin water sampling orientations, preparing for water sampling later in the day.

Proposed Work for next 24 hours:
Continue water sampling. Should be done by early morning if no problems arise.
Load cargo at PFC and receive produced water samples
Tidy deck equipment and prepare for transit and de-mob of McGregor equipment.
Ensure digital logs are completed and backed up.

	Seabed Sampling:		**Water Column:**	
	VV		CTD	Niskin Cast
Today	0		01	01
Cumulative	**6**		4	1

Party Chief Comments:
a) Messenger dropped in water on first niskin cast - was not hooking on to cable properly.
b) Bottom niskin did not trigger on first cast, re-did bottom sample cast.
c) 2000m upstream water station completed
d) Had originally planned to do upstream stations first then work out from the 20m station at the PFC, will do upstream stations then go to 2000 downstream to start, as mate is not comfortable or allowed to be that close to the platform, it must be the Captain. We will work our way in from the 2000m in order, and the Captain will be on at midnight AST and will do the stations close to the PFC.

Daily Survey Report

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Project No. 1113

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Project No. 1113 Report No. 007 Date : March 12, 2016

Encana Deep Panuke EEMP - 2016
Daily Progress Report

Location at 24:00 UTC time: In transit to Halifax -

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600	1021	NNW/5	5	1.0		7.0
1200	1022	NW/4	4	4.0		8.0
1800	1015	WNW/4	4	3.0		7
2400						

Forecast:
SW 25-30kts. 1-2m seas, building to 2-3 this evening. A few flurries or showers, temperatures near zero.

Event Diary in UTC (Local Time AST +4hr to UTC)):

From	To	Description of Events	Code
00:00	00:10	Niskin bottles on deck	op1
00:10	00:15	ctd in water	op1
00:15	00:18	CTD on deck. File saved 018613_20160312_0022_2000m_up.xls	op1
00:18	01:02	Moving to 250mtr US	op1
01:02	01:10	vessel on location 250m up WD 48mtr vessel adjusting Azimuth	op1
01:10	01:18	Start deploying Niskin bottles MK #43 0685843N, 4853437E	op1
01:18	01:23	niskin bottles deployed	op1
01:23	01:30	all niskin samples on deck	op1
01:30	01:33	CTD in water	op1
01:33	01:44	CTD on deck. No data	op1
01:44	01:50	CTD in water	op1
01:50	01:55	CTD on deck. File saved 018613_20160312_250_up.xls	op1
01:55	02:40	Vessel moving to 2000m DS location.	op1
02:40	02:49	Vessel on location 2000mtrs DS WD 47Mtrs Heading 347	op1
02:49	02:53	All niskin bottles in water. Mk 45 0687560 4854915	op1
02:53	02:59	Niskin samples on deck	op1
02:59	03:04	CTD in water	op1
03:04	03:08	CTD on deck. File saved 018613_20160312_0306_2000m_DS.xls	op1
03:08	03:45	Heading to 1000mtrs DS location	op1
03:45	04:13	Toolbox Meeting / Shift change	op1
04:13	04:25	Shift change	op1
04:25	04:33	VSL ON LOCATION 1000ds WD 45M 686790E 4853201N	op1
04:33	04:40	Niskin bottles in water 5m 22m 42m	op1
04:40	04:43	Niskin bottles on deck	op1
04:43	04:45	ctd in water	op1
04:45	05:38	ctd on deck	op1
05:38	05:47	heading to 500m DS	op1
05:47	05:53	vsl on location 500DS 44m wd 686079E 4853164N MK47	op1
05:53	06:02	ALL Niskin bottles in water 5/22/41	op1
06:02	06:04	all Niskin bottles on deck	op1
06:04	06:06	ctd in water	op1
06:06	06:35	ctd on deck	op1
06:35	06:44	vessel heading to site 250m DS	op1
06:44	06:49	vsl on location 250m DS 685906E 4853394N wd 46m mk48	op1
06:49	06:55	all niskin bottles in water 5/23/43	op1
06:55	06:59	all Niskin bottles on deck	op1
06:59	07:00	ctd in water	op1
07:00	07:53	ctd on deck	op1
07:53	08:05	heading to 20m DS	op1
08:05	08:09	vsl in position 20m DS wd 46m 685860E 4853605N mk49	op1
08:09	08:13	all niskin bottles in water	op1
08:13	08:21	all niskin bottles on deck	op1
08:21	08:26	ctd in water	op1
08:26	08:27	ctd on deck	op1
08:27	13:45	Standby for cargo ops	op2
13:45	14:55	Going into PFC for cargo ops	op2
14:55	15:15	finished cargo ops - waiting for clearance to leave from PFC, because of gas alarm on PFC	op2

	15:15	18:15	Leaving PFC area - transit to Halifax - MGS crew to clean and pack during transi	op1
	18:15	0:00	finished cleaning and packing - transit continues	tr

Time Summary (hh:mm): March 12, 2016

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	007:30
Transit	tr	Transit	05:45	019:35
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	10:43	099:40
	op2	Standby	06:48	026:32
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	000:00
Chargeable Subtotal				000:00
Disputed Time	dd	Downtime	00:00	000:00
	do	Other	00:00	000:00
Re-Runs	rr1	McGregor Eq.	00:00	000:00
Breakdown	be1	McGregor Eq.	00:00	000:00
	bv	Vessel	00:00	000:00
Standby	sb1		00:00	000:00
Non-Chargable Subtotal				
TOTAL			23:16	153:17

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	Grab	0		6
	Mussel	0		1
	Water	6		7
	CTD	6		10
	#fish	0		2
Project Total				**14**

Personnel Onboard:	**Total Man Days**	**No. On/Off Today**
McGregor:	14	0/0
Sub-Contract:	35	0/0
Client:	1	0/0
Ship:	105	0/0
Other Reps - ROV crew:	21	0/0

Safety:	**Today**	**Cumulative**	**Comment**
Drills :	0	1	
Incidents :	0	0	
Vessel Induction :	0	7	
Toolbox/Safety Mtg. :	2	14	

Proposed Work for next 24 hours:
Transit to Halifax.
De-mobilize samples, personnel and personal gear.
Take gear to MGS warehouse in Bedford, unload and sub-sample produced water for Aquatox, take to airport

	Seabed Sampling: VV		**Water Column:** CTD	Niskin Cast
Today	0		06	06
Cumulative	**6**		10	7

Party Chief Comments:

a) Water sampling complete
b) Transit to Halifax where MGS crew will unload and take samples with them. Gear is packed, ready to be unloaded.
c) Remaining gear to be unloaded when vessel is offloaded

Daily Survey Report

M/V Atlantic Condor — **McGregor GeoScience Limited**

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Project No.	1113	Report No. 008	Date :	March 13, 2016

Encana Deep Panuke EEMP - 2016
Daily Progress Report

Location at 24:00 UTC time: Halifax Harboud - Pier 9 -

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600						
1200						
1800						
2400						

Forecast:
N/A

Event Diary in UTC (Local Time AST +4hr to UTC)):

	From	To	Description of Events	Code
	00:00	04:10	Transit to Halifax continues	tr
			04:10 UTC vessel alongside at Pier 9	
	04:10	08:00	Demobilize samples, crew, and personal gear, drop off sample to be shipped to Aquatox	md

Time Summary (hh:mm): March 13, 2016

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	03:50	011:20
Transit	tr	Transit	04:10	023:45
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	00:00	099:40
	op2	Standby	00:00	026:32
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	000:00
Chargeable Subtotal				000:00
Disputed Time	dd	Downtime	00:00	000:00
	do	Other	00:00	000:00
Re-Runs	rr1	McGregor Eq.	00:00	000:00
Breakdown	be1	McGregor Eq.	00:00	000:00

	bv	Vessel	00:00	000:00
Standby	sb1		00:00	000:00
Non-Chargable Subtotal				
TOTAL			08:00	161:17

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	Grab	0		6
	Mussel	0		1
	Water	0		7
	CTD	0		10
	#fish	0		2
Project Total				**14**

Personnel Onboard:	Total Man Days	No. On/Off Today
McGregor:	16	0/2
Sub-Contract:	40	0/5
Client:	1	0/0
Ship:	120	0/0
Other Reps - ROV crew:	24	0/0

Safety:	Today	Cumulative
Drills :	0	1
Incidents :	0	0
Vessel Induction :	0	7
Toolbox/Safety Mtg. :	0	14

Comment

Proposed Work for next 24 hours:

N/A

	Seabed Sampling: VV		**Water Column:** CTD	Niskin Cast
Today	0		00	00
Cumulative	**6**		10	7

Party Chief Comments:

a) Vessel alongside at 0410 (0010 AST). Unloaded samples with permission from Peter Taylor.
b) Will drop off remaining samples to appropriate labs on Monday, March 14.
c) Will pick up remaining gear at SBM on Monday

APPENDIX D

2016 Produced Water Toxicity Results (Microtox, Sea Urchin Fertilization and Threespine Stickleback Toxicity) (HITS)

FISH TOXICITY REPORT (LC$_{50}$)

Client: McGregor GeoScience Ltd.
Address: 177 Bluewater Road
Bedford, NS B4B 1H1
Contact: Gillian Forbes

Test Facility: Harris Industrial Testing Service Ltd.
Location: 1320 Ashdale Rd., South Rawdon, Nova Scotia
Canada B0N 1Z0
Ph : 902 757-0232 Fax: 902 757-2839 hits@eastlink.ca

SAMPLE DATA

Lab ID. # 16-113

Sample/Location: Deep Panuke PFC Produced Water (Stripper)
Sampling Method: Grab Sample Homogenized: Yes Sampler: B. Fraser
Date/Time Collected: Mar. 12 2016 0730 Hrs Received: Mar. 14 2016
Date/Time Started: Mar. 14 2016 1430 Hrs Completed: Mar. 18 2016 1430 Hrs
Sample Description: Greyish, opaque liquid which foams when poured and aerated. Mild petroleum odour present.

TEST INFORMATION

Reference Method:
EPS 1/RM/10 July 1990
with 2000 Amendments
Type: LC$_{50}$ Tox 9B
Test Organism: Threespine Stickleback

PRE-TEST PARAMETERS

Pre-test Temperature: 14.0 °C
Pre-test D.O.: 8.5 mg/L
Pre-test pH: 7.0 Adjusted: No
Conductivity of Sample: -- µS/cm
Salinity of Sample: 7 ppt
Salinity of Control: 31.1 ppt

Mandatory 30 minute pre-aeration:
Rate: 6.5 ± 1 ml/min/L
Time: 1400 hrs D.O.: 8.4 mg/L
Continued: _ min. @ _ hrs
Cont'd throughout test by airstone

TEST CONDITIONS

TSS Batch #: 47
Mortality: 1.6% over 7 days prior to test

Test Volume: 16 L Depth: 28.3 cm
Replicates: No
Number of fish per vessel: 10

Loading Density: 0.49 g/L
Mean fork length: 46 mm ± 6.2 mm SD
Range: 39 mm - 59 mm

Mean wet weight: 0.79 g ± 0.11 g SD
Range: 0.65 g - 1.01 g

Photoperiod: 16L/8D
Lux: 100 - 500
Static Test
Duration: 96 hours
Control/Dilution Water: Seawater
Temperature: 15±1°C

TEST PARAMETERS / RESULTS

Conc %	Initial (0 Hrs) Temp °C	D.O mg/L	pH	Sal. ppt	Final (96 Hrs) Temp °C	D.O mg/L	pH	Number Dead	Number Stressed	Comments
100	14.0	8.4	7.0	6.9	14.0	8.7	7.2	**10/10**	**0/10**	All dead @ 1 hr.
50	14.0	8.1	7.1	19.3	15.0	8.6	7.8	**10/10**	**0/10**	All dead @ 17.5 hrs.
25	14.0	8.0	7.3	24.9	15.0	8.7	7.7	**10/10**	**0/10**	All dead @ 17.5 hrs.
12.5	14.5	8.0	7.4	27.5	15.5	7.3	7.5	**5/10**	**0/10**	*
6.25	15.0	7.7	7.5	29.5	15.0	7.2	7.6	**0/10**	**0/10**	
Ctl.	14.0	7.8	7.7	31.1	15.0	8.0	7.8	**0/10**	**0/10**	
Adjusted Ctl.**	14.5	9.0	8.0	6.85	15.0	9.3	8.1	**0/10**	**0/10**	

96 HOUR LC$_{50}$ RESULTS

LC$_{50}$ Value: **12.5%**
95% Confidence Limits: 10.0 – 15.6%
Statistical Method: Spearman Karber - Toxstats

REFERENCE TOXICANT DATA:

Batch: 47
Reference Substance: Phenol
95% C.L.: 14.1 – 16.6 mg/L
Test Date: Feb. 22 – 26 2016
Historical Phenol Mean: 15.8 mg/L
96 Hour LC$_{50}$ for Phenol: 15.3 mg/L
Warning Limits ± 2 SD: 11.8 – 21.2 mg/L

Comments: * 12.5% concentration: 1 dead @ 17.5 hrs; 2 dead, 1 equilibrium loss @ 20.5 hrs; 4 dead @ 41.5 hrs; 5 dead @ 89.5 hrs. **The adjusted control was made by mixing Harris Industrial well water with natural seawater to a salinity of 6.85 ppt. The 100% survival demonstrates that low salinity is not lethal to the Threespine stickleback in this test.

Analyst(s): A. Huybers Verified by: C. Harris C Harris Date: March 21 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

AquaTox Testing & Consulting Inc.
118 Nicholas Beaver Rd.
Guelph ON N1H 6H9
Tel: (519) 763-4412 Fax: (519) 763-4419

TOXICITY TEST REPORT
MICROTOX®

Work Order :	230565
Sample Number :	47091

SAMPLE IDENTIFICATION

Company :	Harris Industrial Testing Service Ltd.	Time Collected :	07:30
Location :	South Rawden NS	Date Collected :	2016-03-12
Substance :	Deep Panuke Produce Water	Sample Volume :	1 x 1L jar
Sampling Method :	Grab	Date Received :	2016-03-14
Sampled By :	GL (McGregor GeoScience)	Date Tested :	2016-03-14
Sample Description :	Cloudy, colourless, moderate odour.	Temp. on arrival :	7.0°C

Test Method : Toxicity Test Using Luminescent Bacteria, Protocol EPS 1/RM/24, Environment Canada, 1992.

TEST RESULTS

Test Endpoint	Value	95% Confidence Limits	Calculation Method
15 minute IC50	1.02%	0.93-1.12	Least Square Regression

The results reported relate only to the sample tested.

REFERENCE TOXICANT DATA

Reagent Batch :	15F4070A	15 minute IC50 :	0.86 mg/L
Expiry Date :	06/2017	95% Confidence Limits :	0.73-1.01 mg/L
Date Tested (yyyy-mm-dd) :	2016-03-14	Historical Mean IC50 :	0.88 mg/L
Reference Substance :	Zinc (as zinc sulphate)	Warning Limits (± 2SD) :	0.71-1.09 mg/L
Statistical Method :	Least Square Regression	Analyst(s):	RD

CONDITIONS OF ACUTE MICROTOX TEST

Test Organism :	*Vibrio fischeri*	Test Initiation Time :	15:45
Reagent Batch :	15F4070A	Observation Time(s) :	15 minutes
Date Reagent Received :	2015-11-24	Sample Pre-aeration/Aeration :	None
Reagent Holding Temperature :	-25 °C	Sample pH :	7.2
Analyzer Model Number :	M500	pH Adjustment :	None
Test Well Temperature :	15.0 ± 0.3 °C	Salinity Adjustment :	Yes
Highest Concentration Tested :	50 %	Final Salinity :	≥2% NaCl
Number of Controls :	2	Dilution Water :	AquaTox Diluent
Number of Concentrations Tested :	8	Sample Storage :	Not applicable
Number of Replicates :	2	Colour Correction :	None
Appearance of Test Solutions :	No changes noted.	Analyst(s):	RD
		Test Method Deviation(s) :	None

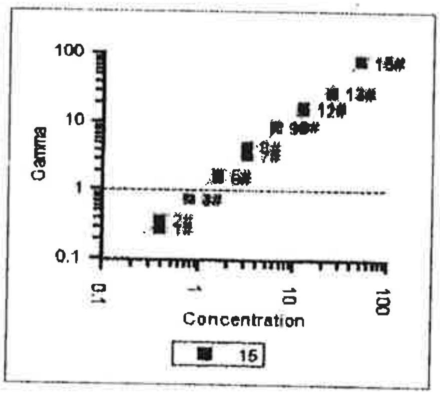
Note: The sample was originally tested at 90% (highest test concentration). However, the IC50 test result was below the lowest test concentration (i.e. < 2.81%). The test was therefore repeated at 50% (highest test concentration) in order to determine the IC50.

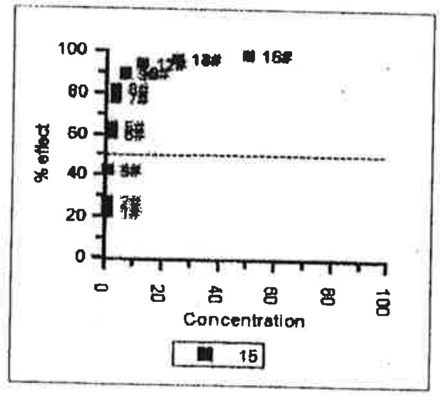
Date: 2016-04-06
yyyy-mm-dd

Approved by: [signature]
Project Manager

AQUATOX

Work Order : 230565
Sample Number : 47091





Time	Sample	Conc. (%)	I0	It	Gamma	%Effect
15 Mins						
	Control	0.00	94	86	0.9218#	
	Control	0.00	89	86	0.9640#	
	Control	0.00	87	84	0.9675#	
	Control	0.00	90	85	0.9467#	
	1	0.39	82	61	0.2723#	21.40%
	2	0.39	89	62	0.3678#	26.89%
	3	0.78	86	47	0.7340#	42.33%
	4	0.78	84	46	0.7487#	42.82%
	5	1.56	92	31	1.771#	63.91%
	6	1.56	84	32	1.492#	59.87%
	7	3.13	91	20	3.385#	77.19%
	8	3.13	89	15	4.542#	81.96%
	9	6.25	93	9	8.491#	89.46%
	10	6.25	98	9	8.926#	89.93%
	11	12.50	91	5	17.21#	94.51%
	12	12.50	86	5	16.06#	94.14%
	13	25.00	93	3	28.30#	96.59%
	14	25.00	93	3	27.73#	96.52%
	15	50.00	90	1	81.30#	98.78%
	16	50.00	96	1	77.36#	98.72%

- included, * - invalid

Statistics:

Data: 15 Mins

EC50 Concentration: 1.021%
(95% Confidence Range: 0.9274 to 1.124)
95% Confidence Factor: 1.101
Estimating Equation: LOG C = 0.8959 x LOG G +0.0091
Correction Factor: 0.9500
Slope: 1.110
Coeff of Determination (R^2): 0.9940

Test Data Reviewed By : JC
Date : 2016-03-15

AQUATOX

AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Rd.
Guelph ON N1H 6H9
Tel: (519) 763-4412 Fax: (519) 763-4419

Sea Urchin Test Report
Fertilization Inhibition

Work Order :	230565
Sample Number :	47091

SAMPLE IDENTIFICATION

Company :	Harris Industrial Testing Service Ltd.		
Location :	South Rawden NS	Date Collected :	2016-03-12
Substance :	Deep Panuke Produce Water	Time Collected :	07:30
Sampling Method :	Grab	Date Received :	2016-03-14
Sampled By :	GL (McGregor GeoScience)	Time Received :	10:30
Temp. on arrival :	7.0°C	Date Tested :	2016-03-15
Sample Description :	Cloudy, colourless, moderate odour.		

Test Method : Fertilization Assay Using Echinoids (Sea Urchins and Sand Dollars). Environment Canada, Conservation and Protection. Ottawa, Ontario. EPS 1/RM/27, 2nd ed. (February 2011).

TEST RESULTS

Effect	Value	95% Confidence Limits	Statistical Method
IC25 (Fertilization)	1.86%	1.82-1.91	Linear Interpolation (CETIS) a

The results reported relate only to the sample tested.

COPPER (AS COPPER SULPHATE) REFERENCE TOXICANT DATA

Date Tested :	2016-03-15	Statistical Method :	Non Linear Regression* (CETIS)[a]
Gamete Batch :	Ur16-03-02	Historical Mean IC25 :	155 µg/L
Test Duration :	20 minutes	Warning Limits (± 2SD) :	79 - 303 µg/L
IC25 Fertilization :	136 µg/L	Analyst(s) :	DK, AS
95% Confidence Limits :	129 - 143 µg/L		

The reference toxicant test was performed under the same experimental conditions as those used with the test sample.

TEST CONDITIONS

Test Vessel :	20 mL glass scintillation vial	Control/Dilution Water[1] :	Artificial Sea Water
Volume per Replicate :	10 mL	Sperm Exposure Time [2]:	20 min
Number of Replicates :	4 per treatment	Egg Exposure Time :	10 min
Depth of Test Solution :	Approx. 3 cm	Total Duration of Test :	20 min
Sperm Density :	40000000 per vessel	pH Adjustment :	None
Sperm : Egg Ratio :	20000 : 1	Sample Filtration :	None
Males Used to Pool Sperm :	3	Test Aeration :	None
Females Used to Pool Eggs :	3	Test Method Deviation(s) :	None

[1]no additional chemicals

[2] 10 min exposure, continued for an additional 10 min after addition of eggs

COMMENTS

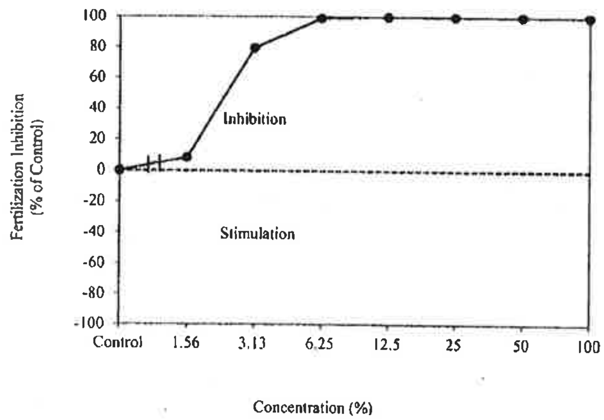
*Binomial weighting (CETIS[a]) was applied.

•All test validity criteria as specified in the test method cited above were satisfied.

•Statistical analysis could not be performed using non linear regression, since a suitable model could not be found. Therefore, test results were calculated using Linear Interpolation (CETIS)[a].

Work Order : 230565
Sample Number : 47091

Sea Urchin Fertilization Inhibition



TEST ORGANISM

Adult Test Organism :	*Lytechinus pictus*
Adult Organism Source :	Marinus Scientific
Source Location :	Garden Grove CA USA
Date Received :	2013-11-13
Holding Water :	Artificial Sea Water
Holding Temperature :	12 - 15 °C
Holding Salinity :	34 ± 2 ‰
Holding Vessel :	Glass aquaria
Adult Mortality Rate :	2.9% (previous 7 days)
Life Stage Tested :	Gamete (sperm/egg)
Gamete Batch Tested :	Ur16-03-02

Reference : Recommended Procedure for the Importation of Test Organisms for Sublethal Toxicity Testing. Environment Canada, September 1999.

REFERENCES

[a] CETIS, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, McKinleyville, Calif. 95519[Program on disk and printed User's Guide].

[c] Environment Canada. 2001. Revised Procedures for Adjusting Salinity of Effluent Samples for Marine Sublethal Toxicity Testing Conducted under Environmental Effects Monitoring (EEM) Programs. Method Development and Applications Section, Environmental Technology Centre, December 2001.

Date : 2016-04-06
yyyy-mm-dd

Approved By :
Project Manager

AQUATOX

Work Order : 230565
Sample Number : 47091

Test Conducted By : AS/DK
Enumerated By : SEC(DK)

FERTILIZATION DATA

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
Control	A	91	9	91	90.5	1.29
	B	90	10	90		
	C	89	11	89		
	D	92	8	92		
Blank	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
1.56	A	81	19	81	83	1.63
	B	83	17	83		
	C	83	17	83		
	D	85	15	85		
3.13	A	20	80	20	18.5	1.91
	B	16	84	16		
	C	20	80	20		
	D	18	82	18		
6.25	A	2	98	2[1]	0.75	0.96
	B	0	100	0		
	C	0	100	0		
	D	1	99	1		
12.5	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
25	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
50	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
100	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		

NOTES :

- No organisms or gametes exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.
- Gamete viability test was performed prior to pooling of test gametes.
- A pre-test was not required.
- Preserved eggs were stored for 7 days prior to enumeration.
- [1] outlier according to Grubbs Test (CETIS)[a]. Outlying data points were not excluded from statistical analysis, since they could not be attributed to error.

Data Reviewed By : IL
Date : 2016-04-06

AQUATOX

Work Order : 230565
Sample Number : 47091

INITIAL WATER CHEMISTRY (100% SAMPLE)

	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)	Pre-aeration Time (h)
Initial Chemistry:	20.5	7.6	8.3	100	14	–
Chemistry after Salinity Adjustment [3]:	20.0	7.8	7.0	95	30	–
Chemistry after Pre-Aeration[3,4]:	–	–	–	–	–	0:00

SALINITY ADJUSTMENT

Method : Direct Salt Addition
Salt Added : Instant Ocean™
Date Adjusted : 2016-03-14
Aging Conditions : Sealed, complete darkness, minimal air space

Volume Adjusted : 500 mL
Amount of Salt Added : 10 g
Aging Time : ~19 hours
Aging Temperature : 4±2°C

Reference : Salinity Adjustment Guidance Document. Environment Canada, revised December 2001[e].

EXPOSURE CONCENTRATIONS WATER CHEMISTRY

Concentration (%)	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)
Control	20.0	8.3	7.3	100	30
Blank	20.0	8.3	7.3	100	30
1.56	20.0	8.4	7.3	100	30
3.13	20.0	–	–	–	–
6.25	20.0	–	–	–	–
12.5	20.0	–	–	–	–
25	20.0	8.3	7.3	100	30
50	20.0	–	–	–	–
100	20.0	8.0	7.1	96	30

* % saturation, adjusted for temperature and barometric pressure
"–" not required/not measured
[3] if required
[4] at <100 bubbles/min

Data Reviewed By : JL
Date : 2016-04-06

APPENDIX E

2016 Marine Water Sampling Field Logs (McGregor)

McGregor GeoScience Limited

McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84
Projection: UTM Zone 20N

Project 1113

Sample Site: 2000m US

Launch Coordinates	**0686114 E**	**4853553 N**	**TWD: 40m**	**Red Bottle Depth (MSL):**	**1**
Date: March 11, 2016	**Time Start (UTC): 23:35**	**Time End (UTC): 00:10**		**Green Bottle Depth (MSL):**	**20**
Sea Conditions:				**Blue Bottle Depth (MSL):**	**35**

Bottle 1 - Red Niskin: Depth 1m		**Bottle 2 - Green Niskin: Mid-Water Depth**		**Bottle 3 - Blue Niskin: 5m Above Seabed**	
Sample Type	**Sample Number**	**Sample Type**	**Sample Number**	**Sample Type**	**Sample Number**
Organic acids 250ml	2000m_surf_US Organic Acids	Organic acids 25ml	2000m_mid_US Organic Acids	Organic acids 250ml	2000m_bot_US Organic Acids
Mercury 100ml	2000m_US Mercury	Mercury 100ml	2000m_mid_US Mercury	Mercury 100ml	2000m_bot_US Mercury
Metals 50ml	2000m_US Metals	Metals 50ml	2000m_mid_US Metals	Metals 50ml	2000m_bot_US Metals
TEH in water 250ml	2000m_US TEHa	TEH in water 250ml	2000m_mid_US TEHa	TEH in water 250ml	2000m_bot_US TEHa
TEH in water 250ml	2000m_US TEHb	TEH in water 250ml	2000m_mid_US TEHb	TEH in water 250ml	2000m_bot_US TEHb
VOCs 40ml	2000m_US VOCa	VOCs 40ml	2000m_mid_US VOCa	VOCs 40ml	2000m_bot_US VOCa
VOCs 40ml	2000m_US VOCb	VOCs 40ml	2000m_mid_US VOCb	VOCs 40ml	2000m_bot_US VOCb
VOCs 40ml	2000m_US VOCc	VOCs 40ml	2000m_mid_US VOCc	VOCs 40ml	2000m_bot_US VOCc
Alkylated Phenols 1L	2000m_US Alk Phenola	Alkylated Phenols 1L	2000m_mid_US Alk Phenola	Alkylated Phenols 1L	2000m_bot_US Alk Phenola
Alkylated Phenols 1L	2000m_US Alk Phenolb	Alkylated Phenols 1L	2000m_mid_US Alk Phenolb	Alkylated Phenols 1L	2000m_bot_US Alk Phenolb
PAHs 250ml	2000m_US PAHa	PAHs 250ml	2000m_mid_US PAHa	PAHs 250ml	2000m_bot_US PAHa
PAHs 250ml	2000m_US PAHb	PAHs 250ml	2000m_mid_US PAHb	PAHs 250ml	2000m_bot_US PAHb
Nitrate/ortho P/Total Nitrogen 200ml	2000m_US Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	2000m_mid_US Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	2000m_bot_US Nitrate/Nitrogen
Sulphides 125ml	2000m_US Sulphides	Sulphides 125ml	2000m_mid_US Sulphides	Sulphides 125ml	2000m_bot_US Sulphides
Total P/Ammonia 100ml	2000m_US Total P/Ammoniaa	Total P/Ammonia 100ml	2000m_mid_US Total P/Ammoniaa	Total P/Ammonia 100ml	2000m_bot_US Total P/Ammoniaa
Total P/Ammonia 100ml	2000m_US Total P/Ammoniab	Total P/Ammonia 100ml	2000m_mid_US Total P/Ammoniab	Total P/Ammonia 100ml	2000m_bot_US Total P/Ammoniab

