Offshore Environmental Effects Monitoring for Deep Panuke

Program Annual Report 2015

McGregor number: *1113-EEMRDP*

Client Project Manager:	M. Thillet
McGregor Project Manager:	T. Ryan, S. Kirchhoff
Interpretation and Report By:	G. Forbes, S. Kirchhoff
McGregor Project Number:	1113

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Executive Summary

McGregor GeoScience Ltd. (McGregor) was contracted by Encana Corporation for provision of Environmental Effects Monitoring (EEM) services for the Deep Panuke natural gas field. The objective of this project is to provide a monitoring program addressing all production operations-related environmental effects monitoring 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 to date 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 2015 findings for the following analyses:

- Chemical characterization of produced water during production (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):
  - PFC legs;
  - Riser Caisson;
  - protective mattresses;

  - concrete protection tunnels;
  - wellheads; and
  - exposed sections of the pipeline to shore.
- Fish Health Assessment (section 6.5):
  - assess fish health on fish;
  - evaluate toxicity; and
  - examine mussel tissues for contaminants.
- Marine wildlife observations (section 6.6 of the EEMP):
  - marine mammals and sea turtles observations;
  - stranded-bird observations;
  - beached bird observation on Sable Island; and
  - OTN final report.
- 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 2015 EEM program include the following:

Produced water chemistry and toxicity:

<u>March 2015:</u>

- Produced water was collected for analysis on March 24th, 2015.
- All results were below CCME guidelines where available for major ions and organic Acids. Nitrogen, orthophosphate, total phosphorus, and sulphides were all found to be well above the RDL, and nitrite to be slightly above RDL (no CCME guidelines available). All other nutrients, major ions and organic acids were not detected.
- Except for PAH naphthalene, benzene, toluene and ethylbenzene results where elevated values were found to be above CCME guidelines; all other parameters (metals, PAHs, alkylated phenols and hydrocarbons) were below CCME guidelines where available.
- Toxicity tests were performed using the produced water collected in March of 2015. The IC25 sea urchin (using *Lytechinus pictus*) fertilization test and the IC50 Microtox test (using *Vibrio fischeri*) were used to measure toxicity. The

IC25 for the sea urchin test was 34.3% produced water. The IC50 for the Microtox test was 5.65% produced water.

- Octylphenol was the only AP that was detected, at the level of 146ng/L.

December 2015:

- Produced water was collected for analysis on December 30th, 2015.
- Nitrogen, orthophosphate and total phosphorus were all well above the RDL, and nitrite was slightly above RDL. The pH of the produced water was 7.10, which is within the CCME guidelines of 7.0-8.7. The organic acids analyzed were not detected.
- Toluene, ethylbenzene 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 470 μg/L, which is well above the CCME guideline of 1.4 μg/L. All other PAH parameters measured were either not detected, or did not have CCME guidelines to be compared
- No APs tested for were detected in the December produced water.

Cloudy water (slightly milky/cloudy patches that were regularly observed on the water surface near the PFC between January and April 2015) was collected on March 7th, 2015, for toxicity testing. The IC25 sea urchin and the IC50 Microtox test results were >100% and >90%, respectively, confirming that the sample was not toxic.

Marine water quality:

- Water quality sampling was conducted on March 25th, 2015, at 7 stations: 2000m, 1000m, 500m, 250m, and 20 m downstream, and 2000m and 250m upstream of the PFC.
- Temperature was similar across all stations sampled and ranged between 1.5°C and 2.0°C. At each station the temperature was warmer at the surface and gradually decreased with depth. More variability in temperature was seen at the 20m downstream and 250m downstream stations for the first 5m and 15m respectively.

- PH was consistent across all stations and depths, and had a narrow range of 7.9 to 8.0.
- Salinity followed similar trends across stations sampled, and increased slightly with depth. Salinity values were similar at stations sampled, and ranged from 31.98 PSU to 32.10 PSU.
- Dissolved oxygen increased with depth at all stations, and ranged from 79% to 89%.
- 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, and mercury, which was above CCME guidelines at all stations and depths sampled (but not detected in produced water samples).
- Any PAH, Total Hydrocarbons including BTEX-TPH detected were below or slightly above laboratory RDLs.
- Alkylated phenols were not detected at any depth of the stations sampled.

Sediment Chemistry and Toxicity:

- The sediment type found at all stations mostly consisted of fine sand;
- Antimony, barium, strontium, thallium and zinc were not present at detectable levels across all stations, which is consistent with 2011 results, and a decrease from the baseline study results from 2008.
- Sulphide levels increased since 2011.
- Aluminum, arsenic, iron, lead manganese and vanadium were detected at similar levels and followed similar trends in regards to levels detected across stations as 2011.
- Mercury levels remain non-detectable.
- PAH and BTEX parameters tested for remain at non detectable levels.
- No alkylated phenols tested for were detected at any of the sediment stations sampled.

Fish habitat alteration:

- Epifauna colonization of WHPS at all well site locations observed had similar species density and assemblages as the 2014 survey. More soft marine growth was present, as the hydroid (*Tubularia sp.)* continues to grow on top of blue mussel (*Mytilus edulis*). Species composition was relatively homogenous across all wellhead sites.
- Dominant fish species at the WHPS continue to be pollock (*Pollachius sp*.) and cunner (*Tautogolabrus adsperus*). As in 2014, Sculpins (*Myoxocephalus sp*.) were also found this year at the WHPS and were not present in the 2012 survey. Like the 2012 - 2014 surveys, Atlantic cod (*Gadus morhua*) was not present in 2015 at the WHPS. Large schools of Gadidae (Either cod or pollock) that were observed by the ROV crew around the PFC structure were not present in 2015. Cunner was the dominant species seen at WHPS and the PFC in 2015.
- Wellheads and protective structures continue to act as an artificial reef/refuge as evidenced by the colonization of the structures as mentioned in the 2006 EA predictions. The structures are attracting fish from the surrounding areas and providing shelter in an otherwise relatively featureless seafloor.
- Blue mussel *Mytilus edulis* continues to be the dominant species at the PFC area and WHPS.
- Marine growth was present on flange covers at H-08, D-41 and F-70 flowlines. There was also marine growth, such as the occasional hydroid and sea star on closing spools on all flowlines.

Fish Health Assessment:

- In either of the mussel samples (control site and the PFC), all PAH's tested for were not detectable.
- APs 4-NP, 4n-OP and NP1EO were detected in the Deep Panuke mussel samples. Control site tissues (Lingcod) had similar or higher 4-NP and 4n-OP present. 4-NP was also detected in lab blanks. NP2EO was not detected in Deep Panuke, control or lab blank samples.

Marine wildlife observations:

- Eleven bird strandings were reported in 2015. One black guillemot was found tangled in twine and released. All other birds were found dead. No birds were found to have oil on them.
- Both the supply vessels the M/V Atlantic Condor and the M/V Atlantic Tern reported wildlife sightings in 2015. The M/V Atlantic Condor observed one tagged gull on April 25th, 2015, and various untagged gulls throughout the year. The M/V Atlantic Tern reported a variety of seabirds, as well as seals, white-sided dolphins, pilot whales, minke whales, sunfish, porbeagle, blue shark, and porpoises.
- Three red bats were observed on the PFC on September 15, 2015.
- Ongoing monitoring of oiling rates in beached birds on Sable Island was conducted over the course of 8 surveys carried out between March and December 2015 (with no surveys in May or November), where 461 beached seabird corpses were collected. Alcids accounted for 58.4% of the total corpses recovered. Of the 461 corpses, 193 (41.9%) were complete (>70% of body intact). The overall oiling rate for all species combined was 0.5%. Only one oiled corpse was collected in 2015.
- Thirty-nine out of the forty NS blue sharks tagged by OTN in 2013 and 2014 were detected the year after their initial tagging. Acoustic receivers positioned on oil and gas industry offshore infrastructure did not detect the tagged sharks, but logged other tagged animals including grey seals and bluefin tuna.

Air Quality Monitoring:

- Sable Island air emissions monitoring
    - No data for NO_x, H_2S, SO_2, O_3 and BAM $PM_{2.5}$ was available for 2015. Supplemental $PM_{2.5}$ data was available from October through the end of 2015. A $PM_{2.5}$ BAM, O_3 autoanalyzer and NO_x analyzer was installed on Sable Island in January of 2016, but awaits calibration in April 2016.
    - The most notable feature of the 2015 air emissions report is that spikes in PM mass and particle number concentrations were associated with long-range transport continental outflow, and not O&G operations.
    - The mean $PM_{2.5}$ for the three months of 2015 was similar in concentration to previous air emission reports.
    - With the new instruments deployed on Sable Island, the 2016 air emissions report will contain far more data and a more fulsome investigation of local and upwind air emissions impacting Sable Island.
- 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” 47% of the time that the facility was producing, a "1" or "2" (light smoke) 53% of the time.

In accordance with objectives stipulated in the Offshore Production EEMP, it is anticipated that the 2016 EEM sampling program will provide analyses and observations for the following monitoring components:

- Produced water chemistry and toxicity (section 6.1 of EEMP);
- Marine water quality monitoring (section 6.2 of EEMP);
- Sediment chemistry and toxicity (section 6.3 of EEMP);
- Fish habitat alteration analyses (section 6.4 of EEMP);
- Fish health assessment (section of 6.5 EEMP);
- Marine wildlife observations (section 6.6 of EEMP); and
- Air quality monitoring (section 6.7 of EEMP).

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GLOSSARY OF TERMS

AC	Autoanalysis Colilert
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
CNLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COPAN	Cohasset and Panuke
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRM	Certified Reference Material
CSR	Comprehensive Study Report
CWS	Canadian Wildlife Service
DIC	Dissolved Inorganic Carbon
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DS	Downstream
DVD	Digital Video Disc/ Digital Versatile Disc
EA	Environmental Assessment
ECSAS	Eastern Canada Seabirds at Sea
EEM	Environmental Effects Monitoring
EEMP	Environmental Effects Monitoring Plan
EPCMP	Environment Protection and Compliance Monitoring Plan
EPS1/RM/35	Reference method for determining acute lethality of sediment to marine or estuarine amphipods
EQG	Environmental Quality Guidelines

EROD	Ethoxyresorufin-O-deethylase
ESRF	Environmental Studies Research Fund
GC	Gas Chromatography
GEP	Gas Export Pipeline
GHG	Greenhouse Gases
GVI	General Visual Inspection
H_2S	Hydrogen Sulphide
hr	Hour
IC	Ion Chromatography
ICP	Inductively Coupled Plasma
ISE	Ion Selective Electrode
km	Kilometre
KP	Kilometre Point
L	Litre(s)
LC49	Bioassay Acute Toxicity Analysis
LAT	Lowest Astronomical Tide
LRMS	Low Resolution Mass Spectrometry
LRT	Long-range Transport
m	metre(s)
mg	milligram(s)
mol	Mole (unit)
MOPU	Mobile Offshore Production Unit
M&NP	Maritimes & Northeast Pipeline
MS	Mass Spectrometry
MV	Motor Vessel
N	North
NA	Not tested for
NB	New Brunswick
ND	Not Detected
NE	North East
NEB	National Energy Board
NMHC	Non-methane hydrocarbons
NO	Nitric oxide
NO_2	Nitrogen dioxide

NOx	Nitrogen Oxides
NOAA	National Oceanic and Atmospheric Administration
NRCan	Natural Resources Canada
NSERC	Natural Sciences and Engineering Research Council of Canada
OES	Optical Emission Spectroscopy
O&G	Oil and Gas
OPR	On-going Precision and Recovery
O_3	Ozone
OWTG	Offshore Waste Treatment Guidelines
OTN	Ocean Tracking Network
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
RADAR	Radio Detection and Ranging
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
SW	South West
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
VHF	Very High Frequency
VIV	Vortex Induced Vibration
VOCs	Volatile Organic Compounds
WBM	Water-based Mud
WGS84	World Geodetic System 1984
WHPS	Wellhead Protection Structure

1 INTRODUCTION

McGregor GeoScience Ltd. (McGregor) was contracted in 2011 by Encana Corporation (Encana) to provide environmental effects monitoring services and data analysis for the Deep Panuke natural gas field. McGregor undertook data analysis and report production as per the Offshore Production Environmental Effects Monitoring Plan (EEMP) (Encana, 2011: DMEN-X00-RP-EH-90-0003). This 2015 report represents the fourth yearly report submitted to Encana.

The 2015 EEMP project team consisted of:

- McGregor GeoScience Ltd. for subsea video data analysis, sampling operations and project reporting;
- SBM/Encana personnel from PFC and supply/standby vessels MV Atlantic Condor, and MV Atlantic Tern sampling operations, marine mammal, sea turtles and bird observation, and for flare plume analysis;
- Zoe Lucas Consulting for Sable Island beached bird survey; and
- Kingfisher Environmental Health Consultants for Sable Island air quality monitoring.

Table 1.1 below provides an overview of the 2015 EEM program including relevant environmental effects monitoring (EEM) components and survey timing.

Table 1.1 - Overview of 2015 EEM Program

EEM Component(s)	*2015 EEM Program*	*Survey Timing*
Produced water chemistry Section 6.1 of EEMP	Produced water collected on Deep Panuke. Chemical characterization and toxicity of produced water.	March and December 2015
Fish Habitat Alteration Section 6.4 of EEMP	Inspection of ROV video data to determine development of benthic communities at the wellheads, wellhead protection structures, PFC legs and pipelines. Collect mussels for fish health assessment.	March to July, 2015
PFC Marine Wildlife Observations Section 6.6 of EEMP	Summarize PFC and vessels observations, including stranded birds.	Continuous
Water quality monitoring	Chemical and oceanographic characterization of the water at three depths at 7 tide-dependent sites around the PFC.	March, 2015
Oiled Bird Study conducted on Sable Island Section 6.6 of EEMP	Eight surveys for beached seabirds were conducted on Sable Island. Species identification, corpse condition and extent of oiling were recorded for seabird specimens.	Throughout 2015
Air Quality Section 6.7 of EEMP	Monitoring of air emissions with air quality monitoring instruments deployed on Sable Island	October to December 2015

EEM Component(s)	*2015 EEM Program*	*Survey Timing*
Flare Plume observations Section 6.7 of EEMP	Systematic flare smoke monitoring was initiated in 2014 using the Ringelmann smoke chart.	Smoke monitoring twice a day throughout 2015
Sediment chemistry and toxicity	Chemical characterization and toxicity at 6 locations near the PFC.	March, 2015

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 1.1a**).

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 production field centre (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 1.1b and 1.1c**), 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 (H_2S). 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 H_2S 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. In addition to the provision of the PFC, SBM will provide personnel to help ensure a smooth transition from the development phase into the project's production phase, and will be responsible for the long-term operations of the production facilities, including logistics. During the production operations phase at Deep Panuke, Encana will remain the operator of record but SBM will own and operate the production facility and oversee day-to-day field operations, as directed by Encana, including production, marine, helicopter and onshore logistics.

Significant project's milestones achieved in 2015 are as follows:

- 2015 was the third year of production operations at Deep Panuke ("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 220 million cubic feet per day in March.
- In order to achieve maximum resource recovery and maximize potential vale, an operating strategy incorporating seasonal production was implemented in 2015. This strategy involved shutting in field production during the warmer months (May 10 to October 28, 2015) when gas prices are historically lower and producing at maximum rates during the colder months when potential for higher gas prices is greatest.
- The annual ROV subsea survey took place over the flowlines, wellheads and export pipeline to shore from February to December 2015.
- H-08, F-70 and M-79A kept producing formation water in 2015, while D-41 kept producing only condensed water throughout the year.
- The following acid treatments were completed in 2015:
    - M-79A on January 8;
    - F-70 on January 26;
    - M-79A on March 12;
    - F-70 on November 3 (failed to restart); and
    - M-79A on December 6.

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

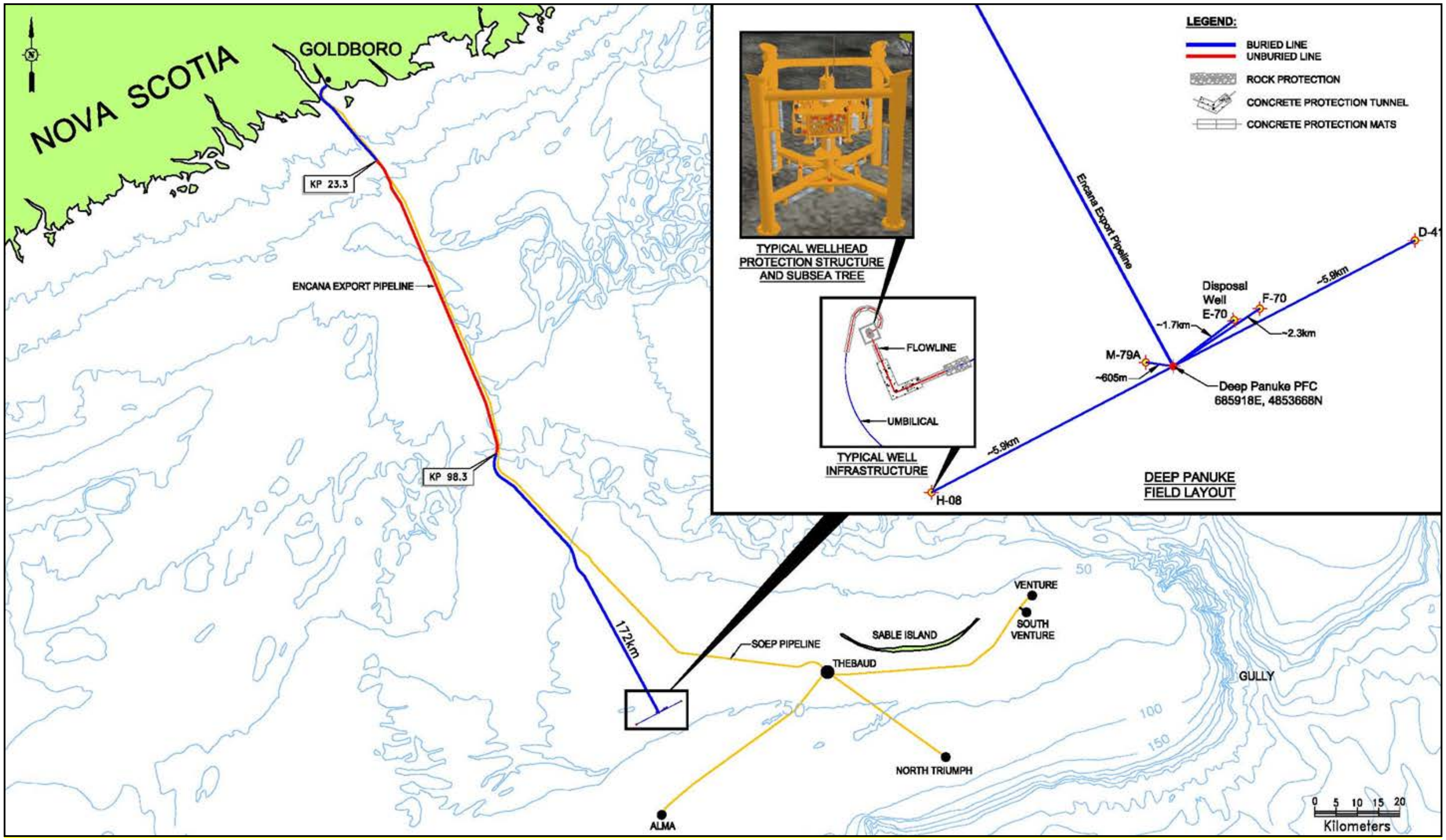


Figure 1.1a Deep Panuke Subsea Production Structures - General Overview (From Offshore Production EEMP - May 21, 2011)

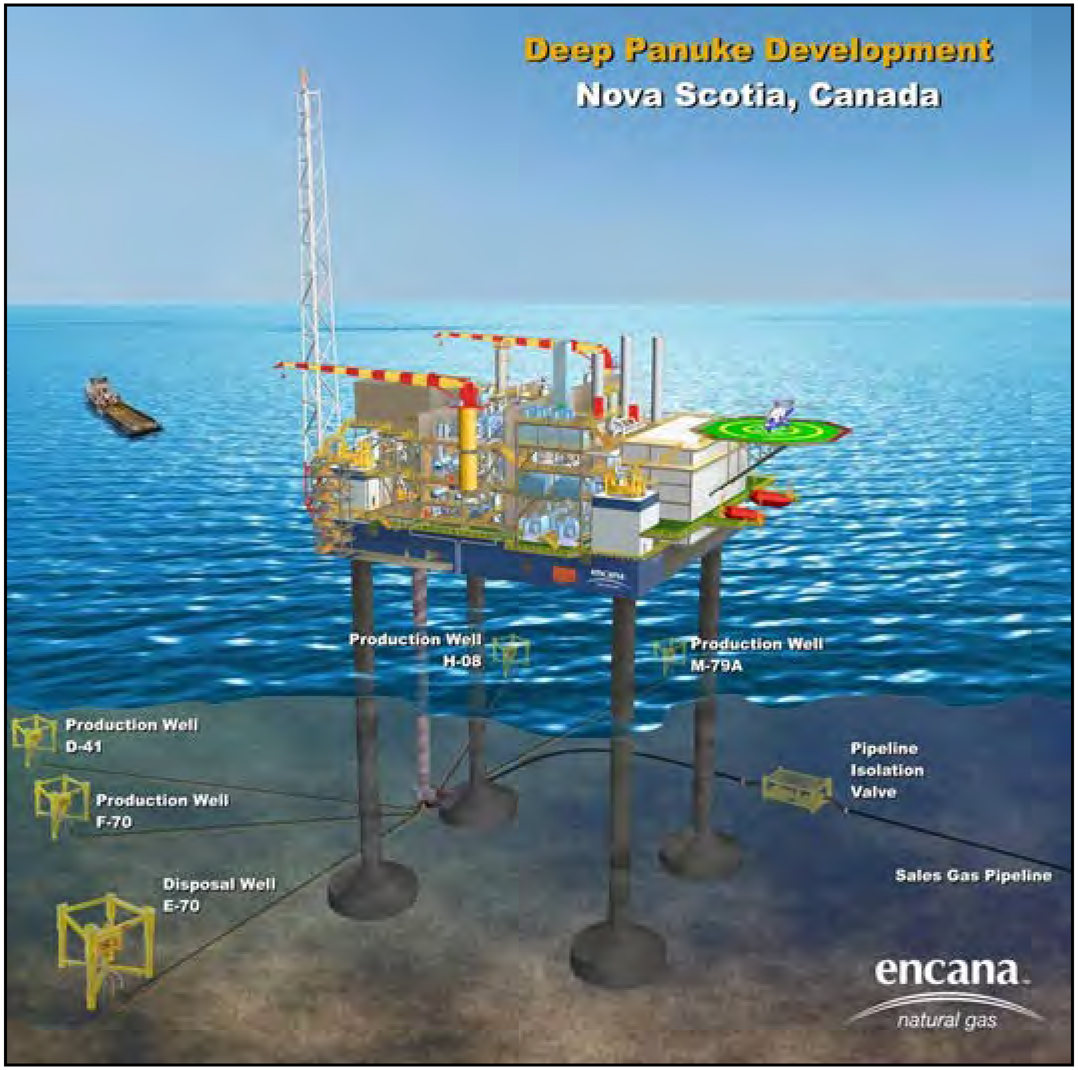


Figure 1.1b Deep Panuke Production Field Centre Rendering (From Offshore Production EEMP - May 21, 2011)

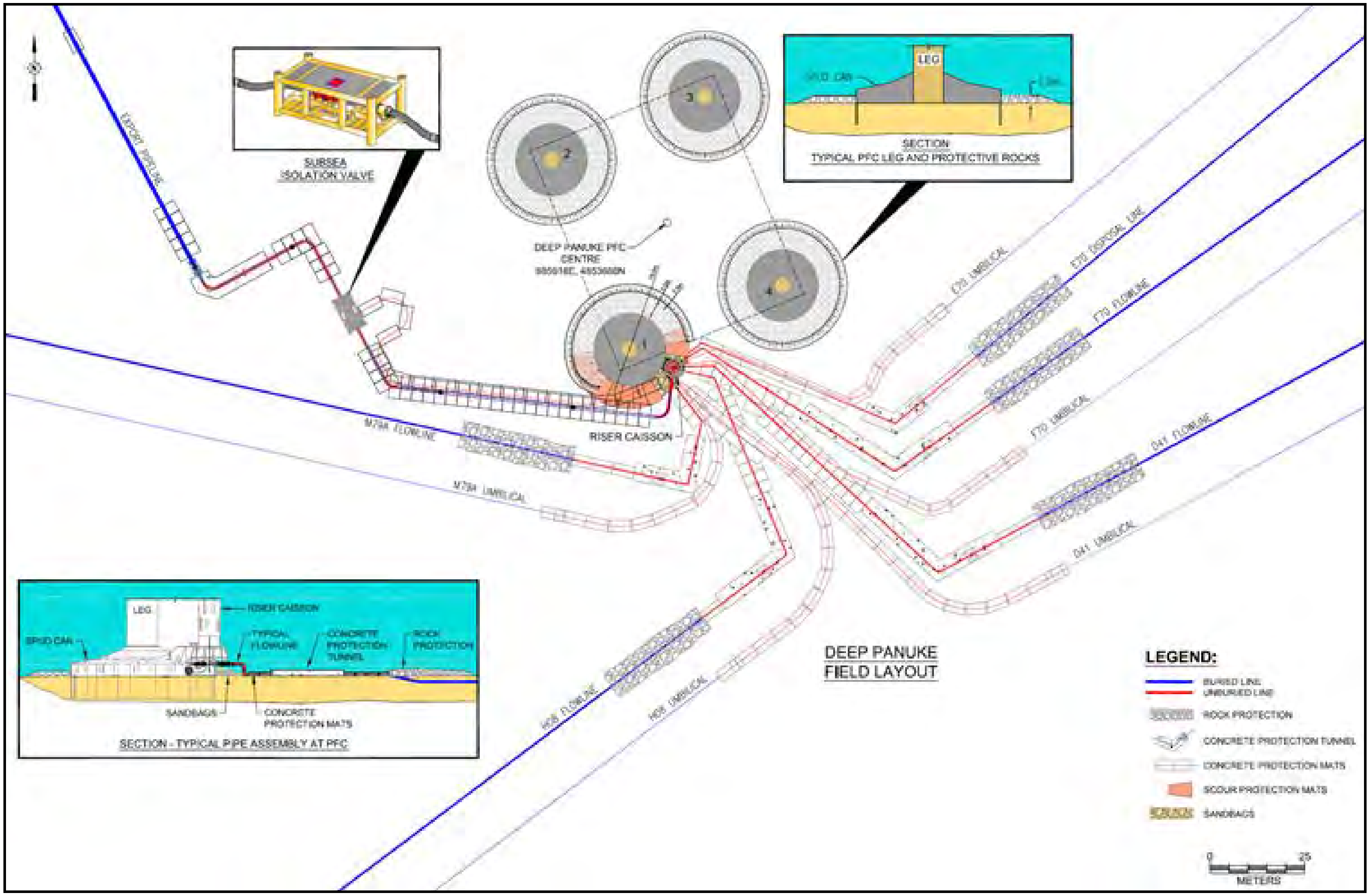


Figure 1.1c Deep Panuke Subsea Production Structures - PFC Area (From Offshore Production EEMP - May 21 2011)

2 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 the ocean disposal of produced water because of the potential danger of chronic ecological harm. The chemicals of greatest environmental concern include aromatic hydrocarbons, some alkylated phenols and a few metals. These chemicals, if present in high enough concentrations lead to bioaccumulation and toxicity in marine organisms.

The proposed 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 weighted average) and 44 mg/L (24-hour arithmetic average) of oil in produced water discharged to the marine environment. Encana’s design target for Deep Panuke is 25 mg/L (30-day weighted average). The concentration of oil in produced water is measured at least every 12 hours and a volume weighted 24-hr rolling average and 30-day rolling average calculated daily.

The chemical composition of produced water is analyzed twice yearly for the following parameters:

- metals (aluminium, antimony, arsenic, barium, boron, cadmium, chromium, cobalt, copper, iron, lead, magnesium, mercury, molybdenum, nickel, selenium, silver, strontium, thorium, tin, uranium, vanadium, zinc);
- non-metals (nitrogen, phosphorus, sulphur, oxygen);
- hydrocarbons: total petroleum hydrocarbons (TPH), poly-aromatic hydrocarbons (PAHs) and alkyl phenols (APs);
- nutrients (nitrate, phosphate, ammonia, organic acids);
- hydrogen sulphide (H,S);
- 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 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

To Examine the potential toxicity of produced water from the Deep Panuke PFC 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

Analyze produced water collected on the Deep Panuke PFC 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 December, 2015 for chemical characterization (See **Table 2.1** and **Table 2.2** for details) and in March of 2015, toxicity tests were performed (See **Table 2.1 and Table 2.15 to Table 2.20**). The toxicity test on Threespine Stickleback was not possible as winter conditions at the time of the sampling operations prevented the capture of the wild specimens needed for this test. In addition, cloudy water (slightly milky/cloudy patches that were regularly observed on the water surface near the PFC between January and April 2015) was collected on March 7th, 2015, for toxicity testing.

Table 2.1 - Produced Water Sampling Details - March

<table>
<tr><td>Sample Date:</td><td>March 24, 2015 at 7am local time</td></tr>
<tr><td>Type of Sample:</td><td>Produced water samples</td></tr>
<tr><td>Test Sample Locations:</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>PFC, produced water discharge line sampling point</td><td>10:00</td><td>NA</td><td>686000</td><td>4853691</td></tr>
<tr><td colspan="5">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. pH and temperature were measured at the time of collection 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</td><td>no preservative</td></tr>
</table>
</td></tr>
</table>

Table 2.2 - Produced Water Sampling Details - December

<table>
<tr><td>Sample Date:</td><td>December 30, 2015 at 8:15am local time</td></tr>
<tr><td>Type of Sample:</td><td>Produced water samples</td></tr>
<tr><td>Test Sample Locations:</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>PFC, produced water discharge line sampling point</td><td>11:15</td><td>NA</td><td>686000</td><td>4853691</td></tr>
<tr><td colspan="5">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. pH and temperature were measured at the time of collection 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>
</table>
</td></tr>
</table>

2.1.5 Analyses

Produced Water Chemistry

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. Temperature, salinity and DO affect the amount of H_2S found in undissociated form. Sulphide H_2S was determined using SM 4500-S2-G. To calculate H_2S, pH, conductivity and temperature measurements recorded during sampling at the PFC were used.

2.1.5.1 Produced Water Chemistry Parameters Analyzed

Table 2.3 - Produced Water Chemistry Parameters Measured

Parameter	Units	RDL March	RDL December	CCME Guidelines	Analysis Method
Nutrients					
Nitrate + Nitrite	mg/L	0.50	0.50	N/A	colorimetry
Nitrate (N)	mg/L	0.50	0.50	1500	colorimetry

Parameter	Units	RDL March	RDL December	CCME Guidelines	Analysis Method
Nitrite (N)	mg/L	0.10	0.10	N/A	colorimetry
Nitrogen (Ammonia)	mg/L	2.5	2.5	N/A	colorimetry
Orthophosphate (P)	mg/L	0.10	0.10	N/A	colorimetry
Major Ions					
Phosphorus	mg/L	0.10	0.020	N/A	AC
Sulphide	mg/L	0.02	0.020	N/A	ISE
Organic Acids					
Formic Acid	mg/L	100	100	N/A	IC
Acetic Acid	mg/L	200	100	N/A	IC
Propionic Acid	mg/L	200	200	N/A	IC
Butyric Acid	mg/L	400	400	N/A	IC
Trace Metals					
Aluminum (Al)	µg/L	500	500	N/A	ICP-MS
Antimony (Sb)	µg/L	100	100	N/A	ICP-MS
Arsenic (As)	µg/L	100	100	12.5	ICP-MS
Barium (Ba)	µg/L	100	100	N/A	ICP-MS
Beryllium (Be)	µg/L	100	100	N/A	ICP-MS
Bismuth (Bi)	µg/L	200	200	N/A	ICP-MS
Boron (B)	µg/L	5000	5000	N/A	ICP-MS
Cadmium (Cd)	µg/L	1.0	1.0	0.12	ICP-MS
Calcium (Ca)	µg/L	10000	10000	N/A	ICP-MS
Chromium (Cr)	µg/L	100	100	Hex = 1.5, Tri = 56	ICP-MS
Cobalt (Co)	µg/L	40	40	N/A	ICP-MS
Copper (Cu)	µg/L	200	200	N/A	ICP-MS
Iron (Fe)	µg/L	5000	5000	N/A	ICP-MS
Lead (Pb)	µg/L	50	50	N/A	ICP-MS
Magnesium (Mg)	µg/L	10000	1000	N/A	ICP-MS
Manganese (Mn)	µg/L	200		N/A	ICP-MS
Mercury (Hg)	µg/L	0.13	0.013	0.016	Cold Vapour AA
Molybdenum (Mo)	µg/L	200	200	N/A	ICP-MS
Nickel (Ni)	µg/L	200	200	N/A	ICP-MS
Potassium (K)	µg/L	10000	10000	N/A	ICP-MS
Selenium (Se)	µg/L	100	100	N/A	ICP-MS
Silver (Ag)	µg/L	10	10	N/A	ICP-MS
Sodium (Na)	µg/L	10000	10000	N/A	ICP-MS
Strontium (Sr)	µg/L	200	2000	N/A	ICP-MS

Parameter	Units	RDL March	RDL December	CCME Guidelines	Analysis Method
Thallium (Tl)	µg/L	10	10	N/A	ICP-MS
Tin (Sn)	µg/L	200	200	N/A	ICP-MS
Titanium (Ti)	µg/L	200	200	N/A	ICP-MS
Uranium (U)	µg/L	10	10	NRG	ICP-MS
Vanadium (V)	µg/L	200	200	N/A	ICP-MS
Zinc (Zn)	µg/L	500	500	N/A	ICP-MS
PAH					
Naphthalene	µg/L	4.0	50	1.4	GC/MS
Benzo(j)fluoranthene	µg/L	0.010	0.020	N/A	GC/MS
Chrysene	µg/L	0.010	0.020	N/A	GC/MS
Benzo(b)fluoranthene	µg/L	0.010	0.020	N/A	GC/MS
Benzo(k)fluoranthene	µg/L	0.010	0.020	N/A	GC/MS
Benzo(a)pyrene	µg/L	0.010	0.020	N/A	GC/MS
Perylene	µg/L	0.010	0.020	N/A	GC/MS
Acenaphthylene	µg/L	0.010	0.40	N/A	GC/MS
Indeno(1,2,3-cd)pyrene	µg/L	0.010	0.020	N/A	GC/MS
Dibenz(a,h)anthracene	µg/L	0.010	0.020	N/A	GC/MS
Benzo(g,h,i)perylene	µg/L	0.010	0.020	N/A	GC/MS
2-Methylnaphthalene	µg/L	1.0	12	N/A	GC/MS
Acenaphthene	µg/L	0.010	0.020	N/A	GC/MS
Fluorene	µg/L	0.20	5.0	N/A	GC/MS
1-Methylnaphthalene	µg/L	1.0	12	N/A	GC/MS
Benzo(a)anthracene	µg/L	0.010	0.02	N/A	GC/MS
Phenanthrene	µg/L	0.20	0.020	N/A	GC/MS
Anthracene	µg/L	0.90	0.40	N/A	GC/MS
Fluoranthene	µg/L	0.010	0.020	N/A	GC/MS
Pyrene	µg/L	0.010	0.020	N/A	GC/MS
BTEX-TPH					
Benzene	mg/L	0.050	0.050	110	PTGC
Toluene	mg/L	0.050	0.050	215	PTGC
Ethylbenzene	mg/L	0.050	0.050	25	PTGC
Xylene (Total)	mg/L	0.10	0.10	N/A	PTGC
C_6 - C_{10} (less BTEX)	mg/L	0.50	0.50	N/A	PTGC
>C_{10}-C_{16} Hydrocarbons	mg/L	0.25	0.059	N/A	PTGC
>C_{16}-C_{21} Hydrocarbons	mg/L	0.050	0.059	N/A	PTGC
>C_{21}-<C_{32} Hydrocarbons	mg/L	0.10	0.12	N/A	PTGC
Modified TPH (Tier1)	mg/L	0.50	0.50	N/A	PTGC

Parameter	Units	RDL March	RDL December	CCME Guidelines	Analysis Method
Reached Baseline at C_{32}	mg/L	N/A	N/A	N/A	PTGC
Alkylated Phenols					
Nonylphenol (NP)	ng/L	10	10	700	LR GC/MS
4-Nonylphenol monoethoxylate (NP1EO)	ng/L	50	50	700	LR GC/MS
4-Nonylphenol diethoxylate (NP2EO)	ng/L	50	50	700	LR GC/MS
4-n-Octylphenol (OP)	ng/L	50	50	N/A	LR GC/MS
Other Measurements					
pH (field)	pH units	N/A	N/A	7.0-8.7	Field meter
Temperature	°C	N/A	N/A	N/A	Field meter
Salinity	PSU	10	10	N/A	Conductivity meter

2.1.5.2 Produced Water Chemistry Analysis QA/QC

- Metals in water: Method Blank, Spike Blank, CRM, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- PAH: Method Blank, Blank Spike, Duplicate Sample, Matrix Spike: 1 per 20 samples, Surrogate for all samples.
- Ammonia in water: Method Blank, Spike Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- $NO_X/NO_2/NO_3$ in water: Method Blank, Spike Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- Ortho-Phos in water: Method Blank, Spike Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- Total Phosphorous in water: Method Blank, Spike Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- Organic acids in water: Method Blank, Spiked Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples.
- Sulphides in water: Spiked Blank, Matrix Spike, Method Blank, Sample Duplicate - Minimum one each per batch, minimum frequency of 1 every 20 samples.
- Alkylated Phenols in water: Blank Spike, Continuous Calibration Blank, OPR (On-going Precision and Recovery) Samples, Sample Duplicate, - minimum one each per batch, minimum frequency of 1 every 20 samples.

- TPH in soil and water - BTEX/C6-C10 - Method Blank, Spiked Blank, Duplicate Sample, Matrix Spike - 1 in 20 - Surrogate for all samples C10-C32 - Method Blank, Blank Spike, Duplicate Sample, Matrix Spike - 1 in 20.
- PAH in soil and water - Method Blank, Blank Spike, Duplicate Sample, Matrix Spike - 1 in 20. Surrogate for all samples

2.1.6 Results

2.1.6.1 Produced Water Chemical Characterization Results

Produced water was collected twice in 2015. Results for nutrients, majors Ions, organic acids, trace Metals, PAHs, alkylated phenols and BTEX-TPH 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 the tables below for all detectable chemical parameters. Maxxam and Axys water quality data for produced water from March and December, 2015, can be found in **Digital Appendix A1 and A2**, respectively.

March 2015 Sampling:
A sample from the PFC produced water discharge line was collected on March 24th, 2015 at 7 am (local time). At the time of collection, water pH was 6.40 and water temperature was 90°C.

- Results for nutrients, majors ions and organic acids are shown in **Table 2.4**. nitrogen, orthophosphate and total phosphorus were all well above the RDL, and nitrite was slightly above RDL. The pH of the produced water was 6.79, which is outside 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.
- Results for metals, PAHs, alkylated phenols and BTEX-TPH can be found in **Table 2.6**, **Table 2.8**, **Table 2.10** and **Table 2.12,** respectively. No metals were found in concentrations above CCME guidelines where available. Barium, boron, calcium, magnesium, potassium, sodium, strontium and thallium were all detected well above RDL, and no CCME guidelines were available for these

elements. All other metals were not detected, or were found to be just slightly above RDL. Naphthalene, toluene, ethylbenzene and benzene results where elevated values 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 660 μg/L, which is well above the CCME guideline of 1.4 μg/L. All other PAH parameters measured were either not detected, or did not have CCME guidelines to be compared to.
- 4-n Octyphenol (OP) was the only AP detected in the cloudy water discharge. 4-n Octyphenol was detected at a concentration level of 146 ng/L, which is above the RL of 83.0, however; no CCME guidelines are available.

<u>December 2015 Sampling:</u>

A sample from the PFC produced water discharge line was collected on December 30th, 2015 at 8:15 am (local time).

- Results for Nutrients, Majors Ions and Organic Acids are shown in **Table 2.5**. Nitrogen, Orthophosphate and Total Phosphorus were all well above the RDL, and Nitrite was slightly above RDL. The pH of the produced water was 7.10, 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.
- Results for Metals, PAHs, Alkylated Phenols and BTEX-TPH can be found in **Table 2.7**, **Table 2.9**, **Table 2.11** and **Table 2.13** respectively. Cadmium and Chromium were both found above CCME guidelines. Barium, Boron, Calcium, Magnesium, Manganese, Potassium, Sodium, Strontium and Thallium were all detected well above RDL, and no CCME guidelines were available for these elements. All other metals were not detected. Toluene, Ethylbenzene and Benzene results where elevated values 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. It should be noted that BTEX vials submitted for testing had headspace (not filled correctly), so results may by biased low for these parameters.

- Naphthalene was found to have elevated levels of 470 μg/L, which is well above the CCME guideline of 1.4 μg/L. All other PAH parameters measured were either not detected, or did not have CCME guidelines to be compared to.
- No APs tested for were detected.

Table 2.4 - Produced Water Quality Results: Nutrients, Major Ions and Organic Acids from March, 2015

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines*
Calculated Parameters					
Nitrate (N)	mg/L	ND	0.50	3962570	200
Inorganics					-
Nitrate + Nitrite	mg/L	ND (1)	0.50	3967667	No data
Nitrite (N)	mg/L	0.11 (2)	0.10	3967668	-
Nitrogen (Ammonia Nitrogen)	mg/L	73	2.5	3967826	No data
Orthophosphate (P)	mg/L	0.31 (2)	0.10	3967663	No data
pH	pH	6.79	N/A	3969669	7.0-8.7
Total Phosphorus	mg/L	1.2	0.10	3965989	No data
Salinity	N/A	160	10	3965983	-
Sulphide	mg/L	0.63	0.020	3964527	No data
Miscellaneous Parameters					-
Formic Acid	mg/L	ND	100	3966839	-
Acetic Acid	mg/L	ND	200	3966839	-
Propionic Acid	mg/L	ND	200	3966839	-
Butyric Acid	mg/L	ND	400	3966839	-

*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
(1) Elevated RDL due to sample matrix.
(2) Elevated reporting limit due to sample matrix.

Table 2.5 - Produced Water Quality Results: Nutrients, Major Ions and Organic Acids from December, 2015

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines*
Calculated Parameters					
Nitrate (N)	mg/L	ND	0.50	4332579	200
Inorganics					-
Nitrate + Nitrite	mg/L	ND (1)	0.50	4334026	No data
Nitrite (N)	mg/L	ND (1)	0.10	4334028	-
Nitrogen (Ammonia Nitrogen)	mg/L	74	2.5	4333670	No data
Orthophosphate (P)	mg/L	0.49 (1)	0.10	4334025	No data
pH	pH	7.10	N/A	4336317	7.0-8.7

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines*
Total Phosphorus	mg/L	0.73	0.020	4337903	No data
Salinity	N/A	150	10	4341562	-
Sulphide	mg/L	1.5	0.020	4335400	No data
Miscellaneous Parameters					-
Formic Acid	mg/L	ND	100	4333838	-
Acetic Acid	mg/L	ND	200	4333838	-
Propionic Acid	mg/L	ND	200	4333838	-
Butyric Acid	mg/L	ND	400	4333838	-

*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
(1) Elevated reporting limit due to sample matrix

Table 2.6 - Produced Water Quality Results: Trace Metals from March, 2015

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Metals					
Total Aluminum (Al)	µg/L	ND	500	3965137	No data
Total Antimony (Sb)	µg/L	ND	100	3965137	No data
Total Arsenic (As)	µg/L	ND	100	3965137	12.5
Total Barium (Ba)	µg/L	19000	100	3965137	No data
Total Beryllium (Be)	µg/L	ND	100	3965137	No data
Total Bismuth (Bi)	µg/L	ND	200	3965137	-
Total Boron (B)	µg/L	89000	5000	3965137	NRG
Total Cadmium (Cd)	µg/L	ND	1.0	3965137	0.12
Total Calcium (Ca)	µg/L	8000000	10000	3965137	No data
Total Chromium (Cr)	µg/L	ND	100	3965137	Hex=1.5, Tri=56
Total Cobalt (Co)	µg/L	ND	40	3965137	No data
Total Copper (Cu)	µg/L	ND	200	3965137	No data
Total Iron (Fe)	µg/L	ND	5000	3965137	No data
Total Lead (Pb)	µg/L	ND	50	3965137	No data
Total Magnesium (Mg)	µg/L	850000	10000	3965137	-
Total Manganese (Mn)	µg/L	270	200	3965137	No data
Total Mercury (Hg)	µg/L	ND	0.13	3967830	0.016
Total Molybdenum (Mo)	µg/L	ND	200	3965137	No data
Total Nickel (Ni)	µg/L	ND	200	3965137	No data
Total Phosphorus (P)	µg/L	ND	10000	3965137	No data
Total Potassium (K)	µg/L	380000	10000	3965137	-
Total Selenium (Se)	µg/L	ND	100	3965137	No data
Total Silver (Ag)	µg/L	ND	10	3965137	No data

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Total Sodium (Na)	µg/L	31000000	10000	3965137	No data
Total Strontium (Sr)	µg/L	730000	2000	3965137	-
Total Thallium (Tl)	µg/L	14	10	3965137	No data
Total Tin (Sn)	µg/L	ND	200	3965137	No data
Total Titanium (Ti)	µg/L	ND	200	3965137	-
Total Uranium (U)	µg/L	ND	10	3965137	NRG
Total Vanadium (V)	µg/L	ND	200	3965137	No data
Total Zinc (Zn)	µg/L	ND	500	3965137	No data

* 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
NRG = No Recommended Guideline

Table 2.7 - Produced Water Quality Results: Trace Metals from December, 2015

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Metals					
Total Aluminum (Al)	µg/L	690	500	4335339	No data
Total Antimony (Sb)	µg/L	ND	100	4335339	No data
Total Arsenic (As)	µg/L	ND	100	4335339	12.5
Total Barium (Ba)	µg/L	25000	100	4335339	No data
Total Beryllium (Be)	µg/L	ND	100	4335339	No data
Total Bismuth (Bi)	µg/L	ND	200	4335339	-
Total Boron (B)	µg/L	87000	5000	4335339	NRG
Total Cadmium (Cd)	µg/L	4.4	1.0	4335339	0.12
Total Calcium (Ca)	µg/L	7100000	10000	4335339	No data
Total Chromium (Cr)	µg/L	320	100	4335339	Hex=1.5, Tri=56
Total Cobalt (Co)	µg/L	ND	40	4335339	No data
Total Copper (Cu)	µg/L	ND	200	4335339	No data
Total Iron (Fe)	µg/L	ND	5000	4335339	No data
Total Lead (Pb)	µg/L	220	50	4335339	No data
Total Magnesium (Mg)	µg/L	790000	10000	4335339	-
Total Manganese (Mn)	µg/L	730	200	4335339	No data
Total Mercury (Hg)	µg/L	ND	0.013	4335520	0.016
Total Molybdenum (Mo)	µg/L	ND	200	4335339	No data
Total Nickel (Ni)	µg/L	ND	200	4335339	No data
Total Phosphorus (P)	µg/L	ND	10000	4335339	No data
Total Potassium (K)	µg/L	360000	10000	4335339	-

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Total Selenium (Se)	µg/L	ND	100	4335339	No data
Total Silver (Ag)	µg/L	ND	10	4335339	No data
Total Sodium (Na)	µg/L	28000000	10000	4335339	No data
Total Strontium (Sr)	µg/L	600000	2000	4335339	-
Total Thallium (Tl)	µg/L	ND	10	4335339	No data
Total Tin (Sn)	µg/L	ND	200	4335339	No data
Total Titanium (Ti)	µg/L	ND	200	4335339	-
Total Uranium (U)	µg/L	ND	10	4335339	NRG
Total Vanadium (V)	µg/L	ND	200	4335339	No data
Total Zinc (Zn)	µg/L	590	500	4335339	No data

* 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
NRG = No Recommended Guideline

Table 2.8 - Produced Water Quality Results: PAHs from March, 2015

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Polyaromatic Hydrocarbons					
1-Methylnaphthalene	µg/L	410 (1)	1.0	3965997	-
2-Methylnaphthalene	µg/L	470 (1)	1.0	3965997	No data
Acenaphthene	µg/L	3.0	0.010	3965997	Insufficient data
Acenaphthylene	µg/L	4.1	0.010	3965997	No data
Anthracene	µg/L	ND (2)	0.90	3965997	Insufficient data
Benzo(a)anthracene	µg/L	1.0	0.010	3965997	Insufficient data
Benzo(a)pyrene	µg/L	0.014	0.010	3965997	Insufficient data
Benzo(b)fluoranthene	µg/L	0.080	0.010	3965997	No data
Benzo(g,h,i)perylene	µg/L	ND	0.010	3965997	-
Benzo(j)fluoranthene	µg/L	0.017	0.010	3965997	-
Benzo(k)fluoranthene	µg/L	ND	0.010	3965997	No data
Chrysene	µg/L	0.93	0.010	3965997	Insufficient data
Dibenz(a,h)anthracene	µg/L	ND	0.010	3965997	No data
Fluoranthene	µg/L	2.0	0.010	3965997	Insufficient data
Fluorene	µg/L	76 (1)	0.20	3965997	Insufficient data
Indeno(1,2,3-cd)pyrene	µg/L	ND	0.010	3965997	No data
Naphthalene	µg/L	660 (1)	4.0	3965997	1.4

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Perylene	µg/L	0.023	0.010	3965997	-
Phenanthrene	µg/L	48 (1)	0.20	3965997	Insufficient data
Pyrene	µg/L	0.97	0.010	3965997	Insufficient data
Surrogate Recovery (%)					
D10-Anthracene	%	73		3965997	
D14-Terphenyl	%	91 (3)		3965997	
D8-Acenaphthylene	%	55		3965997	

* 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
(1) Elevated PAH RDL(s) due to sample dilution.
(2) Elevated PAH RDL(s) due to matrix / co-extractive interference.
(3) PAH sample contained sediment.

Table 2.9 - Produced Water Quality Results: PAHs from December, 2015

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Polyaromatic Hydrocarbons					
1-Methylnaphthalene	µg/L	220 (1)	12	4334902	-
2-Methylnaphthalene	µg/L	300 (1)	12	4334902	No data
Acenaphthene	µg/L	2.5	0.020	4334902	Insufficient data
Acenaphthylene	µg/L	ND (2)	0.40	4334902	No data
Anthracene	µg/L	ND (2)	0.40	4334902	Insufficient data
Benzo(a)anthracene	µg/L	0.073	0.020	4334902	Insufficient data
Benzo(a)pyrene	µg/L	ND	0.020	4334902	Insufficient data
Benzo(b)fluoranthene	µg/L	0.048	0.020	4334902	No data
Benzo(g,h,i)perylene	µg/L	ND	0.020	4334902	-
Benzo(j)fluoranthene	µg/L	ND	0.020	4334902	-
Benzo(k)fluoranthene	µg/L	ND	0.020	4334902	No data
Chrysene	µg/L	0.63	0.020	4334902	Insufficient data
Dibenz(a,h)anthracene	µg/L	ND	0.020	4334902	No data
Fluoranthene	µg/L	1.6	0.020	4334902	Insufficient data
Fluorene	µg/L	55 (1)	5.0	4334902	Insufficient data
Indeno(1,2,3-cd)pyrene	µg/L	ND	0.020	4334902	No data
Naphthalene	µg/L	470 (1)	50	4334902	1.4
Perylene	µg/L	ND	0.020	4334902	-
Phenanthrene	µg/L	38	0.020	4334902	Insufficient data
Pyrene	µg/L	0.86	0.020	4334902	Insufficient

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
					data
Surrogate Recovery (%)					
D10-Anthracene	%	101		4334902	
D14-Terphenyl	%	121 (3)		4334902	
D8-Acenaphthylene	%	100		4334902	

* 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
(1) Elevated PAH RDL(s) due to sample dilution.
(2) Elevated PAH RDL(s) due to matrix / co-extractive interference.
(3) PAH sample contained sediment.

Table 2.10 - Produced Water Quality Results: Alkylated Phenols from March, 2015

	Units	Produced water	RL	CCME Guidelines *
Alkylphenols				
4-Nonylphenols	ng/L	ND	103	700
4-Nonylphenols monoethoxylates	ng/L	ND	550	700
4-Nonylphenols diethoxylates	ng/L	ND	23.3	700
Octylphenol	ng/L	145	83.0	N/A
13C6-4-n-Nonylphenol	% recovery	67.1		-
13C6-NP2EO	% Recovery	59.2		-

RL = Reporting Limit

ND = Not detected

N/A = Not Applicable

Table 2.11 - Produced Water Quality Results: Alkylated Phenols from December, 2015

	Units	Produced water	RL	CCME Guidelines *
Alkylphenols				-
4-Nonylphenols	ng/L	ND	4.61	700
4-Nonylphenols monoethoxylates	ng/L	ND	12.6	700
4-Nonylphenols diethoxylates	ng/L	ND	3.97	700
Octylphenol	ng/L	ND	1.39	N/A
13C6-4-n-Nonylphenol	% recovery	48.5		-
13C6-NP2EO	% Recovery	44.8		-

RL = Reporting Limit

ND = Not detected

N/A = Not Applicable

Table 2.12 - Produced Water Quality Results: BTEX-TPH from March, 2015

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Petroleum Hydrocarbons					
Benzene	mg/L	3.5	0.050	3965117	0.110
Toluene	mg/L	1.6	0.050	3965117	0.215
Ethylbenzene	mg/L	0.058	0.050	3965117	0.025
Total Xylenes	mg/L	0.53	0.10	3965117	No data
C6 - C10 (less BTEX)	mg/L	ND	0.50	3965117	-
>C10-C16 Hydrocarbons	mg/L	15 (1)	0.25	3964725	-
>C16-C21 Hydrocarbons	mg/L	7.6	0.050	3964725	-
>C21-<C32 Hydrocarbons	mg/L	4.5	0.10	3964725	-
Modified TPH (Tier1)	mg/L	27	0.50	3962672	-
Reached Baseline at C32	mg/L	Yes	N/A	3964725	-
Hydrocarbon Resemblance	mg/L	COMMENT (2)	N/A	3964725	-
Surrogate Recovery (%)					
Isobutylbenzene - Extractable	%	104		3964725	
n-Dotriacontane - Extractable	%	107		3964725	
Isobutylbenzene - Volatile	%	103		3965117	

* 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
(1) Elevated TEH RDL(s) due to sample dilution
(2) Fuel oil fraction

Table 2.13 - Produced Water Quality Results: BTEX-TPH from December, 2015

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Petroleum Hydrocarbons					
Benzene	mg/L	3.6	0.050	4334916	0.110
Toluene	mg/L	1.7	0.050	4334916	0.215
Ethylbenzene	mg/L	0.069	0.050	4334916	0.025
Total Xylenes	mg/L	0.57	0.10	4334916	No data
C6 - C10 (less BTEX)	mg/L	ND	0.50	4334916	-
>C10-C16 Hydrocarbons	mg/L	6.5 (1)	0.059	4334916	-
>C16-C21 Hydrocarbons	mg/L	3.3 (1)	0.059	4334916	-
>C21-<C32 Hydrocarbons	mg/L	1.8 (1)	0.12	4334916	-
Modified TPH (Tier1)	mg/L	12	0.50	4334916	-
Reached Baseline at C32	mg/L	Yes	N/A	4334916	-
Hydrocarbon Resemblance	mg/L	COMMENT (2)	N/A	4334916	-

	Units	PRODUCED WATER	RDL	QC Batch	CCME Guidelines *
Surrogate Recovery (%)				4334916	
Isobutylbenzene - Extractable	%	99		4334916	
n-Dotriacontane - Extractable	%	101		4334916	
Isobutylbenzene - Volatile	%	105 (3)		4334916	

* 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
(1) Elevated TEH RDL(s) due to limited sample
(2) One product in the gas/fuel oil range. Fuel oil fraction.
(3) VPH sample contained headspace. VPH sample contained sediment.

Table 2.14 - Produced Water Quality Results: Produced Water Compared to Marine Water Quality Sampling Stations

Parameters	Units	Water Stations	Produced Water March	Produced Water December
Calculated Parameters				
Nitrate (N)	mg/L	0.097 - 0.26	ND	ND
Inorganics				
Nitrate + Nitrite	mg/L	0.11 - 0.14	ND (1)	ND (2)
Nitrite (N)	mg/L	ND - 0.017	0.11 (2)	ND (2)
Nitrogen (Ammonia Nitrogen)	mg/L	ND - 2.2	73	74
Orthophosphate (P)	mg/L	0.022 - 0.026	0.31 (2)	0.49 (2)
pH	pH	7.90 - 7.94	6.79	7.1
Total Phosphorus	mg/L	0.027 - 0.034	1.2	0.73
Salinity	N/A	31.98 - 32.1	160	150
Sulphide	mg/L	ND	0.63	1.5
Miscellaneous Parameters				
Formic Acid	mg/L	ND	ND	ND
Acetic Acid	mg/L	ND	ND	ND
Propionic Acid	mg/L	ND	ND	ND
Butyric Acid	mg/L	ND	ND	ND
Metals				
Total Aluminum (Al)	µg/L	ND	ND	690
Total Antimony (Sb)	µg/L	ND	ND	ND
Total Arsenic (As)	µg/L	ND	ND	ND
Total Barium (Ba)	µg/L	ND	19000	25000
Total Beryllium (Be)	µg/L	ND	ND	ND
Total Bismuth (Bi)	µg/L	ND	ND	ND
Total Boron (B)	µg/L	4100 - 4400	89000	87000
Total Cadmium (Cd)	µg/L	ND - 0.19	ND	4.4

Parameters	Units	Water Stations	Produced Water March	Produced Water December
Total Calcium (Ca)	µg/L	370000 - 400000	8000000	7100000
Total Chromium (Cr)	µg/L	ND - 21	ND	320
Total Cobalt (Co)	µg/L	ND	ND	ND
Total Copper (Cu)	µg/L	ND	ND	ND
Total Iron (Fe)	µg/L	ND	ND	ND
Total Lead (Pb)	µg/L	ND	ND	220
Total Magnesium (Mg)	µg/L	1100000 - 1200000	850000	790000
Total Manganese (Mn)	µg/L	ND	270	730
Total Mercury (Hg)	µg/L	0.038 - 0.062	ND	ND
Total Molybdenum (Mo)	µg/L	ND	ND	ND
Total Nickel (Ni)	µg/L	ND	ND	ND
Total Phosphorus (P)	µg/L	N/A	ND	ND
Total Potassium (K)	µg/L	340000 - 370000	380000	360000
Total Selenium (Se)	µg/L	ND	ND	ND
Total Silver (Ag)	µg/L	ND	ND	ND
Total Sodium (Na)	µg/L	9300000 - 10000000	31000000	28000000
Total Strontium (Sr)	µg/L	7300 - 7700	730000	600000
Total Thallium (Tl)	µg/L	ND	14	ND
Total Tin (Sn)	µg/L	ND	ND	ND
Total Titanium (Ti)	µg/L	ND	ND	ND
Total Uranium (U)	µg/L	2.7 - 3.6	ND	ND
Total Vanadium (V)	µg/L	ND	ND	ND
Total Zinc (Zn)	µg/L	ND	ND	590
Polyaromatic Hydrocarbons				
1-Methylnaphthalene	µg/L	ND - 0.083	410 (3)	220 (3)
2-Methylnaphthalene	µg/L	ND - 0.098	470 (3)	300 (3)
Acenaphthene	µg/L	ND	3	2.5
Acenaphthylene	µg/L	ND	4.1	ND (4)
Anthracene	µg/L	ND	ND (4)	ND (4)
Benzo(a)anthracene	µg/L	ND	1	0.073
Benzo(a)pyrene	µg/L	ND	0.014	ND
Benzo(b)fluoranthene	µg/L	ND - 0.012	0.08	0.048
Benzo(g,h,i)perylene	µg/L	ND - 0.012	ND	ND
Benzo(j)fluoranthene	µg/L	ND	0.017	ND
Benzo(k)fluoranthene	µg/L	ND	ND	ND
Chrysene	µg/L	ND	0.93	0.63
Dibenz(a,h)anthracene	µg/L	ND	ND	ND
Fluoranthene	µg/L	ND	2	1.6
Fluorene	µg/L	ND - 0.02	76 (3)	55 (3)
Indeno(1,2,3-cd)pyrene	µg/L	ND	ND	ND
Naphthalene	µg/L	ND	660 (3)	470 (3)
Perylene	µg/L	ND	0.023	ND
Phenanthrene	µg/L	ND - 0.02	48 (3)	38
Pyrene	µg/L	ND	0.97	0.86
Petroleum Hydrocarbons				

Parameters	Units	Water Stations	Produced Water March	Produced Water December
Benzene	mg/L	ND	3.5	3.6
Toluene	mg/L	ND	1.6	1.7
Ethylbenzene	mg/L	ND	0.058	0.069
Total Xylenes	mg/L	ND	0.53	0.57
C6 - C10 (less BTEX)	mg/L	ND	ND	ND
>C10-C16 Hydrocarbons	mg/L	ND	15 (5)	6.5 (5)
>C16-C21 Hydrocarbons	mg/L	ND	7.6	3.3 (5)
>C21-<C32 Hydrocarbons	mg/L	ND	4.5	1.8 (5)
Modified TPH (Tier1)	mg/L	ND	27	12
Reached Baseline at C32	mg/L	N/A	Yes	Yes
Hydrocarbon Resemblance	mg/L	N/A	COMMENT (6)	COMMENT (6)
Alkylphenols				
4-Nonylphenols	ng/L	ND	ND	ND
4-Nonylphenols monoethoxylates	ng/L	ND	ND	ND
4-Nonylphenols diethoxylates	ng/L	ND	ND	ND
Octylphenol	ng/L	ND	146	ND

1 - Elevated RDL due to sample matrix
2- Elevated reporting limit due to sample matrix
3- Elevated PAH RDLs due to sample dilution
4- Elevated PAH RDLs due to matrix/co-extractive interference
5- Elevated TEH RDLs due to limited sample
6- Fuel oil fraction

2.1.6.2 Produced Water Toxicity Test Results

To assess the toxicity of the produced water, a Microtox test and a sea urchin fertilization test were performed on water collected on March 24th 2015 at the PFC by laboratory personnel.

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 5.65% (**Table 2.15).** Complete results can be found in **Appendix B1**.

Table 2.15 - Produced Water Microtox Results

Substance	Data Collected	Date Tested	Species/Test	15 Minute IC50	95% Confidence Limits
Deep Panuke Produced Water	24/03/2015	27/03/2015	Microtox IC50	5.65%	4.80-6.64

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 34.3% produced water, 25% of the eggs were inhibited from being fertilized. Concentrations of 0.02% to 9% showed similar fertilization numbers to the control (78.25% mean fertilization). See **Table 2.16** and **Table 2.17** for a summary of results, and **Appendix B2** for full results. It should be noted that the maximum salinity for this test method is 32‰. The salinity of the 100% sample was 116‰, therefore concentrations of 9%, 30% and 100% produced water exceeded salinity maximums outlined by Environment Canada for this test.

Table 2.16 - Produced Water Sea Urchin Fertilization Results

Effect	Value	95% Confidence Limits	Statistical Method
IC25 (Fertilization)	34.3%	28.0-39.4	Linear Interpolation

Table 2.17 - Produced Water Sea Urchin Fertilization Data

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
Control	A	76	24	76	78.25	3.30
	B	75	25	75		
	C	82	18	82		

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
	D	80	20	80		
Blank	A	100	100	0	0.25	0.50
	B	99	99	1		
	C	100	100	0		
	D	100	100	0		
0.02	A	-	-	-	-	
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.07	A	-	-	-	-	
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.24	A	-	-	-	-	
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.81	A	79	21	79	80.25	2.22
	B	81	19	81		
	C	83	17	83		
	D	78	22	78		
2.7	A	73	27	73	79.5	4.51
	B	83	17	83		
	C	82	18	82		
	D	80	20	80		
9	A	76	24	76	70.25	7.32
	B	60	40	60		
	C	70	30	70		
	D	75	25	75		
30	A	64	36	64	66	7.70
	B	56	44	56		
	C	73	27	73		
	D	71	29	71		
100	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		

2.1.6.3 Cloudy Water Toxicity Test Results

To assess the toxicity of the cloudy water (slightly milky/cloudy patches that were regularly observed on the water surface near the PFC between January and April 2015), a Microtox test and a sea urchin fertilization test were performed on cloudy water collected on March 7th 2015 by the Atlantic Condor.

2.1.6.3.1 Microtox Toxicity Results

The Microtox IC50 for cloudy water was <90%, meaning that over 90% concentration (100%), less than 50% of the luminescence from the bacteria was inhibited. See **Table 2.18** for final results, and **Appendix B3** for full lab results.

Table 2.18 - Cloudy Water Microtox Results

Substance	Data Collected	Date Tested	Species/Test	15 Minute IC50	95% Confidence Limits
Deep Panuke Cloudy Water Discharge	07/03/2015	10/03/2015	Microtox IC50	>90%	-

2.1.6.3.1 Sea Urchin Fertilization Toxicity Results

The IC25 for cloudy water in the sea urchin fertilization test was >100%, meaning fertilization was not inhibited up to 25%.Concentrations of 0.81% to 100% of cloudy water discharge had slightly increased rates of fertilization compared to the control (92.95% mean fertilization). The salinity of the 100% sample was 35‰, which exceeded the guidelines for the test by Environment Canada, which are 32‰. Therefore, the 100% cloudy water sample exceeded the salinity maximum. See **Table 2.19, Table 2.20** and **Appendix B4** for full results.

Table 2.19 - Cloudy Water Sea Urchin Fertilization Results

Effect	Value	95% Confidence Limits	Statistical Method
IC25 (Fertilization)	>100%	-	-

Table 2.20 - Cloudy Water Sea Urchin Fertilization Data

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
Control	A	90	10	90	92.95	2.22
	B	93	7	93		
	C	95	5	95		

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
	D	91	9	91		
Blank	A	2	98	2	0.5	1.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
0.02	A	-	-	-	-	
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.07	A	-	-	-	-	
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.24	A	-	-	-	-	
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.81	A	95	5	95	94.5	0.58
	B	94	6	94		
	C	94	6	94		
	D	95	5	95		
2.7	A	96	4	96	94.75	0.96
	B	94	6	94		
	C	94	6	94		
	D	95	5	95		
9	A	97	3	97	95.75	0.96
	B	95	5	95		
	C	96	4	96		
	D	95	5	95		
30	A	95	5	95	95.5	1.29
	B	97	3	97		
	C	94	6	94		
	D	96	4	96		
100	A	96	4	96	95.25	0.96
	B	95	5	95		
	C	94	6	94		
	D	96	4	96		

2.1.6.4 Summary and Conclusions

2.1.7 Summary and Conclusions

These data sets represent produced water levels measured while the PFC was operational;

March 2015 Chemistry:

- Except for elevated naphthalene (PAH) levels of 660 µg/L (CCME guideline threshold 1.4 µg/L), benzene levels of 3.5 mg/L (CCME Guideline threshold 0.11 mg/L), ethylbenzene levels of 0.058mg/L (CCME guideline threshold 0.025 mg/L) and toluene levels of 1.6 mg/L (CCME Guideline threshold 0.215 mg/L), metal, non-metal, hydrocarbon and nutrient concentrations in the produced water were all found to fall below threshold levels as defined by the Canadian EQG (CCME Guidelines) where available.
- Octylphenol was the only AP that was detected, at the level of 146ng/L.

December 2015 Chemistry:

- Napthalene was found at a level of 470 µg/L, benzene at 3.6 mg/L, toluene at 1.7 mg/L, and ethylbenzene at the level of 0.069 mg/L, which are all above the CCME water guideline mentioned in the previous paragraph.
- Cadmium was detected at a level of 4.4 µg/L, which is above the CCME guideline of 0.12 µg/L. Chromium was also detected above the CCME guidelines (Hex - 1.5 µg/L, Tri - 56 µg/L) at 320 µg/L. It should be noted that these guidelines are not for outfalls, but are for water quality.
- No APs tested for were detected.

March 2015 Produced Water Toxicity:

- The IC50 for Microtox test was 5.65%.
- The IC25 for the sea urchin fertilization test was 34.3%.

March 2015 Cloudy Water Toxicity:

- The IC50 for the Microtox test was >90% (non-toxic).
- The IC25 for the sea urchin fertilization test was >100% (non-toxic).

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 2.21** below (Table 8.18 from the 2006 Deep Panuke EA).

Table 2.21 – 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 will go down the seawater discharge caisson located in the PFC SE leg and be 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 addition, 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 2.22**). 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 2.22– 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

- To validate 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**] and updated 2015 produced water dispersion modeling.

2.2.3 Objectives

- Analyze 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; and

- Analyze 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 25, 2015 for chemical characterization, at 7 stations. See **Table 2.23** below and **Appendix C** (Daily Progress Reports (DPRs) for details.

Table 2.23 – Marine Water Sampling Details - March

<table>
<tr><td>Survey Date:</td><td>March 25, 2015</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>11:11</td><td>42m</td><td>685199</td><td>4855478</td></tr>
<tr><td>2</td><td>250m US</td><td>13:30</td><td>47m</td><td>686131</td><td>4853799</td></tr>
<tr><td>3</td><td>PFC (20m)</td><td>15:50</td><td>47m</td><td>685842</td><td>4853701</td></tr>
<tr><td>4</td><td>250m DS</td><td>16:38</td><td>49m</td><td>685795</td><td>4853947</td></tr>
<tr><td>5</td><td>500m DS</td><td>17:50</td><td>48m</td><td>686150</td><td>4854095</td></tr>
<tr><td>6</td><td>1000m DS</td><td>19:00</td><td>48m</td><td>686916</td><td>4853661</td></tr>
<tr><td>7</td><td>2000m DS</td><td>20:00</td><td>38m</td><td>687356</td><td>4852283</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 Appendix D. 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>
</table>

<table>
<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 for parameters summarized in **Table 2.24.** 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 be 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 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. To calculate H_2S, pH, conductivity and temperature measurements recorded during sampling at the PFC were used.

2.2.5.1 Parameters Analyzed

Table 2.24 - 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
Nitrogen (Ammonia)	mg/L	0.25	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	100	N/A	IC
Acetic Acid	mg/L	200	N/A	IC
Propionic Acid	mg/L	200	N/A	IC
Butyric Acid	mg/L	400	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	10000	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
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

Parameter	Units	RDL	CEQG Threshold	Analysis Method
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
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				
Nonylphenol (NP)	ng/L	10	0.7	LR GC-MS
4-Nonylphenol monoethoxylate (NP1EO)	ng/L	50	0.7	LR GC-MS
4-Nonylphenol diethoxylate (NP2EO)	ng/L	50	0.7	LR GC-MS
4-n-Octylphenol (OP)	ng/L	50	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

2.2.5.2 Analysis QA/QC

- Metals in water: Method Blank, Spike Blank, CRM, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples

- Mercury in water: Method Blank, Spike Blank, CRM, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- PAH: Method Blank, Blank Spike, Duplicate Sample, Matrix Spike: 1 per 20 samples, Surrogate for all samples.
- Ammonia in water: Method Blank, Spike Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- $NO_X/NO_2/NO_3$ in water: Method Blank, Spike Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- Ortho-Phos in water: Method Blank, Spike Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- Total Phosphorous in water: Method Blank, Spike Blank, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- Organic acids in water: Method Blank, Spiked Blank, Matrix Spike, Duplicate Sample - minimum one each per batch, minimum frequency of 1 every 20 samples.
- Sulphides in water: Spiked Blank, Matrix Spike, Method Blank, Sample Duplicate- Minimum one each per batch, minimum frequency of 1 every 20 samples.
- Alkylated Phenols in water: Blank Spike, Continuous Calibration Blank, OPR (On-going Precision and Recovery) Samples, Duplicate Sample, - minimum one each per batch, minimum frequency of 1 every 20 samples
- TPH in soil and water - BTEX/C6-C10 - Method Blank, Blank Spike, Duplicate Sample, Matrix Spike - 1 in 20 - Surrogate for all samples C10-C32 - Method Blank, Blank Spike, Duplicate Sample, Matrix Spike - 1 in 20.
- PAH in soil and water - Method Blank, Blank Spike, Duplicate Sample, Matrix Spike - 1 in 20. Surrogate for all samples.

2.2.6 Results

2.2.6.1 Marine Water Chemical Characterization

- 2015 Maxxam Marine Water Quality data is included in **Digital Appendix B1;**
- 2015 CTD Data is presented in **Digital Appendix B2** and **Figure 2.2a-g** 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 2.25 and Figure 2.3.** 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 listed in **Table 2.25** to **Table 2.31 and Figure 2.4**;
- Boron, calcium, magnesium, mercury, potassium, sodium, strontium, sulphur and uranium were found at all water stations at all depths sampled
- Mercury was found to be above CCME guidelines (0.016 µg/L) at all depths at all stations. Mercury levels ranged from 0.035 µg/L to 0.062 µg/L at stations sampled.
- Cadmium was detected at the 1000 m and 2000 m downstream stations at the surface (0.19 µg/L at 1000 m and 0.12 µg/L at 2000 m) and mid depth (0.18 µg/L at 1000 m and 0.12 µg/L at 2000 m), as well as the bottom depth at the 2000 m upstream station (0.11 µg/L). CCME guidelines for cadmium are 0.12 µg/L, so both the 1000 m and 2000 m downstream station cadmium levels were above guidelines;
- Chromium was detected at the mid-depth at the 2000 m upstream station at a concentration of 21 µg/L;
- Zinc was detected at the 1000 m downstream station at mid depth at concentration of 390 µg/L, which is below the RDL;
- PAH, Total Hydrocarbons including BTEX-TPH were below or slightly above laboratory RDLs (**Figure 2.5 and Figure 2.6**). Most parameters tested for were not detected. Benzo(b)fluoranthene and benzo(g, h, i)perylene were detected at concentrations of 0.012 µg/L (slightly above RDL) at the surface at station 2000 m upstream. 1-methylnapthalene and 2-methylnathalene were both detected at a concentration of 0.083 µg/L (below RDL) at the bottom at the 20 m downstream station. Phenanthrene and fluorene were both found at concentrations of 0.020 µg/L (below RDL) at the bottom of station 20 m downstream.
- No alkylated phenols tested for (4-Nonylphenols, 4-Nonylphenol monoethoxylates, 4-Nonylphenol diethoxylates, and Octylphenol) were detected at any water station or depth sampled. This is similar to the 2011 results, except

for 5.35ng/L of 4-Nonylphenols found at the bottom depth of the 2000 m downstream station in 2011.

- Notable differences between 2011 (before production) and 2015 are:
    - presence/increase of nutrients (nitrates and orthophosphate) in 2015
    - absence of aluminum and chromium in 2015
    - absence of thallium in the bottom depth samples in 2015
    - absence of toluene and TPHs in 2015
    - presence of cadmium and mercury in 2015
    - presence of the PAH benzo(b)fluoranthene and benzo(g, h, i)perylene at the 2000 m upstream station in 2015
    - presence of 1-methylnapthalene, 2-methylnaphalene, fluorene and pthenathrene at the 20 m downstream station in 2015.

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 both rounds of produced water testing is available in **Table 2.14**.

- The following parameters were detected in produced water samples from March or December, but were not found at detectable levels at all water stations and all sampling depths (March sampling):
    - sulphide
    - aluminum (December only)
    - barium
    - lead (December only)
    - manganese
    - thallium (March only)
    - zinc (December only)
    - acenaphthene
    - acenaphthylene (March only)
    - benzo(a)anthracene
    - benzo(a)pyrene (March only)
    - benzo(j)fluoranthene (March only)
    - chrysene

  - fluoranthene
  - indeno(1,2,3-cd)pyrene
  - naphthalene
  - perylene
  - pyrene
  - benzene
  - toluene
  - ethylbenzene
  - Total Xylenes
  - >C10-C16 Hydrocarbons
  - >C16-C21 Hydrocarbons
  - >C21-<C32 Hydrocarbons
  - Modified TPH (Tier1)
  - octylphenol (March only)

- Nitrate, nitrate + nitrite, mercury, uranium and benzo(g,h,i)perylene were found in one or more water samples, but not in either produced water sample.
- Sulphide was not detected at any water station sampled and was detected at levels of 0.63 mg/L and 1.5 mg/L in the produced water from March and December, respectively.
- Cadmium and chromium, which were found at in water quality samples in March, were not found in the March produced water, but were found in the samples from December.
- 1-methylnaphthalene and 2-methylnaphthalene were only found at the bottom sample at the 20 m downstream station and not detectable at all other stations.
- Benzo(b)fluoranthene was only found at the 2000 m upstream surface stations at a level of 0.012 μg/L. All other stations were had non-detectable levels. Produced water samples in March were 0.08 μg/L and (0.048 μg/L in December).
- Fluorene was only detected at the bottom sample of the 20 m downstream station at a level of 0.02 μg/L. Produced water samples had levels of 76

μg/L and 55 μg/L in March and December, respectively, giving a dilution ratio of 3800:1. Fluorene was not detected at all other stations.

- Phenanthrene was only detected at the bottom sample of the 20 m downstream station at a level of 0.02 μg/L. Produced water samples had levels of 48 μg/L and 38 μg/L in March and December, respectively, giving a dilution ratio of 2400:1. Phenanthrene was not detected at all other stations.

2.2.6.3 CTD

- Water quality sampling was conducted on March 25th, 2015, at 7 stations: 2000 m, 1000 m, 500 m, 250 m, and 20 m downstream, and 2000 m and 250 m upstream of the PFC. Graphs for temperature, pH, salinity and dissolved oxygen can be seen in **Figure 2.2a-g**.
- 2000 m upstream: Temperature was consistent throughout the water column, and varied slightly from 1.58 °C at the surface to 1.56 °C. PH ranged from 7.90 to 7.94, and slightly increased with depth. Salinity ranged from 32.01 PSU at the surface, and increased with depth to 32.07 PSU. Dissolved oxygen increased with depth and ranged from 84.88% to 88.10%.
- 250 m upstream: Temperature was consistent, and ranged from 1.57 °C at the surface and decreased slightly with depth to 1.51 °C. PH had a range from 7.95 to 7.98. Salinity did not vary greatly and ranged from 31.99 PSU to 32.03 PSU (slightly increasing with depth). Dissolved oxygen ranged from 84.55% and increased with depth to 88.20%.
- 20 m downstream: Temperature and salinity were variable for the first 5 m, but then were consistent values from 5m to the bottom. Temperature was 1.67 °C at the surface, and was consistent at 1.50 °C to 1.55 °C from 5 m to the bottom. Salinity ranged from 31.99 PSU to 32.05 PSU, slightly increasing with depth. PH was consistent throughout the water column at 7.9. Dissolved oxygen increased with depth and ranged from 82.3% to 88.1%,
- 250 m downstream: Temperature varied from 1.92 °C to 1.58 °C in the top 15 m of the water column, and then was consistent, ranging from 1.55 °C to 1.58 °C for the rest of the water column. PH was consistent throughout the water column, only varying from 7.91 to 7.92. Salinity was consistent, and varied only slightly

from 31.98 PSU to 32.09 PSU. Dissolved oxygen increased with depth from 85.49% to 87.60%.

- 500 m downstream: Temperature decreased slightly with depth from 1.77 °C at the surface to 1.56 °C at the bottom of the water column. PH increased slightly with depth, from 7.92 to 7.95. Salinity slightly increased with depth, with values between 32.01 PSU and 32.09 PSU. Dissolved oxygen from 86.00% to 88.30% with depth.
- 1000 m downstream: Temperature was 1.82 °C at the surface and deceased with depth to 1.54 °C. PH was consistent, ranging from 7.93 to 7.94. Salinity increased slightly with depth from 32.03 PSU at the surface, to 32.10 PSU at the lowest depth. Dissolved oxygen concentration increased with depth, from 83.09% at the surface to 88.06 %.
- 2000 m downstream: Temperature was 1.80 °C at the surface, and decreased with depth to 1.55 °C. PH was consistent, with all values between 7.92 and 7.93 throughout the water column. Salinity slightly increased with depth from 32.05 PSU at the surface to 32.10 PSU at the bottom. Dissolved oxygen increased with depth, from 79.57% at the surface to 87.97%.

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, and mercury, which was above CCME guidelines at all stations and depths sampled.
- Any PAH, Total Hydrocarbons including BTEX-TPH detected were below or slightly above laboratory RDLs.
- No alkylated phenols test for were detected at any depths sampled at any of the water quality sampling stations.

2.2.7.2 Comparison of Produced Water to Marine Water Quality Sampling Stations:

- Dispersion rates for the hydrocarbons detected in produced water and water samples appear to be within the levels predicted by the model (2006 and 2015 re-modeling).
- Sulphide was not detected at any water sample from any of the 7 stations.

2.2.7.3 CTD summary:

- Temperature was similar across all stations sampled and ranged between 1.5 °C and 2.0 °C. At each station the temperature was warmer at the surface and gradually decreased with depth. More variability in temperature was seen at the 20 m downstream and 250 m downstream stations for the first 5 m and 15 m respectively.
- PH was consistent across all stations and depths, and had a narrow range of 7.9 to 8.0.
- Salinity followed similar trends across stations sampled, and increased slightly with depth. Salinity values were similar at stations sampled, and ranged from 31.98 PSU to 32.10 PSU.
- Dissolved oxygen increased with depth at all stations, and ranged from 79% to 89%.

Table 2.25 – Marine Water Quality for all Sampled Depths at all Stations: Nutrients, Major Ions and Organic Acids

Calculated Parameters (mg/L)	Station 2000m Upstream Surface 2011	Station 2000m Upstream Surface 2015	Station 250m Upstream Surface 2011	Station 250m Upstream Surface 2015	Station 20m Downstream Surface 2011	Station 20m Downstream Surface 2015	Station 250m Downstream Surface 2011	Station 250m Downstream Surface 2015	Station 500m Downstream Surface 2011	Station 500m Downstream Surface 2015	Station 1000m Downstream Surface 2011	Station 1000m Downstream Surface 2015	Station 2000m Downstream Surface 2011	Station 2000m Downstream Surface 2015
Nutrients														
Nitrate + Nitrite	ND	0.13	ND	0.12	ND	0.12	ND	0.13	ND	0.11	ND	0.11	ND	0.14
Nitrate (N)	ND	0.12	ND	0.11	ND	0.12	ND	0.13	ND	0.1	ND	0.097	ND	0.13
Nitrite (N)	ND	0.012	ND	0.01	ND	ND	ND	ND	ND	0.011	ND	0.017	ND	0.01
Nitrogen (Ammonia)	ND	0.097	0.08	0.29	0.19	2.2	0.05	0.63	0.08	ND	ND	0.46	ND	ND
Orthophosphate (P)	0.01	0.026	0.01	0.023	0.01	0.023	0.01	0.022	0.01	0.024	0.01	0.023	0.01	0.025
Major Ions														
Phosphorus	ND	0.031	0.02	0.029	0.02	0.03	0.02	0.027	ND	0.034	ND	0.033	ND	0.031
Sulphide	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
Acetic Acid	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
Butyric Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calculated Parameters (mg/L)	**Station 2000m Upstream Middle 2011**	**Station 2000m Upstream Middle 2015**	**Station 250m Upstream Middle 2011**	**Station 250m Upstream Middle 2015**	**Station 20m Downstream Middle 2011**	**Station 20m Downstream Middle 2015**	**Station 250m Downstream Middle 2011**	**Station 250m Downstream Middle 2015**	**Station 500m Downstream Middle 2011**	**Station 500m Downstream Middle 2015**	**Station 1000m Downstream Middle 2011**	**Station 1000m Downstream Middle 2015**	**Station 2000m Downstream Middle 2011**	**Station 2000m Downstream Middle 2015**
Nutrients														
Nitrate + Nitrite	ND	0.13	ND	0.11	ND	0.14	ND	0.11	ND	0.14	ND	0.12	ND	0.12
Nitrate (N)	ND	0.12	ND	0.099	ND	0.14	ND	0.097	ND	0.13	ND	0.11	ND	0.12
Nitrite (N)	ND	0.012	ND	0.013	ND	ND	ND	0.012	ND	0.01	ND	0.01	ND	ND
Nitrogen (Ammonia)	ND	0.36	0.12	ND	ND	ND	ND	0.31	ND	0.06	ND	0.49	0.05	0.39
Orthophosphate (P)	0.01	0.024	0.01	0.025	0.01	0.022	0.01	0.023	0.01	0.024	0.01	0.026	0.01	0.023
Major Ions														
Phosphorus	ND	0.031	ND	0.029	0.02	0.03	0.02	0.03	ND	0.031	0.02	0.032	ND	0.031
Sulphide	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
Acetic Acid	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
Butyric Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Calculated Parameters (mg/L)	Station 2000m Upstream Bottom 2011	Station 2000m Upstream Bottom 2015	Station 250m Upstream Bottom 2011	Station 250m Upstream Bottom 2015	Station 20m Downstream Bottom 2011	Station 20m Downstream Bottom 2015	Station 250m Downstream Bottom 2011	Station 250m Downstream Bottom 2015	Station 500m Downstream Bottom 2011	Station 500m Downstream Bottom 2015	Station 1000m Downstream Bottom 2011	Station 1000m Downstream Bottom 2015	Station 2000m Downstream Bottom 2011	Station 2000m Downstream Bottom 2015
Nutrients														
Nitrate + Nitrite	ND	0.13	ND	0.12	ND	0.12	ND	0.28	ND	0.12	ND	0.12	ND	0.12
Nitrate (N)	ND	0.12	ND	0.11	ND	0.12	ND	0.26	ND	0.11	ND	0.11	ND	0.12
Nitrite (N)	ND	0.01	ND	0.012	ND	ND	ND	0.01	ND	0.011	ND	0.01	ND	ND
Nitrogen (Ammonia)	0.01	ND	0.05	ND	0.05	1	0.06	ND	ND	0.21	ND	0.22	ND	ND
Orthophosphate (P)	ND	0.025	0.01	0.024	0.01	0.023	0.01	0.025	0.01	0.024	0.01	0.024	0.01	0.024
Major ions														
Phosphorus	ND	0.029	0.02	0.029	0.02	0.031	0.02	0.03	ND	0.028	0.03	0.028	ND	0.029
Sulphide	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
Acetic Acid	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
Butyric Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND – Not detectable

Table 2.26 - Marine Water Quality for Surface Samples at all Stations: Trace Metals

Metals (µg/L)	Station 2000m Upstream Surface 2011	Station 2000m Upstream Surface 2015	Station 250m Upstream Surface 2011	Station 250m Upstream Surface 2015	Station 20m Downstream Surface 2011	Station 20m Downstream Surface 2015	Station 250m Downstream Surface 2011	Station 250m Downstream Surface	Station 500m Downstream Surface 2011	Station 500m Downstream Surface 2015	Station 1000m Downstream Surface 2011	Station 1000m Downstream Surface 2015	Station 2000m Downstream Surface 2011	Station 2000m Downstream Surface 2015
ICP/MS Method														
Total Aluminum (Al)	ND	ND	ND	ND	ND	ND	318	ND	105	ND	ND	ND	ND	ND
Total Antimony (Sb)	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
Total Barium (Ba)	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
Total Bismuth (Bi)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Boron (B)	4410	4100	4530	4200	4670	4400	4610	4300	4510	4400	4490	4300	4530	4200
Total Cadmium (Cd)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.19	ND	0.12
Total Calcium (Ca)	363000	390000	363000	400000	375000	380000	380000	370000	372000	390000	365000	390000	371000	390000
Total	ND	ND	ND	ND	ND	ND	39	ND	151	ND	ND	ND	ND	ND

Metals (µg/L)	Station 2000m Upstream Surface 2011	Station 2000m Upstream Surface 2015	Station 250m Upstream Surface 2011	Station 250m Upstream Surface 2015	Station 20m Downstream Surface 2011	Station 20m Downstream Surface 2015	Station 250m Downstream Surface 2011	Station 250m Downstream Surface	Station 500m Downstream Surface 2011	Station 500m Downstream Surface 2015	Station 1000m Downstream Surface 2011	Station 1000m Downstream Surface 2015	Station 2000m Downstream Surface 2011	Station 2000m Downstream Surface 2015
Chromium (Cr)														
Total Cobalt (Co)	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
Total Iron (Fe)	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
Total Magnesium (Mg)	1240000	1100000	1250000	1200000	1290000	1200000	1310000	1200000	1280000	1200000	1260000	1200000	1270000	1200000
Total Manganese (Mn)	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
Total Nickel (Ni)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Phosphorus (P)		ND		ND		ND		ND		ND		ND		ND
Total Potassium (K)	340000	360000	342000	360000	354000	350000	352000	340000	348000	350000	340000	360000	343000	360000
Total Selenium (Se)	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
Total Sodium (Na)	9560000	9300000	9660000	9500000	10100000	9900000	10100000	9700000	10100000	9900000	9520000	9600000	9720000	9700000
Total Strontium (Sr)	6860	7300	6850	7300	7110	7400	7040	7300	7020	7400	6870	7300	6840	7300
Total Thallium (Tl)	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
Total Titanium (Ti)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Uranium (U)	3.0	3.3	2.8	3.5	3.1	2.8	3.3	3.1	2.7	3.1	3.0	3.2	2.7	3.2
Total Vanadium (V)	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
Cold Vapour AA Method														
Total Mercury (Hg)	ND	0.057	ND	0.058	ND	0.035	ND	0.053	ND	0.062	ND	0.062	ND	0.055

ND – Not detectable

Table 2.27 - Marine Water Quality for Mid-Water Column Samples at all Stations: Trace Metals

Metals (µg/L)	Station 2000m Upstream Middle 2011	Station 2000m Upstream Middle 2015	Station 250m Upstream Middle 2011	Station 250m Upstream Middle 2015	Station 20m Downstream Middle 2011	Station 20m Downstream Middle 2015	Station 250m Downstream Middle 2011	Station 250m Downstream Middle 2015	Station 500m Downstream Middle 2011	Station 500m Downstream Middle 2015	Station 1000m Downstream Middle 2011	Station 1000m Downstream Middle 2015	Station 2000m Downstream Middle 2011	Station 2000m Downstream Middle 2015
ICP/MS Method														
Total Aluminum (Al)	66	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
Total Arsenic (As)	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
Total Beryllium (Be)	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
Total Boron (B)	4660	4200	4750	4200	4650	4300	4710	4300	4780	4400	4790	4300	4820	4200
Total Cadmium (Cd)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.18	ND	0.12
Total Calcium (Ca)	375000	400000	3820000	390000	3750000	380000	3860000	380000	3880000	380000	3850000	390000	3910000	390000
Total Chromium (Cr)	ND	21	84	ND	313	ND	ND	ND	ND	ND	ND	ND	38	ND
Total Cobalt (Co)	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
Total Iron (Fe)	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
Total Magnesium (Mg)	1190000	1200000	1230000	1200000	1200000	1200000	1240000	1200000	1220000	1200000	1230000	1200000	1250000	1200000
Total Manganese (Mn)	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
Total Nickel (Ni)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Potassium (K)	354000	360000	358000	360000	356000	350000	363000	350000	365000	350000	361000	360000	369000	360000
Total Selenium (Se)	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
Total Sodium (Na)	10100000	9600000	10300000	9600000	10200000	9800000	10500000	10000000	10500000	9900000	10400000	9600000	10700000	9600000
Total Strontium (Sr)	7020	7600	7020	7500	6900	7400	7110	7600	7220	7500	7080	7400	7230	7400
Total Thallium (Tl)	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
Total Titanium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Metals (µg/L)	Station 2000m Upstream Middle 2011	Station 2000m Upstream Middle 2015	Station 250m Upstream Middle 2011	Station 250m Upstream Middle 2015	Station 20m Downstream Middle 2011	Station 20m Downstream Middle 2015	Station 250m Downstream Middle 2011	Station 250m Downstream Middle 2015	Station 500m Downstream Middle 2011	Station 500m Downstream Middle 2015	Station 1000m Downstream Middle 2011	Station 1000m Downstream Middle 2015	Station 2000m Downstream Middle 2011	Station 2000m Downstream Middle 2015
(Ti)														
Total Uranium (U)	3.1	3.2	2.8	3.6	2.7	2.7	3.0	3	3.1	2.7	3.0	3.2	2.9	3.3
Total Vanadium (V)	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	390	ND	ND
Cold Vapour AA Method														
Total Mercury (Hg)	ND	0.053	ND	0.057	ND	0.038	ND	0.06	ND	0.06	ND	0.058	ND	0.053

ND – Not detectable

Table 2.28 - Marine Water Quality for the Bottom Samples at all stations: Trace Metals

Metals (µg/L)	Station 2000m Upstream Bottom 2011	Station 2000m Upstream Bottom 2015	Station 250m Upstream Bottom 2011	Station 250m Upstream Bottom 2015	Station 20m Downstream Bottom 2011	Station 20m Downstream Bottom 2015	Station 250m Downstream Bottom 2011	Station 250m Downstream Bottom 2015	Station 500m Downstream Bottom 2011	Station 500m Downstream Bottom 2015	Station 1000m Downstream Bottom 2011	Station 1000m Downstream Bottom 2015	Station 2000m Downstream Bottom 2011	Station 2000m Downstream Bottom 2015
ICP/MS Method														
Total Aluminum (Al)	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
Total Arsenic (As)	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
Total Beryllium (Be)	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
Total Boron (B)	4760	4100	4660	4300	4810	4400	4700	4300	4700	4200	4710	4200	4690	4200
Total Cadmium (Cd)	ND	0.11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Calcium (Ca)	387000	390000	386000	390000	389000	380000	385000	380000	382000	380000	383000	390000	378000	400000
Total Chromium (Cr)	116	ND	194	ND	519	ND	ND	ND	538	ND	ND	ND	ND	ND
Total Cobalt (Co)	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
Total Iron (Fe)	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
Total Magnesium (Mg)	1220000	1100000	1240000	1200000	1240000	1200000	1230000	1200000	1210000	1200000	1240000	1200000	1220000	1200000
Total Manganese (Mn)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Metals (µg/L)	Station 2000m Upstream Bottom 2011	Station 2000m Upstream Bottom 2015	Station 250m Upstream Bottom 2011	Station 250m Upstream Bottom 2015	Station 20m Downstream Bottom 2011	Station 20m Downstream Bottom 2015	Station 250m Downstream Bottom 2011	Station 250m Downstream Bottom 2015	Station 500m Downstream Bottom 2011	Station 500m Downstream Bottom 2015	Station 1000m Downstream Bottom 2011	Station 1000m Downstream Bottom 2015	Station 2000m Downstream Bottom 2011	Station 2000m Downstream Bottom 2015
Total Molybdenum (Mo)	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
Total Potassium (K)	362000	360000	363000	370000	369000	350000	361000	350000	357000	350000	362000	360000	355000	360000
Total Selenium (Se)	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
Total Sodium (Na)	10500000	9400000	10300000	9700000	10600000	10000000	10500000	9800000	10300000	9900000	10400000	9600000	10300000	9600000
Total Strontium (Sr)	7100	7300	6990	7500	7190	7700	7130	7400	7010	7500	7140	7400	7040	7500
Total Thallium (Tl)	979000	ND	966000	ND	989000	ND	969000	ND	948000	ND	960000	ND	943000	ND
Total Tin (Sn)	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
Total Uranium (U)	3.2	3.2	2.8	3.2	2.9	3	2.9	3.1	2.9	3.1	2.8	3.2	2.6	3.3
Total Vanadium (V)	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
Cold Vapour AA Method														
Total Mercury (Hg)	ND	0.057	ND	0.057	ND	0.047	ND	0.057	ND	0.06	ND	0.053	ND	0.053

ND – Not detectable

Table 2.29 - Marine Water Quality for the Surface Samples at all Stations: PAH and Petroleum Hydrocarbon Results

Parameter	Station 2000m Upstream Surface 2011	Station 2000m Upstream Surface 2015	Station 250m Upstream Surface 2011	Station 250m Upstream Surface 2015	Station 20m Downstream Surface 2011	Station 20m Downstream Surface 2015	Station 250m Downstream Surface 2011	Station 250m Downstream Surface 2015	Station 500m Downstream Surface 2011	Station 500m Downstream Surface 2015	Station 1000m Downstream Surface 2011	Station 1000m Downstream Surface 2015	Station 2000m Downstream Surface 2011	Station 2000m Downstream Surface 2015
Polyaromatic Hydrocarbons (µg/L)														
1-Methylnaphthalene	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
Acenaphthene	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
Anthracene	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
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Parameter	Station 2000m Upstream Surface 2011	Station 2000m Upstream Surface 2015	Station 250m Upstream Surface 2011	Station 250m Upstream Surface 2015	Station 20m Downstream Surface 2011	Station 20m Downstream Surface 2015	Station 250m Downstream Surface 2011	Station 250m Downstream Surface 2015	Station 500m Downstream Surface 2011	Station 500m Downstream Surface 2015	Station 1000m Downstream Surface 2011	Station 1000m Downstream Surface 2015	Station 2000m Downstream Surface 2011	Station 2000m Downstream Surface 2015
Benzo(b)fluoranthene	ND	0.012	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
Benzo(j)fluoranthene	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
Chrysene	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
Fluoranthene	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
Indeno(1,2,3-cd)pyrene	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
Perylene	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
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons (mg/L)														
Benzene	ND	ND	0.001	ND	ND	ND	0.001	ND	ND	ND	ND	ND	ND	ND
Toluene	0.004	ND	0.001	ND	0.023	ND	0.001	ND	0.016	ND	0.005	ND	0.016	ND
Ethylbenzene	ND	ND	0.001	ND	ND	ND	0.001	ND	ND	ND	ND	ND	ND	ND
Xylene (Total)	ND	ND	0.002	ND	ND	ND	0.003	ND	ND	ND	ND	ND	ND	ND
C6 - C10 (less BTEX)	ND	ND	0.01	ND	ND	ND	0.01	ND	ND	ND	ND	ND	ND	ND
>C10-C16 Hydrocarbons	ND	ND	0.05	ND	ND	ND	0.05	ND	ND	ND	ND	ND	ND	ND
>C16-C21 Hydrocarbons	ND	ND	0.05	ND	ND	ND	0.05	ND	ND	ND	ND	ND	ND	ND
>C21-<C32 Hydrocarbons	ND	ND	0.1	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	ND
Modified TPH (Tier1)	ND	ND	0.1	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	ND
Reached Baseline at C32	N/A	NA	N/A	N/A	N/A	NA	N/A	N/A	N/A	NA	N/A	NA	N/A	NA
Hydrocarbon Resemblance	NA	NA	N/A	N/A	N/A	NA	N/A	N/A	N/A	NA	N/A	NA	N/A	NA