McGregor GeoScience 1113 Water Sampling Log

McGregor GeoScience Limited

Datum: WGS84 Projection: UTM Zone 20N		Project 1113	Sample Site: 250m UP		
Launch Coordinates	0685843 E	4853437 N	TWD: 48	Red Bottle Depth (MSL):	1
Date: March 12, 2016	Time Start (UTC): 01:10	Time End (UTC): 01:23		Green Bottle Depth (MSL):	24
Sea Conditions:				Blue Bottle Depth (MSL):	47
Bottle 1 - Red Niskin: Depth 1m		Bottle 2 - Green Niskin: Mid-Water Depth		Bottle 3 - Blue Niskin: 5m Above Seabed	
Sample Type	Sample Number	Sample Type	Sample Number	Sample Type	Sample Number
Organic acids 250ml	250m_surf_US Organic Acids	Organic acids 25ml	250m _mid_US Organic Acids	Organic acids 250ml	250m_bot_US Organic Acids
Mercury 100ml	250m_surf_US Mercury	Mercury 100ml	250m _mid_US Mercury	Mercury 100ml	250m_bot_US Mercury
Metals 50ml	250m_surf_US Metals	Metals 50ml	250m _mid_US Metals	Metals 50ml	250m_bot_US Metals
TEH in water 250ml	250m_surf_US TEHa	TEH in water 250ml	250m _mid_US TEHa	TEH in water 250ml	250m_bot_US TEHa
TEH in water 250ml	250m_surf_US TEHb	TEH in water 250ml	250m _mid_US TEHb	TEH in water 250ml	250m_bot_US TEHb
VOCs 40ml	250m_surf_US VOCa	VOCs 40ml	250m _mid_US VOCa	VOCs 40ml	250m_bot_US VOCa
VOCs 40ml	250m_surf_US VOCb	VOCs 40ml	250m _mid_US VOCb	VOCs 40ml	250m_bot_US VOCb
VOCs 40ml	250m_surf_US VOCc	VOCs 40ml	250m _mid_US VOCc	VOCs 40ml	250m_bot_US VOCc
Alkylated Phenols 1L	250m_surf_US Alk Phenola	Alkylated Phenols 1L	250m _mid_US Alk Phenola	Alkylated Phenols 1L	250m_bot_US Alk Phenola
Alkylated Phenols 1L	250m_surf_US Alk Phenolb	Alkylated Phenols 1L	250m _mid_US Alk Phenolb	Alkylated Phenols 1L	250m_bot_US Alk Phenolb
PAHs 250ml	250m_surf_US PAHa	PAHs 250ml	250m _mid_US PAHa	PAHs 250ml	250m_bot_US PAHa
PAHs 250ml	250m_surf_US PAHb	PAHs 250ml	250m _mid_US PAHb	PAHs 250ml	250m_bot_US PAHb
Nitrate/ortho P/Total Nitrogen 200ml	250m_surf_US Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	250m _mid_US Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	250m_bot_US Nitrate/Nitrogen
Sulphides 125ml	250m_surf_US Sulphides	Sulphides 125ml	250m _mid_US Sulphides	Sulphides 125ml	250m_bot_US Sulphides
Total P/Ammonia 100ml	250m_surf_US Total P/Ammoniaa	Total P/Ammonia 100ml	250m _mid_US Total P/Ammoniaa	Total P/Ammonia 100ml	250m_bot_US Total P/Ammoniaa
Total P/Ammonia 100ml	250m_surf_US Total P/Ammoniab	Total P/Ammonia 100ml	250m _mid_US Total P/Ammoniab	Total P/Ammonia 100ml	250m_bot_US Total P/Ammoniab

McGregor GeoScience 1113 Water Sampling Log

McGregor GeoScience Limited

Datum: WGS84 Projection: UTM Zone 20N		Project 1113	Sample Site: 20m DS		
Launch Coordinates	4853605N	685860E	TWD: 46m	Red Bottle Depth (MSL):	41
03/12/2016	Time Start (UTC): 0805	Time End (UTC): 0809		Green Bottle Depth (MSL):	23
Sea Conditions: Choppy, NW 15kts				Blue Bottle Depth (MSL):	3

Bottle 1 - Red Niskin: Depth 1m		Bottle 2 - Green Niskin: Mid-Water Depth		Bottle 3 - Blue Niskin: 5m Above Seabed	
Sample Type	**Sample Number**	**Sample Type**	**Sample Number**	**Sample Type**	**Sample Number**
Organic acids 250ml	20m_surf_DS Organic Acids	Organic acids 25ml	20m_mid_DS Organic Acids	Organic acids 250ml	20m_bot_DS Organic Acids
Mercury 100ml	20m_surf_DS Mercury	Mercury 100ml	20m_mid_DS Mercury	Mercury 100ml	20m_bot_DS Mercury
Metals 50ml	20m_surf_DS Metals	Metals 50ml	20m_mid_DS Metals	Metals 50ml	20m_bot_DS Metals
TEH in water 250ml	20m_surf_DS TEHa	TEH in water 250ml	20m_mid_DS TEHa	TEH in water 250ml	20m_bot_DS TEHa
TEH in water 250ml	20m_surf_DS TEHb	TEH in water 250ml	20m_mid_DS TEHb	TEH in water 250ml	20m_bot_DS TEHb
VOCs 40ml	20m_surf_DS VOCa	VOCs 40ml	20m_mid_DS VOCa	VOCs 40ml	20m_bot_DS VOCa
VOCs 40ml	20m_surf_DS VOCb	VOCs 40ml	20m_mid_DS VOCb	VOCs 40ml	20m_bot_DS VOCb
VOCs 40ml	20m_surf_DS VOCc	VOCs 40ml	20m_mid_DS VOCc	VOCs 40ml	20m_bot_DS VOCc
Alkylated Phenols 1L	20m_surf_DS Alk Phenola	Alkylated Phenols 1L	20m_mid_DS Alk Phenola	Alkylated Phenols 1L	20m_bot_DS Alk Phenola
Alkylated Phenols 1L	20m_surf_DS Alk Phenolb	Alkylated Phenols 1L	20m_mid_DS Alk Phenolb	Alkylated Phenols 1L	20m_bot_DS Alk Phenolb
PAHs 250ml	20m_surf_DS PAHa	PAHs 250ml	20m_mid_DS PAHa	PAHs 250ml	20m_bot_DS PAHa
PAHs 250ml	20m_surf_DS PAHb	PAHs 250ml	20m_mid_DS PAHb	PAHs 250ml	20m_bot_DS PAHb
Nitrate/ortho P/Total Nitrogen 200ml	20m_surf_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	20m_mid_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	20m_bot_DS Nitrate/Nitrogen
Sulphides 125ml	20m_surf_DS Sulphides	Sulphides 125ml	20m_mid_DS Sulphides	Sulphides 125ml	20m_bot_DS Sulphides
Total P/Ammonia 100ml	20m_surf_DS Total P/Ammoniaa	Total P/Ammonia 100ml	20m_mid_DS Total P/Ammoniaa	Total P/Ammonia 100ml	20m_bot_DS Total P/Ammoniaa
Total P/Ammonia 100ml	20m_surf_DS Total P/Ammoniab	Total P/Ammonia 100ml	20m_mid_DS Total P/Ammoniab	Total P/Ammonia 100ml	20m_bot_DS Total P/Ammoniab

McGregor GeoScience Limited

McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84 **Projection: UTM Zone 20N**		**Project 1113**	**Sample Site: 250m DS**		
Launch Coordinates	**685906**	**4853394**	**TWD: 46m**	**Red Bottle Depth (MSL):**	**5**
Date: March 12, 2016	**Time Start (UTC): 0644**	**Time End (UTC): 0649**		**Green Bottle Depth (MSL):**	**23**
Sea Conditions: 1-2m				**Blue Bottle Depth (MSL):**	**46**

Bottle 1 - Red Niskin: Depth 1m		**Bottle 2 - Green Niskin: Mid-Water Depth**		**Bottle 3 - Blue Niskin: 5m Above Seabed**	
Sample Type	**Sample Number**	**Sample Type**	**Sample Number**	**Sample Type**	**Sample Number**
Organic acids 250ml	250m_surf_DS Organic Acids	Organic acids 25ml	250m_mid_DS Organic Acids	Organic acids 250ml	250m_bot_DS Organic Acids
Mercury 100ml	250m_surf_DS Mercury	Mercury 100ml	250m_mid_DS Mercury	Mercury 100ml	250m_bot_DS Mercury
Metals 50ml	250m_surf_DS Metals	Metals 50ml	250m_mid_DS Metals	Metals 50ml	250m_bot_DS Metals
TEH in water 250ml	250m_surf_DS TEHa	TEH in water 250ml	250m_mid_DS TEHa	TEH in water 250ml	250m_bot_DS TEHa
TEH in water 250ml	250m_surf_DS TEHb	TEH in water 250ml	250m_mid_DS TEHb	TEH in water 250ml	250m_bot_DS TEHb
VOCs 40ml	250m_surf_DS VOCa	VOCs 40ml	250m_mid_DS VOCa	VOCs 40ml	250m_bot_DS VOCa
VOCs 40ml	250m_surf_DS VOCb	VOCs 40ml	250m_mid_DS VOCb	VOCs 40ml	250m_bot_DS VOCb
VOCs 40ml	250m_surf_DS VOCc	VOCs 40ml	250m_mid_DS VOCc	VOCs 40ml	250m_bot_DS VOCc
Alkylated Phenols 1L	250m_surf_DS Alk Phenola	Alkylated Phenols 1L	250m_mid_DS Alk Phenola	Alkylated Phenols 1L	250m_bot_DS Alk Phenola
Alkylated Phenols 1L	250m_surf_DS Alk Phenolb	Alkylated Phenols 1L	250m_mid_DS Alk Phenolb	Alkylated Phenols 1L	250m_bot_DS Alk Phenolb
PAHs 250ml	250m_surf_DS PAHa	PAHs 250ml	250m_mid_DS PAHa	PAHs 250ml	250m_bot_DS PAHa
PAHs 250ml	250m_surf_DS PAHb	PAHs 250ml	250m_mid_DS PAHb	PAHs 250ml	250m_bot_DS PAHb
Nitrate/ortho P/Total Nitrogen 200ml	250m_surf_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	250m_mid_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	250m_bot_DS Nitrate/Nitrogen
Sulphides 125ml	250m_surf_DS Sulphides	Sulphides 125ml	250m_mid_DS Sulphides	Sulphides 125ml	250m_bot_DS Sulphides
Total P/Ammonia 100ml	250m_surf_DS Total P/Ammoniaa	Total P/Ammonia 100ml	250m_mid_DS Total P/Ammoniaa	Total P/Ammonia 100ml	250m_bot_DS Total P/Ammoniaa
Total P/Ammonia 100ml	250m_surf_DS Total P/Ammoniab	Total P/Ammonia 100ml	250m_mid_DS Total P/Ammoniab	Total P/Ammonia 100ml	250m_bot_DS Total P/Ammoniab

McGregor GeoScience 1113 Water Sampling Log

McGregor GeoScience Limited

Datum: WGS84 **Projection: UTM Zone 20N**		**Project 1113**	**Sample Site: 500m DS**		
Launch Coordinates	**686079E**	**4853164N**	**TWD: 44m**	**Red Bottle Depth (MSL):**	**5**
03/12/2016	**Time Start (UTC): 0547**	**Time End (UTC): 0553**		**Green Bottle Depth (MSL):**	**22**
Sea Conditions:	**1-2m**			**Blue Bottle Depth (MSL):**	**41**
Bottle 1 - Red Niskin: Depth 1m		**Bottle 2 - Green Niskin: Mid-Water Depth**		**Bottle 3 - Blue Niskin: 5m Above Seabed**	
Sample Type	**Sample Number**	**Sample Type**	**Sample Number**	**Sample Type**	**Sample Number**
Organic acids 250ml	500m_surf_DS Organic Acids	Organic acids 25ml	500m_mid_DS Organic Acids	Organic acids 250ml	500m_bot_DS Organic Acids
Mercury 100ml	500m_surf_DS Mercury	Mercury 100ml	500m_mid_DS Mercury	Mercury 100ml	500m_bot_DS Mercury
Metals 50ml	500m_surf_DS Metals	Metals 50ml	500m_mid_DS Metals	Metals 50ml	500m_bot_DS Metals
TEH in water 250ml	500m_surf_DS TEHa	TEH in water 250ml	500m_mid_DS TEHa	TEH in water 250ml	500m_bot_DS TEHa
TEH in water 250ml	500m_surf_DS TEHb	TEH in water 250ml	500m_mid_DS TEHb	TEH in water 250ml	500m_bot_DS TEHb
VOCs 40ml	500m_surf_DS VOCa	VOCs 40ml	500m_mid_DS VOCa	VOCs 40ml	500m_bot_DS VOCa
VOCs 40ml	500m_surf_DS VOCb	VOCs 40ml	500m_mid_DS VOCb	VOCs 40ml	500m_bot_DS VOCb
VOCs 40ml	500m_surf_DS VOCc	VOCs 40ml	500m_mid_DS VOCc	VOCs 40ml	500m_bot_DS VOCc
Alkylated Phenols 1L	500m_surf_DS Alk Phenola	Alkylated Phenols 1L	500m_mid_DS Alk Phenola	Alkylated Phenols 1L	500m_bot_DS Alk Phenola
Alkylated Phenols 1L	500m_surf_DS Alk Phenolb	Alkylated Phenols 1L	500m_mid_DS Alk Phenolb	Alkylated Phenols 1L	500m_bot_DS Alk Phenolb
PAHs 250ml	500m_surf_DS PAHa	PAHs 250ml	500m_mid_DS PAHa	PAHs 250ml	500m_bot_DS PAHa
PAHs 250ml	500m_surf_DS PAHb	PAHs 250ml	500m_mid_DS PAHb	PAHs 250ml	500m_bot_DS PAHb
Nitrate/ortho P/Total Nitrogen 200ml	500m_surf_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	500m_mid_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	500m_bot_DS Nitrate/Nitrogen
Sulphides 125ml	500m_surf_DS Sulphides	Sulphides 125ml	500m_mid_DS Sulphides	Sulphides 125ml	500m_bot_DS Sulphides
Total P/Ammonia 100ml	500m_surf_DS Total P/Ammoniaa	Total P/Ammonia 100ml	500m_mid_DS Total P/Ammoniaa	Total P/Ammonia 100ml	500m_bot_DS Total P/Ammoniaa
Total P/Ammonia 100ml	500m_surf_DS Total P/Ammoniab	Total P/Ammonia 100ml	500m_mid_DS Total P/Ammoniab	Total P/Ammonia 100ml	500m_bot_DS Total P/Ammoniab

McGregor GeoScience Limited

McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84 **Projection: UTM Zone 20N**		**Project 1113**	**Sample Site: 1000m DS**		
Launch Coordinates	**686790E**	**4853201N**	**TWD: 45**	**Red Bottle Depth (MSL):**	**3**
03/12/2016	**Time Start (UTC): 4:25:00 AM**	**Time End (UTC): 4:33:00 AM**		**Green Bottle Depth (MSL):**	**22**
Sea Conditions:	**1-2m**			**Blue Bottle Depth (MSL):**	**40**
Bottle 1 - Red Niskin: Depth 1m		**Bottle 2 - Green Niskin: Mid-Water Depth**		**Bottle 3 - Blue Niskin: 5m Above Seabed**	
Sample Type	**Sample Number**	**Sample Type**	**Sample Number**	**Sample Type**	**Sample Number**
Organic acids 250ml	1000m_surf_DS Organic Acids	Organic acids 25ml	1000m_mid_DS Organic Acids	Organic acids 250ml	1000m_bot_DS Organic Acids
Mercury 100ml	1000m_surf_DS Mercury	Mercury 100ml	1000m_mid_DS Mercury	Mercury 100ml	1000m_bot_DS Mercury
Metals 50ml	1000m_surf_DS Metals	Metals 50ml	1000m_mid_DS Metals	Metals 50ml	1000m_bot_DS Metals
TEH in water 250ml	1000m_surf_DS TEHa	TEH in water 250ml	1000m_mid_DS TEHa	TEH in water 250ml	1000m_bot_DS TEHa
TEH in water 250ml	1000m_surf_DS TEHb	TEH in water 250ml	1000m_mid_DS TEHb	TEH in water 250ml	1000m_bot_DS TEHb
VOCs 40ml	1000m_surf_DS VOCa	VOCs 40ml	1000m_mid_DS VOCa	VOCs 40ml	1000m_bot_DS VOCa
VOCs 40ml	1000m_surf_DS VOCb	VOCs 40ml	1000m_mid_DS VOCb	VOCs 40ml	1000m_bot_DS VOCb
VOCs 40ml	1000m_surf_DS VOCc	VOCs 40ml	1000m_mid_DS VOCc	VOCs 40ml	1000m_bot_DS VOCc
Alkylated Phenols 1L	1000m_surf_DS Alk Phenola	Alkylated Phenols 1L	1000m_mid_DS Alk Phenola	Alkylated Phenols 1L	1000m_bot_DS Alk Phenola
Alkylated Phenols 1L	1000m_surf_DS Alk Phenolb	Alkylated Phenols 1L	1000m_mid_DS Alk Phenolb	Alkylated Phenols 1L	1000m_bot_DS Alk Phenolb
PAHs 250ml	1000m_surf_DS PAHa	PAHs 250ml	1000m_mid_DS PAHa	PAHs 250ml	1000m_bot_DS PAHa
PAHs 250ml	1000m_surf_DS PAHb	PAHs 250ml	1000m_mid_DS PAHb	PAHs 250ml	1000m_bot_DS PAHb
Nitrate/ortho P/Total Nitrogen 200ml	1000m_surf_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	1000m_mid_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	1000m_bot_DS Nitrate/Nitrogen
Sulphides 125ml	1000m_surf_DS Sulphides	Sulphides 125ml	1000m_mid_DS Sulphides	Sulphides 125ml	1000m_bot_DS Sulphides
Total P/Ammonia 100ml	1000m_surf_DS Total P/Ammoniaa	Total P/Ammonia 100ml	1000m_mid_DS Total P/Ammoniaa	Total P/Ammonia 100ml	1000m_bot_DS Total P/Ammoniaa
Total P/Ammonia 100ml	1000m_surf_DS Total P/Ammoniab	Total P/Ammonia 100ml	1000m_mid_DS Total P/Ammoniab	Total P/Ammonia 100ml	1000m_bot_DS Total P/Ammoniab

McGregor GeoScience 1113 Water Sampling Log

McGregor GeoScience Limited

Datum: WGS84 Projection: UTM Zone 20N		Project 1113	Sample Site: 2000m DS		
Launch Coordinates	685860 E	4853605 N	TWD: 47m	Red Bottle Depth (MSL):	1
Date: March 12, 2016	Time Start (UTC): 02:49	Time End (UTC): 02:53		Green Bottle Depth (MSL):	23
Sea Conditions:				Blue Bottle Depth (MSL):	46

Bottle 1 - Red Niskin: Depth 1m		Bottle 2 - Green Niskin: Mid-Water Depth		Bottle 3 - Blue Niskin: 5m Above Seabed	
Sample Type	**Sample Number**	**Sample Type**	**Sample Number**	**Sample Type**	**Sample Number**
Organic acids 250ml	2000m_surf_DS Organic Acids	Organic acids 25ml	2000m_mid_DS Organic Acids	Organic acids 250ml	2000m_bot_DS Organic Acids
Mercury 100ml	2000m_surf_DS Mercury	Mercury 100ml	2000m_mid_DS Mercury	Mercury 100ml	2000m_bot_DS Mercury
Metals 50ml	2000m_surf_DS Metals	Metals 50ml	2000m_mid_DS Metals	Metals 50ml	2000m_bot_DS Metals
TEH in water 250ml	2000m_surf_DS TEHa	TEH in water 250ml	2000m_mid_DS TEHa	TEH in water 250ml	2000m_bot_DS TEHa
TEH in water 250ml	2000m_surf_DS TEHb	TEH in water 250ml	2000m_mid_DS TEHb	TEH in water 250ml	2000m_bot_DS TEHb
VOCs 40ml	2000m_surf_DS VOCa	VOCs 40ml	2000m_mid_DS VOCa	VOCs 40ml	2000m_bot_DS VOCa
VOCs 40ml	2000m_surf_DS VOCb	VOCs 40ml	2000m_mid_DS VOCb	VOCs 40ml	2000m_bot_DS VOCb
VOCs 40ml	2000m_surf_DS VOCc	VOCs 40ml	2000m_mid_DS VOCc	VOCs 40ml	2000m_bot_DS VOCc
Alkylated Phenols 1L	2000m_surf_DS Alk Phenola	Alkylated Phenols 1L	2000m_mid_DS Alk Phenola	Alkylated Phenols 1L	2000m_bot_DS Alk Phenola
Alkylated Phenols 1L	2000m_surf_DS Alk Phenolb	Alkylated Phenols 1L	2000m_mid_DS Alk Phenolb	Alkylated Phenols 1L	2000m_bot_DS Alk Phenolb
PAHs 250ml	2000m_surf_DS PAHa	PAHs 250ml	2000m_mid_DS PAHa	PAHs 250ml	2000m_bot_DS PAHa
PAHs 250ml	2000m_surf_DS PAHb	PAHs 250ml	2000m_mid_DS PAHb	PAHs 250ml	2000m_bot_DS PAHb
Nitrate/ortho P/Total Nitrogen 200ml	2000m_surf_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	2000m_mid_DS Nitrate/Nitrogen	Nitrate/ortho P/Total Nitrogen 200ml	2000m_bot_DS Nitrate/Nitrogen
Sulphides 125ml	2000m_surf_DS Sulphides	Sulphides 125ml	2000m_mid_DS Sulphides	Sulphides 125ml	2000m_bot_DS Sulphides
Total P/Ammonia 100ml	2000m_surf_DS Total P/Ammoniaa	Total P/Ammonia 100ml	2000m_mid_DS Total P/Ammoniaa	Total P/Ammonia 100ml	2000m_bot_DS Total P/Ammoniaa
Total P/Ammonia 100ml	2000m_surf_DS Total P/Ammoniab	Total P/Ammonia 100ml	2000m_mid_DS Total P/Ammoniab	Total P/Ammonia 100ml	2000m_bot_DS Total P/Ammoniab

APPENDIX F

2016 Sediment Sampling Logs and Photos (McGregor)

McGregor GeoScience Limited

1113 Encana 2016

Datum: WGS84 Projection: Zone 20N

Site: 250 m DS | Core: SED 250m DS | Date: mar 8 | Time (UTC): 0106

Position: N 4853499.36 | E 685734.65

Depth (m bsl): | Penetration (cm): | Sampling Method: VV

Sediment Composition:

Did not get enough sample

Sediment Features: Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________

Sediment Anoxia: None Streaks Patches Layer Depth of Layer from Surface ________

Notes: Samples 1x60ml, 1x120ml, 3x250ml, 1 x ziploc bag

Samples Collected: Bioassay 1L Bag: A B | Metals/PAH/AP Clear 250ml: A B C
VPH 60ml: A | Sulphide Clear 120ml: A
Photo Taken: Yes No

SAMPLE "B"

MARCH 8/2016

Datum: WGS84 Projection: Zone 20N

Site: 250 m DS | Core: SED | Time (UTC): 01:18 UTC

Position: N 4853510 E 685729

Depth (m bsl): 47 | Penetration (cm): 15 cm | Sampling Method: VV

Sediment Composition:

fine grained sand, sand dollar

Sediment Features: Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________

Sediment Anoxia: None Streaks Patches Layer Depth of Layer from Surface ________

Notes:

Samples Collected: Bioassay 1L Bag: A B | Metals/PAH/AP Clear 250ml: A B C
VPH 60ml: A | Sulphide Clear 120ml: A
Photo Taken: Yes No

* check Date - mar 8, not 7 (7 on some sheets)

* DO NOT FORGET ABOUT BLIND SEDIMENT COLLECTION.

McGregor GeoScience Limited 1113 Encana 2016

Datum: WGS84 Projection: Zone 20N

Site: 500m DS | Core: SED 500m DS | Date: 8 March 16 | Time (UTC): 01:57

Position: N 4853244.84 E 685648.84

Depth (m bsl): 46 | Penetration (cm): 15 | Sampling Method: VV

Sediment Composition:

Medium grained sand with shell fragments

Sediment Features: Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________

Sediment Anoxia: None Streaks Patches Layer Depth of Layer from Surface ________

Notes: Samples 1x60ml, 1x120ml, 3x250ml, 2 x ziploc bag

Samples Collected:
Bioassay 1L Bag: A B
VPH 60ml: A
Photo Taken: Yes No
Metals/PAH/AP Clear 250ml: A B C
Sulphide Clear 120ml: A

Datum: WGS84 Projection: Zone 20N

Site: | Core: | Time (UTC):

Position:

Depth (m bsl): | Penetration (cm): | Sampling Method:

Sediment Composition:

Sediment Features: Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________

Sediment Anoxia: None Streaks Patches Layer Depth of Layer from Surface ________

Notes:

Samples Collected:
Bioassay 1L Bag: A B
VPH 60ml: A
Photo Taken: Yes No
Metals/PAH/AP Clear 250ml: A B C
Sulphide Clear 120ml: A

McGregor GeoScience Limited

1113 Encana 2016

Datum: WGS84 Projection: Zone 20N

Site: 1000m DS | Core: SED 1000m DS | Date: March 8/16 | Time (UTC): 02:35

Position: N 4852944.03 | E 685223.2

Depth (m bsl): 42 m | Penetration (cm): 15 | Sampling Method: VV

Sediment Composition:

fine grained sand with small amount of shell fragments

Sediment Features: Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________

Sediment Anoxia: None Streaks Patches Layer Depth of Layer from Surface ________

Notes: Samples 1x60ml, 1x120ml, 3x250ml, 2 x ziploc bag

Samples Collected:
Bioassay 1L Bag: A B
VPH 60ml: A
Photo Taken: Yes No
Metals/PAH/AP Clear 250ml: A B C
Sulphide Clear 120ml: A

Datum: WGS84 Projection: Zone 20N

Site: | Core: | Time (UTC):

Position:

Depth (m bsl): | Penetration (cm): | Sampling Method:

Sediment Composition:

Sediment Features: Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________

Sediment Anoxia: None Streaks Patches Layer Depth of Layer from Surface ________

Notes:

Samples Collected:
Bioassay 1L Bag: A B
VPH 60ml: A
Photo Taken: Yes No
Metals/PAH/AP Clear 250ml: A B C
Sulphide Clear 120ml: A

McGregor GeoScience Limited 1113 Encana 2016

Datum: WGS84 Projection: Zone 20N			
Site: 2000m DS	Core: SED 2000m DS	Date: Mar 8	Time (UTC): 0320
Position: N 4852265.74		E 684491.85	
Depth (m bsl): 40	Penetration (cm):		Sampling Method: VV
Sediment Composition: Fine grained sand, worm			
Sediment Features:	Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification ________		
Sediment Anoxia:	None Streaks Patches Layer Depth of Layer from Surface ________		
Notes:	Samples 1x60ml, 1x120ml, 3x250ml, 2 x ziploc bag		
Samples Collected:	Bioassay 1L Bag: A B VPH 60ml: A Photo Taken: Yes No	Metals/PAH/AP Clear 250ml: A B C Sulphide Clear 120ml: A	

Datum: WGS84 Projection: Zone 20N			
Site:	Core:		Time (UTC):
Position:			
Depth (m bsl):	Penetration (cm):		Sampling Method:
Sediment Composition:			
Sediment Features:	Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification ________		
Sediment Anoxia:	None Streaks Patches Layer Depth of Layer from Surface ________		
Notes:			
Samples Collected:	Bioassay 1L Bag: A B VPH 60ml: A Photo Taken: Yes No	Metals/PAH/AP Clear 250ml: A B C Sulphide Clear 120ml: A	

McGregor GeoScience Limited 1113 Encana 2016

Datum: WGS84 Projection: Zone 20N			
Site: 5000m DS	Core: SED 5000m DS	Date: 8 MAR	Time (UTC): 0426
Position: N 4850141.01		E 682339.81	
Depth (m bsl): 37	Penetration (cm): 15		Sampling Method: VV
Sediment Composition: SAND MED GRAIN			
Sediment Features:	Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification_______		
Sediment Anoxia:	None Streaks Patches Layer Depth of Layer from Surface ________		
Notes:	Samples 1x60ml, 1x120ml, 3x250ml, [illegible] x ziploc bag		
Samples Collected:	Bioassay 1L Bag: A B VPH 60ml: A Photo Taken: Yes No	Metals/PAH/AP Clear 250ml: A B C Sulphide Clear 120ml: A	

Datum: WGS84 Projection: Zone 20N			
Site:	Core:		Time (UTC):
Position:			
Depth (m bsl):	Penetration (cm):		Sampling Method:
Sediment Composition:			
Sediment Features:	Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________		
Sediment Anoxia:	None Streaks Patches Layer Depth of Layer from Surface ________		
Notes:			
Samples Collected:	Bioassay 1L Bag: A B VPH 60ml: A Photo Taken: Yes No	Metals/PAH/AP Clear 250ml: A B C Sulphide Clear 120ml: A	

McGregor GeoScience Limited

1113 Encana 2016

Datum: WGS84 Projection: Zone 20N			
Site: 5000m US	Core: SED 5000m US	Date: 8 MAR 2016	Time (UTC): 05:28
Position: N 4857175.68		E 689476.61	
Depth (m bsl): 38	Penetration (cm): 15		Sampling Method: VV
Sediment Composition:	SAND MED GRAIN		
Sediment Features:	Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________		
Sediment Anoxia:	None Streaks Patches Layer Depth of Layer from Surface ________		
Notes:	Samples 1x60ml, 1x120ml, 3x250ml, 2 x ziploc bag		
Samples Collected:	Bioassay 1L Bag: A B VPH 60ml: A Photo Taken: Yes No	Metals/PAH/AP Clear 250ml: A B C Sulphide Clear 120ml: A	

Datum: WGS84 Projection: Zone 20N			
Site:	Core:		Time (UTC):
Position:			
Depth (m bsl):	Penetration (cm):		Sampling Method:
Sediment Composition:			
Sediment Features:	Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________		
Sediment Anoxia:	None Streaks Patches Layer Depth of Layer from Surface ________		
Notes:			
Samples Collected:	Bioassay 1L Bag: A B VPH 60ml: A Photo Taken: Yes No	Metals/PAH/AP Clear 250ml: A B C Sulphide Clear 120ml: A	

McGregor GeoScience Limited

1113 Encana 2016 Blind Sediment Collection

Datum: WGS84 Projection: Zone 20N 2000 m

Site: Core: Date: Time (UTC):

Position:

Depth (m bsl): Penetration (cm): Sampling Method: **VV**

Sediment Composition:

Sediment Features: Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________

Sediment Anoxia: None Streaks Patches Layer Depth of Layer from Surface ________

Notes:

Samples Collected: Bioassay 1L Bag: A B Metals/PAH/AP Clear 250ml: A B C
VPH 60ml: A Sulphide Clear 120ml: A
Photo Taken: Yes No

Datum: WGS84 Projection: Zone 20N

Site: Core: Time (UTC):

Position:

Depth (m bsl): Penetration (cm): Sampling Method:

Sediment Composition:

Sediment Features: Burrows? Tubes? Casts? Smell _____ Color __ Sediment Stratification________

Sediment Anoxia: None Streaks Patches Layer Depth of Layer from Surface ________

Notes:

Samples Collected: Bioassay 1L Bag: A B Metals/PAH/AP Clear 250ml: A B C
VPH 60ml: A Sulphide Clear 120ml: A
Photo Taken: Yes No

APPENDIX G

2016 Sediment Toxicity Results (HITS)

AMPHIPOD TOXICITY REPORT (Single Concentration)

Client:	McGregor GeoScience Ltd.	Test Facility:	Harris Industrial Testing Service Ltd.
Address:	177 Bluewater Road Bedford, NS B4B 1H1	Location:	1320 Ashdale Rd., South Rawdon, Nova Scotia Canada B0N 1Z0
Contact:	Gillian Forbes	Tel : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info	

SAMPLE DATA

Sample Type/Location: Control Sediment — Lab ID. # 16-134-Ctl
Date/Time Collected: Mar. 16 2016 — Sampler: D. Swanston
Method of Collection: Grab — Received: Mar. 24 2016
Date Sediment Prepared/Added: Mar. 28 2016
Date/Time Test Started: Mar. 29 2016 1100 – 1300 Hrs — Completed: Apr. 08 2016 1100 – 1300 Hrs
Sample Description: Greyish, fine-grained sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 17
Source: NW Seacology, North Vancouver, BC
Date Collected: Mar. 16 2016
Date Received: Mar. 24 2016
Approx. size: 4 - 5 mm

Exposure tanks: 1 litre glass jars
No. of replicates per conc. : 5
No. of organisms per replicate : 20

Volume of seawater: 775 mls
Source: Lawrencetown Bridge, NS
Volume of sediment : 175 mls

Test temperature : 15 ± 2 ^{0}C
Aeration : continuous
Aeration rate : minimal
Lighting: continuous @ 684 lux
Test duration : 10 Days

PARAMETERS

Pore Water Analyses: pH: 7.5 Salinity ‰: 18.2 **Ammonia total (NH_3-N): 0.40 mg/L** **Ammonia unionized (NH_3): 0.004 mg/L**

	Range: Initial / 3 times per week / Final			Salinity ‰		NH_3-N mg/L	
Sample ID	Temp.^{0} C	D.O mg/L	pH	Initial	Final	Initial	Final
Control	13.0 – 16.0	7.3 – 8.2	7.7 – 7.8	29.5	30.7	0.04	0.04

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Control Organisms:	Number Surviving	20/20	19/20	20/20	20/20	20/20	99/100

10 DAY TEST RESULTS

Mean % Survival of 5 Control Replicates = 99 % ± 0.45 SD

REFERENCE TOXICANT DATA Batch # 17

Reference Substance: $CdCl_2$
95% C.L.: 8.64 – 12.5 mg/L
Test Date: Mar. 29 – Apr. 02 2016
Historical $CdCl_2$ Mean: 17.3 mg/L
96 Hour LC_{50} for $CdCl_2$: 10.4 mg/L
Warning Limits ± 2 SD: 8.20 – 36.6 mg/L

Comments:

Analyst(s): G. Harris and A. Huybers Verified by: C. Harris C Harris Date: Apr. 11 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

AMPHIPOD TOXICITY REPORT (Single Concentration)

Client:	McGregor GeoScience Ltd.	Test Facility:	Harris Industrial Testing Service Ltd.
Address:	177 Bluewater Road Bedford, NS B4B 1H1	Location:	1320 Ashdale Rd., South Rawdon, Nova Scotia Canada B0N 1Z0
Contact:	Gillian Forbes		Tel : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info

SAMPLE DATA

Sample Type/Location:	Deep Panuke BLIND Sample	Lab ID. #	16-134-A
Date/Time Collected:	Mar. 08 2016 0320 UTC Hrs	Sampler:	JS
Method of Collection:	Grab	Received:	Mar. 14 2016
Date Sediment Prepared/Added:	Mar. 28 2016		
Date/Time Test Started:	Mar. 29 2016 1100 – 1300 Hrs	Completed:	Apr. 08 2016 1100 – 1300 Hrs

Sample Description: Light brown, coarse sand with live amphipods present and removed prior to test preparation.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 17
Source: NW Seacology, North Vancouver, BC
Date Collected: Mar. 16 2016
Date Received: Mar. 24 2016
Approx. size: 4 - 5 mm

Exposure tanks: 1 litre glass jars
No. of replicates per conc. : 5
No. of organisms per replicate : 20
Volume of seawater: 775 mls
Source: Lawrencetown Bridge, NS
Volume of sediment : 175 mls

Test temperature : 15 ± 2 ^{0}C
Aeration : continuous
Aeration rate : minimal
Lighting: continuous @ 684 lux
Test duration : 10 Days

PARAMETERS

Ammonia total (NH_3-N): 0.08 mg/L

Pore Water Analyses: pH: 7.4 Salinity ‰: 32.7 **Ammonia unionized (NH_3): 0.0006 mg/L**

	Range: Initial / 3 times per week / Final			Salinity ‰		NH_3-N mg/L	
Sample	Temp.^{0} C	D.O mg/L	pH	Initial	Final	Initial	Final
BLIND	13.0 – 16.0	7.6 – 8.3	7.8 – 7.9	31.5	31.9	0.02	0.03
Control	13.0 – 16.0	7.3 – 8.2	7.7 – 7.8	29.5	30.7	0.04	0.04

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	20/20	18/20	20/20	19/20	19/20	96/100
Control Organisms:	Number Surviving	20/20	19/20	20/20	20/20	20/20	99/100

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 96 % ± 0.84 SD

Mean % Survival of 5 Control Replicates = 99 % ± 0.45 SD

REFERENCE TOXICANT DATA Batch # 17

Reference Substance: $CdCl_2$
95% C.L.: 8.64 – 12.5 mg/L

Test Date: Mar. 29 – Apr. 02 2016
Historical $CdCl_2$ Mean: 17.3 mg/L

96 Hour LC_{50} for $CdCl_2$: 10.4 mg/L
Warning Limits ± 2 SD: 8.20 – 36.6 mg/L

Comments:

Analyst(s): G. Harris and A. Huybers Verified by: C. Harris C Harris Date: Apr. 11 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

AMPHIPOD TOXICITY REPORT (Single Concentration)

Client:	McGregor GeoScience Ltd.	Test Facility:	Harris Industrial Testing Service Ltd.
Address:	177 Bluewater Road Bedford, NS B4B 1H1	Location:	1320 Ashdale Rd., South Rawdon, Nova Scotia Canada B0N 1Z0
Contact:	Gillian Forbes		Tel : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info

SAMPLE DATA

Sample Type/Location: Deep Panuke SED 250 m DS — Lab ID. # 16-134-B
Date/Time Collected: Mar. 08 2016 0118 UTC Hrs — Sampler: JS
Method of Collection: Grab — Received: Mar. 14 2016
Date Sediment Prepared/Added: Mar. 28 2016
Date/Time Test Started: Mar. 29 2016 1100 – 1300 Hrs — Completed: Apr. 08 2016 1100 – 1300 Hrs
Sample Description: Very fine, grey sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration (100%) Tox 49
Organism: *Eohaustorius estuarius* Batch # 17
Source: NW Seacology, North Vancouver, BC
Date Collected: Mar. 16 2016
Date Received: Mar. 24 2016
Approx. size: 4 - 5 mm

Exposure tanks: 1 litre glass jars
No. of replicates per conc. : 5
No. of organisms per replicate : 20
Volume of seawater: 775 mls
Source: Lawrencetown Bridge, NS
Volume of sediment : 175 mls

Test temperature : 15 ± 2 ^{0}C
Aeration : continuous
Aeration rate : minimal
Lighting: continuous @ 684 lux
Test duration : 10 Days

PARAMETERS

Pore Water Analyses: pH: 7.2 Salinity ‰: 32.3 **Ammonia-N (NH_3-N): 3.5 mg/L**
Ammonia unionized (NH_3): 0.017 mg/L

Range: Initial / 3 times per week / Final

Sample	Temp.^{0} C	D.O mg/L	pH	Salinity ‰ Initial	Salinity ‰ Final	NH_3-N mg/L Initial	NH_3-N mg/L Final
SED 250 m DS	13.0 – 16.0	7.3 – 8.4	7.7 – 8.0	31.4	31.9	0.27	0.03
Control	13.0 – 16.0	7.3 – 8.2	7.7 – 7.8	29.5	30.7	0.04	0.04

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	20/20	18/20	19/20	19/20	20/20	96/100
Control Organisms:	Number Surviving	20/20	19/20	20/20	20/20	20/20	99/100

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 96 % ± 0.84 SD

Mean % Survival of 5 Control Replicates = 99 % ± 0.45 SD

REFERENCE TOXICANT DATA Batch # 17

Reference Substance: $CdCl_2$
95% C.L.: 8.64 – 12.5 mg/L

Test Date: Mar. 29 – Apr. 02 2016
Historical $CdCl_2$ Mean: 17.3 mg/L

96 Hour LC_{50} for $CdCl_2$: 10.4 mg/L
Warning Limits ± 2 SD: 8.20 – 36.6 mg/L

Comments:

Analyst(s): G. Harris and A. Huybers Verified by: C. Harris C Harris Date: Apr. 11 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

AMPHIPOD TOXICITY REPORT (Single Concentration)

Client: McGregor GeoScience Ltd. Address: 177 Bluewater Road Bedford, NS B4B 1H1 Contact: Gillian Forbes	Test Facility: Harris Industrial Testing Service Ltd. Location: 1320 Ashdale Rd., South Rawdon, Nova Scotia Canada B0N 1Z0 Tel : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info

SAMPLE DATA

Sample Type/Location: Deep Panuke SED 500 m DS — Lab ID. # 16-134-C
Date/Time Collected: Mar. 08 2016 0157 UTC Hrs — Sampler: CMD
Method of Collection: Grab — Received: Mar. 14 2016
Date Sediment Prepared/Added: Mar. 28 2016
Date/Time Test Started: Mar. 29 2016 1100 – 1300 Hrs — Completed: Apr. 08 2016 1100 – 1300 Hrs
Sample Description: Beige, coarse sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 17
Source: NW Seacology, North Vancouver, BC
Date Collected: Mar. 16 2016
Date Received: Mar. 24 2016
Approx. size: 4 - 5 mm

Exposure tanks: 1 litre glass jars
No. of replicates per conc. : 5
No. of organisms per replicate : 20

Volume of seawater: 775 mls
Source: Lawrencetown Bridge, NS
Volume of sediment : 175 mls

Test temperature : 15 ± 2 °C
Aeration : continuous
Aeration rate : minimal
Lighting: continuous @ 684 lux
Test duration : 10 Days

PARAMETERS

Ammonia total (NH_3-N): 0.13 mg/L

Pore Water Analyses: pH: 7.4 Salinity ‰: 32.4 **Ammonia unionized (NH_3): 0.0008 mg/L**

Sample	Temp.° C	D.O mg/L	pH	Salinity ‰ Initial	Salinity ‰ Final	NH_3-N mg/L Initial	NH_3-N mg/L Final
	Range: Initial / 3 times per week / Final						
SED 500 m DS	13.0 – 16.0	7.8 – 8.2	7.8 – 8.0	31.5	31.8	0.03	0.07
Control	13.0 – 16.0	7.3 – 8.2	7.7 – 7.8	29.5	30.7	0.04	0.04

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	10/20	11/20	13/20	11/20	9/20	54/100
Control Organisms:	Number Surviving	20/20	19/20	20/20	20/20	20/20	99/100

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 54 % ± 1.48 SD

Mean % Survival of 5 Control Replicates = 99 % ± 0.45 SD

REFERENCE TOXICANT DATA Batch # 17

Reference Substance: $CdCl_2$
95% C.L.: 8.64 – 12.5 mg/L
Test Date: Mar. 29 – Apr. 02 2016
Historical $CdCl_2$ Mean: 17.3 mg/L
96 Hour LC_{50} for $CdCl_2$: 10.4 mg/L
Warning Limits ± 2 SD: 8.20 – 36.6 mg/L

Comments: More coarse than other samples with many shell fragments present.

Analyst(s): G. Harris and A. Huybers Verified by: C. Harris C Harris Date: Apr. 11 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

AMPHIPOD TOXICITY REPORT (Single Concentration)

Client: McGregor GeoScience Ltd.
Address: 177 Bluewater Road
Bedford, NS B4B 1H1
Contact: Gillian Forbes

Test Facility: Harris Industrial Testing Service Ltd.
Location: 1320 Ashdale Rd., South Rawdon, Nova Scotia
Canada B0N 1Z0
Tel : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info

SAMPLE DATA

Lab ID. # 16-134-D

Sample Type/Location: Deep Panuke SED 1000 m DS
Date/Time Collected: Mar. 08 2016 0235 UTC Hrs
Method of Collection: Grab
Date Sediment Prepared/Added: Mar. 28 2016
Date/Time Test Started: Mar. 29 2016 1100 – 1300 Hrs
Sample Description: Medium-grained, beige sand.

Sampler: CMD
Received: Mar. 14 2016
Completed: Apr. 08 2016 1100 – 1300 Hrs

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 17
Source: NW Seacology, North Vancouver, BC
Date Collected: Mar. 16 2016
Date Received: Mar. 24 2016
Approx. size: 4 - 5 mm

Exposure tanks: 1 litre glass jars
No. of replicates per conc. : 5
No. of organisms per replicate : 20

Volume of seawater: 775 mls
Source: Lawrencetown Bridge, NS
Volume of sediment : 175 mls

Test temperature : 15 ± 2 ^{0}C
Aeration : continuous
Aeration rate : minimal
Lighting: continuous @ 684 lux
Test duration : 10 Days

PARAMETERS

Pore Water Analyses: pH: 7.4 Salinity ‰: 32.2 **Ammonia-N (NH_3-N): 0.31 mg/L** **Ammonia unionized (NH_3): 0.002 mg/L**

Range: Initial / 3 times per week / Final

Sample	Temp.^{0} C	D.O mg/L	pH	Salinity ‰ Initial	Salinity ‰ Final	NH_3-N mg/L Initial	NH_3-N mg/L Final
SED 1000 m DS	13.0 – 16.0	7.9 – 8.4	7.8 – 8.1	31.5	31.9	0.07	0.09
Control	13.0 – 16.0	7.3 – 8.2	7.7 – 7.8	29.5	30.7	0.04	0.04

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	19/20	19/20	18/20	19/20	20/20	95/100
Control Organisms:	Number Surviving	20/20	19/20	20/20	20/20	20/20	99/100

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 95 % ± 0.71 SD

Mean % Survival of 5 Control Replicates = 99 % ± 0.45 SD

REFERENCE TOXICANT DATA Batch # 17

Reference Substance: $CdCl_2$
95% C.L.: 8.64 – 12.5 mg/L

Test Date: Mar. 29 – Apr. 02 2016
Historical $CdCl_2$ Mean: 17.3 mg/L

96 Hour LC_{50} for $CdCl_2$: 10.4 mg/L
Warning Limits ± 2 SD: 8.20 – 36.6 mg/L

Comments:

Analyst(s): G. Harris and A. Huybers Verified by: C. Harris C Harris Date: Apr. 11 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

AMPHIPOD TOXICITY REPORT (Single Concentration)

Client: McGregor GeoScience Ltd.	Test Facility: Harris Industrial Testing Service Ltd.
Address: 177 Bluewater Road Bedford, NS B4B 1H1	Location: 1320 Ashdale Rd., South Rawdon, Nova Scotia Canada B0N 1Z0
Contact: Gillian Forbes	Tel : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info

SAMPLE DATA

Sample Type/Location:	Deep Panuke SED 2000 m DS		Lab ID. # 16-134-E
Date/Time Collected:	Mar. 07 2016 0320 UTC Hrs	Sampler:	CMD
Method of Collection:	Grab	Received:	Mar. 14 2016
Date Sediment Prepared/Added:	Mar. 28 2016		
Date/Time Test Started:	Mar. 29 2016 1100 – 1300 Hrs	Completed:	Apr. 08 2016 1100 – 1300 Hrs

Sample Description: Medium-grained, beige sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 17
Source: NW Seacology, North Vancouver, BC
Date Collected: Mar. 16 2016
Date Received: Mar. 24 2016
Approx. size: 4 - 5 mm

Exposure tanks: 1 litre glass jars
No. of replicates per conc. : 5
No. of organisms per replicate : 20

Volume of seawater: 775 mls
Source: Lawrencetown Bridge, NS
Volume of sediment : 175 mls

Test temperature : 15 ± 2 ^{0}C
Aeration : continuous
Aeration rate : minimal
Lighting: continuous @ 684 lux
Test duration : 10 Days

PARAMETERS

Ammonia total (NH_3-N): 0.10 mg/L

Pore Water Analyses: pH: 7.3 Salinity ‰: 32.9 **Ammonia unionized (NH_3): 0.0005 mg/L**

Range: Initial / 3 times per week / Final

Sample	Temp.^{0} C	D.O mg/L	pH	Salinity ‰ Initial	Salinity ‰ Final	NH_3-N mg/L Initial	NH_3-N mg/L Final
SED 2000 m DS	13.0 – 16.0	7.9 – 8.4	7.8 – 8.0	31.5	31.7	0.07	0.01
Control	13.0 – 16.0	7.3 – 8.2	7.7 – 7.8	29.5	30.7	0.04	0.04

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	19/20	19/20	20/20	20/20	19/20	97/100
Control Organisms:	Number Surviving	20/20	19/20	20/20	20/20	20/20	99/100

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 97 % ± 0.56 SD

Mean % Survival of 5 Control Replicates = 99 % ± 0.45 SD

REFERENCE TOXICANT DATA Batch # 17

Reference Substance: $CdCl_2$
95% C.L.: 8.64 – 12.5 mg/L

Test Date: Mar. 29 – Apr. 02 2016
Historical $CdCl_2$ Mean: 17.3 mg/L

96 Hour LC_{50} for $CdCl_2$: 10.4 mg/L
Warning Limits ± 2 SD: 8.20 – 36.6 mg/L

Comments:

Analyst(s): G. Harris and A. Huybers Verified by: C. Harris C Harris Date: Apr. 11 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

AMPHIPOD TOXICITY REPORT (Single Concentration)

Client:	McGregor GeoScience Ltd.	Test Facility:	Harris Industrial Testing Service Ltd.
Address:	177 Bluewater Road Bedford, NS B4B 1H1	Location:	1320 Ashdale Rd., South Rawdon, Nova Scotia Canada B0N 1Z0
Contact:	Gillian Forbes		Tel : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info

SAMPLE DATA

Sample Type/Location:	Deep Panuke SED 5000 m DS	Lab ID. #	16-134-F
Date/Time Collected:	Mar. 08 2016 0426 UTC Hrs	Sampler:	JS
Method of Collection:	Grab	Received:	Mar. 14 2016
Date Sediment Prepared/Added:	Mar. 28 2016		
Date/Time Test Started:	Mar. 29 2016 1100 – 1300 Hrs	Completed:	Apr. 08 2016 1100 – 1300 Hrs

Sample Description: Medium-grained, beige sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 17
Source: NW Seacology, North Vancouver, BC
Date Collected: Mar. 16 2016
Date Received: Mar. 24 2016
Approx. size: 4 - 5 mm

Exposure tanks: 1 litre glass jars
No. of replicates per conc. : 5
No. of organisms per replicate : 20

Volume of seawater: 775 mls
Source: Lawrencetown Bridge, NS
Volume of sediment : 175 mls

Test temperature : 15 ± 2 ^{0}C
Aeration : continuous
Aeration rate : minimal
Lighting: continuous @ 684 lux
Test duration : 10 Days

PARAMETERS

Ammonia total (NH_3-N): 0.07 mg/L

Pore Water Analyses: pH: 7.3 Salinity ‰: 32.9 **Ammonia unionized (NH_3): 0.0003 mg/L**

Sample	Range: Temp.^{0} C	Initial / 3 times per week / Final D.O mg/L	pH	Salinity ‰ Initial	Salinity ‰ Final	NH_3-N mg/L Initial	NH_3-N mg/L Final
SED 5000 m DS	13.0 – 16.0	7.6 – 8.4	7.8 – 8.0	31.8	31.9	0.07	0.00
Control	13.0 – 16.0	7.3 – 8.2	7.7 – 7.8	29.5	30.7	0.04	0.04

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	17/20	20/20	19/20	20/20	20/20	96/100
Control Organisms:	Number Surviving	20/20	19/20	20/20	20/20	20/20	99/100

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 96 % ± 1.30 SD

Mean % Survival of 5 Control Replicates = 99 % ± 0.45 SD

REFERENCE TOXICANT DATA Batch # 17

Reference Substance: $CdCl_2$
95% C.L.: 8.64 – 12.5 mg/L

Test Date: Mar. 29 – Apr. 02 2016
Historical $CdCl_2$ Mean: 17.3 mg/L

96 Hour LC_{50} for $CdCl_2$: 10.4 mg/L
Warning Limits ± 2 SD: 8.20 – 36.6 mg/L

Comments:

Analyst(s): G. Harris and A. Huybers Verified by: C. Harris C Harris Date: Apr. 11 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

AMPHIPOD TOXICITY REPORT (Single Concentration)

Client: McGregor GeoScience Ltd.
Address: 177 Bluewater Road
Bedford, NS B4B 1H1
Contact: Gillian Forbes

Test Facility: Harris Industrial Testing Service Ltd.
Location: 1320 Ashdale Rd., South Rawdon, Nova Scotia
Canada B0N 1Z0
Tel : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info

SAMPLE DATA

Sample Type/Location: Deep Panuke SED 5000 m US — Lab ID. # 16-134-G
Date/Time Collected: Mar. 08 2016 0528 UTC Hrs — Sampler: JS
Method of Collection: Grab — Received: Mar. 14 2016
Date Sediment Prepared/Added: Mar. 28 2016
Date/Time Test Started: Mar. 29 2016 1100 – 1300 Hrs — Completed: Apr. 08 2016 1100 – 1300 Hrs
Sample Description: Medium-grained, beige sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 17
Source: NW Seacology, North Vancouver, BC
Date Collected: Mar. 16 2016
Date Received: Mar. 24 2016
Approx. size: 4 - 5 mm

Exposure tanks: 1 litre glass jars
No. of replicates per conc. : 5
No. of organisms per replicate : 20

Volume of seawater: 775 mls
Source: Lawrencetown Bridge, NS
Volume of sediment : 175 mls

Test temperature : 15 ± 2 ^{0}C
Aeration : continuous
Aeration rate : minimal
Lighting: continuous @ 684 lux
Test duration : 10 Days

PARAMETERS

Ammonia total (NH_3-N): 0.40 mg/L

Pore Water Analyses: pH: 7.4 Salinity ‰: 32.6 **Ammonia unionized (NH_3): 0.003 mg/L**

	Range: Initial / 3 times per week / Final			Salinity ‰		NH_3-N mg/L	
Sample	Temp.^{0} C	D.O mg/L	pH	Initial	Final	Initial	Final
SED 5000 m US	13.0 – 16.0	7.7 – 8.4	7.7 – 8.0	31.0	31.8	0.02	0.01
Control	13.0 – 16.0	7.3 – 8.2	7.7 – 7.8	29.5	30.7	0.04	0.04

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	20/20	19/20	19/20	20/20	20/20	98/100
Control Organisms:	Number Surviving	20/20	19/20	20/20	20/20	20/20	99/100

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 98 % ± 0.55 SD

Mean % Survival of 5 Control Replicates = 99 % ± 0.45 SD

REFERENCE TOXICANT DATA Batch # 17

Reference Substance: $CdCl_2$
95% C.L.: 8.64 – 12.5 mg/L

Test Date: Mar. 29 – Apr. 02 2016
Historical $CdCl_2$ Mean: 17.3 mg/L

96 Hour LC_{50} for $CdCl_2$: 10.4 mg/L
Warning Limits ± 2 SD: 8.20 – 36.6 mg/L

Comments:

Analyst(s): G. Harris and A. Huybers Verified by: C. Harris C Harris Date: Apr. 11 2016

Accredited by the Canadian Association for Laboratory Accreditation (CALA). The test included in this report is within the scope of this accreditation. The results reported apply only to the sample tested. Results are based on nominal concentrations.

Toxicity results for *Eohaustorius estuarius*
exposed to sediments
from Deep Panuke

For:
McGregor GeoScience Ltd.
Bedford NS

Submitted by:

HITS
AQUATIC TOXICITY TESTING

Harris Industrial Testing Service Ltd.
1320 Ashdale Road
South Rawdon, NS
B0N 1Z0

Authorized by:

Gary Harris
April 12, 2016

TABLE OF CONTENTS

1.0 Introduction

McGregor GeoScience Ltd. of Bedford, NS, supplied Harris Industrial Testing Service Ltd. (HITS), with sediment samples collected at Deep Panuke on March 07 and 08, 2016. These grab samples were collected and transported by boat to Halifax and delivered to Harris Industrial Testing Lab in South Rawdon, N.S. on March 14, 2016. They were transported in sealed polyethylene bags on ice in a cooler. The samples were refrigerated (kept in the dark at 4 ± 2 °C) in the HITS lab until testing.

Sample/Location	Lab ID
SED BLIND SAMPLE	16-134-A
SED 250 m DS	16-134-B
SED 500 m DS	16-134-C
SED 1000 m DS	16-134-D
SED 2000 m DS	16-134-E
SED 5000 m DS	16-134-F
SED 5000 m US	16-134-G

The samples were tested for acute lethality using the estuarine amphipod *Eohaustorius estuarius.*

2.0 Materials and Methods

These tests were conducted in accordance with Environment Canada's "Biological Test Method: Reference Method for Determining Acute Lethality of Sediment to Marine or Estuarine Amphipods", EPS 1/RM/35, December 1998.

The grain size (see Table 2) and TOC (see Table 3) analyses were conducted by the client. The organism of choice for this test is *E. estuarius*.

HITS Lab Method "Tox 49" is held on file in the lab. This method describes the following:

- reception and acclimation of amphipods;
- preparation of control sediment;
- preparation of samples;
- preparation of reference toxicant;
- conduct of testing.

E. Estuarius (Batch # 17) were purchased from NW Seacology, North Vancouver, BC. Collection took place on March 16, 2016. They were shipped March 23, 2016 via Air Canada overnight and picked up at Air Canada Cargo by HITS staff on March 24, 2016. Organisms were held at the lab in site sediment covered with aerating seawater at test temperature (15 ± 2 °C) in continuous light for 5 days prior to the commencement of testing. Organism health during the acclimation period met the validity criteria.

Pre-sieved control (home) sediment was received in sealed polyethylene bags with the amphipod shipment and was kept in the dark at 4 ± 2 °C until use.

2.1 *Pre-test Procedure*

Pre-test procedures conducted on March 28, 2016 were as follows:

- ~15 ml of pore water was extracted from each sediment and the following parameters were measured: pH, salinity, total Ammonia (NH_3-N);
- Unionized Ammonia (NH_3) was estimated;
- 175 ml of each test sediment was measured and added to each of five replicate exposure jars;
- 175 ml of the control sediment was measured and added to each of five replicate exposure jars for the control test;
- 775 ml of clean seawater, collected at high tide from Lawrencetown Bridge (the same source as the acclimation water), with a D.O. of 90 – 100% saturation was added to each test jar;
- Each prepared replicate jar was held at 15 ± 2 °C and aerated overnight prior to the start of the test.

2.2 *Test Initiation Procedure*

Test initiation on March 29, 2016 was as follows:

- 20 *E. estuarius* amphipods were added to all test chambers;
- Dissolved oxygen (D.O.), pH, salinity, ammonia and temperature were measured in 1 replicate of each test sediment and control;
- A reference toxicant test using Cadmium Chloride was initiated on Batch # 17 organisms in seawater only (as per EPS 1/RM/35).

2.3 *Test Conditions*

Test conditions were as follows:

- The reference toxicant test was conducted for 96 hours with no exposure to light and no aeration;
- The amphipod sediment test was conducted for a 10-day period under continuous fluorescent lighting at 15 ± 2 °C with minimal aeration;
- D.O., pH, salinity, and temperature were measured on day 0, 2, 3, 6, and 8 throughout the 10-day test and at termination for each sample.

2.4 *Test Termination Procedure*

Test termination on April 08, 2016 was as per the following procedure:

- D.O., pH, salinity, temperature and ammonia were measured (refer to *Amphipod Toxicity Reports)* in 1 replicate of each test sediment and control;
- The contents of each test vessel were sieved through a 0.5 mm sieve. The sieve was agitated gently in a pan of clean seawater. The organisms were pipetted from the sieve into a weigh boat with a clean glass pipette. Amphipods found at the surface were noted and missing organisms were assumed dead.

- The biological endpoint for the 10-day test is the mean (± SD) percentage of amphipods that survived in each treatment (including the control) during the 10-day test.
- Survival rates between the control sample and the test samples were statistically compared using the one-tailed *Student's t-test* (Tidepool Scientific Software, 2001 – 2014. Comprehensive Environmental Toxicity Information System – CETIS v1.8.7.20) as per EPS 1/RM/35.

3.0 Results and Conclusions

- All monitored parameters, D.O., pH, temperature and salinity were within acceptable levels throughout the 10-day exposure period;
- 10-day survival in the control sediment exceeded the 90% requirement for a valid test;
- The reference toxicant result fell within this lab's warning limits (*i.e.*, ± 2 S.D. from the mean);
- All test validity criteria for the sediment test method were satisfied;
- No organisms exhibiting unusual appearance, or undergoing unusual treatment were used in the test;
- The sediment 500 m DS was much coarser than the other sediments tested. Many shell fragments were found at termination. Survival was 54%.

  In keeping with Environment Canada (1997), the following … guidance is recommended when judging if samples of test sediment pass or fail a 10-day test for sediment toxicity:

  - *In the absence of an acceptable reference sediment, the test sediment is judged to have failed this sediment toxicity test if the mean 10-day survival rate for the replicate groups of test organisms exposed to this sediment is more than 30% lower than that in the control sediment and is significantly different.*

- Statistically, there was no significant difference between the survival in the control sediment and the survival in all the test sediments except SED 500 m DS*. The mean survival rate for this sediment was 45% lower than in the control sediment.

- All samples as tested were found to be non-toxic to the amphipod *Eohaustorius estuarius* except SED 500 m DS*. The control sediment as tested was found to be non-toxic (refer to *Table 1*).