ND – Not detectable, NA – Not applicable

Table 2.30 - Marine Water Quality for the Mid Water Column Samples at all Stations: PAH Polyaromatic Hydrocarbon Results

Parameter	Station 2000m Upstream Middle 2011	Station 2000m Upstream Middle 2015	Station 250m Upstream Middle 2011	Station 250m Upstream Middle 2015	Station 20m Downstream Middle 2011	Station 20m Downstream Middle 2015	Station 250m Downstream Middle 2011	Station 250m Downstream Middle 2015	Station 500m Downstream Middle 2011	Station 500m Downstream Middle 2015	Station 1000m Downstream Middle 2011	Station 1000m Downstream Middle 2015	Station 2000m Downstream Middle 2011	Station 2000m Downstream Middle 2015
Polyaromatic Hydrocarbons (µg/L)														
1-Methylnaphthalene	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
Acenaphthene	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
Anthracene	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
Benzo(a)pyrene	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
Benzo(g,h,i)perylene	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
Benzo(k)fluoranthene	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
Dibenz(a,h)anthracene	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
Fluorene	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
Naphthalene	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
Phenanthrene	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
Total Petroleum Hydrocarbons (mg/L)														
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	0.009	ND	0.021	ND	0.018	ND	0.009	ND	0.04	ND	0.004	ND	0.038	ND
Ethylbenzene	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
C6 - C10 (less BTEX)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND
>C10-C16 Hydrocarbons	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
>C21-<C32 Hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Parameter	Station 2000m Upstream Middle 2011	Station 2000m Upstream Middle 2015	Station 250m Upstream Middle 2011	Station 250m Upstream Middle 2015	Station 20m Downstream Middle 2011	Station 20m Downstream Middle 2015	Station 250m Downstream Middle 2011	Station 250m Downstream Middle 2015	Station 500m Downstream Middle 2011	Station 500m Downstream Middle 2015	Station 1000m Downstream Middle 2011	Station 1000m Downstream Middle 2015	Station 2000m Downstream Middle 2011	Station 2000m Downstream Middle 2015
Modified TPH (Tier1)	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
Hydrocarbon Resemblance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ND – Not detectable, NA – Not applicable

Table 2.31 - Marine Water Quality for the Bottom Samples at all Stations: PAH Polyaromatic Hydrocarbon Results

Parameter	Station 2000m Upstream Bottom 2011	Station 2000m Upstream Bottom 2015	Station 250m Upstream Bottom 2011	Station 250m Upstream Bottom 2015	Station 20m Downstream Bottom 2011	Station 20m Downstream Bottom 2015	Station 250m Downstream Bottom 2011	Station 250m Downstream Bottom 2015	Station 500m Downstream Bottom 2011	Station 500m Downstream Bottom 2015	Station 1000m Downstream Bottom 2011	Station 1000m Downstream Bottom 2015	Station 2000m Downstream Bottom 2011	Station 2000m Downstream Bottom 2015
Polyaromatic Hydrocarbons (µg/L)														
1-Methylnaphthalene	ND	ND	ND	ND	ND	0.083	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND	ND	ND	0.098	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	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
Anthracene	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
Benzo(a)pyrene	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
Benzo(g,h,i)perylene	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
Benzo(k)fluoranthene	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
Dibenz(a,h)anthracene	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
Fluorene	ND	ND	ND	ND	ND	0.02	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
Naphthalene	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
Phenanthrene	ND	ND	ND	ND	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons (mg/L)														

Parameter	Station 2000m Upstream Bottom 2011	Station 2000m Upstream Bottom 2015	Station 250m Upstream Bottom 2011	Station 250m Upstream Bottom 2015	Station 20m Downstream Bottom 2011	Station 20m Downstream Bottom 2015	Station 250m Downstream Bottom 2011	Station 250m Downstream Bottom 2015	Station 500m Downstream Bottom 2011	Station 500m Downstream Bottom 2015	Station 1000m Downstream Bottom 2011	Station 1000m Downstream Bottom 2015	Station 2000m Downstream Bottom 2011	Station 2000m Downstream Bottom 2015
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	0.014	ND	0.013	ND	0.003	ND	0.002	ND	0.024	ND	0.009	ND	0.012	ND
Ethylbenzene	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
C6 - C10 (less BTEX)	0.01	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
>C16-C21 Hydrocarbons	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
Modified TPH (Tier1)	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
Hydrocarbon Resemblance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

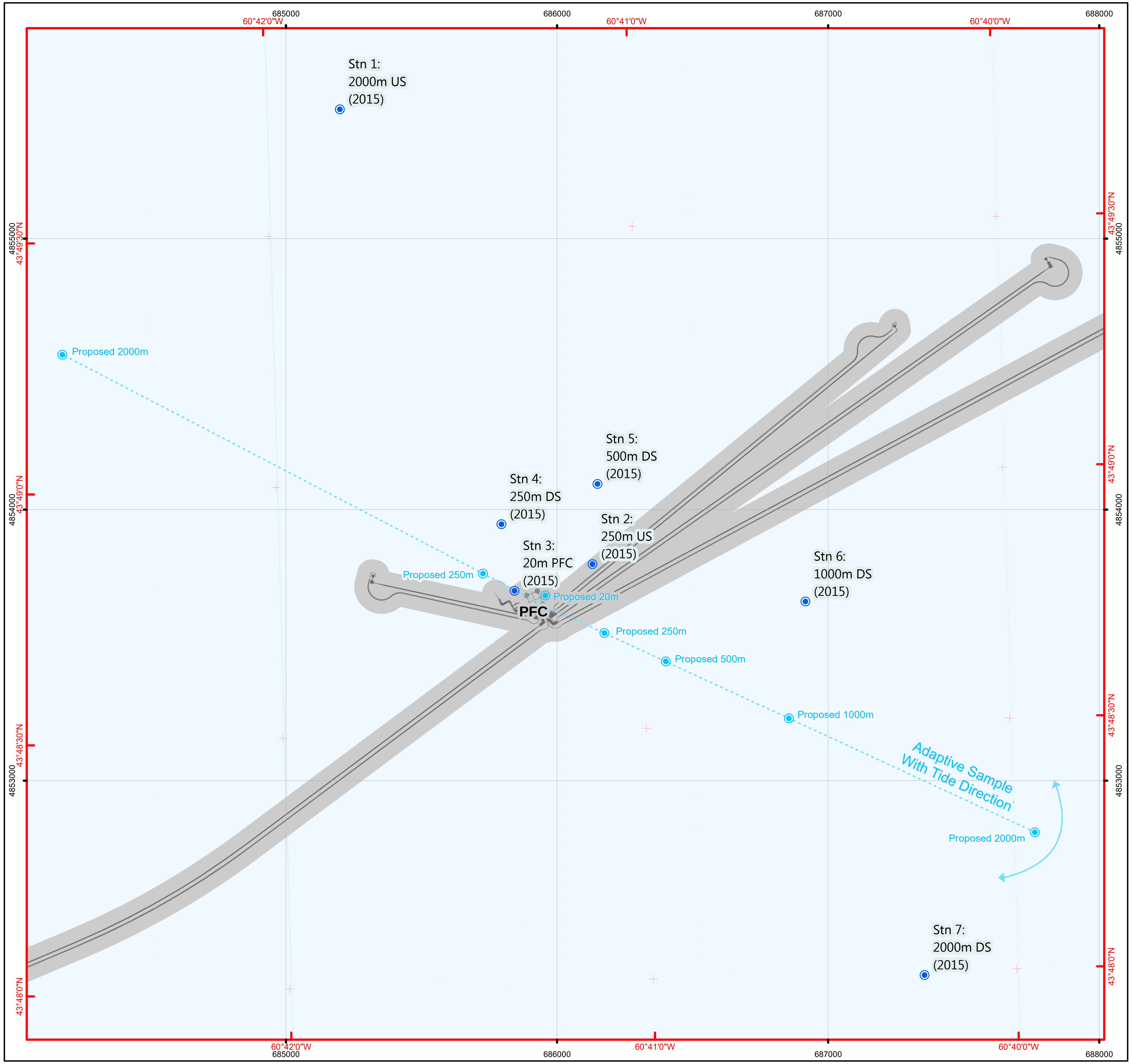
ND – Not detectable, NA – Not applicable

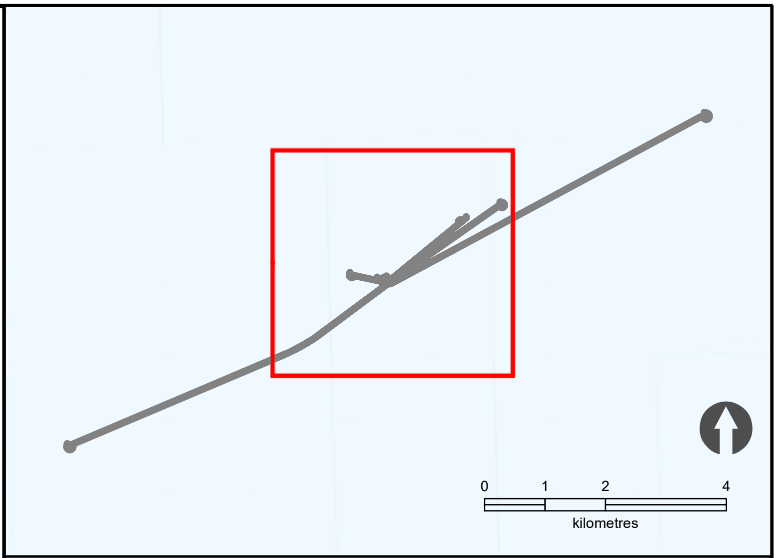
Table 2.32 - Marine Water Quality for all Sampled Depths at all Stations: Alkylated Phenol Results

Alkylated Phenols	Units	2000m Upstream Surface 2011	2000m Upstream Surface 2015	250m Upstream Surface 2011	250m Upstream Surface 2015	20m Dowstream Surface 2011	20m Dowstream Surface 2015	250m Downstream Surface 2011	250m Downstream Surface 2015	500m Downstream Surface 2011	500m Downstream Surface 2015	1000m Downstream Surface 2011	1000m Downstream Surface 2015	2000m Downstream Surface 2011	2000m Downstream Surface 2015
4-Nonylphenols	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nonylphenol monoethoxylates	ng/L	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
Octylphenol	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13C6-4-n-Nonylphenol	% Recovery	95.0	91.0	97.3	80.9	93.0	78.9	94.8	77.1	90.1	89.8	86.4	83.9	92.1	91.0
13C6-NP2EO	% Recovery	106.0	42.0	107.0	41.9	103.0	42.6	32.3	32.9	96.2	50.6	97.3	46.0	91.2	42.0
4-Nonylphenols	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nonylphenol monoethoxylates	ng/L	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

Alkylated Phenols	Units	2000m Upstream Mid Depth 2011	2000m Upstream Mid Depth 2015	250m Upstream Mid Depth 2011	250m Upstream Mid Depth 2015	20m Downstream Mid Depth 2011	20m Downstream Mid Depth 2015	250m Downstream Mid Depth 2011	250m Downstream Mid Depth 2015	500m Downstream Mid Depth 2011	500m Downstream Mid Depth 2015	1000m Downstream Mid Depth 2011	1000m Downstream Mid Depth 2015	2000m Downstream Mid Depth 2011	2000m Downstream Mid Depth 2015
Octylphenol	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13C6-4-n-Nonylphenol	% Recovery	93.4	89.1	88.1	84.1	86.4	76.2	67.4	71.8	58.7	91.2	49.5	88.2	51.9	89.1
13C6-NP2EO	% Recovery	100.0	51.1	95.2	50.1	91.4	33.8	56.8	25.8	65.2	50.6	49.0	47.9	65.0	51.1
Alkylated Phenols	**Units**	**2000m Upstream Bottom 2011**	**2000m Upstream Bottom 2015**	**250m Upstream Bottom 2011**	**250m Upstream Bottom 2015**	**20m Downstream Bottom 2011**	**20m Downstream Bottom 2015**	**250m Downstream Bottom 2011**	**250m Downstream Bottom 2015**	**500m Downstream Bottom 2011**	**500m Downstream Bottom 2015**	**1000m Downstream Bottom 2011**	**1000m Downstream Bottom 2015**	**2000m Downstream Bottom 2011**	**2000m Downstream Bottom 2015**
4-Nonylphenols	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.35	ND
4-Nonylphenol monoethoxylates	ng/L	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
Octylphenol	ng/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13C6-4-n-Nonylphenol	% Recovery	28.7	87.2	41.9	83.9	50.2	71.4	52.2	77.5	34.9	90.4	47.0	85.4	46.5	87.2
13C6-NP2EO	% Recovery	53.3	46.4	67.5	50.5	56.3	32.4	54.2	39.5	50.7	46.2	40.9	39.3	49.1	46.4

ND – Not detectable





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Projection: Transverse Mercator
Datum: WGS 1984
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

0 100 200 300 400 500 1,000
metres

Water Sample
◉ Proposed
◉ Acquired 2015

— Structures
▨ 50m Buffer Zone

Note:
Map scale 1:15,000 when printed on 11x17 size paper

encana natural gas

Encana

2015 Water Sample Locations

Deep Panuke Survey Area

Scotian Shelf

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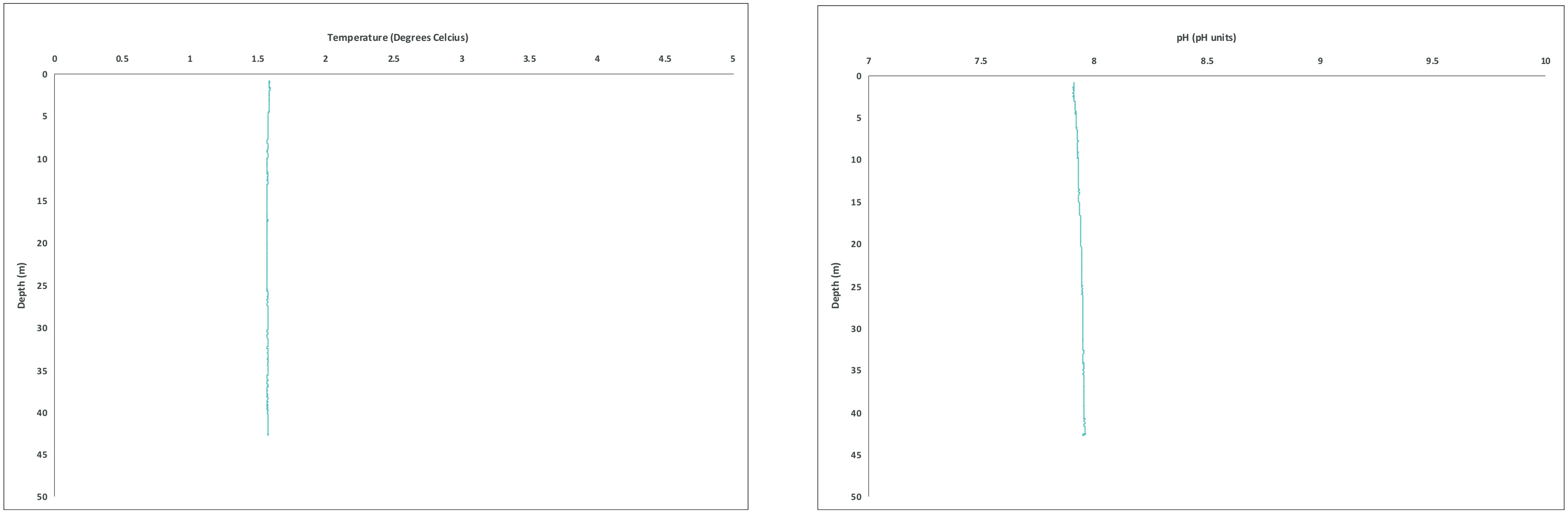
Bedford, Nova Scotia, Canada

Date Saved: 26/01/2016 1:10:29 PM

Figure: 2 - 1

McGregor Project No.:1113

Filename: 1113_ENCANA_water_2016



2000m Upstream

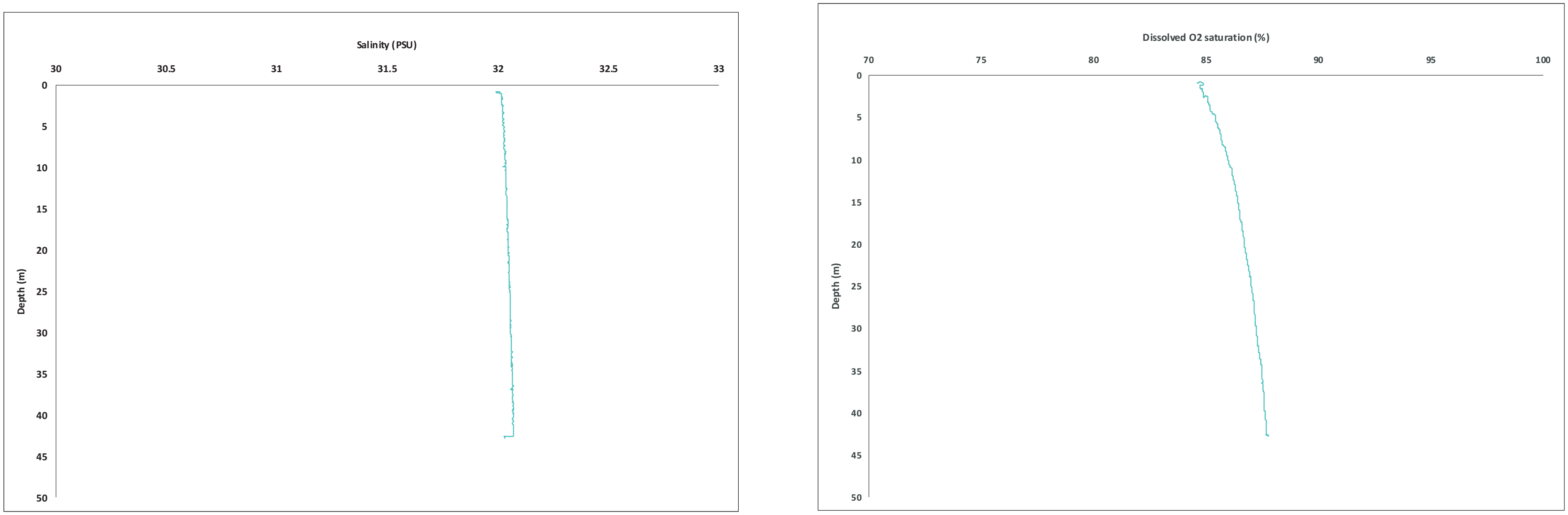


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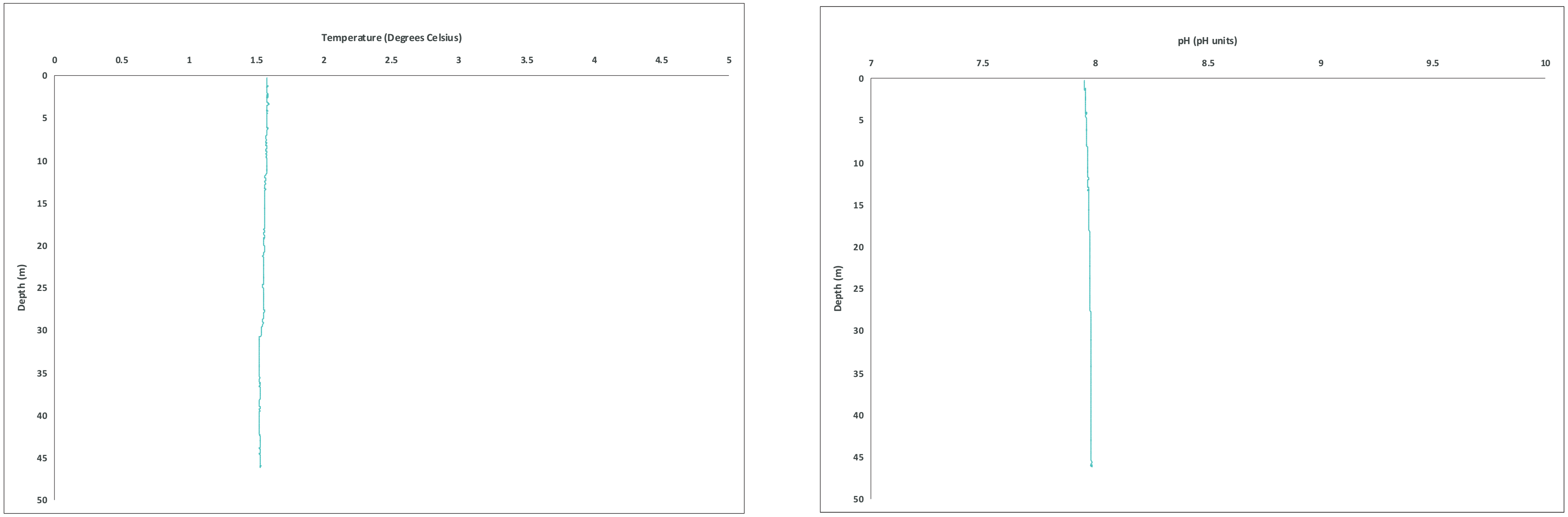
Figure 2.2a Temperature, ph, salinity and dissolved oxygen using a CTD, at the 2000m upstream station in 2015



250m Upstream

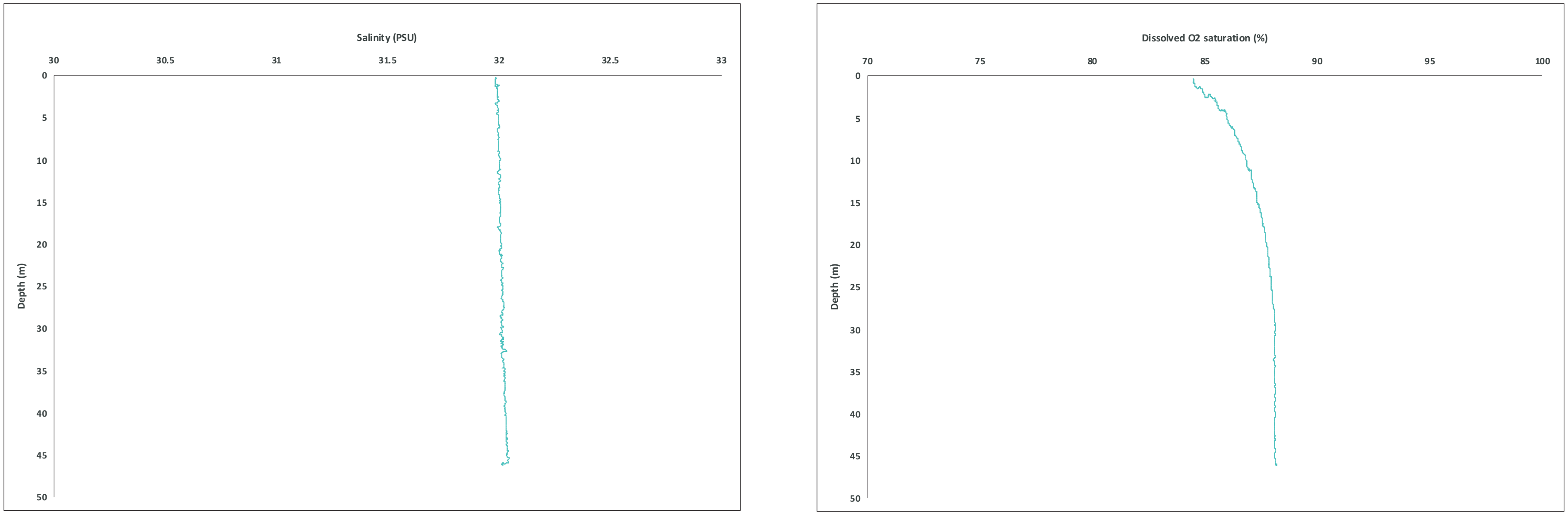


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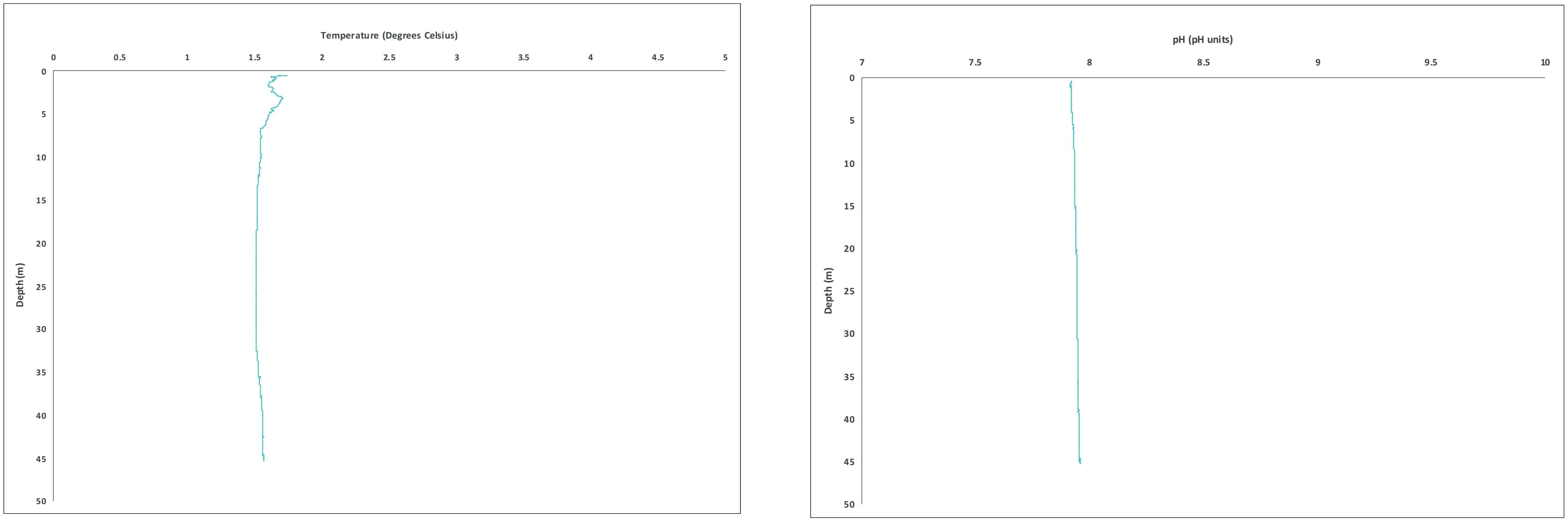
Figure 2.2b Temperature, ph, salinity and dissolved oxygen using a CTD, at the 250m upstream station in 2015

Figure 2.2b



20m Downstream

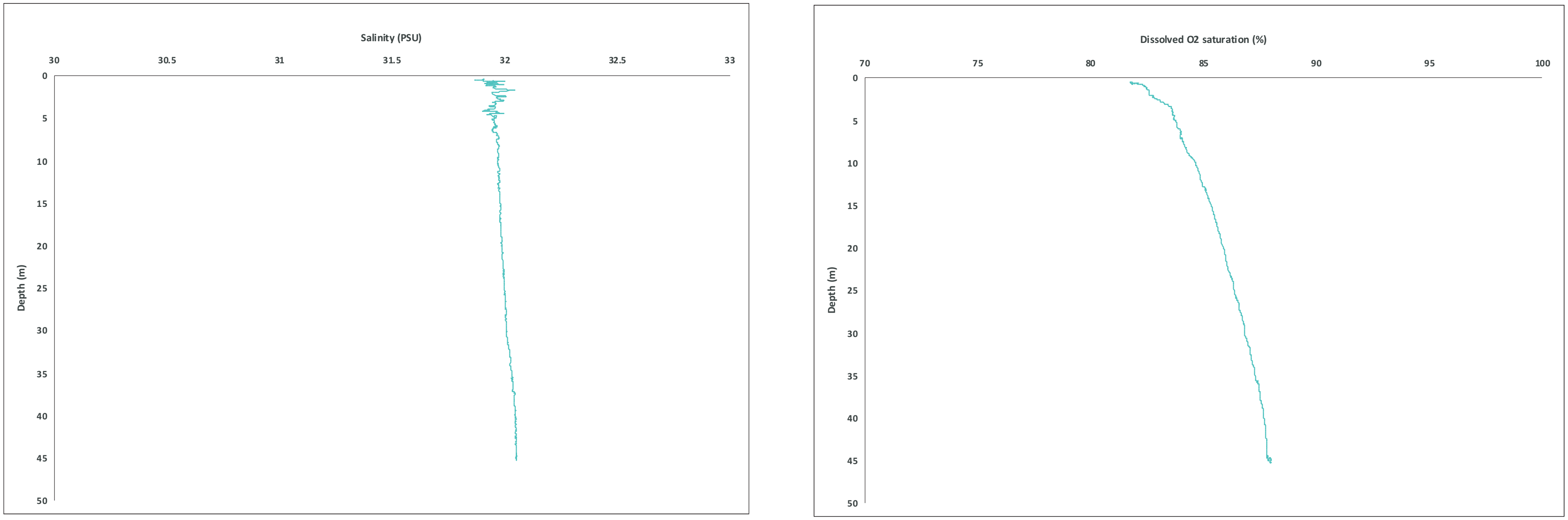


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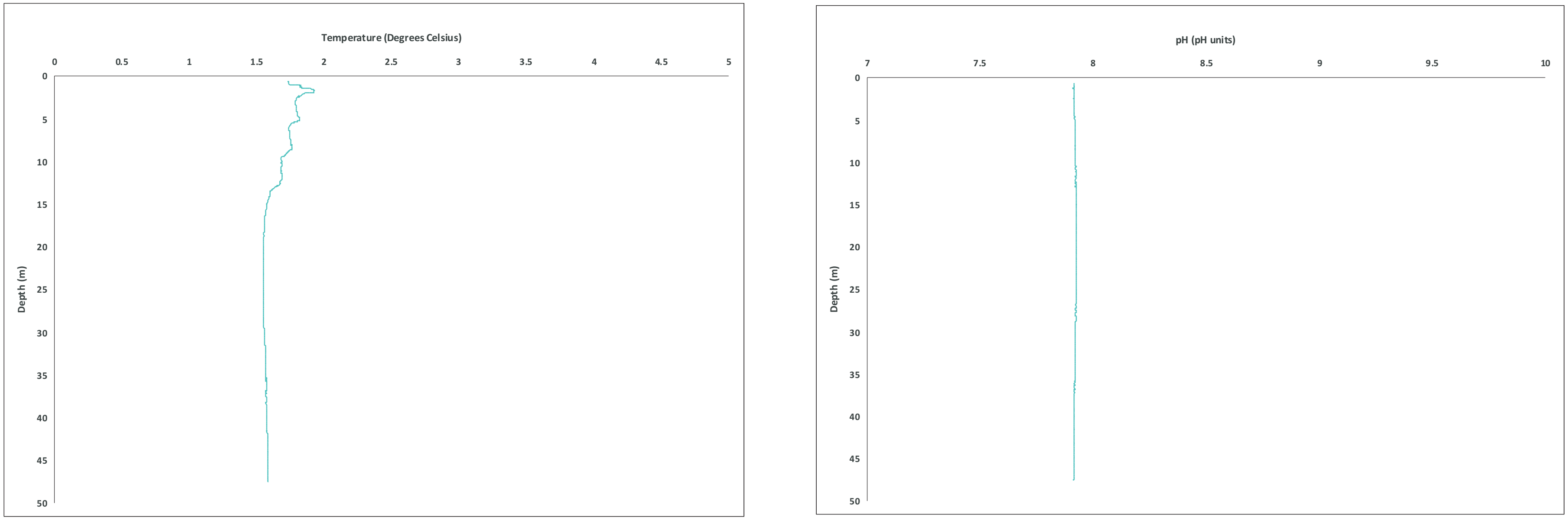
Figure 2.2c Temperature, ph, salinity and dissolved oxygen using a CTD at the 20m downstream station in 2015

Figure 2.2c



250m Downstream

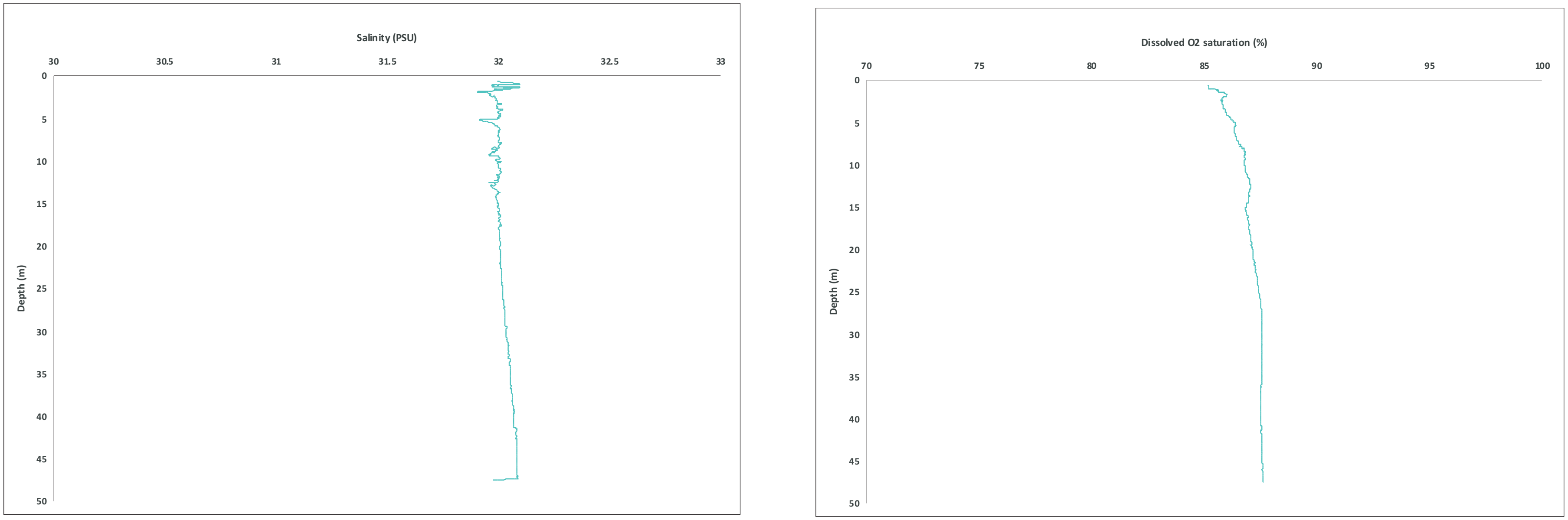


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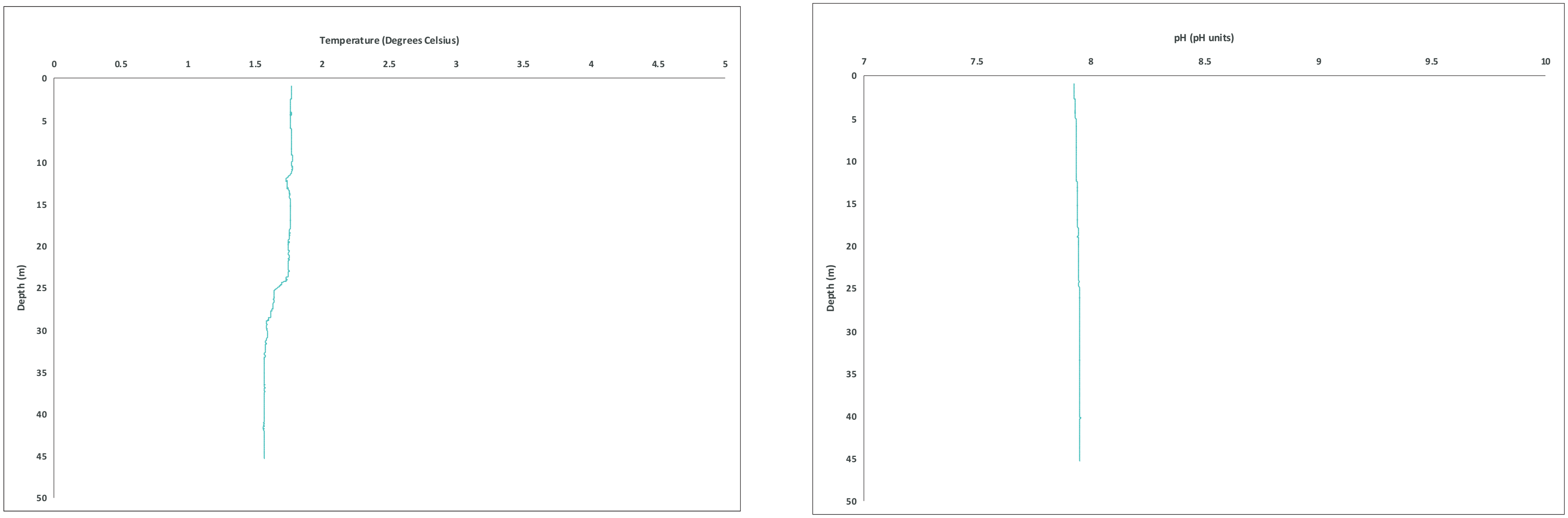
Figure 2.2d Temperature, ph, salinity and dissolved oxygen using a CTD, at the 250m downstream station in 2015 Figure 2.2d



500m Downstream

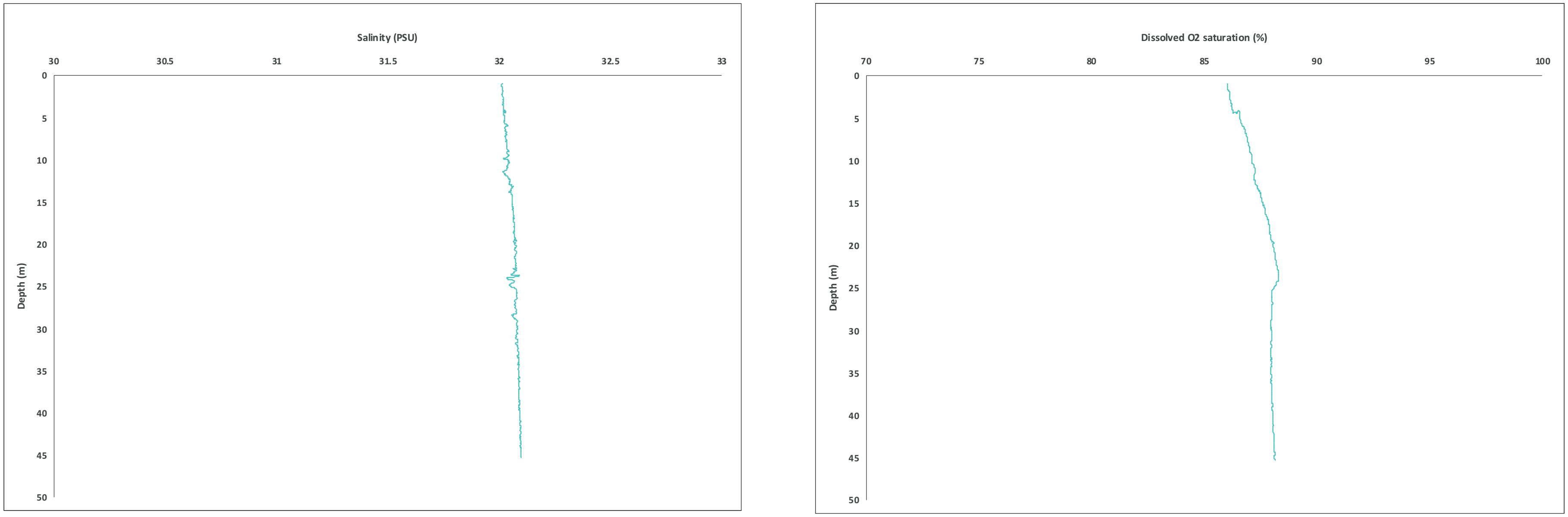


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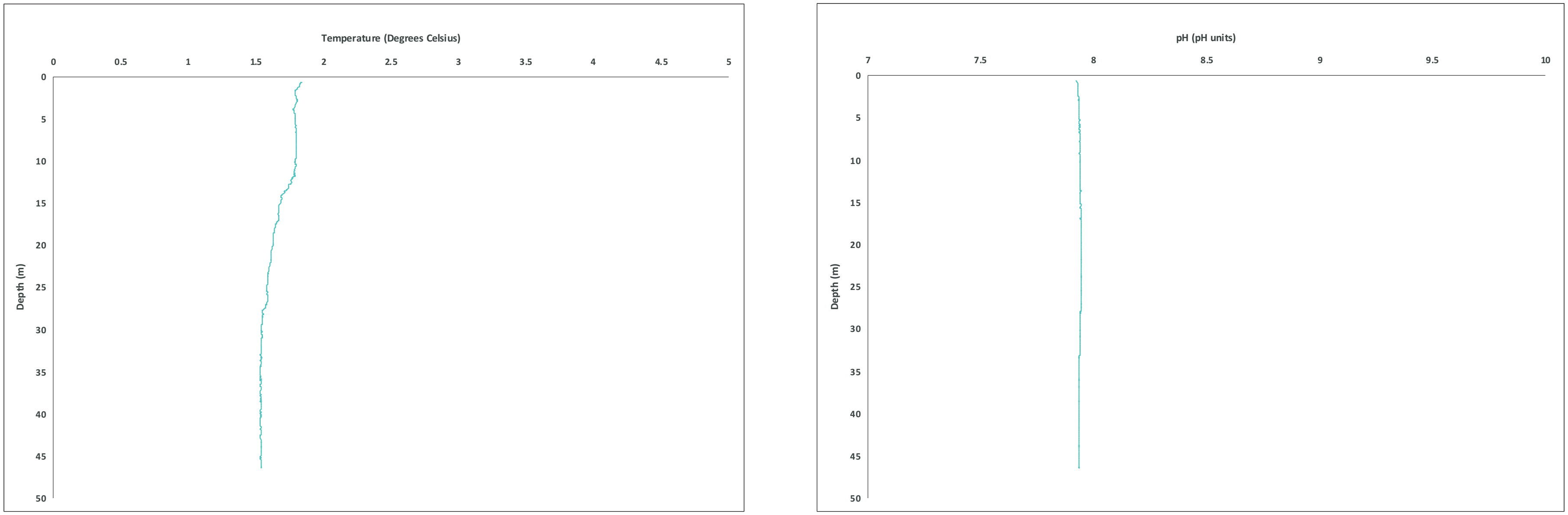
Figure 2.2e Temperature, ph, salinity and dissolved oxygen using a CTD, at the 500m downstream station in 2015 Figure 2.2e



1000m Downstream

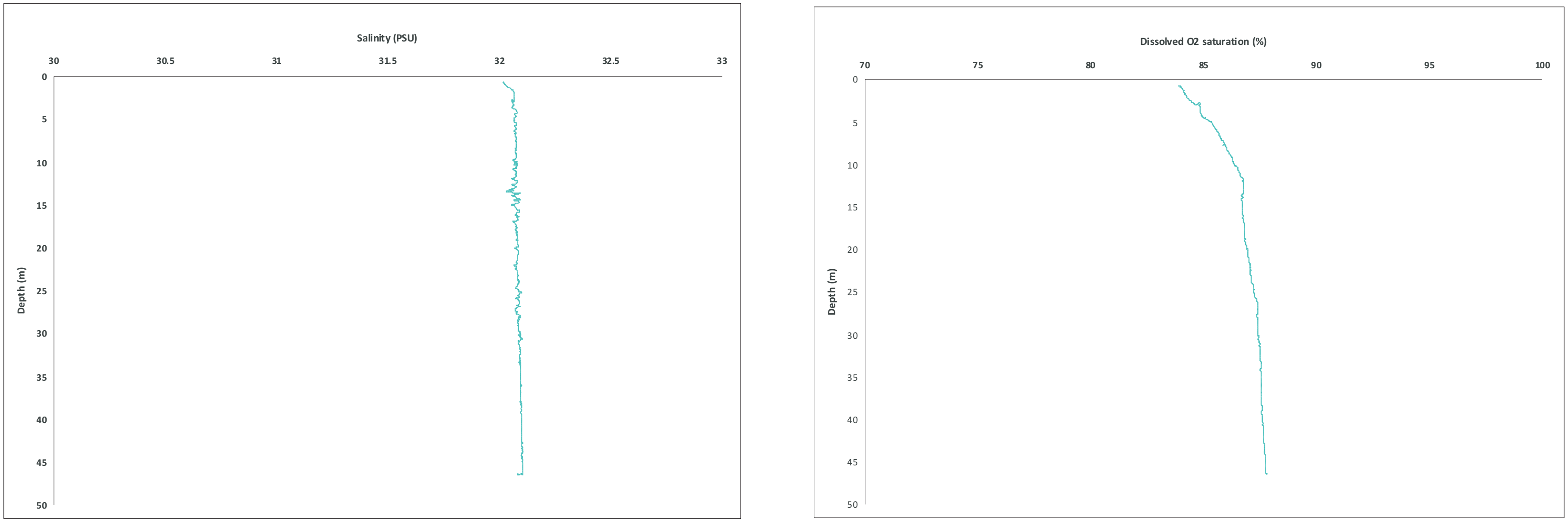


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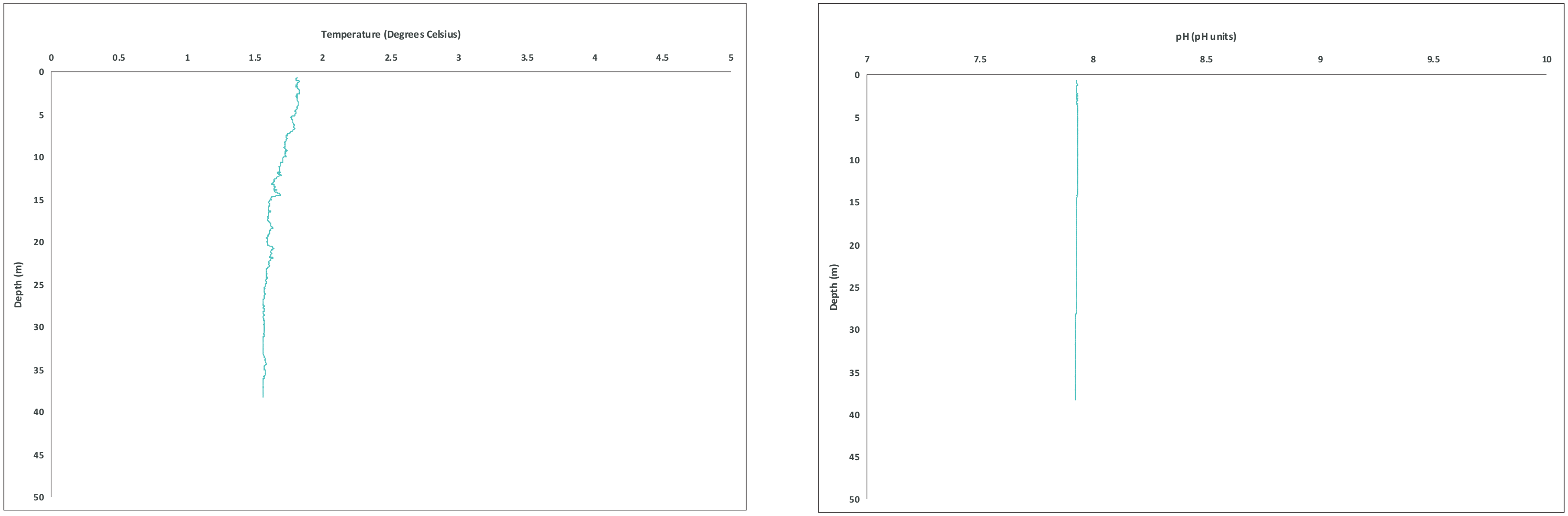
Figure 2.2f Temperature, ph, salinity and dissolved oxygen using a CTD, at the 1000m downstream station in 2015



2000m Downstream

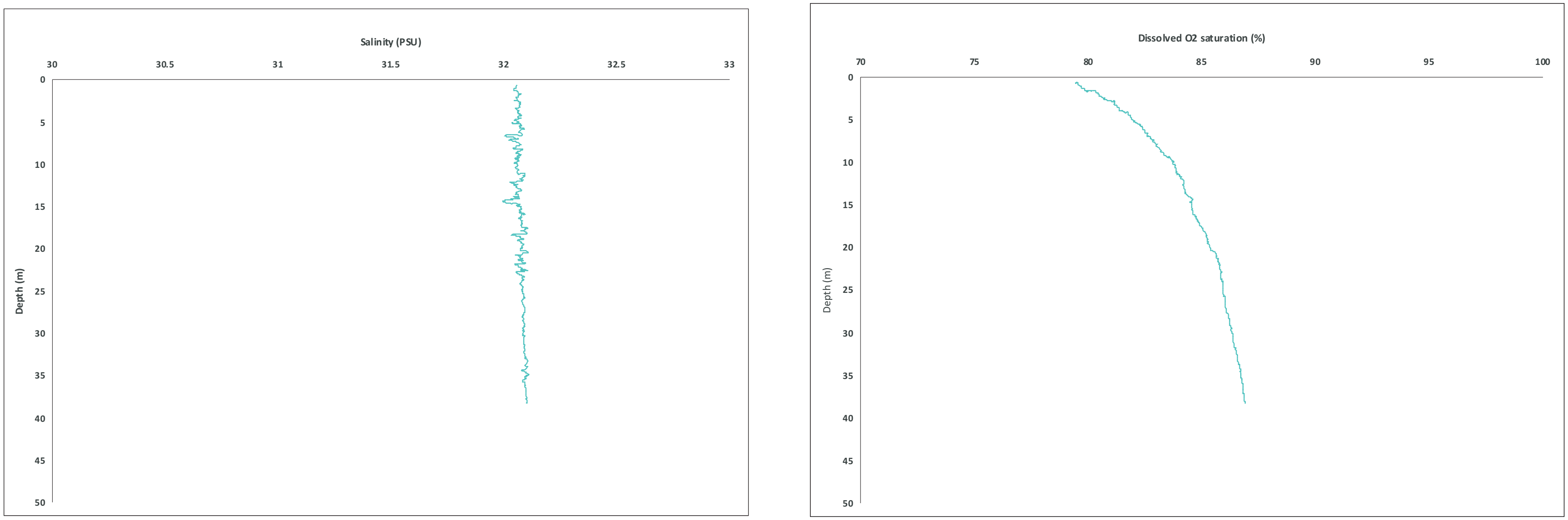


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Figure 2.2g Temperature, ph, salinity and dissolved oxygen using a CTD, at the 2000m downstream station in 2015

Figure 2.2g

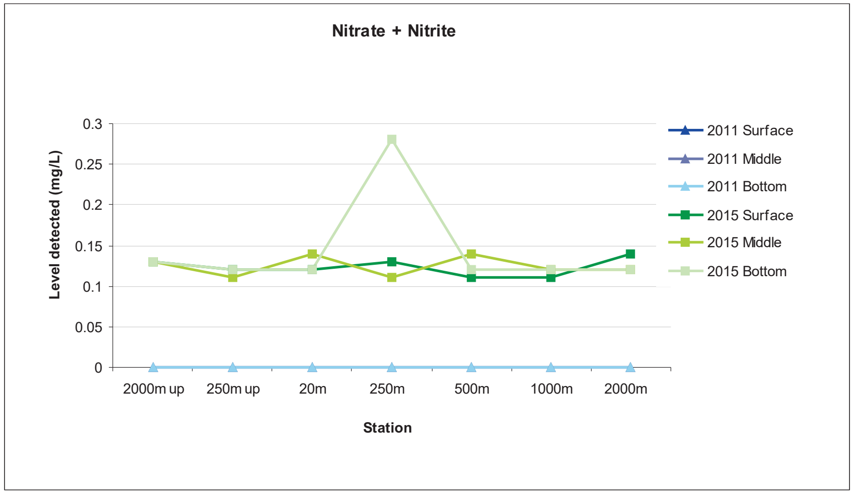

Figure 2.3a - Comparison of nitrate+nitrite detected at water stations in 2011 and 2015. The nitrate+nitrite in produced water in 2015 was ND in March and December.

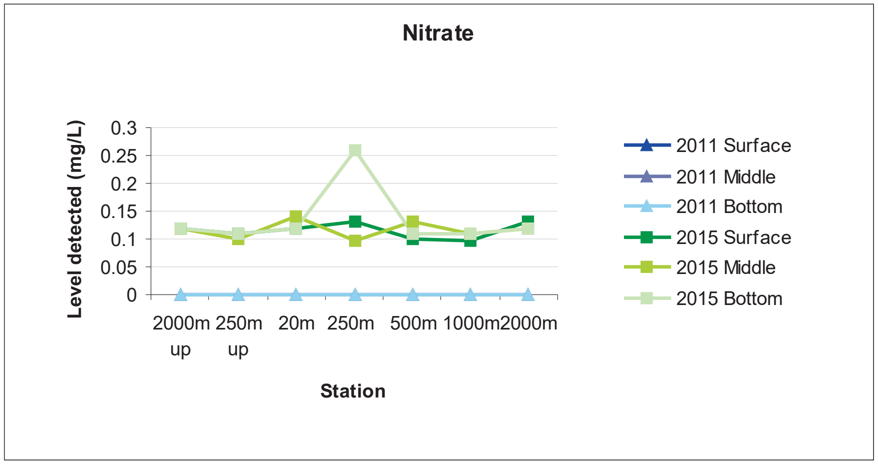

Figure 2.3b - Comparison of nitrate detected at water stations in 2011 and 2015. The nitrate in produced water in 2015 was ND in March and December.

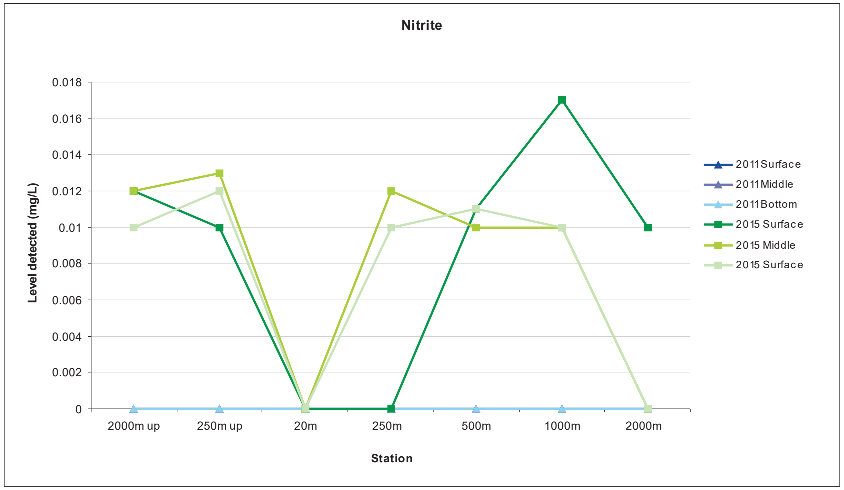

Figure 2.3c - Comparison of nitrite detected at water stations in 2011 and 2015. The nitrite in produced water in 2015 was 0.11mg/L and ND in March and December, respectively.

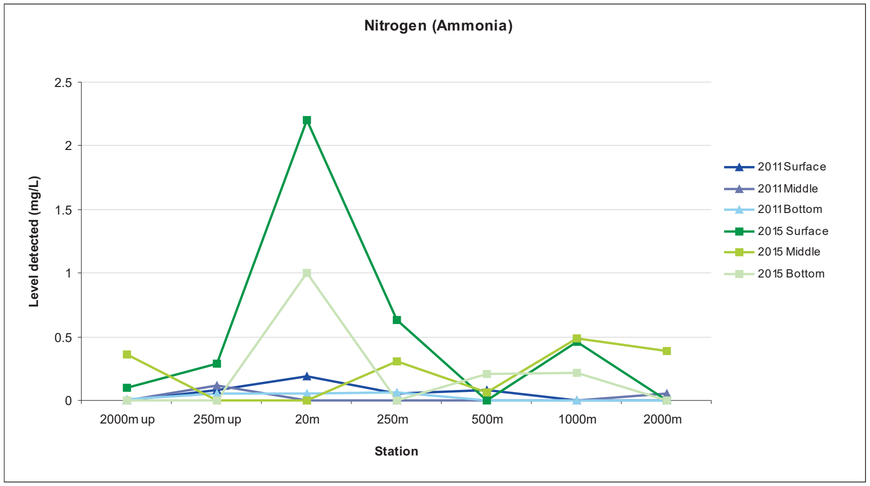

Figure 2.3d - Comparison of nitrogen (ammonia) detected at water stations in 2011 and 2015. The nitrogen (ammonia) in produced water in 2015 was 73 and 74mg/L in March and December, respectively.

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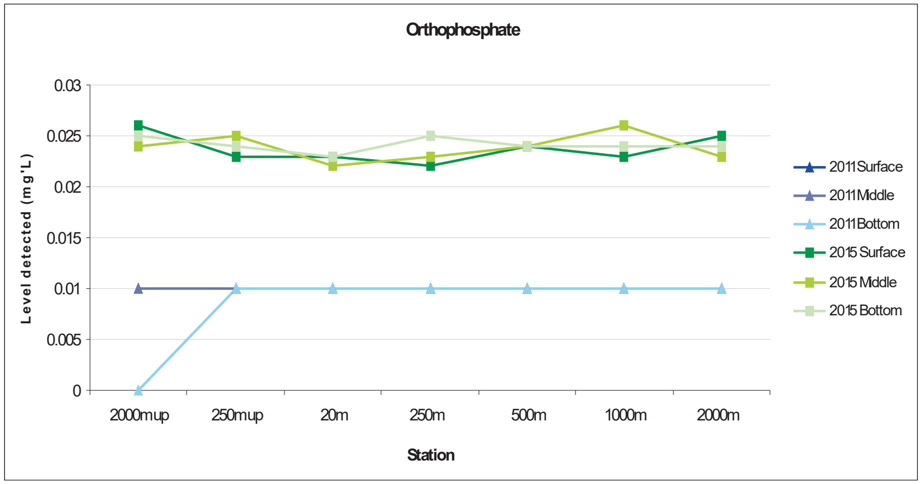
Figure 2.3 Comparisons of nutrients and major ions tested for in water in, 2011 and 2015 Figure 2.3



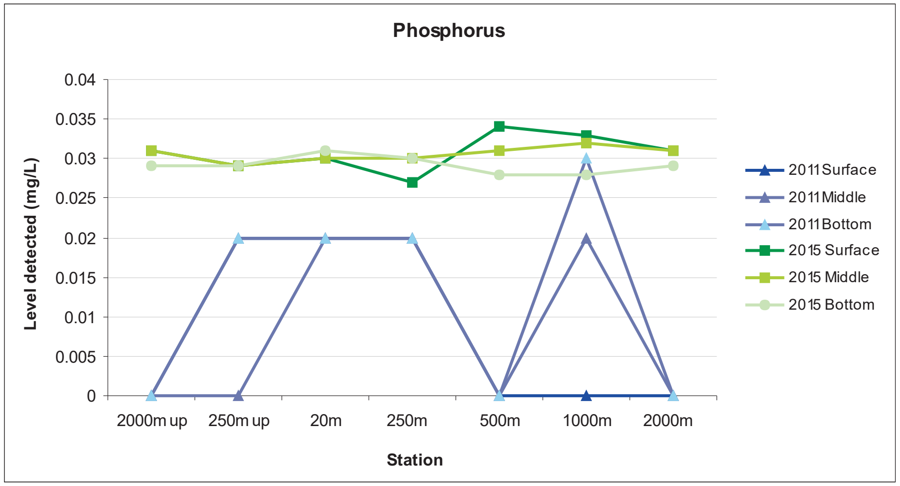


Figure 2.3e - Comparison of orthophosphate detected at water stations in 2011 and 2015. The orthophosphate in produced water in 2015 was 0.31 and 0.49mg/L in March and December, respectively.

Figure 2.3f - Comparison of phosphorus detected at water stations in 2011 and 2015. The phosporus in produced water in 2015 was 1.2 and 0.73mg/L in March and December, respectively

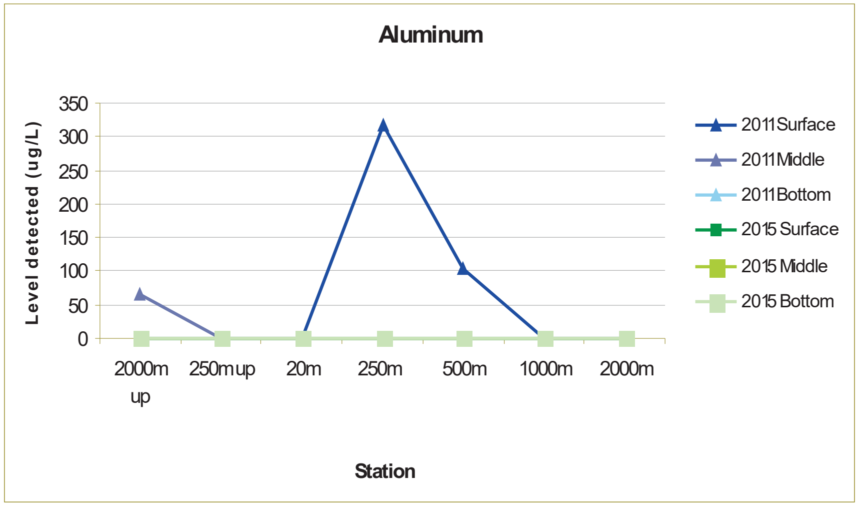


Figure 2.4a - Comparison of aluminum detected at water stations in 2011 and 2015. The aluminum in produced water in 2015 was ND and 690µg/L in March and December, respectively.

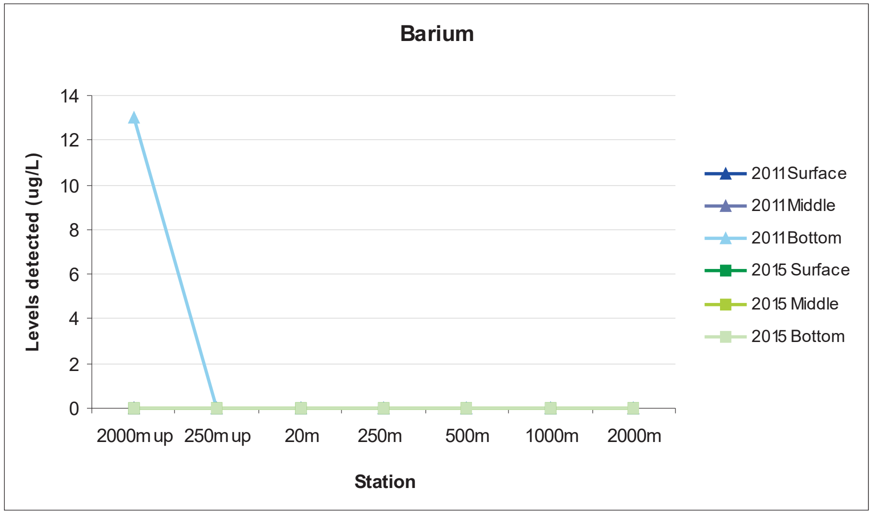


Figure 2.4b - Comparison of barium detected at watert stations in 2011 and 2015. The barium in produced water in 2015 was 19000 and 25000µg/L in March and December, respectively.

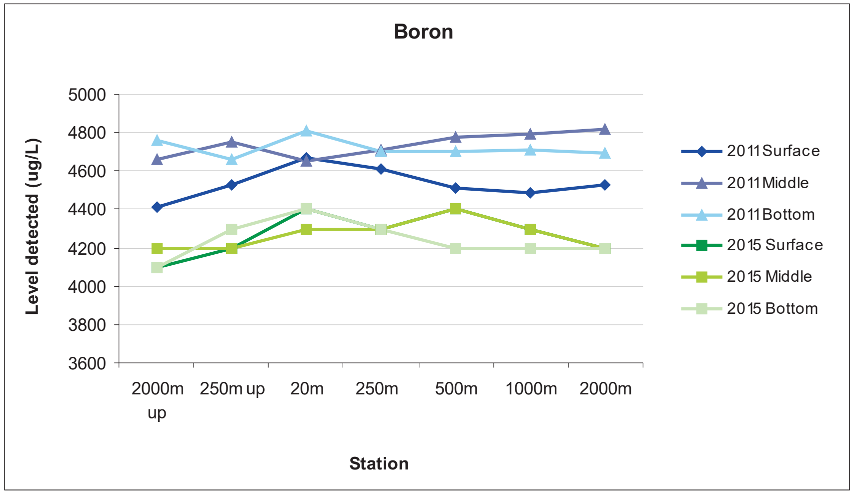


Figure 2.4c - Comparison of boron detected at water stations in 2011 and 2015. The boron in produced water in 2015 was 89000 and 87000µg/L in March and December, respectively.

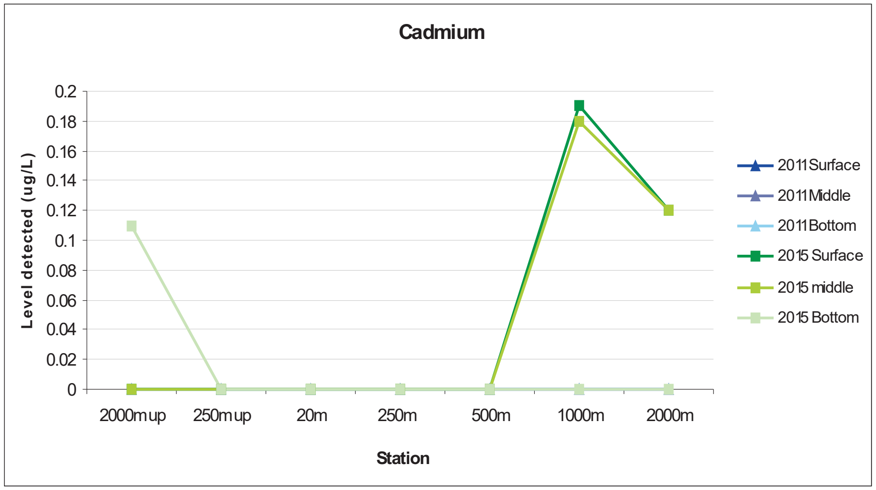


Figure 2.4d - Comparison of cadmium detected at water stations in 2011 and 2015. The cadmium in produced water in 2015 was ND and 4.4µg/L in March and December, respectively.

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Figure 2.4 Comparisons of metals tested for in water in, 2011 and 2015 Figure 2.4

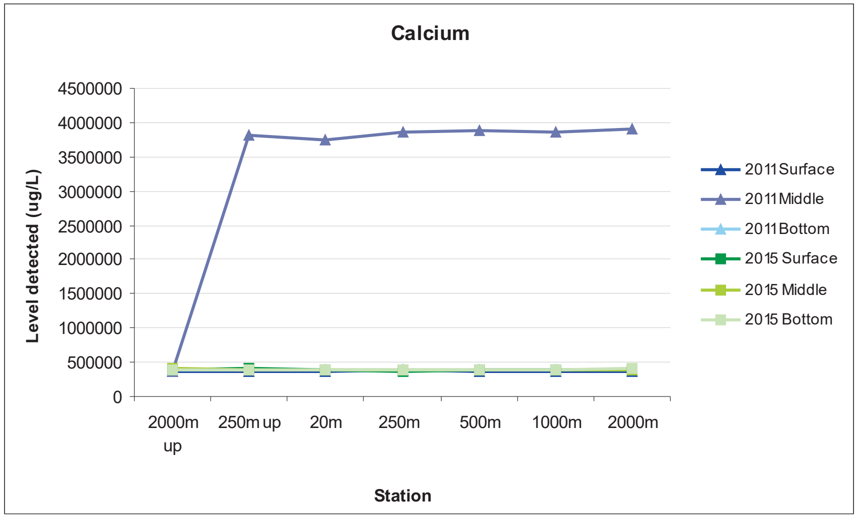

Figure 2.4e - Comparison of calcium detected at water stations in 2011 and 2015. The calcium in produced water in 2015 was 8000000 and 7100000µg/L in March and December, respectively.

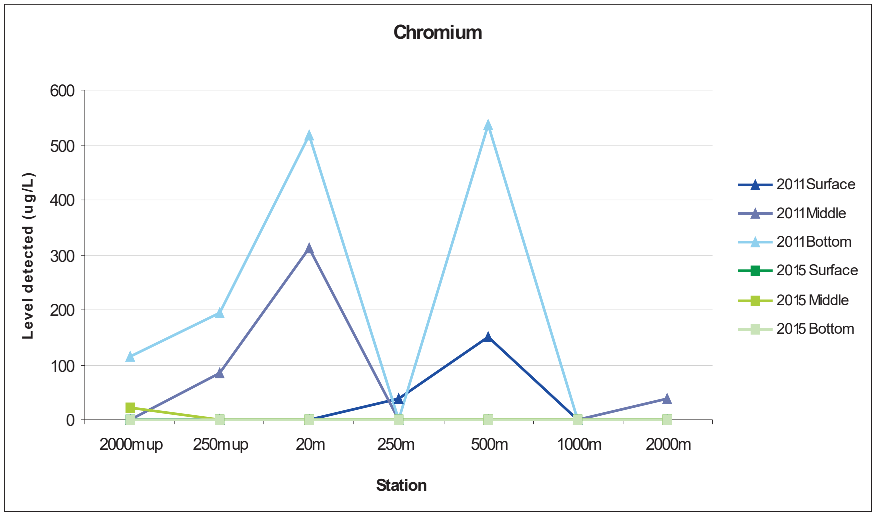

Figure 2.4f - Comparison of chromium detected at water stations in 2011 and 2015. The chromium in produced water in 2015 was ND and 320µg/L in March and December, respectively

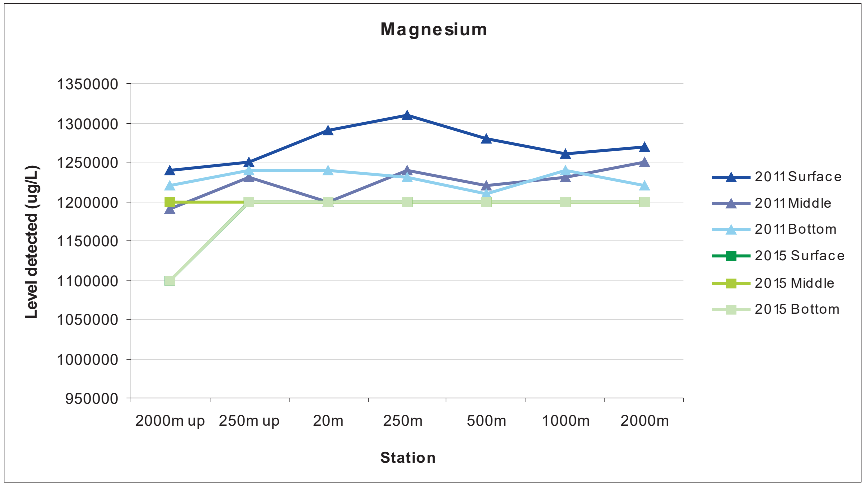

Figure 2.4g - Comparison of magnesium detected at water stations in 2011 and 2015. The magnesium in produced water in 2015 was 850000 and 750000µg/L in March and December, respectively

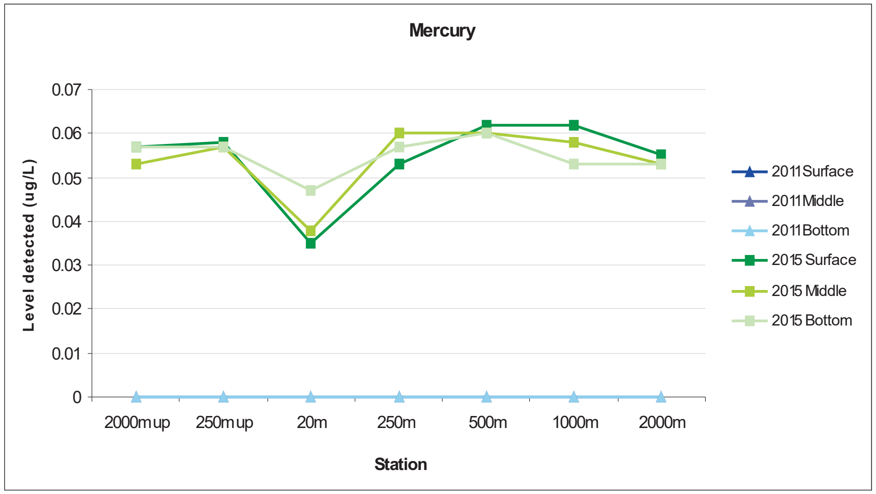

Figure 2.4h - Comparison of mercury detected at water stations in 2011 and 2015. The mercury in produced water in 2015 was ND in March and December.

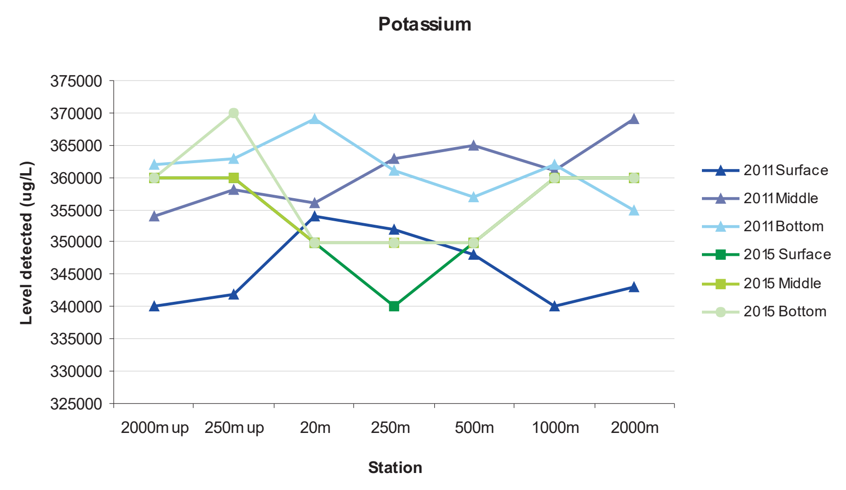

Figure 2.4i - Comparison of potassium detected at water stations in 2011 and 2015. The potassium in produced water in 2015 was 380000 and 360000µg/L in March and December, respectively.

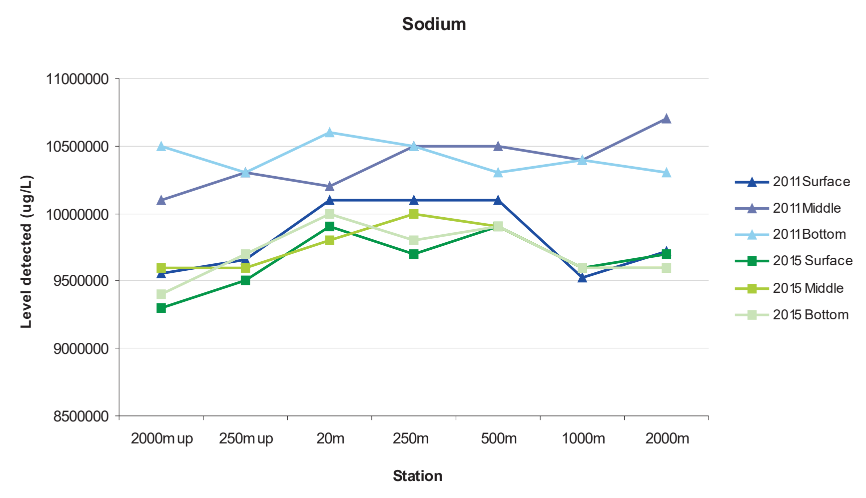

Figure 2.4j - Comparison of sodium detected at water stations in 2011 and 2015. The sodium in produced water in 2015 was 31000000 and 28000000µg/L in March and December, respectively.

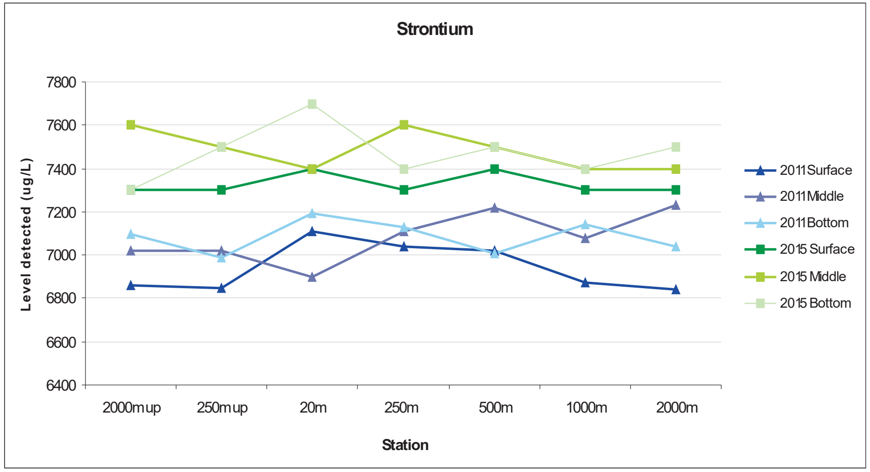

Figure 2.4k - Comparison of strontium detected at water stations in 2011 and 2015. The strontium in produced water in 2015 was 730000 and 600000µg/L in March and December, respectively.

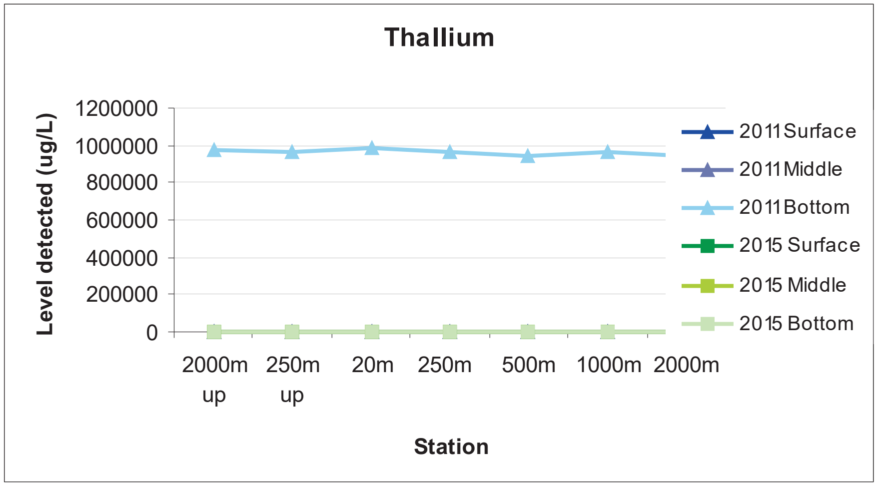

Figure 2.4l - Comparison of thallium detected at water stations in 2011 and 2015. The thallium in produced water in 2015 was 14µg/L and ND in March and December, respectively.

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Figure 2.4 Comparisons of metals tested for in sediment in 2011 and 2015 Figure 2.4

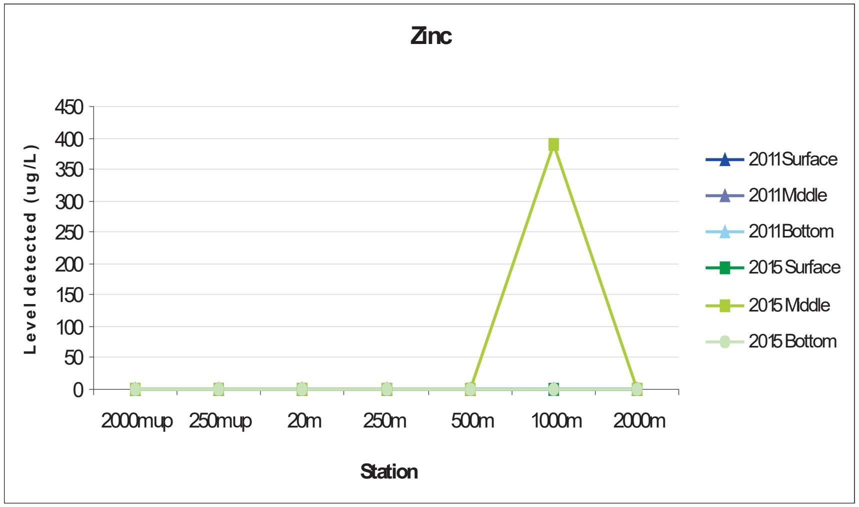


Figure 2.4m - Comparison of zinc detected at water stations in 2011 and 2015. The zinc in produced water in 2015 was ND and 590µg/L in March and December, respectively.

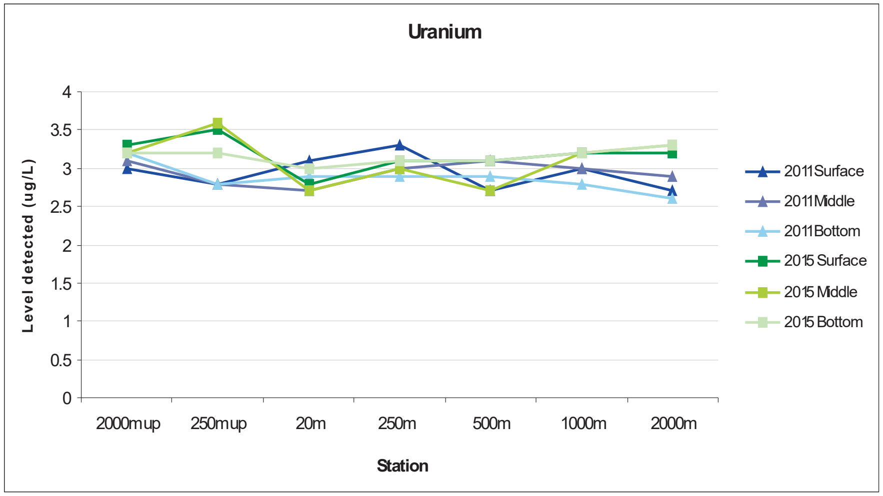


Figure 2.4n - Comparison of uranium detected at water stations in 2011 and 2015. The uranium in produced water in 2015 was ND in March and December.

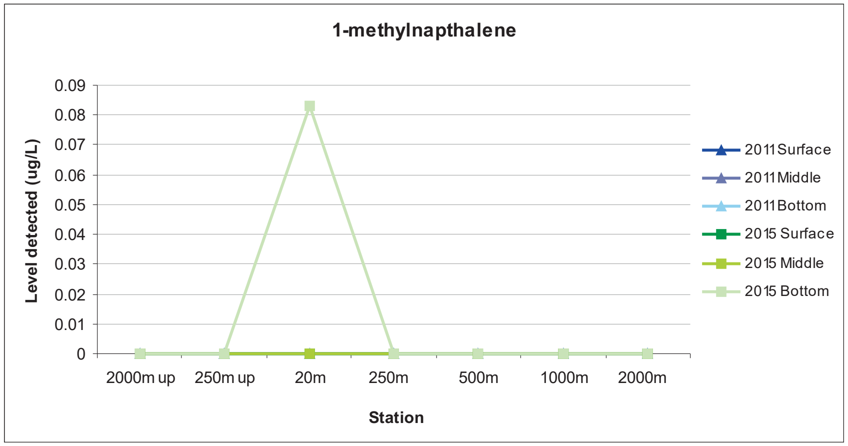


Figure 2.5a - Comparison of 1-methylnapthalene detected at water stations in 2011 and 2015. The 1-methylnapthalene in produced water in 2015 was 410 and 220µg/L in March and December, respectively.

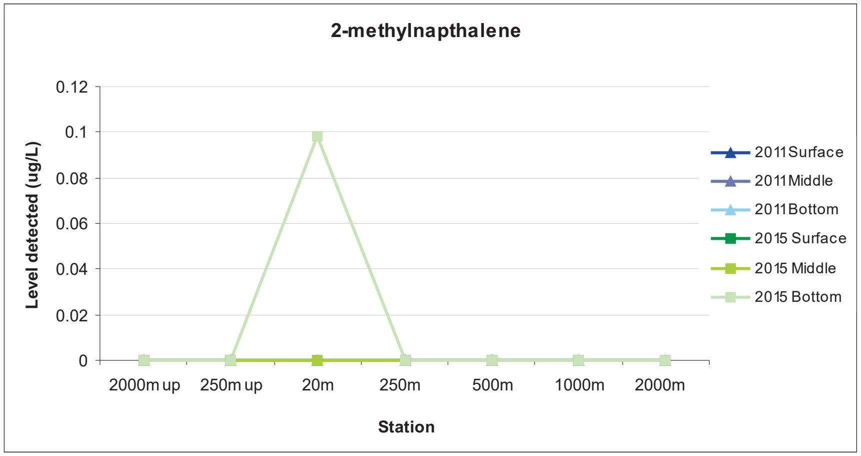


Figure 2.5b - Comparison of 2-methylnapthalene detected at water stations in 2011 and 2015. The 2-methylnapthalene in produced water in 2015 was 470 and 300µg/L in March and December, respectively.

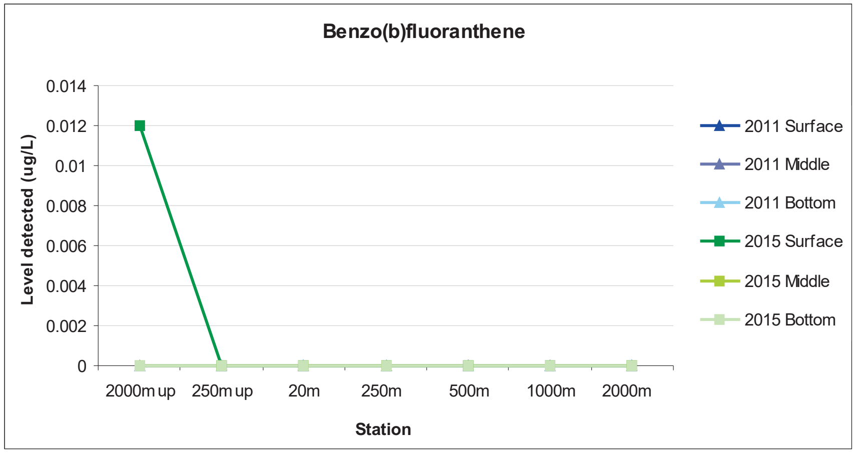


Figure 2.5c - Comparison of benzo(b)fluoranthene detected at water stations in 2011 and 2015. The benzo(b)fluoranthene in produced water in 2015 was 0.08 and 0.048µg/L in March and December, respectively.

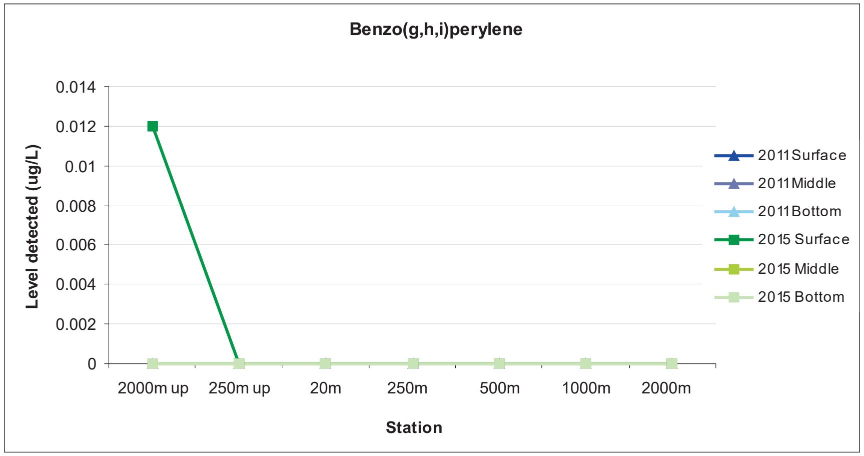


Figure 2.5d - Comparison of benzo(g,h,i)perylene detected at water stations in 2011 and 2015. The benzo(g,h,i)perylene in produced water in 2015 was ND in March and December.

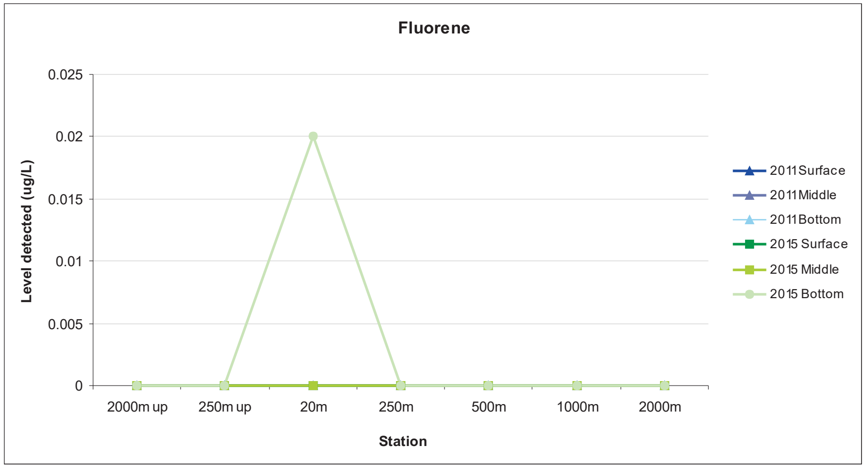


Figure 2.5e - Comparison of fluorene detected at water stations in 2011 and 2015. The calcium in fluorene water in 2015 was 73 and 55μg/L in March and December, respectively.

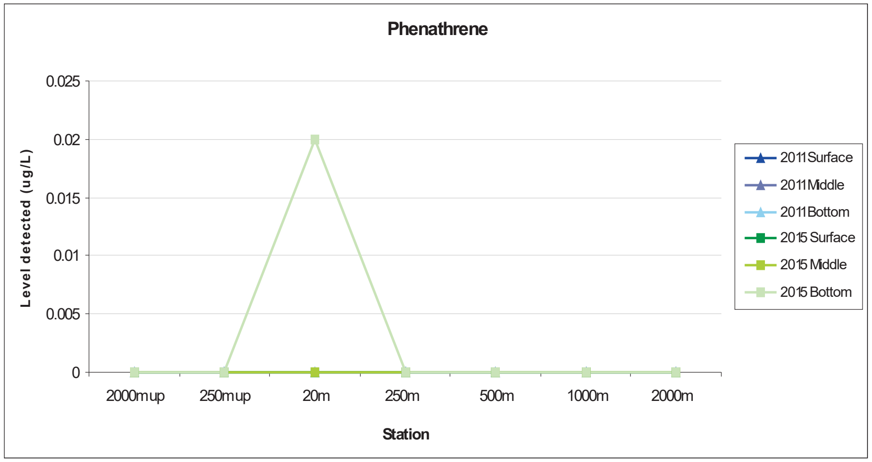


Figure 2.5f - Comparison of phenanthrene detected at water stations in 2011 and 2015. The phenanthrene in produced water in 2015 was 48 and 38μg/L in March and December, respectively

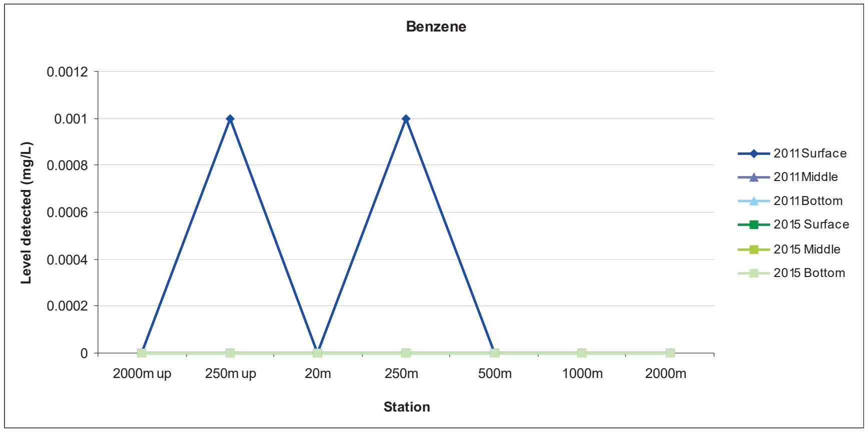


Figure 2.6a - Comparison of benzene detected at water stations in 2011 and 2015. The benzene in produced water in 2015 was 3.5 and 3.6mg/L in March and December, respectively.

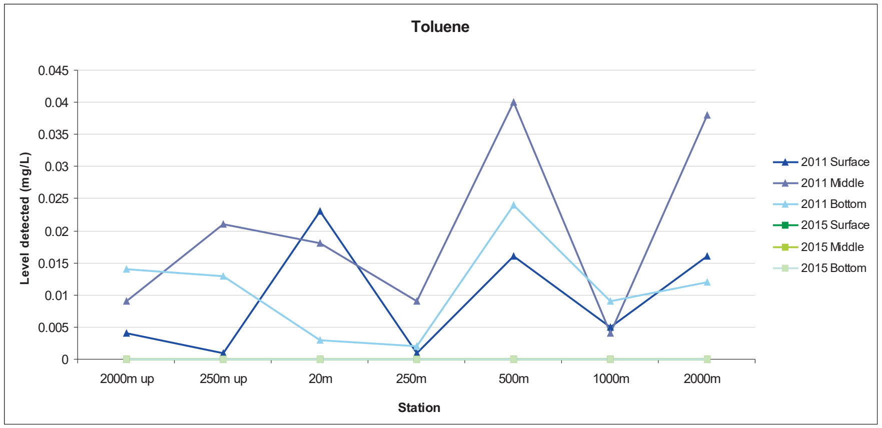


Figure 2.6b - Comparison of toluene detected at sediment stations in 2011 and 2015. The toluene in produced water in 2015 was 1.6 and1.7mg/L in March and December, respectively.

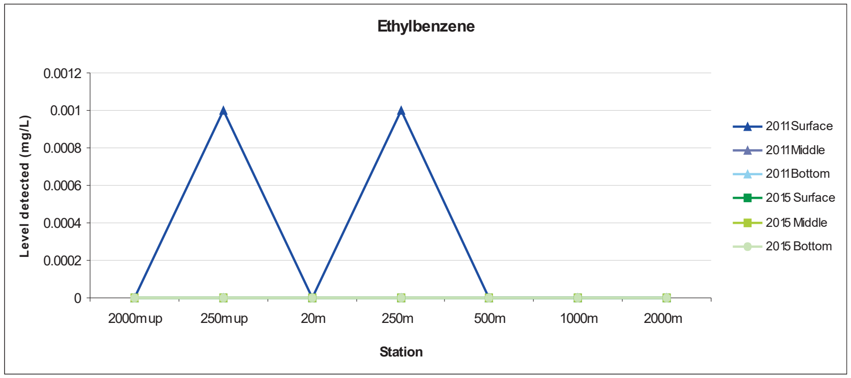


Figure 2.6c - Comparison of ethylbenzene detected at water stations in 2011 and 2015. The ethylbenzene in produced water in 2015 was 0.058 and 0.069mg/L in March and December, respectively.

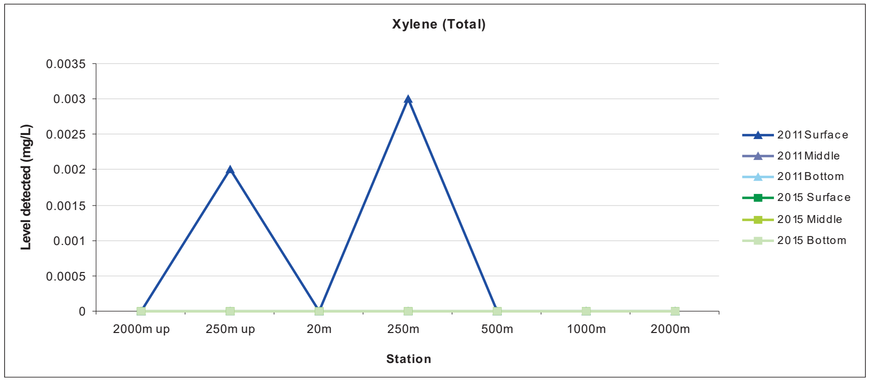


Figure 2.6d - Comparison of total xylenes detected at water stations in 2011 and 2015. The total xylenes in produced water in 2015 was 0.53 and 0.57mg/L in March and December, respectively.

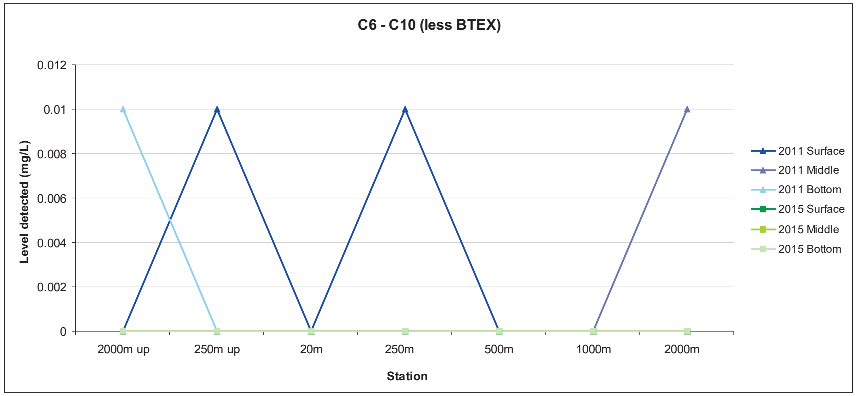


Figure 2.6e - Comparison of C6-C10 hydrocarbons less BTEX detected at water stations in 2011 and 2015. The C6-C10 hydrocarbons in produced water in 2015 was ND in March and December.