Table 1: Toxicity Results of *E. Estuarius* exposed to sediments

Sample Location	**Lab ID**	**Survival**	**Survival** (± SD) %
SED BLIND SAMPLE	16-134-A	96/100	96 ± 0.84
SED 250 m DS	16-134-B	96/100	96 ± 0.84
SED 500 m DS	16-134-C	54/100*	54 ± 1.48
SED 1000 m DS	16-134-D	95/100	95 ± 0.71
SED 2000 m DS	16-134-E	97/100	97 ± 0.56
SED 5000 m DS	16-134-F	96/100	96 ± 1.30

HITS

SED 5000 m US	16-134-G	98/100	96 ± 0.55
Control	16-134-Ctl	99/100	99 ± 0.45

Table 2: Sediment Quality: Particle Size Analysis Results

RESULTS OF ANALYSES OF SOIL

Maxxam ID		CAA414	CAA415	CAA416	CAA417	CAA418	CAA419		
Sampling Date		2016/03/08 13:18	2016/03/08 13:57	2016/03/08 14:35	2016/03/08 15:20	2016/03/08 17:28	2016/03/08 16:26		
COC Number		546009-01-01	546009-01-01	546009-01-01	546009-01-01	546009-01-01	546009-01-01		
	UNITS	**SED 250 M**	**SED 500 M**	**SED 1000 M**	**SED 2000 M**	**SED 5000 M up**	**SED 5000 M do**	**RDL**	**QC Batch**
Inorganics									
< -1 Phi (2 mm)	%	100	99	100	100	100	100	0.10	4427445
< 0 Phi (1 mm)	%	100	92	100	100	100	100	0.10	4427445
< +1 Phi (0.5 mm)	%	99	61	89	97	90	87	0.10	4427445
< +2 Phi (0.25 mm)	%	83	11	22	28	13	9.3	0.10	4427445
< +3 Phi (0.12 mm)	%	4.9	0.82	1.2	1.2	0.90	0.88	0.10	4427445
< +4 Phi (0.062 mm)	%	1.0	0.65	0.87	0.90	0.74	0.76	0.10	4427445
< +5 Phi (0.031 mm)	%	1.0	0.58	0.87	0.89	0.69	0.75	0.10	4427445
< +6 Phi (0.016 mm)	%	1.0	0.65	0.80	0.85	0.71	0.79	0.10	4427445
< +7 Phi (0.0078 mm)	%	1.0	0.72	0.81	0.92	0.59	0.75	0.10	4427445
< +8 Phi (0.0039 mm)	%	1.0	0.68	0.98	0.86	0.64	0.78	0.10	4427445
< +9 Phi (0.0020 mm)	%	1.1	0.62	0.96	0.92	0.64	0.76	0.10	4427445
Gravel	%	ND	0.78	ND	ND	ND	ND	0.10	4427445
Sand	%	99	99	99	99	99	99	0.10	4427445
Silt	%	ND	ND	ND	ND	0.10	ND	0.10	4427445
Clay	%	1.0	0.68	0.98	0.86	0.64	0.78	0.10	4427445

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
ND = Not detected

Table 3: Sediment Quality: Total Organic Carbon Analysis Results

RESULTS OF ANALYSES OF SOIL

Maxxam ID		CAA414	CAA415	CAA416	CAA417	CAA418	CAA419
Sampling Date		2016/03/08 13:18	2016/03/08 13:57	2016/03/08 14:35	2016/03/08 15:20	2016/03/08 17:28	2016/03/08 16:26
COC Number		546009-01-01	546009-01-01	546009-01-01	546009-01-01	546009-01-01	546009-01-01
	UNITS	**SED 250 M**	**SED 500 M**	**SED 1000 M**	**SED 2000 M**	**SED 5000 Mup**	**SED 5000 Mdo**
Inorganics							
Moisture	%	18	14	15	16	17	17
Organic Carbon (TOC)	g/kg	0.59	ND	ND	ND	ND	ND

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
ND = Not detected

4.0 References

Environment Canada. 1998. Biological Test Method: Reference Method for Determining Acute Lethality of Sediment to Marine or Estuarine Amphipods. Report EPS 1/RM/35. Environment Canada, Environmental Protection, Ottawa, December 1998.

Environment Canada. 1992 with 1998 Amendments. Biological Test Method: Acute Test for Sediment Toxicity Using Marine or Estuarine Amphipods. Report EPS 1/RM/26. Environment Canada, Environmental Protection, Ottawa, December 1998.

APPENDIX H

2016 Fish Habitat Alteration Video Assessments (Stantec)

Table A-1: Marine Fauna Observed During 2016 Survey in Representative GEP Segments

		Start KP											
Fauna	**Fauna (Latin name)**	**23.222***	**24.235**	**25.873**	**27.495**	**29.211**	**31.134**	**32.984**	**35.072**	**36.864**	**38.646**	**40.627**	**42.787**
Comb Jelly	Ctenophore	O						R					
Tubularia? Spp.	Tubularia Spp.	C						O					
Polymastia	*Polymastia sp.*												
Encrusting sponge	Porifera							R					
Sponge	Porifera	6											
Corymorpha sp.	Corymorpha sp.												
Sea anemone	Actinaria	1						11					11
Cerianthus sp.	*Cerianthus sp.*												
Soft Coral	Alcyonacea												
Colus sp.	*Colus sp.*												
Jonah crab	*Cancer borealis*	1						3					9
Snow crab	*Chionoecetes opilio*							27					11
Toad crab	*Hyas sp.*												
Portly spider crab	*Libinia emarginata*												
Northern Stone Crab	*Lithodes maja*												
Shrimp	Pandalidae												O
Ceramaster	*Ceremaster sp.*							6					9
Crossaster	*Crossaster sp.*												7
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*	27						86					83
Hippasteria sp	*Hippasteria sp.*												
Cushion star	*Poriania*												
Solaster	*Solaster sp.*	2						3					2
Basket star	*Gorgoncephalus sp.*							1					
Sand dollar	*Echinarachnius parma*												
Sea urchin	*Strongylocentrotus sp.*												
Sea cucumber	*Cucumaria frondosa*												
Feather star	Crinoidea												
Sea potato	*Boltenia ovifera*												
Tunicate	Tunicata												
Atlantic Wolffish	*Anarhichas lupus*												
Gadoid	Gadidae												
Atlantic Cod	*Gadus morhua*												
Sea Raven	*Hemitripterus americanus*												
Atlantic Hagfish	*Mixine glutinosa*												1
Sculpin	*Myoxocephalus sp.*												1
Flatfish	Pleuronectiformes							1					1
Pollock	*Pollachius sp.*												
Redfish	*Sebastes sp.*							3					6
Eelpout/Ocean pout?	Zoarcidae												2
Haddock	*Melanogrammis aeglefinus*												1
American Lobster	*Homarus americanus*	1											
Unidentified Fish		1											
Unidentified Worm													
Jonah crab (Dead/exoskeleton)	*Cancer borealis*												
		23.429*	**24.573**	**26.317**	**27.893**	**29.869**	**31.517**	**33.497**	**35.450**	**37.354**	**39.101**	**41.140**	**43.186**
		End KP											

*KP 17.209 to KP 17.461 surveyed in 2016

Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

		Start KP											
Fauna	**Fauna (Latin name)**	**44.807**	**46.370**	**48.567**	**50.746**	**52.480**	**54.717**	**56.772**	**59.236**	**61.669**	**63.882**	**66.430**	**68.353**
Comb jelly	Ctenophore					R							
Tubularia? spp.	Tubularia spp.					R					R		
Polymastia	*Polymastia sp.*												
Encrusting sponge	Porifera					O					O		
Sponge	Porifera					1							
Corymorpha sp.	Corymorpha sp.												
Sea anemone	Actinaria					12					22		
Cerianthus sp.	*Cerianthus sp.*					3							
Soft Coral	Alcyonacea												
Colus sp.	*Colus sp.*												
Jonah crab	*Cancer borealis*					35					8		
Snow crab	*Chionoecetes opilio*					4							
Toad crab	*Hyas sp.*												
Portly spider crab	*Libinia emarginata*												
Northern Stone Crab	*Lithodes maja*					1							
Shrimp	Pandalidae					R							
Ceramaster	*Ceremaster sp.*					2					8		
Crossaster	*Crossaster sp.*					1							
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*					375					53		
Hippasteria sp	*Hippasteria sp.*												
Cushion star	*Poriania*												
Solaster	*Solaster sp.*					1							
Basket star	*Gorgoncephalus sp.*												
Sand dollar	*Echinarachnius parma*												
Sea urchin	*Strongylocentrotus sp.*												
Sea cucumber	*Cucumaria frondosa*					4					1		
Feather star	Crinoidea												
Sea potato	*Boltenia ovifera*												
Tunicate	Tunicata												
Atlantic Wolffish	*Anarhichas lupus*										12		
Gadoid	Gadidae												
Atlantic Cod	*Gadus morhua*					4							
Sea Raven	*Hemitripterus americanus*												
Atlantic Hagfish	*Mixine glutinosa*					1							
Sculpin	*Myoxocephalus sp.*												
Flatfish	Pleuronectiformes					1							
Pollock	*Pollachius sp.*					6					2		
Redfish	*Sebastes sp.*					1125					2000		
Eelpout/Ocean pout?	Zoarcidae												
Haddock	*Melanogrammis aeglefinus*												
American Lobster	*Homarus americanus*												
Unidentified Fish													
Unidentified Worm						12					8		
Jonah crab (Dead/exoskeleton)	*Cancer borealis*					1					2		
		45.175	**46.864**	**49.013**	**51.175**	**52.937**	**55.190**	**57.295**	**59.795**	**62.170**	**64.474**	**66.852**	**68.952**
		End KP											

Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

		Start KP											
Fauna	**Fauna (Latin name)**	**70.947**	**73.297**	**75.587**	**78.183**	**80.354**	**83.016**	**85.448**	**88.109**	**90.347**	**92.825**	**95.361**	**97.378**
Comb jelly	Ctenophore												
Tubularia? spp.	Tubularia spp.		R								R		
Polymastia	*Polymastia sp.*												
Encrusting sponge	Porifera						O						
Sponge	Porifera						1						
Corymorpha sp.	Corymorpha sp.												
Sea anemone	Actinaria		27				2				15		
Cerianthus sp.	*Cerianthus sp.*		36				46				25		
Soft Coral	Alcyonacea												
Colus sp.	*Colus sp.*												
Jonah crab	*Cancer borealis*		9				22				90		
Snow crab	*Chionoecetes opilio*												
Toad crab	*Hyas sp.*												
Portly spider crab	*Libinia emarginata*												
Northern Stone Crab	*Lithodes maja*		2				2				5		
Shrimp	Pandalidae		R								R		
Ceramaster	*Ceremaster sp.*		10				1				19		
Crossaster	*Crossaster sp.*												
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*		65				86				73		
Hippasteria sp	*Hippasteria sp.*												
Cushion star	*Poriania*												
Solaster	*Solaster sp.*		1				5						
Basket star	*Gorgoncephalus sp.*												
Sand dollar	*Echinarachnius parma*						1						
Sea urchin	*Strongylocentrotus sp.*												
Sea cucumber	*Cucumaria frondosa*						1				8		
Feather star	Crinoidea												
Sea potato	*Boltenia ovifera*												
Tunicate	Tunicata												
Atlantic Wolffish	*Anarhichas lupus*		4				1						
Gadoid	Gadidae												
Atlantic Cod	*Gadus morhua*												
Sea Raven	*Hemitripterus americanus*												
Atlantic Hagfish	*Mixine glutinosa*		4				1						
Sculpin	*Myoxocephalus sp.*										1		
Flatfish	Pleuronectiformes										4		
Pollock	*Pollachius sp.*										1		
Redfish	*Sebastes sp.*		1650				700				4		
Eelpout/Ocean pout?	Zoarcidae		1								12		
Haddock	*Melanogrammis aeglefinus*												
American lobster	*Homarus americanus*												
Unidentified Fish													
Unidentified Worm											3		
		71.478	**73.869**	**76.202**	**78.538**	**80.941**	**83.552**	**86.019**	**88.662**	**90.865**	**93.349**	**95.808**	**97.890**
		End KP											

Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table A-2: Marine Fauna Observed During 2014-2016 Surveys in Representative GEP Segments

		Start KP																							
		23.222			32.984			42.787			52.48			63.882			73.297			83.016			92.825		
Fauna	Latin Name	2014	2015	2016*	2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016
Porifera																									
Polymastia	*Polymastia spp.*							3			23			12	19		14	60		3					
Encrusting sponge	Porifera				O		R				R		O			O				R		O			
Sponge	Porifera			6	46			8			61		1	180	255		26	30		4	3	1	1		
	Sub-total			**6**				**11**						**192**	**274**		**40**	**90**			**3**		**1**		
Anthozoa																									
Sea anemone	Actinaria	1		1	800		11	32		11	61		12	113	4	22	55	50	27	5	7	2	35		15
Cerianthus sp	*Cerianthus sp.*		11										3		2		27	21	36	457	284	46	13		25
Soft Coral	*Alcyonacea*		13		7																				
	Sub-total	**1**	**24**	**1**	**807**		**11**	**32**		**11**	**61**		**15**	**113**	**6**	**22**	**82**	**71**	**63**	**462**	**291**	**48**	**48**		**40**
Mollusca																									
Buccinum sp.	*Buccinum sp.*										2			1											
Colus sp.	*Colus sp.*														3										
Neptunea sp.	*Neptunea sp.*	1						1																	
	Sub-total	**1**						**1**			**2**			**1**	**3**										
Crustacea																									
Jonah crab	*Cancer borealis*			1	10		3	13		9	21		35	14	18	8	38	64	9	129	112	22	115		90
Cancer sp.	*Cancer sp.*																			4					
Snow crab	*Chionoecetes opilio*	24	26		102		27	100		11	19		4	11	6		1	2		2	2		2		
Unid. Decapod	Decapoda				2			1																	
Lobster	*Homarus americanus*			1																					
Toad Crab	*Hyas sp.*														1										
Portly Spider Crab	*Libinia emarginata*																								
Northern Stone Crab	*Lithodes maja*												1				1	2	2	6	2	2	3		5
Hermit crab	*Pagurus sp.*																						1		
Shrimp	*Pandalidae*				126		6	29		O			R						R	4					R
	Sub-total	**24**	**26**	**2**	**240**		**36**	**143**			**40**			**25**	**25**	**8**	**40**	**68**		**145**	**116**	**24**	**121**		
Echinodermata																									
Ceramaster	*Ceremaster sp.*									9			2			8			10			1	1		19
Crossaster	*Crossaster sp.*	8	2					19		7			1												
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*	3		27	102		86	64		83	617		375	762	190	53	1525	346	65	3694	450	86	2110		73
Hippasteria sp.	*Hippasteria sp.*				5			16			1			12	4		4	7		5	3		28		
Pteraster sp.	*Pteraster sp.*													2						1					
Solaster	*Solaster sp.*	1	3	2	3		3	13		2	8		1	2			2	2	1	7	1	5			
Basket star	*Gorgoncephalus sp.*	17	23		1		1	2							44						39				
Sand dollar	*Echinarachnius parma*										7			9								1			
Sea urchin	*Strongylocentrotus sp.*	51	74		2						487										5		1		
Sea cucumber	*Cucumaria frondosa*	6	1					3			17		4	9	4	1	2	5		11		1	15		8
	Sub-total	**86**	**103**	**29**	**113**		**90**	**117**		**101**	**1137**		**383**	**796**	**242**	**62**	**1533**	**360**	**76**	**3718**	**498**	**94**	**2155**		**100**
Pisces																									
Atlantic Wolffish	*Anarhichas lupus*													5	6	12		2	4	2		1			
Atlantic Herring	*Clupea harengus*																						~20		
Gadoid	Gadidae	9			2			2										13							
Atlantic Cod	*Gadus morhua*				1						16		4	26			3	6		2			3		
Sea Raven	*Hemitripterus americanus*														2					1					
Monkfish	*Lophius sp.*																						1		
Blenny	*Lumpenus sp.*				3									1						2			1		
Atlantic Hagfish	*Myxine glutinosa*									1	1		1		1				4	6		1			
Sculpin	*Myoxocephalus sp.*				1					1								2			1		2		1
Flatfish	Pleuronectiformes						1	1		1			1										9		4
Pollock	*Pollachius sp.*						3						6		47	2				~50	560				1
Redfish	*Sebastes sp.*	1	1		8					6	209		1125	1434	1635	2000	2511	1661	1650	489		700	3		4
Hake	*Urophycis sp.*				4															19			4		
Eelpout/Ocean pout?	Zoarcidae									2									1						12
Haddock	*Melanogrammis aeglefinus*		1							1					3			2							
Unidentified Fish		1	2	1	2			1						2			2			1	2		2		
	Sub-total	**11**	**4**	**1**	**21**		**4**	**4**		**12**	**226**		**1137**	**1468**	**1694**	**2014**	**2516**	**1686**	**1659**	**522**	**563**	**702**	**25**		**22**
Miscellaneous																									
Brachiopod	*Terebratulina sp.*				F												C								
Corymorpha sp.	*Corymorpha sp.*										1							1					4		
Hydrozoa	Hydrozoa	F																							
Tubularia? Spp.	*Tubularia Spp.*			C			O						R			R			R						R
Tunicate	Tunicata										C			S	C		S	C		A	2		C		
Comb Jelly	Ctenophore			O			R						R												
Unidentified Worm				1									12			8									3
Jonah crab (dead/exoskelton)	*Cancer borealis*										2		1	6	2	2	11	11		12	8		3		
			23.429			**33.497**			**43.186**			**52.937**			**64.474**			**73.869**			**83.552**			**93.349**	
		End KP																							

Notes:

Segment was not surveyed in 2015

*KP 17.209 to KP 17.461 surveyed in 2016

Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

APPENDIX I

2016 Mussel Sampling Logs and Photos (McGregor)

McGregor GeoScience Limited

McGregor GeoScience Mussel Sampling Log
1113 Encana 2016

Datum: WGS84
Projection: UTM Zone 20N

Project 1113 **Sample Site:** DEEP PANUKE SW LEG

Launch Coordinates **X:** **Y:** **Depth:**

Date: 8 MAR 2016 **Time Start (UTC):** 1225 **Time End (UTC):** 1254
Sea Conditions:

Mussel Bag A	Height (mm)	Length (mm)	Width (mm)	Notes
1A	029	078	035	
2A	020	064	031	
3A	021	071	032	
4A	026	072	031	
5A	024	078	035	
6A	024	079	031	
7A	029	081	039	
8A	022	074	037	
9A	027	080	036	
10A	021	069	035	

Mussel Bag B	Height (mm)	Length (mm)	Width (mm)	Notes
1B	027	081	033	
2B	031	089	035	
3B	029	077	035	
4B	029	085	039	
5B	025	084	038	
6B	029	079	033	
7B	027	080	035	
8B	027	080	037	
9B	026	078	034	
10B	030	082	034	

Mussel Bag C	Height (mm)	Length (mm)	Width (mm)	Notes
1C	025	077	034	
2C	024	071	032	
3C	025	075	034	
4C	025	076	033	
5C	020	075	034	
6C	032	078	035	
7C	027	077	033	
8C	022	073	032	
9C	026	078	033	
10C	020	070	032	

Other Comments:

McGregor GeoScience Limited

McGregor GeoScience Mussel Sampling Log
1113 Encana 2016

Datum: WGS84
Projection: UTM Zone 20N

Project 1113 **Sample Site:** Commercial Sobeys

Launch Coordinates **X:** **Y:** **Depth:**

Date: Mar. 14/16 **Time Start (UTC):** **Time End (UTC):**

Sea Conditions:

Mussel Bag A	Height (mm)	Length (mm)	Width (mm)	Notes
1A	022	066	028	
2A	022	062	029	
3A	020	061	026	
4A	021	058	025	
5A	023	061	028	
6A	022	066	030	
7A	022	061	028	
8A	020	063	027	
9A	021	060	027	
10A	023	063	030	

Mussel Bag B	Height (mm)	Length (mm)	Width (mm)	Notes
1B	023	060	026	
2B	022	065	029	
3B	022	060	026	
4B	021	057	028	
5B	022	065	031	
6B	022	061	028	
7B	021	067	030	
8B	020	064	027	
9B	022	059	028	
10B	018	058	029	

Mussel Bag C	Height (mm)	Length (mm)	Width (mm)	Notes
1C	029	054	025	
2C	018	055	027	
3C	018	055	025	
4C	019	056	025	
5C	024	058	026	
6C	018	057	025	
7C	018	056	025	
8C	019	055	025	
9C	018	054	025	
10C	017	051	024	

Other Comments:


McGregor GeoScience Limited
Tel: 902-420-0313 www.mcgregor-geoscience.com
177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project #: 1113 Encana
Sample: Control mussels - C
Site: Control - Sobeys - Commercial
Date Collected: March 14, 2016 Collected by: GJF
Comments: From PEI - purchased at Sobeys in Bedford, NS.
WESTCOTT
MADE IN CHINA


McGregor GeoScience Limited
Tel: 902-420-0313 www.mcgregor-geoscience.com
177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project #: 1113 ENCANA
Sample: MUSSELS BAG A
Site: DEEP PANUKE
Date Collected: 8 MAR 2016 Collected by:
Comments: X10


McGregor GeoScience Limited
ENCANA PROJECT 1113
DATE: 8 MAR 2016
TIME: 12:30 UTC
DEPTH:
STATION: A
cm
McGregor GeoScience Limited
Project#: 1113 ENCANA
Sample: MUSSELS BAG A
Site: DEEP PANUKE
Date Collected: 8 MAR 2016 Collected by:
Comments: X10


McGregor GeoScience Limited
Tel: 902-420-0313 www.mcgregor-geoscience.com
177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project#: 1113 ENCANA
Sample: MUSSELS BAG A
Site: DEEP PANUKE
Date Collected: 8 MAR 2016 Collected by:
Comments: X10


McGregor GeoScience Limited
Tel: 902-420-0313 www.mcgregor-geoscience.com
177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project #: 1113 ENCANA
Sample: MUSSEL BAG C
Site: DEEP PANUKE
Date Collected: 8 MAR 2016 Collected by:
Comments: X10


McGregor GeoScience Limited
ENCANA PROJECT 1113
DATE: 8 MAR 2016
TIME: 12:30 UTC
DEPTH:
STATION: B
cm


McGregor GeoScience Limited
Tel: 902-420-0313 www.mcgregor-geoscience.com
177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project#: 1113 Encana
Sample: Control Mussels A
Site: Sobeys- Commercial Control
Date Collected: Mar 14, 2016 Collected by: GF
Comments: Purchased from Sobeys in Bedford NS - from PEI
WESTCOTT
MADE IN CHINA


McGregor GeoScience Limited
Tel: 902-420-0313 www.mcgregor-geoscience.com
177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project#: 1113 Encana
Sample: Control Mussels B
Site: Sobeys - commercial Control
Date Collected: Mar 14, 2016 Collected by: GF
Comments: Purchased from Sobeys in Bedford, NS - from PEI
WESTCOTT
MADE IN CHINA

APPENDIX J

2016 Fish Sampling Logs and Photos (McGregor)

1. Identification

ID Number: PFC-001 Other Reference:

2. Capture data

Date: MARCH 8 2016 Hour: 15:15 UTC

Location, site or coordinates: MARK 14 – UTM (Zone 20N – East 0685589 m, North 4853236 m)

3. Bio data:

Species: Atlantic cod (*Gadus morhua*) Total weight (grams): 740g

Length (head to fork): in cm: 45 cm Sex & Gonads weight: Immature

Photo taken (yes /no) Yes

Additional comments: N/O

4. Killing method

According CCAC guidelines on: euthanasia of animals used in science
Benzocaine overdose follow by immediate exsanguination by severing multiple and bilateral gill arches.

5. Comments

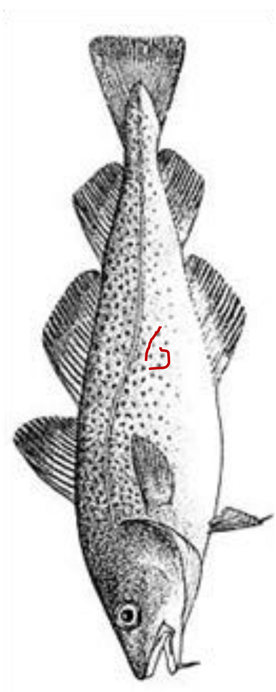
External examination:
In the left side at the level of the pectoral fin there are 2 approximately 2 mm wide and 3 cm long Linear and circular skin pale white and smooth lines (Interpret as scars)

Internal examination:
There is minimal amount of adipose tissue surrounding the abdominal viscera.

- **Gall Bladder**: The gall bladder contains approximately 0.05 mL of bile.
- **Liver**: Liver is small. In the subserosa there is a (thin 0.5 mm) and coiled elevation (interpret as a nematode)
- **Stomach**: Contains abundant 2-3 cm long crustaceans (photo taken) and a 4 cm long and flat orange organism (unidentified)
- Intestine is full and contains similar crustaceans as observed in the stomach.
- **Swim bladder**: A patch approximately 2 cm long, star shape and orange and slightly granular is observed in the internal aspect at the level of the trunk kidney (possibly a normal anatomic structure, sample taken for confirmation)

Not additional comments

6. Gross Exam



6. Samples Taken

Histology protocol samples

- Gills – Left second arch
- Liver
- Kidney: Head and trunk
- Gonads

Histology additional samples

- Brain, spleen, stomach, intestine, pyloric caeca, heart, skeletal muscle and skin
- Swim bladder orange patch
- Liver: Subcapsular coiled, white and thin protrusion

Additional samples as requested by McGregor Geoscience Field party chief

- Otolith
- Liver – (all taken except required for histologic samples)
- Skeletal muscle: At the level of the dorsal fin (20 grams)

Liver and skeletal muscle froze in individual bags

All samples identify with code PFC-001

Pathologist Carlos Lopez Mendez, DVM, MSc, MVSc, MRCVS

1. Identification

ID Number: PFC-002 Other Reference:

2. Capture data

Date: MARCH 10 2016 Hour: 21:15 UTC

Depth: 46 m Location: UTM (Zone 20N – East 068608 m, North 4853645 m)

3. Bio data:

Species: Longhorn Sculpin (*Myoxocephalus octodecemspinosus)*

Total weight (grams): 149 g

Length (head to fork): in cm: 23 cm - Sex & Gonads weight: Male – See comments

Photo taken (yes /no) Yes

4. Killing method

According CCAC guidelines on: euthanasia of animals used in science
Benzocaine overdose follow by immediate exsanguination by severing multiple and bilateral gill arches.

5. Comments

Gonads weight:
Scale show variations of up to 15 grams due to the movement of the vessel, Weight of the gonads can not be achieved

External examination:
Not significant findings, good body condition.

Internal examination:
- **Spleen:** In the caudal apex there is a 2 mm white and round focal nodule. A similar area is also observed in the peritoneal serosa (possibly a parasite).
- **Gall Bladder** : Empty.

Not additional comments

6. Gross Exam

6. Samples Taken

Histology protocol samples
- Gills – Left second arch
- Liver
- Kidney: Head and trunk
- Gonads

Histology additional samples

- Brain, spleen, stomach, intestine, heart, skeletal muscle and skin

Additional samples as requested by McGregor Geoscience Field party chief

- Otolith
- Liver – (all taken except required for histologic samples)
- Skeletal muscle: At the level of the dorsal fin (20 grams)

Liver and skeletal muscle froze in individual bags

All samples identify with code PFC-002

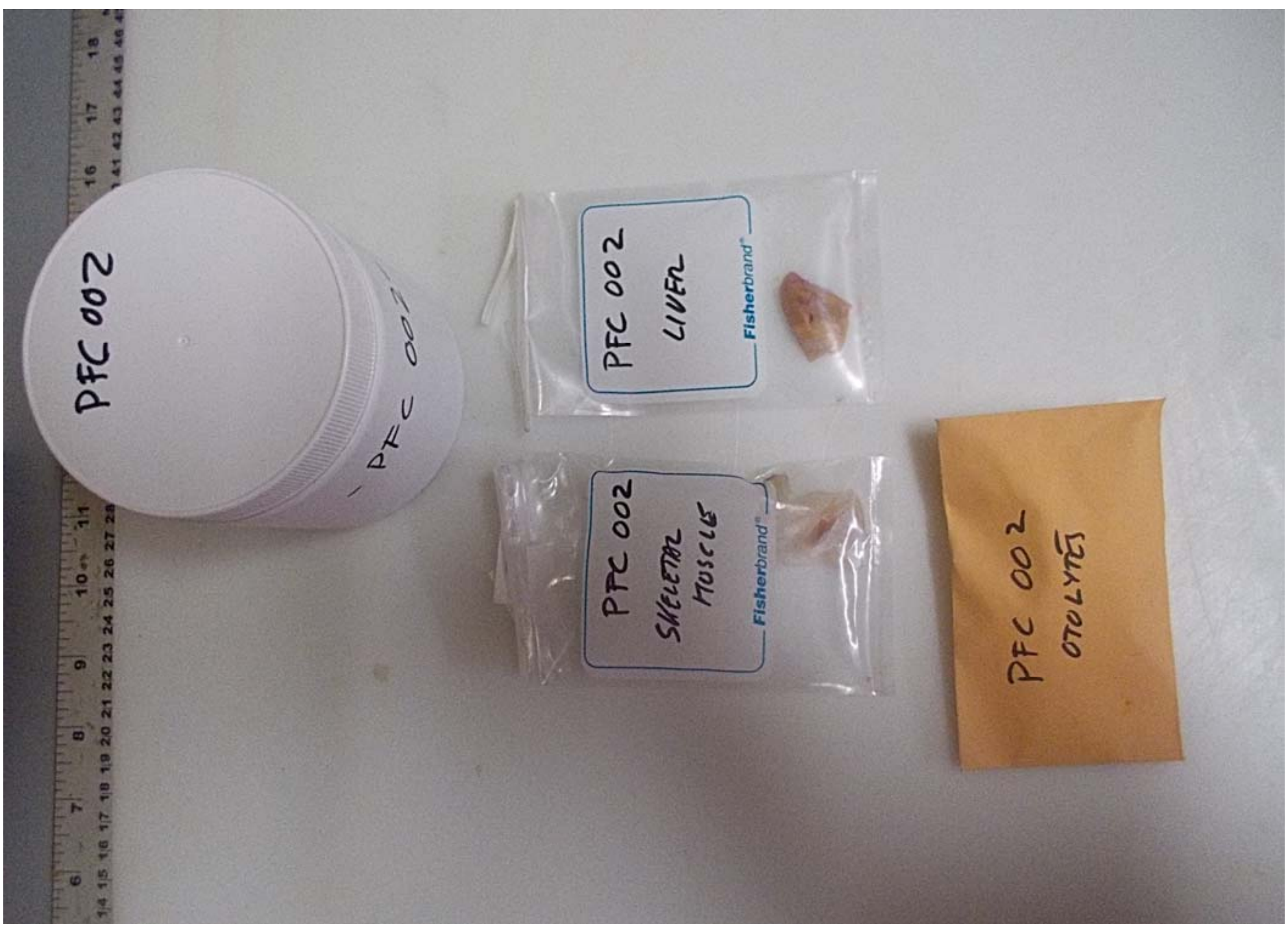
Pathologist Carlos Lopez Mendez, DVM, MSc, MVSc, MRCVS


CENTIMETRES
Cat. No. 09-016
INCHES/POUCES
Fisher Scientific
www.fishersci.ca
1-800-234-7437
McGregor GeoScience Limited
Project#: PFC 002 —
Sample:
Site:
Date Collected:
Collected by:
WHMIS: • Health •Flammability • Reactivity • Protection
Preservative:


CENTIMETRES
Cat. No. 09-016
INCHES/POUCES
Fisher Scientific
www.fishersci.ca
1-800-234-7437
McGregor GeoScience Limited
Project#: PFC 002 —
Sample:
Site:
Date Collected:
Collected by:
WHMIS: • Health •Flammability • Reactivity • Protection
Preservative:

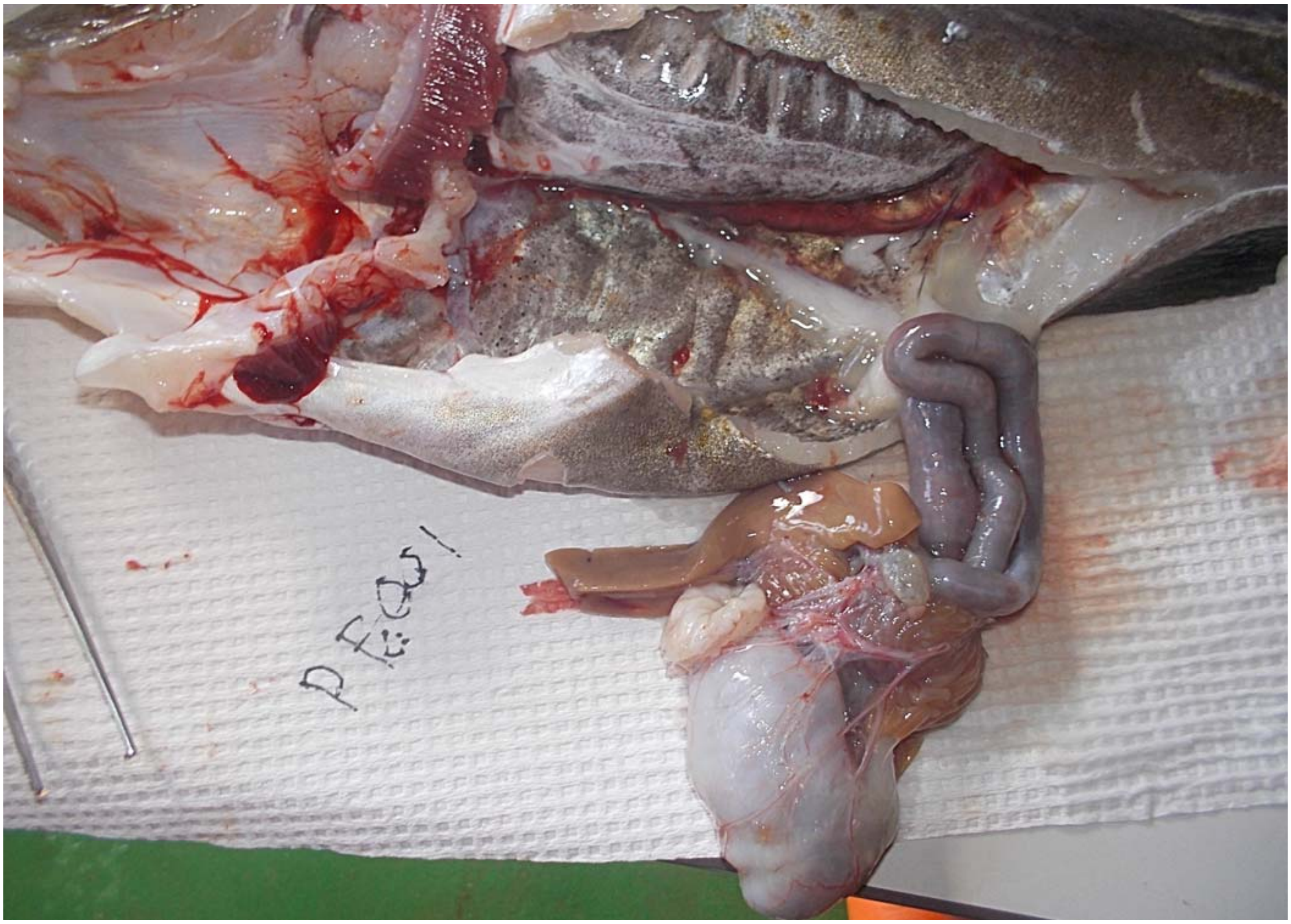

CENTIMETRES
Cat. No. 09-016
INCHES/POUCES
Fisher Scientific
www.fishersci.ca
1-800-234-7437
McGregor GeoScience Limited
Project #: PFC 002 —
Sample:
Site:
Date Collected:
Collected by:
WHMIS: • Health • Flammability • Reactivity • Protection
Preservative:


CENTIMETRES
Cat. No. 09-016
INCHES/POUCES
Fisher Scientific
www.fishersci.ca
1-800-234-7437
McGregor GeoScience Limited
Project #: PFC 002 —
Sample:
Site:
Date Collected:
Collected by:
WHMIS: • Health • Flammability • Reactivity • Protection
Preservative:


PFC 002
PFC 002 LIVER
Fisherbrand
PFC 002 SKELETAL MUSCLE
Fisherbrand
PFC 002 OTOLYTES

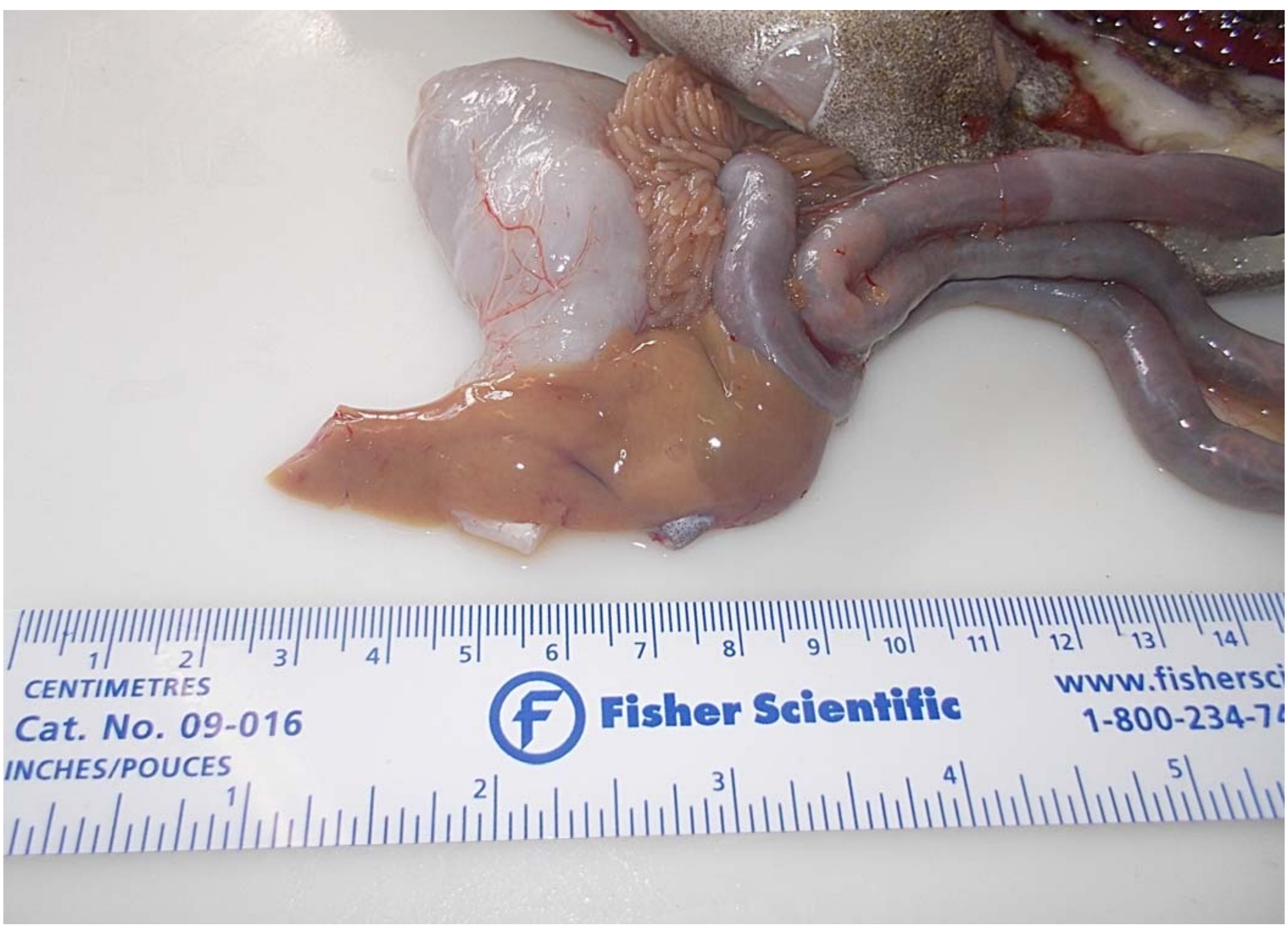

PFC
Fisherbrand


McGregor GeoScience Limited
Encana
Project: 1113
DATE:
March 8/2016
TIME:
15:15 UTC
DEPTH:
45m
STATION:
PFC -mark 14
FISH ID:
COD
FISH #:
PFC-001
cm




TIME
STATION
FISH ID:
FISH #:
PFC - 001
cm
TIRER


-016
Fisher Scientific
www.fis
1-800-


CENTIMETRES
Cat. No. 09-016
INCHES/POUCES
Fisher Scientific
www.fishersci
1-800-234-74

McGregor GeoScience Limited
Encana
Project: 1113
DATE:
10/MARCH/2016
TIME:
21:15
DEPTH:
46m
STATION:
FISH ID:
FISH #:
cm

APPENDIX K

2016 Fish Health Assessment Results (AVC)

University of Prince Edward Island AVC No: 6921 Atlantic Veterinary College
550 University Ave., Charlottetown, PEI C1A 8K8, Canada Diagnostic Services
Laboratories (902) 566-0863 Post Mortem (902) 566-0864 Fax (902) 566-0871

|OPERATIONS MANAGER |
|MCGREGOR GEOSCIENCE LTD Client No: FH00757 |
|177 BLUEWATER ROAD |
|BEDFORD, NS B4B 1H1 |
| |
Phone: 902-420-0313 ext 105
Specimen: OTHER AQUATIC TISSUE x1 Rec: 18-APR-16	Submitted By: Sample
ID: LONG NOSE SCULPIN

Clinical History
ID Number: PFC-002

Capture Data
Date: MARCH 10 2016
Hour: 21:15 UTC
Depth: 46 m
Location: UTM (Zone 20N East 068608 m, North 4853645 m)

Bio Data:
Species: Longhorn Sculpin (Myoxocephalus octodecemspinosus) Total weight (grams): 149 g
Length (head to fork): in cm: 23 cm
Sex: Male

Killing method:
According to CCAC guidelines

Gonads weight: Scale show variations of up to 15 grams due to the movement of the vessel, Weight of the gonads can not be achieved

External examination: Not significant findings, good body condition.

Internal examination:
Spleen: In the caudal apex there is a 2 mm white and round focal nodule. A similar area is also observed in the peritoneal serosa (possibly a parasite).
Gall Bladder :Empty.
Not additional comments

HISTOPATHOLOGY

Slide/tissue
(1): Gills, Kidney, testis, spinal cord, stomach.
(2): Head kidney, skeletal muscle.
(3): Heart, liver, stomach,intestine, pancreas, serosa, brain, heart.

Multiple tissues: Multifocally and more prominently in gills, kidney and heart,there are numerous oval to round 10 to 50 microns structures with a 2-3 microns refractile capsule and commonly surrounded by thim rim of fibroblast. (structures most likely represent various developmental stages of a trematode eggs)

All other tissues: Non Significant abnormalities detected.

Morphologic Diagnosis
Multiple tissues: Variably encapsulated metazoan eggs (most likely trematode)

Comments:
All tissues within the normal range. The presence of parasites are common in wild life populations.
Please do not hesitate to contact us should you have any question related to this case.

D. Groman / C. Lopez Fish
Pathologists
Signed and dated
07-OCT-16

Please consult your veterinarian for interpretation of results.

University of Prince Edward Island AVC No: 6920 Atlantic Veterinary College
550 University Ave. , Charlottetown, PEI C1A 8K8, Canada Diagnostic Services
Laboratories (902) 566-0863 Post Mortem (902) 566-0864 Fax (902) 566-0871

|OPERATIONS MANAGER |
|MCGREGOR GEOSCIENCE LTD Client No: FH00757 |
|177 BLUEWATER ROAD |
|BEDFORD, NS B4B 1H1 |
Phone: 902-420-0313 ext 105
Specimen: ATLANTIC COD TISSUE x1 Rec: 18-APR-16	Submitted By: Sample
ID:	

CLINICAL HISTORY
ID Number: PFC-001

Capture data:
Date: 8 March, 2016.
Hour: 15:15 UTC

Location, site or coordinates:
MARK 14 UTM (Zone 20N East 0685589 m, North 4853236 m)

Bio data:
Species: Atlantic cod (Gadus morhua)
Total weight (grams):
740g Length (head to fork): in cm: 45 cm Sex & Gonads weight: Immature Photos were taken.

Killing method:
According to CCAC guidelines

GROSS
External examination:
In the left side at the level of the pectoral fin there are 2 approximately 2 mm wide and 3 cm long Linear and circular skin pale white and smooth lines (Interpret as scars)

Internal examination: There is minimal amount of adipose tissue surrounding the abdominal viscera.

Gall Bladder: The gall bladder contains approximately 0.05 mL of bile, sample was not taken.

Liver: Liver is small. In the subserosa there is a (thin 0.5 mm) and coiled elevation (interpret as a nematode)

Stomach: Contains abundant 2-3 cm long crustaceans (photo taken) and a 4 cm long and flat orange organism (unidentified)

Intestine is full and contains similar crustaceans as observed in the stomach.

Swim bladder: A patch approximately 2 cm long, star shape and orange and slightly granular is observed in the internal aspect at the level of the trunk kidney (possibly a normal anatomic structure, sample taken for confirmation) Not additional comments

HISTOPATHOLOGY

Slide/tissue:.
(1) Gills, Liver, head kidney
(2) Heart, trunk kidney, head kidney, intesine
(3) Brain, piloric caeca, pancreas.

Gills: Multifocally there are up to 150 microns xenomas, oval shape and laden with hundreds of 3-4 microns acorn shape spore with a dense polar area and overall slighly refractile (Interpret as Microsporidian).

Head kidney: Numerous xenomas randomly distribute.

Liver: Multifocally and within the large bile ducts there are few coiled metazoan larvae (likely a Trematode)

Trunk kidney: Multifocally there are numerous xenomas as abovely described. In addition and within the ureter there is an unidentified protozoan.

Intestine:Within the lumina there is a 700 microns cross section of a metazoan featuring a body cavity, a prominent and striated muscular layer, a thick scaloped cuticule layer (most likely a Acanthocephalan)

Heart: Multifocally there are numerous microsporidian xenomas as abovely described

Piloric caeca: Multifocally there are numerous metazoans featuring oral suckers, absence of cavity, and a digestive tract (most likely a tremadode)

Brain: Within the saccus dorsalis there are few large up to 250 microns microsporidian xenomas.

Peritoneum: Multifocally, there are few cross sections up to 200 microns wide of a metazoan featuring cuticle, a pseudocoelomic cavity, a simple digestive tract, platymiryan muscular layer) likely a nematode.

No other significant abnormalities

Morphologic Diagnosis;
Multiple tissues: Microsporidian xenomas
Liver: Bile ducts, metazoan (likely trematode) Piloric caecae: multiple metazoan (likely trematode)
Intestine: Metazoan (likely acanthocephala) Abdominal cavity: Metazoan (likely a nematode)

Comments:
No significant abnormalities has been found in this specimen. The large number of parasites observed is a common finding present on wild life fish Please do not hesitate to contact us should you have any question related to this case.

D. Groman / C. Lopez Fish
Pathologists
Signed and dated
07-OCT-16

Please consult your veterinarian for interpretation of results.

APPENDIX L

2016 Sable Island Beached Bird Report (Zoe Lucas Consulting)

OFFSHORE ENVIRONMENTAL EFFECTS MONITORING PROGRAM
SABLE OFFSHORE ENERGY PROGRAM
SUMMARY REPORT for Year 2016

COMPONENT: Beached Seabird Surveys on Sable Island

REPORTING ORGANIZATION: Zoe Lucas, Sable Island

1. Background:

Since 1993, regular surveys for beached birds have been conducted on Sable Island to monitor trends in numbers and rates of oiling in beached seabirds, and to collect specimens of contamination for gas chromatographic analysis to generically identify oil types.

Results of analysis of oil samples collected on Sable Island during 1996-2005 are reported in [1], and results of beached bird surveys conducted on the island during 1993-2009 are reported in [2]. Also, corpses of fulmars and shearwaters collected during the surveys have been used in a study of plastic ingestion, and the results are reported in [3]. See References, Section 8.

2. Goal:

By monitoring numbers and oiling rates in beached seabirds on Sable Island, industry and regulators can identify and correct potential sources of oil contamination arising from industry operations.

3. Objectives:

- To monitor trends in oiling rate in beached seabird corpses.
- To generically identify oil types found on seabird feathers and in pelagic tar.

4. 2016 Sampling:

Contractor: Zoe Lucas, Sable Island.

- During 2016, eight surveys for beached seabirds were conducted on Sable Island, with no surveys done during February, March, April and December.

- All surveys were conducted by Zoe Lucas.

- Species identification, corpse condition and extent of oiling were recorded for seabird specimens. When possible, the time since death was estimated based on freshness of tissues and degree of scavenging and sandblasting.

- The oiling rate is the fraction of oiled birds of the total number of birds coded for oil (i.e., with >70% of body intact) during 2016.

5. Analyses

5.a. Lab Analyses

Samples of oiled feathers were collected from beached bird corpses for analysis and generic identification of oil type. Oil samples were packaged in aluminum foil, labeled, kept frozen for periods ranging from one week to several months, and delivered to the laboratory for gas chromatographic analysis (Maxxam Analytics). Interpretation of GC/FID results were conducted by MacGregor & Associates (Halifax) Ltd.

Oil specimens were solid samples (oiled seabird feathers) and were extracted with Hexane. This extract, filtered to remove solids, was injected on a glass capillary column (HP5-MS) on an HP 6890 Gas Chromatograph with Flame Ionization Detector (GC/FID). Outputs from the GC were retrieved on HP Chemstation software, with chromatograms produced and assessed manually. Concurrently standard oils such as Marine Diesel, Jet (Helicopter) Fuel, Heavy Fuel Oil (Bunker C), Arabian Crude Oil, Lubricating Oil and n-alkane standards (C12 to C36) were run under the same conditions. This permitted identification of the n-alkane peaks in the sample and standard oil chromatograms. The n-alkane maximum, range of n-alkanes and unresolved peak maximum were identified by carbon number and relative response. These results were compared to standard oils to permit identification of oil within that class and determine roughly degree of weathering or time at sea. Oils with mixtures of fuel and lube oil were identified as bilge or slop tank sources, oils identified as heavy fuel oil or marine diesel oil were identified as fuel oil sources, and those identified as crude oil were identified as tanker cargo oil sources.

5.b. Data Analyses

For oiling rate and number of clean birds/km (see Section 9, Figures 1 - 7), annual trends were first analyzed with generalized linear models (with Poisson links for densities and binomial links for oiling rate), but yielded excessive overdispersion even after corrections. Thus, instead data were transformed (log transformation for densities, arcsine transformation for oiling rate) and analyzed by least squares regression. Statistically significant trends ($P < 0.05$) are marked with an asterisk (*).

6. Results

Results are presented in Section 9, Table 9.1 and Figures 9.1 to 9.7.

7. Summary

- During 2016, 149 beached seabird corpses were collected on Sable Island. Alcids accounted for 28.9% of total recovered (Table 9.1). Of the 149 corpses, 98 (65.8%) were complete (i.e. with >70% of body intact, Codes 0 - 3).

- The overall oiling rate (Table 9.1) for all species combined (based on complete corpses, Codes 0 to 3) was 0.0% (compared with 0.5% in 2015 and 3.2% in 2014). In particular, the oiling rate for alcids was 0.0% (compared with 1.7% in 2015 and 7.9% in 2014).

- Although none of 98 complete corpses were oiled, of the 51 incomplete corpses (Code 4) one—an Atlantic Puffin, comprised of wings, tail and feet, and found in January—showed a trace of oil on the tail. Since the oiling rate is based on complete corpses, this specimen is not represented in the reported oiling rate of 0.0% for alcids (Table 9.1, and Figure 9.5). Analysis of the oil determined it to be engine room bilge, probably from a coastal or supply vessel running on Marine Diesel, and the sample was relatively unweathered (likely <2 weeks old), indicating a nearby source. (Clive MacGregor, pers. comm. May 2016).

8. References

[1] Lucas, Z. and C. MacGregor. 2006. *Characterization and source of oil contamination on the beaches and seabird corpses, Sable Island, Nova Scotia, 1996-2005*. Marine Pollution Bulletin 52: 778-789.

[2] Lucas, Z., A. Horn, and B. Freedman. 2012. *Beached bird surveys on Sable Island, Nova Scotia, 1993 to 2009, show a decline in the incidence of oiling.* Proceedings of the Nova Scotian Institute of Science 47, Part 1, 91-129.

[3] Bond, A.L., J.F. Provencher, P.-Y. Daoust and Z.N. Lucas. 2014. *Plastic ingestion by fulmars and shearwaters at Sable Island, Nova Scotia, Canad*a. Marine Pollution Bulletin 87: 68-75.

9. Table & Figures

Table 9.1.

Beached seabird corpses collected on Sable Island during 2016. Totals & linear densities for clean complete corpses (Code 0) for winter (November-April) and summer (May-October), and annual oiling rate based on complete corpses (i.e. with >70% of body intact, Codes 0 - 3).

Oiling scale:

(0) Complete corpse, clean plumage
(1) Complete corpse, slight surface oiling, or <10% of the body oiled
(2) Complete corpse, moderate oil, penetrating to the base of feathers, 10-25% oiled
(3) Complete corpse, heavy oil, >25% oiled
(4) Incomplete corpse, less than 60% of the plumage present

Bird species & groups	Total [1] number corpses	Code 0 number Winter	Code 0 number Summer	Code 0 number/km Winter	Code 0 number/km Summer	Oiling rate %
Northern Fulmar	9	2	3	0.0147	0.0074	0
Shearwater	41	0	37	0	0.0907	0
Northern Gannet	20	8	10	0.0588	0.0245	0
Larus Gulls	22	8	13	0.0588	0.0319	0
Alcids [2]	43	7	6	0.0515	0.0147	0
Other species [3]	14	1	3	0.0074	0.0074	0
Common & Thick-billed Murres [4]	9	5	4	0.0368	0.0098	0
Dovekie [4]	9	1	1	0.0074	0.0025	0

[1] Codes 0 - 4 combined (i.e., complete and incomplete corpses).
[2] All alcid species combined (Razorbill, Atlantic Puffin, Common and Thick-billed Murre, Dovekie, and unidentified large alcids).
[3] Other species: one Double-crested Cormorant, three Leach's Storm-petrel, four Common Tern, six Black-legged Kittiwake - none were oiled.
[4] Common & Thick-billed Murres and Dovekies are included in the overall totals for Alcids.

Figure 9.1. Northern Fulmar
Corpses/km: $F_{1,22}$=0.4460, P=0.5112
Oiling rate: $F_{1,22}$=20.7976, P=0.0002*

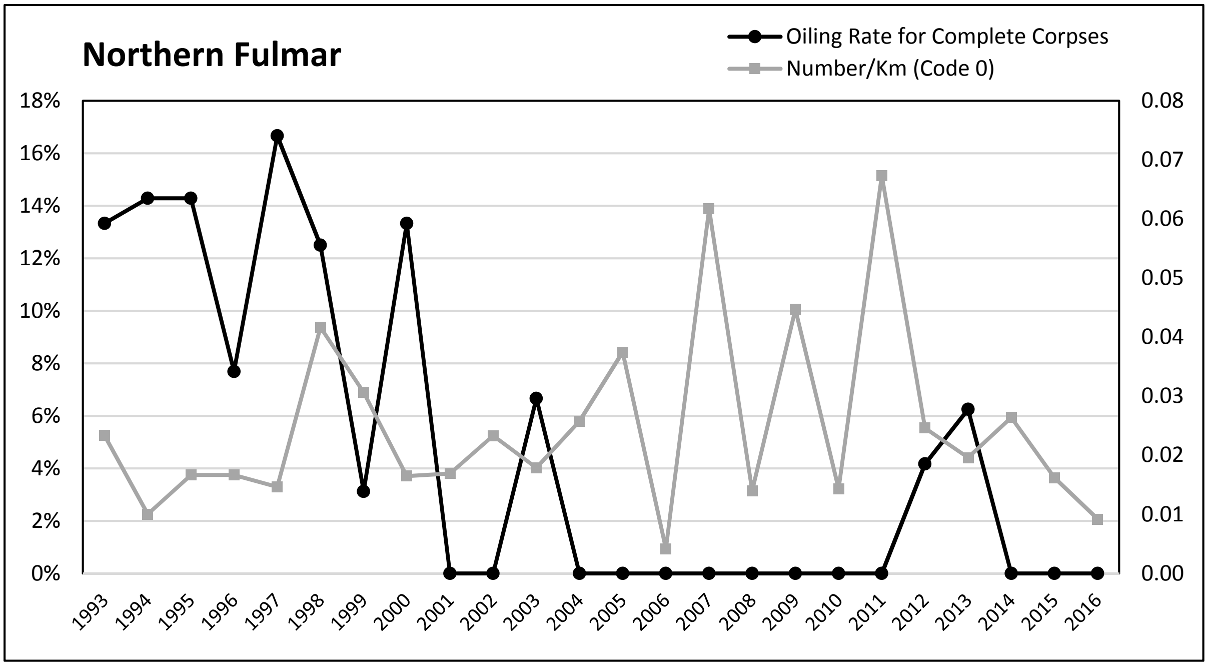


Figure 9.2. Shearwaters
Corpses/km: $F_{1,22}$=0.0542, P=0.8181
Oiling rate: $F_{1,22}$=9.5823, P=0.0053*

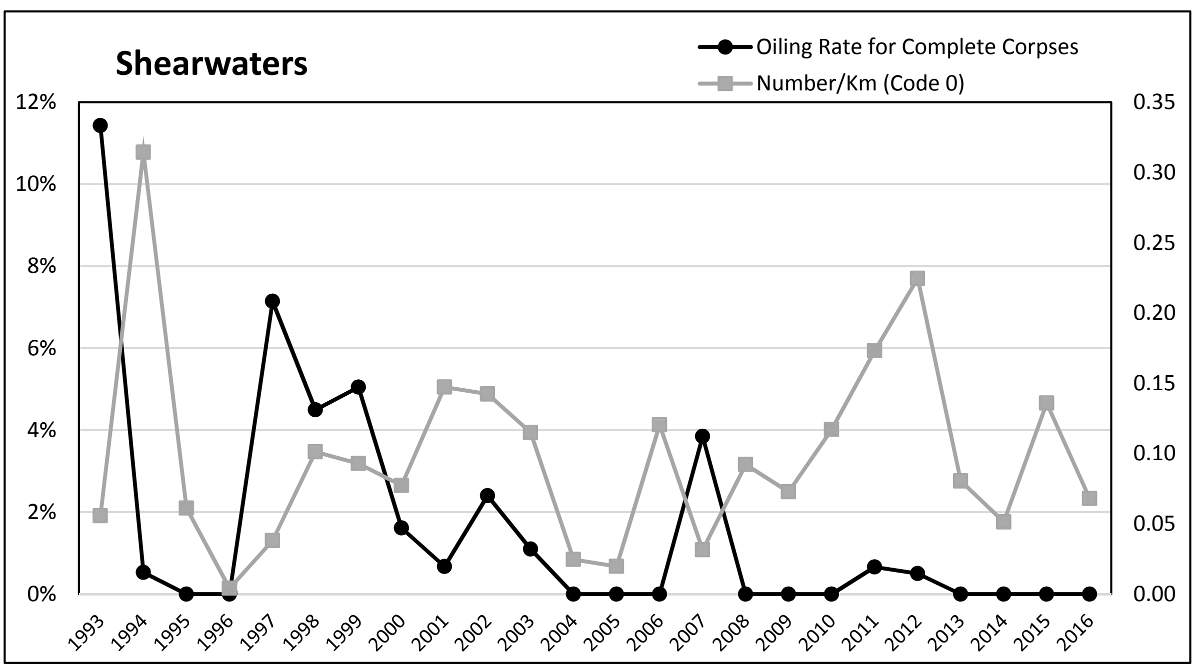


Figure 9.3. Northern Gannet
Corpses/km: $F_{1,22}$=0.0610, P=0.8071
Oiling rate: $F_{1,22}$=9.6309, P=0.0052*

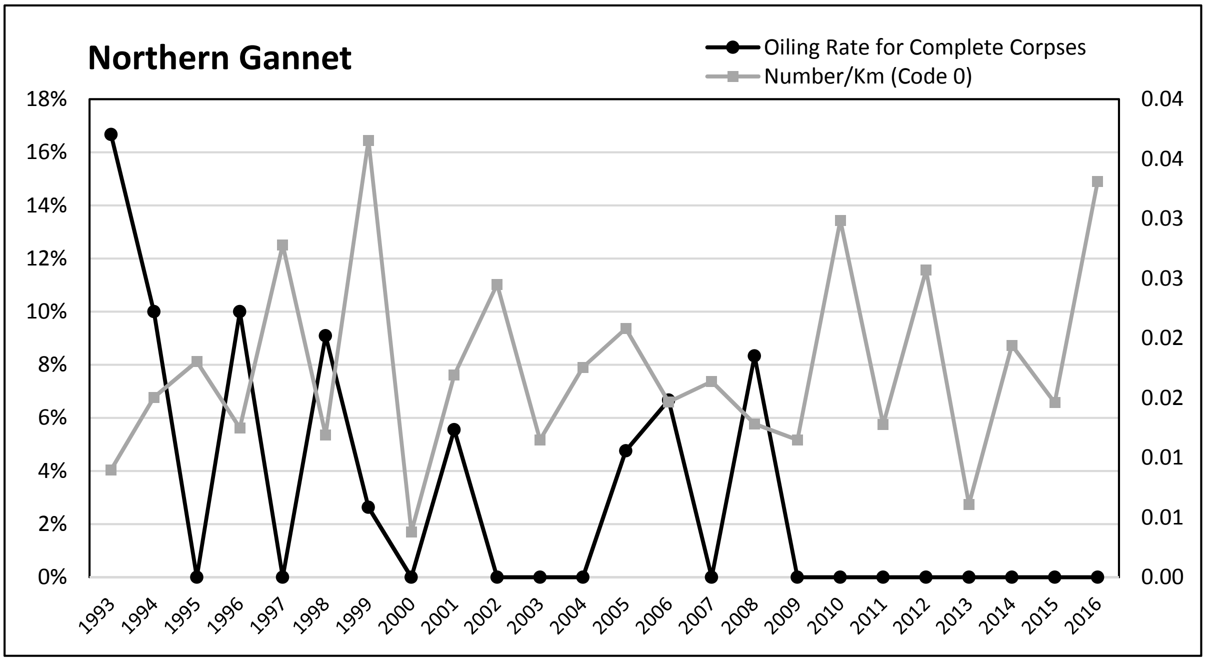


Figure 9.4. Larus Gulls
Corpses/km: $F_{1,22}$=0.0612, P=0.8069
Oiling rate: $F_{1,22}$=16.4500, P=0.0005*