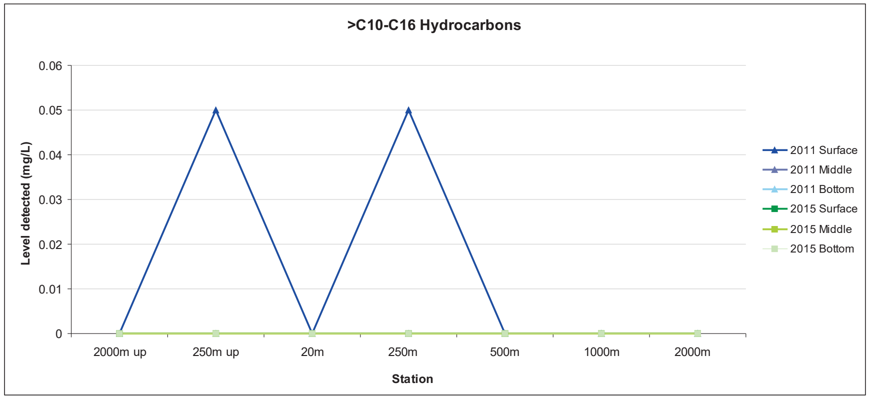


Figure 2.6f - Comparison of <C10-C16 hydrocarbons detected at water stations in 2011 and 2015. The <C10-C16 hydrocarbons in produced water in 2015 was 15 and 6.5mg/L in March and December, respectively

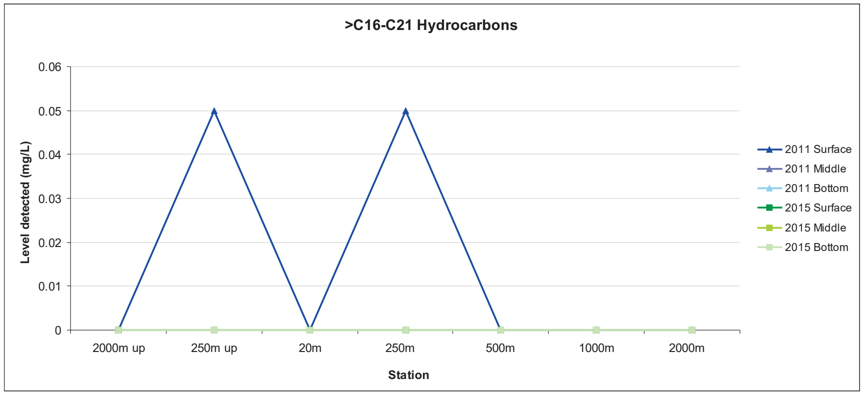


Figure 2.6g - Comparison of <C16-C21 hydrocarbons detected at water stations in 2011 and 2015. The <C16-C21 hydrocarbons in produced water in 2015 was 7.6 and 3.3mg/L in March and December, respectively

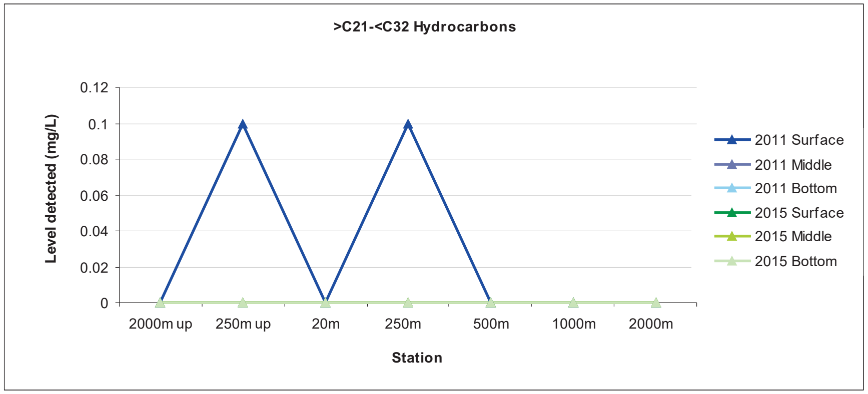


Figure 2.6h - Comparison of <C21-<C32 hydrocarbons detected at water stations in 2011 and 2015. The <C21-<C32 hydrocarbons in produced water in 2015 was 4.5 and 1.8mg/L in March and December, respectively.

Figure 2.6 Comparisons of TPHs tested for in sediment in 2011 and 2015

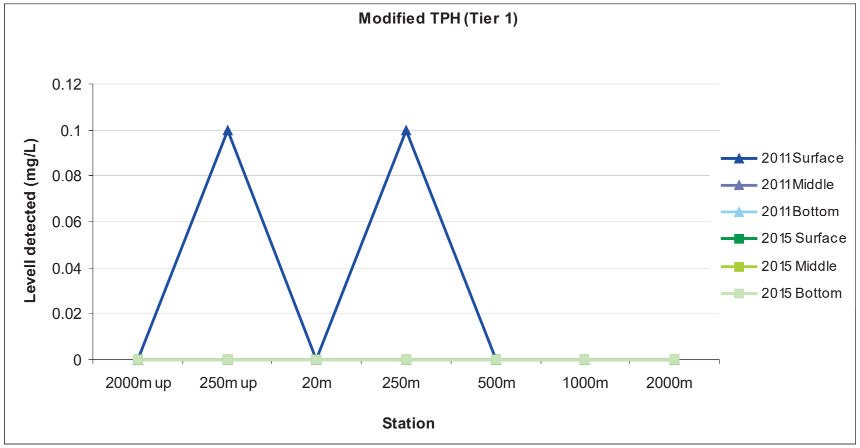


Figure 2.6i - Comparison of modified TPH (Tier 1) detected at water stations in 2011 and 2015. The modified TPH (Tier 1) in produced water in 2015 was 27 and 12mg/L in March and December, respectively.

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 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).

2.3.2 EEMP Goal

To validate predictions re sediment toxicity made in the 2006 Deep Panuke EA [EA predictions #1, 2, 3, 4, 5, 6, 7 & 8 in **Table 3.1**].

2.3.3 Objectives

Determine the dispersion of key drilling and production chemical parameters at drill sites and production site.

2.3.4 Sampling

Sediment was collected on March 24 and 26, 2015 at 6 stations for physical and chemical characterization. See **Table 2.33** below for sampling details.

Table 2.33 - 2015 Sediment Sampling Details

<table>
<tr><td>Survey Date:</td><td>March 24, 26, 2015</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>20:00</td><td>46</td><td>685735</td><td>4853499</td></tr>
<tr><td>500m DS</td><td>13:20</td><td>45</td><td>685649</td><td>4853245</td></tr>
<tr><td>1000m DS</td><td>13:46</td><td>42</td><td>685223</td><td>4852944</td></tr>
<tr><td>2000m DS</td><td>14:09</td><td>40</td><td>684492</td><td>4852266</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>19:00</td><td>39</td><td>689477</td><td>4857176</td></tr>
<tr><td>5000m DS SW</td><td>14:45</td><td>38</td><td>682340</td><td>4850141</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 11 stations both upstream and downstream from the PFC. Sediment sampling locations are available in Figure 2.7. Logs are available in Appendix F1.

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 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 (Appendix F1, fully described and sub-sampled and logged).</td></tr>
</table>

<table>
<tr><td>Sample Preparation:</td><td>Samples were collected and subsampled into the following for subsequent analysis:
<table><tr><th>Parameter</th><th>Preservative</th></tr><tr><td>PSA and TOC</td><td>no preservative</td></tr><tr><td>Metal scan (incl. Hg)</td><td>no preservative</td></tr><tr><td>BTEX/TPH/PAHs</td><td>no preservative</td></tr><tr><td>Sulphide</td><td>Zinc Acetate</td></tr></table></td></tr>
</table>

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 2.34**, including analysis methods and reportable detection limits. Major ions were determined by inductively coupled atomic photometry (ICAP). Metals were determined Inductively Coupled Plasma Mass Spectrometry (ICP-MS), except mercury, which was determined using cold vapour atomic absorption (CVAA). Following analysis, metal/Al ratios were calculated for comparison of concentrations across the stations and with previous studies in order to compensate for the effects of sediment grain size characteristics on metal concentrations (i.e. to specifically address footnote #40 in EEMP in connection to Ba/Al ratio. 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 Total Petroleum Hydrocarbons (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.

Sediment samples were dispatched for acute toxicity testing by Harris Industrial testing Services (subcontractor). A single concentration amphipod test as per reference method EPS1/RM/35 December 1998 was undertaken using sediment samples from each of the 6 stations.

Single concentration tests using the amphipod *Eohaustorius estuarius* were undertaken instead of using the amphipod *Rhepoxynius abronius* due to the availability of this test species (following personal communication with G. Harris of Harris Industrial Testing.) All tests were conducted to the methods, guidelines and procedures outlined in Environment Canada document EPS1/RM/35 December 1998. Survival of replicate samples from each sampling station after a 10 day period were compared against survival of organisms exposed to control (clean) sediments.

2.3.5.1 Parameters Analyzed

Table 2.34 - 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	0.10	CVAA
Molybdenum (Mo)	mg/kg	2	ICP-MS
Nickel (Ni)	mg/kg	2	ICP-MS
Rubidium (Rb)	mg/kg	2	ICP-MS
Selenium (Se)	mg/kg	2	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

Parameter	Units	RDL	Analysis Method
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	ug/g	0.50	ISE
Alkylated Phenols			
Nonylphenol (NP)	ng/L	5	LRMS
4-Nonylphenol monoethoxylate (NP1EO)	ng/L	25	LRMS
4-Nonylphenol diethoxylate (NP2EO)	ng/L	25	LRMS
4-n-Octylphenol (OP)	ng/L	25	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

2.3.5.2 Analysis QA/QC

- Particle Size: Sample Duplicate, Minimum frequency of 1 every 20 samples
- Metals in soil: Method Blank, Spiked Blank, CRM, Sample Duplicate, Matrix Spike - minimum one each per batch, minimum frequency of 1 every 20 samples
- Mercury: Method Blank, Spiked Blank, Matrix Spike, QC Standard, Sample duplicate.
- BTEX-TPH in soil: Method Blank, Spiked Blank, Duplicate Sample, Matrix Spike 1 per 20 samples, Surrogate for all samples. C10-C32 – Method Blank, Spiked Blank, Duplicate Sample, Matrix Spike.
- PAH: Method Blank, Spiked Blank, Duplicate Sample, Matrix Spike: 1 per 20 samples, Surrogate for all samples.
- Sulphide in soil: Method Blank, Sample Duplicates 1 per 20 samples, Matrix Spike, Method Blank, 1 per 20 samples
- Alkylated Phenols: Method Blank (MB): 1 per 20 samples, On-going Precision and Recovery (OPR) Samples – spiked reference matrix (SPM) analyzed with each batch.
- TOC in soil: Method Blank, CRM, Sample Duplicate, QC Standard - minimum one each per batch, minimum frequency of 1 every 20 samples

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 2.35** through **Table 2.39,** respectively, and in **Figure 2.8** and **Digital Appendix C**;
- CEQG for sediment quality are included in **Appendix F1;**
- The sediment type at all stations consisted of mostly fine to medium sand. A small percentage of clay was present at each station. A small percentage of gravel was found at station SED 250M and, small amounts of silt were found at stations SED 250M and SED 500M.
- Aluminum levels in 2015 were similar or slightly lower at all stations than in 2011;
- Arsenic was only detected at the 5000 m downstream station at 2.7g/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 5000 m downstream sediment station in 2015.
- Iron followed similar trends to the distribution across stations as the 2011 data. 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 2011, 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 2011, 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 10 to 32 mg/kg in 2015.
- Vanadium followed similar trends in detected levels across sites as 2011, where the highest detection was at the 250m site, and all other sites had similar or lower lead levels than 5000m upstream reference site. Levels of vanadium ranged from 3.0 - 6.7 mg/kg in 2015.
- Mercury concentrations remain below laboratory RDL (not detectable) for all benthic stations.

- Antimony, arsenic, barium, strontium, thallium and zinc were not present at detectable levels across all stations, which is consistent with 2011 results and a decrease from the baseline study results from 2008.
- Chromium was found at the 250 m station and the 5000m downstream station at levels of 4.4 and 2.1mg/kg, respectively. Trends in chromium detection and distribution over the sites sampled were similar to 2011, other than the detected levels at the 5000m downstream site in 2015. These values are well below CCME guidelines.
- PAH and BTEX-TPH remain below laboratory RDL (not detected) for all benthic stations.
- Sulphide levels were >0.50mg/g for all benthic stations, and have increased since 2011.
- TOC concentrations were not detectable at all stations, except for SED 250M (0.49g/kg) which is at approximately the same levels as the 2008 and 2011 survey (low).
- No alkylated phenols that were tested for were detected at any of the sediment stations sampled.

Table 2.35 - Sediment Quality: 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	%	19	16	15	17	16	17
< -1 Phi (2 mm)	%	100	100	100	100	100	100
< 0 Phi (1 mm)	%	99	100	99	99	100	100
< +1 Phi (0.5 mm)	%	99	89	87	86	92	87
< +2 Phi (0.25 mm)	%	80	18	15	20	14	9.3
< +3 Phi (0.12 mm)	%	4.8	2.1	1.6	1.4	1.5	1.8
< +4 Phi (0.062 mm)	%	1.7	1.6	1.3	1.2	1.4	1.7
< +5 Phi (0.031 mm)	%	1.8	1.2	1.3	1.1	1.4	1.7
< +6 Phi (0.016 mm)	%	1.4	1.1	1.4	1.4	1.3	1.8
< +7 Phi (0.0078 mm)	%	1.6	1.1	1.2	1.2	1.1	1.8
< +8 Phi (0.0039 mm)	%	1.5	1.1	1.4	1.3	1.3	1.7
< +9 Phi (0.0020 mm)	%	1.4	1.2	1.2	1.4	1.0	1.6
Gravel	%	0.27	ND	ND	ND	ND	ND
Sand	%	98	98	99	99	99	98
Silt	%	0.16	0.43	ND	ND	ND	ND
Clay	%	1.5	1.1	1.4	1.3	1.3	1.7

ND – not detected

Table 2.36 - Sediment Quality: Metal Results

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

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

Table 2.37 - Sediment Quality: Petroleum Hydrocarbon and PAH Results

Parameter	5000 US (NE) 2011	5000 US (NE) 2015	250 DS 2011	250 DS 2015	500 DS 2011	500 DS 2015	1000 DS 2011	1000 DS 2015	2000 DS 2011	2000 DS 2015	5000 DS (SW) 2011	5000 DS (SW) 2015	CCME Guidelines	
Total Petroleum Hydrocarbons (mg/kg)													**ISQG**	**PEL**
Benzene	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	-	-
Ethylbenzene	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	-	-
C6 - C10 (less BTEX)	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	-	-
>C16-C21 Hydrocarbons	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	-	-
Modified TPH (Tier1)	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	-	-
Hydrocarbon Resemblance	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	-	-
2-Methylnaphthalene	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	0.00671	0.0889
Acenaphthylene	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	0.0469	0.245
Benzo(a)anthracene	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	0.0888	0.763
Benzo(b)fluoranthene	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	-	-
Benzo(j)fluoranthene	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	-	-
Chrysene	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	-	-
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.113	1.494

Parameter	**5000 US (NE) 2011**	**5000 US (NE) 2015**	**250 DS 2011**	**250 DS 2015**	**500 DS 2011**	**500 DS 2015**	**1000 DS 2011**	**1000 DS 2015**	**2000 DS 2011**	**2000 DS 2015**	**5000 DS (SW) 2011**	**5000 DS (SW) 2015**	**CCME Guidelines**	
Fluorene	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	-	-
Naphthalene	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	-	-
Phenanthrene	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	0.153	1.398

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

Table 2.38 - Sediment Quality: Sulphide Results Comparing 2015 and 2011 Surveys

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

1 - Sample analyzed past hold time: sample was received on hold time expiry data which did not allow sufficient time for preparation and analysis
2 - Matrix spike exceeds acceptance limits due to matrix interference. Re-analysis yields similar results.
3 - RDL raised due to sample matrix interference.
ISQG - Interim Sediment Quality Guidelines
PEL - Probable Effect Level

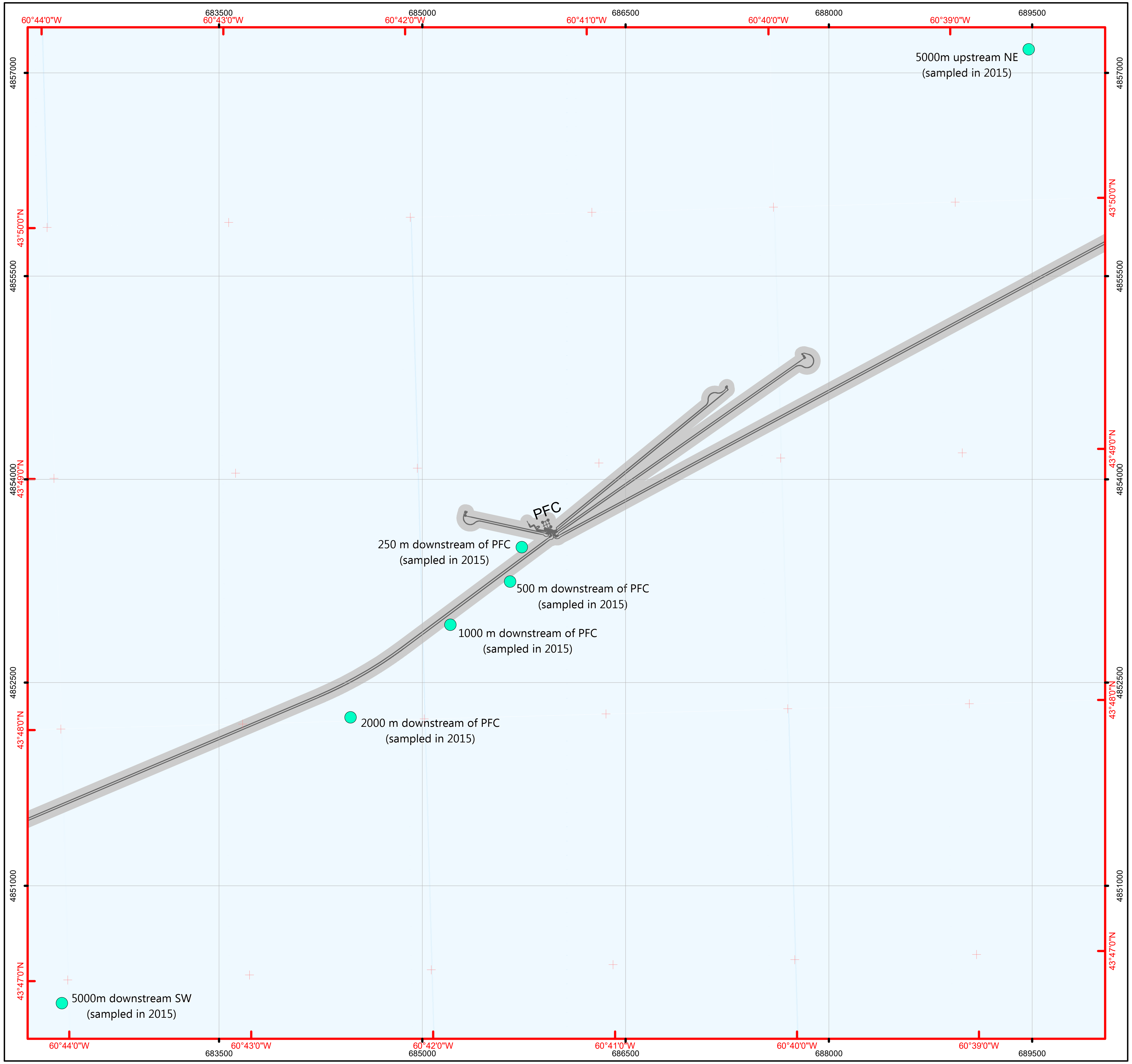
Table 2.39 - Sediment Quality: Alkylated Phenol Results Comparing 2011 to 2015

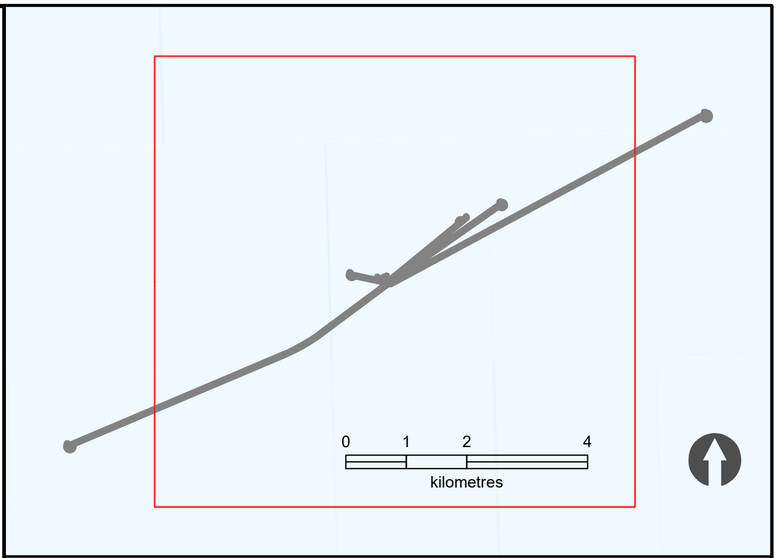
Parameter	5000 US (NE) 2011	5000 US (NE) 2015	250 DS 2011	250 DS 2015	500 DS 2011	500 DS 2015	1000 DS 2011	1000 DS 2015	2000 DS 2011	2000 DS 2015	5000 DS (SW) 2011	5000 DS (SW) 2015	CCME Guidelines	
Alkylated Phenol (ng/L)													ISQG	PEL
Nonylphenol (NP)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1 mg/kg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

ISQG - Interim Sediment Quality Guidelines
PEL - Probable Effect Level

2.3.7 Summary and Conclusions

- The sediment type found at all stations mostly consisted of fine sand;
- Antimony, barium, strontium, thallium and zinc were not present at detectable levels across all stations, which is consistent with 2011 results, and a decrease from the baseline study results from 2008;
- Sulphide levels increased since 2011;
- Aluminum, arsenic, iron, lead manganese and vanadium were detected at similar levels and followed similar trends in regards to levels detected across stations as 2011.
- Mercury levels remain non-detectable;
- PAH and BTEX parameters tested for remain at non detectable levels;
- No alkylated phenols tested for were detected at any of the sediment stations sampled.
- Raw data has been presented in the results for comparison. 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). The data was not normalized to aluminum in this report, as it was in 2011 for the 2008 and 2011 data, as increased levels of aluminum is 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. However, it should be noted that increased aluminum levels in 2008 baseline data could be related to the higher levels of metals also found in 2008.





WGS 1984 UTM Zone 20N
Projection: Transverse Mercator
Datum: WGS 1984
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

0 500 1,000 2,000
metres

● Sample Location
— Deep Panuke structures
▨ 50m Buffer Zone

Note:
Map scale 1:30,000 when printed on 11x17 size paper

encana natural gas

Encana

2015 Grab Sample Locations

Deep Panuke Survey Area

Scotian Shelf

McGregor GeoScience Limited

McGregor GeoScience Ltd.
Bedford, Nova Scotia, Canada

Date Saved: 26/01/2016 1:11:11 PM

Figure: 2 - 7

McGregor Project No.: 1113

Filename: 1113_ENCANA_grabs_2016

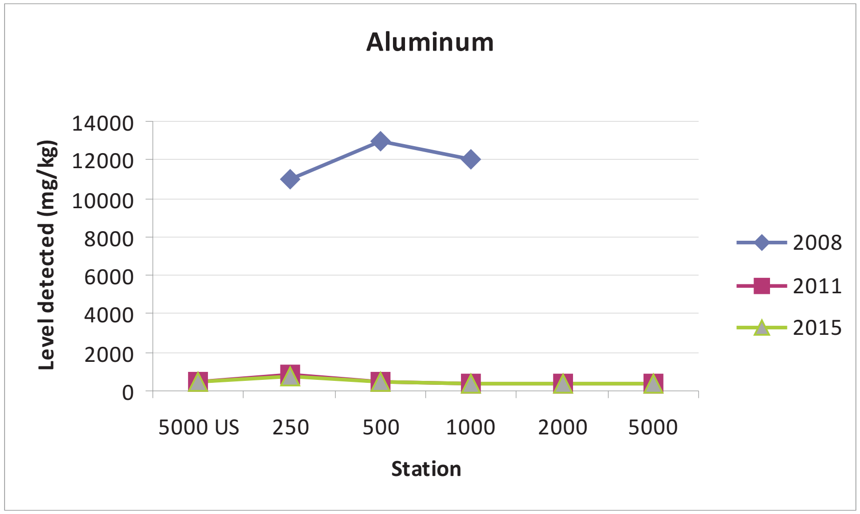


Figure 2.8a - Comparison of aluminum detected at sediment stations in 2008, 2011 and 2015. The aluminum in produced water in 2015 was ND and 690µg/L in March and December, respectively.

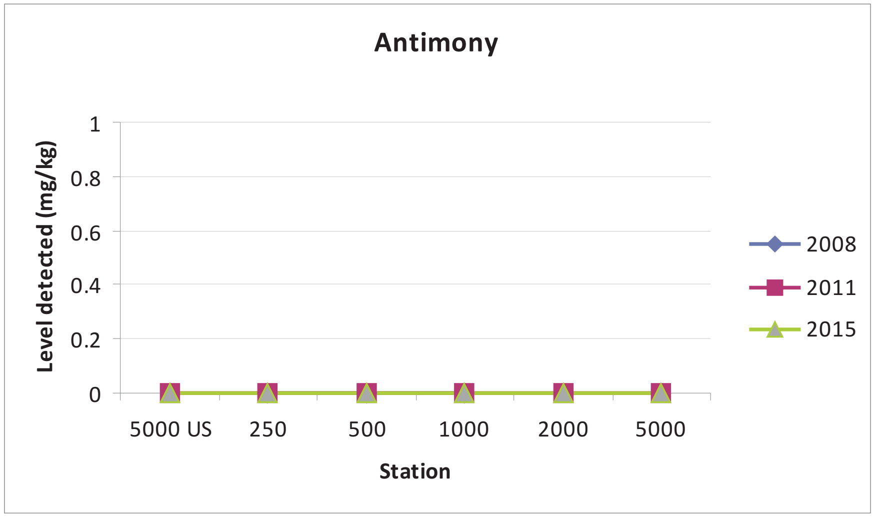


Figure 2.8b - Comparison of antimony detected at sediment stations in 2008, 2011 and 2015. The antimony in produced water in 2015 was ND in March and December.

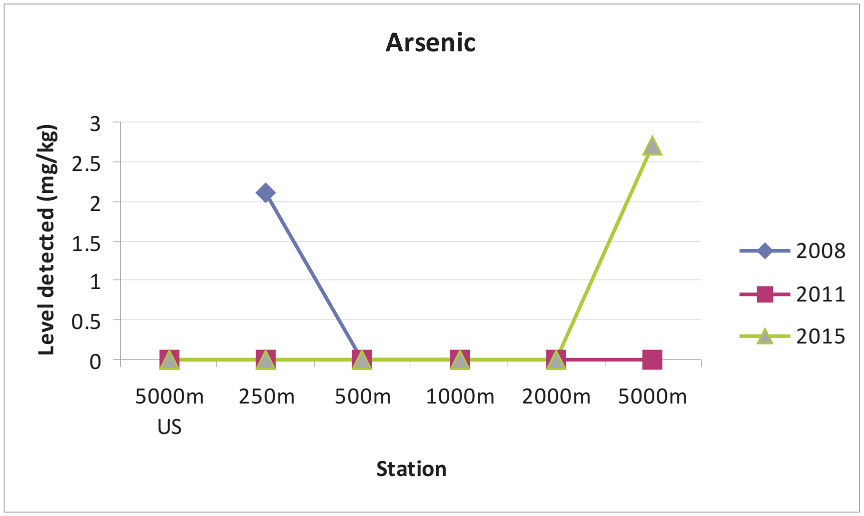


Figure 2.8c - Comparison of arsenic detected at sediment stations in 2008, 2011 and 2015. The arsenic in produced water in 2015 was ND in March and December.

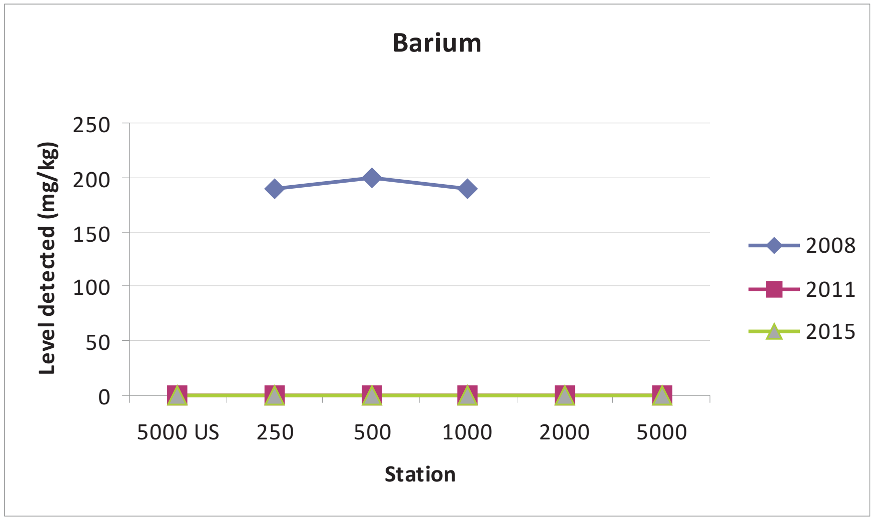


Figure 2.8d - Comparison of barium detected at sediment stations in 2008, 2011 and 2015. The barium in produced water in 2015 was 19000 and 25000µg/L in March and December, respectively.

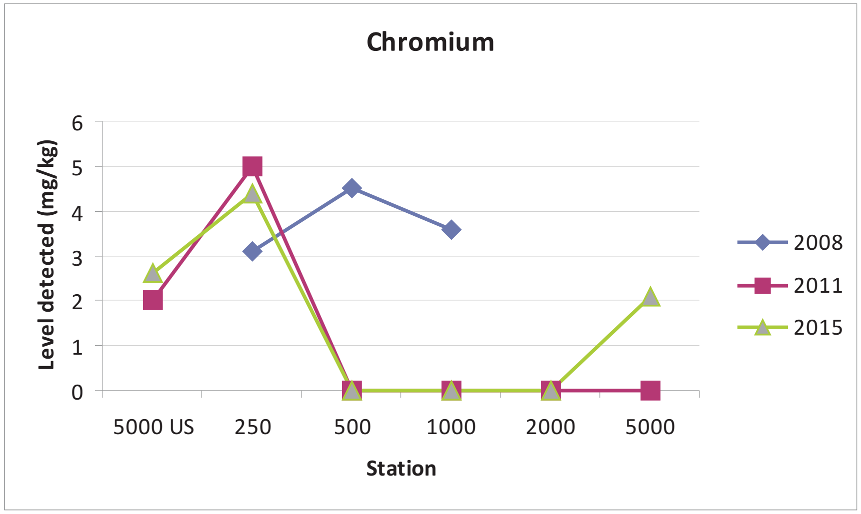


Figure 2.8e - Comparison of chromium detected at sediment stations in 2008, 2011 and 2015. The chromium in produced water in 2015 was ND and 320µg/L in March and December, respectively.

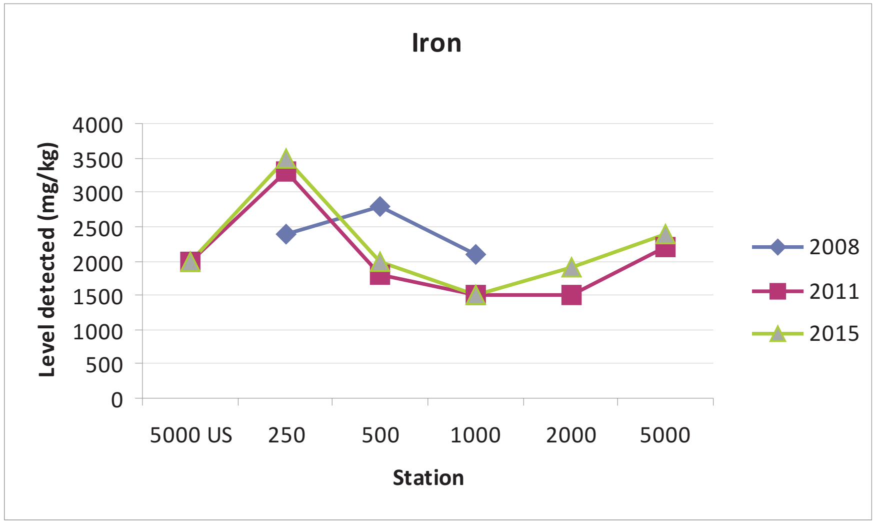


Figure 2.8f - Comparison of iron detected at sediment stations in 2008, 2011 and 2015. The iron in produced water in 2015 was ND in March and December.

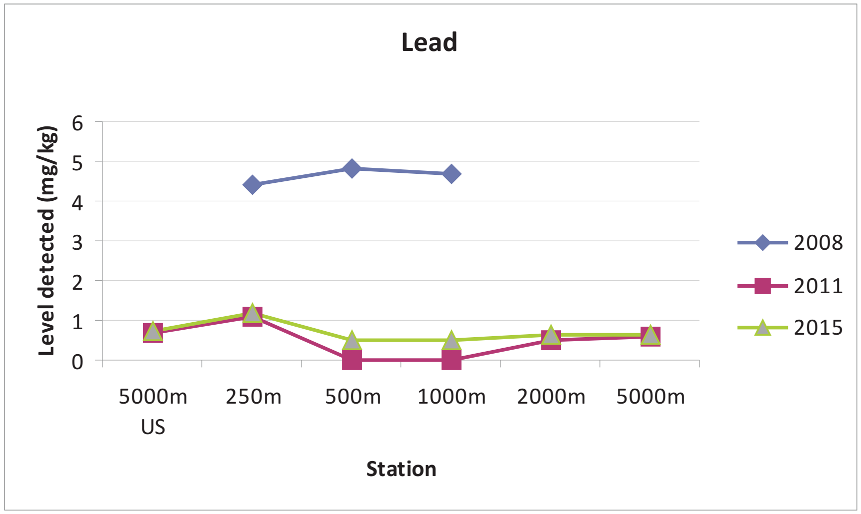


Figure 2.8g - Comparison of lead detected at sediment stations in 2008, 2011 and 2015. The lead in produced water in 2015 was ND in March and 220µg/L in December.

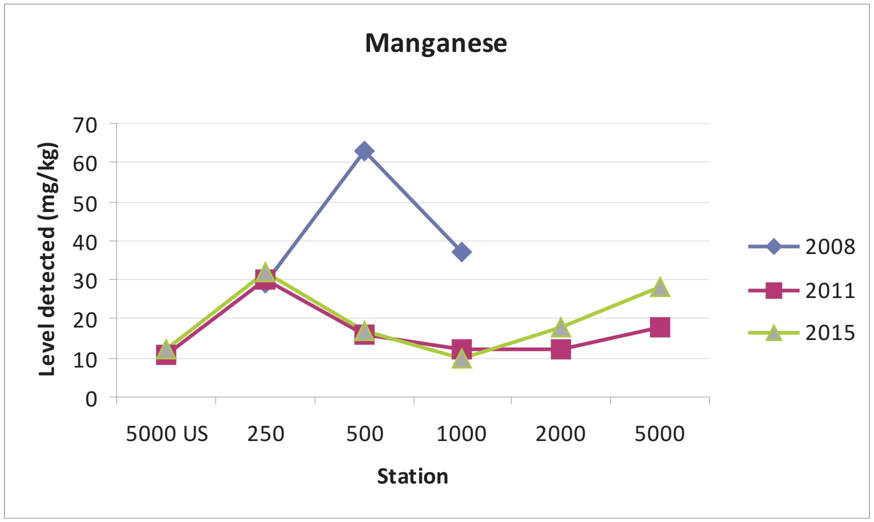


Figure 2.8h - Comparison of manganese detected at sediment stations in 2008, 2011 and 2015. The manganese in produced water in 2015 was 270 and 730µg/L in March and December, respectively.

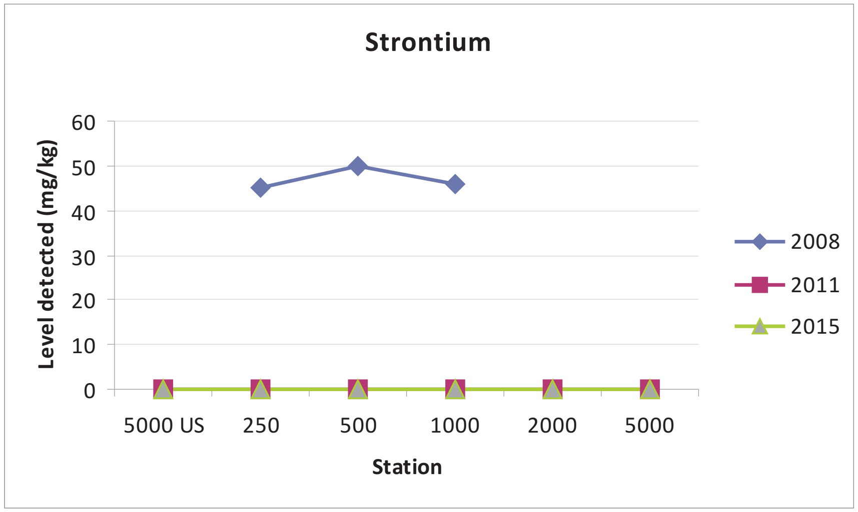


Figure 2.8i - Comparison of strontium detected at sediment stations in 2008, 2011 and 2015. The strontium in produced water in 2015 was 730000 and 600000µg/L in March and December, respectively.

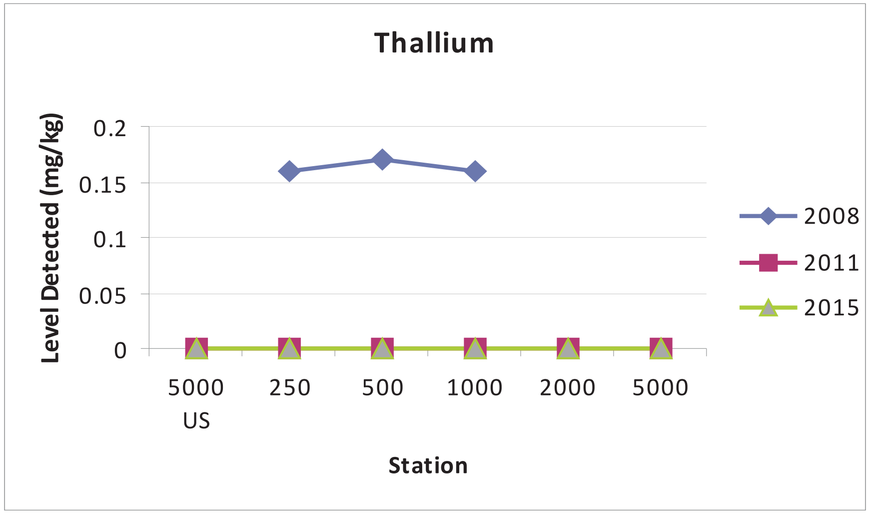


Figure 2.8j - Comparison of thallium detected at sediment stations in 2008, 2011 and 2015. The thallium in produced water in 2015 was 14µg/L in March and ND in December.

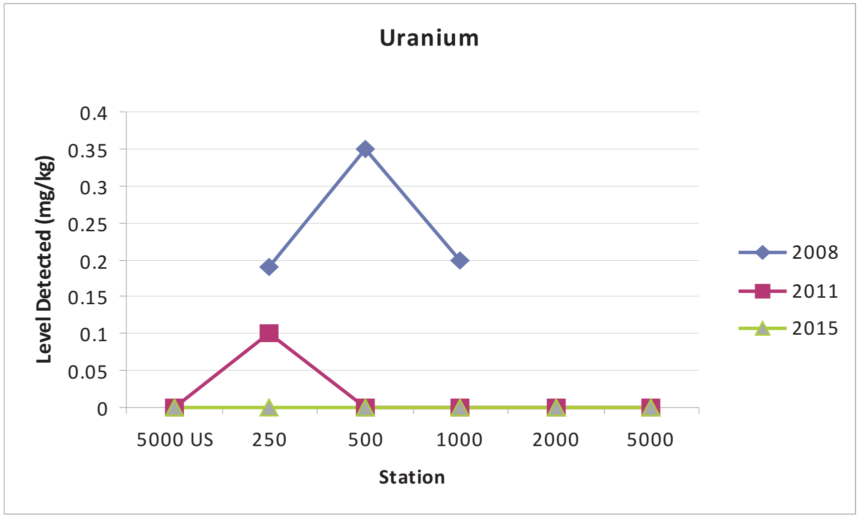


Figure 2.8k - Comparison of uranium detected at sediment stations in 2008, 2011 and 2015. The uranium in produced water in 2015 was ND in March and December.

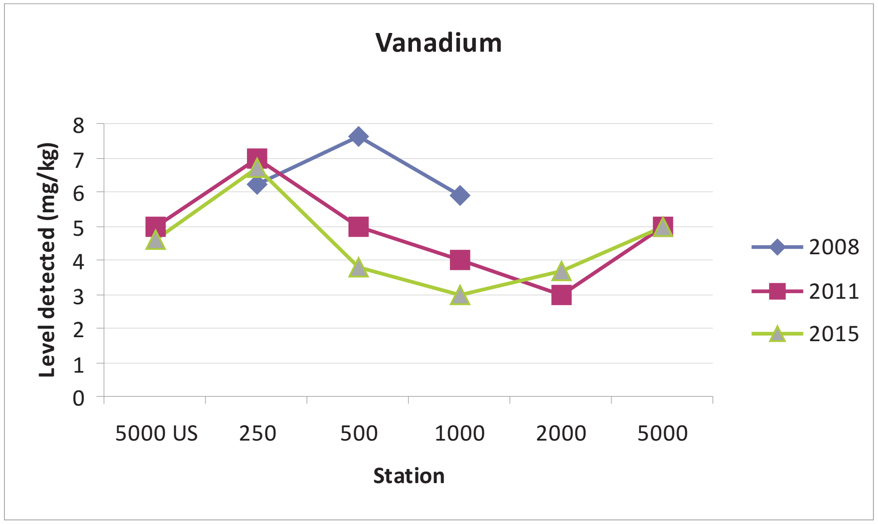


Figure 2.8l - Comparison of vanadium detected at sediment stations in 2008, 2011 and 2015. The vanadium in produced water in 2015 was ND in March and December.

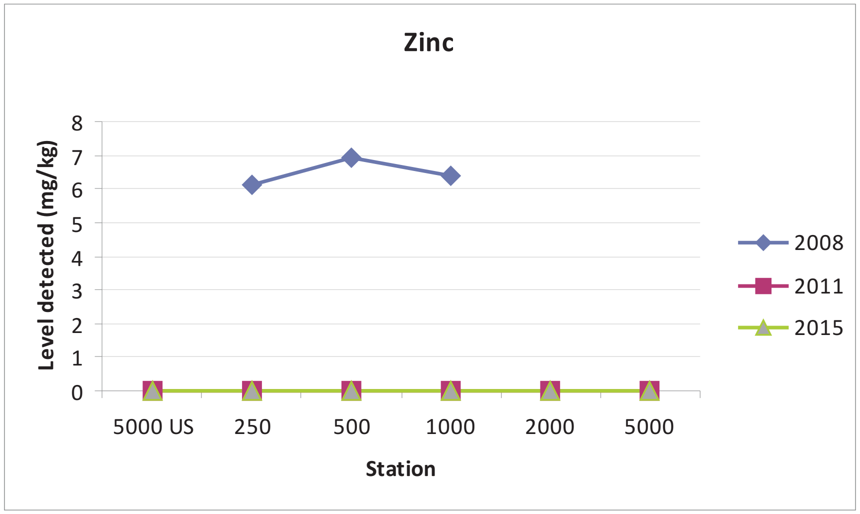


Figure 2.8m - Comparison of zinc detected at sediment stations in 2008, 2011 and 2015. The zinc in produced water in 2015 was ND and 590µg/L in March and December, respectively.

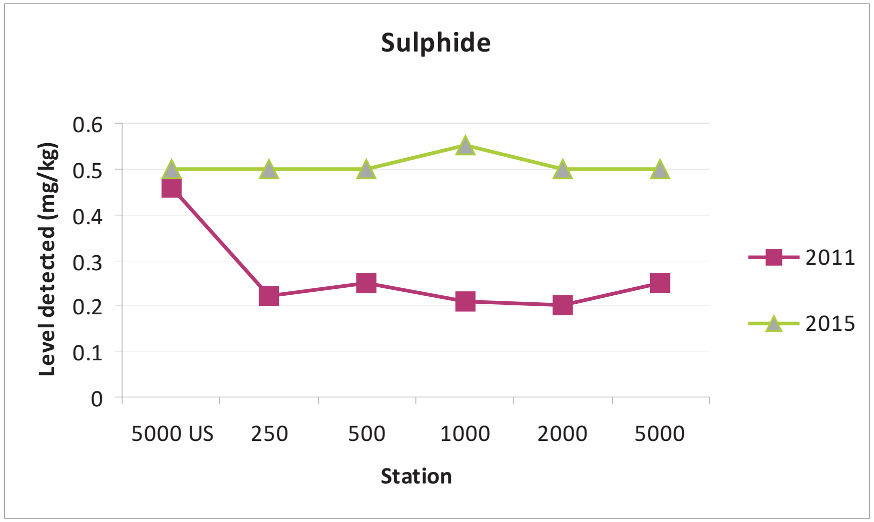


Figure 2.8n - Comparison of sulphide detected at sediment stations in 2011 and 2015. The sulphide in produced water in 2015 was 0.63 and 1.5mg/L in March and December, respectively.

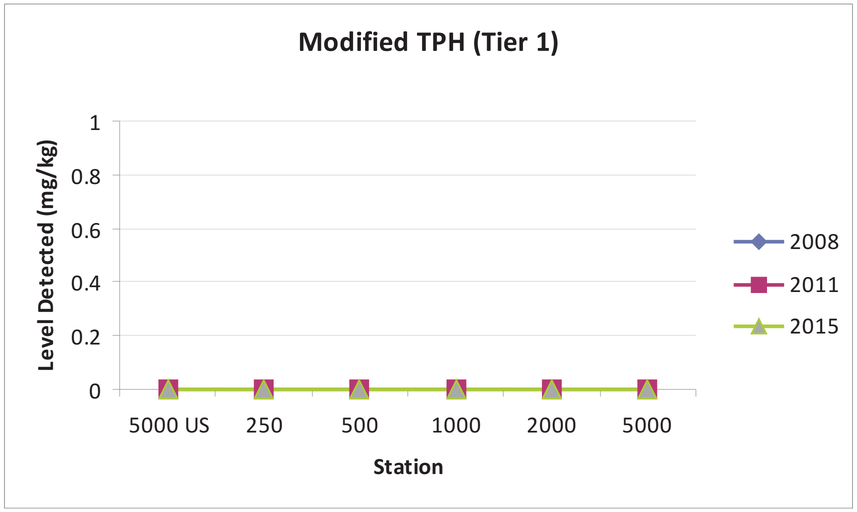


Figure 2.8o - Comparison of modified TPH (Tier 1) detected at sediment stations in 2008, 2011 and 2015. The modified TPH (Tier 1) in produced water in 2015 was 27 and 12mg/L in March and December, respectively.

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.

The field sampling program in 2011, reported in the 2011 Offshore Environmental Effects Monitoring for Deep Panuke Program Annual Report (DMMG-X00-RP-EH-90-0001.03U), presented results from a laboratory-based sediment toxicity bioassays 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. Lab method "Tox 49" was used for the bioassay using *Eohaustorius estuarius* as the test species on sediments collected during the 2015 monitoring program. All sediments were found to be non-toxic.

2.4.2 EEMP Goal

To validate predictions re 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].

2.4.3 Objectives

Use a suitable indicator species to evaluate acute toxicity of sediments collected at drill sites and at the production site.

2.4.4 Sampling

Sampling of six sediment stations took place in March of 2015 (**Table 2.40**), as well as laboratory-based sediment toxicity bioassays tests (see Section 1).

Table 2.40 - Sediment Sampling details - March, 2015

<table>
<tr><td>Survey Date:</td><td>March 24, 26, 2015</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>20:00</td><td>46</td><td>685734</td><td>4853500</td></tr>
<tr><td>500m DS</td><td>13:20</td><td>45</td><td>685648</td><td>4853245</td></tr>
<tr><td>1000m DS</td><td>13:46</td><td>42</td><td>685207</td><td>4852928</td></tr>
<tr><td>2000m DS</td><td>14:09</td><td>40</td><td>684470</td><td>4852243</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>19:00</td><td>39</td><td>689475</td><td>4857175</td></tr>
<tr><td>5000m DS SW</td><td>14:45</td><td>38</td><td>682340</td><td>4850135</td></tr>
<tr><td colspan="5">WGS84 UTM Zone 20N</td></tr>
</table>
</td></tr>
<tr><td>Number of Samples/Locations:</td><td>
<p>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 2.7. Logs are available in Appendix F.</p>
<p>Field stations:</p>

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);

<p>Reference stations:</p>

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>
<p>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.</p>
<p>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.</p>
</td></tr>
</table>

Sample Preparation:	<table><tr><th>Parameter</th><th>Preservative</th></tr><tr><td>Lab-based sediment bioassay</td><td>no preservative</td></tr></table>

2.4.5 Analysis

Analysis was subcontracted 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 ± 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 ± 2 °C until use.

Pre-test procedures conducted on April 20, 2015 were as follows:

- ~15 ml of pore water was extracted from each sediment and parameters were measured (pH, salinity and Ammonia (NH_3-N mg/L);
- 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;
- 775ml 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.

The 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 light at 15 ± 2 °C with minimal aeration;
- D.O., pH, salinity, and temperature were measured on non-consecutive days throughout the 10 day test and at termination for each sample.

2.4.5.1 Parameters Analyzed

The organism of choice for these tests was *E. estuarius* purchased from NW Seacology, North Vancouver, BC. Collection took place on April 11th, 2015. Organisms were received in Dartmouth, NS on April 15th, 2015 and held at the lab in site sediment covered with aerating seawater at test temperature (15 ± 2 °C) in continuous light for 6 days prior to commencement of testing. Organism health during the acclimation period met the validity criteria.

2.4.5.2 Analysis QA/QC

- D.O., pH, salinity, temperature and ammonia were measured at the beginning and end of the 10 day test (refer to *Amphipod Toxicity Reports)* for each sample;
- 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 survival of amphipods that survived in each treatment (including the control) during the 10 day test. days.

2.4.6 Results

- No organisms exhibiting unusual appearance, or undergoing unusual treatment were used in the test (**Table 2.41**);
- Statistically, there was no significant difference between the survival in the control sediment and the survival in the test sediments.
- The samples and control sediment as tested were found to be non-toxic to the amphipod *Eohaustorius estuarius*.
- Harris Industrial's full report is available in **Appendix F**.

Table 2.41 - Toxicity Results of *E. estuarius* Exposed to Sediments

Sample Location	Lab ID	Mortality	Survival (±SD)%
5000 US (NE)	15-135-F	4/100	96 ± 0.75
250 DS	15-135-G	4/100	96 ± 0.75
500 DS	15-135-B	2/100	98 ± 0.49
1000 DS	15-135-C	3/100	97 ± 0.49
2000 DS	15-135-D	4/100	96 ± 0.75
5000 DS (SW)	15-135-E	19/100* 2/80**	81 ± 6.62* 97 ± 0.5**

Sample Location	Lab ID	Mortality	Survival (±SD)%
BLIND	15-135-A	5/100	95 ± 0.63
Control Sediment	15-135-Ctl	2/100	98 ± 0.49

2.4.7 Summary and Conclusions

- All monitored parameters, DO, 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 Harris Industrial Testing Service Ltd.'s warning limits (i.e. ± 2 S.D. from mean);
- All test validity criteria for the sediment test method were satisfied;
- All collected sediments were non-toxic;
- In replicate #4 - 5000 m Downstream, a large polychaete (~4.5 cm long) was found at termination. Only 3 amphipods were remaining in the test vessel, therefore Replicate #4 was deemed to be an outlier. Survival including the outlier was 81% (* in Table 2.40). Survival without the outlier (4 replicates) was 97% (** in Table 2.40).

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 know 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 m – 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

To validate 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**].

2.5.3 Objectives

Assess the extent of fish habitat created by new hard substrate provided by subsea production structures installed for the Deep Panuke natural gas field. Compare species found and coverage of structures to previous years.

2.5.4 Sampling

2.5.4.1 Subsea Structures

Collect 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, SSIV valve and subsea wellheads and exposed sections of the export pipeline to shore) 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 (spring and summer 2015) and of the PFC area (July 2015) were provided on a hard-drive and DVD and viewed with video software. After initial viewing, inspection tasks, length and subsea structure were recorded for each video segment. A qualified marine taxonomist analyzed the general visual inspection (GVI) with the aid of 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 2015 was compared to the 2014 video data.

2.5.5.2 Cuprotect Coated Structures

Subsea inspection videos of structures coated with the Cuprotect antifouling products in the PFC riser/spools and wellhead areas (June 2015) were provided on a hard-drive DVD and viewed with video software. Cuprotect coated structures include sections of pipeline spool covers, flange covers, vortex induced vibration (VIV) suppression strakes, disposal flowline and export pipeline in the PFC riser caisson area. After initial viewing, inspection tasks, length and subsea structure were recorded for each video segment. A qualified marine taxonomist analyzed the general visual inspection (GVI) video with the aid of 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.

2.5.5.3 GEP and Flowlines

Videos of the export pipeline subsea inspection survey (May 2015) were provided on external hard drive and viewed with Visual Review video software. After initial viewing, exposed and unexposed sections of GEP and production flowlines were recorded for each video segment. A qualified marine taxonomist analyzed the video with the aid of inspection drawings to identify all fish and mega-fauna associated with each pipeline. Video clips of ~250 to ~500 m each from KP 23 to 98 (exposed GEP) from the 2015 survey data (same locations as surveyed in 2011, 2012, 2013 and 2014) were analyzed and quantitative values were recorded for all fish and epifauna encountered. 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.

Video was sub-sampled for the GEP video footage to analyze all exposed sections of the pipeline. Ten kilometre intervals were chosen starting at KP 23.222 and qualitative data was standardised to 1-km reaches. Fauna was assessed by major group in 8 videos across the exposed GEP for graphical analysis and compared with data obtained from the 2011, 2012, 2013 and 2014 surveys. It should be noted that not all of the GEP from KP 23 to KP 98 was inspected in 2015, therefore not all sections could be compared to previous years. Only video from KP sections 18 - 23 and 59 - 90 were surveyed.

Areas of the GEP and flowlines that were outside the sub-sampled area of exposed GEP from KP 23 to KP 98 were also reviewed. Remaining pipe from KP 18 to KP 23, KP 167

KP 170, and flowlines (coming from wellheads H-08, M-79A, E-70, F-70 and D-41) were reviewed and divided into exposed and buried pipe, and bottom types for the buried sections (*e.g.* covered in sand or rock). Abundance values were then given for each segment (SACFOR scale; Joint Nature Conservation Committee, 2011) and summarized into characterizing species for each bottom type.

2.5.6 Analysis QA/QC

2.5.6.1 Video:

- All identifications were agreed upon by two taxonomists and compared to species from the 2011, 2012, 2013 and 2014 reports for reference. All structures shown in the videos were identified using the commentary.

2.5.7 Results

2.5.7.1 Subsea Structures

- Abundances and species present were comparable to the 2014 survey of the WHPS at each location. As in 2014, the common species observed include the dominant blue mussel *Mytilus edulis*, the hydroid *Tubularia* spp., the orange-footed sea cucumber *Cucumaria frondosa*, the frilled anemone *Metridium senile*, and the sea star *Asterias vulgaris*.
- Like 2014, zonation was observed occurring on each WHPS in different locations. The bottom zone was mainly colonized by mussel (*Mytilus edulis),* sea cucumbers (*Cucumaria frondosa*) in varying densities, with the crabs (Cancer spp.), and the sea star *Asterias vugaris* on the surrounding seafloor. The top zone was colonized mainly by blue mussels (*Mytilus edulis*), frilled anemone (*Metridium senile)* and hydroids (Tubularia spp.) (**Table 2.42-Table 2.46; Figures 2.9a-e**). Dense mussels extended from 0.5-4.0 metres above the seafloor to the top of the structure. Total fouling of the WHPS was estimated to be between 85% to 95% for all structures. Percentage of marine growth coverage was 100% in most areas of the WHPS, except for areas that are periodically cleaned, such as the base of legs and the subsea tree panel. Increased coverage of *Tubularia sp*. was observed in 2015 compared to 2014, as it continues to grow with the frilled anemones, on top of blue mussel, especially

on the upper portion of the legs and upper horizontal brackets (**Table 2.42-Table 2.46; Figure 2.10**).

- Crustaceans included the occasional crab (*Cancer sp.*), which were usually on the surrounding seafloor. A lobster was observed near a concrete tunnel at the H-08 wellsite in July, and a blue lobster was observed under the base of a leg at the H-08 WHPS in August. Blue lobsters are rare (1 in 2 million) (Lobster Institute, University of Maine), and this variation in colour can be caused by a genetic mutation, resulting in elevated levels of protein.
- As in 2014, sculpin (*Myoxocephalus* sp.) was the only fish species observed that lives on the sea bottom on the WHPS in the 2015 survey.
- Zonation of the PFC legs was similar to 2014. 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 2.47; Figure 2.11**).
- A halibut was observed in July on the F-70 tunnel at the PFC.

Table 2.42 - April 2015 Survey of E-70 WHPS compared to August 2014 Survey

Wellhead Site	Structure	Fauna	August 2014 Abundance	April 2015 Abundance	April 2015 Number	Description
E-70	WHPS	*Metridium senile*	A	A	-	Some sea stars on surrounding seafloor. Dense mussel and hydroids. *Metridium* dense in patches. Some sea cucumbers on lower parts of the WHPS and surrounding seafloor.
		Tubularia? spp.	S	S	-	
		Mytilus edulis	S	S	-	
		Cucumaria frondosa	C	C/O	-	
		Asterias vulgaris	A	A	-	
		Henricia sp.	C	A	-	
		Tautogoabrus adspersus	~70	-	-	
	Seasea Tree	*Metridium senile*	C	C	-	Dense marine growth coverage (100%) on umbilcals coming from the tree. *Metridium* and hydroids on the top of
		Tubularia? spp.	S	S	-	
		Mytilus edulis	S	S	-	
		Asterias vulgaris	A	C	-	
		Henricia sp.	C	C	-	

Wellhead Site	Structure	Fauna	August 2014 Abundance	April 2015 Abundance	April 2015 Number	Description
		Tautogoabrus adspersus	20	-	-	the tree. Less marine growth on the tree panel, appears to have been cleaned.
		Porifera (encrusting)	-	O	-	

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

Table 2.43 - March 2015 Survey of F-70 WHPS Compared to August 2014 Survey

Wellhead Site	Structure	Fauna	August 2014 Abundance	March 2015 Abundance	March 2015 Number	Description
F-70	WHPS (March)	Porifera (encrusting)	R	-	-	Dense patches of *Metridium* on bottom of legs and top brackets. Dense mussels and hydroids. Mussels more evident on lower brackets. 100% marine growth coverage on most areas (that were not previously cleaned) Some sea stars present on surrounding seafloor.
		Metridium senile	S/A	S/A	-	
		Tubularia? spp.	A	S	-	
		Hydroids	S	S	-	
		Mytilus edulis	S/A	S/A	-	
		Cancer sp.	5	-	-	
		Cucumaria frondosa	A	-	-	
		Asterias vulgaris	C	C	-	
		Henricia sp.	C	C	-	
		Hemitripterus sp.	1	-	-	
		Pollachius sp.	~300	-	-	
		Tautogoabrus adspersus	~100	-	-	
		Unidentified fish	6	-	-	

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

Table 2.44 - April 2015 Survey of M-79A WHPS Compared to August 2014 Survey

Wellhead Site	Structure	Fauna	August 2014 Abundance	April 2015 Abundance	April 2015 Number	Description
M-79A	WHPS	*Metridium senile*	A	A	-	*Cucumarina* on bottom of legs and surrounding seafloor Less *Metridium* and mussels than other WHPS and more hydroids - recent cleaning? 100% coverage except for base of legs
		Tubularia? spp.	A	S	-	
		Campanulariidae? sp.	-	-	-	
		Ctenophora	C	-	-	
		Mytilus edulis	S	C	-	
		Cucumaria frondosa	O	F	-	
		Asterias vulgaris	C	C	-	
		Henricia sp.	-	C	-	
		Ophiuroidea	R	-	-	
		Myoxocephalus sp.	-	-	2	

Wellhead Site	Structure	Fauna	August 2014 Abundance	April 2015 Abundance	April 2015 Number	Description
		Pollachius sp.	-	-	-	
		Tautogoabrus adspersus	C	-	-	
		Unidentified fish	C		4	
	Subsea Tree	*Tubularia? spp.*	S	S		
		Mytilus edulis	A	A	-	
		Asterias vulgaris	C	C	-	
		Henricia sp.	C	O	-	
		Metridium senile	-	C	-	
		Pollachius sp.	-	-	1	
	Concrete mats	*Cucumaria frondosa*	-	S	-	
		Metridium senile	-	C	-	
		Cancer sp	-	-	1	

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

Table 2.45 - June 2015 Survey of D-41 WHPS Compared to 2014 December Survey

Wellhead Site	Structure	Fauna	December 2014 Abundance	June 2015 Abundance	June 2015 Number	Description
D-41	WHPS	Porifiera	R	-	-	*Metridium* dense in patches - dominant on top half of legs and top brackets Hydroids very dense in patches Hydroids 100% coverage on lower half of legs
		Metridium senile	S	S	-	
		Tubularia? spp.	S	S	-	
		Mytilus edulis	S	C	-	
		Cancer sp.	1	-	-	
		Cucumaria frondosa	C	-	-	
		Asterias vulgaris	C	C	-	
		Ophiuroidea	O	O	-	
		Myoxocephalus sp.	4	-	-	
		Tautogoabrus adspersus	~70	-	>100	
	Subsea Tree and Closing Spools	*Metridium senile*	S	S/A	-	100% marine growth coverage on structure *Mytilus edulis* (mussel) super abundant and underneath soft growth species such as hydroids and *Metridium* (appear to be growing on top of mussels).
		Tubularia? spp.	A	S/A	-	
		Hydoids	A	S/A	-	
		Mytilus edulis	S	A	-	
		Henricia sp.	-	C	-	
		Asterias vulagaris	C	C	-	
		Tautogoabrus adspersus	100	-	>200	
	Concrete Mats	*Cucumaria frondosa*	-	S	-	
		Tautogoabrus adspersus	-	-	50	
		Metridium senile	-	C	-	

Wellhead Site	**Structure**	**Fauna**	**December 2014 Abundance**	**June 2015 Abundance**	**June 2015 Number**	**Description**
		Asterias vulagaris	-	C	-	
	Concrete Protection Tunnel	*Cucumaria frondosa*	-	A	-	
		Tautogoabrus adspersus	-	10	-	
		Metridium senile	-	C	-	
		Asterias vulgaris	-	C	-	
		Myoxocephalus sp.	-	-	5	
	Closing spool	Hydroid	-	A	-	*Tautogoabrus adspersus* (Cunner) >50
		Metridium senile	-	A	-	

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

Table 2.46 - June 2015 Survey of H-08 WHPS Compared to 2014 September Survey

Wellhead Site	**Structure**	**Fauna**	**September 2014 Abundance**	**June 2015 Abundance**	**June 2015 Number**	**Description**
H-08	WHPS	*Metridium senile*	A	C	-	Less *Metridium* than other WHPS More mussels visible than other WHPS, less hydroid and *Metridium* coverage Sea cucumbers around base of legs only Soft growth on top of hard growth (mussels). Brittle stars, sculpin, sea stars and cancer sp. on surrounding seafloor.
		Tubularia? spp.	C	A	-	
		Mytilus edulis	S	S	-	
		Cucumaria frondosa	R	O	-	
		Asterias vulgaris	F	C	-	
		Myoxocephalus sp.	-	O	1	
		Pollachius sp.	S/A	-	-	
		Tautogoabrus adspersus	F	F	~10	
		Urophysis sp.	1	-	-	
		Cancer so.	-	O	6	
		Ophiuroidea	-	O	-	
		Henricia sp.	-	C	-	
	Subsea tree	*Mytilus edulis*	-	S	-	Close to 100% coverage Dense mussel
		Tubularia? spp.	-	S	-	
		Henricia sp.	-	C	-	
		Asterias vulgaris	-	C	-	
		Metridium senile	-	C	-	
	Concrete Mats	*Myxocephalus sp.*	-	C	5	
		Cucumaria frondosa	-	S	-	
		Asterias sp.	-	C	-	
		Euspira heros	-	O	1	
		Cancer sp.	-	O	1	
		Unknown fish	-	O	1	
	Concrete	*Cucumaria frondosa*	-	S	-	

Wellhead Site	Structure	Fauna	September 2014 Abundance	June 2015 Abundance	June 2015 Number	Description
	Protection Tunnel	*Myxocephalus sp.*	-	F	3	
		Asterias vulgaris	-	C	-	
	Closing spools	*Mytilus edulis*	-	A	-	100% coverage at top, 50% coverage or less at bottom.
		Hydroids	-	C	-	
		Asterias vulgaris	-	C	3	
		Henricia sp.	-	C	2	

Table 2.47 - Summer 2015 Survey of PFC legs Compared to 2014 Summer Survey

Wellhead site	Structure	Fauna	Summer 2014 Abundance	Summer 2015 Abundance	Summer 2015 Number	Description
PFC	Riser Caisson (June)	*Mytilus edulis*	S	S	-	Dense mussel coverage over the entire structure with frequent hydroids and sea stars over the entire structure from 15m water depth and below. 75-125mm thickness of marine growth on structure. *Metridium* senile more prevalent closer to surface around 15m water depth.
		Metridium senile	O	O	-	
		Asterias vulgaris	F	F	-	
		Tautogolabrus adspersus	25	-	>50	
		Unidentified fish	F	-	-	
		Ophiuroidea	-	R	1	
		Tubularia sp.		C	-	
	PFC Leg 1 (July)	*Metridium senile*	-	C	-	Few marine organisms at the base of the leg, around 10% coverage with some *Asterias*, *Metridium* and sea cucumbers. Dense mussels start around 5m 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 20m and up. Some *Metridium* is present closer to the surface (25m and up). Cunner were present at the base of all legs of the PFC.
		Tubularia? spp.	F	A	-	
		Mytilus edulis	A	S	-	
		Asterias vulgaris	C	A	-	
		Ophiuroidea	-	O	-	
		Cancer sp.	-	2	-	
		Tautogolabrus adspersus	C	A	>200	
		Pollachius sp.	-	-	>200	
		Unidentified fish	O	-	-	
		Henricia sp.	-	C	-	
	PFC Leg 2 (July)	*Metridium senile*	F	C	-	
		Tautogolabrus adspersus	-	-	~13	
		Tubularia? spp.	F	A	-	
		Mytilus edulis	S	S	-	
		Ophiuroidea	-	O	-	
		Cucumaria frondosa	-	O	-	
		Asterias vulgaris	C	C	-	
		Henricia sp.	-	O	-	
	PFC Leg 3	*Metridium senile*	F	C	-	

Wellhead site	Structure	Fauna	Summer 2014 Abundance	Summer 2015 Abundance	Summer 2015 Number	Description
	(July)	*Tautogolabrus adspersus*	-	-	3	
		Ophiuroidea	-	O	-	
		Tubularia? spp.	F	C	-	
		Henricia sp.	-	O	-	
		Mytilus edulis	S	S	-	
		Solaster endeca	-	R	1	
		Asterias vulgaris	C	-	C	
	PFC Leg 4 (July)	*Metridium senile*	F	F	-	
		Tubularia? spp.	F	F	-	
		Mytilus edulis	S	S	-	
		Ophiuroidea	-	O	-	
		Asterias vulgaris	F	C	-	
		Tautogolabrus adspersus	-	-	>250	
	Protection Tunnel (M79A)	*Cucumaria frondosa*	-	S	-	
		Metridium senile	-	O	-	
		Asterias vulgaris	-	O	-	
		Hemitripterus americanus	-	-	5	
		Henricia sp.	-	R	-	

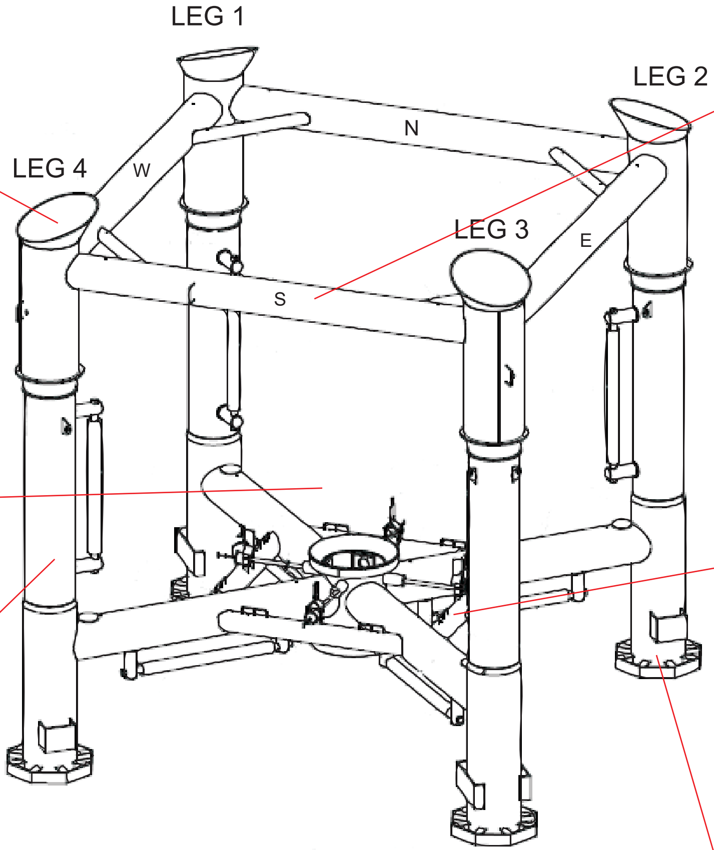
***** Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Station H-08

Dense mussels with frilled anemone and sea star at the top of Leg 4

Dense mussel coverage with sea stars and hydroids on the subsea tree / flowline.

Dense mussel with hydroids and frilled anemone at MG 10, on the lower part of Leg 4



Wellhead Protection Structure

Dense mussel with occasional seastars and frilled anemone on the south horizontal bracket.

Dense mussel and hydroids with sea stars on the lower level, between Legs 2 and 3.

Mussel, hydroids, sea stars, sea cucumbers and frilled anemone at the base of Leg 2.

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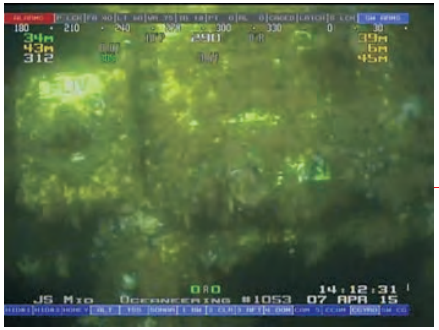
Figure 2.9a Wellhead Protection Structures and Associated Fauna at H-08

Figure 2.9a

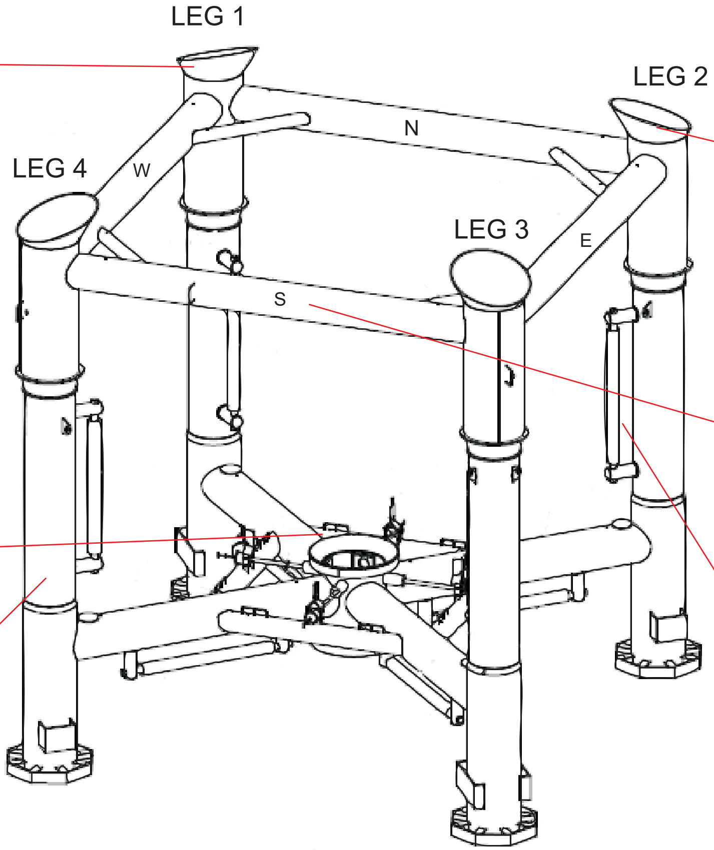
Station M-79A

Mussel with hydroids and frilled anemone at the top of Leg 1.



Dense hydroids on the subsea tree panel.

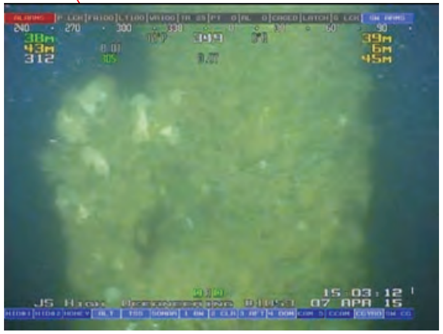
Hydroids and some frilled anemones on the lower part of Leg 4.



Wellhead Protection Structure

Mussel with hydroids on top, and occasional sea stars at the to of Leg 2.

South horizontal bracket with frilled anemone and sea star on top of blue mussel.



Dense mussel with hydroids over top, and some frilled anemone on Anode 6, mid-way up Leg 2.

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Figure 2.9b Wellhead Protection Structures and Associated Fauna at M-79A

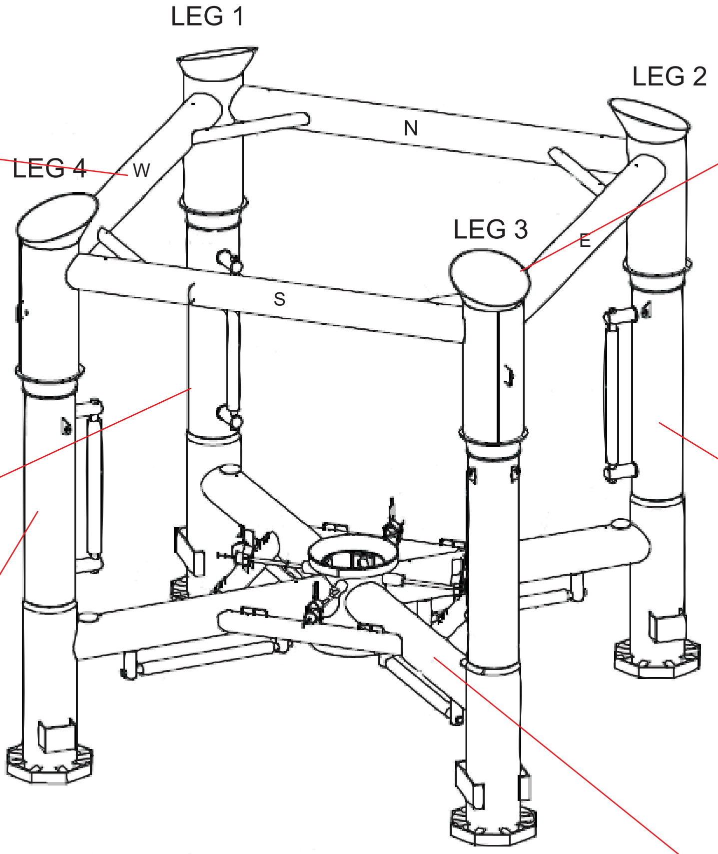
Figure 2.9b

Station F-70

West horizontal bracket, with dense blue mussel, hydroids, frilled anemone and sea stars

Mid-way up Leg 1. Dense mussel, covered in hydroids, frilled anemone and sea star.

Dense frilled anemone at the bottom Leg 4.



Wellhead Protection Structure

Dense frilled anemone at the top of Leg 3

Dense mussel with hydroids, frilled anemone and sea stars midway up Leg 2

Dense mussel with hydroids over top, interspersed with frilled anemone on the lower crossbar off of Leg 3.

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Figure 2.9c Wellhead Protection Structures and Associated Fauna at F-70

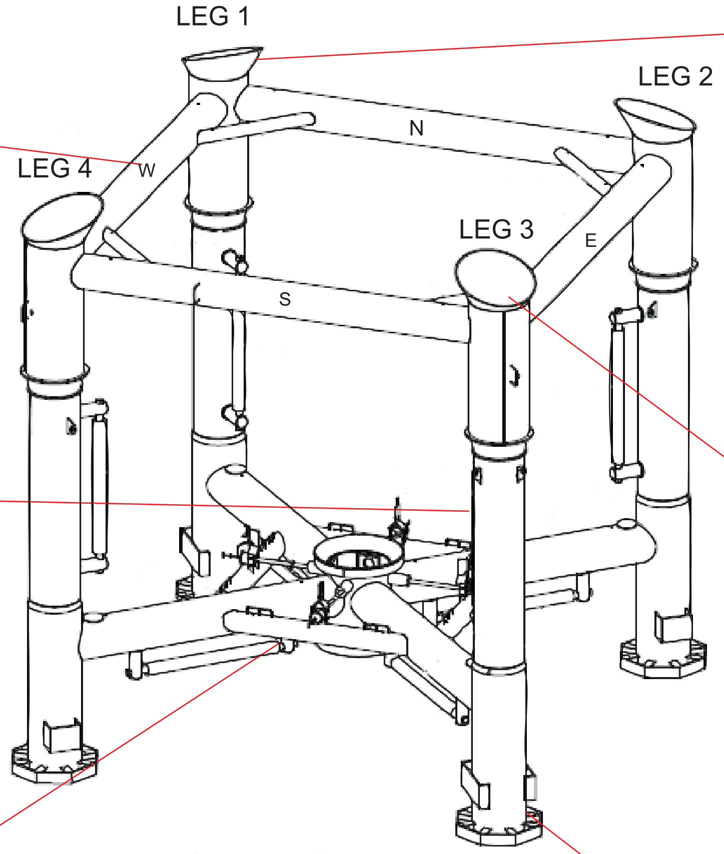
Figure 2.9c

Station D-41

Dense frilled anemone on the west horizontal crossbar between Legs 1 and 4.

Dense mussel and hydroid on Anode 7 on Leg 3.

Frilled anemone on the lower level off of Leg 3.



Wellhead Protection Structure

Dense frilled anemone on the top of Leg 1

Dense patches of frilled anemones at the top of Leg 3

Hydroids at the base of Leg 3.

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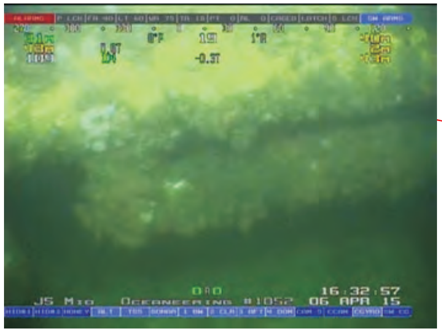
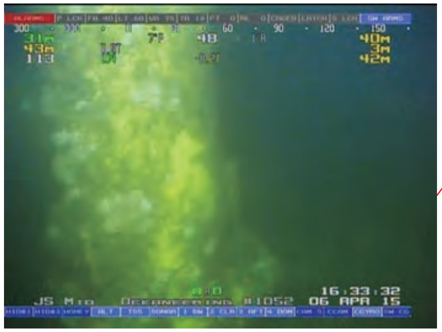
Figure 2.9d Wellhead Protection Structures and Associated Fauna at D-41

Station E-70

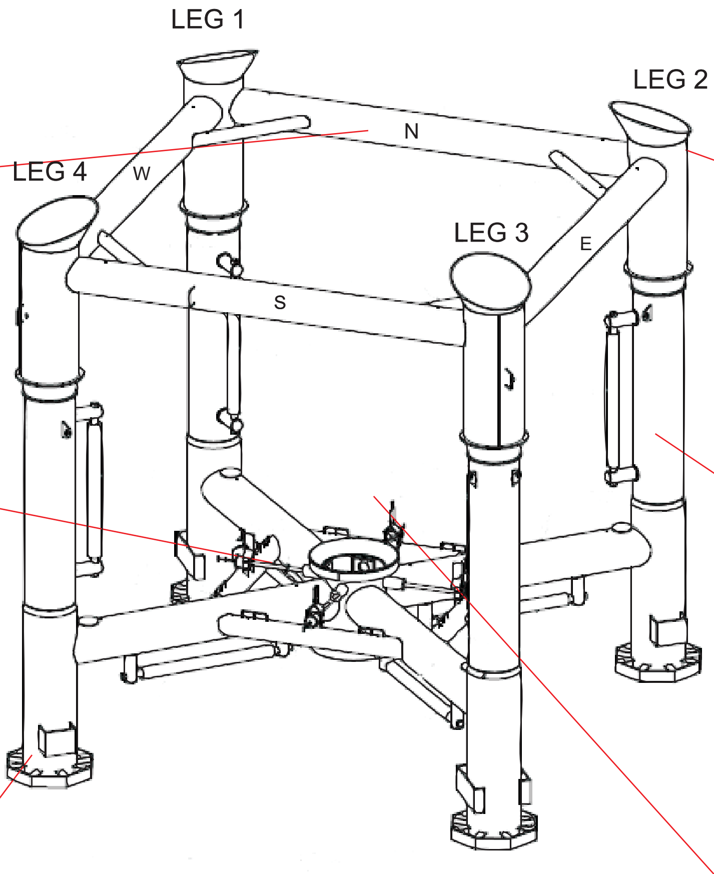
Dense mussel with hydroids and frilled anemone on the north crossbar between Legs 1 and 2.



Blue mussel with hydroids and frilled anemone on Anode 1.

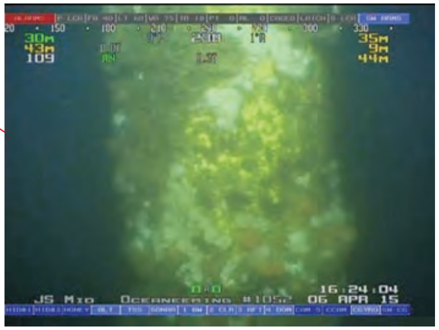


Some hydroid and frilled anemone at the bottom of Leg 4.



Wellhead Protection Structure

Dense frilled anemone and hydroids, likely on top of blue mussel at the top of Leg 2.



Hydroids and frilled anemone, midway up Leg 2.

Blue mussel and hydroids on the subsea tree.

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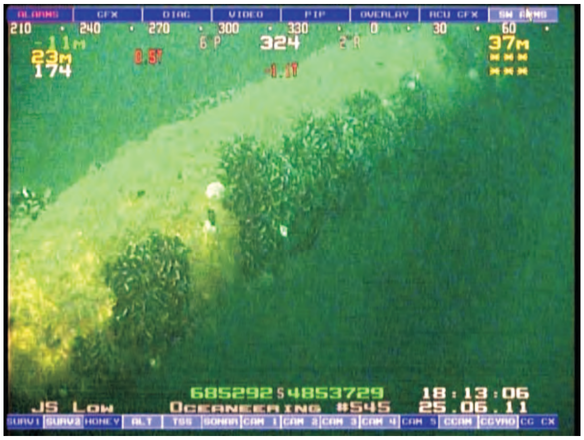
Figure 2.9e Wellhead Protection Structures and Associated Fauna at E-70

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.

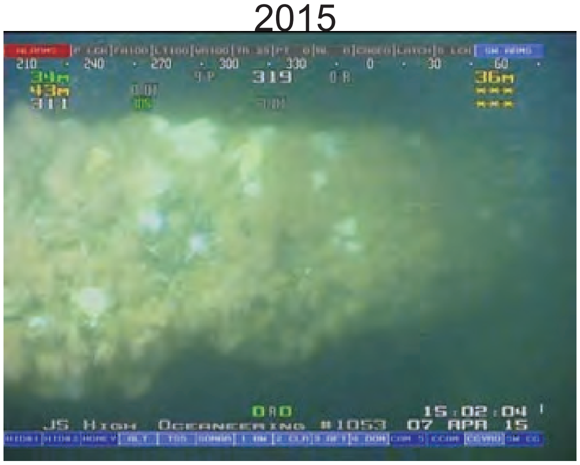
2013

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.

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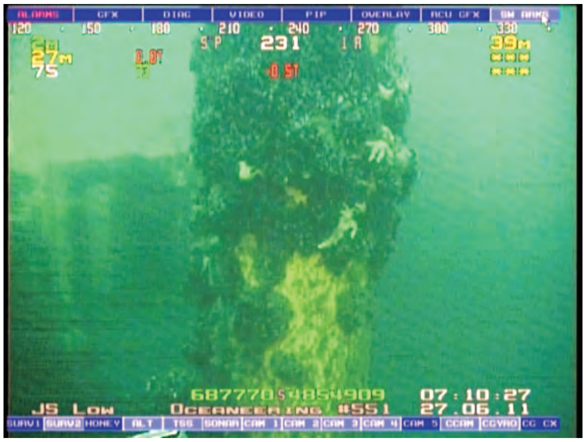
Figure 2.10a - Comparison of 2011-2015 Surveys at WHPS M79-A

Figure 2.10a

2011

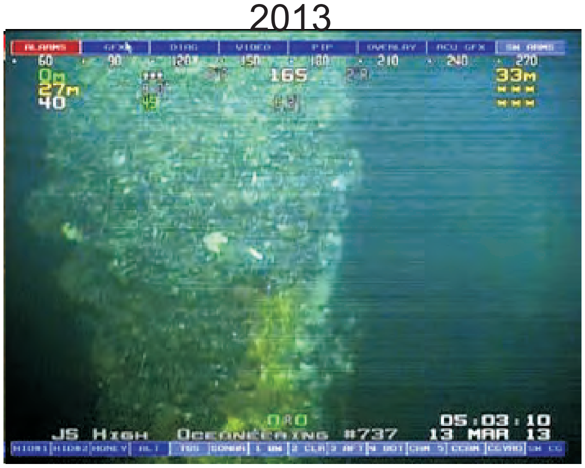


Blue mussel growth star at 4 m above the seafloor on Leg 2 at WHPS F-70 in the 2011 survey.

2012

Similar growth to Leg 2 in the 2012 survey.

2013



More dense blue mussel growth and coverage on Leg 2 at WHPS F-70 in the 2013 survey.

2014

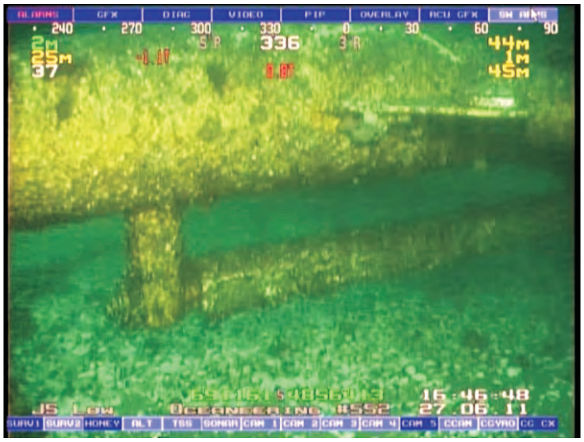
Dense mussel coverage, but also additional frilled anemone and hydroids in the 2014 survey.

2015

Additional frilled anemone, hydroids and seastars colonizing on top of dense blue mussel.

Figure 2.10b Comparison of 2011-2015 Surveys of Midway up Leg 2 at WHPS F-70 Figure 2.10b

2011



Little marine growth at the base of Leg 4 and HB01-4 at WHPS D-41 in the 2011 survey.

2012

Similar sparse marine growth at D-41 in 2012.

2013

Similar sparse marine growth at the base of a leg of WHPS D-41. Possible cleaning may have taken place.

2014

Dense mussel coverage on Anode 4. Increased numbers of frilled anemones in the 2014 survey, as opposed to sea cucumbers in 2013.

2015

Dense blue mussel and hydroid coverage (100%), with patches of frilled anemone in the 2015 survey at the base of Leg 4.

Figure 2.10c Comparison of 2011-2015 Surveys at the Base of Leg 4 at WHPS D-41 Figure 2.10c

2.5.7.2 Cuprotect Coated Structures

- Mussel species, *Mytilus edulis*, were a new species for Cuprotect coated structures and PFC area structures in 2013, and continue to be the dominant species in those areas into the 2014 and 2015 surveys. (**Table 2.48, Figure 2.12-2.13**).
- Dense mussels and some sea stars, hydroids and frilled anemones covered most part of PFC structure. Straps on Cuprotect coated structures were the main areas of colonization for species found such as the mussel *Mytilus edulis* and hydroid species. However, many closing spools and flange insulation covers had species growing on Cuprotect areas.
- D-41 flange insulation cover F3 had over 50% growth coverage, comprised of sea cucumbers, hydroids and *Metridium* sp.
- H-08 flange cover F3 had 50% coverage of *Metridium sp*. growth on Cuprotect areas, and F4 had 100% growth coverage, comprised of sea stars, mussel and hydroids. Flange insulation cover F3 at flowline F-70 had sea cucumbers on the Cuprotect region. M79-A and F-70 flange insulation covers had mussels and hydroids on straps only.
- The closing spool for E-70 had 1 *Asterias sp*. present, as well as hydroids.
- The F-70 closing spool had two hydroids and one sea cucumber.
- The D-41 closing spool bend had four sea stars and two hydroids present.
- M79-A closing spool had sea stars and sea cucumbers present after the bend near the seafloor.
- Cunner were the most dominant fish species around the Cuprotect coated structures, and were mainly seen around the base of the rider caisson and closing spools.

Table 2.48 - Cuprotect Coated Structures Summer 2014 Compared to Spring 2015

Wellhead site	Structure	Fauna	Summer 2014 Abundance	Summer 2015 Abundance	Summer 2015 Number	Description
PFC	Base of Riser Caisson (June)	*Tubularia? spp.*	-	A	-	
		Mytilus edulis	S	S	-	
		Asterias vulgaris	F	O	-	
		Cucumaria frondosa	C	-	-	
		Metridium senile	-	O	-	

Wellhead site	Structure	Fauna	Summer 2014 Abundance	Summer 2015 Abundance	Summer 2015 Number	Description
		Tautogolabrus adspersus	5	-	>100	
		Gadoid	-	2	-	
		Gadus morhua	-	1	-	
		Cancer sp.	-	1	-	
	GEP Closing Spool (June)	*Tautogolabrus adspersus*	-	-	>50	One clump of mussels growing on GEP closing spool with Cuprotect Sea cucumbers Super abundant on surrounding seafloor Sea stars Abundant on surrounding seafloor
		Mytilus edulis	-	R	-	
		Melanogrammus aeglefinus	-	-	1	
		Metridium senile	-	A	-	
		Asterias sp.	-	C	1	
	GEP Closing Spool Flange (June)	*Algal growth*	-	F	-	Slight algal growth, one sea star on joint piece. Abundant sea cucumber on surrounding seafloor. Occasional sea star on surrounding seafloor.
		Asterias sp.	-	C	1	
	GEP Closing Spool Near Mats (June)	*Metridium senile*	-	C	2	
		Asterias sp.	-	C	1	
		Tautogolabrus adspersus	-	-	~20	
E-70	Closing spool E-70 (Aug)	*Tubularia? spp.*	C	C	5	
		Mytilus edulis	C	-	-	
		Tautogolabrus adspersus	~20	-	-	
		Asterias sp.	-	-	1	
F-70	Closing spool F-70 (Aug)	*Metridium senile*	C	-	-	Only two hydroids on actual Cuprotect area. Many hydroids and mussels on straps between strakes. Sea cucumbers on closing spool near seabed.
		Tubularia? spp.	C	C	-	
		Mytilus edulis	C	C	-	
		Asterias vulgaris	C	-	-	
		Cucumaria frondosa	-	C	2	
	F1 Insulation cover	*Mytilus edulis*	-	C	-	Mussels and hydroids on straps
		Tubularia? spp.	-	C	-	
D41	D41 Closing Spool (June)	*Asterias sp.*	-	C	4	Mussel and hydroid present

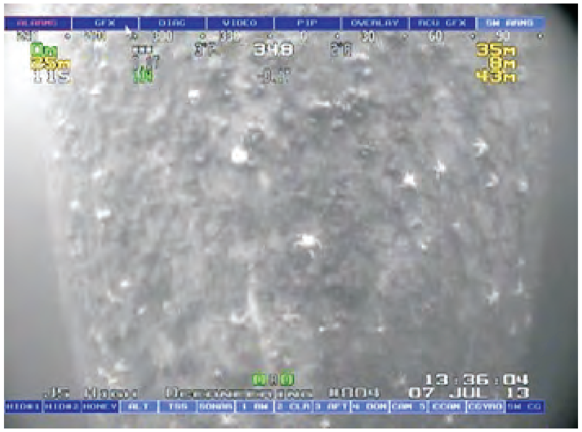
Wellhead site	Structure	Fauna	Summer 2014 Abundance	Summer 2015 Abundance	Summer 2015 Number	Description
		Tubularia? spp.	-	C	2	on straps, growth outward. Cuprotect on closing spool bend had four sea stars and two hydroids.
		Mytilus edulis	-	C	-	
M79-A	Closing spool M79-A (June)	*Tubularia? spp.*	A	A	2	Mussels and hydroids on straps, with growth outward from them Two hydroids Sea stars and sea cucumber on closing spool bend near seafloor
		Mytilus edulis	A	A	-	
		Asterias vulgaris	C	-	2	
		Cucumaria frondosa	-	-	3	
	F1 Flange cover (June)	*Mytilus edulis*	-	F	-	Mussel and hydroids on straps
		Tubularia? spp.	-	F	-	
	Flowline at PFC (June)	*Mytilus edulis*	-	O	-	Cuprotect areas seem to be free of marine growth Possibly some growth (hydroids on strakes)
		Tubularia? spp.	-	O	-	
F-70	F-70 Flange (Aug)	*Metridium senile*	A	-	-	100% coverage
		Mytilus edulis	A	-	-	
	F4 Flange Insulation Cover (F-70) (Aug)	*Tubularia? spp.*	C	-	-	
		Mytilus edulis	C	-	--	
		Cucumaria frondosa	C	-	-	
	F3 Flange Insulation Cover Insulation Cover (F-70) (Aug)	*Cucumaria frondosa*	C	-	-	
D-41	F3 Insulation cover (June)	*Cucumaria frondosa*	-	A	-	50% coverage. Growth on Cuprotect coated area
		Metridium senile	-	C	-	
	F4 Insulation cover (June)	*Cucumaria frondosa*	-	C	-	
		Tubularia? spp.	-	O	-	
		Henricia sp.	-	--	1	
		Cancer sp.	-	-	1	
	Closing Spools (June)	*Asterias sp.*	-	-	3	Sea raven near by
		Henricia sp.	-	-	2	
		Euspira heros	-	-	2	
		Cucumaria frondosa	-	-	12	
	F3 Insulation Cover (June)	*Cucumaria frondosa*	-	C	-	Hermit crabs and moonsnails in surrounding area
		Henricia sp.	-	-	1	

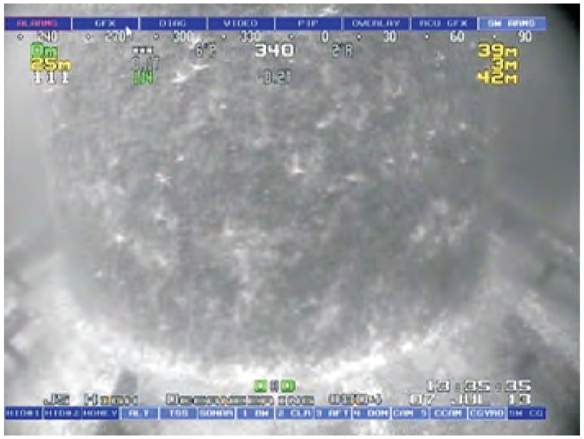
Wellhead site	Structure	Fauna	Summer 2014 Abundance	Summer 2015 Abundance	Summer 2015 Number	Description
		Metridium senile	-	-	10	(on strap) Over 50% coverage on Cuprotect insulation cover
		Asterias sp.	-	-	2	
		Tubularia? spp.	-	A	-	
	F4 Insulation Cover (June)	*Henricia sp.*	-	C	-	100% coverage
		Mytilus edulis	-	S	-	
		Tubularia? spp.	-	A	-	

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

2013 Survey


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


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


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

2014 Survey


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


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


Less marine growth than 2013, possibly due to cleaning.

2015 Survey

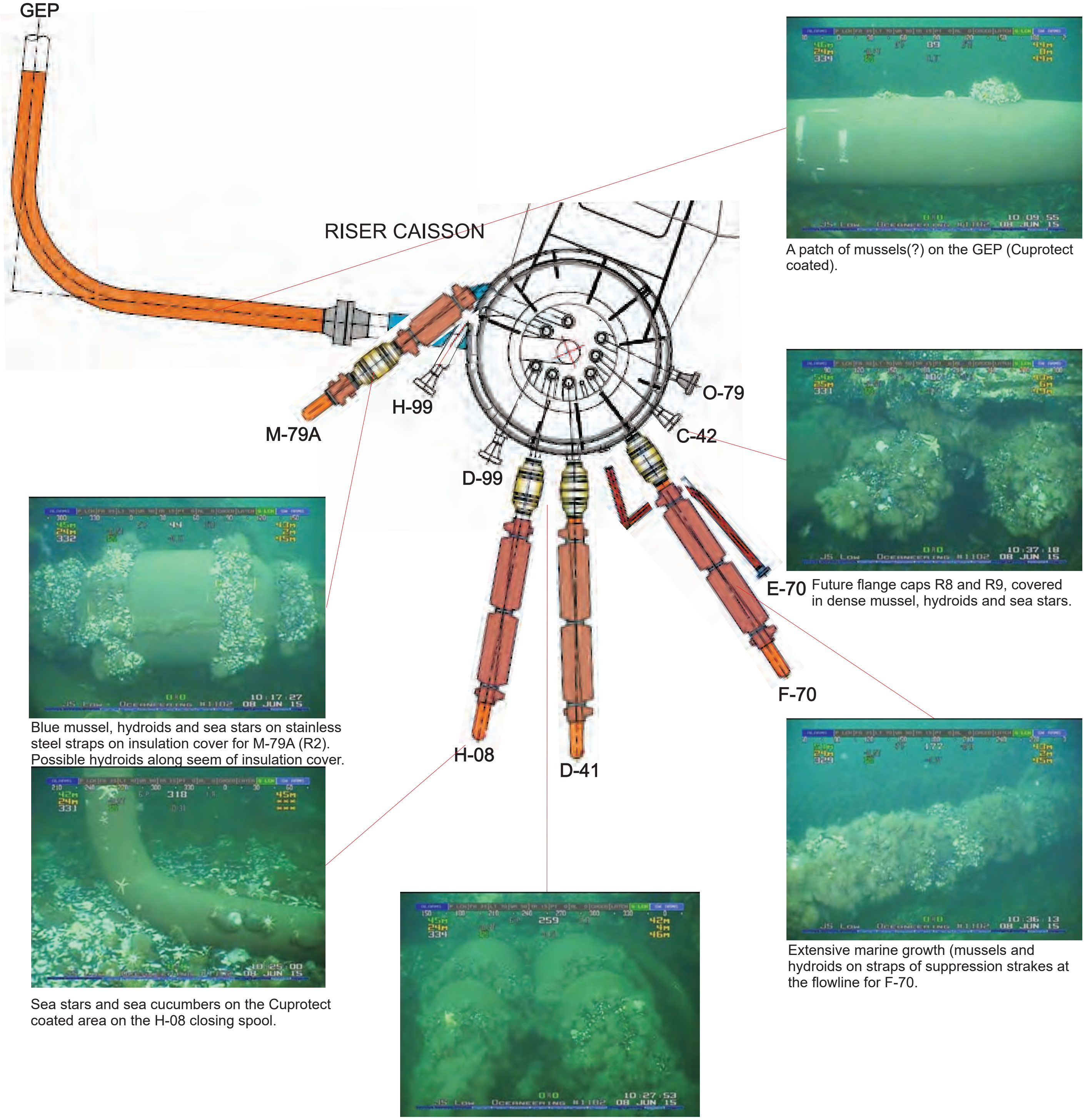

Similar mussel coverage to 2014 near the top of the leg with some possible *Metridium senile*.


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


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

Figure 2.11 - Comparison of PFC Legs from 2013, 2014 and 2015 survey

PFC Subsea Riser Caisson



A patch of mussels(?) on the GEP (Cuprotect coated).

Future flange caps R8 and R9, covered in dense mussel, hydroids and sea stars.

Blue mussel, hydroids and sea stars on stainless steel straps on insulation cover for M-79A (R2). Possible hydroids along seem of insulation cover.

Extensive marine growth (mussels and hydroids on straps of suppression strakes at the flowline for F-70.

Sea stars and sea cucumbers on the Cuprotect coated area on the H-08 closing spool.

Flange insulation covers for H-08 (right) and D-41 (left). Mussel and hydroid colonization on straps around the insulation covers and suppression strakes.

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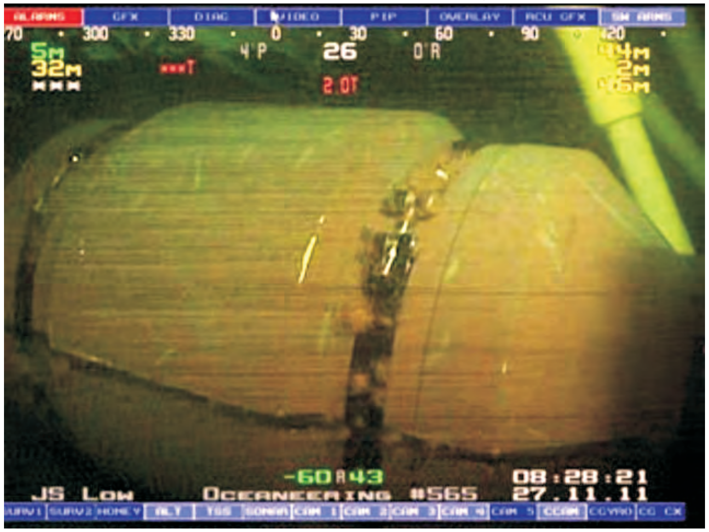
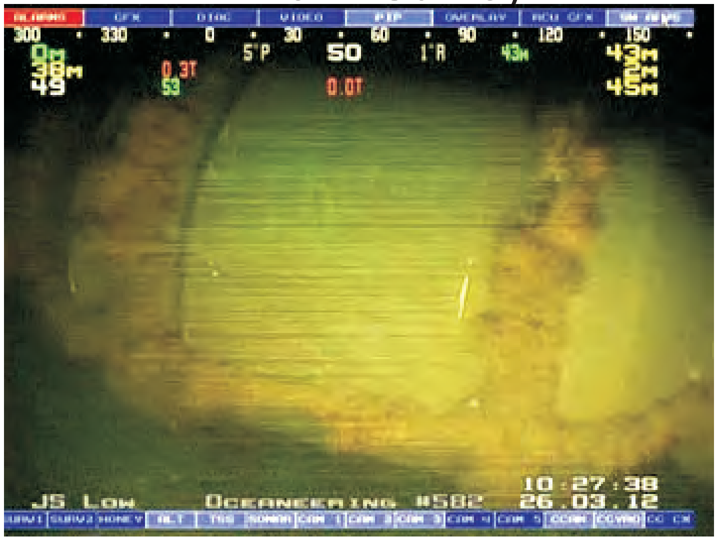
Figure 2.12 Photos of Cuprotect Coated Structures at the Riser Caisson Figure 2.12

2011 Survey



Tubularian hydroids sparsely colonizing straps of insulation cover of flowline M-79A in 2011 the survey

2012 Survey



Significantly greater colonization of Tubularian hydroids on straps of insulation cover M-79A flowline in 2012

2013 Survey

Similar coverage for colonization on the straps of the insulation cover for the M-79 flowline in 2013. The organisms colonising have changed from hydroids to primarily blue mussel.

2015 Survey

Similar mussel growth to 2013, with additional hydroids. Possible hydroid colonization along the horizontal seam of the insulation cover. (2014 photo not good quality to compare).

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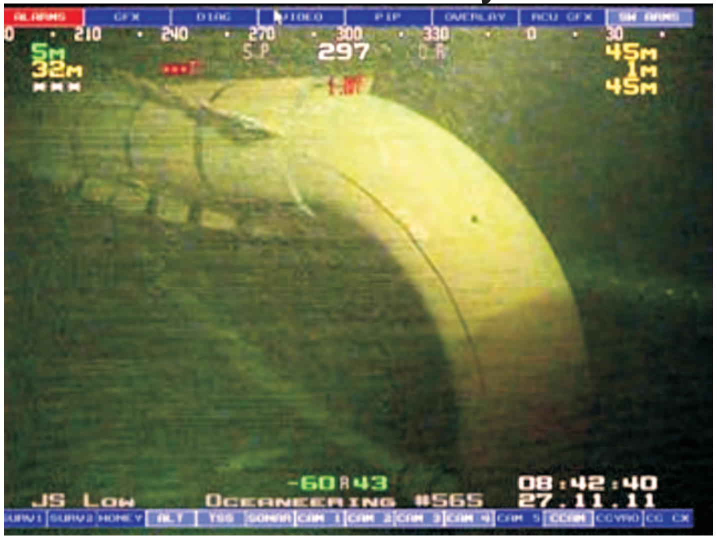
Figure 2.13a Comparison of 2011, 2012, 2013 and 2015 Cuprotect Coated M-79A flange Insulation Cover

Figure 2.13a

2011 Survey



Absence of Tubularian hydroids on suppression strakes of D-41 in the 2011 survey.

2012 Survey

Colonization of Tubularian hydroids on supression strakes of D-41 in 2012. Note the colonized in 2012 does not have any straps in the general area in 2011.

2013 Survey

Colonization of blue mussel and hydroids on the supression strakes of D-41 in the 2013 survey. The majority of colonization is on the straps, but some hydroids are starting to colonize inbetween.

2015 Survey

Increase in blue mussel from 2013, and decrease of hydroids present. Possible sea stars.

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Figure 2.13b Comparison of 2011, 2012, 2013 and 2015 Cuprotect Coated Strakes on the D-41 Flowline Figure 2.13b

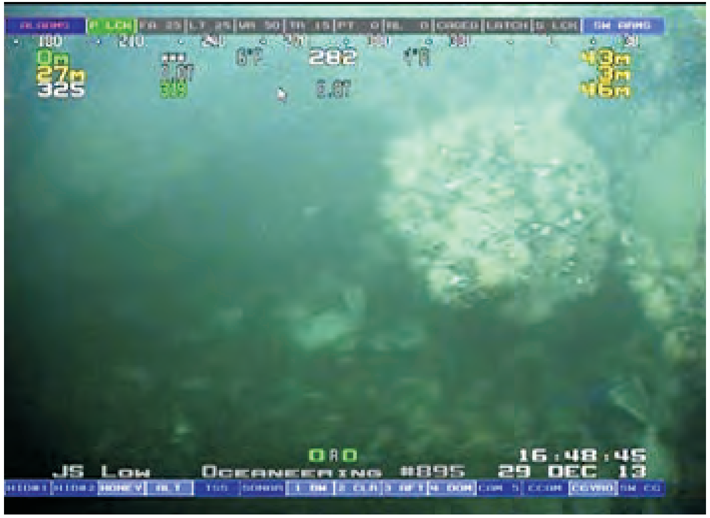
2011 Survey

Some hydroid coverage on future flange cap R-8 in 2011.

2012 Survey

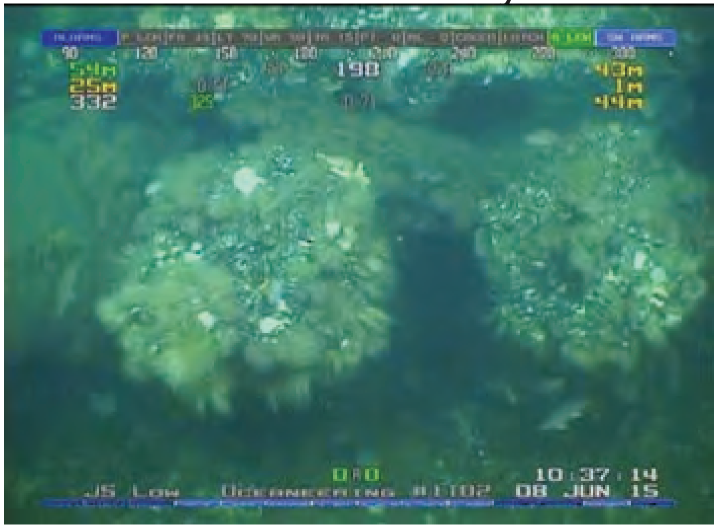
Increased coverage of future flange caps R-8 and R-9 by hydroids in the 2012 survey.

2013 Survey



100% coverage of future flange cap. Increased blue mussel colonization with hydroids interspersed, in the 2013 survey.

2015 Survey



Similar coverage of mussel and hydroids (100%) as 2013. Additional sea stars present on future flange caps R-8 and R-9 in the 2015 survey.

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Figure 2.13c Comparison of 2011, 2012, 2013 and 2015 on Future Flange Caps

Figure 2.13c

2.5.7.3 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 Appendix H, Fish Habitat Alteration Video Assessments; Figures 2.14 to 2.19**);
- Thirteen video clips were analysed along the GEP in 2015, as opposed to the usual 36 video clips that have been analyzed in previous years. The GEP was not surveyed from KP 23.505 to KP 59.965, and from KP 90.034 to KP 166.910. Because of the missing video clips, the 2015 numbers were compared to the same 13 video clips of 2014.
- 12912 redfish were seen in the 13 videos analyzed in 2015 compared to 14653 in 2014. These fish were commonly found wherever the pipeline created a hollow pocket in the seafloor. 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 (**Figure 2.16**).
- Thirty-four Atlantic cod were seen in the 13 videos analyzed in 2015. In 2014, 115 individuals were seen in the same 13 videos analyzed. 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. In 2015, 94 unidentified gadoids were seen along the 13 analyzed clips of the GEP. In 2014, 9 unidentified gadoids were found in the analyzed sections of pipe along the GEP (**Figure 2.16**). Seasonal differences could also account for a difference in numbers, the 2014 video was collected in June, and the 2015 video was collected in May.
- No flatfish (Pleuronectidae) were observed in 2015 video clips. In 2014, 18 flatfish were observed (in 13 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. For example, no flatfish were observed in 2013. (**Figure 2.16**).
- Numbers of Atlantic wolffish increased from 2014 to 2015. A total of 29 Atlantic wolffish were found in the 13 video clips analysed, compared to 16 in same 13

video clips in 2014, and 22 Atlantic wolffish (*Anarhichas lupus*) found in the 36 sections analyzed of the GEP in 2014. The Atlantic wolffish is notable, as it is considered a species of special concern under the Species at Risk Act. In many of the 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 2.16)**.

- Snow crab (*Chionoecetes opilio*) were observed in 9 of the 13 videos analyzed in 2015, totalling to 43 individuals sighted. In 2014 snow crab was observed in 33 of 36 videos analyzed, totalling 1352 individuals sighted. In the comparable 13 video clips, 213 snow crab were observed and present in 10 out of the 13 videos. In 2015, 1031 Jonah crabs (*Cancer borealis*) were observed in the 13 videos analyzed. In 2014, 1285 individuals observed in the 13 videos analyzed. No hermit crabs (*Pagurus sp*.) were observed in 2015 videos analyzed. One hermit crab was observed in the 13 video clips analyzed in 2014. This may be due to video quality, as many hermit crabs are small in size. Fifteen Northern Stone crabs (*Lithodes maja*) were observed in the 13 video clips from 2015. 66 individuals were observed in the 13 clips in 2014 (**Figure 2.17**).
- Like past survey years, crustaceans (**Figure 2.17**) were observed on video sitting on top of the pipe and climbing on it.
- 5651 commonly observed sea stars (*Asterias* sp. and *Henricia* sp.) were present in the 13 video clips analyzed in 2015 (**Figure 2.15**). In comparison, 25557 sea stars were found in the same video clips in 2014. The small size of many of the sea stars inhabiting the pipeline makes it difficult to obtain exact numbers. Superior video quality in 2012 and 2014 may be a factor in decreased numbers of the 2013 and 2015 surveys. As mentioned in the 2012 survey report, common sea star numbers went up by almost 150% compared to 2011, possibly due to video quality, making comparison between the annual surveys difficult to interpret.
- Comparison of faunal diversity by major group between the 2011, 2012, 2013, 2014, and 2015 surveys are shown in **Figure 2.15**. The graphs indicate a similar abundance of organisms for many species groups across the 8 transects selected. Notable differences are the decrease in echinoderm numbers at KP 64, 73 and 83, and the decrease in fish numbers at KP 73. Due to the small size and abundance of echinoderms. Video quality likely plays a factor in the echinoderm

numbers reported from year to year. Video and lighting also plays a factor in the number of fish reported.

- Many dead crabs, or crab exoskeletons from molting were found near the GEP. In 2015 12 of the 13 videos analyzed had dead crabs, ranging from 1 to 20 in each video clip. In 2014 at least 17 of the 36 videos analyzed had dead crabs present, ranging from 1 to 12 in each video. The majority were Jonah crabs, and only 1 individual was snow crab.
- Garbage and debris were also found at the GEP, which appears to act as a physical barrier that traps garbage. Garbage was found in at least 10 of the 13 videos analysed. The most common item found were beer/soda cans, followed by rubber fishing gloves, glass bottles and other debris (**Figure 2.19**).
- Flowlines from the PFC to the wellheads are mostly buried, either with rock or sand. (**Figure 2.18**). The most abundant species were consistent across all five flowlines. Common species included sea cucumber (*Cucumaria frondosa*), *Cancer sp*., and sea stars. In the rocky areas, sea cucumbers were the most prevalent species, usually being super abundant. In sandy areas the most dominant species were sea stars, being “Occasional” to “Frequent” on the SACFOR scale. The majority of the video for the flowlines was of poor quality, so it was difficult to identify to a species or genus level.
- Buried sections of the GEP and flowlines were covered by sand, rock, or a mixture of the two (**Table 2.49**). Dominant species found on the flowlines in 2015 were mostly consistent with those found in the 2014 survey. The main epifauna found on sandy sections of the buried flowlines and GEP were sea stars, sand dollars, and the occasional Jonah crab (*Cancer borealis*). In 2014, other species that were found in sandy sections of the buried flowlines included flatfish, gadoids (cod, pollock or haddock), and hake. In the 2015 survey, only the occasional sculpin was observed on the flowlines (E-70 and H-08), as well as two unidentified fish (one in a sand-rock section of the H-08 flowline and one at the concrete mat at F-70). Epifauna on the rocky sections of the GEP and flowlines were mainly sea cucumbers and sea stars, with the occasional Jonah crab. On exposed sections of the flowlines, sea cucumbers were super abundant. On concrete mattresses sea cucumbers were also super abundant, and on concrete protection tunnels, sea cucumbers were frequent to super abundant, with occasional sea stars. Uncommon, notable species found on the flowlines was a

sunstar found at the D-41 flowline. Decreased species diversity from 2014 to 2015 is likely due to poor video quality from the 2015 survey.

- Video footage from KP 167 to KP 170 was provided. The video quality was poor throughout the videos. No exposed sections of pipe were visible. Substrate types consisted of rock dumps and sand. Rock dumps appeared to be covered in sea cucumbers, with possibly occasional sea stars. Sandy sections of buried pipeline did not have any visible species, but this is likely due to the poor video quality due to high amounts of marine snow.

Table 2.49 - Species abundances along flowlines by substrate type – May 2015

Flowline	Substrate	Species	Abundance
D-41	Sand	Sea cucumber	O
		Sea star	O
		Sand dollar	O
		Cancer sp.	O
	Rock	Sea cucumber	S
		Sea star	O
		Cancer sp.	O
		Sunstar	R
	Rock-Sand	Sea cucumber	C
		Sea star	F
	Sand-Rock	Sea cucumber	A
	Sand-Shell	Kelp	O
		Sea star	O
		Sea cucumber	R
		Sand dollar	O
E-70	Sand	Sea star	F
		Sand dollar	F
		Sea cucumber	R
		Sculpin	O
	Rock-Shell	Sea cucumber	S
		Sea star	F
	Sand-Shell	Sea star	F
		Sea cucumber	O
	Rock	Sea cucumber	S
		Sea star	F
	Concrete Mat	Sea cucumber	S
		Sea star	C
	Concrete tunnel	Sea cucumber	C
		Sea star	O
F-70	Exposed Flowline	Sea cucumber	A
	Rock	Cancer sp.	O
		Sea star	F

Flowline	Substrate	Species	Abundance
		Sea cucumber	S
	Sand	Sea star	O
		Sea cucumber	C
		Sand dollar	C
	Concrete tunnel	Sea cucumber	F
		Sea star	F
	Rock-Sand	Sea cucumber	C
		Sea star	F
	Concrete mats	Sea cucumber	C
		Sea star	O
		Unidentified fish	C
H-08	Sand	Sea cucumber	O
		Cancer sp.	O
		Sand dollar	R
		Sea star	O
	Sand-Rock	Sea cucumber	O
		Cancer sp.	R
		Sea star	O
		Unidentified fish	R
	Rock	Sea cucumber	A
		Sculpin	O
		Sea star	O
		Cancer sp.	O
	Rock-Sand	Cancer sp.	O
		Sea star	F
		Sea cucumber	A
	Concrete mats	Sea cucumber	A
M79-A	Sand	Sea cucumber	O
		Sea star	O
	Rock	Sea cucumber	S
		Sea star	O
	Concrete tunnel	Sea cucumber	S
		Sea star	F

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

2.5.8 Summary and Conclusions

2.5.8.1 Subsea Structures

- Epifauna colonization of WHPS at all well site locations observed varied little from the 2014 survey. 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 and base of the riser caisson. For example, at WHPS F-70 pollock were present in large numbers in the 2014 summer video survey, compared to the spring 2015 video survey, where no pollock were present.
- Zonation of the PFC legs was similar to 2014. 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 2.47; Figure 2.11**).
- Wellheads and protective structures appear to continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures, as mentioned in the 2006 EA predictions. The structures are attracting fish from the surrounding areas and providing shelter in an otherwise relatively featureless seafloor.
- Notable species include a lobster at the H-08 concrete protection tunnel, and a blue lobster at the base of a WHPS leg.

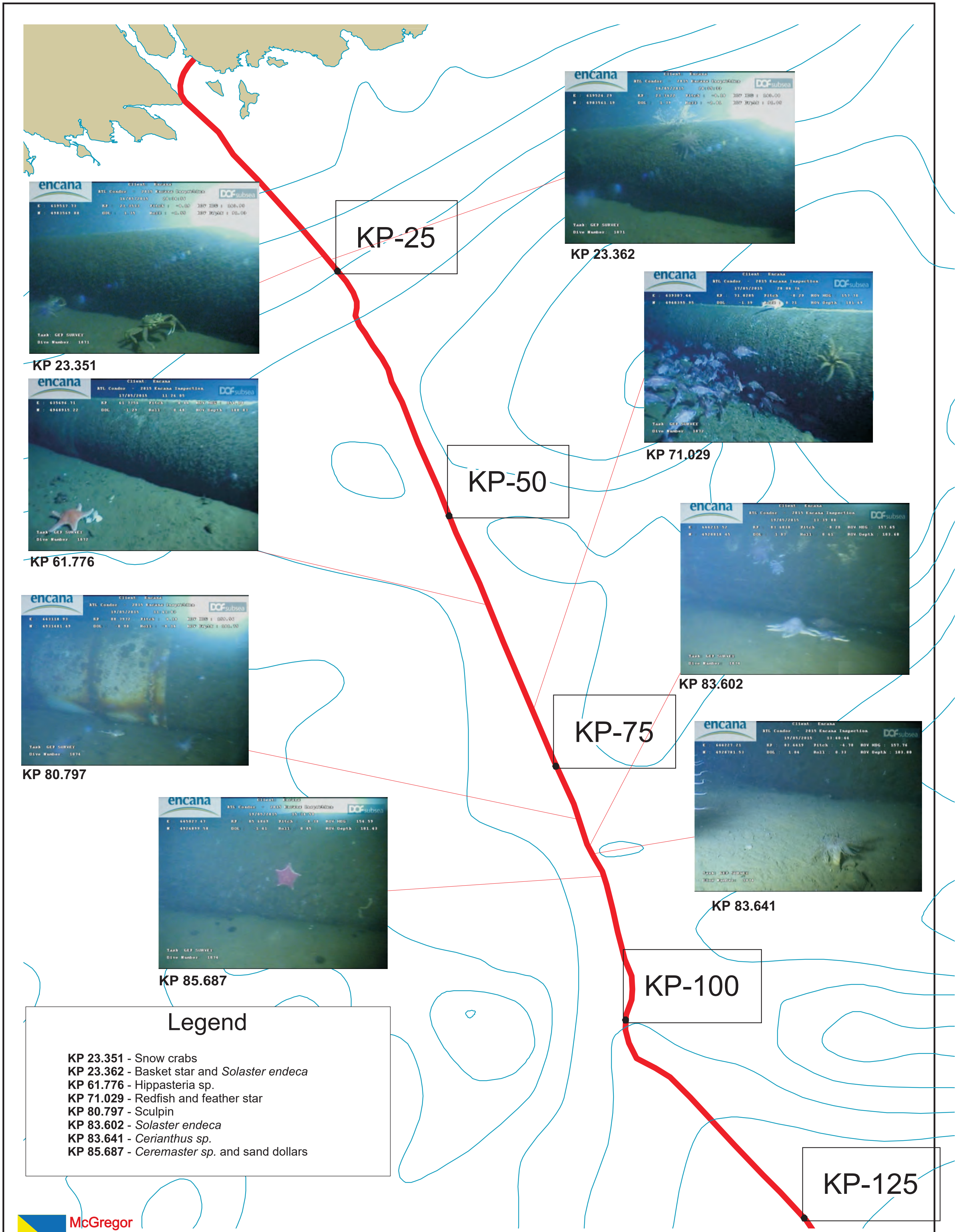
2.5.8.2 Cuprotect Coated Structures

- The main colonizing species of epifauna on non-Cuprotect coated structures continues to be the blue mussel *Mytilis edulis.* Non-Cuprotect coated structures around the base of the riser caisson include the future flange caps, sandbags and concrete protection mats, and the Inconel 625 steel straps which hold insulation covers in place.
- Structures with Cuprotect coating continue to be free mostly free of epifaunal growth. Exceptions included a few sea stars, hydroids and sea cucumbers on flange insulation covers and closing spools.

2.5.8.3 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 cod) and invertebrates.

- Commercial fish species recorded from the video analysis were Atlantic cod, pollock, haddock, redfish and hagfish.
- Commercial crustaceans observed in the analyzed video were snow crabs and Jonah crabs. Jonah crabs were the most abundant crustacean in the 13 videos analysed, which is consistent with the same video sections of 2014. American lobsters were not observed in 2015 (in the 13 video clips analysed).
- Other commercial invertebrates observed include the orange-footed sea cucumber.
- No new species found this year near the GEP in the video clips analysed.
- Atlantic wolfish were observed near the GEP, and appear to be using it as a refuge burrow. Numbers observed at the GEP are increasing year to year.
- 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 pipe or sitting on top of it in this particular project, however, as the pipe is not a physical barrier for other crustaceans found near the GEP, 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, dead crustaceans or possible exoskeletons from molting were found along the GEP in 2015.
- Garbage and debris continue to collect at the GEP, due to it being a physical barrier. The most common items are beer/soda cans and rubber fishing gloves.
- Habitat/substrate types along the flowlines were consistent with previous years and are a mix of sandy and rocky sections. Each substrate continues of have core groups of species inhabiting them. Sandy areas are mainly inhabited by sea cucumbers, sea stars, sand dollars and occasional Jonah crabs. Rocky areas are inhabited by sea cucumbers, with occasional sea stars and crabs. Exposed flowlines and other structures such as concrete mats and tunnels were colonized by sea cucumbers. No new species were observed in the flowline areas in the 2015 survey.



Legend

KP 23.351 - Snow crabs
KP 23.362 - Basket star and *Solaster endeca*
KP 61.776 - Hippasteria sp.
KP 71.029 - Redfish and feather star
KP 80.797 - Sculpin
KP 83.602 - *Solaster endeca*
KP 83.641 - *Cerianthus sp.*
KP 85.687 - *Ceremaster sp.* and sand dollars

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GeoScience
Limited

Figure 2.14 Representative Stills from ROV Footage Along GEP

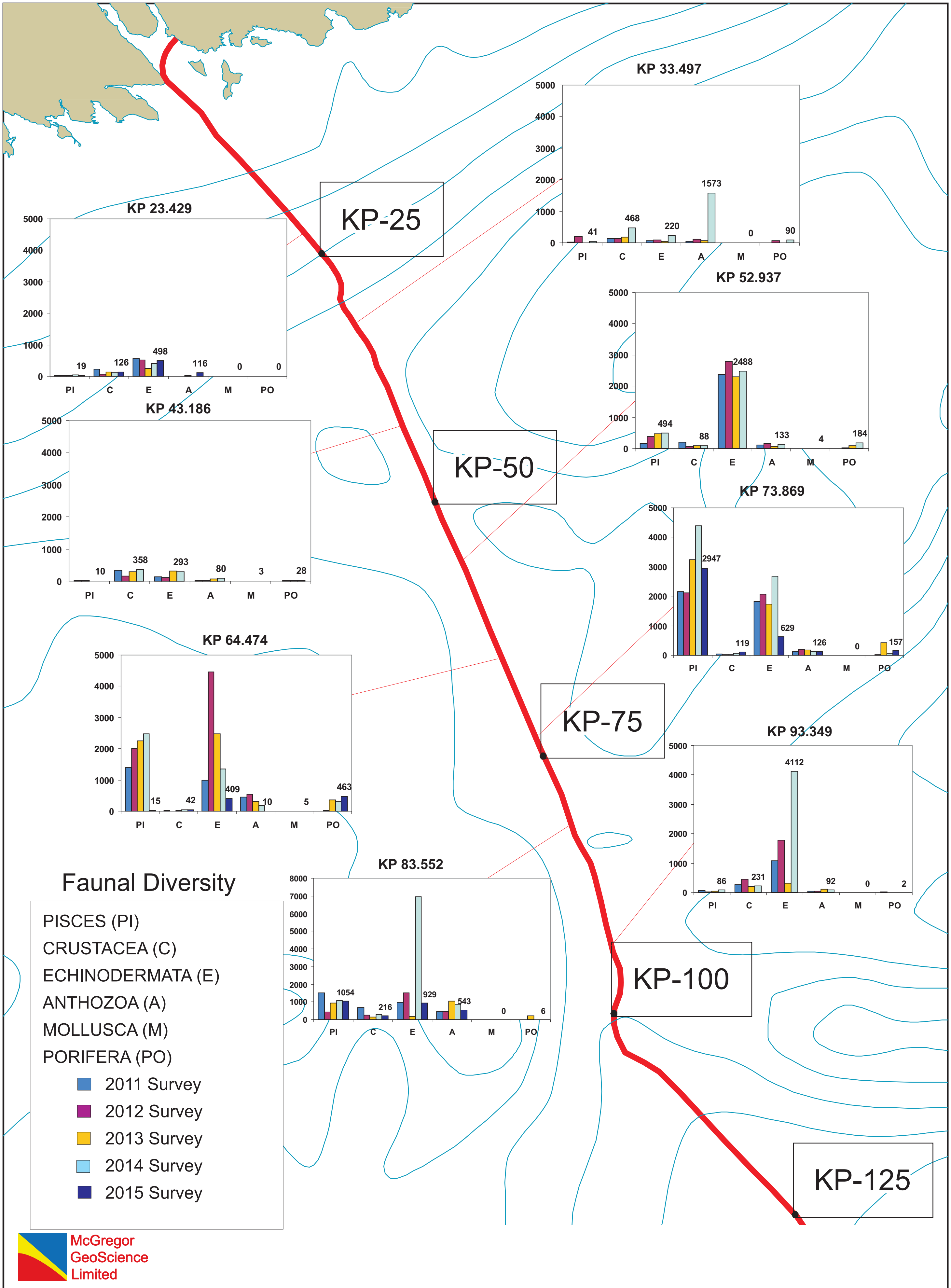
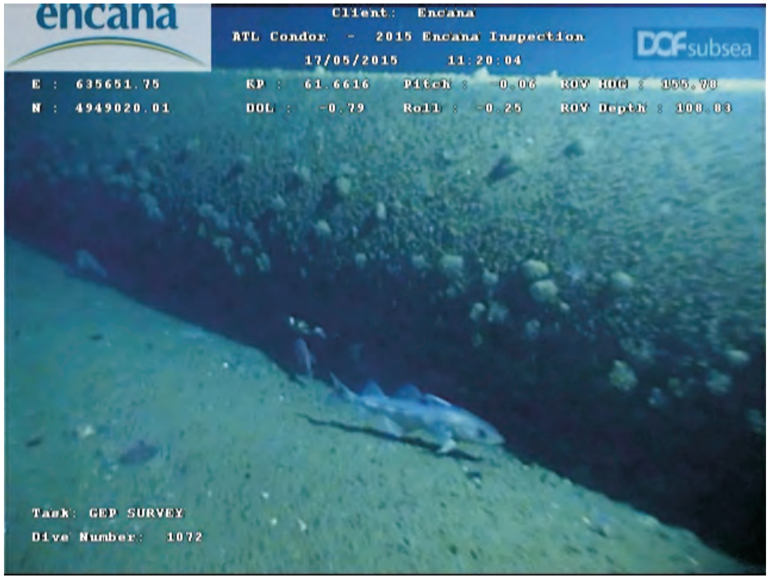


Figure 2.15 Standardized Faunal Composition of Exposed GEP at 10 km Intervals from 2011-2015 Survey

Figure 2.15



A Gadoid at KP 61.66.

Redfish at KP 85.59.

A Halibut on top of the F70 tunnel at the PFC south face.

A wolffish at KP 85.58.

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Figure 2.16 Fish Diversity from the 2015 Video Survey

A lobster along the GEP at KP 20.95.

A blue lobster at WHPS H-08

Three Northern Stone Crabs at KP 80.72.

A Jonah crab on the GEP at KP 85.55.

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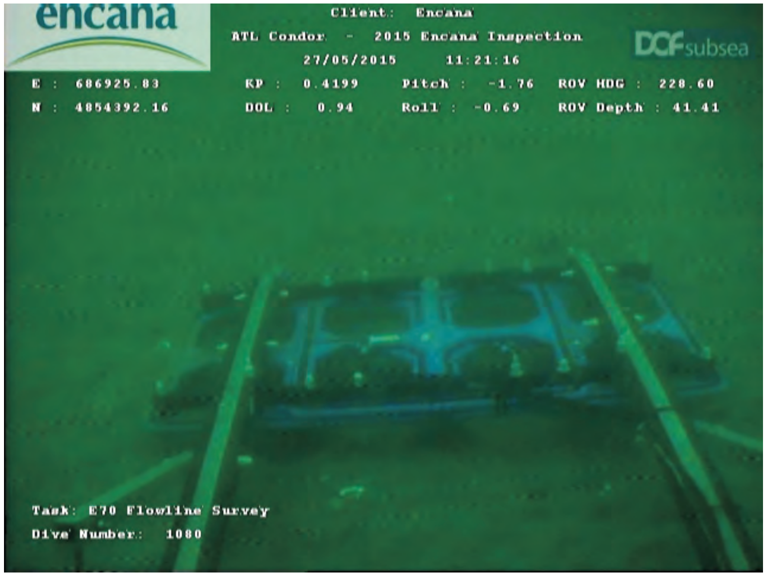
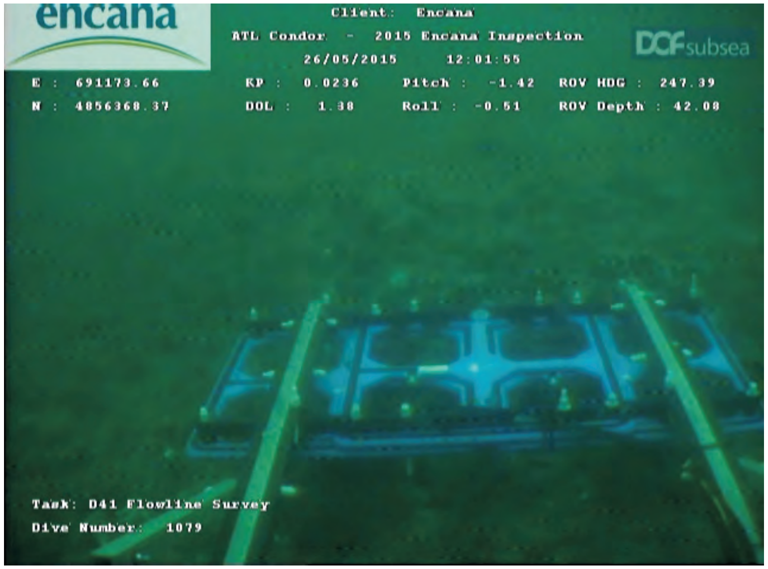
Figure 2.17 Crustaceans Along the GEP and in the PFC Area from the 2015 Survey

Figure 2.17

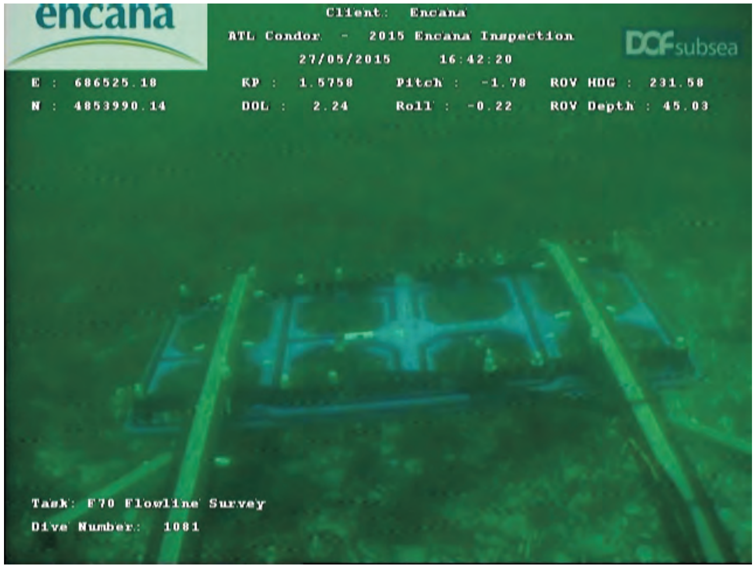


Sandy substrate at flowline E-70

Transition from rocky to sandy substrate at flowline H-08



A rock dump with super abundant sea cucumbers at flowline D-41



Shell hash and rock substrate at F-70 flowline

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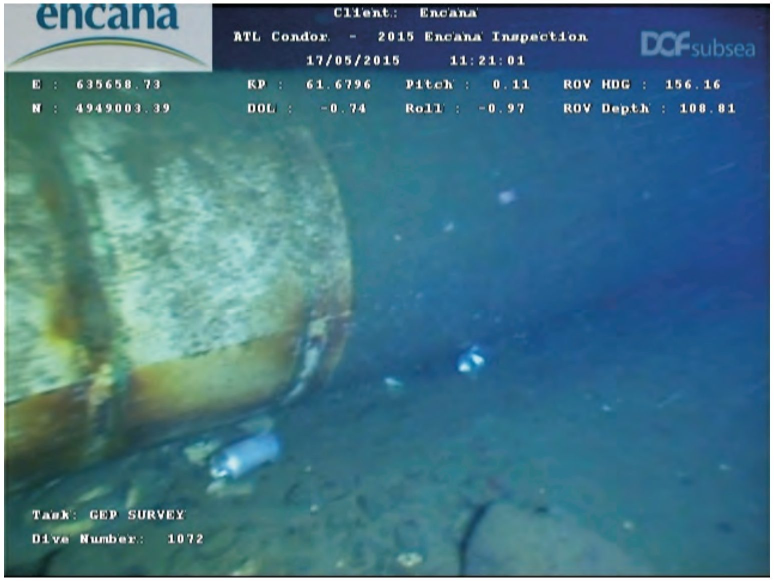
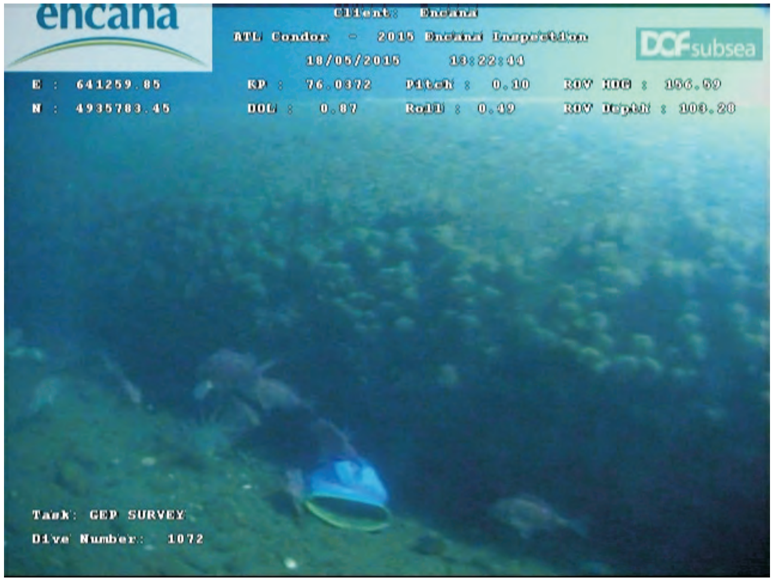
Figure 2.18 Flowline Substrates from the 2015 Video Survey



Two beer/soda cans at KP 61.68 along the GEP.



A rubber fishing glove at KP 76.04.

A fishing net at KP 78.24.

Plastic debris at KP 85.58

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Figure 2.19 Trash/debris Along the GEP in the 2015 Survey

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 starts 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, polycyclic aromatic hydrocarbons (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

To validate predictions made in the 2006 Deep Panuke EA re fish health [EA predictions #1, 3, 4, 5, 6, and 7] in **Table 3.1.**

2.6.3 Objectives

To examine the tissues of shellfish species collected on PFC legs (i.e., blue mussels) for possible body burden due to petroleum contamination.

2.6.4 Sampling

2.6.4.1 Mussel Sampling

Collect mussels annually using an ROV attachment to scrape the SW leg of the PFC, during planned water quality field surveys. See **Figure 2.20** for mussel sampling location, and **Figures 2.21a-b** for mussel photos from the field.

2.6.5 Analysis

2.6.5.1 Mussel Sampling

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. Parameters analysed in the mussel tissues are listed in the **Table 2.50** 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 2.50 - 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

Parameter	Units	RDL	Analysis
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			
Nonylphenol (NP)	ng/g	0.500	LC-MS
4-Nonylphenol monoethoxylate (NP1EO)	ng/g	0.500	LC-MS
4-Nonylphenol diethoxylate (NP2EO)	ng/g	0.500	LC-MS
4-n-Octylphenol (OP)	ng/g	0.500	LC-MS

2.6.6 Analysis QA/QC

2.6.6.1 Mussel Sampling:

- Commercial mussels were purchased at Sobeys on March 27th, 2015, to be compared to those collected at the PFC.
- PAH: Reagent Blank, Matrix Spike, Spiked Blank, Method Blank, Sample Duplicate, Surrogate.
- APs: Method Blank 1 per 20 samples, On-going Precision and Recovery Samples – spiked reference matrix (SPM) analyzed with each batch.

2.6.7 Results

2.6.7.1 Mussel Collection

All PAH's tested for were not detectable in either of the mussel samples (control site and the PFC). See Table 2.51 for results and **Digital Appendix D** for the full report by Maxxam Analytics. Mussels collected were also tested for alkylated phenols (**Table 2.51 and Table 2.52).** Mussels collected from the Deep Panuke site had detectable levels of 4-NP, 4n-OP and NP1EO. The control tissue (wild Lingcod) had similar levels of 4-NP to Deep Panuke (16.3 ng/g for the control and 17.5 ng/g at Deep Panuke) and higher levels of 4n-OP (1.1 ng/g for the control and 0.59 ng/g for Deep Panuke). NP1EO was not detected in the control sample, and was found at 1.28 ng/g in the Deep Panuke mussels. NP2EO was not detected in the Deep Panuke sample or the control.

Table 2.51 - Comparison of PAH Levels in Mussels from Deep Panuke and Control Site

Parameter	Units	DEEP PANUKE A+ B	CONTROL SITE A+ B	RDL	QC Batch	CCME Guidelines
Polyaromatic Hydrocarbons						
1-Methylnaphthalene	mg/kg	ND	ND	0.050	3973257	-
2-Methylnaphthalene	mg/kg	ND	ND	0.050	3973257	-
Acenaphthene	mg/kg	ND	ND	0.050	3973257	-
Acenaphthylene	mg/kg	ND	ND	0.050	3973257	-
Anthracene	mg/kg	ND	ND	0.050	3973257	-
Benzo(a)anthracene	mg/kg	ND	ND	0.050	3973257	-
Benzo(a)pyrene	mg/kg	ND	ND	0.050	3973257	-
Benzo(b)fluoranthene	mg/kg	ND	ND	0.050	3973257	-
Benzo(g,h,i)perylene	mg/kg	ND	ND	0.050	3973257	-
Benzo(j)fluoranthene	mg/kg	ND	ND	0.050	3973257	-
Benzo(k)fluoranthene	mg/kg	ND	ND	0.050	3973257	-
Chrysene	mg/kg	ND	ND	0.050	3973257	-
Dibenz(a,h)anthracene	mg/kg	ND	ND	0.050	3973257	-
Fluoranthene	mg/kg	ND	ND	0.050	3973257	-
Fluorene	mg/kg	ND	ND	0.050	3973257	-
Indeno(1,2,3-cd)pyrene	mg/kg	ND	ND	0.050	3973257	-
Naphthalene	mg/kg	ND	ND	0.050	3973257	-
Perylene	mg/kg	ND	ND	0.050	3973257	-
Phenanthrene	mg/kg	ND	ND	0.050	3973257	-
Pyrene	mg/kg	ND	ND	0.050	3973257	-
Surrogate Recovery (%)						-
D10-Anthracene	%	104	109	-	3973257	-
D14-Terphenyl	%	101	99	-	3973257	-
D8-Acenaphthylene	%	102	105	-	3973257	-

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
ND = Not Detected

Table 2.52 - Comparison of AP Levels in Mussels from Deep Panuke and Control Site

Parameter	Units	Conc. Found	Reporting Limit	Retention Time	CCME Guidelines
Deep Panuke					
4-NP	ng/g	17.5	0.472	13:04	-
4n-OP	ng/g	0.59	0.472	13:04	-
NP1EO	ng/g	1.28	0.472	13:11	-
NP2EO	ng/g	ND	0.472	-	-
Control Site					
4-NP	ng/g	16.3	0.49	13:04	-
4n-OP	ng/g	1.1	0.49	13:21	-
NP1EO	ng/g	ND	0.49	-	-
NP2EO	ng/g	ND	0.49	-	-

Parameter	Units	Conc. Found	Reporting Limit	Retention Time	CCME Guidelines
Lab Blank					
4-NP	ng/g	9.11	0.5	13:04	-
4n-OP	ng/g	ND	0.5	-	-
NP1EO	ng/g	ND	0.5	-	-
NP2EO	ng/g	ND	0.5	-	-

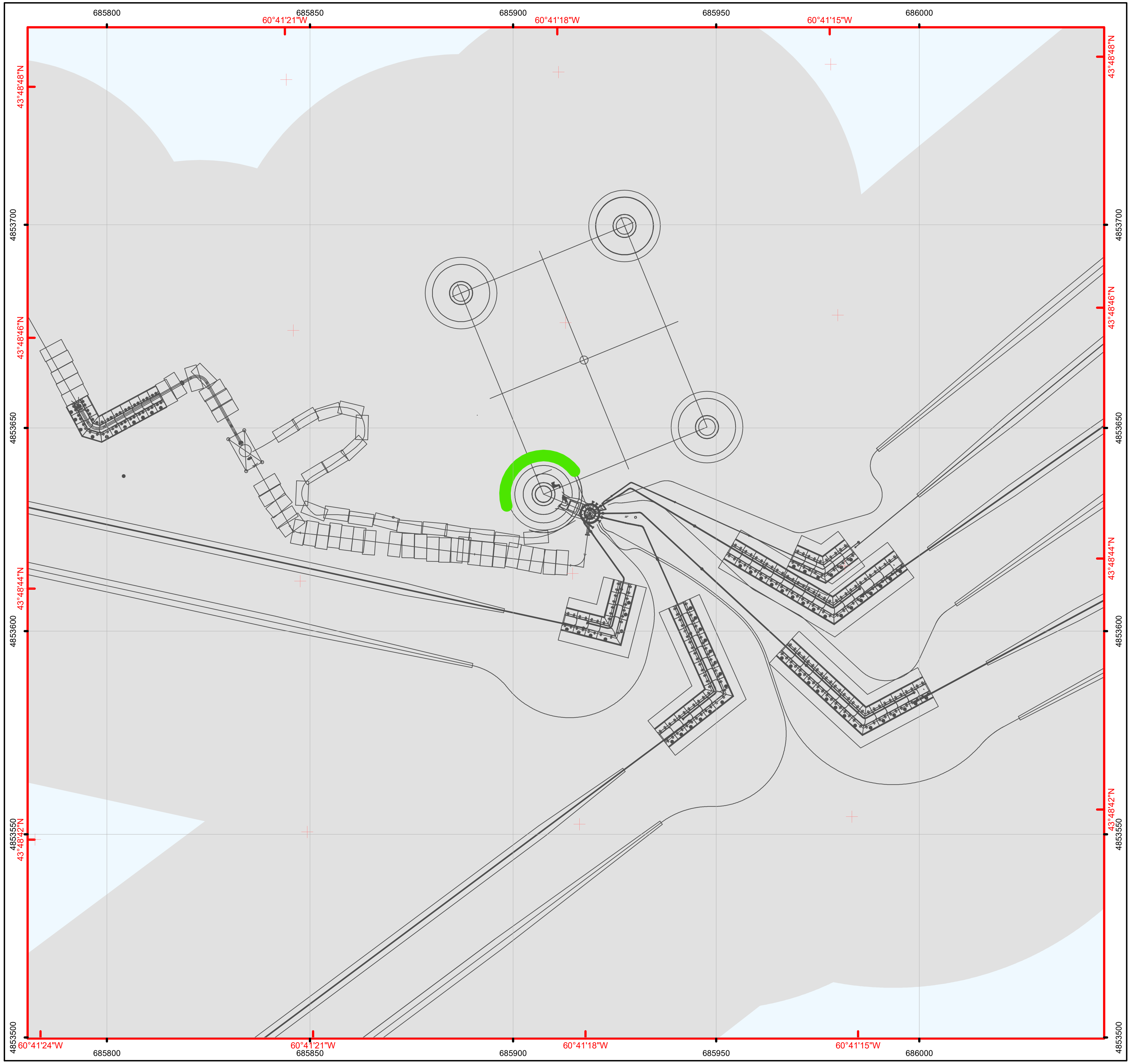
Table 2.53 - Surrogate analysis used to quantify percent recovery for APs in mussel tissue

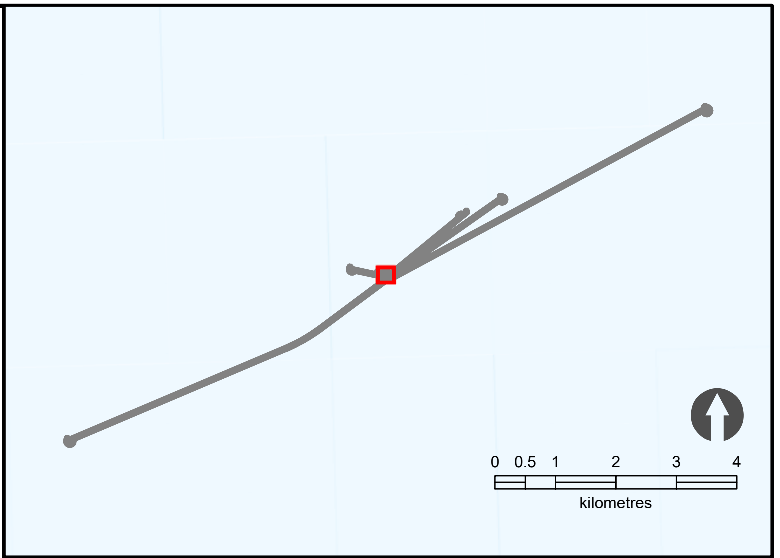
Parameter	Units	Spike Conc.	Conc. Found	R(%)2	Retention Time
Deep Panuke					
13C6-4-NP	ng absolute	1710	1380	80.9	14:14
13C6-NP1EO	ng absolute	4990	3150	63.1	14:22
Control Site					
13C6-4-NP	ng absolute	1710	1690	98.8	14:12
13C6-NP1EO	ng absolute	4990	4330	86.8	14:22
Lab Blank					
13C6-4-NP	ng absolute	1710	1760	103	14:14
13C6-NP1EO	ng absolute	4990	4990	100	14:22

2.6.8 Summary and Conclusions

2.6.8.1 Mussel Sampling

- No PAH parameters tested for were detected in the mussels collected from the PFC or the commercial control mussels.
- 4-NP, 4n-OP and NP1EO were detected in the Deep Panuke mussel samples. Control site tissues (Lingcod) had similar or higher 4-NP and 4n-OP present. 4-NP was also detected in lab blanks. NP2EO was not detected in Deep Panuke, control or lab blank samples.





WGS 1984 UTM Zone 20N
Projection: Transverse Mercator
Datum: WGS 1984
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

0 5 10 15 20 25 50
metres

- 🟩 Shellfish Sampling Area
- — Deep Panuke Structure
- ▨ 50m Buffer Zone

Note:
Map scale 1:1,000 when printed on 11x17 size paper

encana natural gas

Encana

2015 General Shellfish Sampling Location

Deep Panuke Survey Area

Scotian Shelf

McGregor GeoScience Limited

McGregor GeoScience Ltd.
Bedford, Nova Scotia, Canada

Date Saved: 26/01/2016 1:05:36 PM

Figure: 2 - 20

McGregor Project No.: 1113

Filename: 1113_ENCANA_shellfish_2016

PFC Mussel Bag A

PFC Mussel Bag B

PFC Mussel Bag C

McGregor
GeoScience
Limited

Figure 2.21a Mussels Sampled from the PFC SW Leg

Control Mussel Bag A

Control Mussel Bag B

McGregor
GeoScience
Limited

Figure 2.21b Commerical Mussels used as a Control Group Figure 2.21b

2.7 MARINE WILDLIFE OBSERVATIONS

2.7.1 Background

Stranded Birds Handling

In 2012 and early 2013, Encana worked with ExxonMobil and the CNSOPB to improve stranded bird handling procedures and strengthen awareness of these procedures on offshore platforms and vessels. As a result, Encana/ExxonMobil have jointly developed a draft bird monitoring and handling protocol to ensure consistent measures are implemented on offshore platforms and vessels in Nova Scotia. These measures include dedicated personnel responsible for implementing the protocol, directions on how to handle different types of stranded birds, offshore personnel awareness/training, reference material, performance review, etc. This draft protocol was submitted to the CNSOPB and Environment Canada for review along with specific questions on bird handling procedures. To address these questions, Environment Canada started to develop a guidance protocol to handle stranded birds offshore. The final protocol is still pending. Environment Canada is expected to consult with CAPP on the draft protocol. Once Environment Canada’s protocol is issued, Encana will finalize their own bird handling protocol, incorporate it into its Production EPCMP and roll it out to the PFC and vessels, including training of relevant personnel and provision of reference material.

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.

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.

Ocean Tracking Network

In 2013, through the Deep Panuke Education & Training and R&D Fund, Encana supported a multi-year research project on movements and residence of Nova Scotia's acoustically tagged Blue sharks by Dalhousie University's Ocean Tracking Network (OTN). As part of the program, hydrophones have been deployed on local O&G infrastructure since 2013 to feed into the OTN network, including on Deep Panuke's wave buoy mooring and ROV in 2013.

2.7.2 EEMP Goal

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

- Record any stranded (live or dead) birds on the Deep Panuke PFC and vessels;
- Record the behaviour of any birds, marine mammals and sea turtles observed in the vicinity of the Deep Panuke PFC and vessels;
- Identify the oil type/source on feathers of beached seabirds found on Sable Island;
- Identify movements of Nova Scotia's acoustically tagged Blue sharks.

2.7.4 Sampling

- Record any stranded (live or dead) birds on the Deep Panuke PFC and vessels;
- Record the behaviour of any birds, marine mammals and sea turtles observed in the vicinity of the Deep Panuke PFC and vessels;
- Identify the oil type/source on feathers of beached seabirds found on Sable Island;
- Monitor tagged animals (*e.g.* blue sharks) in the vicinity of the PFC or pipeline.

2.7.5 Analysis

- Oil types observed on feathers from beached seabirds collected on Sable Island were monitored (**Appendix I1**);
- Stranded birds were identified by support vessels (**Appendix I2**);
- Wildlife seen from the PFC and support vessels was recorded daily (**Appendix I3**);
- Forty Blue sharks were tagged in 2013 and 2014 and monitored in 2013, 2014 and 2015 by OTN with acoustic receivers, including hydrophones placed on offshore industry infrastructure (Final Report in **Appendix I4**).

2.7.6 Parameters Analyzed

Table 2.54 - Marine Wildlife Observations in 2015

	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)
OTN	Blue sharks monitoring via acoustic tags and receivers	Continuous with data downloads periodically	Use acoustic receivers to record tagged animals. Report by OTN.	Acoustic receivers track if there activity of tagged animals near PFC/pipeline

2.7.7 Results

2.7.7.1 Marine Wildlife Observations

Stranded Seabird Summary

- On-going monitoring for stranded birds was conducted in 2015 on the PFC and support vessels Atlantic Tern and the Atlantic Condor.
- A total of 11 stranded birds were reported. Species found were a songbird, Leach's storm-petrels, black guillemot, great black-backed gull, yellow warbler, yellow-breasted chat and a purple finch.

- One black guillemot was released, and all other stranded birds were found dead, and disposed of at sea.
- Unusual observations of non-stranded birds were also recorded. On October 18th, three falcons were reported as being seen around the PFC for a couple of days.

For complete description of these stranded birds events, refer to the report "Live Seabird – 2015 Salvage Report", **Appendix I2**.

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 2015.
- The Atlantic Condor observed one tagged gull on April 25th, 2015, and various untagged gulls throughout the year.
- The Atlantic Tern observed a variety of marine wildlife in 2015:
    - January: Gulls, shearwaters, dovekie, tern, seals, sandpiper, black-Legged kittiwake, northern fulmar
    - February: N/A
    - March: Gulls, shearwater, seals, terns, dovekies
    - April: Gulls, gannets, seals, brown-headed cowbird, American pipit, long-tailed jaeger
    - May: Gulls, seals, minke whales, yellow warbler, greater shearwaters, fulmars, porpoises, gannets
    - June: Gulls, shearwaters, seals, northern fulmar, minke whales, double-crested cormorant, alcids
    - July: Gulls, porpoises, seals, Atlantic terns, ocean sunfish, dolphins, tern, white-sided dolphins, Blue shark
    - August: Gulls, terns, seals, white-sided dolphins, long-tailed jaeger, minke whale, gannets, terns
    - September: Gulls, seals, silver hake, jaeger, pilot whale, terns, minke whale, porbeagle shark, gannets, white-side dolphins
    - October: Gulls, gannets, seals, terns, sunfish, dolphin
    - November: Gulls, seals, gannet, terns
    - December: Gulls, seal, terns

- Three red bats were observed on the PFC on September 15, 2015. The Department of Natural Resources was contacted. The bats left on their own the same day.

For complete details on marine wildlife observed from the supply vessels and PFC, refer to **Appendix I3** "2015 Observations from Supply Vessels and PFC of Marine Wildlife".

Sable Island Beached Bird Surveys Summary

- Between March and December, 2015, eight surveys for beached seabirds were conducted on Sable Island, with no surveys during January, February, May and November.
- During 2014, the corpses and fragments of 461 beached seabird corpses were collected on Sable Island. Aclids accounted for 58.4% of the total corpses recovered. Of the 461 corpses, 193 (41.9%) were complete (i.e. with >70% of body intact).
- Seasonal occurrence of *clean* complete corpses (Code 0) varied by bird group and species. Most alcids occurred in the winter (79.3%). More Northern Fulmars (80%) and Northern Gannets (66.7%), and all shearwaters, occurred in summer.
- The overall oiling rate for all species combined (based on complete corpses, Codes 0 to 3) was 0.5% (compared with <3.2% in 2014). Only one oiled corpse was recovered in 2015, a Thick-billed Murre. The oiling rate for alcids was 1.7% (compared with 7.9% in 2014).
- The single oiled bird corpse occurred during April, and a sample of oiled feathers was collected. Analysis of the oil determined it to be a weathered mixture of Heavy Fuel Oil and Lube Oil, and very typical of long haul commercial vessel running on Heavy Fuel Oil (e.g. container vessel, bulk carrier, etc.) having discharged engine room bilge oil either directly or after storage in slop tank.

For complete details on the Sable Island Beached Seabird study, refer to **Appendix I2** "2015 Beached Seabird Survey on Sable Island ".

Ocean Network Tracking Report Summary

39 out of the 40 Blue sharks tagged in 2013 and 2014 were detected the year after their initial tagging showing that they had survived catch-and-release angling. In summer and autumn, the animals mostly occupied the continental shelf off Nova Scotia at distances of about 20-40 km offshore, but moved away from the area to overwinter. Some animals were detected off Halifax in the summer of the year after their initial tagging showing certain individuals exhibited site fidelity to the region. Other tagged sharks were detected in the Gulf of Maine, Gulf of St. Lawrence and off Sable Island. None of the animals tagged in 2013 were detected in Nova Scotia in 2015, two years after tagging. Data to test if the animals tagged in 2013 or 2014 will return in 2016 will not be available until late 2016. Acoustic receivers positioned on oil and gas industry offshore infrastructure did not detect the tagged sharks, but logged other tagged animals including grey seals and Bluefin tuna. For complete details on the program, refer to **Appendix I4** "2016 OTN Final Report".

2.7.8 Summary and Conclusions

- Eleven bird strandings were reported in 2015. One black guillemot was found tangled in twine and released. All other birds were found dead. No birds were found to have oil on them.
- Both the supply vessels the M/V Atlantic Condor and the M/V Atlantic Tern reported wildlife sightings in 2015. The M/V Atlantic Condor observed one tagged gull on April 25th, 2015, and various untagged gulls throughout the year. The M/V Atlantic Tern reported a variety of seabirds, as well as seals, white-sided dolphins, pilot whales, minke whales, sunfish, porbeagle, blue shark, and porpoises.
- Three red bats were observed on the PFC on September 15, 2015.
- Monitoring of oiling rates in beached birds on Sable Island was conducted over the course of eight surveys carried out between March, and December 2015, where 461 beached seabird corpses were collected. Alcids accounted for 58.4% of the total corpses recovered. A single oiled bird corpse was found. Of the 461 corpses, 193 (41.9%) were complete (>70% of body intact). The oiling rate for all species combined was 0.5%.

- 39 out of the 40 NS Blue sharks tagged by OTN in 2013 and 2014 were detected the year after their initial tagging. Acoustic receivers positioned on oil and gas industry offshore infrastructure did not detect the tagged sharks, but logged other tagged animals including grey seals and Bluefin tuna.

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

- 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

- Provide baseline information on the air quality on Sable Island;
- Monitor trends in air quality on Sable Island as the Deep Panuke development comes on-stream; and
- Investigate the possible relationship of anomalies (spikes of contaminants) in air quality measurements on Sable Island with flaring patterns on the PFC during production operations.

2.8.4 Sampling

Flare smoke monitoring:

- Systematic flare smoke monitoring on the PFC started on January 1, 2015 and the flare smoke shade was monitored twice daily (morning and afternoon), assessing it using the Ringelmann smoke chart.

For more details about the flare smoke monitoring, refer to **Appendix J** "2015 Flare Plume Observations".

Sable island air quality:

- Continuously measured 3031 particle counts and fine airborne particulate matter ($PM_{1/2.5/4.0/10/TSP}$) from October to December of 2015.

For more details about Sable island air quality monitoring, refer to **Appendix K** "2015 Sable Island Air Quality Monitoring".

2.8.5 Analysis

- 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.

2.8.6 Results

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” 47% of the time that the facility was producing, a "1" or "2" (light smoke) 53% of the time (see **Table 2.55** and **Appendix J** for full details).
- The smoky flare observed during 2014 and the first quarter of 2015 was gone when production restarted at the end of October 2015. This is partly explained by maintenance conducted during the seasonal shutdown. During the Pressure Safety Valve (PSV) recertification campaign, it was noted that some PSVs were passing due to debris on the seal. These were corrected to ensure they did no longer let “heavy ends” get through. However, smoky flare was observed again in December, the specific cause is not yet known.

Table 2.55 - Ringelmann Flare Smoke Observations in 2015

Ringelmann Smoke Category	Morning Observations		Afternoon Observations	
	# Production Days	% Production Time	# Production Days	% Production Time
0	93	47%	93	47%
1	79	40%	77	39%
2	27	14%	29	15%
3	0	0%	0	0%
Total	199	100%	199	100%

Sable Island air quality monitoring:

- The following air quality metrics measured on Sable Island in 2015 from October to December:
    - 3031 particle counts
    - fine airborne particulate matter ($PM_{1/2.5/4.0/10/TSP}$)
- In 2014, Nova Scotia Environment changed 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/sampler for O_3, NO_x, H_2S, SO_2 and also $PM_{2.5}$ via a MetOne Beta Attenuation Monitor (BAM). Due to protracted contract negotiations with NRCan, funding for replacement instruments was not concluded until late 2015.
- This meant that O_3, NO_x, H_2S, SO_2 and also $PM_{2.5}$ (via the BAM) were not measured over the course of 2015. In addition, the Thermo 5012 MAAP black carbon analyzer was found to be choked with sea salt and sand and was not repairable, with no data available for 2015. Consequently there were no air emission threshold breaches reported for 2015. However, there were some supplemental $PM_{2.5}$ data available via a TSI DRX automatic analyzer for the last three months of 2015 (supplied by Dr. Mark Gibson at Dalhousie University).
- In January 2016 replacement PM2.5 (BAM), O_3 and NO_x instruments were installed on Sable Island but this data will feature in next year's air emissions report. In addition, a replacement total-VOC instrument was installed on Sable Island (ppbRAE). In October 2015, a TSI Aerosol Particle Sizer (APS) model 3321 was installed. The APS measures size-resolved particle number counts from 500 nm (0.5 µm) to 20,000 nm (20 µm) in 56 size fractions. In addition, a TSI Ultrafine particle monitor, model 3031, was also installed. The 3031

measures size-resolved particle number counts from 20 nm to 500 nm in six size fractions. Together the Ultrafine 3031 and APS 3321 cover the particle size range associated with fresh combustion particles and gas-to-particle conversion particles, particles associated with 'aged' aerosol smog from continental outflow and particles related to sea salt spray and long-range re-suspended fugitive dust.

- The 2015 annual report features the 3031 and DRX data from October 1 – December 31 2015, with intermittent data for the APS from September 30 – October 7 2015, October 14 – October 18 2015 and December 24 – December 31 2015. These 3031 and APS are wholly new measurements on Sable Island and represent a new and powerful means of identifying sources of particulate air pollution impacting the Island. A new Thermo black carbon instrument will arrive in Halifax on March 2 2016 and will be installed in April 2016. The new Teledyne-API H2S, SO2 autoanalyzers (purchased with ESRF funding) arrived in Halifax on February 23 2016 and are undergoing testing. These instruments will be installed on Sable Island in April 2016.
- The 2015 data completeness for temperature, wind direction and wind speed was 96.38%, 100.00% and 99.44% respectively, which can be considered excellent data capture. The mean (min : max, *units* °C) 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 6 sensor malfunction. It was found that the average wind vector for 2015 was 241°, which is consistent with prevailing winds in the North West (NW) Atlantic.
- The data completeness for the 3031 Ultrafine particle number counts, in the range 20-30, 30-50, 50-70, 70-100,100-200 and 200-800 nm was 96.02%, and for the entire year was only 24.66%. The low annual data completeness is due to the instrument only being installed during the last three months of 2015.
- The mean (min:max) air pollution metric concentrations observed on Sable Island during the period of October to December 2015 are shown in **Table 2.56**.:

Table 2.56 - Mean (min:max) Values for Air Particles on Sable Island

3031 Particle counts (nm)	**mean (nm)**	**min (nm)**	**max (nm)**
20-30	343.1	0	10577.3
30-50	336.9	0	9588
50-70	179.5	0	4463.7
70-100	143.47	0	4195.5
100-200	168.2	0	4455.75
200-800	25.57	0	503
PM1/2.5/4.0/10/TSP Mass concentration	**mean µg/m3**	**min µg/m3**	**max µg/m3**
PM1	13.8	9	34.5
PM2.5	14.32	9	37.0
PM4.0	14.50	9	37.0
PM10	14.60	9	37.5
PMTSP	14.60	9	37.5

- The most important feature of the 2015 air missions report is that the spikes in PM mass and particle number concentrations were associated with long-range transport continental outflow, and not from O&G operations or associated with ocean biogenic fluxes.
- With the new instruments deployed on Sable Island, the 2016 air emissions report will contain far more data and investigation of local and upwind air emissions impacting Sable Island.

2.8.7 Summary and Conclusions

- 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” 47% of the time that the facility was producing, a "1" or "2" (light smoke) 53% of the time
- No data for NO_x, H_2S, SO_2, O_3 and BAM $PM_{2.5}$ was available for 2015. Supplemental PM2.5 data was available from October through the end of 2015. $PM_{2.5}$ BAM, O_3 autoanalyzers and a NO_x analyzer were installed on Sable Island in January of 2016, but await calibration in April 2016.
- The most notable feature of the 2015 air emissions report is that spikes in PM mass and particle number concentrations were associated with LRT continental outflow, and not O&G operations.

- The mean $PM_{2.5}$ for the three months of 2015 was similar in concentration to previous air emission reports.
- With the new instruments deployed on Sable Island, the 2016 air emissions report will contain far more data and a more fulsome investigation of local and upwind air emissions impacting Sable Island.

3 ENVIRONMENTAL ASSESSMENT (EA) PREDICTIONS

Table 3.1 - EEM Related Environment Assessment (EA) Predictions and 2015 Results

#	*EA Predictions*	*Relevant Section of 2006 EA*	*VEC(s)*	*EEM Component(s)*	*2015 Plan*	*2015 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.	Produced water was collected in March and December of 2015. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Cadmium and chromium were found to be above CCME guidelines in December only. No APs were detected at any depths at stations sampled. AP results are not yet available from December. PFC and WHPS had similar species composition and growth to 2014. Additional soft marine growth (hydroids) colonized on existing hard marine growth (blue mussel). Mussels were collected from the SW leg of the PFC in March of 2015. No PAH's were found at detectable levels in either the control mussels or those collected from the PFC. APs 4-NP, 4n-OP and NP1EO were all found above RDL in the mussels samples from Deep Panuke, however similar levels of 4-NP and 4-NOp 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	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

#	*EA Predictions*	*Relevant Section of 2006 EA*	*VEC(s)*	*EEM Component(s)*	*2015 Plan*	*2015 Results*
	re-colonized from adjacent areas.					negative impacts, and possible "reef" effects attracting mobile organisms into the vicinity of the subsea structures. EA prediction has been confirmed.
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. Fish Health Assessment to be performed once a year (Mussel toxicity) Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	Produced water was collected in March and December of 2015. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Cadmium and chromium were found to be above CCME guidlines in December only. No APs were detected at any depths at stations sampled. AP results from December are not yet available. Water sampling was conducted in March of 2015. Mercury levels were above CCME guidelines at all stations. Cadmium levels were also found to be above CCME guidelines at the 1000m and 2000m downstream stations. All other parameters measured were below CCME guidelines where available. No APs were detected at any depths at stations sampled. All bottom temperature at stations sampled were within 0.04 °C for the bottom temperature at the 2000 m upstream station. Sediment was collected at 6 stations in March of 2015. Mussels were collected from the SW leg of the PFC in March of 2015. No PAH's were found at detectable levels in either the

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2015 Plan	2015 Results
						control mussels or those collected from the PFC. APs 4-NP, 4n-OP and NP1EO were all found above RDL in the mussels samples from Deep Panuke, however similar levels of 4-NP and 4-NOp were detected in control tissues. PFC and WHPS had similar species composition and growth to 2014. Additional soft marine growth (hydroids) colonized on existing hard marine growth (blue mussel).
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. Fish Health Assessment to be performed once a year (Mussel toxicity) Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	Produced water was collected in March and December of 2015. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Cadmium and chromium were found to be above CCME guidelines in December only. No APs were detected at any depths at stations sampled. AP results are not yet available from December. Water quality sampling was conducted in March of 2015. Mercury levels were above CCME guidelines at all stations. Cadmium levels were also found to be above CCME guidelines at the 1000 m and 2000 m downstream stations. All other parameters measured were below CCME guidelines where available. No APs were detected at any depths at stations sampled. Salinity at bottom depths was

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2015 Plan	2015 Results
						between 31.888 PSU and 32.096 across all stations. There was little variation in salinity between the 20 m station and the 2000 m upstream station (a difference of 0.018 PSU), and a difference of 0.074 between the 500, downstream site and the 2000m upstream site. Sediment was collected in March of 2015. Mussels were collected from the SW leg of the PFC in March of 2015. No PAH's were found at detectable levels in either the control mussels or those collected from the PFC. APs 4-NP, 4n-OP and NP1EO were all found above RDL in the mussels samples from Deep Panuke, however similar levels of 4-NP and 4-NOp were detected in control tissues. PFC and WHPS had similar species composition and growth to 2014. Additional soft marine growth (hydroids) colonized on existing hard marine growth (blue mussel).
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. Fish Health Assessment to be	Produced water was collected in March and December of 2015. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Cadmium and chromium were found to be above CCME guidelines in December only. No APs were detected at any depths at stations sampled. AP results are not yet available for December.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2015 Plan	2015 Results
					performed once a year (Mussel toxicity) Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	Water quality sampling was conducted in March of 2015. Mercury levels were above CCME guidelines at all stations. Cadmium levels were also found to be above CCME guidelines at the 1000m and 2000m downstream stations. All other parameters measured were below CCME guidelines where available. No APs were detected at any depths at stations sampled. Mussels were collected from the SW leg of the PFC in March of 2015. No PAH's were found at detectable levels in either the control mussels or those collected from the PFC. APs 4-NP, 4n-OP and NP1EO were all found above RDL in the mussels samples from Deep Panuke, however similar levels of 4-NP and 4-NOp were detected in control tissues. PFC and WHPS had similar species composition and growth to 2014. Additional soft marine growth (hydroids) colonized on existing hard marine growth (blue mussel).
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	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.	Produced water was collected in March and December of 2015. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene, toluene, and ethylbenzene. Cadmium and chromium were found to be above CCME guidelines in December only. No APs were detected at any depths at stations sampled. AP results not yet available for December.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2015 Plan	2015 Results
	result in fish being exposed to extremely low concentrations of Alkylated phenols that are unlikely to elicit measurable effects.				Fish Health Assessment to be performed once a year (Mussel toxicity) Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	Water quality sampling was conducted in March of 2015. Mercury levels were above CCME guidelines at all stations. Cadmium levels were also found to be above CCME guidelines at the 1000m and 2000m downstream stations. All other parameters measured were below CCME guidelines where available. No APs were detected at any depths at stations sampled. Sediment was collected in March of 2015. Mussels were collected from the SW leg of the PFC in March of 2015. No PAH's were found at detectable levels in either the control mussels or those collected from the PFC. APs 4-NP, 4n-OP and NP1EO were all found above RDL in the mussels samples from Deep Panuke, however similar levels of 4-NP and 4-NOp were detected in control tissues. PFC and WHPS had similar species composition and growth to 2014. Additional soft marine growth (hydroids) colonized on existing hard marine growth (blue mussel). Video surveys spanned between March and July of 2015.
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	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)

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2015 Plan	2015 Results
	benthic boundary layer.					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)	2015 Plan	2015 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. It is unclear if the GEP acted as a physical barrier to a lobster observed near the pipeline.
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 2015. Marine Water Quality to be performed once a year in conjunction with produced water testing. OTN tracking project did not occur in 2015.	Presence of wildlife near the PFC has been observed sporadically but these observations cannot affirm the nature of the 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	Acadia Bird Study was not done in 2015, as it finished in 2014. Vessel and platform observations to continue in 2015.	Eleven bird strandings were reported in 2015. One black guillemot was found tangled in twine and released. All other birds were found dead. No birds found had oil on them.
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.	0.5% oiling for all species of beached birds found on Sable Island (a single oiled bird corpse in April 2015). Samples of oiled feathers were collected from one corpse, and the samples were determined to moderately weathered heavy oil fuel and lube oil.
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. .	Data was only available from October to December of 2015 for fine particulate matter. As a result of no data, no breaches of National Air Quality Standards, CAAQO or Canada

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2015 Plan	2015 Results
						Wide Standard for any of the air pollution metrics.
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.	Data was only available from October to December of 2015 for fine particulate matter. As a result of no data, no breaches of National Air Quality Standards, CAAQO or Canada Wide Standard for any of the air pollution metrics.

4 RECOMMENDED EEM PROGRAM FOR 2016

Table 4.1 - Summary of Deep Panuke 2015 Offshore EEMP Sampling Activities, Analysis, and 2016 Recommendations

EEMP Component	2015 Sampling			2015 Analysis		2016 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 once in March 2015.	Water quality composition conducted in March 2015	Trace metals; BTEX, TPH, PAHs; APs; nutrients; organic acids; major ions and physical parameters	Continue produced water sampling in 2016; to be collected and analyzed twice a year.
			Annually after First Gas Microtox and sea urchin fertilization tests done on produced water and cloudy discharge water in March 2015. Threespine sticklebacks were not available for testing.	Toxicity on sea urchin eggs and Microtox test	IC25 (Fertilization) 15 min IC50 bioassay	Continue yearly sampling into 2016.
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	Water quality composition	Trace metals; BTEX, TPH, PAHs; APs; nutrients; organic acids; major ions and physical parameters	Conduct marine water sampling program into 2016.
Sediment Chemistry and Toxicity	3 near-field benthic sampling locations and 2 far-field reference sites	Grab Sample - Van Veen	In 2011 (prior to First Gas and post 2010 drilling and completion activities), then annually for the following three years	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 2016. As done in 2015, no sampling at 5 wellsite locations but focus on sampling locations downstream and upstream from PFC site (4 near-field sites 250, 500, 1,000 and 2,000 m downstream (SW) and 2 far-field sites 5,000 m upstream and downstream)
				LC49 bioassay acute toxicity analysis	Suitable marine amphipod species such as *Rhepoxynius abronius* or *Eohaustoriux estuaries*	Conduct LC49 bioassay and test in 2016. As done in 2015, discontinue 5 wellsite locations and focus on sampling locations

EEMP Component	2015 Sampling			2015 Analysis		2016 Recommendations
	Location	Type/Method	Frequency/Duration	Type/Method	Parameters	
						downstream and upstream from PFC site (4 near-field sites 250, 500, 1,000 and 2,000 m downstream (SW) and 2 far-field sites 5,000 m upstream and downstream)
Fish Habitat	Subsea production structures	ROV video- camera survey	Annually (using planned activities, *e.g.* routine inspection and storm scour surveys)	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 2016 with annual ROV footage of wellsites, PFC and pipeline.
Fish Health Assessment	Mussels: PFC SW leg	Mussels: scraping Fish: angling	Mussels: annually after First Gas Fish: every 3 years after First Gas	Mussels: body burden Fish: enzyme induction, pathology	Mussels: body burden analysis for potential petroleum contaminants (*e.g.* PAHs, APs, sulphides)	Continue mussel health assessment into 2016. Fish health assessment to start in 2016.
	Fish: immediate vicinity of PFC and suitable far-field reference sites	**No Sampling Fish Conducted in 2015**	**No Sampling Fish Conducted in 2015**	**No Sampling Fish Conducted in 2015**	Fish: body burden analysis for potential petroleum contaminants (*e.g.* PAHs, APs, sulphides) and enzyme activity; haematology; EROD activity; gross and tissue (particularly liver/gill) histopathology *Note*: standard characteristics of mussels/fish will also be Collected (*e.g.* length, weight, sex, etc) **No Fish Sampling Conducted in 2015**	
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 2016; updated stranded bird handling protocol to be finalized and implemented once regulatory feedback has been received
		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 2016; conduct in conjunction with daily deck sweeps for stranded birds

EEMP Component	2015 Sampling			2015 Analysis		2016 Recommendations
	Location	Type/Method	Frequency/Duration	Type/Method	Parameters	
	Sable, Country and Bon Portage Islands, NE Nova Scotia, PFC area (Acadia bird monitoring research study)	Bird monitoring with radar technology; radio and satellite transmitters; camera	Three-year program (2011 to 2014)	Analysis of radar, transmitters, camera	Specific research/analysis parameters outlined in NSERC proposal	Study completed. Examine feasibility of in-kind contribution to continuing Acadia research; such as redeployment of VHF receivers on supply vessels.
	Transects between PFC and shoreline	Visual monitoring of seabird distributions using CWS ECSAS protocol	Seasonal bird movements and potential bird-platform interactions were monitored as part of large-scale instrument-based Acadia study into 2014.			See above
	Sable Island	Beached bird surveys	Approx. 10 surveys/year	Based on CWS protocol	Oiling rate (standardized approach)	Continue into 2016.
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 2016.
	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.

References

Baseline Benthic Study for the Deep Panuke Subsea Pipeline and Production Facility, 2006

Baseline Benthic Study for the Deep Panuke Subsea Pipeline and Production Facility, 2008.

COSEWIC Species Database. Available at : http://www.cosewic.gc.ca/eng/sct1/searchdetail_e.cfm

Deep Panuke Production Environment Protection and Compliance Monitoring Plan (EPCMP), Encana: DMEN-X00-RP-EH-90-0002.

Carvalho, A., & Schropp, S. Development of an Interpretive Tool for Assessment of Metal Enrichment in Florida Freshwater Sediment (2002). Florida Department of Environmental Protection.

Environment Canada (1992). Biological Test Method: Toxicity Using Bioluminescent Bacteria. *Environmental Protection Series, Report EPS 1/RM/24.*

Environment Canada (2011). Biological Test Method: Fertilization Assay Using Echinoids (Sea Urchins and Sand Dollars). *Environmental Protection Series, EPS 1/RM/27 - Second Edition.*

Environmental Effects Monitoring Plan (EEMP), Encana, 2011: DMEN-X00-RP-EH-90-0003.

JNCC (2011). SACFOR abundance scale. Available at: http://jncc.defra.gov.uk/page-2684

Lee, K., & Neff, J. (2011). Produced water - environmental risks and advances in mitigation technologies. New York, NY: Springer Science + Business Media.

Lobster Institute, University of Maine. One in a Million?. Orono, ME. Retrieved from: http://umaine.edu/lobsterinstitute/files/2011/12/LobsterColorsWeb.pdf

Martec Ltd., CEF Consultants Ltd., DRDC Atlantic, St. Francis Xavier University (2004). *Effects of pipelines/gathering lines on snow crab and lobster.* Halifax, NS. Retrieved from: http://www.esrfunds.org/pdf/150.pdf

Stephenson, M.T. (1992). *A survey of produced water studies*. New York, NY: Plenum Press.

APPENDICES

APPENDIX A

CEQG for Marine Water Quality

Canadian Water Quality Guidelines for the Protection of Aquatic Life

INTRODUCTION

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.

References

CCREM (Canadian Council of Resource and Environment Ministers). 1987. Canadian water quality guidelines. Prepared by the Task Force on Water Quality Guidelines.

Reference listing:

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

For further scientific information, contact:

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

For additional copies, contact:

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

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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

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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	
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

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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	
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

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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	
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

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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	
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

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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	
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 B1

Produced Water Toxicity and Sea Urchin Fertilization Results

AQUATOX
AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Rd.
RR 3
Guelph ON N1H 6H9
Tel: (519) 763-4412 Fax: (519) 763-4419

Sea Urchin Test Report

Fertilization Inhibition

Work Order : 227837
Sample Number : 43380

SAMPLE IDENTIFICATION

Company : Harris Industrial Testing Service Ltd.
Location : South Rawden NS
Substance : Deep Panuke Produce Water
Sampling Method : Grab
Sampled By : I. Fraser
Temp. on arrival : 14.0°C
Sample Description : Cloudy, gray, strong odour.

Date Collected : 2015-03-24
Time Collected : 06:50
Date Received : 2015-03-25
Time Received : 08:45
Date Tested : 2015-03-26

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), with deviation(s) as noted below.

TEST RESULTS

Effect	Value	95% Confidence Limits	Statistical Method
IC25 (Fertilization)	34.3%	28.0-39.4	Linear Interpolation (CETIS) a

The results reported relate only to the sample tested.

COPPER (AS COPPER SULPHATE) REFERENCE TOXICANT DATA

Date Tested : 2015-03-26
Gamete Batch : Ur15-03-04
Test Duration : 20 minutes
IC25 Fertilization : 172 µg/L
95% Confidence Limits : 148 - 195 µg/L

Statistical Method : Non-Linear Regression* (CETIS)[a]
Historical Mean IC25 : 143 µg/L
Warning Limits (± 2SD) : 69 - 298 µg/L
Analyst(s) : DK, SEC

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
Volume per Replicate : 10 mL
Number of Replicates : 4 per treatment
Depth of Test Solution : Approx. 3 cm
Sperm Density : 40000000 per vessel
Sperm : Egg Ratio : 20000 : 1
Males Used to Pool Sperm : 4
Females Used to Pool Eggs : 3

Control/Dilution Water[1] : Artificial Sea Water
Sperm Exposure Time [2]: 20 min
Egg Exposure Time : 10 min
Total Duration of Test : 20 min
pH Adjustment : None
Sample Filtration : None
Test Aeration : None
Test Method Deviation(s) : Yes (see 'Comments')

[1] no additional chemicals

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

COMMENTS

Noted Deviation(s): The salinity of the 100% sample as submitted was 116‰. Salinity of the 9%, 30% and 100% exposure concentrations exceeded the maximum of 32‰ allowed by the test method cited above.

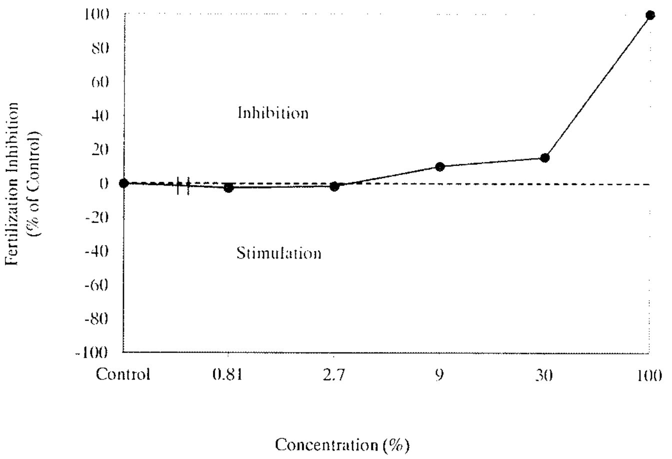
*Binomial weighting (CETIS[a]) was applied.

•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]. In test concentrations where fertilization was greater than the control, data were replaced with control values for the purposes of statistical analysis, as recommended by Environment Canada (2005).

Work Order : 227837
Sample Number : 43380

Sea Urchin Fertilization Inhibition



TEST ORGANISM

Adult Test Organism :	*Lytechinus pictus*	Holding Salinity :	34 ± 2 ‰
Adult Organism Source :	Marinus Scientific	Holding Vessel :	Glass aquaria
Source Location :	Garden Grove CA USA	Adult Mortality Rate :	0% (previous 7 days)
Date Received :	2013-11-12	Life Stage Tested :	Gamete (sperm/egg)
Holding Water :	Artificial Sea Water	Gamete Batch Tested :	Ur15-03-04
Holding Temperature :	12 - 15 °C		

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].

[e] 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.

Environment Canada, 2005. Guidance Document on Statistical Methods for Environmental Toxicity Tests. Environmental Protection Series, Ottawa, Ont., Rept. EPS 1/RM/46.

Date : 2015-04-17
yyyy-mm-dd

Approved By :
Project Manager

Work Order : 227837
Sample Number : 43380

FERTILIZATION DATA

Test Conducted By : DK/SEC
Enumerated By : DK

Concentration (%)	**Replicate**	**Fertilized**	**Unfertilized**	**% Fertilized**	**Treatment Mean Fertilization (%)**	**Standard Deviation**
Control	A	76	24	76	**78.25**	**3.30**
	B	75	25	75		
	C	82	18	82		
	D	80	20	80		
Blank	A	0	100	0	**0.25**	**0.50**
	B	1	99	1		
	C	0	100	0		
	D	0	100	0		
0.02	A	–	–	–	–	–
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.07	A	–	–	–	–	–
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.24	A	–	–	–	–	–
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.81	A	79	21	79	**80.25**	**2.22**
	B	81	19	81		
	C	83	17	83		
	D	78	22	78		
2.7	A	73	27	73	**79.5**	**4.51**
	B	83	17	83		
	C	82	18	82		
	D	80	20	80		
9	A	76	24	76	**70.25**	**7.32**
	B	60	40	60		
	C	70	30	70		
	D	75	25	75		
30	A	64	36	64	**66**	**7.70**
	B	56	44	56		
	C	73	27	73		
	D	71	29	71		
100	A	0	100	0	**0**	**0.00**
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		

"–" = not counted/not required

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 conducted prior to testing.
- Preserved eggs were stored for 1 day prior to enumeration.
- No outlying data points were detected according to Grubbs Test (CETIS)[a]

Data Reviewed By : VC
Date : 2015-04-14

Work Order : 227837
Sample Number : 43380

INITIAL WATER CHEMISTRY (100% SAMPLE)

	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)	Pre-aeration Time (h)
Initial Chemistry:	20.0	6.7	1.8	24	116	–
Chemistry after Salinity Adjustment [3]:	–	–	–	–	–	–
Chemistry after Pre-Aeration[3,4]:	20.0	6.8	2.5	34	116	0:20

SALINITY ADJUSTMENT

Method :	Not applicable[5]	Volume Adjusted :	Not applicable[5]
Salt Added :	Not applicable[5]	Amount of Salt Added :	Not applicable[5]
Date Adjusted :	Not applicable[5]	Aging Time :	Not applicable[5]
Aging Conditions :	Not applicable[5]	Aging Temperature :	Not applicable[5]

[5]Note: The 100% effluent did not require salinity adjustment since the initial sample salinity was 116‰. Therefore the effluent was tested as received.

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

EXPOSURE CONCENTRATIONS WATER CHEMISTRY

Concentration (%)	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)
Control	20.0	8.2	7.2	99	30
Blank	20.0	8.2	7.2	99	30
0.02	20.0	8.2	7.2	99	30
0.07	20.0	–	–	–	–
0.24	20.0	–	–	–	–
0.81	20.0	–	–	–	–
2.7	20.0	8.1	7.2	99	30
9	20.0	8.0	7.1	98	38
30	20.0	7.6	6.9	95	54
100	20.0	6.8	2.5	34	116

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

Data Reviewed By : SF
Date : 2015-04-17

AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Rd.
RR 3
Guelph ON N1H 6H9
Tel: (519) 763-4412 Fax: (519) 763-4419

MICROTOX® ACUTE TOXICITY TEST REPORT

Work Order : 227837
Sample Number : 43380

SAMPLE IDENTIFICATION

Company :	Harris Industrial Testing Service Ltd.	Time Collected :	06:50
Location :	South Rawden NS	Date Collected :	2015-03-24
Substance :	Deep Panuke Produce Water	Sample Volume :	2 x 1L jars
Sampling Method :	Grab	Date Received :	2015-03-25
Sampled By :	I. Fraser	Date Tested :	2015-03-27
Sample Description :	Cloudy, gray, strong odour.	Temp. on arrival :	14.0°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	5.65%	4.80-6.64	Least Square Regression

The results reported relate only to the sample tested.

REFERENCE TOXICANT DATA

Reagent Batch :	14J4128	15 minute IC50 :	0.87 mg/L
Expiry Date :	09/2016	95% Confidence Limits :	0.71-1.08 mg/L
Date Tested (yyyy-mm-dd) :	2015-03-05	Historical Mean IC50 :	0.75 mg/L
Reference Substance :	Zinc (as zinc sulphate)	Warning Limits (± 2SD) :	0.50-1.12 mg/L
Statistical Method :	Least Square Regression	Analyst(s):	AS

CONDITIONS OF ACUTE MICROTOX TEST

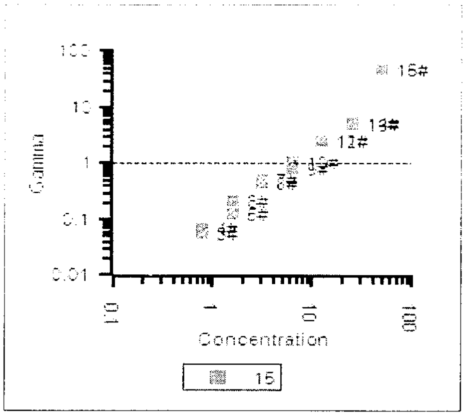
Test Organism :	*Vibrio fischeri*	Test Initiation Time :	13:18
Reagent Batch :	14J4128	Observation Time(s) :	15 minutes
Date Reagent Received :	2015-02-10	Sample Pre-aeration/Aeration :	None
Reagent Holding Temperature :	-20 °C	Sample pH :	6.8
Analyzer Model Number :	M500	pH Adjustment :	None
Test Well Temperature :	15.0 ± 0.3 °C	Salinity Adjustment :	Not required
Highest Concentration Tested :	50 %	Final Salinity :	≥2% NaCl
Number of Controls :	2	Dilution Water :	AquaTox Diluent
Number of Concentrations Tested :	8	Sample Storage :	4±2 °C
Number of Replicates :	2	Colour Correction :	None
Appearance of Test Solutions :	No changes noted.	Analyst(s):	CN/DK
		Test Method Deviation(s) :	None

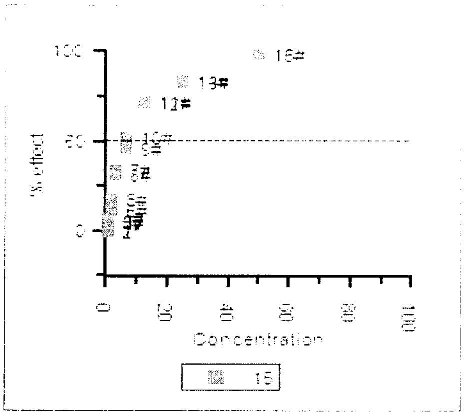
Date: 2015-04-17
yyyy-mm-dd

Approved by:
Project Manager

Accredited to ISO/IEC 17025 by the Canadian Association for Laboratory Accreditation Inc. (CALA)

Work Order : 227837
Sample Number : 43380





Time	Sample	Conc. (%)	I0	It	Gamma	%Effect
15 Mins						
	Control	0.00	86	76	0.8819#	
	Control	0.00	100	86	0.8582#	
	Control	0.00	97	85	0.8799#	
	Control	0.00	93	87	0.9345*	
	1	0.39	95	83	0.0063*	0.63%
	2	0.39	92	81	-0.0063*	-0.64%
	3	0.78	99	82	0.0555#	5.26%
	4	0.78	98	80	0.0680#	6.37%
	5	1.56	89	69	0.1271#	11.28%
	6	1.56	97	69	0.2187#	17.95%
	7	3.13	102	59	0.5226#	34.32%
	8	3.13	101	61	0.4541#	31.23%
	9	6.25	92	44	0.8424#	45.72%
	10	6.25	97	41	1.078#	51.87%
	11	12.50	100	24	2.604#	72.25%
	12	12.50	99	25	2.490#	71.35%
	13	25.00	95	14	4.892#	83.03%
	14	25.00	96	14	5.148#	83.74%
	15	50.00	95	2	48.58#	97.98%
	16	50.00	96	2	48.40#	97.98%

- included, * - invalid

Statistics:

Data: 15 Mins

EC50 Concentration: 5.646%
(95% Confidence Range: 4.801 to 6.639)
95% Confidence Factor: 1.176
Estimating Equation: LOG C = 0.6581 x LOG G +0.7518
Correction Factor: 0.8733
Slope: 1.467
Coeff of Determination (R^2): 0.9657

Test Data Reviewed By :
Date : 2015-03-30

CHAIN OF CUSTODY RECORD

AQUATOX

AquaTox Work Order No: 227837

Shipping Address: AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Road, RR #3
Guelph, Ontario Canada N1H 6H9

Voice: (519) 763-4412 **Fax:** (519) 763-4419

P.O. Number: McGREGOR #2
Field Sampler Name (print): ISAAC FRASER
Signature:
Affiliation:
Sample Storage (prior to shipping): N/A
Custody Relinquished by: GARY HARRIS
Date/Time Shipped: MARCH24/15

Client: HARRIS INDUSTRIAL TESTING SVC. LTD.
1320 ASHDALE RD. SO RAWDON
NS B0N 1Z0
Phone: 902·7570232
Fax: 902 757 02839
Contact: CAROL HARRIS hits@eastlink.ca

Sample Identification					Analyses Requested								Sample Method and Volume		
Date Collected (yyyy-mm-dd)	Time Collected (e.g. 14:30, 24 hr clock)	Sample Name	AquaTox Sample Number	Temp. on arrival	Silverside Growth	Sea Urchin Fertilization	Champia Reproduction	Blue Mussel Larval Development	Sea Urchin Larval Development	Marine Amphipod Survival	Marine Polycheate Survival and Growth	Microtox ~~Solid phase~~)	[✓ Grab]	Composite	# of Containers and Volume (eg. 2 x 1L, 3 x 10L, etc.)
2015 03-24	0650	DEEP PANUKE PRODUCE WATER	43380	14.0		✓						✓			2 X 1L

For Lab Use Only
Received By: AW
Date: 2015 03-24
Time: 0845
Storage Location:
Storage Temp.(°C)

Please list any special requests or instructions:

AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Rd.
RR 3
Guelph ON N1H 6H9
Tel: (519) 763-4412 Fax: (519) 763-4419

PRELIMINARY

MICROTOX® REPORT SUMMARY

Workorder No: 227837

Gary Harris
Harris Industrial Testing Service Ltd.
1320 Ashdale Rd.
South Rawden NS
B0N 1Z0

RESULTS

Substance	Date Collected	Date Tested	Species / Test	15 Minute IC50	95% Confidence Limits
Deep Panuke Produce Water	2015-03-24	2015-03-27	Microtox IC50	5.65 %	4.80-6.64

Test Protocols

Environment Canada. 1992. Toxicity Test Using Luminescent Bacteria (Vibrio fischeri). Environment Canada, Conservation and Protection. Ottawa ON. Reference Method EPS 1/RM/24.