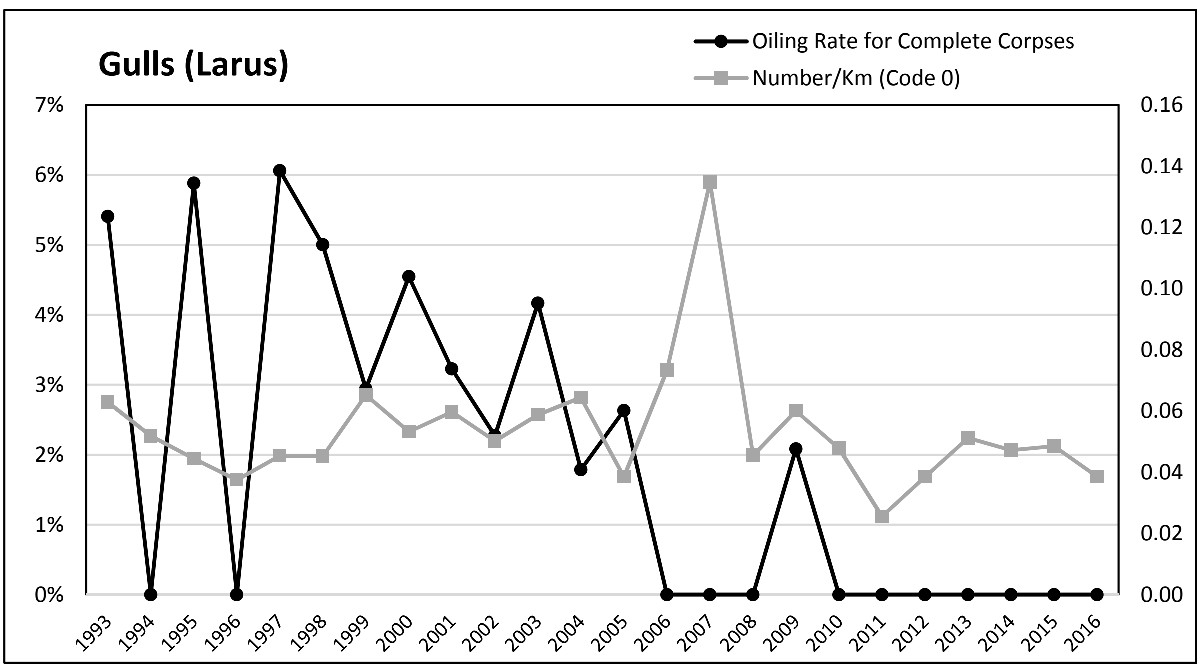


Figure 9.5. Alcids (all species combined)
Corpses/km: $F_{1,22}$=0.1988, P=0.66
Oiling rate: $F_{1,22}$=57.9611, P<0.0001*

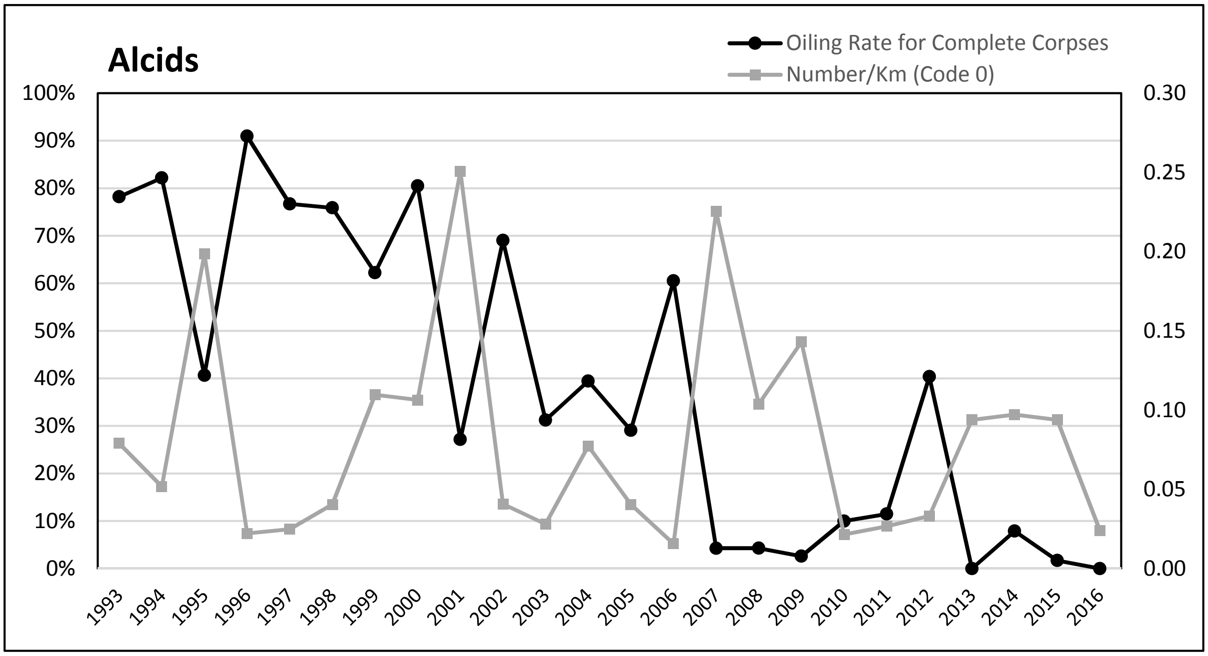


Figure 9.6. Thick-billed & Common Murres
Corpses/km: $F_{1,22}$=0.1321, P=0.7198
Oiling rate: $F_{1,22}$=24.1756, P<0.0001*

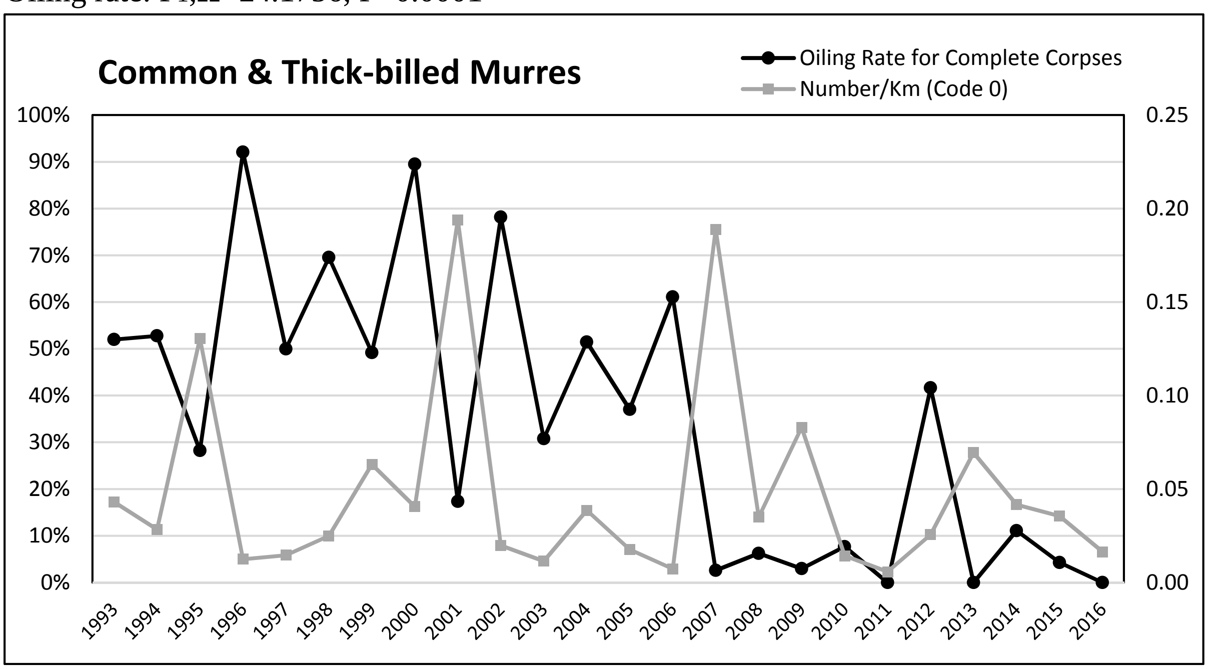
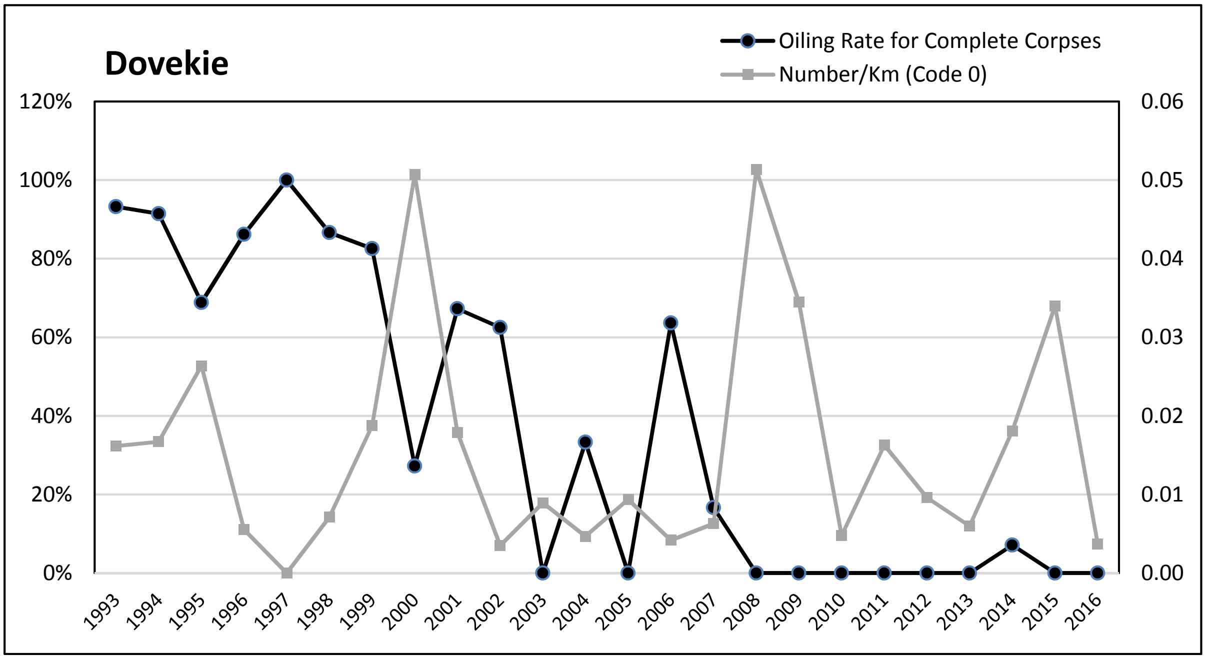


Figure 9.7. Dovekie
Corpses/km: $F_{1,22}$=0.1053, P=0.7486
Oiling rate: $F_{1,22}$=59.8903, P<0.0001*



APPENDIX M

2016 Live Seabird Salvage Report

Report of “Live” Migratory Seabirds Salvaged
Under The Authority of a Federal Migratory Bird Permit

In compliance with the provisions of the Migratory Birds Convention Act and Regulations, I am submitting a complete report of the number of specimens of each species of live migratory birds recovered between the following dates:

From January 1, 2016 to December 31, 2016 under the authority of Permit # LS 2568.

NAME Marielle Thillet (Environmental Advisor)____________ TELEPHONE # ____(902) 492-5422__
(PLEASE PRINT)

ORGANIZATION _____ Encana Corporation ______________ FAX # ______________________________

ADDRESS ___1701 Hollis Street, Halifax, NS __________ POSTAL CODE _____ B3J 3M8_________

E-mail marielle.thillet@encana.com

SIGNATURE ____ DATE January 9, 2017

Return to: Permit Section, Atlantic Region
Canadian Wildlife Service
PO Box 6227
Sackville NB E4L 1G6

Phone: 506-364-5068
Fax: 506-364-5062
e-mail: ec.scfatlpermis-cwsatlpermits.ec@canada.ca

Renew Permit ? Yes _X__ No _____
If yes, you will need to complete a permit application form. Please contact the Permit Section above for an updated form.

(a) Production Field Centre (PFC) Production [Jan-Dec, 2016 (ongoing)]

Vessel Name: PFC and two support (supply and standby) vessels (Atlantic Tern and Atlantic Condor)

Position: PFC area (see attached map) and support vessels between PFC area and Halifax

General activity of vessel: as per above

Search effort for live birds:
- opportunistically by all platform / vessel staff at all times

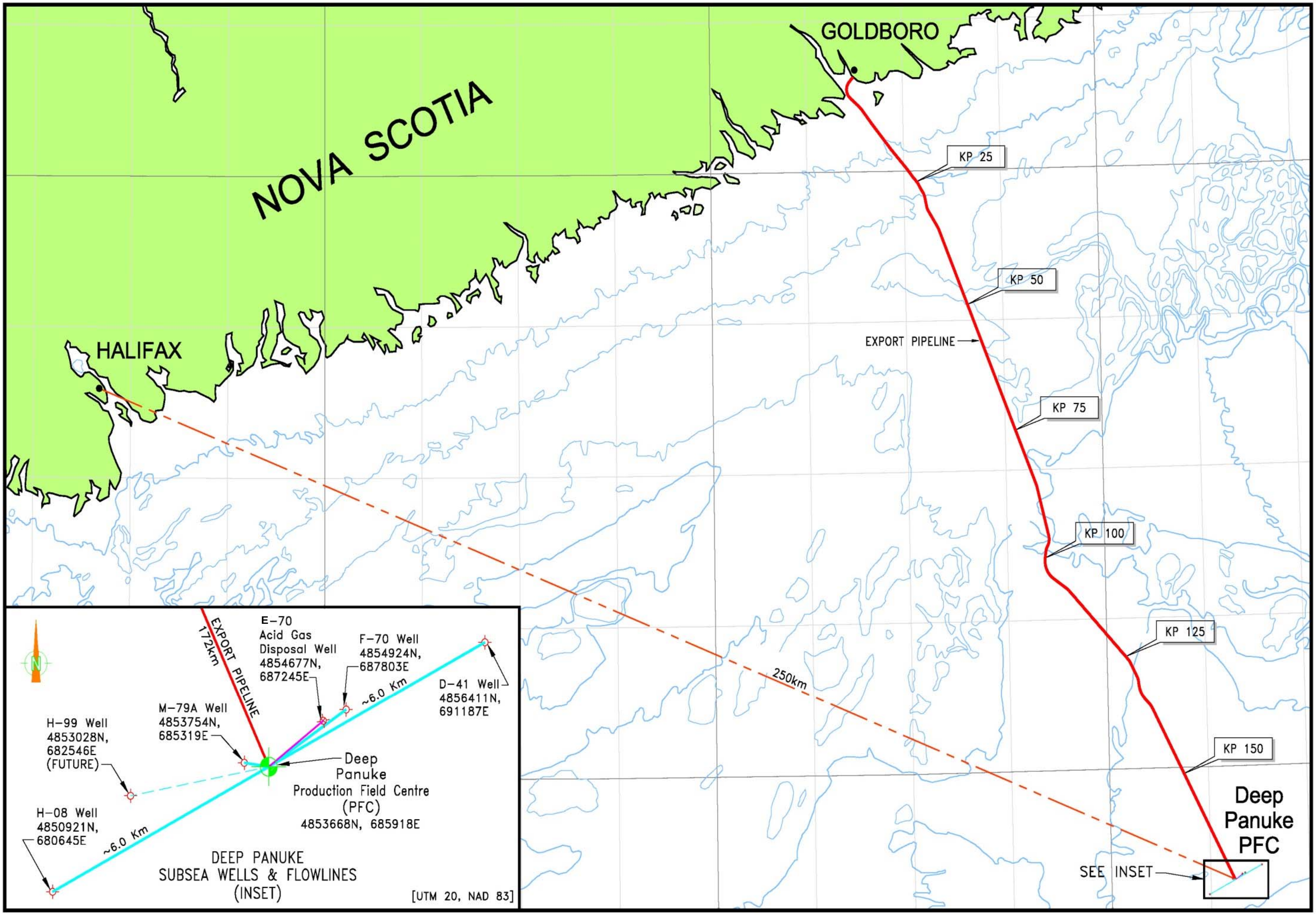
(b) Subsea Asset Inspection Survey [Feb-Dec 2016]

Vessel Name: Atlantic Condor

Position: between PFC and well locations (H-08, M-79A, F-70, D-41 and E-70) and along gas export pipeline route (see attached map)

General activity of vessel: ROV survey of subsea equipment

Search effort for live birds: opportunistically by all vessel staff



NOVA SCOTIA
GOLDBORO
HALIFAX
KP 25
KP 50
EXPORT PIPELINE
KP 75
KP 100
KP 125
KP 150
250km
Deep Panuke PFC
SEE INSET
EXPORT PIPELINE
172km
E-70
Acid Gas
Disposal Well
4854677N,
687245E
F-70 Well
4854924N,
687803E
~6.0 Km
D-41 Well
4856411N,
691187E
M-79A Well
4853754N,
685319E
H-99 Well
4853028N,
682546E
(FUTURE)
Deep
Panuke
Production Field Centre
(PFC)
4853668N, 685918E
H-08 Well
4850921N,
680645E
~6.0 Km
DEEP PANUKE
SUBSEA WELLS & FLOWLINES
(INSET)
[UTM 20, NAD 83]

Instructions:

Position of vessel: Latitude and longitude/UTM/geo-location where the activities will be conducted.

Activity of vessel: brief description. Examples: drilling, seismic, stand-by, production.

Search effort for birds: describe how birds were found. Examples: opportunistically by all staff, daily/nightly (or other interval) rounds by # of observers.

Table:

Complete at least one line for each day that birds are found.

Date: date when bird was first found.

Species: use AOU codes if possible, see Appendix below. Otherwise, write species name in full. Do not use generic terms (e.g. turr, songbird, gull). If more space is required, use comment section.

Condition (when found): briefly describe the condition of the bird. Examples: oiled, wet or dry; active, dazed, lethargic,

Action taken: describe what was done. Examples: held and released that night, released immediately, sent onshore for rehabilitation, dead and sent to CWS office.

Fate of bird: describe what happened to the bird. This may require some follow-up. Examples: released alive on site, died and disposed of on site, died onshore, released alive onshore.

Retrieval and Release of Birds on Deep Panuke PFC Year 2016

					Captured Alive				
			Found Dead		Un-oiled		Oiled*		Comments
Date	Species	Total	DOAS	Oiled*	DIC	Rls'd	DIC	SFR	Condition / Action Taken / Fate of Bird
06-06-2016	Sooty Shearwater	1	Y	N					Blew over the side before crew could examine. (photo 1)
23-11-2016	Sharp-shinned Hawk	1	N	N					Dry, fresh carcass, no oil. Flew carcass back to ECCC, sent for necropsy; results pending. (photos 2 and 3)
23-11-2016	Female Baltimore Oriole	1	N	N					Dry, fresh carcass, no oil. Flew carcass back to ECCC, sent for necropsy; results pending. (photo 4)
23-11-2016	Songbird	1	Y	N					Dry, old carcass, too desiccated to ID species. No oil. Disposed of at sea (too desiccated for analysis).
23-11-2016	Unknown (too far/ desiccated to ID)	3	N	N					Old carcasses, too desiccated and far to ID species. Not accessible (top of coolers).
23-11-2016	Songbird	1	N	N					Old carcass, too desiccated and far to ID species. No oil. Not accessible (under grating).
23-11-2016	LHSP	1	N	N					Old carcass, no oil. Not accessible (under grating).

DOAS – Disposed of at Sea.
DIC – Died in Care.
Rls'd – Released.
SFR – Sent for Rehab.

***Oiled Birds**: **Both live and dead birds are to be sent to shore for treatment of the birds and /or analysis of the oil.**

Photo 1

Photos 2 and 3

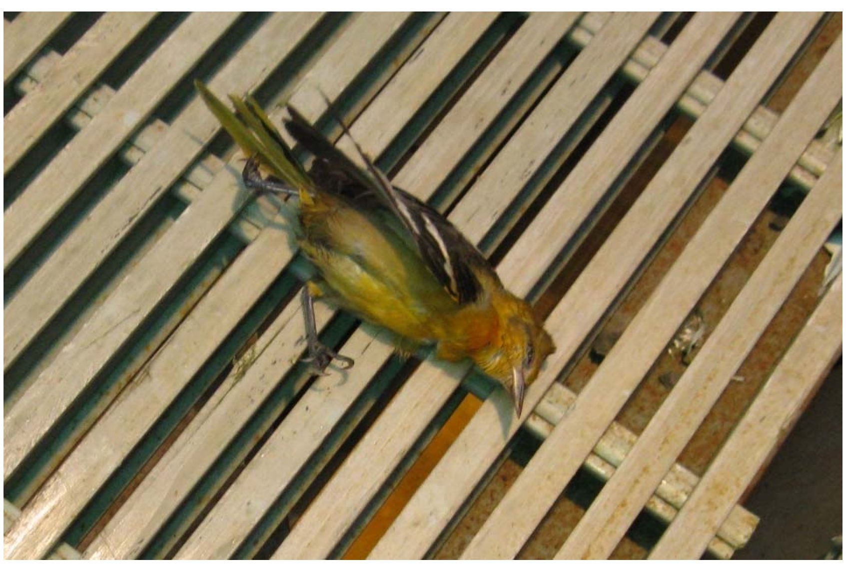


Photo 4

Appendix. AOU Codes for common bird species observed on the Grand Banks, includes a list of rarely seen species and our own codes for unknown species.

Common Name	AOU Code	Latin Name
COMMONLY SEEN BIRDS		
Atlantic Puffin	ATPU	*Fratercula arctica*
Black-headed Gull	BHGU	*Larus ribindus*
Black-legged Kittiwake	BLKI	*Rissa tridactyla*
Common Murre	COMU	*Uria aalge*
Cory's Shearwater	COSH	*Calonectus diomedea*
Dovekie	DOVE	*Alle alle*
Great Black-backed Gull	GBBG	*Larus marinus*
Glaucous Gull	GLGU	*Larus hyperboreus*
Greater Shearwater	GRSH	*Puffinus gravis*
Great Skua	GRSK	*Stercorarius skua*
Herring Gull	HERG	*Larus argentatus*
Iceland Gull	ICGU	*Larus glaucoides*
Lesser Black-backed Gull	LBBG	*Larus fuscus*
Leach's Storm-petrel	LHSP	*Oceanodroma leucorhoa*
Long-tailed Jaeger	LTJA	*Stercorarius longicaudis*
Manx Shearwater	MXSH	*Puffinus puffinus*
Northern Fulmar	NOFU	*Fulmarus glacialis*
Northern Gannet	NOGA	*Morus bassanus*
Parasitic Jaeger	PAJA	*Stercorarius parasiticus*
Pomarine Jaeger	POJA	*Stercorarius pommarinus*
Ring-billed Gull	RBGU	*Larus delawarensis*
Sooty Shearwater	SOSH	*Puffinus griseus*
Thick-billed Murre	TBMU	*Uria lomvia*
UNKNOWN BIRD CODES		
Unknown	UNKN	
Unknown Alcid	ALCI	
Unknown Gull	UNGU	
Unknown Jaeger	UNJA	
Unknown Kittiwake	UNKI	
Unknown Murre	UNMU	
Unknown Shearwater	UNSH	
Unknown Storm-petrel	UNSP	
Unknown Tern	UNTE	
RARELY SEEN BIRDS AND POTENTIAL BIRDS		
Black-browed Albatross	BBAL	*Diomedea melanophris*
Common Eider	COEI	*Somateria mollissima*
Common Tern	COTE	*Sterna hirundo*
Ivory Gull	IVGU	*Pagophila eburnea*
Long-tailed Duck	LTDU	*Clngula hyemalis*
Ruddy Turnstone	RUTU	*Arenaria interpres*
Sabine's Gull	SAGU	*Xema sabini*
Wilson's Storm-petrel	WISP	*Oceanites oceanicus*

APPENDIX N

2016 Sable Island Air Quality Monitoring (Kingfisher Environmental Health Consultants)

Kingfisher Environmental Health Consultants
Protecting People, Places and the Planet

EXXONMOBIL / Encana
2016 Environmental Effects Monitoring Report

March 10, 2017

REGISTERED PROFESSIONAL ENGINEER
DATE 03/10/17
M. D. Gibson
11647
PROVINCE OF NOVA SCOTIA

Submitted By: Dr. Mark Gibson C.Sci C.Chem P.Chem P.Eng
Director, Kingfisher Environmental Health Consultants

Acronyms

APS	TSI Aerodynamic Particle Sizer, model 3321
AS	Air Server
BAM	Beta Attenuation Monitor
BC	Black carbon
CH_4	Methane
ECCC	Environment and Climate Change Canada
ESRF	Environmental Studies Research Funds
GC	Gas Chromatograph
H_2S	Hydrogen Sulfide
O_3	Ground-level ozone
LRT	Long-Range Transport
MS	Mass Spectrometer
NAPS	National Air Pollution Surveillance network
NMHC	total-Non Methane Hydrocarbons
NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NSE	Nova Scotia Environment
PM	Particulate matter
$PM_{1/2.5/4/10/TSP}$	Atmospheric particles with a median aerodynamic diameter less than, or equal to, 1.0 µm, 2.5 µm, 4.0 µm (also known as respirable particles), 10 µm and total suspended particles below 60 µm.
SO_2	Sulfur dioxide
TD	Thermal Desorber
UFP	TSI Ultrafine Particle number counter, model 3031
VOC	Volatile organic compounds
WHO	World Health Organization

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1. Executive Summary

Kingfisher Environmental Health Consultants (KEHC) were contracted to complete a number of specific tasks related to environmental effects monitoring on Sable Island for Encana and Exxon Mobil that include: acquisition of meteorological and air quality data pertaining to monitoring on Sable Island for 2016, conducting data analysis and graphing of air quality and meteorological data, investigating spikes in air monitoring data and contacting Sable Offshore Energy Project (SOEP)/Encana to identify potential correlation with a particular facility's operations, as required.

In terms of off shore oil and gas production activity, Deep Panuke had several extended shutdown periods in 2016 for maintenance, repair and/or seasonal production (Jan 15-26; Mar 20-May 26; May 29-Jun 16; Oct 14-25 and Nov 1-8). ExxonMobil had a planned field-wide maintenance shutdown between September 15 and October 7 2016.

In 2014, Nova Scotia Environment change their air quality mandate to focus their attention on air-zones in populated areas of the Nova Scotia mainland. This resulted in a cessation of their management of certain air quality instruments on Sable Island. The instruments that were affected included automatic analyzers/samplers for O_3, NO_x, H_2S, SO_2 and also $PM_{2.5}$ via a MetOne Beta Attenuation Monitor (BAM 1020). In addition, the Thermo 5012 MAAP black carbon analyzer was found to be choked with sea salt and sand, and later found not to be repairable. Due to protracted contract negotiations with NRCan, funding for replacement instruments was not concluded until late 2015. New H_2S, SO_2 and BC instruments were purchased in early 2016. A refurbished O_3 analyzer was kindly supplied by Environment and Climate Change Canada (ECCC) and a $PM_{2.5}$ (BAM 1020) was supplied in-kind by Dr. Gibson’s Atmospheric Forensics Research Group (AFRG). These instruments were installed on Sable Island in Q1 of 2016. Therefore, 2016 had reasonable environmental effects monitoring coverage. This report features data, where available, between January 1st 2016 – December 31st 2016 for the Ultrafine 3031, APS 3321, O_3, H_2S, SO_2, NO_x, BC, and DRX $PM_{TSP/10/4/2.5/1}$.

The 2016 data completeness for temperature, wind direction and wind speed was 96%, 100% and 99% respectively, which can be considered excellent data capture for these meteorological variables. The mean (min : max) temperature and wind speed was found to be 9.04 (-11.4 : 53.8°C), 25.39 km/h (0 : 84 km/h). The maximum temperature of 53.8°C seems unlikely and suggests there might be a temperature sensor malfunction. It was found that the average wind vector for 2016 was found to be 256°, which is consistent with prevailing winds in the North West (NW) Atlantic.

The BC data completeness for 2016 was only 16.7%, due to late deployment of the instrument (Q3). The mean (min : max $\mu g/m^3$) for BC was 0.955 (0 : 6.59 $\mu g/m^3$). The median BC concentration is similar to that found in Halifax (Gibson et al., 2013). This is surprising given that Sable Island is a remote marine location. It may be a result of on island fossil fuel combustion sources, e.g. aircraft, diesel generators, or long-range transport. However, with a paucity of BC data it is difficult to determine the exact source of this metric at this time.

The 2016 data completeness for the DRX $PM_{1/2.5/4.0/10}$ and total mass concentration was 98%. The mean (min : max) for the $PM_{TSP/10/4/2.5/1}$ total mass concentration was PM_1 = 11.7 (0 : 120 $\mu g/m^3$), $PM_{2.5}$ = 12.5 (0 : 123 $\mu g/m^3$), PM_4 = 12.8 (0: 124 $\mu g/m^3$), PM_{10} = 13.0 (0 : 127 $\mu g/m^3$) and TSP = 13.0 (0 : 127 $\mu g/m^3$) respectively. There were no threshold or air quality standard breaches for $PM_{2.5}$ in 2016.

Due to various instrument malfunctions, the 2016 data completeness for the APS was 53.64%. The mean (min : max *units* = #) for the APS size fractions particle number counts were <0.523µm = 124275 (360 : 1963180 #), 1.486µm = 3196 (0 : 86875 #), 2.458µm = 615.5 (0 : 23737 #), 3.523µm = 141.2 (0 : 8779 #), 5.829µm = 12.99 (0 : 2743 #), 7.234µm = 3.922 (0 : 1358 #) and 10.37µm = 0.558 (0 : 159 #) respectively. The data completeness over the operation period for the UFP particle number counts, in the range 20-30, 30-50, 50-70, 70-100,100-200 and 200-800 nm for 2016 was 93%, which can be considered excellent data capture. The mean (min : max *units* = #) UFP 3031 particle number counts, in the various size ranges, were as follows: 20-30 nm = 328.39 (16.11 : 2197.13 #), 30-50 nm = 361.20 (8.05 : 10023.75 #), 50-70 nm = 228.17 (1.44: 5739.00 #), 70-100 nm = 206.11 (0.75 : 4373.75 #), 100-200 nm = 253.51 (3.98 : 8193.00 #) and 200-800 nm = 43.46 (2.80 : 1077.753 #) respectively.