APPENDIX B2

Cloudy Water Discharge Toxicity and Sea Urchin Fertilization Results

AQUATOX
AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Rd.
RR 3
Guelph ON N1H 6H9
Tel: (519) 763-4412 Fax: (519) 763-4419

MICROTOX® ACUTE TOXICITY TEST REPORT

Work Order : 227712
Sample Number : 43207

SAMPLE IDENTIFICATION

Company :	Harris Industrial Testing Service Ltd.	Time Collected :	10:00
Location :	South Rawden NS	Date Collected :	2015-03-07
Substance :	Deep Panuke	Sample Volume :	2 x 1L jars
Sampling Method :	Not given	Date Received :	2015-03-10
Sampled By :	M. N.	Date Tested :	2015-03-10
Sample Description :	Clear, colourless, odourless	Temp. on arrival :	9.0°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	>90%	-	-

The results reported relate only to the sample tested.

REFERENCE TOXICANT DATA

Reagent Batch :	14J4128	15 minute IC50 :	0.87 mg/L
Expiry Date :	09/2016	95% Confidence Limits :	0.71-1.08 mg/L
Date Tested (yyyy-mm-dd) :	2015-03-05	Historical Mean IC50 :	0.75 mg/L
Reference Substance :	Zinc (as zinc sulphate)	Warning Limits (± 2SD) :	0.50-1.12 mg/L
Statistical Method :	Least Square Regression	Analyst(s):	AS

CONDITIONS OF ACUTE MICROTOX TEST

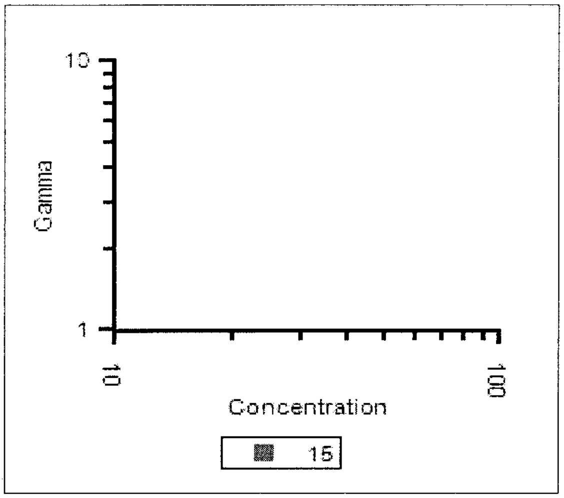
Test Organism :	*Vibrio fischeri*	Test Initiation Time :	11:25
Reagent Batch :	14J4128	Observation Time(s) :	15 minutes
Date Reagent Received :	2015-02-10	Sample Pre-aeration/Aeration :	None
Reagent Holding Temperature :	-23 °C	Sample pH :	7.9
Analyzer Model Number :	M500	pH Adjustment :	None
Test Well Temperature :	15.0 ± 0.3 °C	Salinity Adjustment :	Not required
Highest Concentration Tested :	90 %	Final Salinity :	≥2% NaCl
Number of Controls :	2	Dilution Water :	AquaTox Diluent
Number of Concentrations Tested :	6	Sample Storage :	4±2 °C
Number of Replicates :	2	Colour Correction :	None
Appearance of Test Solutions :	No changes noted.	Analyst(s):	CN
		Test Method Deviation(s) :	None

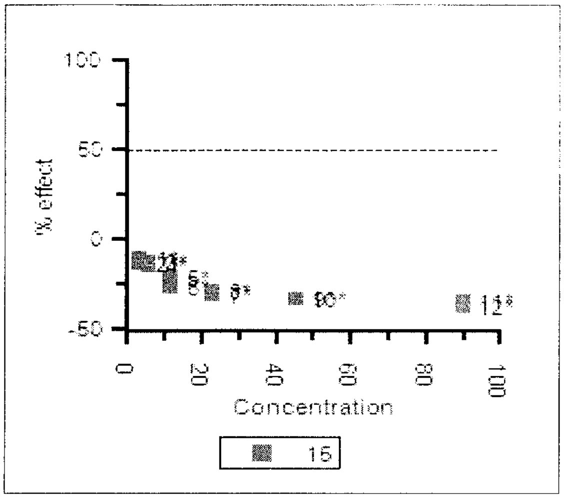
Date: 2015-03-13
yyyy-mm-dd

Approved by:
Project Manager

Accredited to ISO/IEC 17025 by the Canadian Association for Laboratory Accreditation Inc. (CALA)

Work Order : 227712
Sample Number : 43207





Time	Sample	Conc. (%)	I0	It	Gamma	%Effect
15 Mins						
	Control	0.00	93	108	1.157#	
	Control	0.00	96	109	1.135#	
	Control	0.00	94	109	1.167#	
	Control	0.00	90	108	1.204#	
	1	2.81	90	116	-0.0923*	-10.17%
	2	2.81	85	113	-0.1196*	-13.58%
	3	5.63	88	115	-0.1061*	-11.87%
	4	5.63	88	117	-0.1207*	-13.73%
	5	11.25	87	122	-0.1747*	-21.17%
	6	11.25	86	126	-0.2060*	-25.94%
	7	22.50	90	137	-0.2301*	-29.89%
	8	22.50	90	135	-0.2209*	-28.35%
	9	45.00	90	139	-0.2452*	-32.49%
	10	45.00	90	140	-0.2447*	-32.39%
	11	90.00	89	139	-0.2526*	-33.79%
	12	90.00	91	145	-0.2718*	-37.32%

- included, * - invalid

Statistics:

Data: 15 Mins

Detected hormesis.
Highest % effect: -10.17%
Correction Factor: 1.166

Test Data Reviewed By : JC
Date : 2015-03-12

AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Rd.
RR 3
Guelph ON N1H 6H9
Tel: (519) 763-4412 Fax: (519) 763-4419

Sea Urchin Test Report
Fertilization Inhibition

Work Order : 227712
Sample Number : 43207

SAMPLE IDENTIFICATION

Company :	Harris Industrial Testing Service Ltd.		
Location :	South Rawden NS	Date Collected :	2015-03-07
Substance :	Deep Panuke	Time Collected :	10:00
Sampling Method :	Not given	Date Received :	2015-03-10
Sampled By :	M. N.	Time Received :	09:00
Temp. on arrival :	9.0°C	Date Tested :	2015-03-10
Sample Description :	Clear, colourless, odourless		

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), with deviation(s) as noted below.

TEST RESULTS

Effect	Value	95% Confidence Limits	Statistical Method
IC25 (Fertilization)	>100%	-	-

The results reported relate only to the sample tested.

COPPER (AS COPPER SULPHATE) REFERENCE TOXICANT DATA

Date Tested :	2015-03-10	Statistical Method :	Non-Linear Regression* (CETIS)
Gamete Batch :	Ur15-03-01	Historical Mean IC25 :	136 µg/L
Test Duration :	20 minutes	Warning Limits (± 2SD) :	61 - 301 µg/L
IC25 Fertilization :	104 µg/L	Analyst(s) :	DK
95% Confidence Limits :	100 - 108 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) :	Yes (see 'Comments')

[1] no additional chemicals
[2] 10 min exposure, continued for an additional 10 min after addition of eggs

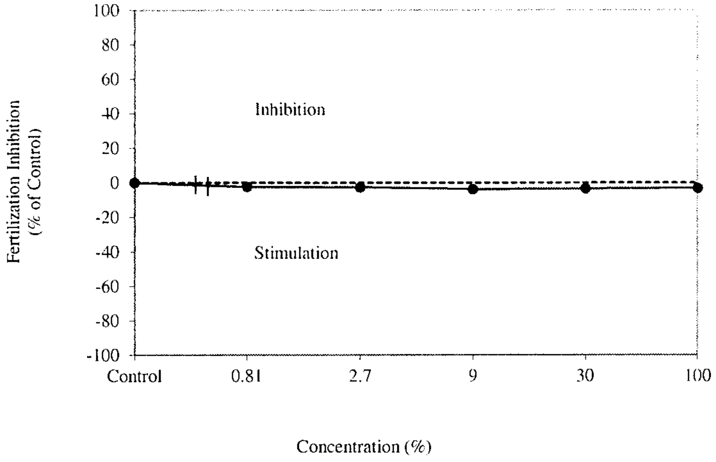
COMMENTS

Noted Deviation(s): The salinity of the 100% sample as submitted was 35‰. Therefore, salinity of the 100% exposure concentration exceeded the maximum of 32‰ allowed by the test method cited above.

*Binomial weighting (CETIS[a]) was applied.
•All test validity criteria as specified in the test method cited above were satisfied.

Work Order : 227712
Sample Number : 43207

Sea Urchin Fertilization Inhibition



TEST ORGANISM

Adult Test Organism : *Lytechinus pictus*
Adult Organism Source : Marinus Scientific
Source Location : Garden Grove CA USA
Date Received : 2013-11-12
Holding Water : Artificial Sea Water
Holding Temperature : 12 - 15 °C

Holding Salinity : 34 ± 2 ‰
Holding Vessel : Glass aquaria
Adult Mortality Rate : 0% (previous 7 days)
Life Stage Tested : Gamete (sperm/egg)
Gamete Batch Tested : Ur15-03-01

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

REFERENCES

[a] CETIS, © 2001-2007. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, McKinleyville, Calif. 95519 [Program on disk and printed User's Guide].

[b] Grubbs, F.E., 1969. Procedures for detecting outlying observations in samples. Technometrics, 11:1-21.

[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 : 2015-03-13
yyyy-mm-dd

Approved By :
Project Manager

Work Order : 227712
Sample Number : 43207

FERTILIZATION DATA

Test Conducted By : DK
Enumerated By : DK

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
Control	A	90	10	90	**92.25**	**2.22**
	B	93	7	93		
	C	95	5	95		
	D	91	9	91		
Blank	A	2	98	2	**0.5**	**1.00**
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
0.02	A	–	–	–	–	–
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.07	A	–	–	–	–	–
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.24	A	–	–	–	–	–
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.81	A	95	5	95	**94.5**	**0.58**
	B	94	6	94		
	C	94	6	94		
	D	95	5	95		
2.7	A	96	4	96	**94.75**	**0.96**
	B	94	6	94		
	C	94	6	94		
	D	95	5	95		
9	A	97	3	97	**95.75**	**0.96**
	B	95	5	95		
	C	96	4	96		
	D	95	5	95		
30	A	95	5	95	**95.5**	**1.29**
	B	97	3	97		
	C	94	6	94		
	D	96	4	96		
100	A	96	4	96	**95.25**	**0.96**
	B	95	5	95		
	C	94	6	94		
	D	96	4	96		

"–" = not counted/not required

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 conducted prior to testing.
- Preserved eggs were stored for 1 day prior to enumeration.
- No outlying data points were detected according to Grubbs Test^{h}.

Data Reviewed By : VC
Date : 2015-03-12

Work Order :	227712
Sample Number :	43207

INITIAL WATER CHEMISTRY (100% SAMPLE)

	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)	Pre-aeration Time (h)
Initial Chemistry:	20.0	7.9	8.4	112	35	–
Chemistry after Salinity Adjustment [3]:	–	–	–	–	–	–
Chemistry after Pre-Aeration[3,4]:	20.0	7.9	7.4	101	35	0:20

SALINITY ADJUSTMENT

Method :	Not applicable[5]	Volume Adjusted :	Not applicable[5]
Salt Added :	Not applicable[5]	Amount of Salt Added :	Not applicable[5]
Date Adjusted :	Not applicable[5]	Aging Time :	Not applicable[5]
Aging Conditions :	Not applicable[5]	Aging Temperature :	Not applicable[5]

[5]Note: The 100% effluent did not require salinity adjustment since the initial sample salinity was 35‰. Therefore the effluent was tested as received.

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

EXPOSURE CONCENTRATIONS WATER CHEMISTRY

Concentration (%)	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)
Control	20.0	8.1	7.3	100	30
Blank	20.0	8.1	7.3	100	30
0.02	20.0	8.1	7.3	100	30
0.07	20.0	–	–	–	–
0.24	20.0	–	–	–	–
0.81	20.0	–	–	–	–
2.7	20.0	–	–	–	–
9	20.0	8.1	7.3	100	30
30	20.0	8.0	7.3	100	31
100	20.0	7.9	7.4	101	35

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

Data Reviewed By : VC
Date : 2015-03-12

CHAIN OF CUSTODY RECORD

AQUATOX

AquaTox Work Order No: 227712

Shipping Address: AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Road, RR #3
Guelph, Ontario Canada N1H 6H9

Voice: (519) 763-4412 **Fax:** (519) 763-4419

P.O. Number: McGREGOR

Field Sampler Name (print): ATLANTIC CONDOR - MATTHEW NICKERSON

Signature: —

Affiliation: ENCANA

Sample Storage (prior to shipping):

Custody Relinquished by: C. HARRIS

Date/Time Shipped: MAR. 09 2015

Client:
HARRIS INDUSTRIAL TESTING SVC LTD
1320 ASHDALE RD. SO. RAWDON
NS BONIZO

Phone: 902 757-0232

Fax: 902 757-0289

Contact: CAROL HARRIS hits@eastlink.ca

Sample Identification					Analyses Requested									Sample Method and Volume		
Date Collected (yyyy-mm-dd)	Time Collected (e.g. 14:30, 24 hr clock)	Sample Name	AquaTox Sample Number	Temp. on arrival	Rainbow Trout Single Concentration	Rainbow Trout LC50	*Daphnia magna* Single Concentration	*Daphnia magna* LC50	Fathead Minnow Survival & Growth	*Ceriodaphnia dubia* Survival & Reproduction	*Lemna minor* Growth	*Pseudokirchneriella subcapitata* Growth	Microtox	Grab	Composite	# of Containers and Volume (eg. 2 x 1L, 3 x 10L, etc.)
2015-03-07	1000	DEEP PANUKE	43207	9.0									✓			2 X 1L DK

For Lab Use Only

Received By: DK

Date: 2015-03-10

Time: 9:00

Storage Location:

Storage Temp.(°C)

Please list any special requests or instructions:

ECHINOID FERTILIZATION - PERMISSION TO CONDUCT TEST IF AQUATOX IS UNABLE TO INITIATE WITHIN 3 DAY TIME LIMIT.

Sample name on containers is Cloudy Seawater

AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Rd.
RR 3
Guelph ON N1H 6H9
Tel: (519) 763-4412 Fax: (519) 763-4419

PRELIMINARY

MICROTOX® REPORT SUMMARY

Workorder No: 227712

Gary Harris
Harris Industrial Testing Service Ltd.
1320 Ashdale Rd.
South Rawden NS
B0N 1Z0

RESULTS

Substance	Date Collected	Date Tested	Species / Test	15 Minute IC50	95% Confidence Limits
DEEP PANUKE	2015-03-07	2015-03-10	Microtox IC50	>90 %	-

Test Protocols

Environment Canada. 1992. Toxicity Test Using Luminescent Bacteria (Vibrio fischeri). Environment Canada, Conservation and Protection. Ottawa ON. Reference Method EPS 1/RM/24.

APPENDIX C

Daily Progress Reports

Daily Survey Report

M/V Atlantic Condor
e-Mail skirchhoff@mcgregor-geoscience.com
Irridium Tel. (011) 88177702324
FBB Tel. 881-677-702-323
V-Sat (902) 482-8069

McGregor GeoScience Limited
Project No. 1113

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
Attn: Peter Taylor e-Mail peter.taylor@sbmoffshore.com@encana.com

Project No. 1113
Report No. 001
Date : 2015-23-03
Page 1 of 2

Encana Deep Panuke EEMP - 2015
Daily Progress Report

Location at 24:00 Local AST time: 44° 11.5N ; 62°18.7W

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp ℃	Water Temp ℃	Visibility nm
-	-	-	-	-	-	-
1200	1013	WNN 11-16 kts	Dockside	-1.0	-	5.5-11
1800	1014	W 11-16kts	0.1-0.45	0.0	-	5.5-11
2400	1020	W 11-16kts	0.45-1.2	-5.0	-	5.5-11

Forecast: Northerlies to diminish to light Tuesday through to Wednesday.

Event Diary (Local Time - AST (+3hr to UTC)):

	From	To	Description of Events	Code
	11:00	17:08	Mobilizing at the SBM yard and Atlantic Condor	md
	17:08	24:00	Depart Dock and begin transit to Encana Deep Panucke PFC	tr

Time Summary (hh:mm): 2015-23-03

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	06:08	006:08
Transit	tr	Transit	06:52	006:52
Calibrations	cal	Calibrations	00:00	000:00
Mob/Demob Subtotal				
Operational	op1	Data Acq.	00:00	000:00
	op2	Standby	00:00	000:00
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			13:00	13:00

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	3/0
Sub-Contract:		1/0
Client:	0	0/0
Ship:	11	11/0
Other Reps - ROV crew:	4	3/0
	17	

Fuel:	Used Since Last Update	Cumulative	Remaining
	(L)	(L)	(L)
IFO-30	172 000		
Lube Oil:	9 379		
Fresh Water:	506 000		

Safety:	Today	Cumulative	Comment
Drills :	0	0	
Incidents :	0	0	
Vessel Induction :	1	1	All new persons were given a vessel safety induction
Toolbox/Safety Mtg. :	1	1	Safety meeting re deck operations. JSA reviewed by MGL personnel

Proposed Work for next 24 hours:
Transit, equipment testing at PFC, Mussel collection with ROV, sediment collection

Seabed Sampling:

	GC	BxC
Today	0	0
Cumulative	**0**	**0**

Water Column:

(Cumulative)

CTD	Niskin Cast
0	0

Party Chief Comments:

a) McGregor container loaded at 17:00 UTC
b) Deborah Livingston was not permitted onboard due to H2S certification originating from a French Company (needed Enform H2S Alive)
c) It was decided that the work could be completed with only two Mcgregor employee (SK and GF) and that additional help would be provided by the crew.
d) Captain requested certification for Niskin bottle cable (Rainbow Net and Rigging) and blocks (Hercules). Tim ryan will forward them on in the morning.
e) Reviewed JSA with Gillian Forbes for Grab, mussel collection, water collection and CTD deployment

Daily Survey Report

M/V Atlantic Condor
e-Mail skirchhoff@mcgregor-geoscience.com
Irridium Tel. (011) 88177702324
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V-Sat (902) 482-8069

McGregor GeoScience Limited
Project No. 1113

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
Attn: Peter Taylor e-Mail peter.taylor@sbmoffshore.com@encana.com

Project No. 1113
Report No. 002
Date : 2015-24-03
Page 1 of 2

Encana Deep Panuke EEMP - 2015
Daily Progress Report

Location at 24:00 Local AST time: 43° 50.2N ; 60°42.0W

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp ℃	Water Temp ℃	Visibility nm
0600	1020	Light	2.4-4.0	-3.0	-	5.5-11
1200	1023	NW 7-10kts	2.4-4.1	-2.0	-	5.5-11
1800	1024	NW 7-10kts	1.2-2.4	0.0	-	5.5-11
2400	1024	NW 7-10kts	1.2-2.4	0.0	-	5.5-11

Forecast: North Westerlies to stay light through to Wednesday.

Event Diary (Local Time - AST (+3hr to UTC)):

	From	To	Description of Events	Code
	00:00	07:21	transit to Encana Deep Panuke PFC, arrival 3 nm from PFC	tr
	07:21	09:55	RBR CTD pH calibration	cal
	09:55	10:30	Aborted ops due to strong smell originating from the produced water sheen.	sbo
	10:30	12:50	ROV ops to collect mussels along SW leg	op1
	12:50	13:30	Collecting cargo from PFC	sbo
	13:30	14:31	Mussel subsampling	op1
	14:31	16:00	Prepping grab, A. Condor and McGregor toolboxes and JSAs, transitting to SED5000MUPS station	op1
	16:00	16:40	Sampling at station SED5000MUPS for sediment	op1
	16:40	16:52	transit to Encana Deep Panuke PFC, arrival 3 nm from PFC	op1
	16:52	17:37	Sampling for sediment at SED250MDOS	op1
	17:37	24:00	Standby. End of operations at 18:00 due to lack of mate for DP operations.	sb1

Time Summary (hh:mm):

2015-24-03 Page 2 of 2

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	006:08
Transit	tr	Transit	07:21	014:13
Calibrations	cal	Calibrations	02:34	002:34
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	06:27	006:27
	op2	Standby	00:00	000:00
Standby	sbo	Other	00:00	000:00
	sbw	Weather	01:15	001:15
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		06:23	006:23
Non-Chargable Subtotal				
TOTAL			24:00	37:00

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	03	3		3
Project Total	**03**	**3**		**3**

Personnel Onboard:	**Total Man Days**	**No. On/Off Today**
McGregor:	2	3/0
Sub-Contract:		1/0
Client:	0	0/0
Ship:	11	11/0
Other Reps - ROV crew:	4	3/0
	17	

Fuel:	**Used Since Last Update**	**Cumulative**	**Remaining**
	(L)	(L)	(L)
IFO-30	169 000		
Lube Oil:	9 379		
Fresh Water:	504 000		

Safety:	**Today**	**Cumulative**
Drills :	0	0
Incidents :	0	0
Vessel Induction :	0	1
Toolbox/Safety Mtg. :	2	3

Comment

toolbox meeting with MGL employee and Toolbox meeting with A. Condor personnel.

Proposed Work for next 24 hours:

Water quality program consisting water samples collection (3 depth) and CTD deployment at 7 stations around the PFC.

Seabed Sampling:

	GC	BxC
Today	0	2
Cumulative	**0**	**2**

Water Column:

(Cumulative)

CTD	Niskin Cast
0	0

Party Chief Comments:

a) Received the certification for cable but no for blocks. A certified vessel cable and blocks were used for the MGL grab.
b) ROV mussel collecting tool was too flexible to be used properly by the crew. A stronger device will be needed next time around.
c) ROV collected video of their effort and copied it on DVD for MGL.
d) Because of difficulties of using the mussel collecting tool, the ROV was not able to clear a 1 m2 area to collect mussels the following year.
e) JSA and toolbox meeting took place amongst MGL employees and again with Atlantic Condor employees.
f) The lack of a second mate does not allow the vessel to carry out DP operations beyond the 12 hour shift. Ops are obligated to terminate at 18:00.

Daily Survey Report

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

e-Mail skirchhoff@mcgregor-geoscience.com **Project No.** 1113
Irridium Tel. (011) 88177702324
FBB Tel. 881-677-702-323
V-Sat (902) 482-8069

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
Attn: Peter Taylor e-Mail peter.taylor@sbmoffshore.com@encana.com

Project No. 1113 Report No. 003 Date : 2015-25-03 Page 1 of 2

Encana Deep Panuke EEMP - 2015
Daily Progress Report

Location at 24:00 Local AST time: 43°47.8N ; 60°35.9W

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp °C	Water Temp °C	Visibility nm
0600	1023	NW 11-16kts	1.2-2.4	0.0	-	5.5-11
1200	1025	NW 11-16kts	1.2-2.4	0.0	-	5.5-11
1800	1026	NW 11-16kts	1.2-2.4	3.0	-	5.5-11
2400	1027	NWW 11-16kts	1.2-2.4	1.0	-	5.5-11

Forecast: Light to moderate South Westerlies

Event Diary (Local Time - AST (+3hr to UTC)):

	From	To	Description of Events	Code
	00:00	06:45	Standing by near first sampling station.	sb1
	06:45	07:52	Prepping: cable for niskin, coolers and Niskins	op1
	07:52	08:11	JSA and toolbox meetings	op1
	08:11	09:34	Collected water at the 2000MUPS station	op1
	09:34	09:54	Deployed and recovered CTD, check data.	op1
	09:54	10:10	Transit to 250MUPS station	tr
	10:10	10:57	Collected water at the 250MUPS station	op1
	10:57	11:51	Deployed and recovered CTD, check data.	op1
	11:51	12:29	Standing by	sb1
	12:29	12:30	Transit to 20MDOS station	tr
	12:30	12:53	Collected water at the 20MDOS station	op1
	12:53	13:09	Deployed and recovered CTD, check data.	op1
	13:09	13:15	Transit to 250MDOS station	tr
	13:15	13:56	Collected water at the 250MDOS station	op1
	13:56	14:11	Deployed and recovered CTD, check data.	op1
	14:11	14:16	Transit to 500MDOS station	tr
	14:16	15:00	Collected water at the 500MDOS station	op1
	15:00	15:14	Deployed and recovered CTD, check data.	op1
	15:14	15:20	Transit to 1000MDOS station	tr
	15:20	16:00	Standing by	sb1
	16:00	16:13	Collected water at the 1000MDOS station	op1
	16:13	16:28	Deployed and recovered CTD, check data.	op1
	16:28	16:30	transit to 2000MDOS station	tr
	16:30	17:30	Collected water at the 2000MDOS station, mid water niskin broke (pulled too close to ship), 2nd drop was necessary	op1
	17:30	18:06	Deployed and recovered CTD, check data.	op1
	18:06	24:00	Standing by, ops finished for the day	sb1

Time Summary (hh:mm): 2015-25-03 Page 2 of 2

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	006:08
Transit	tr	Transit	00:36	014:49
Calibrations	cal	Calibrations	00:00	002:34
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	09:27	015:54
	op2	Standby	00:00	000:00
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	001:15
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		13:57	020:20
Non-Chargable Subtotal				

TOTAL			24:00	61:00

Survey Progress

	# Stations	**Daily Total # Stations**		**Cumulative to Date Stations**
Survey Station	07	7		10
Project Total	**10**	**10**		**10**

Personnel Onboard:	**Total Man Days**	**No. On/Off Today**
McGregor:	2	3/0
Sub-Contract:		1/0
Client:	0	0/0
Ship:	11	11/0
Other Reps - ROV crew:	4	3/0
	17	

Fuel:	**Used Since Last Update**	**Cumulative**	**Remaining**
	(L)	(L)	(L)
IFO-30	162 000		
Lube Oil:	9 359		
Fresh Water:	502 000		

Safety:	**Today**	**Cumulative**
Drills :	0	0
Incidents :	0	0
Vessel Induction :	0	1
Toolbox/Safety Mtg. :	2	5

Comment

toolbox meeting with MGL employee and Toolbox meeting with A. Condor personnel.

Proposed Work for next 24 hours:

Collected remaining Sediment stations and recover Produced Water cooler from PFC and then head back to HFX

Seabed Sampling:

	GC	BxC
Today	0	2
Cumulative	**0**	**2**

Water Column:

(Cumulative)

CTD	Niskin Cast
7	8

Party Chief Comments:

a) One niskin bottle broke as it was being pulled up too close to the vessel.

Daily Survey Report

M/V Atlantic Condor
e-Mail skirchhoff@mcgregor-geoscience.com
Irridium Tel. (011) 88177702324
FBB Tel. 881-677-702-323
V-Sat (902) 482-8069

McGregor GeoScience Limited
Project No. 1113

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
Attn: Peter Taylor e-Mail peter.taylor@sbmoffshore.com@encana.com

Project No. 1113
Report No. 004
Date : 2015-26-03
Page 1 of 2

Encana Deep Panuke EEMP - 2015
Daily Progress Report

Location at 24:00 Local AST time: 43°47.8N ; 60°35.9W

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp ℃	Water Temp ℃	Visibility nm
0600	1023	SW 11-16kts	1.2-2.4	1.0	-	5.5-11
1200	1025	SW 11-16kts	1.2-2.4	3.0	-	5.5-11
1800	1016	SW 11-16kts	1.2-2.4	5.0	-	1.0-2.0
2400	-	-	-	-	-	-

Forecast: Winds and sea picking up throughout the day to WSW strong.

Event Diary (Local Time - AST (+3hr to UTC)):

	From	To	Description of Events	Code
	00:00	06:30	Standing, waiting on cargo transfer from PFC.	sb1
	06:30	09:30	Attempted cargo transfer but smell from sheen shut down cargo ops	sb1
	09:30	10:20	Transit to sediment sampling station SED500MDOS	op1
	10:20	10:43	Collected sediment at station SED500MDOS	op1
	10:43	10:46	transit to SED 1000MDOS	tr
	10:46	11:07	Sampling sediment at SED1000MDOS	op1
	11:07	11:09	Transit to SED2000MDOS	tr
	11:09	11:18	1st attempt at getting sediment at SED2000MDOS	op1
	11:18	11:45	2nd attempt with van veen	op1
	11:45	11:48	Transit to SED5000MDOS station	tr
	11:48	12:05	Collected sediment at SED5000MDOS	op1
	12:05	13:09	Deployed and recovered CTD, check data.	sb1
	13:09	14:55	Waiting for cargo transfer from PFC	sb1
	14:55	15:40	Cargo transfer	sb1
	15:40	24:00	transit to back to Halifax.	tr

Time Summary (hh:mm): 2015-26-03 Page 2 of 2

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	00:00	006:08
Transit	tr	Transit	08:28	023:17
Calibrations	cal	Calibrations	00:00	002:34
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	02:27	018:21
	op2	Standby	00:00	000:00
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	001:15
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		13:05	033:25
Non-Chargable Subtotal				
TOTAL			24:00	85:00

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	04	4		14
Project Total	**14**	**14**		**14**

Personnel Onboard:	**Total Man Days**	**No. On/Off Today**
McGregor:	2	3/0
Sub-Contract:		1/0
Client:	0	0/0
Ship:	11	11/0
Other Reps - ROV crew:	4	3/0
	17	

Fuel:	**Used Since Last Update**	**Cumulative**	**Remaining**
	(L)	(L)	(L)
IFO-30	156		
Lube Oil:	9 359		
Fresh Water:	500000		

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

Comment

toolbox meeting with MGL employee and Toolbox meeting with A. Condor personnel.

Proposed Work for next 24 hours:

demob equipment, head back to HFX, offload cargo.

Seabed Sampling:

	GC	BxC
Today	0	4
Cumulative	**0**	**6**

Water Column:

(Cumulative)

CTD	Niskin Cast
7	8

Party Chief Comments:

Daily Survey Report

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

e-Mail skirchhoff@mcgregor-geoscience.com **Project No.** 1113
Irridium Tel. (011) 88177702324
FBB Tel. 881-677-702-323
V-Sat (902) 482-8069

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
Attn: Peter Taylor e-Mail peter.taylor@sbmoffshore.com@encana.com
Project No. 1113 Report No. 004 Date : 2015-26-03 Page 1 of 2

Encana Deep Panuke EEMP - 2015
Daily Progress Report

Location at 24:00 Local AST time: -

Time (Local AST)	Pressure (mb)	Wind (Dir/Knts)	Sea M	Air Temp ℃	Water Temp ℃	Visibility nm
0600	1023	SW 11-16kts	1.2-2.4	1.0	-	5.5-11
-	-	-	-	-	-	
-	-	-	-	-	-	-
-	-	-	-	-	-	-

Forecast: -

Event Diary (Local Time - AST (+3hr to UTC)):

	From	To	Description of Events	Code
	00:00	07:30	Transit to HFX	tr
	07:30	09:00	Cargo off ship	md
			End of EEMP Sampling operations	

Time Summary (hh:mm): 2015-26-03 Page 2 of 2

Item	Code	Description	Today	Cumulative
Mob/Demob	md	Mob/Demob	01:30	007:38
Transit	tr	Transit	07:30	030:47
Calibrations	cal	Calibrations	00:00	002:34
Mob/Demob Subtotal				000:00
Operational	op1	Data Acq.	00:00	018:21
	op2	Standby	00:00	000:00
Standby	sbo	Other	00:00	000:00
	sbw	Weather	00:00	001:15
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	033:25
Non-Chargable Subtotal				
TOTAL			09:00	94:00

Survey Progress

	# Stations	Daily Total # Stations		Cumulative to Date Stations
Survey Station	00	0		14
Project Total	**14**	**14**		**14**

Personnel Onboard:	**Total Man Days**	**No. On/Off Today**
McGregor:	2	3/0
Sub-Contract:		1/0
Client:	0	0/0
Ship:	11	11/0
Other Reps - ROV crew:	4	3/0
	17	

Fuel:	**Used Since Last Update**	**Cumulative**	**Remaining**
	(L)	(L)	(L)
IFO-30	-		
Lube Oil:	9 359		
Fresh Water:	-		

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

Comment

toolbox meeting with MGL employee and Toolbox meeting with A. Condor personnel.

Proposed Work for next 24 hours:

demob equipment

Seabed Sampling:

	GC	BxC
Today	0	0
Cumulative	**0**	**6**

Water Column:

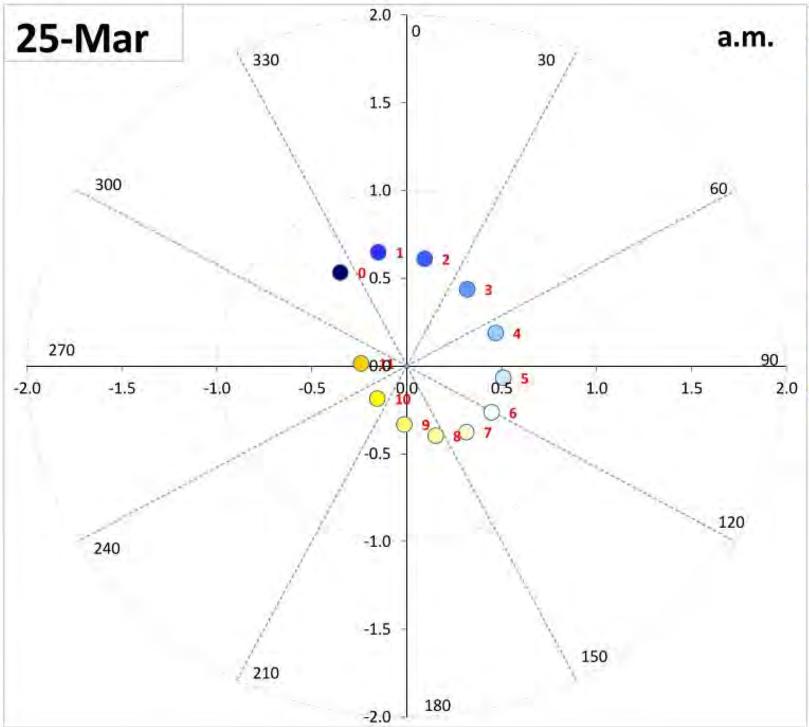
(Cumulative)

CTD	Niskin Cast
7	8

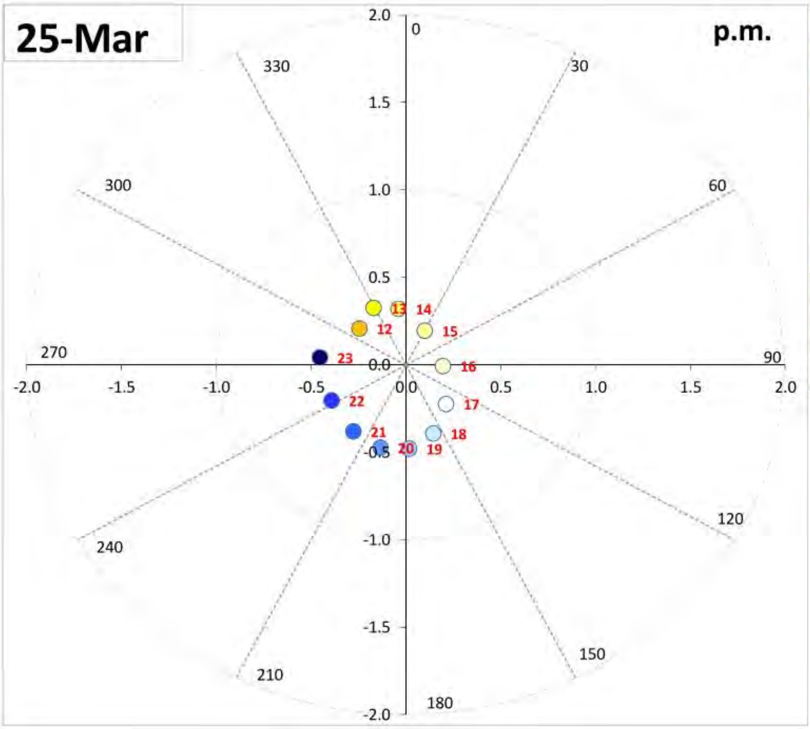
Party Chief Comments:

APPENDIX D

Tide and Current Predictions for Water Sampling



	Date	Time	Dir(°T)	Spd (kts)
0	25-Mar	00:00	327	0.64
1	25-Mar	01:00	347	0.66
2	25-Mar	02:00	9	0.62
3	25-Mar	03:00	36	0.54
4	25-Mar	04:00	68	0.50
5	25-Mar	05:00	98	0.51
6	25-Mar	06:00	121	0.52
7	25-Mar	07:00	140	0.49
8	25-Mar	08:00	159	0.43
9	25-Mar	09:00	182	0.33
10	25-Mar	10:00	220	0.24
11	25-Mar	11:00	274	0.24

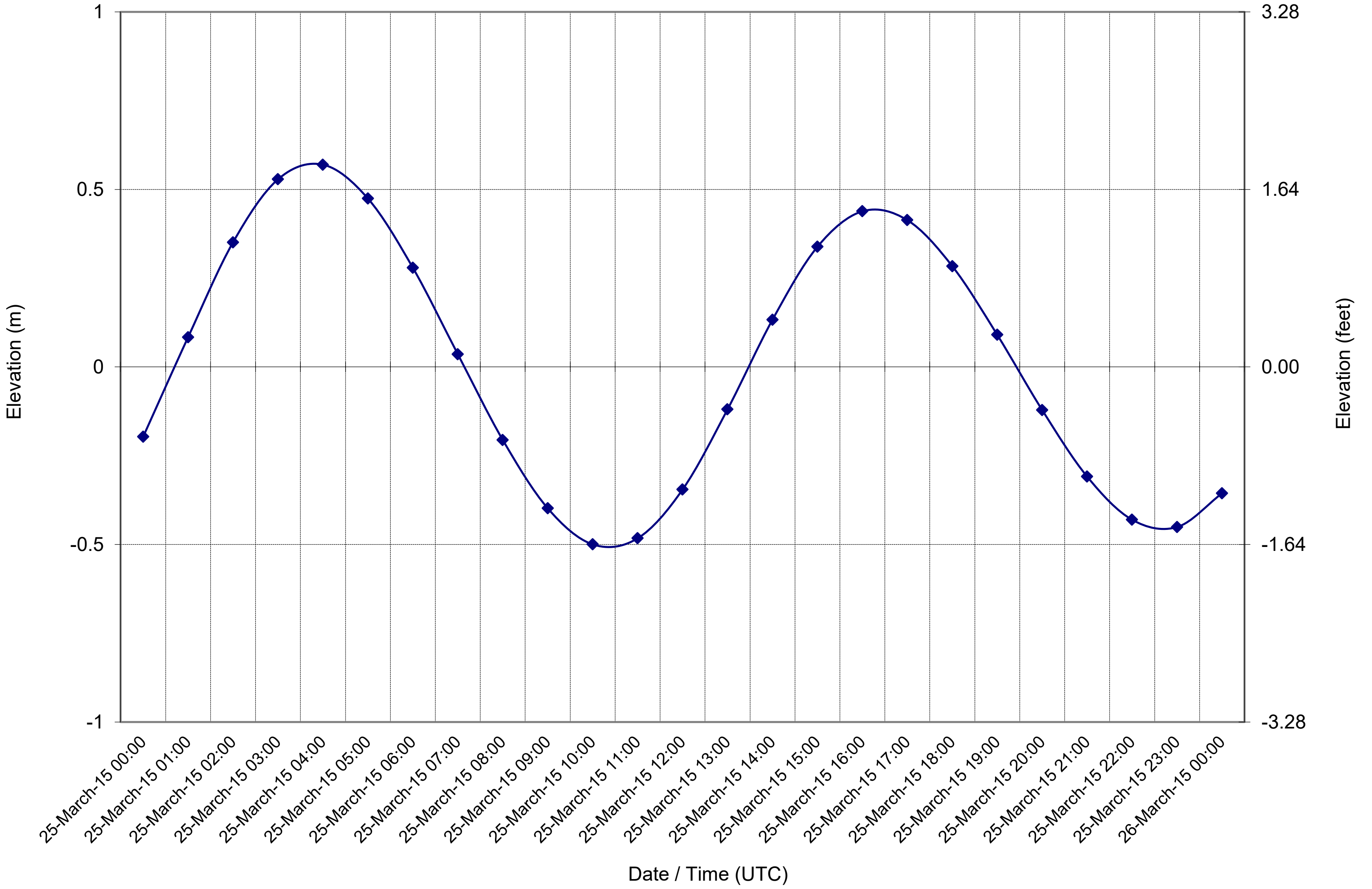


	Date	Time	Dir(°T)	Spd (kts)
12	25-Mar	12:00	310	0.32
13	25-Mar	13:00	332	0.37
14	25-Mar	14:00	353	0.32
15	25-Mar	15:00	27	0.22
16	25-Mar	16:00	92	0.20
17	25-Mar	17:00	136	0.31
18	25-Mar	18:00	160	0.42
19	25-Mar	19:00	178	0.48
20	25-Mar	20:00	196	0.49
21	25-Mar	21:00	216	0.47
22	25-Mar	22:00	243	0.44
23	25-Mar	23:00	275	0.46

Tidal Elevation Prediction above M.S.L.

25 March 2015

43.81 ºN
60.68 ºW



APPENDIX E

2015 Water Quality Sampling Field Logs

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McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84
Projection: UTM Zone 20N

Project 1113

Sample Site: 2000m US

Launch Coordinates	**Lat: 43°49.750'N**	**Long: 60°41.800'W**	**TWD: 42m**	**Red Bottle Depth (MSL):**	**1m**
Date: Mar. 25, 2015	**Time Start (UTC): 11:11**	**Time End (UTC): 11:36**		**Green Bottle Depth (MSL):**	**20m**
Sea Conditions: Choppy NW 10-15kts				**Blue Bottle Depth (MSL):**	**37m**

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

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McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84
Projection: UTM Zone 20N

Project 1113

Sample Site: 250m UP

Launch Coordinates	**Lat: 43°48.830'N**	**Long: 60°41.140'W**	**TWD: 47m**	**Red Bottle Depth (MSL):**	**1m**
Date: Mar 25, 2015	**Time Start (UTC): 13:30**	**Time End (UTC): 14:51**		**Green Bottle Depth (MSL):**	**23m**
Sea Conditions: Choppy, NW 15kts				**Blue Bottle Depth (MSL):**	**40m**

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

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McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84
Projection: UTM Zone 20N

Project 1113

Sample Site: 20m DS

Launch Coordinates	**Lat: 43°48.4688'N**	**Long: 60°4121.41'N**	**TWD: 47m**	**Red Bottle Depth (MSL):**	**1m**
Date: Mar. 25, 2015	**Time Start (UTC): 15:29**	**Time End (UTC): 15:50**		**Green Bottle Depth (MSL):**	**23m**
Sea Conditions: Choppy, NW 15kts				**Blue Bottle Depth (MSL):**	**42m**

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

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McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84
Projection: UTM Zone 20N

Project 1113

Sample Site: 250m DS

Launch Coordinates	**Lat: 43°4854.88'N**	**Long: 60°4123.26'W**	**TWD: 49m**	**Red Bottle Depth (MSL):**	**1m**
Date: Mar. 25, 2015	**Time Start (UTC): 16:38**	**Time End (UTC): 16:56**		**Green Bottle Depth (MSL):**	**25m**
Sea Conditions:				**Blue Bottle Depth (MSL):**	**44m**

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 Limited

McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84 **Projection: UTM Zone 20N**		**Project 1113**	**Sample Site: 500m DS**		
Launch Coordinates	**Lat: 43°48.59.37 N**	**Long: 60°4107.22'W**	**TWD: 48m**	**Red Bottle Depth (MSL):**	**1m**
Date: Mar. 25, 2015	**Time Start (UTC): 17:50**	**Time End (UTC): 17:56**		**Green Bottle Depth (MSL):**	**24m**
Sea Conditions: choppy NW 15kts				**Blue Bottle Depth (MSL):**	**43m**

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

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McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84
Projection: UTM Zone 20N

Project 1113

Sample Site: 1000m DS

Launch Coordinates	**Lat: 43°4844.62 N**	**Long: 60°4033.45 W**	**TWD: 48m**	**Red Bottle Depth (MSL):**	**1m**
Date: Mar 25, 2015	**Time Start (UTC): 19:00**	**Time End (UTC): 19:57**		**Green Bottle Depth (MSL):**	**24m**
Sea Conditions: Choppy NW 15 kts				**Blue Bottle Depth (MSL):**	**43m**

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

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McGregor GeoScience 1113 Water Sampling Log

Datum: WGS84 **Projection: UTM Zone 20N**		**Project 1113**	**Sample Site: 2000m DS**		
Launch Coordinates	**Lat: 43°4759.6' N**	**60°4015.52' W**	**TWD: 38m**	**Red Bottle Depth (MSL):**	**1m**
Date: Mar. 25, 2015	**Time Start (UTC): 20:00**	**Time End (UTC): 21:06**		**Green Bottle Depth (MSL):**	**22m**
Sea Conditions: Choppy NW 10-15kts				**Blue Bottle Depth (MSL):**	**35m**

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 F1

2015 Sediment Sampling Field Logs

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1113 Encana 2015

Datum: WGS84 Projection: Zone 20N

Site: 250 m DS **Core: SED 250m DS** **Date: March 24, 2015** **Time (UTC): 20:15**

Position: **N 4853499.85** **E 685734.22**

Depth (m bsl): 46m Penetration (cm): 10cm Sampling Method: **VV**

Sediment Composition: Sand,slightly muddy, uniform throughout. 1 amphipod, 3 sand dollars, 1 razor clam, 1 small flatfish.

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. Mostly-full grab

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

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Project #: 1113 ENCANA EEMP
Sample: SED 500 DS SEDIMENT
Site: SED 500 DS -> BAG A
Date Collected: MARCH 26 2015 Collected by: SK, GF
Comments:

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GeoScience
Limited

1113 Encana 2015

Datum: WGS84 Projection: Zone 20N

Site: **500m DS** **Core:** **SED 500m DS** **Date:** **March 26, 2015** **Time (UTC):** **13:20**

Position: **N 4853245.49** **E 685647.85**

Depth (m bsl): 45m Penetration (cm): 15cm Sampling Method: **VV**

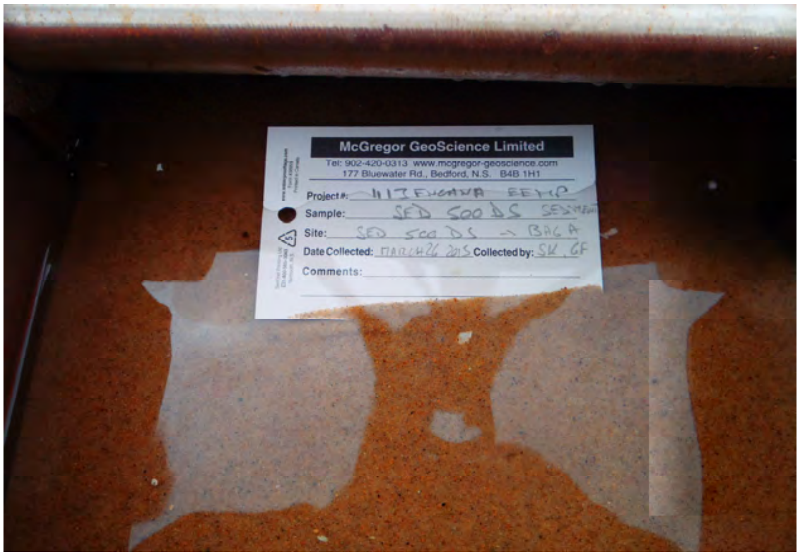
Sediment Composition: Sand, light coloured, uniform. Sheen on water inside grab. One amphipod seen, no other flora or fauna.

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
Metals/PAH/AP Clear 250ml: A B C
VPH 60ml: A
Sulphide Clear 120ml: A
Photo Taken: [✓ Yes] No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177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project #: 1113 ENCANA EEMP
Sample: SED 500 DS SEDIMEN
Site: SED 500 DS → BAG A
Date Collected: MARCH 26 2015 Collected by: SK, GF
Comments:

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1113 Encana 2015

Datum: WGS84 Projection: Zone 20N

Site: 1000m DS **Core: SED 1000m DS** **Date: March 25, 2015** **Time (UTC): 13:46**

Position: **N 4852927.54** **E 685207.27**

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

Sediment Composition: Sand - uniform throughout. Sheen on water - small shells, no fauna/flora

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

Metals/PAH/AP Clear 250ml: A B C

VPH 60ml: A

Sulphide Clear 120ml: A

Photo Taken: [✓ Yes] No

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Project #: 1113 Encana

Sample: SED-1000 m - DS - A

Site: SED-1000m - DS

Date Collected: Mar 26/2015 Collected by: GF/BK

Comments:

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1113 Encana 2015

Datum: WGS84 Projection: Zone 20N

Site: 2000m DS **Core: SED 2000m DS** **Date: March 26, 2015** **Time (UTC): 14:11**

Position: **N 4852243.24** **E 684470.43**

Depth (m bsl): 40m Penetration (cm): 15cm Sampling Method: **VV**

Sediment Composition: Sand - uniform throughout. Polychaete in grab.

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 - Ist attempt failed to grab sediment, second attempt OK at 14:24

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


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177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project #: 1113 Encana
Sample: SED-2000m DS -A
Site: SED-2000m DS
Date Collected: March 26/15 Collected by: GF/SK
Comments:

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1113 Encana 2015

Datum: WGS84 Projection: Zone 20N

Site: 5000m DS SW **Core: SED 5000m DS** **Date: March 26, 2015** **Time (UTC): 14:45**

Position: **N 4850134.72** **E 682339.75**

Depth (m bsl): 38m Penetration (cm): 15cm Sampling Method: **VV**

Sediment Composition: Sand - uniform throughout. One amphipod.

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
Metals/PAH/AP Clear 250ml: A B C
VPH 60ml: A
Sulphide Clear 120ml: A
Photo Taken: [✓ Yes] No

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Tel: 902-420-0313 www.mcgregor-geoscience.com
177 Bluewater Rd., Bedford, N.S. B4B 1H1
Project#: 1113 Encana
Sample: SED-5000m-DS-A
Site: SED-5000m-DS
Date Collected: Mar 26/15 Collected by: GF/SK
Comments:

McGregor GeoScience Limited

1113 Encana 2015

Datum: WGS84 Projection: Zone 20N

Site: 5000m US NE **Core: SED 5000m US** **Date: March 26, 2015** **Time (UTC): 19:00**

Position: **N 4857174.75** **E 689474.69**

Depth (m bsl): 39m Penetration (cm): 15cm Sampling Method: **VV**

Sediment Composition: Sand - light colour - uniform throughout

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
Metals/PAH/AP Clear 250ml: A B C
VPH 60ml: A
Sulphide Clear 120ml: A
Photo Taken: [✓ Yes] No

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1113 Encana 2015 Blind Sediment Collection

Datum: WGS84 Projection: Zone 20N

Site: **1000m DS** **Core:** **1000m DS** **Date:** **March 26, 2015** **Time (UTC):** **13:46**

Position: **N 4852927.54** **E 685207.27**

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

Sediment Composition: Sand - uniform throughout. No flora/fauna, just small shells.

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

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

Notes: Sheen on water

Samples Collected: Bioassay 1L Bag: A B

Photo Taken: [✓ Yes] No

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Project#: 1113 Encana
Sample: SED-1000 m - DS - A
Site: SED-1000m - DS
Date Collected: Mar 26/2015 Collected by: GF/BK
Comments:

APPENDIX F2

CEQG Sediment Quality Guidelines

Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

INTRODUCTION

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

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

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

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

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

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

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

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

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

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

Canadian ISQGs are recommended for total concentrations of chemicals in freshwater and marine surficial sediments (i.e., top 5 cm), as quantified by standardized analytical protocols for each chemical. For the analytical quantification of metals in sediments, the choice of digestion method is dependent on the intended use of the results (e.g., for quantification of the 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.

References

CCME (Canadian Council of Ministers of the Environment). 1995. Protocol for the derivation of Canadian sediment quality guidelines for the protection of aquatic life. CCME EPC-98E. Prepared by Environment Canada, Guidelines Division, Technical Secretariat of the CCME Task Group on Water Quality Guidelines, Ottawa. [Reprinted in Canadian environmental quality guidelines, Chapter 6, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]

Chapman, P.M. 1995. Sediment quality assessment: Status and outlook. J. Aquat. Ecosyst. Health 4:183–194.

Long, E.R. 1992. Ranges in chemical concentrations in sediments associated with adverse biological effects. Mar. Pollut. Bull. 24:38–45.

Long, E.R., and D.D. MacDonald. 1992. National status and trends program approach. In: Sediment classification methods compendium, EPA 82-3-R-92-006, B. Baker and M. Kravitz, eds. U.S. Environmental Protection Agency, Office of Water (WH-56), Sediment Technical Oversight Committee, Washington, DC.

Long, E.R., and L.G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. National Oceanic and Atmospheric Administration. Seattle, WA.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ. Manage. 19:81–97.

Luoma, S.N., and J.L. Carter. 1993. Understanding the toxicity of contaminants in sediments: Beyond the bioassay-based paradigm. Environ. Toxicol. Chem. 12:793–796.

MacDonald, D.D. 1994. Approach to the assessment of sediment quality in Florida coastal waters. Vol. I. Prepared for the Florida Department of Environmental Protection. MacDonald Environmental Sciences, Ltd., Ladysmith, BC.

Reference listing:

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

For further scientific information, contact:

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

For additional copies, contact:

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

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Aussi disponible en français.

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 G

Sediment Toxicity Results

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:

G Harris

Gary Harris
May 05, 2015

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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 24 and 26, 2015. These grab samples were collected and transported by boat to Halifax and picked up by HITS at the McGregor facility on March 30, 2015. 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	15-135-A
SED 500 DOS	15-135-B
SED 1000 DOS	15-135-C
SED 2000 DOS	15-135-D
SED 5000 DOS	15-135-E
SED 5000 UPS	15-135-F
SED 250 DOS	15-135-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 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 # 15) were purchased from NW Seacology, North Vancouver, BC. Collection took place on April 11, 2015. They were shipped by Fed Ex overnight express and picked up at the Fed Ex depot in Dartmouth NS by HITS staff on April 15, 2015. Organisms were held at the lab in site sediment covered with aerating seawater at test temperature (15 ± 2 °C) in continuous light for 6 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 April 20, 2015 were as follows:

- ~15 ml of pore water was extracted from each sediment and parameters were measured (pH, salinity and Ammonia (NH_3-N mg/L);
- 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 April 21, 2015 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 # 15 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 non-consecutive days throughout the 10-day test and at termination for each sample.

2.4 Test Termination Procedure

Test termination on May 01, 2015 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.

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;
- In replicate #4 – 5000 DOS, a large polychaete (~4.5 cms long) was found at termination. Only 3 amphipods were remaining in the test vessel, therefore Replicate #4 was deemed to be an outlier. Survival including the outlier was 81%*. Survival without the outlier (4 replicates) was 97%**. (See Table 1.)

  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 the test sediments.

- The samples as tested were found to be non-toxic to the amphipod *Eohaustorius estuarius* and 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	15-135-A	95/100	95 ± 0.63
SED 500 DOS	15-135-B	98/100	98 ± 0.49
SED 1000 DOS	15-135-C	97/100	97 ± 0.49
SED 2000 DOS	15-135-D	96/100	96 ± 0.75
SED 5000 DOS	15-135-E	81/100* (78/80)**	81 ± 6.62* 97 ± 0.5**
SED 5000 UPS	15-135-F	96/100	96 ± 0.75
SED 250 DOS	15-135-G	96/100	96 ± 0.75
Control Sediment	15-135-Ctl	98/100	98 ± 0.49

Table 2: Sediment Quality: Particle Size Analysis Results

	Units	SED 250 M	SED 500 M	SED 1000 M	SED 2000 M	SED 5000 MUP	SED 5000 MDO
Inorganics							
< -1 Phi (2 mm)	%	100	100	100	100	100	100
< 0 Phi (1 mm)	%	99	100	99	99	100	100
< +1 Phi (0.5 mm)	%	99	89	87	86	92	87
< +2 Phi (0.25 mm)	%	80	18	15	20	14	9.3
< +3 Phi (0.12 mm)	%	4.8	2.1	1.6	1.4	1.5	1.8
< +4 Phi (0.062 mm)	%	1.7	1.6	1.3	1.2	1.4	1.7
< +5 Phi (0.031 mm)	%	1.8	1.2	1.3	1.1	1.4	1.7
< +6 Phi (0.016 mm)	%	1.4	1.1	1.4	1.4	1.3	1.8
< +7 Phi (0.0078 mm)	%	1.6	1.1	1.2	1.2	1.1	1.8
< +8 Phi (0.0039 mm)	%	1.5	1.1	1.4	1.3	1.3	1.7
< +9 Phi (0.0020 mm)	%	1.4	1.2	1.2	1.4	1.0	1.6
Gravel	%	0.27	ND	ND	ND	ND	ND
Sand	%	98	98	99	99	99	98
Silt	%	0.16	0.43	ND	ND	ND	ND
Clay	%	1.5	1.1	1.4	1.3	1.3	1.7

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.

AMPHIPOD TOXICITY REPORT (Single Concentration)

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

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 hits@eastlink.ca

SAMPLE DATA

Sample Type/Location: Deep Panuke – SED 250 DOS
Lab ID. # 15-135-G
Date/Time Collected: Mar. 24 2015 1958 Hrs
Sampler: S. Kirchhoff & G. Forbes
Method of Collection: Grab
Received: Mar. 30 2015
Date Sediment Prepared/Added: Apr. 20 2015 1100 – 1300 Hrs
Date/Time Test Started: Apr. 21 2015 0900 – 1000 Hrs
Completed: May 01 2015 0900 – 1130 Hrs
Sample Description: Light brown sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 15
Source: NW Seacology, North Vancouver, BC
Date Collected: Apr. 11 2015
Date Received: Apr. 15 2015
Approx. size: 4 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 @ 636 lux
Test duration : 10 Days

TEST PARAMETERS

Pore Water Analysis: pH: 7.6 Salinity ppt: 31 Ammonia (NH_3-N mg/L): 0.08

		Range: Initial / 3 times per week / Final		Salinity ppt		NH_3-N mg/L	
Conc. %	Temp. °C	D.O mg/L	pH	Initial	Final	Initial	Final
100	14.5 – 16.5	7.6 – 8.0	7.8 – 7.9	30.6	30.2	0.05	0.00
Control	14.5 – 16.0	7.8 – 8.2	7.7 – 7.9	29.2	28.3	0.06	0.07

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	20/20	20/20	19/20	18/20	19/20	96
Control Organisms:	Number Surviving	20/20	20/20	20/20	19/20	19/20	98

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 96 % ± 0.75 SD

Mean % Survival of 5 Control Replicates = 98 % ± 0.49 SD

REFERENCE TOXICANT DATA Batch # 15

Reference Substance: $CdCl_2$
95% C.L.: 6.88 – 11.1 mg/L

Test Date: Apr. 21 – 25 2015
Historical $CdCl_2$ Mean: 17.2 mg/L

96 Hour LC_{50} for $CdCl_2$: 8.76 mg/L
Warning Limits ± 2 SD: 8.66 – 34.2 mg/L

Comments:

Analyst(s): G. Harris & A. Huybers

Verified by: C. Harris C Harris

Date: May 04 2015

AMPHIPOD TOXICITY REPORT (Single Concentration)

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

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 hits@eastlink.ca

SAMPLE DATA

Lab ID. # 15-135-B
Sample Type/Location: Deep Panuke – SED 500 DOS
Date/Time Collected: Mar. 26 2015 1300 Hrs
Sampler: S. Kirchhoff & G. Forbes
Method of Collection: Grab
Received: Mar. 30 2015
Date Sediment Prepared/Added: Apr. 20 2015 1100 – 1300 Hrs
Date/Time Test Started: Apr. 21 2015 0900 – 1000 Hrs
Completed: May 01 2015 0900 – 1130 Hrs
Sample Description: Light brown sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 15
Source: NW Seacology, North Vancouver, BC
Date Collected: Apr. 11 2015
Date Received: Apr. 15 2015
Approx. size: 4 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 @ 636 lux
Test duration : 10 Days

TEST PARAMETERS

Pore Water Analysis: pH: 7.4 Salinity ppt: 32 Ammonia (NH_3-N mg/L): 0.06

Range: Initial / 3 times per week / Final

Conc. %	Temp. °C	D.O mg/L	pH	Salinity ppt		NH_3-N mg/L	
				Initial	Final	Initial	Final
100	14.5 – 16.5	7.2 – 8.0	7.6 – 7.8	30.6	29.5	0.03	0.00
Control	14.5 – 16.0	7.8 – 8.2	7.7 – 7.9	29.2	28.3	0.06	0.07

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	20/20	19/20	20/20	20/20	19/20	98
Control Organisms:	Number Surviving	20/20	20/20	20/20	19/20	19/20	98

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 98 % ± 0.49 SD

Mean % Survival of 5 Control Replicates = 98 % ± 0.49 SD

REFERENCE TOXICANT DATA Batch # 15

Reference Substance: $CdCl_2$
95% C.L.: 6.88 – 11.1 mg/L
Test Date: Apr. 21 – 25 2015
Historical $CdCl_2$ Mean: 17.2 mg/L
96 Hour LC_{50} for $CdCl_2$: 8.76 mg/L
Warning Limits ± 2 SD: 8.66 – 34.2 mg/L

Comments:

Analyst(s): G. Harris & A. Huybers Verified by: C. Harris C Harris Date: May 01 2015

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:	Stephane Kirchhoff	Tel : 902 757-0232	Fax: 902 757-2839 hits@eastlink.ca

SAMPLE DATA

Sample Type/Location:	Deep Panuke – SED 1000 DOS		Lab ID. # 15-135-C
Date/Time Collected:	Mar. 26 2015 1346 Hrs	Sampler:	S. Kirchhoff & G. Forbes
Method of Collection:	Grab	Received:	Mar. 30 2015
Date Sediment Prepared/Added:	Apr. 20 2015 1100 – 1300 Hrs		
Date/Time Test Started:	Apr. 21 2015 0900 – 1000 Hrs	Completed:	May 01 2015 0900 – 1130 Hrs

Sample Description: Light brown sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998	Exposure tanks: 1 litre glass jars	Test temperature : 15 ± 2 °C
Type: Single Concentration Tox 49	No. of replicates per conc. : 5	Aeration : continuous
Organism: *Eohaustorius estuarius* Batch # 15	No. of organisms per replicate : 20	Aeration rate : minimal
Source: NW Seacology, North Vancouver, BC		Lighting: continuous @ 636 lux
Date Collected: Apr. 11 2015	Volume of seawater: 775 mls	Test duration : 10 Days
Date Received: Apr. 15 2015	Source: Lawrencetown Bridge, NS	
Approx. size: 4 mm	Volume of sediment : 175 mls	

TEST PARAMETERS

Pore Water Analysis: pH: 7.6 Salinity ppt: 32 Ammonia (NH_3-N mg/L): 0.03

	Range: Initial / 3 times per week / Final			Salinity ppt		NH_3-N mg/L	
Conc. %	Temp. °C	D.O mg/L	pH	Initial	Final	Initial	Final
100	14.5 – 16.0	7.5 – 8.0	7.7 – 7.8	30.4	29.6	0.00	0.00
Control	14.5 – 16.0	7.8 – 8.2	7.7 – 7.9	29.2	28.3	0.06	0.07

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	19/20	20/20	19/20	19/20	20/20	97
Control Organisms:	Number Surviving	20/20	20/20	20/20	19/20	19/20	98

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 97 % ± 0.49 SD

Mean % Survival of 5 Control Replicates = 98 % ± 0.49 SD

REFERENCE TOXICANT DATA Batch # 15

Reference Substance: $CdCl_2$	Test Date: Apr. 21 – 25 2015	96 Hour LC_{50} for $CdCl_2$: 8.76 mg/L
95% C.L.: 6.88 – 11.1 mg/L	Historical $CdCl_2$ Mean: 17.2 mg/L	Warning Limits ± 2 SD: 8.66 – 34.2 mg/L

Comments:

Analyst(s): G. Harris & A. Huybers Verified by: C. Harris C Harris Date: May 01 2015

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: Stephane Kirchhoff

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 hits@eastlink.ca

SAMPLE DATA

Sample Type/Location: Deep Panuke – SED 2000 DOS
Lab ID. # 15-135-D
Date/Time Collected: Mar. 26 2015 1418 Hrs
Sampler: S. Kirchhoff & G. Forbes
Method of Collection: Grab
Received: Mar. 30 2015
Date Sediment Prepared/Added: Apr. 20 2015 1100 – 1300 Hrs
Date/Time Test Started: Apr. 21 2015 0900 – 1000 Hrs
Completed: May 01 2015 0900 – 1130 Hrs
Sample Description: Light brown sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 15
Source: NW Seacology, North Vancouver, BC
Date Collected: Apr. 11 2015
Date Received: Apr. 15 2015
Approx. size: 4 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 @ 636 lux
Test duration : 10 Days

TEST PARAMETERS

Pore Water Analysis: pH: 7.6 Salinity ppt: 32 Ammonia (NH_3-N mg/L): 0.07

Range: Initial / 3 times per week / Final

				Salinity ppt		NH_3-N mg/L	
Conc. %	Temp. °C	D.O mg/L	pH	Initial	Final	Initial	Final
100	14.5 – 16.0	7.4 – 8.0	7.7 – 7.8	30.1	30.3	0.05	0.04
Control	14.5 – 16.0	7.8 – 8.2	7.7 – 7.9	29.2	28.3	0.06	0.07

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	19/20	18/20	20/20	19/20	20/20	96
Control Organisms:	Number Surviving	20/20	20/20	20/20	19/20	19/20	98

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 96 % ± 0.75 SD

Mean % Survival of 5 Control Replicates = 98 % ± 0.49 S.D.

REFERENCE TOXICANT DATA Batch # 15

Reference Substance: $CdCl_2$
95% C.L.: 6.88 – 11.1 mg/L
Test Date: Apr. 21 – 25 2015
Historical $CdCl_2$ Mean: 17.2 mg/L
96 Hour LC_{50} for $CdCl_2$: 8.76 mg/L
Warning Limits ± 2 SD: 8.66 – 34.2 mg/L

Comments:

Analyst(s): G. Harris & A. Huybers
Verified by: C. Harris C Harris
Date: May 01 2015

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: Stephane Kirchhoff

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 hits@eastlink.ca

SAMPLE DATA

Sample Type/Location: Deep Panuke – SED 5000 DOS
Lab ID. # 15-135-E
Date/Time Collected: Mar. 26 2015 1445 Hrs
Sampler: S. Kirchhoff & G. Forbes
Method of Collection: Grab
Received: Mar. 30 2015
Date Sediment Prepared/Added: Apr. 20 2015 1100 – 1300 Hrs
Date/Time Test Started: Apr. 21 2015 0900 – 1000 Hrs
Completed: May 01 2015 0900 – 1130 Hrs
Sample Description: Light brown sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 15
Source: NW Seacology, North Vancouver, BC
Date Collected: Apr. 11 2015
Date Received: Apr. 15 2015
Approx. size: 4 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 @ 636 lux
Test duration : 10 Days

TEST PARAMETERS

Pore Water Analysis: pH: 7.4 Salinity ppt: 33 Ammonia (NH_3-N mg/L): 0.01

Range: Initial / 3 times per week / Final

				Salinity ppt		NH_3-N mg/L	
Conc. %	Temp. °C	D.O mg/L	pH	Initial	Final	Initial	Final
100	14.5 – 16.0	6.8 – 8.1	7.6 – 7.8	30.3	30.6	0.08	0.14
Control	14.5 – 16.0	7.8 – 8.2	7.7 – 7.9	29.2	28.3	0.06	0.07

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	19/20	20/20	19/20	3/20*	20/20	81*
Control Organisms:	Number Surviving	20/20	20/20	20/20	19/20	19/20	98

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 81* % ± 6.62 SD

Mean % Survival of 4 Test Replicates = 97 % ± 0.50 SD**

Mean % Survival of 5 Control Replicates = 98 % ± 0.49 SD

REFERENCE TOXICANT DATA Batch # 15

Reference Substance: $CdCl_2$
95% C.L.: 6.88 – 11.1 mg/L
Test Date: Apr. 21 – 25 2015
Historical $CdCl_2$ Mean: 17.2 mg/L
96 Hour LC_{50} for $CdCl_2$: 8.76 mg/L
Warning Limits ± 2 SD: 8.66 – 34.2 mg/L

Comments: *Large polychaete (~2 inches long) found at termination in sediment Replicate #4. Only 3 amphipods remaining in test vessel therefore replicate #4 was deemed to be an outlyer. Survival including the outlyer = 81%, **survival without the outlyer (4 replicates) = 97%.

Analyst(s): G. Harris & A. Huybers
Verified by: C. Harris C Harris
Date: May 01 2015

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: Stephane Kirchhoff

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 hits@eastlink.ca

SAMPLE DATA

Sample Type/Location: Deep Panuke – SED 5000 UPS
Lab ID. # 15-135-F
Date/Time Collected: Mar. 24 2015 1900 Hrs
Sampler: S. Kirchhoff & G. Forbes
Method of Collection: Grab
Received: Mar. 30 2015
Date Sediment Prepared/Added: Apr. 20 2015 1100 – 1300 Hrs
Date/Time Test Started: Apr. 21 2015 0900 – 1000 Hrs
Completed: May 01 2015 0900 – 1130 Hrs
Sample Description: Light brown sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 15
Source: NW Seacology, North Vancouver, BC
Date Collected: Apr. 11 2015
Date Received: Apr. 15 2015
Approx. size: 4 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 @ 636 lux
Test duration : 10 Days

TEST PARAMETERS

Pore Water Analysis: pH: 7.4 Salinity ppt: 31 Ammonia (NH_3-N mg/L): 0.05

Range: Initial / 3 times per week / Final

Conc. %	Temp. °C	D.O mg/L	pH	Salinity ppt		NH_3-N mg/L	
				Initial	Final	Initial	Final
100	14.5 – 16.0	7.8 – 8.0	7.7 – 7.8	30.2	29.8	0.00	0.00
Control	14.5 – 16.0	7.8 – 8.2	7.7 – 7.9	29.2	28.3	0.06	0.07

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	19/20	18/20	19/20	20/20	20/20	96
Control Organisms:	Number Surviving	20/20	20/20	20/20	19/20	19/20	98

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 96 % ± 0.75 SD

Mean % Survival of 5 Control Replicates = 98 % ± 0.49 SD

REFERENCE TOXICANT DATA Batch # 15

Reference Substance: $CdCl_2$
95% C.L.: 6.88 – 11.1 mg/L
Test Date: Apr. 21 – 25 2015
Historical $CdCl_2$ Mean: 17.2 mg/L
96 Hour LC_{50} for $CdCl_2$: 8.76 mg/L
Warning Limits ± 2 SD: 8.66 – 34.2 mg/L

Comments:

Analyst(s): G. Harris & A. Huybers
Verified by: C. Harris C Harris
Date: May 04 2015

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: Stephane Kirchhoff

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 hits@eastlink.ca

SAMPLE DATA

Sample Type/Location: Deep Panuke – SED BLIND
Lab ID. # 15-135-A
Date/Time Collected: Mar. 26 2015
Sampler: S. Kirchhoff & G. Forbes
Method of Collection: Grab
Received: Mar. 30 2015
Date Sediment Prepared/Added: Apr. 20 2015 1100 – 1300 Hrs
Date/Time Test Started: Apr. 21 2015 0900 – 1000 Hrs
Completed: May 01 2015 0900 – 1130 Hrs
Sample Description: Light brown sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 15
Source: NW Seacology, North Vancouver, BC
Date Collected: Apr. 11 2015
Date Received: Apr. 15 2015
Approx. size: 4 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 @ 636 lux
Test duration : 10 Days

TEST PARAMETERS

Pore Water Analysis: pH: 7.4 Salinity ppt: 32 Ammonia (NH_3-N mg/L): 0.19

Range: Initial / 3 times per week / Final

				Salinity ppt		NH_3-N mg/L	
Conc. %	Temp. °C	D.O mg/L	pH	Initial	Final	Initial	Final
100	14.5 – 16.5	7.0 – 8.0	7.7	29.8	29.2	0.03	0.00
Control	14.5 – 16.0	7.8 – 8.2	7.7 – 7.9	29.2	28.3	0.06	0.07

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Test Organisms:	Number Surviving	19/20	20/20	19/20	18/20	19/20	95
Control Organisms:	Number Surviving	20/20	20/20	20/20	19/20	19/20	98

10 DAY TEST RESULTS

Mean % Survival of 5 Test Replicates = 95 % ± 0.63 SD

Mean % Survival of 5 Control Replicates = 98 % ± 0.49 SD

REFERENCE TOXICANT DATA Batch # 15

Reference Substance: $CdCl_2$
95% C.L.: 6.88 – 11.1 mg/L
Test Date: Apr. 21 – 25 2015
Historical $CdCl_2$ Mean: 17.2 mg/L
96 Hour LC_{50} for $CdCl_2$: 8.76 mg/L
Warning Limits ± 2 SD: 8.66 – 34.2 mg/L

Comments:

Analyst(s): G. Harris & A. Huybers Verified by: C. Harris C Harris Date: May 01 2015

AMPHIPOD TOXICITY REPORT (Single Concentration)

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

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 hits@eastlink.ca

SAMPLE DATA

Sample Type/Location: Control Sediment
Lab ID. # 15-135-Ctl
Date/Time Collected: Apr. 11 2015
Sampler: D. Swanston
Method of Collection: Grab
Received: Apr. 15 2015
Date Sediment Prepared/Added: Apr. 20 2015 1100 – 1300 Hrs
Date/Time Test Started: Apr. 21 2015 0900 – 1000 Hrs
Completed: May 01 2015 0900 – 1130 Hrs
Sample Description: Blackish-grey sand.

TEST CONDITIONS

Reference Method: EPS 1/RM/35 Dec. 1998
Type: Single Concentration Tox 49
Organism: *Eohaustorius estuarius* Batch # 15
Source: NW Seacology, North Vancouver, BC
Date Collected: Apr. 11 2015
Date Received: Apr. 15 2015
Approx. size: 4 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 @ 636 lux
Test duration : 10 Days

TEST PARAMETERS

Pore Water Analysis: pH: 8.2 Salinity ppt: 32 Ammonia (NH_3-N mg/L): 0.13

	Range: Initial / 3 times per week / Final			Salinity ppt		NH_3-N mg/L	
Conc. %	Temp. 15 °C	D.O mg/L	pH	Initial	Final	Initial	Final
Control	14.5 – 16.0	7.8 – 8.2	7.7 – 7.9	29.2	28.3	0.06	0.07

TEST RESULTS

		Rep. #1	Rep. #2	Rep. #3	Rep. #4	Rep. #5	Total
Control Organisms:	Number Surviving	20/20	20/20	20/20	19/20	19/20	98

10 DAY TEST RESULTS

Mean % Survival of 5 Control Replicates = 98 % ± 0.49 SD

REFERENCE TOXICANT DATA Batch # 15

Reference Substance: $CdCl_2$
95% C.L.: 6.88 – 11.1 mg/L

Test Date: Apr. 21 – 25 2015
Historical $CdCl_2$ Mean: 17.2 mg/L

96 Hour LC_{50} for $CdCl_2$: 8.76 mg/L
Warning Limits ± 2 SD: 8.66 – 34.2 mg/L

Comments:

Analyst(s): G. Harris & A. Huybers

Verified by: C. Harris C Harris

Date: May 01 2015

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APPENDIX H

Fish Habitat Alteration Video Assessments 2015

		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**
Polymastia	*Polymastia sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Encrusting sponge	Porifera		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sponge*	Porifera		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Corymorpha sp.	Corymorpha sp.		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sea anemone	Actinaria	11	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
*Cerianthus sp**	*Cerianthus sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Soft Coral*	Alcyonacea	13	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Colus sp.	*Colus sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Jonah crab	*Cancer borealis*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Snow crab	*Chionoecetes opilio*	26	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Toad crab	*Hyas sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Portly spider crab	*Libinia emarginata*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Northern Stone Crab	*Lithodes maja*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Shrimp	Pandalidae		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Ceramaster	*Ceremaster sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Crossaster	*Crossaster sp.*	2	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Hippasteria sp	*Hippasteria sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cushion star	*Poriania*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Solaster	*Solaster sp.*	3	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Basket star	*Gorgoncephalus sp.*	23	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sand dollar	*Echinarachnius parma*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sea urchin	*Strongylocentrotus sp.*	74	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sea cucumber	*Cucumaria frondosa*	1	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
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*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sculpin	*Myoxocephalus sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Flatfish	Pleuronectiformes		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Pollock (?)	*Pollachius sp.*		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Redfish	*Sebastes sp.*	1	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Eelpout/Ocean pout?	Zoarcidae		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Haddock	*Melanogrammis aeglefinus*	1	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Unid. Fish		2	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dead snow crab			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dead cancer crab			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - cup			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - cloth			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - cylinder			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - beer/soda can			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - glove			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - spool			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - net			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - plastic			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Garbage - glass bottle			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
		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											

▨ Not surveyed in 2015

		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**
Polymastia	*Polymastia sp.*									4	19	F	114
Encrusting sponge	Porifera									R			O
Sponge*	Porifera									C	255	F	O
Corymorpha sp.	Corymorpha sp.												1
Sea anemone	Actinaria									28	4	28	63
*Cerianthus sp**	*Cerianthus sp.*									3	2	2	
Soft Coral*	Alcyonacea												
Colus sp.	*Colus sp.*										3	1	
Jonah crab	*Cancer borealis*										18	7	46
Snow crab	*Chionoecetes opilio*									1	6		1
Toad crab	*Hyas sp.*										1	1	
Portly spider crab	*Libinia emarginata*												
Northern Stone Crab	*Lithodes maja*												
Shrimp	Pandalidae												1
Ceramaster	*Ceremaster sp.*												
Crossaster	*Crossaster sp.*												
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*									81	190	185	214
Hippasteria sp	*Hippasteria sp.*									4	4	3	2
Cushion star	*Poriania*											1	
Solaster	*Solaster sp.*											1	1
Basket star	*Gorgoncephalus sp.*												
Sand dollar	*Echinarachnius parma*									11	44	10	2
Sea urchin	*Strongylocentrotus sp.*												1
Sea cucumber	*Cucumaria frondosa*									14	4	8	11
Feather star	Crinoidea												
Sea potato	*Boltenia ovifera*												1
Tunicate	Tunicata									C	C	C	C
Atlantic Wolffish	*Anarhichas lupus*									1	6	4	6
Gadoid	Gadidae									23		28	16
Atlantic Cod	*Gadus morhua*									1	2	4	9
Sea Raven	*Hemitripterus americanus*												
Atlantic Hagfish	*Mixine glutinosa*										1		
Sculpin	*Myoxocephalus sp.*												
Flatfish	Pleuronectiformes												
Pollock (?)	*Pollachius sp.*										47		
Redfish	*Sebastes sp.*									547	1635	1549	1459
Eelpout/Ocean pout?	Zoarcidae									1			
Haddock	*Melanogrammis aeglefinus*									1	3		1
Unid. Fish										1			
Dead snow crab										1			
Dead cancer crab										2	2	3	6
Garbage - cup											1		
Garbage - cloth											1		
Garbage - cylinder											1		
Garbage - beer/soda can													1
Garbage - glove													
Garbage - spool													
Garbage - net													
Garbage - plastic													
Garbage - glass bottle													
		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											

▨ Not surveyed in 2015

		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**
Polymastia	*Polymastia sp.*	387	60	6	2	4		1		▨	▨	▨	▨
Encrusting sponge	Porifera	R		R				O		▨	▨	▨	▨
Sponge*	Porifera	14	30	29	3	3	3	3		▨	▨	▨	▨
Corymorpha sp.	Corymorpha sp.		1	1						▨	▨	▨	▨
Sea anemone	Actinaria	129	50	39	5	11	7		7	▨	▨	▨	▨
*Cerianthus sp**	*Cerianthus sp.*	37	21	182	116	196	284	430	166	▨	▨	▨	▨
Soft Coral*	Alcyonacea									▨	▨	▨	▨
Colus sp.	*Colus sp.*	1		1						▨	▨	▨	▨
Jonah crab	*Cancer borealis*	51	64	148	119	88	112	182	196	▨	▨	▨	▨
Snow crab	*Chionoecetes opilio*	1	2		3	1	2			▨	▨	▨	▨
Toad crab	*Hyas sp.*							1		▨	▨	▨	▨
Portly spider crab	*Libinia emarginata*							2		▨	▨	▨	▨
Northern Stone Crab	*Lithodes maja*		2	4	1	3	2	1	2	▨	▨	▨	▨
Shrimp	Pandalidae									▨	▨	▨	▨
Ceramaster	*Ceremaster sp.*							1		▨	▨	▨	▨
Crossaster	*Crossaster sp.*									▨	▨	▨	▨
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*	251	346	955	99	536	450	726	1618	▨	▨	▨	▨
Hippasteria sp	*Hippasteria sp.*	1	7	11	7	5	3	9	3	▨	▨	▨	▨
Cushion star	*Poriania*									▨	▨	▨	▨
Solaster	*Solaster sp.*	2	2	4	1	4	1	3	2	▨	▨	▨	▨
Basket star	*Gorgoncephalus sp.*									▨	▨	▨	▨
Sand dollar	*Echinarachnius parma*					90	39	202	106	▨	▨	▨	▨
Sea urchin	*Strongylocentrotus sp.*									▨	▨	▨	▨
Sea cucumber	*Cucumaria frondosa*	7	5	7	2	5	5		1	▨	▨	▨	▨
Feather star	Crinoidea	1								▨	▨	▨	▨
Sea potato	*Boltenia ovifera*			1				1		▨	▨	▨	▨
Tunicate	Tunicata	C	C	C	C			C	C	▨	▨	▨	▨
Atlantic Wolffish	*Anarhichas lupus*	6	2		1		2	1		▨	▨	▨	▨
Gadoid	Gadidae	7	13	6						▨	▨	▨	▨
Atlantic Cod	*Gadus morhua*	10	6	1	1					▨	▨	▨	▨
Sea Raven	*Hemitripterus americanus*			1						▨	▨	▨	▨
Atlantic Hagfish	*Mixine glutinosa*									▨	▨	▨	▨
Sculpin	*Myoxocephalus sp.*		2		1	1	1	1		▨	▨	▨	▨
Flatfish	Pleuronectiformes							1		▨	▨	▨	▨
Pollock (?)	*Pollachius sp.*									▨	▨	▨	▨
Redfish	*Sebastes sp.*	2164	1661	675	608	768	560	690	595	▨	▨	▨	▨
Eelpout/Ocean pout?	Zoarcidae									▨	▨	▨	▨
Haddock	*Melanogrammis aeglefinus*		2							▨	▨	▨	▨
Unid. Fish							2			▨	▨	▨	▨
Dead snow crab										▨	▨	▨	▨
Dead cancer crab		20	11	10	6	4	8	4	1	▨	▨	▨	▨
Garbage - cup										▨	▨	▨	▨
Garbage - cloth										▨	▨	▨	▨
Garbage - cylinder										▨	▨	▨	▨
Garbage - beer/soda can		2	2	2	1	2	2			▨	▨	▨	▨
Garbage - glove		1		2						▨	▨	▨	▨
Garbage - spool			1							▨	▨	▨	▨
Garbage - net					1					▨	▨	▨	▨
Garbage - plastic								1		▨	▨	▨	▨
Garbage - glass bottle									1	▨	▨	▨	▨
		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											

▨ Not surveyed in 2015

APPENDIX I1

2015 Sable Island Beached Bird Report

OFFSHORE ENVIRONMENTAL EFFECTS MONITORING PROGRAM
SABLE OFFSHORE ENERGY PROGRAM
SUMMARY REPORT for Year 2015

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. 2015 Sampling:

Contractor: Zoe Lucas, Sable Island.

- During 2015, eight surveys for beached seabirds were conducted on Sable Island, with no surveys done during January, February, May and November.

- 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 2015.

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 2015, the corpses and fragments of 461 beached seabird corpses were collected on Sable Island. Alcids accounted for 58.4% of total corpses recovered (Table 9.1). Of the 461 corpses, 193 (41.9%) were complete (i.e. with >70% of body intact, Codes 0 - 3).

- Seasonal occurrence of *clean* complete corpses (Code 0) varied by bird group and species (Table 9.1). Most alcids occurred in winter (79.3%). More Northern Fulmars (80%) and Northern Gannets (66.7%), and all shearwaters, occurred in summer.

- The overall oiling rate for all species combined (based on complete corpses, Codes 0 to 3) was 0.5% (compared with 3.2% in 2014). Only one oiled corpse was recovered in 2015, a Thick-billed Murre. The oiling rate for alcids was 1.7% (compared with 7.9% in 2014).

- The single oiled bird corpse occurred during April, and a sample of oiled feathers was collected. Analysis of the oil determined it to be a weathered mixture of Heavy Fuel Oil and Lube Oil, and very typical of a long haul commercial vessel running on Heavy Fuel Oil (e.g. container vessel, bulk carrier, etc.) having discharged engine room bilge oil either directly or after storage in a slop tank (Clive MacGregor, pers. comm. January 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 2015. 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	Code 1 oiled bird	Oiling rate %
Northern Fulmar	13	2	8	0.009	0.021	0	0
Shearwater	120	0	84	0	0.216	0	0
Northern Gannet	14	3	6	0.013	0.015	0	0
Larus Gulls	39	12	18	0.052	0.046	0	0
Alcids [2]	269	46	12	0.201	0.031	1	1.7
Common & Thick-billed Murres	*44*	*16*	*6*	*0.070*	*0.015*	*1*	*4.3*
Dovekie	*155*	*21*	*0*	*0.092*	*0*	*0*	*0*
Other species [3]	6	0	1	0	0.003	0	0

[1] Codes 0 - 4 combined.

[2] All alcid species combined (Razorbill, Atlantic Puffin, Common and Thick-billed Murre, Dovekie, and unidentified large alcids).

[3] Other species: four Common Terns, one Arctic Tern and one Black-legged Kittiwake. Of these only one, a Common Tern, was a complete corpse. None of the corpses or fragments was oiled.

Figure 9.1. Northern Fulmar
Corpses/km: $F_{1,21}$=1.15, P=0.30
Oiling rate: $F_{1,21}$=22.86, P=0.0001*

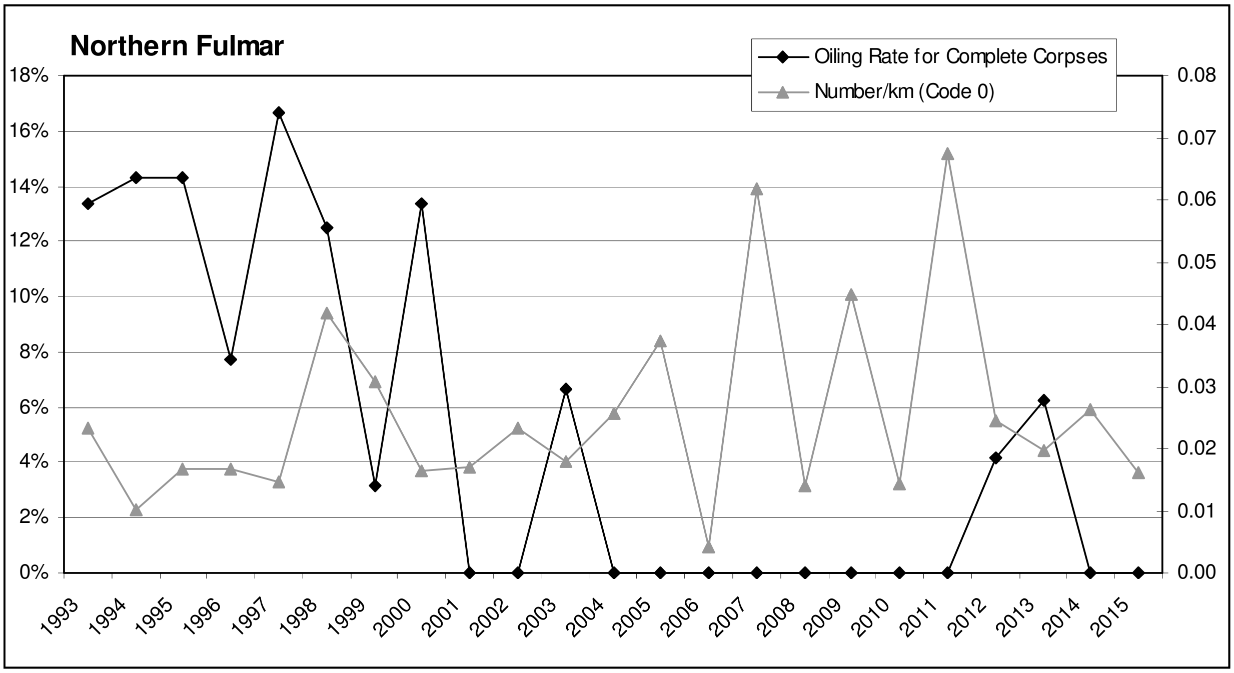


Figure 9.2. Shearwaters
Corpses/km: $F_{1,21}$=0.09, P=0.76
Oiling rate: $F_{1,21}$=7.99, P=0.010*

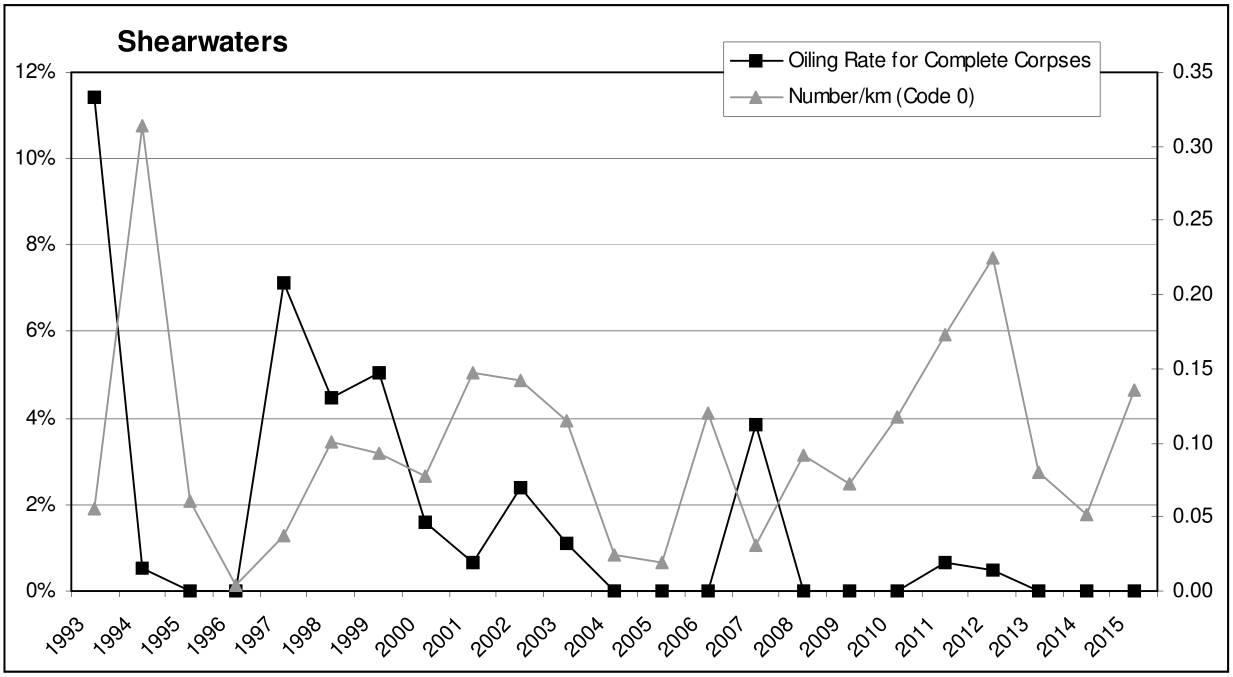


Figure 9.3. Northern Gannet
Corpses/km: $F_{1,21}$=0.05, P=0.82
Oiling rate: $F_{1,21}$=9.49, P=0.006*

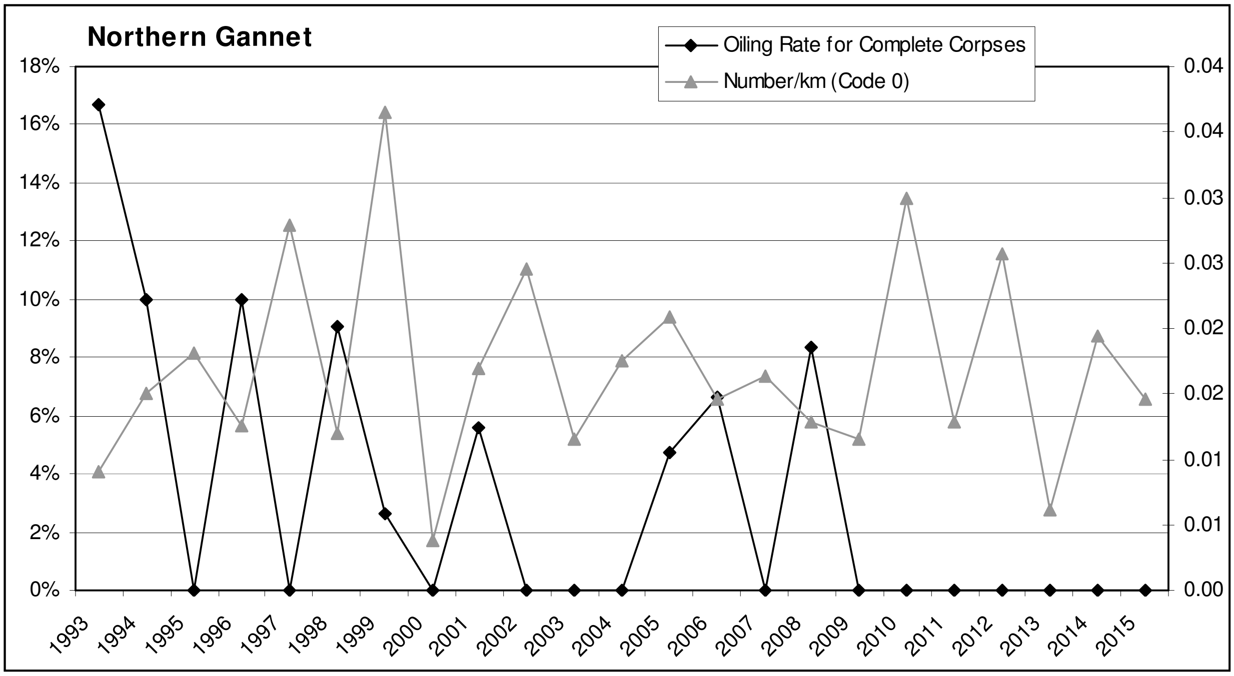


Figure 9.4. Larus Gulls
Corpses/km: $F_{1,21}$=0.00, P=0.97
Oiling rate: $F_{1,21}$=16.90, P=0.0005*

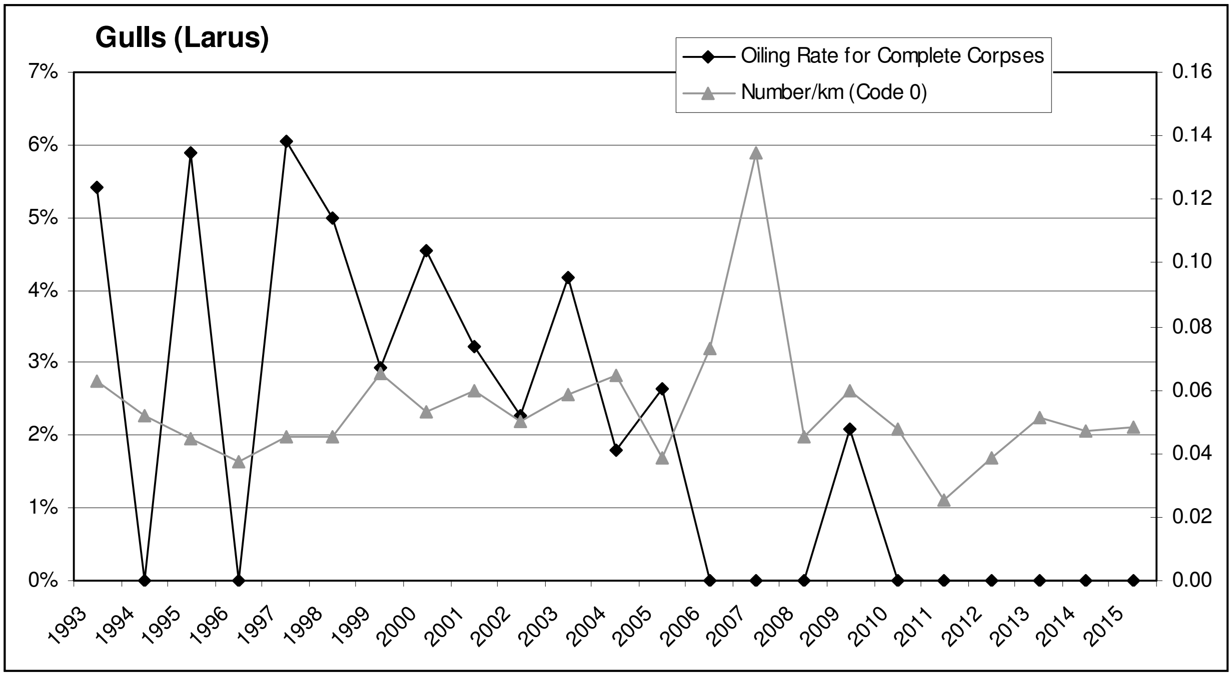


Figure 9.5. Alcids (all species combined)
Corpses/km: $F_{1,21}$=0.02, P=0.88
Oiling rate: $F_{1,21}$=45.19, P<.0001*

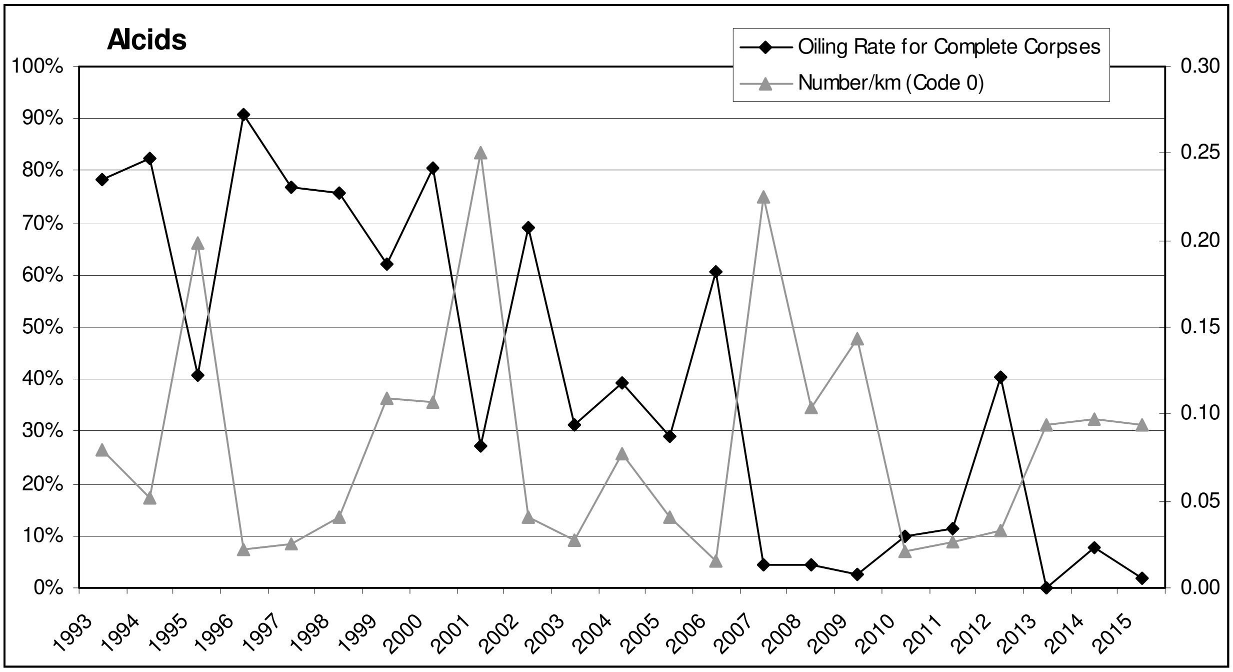


Figure 9.6. Thick-billed & Common Murres
Corpses/km: $F_{1,21}$=0.03, P=0.86
Oiling rate: $F_{1,21}$=17.06, P=0.0005*

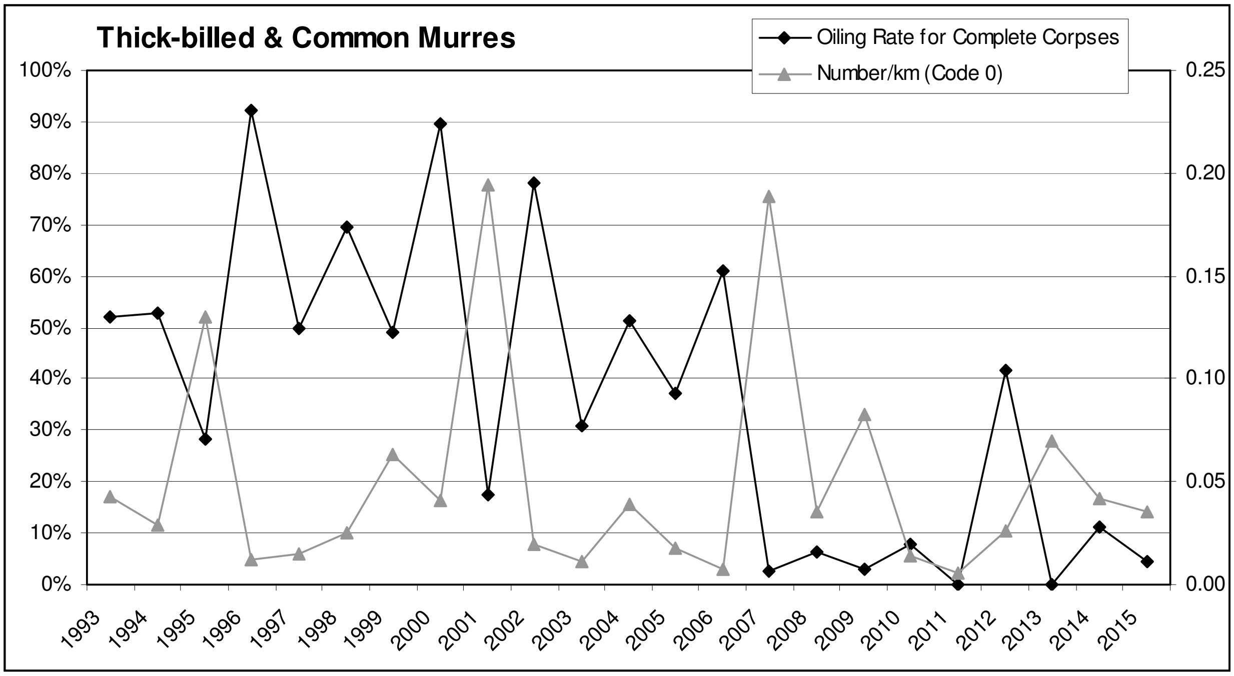
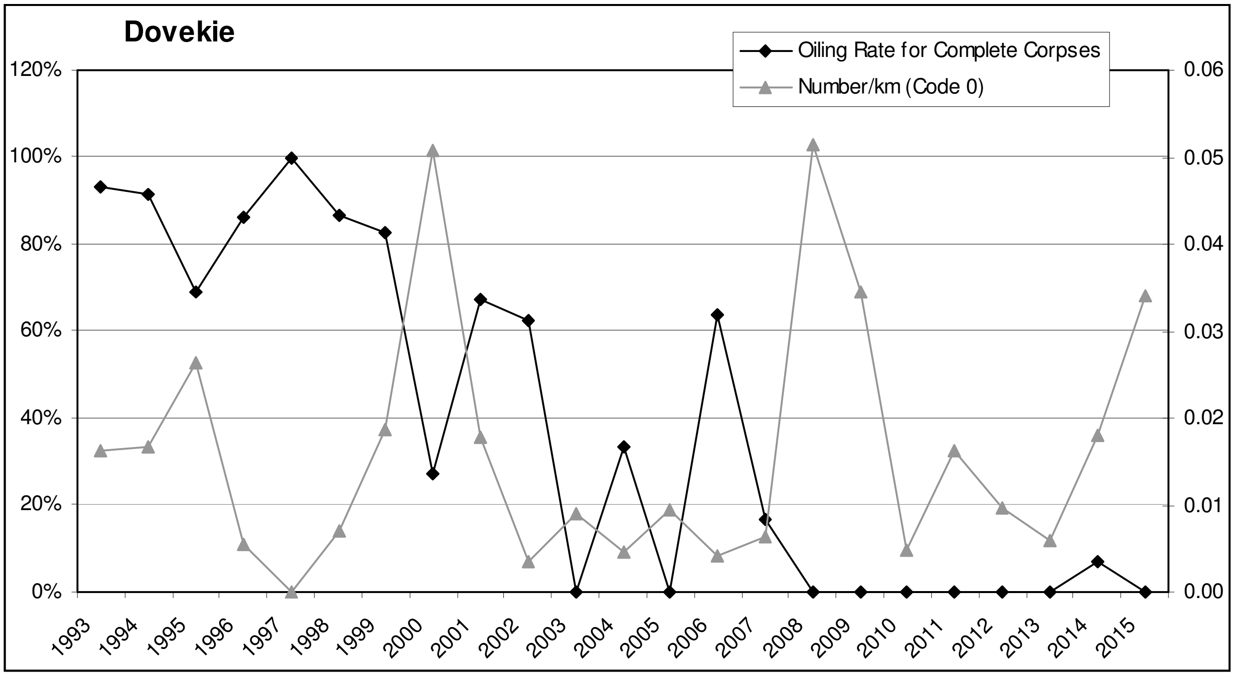


Figure 9.7. Dovekie
Corpses/km: $F_{1,21}$=0.00, P=0.95
Oiling rate: $F_{1,21}$=61.76, P<0.0001*



APPENDIX I2

2015 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, 2015 to December 31, 2015 under the authority of Permit # LS 2568.

NAME _ Marielle Thillet (Environmental Advisor) ___________ TELEPHONE # ________(902) 492-5422
(PLEASE PRINT)

ORGANIZATION _________ Encana Corporation _______________ FAX # (902) 425-2766

ADDRESS _________1701 Hollis Street, Halifax, NS _______ POSTAL CODE _____ B3J 3M8___

E-mail marielle.thillet@encana.com

SIGNATURE ____ DATE ________ January 26, 2015____

Return to:
Permit Section, Atlantic Region
Canadian Wildlife Service
PO Box 6227
Sackville NB E4L 1G6

Phone: 506-364-5044
Fax: 506-364-5062
e-mail: permi.atl@ec.gc.ca

Renew Permit ? Yes __X___ **No** _____ If yes, please forward any required changes.

(a) Production Field Centre (PFC) Production [Jan-Dec, 2015 (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

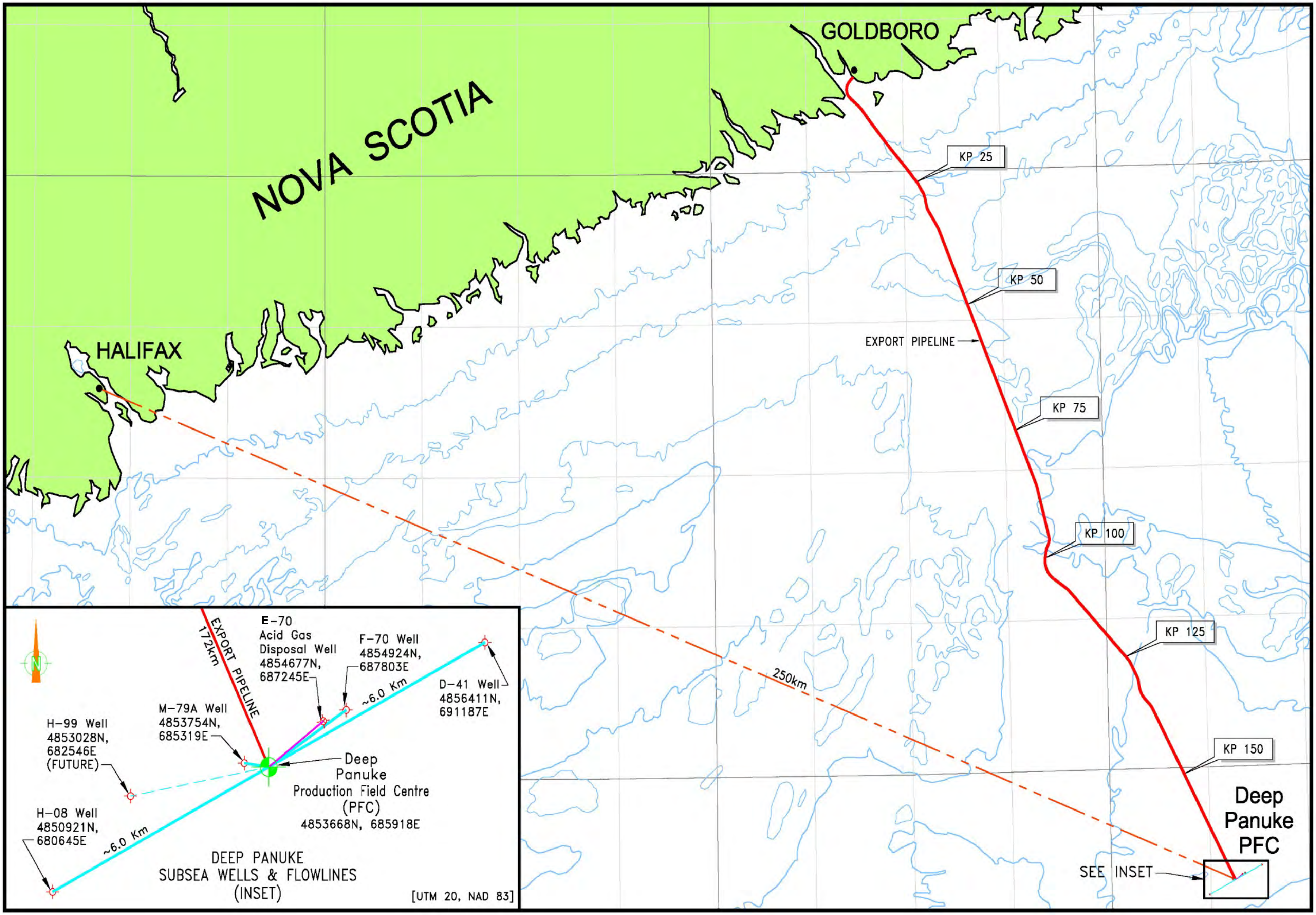
(b) Subsea Asset Inspection Survey [Feb-Dec 2015]

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
HALIFAX
GOLDBORO
KP 25
KP 50
EXPORT PIPELINE
KP 75
KP 100
KP 125
KP 150
250km
Deep Panuke PFC
SEE INSET
EXPORT PIPELINE
172km
N
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 or a general description (e.g. SE Grand Banks) if the vessel is moving.

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 2014

					Captured Alive				
			Found Dead		Un-oiled		Oiled*		Comments
Date (2014)	Species	Total	DOAS	Oiled*	DIC	Rls'd	DIC	SFR	Condition Action Taken Fate of Bird
Mar 3, 2015	Songbird, unknown	1	Y	N					Found in Module 1, Level 1 near PW stripper; wet, no oil, old carcass (see photo 1)
Mar 3, 2015	Potential LHSP, too desiccated to confirm	2	N	N					Under grating around essential generator; wet, no oil, old carcasses; inaccessible (see photos 2a and 2b)
Mar 10, 2015	LHSP	1	Y	N					Main Deck East side (near to methanol storage tank); fresh carcass. Wet and dirty, but no sign of oil contamination; disposed of at sea (see photo 3)
Jun 8, 2015	Black Guillemot	1				1			Noticed on West side of PFC near leg entangled into fishing twine. Called ATL Condor who released FRC to rescue bird. Had orange twin wrapped around his wing and a few around his head. After catching the bird we cut the twine off and released the bird. Still feisty and pecking the handler when removed rope. Seemed to be fine swimming away. FRC back onboard at 1420. No intrinsically safe camera was onboard the FRC at the time and didn't want to stress the bird any more than we needed. (see photo 4)
Jul 22, 2015	GBBG	1	Y	N					Found on deck. Broken neck. Wet and dead. Disposed of at sea. (see photo 5)
Aug 14, 2015	Yellow-warbler (male)	1	N	N					Found in NW Jack house 20:00 sitting on the work bench. Dry, no oil. Found dead. Transferred to CWS via boat. CWS confirmed species identification; decided not to conduct necropsy on the bird and disposed of it. CWS expects bird likely got stranded on its southerly migration to wintering grounds in the south eastern US. (see photo 6)
Oct 10, 2015	Yellow Breasted Chat	1	Y	N					Found in Hull Bay 4 – must have flown in during cargo ops. Clean, dead. CWS confirmed species identification and indicated it was very unusual sighting offshore as its breeding range only extends up to New York. (see photo 7)
Oct 18, 2015	LHSP	1	Y	N					Half eaten. Worker didn't want to bring what was left in – no picture taken.

					Captured Alive				
			Found Dead		Un-oiled		Oiled*		Comments
Date (2014)	Species	Total	DOAS	Oiled*	DIC	Rls'd	DIC	SFR	Condition Action Taken Fate of Bird
Nov 11, 2015	Unknown, too desiccated to confirm	1	Y	N					Found in Module 4, Level 2 under cooling water exchanger. Unknown species (too old to say), expect songbird because of small size. Found dead, dry, not oiled, very old carcass. Disposed at sea. (see photo 8)
Nov 20, 2015	Purple Finch	1	Y	N					Bird was found MOD LVL 1. Clean, dead, disposed at sea. CWS confirmed species identification. (see photo 9)

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.**

FOR INFORMATION: Unusual Observations of Non-Stranded Birds

- 18-Oct-2015: Three falcons have been reported around the PFC for a couple of days.


Photo 1


Photo 2a


Photo 2b


Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

Photo 8

Photo 9

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 I3

2015 Observations from Supply Vessels and PFC of Marine Wildlife

CONDOR

Date	Wildlife Sightings
January 1 2015	Various untagged gulls
January 2 2015	Various untagged gulls
January 3 2015	Various untagged gulls
January 4 2015	Various untagged gulls
January 5 2015	Various untagged gulls
January 6 2015	Various untagged gulls
January 7 2015	Various untagged gulls
January 8 2015	Various untagged gulls
January 9 2015	Various untagged gulls
January 10 2015	Various untagged gulls
January 11 2015	Various untagged gulls
January 12 2015	Various untagged gulls
January 13 2015	Various untagged gulls
January 14 2015	Various untagged gulls
January 15 2015	Various untagged gulls
January 16 2015	Various untagged gulls
January 17 2015	Various untagged gulls
January 18 2015	Various untagged gulls
January 19 2015	Various untagged gulls
January 20 2015	Various untagged gulls
January 21 2015	Various untagged gulls
January 22 2015	Various untagged gulls
January 23 2015	Various untagged gulls
January 24 2015	Various untagged gulls
January 25 2015	Various untagged gulls
January 26 2015	Various untagged gulls
January 27 2015	Various untagged gulls
January 28 2015	Various untagged gulls
January 29 2015	Various untagged gulls
January 30 2015	Various untagged gulls
January 31 2015	Various untagged gulls
February 01 2015	Various untagged gulls
February 02 2015	Various untagged gulls
February 03 2015	Various untagged gulls
February 04 2015	Various untagged gulls
February 05 2015	Various untagged gulls
February 06 2015	Various untagged gulls
February 07 2015	Various untagged gulls
February 08 2015	Various untagged gulls
February 09 2015	Various untagged gulls
February 10 2015	Various untagged gulls
February 11 2015	Various untagged gulls
February 12 2015	Various untagged gulls
February 13 2015	Various untagged gulls

CONDOR

Date	Wildlife Sightings
February 14 2015	Various untagged gulls
February 15 2015	Various untagged gulls
February 16 2015	Various untagged gulls
February 17 2015	Various untagged gulls
February 18 2015	Various untagged gulls
February 19 2015	Various untagged gulls
February 20 2015	Various untagged gulls
February 21 2015	Various untagged gulls
February 22 2015	Various untagged gulls
February 23 2015	Various untagged gulls
February 24 2015	Various untagged gulls
February 25 2015	Various untagged gulls
February 26 2015	Various untagged gulls
February 27 2015	Various untagged gulls
February 28 2015	Various untagged gulls
March 1 2015	Various untagged gulls
March 2 2015	Various untagged gulls
March 3 2015	Various untagged gulls
March 4 2015	Various untagged gulls
March 5 2015	Various untagged gulls
March 6 2015	Various untagged gulls
March 7 2015	Various untagged gulls
March 8 2015	Various untagged gulls
March 9 2015	Various untagged gulls
March 10 2015	Various untagged gulls
March 11 2015	Various untagged gulls
March 12 2015	Various untagged gulls
March 13 2015	Various untagged gulls
March 14 2015	Various untagged gulls
March 15 2015	Various untagged gulls
March 16 2015	Various untagged gulls
March 17 2015	Various untagged gulls
March 18 2015	Various untagged gulls
March 19 2015	Various untagged gulls
March 20 2015	Various untagged gulls
March 21 2015	Various untagged gulls
March 22 2015	Various untagged gulls
March 23 2015	Various untagged gulls
March 24 2015	Various untagged gulls
March 25 2015	Various untagged gulls
March 26 2015	Various untagged gulls
March 27 2015	Various untagged gulls
March 28 2015	Various untagged gulls
March 29 2015	Various untagged gulls
March 30 2015	Various untagged gulls

CONDOR

Date	Wildlife Sightings
March 31 2015	Various untagged gulls
April 01 2015	Various untagged gulls
April 02 2015	Various untagged gulls
April 03 2015	Various untagged gulls
April 04 2015	Various untagged gulls
April 05 2015	Various untagged gulls
April 06 2015	Various untagged gulls
April 07 2015	Various untagged gulls
April 08 2015	Various untagged gulls
April 09 2015	Various untagged gulls
April 10 2015	Various untagged gulls
April 11 2015	Various untagged gulls
April 12 2015	Various untagged gulls
April 13 2015	Various untagged gulls
April 14 2015	Various untagged gulls
April 15 2015	Various untagged gulls
April 16 2015	Various untagged gulls
April 17 2015	Various untagged gulls
April 18 2015	Various untagged gulls
April 19 2015	Various untagged gulls
April 20 2015	Various untagged gulls
April 21 2015	Various untagged gulls
April 22 2015	Various untagged gulls
April 23 2015	Various untagged gulls
April 24 2015	Various untagged gulls
April 25 2015	1 tagged Gull
April 26 2015	Various untagged Gulls
April 27 2015	Various untagged Gulls
April 28 2015	Various untagged Gulls
April 29 2015	Various untagged Gulls
April 30 2015	Various untagged Gulls
May 1 2015	Various untagged Gulls
May 2 2015	Various untagged Gulls
May 3 2015	Various untagged Gulls
May 4 2015	Various untagged Gulls
May 5 2015	Various untagged Gulls
May 6 2015	Various untagged Gulls
May 7 2015	Various untagged Gulls
May 8 2015	Various untagged Gulls
May 9 2015	Various untagged Gulls
May 10 2015	Various untagged Gulls
May 11 2015	Various untagged Gulls
May 12 2015	Various untagged Gulls
May 13 2015	Various untagged Gulls
May 14 2015	Various untagged Gulls

CONDOR	
Date	**Wildlife Sightings**
May 15 2015	Various untagged Gulls
May 16 2015	Various untagged Gulls
May 17 2015	Various untagged Gulls
May 18 2015	Various untagged Gulls
May 19 2015	Various untagged Gulls
May 20 2015	Various untagged Gulls
May 21 2015	Various untagged Gulls
May 22 2015	Various untagged Gulls
May 23 2015 (Updated)	Various untagged Gulls
May 24 2015	Various untagged Gulls
May 25 2015	Various untagged Gulls
May 26 2015	Various untagged Gulls
May 27 2015	Various untagged Gulls
May 28 2015	Various untagged Gulls
May 29 2015	Various untagged Gulls
May 30 2015	Various untagged Gulls
May 31 2015	Various untagged Gulls
June 1 2015	Various untagged Gulls
June 2 2015	Various untagged Gulls
June 3 2015	Various untagged Gulls
June 4 2015	Various untagged Gulls
June 5 2015	Various untagged Gulls
June 6 2015	Various untagged Gulls
June 7 2015	Various untagged Gulls
June 8 2015	Various untagged Gulls
June 9 2015	Various untagged Gulls
June 10 2015	Various untagged Gulls
June 11 2015	Various untagged Gulls
June 12 2015	Various untagged Gulls
June 13 2015	Various untagged Gulls
June 14 2015	Various untagged Gulls
June 15 2015	Various untagged Gulls
June 16 2015	Various untagged Gulls
June 17 2015	Various untagged Gulls
June 18 2015	Various untagged Gulls
June 20 2015	Various untagged Gulls
June 21 2015	Various untagged Gulls
June 24 2015	Various untagged Gulls
June 25 2015	Various untagged Gulls
June 26 2015	Various untagged Gulls
June 27 2015	Various untagged Gulls
June 28 2015	Various untagged Gulls
June 29 2015	Various untagged Gulls
June 30 2015	Various untagged Gulls
July 1 2015	Various untagged Gulls

CONDOR

Date	Wildlife Sightings
July 2 2015	Various untagged Gulls
July 3 2015	Various untagged Gulls
July 4 2015	Various untagged Gulls
July 5 2015	Various untagged Gulls
July 6 2015	Various untagged Gulls
July 7 2015	Various untagged Gulls
July 8 2015	Various untagged Gulls
July 9 2015	Various untagged Gulls
July 10 2015	Various untagged Gulls
July 11 2015	Various untagged Gulls
July 12 2015	Various untagged Gulls
July 13 2015	Various untagged Gulls
July 14 2015	Various untagged Gulls
July 15 2015	Various untagged Gulls
July 16 2015	Various untagged Gulls
July 17 2015	Various untagged Gulls
July 18 2015	Various untagged Gulls
July 19 2015	Various untagged Gulls
July 20 2015	Various untagged Gulls
July 21 2015	Various untagged Gulls
July 22 2015	Various untagged Gulls
July 23 2015	Various untagged Gulls
July 24 2015	Various untagged Gulls
July 25 2015	Various untagged Gulls
July 26 2015	Various untagged Gulls
July 27 2015	Various untagged Gulls
July 28 2015	Various untagged Gulls
July 29 2015	Various untagged Gulls
July 30 2015	Various untagged Gulls
July 31 2015	Various untagged Gulls
August 01 2015	Various untagged Gulls
August 02 2015	Various untagged Gulls
August 03 2015	Various untagged Gulls
August 04 2015	Various untagged Gulls
August 05 2015	Various untagged Gulls
August 06 2015	Various untagged Gulls
August 07 2015	Various untagged Gulls
August 08 2015	Various untagged Gulls
August 09 2015	Various untagged Gulls
August 10 2015	Various untagged Gulls
August 11 2015	Various untagged Gulls
August 12 2015	Various untagged Gulls
August 13 2015	Various untagged Gulls
August 14 2015	Various untagged Gulls
August 15 2015	Various untagged Gulls

CONDOR

Date	Wildlife Sightings
August 16 2015	Various untagged Gulls
August 17 2015	Various untagged Gulls
August 18 2015	Various untagged Gulls
August 19 2015	Various untagged Gulls
August 20 2015	Various untagged Gulls
August 21 2015	Various untagged Gulls
August 22 2015	Various untagged Gulls
August 23 2015	Various untagged Gulls
August 24 2015	Various untagged Gulls
August 25 2015	Various untagged Gulls
August 26 2015	Various untagged Gulls
August 27 2015	Various untagged Gulls
August 28 2015	Various untagged Gulls
August 29 2015	Various untagged Gulls
August 30 2015	Various untagged Gulls
August 31 2015	Various untagged Gulls
September 1 2015	Various untagged Gulls
September 02 2015	Various untagged Gulls
September 03 2015	Various untagged Gulls
September 04 2015	Various untagged Gulls
September 05 2015	Various untagged Gulls
September 06 2015	Various untagged Gulls
September 07 2015	Various untagged Gulls
September 08 2015	Various untagged Gulls
September 09 2015	Various untagged Gulls
September 10 2015	Various untagged Gulls
September 11 2015	Various untagged Gulls
September 12 2015	Various untagged Gulls
September 13 2015	Various untagged Gulls
September 14 2015	Various untagged Gulls
September 15 2015	Various untagged Gulls
September 16 2015	Various untagged Gulls
September 17 2015	Various untagged Gulls
September 18 2015	Various untagged Gulls
September 19 2015	Various untagged Gulls
September 20 2015	Various untagged Gulls
September 21 2015	Various untagged Gulls
September 22 2015	Various untagged Gulls
September 23 2015	Various untagged Gulls
September 24 2015	Various untagged Gulls
September 25 2015	Various untagged Gulls
September 26 2015	Various untagged Gulls
September 27 2015	Various untagged Gulls
September 28 2015	Various untagged Gulls
September 29 2015	Various untagged Gulls

CONDOR

Date	Wildlife Sightings
September 30 2015	Various untagged Gulls
October 1 2015	Various untagged Gulls
October 2 2015	Various untagged Gulls
October 3 2015	Various untagged Gulls
October 4 2015	Various untagged Gulls
October 5 2015	Various untagged Gulls
October 6 2015	Various untagged Gulls
October 7 2015	Various untagged Gulls
October 8 2015	Various untagged Gulls
October 9 2015	Various untagged Gulls
October 10 2015	Various untagged Gulls
October 11 2015	Various untagged Gulls
October 12 2015	Various untagged Gulls
October 13 2015	Various untagged Gulls
October 14 2015	Various untagged Gulls
October 15 2015	Various untagged Gulls
October 16 2015	Various untagged Gulls
October 17 2015	Various untagged Gulls
October 18 2015	Various untagged Gulls
October 19 2015	Various untagged Gulls
October 20 2015	Various untagged Gulls
October 21 2015	Various untagged Gulls
October 22 2015	Various untagged Gulls
October 23 2015	Various untagged Gulls
October 24 2015	Various untagged Gulls
October 25 2015	Various untagged Gulls
October 26 2015	Various untagged Gulls
October 27 2015	Various untagged Gulls
October 28 2015	Various untagged Gulls
October 29 2015	Various untagged Gulls
October 30 2015	Various untagged Gulls
October 31 2015	Various untagged Gulls
November 1 2015	Various untagged Gulls
November 02 2015	Various untagged Gulls
November 03 2015	Various untagged Gulls
November 04 2015	Various untagged Gulls
November 05 2015	Various untagged Gulls
November 06 2015	Various untagged Gulls
November 07 2015	Various untagged Gulls
November 08 2015	Various untagged Gulls
November 09 2015	Various untagged Gulls
November 10 2015	Various untagged Gulls
November 11 2015	Various untagged Gulls
November 12 2015	Various untagged Gulls
November 13 2015	Various untagged Gulls

CONDOR

Date	Wildlife Sightings
November 14 2015	Various untagged Gulls
November 15 2015	Various untagged Gulls
November 16 2015	Various untagged Gulls
November 17 2015	Various untagged Gulls
November 18 2015	Various untagged Gulls
November 19 2015	Various untagged Gulls
November 20 2015	Various untagged Gulls
November 21 2015	Various untagged Gulls
November 22 2015	Various untagged Gulls
November 23 2015	Various untagged Gulls
November 24 2015	Various untagged Gulls
November 25 2015	Various untagged Gulls
November 26 2015	Various untagged Gulls
November 27 2015	Various untagged Gulls
November 28 2015	Various untagged Gulls
November 29 2015	Various untagged Gulls
November 30 2015	Various untagged Gulls
December 1 2015	Various untagged Gulls
December 2 2015	Various untagged Gulls
December 3 2015	Various untagged Gulls
December 4 2015	Various untagged Gulls
December 5 2015	Various untagged Gulls
December 6 2015	Various untagged Gulls
December 7 2015	Various untagged Gulls
December 8 2015	Various untagged Gulls
December 9 2015	Various untagged Gulls
December 10 2015	Various untagged Gulls
December 11 2015	Various untagged Gulls
December 12 2015	Various untagged Gulls
December 13 2015	Various untagged Gulls
December 14 2015	Various untagged Gulls
December 15 2015	Various untagged Gulls
December 16 2015	Various untagged Gulls
December 17 2015	Various untagged Gulls
December 18 2015	Various untagged Gulls
December 19 2015	Various untagged Gulls
December 20 2015	Various untagged Gulls
December 21 2015	Various untagged Gulls
December 22 2015	Various untagged Gulls
December 23 2015	Various untagged Gulls
December 24 2015	Various untagged Gulls
December 25 2015	Various untagged Gulls
December 26 2015	Various untagged Gulls
December 27 2015	Various untagged Gulls
December 28 2015	Various untagged Gulls

CONDOR	
Date	**Wildlife Sightings**
December 29 2015	Various untagged Gulls
December 30 2015	Various untagged Gulls
December 31 2015	Various untagged Gulls

TERN	
Date	**Wildlife Sightings**
Jan 01 2015	NA
Jan 02 2015	NA
Jan 03 2015	NA
Jan 04 2015	NA
Jan 05 2015	NA
Jan 06 2015	NA
Jan 07 2015	NA
Jan 08 2015	NA
Jan 09 2015	NA
Jan 10 2015	NA
Jan 11 2015	Seagulls
Jan 12 2015	Seagulls
Jan 13 2015	Seagulls ,Shearwaters
Jan 14 2015	Seagulls ,Shearwaters
Jan 15 2015	Seagulls ,Shearwaters
Jan 16 2015	Seagulls
Jan 17 2015	Seagulls
Jan 18 2015	Seagulls
Jan 19 2015	Seagulls ,Dovekie,Tern, seal
Jan 20 2015	Seagulls. Tern
Jan 21 2015	Seagulls.
Jan 22 2015	Seagulls, seal
Jan 23 2015	Seagulls, seal
Jan 24 2015	Seagulls, 1 Purple Sandpiper
Jan 25 2015	Gulls, 1 Seal
Jan 26 2015	Gulls,
Jan 27 2015	Gulls, Black-legged Kittiwake,Northern Fulmar
Jan 28 2015	Gulls, Black-legged Kittiwake,Northern Fulmar
Jan 29 2015	Gulls, seals
Jan 30 2015	Gulls,
Jan 31 2015	N/A
Feb 1 2015	N/A
Feb 2 2015	N/A
Feb 3 2015	N/A
Feb 4 2015	N/A
Feb 5 2015	N/A
Feb 6 2015	N/A
Feb 7 2015	N/A
Feb 8 2015	N/A
Feb 9 2015	N/A
Feb 10 2015	N/A
Feb 11 2015	N/A
Feb 12 2015	N/A
Feb 13 2015	N/A

TERN

Date	Wildlife Sightings
Feb 14 2015	N/A
Feb 15 2015	N/A
Feb 16 2015	N/A
Feb 17 2015	N/A
Feb 18 2015	N/A
Feb 19 2015	N/A
Feb 20 2015	N/A
Feb 21 2015	N/A
Feb 22 2015	N/A
Feb 23 2015	N/A
Feb 24 2015	N/A
Feb 25 2015	N/A
Feb 26 2015	N/A
Feb 27 2015	N/A
Feb 28 2015	N/A
Mar 1 2015	N/A
Mar 2 2015	N/A
Mar 3 2015	N/A
Mar 4 2015	N/A
Mar 5 2015	N/A
Mar 6 2015	N/A
Mar 7 2015	N/A
Mar 8 2015	Sea Gulls, Shearwaters
Mar 9 2015	Sea Gulls, Shearwaters
Mar 10 2015	Sea Gulls, Shearwaters
Mar 11 2015	Sea Gulls, Seals
Mar 12 2015	Sea Gulls, Seals
Mar 13 2015	Sea Gulls
Mar 14 2015	Sea Gulls
Mar 15 2015	Sea Gulls, Tern
Mar 16 2015	Sea Gulls,
Mar 17 2015	Sea Gulls,
Mar 18 2015	Sea Gulls, Tern
Mar 19 2015	Sea Gulls, Tern
Mar 20 2015	Sea Gulls, Tern
Mar 21 2015	N
Mar 22 2015	Sea Gulls, Seals
Mar 23 2015	Sea Gulls,
Mar 24 2015	Sea Gulls,
Mar 25 2015	Sea Gulls,
Mar 26 2015	Sea Gulls,
Mar 27 2015	Sea Gulls, Dovekie
Mar 28 2015	Sea Gulls, Dovekie
Mar 29 2015	Sea Gulls, Tern
Mar 30 2015	Sea Gulls, Dovekie

TERN

Date	Wildlife Sightings
Mar 31 2015	NA
April 1 2015	NA
April 2 2015	NA
April 3 2015	NA
April 4 2015	NA
April 5 2015	NA
April 6 2015	NA
April 7 2015	NA
April 8 2015	NA
April 9 2015	NA
April 10 2015	NA
April 11 2015	NA
April 12 2015	NA
April 13 2015	Sea Gulls, Seals
April 14 2015	Sea Gulls, Gannets, Seals
April 15 2015	Sea Gulls, Brown-Headed Cowbird, Seals
April 16 2015	Sea Gulls, Seals
April 17 2015	Sea Gulls, Seals
April 18 2015	Sea Gulls, Seals
April 19 2015	Sea Gulls, Seals
April 20 2015	Sea Gulls, Seals
April 21 2015	Sea Gulls, Seals, American Pipit
April 22 2015	Sea Gulls, Seals, Long-tailed Jaeger
April 23 2015	Sea Gulls, Seals
April 24 2015	Sea Gulls, Seals
April 25 2015	Sea Gulls, Seals
April 26 2015	0
April 27 2015	0
April 28 2015	0
April 29 2015	0
April 30 2015	0
May 01 2015	0
May 02 2015	0
May 03 2015	Seaguls
May 04 2015	Seaguls
May 05 2015	Small Black Whale
May 06 2015	Black Seal
May 07 2015	Seagul
May 08 2015	Seaguls and seals
May 09 2015	Minke Whale
May 10 2015	0
May 11 2015	Seaguls, Yellow Warbler, Seals
May 12 2015	None
May 13 2015	Seaguls
May 14 2015	Seaguls

TERN	
Date	**Wildlife Sightings**
May 15 2015	Very Small bird, Petrel?
May 16 2015	Seaguls, seals
May 17 2015	Greater Sheerwaters, Flumars
May 18 2015	Seaguls
May 19 2015	Seals
May 20 2015	Seaguls
May 21 2015	None
May 22 2015	None
May 23 2015	Greater sheerwater, seal
May 24 2015	sheerwaters
May 25 2015	Porpoise
May 26 2015	none
May 27 2015	none
May 28 2015	Gulls, Seals
May 29 2015	Gulls, Gannets
May 30 2015	Gulls
May 31 2015	Gulls
June 01 2015	Gulls, Sheerwater
June 02 2015	Gulls, Seals
June 03 2015	Gulls, Alcids
June 04 2015	Gulls, Seals
June 05 2015	Gulls, Grey Seals
June 06 2015	Gulls, Northern Fulmar, Grey Seals
June 07 2015	Gulls, Grey Seals
June 08 2015	Gulls, Grey Seals, Minke Whale
June 09 2015	Gulls, Grey Seals
June 10 2015	Gulls, Grey Seals
June 11 2015	Gulls, Grey Seals
June 12 2015	Gulls, Grey Seals, Double-crested cormorant
June 13 2015	Gulls, Grey Seals, Mink Whale
June 14 2015	Gulls, Grey Seals
June 15 2015	Gulls, Grey Seals
June 16 2015	Gulls, Grey Seals
June 17 2015	Gulls, Grey Seals
June 18 2015	Gulls, Grey Seals, Mink Whales
June 19 2015	Gulls, Grey Seals,
June 20 2015	Gulls, Grey Seals, Alcids
June 21 2015	Gulls, Grey Seals, Alcids
June 22 2015	Gulls, Grey Seals, Alcids
June 23 2015	Gulls, Grey Seals, Alcids
June 24 2015	Gulls
June 25 2015	Gulls
June 26 2015	Seal
June 27 2015	seagulls
June 28 2015	seagulls & Shearwater

TERN

Date	Wildlife Sightings
June 29 2015	seagulls
June 30 2015	seagulls
July 01 2015	seagulls
July 02 2015	seagulls
July 03 2015	seals
July 04 2015	Seagulls
July 05 2015	Seagulls & porpoises
July 06 2015	Seagulls, seals, Atlantic Tern, Ocean Sunfish
July 07 2015	Seagulls
July 08 2015	Seagulls & Tern
July 09 2015	Seagulls, seals & Dolphins
July 10 2015	Seagulls
July 11 2015	Seagulls, Seals and Dolphins
July 12 2015	Seagulls & Seals
July 13 2015	Seagulls
July 14 2015	Seagulls & Seals
July 15 2015	Seagulls
July 16 2015	Seagulls
July 17 2015	Seagulls, Ocean Sunfish & Seals
July 18 2015	Seagulls & Ocean Sunfish
July 19 2015	Seagulls & seals
July 20 2015	0
July 21 2015	0
July 22 2015	0
July 23 2015	Gulls
July 24 2015	Gulls
July 25 2015	Gulls, Tern
July 26 2015	Gulls
July 27 2015	Gulls
July 28 2015	Gulls, White sided dolphins
July 29 2015	Gulls, White sided dolphins, Blue Shark
July 30 2015	Gulls
July 31 2015	Gulls
Aug 1 2015	Gulls
Aug 2 2015	Gulls, Tern, Seals
Aug 3 2015	Gulls, Tern
Aug 4 2015	Gulls
Aug 5 2015	Gulls, Terns
Aug 6 2015	Gulls, Terns, Seals
Aug 7 2015	Gulls, Terns, Seals, White sided dolphins
Aug 8 2015	Gulls, Seals
Aug 9 2015	Gulls, Seals
Aug 10 2015	Gulls, Seals, Long-Tailed Jaeger
Aug 11 2015	Gulls, Seals
Aug 12 2015	Gulls, Seals

TERN

Date	Wildlife Sightings
Aug 13 2015	Gulls, White Sided Dolphins
Aug 14 2015	Gulls, Seals
Aug 15 2015	Gulls, White Sided Dolphins
Aug 16 2015	Gulls, White Sided Dolphins, Seals
Aug 17 2015	0
Aug 18 2015	0
Aug 19 2015	0
Aug 20 2015	N/A
Aug 21 2015	Gulls
Aug 22 2015	Seal
Aug 23 2015	Gulls, dophins, Minke Whale
Aug 24 2015	Gulls
Aug 25 2015	Gannets
Aug 26 2015	gulls
Aug 27 2015	seal
Aug 28 2015	Tern, gulls
Aug 29 2015	gulls
Aug 30 2015	gulls, seals
Aug 31 2015	gulls,
Sept 1 2015	gulls
Sept 2 2015	gulls, seals
Sept 3 2015	gulls
Sept 4 2015	gulls
Sept 5 2015	various gulls
Sept 6 2015	various gulls
Sept 7 2015	various gulls
Sept 8 2015	various gulls
Sept 9 2015	gulls, Silver Hake fish
Sept 10 2015	gulls, Jaeger
Sept 11 2015	gulls, Pilot Whale
Sept 12 2015	Tern
Sept 13 2015	Tern, Minke Whale, Porbeagle shark
Sept 14 2015	Various gulls
Sept 15 2015	Various gulls
Sept 16 2015	0
Sept 17 2015	Gulls, Seals
Sept 18 2015	Gulls
Sept 19 2015	Gulls, Tern
Sept 20 2015	Gulls, Gannets
Sept 21 2015	Gulls
Sept 22 2015	Gulls, Gannets
Sept 23 2015	Gulls
Sept 24 2015	Gulls, White sided dolphins
Sept 25 2015	Gulls
Sept 26 2015	Gulls

TERN

Date	Wildlife Sightings
Sept 27 2015	Gulls, Gannets, Terns
Sept 28 2015	Gulls
Sept 29 2015	Gulls, White sided dolphins
Sept 30 2015	Gulls
Oct 01 2015	Gulls, Gannets
Oct 02 2015	Gulls, Seals
Oct 03 2015	Gulls
Oct 04 2015	Gulls, Terns
Oct 05 2015	Gulls
Oct 06 2015	Gulls
Oct 07 2015	Gulls, Sun fish
Oct 08 2015	Gulls
Oct 09 2015	Gulls, Tern
Oct 10 2015	Gulls
Oct 11 2015	Gulls, Seals
Oct 12 2015	Gulls, Seal
Oct 13 2015	0
Oct 14 2015	none
Oct 15 2015	none
Oct 16 2015	none
Oct 17 2015	none
Oct 18 2015	none
Oct 19 2015	Seaguls
Oct 20 2015	Seaguls
Oct 21 2015	Seaguls
Oct 22 2015	Seaguls
Oct 23 2015	Seaguls…lots of seaguls
Oct 24 2015	Seaguls…lots of seaguls
Oct 25 2015	Seaguls
Oct 26 2015	Seaguls
Oct 27 2015	none
Oct 28 2015	Seaguls
Oct 29 2015	none
Oct 30 2015	small dolphin
Oct 31 2015	Seal
Nov 01 2015	Seaguls
Nov 02 2015	Seal
Nov 03 2015	Seaguls
Nov 04 2015	gannet
Nov 05 2015	Seagul
Nov 06 2015	none
Nov 07 2015	none
Nov 08 2015	none
Nov 09 2015	none
Nov 10 2015	none

TERN

Date	Wildlife Sightings
Nov 11 2015	none
Nov 12 2015	none
Nov 13 2015	none
Nov 14 2015	none
Nov 15 2015	none
Nov 16 2015	none
Nov 17 2015	Gulls
Nov 18 2015	Gulls
Nov 19 2015	Gulls
Nov 20 2015	Gulls
Nov 21 2015	Gulls
Nov 22 2015	Gulls
Nov 23 2015	Gulls, Terns
Nov 24 2015	Gulls
Nov 25 2015	Gulls
Nov 26 2015	Gulls
Nov 27 2015	Gulls, Seal
Nov 28 2015	Gulls, Tern
Nov 29 2015	Gulls, Seal
Nov 30 2015	Gulls,Terns
Dec 1 2015	Gulls
Dec 2 2015	Gulls
Dec 3 2015	Gulls
Dec 4 2015	Gulls, Terns
Dec 5 2015	Gulls
Dec 6 2015	Gulls
Dec 7 2015	Gulls
Dec 8 2015	Gulls
Dec 9 2015	none
Dec 10 2015	none
Dec 11 2015	none
Dec 12 2015	none
Dec 13 2015	none
Dec 14 2015	none
Dec 15 2015	none
Dec 16 2015	none
Dec 17 2015	gulls
Dec 18 2015	gulls
Dec 19 2015	gulls
Dec 20 2015	gulls
Dec 21 2015	gulls
Dec 22 2015	gulls
Dec 23 2015	gulls
Dec 24 2015	gulls
Dec 25 2015	gulls

TERN	
Date	**Wildlife Sightings**
Dec 26 2015	gulls
Dec 27 2015	gulls, seal
Dec 28 2015	gulls,
Dec 29 2015	gulls,
Dec 30 2015	gulls,
Dec 31 2015	gulls,

PFC Wildlife Sightings:

Three red bats (See photos below) were observed on the PFC on September 15, 2015. Department of Natural Resources was contacted, the bats left later that day, on their own volition.

APPENDIX I4

OTN Final Report - Blue Shark Tagging

Final Report on Deep Panuke E&T and R&D Fund Study Agreement DP-ENV-01
8 March 2016

Acoustic tracking of marine species in Nova Scotia waters from receivers positioned on NS offshore oil and gas infrastructure, with special consideration of the movement, site fidelity, and recreational fisheries survival of immature female blue sharks (*Prionace glauca*)

Fred Whoriskey, Brendal Davis, Katerina Fupsova, Jessica Hurtubise, Manuel Dureuil, Boris Worm, Jon Pye and Chris Harvey Clark.

Ocean Tracking Network, Dalhousie University
Steele Ocean Sciences Building
1355 Oxford St., POB 15,000
Halifax, NS, B3H 4R2

Contact: fwhoriskey@dal.ca

EXECUTIVE SUMMARY

With Deep Panuke E&T and R&D Fund support from Encana Corporation, Dalhousie University's Ocean Tracking Network (OTN) initiated a program to track and document the habitat use of female juvenile blue sharks (*Prionace glauca*) off the coast of Nova Scotia, a "hotspot" for these highly-exploited animals. Forty sharks (20 per year) caught by anglers were acoustically tagged and released in summer of 2013 and 2014, and 39 of them were detected post-release showing that they had survived catch-and-release angling. In summer and autumn, the animals mostly occupied the continental shelf off Nova Scotia at distances of about 20-40 km offshore, but moved away from the area to overwinter. Animals tagged in 2013 (60%) and 2014 (32%) were detected off Halifax in the summer of the year after their initial tagging, showing certain individuals exhibited site fidelity to the region. Other tagged sharks were detected in the Gulf of Maine, Gulf of St. Lawrence and off Sable Island. No evidence was found for diel variation in either inshore/offshore movement or activity patterns for the tagged sharks. Acoustic receivers positioned on oil and gas industry offshore infrastructure did not detect the tagged sharks, but logged other tagged animals including grey seals and Bluefin tuna. The immature female sharks we studied may avoid offshore areas due to dangers posed by mature males. Results from his work will help inform offshore development, fisheries management and the design of Marine Protected Areas.

INTRODUCTION

In the 2012 Deep Panuke E&T and R&D Fund competition, Dalhousie University's Ocean Tracking network submitted a successful proposal entitled: *Acoustic tracking of marine species in Nova Scotia waters from receivers positioned on NS offshore oil and gas platforms*. The proposal built on Nova Scotia's technical excellence in the manufacture and operation of acoustic telemetry systems to track the movements of aquatic animals, and the opportunities that a partnership with the offshore oil and gas industry offered to expand our acoustic tracking capabilities and implement fundamental and applied science projects that could provide information of interest to multiple stakeholder groups.

The specific issues that the proposed research addressed were:

- Document the movements and marine habitats used by valued marine species in the North West Atlantic Ocean, and Nova Scotia waters in particular
- Acoustically tag a currently understudied top predator (blue sharks) to provide fundamental information about the species' distribution and survival in Nova scotia waters
- Expand the capacity of North American east coast acoustic telemetry networks by augmenting current acoustic receiver coverage in the region by deployments of new receivers on infrastructure associated with the offshore oil and gas industry, and through training new professionals

Specific project objectives were:

- Conduct a pilot project to deploy and maintain sonic receiver units on appropriate offshore oil and gas infrastructure in NS to complement existing receiver coverage
- QA/QC the data from detections of tagged animals at these sites and store it in the OTN data warehouse
- Capture, acoustically tag and release 20 blue sharks per year for two years
- Transmit recorded detection information from the data warehouse to the national and international investigators who have tagged the fish
- Use the NS information, along with that obtained from other OTN acoustic receiver lines, to document movements, habitat use, and survival of sonically tagged marine animals, many of which are highly migratory (e.g., we are recording the movements of Bluefin tuna through NS waters from the Gulf of Mexico into the Gulf of St. Lawrence)
- Make the information freely available to end users, industry and the public
- Train 18 students per year in the use of the tracking technology and animal tagging
- If the pilot project proves successful, expand it to other offshore oil and gas platforms globally

The blue shark, *Prionace glauca*, was chosen as the focal species for this work because it is a highly migratory pelagic predator with a circum-global distribution (Nakano & Stevens 2008). The species is the world's most abundant pelagic shark (Campana et al. 2011; Litvinov 2006), and it is subjected to one of the highest catches in commercial fisheries. Blue sharks are also the most frequently caught pelagic shark species in the rapidly increasing recreational shark fishery (Babcock 2008, Campana et al. 2006). There is great concern in general about the health of global shark populations due to overexploitation.

Mark-recapture studies suggest a single population of blue sharks exist in the North Atlantic Ocean (Kohler et al. 2002). The blue shark is known to segregate by sex and life stages (Tavares et al. 2012, Vandeperre et al. 2014). Average individual life spans of about 15 years have been estimated, with maximum life spans estimated at 21 - 26 years (Skomal & Natanson 2002). Males mature at a fork length of 193 to 210 cm while females mature at 185 cm (Campana et al. 2005, Pratt 1979), corresponding to ages of about 4-6 years and 5-7 years, respectively (Kohler et al. 2002, Nakano & Stevens 2008). Sub-mature females (145 to 185 cm fork length) are capable of storing spermatozoa for later insemination (Pratt 1979).

In Canadian waters, the blue shark has historically been encountered off southeastern Newfoundland, the Grand Banks, the Gulf of St. Lawrence, the Scotian Shelf and in the Bay of Fundy (Campana et al. 2005). Catches since 1993 indicate that the Nova Scotia and Newfoundland region are predominantly occupied by juvenile females (Campana et al. 2006). Tagging programs using external tags have shown the blue shark can be highly migratory (Kohler et al. 2002, Kohler & Turner 2008). In the North Atlantic Ocean some trans-oceanic movement of blue sharks has been observed, but instances of individuals crossing the equator are very rare. Seasonal migrations have been observed in the western as well as the eastern North Atlantic (Campana et al. 2011, Kohler & Turner 2008, Nakano & Stevens 2008, Queiroz et al. 2005 Stevens 1976). Blue sharks tolerate a wide temperature range, but prefer water at 11°-22°C (Nakano & Nagasawa 1996, Queiroz et al. 2010). Thus movements away from eastern Canada in winter to avoid the cold are to be expected.

The exact overwintering areas for different life stages of Nova Scotia blue sharks are unknown, but limited work suggested that they may be in Gulf Stream, the area east of the Gulf Stream, and the Sargasso Sea (Stevens 1990). Campana et al. (2011) observed that juvenile blue sharks satellite-tagged on or near the continental shelf remained in this region during summer, then moved south and/or east between September and February with the majority moving in late October. These sharks were released between August and October and most were monitored only until December of the tagging year, however, two sharks were tracked until March of the following year. Small differences in migration time were observed between different years, and associations between the movements, water current, and temperature of the water were noted. The majority of the tagged sharks moved to the Gulf Stream, although one shark relocated to the southeast of Cuba. The sharks remained within the Gulf Stream, its rings, or the Sargasso Sea for up to six following months (Campana et al. 2011). Due to tag battery expiry, it could not be determined if sharks remained in or near the Gulf Stream during the late winter and early spring, or returned to their original tagging area. Given that blue shark fishery catches in Nova Scotia waters are consistently dominated by juvenile and sub-adult females, this may suggest previously undocumented inter-year site fidelity for these age classes to the region.

Given these considerations, we added the following scientific objectives to our work to complement the overall project objectives:

- Determine the survival of the sharks following catch and release angling;
- Establish residency patterns in Nova Scotia waters, to determine if individual sharks showed the inter-year site fidelity to this region; and
- Analyze the differences in activity level between day and night as well as determine if diel inshore-offshore movements occurred. Assuming that more detections will be recorded when sharks are more active, we predicted that we would observe more frequent detections during night hours, as nocturnal tendencies have been previously observed among blue sharks (Sciarrotta & Nelson 1977).

METHODS

Tagging procedure

Forty angled blue sharks were tagged over two years with Vemco V16 (<1% of the animal's body weight) coded acoustic transmitters with life expectancies of 6 (n=20) or 10 (n=20) years. All sharks were captured, tagged, and released within 31 - 42 km off shore. Sharks captured with injuries unrelated to the angling process (bites from predators, wounds from previous encounters with long lines) were excluded from tagging as their condition could have resulted in altered behaviour or early mortality.

Tagging took place off Eastern Passage, Nova Scotia (Figure 1) during July-August 2013 and August 2014 using a small (10.36 m), licensed commercial recreational fishing charter vessel. Sharks were attracted to the area with a chum-slick and captured using rod-and-reel fishing lines with barbless J-hooks. Sharks were brought to the vessel and put into a state of tonic immobility by placing them with their ventral side up (Henningsen 1994). For each individual, the fork length and girth were measured prior to tag implantation.

The acoustic tags were surgically implanted into the peritoneal cavity, midway between the pectoral and anal fins, via a 3-4 cm incision in the abdominal wall. The incision was closed using silk sutures. Water was pumped over the gills throughout the entire procedure. Aseptic techniques were used during the surgery, with the time out of water not exceeding 7 minutes. Sharks were immediately released following surgery. All handling procedures were approved by the Animal Care Committee of Dalhousie University.

To monitor the movement of the acoustically tagged sharks, the Ocean Tracking Network (OTN) acoustic receiver network (Figure 1) was used. Moored receivers in the region were: the OTN Halifax Line, extending from the Halifax shore to the edge of the continental shelf; the OTN Cabot Strait Line, covering the area between Cape Breton Island and Newfoundland; the Strait of Canso, connecting mainland NS and Cape Breton Island; the Minas Passage, monitoring the use of the Bay of Fundy; and around Sable Island. Mobile receivers were also mounted on the OTN autonomous marine vehicles (a Liquid Robotics Wave Glider, and two Slocum electric gliders) and fixed to the backs of grey seals (*Halichoerus grypus*; termed bioprobes; Figure 2), and were operational at various times during the study in the area.

Data Analysis

Detections of the fish on acoustic receivers were used to determine if the fish had survived the live release procedure. Given the relatively limited array of acoustic receivers in the study area, estimates of survival based on detections would be conservative as the absence of detection of a given animal may have simply indicated that the movements of a fish after release did not bring it into range of a receiver. Detections of all tagged animals were collated after periods of 1, 14, 30, and 60 days after release. Campana et al. (2009) live-released blue sharks bycaught in the commercial long-line fishery and estimated that 95% of non-surviving sharks died within less than 12 days post-release; also, that 60 days is a sufficient period to account for mortality caused by starvation in cases where feeding was compromised by capture (e.g., hooking in the stomach) or handling.

Spatial analysis was conducted using ArcGIS. Bathymetry data was obtained from NOAA's National Geophysical Data Centre (http://maps.ngdc.noaa.gov/). When a fish was detected on a given receiver, the detection position was assigned as the coordinates of that receiver.

To determine if there were diurnal differences in activity, the number of detections of the tagged animals during daylight and night periods were compared. It was assumed that if the fish were more active in one period versus the other, then there would be more detections in the most active period. In addition, to test for a diel pattern of offshore (day) versus inshore (night) movements of blue sharks (e.g., Sciarrotta & Nelson 1977), the mean, minimum, and maximum distance from shore of detections of tagged animals in day versus night was compared. These comparisons were done individually for each tagged shark using data from the Halifax line during August and September of both years. This was the period when the sharks had established their summer residency in the region. After this time, an offshore overwintering migration began and not enough data was available for statistical comparisons.

A Chi-square test was used to statistically compare day versus night activity data, with the null hypothesis of equal probabilities of detection of tagged individuals in both day and night. A Wilcoxon signed-rank test was used to statistically compare the distances from shore between day and night, with the null hypothesis of equal distance of detection of tagged individuals in both day and night. Day time was defined as the time between sunrise and sunset using the calculator of the National Research Council Canada (www.nrc-cnrc.gc.ca) for the latitude of Halifax. The significance in the difference between mean distances from shore was tested using Wilcoxon signed-rank test. The expected numbers of detections in each period under the null hypotheses were weighted based on the daily number of hours of day and night in the region.

RESULTS

All specific issues and project objectives from the original proposal have been met. Twenty recreationally- angled blue sharks per year (Table 1) were acoustically tagged as planned, and their movements and survival documented. In association with Encana, and Exxon Mobil, additional acoustic telemetry receivers were deployed on Nova Scotia offshore oil and gas infrastructure (Fig. 1), and a mobile receiver was attached to the Remotely Operated Vehicle (ROV) that conducted an annual survey of the pipeline from the Deep Panuke site to the mainland. While these deployments did not detect any of the tagged blue sharks, they did register other acoustically tagged animals (Table 2). These detections have been stored in the OTN data warehouse, and forwarded to the investigators who originally tagged the animals. All blue shark detection data has also been stored in the OTN data warehouse, and has been made freely available to the scientific community. The capture and tagging of the blue sharks was incorporated into a new course at Dalhousie University dealing with the ecology of sharks and rays. More than 20 students per year were trained, being taken out to sea and participating in the capture and tagging of the animals. Two of these students subsequently conducted honors theses research working on data from the project. Finally, additional receivers were deployed on Exxon Mobil infrastructure off Nova Scotia in 2015 and we are currently in discussions with Shell Oil (Ruth Perry), about incorporating acoustic telemetry capabilities on their offshore sites globally. Detailed results on the findings about the biology of blue sharks are given below.

Capture, release and inter-year detection of blue sharks

Twenty juvenile and sub-adult females ranging in size from 103 to 165 cm fork length (mean = 143.8 cm; Table 1) were caught and tagged each year. Based on literature size-at-age estimates for the species (Skomal and Natanson 2003, MacNeil and Campana 2002), these animals were 1-4 years old. Thirty nine of the 40 sharks were detected by the receiver network at some point after their live release. The shortest time between release and last recorded detection was 10 hours and the longest time to date was 482.71 days. Pooling data from both years, only four animals (10%) were detected for less than one day (24 h) post release, whereas 75%, 65% and 57.5% of the tagged sharks were detected for at least 14, 30 and 60 days post-release, respectively. One shark, (Ophelia) was recorded only once, in 2013 one hour post-release, but was detected for 156 hours in 2014. This pattern of repeated detections provides strong evidence for blue shark survival of catch-and-release angling.

Some of the acoustically tagged sharks showed inter-year site fidelity to the Halifax region (Table 4). Sixty and 30% of the animals tagged in 2013 and 2014, respectively, were recorded off of Nova Scotia by the OTN receivers in the year after initial tagging. However, none of the animals tagged in 2013 were detected in Nova Scotia in 2015, two years after tagging. Data to test if the animals tagged in 2014 will return two years after initial marking will not be available until late 2016.

Seasonal distribution and movement patterns

Between July and October 2013, tagged sharks were primarily detected on the inshore part of the OTN Halifax Line, at distances ranging from approximately 4 to 76 km from the shore, with most detections occurring at a distances of about 20-40 km. In addition, two sharks (Brianna and Wryley) were detected by OTN gliders flying transects perpendicular to the coast south of the Halifax Line, at distances of 18 to 21 km from the shoreline. Five sharks (Brandy, Brianna, Skylar, Sophie, and Wryley) were detected by mobile receivers (bioprobes) mounted on grey seals, 27-48 km off shore and to the south of the Halifax Line. The shark-seal encounters occurred between August 14 and August 24, 2013. The one long-distance migrant that was detected away from the Halifax area in 2013 (Percy) was recorded near Sable Island on September 27, approximately 280 km from its point of release (Figure 3).

Starting in November 2013, offshore movement of the sharks became apparent, with detections spread across the OTN Halifax line from approximately 27 to 159 km offshore (Figure 4). However, only seven of the 20 2013 tagged sharks (Blueberry, Brianna, Eva, Finnigan, Lucy, Skylar, and Wryley) were detected during this period. By December 2013 only one shark (Finnigan) was detected by receivers of the OTN Halifax Line, near the edge of the continental shelf (approximately 144-146 km offshore); Figure 5). This individual was detected 17 times on December 25, 2013. After December 2013 there was a five month period where none of the tagged animals were recorded by any of the acoustic receivers in the region.

In June 2014, sharks tagged in 2013 began being detected again on receivers of the Halifax line. Detections were scattered across the OTN Halifax Line with the majority of detections being found in the innermost half of the receiver array (Figure 6). During this period five sharks tagged during the previous summer (Brandy, Hayley, Lola, Ophelia, and Sophie) were detected again in Nova Scotia coastal waters. After June additional animals tagged off Halifax in 2013 reappeared in the Halifax region in 2014. Brianna, Eva, and Percy were detected for the first time during July 2014, and Skylar and Xena were detected in August 2014. Of the 20 sharks tagged in 2013, ten individuals (50%) returned to Nova Scotia coastal waters in 2014, including one animal detected in the Cabot Strait.

Sharks detected in July-September 2014 were again predominantly registered on the inner part of the OTN Halifax Line, with the exception of Brianna who was detected on the OTN Cabot Strait line between Cape Breton and Newfoundland in July 2014, and Finnigan who was detected on the central Maine shelf in August. All detections observed between July and September 2014 of the 2013 sharks, as well as of the additional 20 sharks tagged in August 2014, showed a similar distribution pattern to that observed in 2013 (Figures 3, 7). The sharks were recorded on receivers positioned from approximately 2 to 76 km offshore with most detections occurring about 20-40 km from shore.

Six animals tagged in 2014 and which returned to the Halifax region in 2015 showed a similar residence pattern to that observed for the tagged sharks in other years. The animals occupied a restricted band in coastal waters over the summer, moving offshore as conditions cooled with the onset of autumn.

There was a difference evident in the time that the sharks initiated offshore movements in 2014 compared to 2013. Offshore detections (up to 102 km) were observed by October in 2014 (Figure 8) and continued into November (Figure 9), whereas in 2013 fish were not found offshore until November-December (Figures 4, 5). One shark tagged in 2013 started its offshore migration in October 2014, all other sharks tagged in 2013 stayed inshore until November 2014.

Diel activity patterns and movements

Data from August and September 2013 and 2014 were analyzed in order to determine if there was evidence for diel activity patterns in the tagged sharks. Detections in the day versus the night of individual sharks, for which there were sufficient data, were compared (χ^2). Only two of 66 tests (Lola and Tika in August 2013; 3.03%) showed significant differences in the number of day time vs night time detections, suggesting that, in general, the animals did not show diel activity patterns. Both of the sharks that did show significant differences had more detections during the night.

Due to changing photoperiods, comparisons were done separately for August and September for animals with sufficient data to see if there was evidence of a diel movement toward the coast at night. There were no significant differences in the mean, maximum, and minimum distance of the fish that were detected from the coast in the daytime versus nighttime (Table 4), providing no evidence of diel inshore/offshore migrations.

DISCUSSION

Post-release survival

The high rate of detection of tagged fish over extended periods post-release (90% of individuals detected 1 d after release, 75% of individuals detected 14 d after release) indicated that blue sharks exhibited high catch-and-release survival post-angling. These animals had the additional stress of the tag implantation procedures, so the high rates of detection are very encouraging. Our receiver network was geographically limited; due to this, we may have failed to detect a number of the tagged-and-released sharks that were still alive. For example, one individual caught-and-released off of Halifax in 2013 was detected for approximately one hour immediately post-release by receivers of the Halifax line, followed by no detections anywhere for the rest of the year. In 2014, this animal returned to the Nova Scotia region (Cabot Strait) and was in range of various receivers for a total of 156 hours. Based on this, we believe our survival estimates are minimums. Campana et al.'s (2009) findings showed that sharks with minor injuries at the time of release from commercial long-line fisheries tended to survive (hooking mortality 35% and additional discard mortality 19%).

Movement, migration, and residency patterns

In both 2013 and 2014, from their arrival in the region until they began autumn offshore movements tagged shark detections primarily occurred in the near shore part of the continental shelf. Most detections occurred near Halifax, primarily on the OTN Halifax receiver line but also including detections from autonomous marine vehicles and grey seals carrying satellite-linked mobile receivers. The exceptions included three sharks, one that had moved to Sable Island (280 km from its release point), a second to the Cabot Strait (540 km from its release point), and a third to the central Maine shelf in US waters (Shark ID 26662 (Finnigan), detected multiple times on 3 August 2014 the year after its tagging by a receiver on Gulf of Maine Buoy E01, 49°42.98’N, 069°21.30’W; about 460 km from the shark’s release point). No sharks were detected by any OTN equipment in the study region between January 2013 and May 2014. These juvenile and sub-adult females could be overwintering in warmer offshore areas associated with the Gulf Stream, as is believed to occur with adult male and female blue sharks (Campana et al. 2011, Kohler & Turner, 2008, Nakano & Stevens, 2008). However, if immature female blue sharks segregate from the adults in coastal areas in summer/fall at least in part to avoid damaging forced copulations, then perhaps they should avoid adult overwintering areas. Given the current paucity of acoustic telemetry receivers in deep waters off the continental shelf, future satellite tagging studies are the most promising avenue to define the overwintering areas of these immature female blue sharks.

Inter-year site fidelity

Site fidelity, defined as a tendency to return to and reuse a previously occupied areas (Switzer 1993) is common at a regional scale among migratory sharks including white sharks (*Carcharodon carcharias*) (Jorgensen et al. 2010), tiger sharks (*Galeocerdo cuvier*) (Meyer et al. 2010), broadnose sevengill sharks (*Notorynchus cepedianus*) (Barnett et al. 2011) and immature lemon sharks (*Negaprion brevirostris*) (Chapman et al. 2009). The main reasons for site fidelity include mating, pupping, feeding, and reuse of natal sites (Switzer 1993, Chapman et al. 2009). Vandeperre at al. (2014) reported that four blue sharks (three juveniles and one sub-adult) tagged in the Azores archipelago of the Central North Atlantic Ocean also showed regional site fidelity, initially dispersing then returning back to the region during the winter season. Our work is the first to document inter-year site fidelity to locally restricted geographic areas for highly migratory blue sharks. This area could be providing mulitple benefits to the individuals that use it (e.g., protection from adult males, shelter, feeding opportunities), and presumably, the familiarity the animals have with the region due to previous experience with it enhances these benefits. The distance the sharks have to cover to return to the area following their winter migration, and the cues they use to home back to the site, are presently unknown. The fraction of the sharks returning may be the majority of the surviving sharks given the species high annual mortality rate. Previous reports suggest that instantaneous natural mortality rate for blue sharks is approximately 23% (Campana et al. 2005). A separate analysis based on demographics and life history characteristics predicts an even higher annual mortality rate, up to 47% for juveniles older than one year (Campana et al. 2005). This may also explain why there were not detections of the 2013 tagged animals in 2015, two years after their release.

Diel behaviour

Many aquatic species show diel patterns of movements, either horizontally from place to place or vertically in the water column, frequently associated with feeding (Klimley et al. 1988, Narver 1970, Sims et al. 2005). One study from California showed nocturnal inshore-offshore diel movements of blue sharks (Sciarrotta & Nelson 1977). Campana et al. (2011) observed diurnal dive patterns among blue sharks when residing in the warm waters of the Gulf Stream. The sharks occupied shallower waters during the day and deep waters during the night. In the present study, there was no evidence from the tagged sharks of a diel inshore-offshore movement, nor of increased numbers of detections (a surrogate for activity) of animals at night compared to during the day. This suggests that the habitat that the animals are occupying is the primary driver of the animal's behaviour. Perhaps the site where the sharks are found either provides for all of their needs, or that some essential element (perhaps shelter, prey availability, or lack of potential predators) is found only here. Unfortunately, the technology used did not permit us to determine the depth of the tagged sharks, which would have addressed the possibility of diel vertical migration.

Benefits of acoustic receivers on offshore oil and gas infrastructure

Although we did not have any detections of this study's tagged blue sharks on the receivers placed on the infrastructure associated with offshore platforms, this may simply reflect the fact the juvenile sharks avoid these areas where potentially dangerous large adults are known to occur. There were also no detections on the ROV which followed the pipeline bringing product in from the offshore energy fields. Tagged animals could have been scared away from the lights and noise of this ROV, but the absence of detections might also reflect the timing of the mission which happened when many tagged animals typically move away from our coast to overwinter. By contrast, we were encouraged by the detections that were recorded in this pilot program of other tagged species. Marine acoustic telemetry depends on partnerships deploying as many receivers as possible to cover as large an area as possible. Mooring receivers in offshore locations is very difficult and expensive, much more so than the cost of purchasing the receivers, and the ability to add acoustic receivers to existing infrastructures such as those at offshore oil and gas platforms is a tremendous benefit to the scientific community. Results from such studies provide information about the movement patterns and habitat use of valued species, which can assist with and/or reduce risk associated with future offshore developments by allowing the development in advance of mitigation activities. We hope that such collaborations will continue to be welcome in the future.

References

Aires-da-Silva, A., & Gallucci, V. (2007). Demographic and risk analyses applied to management and conservation of the blue shark (*Prionace glauca*) in the North Atlantic Ocean. *Marine and Freshwater Research, 58*, 570–580.

Babcock, E. A. (2008). Recreational fishing for pelagic sharks worldwide. *Sharks of the open ocean: biology, fisheries and conservation*, 193-204.

Barnett, A., Abrantes, K. G., Stevens, J. D., & Semmens, J. M. (2011). Site fidelity and sex-specific migration in a mobile apex predator: implications for conservation and ecosystem dynamics. *Animal Behaviour*, 81, 1039–1048.

Campana, S. E., Dorey, A., Fowler, M., Joyce, W., Wang, Z., Wright, D., & Yashayaev, I. (2011). Migration pathways, behavioural thermoregulation and overwintering grounds of blue sharks in the Northwest Atlantic. *PloS One, 6*, e16854.

Campana, S. E, Joyce, W., & Manning, M. (2009). Bycatch and discard mortality in commercially caught blue sharks *Prionace glauca* assessed using archival satellite pop-up tags. *Marine Ecology Progress Series, 387*, 241–253.

Campana, S. E., Marks, L., Joyce, W., & Kohler, N. (2005). Catch, by-catch and indices of population status of blue shark (*Prionace glauca*) in the Canadian Atlantic. *Col.Vol. Sci. Pap. ICCAT, 58*(3), 891–934.

Campana, S. E., Marks, L., Joyce, W., & Kohler, N. E. (2006). Effects of recreational and commercial fishing on blue sharks (*Prionace glauca*) in Atlantic Canada, with inferences on the North Atlantic population. *Canadian Journal of Fisheries and Aquatic Sciences, 63*, 670–682.

Chapman, D. D., Babcock, E. A., Gruber, S. H., Dibattista, J. D., Franks, B. R., Kessel, S. A. & Feldheim, K. A. (2009). Long-term natal site-fidelity by immature lemon sharks (*Negaprion brevirostris*) at a subtropical island. *Molecular Ecology, 18*, 3500–3507.

Henningsen, A. D. (1994). Tonic Immobility in 12 Elasmobranchs: use as an aid in captive husbandry. *Zoo Biology, 13*, 325–332.

Jorgensen, S. J., Reeb, C. A., Chapple, T. K., Anderson, S., Perle, C., Van Sommeran, S. R., & Block, B. A. (2010). Philopatry and migration of Pacific white sharks. Proceedings. *Biological Sciences / The Royal Society, 277*, 679–688.

Klimley, A. P., Butler, S. B., Nelson, D. R., & Stull, A. T. (1988). Diel movements of scalloped hammerhead sharks, *Sphyrna lewini* Griffith and Smith, to and from a seamount in the Gulf of California. *Journal of Fish Biology*, *33*, 751–761.

Kohler, N. E., & Turner, P. A. (2008). Stock structure of the blue shark (*Prionace glauca*) in the North Atlantic Ocean based on tagging data. *Sharks of the Open Ocean: Biology, Fisheries and Conservation*, 339-350.

Litvinov, F. F. (2006). On the role of dense aggregations of males and juveniles in the functional structure of the range of the blue shark *Prionace glauca*. *Journal of Ichthyology, 46*(8), 613–624.

MacNeil, M. A., & Campana, S. E. (2002). Comparison of whole and sectioned vertebrae for determining the age of young blue shark (*Prionace glauca*). *Journal of Northwest Atlantic Fishery Science*, *30*, 77-82.

Meyer, C. G., Papastamatiou, Y. P., & Holland, K. N. (2010). A multiple instrument approach to quantifying the movement patterns and habitat use of tiger (*Galeocerdo cuvier*) and Galapagos sharks (*Carcharhinus galapagensis*) at French Frigate Shoals, Hawaii. *Marine Biology, 157*, 1857–1868.

Nakano, H., & Nagasawa, K. (1996). Distribution of pelagic elasmobranchs caught by salmon research gillnets in the North Pacific. *Fisheries Science, 62*, 860–865.

Nakano, H., & Stevens, J. D. (2008). The biology and ecology of the blue shark, *Prionace glauca*. *Sharks of the open ocean: Biology, Fisheries and Conservation*, 140-151.

Narver, D. W. (1970). Diel vertical movements and feeding of underyearling sockeye salmon and the limnetic zooplankton in Babine Lake, British Columbia. *Journal of the Fisheries Research Board of Canada, 27*, 281–316.

Pratt, H. L. (1979). Reproduction in the blue shark, *Prionace glauca*. *Fishery Bulletin, 77*, 445–470.

Queiroz, N., Humphries, N.E, Noble, L.R, Santos, A. M, & Sims, D. E. (2010). Short-term movements and diving behaviour of satellite-tracked blue sharks *Prionace glauca* in the northeastern Atlantic Ocean. *Marine Ecology Progress Series, 406*, 265–279.

Queiroz, N., Lima, F. P., Maia, A., Ribeiro, P. a., Correia, J. P., & M. Santos, A. (2005). Movement of blue shark, *Prionace glauca*, in the north-east Atlantic based on mark–recapture data. *Journal of the Marine Biological Association of the UK, 85*, 1107.

Sciarrotta, T. C., & Nelson, D. R. (1977). Diel behavior of the blue shark, *Prionace glauca*, near Santa Catalina Island, California. *Fishery Bulletin, 75*, 519–528.

Sims, D. W., Southall, E. J., Tarling, G. A., & Metcalfe, J. D. (2005). Habitat-specific normal and reverse diel vertical migration in the plankton-feeding basking shark. *Journal of Animal Ecology, 74*, 755–761.

Skomal, G. B., & Natanson, L. J. (2002). Age and growth of the blue shark, *Prionace glauca*, in the North Atlantic Ocean. *Col. Vol. Sci. Pap. ICCAT, 54*, 1212–1230.

Skomal, G. B., & Natanson, L. J. (2003). Age and growth of the blue shark (*Prionace glauca*) in the North Atlantic Ocean. *Fishery Bulletin*, *101*, 627-639.

Stevens, J. D. (1976). First results of shark tagging in the north-east Atlantic, 1972-1975. *Journal of the Marine Biological Association of the United Kingdom, 56*, 929–937.

Stevens, J. D. (1990). Further results from a tagging study of pelagic sharks in the north-east Atlantic. *Journal of the Marine Biological Association of the United Kingdom, 70*, 707–720.

Switzer, P. V. (1993). Site fidelity in predictable and unpredictable habitats. *Evolutionary Ecology, 7*, 533–555.

Tavares, R., Ortiz, M., & Arocha, F. (2012). Population structure, distribution and relative abundance of the blue shark (*Prionace glauca*) in the Caribbean Sea and adjacent waters of the North Atlantic. *Fisheries Research, 129-130*, 137–152.

Vandeperre, F., Aires-da-Silva, A., Fontes, J., Santos, M., Serrão Santos, R., & Afonso, P. (2014). Movements of blue sharks (*Prionace glauca*) across their life history. *PloS One, 9*: e103538.

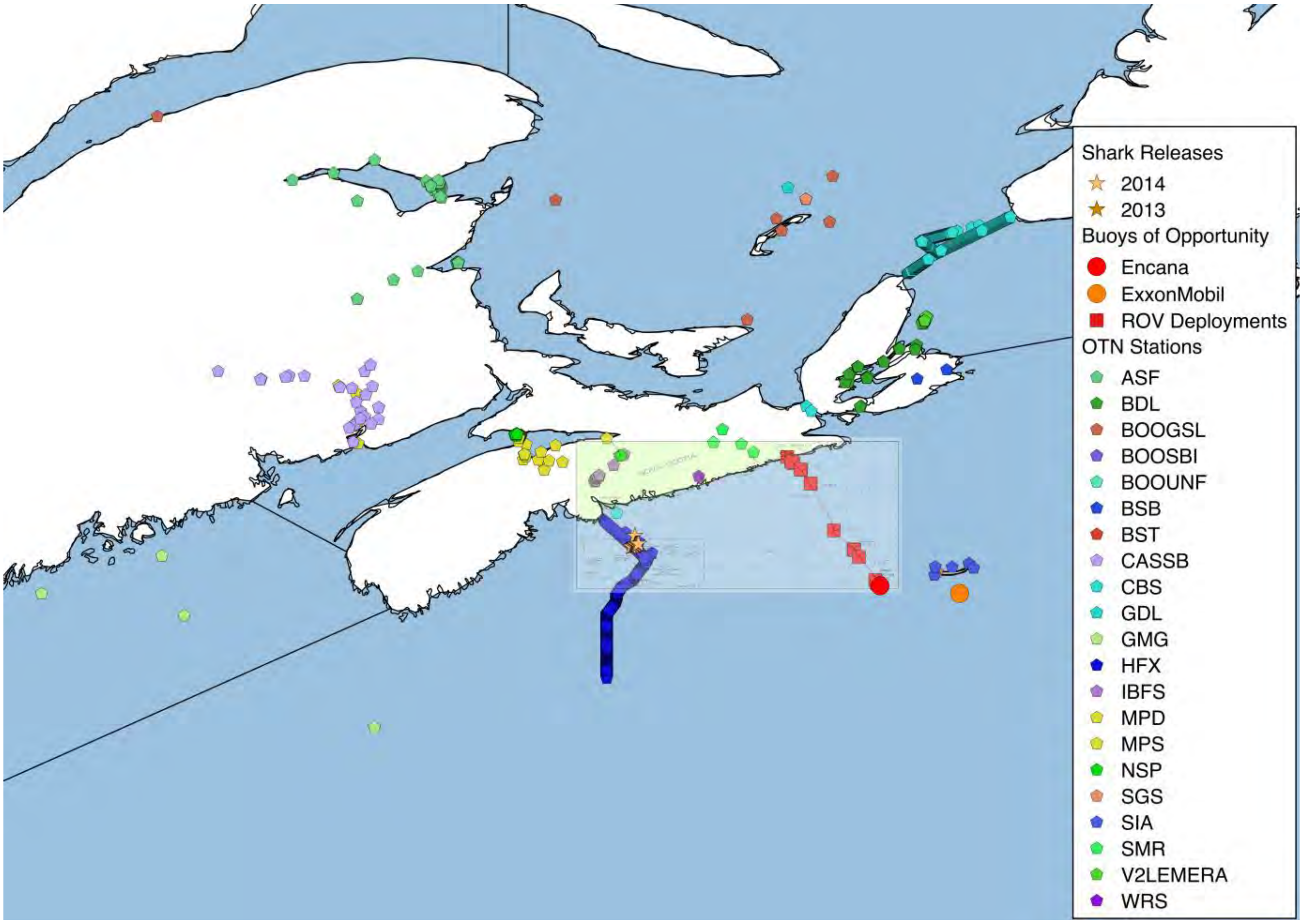


Figure 1. Study, release, and receiver sites. Map showing the study area, the release locations of tagged blue sharks (n=40), and positions of acoustic receivers including at offshore energy sites in the Atlantic Region and the Gulf of Maine.

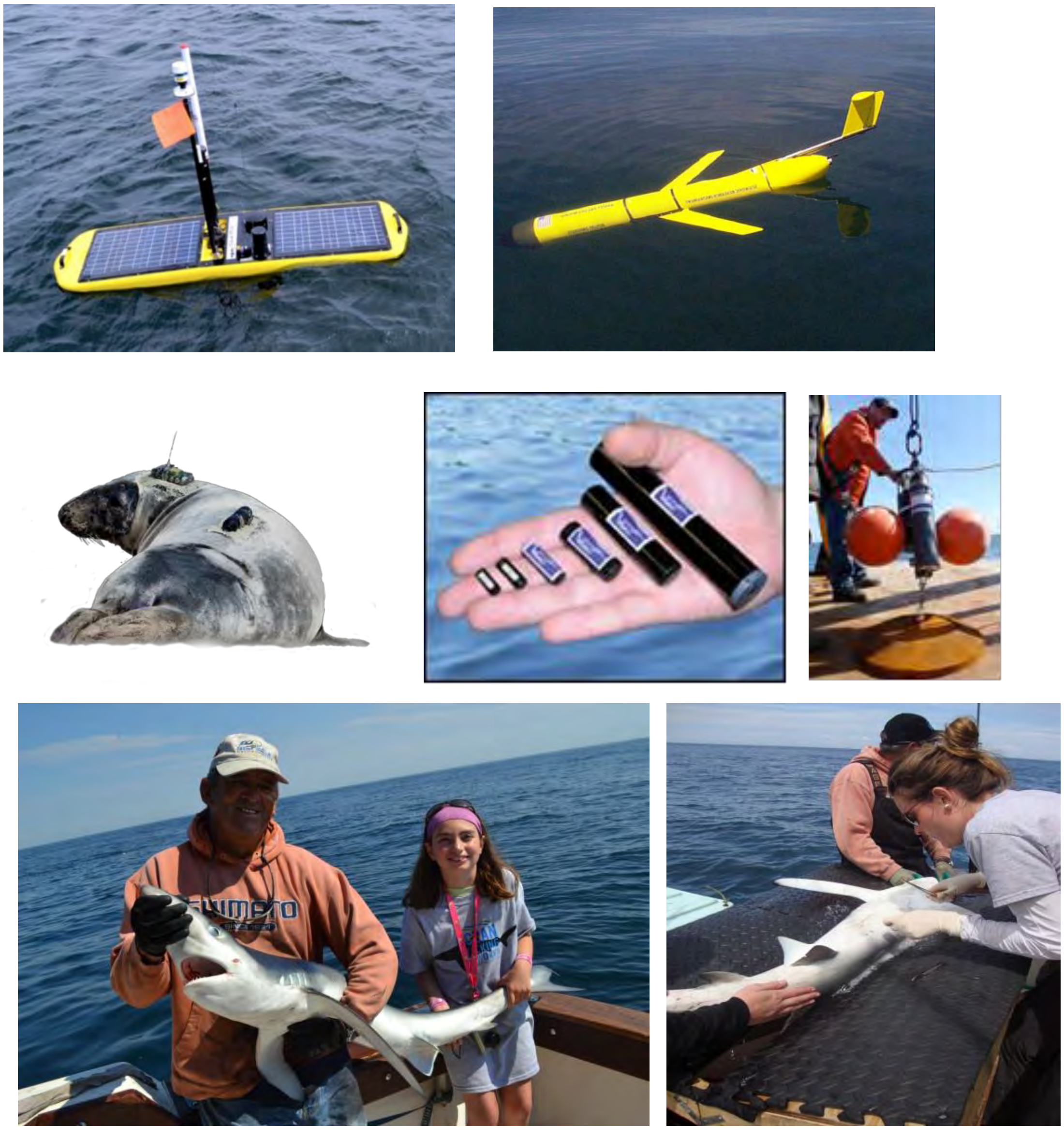


Figure 2: The technology used in acoustic tracking. Top row, Liquid Robotics Wave Glider (left); Slocum electric glider (right). Lower row, a grey seal bioprobe with the acoustic receiver on its flank and the satellite transmission system that transmits tag detection data via satellite on its head (left); acoustic tag models (middle); an acoustic receiver unit with its mooring and acoustic release. Bottom row: Left, an angled blue shark being transferred to surgery for tag implantation (right).

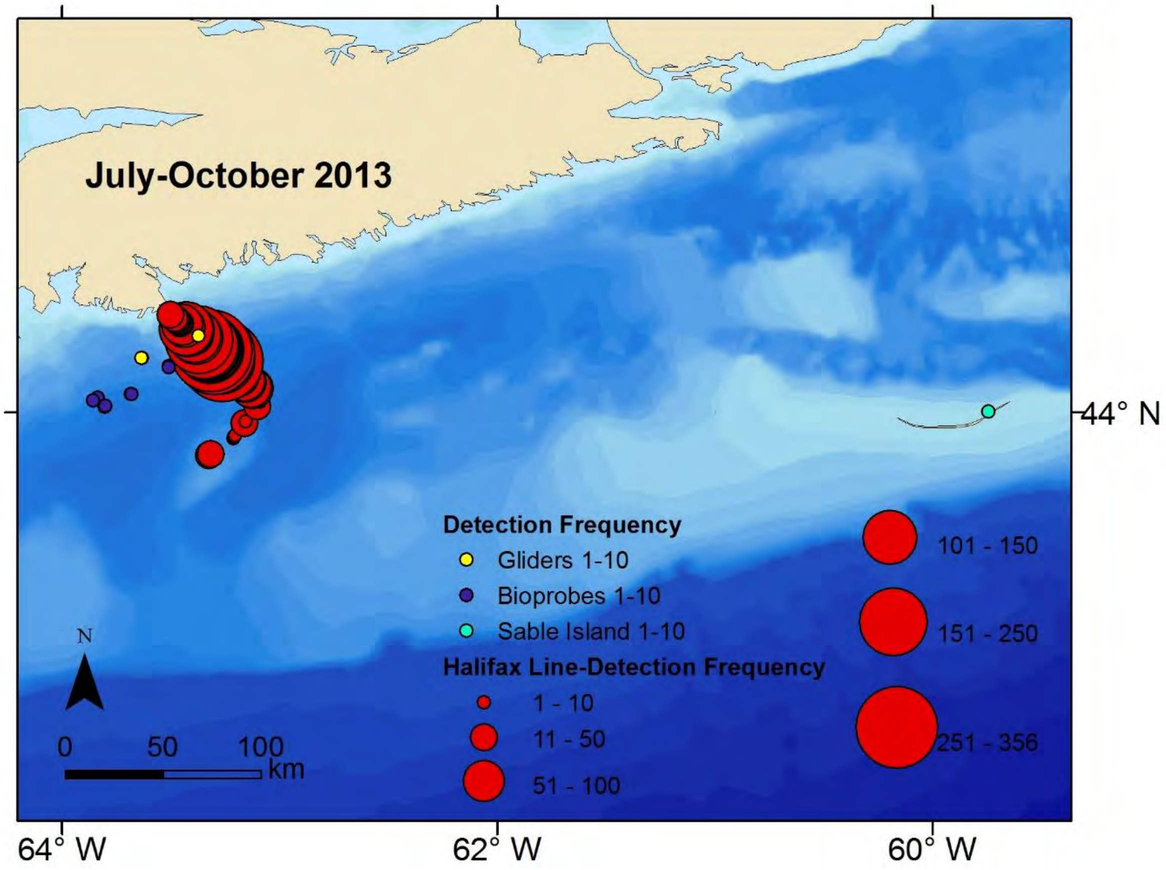


Figure 3. Summer and fall 2013 detections. Locations and frequency of detections of juvenile and sub-adult female blue sharks (n=20) recorded by the OTN Halifax Line, gliders, bioprobes, and a stationary receiver by Sable Island between July and October.

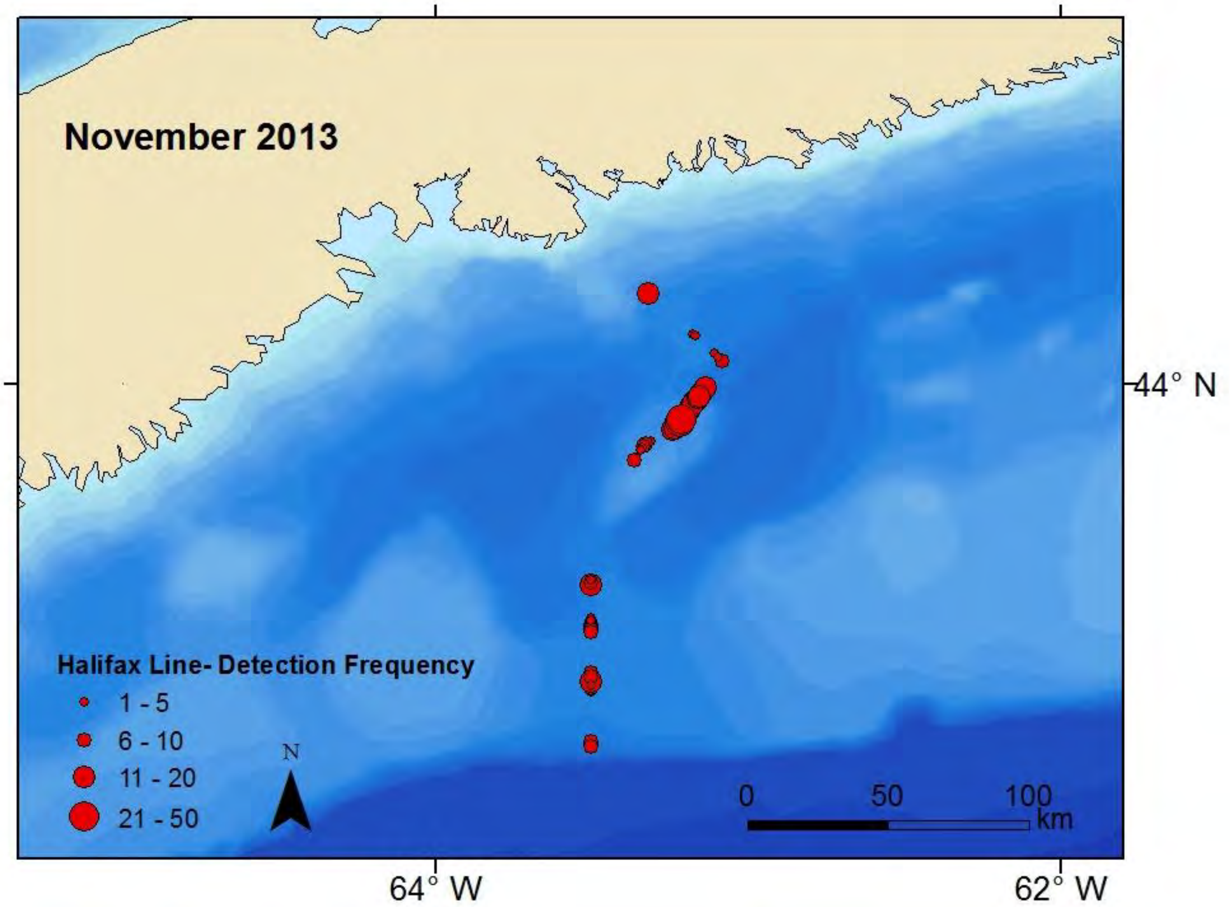


Figure 4. November 2013 detections. Locations and frequency of detections of juvenile and sub-adult female blue sharks (n=7) recorded by the OTN Halifax Line during November 2013

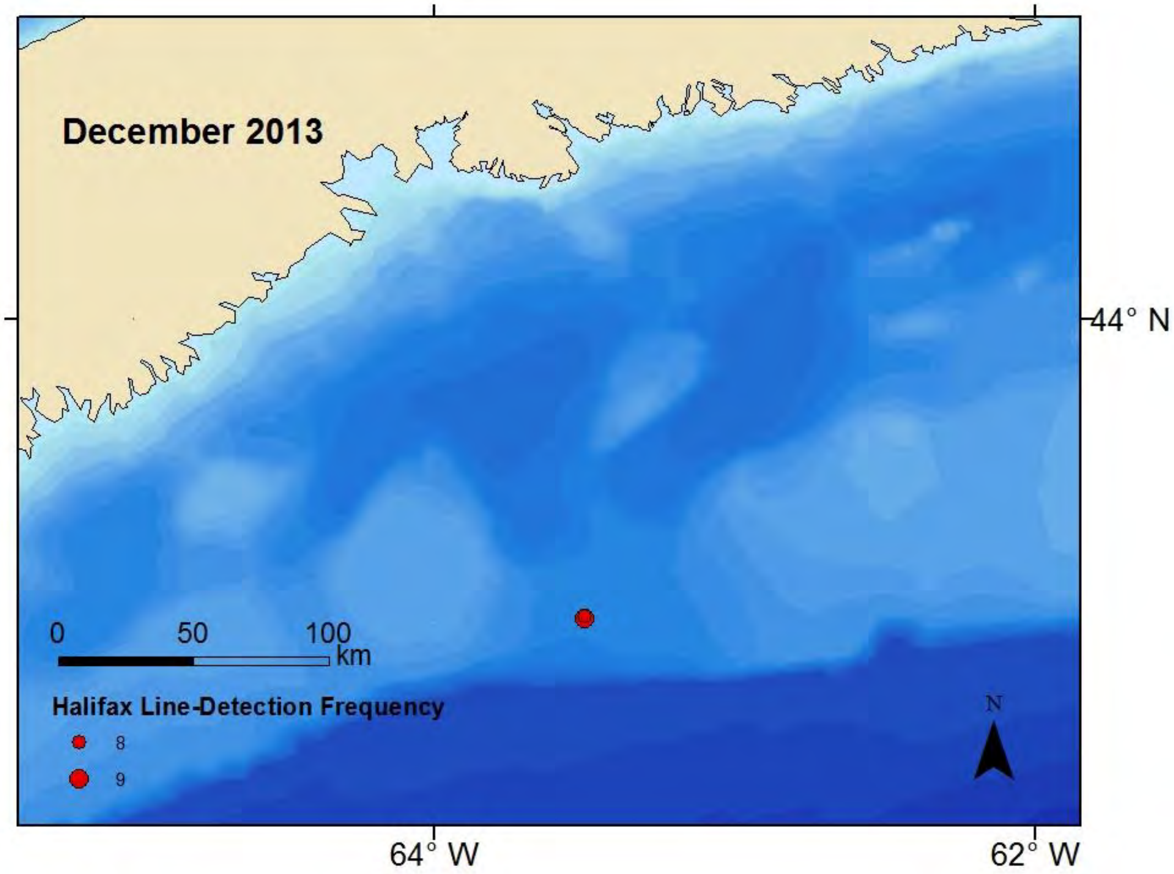


Figure 5. December 2013 detections. Locations and frequency of detections of juvenile and sub-adult female blue sharks (n=1) recorded by the OTN Halifax Line during December 2013.