The data completeness over the operation period for NO_x, O_3 and SO_2 was 67% respectively and 65% for H_2S, which can be considered as insufficient data capture for representative annual data analysis. This low data capture for these metrics was due to the new instruments not being installed until the end of Q1 2016. The mean (min : max *units* = ppbv) NOx, O_3, SO_2 and H_2S were as follows: NO_x = 1.15 (0 : 7 ppbv), O_3 = 25.10 (14 : 42 ppbv), SO_2 = 0.74 (0 : 3 ppbv), H_2S = 0.35 (0 : 6 ppbv) respectively. There were no threshold or air quality standard breaches for O_3 in 2016. However, there was a spike in H_2S of 6.01 ppbv on 17/07/16. This spike was above the operating threshold value of 3.11 ppbv. However, it was well below the 1-hr Nova Scotia air quality objective of 30 ppbv. This H_2S spike is obviously linked to the elevated SO_2 level of 3.04 ppbv that occurred on the same day. However, the SO_2 level was below the operational spike threshold of 6.0 ppbv and well below the 1-hr Canada Ambient Air Quality Objectives threshold of 344 ppbv. Scrutiny of the air mass back trajectories for this day showed that air flow passed over both the Deep Panuke and Thebaud platforms preceding and during observations on Sable Island. The spike might be due to an issue with flaring of H_2S on the Deep Panuke platform at the time. On 05/10/16 there was an elevated level in NO_x of 7.16 ppbv. This happened a few days after the ExxonMobil platform wide maintenance shutdown. The air flow during the spike observations was directly over the Thebaud platform. Therefore, it could be a possible source. However, NO_x level was below the operational spike threshold set at 17 ppbv and well below the Canada Ambient Air Quality Objective of 213 ppbv.

2. RATIONALE & BACKGROUND

Sable Island is also one of the most important locations in the world for conducting climate monitoring with weather records dating back to the 1871 (Inkpen et al., 2009, GreenHorseSociety, 2012). Because the Island is 160 km from main land Nova Scotia it can be thought of as a truly marine influenced sampling location. Thus, it is in the perfect position to monitor emission from the ocean as well as continental outflow from North America (Inkpen et al., 2009). While sources of anthropogenic $PM_{2.5}$, total-VOCs and trace reactive gases are well known, it is recognized that there are still large gaps in knowledge with regards to biogenic emissions of terpenes and other VOC emissions from terrestrial (forest fires and vegetation) and marine sources (phytoplankton and direct emissions from the ocean) that act as pre-cursors of intermediate harmful chemical species, e.g. formaldehyde and glyoxal, pre-cursors of cloud condensation nuclei (CCN), secondary organic aerosols (SOA) and O_3; all of which perturb climate, earth systems and health (Gibson et al., 2013c, Gibson et al., 2013a, Palmer et al., 2013, Gibson et al., 2009b, Gibson et al., 2009a, Monks et al., 2009, Palmer and Shaw, 2005). In addition the transport of nitrogen and sulphur aerosol species from local and upwind continental sources can impact the terrestrial and aquatic flora and fauna on Sable Island (Gibson et al., 2013a). Therefore, understanding local and long-range upwind sources of $PM_{2.5}$, $PM_{2.5}$ chemical components, VOCs and trace reactive gases to the Sable Island airshed is important, not just for local air quality, but from the perspective of climate inventories and climate forcing (Monks et al., 2009).

Two detailed air emission reports have been conducted pertaining to the Sable Island airshed, (Inkpen et al., 2009) and (Waugh et al., 2010). The Environment Canada project report "Sable Island Air Monitoring Program Report 2003-2006", identified a knowledge gap in monitoring to adequately identify impacts from the offshore O&G pointing to the need for enhanced on-island monitoring of industrial emissions, including VOC and PM speciation in the Scotian Shelf Airshed (SSA) (Inkpen et al., 2009). Waugh et al., (2010) mention in their report that some of the short-term spikes in data might be due to local source influences resulting from offshore oil and gas (O&G) activities in the vicinity of Sable Island (Waugh et al., 2010).

Sable Island's unique location in the Atlantic ensures that it receives significant transboundary air pollutant flows from areas in the NE US and the Windsor - Québec corridor as well as significant amounts of sea salt (Waugh et al., 2010). Frontal systems have been shown to "push" pollution into narrow "vertical bands" of high concentrations ahead of the front and have been identified as causing relatively large, but short-lived, spikes in air quality data on Sable Island (Waugh et al., 2010). In addition, previous studies have shown that seasonal fluxes of natural marine emissions (terpenes, dimethylsulfide, VOCs) are likely to react in the atmosphere to form secondary O_3 and $PM_{2.5}$ which further contribute to the total air pollution mix on Sable Island (Gibson et al., 2013c, Gantt et al., 2010). Waugh et al., (2010) reported several long-range transport (LRT) events that were identified from air mass back trajectories, synoptic charts and maps of air pollution monitoring data in the NE US and E Canada prior to the air mass reaching Sable Island. These air pollution maps were obtained from the US data base AIRNow (http://airnow.gov/) (Waugh et al., 2010).

Because of the recommendations of the Inkpen et al., (2009) and Waugh et al., (2010) reports, funding was made available through the Environmental Studies Research Funds (ESRF) for a four-year project, the aim of which is to unambiguously apportion the source contribution of the O&G facility operations to the total concentration of VOC's on Sable Island. This ESRF funding was awarded to Dr.s' Mark Gibson and Susanne Craig (both now with the Department of Civil and Resource Engineering; Associate Professor and Adjunct Professor respectively). The ESRF project will also have the value added component of being able to apportion the marine and LRT emissions/pollution impacting the Sable Island airshed. A feature of this project is the live streaming of the continuous monitoring data to a website data display. After a successful demonstration of the data display between 2013 and 2015, it was deemed to be no longer required. Data is now retrieved from the Sable Island instruments on a weekly basis by ECCC/AFRG staff/students and emailed to Dr. Gibson.

The O&G industry has had a presence on the Scotian shelf since the late 1960's (CNSOPB, 1990). Currently, Exxon Mobil have a number of platforms in operation at five fields offshore Nova Scotia: Thebaud, Venture, North Triumph, Alma and South Venture. A platform at Thebaud provides central facilities for gathering and dehydration. A second platform provides compression of the gas from all fields, while a third platform at this location provides wellhead facilities for the Thebaud field itself. Hydrocarbons produced at the four other platforms are transported through a system of subsea flowlines to the Thebaud platform. After dehydration at Thebaud, the raw gas is transported through a subsea flowline to landfall at Goldboro, Nova Scotia, and to a gas processing plant located nearby. There the gas is conditioned by the removal of natural gas liquids (NGLs) to meet high quality sales gas specifications. The sales gas is then shipped to markets in eastern Canada and the northeastern United States, through the Maritimes & Northeast Pipeline (M&NP). NGLs are transported by pipeline to the Point Tupper Fractionation Plant for final processing before being sent to market in the form of propane, butane and condensate (Per. Comm, Environmental Manager – Exxon Mobil).

Encana's Deep Panuke offshore gas field involves the production of natural gas approximately 250 km southeast of Halifax and the transportation of that gas via subsea pipeline to shore, and ultimately, to markets in Canada and the United States. On August 7th, 2013, the first well was opened though "First Gas", i.e. full production rate, was not achieved until December 2013. The Project utilizes a jack-up type offshore platform as its Production Field Centre (PFC) tied back to production wells with subsea flowlines and umbilicals (CNSOPB, 2013). Deep Panuke is a sour gas reserve with raw gas containing approximately 0.18 mol % H_2S. The H_2S and CO_2 (acid gas) are removed from the raw gas stream to acceptable levels and injected into a dedicated underground disposal well. During upset of the acid gas injection system, the acid gas is flared on the PFC. Figure 1 and Table 1 below presents the geographical location of the O&G platforms surrounding Sable Island on a map and table form (source:

http://www.cnsopb.ns.ca/pdfs/sable_area_platforms.pdf). Figure 2 shows the locations of facilities on Sable Island and on-island combustion sources.

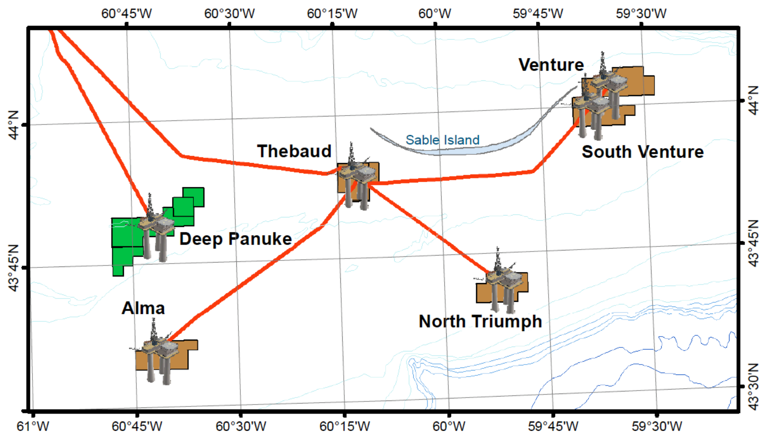

Figure 1. Location of the O&G platforms surrounding Sable Island

Table 1. Geographic locations of the O&G platforms surrounding Sable Island

	Platform Centre Location - NAD83			
	Geographic		UTM (Zone 20)	
Platform Name	Latitude	Longitude	Northing	Easting
Thebaud	43° 53' 28.4" N	60° 11' 57.2" W	4863604.8	724963.3
Thebaud Process Jacket	43° 53' 30.8" N	60° 12' 00.0" W	4863676.7	724898.3
Venture	44° 01' 59.8" N	59° 34' 54.3" W	4881245.1	773902.9
North Triumph	43° 41' 56.6" N	59° 51' 13.6" W	4843261.4	753522.2
Alma	43° 35' 47.1" N	60° 41' 19.3" W	4829644.9	686560.9
South Venture	43° 59' 50.6" N	59° 37' 38.6" W	4876899.3	770420.7
Deep Panuke	43° 48' 45.704" N	60° 41' 18.126" W	4853666.9	685917.2

	Platform Centre Location - NAD27			
	Geographic		UTM (Zone 20)	
Platform Name	Latitude	Longitude	Northing	Easting
Thebaud	43° 53' 28.1" N	60° 11' 59.9" W	4863377.6	724909.9
Thebaud Process Jacket	43° 53' 30.5" N	60° 12' 02.7" W	4863449.5	724844.9
Venture	44° 01' 58.0" N	59° 34' 12.5" W	4881019.4	773848.6
North Triumph	43° 41' 56.4" N	59° 51' 16.4" W	4843035.7	753467.9
Alma	43° 35' 46.8" N	60° 41' 22.0" W	4829417.0	686507.0
South Venture	43° 59' 50.4" N	59° 37' 41.4" W	4876673.5	770366.4
Deep Panuke	43° 48' 45.439" N	60° 41' 20.804" W	4853441.1	685863.0

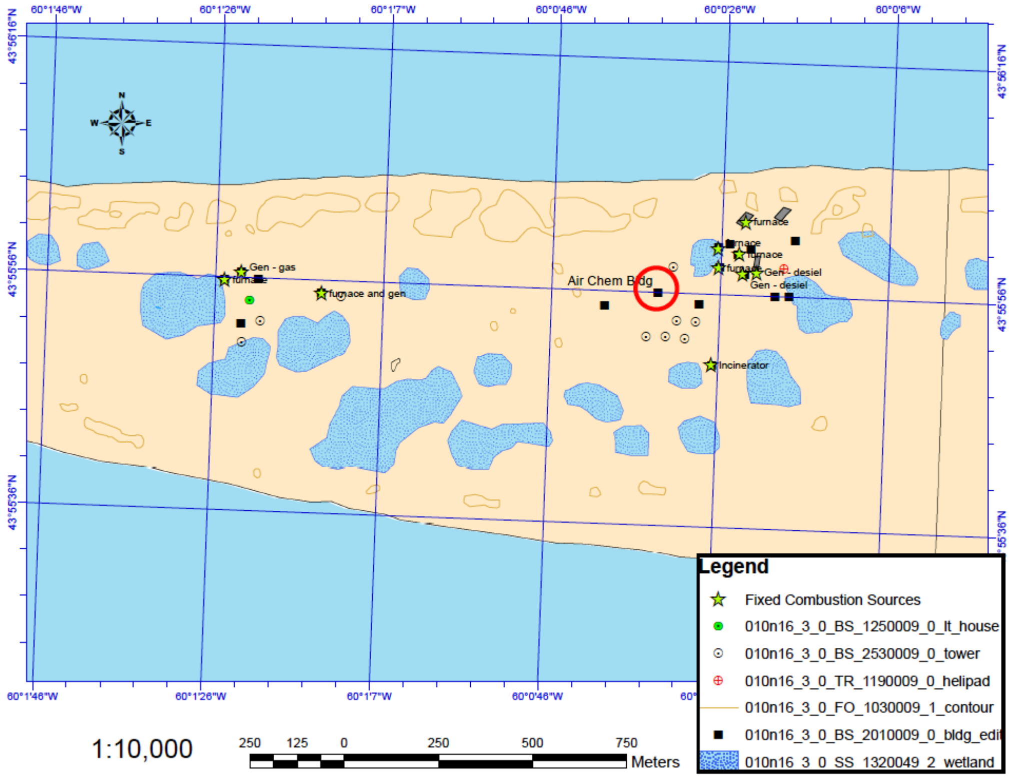

Figure 2. Location of facilities and on-Island combustion sources on Sable Island.

3. GOALS

The goal of the air quality-monitoring component of the EEM program is to collect information on potential effects originating from the offshore platforms that may affect Sable Island or that can be monitored from the island. Sable Island provides a unique platform upon which to augment the offshore EEM program.

4. OBJECTIVES

Acquire a better understanding of both ambient air concentrations in the Sable area and quantitatively identify any possible effects from offshore operations, while taking into consideration localized emission sources on Sable Island itself including air traffic to and from the island, diesel electric supply and waste incinerations at the research station.

5. Change in Nova Scotia Environment's Role in Air Monitoring on Sable Island

As of January 2015, Nova Scotia Environment no longer manage the criteria air pollution measurements on Sable Island. In the interim, this has since reverted to Dr. Mark Gibson at Dalhousie University in collaboration with ECCC as part of the ESRF Source apportionment of aerosols and PM on Sable Island research program. The long-term monitoring of air pollutants and atmospheric chemistry on Sable Island is uncertain after the end of the ESRF research contract in Q4 2017. However, Dr. Gibson's group, in collaboration with ECCC, will likely maintain the measurements for the foreseeable future.

6. MATERIALS AND METHODS

6.1 Instrumentation on Sable Island

Table 2 provides a summary of the air pollution instrumentation that are currently deployed on Sable Island. Table 2 also provides the funding/in-kind contributor and the temporal resolution of the measurement of sample collection.

Table 2. Summary of instrumentation on Sable Island and funding source

Equipment	Contributor	Comments
Air Monitoring Shed	ESRF (100%)	
Teledyne NO_x Analyzer	ECCC (100%)	Hourly
METOne BAM $PM_{2.5}$	Gibson in-kind 2016 - (100%)	Hourly
Teledyne H_2S Analyzer	ESRF Funding (Gibson/Craig) (100%)	Hourly
Teledyne SO_2 Analyzer	ESRF Funding (Gibson/Craig) (100%)	Hourly
TECO O_3 Analyzer	ECCC (100%)	Hourly
Thermo Partisol 2000 dichotomous sampler Federal Reference Method	EC - NAPS (100%)	24-hr, simultaneous, integrated filter sample of $PM_{2.5}$ (fine) and $PM_{2.5-10}$ (coarse) particle mass
TSI 3031 Ultrafine particle monitor	ESRF Funding (Gibson/Craig)	15-min
TSI 3321 Aerodynamic Particle Sizer	ESRF Funding (Gibson/Craig)	1-15 min
TSI DRX DustTrak 8533 for Total PM, PM_{10}, $PM_{4.0}$, $PM_{2.5}$ and PM_1	ESRF Funding (Gibson/Craig)	1-60 min
Thermo 5012 black carbon analyzer	ESRF Funding (Gibson/Craig) ***Replaced by new unit April 2016***	Hourly
Data display and data archive	ESRF Funding (Gibson/Craig) ***No longer in use***	N/A

6.2 Data Acquisition

The air pollution data that was available in 2016 include the TSI DRX $PM_{TSP/10/4/2.5/1}$ mass concentration instrument, the TSI 3031 Ultrafine particle number counter, TSI 3321 APS particle number counter, O_3, NO_x, SO_2, BC and H_2S.

6.3 Air Quality Standards pertaining to Sable Island

Table 3 contains the air quality standards for Canada, Nova Scotia and the World Health Organization (WHO). These air quality regulations will be used for comparison with the 2013 air quality data pertaining to Sable Island.

Table 3. Nova Scotia Air Quality Regulations (*Environment Act*) and *Canadian Environmental Protection* Act Ambient Air Quality Objectives (Suggested air monitoring thresholds - $\mu g/m^3$ (ppb))

Pollutant and units (alternative units in brackets)	Averaging Time Period	Nova Scotia	Canada				
		Maximum Permissible Ground Level Concentration	Canada Wide Standards	Ambient Air Quality Objectives			World Health Organization (WHO)
				Maximum Desirable	Maximum Acceptable	Maximum Tolerable	
Nitrogen dioxide $\mu g/m^3$ (ppb)	1 hour	400 (213)	-	-	400 (213)	1000 (532)	(105)
	24 hour	200 (106)	-	-	**200 (106)**	300 (160)	
	Annual	100 (53)	-	60 (32)	100 (53)	-	(21)
Sulfur dioxide $\mu g/m^3$ (ppb)	1 hour	900 (344)	-	450 (172)	900 (344)	-	
	24 hour	300 (115)	-	150 (57)	**300 (115)**	800 (306)	(7.5)
	Annual	60 (23)	-	30 (11)	60 (23)	-	
Total Suspended Particulate Matter (TSP) $\mu g/m^3$	24 hour	120	-	-	120	400	
	Annual	70 (geometric mean)	-	60	70	-	
PM2.5 (fine) $\mu g/m^3$	24 hour, 98th percentile over 3 consecutive years	-	28 (reducing to 27 by 2020)	-	-	-	
	24 hour				**120**		25
	Annual			60	70		10
PM10-2.5 (coarse) $\mu g/m^3$		-	-	-	-	-	
PM_{10} (sum of fine and coarse)	Annual						50
Carbon Monoxide mg/m^3 (ppm)	1 hour	34.6 (30)	-	15 (13)	35 (31)	-	
	8 hour	12.7 (11)	-	6 (5)	15 (13)	20 (17)	
Oxidants – ozone $\mu g/m^3$ (ppb)	1 hour	160 (82)	-	100 (51)	**160 (82)**	300 (153)	
	8 hour, based on 4th highest annual value, averaged over 3 consecutive years	-	(65) (Brownell et al.)	-	-	-	(50)
	24 hour	-	-	30 (15)	50 (25)	-	
	Annual	-	-	-	30 (15)	-	
Hydrogen sulphide $\mu g/m^3$ (ppb)	1 hour	42 (30)	-	-	-	-	
	24 hour	**8 (6)**	-	-	-	-	

6.4 On Island Emission Sources

Because of the need to provide power, space heating, water heating and cooking facilities it was necessary to install generators, furnaces and cooking appliance infrastructure on Sable Island to meet this requirement. Because of the anticipated impact on air quality measurements from these heating appliances and power generators, they were situated as far away as possible to the East of the air chemistry building (per. comm. Gerry Forbes, 2013). The combustion sources on Sable Island include:

- Generators
- All-purpose utility vehicle and vehicle garage
- Furnace at Operations building
- Furnace at the staff house
- Furnace at the OIC house
- Furnace at the Triplex

6.5 Air Emission Spike Thresholds and Threshold Breaches

Air emission monitoring thresholds values were calculated by Dr. Mark Gibson (Dalhousie University) in consultation with Encana and Exxon Mobil. The threshold values were calculated using extreme value analysis. These thresholds were established for monitoring purposes to identify possible "spikes" in air emissions parameters on Sable Island that could be related to O&G production operations. They are not regulatory thresholds, and are well below any international / Canadian / provincial health impact thresholds (see Table 4). A spike is not a reportable incident but only indicates that an air parameter is above typical background levels. All spikes are investigated to determine if they are related to O&G operations near to Sable Island. Investigations include contacting the O&G facility operators, conducting air mass back-trajectory analysis and pollution rose analysis to determine the long-range and local upwind sources respectively. Table 4 provides the threshold values chosen for the air emission evaluation of O&G operations.

Table 4. Air emission 'spike' thresholds for Sable Island

Metric	Reference: extreme value analysis (1-hr data period) [1]	Suggested threshold value (1-hr)	Canada Ambient Air Quality Objectives [3]
NOx [2]	3/year return threshold for data available from 01/01/10 to 16/07/10	17.0 ppbv	213 ppb (1-hr)
SO_2	1/year return threshold for data available from 01/04/08 to 01/10/11	6.0 ppbv	344 ppb (1-hr)
H_2S	1/year return threshold for data available from 02/05/12 to 09/10/12	3.11 ppbv	30 ppb (1-hr, NS)
$PM_{2.5}$	1/year return threshold for data available from 01/01/07 to 01/10/11	168.0 µg/m^3	120 µg/m^3 (24-hr)
Ozone	1/year return threshold for data available from 01/01/07 to 01/04/11 (1-hr data period)	104.0 ppbv	82 ppb (1-hr)

Note 1: An extreme value analysis (see Appendix 4 for details) was conducted on air emissions data available between 2007 and 2011. For each metric, the period mentioned in this column indicates the period for which data was available for this specific metric during these five years. For H_2S, the data available for these five years was poor quality; therefore, 2012 H_2S emission data was obtained from NSE to calculate the H_2S threshold. All thresholds will be reviewed on an annual basis and recalculated with the new emissions data that becomes available.

Note 2: A higher return threshold (3/year) was used for the extreme value analysis for NOx (which should result in a higher number of spikes to investigate) because "elevated pollution events" identified during the 2003-2006 ESRF study for this parameter were linked to oil and gas operations as a possible causal factor.

Note 3: Canada Ambient Air Quality Objectives (CAAQO), maximum acceptable 1-hr thresholds are provided as a reference. For $PM_{2.5}$, the 24-hr CAAQO threshold was provided because a 1-hr threshold was not available. For H_2S, the Nova Scotia 1-hr ground-level concentration threshold was used because a CAAQO threshold was not available. The ozone "spike" threshold is higher than the CAAQO threshold because of historical elevated ozone levels in the area.

6.6 Annual NOAA HYSPLIT air mass back trajectory analysis

In an effort to identify upwind source regions, 5-day air mass back trajectories were run twice per day for the whole of 2016. These were referred to if required. They are available upon request.

7. RESULTS AND DISCUSSION

This section covers data analysis results, graphing and additional analysis results related to the assessment of air quality on Sable Island in 2016.

7.1 Meteorological Variables

Table 5 contains the descriptive statistics and data completeness for 2016 meteorological variables.

Table 5. Descriptive statistics and data completeness for hourly 2016 Meteorological Data Descriptive Statistics.

Variable	**Temperature (°C)**	**Wind Direction (°)**	**Wind Speed (km/hr)**
n	8414	8441	8535
n missing	370	343	249
Mean	9.43	256.0 (obtained from WRPLOT)	25.36
St Dev	7.35	N/A	12.79
Min	-9.7	N/A	0
25 pct	3.8	N/A	17
Median	9.4	N/A	24
75 pct	15.2	N/A	34
Max	53.8	N/A	91
IQR	11.4	N/A	17
Data Completeness (annual)	95.79%	96.10%	97.17%

From Table 5, it can be seen that the data completeness for temperature, wind direction and wind speed was 95.79%, 96.10% and 97.17% respectively, which can be considered excellent data completeness. It can also been seen from Table 5 that the mean (min : max *units*) temperature and wind speed was found to be 9.43 (-9.7 : 53.8°C), 256.0 (n/a : n/a °) and 25.36 km/h (0 : 91 km/h). The maximum temperature of 53.8°C seems unlikely, and may be a result of excess solar radiation heating from a nearby surface or the temperature sensor is faulty. This was also the exact same max temperature reading observed in 2015, giving further evidence that this is likely not a correct or representative observation. It is recommended that the meteorological sensors be checked by ECCC to determine if they require calibration or replacement.

Figure 3 below provides the wind rose generated using LakesEnvironmental WRPLOT software. The average wind vector was calculated to be 256º.

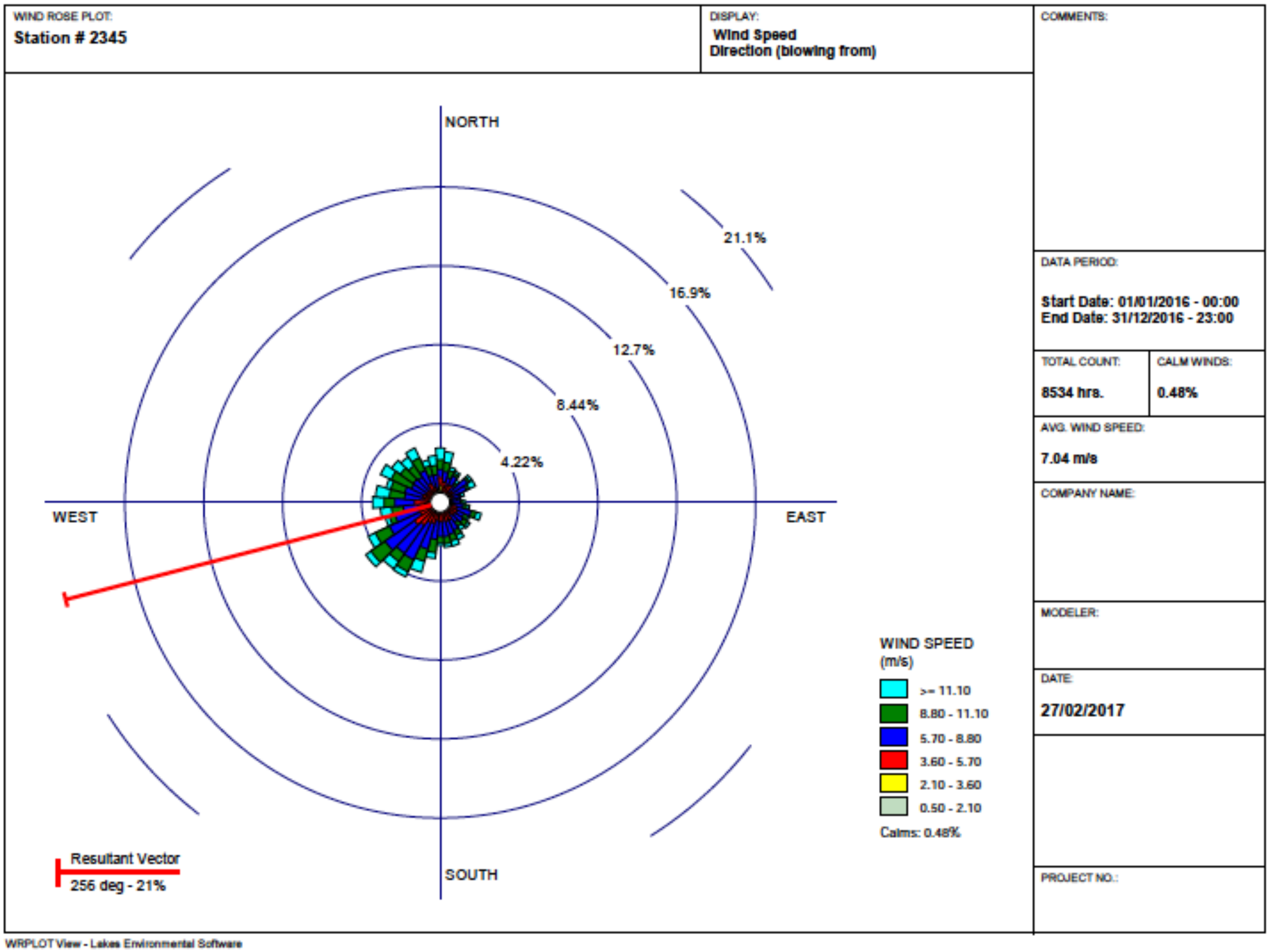

Figure 3. Wind rose for Sable Island (January 1st 2016 to December 31st 2016)

7.2 Black Carbon

Table 6 contains the descriptive statistics and data completeness for the new black carbon instrument that was deployed in October 2016.

Table 6. Black carbon [µg/m^3] descriptive statistics.

Variable	Value
n	80703
n missing	0
Mean	0.955
St Dev	1.22
Min	0
25 pct	0.22
Median	0.47
75 pct	1.06
Max	6.59
IQR	0.84
Data Completeness	100%
Data Completeness (annual)	16.70%

There was not sufficient contiguous BC carbon data (16.7% data completeness) in 2016 with which to construct a meaningful time series plot. The mean (min : max µg/m^3) for BC was 0.955 (0 : 6.59 µg/m^3). The median BC concentration is similar to that found in Halifax (Gibson et al., 2013). This is surprising given that Sable Island is a marine location. It may be a result of on island fossil fuel combustion sources, e.g. aircraft, diesel generators, or long-range transport. However, with a paucity of BC data it is difficult to determine the exact source of this metric at this time.

7.3 $PM_{TSP/10/4/2.5/1}$

Table 7 contains the descriptive statistics and data completeness for 2016 TSI DRX $PM_{TSP/10/4/2.5/1}$ mass concentration. The DRX was cleaned and re-calibrating in January 2016 and cleaned every 3-months thereafter.

Table 7. 2016 DRX Descriptive Statistics for $PM_{TSP/10/4/2.5/1}$ mass concentration.

Variable	PM_1 [$\mu g/m^3$]	$PM_{2.5}$ [$\mu g/m^3$]	PM_4 [$\mu g/m^3$]	PM_{10} [$\mu g/m^3$]	TSP (<60μm) [$\mu g/m^3$]
n	37464	37464	37464	37464	37464
n missing	745	745	745	745	745
Mean	11.7	12.5	12.8	13	13
St Dev	9.42	9.99	10.1	10.2	10.2
Min	0	0	0	0	0
25 pct	5	6	6	6	6
Median	9	9	10	10	10
75 pct	15	16	17	17	17
Max	120	123	124	127	127
IQR	10	10	11	11	11
Data Completeness (annual)	98.05	98.05	98.05	98.05	98.05

From Table 7 it can be seen that the annual data completeness for the DRX $PM_{1/2.5/4.0/10}$ and total mass concentration was 98%, which is excellent. It can also been seen from Table 7 that the mean (min : max) for the $PM_{TSP/10/4/2.5/1}$ total mass concentration was PM_1 = 11.7 (0 : 120 μg/m^3), $PM_{2.5}$ = 12.5 (0 : 123 μg/m^3), PM_4 = 12.8 (0: 124 μg/m^3), PM_{10} = 13.0 (0 : 127 μg/m^3) and TSP = 13.0 (0 : 127 μg/m^3) respectively. The similarity in the PM mass concentration observed during 2016, from the total through to $PM_{1.0}$ size fractions, implies that the aerosol below TSP observed on Sable Island is many composed of fine aerosols (e.g., gas-to-particle conversion, LRT or fresh local combustion sources).