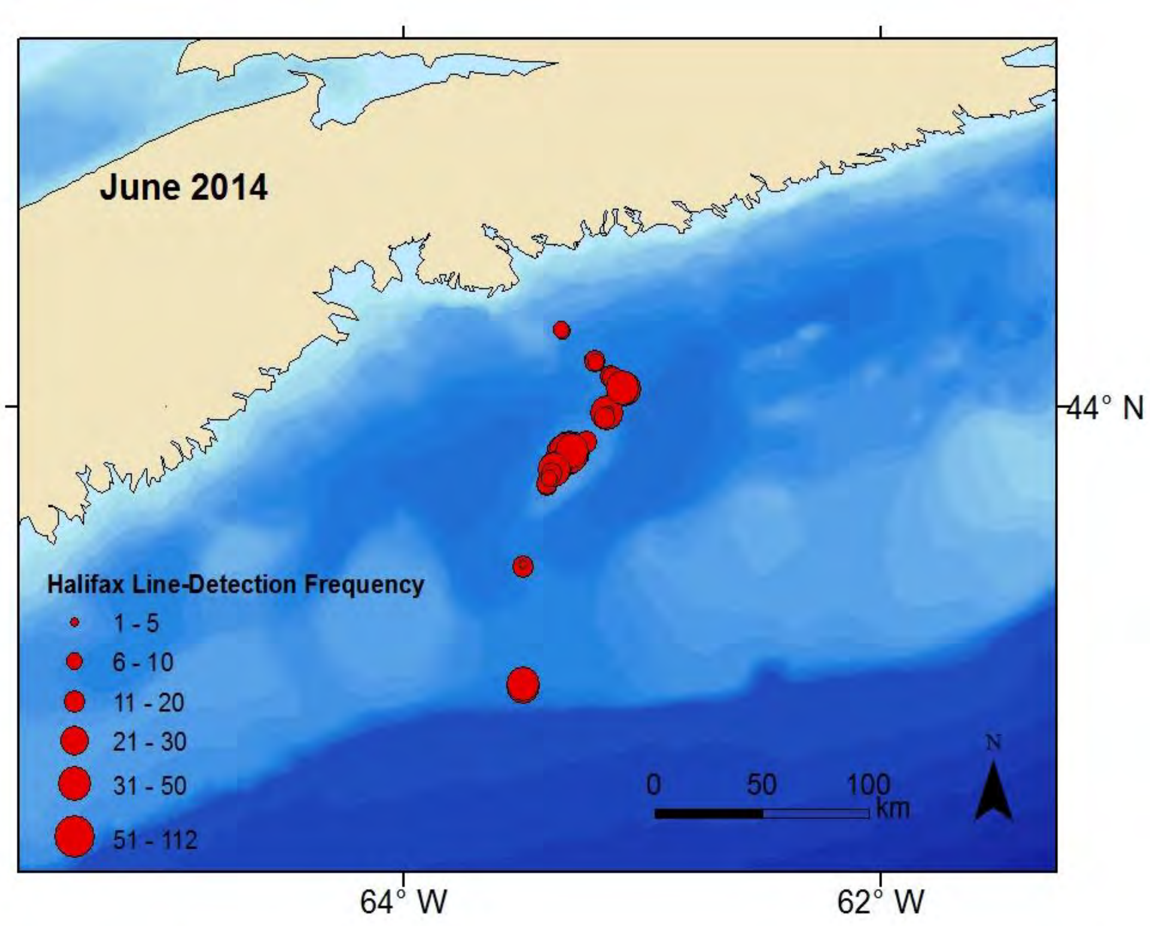


Figure 6. June 2014 detections. Locations and frequency of detections of juvenile and sub-adult female blue sharks (n=5) recorded by the OTN Halifax Line during June 2014.

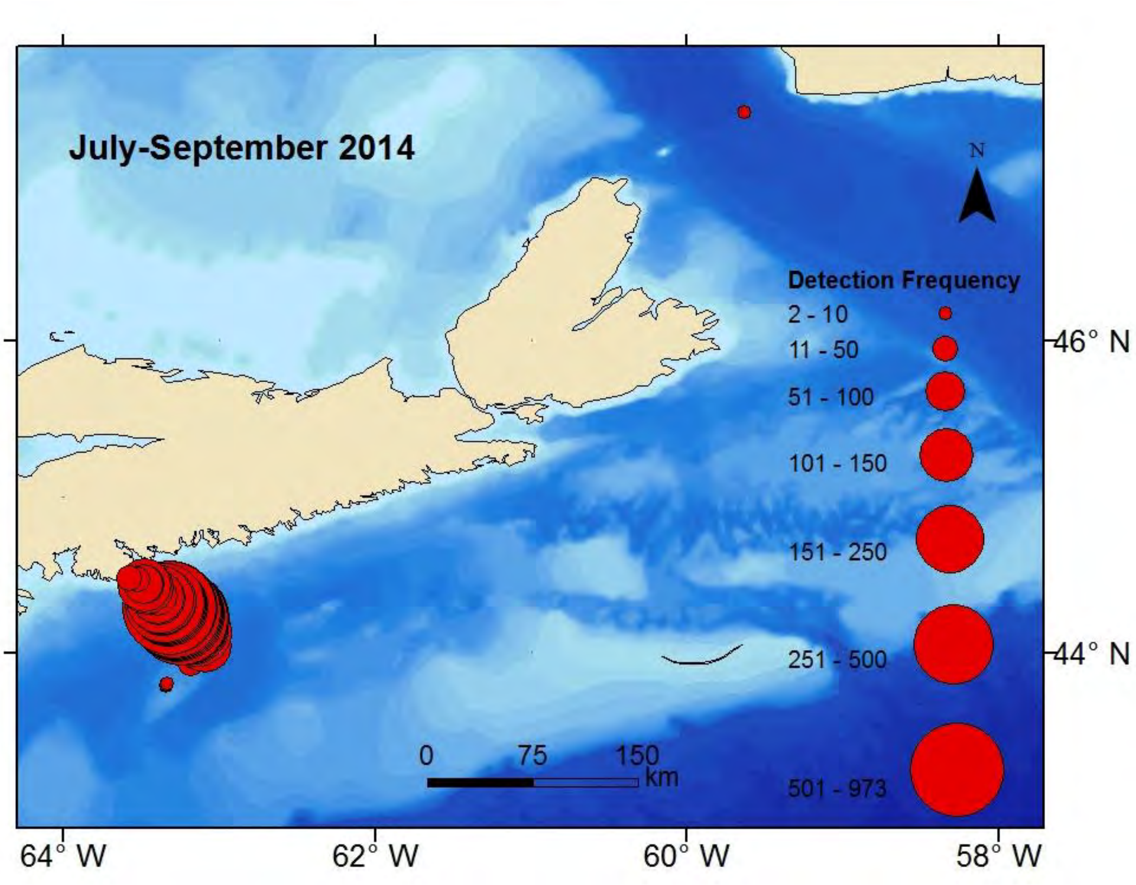


Figure 7. Summer and fall 2014 detections. Locations and frequency of detections of juvenile and sub-adult female blue sharks (n=29) recorded by the OTN Halifax Line and the OTN Cabot Strait Line between July and September 2014.

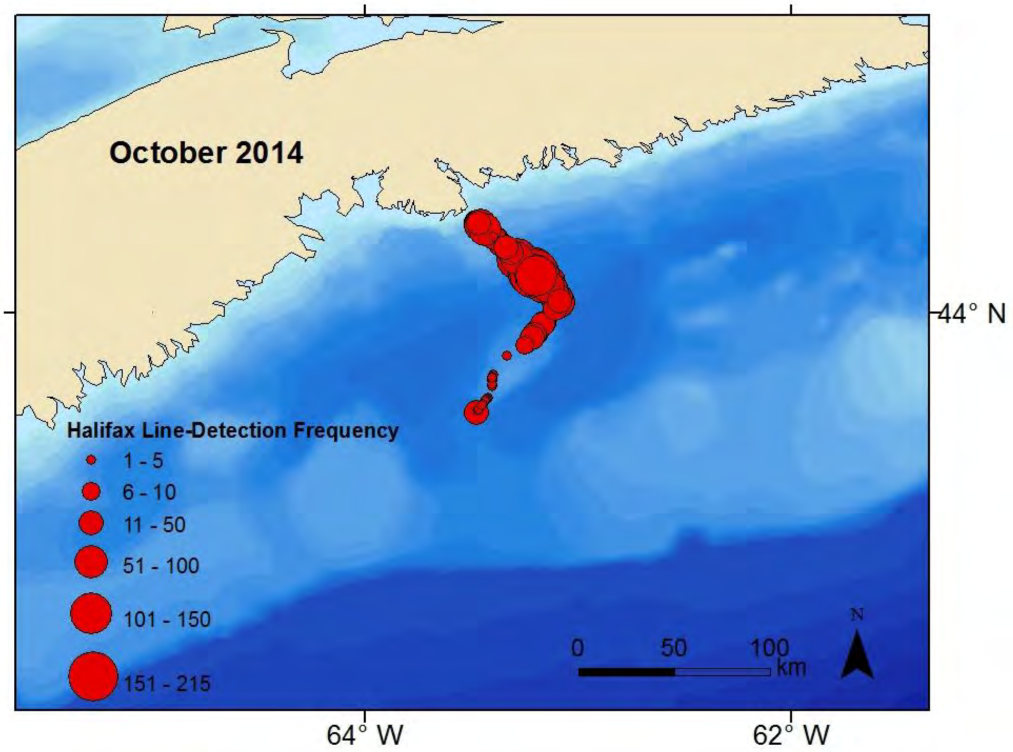


Figure 8. October 2014 detections. Locations and frequency of detections of juvenile and sub-adult female blue sharks (n=15) recorded by the OTN Halifax Line during October 2014.

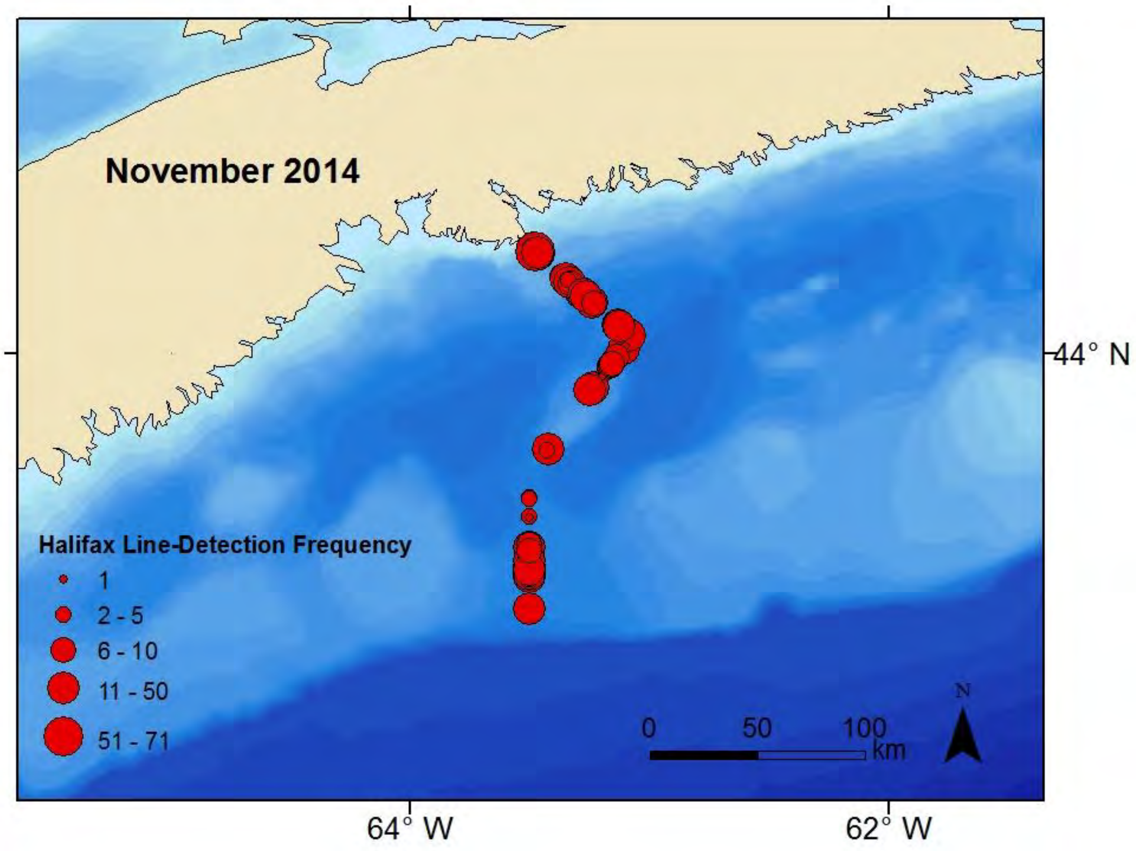


Figure 9. November 2014 detections. Locations and frequency of detections of juvenile and sub-adult female blue sharks (n=14) recorded by the OTN Halifax Line during November 2014.

Table 1: The tagged blue sharks and their points of release. FL = fork length; Lat and Long are latitude and longitude; dd = decimal degrees.

Animal ID	Tag ID	Deployed	FL (cm)	Lat release (dd)	Long release (dd)	Sex
Aillison	24407	28-Aug-14	141	44.22511	63.18984	F
Alyssa	26668	31-Jul-13	156	44.21659	63.23805	F
Betty	24391	23-Aug-14	136	44.21721	63.20468	F
Big Momma	24394	23-Aug-14	165	44.21061	63.21628	F
Blue Rodeo	24404	28-Aug-14	135	44.21000	63.20071	F
Blueberry	26661	1-Aug-13	152	44.17669	63.23979	F
Bonkers	24393	23-Aug-14	128	44.21355	63.21137	F
Brandy	26656	2-Aug-13	140	44.20226	63.24866	F
Brendal	24410	28-Aug-14	165	44.22905	63.17156	F
Brianna	26664	31-Jul-13	141	44.21387	63.24617	F
Casey	24399	25-Aug-14	142	44.20827	63.21504	F
Celyppso	24408	28-Aug-14	131	44.22631	63.18673	F
Eva	26651	13-Jul-13	160	44.20916	63.27934	F
Finnigan	24398	25-Aug-14	103	44.20510	63.22421	F
Finnigan	26662	1-Aug-13	143	44.18141	63.22412	F
Hayley	26660	1-Aug-13	151	44.18111	63.22008	F
Helga	24402	25-Aug-14	163	44.22207	63.20322	F
Hey Jude	24405	28-Aug-14	155	44.21440	63.20220	F
Hooker	24401	25-Aug-14	147	44.21264	63.20846	F
Janina	26666	31-Jul-13	149	44.22348	63.24687	F
Katelyn	24392	23-Aug-14	131	44.81566	63.20911	F
Keesh	24396	23-Aug-14	135	44.19939	63.24085	F
Leia	26659	1-Aug-13	137	44.18082	63.22768	F
Lola	26667	23-Jul-13	139	44.20175	63.21962	F
Lucy	26657	1-Aug-13	162	44.17844	63.23646	F
Lucy-14	24395	23-Aug-14	152	44.21009	63.21849	F
Meeko	26654	2-Aug-13	130	44.20345	63.25824	F
Nikki	24400	25-Aug-14	131	44.31164	63.20907	F
Ophelia	26669	2-Aug-13	129	44.20432	63.26720	F
Percy	26652	2-Aug-13	138	44.20216	63.24593	F
Riley	26653	13-Jul-13	158	44.21458	63.23736	F
Salty Dog	24409	28-Aug-14	152	44.72760	63.17982	F
Skylar	26670	31-Jul-13	162	44.21658	63.23802	F
Sophie	26655	23-Jul-13	153	44.21245	63.22715	F
Suzy Q	24406	28-Aug-14	155	44.21790	63.19890	F
Tail Slap	24397	23-Aug-14	147	44.19939	63.24720	F
Tika	26665	31-Jul-13	152	44.20386	63.24852	F

Tiny Turner	24403	25-Aug-14	107	44.22003	63.20159	F
Wryley	26663	31-Jul-13	116	44.17254	63.23924	F
Xena	26658	2-Aug-13	164	44.20221	63.23848	F

Table 2. Acoustic receivers placed on industry offshore infrastructure, and the detections of acoustically tagged animals on them. ND = no data. The Exxon Mobil Thebaud, Venture and Alma site receivers were placed in 2015 for the first time, and have not yet been retrieved for data collection.

Site	*Water Depth m*	*Instrument depth m*	*Date deployed*	*Date data recovered*	*No. detections*	*No. animals*	*Species detected*
Encana Deep Panuke	*40*	*10*	*2013-02-25*	*2013-10-18*	*2*	*1*	*Grey seal (1)*
Exxon Mobil Triumph	*80*	*15*	*2013-09-30*	*2014-09-27*	*37*	*7*	*Bluefin tuna (4), grey seal (3)*
Exxon Mobil Thebaud	*30*	*20*	*2015-03-10*	*ND*	*ND*	*ND*	
Exxon Mobil Venture	*25*	*15*	*2015-03-07*	*ND*	*ND*	*ND*	
Exxon Mobil Alma	*63*	*45*	*2015-03-09*	*ND*	*ND*	*ND*	
Encana ROV	*See Fig1*	*Variable*	*See Fig 1*	*See Fig 1*	*0*	*0*	

Table 3. Number of tagged blue sharks detected in the year of release, and in subsequent years. Detections given as percentages of original group tagged are given in parentheses.

Year Tagged	2013	2014	2015	Total sharks tagged
2013	20 (100%)	12 (60%)	0 (0%)	20
2014		19 (95%)	6 (30%)	20

Table 4. Results of the Wilcoxon signed-rank tests for differences in mean, maximum, and minimum distance from shore, between day and night.

Month	Distance	p-value
August 2013	Minimum	1.000
August 2013	Maximum	0.505
August 2013	Mean	0.351
September 2013	Minimum	1.000
September 2013	Maximum	0.590
September 2013	Mean	0.590
August 2014	Minimum	0.802
August 2014	Maximum	0.079
August 2014	Mean	0.258
September 2014	Minimum	0.712
September 2014	Maximum	0.076
September 2014	Mean	0.205

APPENDIX J

2015 Flare Plume Monitoring

	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
2015-01-01	1	0	1	0
2015-01-02	1	0	1	0
2015-01-03	1	0	1	0
2015-01-04	1	0	1	0
2015-01-05	1	0	1	0
2015-01-06	1	0	1	0
2015-01-07	1	0	1	0
2015-01-08	1	0	1	0
2015-01-09	2	0	2	0
2015-01-10	2	0	2	0
2015-01-11	2	0	2	0
2015-01-12	2	0	2	0
2015-01-13	2	0	2	0
2015-01-14	1	0	2	0
2015-01-15	1	0	2	0
2015-01-16	1	0	1	0
2015-01-17	2	0	2	0
2015-01-18	2	0	2	0
2015-01-19	2	0	2	0
2015-01-20	2	0	2	0
2015-01-21	2	0	2	0
2015-01-22	2	0	2	0
2015-01-23	2	0	2	0
2015-01-24	1	0	1	0
2015-01-25	1	0	1	0
2015-01-26	1	0	1	0
2015-01-27	1	0	1	0
2015-01-28	1	0	1	0
2015-01-29	1	0	1	0
2015-01-30	1	0	1	0
2015-01-31	1	0	1	0
2015-02-01	1	0	1	0
2015-02-02	1	0	1	0
2015-02-03	1	0	1	0
2015-02-04	1	0	1	0
2015-02-05	1	0	1	0
2015-02-06	1	0	1	0
2015-02-07	1	0	1	0
2015-02-08	1	0	1	0
2015-02-09	1	0	1	0
2015-02-10	1	0	1	0
2015-02-11	1	0	1	0
2015-02-12	1	0	1	0
2015-02-13	1	0	1	0
2015-02-14	1	0	1	0
2015-02-15	1	0	1	0
2015-02-16	1	0	1	0
2015-02-17	1	0	1	0
2015-02-18	1	0	1	0

	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
2015-02-19	1	0	1	0
2015-02-20	1	0	1	0
2015-02-21	1	0	1	0
2015-02-22	1	0	1	0
2015-02-23	1	0	1	0
2015-02-24	1	0	1	0
2015-02-25	1	0	1	0
2015-02-26	1	0	1	0
2015-02-27	1	0	1	0
2015-02-28	1	0	1	0
2015-03-01	1	0	1	0
2015-03-02	2	0	2	0
2015-03-03	2	0	2	0
2015-03-04	2	0	2	0
2015-03-05	1	0	1	0
2015-03-06	1	0	1	0
2015-03-07	1	0	1	0
2015-03-08	1	0	1	0
2015-03-09	1	0	1	0
2015-03-10	1	0	1	0
2015-03-11	1	0	1	0
2015-03-12	1	0	1	0
2015-03-13	1	0	1	0
2015-03-14	1	0	1	0
2015-03-15	1	0	1	0
2015-03-16	1	0	1	0
2015-03-17	1	0	1	0
2015-03-18	1	0	1	0
2015-03-19	1	0	1	0
2015-03-20	1	0	1	0
2015-03-21	1	0	1	0
2015-03-22	0	0	0	0
2015-03-23	0	0	0	0
2015-03-24	0	0	0	0
2015-03-26	0	0	0	0
2015-03-27	0	0	0	0
2015-03-28	0	0	0	0
2015-03-29	0	0	0	0
2015-03-30	0	0	0	0
2015-03-31	0	0	0	0
2015-04-01	0	0	0	0
2015-04-02	0	0	0	0
2015-04-03	0	0	0	0
2015-04-04	0	0	0	0
2015-04-05	0	0	0	0
2015-04-06	0	0	0	0
2015-04-07	0	0	0	0
2015-04-08	0	0	0	0
2015-04-09	0	0	0	0

	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
2015-04-10	0	0	0	0
2015-04-11	0	0	0	0
2015-04-12	0	0	0	0
2015-04-13	0	0	0	0
2015-04-14	0	0	0	0
2015-04-15	0	0	0	0
2015-04-16	0	0	0	0
2015-04-17	0	0	0	0
2015-04-18	0	0	0	0
2015-04-19	0	0	0	0
2015-04-20	0	0	0	0
2015-04-21	0	0	0	0
2015-04-22	0	0	0	0
2015-04-23	0	0	0	0
2015-04-24	0	0	0	0
2015-04-25	0	0	0	0
2015-04-26	0	0	0	0
2015-04-27	0	0	0	0
2015-04-28	0	0	0	0
2015-04-29	0	0	0	0
2015-04-30	0	0	0	0
2015-05-01	0	0	0	0
2015-05-02	0	0	0	0
2015-05-03	0	0	0	0
2015-05-04	0	0	0	0
2015-05-05	0	0	0	0
2015-05-06	0	0	0	0
2015-05-07	0	0	0	0
2015-05-08	0	0	0	0
2015-05-09	0	0	0	0
2015-05-10	0	0	0	0
2015-05-11	0	Facility shutdown	0	Facility shutdown
2015-05-12	0	Facility shutdown	0	Facility shutdown
2015-05-13	0	Facility shutdown	0	Facility shutdown
2015-05-14	0	Facility shutdown	0	Facility shutdown
2015-05-15	0	Facility shutdown	0	Facility shutdown
2015-05-16	0	Facility shutdown	0	Facility shutdown
2015-05-17	0	Facility shutdown	0	Facility shutdown
2015-05-18 (2)	0	Facility shutdown	0	Facility shutdown
2015-05-18	0	Facility shutdown	0	Facility shutdown
2015-05-19	0	Facility shutdown	0	Facility shutdown

	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
2015-05-20	0	Facility shutdown	0	Facility shutdown
2015-05-21	0	Facility shutdown	0	Facility shutdown
2015-05-22	0	Facility shutdown	0	Facility shutdown
2015-05-23	0	Facility shutdown	0	Facility shutdown
2015-05-24	0	Facility shutdown	0	Facility shutdown
2015-05-25	0	Facility shutdown	0	Facility shutdown
2015-05-26	0	Facility shutdown	0	Facility shutdown
2015-05-27	0	Facility shutdown	0	Facility shutdown
2015-05-28	0	Facility shutdown	0	Facility shutdown
2015-05-29	0	Facility shutdown	0	Facility shutdown
2015-05-30	0	Facility shutdown	0	Facility shutdown
2015-05-31	0	Facility shutdown	0	Facility shutdown
2015-06-01	0	Facility shutdown	0	Facility shutdown
2015-06-02	0	Facility shutdown	0	Facility shutdown
2015-06-03	0	Facility shutdown	0	Facility shutdown
2015-06-04	0	Facility shutdown	0	Facility shutdown
2015-06-05	0	Facility shutdown	0	Facility shutdown
2015-06-06	0	Facility shutdown	0	Facility shutdown
2015-06-07	0	Facility shutdown	0	Facility shutdown
2015-06-08	0	Facility shutdown	0	Facility shutdown
2015-06-09	0	Facility shutdown	0	Facility shutdown
2015-06-10	0	Facility shutdown	0	Facility shutdown
2015-06-11	0	Facility shutdown	0	Facility shutdown
2015-06-12	0	Facility shutdown	0	Facility shutdown
2015-06-13	0	Facility shutdown	0	Facility shutdown
2015-06-14	0	Facility shutdown	0	Facility shutdown
2015-06-15	0	Facility shutdown	0	Facility shutdown
2015-06-16	0	Facility	0	Facility

	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
		shutdown		shutdown
2015-06-17	0	Facility shutdown	0	Facility shutdown
2015-06-18	0	Facility shutdown	0	Facility shutdown
2015-06-19	0	Facility shutdown	0	Facility shutdown
2015-06-20	0	Facility shutdown	0	Facility shutdown
2015-06-21	0	Facility shutdown	0	Facility shutdown
2015-06-22	0	Facility shutdown	0	Facility shutdown
2015-06-23	0	Facility shutdown	0	Facility shutdown
2015-06-24	0	Facility shutdown	0	Facility shutdown
2015-06-25	0	Facility shutdown	0	Facility shutdown
2015-06-26	0	Facility shutdown	0	Facility shutdown
2015-06-27	0	Facility shutdown	0	Facility shutdown
2015-06-28	0	Facility shutdown	0	Facility shutdown
2015-06-29	0	Facility shutdown	0	Facility shutdown
2015-06-30	0	Facility shutdown	0	Facility shutdown
2015-07-01	0	Facility shutdown	0	Facility shutdown
2015-07-02	0	Facility shutdown	0	Facility shutdown
2015-07-03	0	Facility shutdown	0	Facility shutdown
2015-07-04	0	Facility shutdown	0	Facility shutdown
2015-07-05	0	Facility shutdown	0	Facility shutdown
2015-07-06	0	Facility shutdown	0	Facility shutdown
2015-07-07	0	Facility shutdown	0	Facility shutdown
2015-07-08	0	Facility shutdown	0	Facility shutdown
2015-07-09	0	Facility shutdown	0	Facility shutdown
2015-07-10	0	Facility shutdown	0	Facility shutdown
2015-07-11	0	Facility shutdown	0	Facility shutdown
2015-07-12	0	Facility shutdown	0	Facility shutdown
2015-07-13	0	Facility shutdown	0	Facility shutdown

	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
2015-07-14	0	Facility shutdown	0	Facility shutdown
2015-07-15	0	Facility shutdown	0	Facility shutdown
2015-07-16	0	Facility shutdown	0	Facility shutdown
2015-07-17	0	Facility shutdown	0	Facility shutdown
2015-07-18	0	Facility shutdown	0	Facility shutdown
2015-07-19	0	Facility shutdown	0	Facility shutdown
2015-07-20	0	Facility shutdown	0	Facility shutdown
2015-07-21	0	Facility shutdown	0	Facility shutdown
2015-07-22	0	Facility shutdown	0	Facility shutdown
2015-07-23	0	Facility shutdown	0	Facility shutdown
2015-07-24	0	Facility shutdown	0	Facility shutdown
2015-07-25	0	Facility shutdown	0	Facility shutdown
2015-07-26	0	Facility shutdown	0	Facility shutdown
2015-07-27	0	Facility shutdown	0	Facility shutdown
2015-07-28	0	Facility shutdown	0	Facility shutdown
2015-07-29	0	Facility shutdown	0	Facility shutdown
2015-07-30	0	Facility shutdown	0	Facility shutdown
2015-07-31	0	Facility shutdown	0	Facility shutdown
2015-08-01	0	Facility shutdown	0	Facility shutdown
2015-08-02	0	Facility shutdown	0	Facility shutdown
2015-08-03	0	Facility shutdown	0	Facility shutdown
2015-08-04	0	Facility shutdown	0	Facility shutdown
2015-08-05	0	Facility shutdown	0	Facility shutdown
2015-08-06	0	Facility shutdown	0	Facility shutdown
2015-08-07	0	Facility shutdown	0	Facility shutdown
2015-08-08	0	Facility shutdown	0	Facility shutdown
2015-08-09	0	Facility shutdown	0	Facility shutdown
2015-08-10	0	Facility	0	Facility

	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
		shutdown		shutdown
2015-08-11	0	Facility shutdown	0	Facility shutdown
2015-08-12	0	Facility shutdown	0	Facility shutdown
2015-08-13	0	Facility shutdown	0	Facility shutdown
2015-08-14	0	Facility shutdown	0	Facility shutdown
2015-08-15	0	Facility shutdown	0	Facility shutdown
2015-08-16	0	Facility shutdown	0	Facility shutdown
2015-08-17	0	Facility shutdown	0	Facility shutdown
2015-08-18	0	Facility shutdown	0	Facility shutdown
2015-08-19	0	Facility Shutdown	0	Facility Shutdown
2015-08-20	0	Facility Shutdown	0	Facility Shutdown
2015-08-21	0	Facility Shutdown	0	Facility Shutdown
2015-08-22	0	Facility Shutdown	0	Facility Shutdown
2015-08-23	0	Facility Shutdown	0	Facility Shutdown
2015-08-24	0	Facility Shutdown	0	Facility Shutdown
2015-08-25	0	Facility Shutdown	0	Facility Shutdown
2015-08-26	0	Facility Shutdown	0	Facility Shutdown
2015-08-27	0	Facility Shutdown	0	Facility Shutdown
2015-08-28	0	Facility Shutdown	0	Facility Shutdown
2015-08-29	0	Facility Shutdown	0	Facility Shutdown
2015-08-30	0	Facility Shutdown	0	Facility Shutdown
2015-08-31	0	Facility Shutdown	0	Facility Shutdown
2015-09-01	0	Facility Shutdown	0	Facility Shutdown
2015-09-02	0	Facility Shutdown	0	Facility Shutdown
2015-09-03	0	Facility Shutdown	0	Facility Shutdown
2015-09-04	0	Facility Shutdown	0	Facility Shutdown
2015-09-05	0	Facility Shutdown	0	Facility Shutdown
2015-09-06	0	Facility Shutdown	0	Facility Shutdown

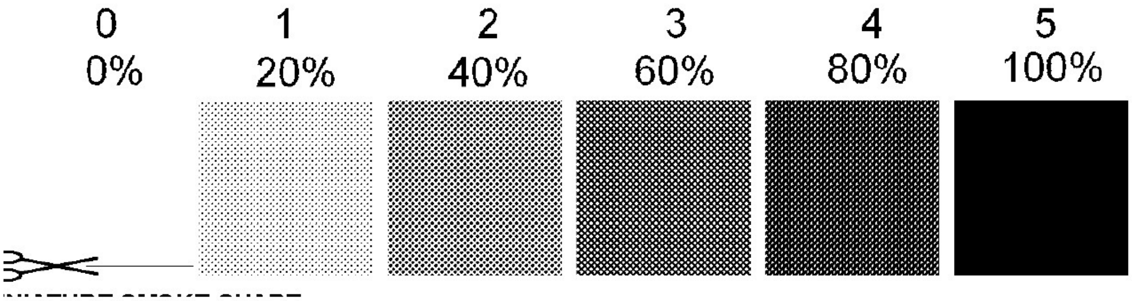
	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
2015-09-07	0	Facility Shutdown	0	Facility Shutdown
2015-09-08	0	Facility Shutdown	0	Facility Shutdown
2015-09-09	0	Facility Shutdown	0	Facility Shutdown
2015-09-10	0	Facility Shutdown	0	Facility Shutdown
2015-09-11	0	Facility Shutdown	0	Facility Shutdown
2015-09-12	0	Facility Shutdown	0	Facility Shutdown
2015-09-13	0	Facility Shutdown	0	Facility Shutdown
2015-09-14	0	Facility Shutdown	0	Facility Shutdown
2015-09-15	0	Facility Shutdown	0	Facility Shutdown
2015-09-16	0	Facility Shutdown	0	Facility Shutdown
2015-09-17	0	Facility Shutdown	0	Facility Shutdown
2015-09-18	0	Facility Shutdown	0	Facility Shutdown
2015-09-19	0	Facility Shutdown	0	Facility Shutdown
2015-09-20	0	Facility Shutdown	0	Facility Shutdown
2015-09-21	0	Facility Shutdown	0	Facility Shutdown
2015-09-22	0	Facility Shutdown	0	Facility Shutdown
2015-09-23	0	Facility Shutdown	0	Facility Shutdown
2015-09-24	0	Facility Shutdown	0	Facility Shutdown
2015-09-25	0	Facility Shutdown	0	Facility Shutdown
2015-09-26	0	Facility Shutdown	0	Facility Shutdown
2015-09-27	0	Facility Shutdown	0	Facility Shutdown
2015-09-28	0	Facility Shutdown	0	Facility Shutdown
2015-09-29	0	Facility Shutdown	0	Facility Shutdown
2015-09-30	0	Facility Shutdown	0	Facility Shutdown
2015-10-01	0	Facility Shutdown	0	Facility Shutdown
2015-10-02	0	Facility Shutdown	0	Facility Shutdown
2015-10-03	0	Facility Shutdown	0	Facility Shutdown
2015-10-04	0	Facility	0	Facility

	Morning		Afternoon	
Date (yyyy-mm-dd)	Flare colour	Observations	Flare colour	Observations
		Shutdown		Shutdown
2015-10-05	0	Facility Shutdown	0	Facility Shutdown
2015-10-06	0	Facility Shutdown	0	Facility Shutdown
2015-10-07	0	Facility Shutdown	0	Facility Shutdown
2015-10-08	0	Facility Shutdown	0	Facility Shutdown
2015-10-09	0	Facility Shutdown	0	Facility Shutdown
2015-10-10	0	Facility Shutdown	0	Facility Shutdown
2015-10-11	0	Facility Shutdown	0	Facility Shutdown
2015-10-12	0	Facility Shutdown	0	Facility Shutdown
2015-10-13	0	Facility Shutdown	0	Facility Shutdown
2015-10-14	0	Facility Shutdown	0	Facility Shutdown
2015-10-15	0	Facility Shutdown	0	Facility Shutdown
2015-10-16	0	Facility Shutdown	0	Facility Shutdown
2015-10-17	0	Facility Shutdown	0	Facility Shutdown
2015-10-18	0	Facility Shutdown	0	Facility Shutdown
2015-10-19	0	Facility Shutdown	0	Facility Shutdown
2015-10-20	0	Facility Shutdown	0	Facility Shutdown
2015-10-21	0	Facility Shutdown	0	Facility Shutdown
2015-10-22	0	Facility Shutdown	0	Facility Shutdown
2015-10-23	0	Plant Live with buy back gas.	0	0
2015-10-24	0	Plant Live with buy back gas.	0	0
2015-10-25	0	Plant Live with buy back gas.	0	0
2015-10-26	0	Plant Live with buy back gas.	0	0
2015-10-27	0	Plant Live with buy back gas.	0	0
2015-10-28	0	Plant Live with buy back gas.	0	0
2015-10-29	0	Plant Live with buy back gas.	0	0
2015-10-30	0	Plant Live with buy back gas.	0	0
2015-10-31	0	0	0	0
2015-11-01	0	0	0	0

	Morning		Afternoon	
Date (yyyy-mm-dd)	**Flare colour**	**Observations**	**Flare colour**	**Observations**
2015-11-02	0	0	0	0
2015-11-03	0	0	0	0
2015-11-04	0	0	0	0
2015-11-05	0	0	0	0
2015-11-06	0	0	0	0
2015-11-07	0	0	0	0
2015-11-08	0	0	0	0
2015-11-09	0	0	0	0
2015-11-10	0	0	0	0
2015-11-11	0	0	0	0
2015-11-12	0	0	0	0
2015-11-13	0	0	0	0
2015-11-14	0	0	0	0
2015-11-15	0	0	0	0
2015-11-16	0	0	0	0
2015-11-17	0	0	0	0
2015-11-18	0	0	0	0
2015-11-19	0	0	0	0
2015-11-20	0	0	0	0
2015-11-21	0	0	0	0
2015-11-22	0	0	0	0
2015-11-23	0	0	0	0
2015-11-24	0	0	0	0
2015-11-25	0	0	0	0
2015-11-26	0	0	0	0
2015-11-27	0	0	0	0
2015-11-28	0	0	0	0
2015-11-29	0	0	0	0
2015-11-30	0	0	0	0
2015-12-01	0	0	0	0
2015-12-02	0	0	0	0
2015-12-03	0	0	0	0
2015-12-04	0	0	0	0
2015-12-05	0	0	0	0
2015-12-06	1	0	1	0
2015-12-07	1	0	1	0
2015-12-08	1	0	1	0
2015-12-09	1	0	1	0
2015-12-10	1	0	1	0
2015-12-11	1	0	1	0
2015-12-12	1	0	1	0
2015-12-13	1	0	1	0
2015-12-14	1	0	1	0
2015-12-15	2	0	2	0
2015-12-16	2	0	2	0
2015-12-17	2	0	2	0
2015-12-18	2	0	2	0
2015-12-19	1	0	1	0
2015-12-20	1	0	1	0

	Morning		Afternoon	
Date (yyyy-mm-dd)	**Flare colour**	**Observations**	**Flare colour**	**Observations**
2015-12-21	2	0	2	0
2015-12-22	2	0	2	0
2015-12-23	2	0	2	0
2015-12-24	2	0	2	0
2015-12-25	1	0	1	0
2015-12-26	1	0	1	0
2015-12-27	1	0	1	0
2015-12-28	2	0	2	0
2015-12-29	2	0	2	0
2015-12-30	2	0	2	0
2015-12-31	2	0	2	0
#0	93	47%	93	47%
#1	79	40%	77	39%
#2	27	14%	29	15%
#3	0	0%	0	0%
	199	100%	199	100%

Ringelmann smoke chart:



The smoky flare observed during 2014 and the first quarter of 2015 was gone when production restarted at the end of October 2015. This is partly explained by maintenance conducted during the seasonal shutdown. During the Pressure Safety Valve (PSV) recertification campaign, it was noted that some PSVs were passing due to debris on the seal. These were corrected to ensure they did no longer let “heavy ends” get through. However, smoky flare was observed again in December, the specific cause is not yet known.

APPENDIX K

2015 Sable Island Air Quality Monitoring

EXXONMOBIL / Encana AIR EMISSIONS ANALYSIS FOR 2015

March 1 2016

Submitted By: Dr. Mark Gibson
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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Executive Summary

Kingfisher Environmental Health Consultants was contracted to complete a number of specific tasks related to air emissions on Sable Island for Encana and Exxon Mobil that include: acquisition of meteorological and air quality data pertaining to monitoring on Sable Island for 2015, conducting data analysis and graphing of air quality and meteorological data, investigating spikes in air monitoring data, checking wind direction/wind speed and contacting Sable Offshore Energy Project (SOEP)/Encana to identify potential correlation with a particular facility's operations, as required.

In terms of offshore oil and gas production activity, Deep Panuke only produced between January 1 – May 10 2015 and between October 28 – December 31 2015. ExxonMobil shut down their Sable Project between September 2 2015 and September 12 2015 for a planned field-wide maintenance campaign.

In 2014, Nova Scotia Environment changed 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/sampler for O_3, NO_x, H_2S, SO_2 and also $PM_{2.5}$ via a MetOne Beta Attenuation Monitor (BAM). Due to protracted contract negotiations with NRCan, funding for replacement instruments was not concluded until late 2015. This meant that O_3, NO_x, H_2S, SO_2 and $PM_{2.5}$ (via the BAM) were not measured over the course of 2015. In addition, the Thermo 5012 MAAP black carbon analyzer was found to be choked with sea salt and sand and was not repairable, with no data available for 2015. Consequently there were no air emission threshold breaches reported for 2015. However, there were some supplemental $PM_{2.5}$ data available via a TSI DRX automatic analyzer for the last three months of 2015 (supplied by Dr. Mark Gibson at Dalhousie University). The DRX $PM_{2.5}$ data will be presented in this report. In January 2016 replacement $PM_{2.5}$ (BAM), O_3 and NO_x instruments were installed on Sable Island but this data will feature in next years air emissions report. All but the O_3 analyzer were supplied by Dr. Gibson. The O_3 autoanalyzer was supplied and calibrated by Environment and Climate Change Canada (Dartmouth office). In addition, a replacement total-VOC instrument was installed on Sable Island (ppbRAE). The ppbRAE has a lower VOC detection limit than the previous Thermo 55i that malfunction in late 2014 and was not repairable. In October 2015 the TSI DRX was serviced and calibrated. The DRX photometer mass concentrations presented in this report were corrected to gravimetric BAM equivalents. In October 2015, a TSI Aerosol Particle Sizer (APS) model 3321 was installed. The APS measures size-resolved particle number counts from 500 nm (0.5 µm) to 20,000 nm (20 µm) in 56 size fractions. In addition, a TSI Ultrafine particle monitor, model 3031, was also installed. The 3031 measures size-resolved particle number counts from 20 nm to 500 nm in six size fractions. Together the Ultrafine 3031 and APS 3321 cover the particle size range associated with fresh combustion particles and gas-to-particle conversion particles, particles associated with 'aged' aerosol smog from continental outflow and particles related to sea salt spray and long-range re-suspended fugitive dust. This report features the 3031 and DRX data from October 1 – December 31 2015, with intermittent data for the APS from September 30 – October 7 2015, October 14 – October 18 2015 and December 24 – December 31 2015. These 3031 and APS are wholly new measurements on Sable Island and represent a new and powerful means of identifying sources of particulate air pollution impacting the Island. A new Thermo black carbon instrument will arrive in Halifax on March 2 2016 and will be installed in April 2016. The new Teledyne-API H_2S, SO_2 autoanalyzers (purchased with ESRF funding) arrived in Halifax on February 23 2016 and are undergoing testing. These instruments will be installed on Sable Island in April 2016.

The 2015 data completeness for temperature, wind direction and wind speed was 96.38%, 100.00% and 99.44% respectively, which can be considered excellent data capture. The mean (min : max, *units* °C) 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 2015 was 241°, which is consistent with prevailing winds in the North West (NW) Atlantic.

The data completeness for the 3031 Ultrafine particle number counts, in the range 20-30, 30-50, 50-70, 70-100,100-200 and 200-800 nm was 96.02%, and for the entire year was only 24.66%. The low annual data completeness is due to the instrument only being installed during the last three months of 2015. The mean (min : max *units* = #) 3031 particle number counts, in the various size ranges, were as follows: 20-30 nm = 343.1 (0 : 10577.3 #), 30-50 nm = 336.9 (0 : 9588 #), 50-70 nm = 179.5 (0: 4463.75 #), 70-100 = 143.47 nm (0 : 4195.5 #), 100-200 nm = 168.2 (0 : 4455.75 #) and 200-800 nm = 25.57 (0 : 503 #) respectively. The mean (min : max *units* = $\mu g/m^3$) for the DRX sampled $PM_{1/2.5/4.0/10/TSP}$ mass concentration spanning October, through December 2015 was: PM_1 = 13.8 (9 : 34.5 $\mu g/m^3$), $PM_{2.5}$ = 14.32 (9 : 37.0 $\mu g/m^3$), PM_4 = 14.50 (9: 37.0 $\mu g/m^3$), PM_{10} = 14.60 (9 : 37.5 $\mu g/m^3$) and TSP = 14.60 (9 : 37.5 $\mu g/m^3$) respectively. The mean $PM_{2.5}$ was found to be below the CWS of 28 $\mu g/m^3$. The mean (min : max, *units* #) for the APS $PM_{1/2.5/4.0/10/20}$ integrated size fraction particle number counts were as follows: < 1 nm = 187718 (14789 : 959125 #), 2.5 nm = 235568 (15357 : 1052303 #), 4.0 nm = 238763 (15376: 1073197 #), 10 nm = 239258 (15378 : 1082099 #) and 20 nm = 239262 (15378 : 1082167 #) respectively.

The most important feature of the 2015 air missions report is that the spikes in PM mass and particle number concentrations were associated with LRT continental outflow, and not from O&G operations or associated with ocean biogenic fluxes.

With the new instruments deployed on Sable Island, the 2016 air emissions report will contain far more data and investigation of local and upwind air emissions impacting Sable Island.

RATIONALE & BACKGROUND

Sable Island is 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 a number of 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 Drs Mark Gibson and Susanne Craig, Departments of Process Engineering and Applied Science and Oceanography respectively. This 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. In addition, threshold concentrations for O&G relevant air pollutants have been set to alert Encana and Exxon Mobil in the event of spikes in air pollution concentrations. When this occurs, Dr. Gibson works in concert with the O&G facility operators to determine if the spike was related to O&G facility activity or a result of another local or LRT source. This will provide O&G facility operators with the ability to quickly respond to any air pollution spikes.

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 development involves the production of natural gas from an offshore field located 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. At the end of commissioning activities, the platform flared nitrogen and buy-back sales-quality natural from June 3rd to August 7th, 2013. On August 7th, 2013, the first well was opened and the platform started flaring acid gas, though "First Gas", i.e. full production rate, was not achieved until December 2013. In 2015, Deep Panuke started seasonal production operations, shutting down from May 10 – October 28. The production field 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). 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).

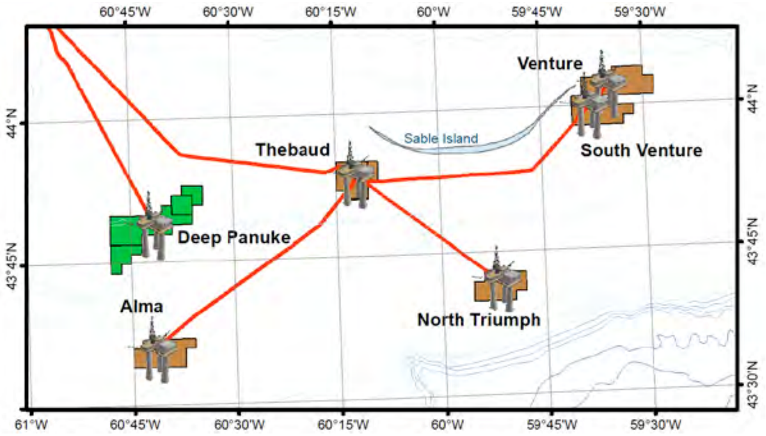


Figure 1. Location of the O&G platforms surrounding Sable Island

Table 1. Geographic locations of the O&G platforms surrounding Sable Island

Platform Name	Platform Centre Location - NAD83			
	Geographic		UTM (Zone 20)	
	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 Name	Platform Centre Location - NAD27			
	Geographic		UTM (Zone 20)	
	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 shows the locations of facilities on Sable Island and on-island combustion sources.

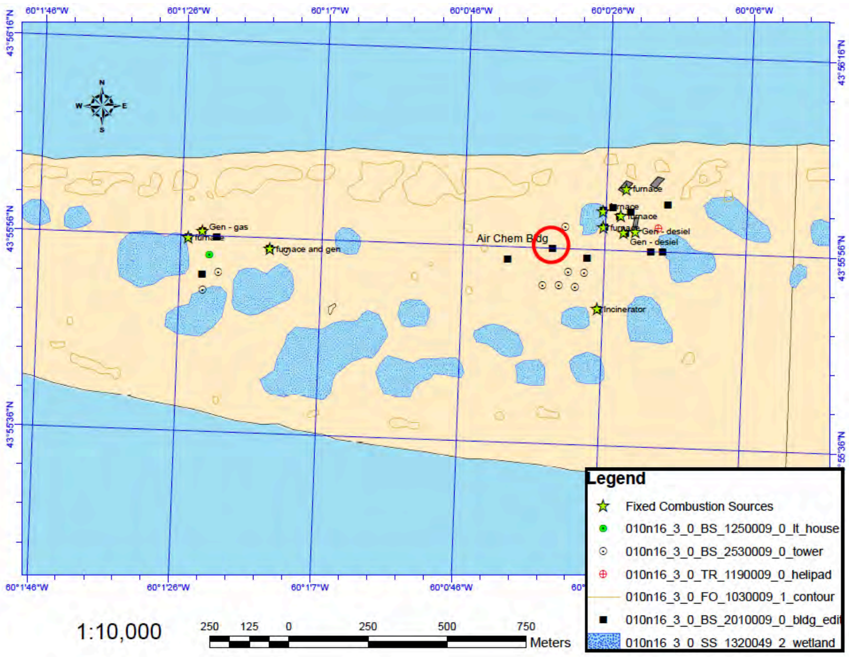


Figure 2. Location of facilities and on-Island combustion sources on Sable Island.

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.

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.

Change in Nova Scotia Environment's Role in Air Monitoring on Sable Island

From 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 Environment Canada 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 on 31 March 2017.

MATERIALS AND METHODS

Instrumentation on Sable Island

Table 2 provides a summary of the air pollution instrumentation that is currently, or shortly to be deployed in 2016, 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) ***Deployed October 2015***	15-min
TSI 3321 Aerodynamic Particle Sizer	ESRF Funding (Gibson/Craig) ***Deployed October 2015***	1-15 min
Thermo 55i total VOC Analyzer	ESRF Funding (Gibson/Craig) ***Replaced by a ppbRAE January 2016***	Hourly
TSI DRX DustTrak 8533 for Total PM, PM_{10}, $PM_{2.5}$ and PM_1	ESRF Funding (Gibson/Craig) ***Deployed March 21, 2013***	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) ***Running***	N/A
Markes International MTS-32, for the collection of 32-daily VOC species samples onto thermal desorption tubes for analysis back in Halifax	ESRF Funding (Gibson/Craig) ***Deployed in October 2015***	24-hr

Data Acquisition

The only air pollution data that was available in 2015 was from the TSI DRX PM$_{1/2.5/4/10/TSP}$ mass concentration instrument, the TSI 3031 Ultrafine particle (UFP) number counter and TSI 3321 APS particle number counter (APS).

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 - μg/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 μg/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 μg/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) μg/m^3	24 hour	120	-	-	120	400	
	Annual	70 (geometric mean)	-	60	70	-	
PM2.5 (fine) μg/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) μg/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 μg/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 μg/m^3 (ppb)	1 hour	42 (30)	-	-	-	-	
	24 hour	**8 (6)**	-	-	-	-	

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 & vehicle garage
- Furnace at Operations building
- Furnace at the staff house
- Furnace at the OIC house
- Furnace at the Triplex

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 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
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 [3]	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)
Total VOC [4]	1/year return threshold to be calculated based on 2013 data	to be determined in Q1/2017 (ppbv)	N/A as no data available in 2015

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 results 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: When Deep Panuke first starts flaring acid gas during the start-up phase, in addition to the automatic alarm system (i.e. even if H_2S levels are below the alarm threshold), H_2S data will be monitored by Dalhousie personnel in real-time to confirm EA predictions that levels of H_2S generated by acid gas flaring would be negligible on Sable Island. Observer(s) will be monitoring H_2S values in conjunction with acid gas flaring activities and weather conditions to identify any potential correlation between acid gas flaring and H_2S levels on the island.

Note 4: Threshold value of total VOC to be calculated using the first 12 months of monitoring data from the new total-VOC analyzer (ppbRAE) installed on Sable Island in Q1 of 2016.

Note 5: 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.

Annual NOAA HYSPLIT air mass back trajectory analysis

In an effort to identify local and long-range upwind source regions, 5-day air mass back tracjectories were run twice per day for the whole of 2015. These appear in Appendix A. NOAA HYSPLIT runs were completed online at the following link http://ready.arl.noaa.gov/hysplit-bin/trajasrcm.pl.

RESULTS AND DISCUSSION

This section covers data analysis results, graphing and additional analysis results related to the assessment of air quality on Sable Island.

Sable Island Air Quality and Meteorological Data for 2015

Table 4 contains the descriptive statistics and data completeness for 2015 meteorological variables.

Table 5. Descriptive statistics and data completeness for hourly 2015 Meteorological Data Descriptive Statistics.

Variable	Temperature *[°C]*	Wind Direction *[°]*	Wind Speed *[km/h]*
n	8443	8760	8711
n missing	317	0	49
Mean	9.04	201.36	25.39
St Dev	7.20	98.96	12.60
Min	-11.4	0	0
25 pct	4.1	130	17
Median	8.9	220	24
75 pct	14.9	280	34
Max	53.8	360	84
IQR	10.8	150	17
Data Completeness (annual)	96.38%	100.00%	99.44%

From Table 4 it can be seen that the data completeness for temperature, wind direction and wind speed was 96.38%, 100.00% and 99.44% respectively, which can be considered excellent data completeness. It can also been seen from Table 4 that the mean (min : max, *units* °C) 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 may be a result of excess solar radiation heating from a near by surface or the temperature sensor is faulty. It is recommended that the meteorological sensors be checked to determine if they require calibration or replacement.

Table 5 contains the descriptive statistics and data completeness for the new TSI 3031 Ultrafine particle number counter.

Table 6. TSI Ultrafine particle number counter model 3031 descriptive statistics

Variable	20-30 nm *[particle #/cm^3]*	30-50 nm *[particle #/cm^3]*	50-70 nm *[particle #/cm^3]*	70-100 nm *[particle #/cm^3]*	100-200 nm *[particle #/cm^3]*	200-800 nm *[particle #/cm^3]*
n	2122	2122	2122	2122	2122	2122
n missing	88	88	88	88	88	88
Mean	343.1	336.9	179.5	143.47	168.2	25.574
St Dev	530.1	504.1	265.86	208.76	218.91	38.015
Min	0	0	0	0	0	0
25 pct	33.4	20.5	7.44	8.5	18.5	1.25
Median	158.6	159.5	100.25	82.38	120.88	13.75
75 pct	442.2	458.8	245.56	191.06	230.06	34.75
Max	10577.3	9588	4463.75	4195.5	4455.75	503
IQR	408.8	438.3	238.13	182.56	211.56	33.5
Data Completeness	96.02%	96.02%	96.02%	96.02%	96.02%	96.02%
Data Completeness (annual)	24.66%	24.66%	24.66%	24.66%	24.66%	24.66%

From Table 5 it can be seen that 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 was 96.02%, and for the entire year was only 24.66%. The low annual data completeness is due to the instrument only being installed during the last three months of 2015. It can also been seen from Table 5 that the mean (min : max *units* = #) 3031 particle number counts, in the various size ranges, were as follows: 20-30 nm = 343.1 (0 : 10577.3 #), 30-50 nm = 336.9 (0 : 9588 #), 50-70 nm = 179.5 (0: 4463.75 #), 70-100 = 143.47 nm (0 : 4195.5 #), 100-200 nm = 168.2 (0 : 4455.75 #) and 200-800 nm = 25.57 (0 : 503 #) respectively. The larger mean particle number count for the smaller particle size fits the theory of gas-to-particle conversion to form many 'small' particles, e.g. ocean emissions of dimethylsulfide, isoprene and halogen reacting to form secondary condensation cloud condensation nuclei (CCN) particles. In addition, fresh combustion particles can also contribute to the 'small' particle size range of 20-50 nm. After this size range the number drops considerably, again following the theory of particle physics. This is because particles in aged air masses coagulate to form fewer larger particles, or are washed out by rain. Daily and hourly time series analysis will investigate the peaks and valleys in ultrafine particle concentrations to aid in the determination their source. Moreover, UFP # has very little corresponding mass, virtually undetectable using a mass concentration instrument such as a BAM or the TSI DRX presented in this report.

Table 6 contains the descriptive statistics and data completeness for 2015 TSI DRX $PM_{1/2.5/4/10/TSP}$ mass concentration.

Table 7. DRX Descriptive Statistics

Variable	PM_1 *[µg/m³]*	$PM_{2.5}$ *[µg/m³]*	PM_4 *[µg/m³]*	PM_{10} *[µg/m³]*	Total *[µg/m³]*
n	1875	1875	1875	1875	1875
n missing	66	66	66	66	66
Mean	13.837	14.316	14.505	14.604	14.606
St Dev	3.849	4.204	4.25	4.269	4.268
Min	9	9	9	9	9
25 pct	11	11.5	11.5	11.5	11.5
Median	13	13	13.5	13.5	13.5
75 pct	15.5	16	16.5	16.5	16.5
Max	34.5	37	37	37.5	37.5
IQR	4.5	4.5	5	5	5
Data Completeness	96.60%	96.60%	96.60%	96.60%	96.60%
Data Completeness (annual)	24.66%	24.66%	24.66%	24.66%	24.66%

From Table 6 it can be seen that the data completeness over the operation period for the DRX $PM_{1/2.5/4.0/10}$ and total mass concentration was 96.6%, and for the entire year was only 24.66%. The lack of data for 75.34% of the year was due to the instrument only being re-deployed after service in October 2915. It can also been seen from Table 6 that the mean (min : max) for the $PM_1/_{2.5/4.0/10}$ and total mass concentration was PM_1 = 13.8 (9 : 34.5 µg/m^3), $PM_{2.5}$ = 14.32 (9 : 37.0 µg/m^3), PM_4 = 14.50 (9: 37.0 µg/m^3), PM_{10} = 14.60 (9 : 37.5 µg/m^3) and TSP = 14.60 (9 : 37.5 µg/m^3) respectively. The similarity in the PM mass concentration observed for the latter three months of 2015, from the total through to $PM_{1.0}$ size fractions, implies that the aerosol below 10 microns observed on Sable Island is many composed of fine aerosols (e.g., gas-to-particle conversion, LRT or fresh local combustion sources). Time series analysis will investigate the peaks and valleys in the $PM_{1/2.5/4.0/10/TSP}$ mass concentration, to aid in the determination their source.

Table 7 contains the descriptive statistics and data completeness for 2015 TSI APS particle number counts in the size fractions below 1.0, 2.5, 4.0 10.0 and 20.0 microns. 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 correspond with the TSI DRX particle mass concentration size fractions.

Table 8. APS Descriptive Stats

Variable	PM_1 *[particle #/cm^3]*	$PM_{2.5}$ *[particle #/cm^3]*	PM_4 *[particle #/cm^3]*	PM_{10} *[particle #/cm^3]*	PM_{20} *[particle #/cm^3]*
n	427	427	427	427	427
n missing	1783	1783	1783	1783	1783
Mean	187718	235568	238763	239258	239262
StDev	162447	194044	196688	197270	197275
Min	14789	15357	15376	15378	15378
25 pct	89103	107611	109192	109241	109241
Median	132104	168667	171069	172963	172965
75 pct	235594	297258	302142	303245	303249
Max	959125	1052303	1073197	1082099	1082167
IQR	146491	189647	192950	194005	194008
Data Completeness	19.32%	19.32%	19.32%	19.32%	19.32%
Data Completeness (annual)	5.75%	5.75%	5.75%	5.75%	5.75%

From Table 7 it can be seen that the data completeness over the operation period for the APS $PM_{1/2.5/4.0/10/20}$ was 16.32%, and for the entire year was only 5.75%. The lack of data for 95.4% of the year was due to the instrument only being re-deployed after service in October 2915 and some instrument malfunctions faced after deployment (uninterrupted power supply failure). It can also been seen from Table 7 that the mean (min : max, *units* = #) for the APS $PM_{1/2.5/4.0/10/20}$ size fraction particle number counts were was 1 nm = 187718 (14789 : 959125 #), 2.5 nm = 235568 (15357 : 1052303 #), 4.0 nm = 238763 (15376: 1073197 #), 10 nm = 239258 (15378 : 1082099 #) and 20 nm = 239262 (15378 : 1082167 #) respectively. The increase in particle number counts observed from the fine mode (1 microns) to 20 microns fits with the theory that sea salt spray will impact the larger size particle size fractions. It is unlikely to be due to fresh combustion or oil and gas production operations (O&G). Time series analysis will investigate the peaks and valleys in the APS $PM_{1/2.5/4.0/10/20}$, to aid in the determination their source.

Figure 3 presents a daily average time-series of TSI Ultrafine model 3031 particle number between 20 nm and 800 nm.

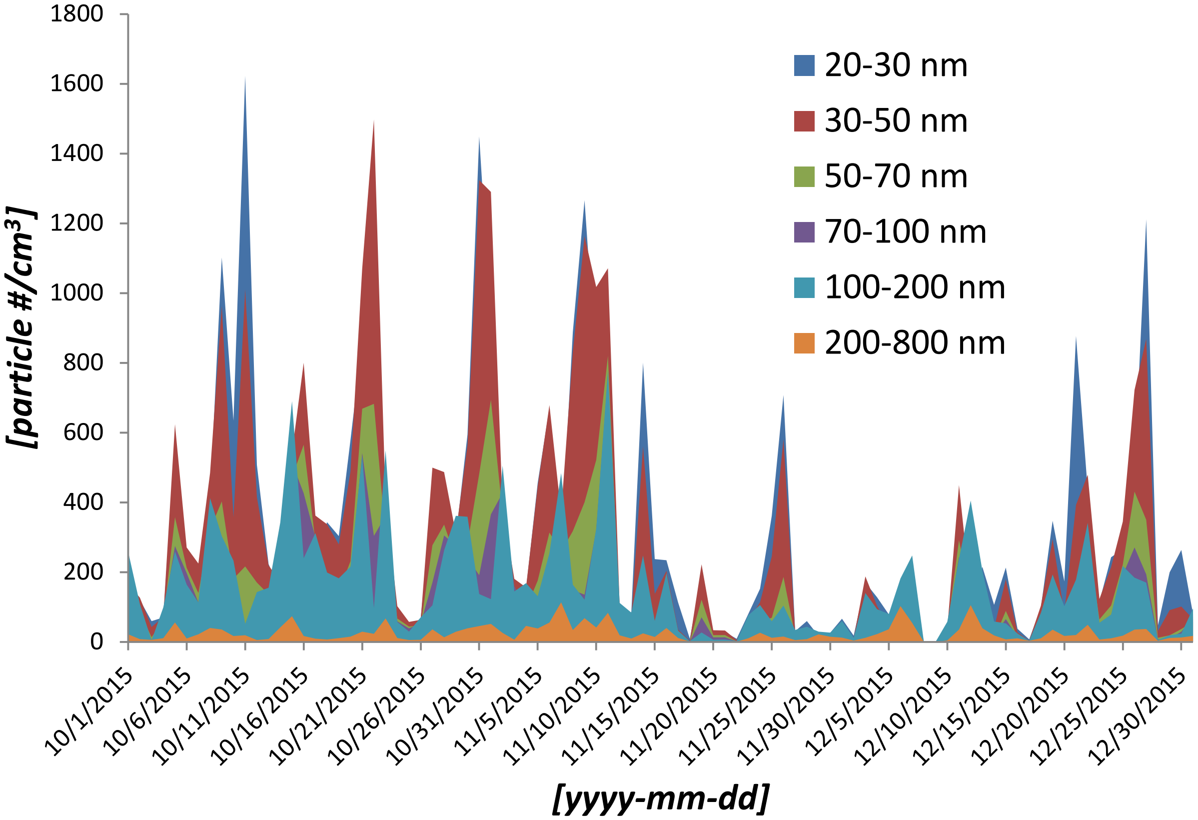


Figure 3. TSI Ultrafine model 3031 particle number daily time series

To provide insight into the five spikes observed in the Ultrafine particle (UFP) time-series shown in Figure 7, the HYSPLIT, 5-day air mass backtrajectories found in Appendix A were used. Analyzing the HYSPLIT back trajectories for the spikes in UFP observed on 8th, 10th, 22nd, 31st October, 9th November, 25th November, 21st December and 27th December showed that all air masses originated from known continental source regions of fossil fuel combustion that include the NE US, Southern Ontario, Northern Ontario, Quebec and Nova Scotia en-route to Sable Island. Without chemical species information is unknown whether the UFP originate from the main land or the ocean surrounding Sable Island. The air flow associated with these two spikes are however unlikely to be associated with O&G production activity as the air flow is from the opposite direction to the platforms that surround Sable Island. Using the NASA MODIS satellite true color image archive (example shown in Figure 4) and a timeseries of Aqua MODIS chlorophyll-a (Figure 5) showed that there was little phytoplankton bloom activity during the last three months of 2015.

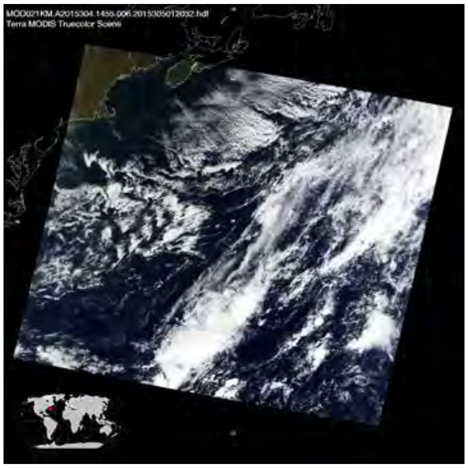


Figure 4. NASA TERRA MODIS true color satellite image

Figure 5 provides a time-series of Chlorophyll-a concentration in the NW Atlantic (including the Scotian Shelf around Sable Island). This chlorophyll-a time-series is especially useful to determine if any UFP, APS # counts or DRX PM mass concentrations are associated with biogenic fluxes from the ocean.

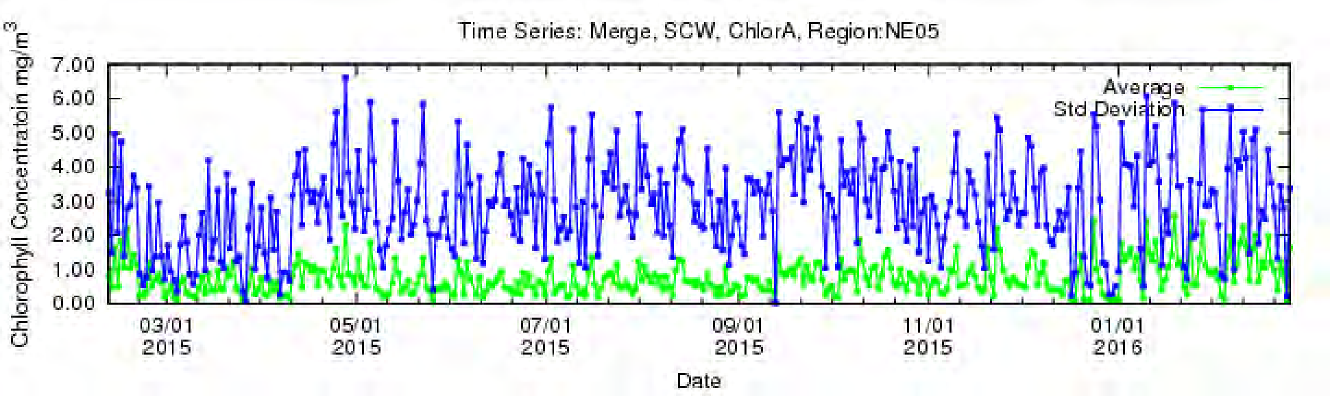


Figure 5. Time-series of Chlorophyll-A concentration in the NW Atlantic (including the Scotian Shelf around Sable Island)

Therefore, the spikes in UFP for the last three months of 2015 are likely associated with continental outflow of primary and secondary ultrafine particles likely associated with anthropogenic combustion sources (oil, coal, wood and gas) used for transport, space heating and power. It is also likely that, given the time of year, the UFP are not associated with biogenic emissions (volatile organic compounds emitted from vegetation) or wildfires. The low particle numbers associated with 3rd, October and 22nd November are associated with 5-day air mass back trajectories from solely the marine environment. The low UFP number concentrations observed on 17th December were associated with air mass backtrajectories originating from Northern Labrador which is a region with low emissions of aerosols at this time of year.

Figure 6 provides an hourly time-series of TSI Ultrafine model 3031 particle number counts. The hourly time series are provided to investigate finer diurnal trends that might not be apparent in the daily average times series plots.

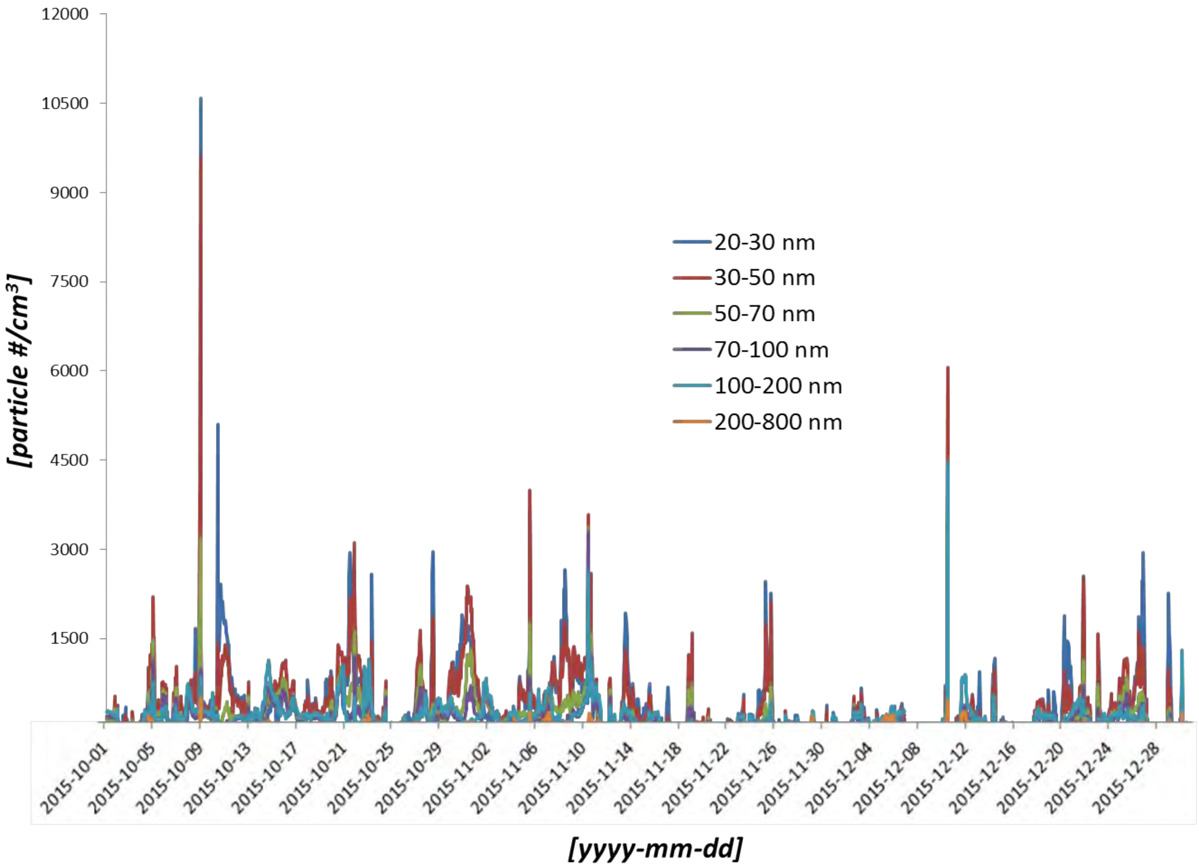


Figure 6. Hourly time-series for the TSI Ultrafine particle counter model 3031

The spikes in the hourly UFP seen in Figure 5 follow the same association as for the daily UFP spikes, i.e. associated with continental outflow from known source regions in the NE US and Eastern Canada and not from air flow from the direction of the O&G platforms.

Figure 9 provides a daily time-series of TSI DRX $PM_{1/2.5/4/10/TSP}$ mass concentration for October through December 2015.

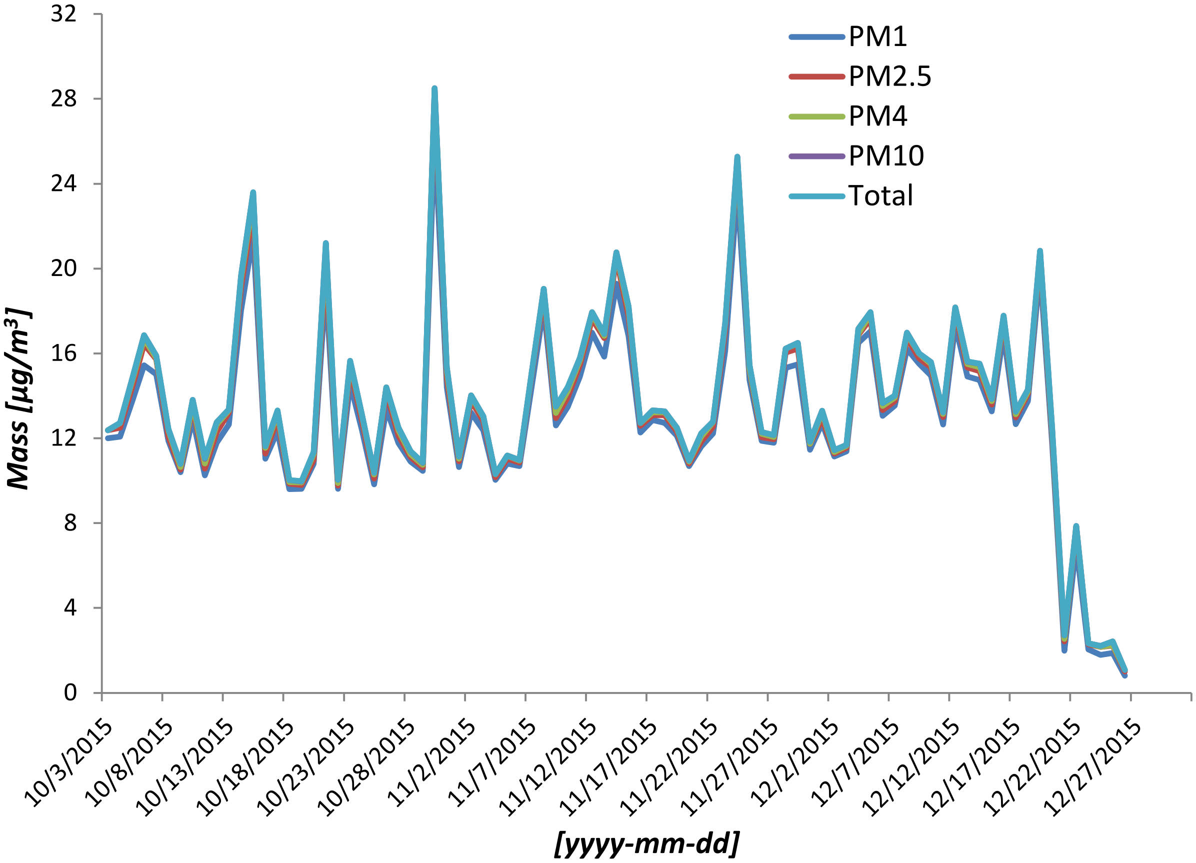


Figure 7. Daily time series TSI DRX $PM_{1/2.5/4/TSP}$ mass concentration

As can be seen from Figure 9, the DRX failed on December 21, 2015. Upon inspection it was found that sea salt crystals entered the optics chamber and fouled the sensor optics. The instrument functioned normally after cleaning and re-calibrating in January 2016.

HYSPLIT was used to investigate the spikes in the DRX $PM_{1/2.5/4/10/TSP}$. The 5-day HYSPLIT air mass backtrajectories associated with the daily spike on the 14th October are from the SW which crosses Thebaub and Deep Panuke. However, Deep Panuke was not producing at the time and therefore is not the source of the elevated PM mass concentration. However, going back further (3-5-days) the air parcel originated from the know source regions in the NE US. Therefore, the increase in $PM_{2.5}$ to 22 $\mu g/m^3$ is likely associated with LRT of primary and secondary aerosol from the continent, rather than from O&G operation emissions on Thebaub platform.

CONCLUSIONS

Due to NSE ceasing management of the NO_x, H_2S, SO_2, O_3, NO_x and BAM $PM_{2.5}$, there was no available data for these air emission metrics for the whole of 2015. In January 2016 a calibrated O_3 autoanalyzer (ECCC in-kind) and $PM_{2.5}$ BAM (Gibson in-kind) was installed on Sable Island. In addition, a NOx analyzer is installed (ECCC in-kind) but awaits calibration (April 2016). New Teledyne-API H_2S, SO_2 autoanalyzers (Gibson – ESRF funds) will be installed in April 2016 together with a replacement Thermo black carbon instrument that failed and could not be repaired (Gibson – ESRF). However, supplemental $PM_{2.5}$ data was available from October through to the end of 2015 from a TSI DRX instrument (Gibson – ESRF funds). In addition, ultrafine and coarse particle number counts were also measured from October through to the end of 2015 (Gibson – ESRF funds).

The 2015 data completeness for temperature, wind direction and wind speed was 96.38%, 100.00% and 99.44% respectively. The mean temperature and wind speed was found to be 9.04°C, 25.39 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 2015 was 241° which is consistent with prevailing winds in the North West (NW) Atlantic.

The data completeness for the UFP number counts over the three months of operation was 96.02%, and consequently 24.66% for the entire year. The mean UFP particle number counts, in the various size ranges, were as follows: 20-30 nm = 343.1 #, 30-50 nm = 336.9 #, 50-70 nm = 179.5 #, 70-100 nm = 143.47 #, 100-200 nm = 168.2 # and 200-800 nm = 25.57 # respectively. The mean DRX sampled $PM_{1/2.5/4.0/10/TSP}$ mass concentration spanning October, through December 2015 was: PM_1 = 13.8 μg/m^3, $PM_{2.5}$ = 14.32 μg/m^3, PM_4 = 14.50 μg/m^3, PM_{10} = 14.60 μg/m^3 and TSP = 14.60 μg/m^3 respectively. The mean $PM_{2.5}$ was found to be below the CWS of 28 μg/m^3. The mean for the integrated APS $PM_{1/2.5/4.0/10/20}$ size fraction particle number counts were as follows: < 1 nm = 187718 #, 2.5 nm = 235568 #, 4.0 nm = 238763 #, 10 nm = 239258 # and 20 nm = 239262 # respectively.

The most important feature of the 2015 air missions report is that the spikes in PM mass and particle number concentrations were associated with LRT continental outflow, and not from O&G operations or associated with ocean biogenic fluxes. The mean $PM_{2.5}$ for the 3-months of 2015 was similar in concentration to previous air emissions reports.

With the new instruments deployed on Sable Island, the 2016 air emissions report will contain far more data and a more fulsome investigation of local and upwind air emissions impacting Sable Island.

RECOMMENDATIONS

It is recommended that further monitoring be conducted for NO_x, H_2S, SO_2, BC and $PM_{2.5}$ between the on-island combustion sources and the Venture platforms under Easterly airflow. This would confirm whether the Easterly wind directional dependence for NO_x, $PM_{2.5}$ and BC were due to on-Island emission sources or O&G production.

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 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, size-resolved particle number and total VOCs managed 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.

REFERENCES

BROWNELL, D. K., MOORE, R. M. & CULLEN, J. J. 2010. Production of methyl halides by Prochlorococcus and Synechococcus. *Global Biogeochem. Cycles,* 24**,** GB2002.

CNSOPB 1990. Annual Report. 22.

CNSOPB 2013. Encana's Deep Panuke Project.

GANTT, B., NICHOLAS, M., ZHANG, Y. & XU, J. 2010. The effect of marine isoprene emissions on secondary organic aerosol and ozone formation in the coastal United States. *Atmospheric Environment,* 44**,** 115-121.

GIBSON, M. D., GUERNSEY, J. R., BEAUCHAMP, S., WAUGH, D., HEAL, M. R., BROOK, J. R., MAHER, R., GAGNON, G. A., MCPHERSON, J. P., BRYDEN, B., GOULD, R. & TERASHIMA, M. 2009a. Quantifying the Spatial and Temporal Variation of Ground-level Ozone in the Rural Annapolis Valley, Nova Scotia, Canada using Nitrite-impregnated Passive Samplers. *Journal of the Air & Waste Management Association,* 59**,** 310-320.

GIBSON, M. D., HEAL, M. R., BACHE, D. H., HURSTHOUSE, A. S., BEVERLAND, I. J., CRAIG, S. E., CLARK, C. F., JACKSON, M. H., GUERNSEY, J. R. & JONES, C. 2009b. Using Mass Reconstruction along a Four-Site Transect as a method to interpret PM10 in West-Central Scotland, United Kingdom. *Journal of the Air and Waste Management Association,* 59**,** 1429-1436.

GIBSON, M. D., HEAL, M. R., LI, Z., KUCHTA, J., KING, G. H., HAYES, A. & LAMBERT, S. 2013a. The spatial and seasonal variation of nitrogen dioxide and sulfur dioxide in Cape Breton Highlands National Park, Canada, and the association with lichen abundance. *Atmospheric Environment,* 64**,** 303-311.

GIBSON, M. D., KUNDU, S. & SATISH, M. 2013b. Dispersion model evaluation of PM2.5, NOx and SO2 from point and major line sources in Nova Scotia, Canada using AERMOD Gaussian plume air dispersion model. *Atmospheric Pollution Research,* 4**,** 157-167.

GIBSON, M. D., PIERCE, J. R., WAUGH, D., KUCHTA, J. S., CHISHOLM, L., DUCK, T. J., HOPPER, J. T., BEAUCHAMP, S., KING, G. H., FRANKLIN, J. E., LEAITCH, W. R., WHEELER, A. J., LI, Z., GAGNON, G. A. & PALMER, P. I. 2013c. Identifying the sources driving observed PM2.5 temporal variability over Halifax, Nova Scotia, during BORTAS-B. *Atmos. Chem. Phys.,* 13**,** 7199-7213.

GREENHORSESOCIETY 2012. Sable Island Greenhorse Society.

INKPEN, T., HINGSTON, M., WAUGH, D., KEAST, S., MCPHERSON, J., WORTHY, D. & FORBES, G. 2009. Sable Island Air Monitoring Program Report: 2003-2006 *Meteorological Service of Canada* Atlantic Region Science Technical Report

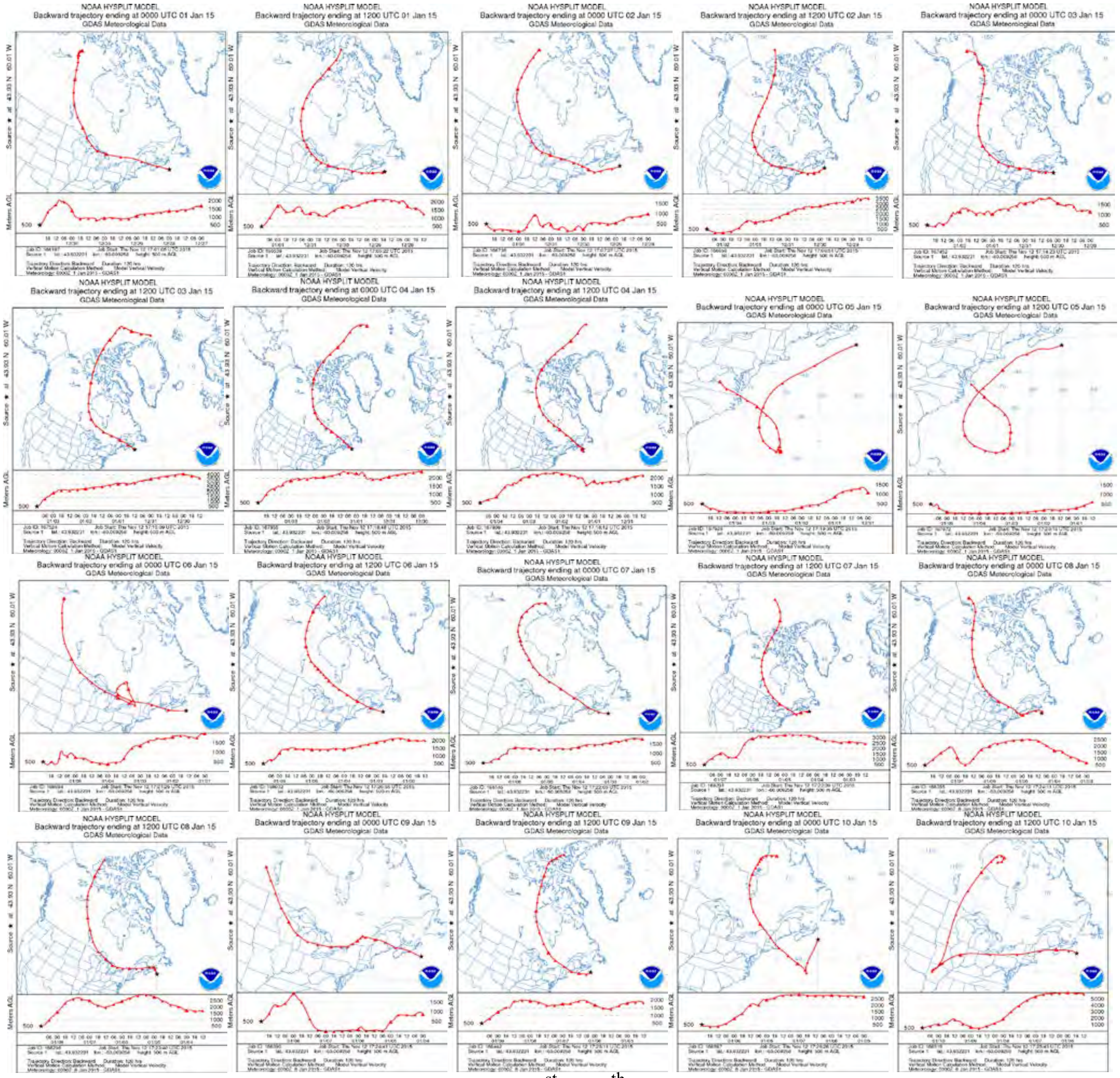
MONKS, P. S., GRANIER, C., FUZZI, S., STOHL, A., WILLIAMS, M. L., AKIMOTO, H., AMANN, M., BAKLANOV, A., BALTENSPERGER, U., BEY, I., BLAKE, N., BLAKE, R. S., CARSLAW, K., COOPER, O. R., DENTENER, F., FOWLER, D., FRAGKOU, E., FROST, G. J., GENEROSO, S., GINOUX, P., GREWE, V., GUENTHER, A., HANSSON, H. C., HENNE, S., HJORTH, J., HOFZUMAHAUS, A., HUNTRIESER, H., ISAKSEN, I. S. A., JENKIN, M. E., KAISER, J., KANAKIDOU, M., KLIMONT, Z., KULMALA, M., LAJ, P., LAWRENCE, M. G., LEE, J. D., LIOUSSE, C., MAIONE, M., MCFIGGANS, G., METZGER, A., MIEVILLE, A., MOUSSIOPOULOS, N., ORLANDO, J. J., O'DOWD, C. D., PALMER, P. I., PARRISH, D. D., PETZOLD, A., PLATT, U., PÖSCHL, U., PRÉVÔT, A. S. H., REEVES, C. E., REIMANN, S., RUDICH, Y., SELLEGRI, K., STEINBRECHER, R., SIMPSON, D., TEN BRINK, H., THELOKE, J., VAN DER WERF, G. R., VAUTARD, R., VESTRENG, V., VLACHOKOSTAS, C. & VON GLASOW, R. 2009. Atmospheric composition change – global and regional air quality. *Atmospheric Environment,* 43**,** 5268-5350.

PALMER, P. I., PARRINGTON, M., LEE, J. D., LEWIS, A. C., RICKARD, A. R., BERNATH, P. F., DUCK, T. J., WAUGH, D. L., TARASICK, D. W., ANDREWS, S., ARUFFO, E., BAILEY, L. J., BARRETT, E., BAUGUITTE, S. J. B., CURRY, K. R., CARLO, P. D., CHISHOLM, L., DAN, L., DRUMMOND, J. R., FORSTER, G., FRANKLIN, J. E., GIBSON, M. D., GRIFFIN, D., HELMIG, D., HOPKINS, J. R., HOPPER, J. T., JENKIN, M. E., KINDRED, D., KLIEVER, J., BRETON, M. L., MATTHIESEN, S., MAURICE, M., MOLLER, S., MOORE, D. P., ORAM, D. E., O'SHEA, S. J., OWEN, R. C., PAGNIELLO, C. M. L. S., PAWSON, S., PERCIVAL, C. J., PIERCE, J. R., PUNJABI, S., PURVIS, R. M., REMEDIOS, J. J., ROTERMUND, K. M., SAKAMOTO, K. M., STRAWBRIDGE, K. B., STRONG, K., TAYLOR, J., TRIGWELL, R., TERESZCHUK, K. A., WALKER, K. A., WEAVER, D., WHALEY, C. & YOUNG, J. C. 2013. Quantifying the impact of BOReal forest fires on Tropospheric oxidants over the Atlantic using Aircraft and Satellites (BORTAS) experiment: design, execution and science overview. *Atmos. Chem. Phys.,* 13**,** 6239-6261.

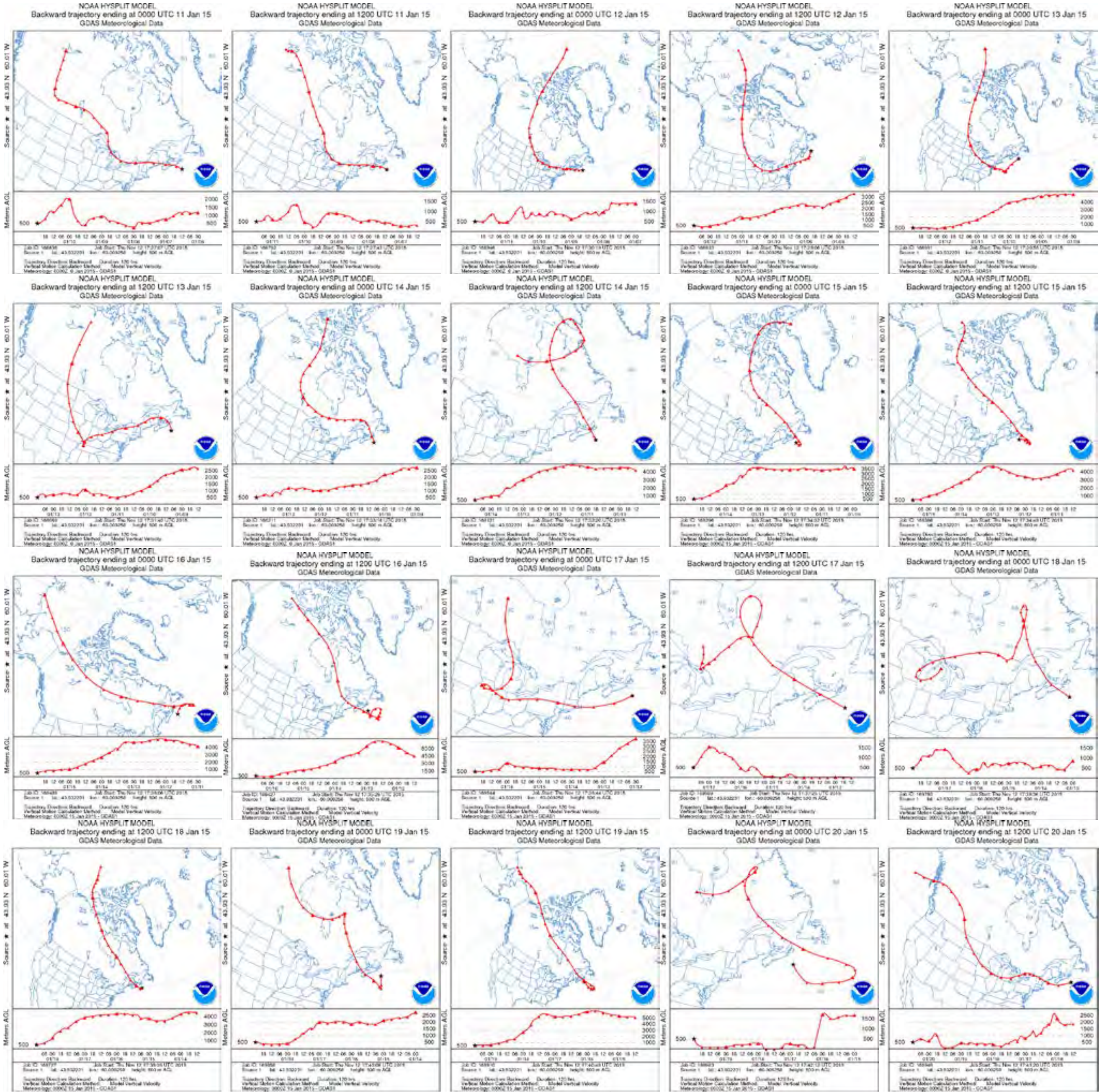
PALMER, P. I. & SHAW, S. L. 2005. Quantifying global marine isoprene fluxes using MODIS chlorophyll observations. *Geophys. Res. Lett.,* 32**,** L09805.

WAUGH, D., INKPEN, T., HINGSTON, M., KEAST, S., MCPHERSON, J., WORTHY, D. & FORBES, G. 2010. Sable Island Air Monitoring Program Report No: 2003-2006. *Environmental Studies Research Funds,* Report No. 181**,** 1-56.