Figure 4 provides a daily time-series of TSI DRX $PM_{TSP/10/4/2.5/1}$ mass concentration from January 1st 2016 to December 31st 2016.

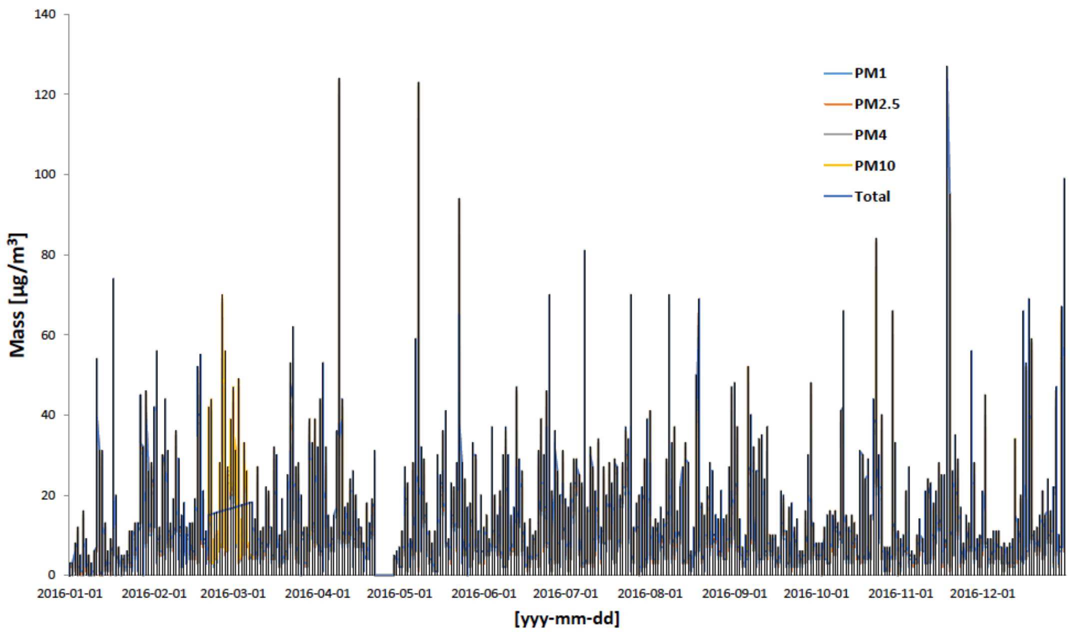

Figure 4. Daily time series TSI DRX $PM_{TSP/10/4/2.5/1}$ mass concentration

As can be seen from Figure 4, the DRX did not collect data in May 2016 for two weeks. Regarding Table 4, it can be seen in Figure 4 and Table 7, there were no breaches of the suggested threshold value (1-hr) or the Canada Ambient Air Quality Objectives (24-hr) for $PM_{2.5}$.

7.4 Coarse Aerosol Particle Number

Table 8 contains the descriptive statistics and data completeness for 2016 TSI APS particle number counts in the size fractions below 0.523, 1.486, 2.4858, 3.52, 5.829, 7.234 and 10.37 µm. These size fractions were created from averaging the relevant 56 size fractions. This was done to reduce the amount of detail which would not be appropriate for this report. The size bins were also chosen to roughly correspond with the TSI DRX particle mass concentration size fractions above.

Table 8. 2016 APS 3321 Descriptive Stats

APS (particle count)	<0.523µm	1.486µm	2.458µm	3.523µm	5.829µm	7.234µm	10.37µm
n	20497	20497	20497	20497	20497	20497	20497
n missing	14623	14623	14623	14623	14623	14623	14623
Mean	124275	3196	615.5	141.2	12.99	3.922	0.558
St Dev	124915.6	3800.9	1058.61	405.46	73.84	29.34	3.64
Min	360	0	0	0	0	0	0
25 pct	46486	1129	106	9	0	0	0
Median	87494	2349	358	39	2	1	0
75 pct	149455	4054	763	132	8	2	0
Max	1963180	86875	23737	8779	2743	1358	159
IQR	102969	2925	657	123	8	2	0
Data Completeness (annual)	53.64	53.64	53.64	53.64	53.64	53.64	53.64

From Table 8, it can be seen that the data completeness over the operation period for the APS was 53.64%. Unfortunately, this instrument suffered from a number of malfunctions, e.g. pump failure and mother board failure. A second instrument was borrowed from the University of Calgary, Department of Chemistry. It can also been seen from Table 8 that the mean (min : max *units* = #) for the APS size fractions particle number counts were <0.523µm = 124275 (360 : 1963180 #), 1.486µm = 3196 (0 : 86875 #), 2.458µm = 615.5 (0 : 23737 #), 3.523µm = 141.2 (0 : 8779 #), 5.829µm = 12.99 (0 : 2743 #), 7.234µm = 3.922 (0 : 1358 #) and 10.37µm = 0.558 (0 : 159 #) respectively. The reduction in particle number counts observed from the <0.523µm to 10.37µm size range fits perfectly with the theory of particle size distributions in the atmosphere. The high PM# in the <0.523 µm size fraction likely being related to aged aerosol and the >2.458 µm likely related to sea salt spray and sand particulate.

7.5 Ultrafine particle number counts

Table 9 contains the descriptive statistics and data completeness for the new TSI 3031 Ultrafine particle number counter.

Table 9. 2016 Daily Ultrafine particle number counts (01/0116 to 31/12/16)

variable	20-30 nm	30-50 nm	50-70 nm	70-100 nm	100-200 nm	200-800 nm
N	366.00	366.00	366.00	366.00	366.00	366.00
N missing	24.00	24.00	24.00	24.00	24.00	24.00
Mean	328.39	361.20	228.17	206.11	253.51	43.46
St. dev	312.36	468.94	273.19	236.78	260.94	51.51
Min	16.11	8.05	1.44	0.75	3.98	2.80
25 pct	115.04	121.14	69.33	64.89	101.61	18.00
Median	223.15	245.77	154.94	133.45	183.90	32.13
75 pct	382.42	483.98	301.22	277.07	321.43	53.12
IQR	267.39	362.83	231.89	212.18	219.83	35.12
Max	2197.13	10023.75	5739.00	4373.75	8193.00	1077.75
Completeness	93.44	93.44	93.44	93.44	93.44	93.44
Annual completeness	93.44	93.44	93.44	93.44	93.44	93.44

From Table 9, the data completeness over the operation period for the particle number counts, in the range 20-30, 30-50, 50-70, 70-100,100-200 and 200-800 nm for 2016 was 93%, which can be considered excellent data capture. It can also been seen from Table 9 that the mean (min : max *units* = #) 3031 particle number counts, in the various size ranges, were as follows: 20-30 nm = 328.39 (16.11 : 2197.13 #), 30-50 nm = 361.20 (8.05 : 10023.75 #), 50-70 nm = 228.17 (1.44: 5739.00 #), 70-100 nm = 206.11 (0.75 : 4373.75 #), 100-200 nm = 253.51 (3.98 : 8193.00 #) and 200-800 nm = 43.46 (2.80 : 1077.753 #) respectively. The higher number count in the small size fractions (20-50 nm) is again typical of atmospheric particle size distributions. This size distribution being related to gas-to-particle conversion of marine emitted gases, long-range-transport gases, secondary ozone reaction particulate or fossil fuel combustion gases.

Figure 5 presents a daily average time-series of 2016 TSI Ultrafine model 3031 particle number between 20 nm and 800 nm (01/0116 to 31/12/16).

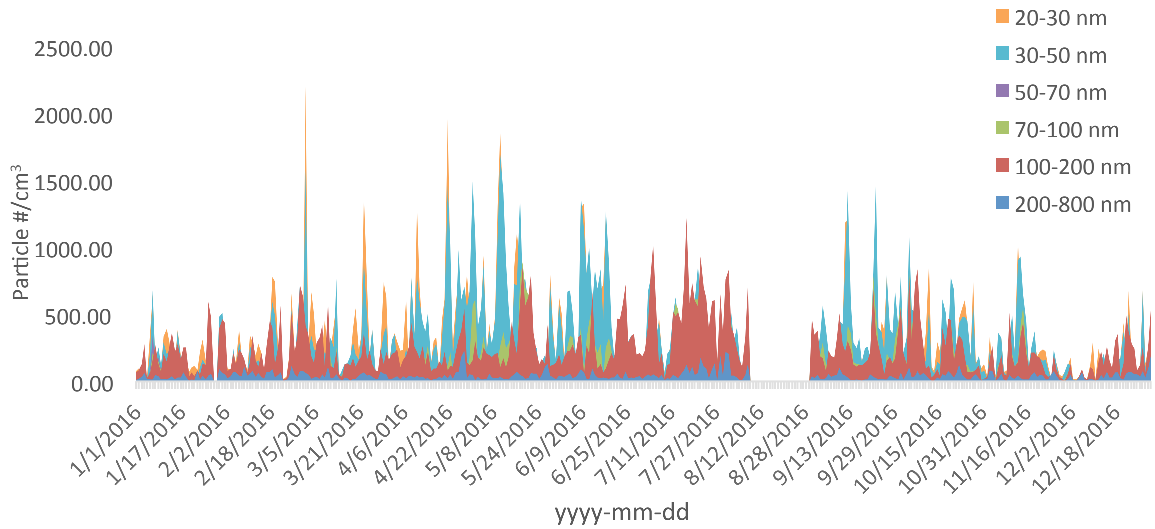

Figure 5. TSI Ultrafine model 3031 particle number daily time series (01/01/16 to 31/01/16)

Analysis of marine chlorophyll concentrations and visible satellite images provided evidence that the spikes in the hourly UFP seen in Figure 5 are related to gas-to-particle conversion of phytoplankton bloom emissions, and not O&G operations. The missing data was due to a pump failure.

7.6 NO_x, O_3, SO_2 and H_2S

Table 10 below provides the descriptive statistics for 2016 NO_x, O_3, SO_2 and H_2S observed on Sable Island.

Table 10. Descriptive statistics for 2016 NO_x, O_3, SO_2 and H_2S

variable	NO_x (ppbv)	O_3 (ppbv)	SO_2 (ppbv)	H_2S (ppbv)
N	184	184	184	184
N missing	0	0	0	5
Mean	1.15	25.10	0.74	0.35
St. dev	0.74	5.65	0.37	0.46
Min	0	14	0	0
25 pct	0.72	21.81	0.49	0.19
Median	1.02	25.48	0.75	0.32
75 pct	1.442	29.80	0.91	0.42
IQR	0.72	7.99	0.42	0.23
Max	7	42	3	6
Completeness	100	100	100	97.3
missing dataset	0	0	0	5
Annual completeness	67%	67%	67%	65%

From Table 10, the data completeness over the operation period for NO_x, O_3 and SO_2 was 67% and 65% for H_2S, which can be considered as insufficient data capture for representative annual data analysis. This low data capture was due to the new instruments not being installed until the end of Q1 2016. It can also been seen from Table 10 that the mean (min : max *units* = ppbv) NOx, O_3, SO_2 and H_2S were as follows: NO_x = 1.15 (0 : 7 ppbv), O_3 = 25.10 (14 : 42 ppbv), SO_2 = 0.74 (0 : 3 ppbv), H_2S = 0.35 (0 : 6 ppbv) respectively. The H_2S is likely to be due to emissions from the nearby O&G platforms.

Figure 6 below is a time series of NOx observed on Sable Island from 01/05/16 to 31/1216

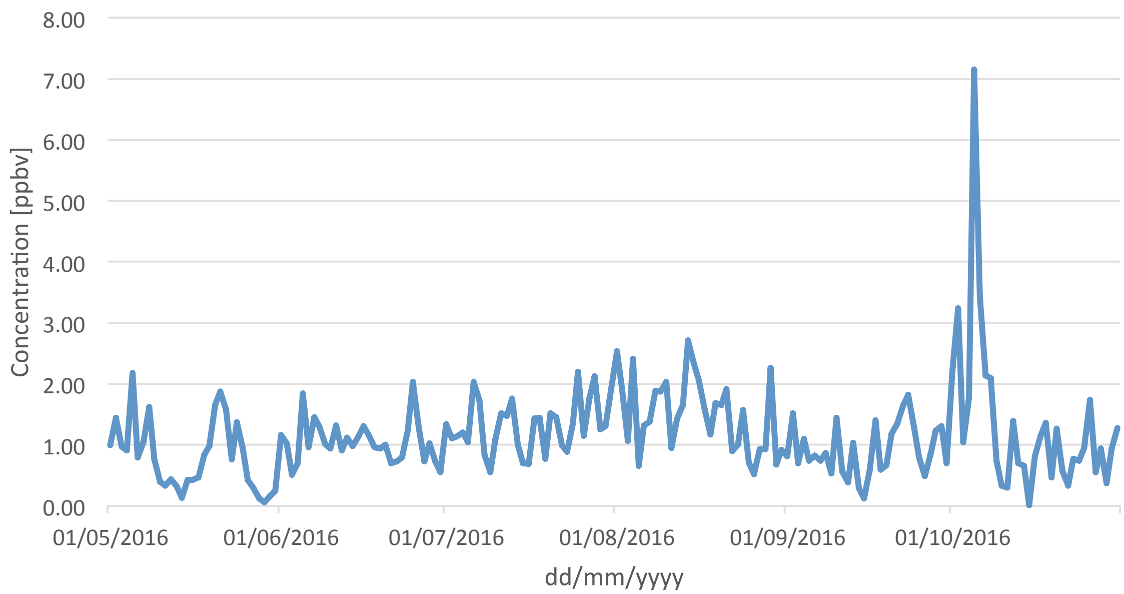

Figure 6. 2016 NO_x time series

Figure 6 shows background NOx of 1.15 ppbv. However, on 05/10/16 there is an elevated level of 7.16 ppbv. This happened a few days after the ExxonMobil platform wide maintenance shutdown. The air flow during the spike observations was directly over the Thebaud platform. Therefore, it could be a possible source. However, the NO_x level was below the operational spike threshold set at 17 ppbv and well below the Canada Ambient Air Quality Objective of 213 ppbv.

Figure 7 below provides a time series of H_2S from 05/01/16 to 21/10/016.

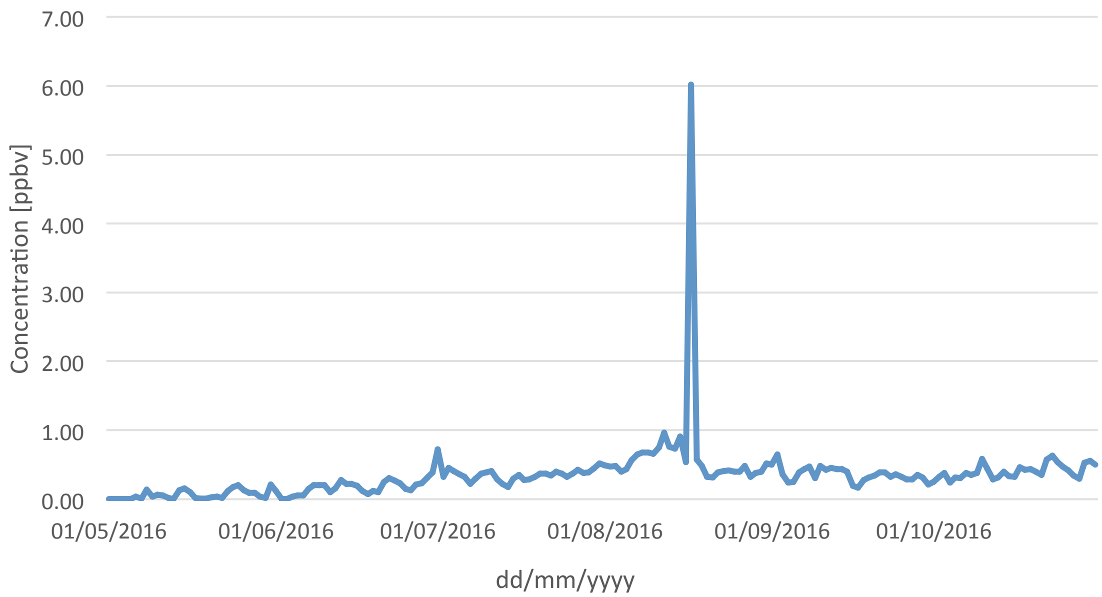

Figure 7. H_2S time series from 05/01/16 to 31/10/16

Figure 7 shows a spike in H_2S of 6.01 ppbv on 17/07/16. This is above the operating spike threshold value of 3.11 ppbv. However, it is well below the 1-hr Nova Scotia air quality objective of 30 ppbv. This spike is obviously linked to the elevated SO_2 level of 3.04 ppbv that occurred on the same day. However, the SO_2 level was below the operational spike threshold of 6.0 ppbv and well below the 1-hr Canada Ambient Air Quality Objectives threshold of 344 ppbv. Scrutiny of the air mass back trajectories (Figure 8) for this day showed that air flow passed over both the Deep Panuke and Thebaud platforms preceding and during observations on Sable Island. The visible satellite image shows a little haze to the south east of Sable Island which is likely related to smoke generated from the wildfires in the NE US as shown in Figure 8. However, these wildfires were unlikely to have caused the spike in H_2S (an anaerobic sour gas) and SO_2 observed on the 17/07/16. The spike might be due to an issue with flaring of H_2S on the Deep Panuke platform at the time.

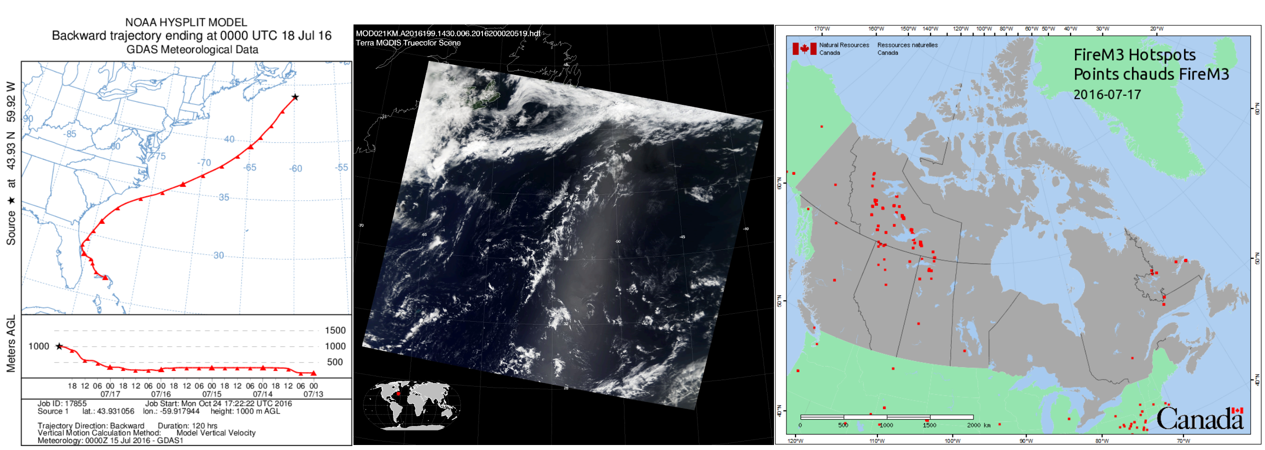

Figure 8. Back trajectory at 8pm 17/07/16 (left), TERRA MODIS visible image 2.30pm 17/01/16 (middle) Fire Hotspots 17/07/16 (right)

Figure 9 below provides a time series of SO_2 from 05/01/16 to 10/31/16.

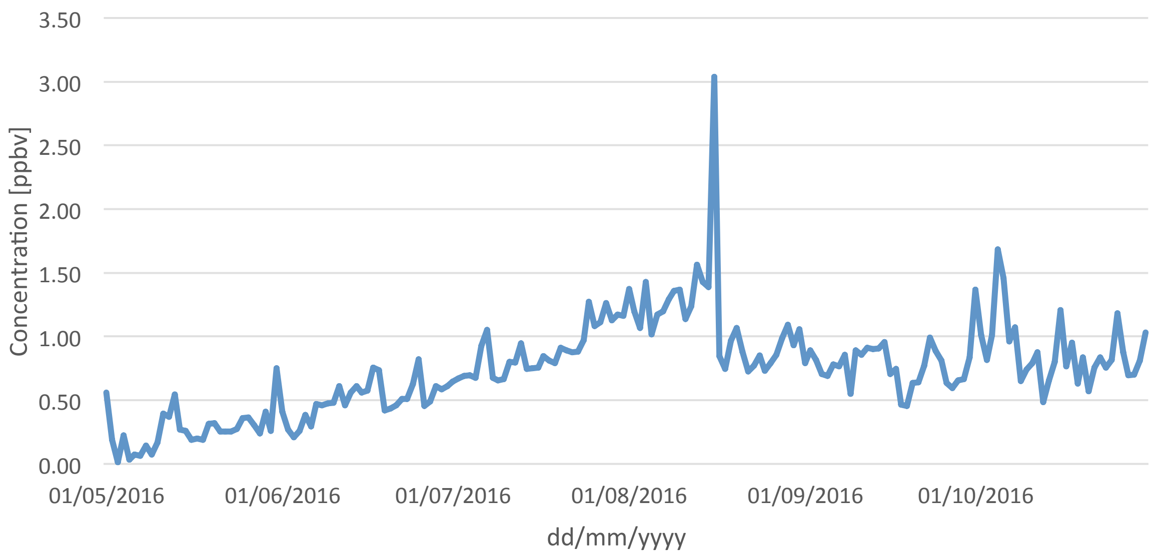

Figure 9. SO_2 time series from 05/01/16 to 31/10/16

Figure 10 below provides a time series of O_3 observations on Sable Island between 05/01/16 to 31/10/16.

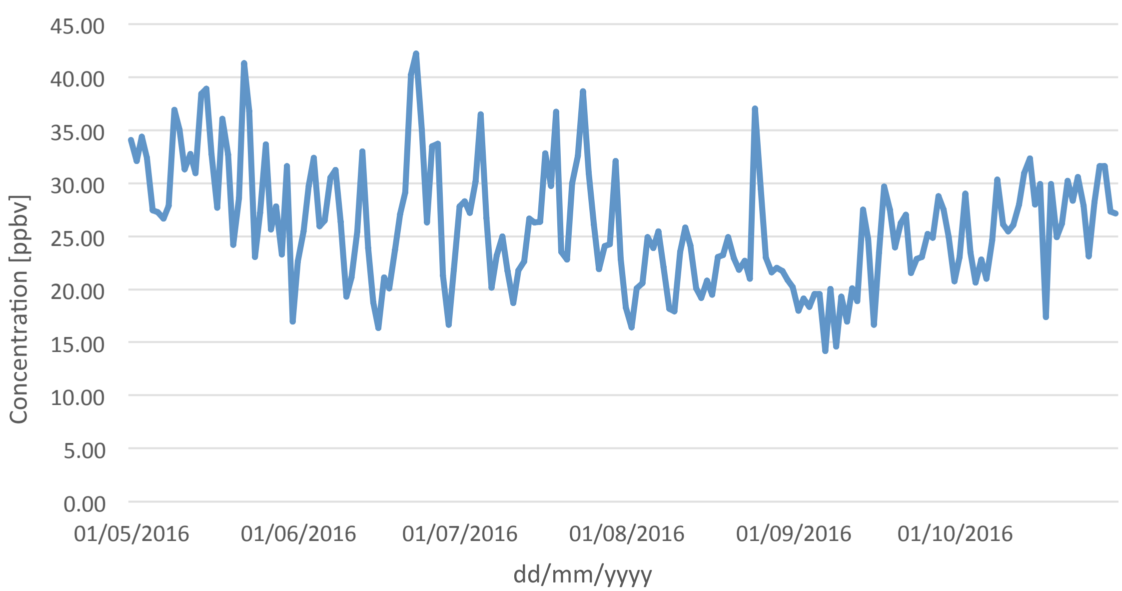

Figure 10. O_3 time series from 05/01/16 to 31/10/16

Regarding Table 4, Table 10 and Figure 9, there are no threshold breaches or excursions above the Canadian Ambient Air Quality Objective for O_3 on Sable Island during the 2016 measurement period. The O_3 concentrations observed are typical for the region, being slightly elevated after the Spring maximum O_3 that occurs during April, a typical steady decline in daily O_3 concentrations over the summer with a slight rise again observed heading into the winter season (Gibson et al., 2009).

8. CONCLUSIONS

In January 2016 a calibrated Thermo 49i O_3 autoanalyzer (ECCC in-kind) and MetOne1020 BAM (Gibson in-kind) was installed on Sable Island. In addition, new NO_x (ECCC in-kind) SO_2 and H_2S analyzers were installed in April 2016. A new Thermo MAAP 5012 BC instrument was install in Q3 of 2016. Data completeness for the DRX TSI, TSI UFP and weather data were > 90%. The BC data completeness was only 16%.

The average wind vector for 2016 was 256° which is consistent with prevailing winds in the North West (NW) Atlantic.

The data completeness for 2016 was only 16.7%, due to late deployment of the instrument (Q3). The mean (min : max µg/m^3) for BC was 0.955 (0 : 6.59 µg/m^3). The median BC concentration is similar to that found in Halifax (Gibson et al., 2013). This is surprising given that Sable Island is a remote marine location. It may be a result of on island fossil fuel combustion sources, e.g. aircraft, diesel generators, or long-range transport. However, with a paucity of BC data it is difficult to determine the exact source of this metric at this time.

The 2016 data completeness for the DRX $PM_{1/2.5/4.0/10}$ and total mass concentration was 98%. The mean (min : max) for the $PM_{TSP/10/4/2.5/1}$ total mass concentration was PM_1 = 11.7 (0 : 120 µg/m^3), $PM_{2.5}$ = 12.5 (0 : 123 µg/m^3), PM_4 = 12.8 (0: 124 µg/m^3), PM_{10} = 13.0 (0 : 127 µg/m^3) and TSP = 13.0 (0 : 127 µg/m^3) respectively. There were no threshold or air quality standard breaches for $PM_{2.5}$ in 2016.

Due to various instrument malfunctions, the 2016 data completeness for the APS was 53.64%. The mean (min : max *units* = #) for the APS size fractions particle number counts were <0.523µm = 124275 (360 : 1963180 #), 1.486µm = 3196 (0 : 86875 #), 2.458µm = 615.5 (0 : 23737 #), 3.523µm = 141.2 (0 : 8779 #), 5.829µm = 12.99 (0 : 2743 #), 7.234µm = 3.922 (0 : 1358 #) and 10.37µm = 0.558 (0 : 159 #) respectively. The data completeness over the operation period for the UFP particle number counts, in the range 20-30, 30-50, 50-70, 70-100,100-200 and 200-800 nm for 2016 was 93%, which can be considered excellent data capture. The mean (min : max *units* = #) UFP 3031 particle number counts, in the various size ranges, were as follows: 20-30 nm = 328.39 (16.11 : 2197.13 #), 30-50 nm = 361.20 (8.05 : 10023.75 #), 50-70 nm = 228.17 (1.44: 5739.00 #), 70-100 nm = 206.11 (0.75 : 4373.75 #), 100-200 nm = 253.51 (3.98 : 8193.00 #) and 200-800 nm = 43.46 (2.80 : 1077.753 #) respectively.

The data completeness over the operation period for NO_x, O_3 and SO_2 was 67% respectively and 65% for H_2S, which can be considered as insufficient data capture for representative annual data analysis. This low data capture for these metrics was due to the new instruments not being installed until the end of Q1 2016. The mean (min : max *units* = ppbv) NOx, O_3, SO_2 and H_2S were as follows: NO_x = 1.15 (0 : 7 ppbv), O_3 = 25.10 (14 : 42 ppbv), SO_2 = 0.74 (0 : 3 ppbv), H_2S = 0.35 (0 : 6 ppbv) respectively.

There were no threshold or air quality standard breaches for O_3 in 2016. However, there was a spike in H_2S of 6.01 ppbv on 17/07/16. This H_2S spike was above the operating threshold value of 3.11 ppbv. However, it was well below the 1-hr Nova Scotia air quality objective of 30 ppbv. This H_2S spike is obviously linked to the elevated SO_2 level of 3.04 ppbv that occurred on the same day. However, the SO_2 level was below the operational spike threshold of 6.0 ppbv and well below the 1-hr Canada Ambient Air Quality Objectives threshold of 344 ppbv. Scrutiny of the air mass back trajectories for this day showed that air flow passed over both the Deep Panuke and Thebaud platforms preceding and during observations on Sable Island. The spike might be due to an issue with flaring of H_2S on the Deep Panuke platform at the time. On 05/10/16 there was an elevated level in NOx of 7.16 ppbv. This happened a few days after the ExxonMobil platform wide maintenance shutdown. The air flow during the spike observations was directly over the Thebaud platform. Therefore, it could be a possible source. However, NO_x level was below the operational spike threshold set at 17 ppbv and well below the Canada Ambient Air Quality Objective of 213 ppbv.

9. RECOMMENDATIONS

It is recommended that near real-time $PM_{2.5}$ chemical composition be monitored on Sable Island. This would allow immediate source identification and provide threshold breach alerts rather than waiting for over a year for data to become available. In addition, the $PM_{2.5}$ chemical data currently available is only collected once every 6th days so transient and episodic episodes may be missed. Therefore, it is recommended that an instrument such as an Aerodyne, Aerosol Chemical Speciation Monitor (real-time chloride, organic matter, sulfate, nitrate and ammonium) be added to Sable Island's air quality monitoring program to provide real time $PM_{2.5}$ chemical composition surveillance. The recently deployed $PM_{2.5}$ black carbon and size-resolved particle number would complement these measurements. Together, these measurements would provide a full suite of air pollutants to optimize the identification of local and LRT sources and to alert O&G facility operators to any incidences of air quality threshold breaches. It is likely that ECCC will deploy an Aerodyne, Aerosol Chemical Speciation Monitor soon, this would address this recommendation.

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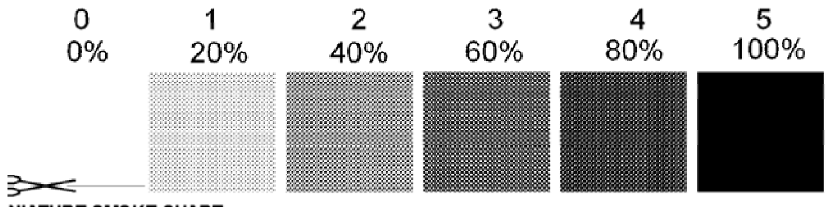
APPENDIX O

2016 Flare Plume Monitoring



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CALENDAR DAYS					TOTAL	
#0	146	40%	69	19%	215	29%
#1	197	54%	275	75%	472	64%
#2	23	6%	20	5%	43	6%
#3	0	0%	2	1%	2	0.3%
	366	100%	366	100%	732	100%

DURING PRODUCTION DAYS ONLY					TOTAL	
#0	89	35%	25	10%	114	22%
#1	146	57%	211	82%	357	69%
#2	22	9%	19	7%	41	8%
#3	0	0%	2	1%	2	0.4%
	257	100%	257	100%	514	100%