APPENDIX A



January 01st – 10th, 2015



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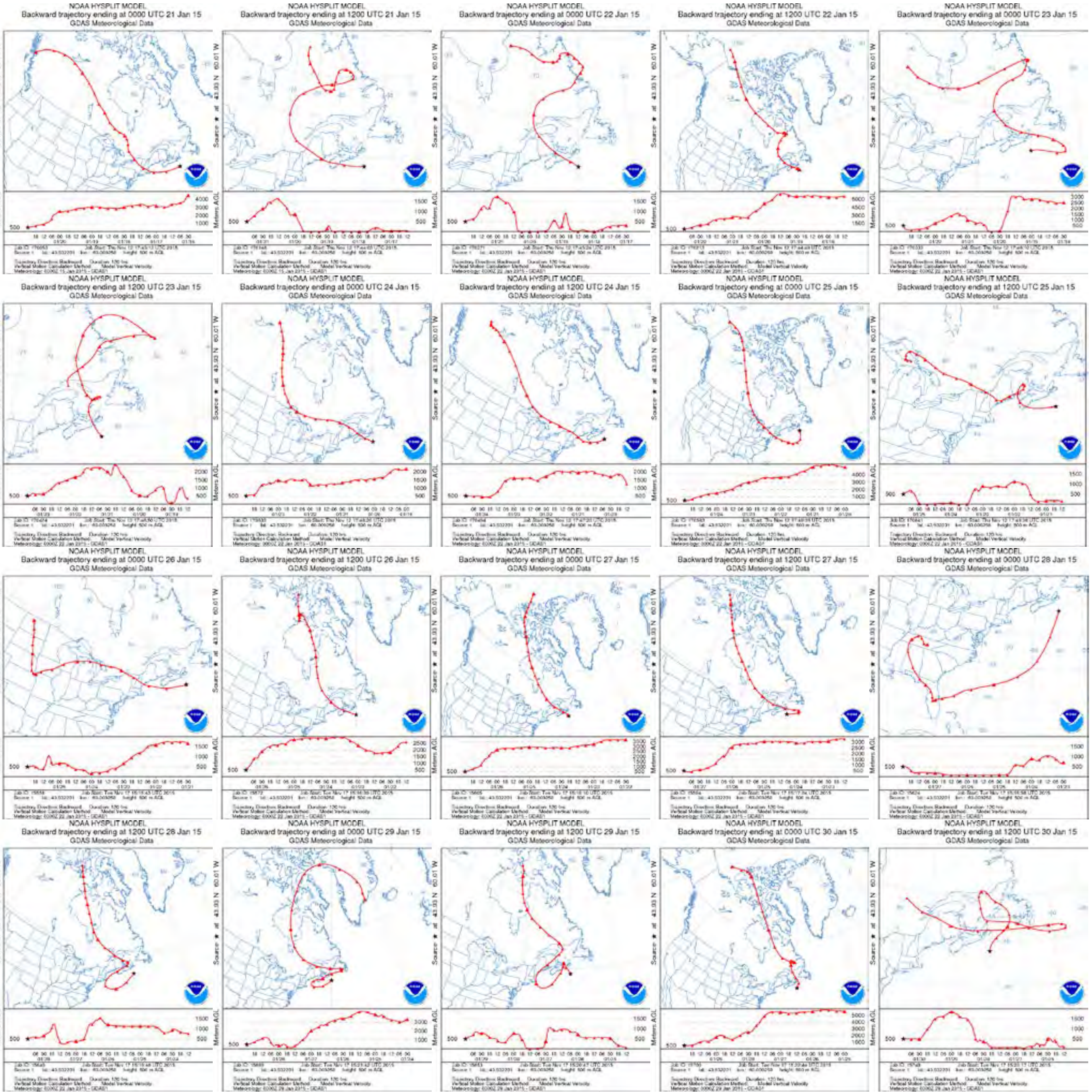

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Backward trajectory ending at 0000 UTC 21 Jan 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 21 Jan 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 22 Jan 15
GDAS Meteorological Data

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Backward trajectory ending at 1200 UTC 22 Jan 15
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NOAA HYSPLIT MODEL
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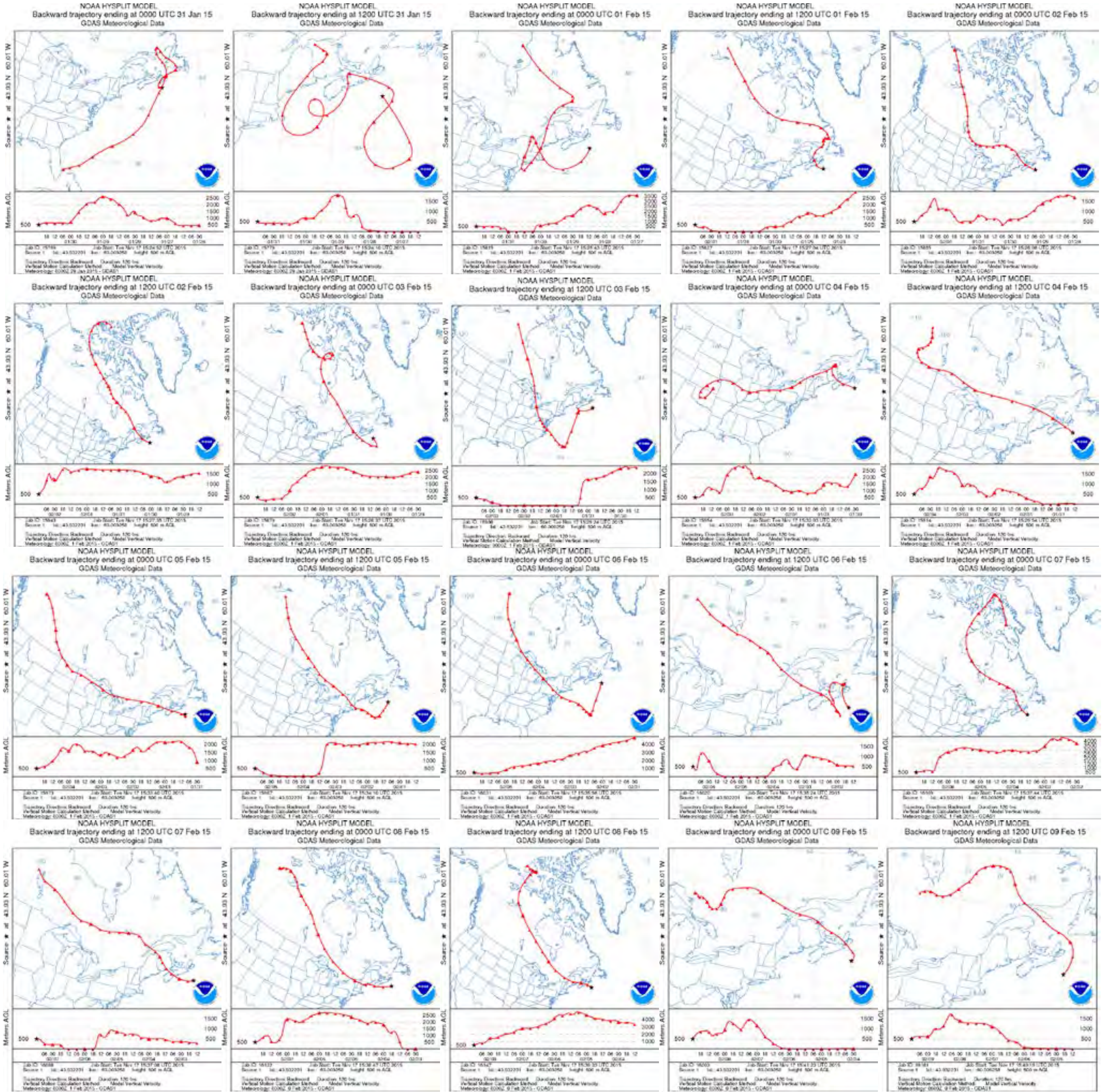
January 21st – 30th, 2015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GDAS Meteorological Data

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GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 01 Feb 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 01 Feb 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
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GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 02 Feb 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
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NOAA HYSPLIT MODEL
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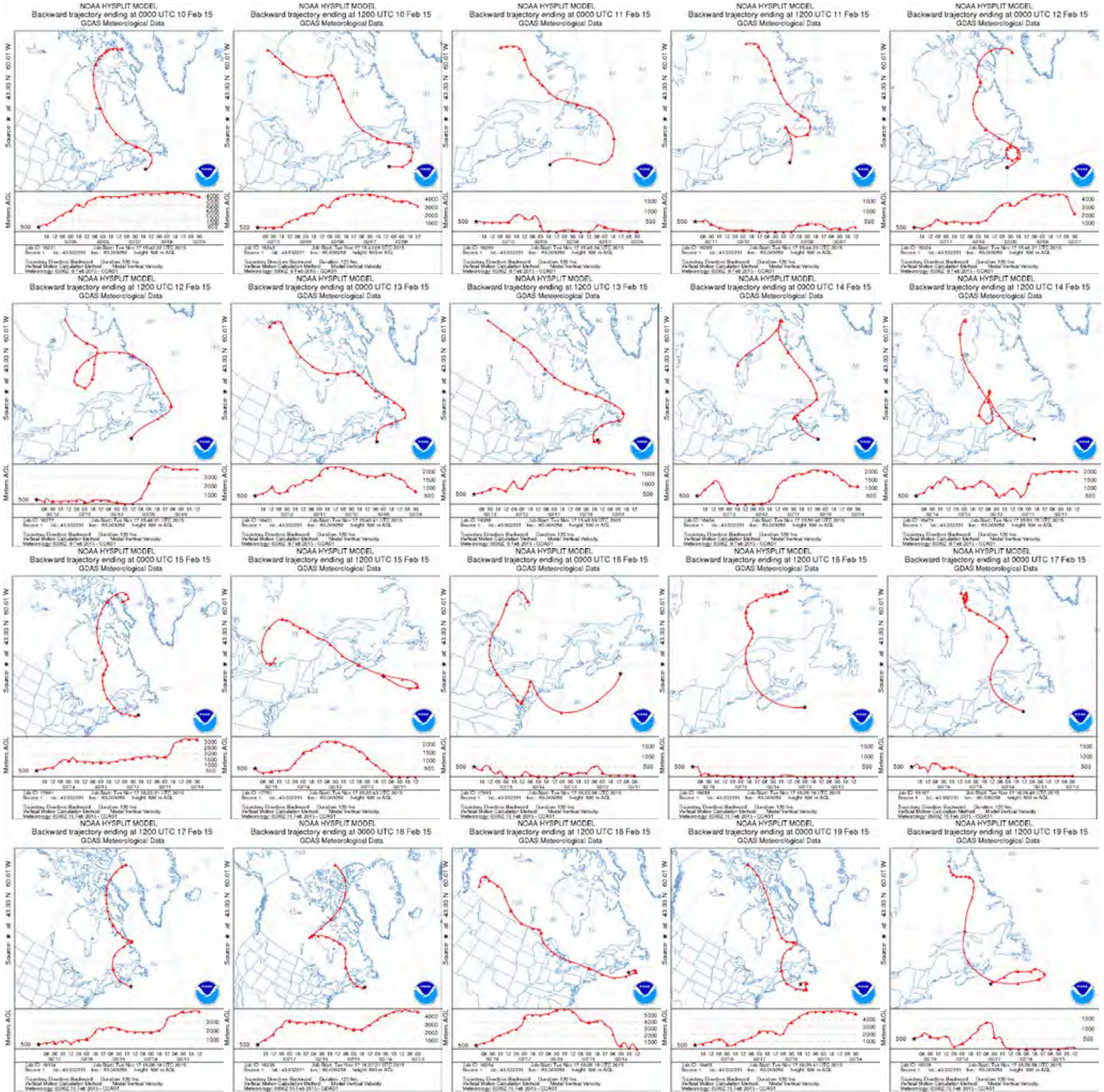
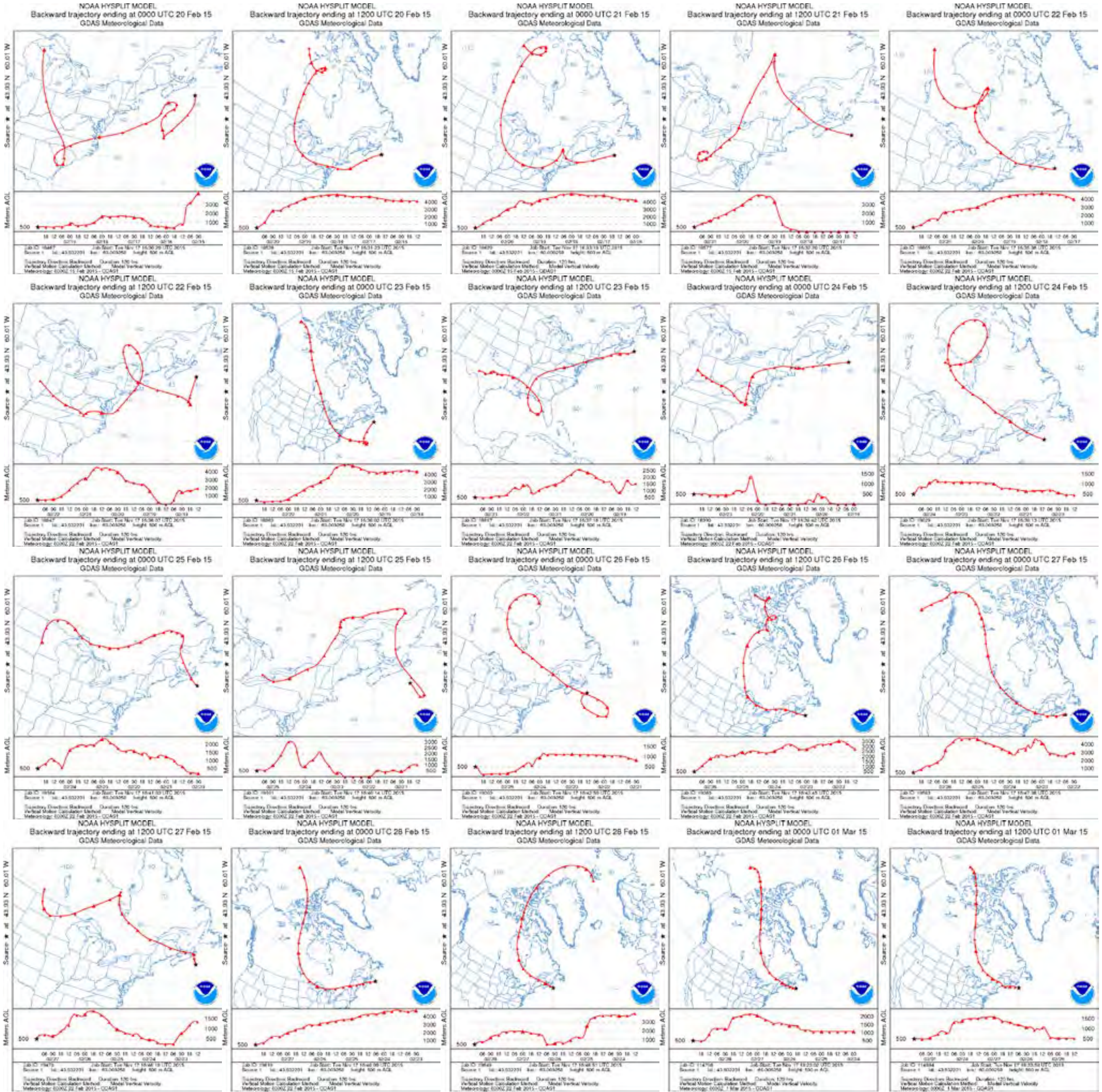
GDAS Meteorological Data

January 31st – February 09th, 2015



February 10th – 19th, 2015



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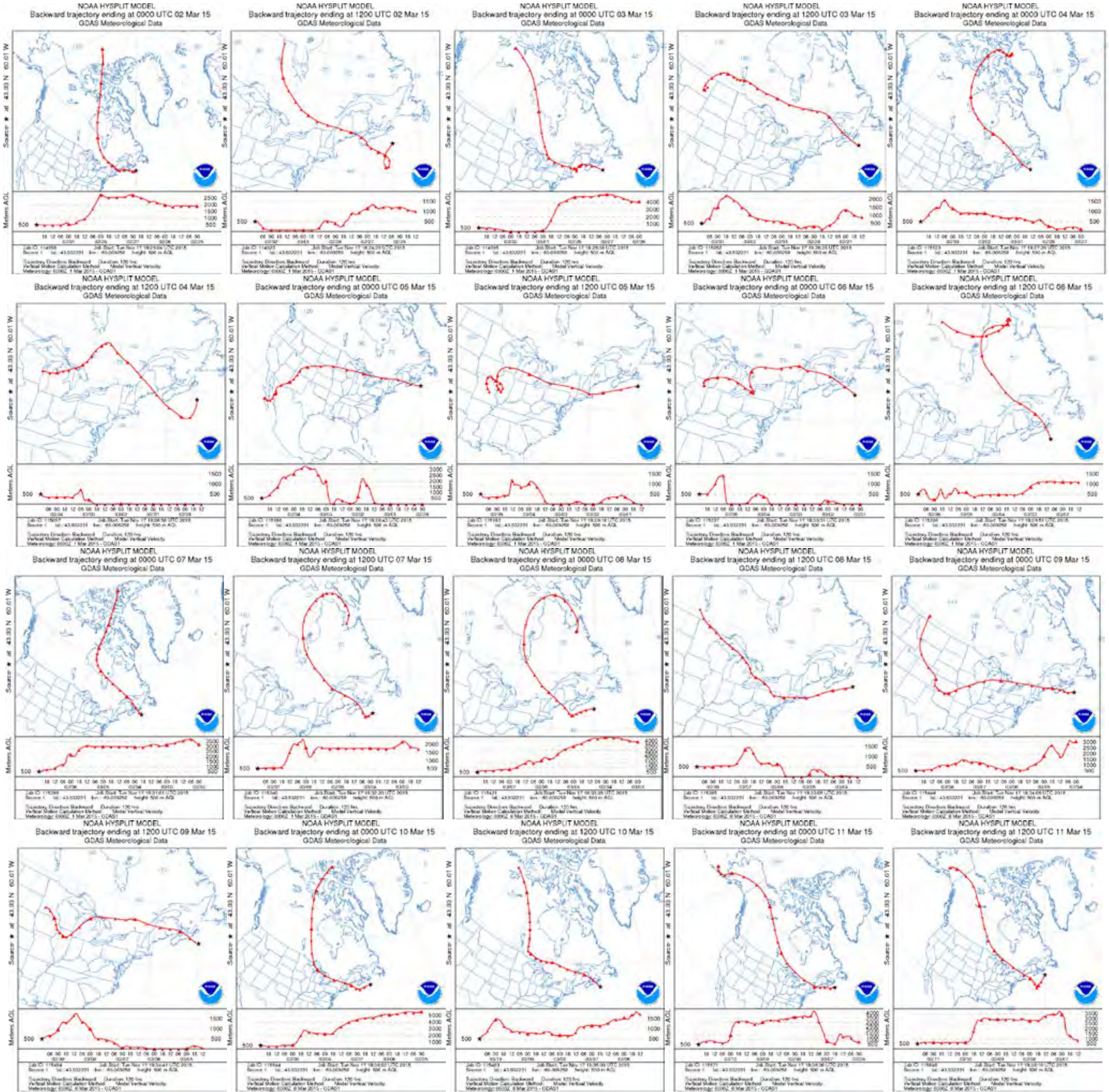

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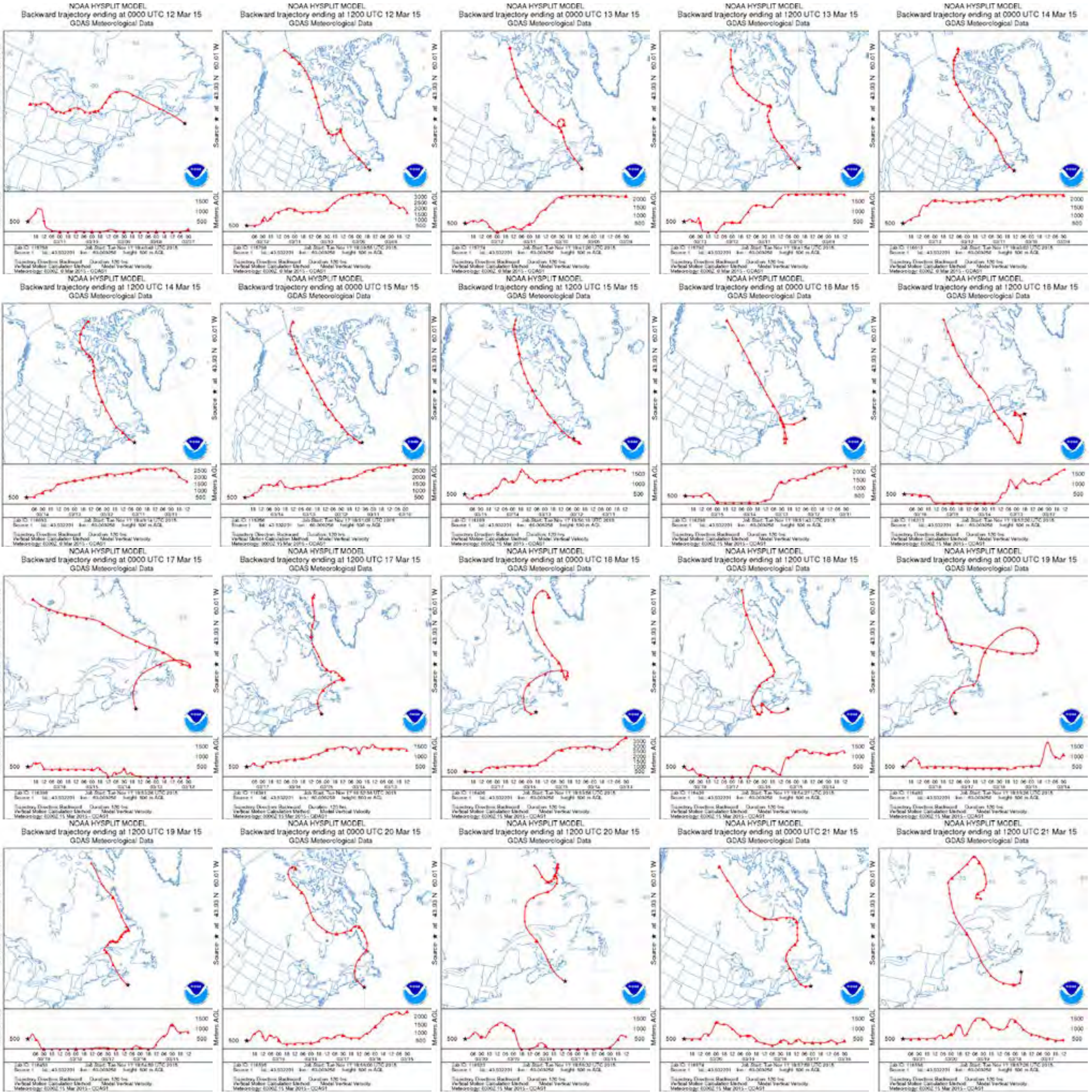

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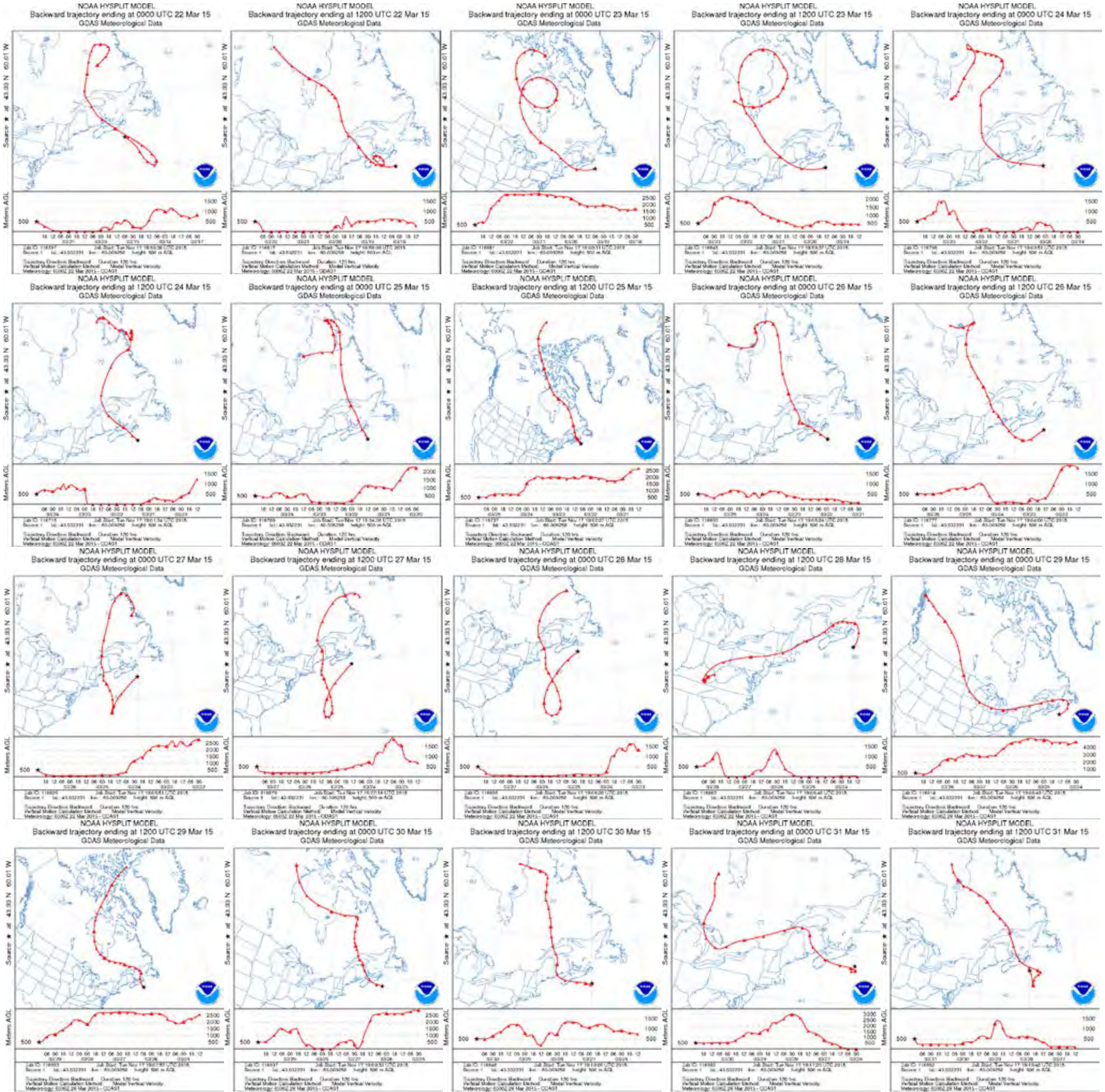
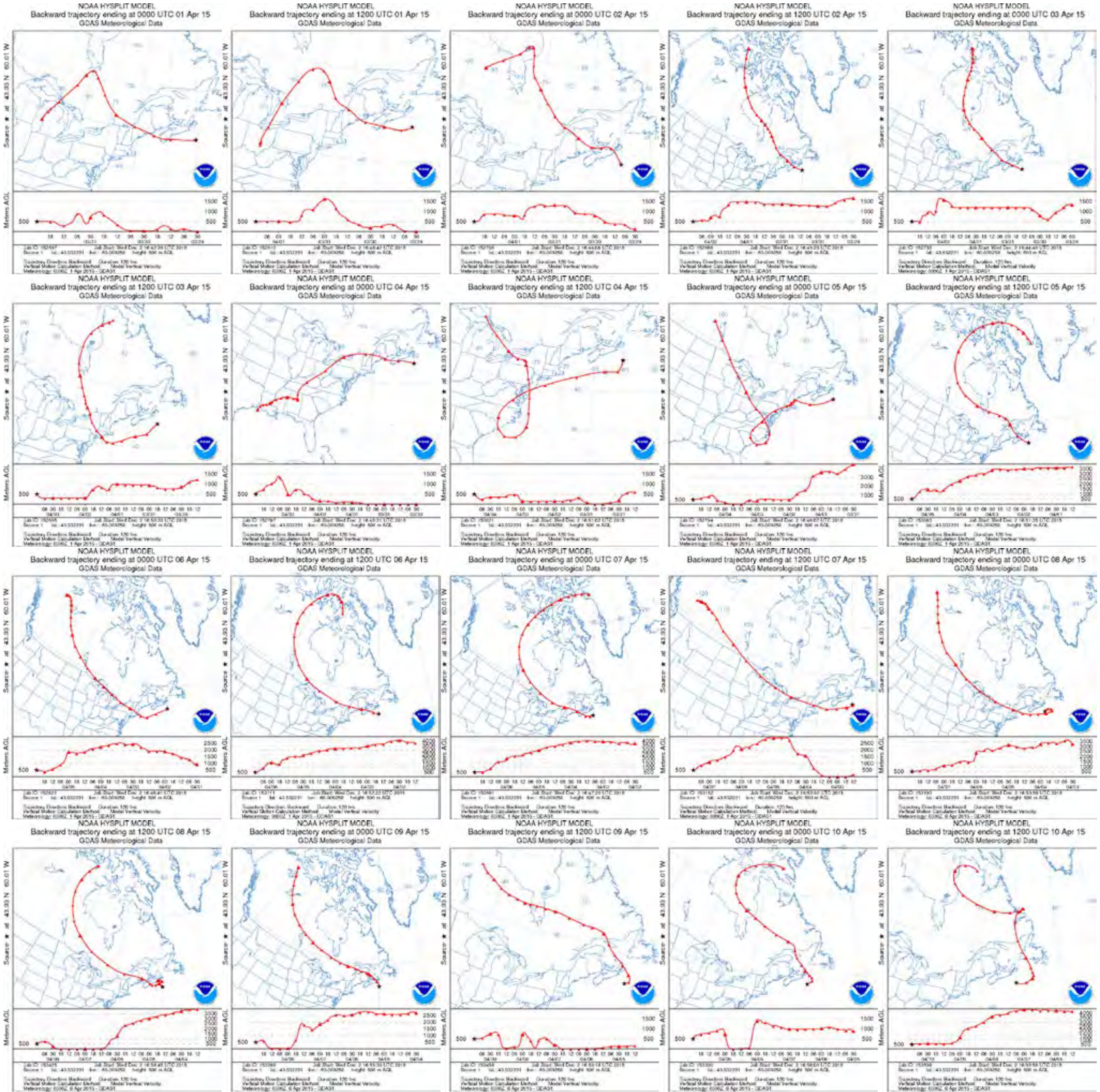


March 22nd – 31st, 2015



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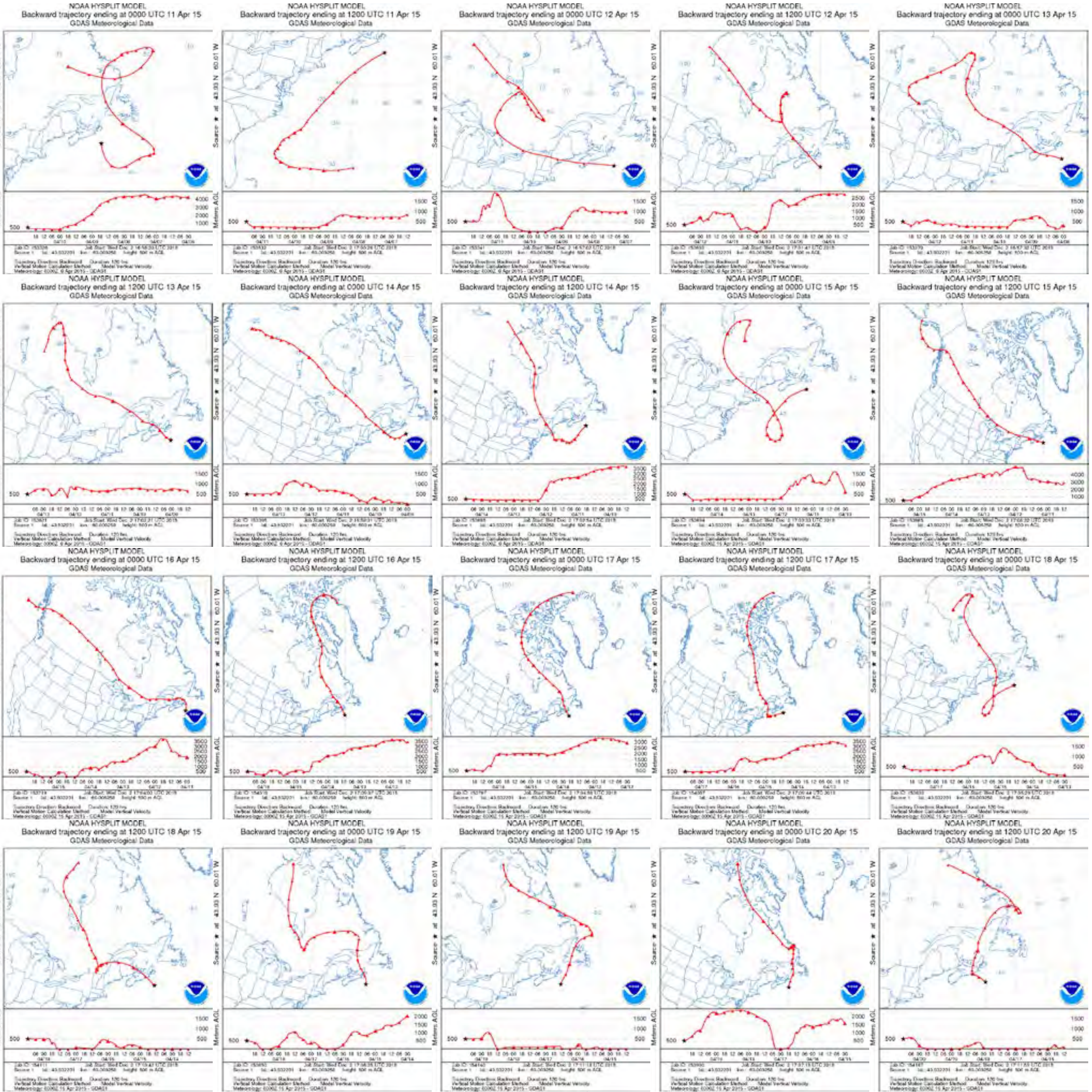
April 01st – 10th, 2015



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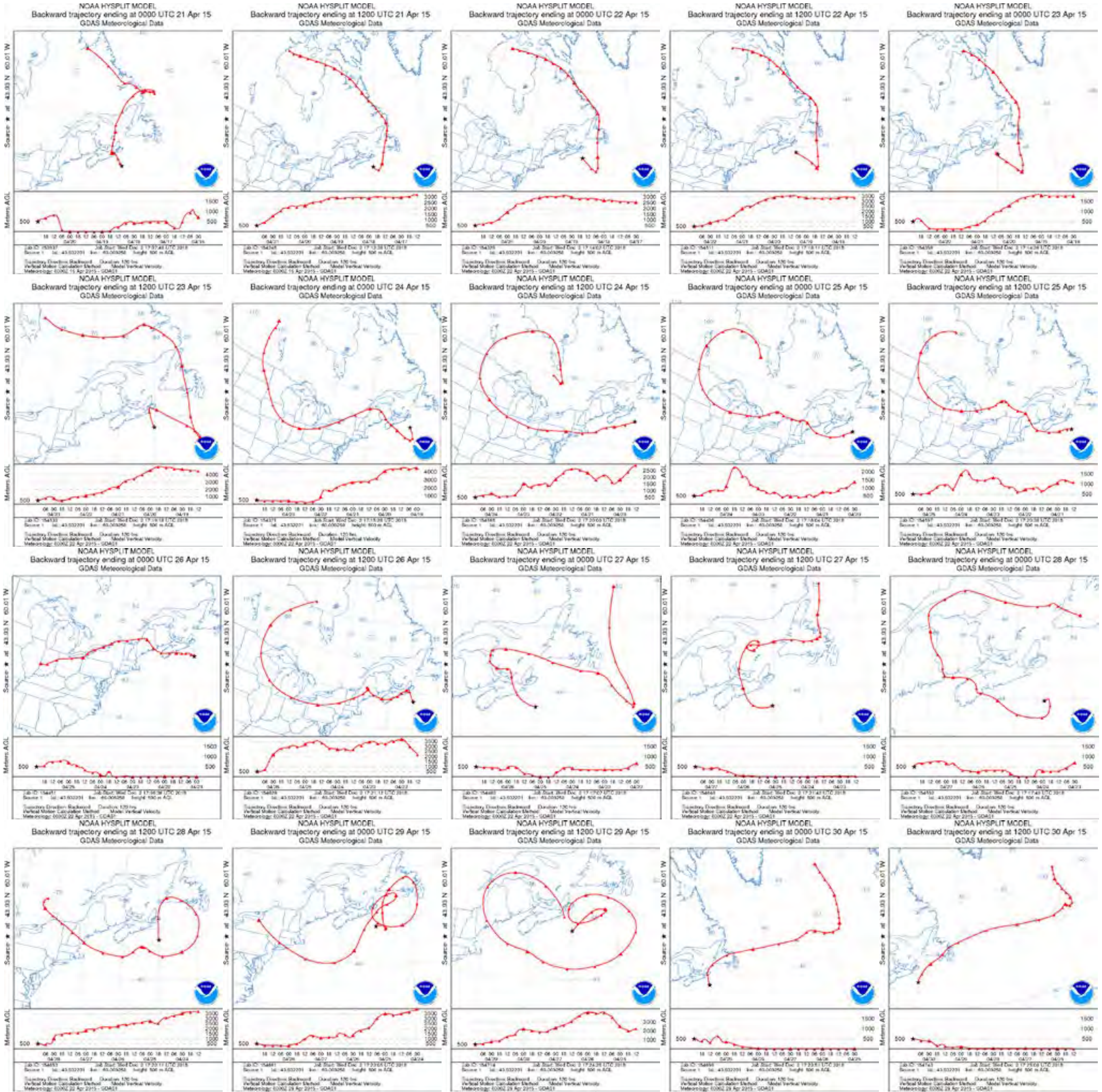

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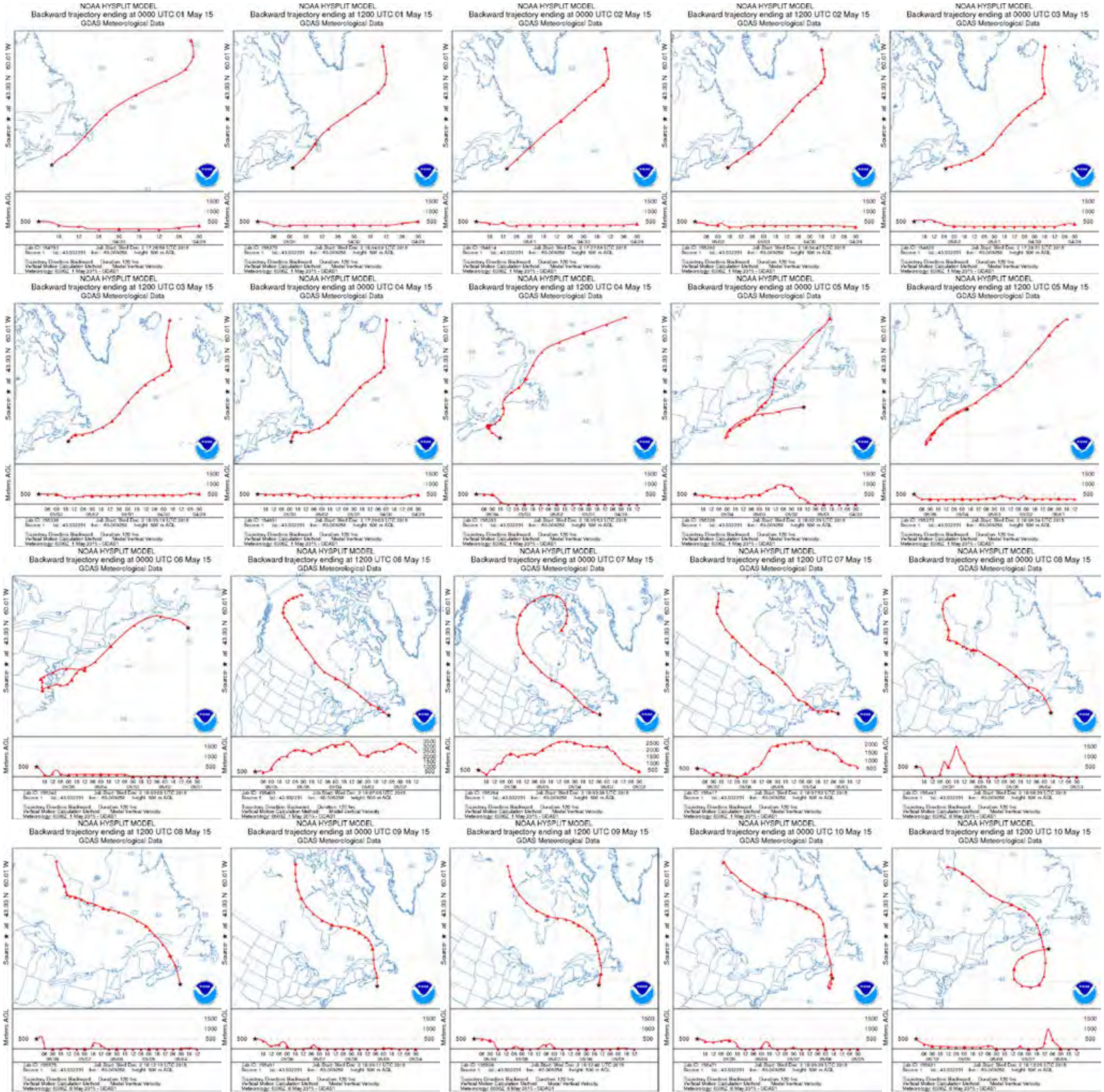

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GDAS Meteorological Data

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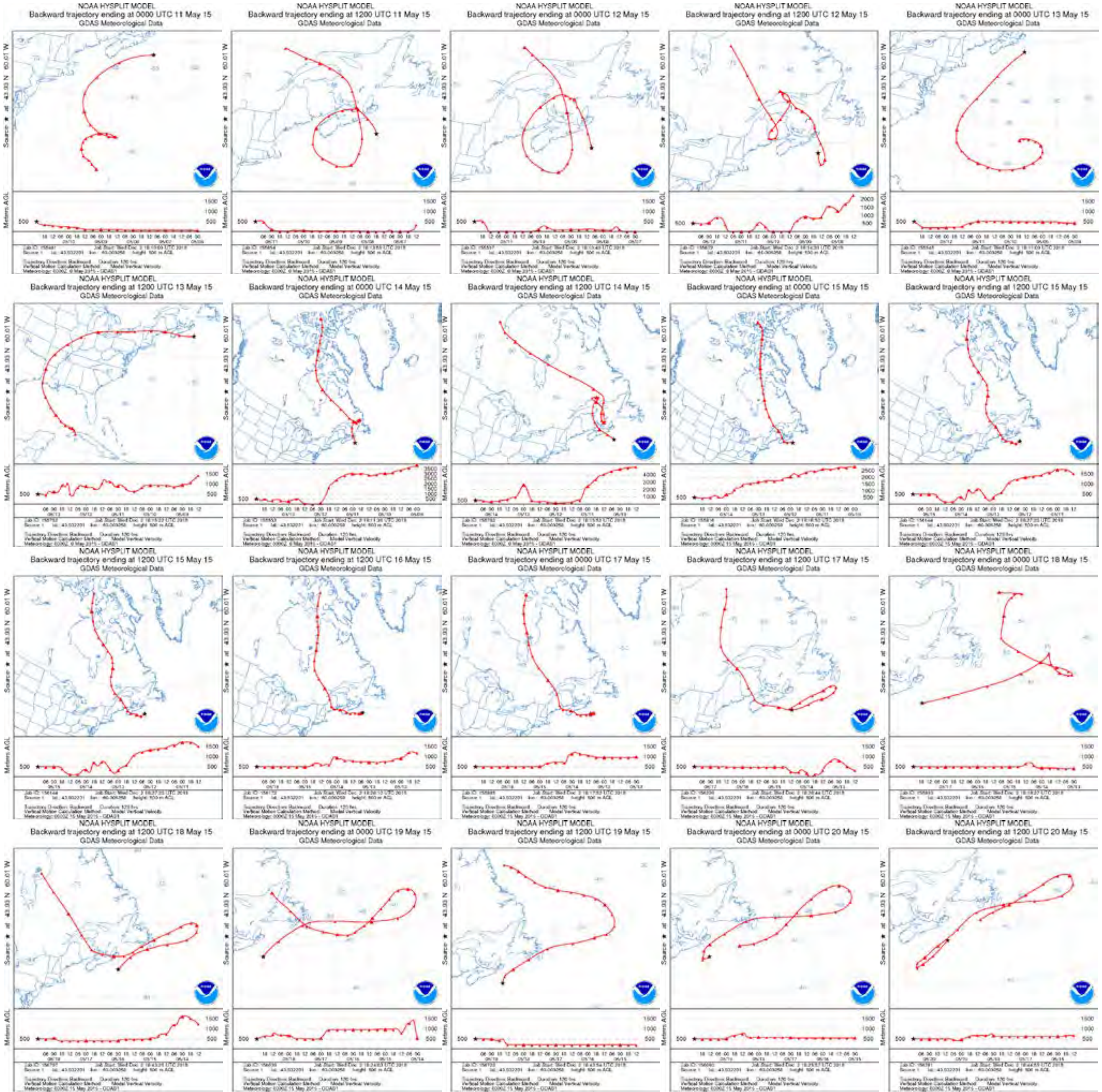
May 01st – 10th, 2015



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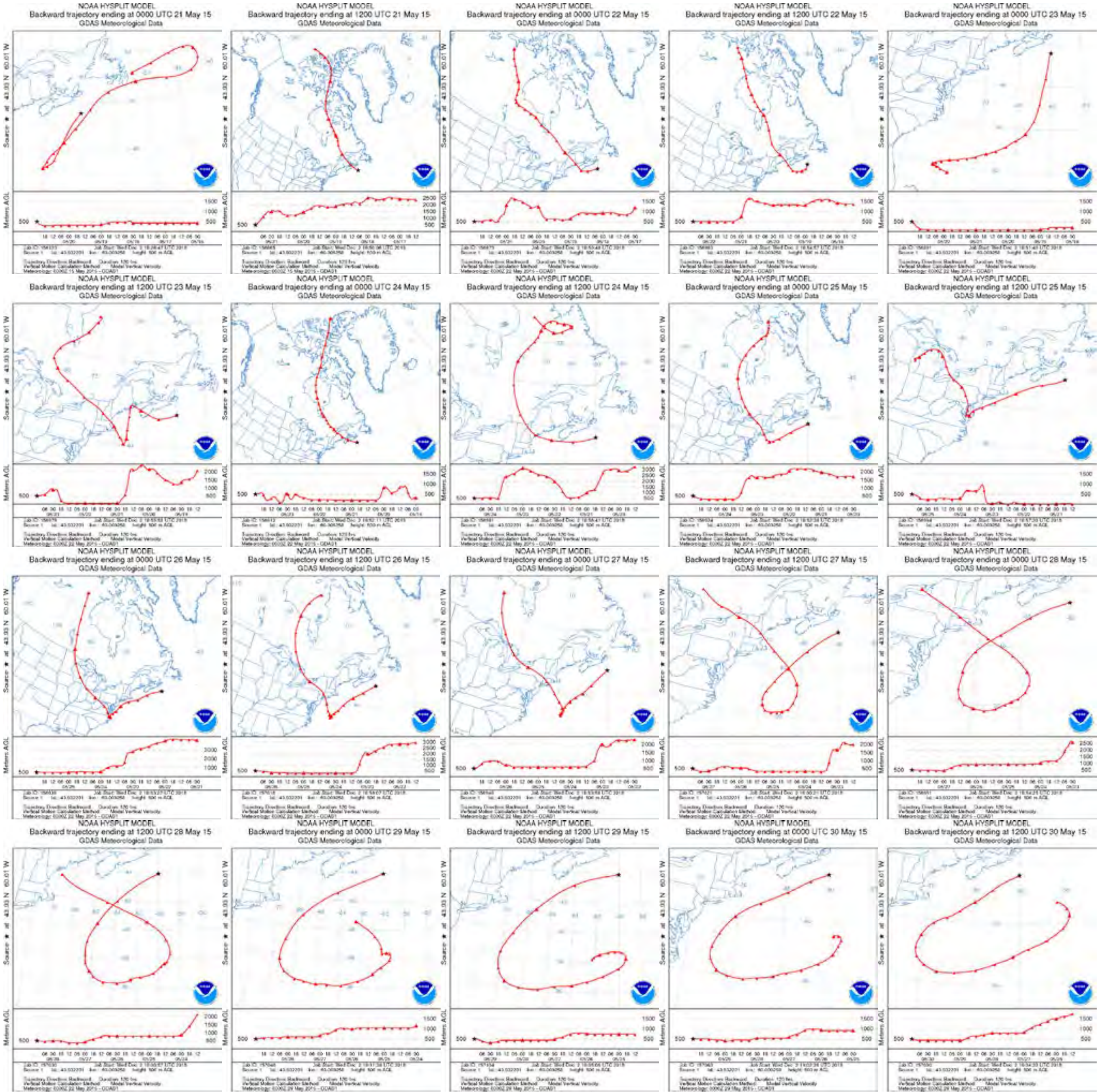

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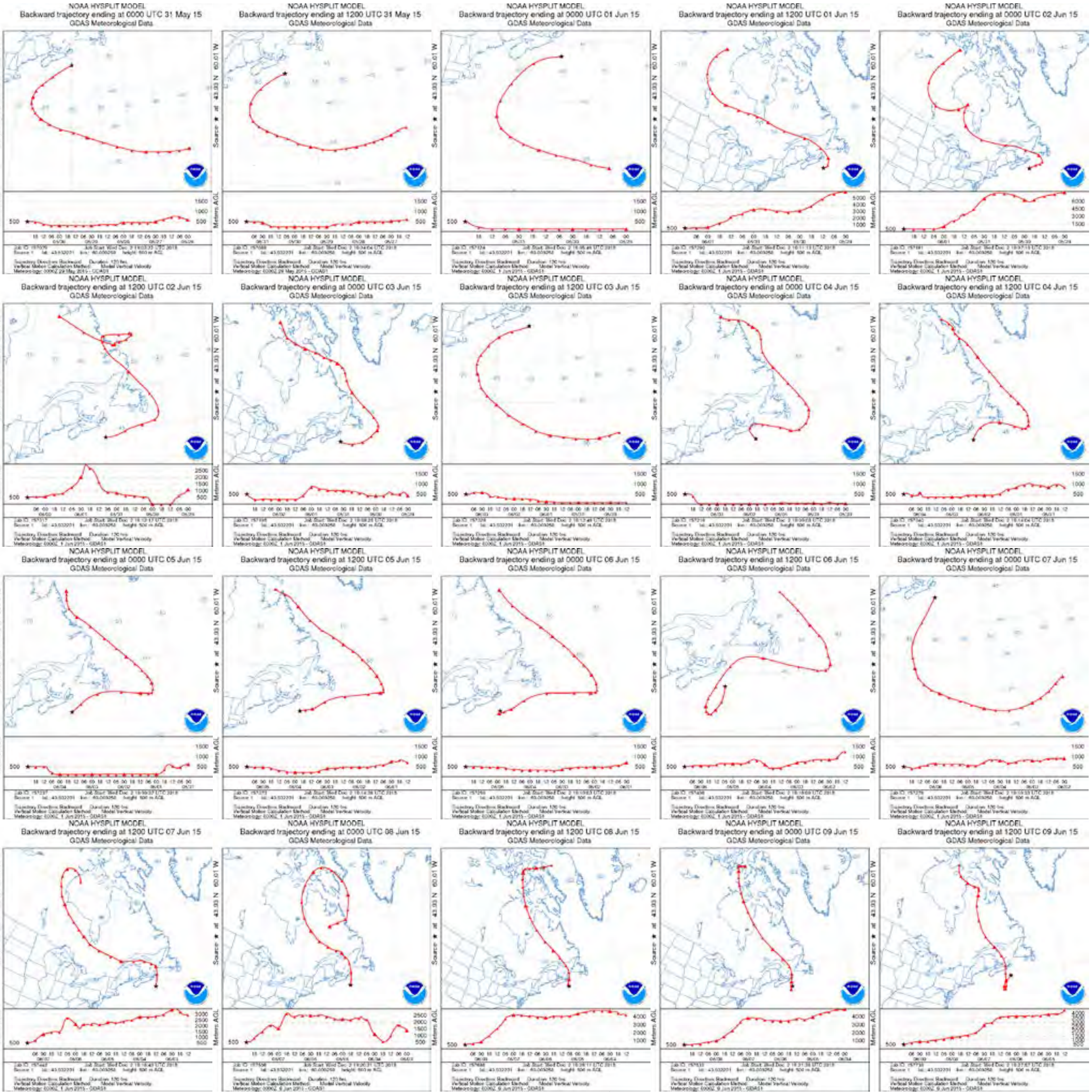

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GDAS Meteorological Data

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NOAA HYSPLIT MODEL
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GDAS Meteorological Data

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GDAS Meteorological Data

NOAA HYSPLIT MODEL
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GDAS Meteorological Data

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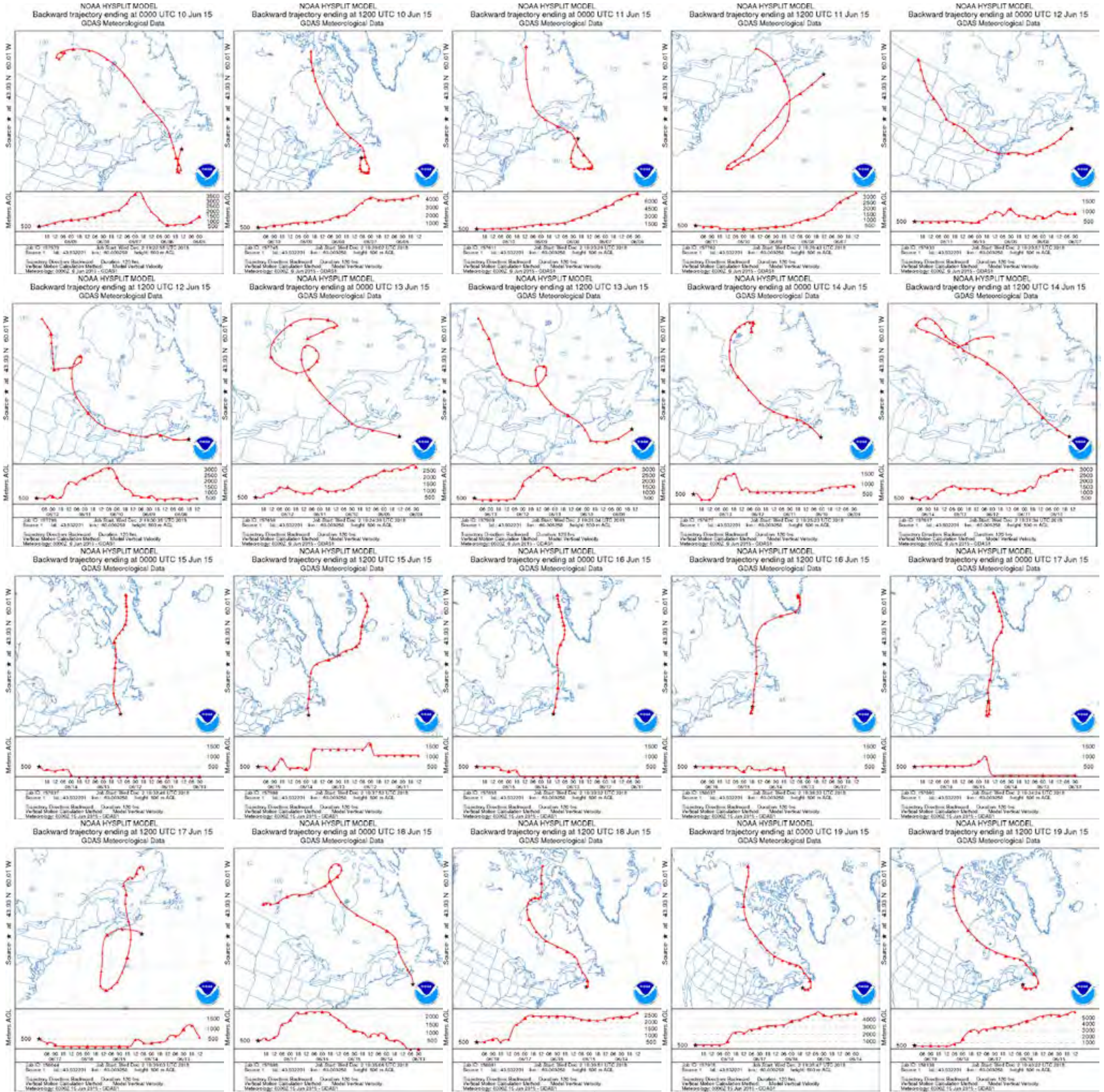

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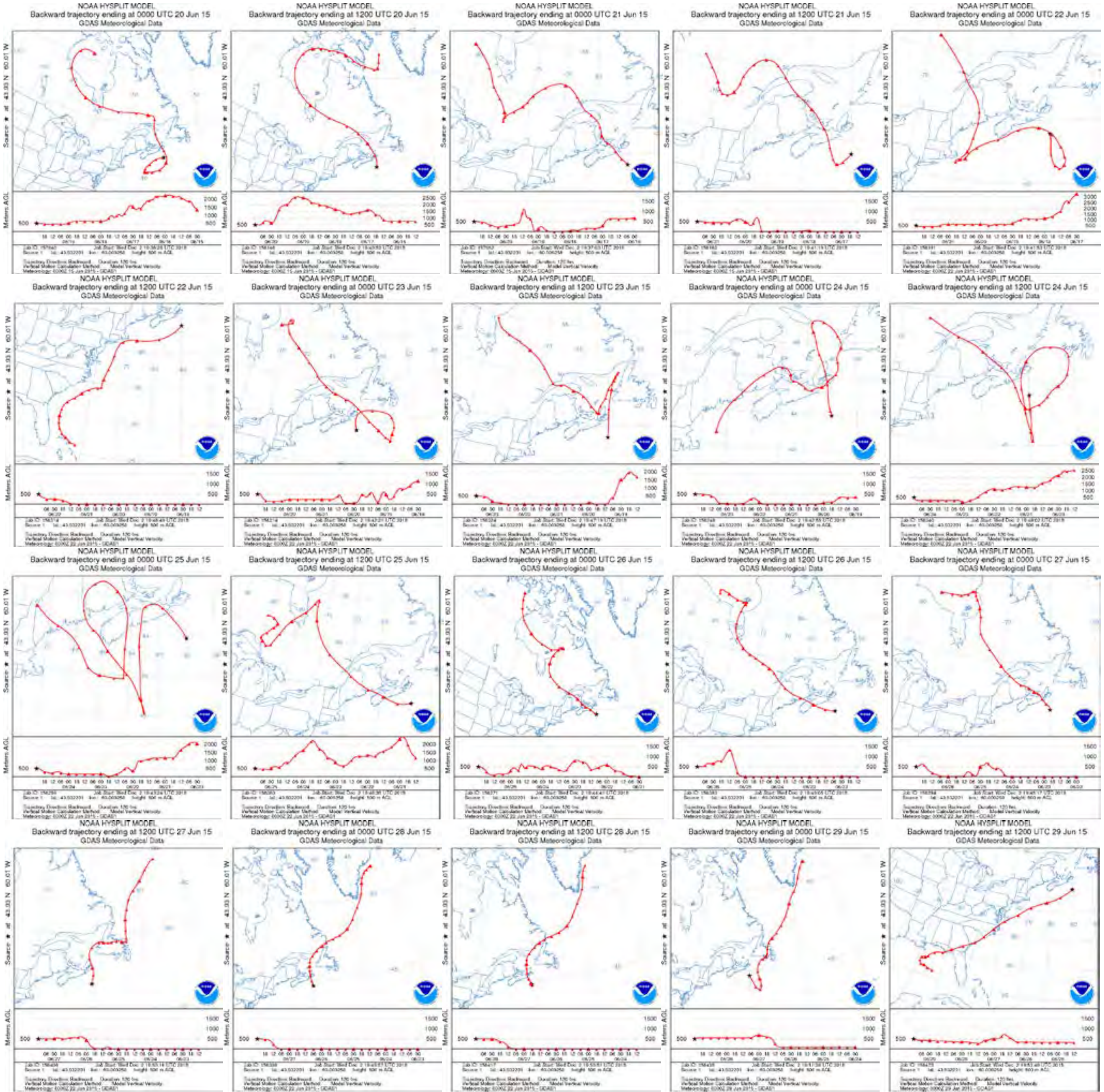

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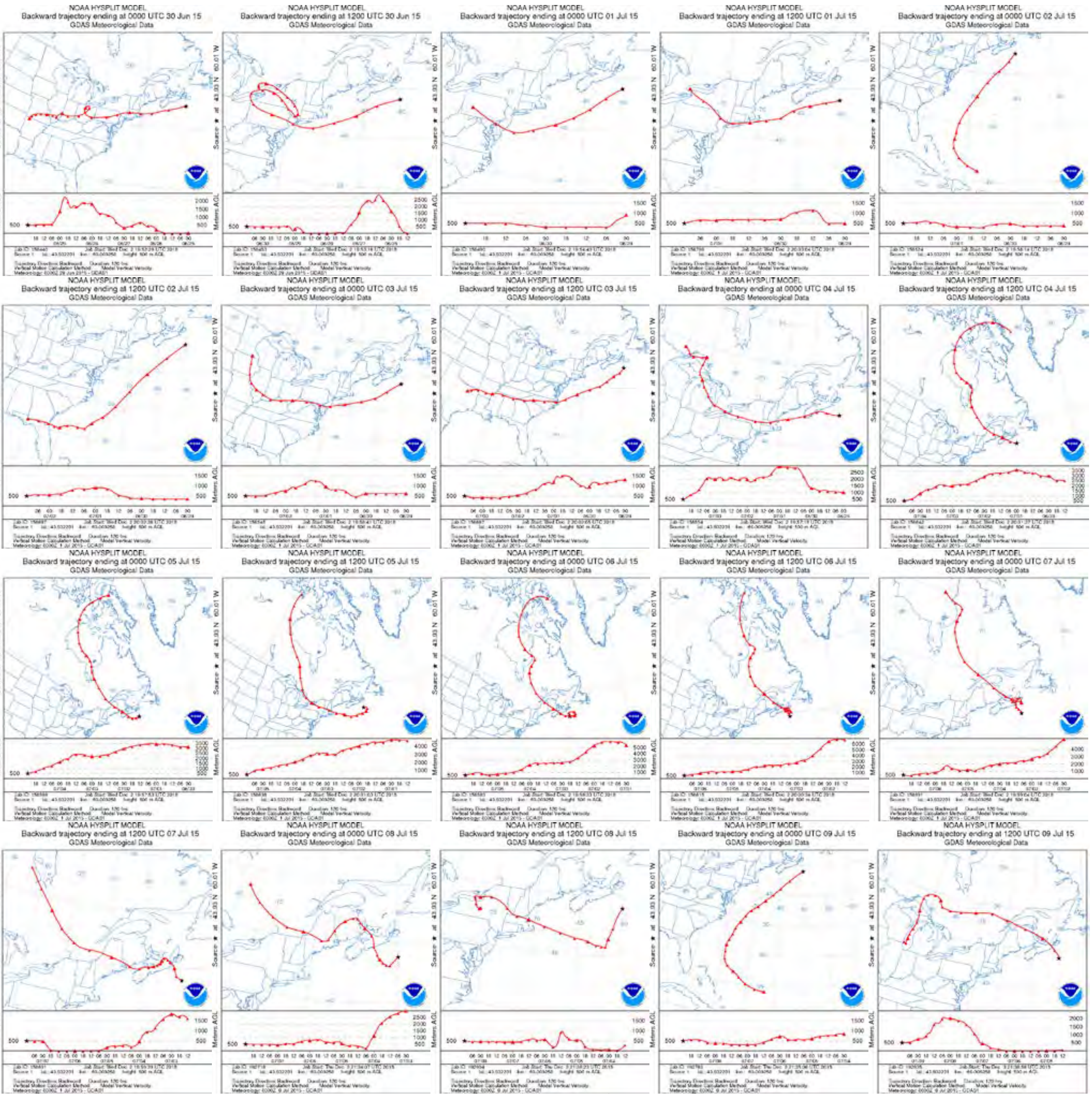
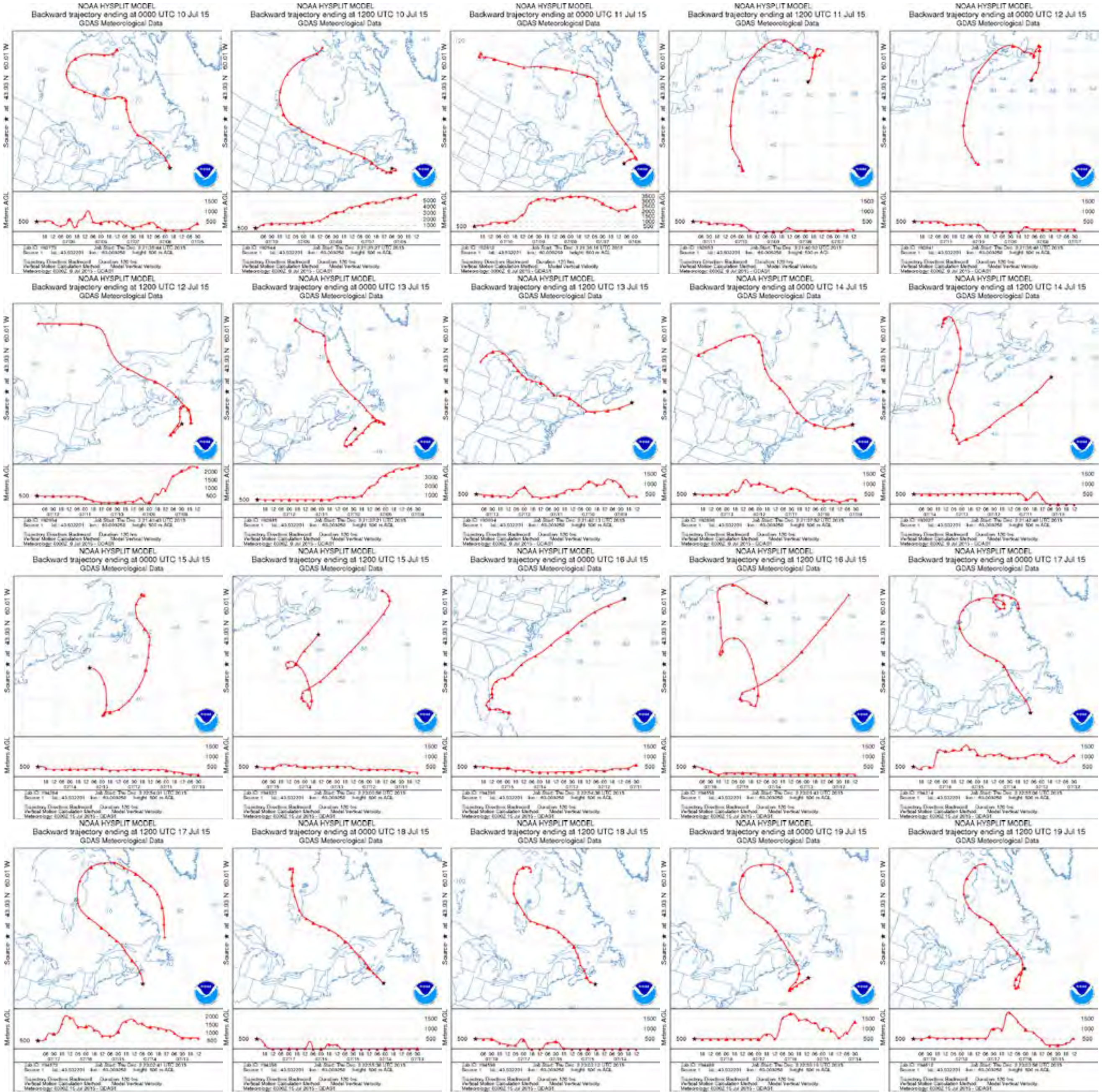
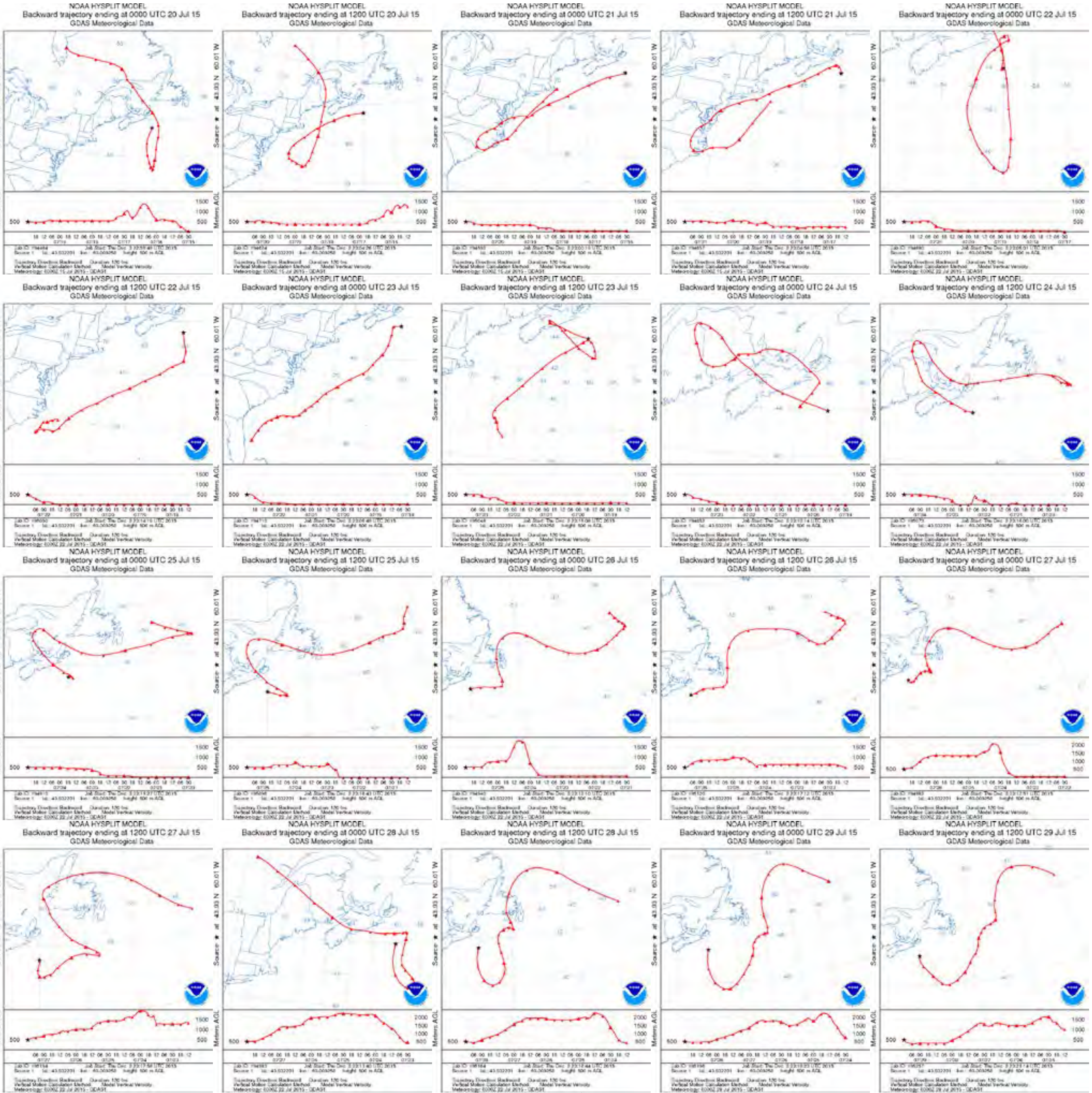


June 30th – July 09th, 2015



July 10th – 19th, 2015



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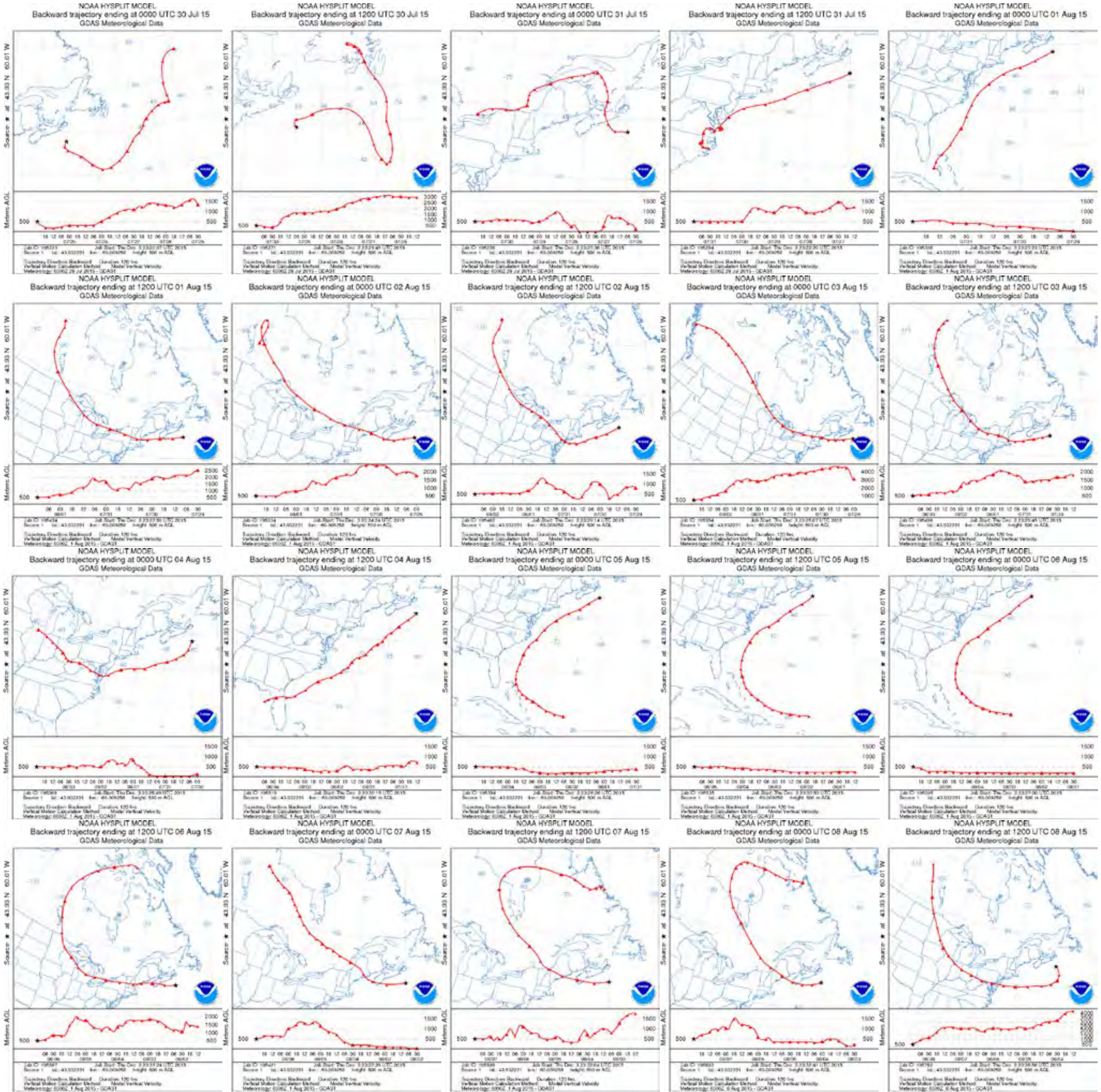

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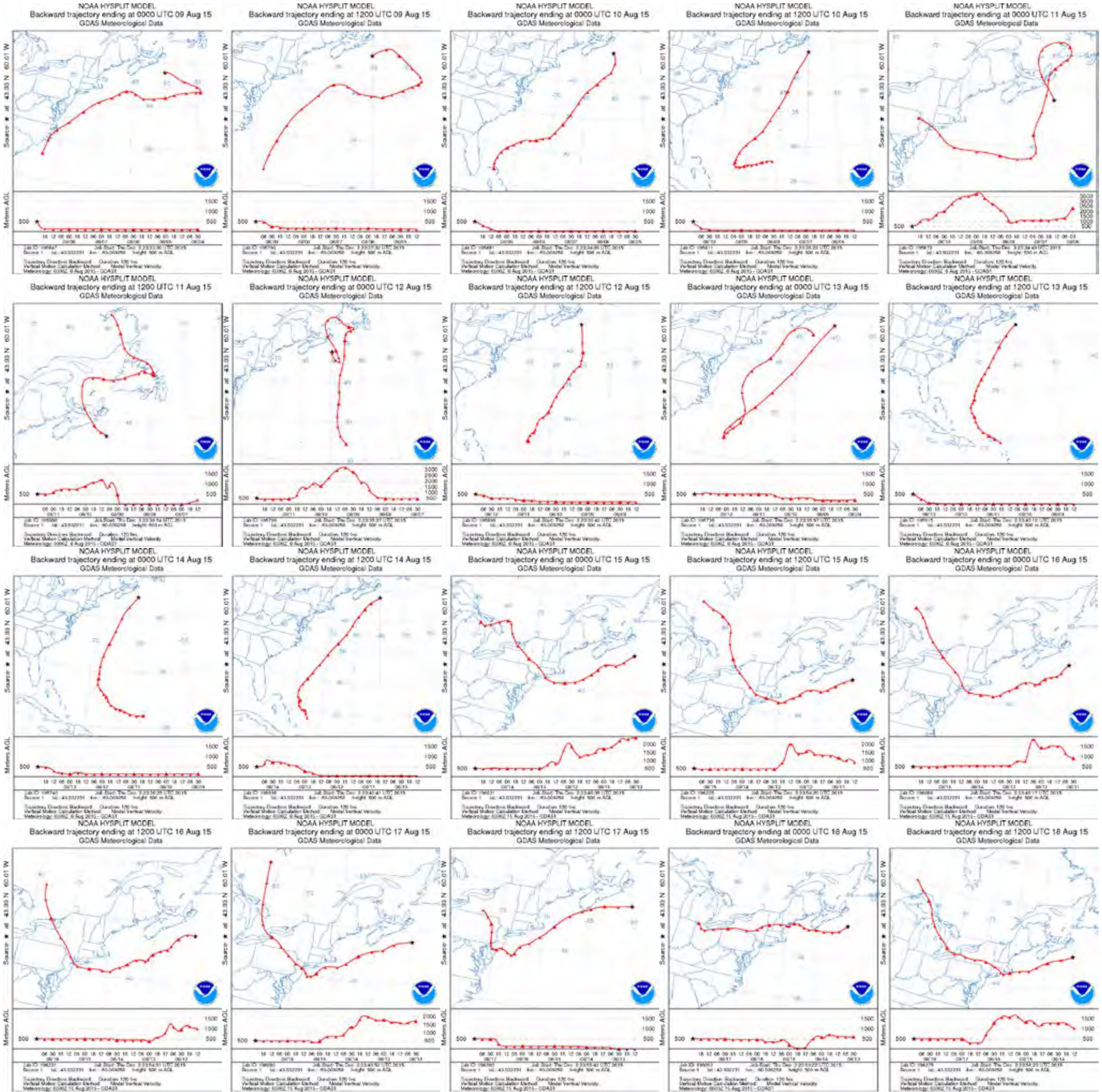

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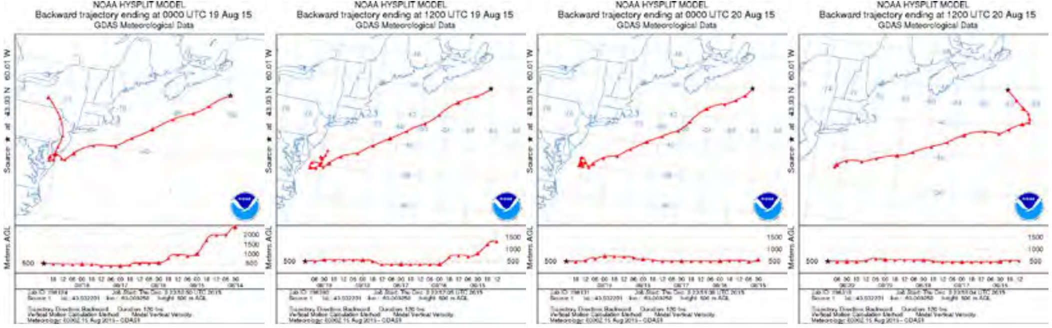

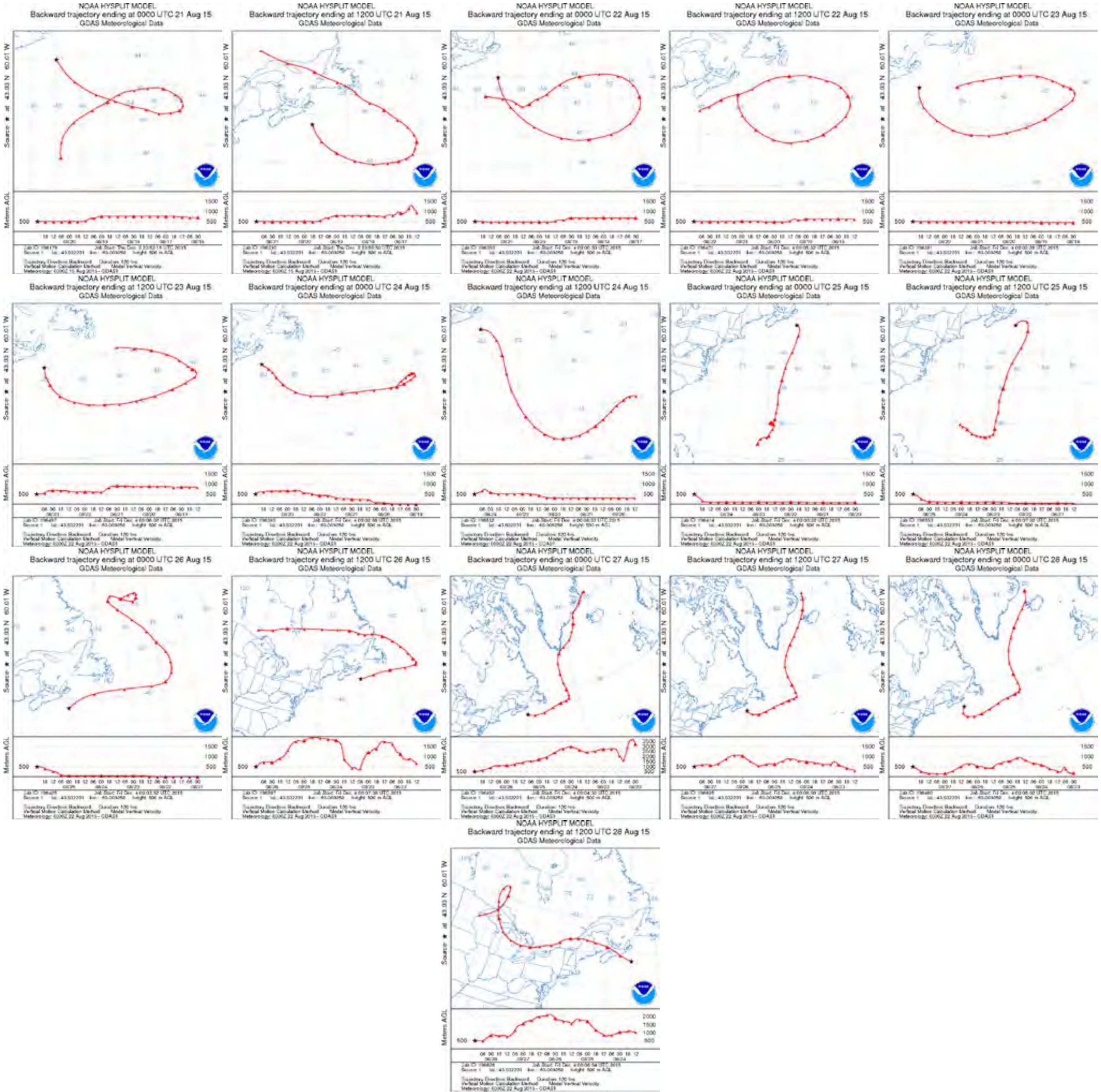

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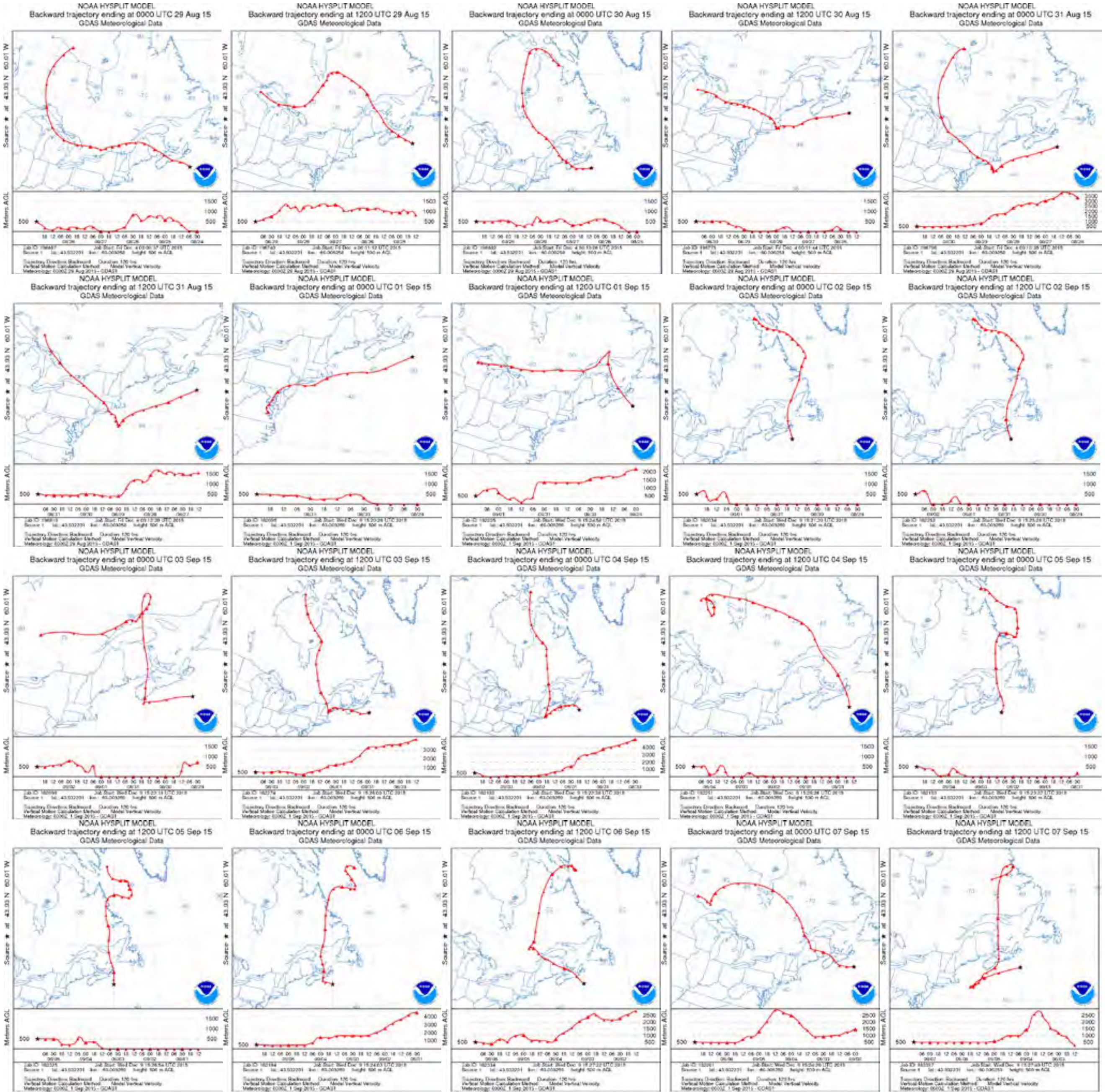

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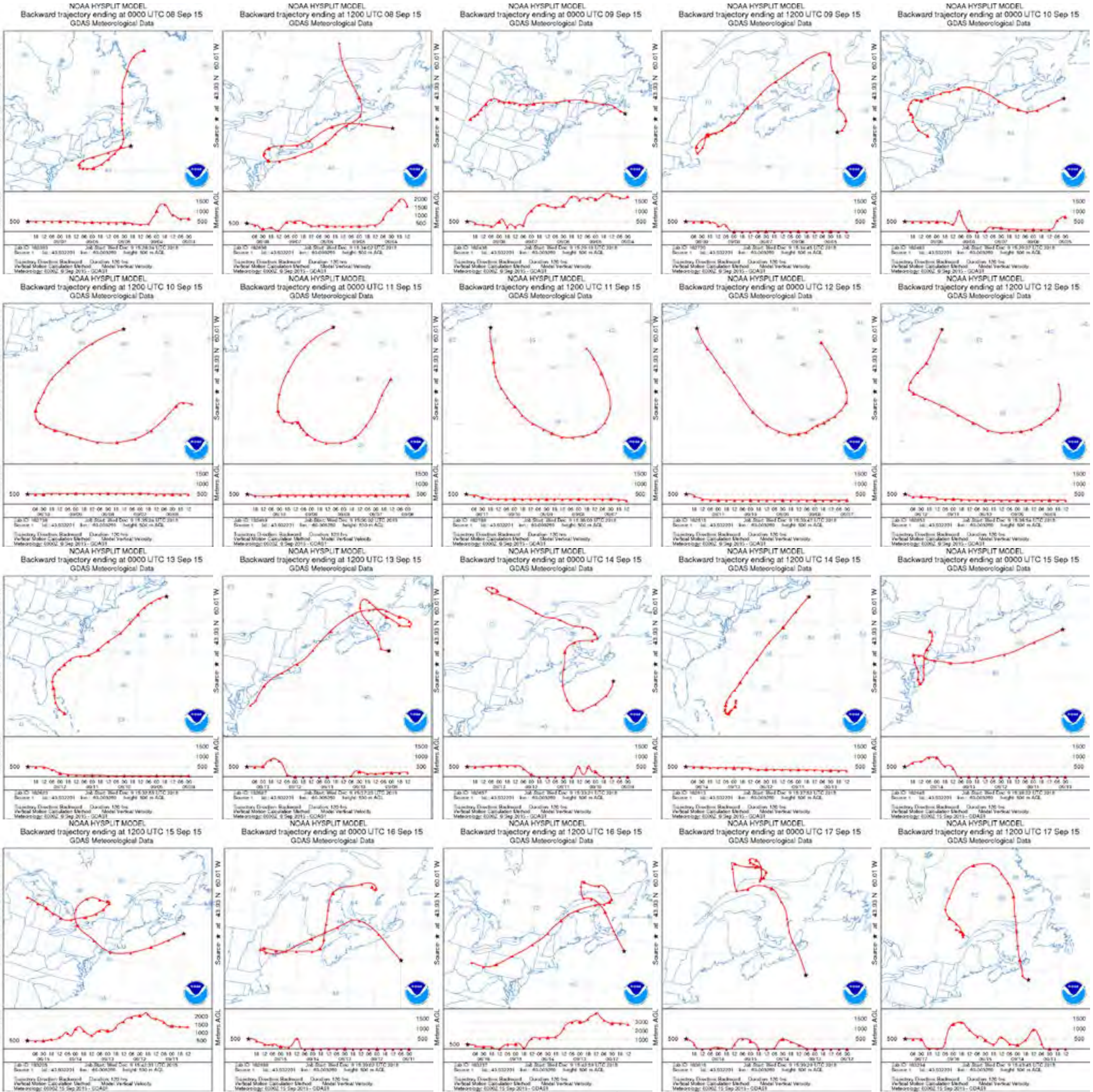

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GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 08 Sep 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
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GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 15 Sep 15
GDAS Meteorological Data

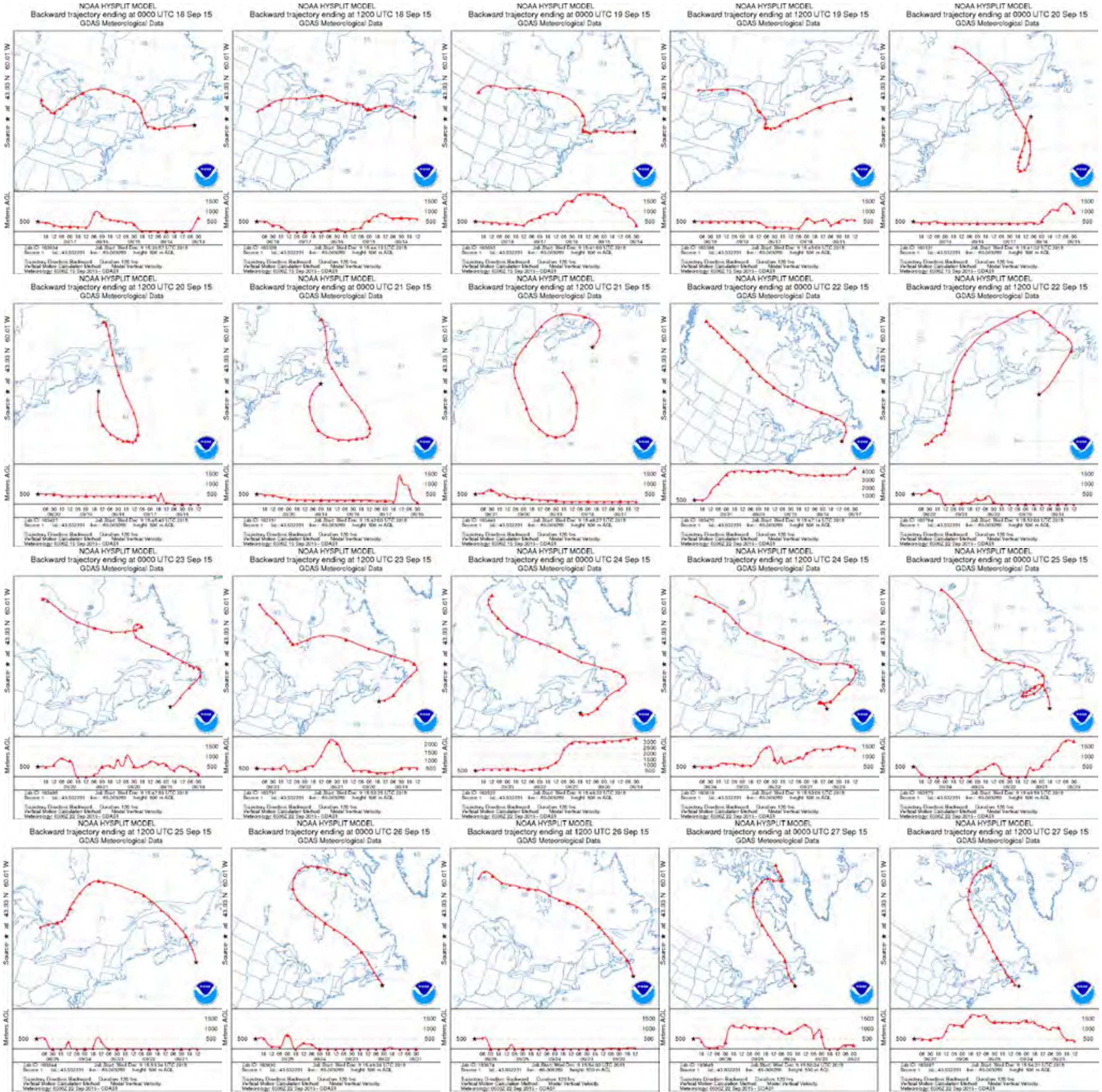
NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 16 Sep 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 16 Sep 15
GDAS Meteorological Data

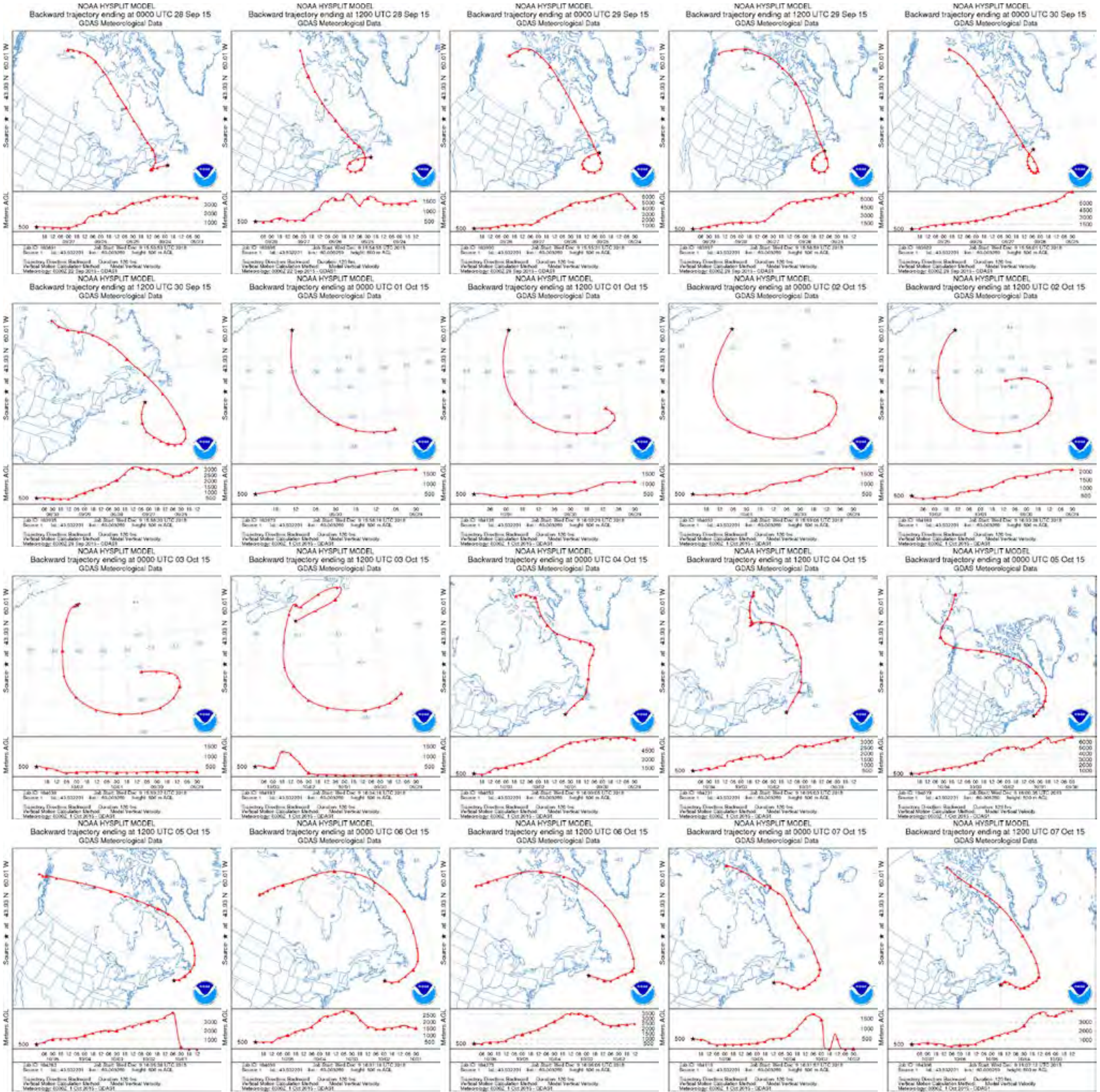
NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 17 Sep 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 17 Sep 15
GDAS Meteorological Data

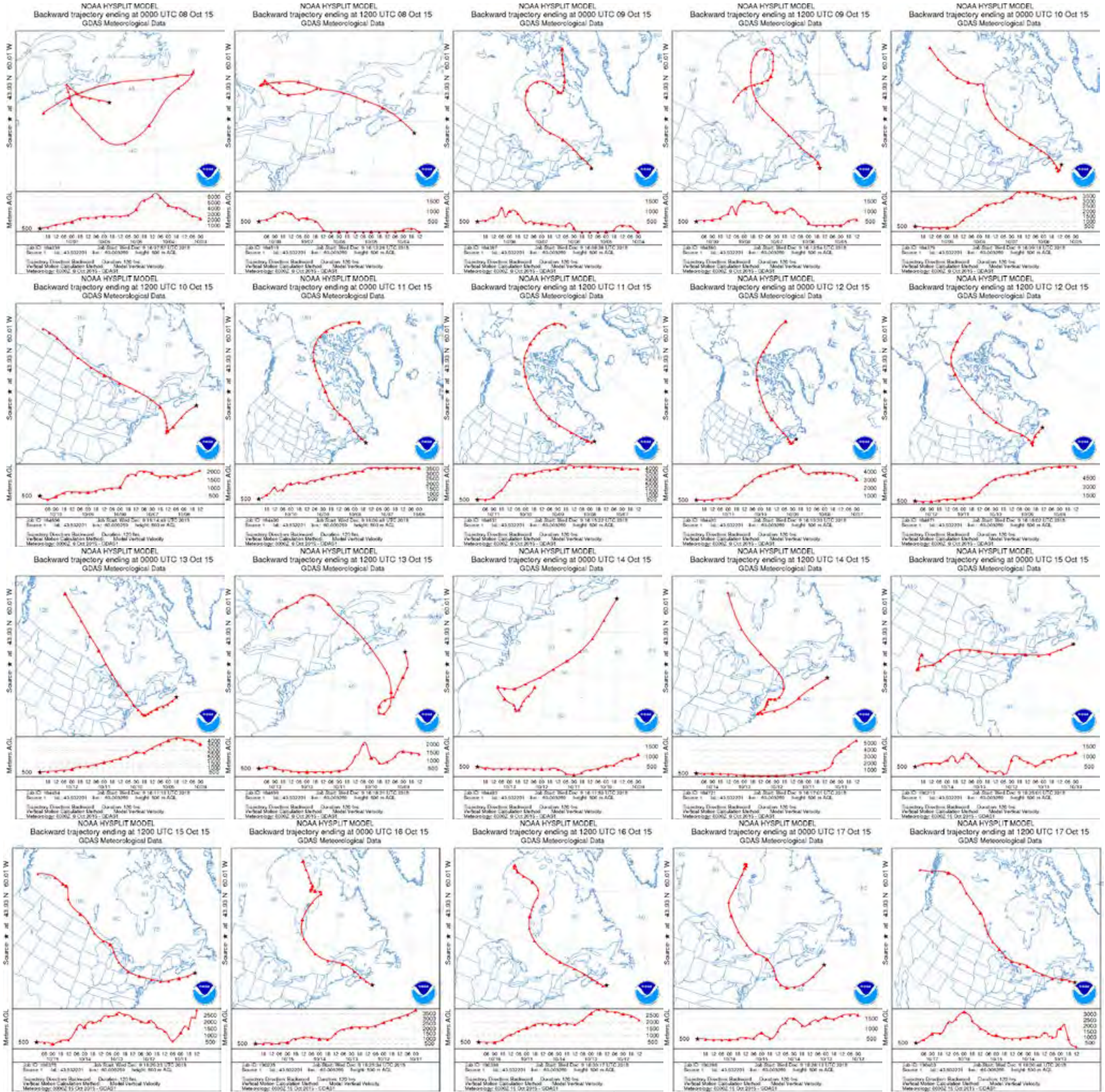
September 08th – 17th, 2015



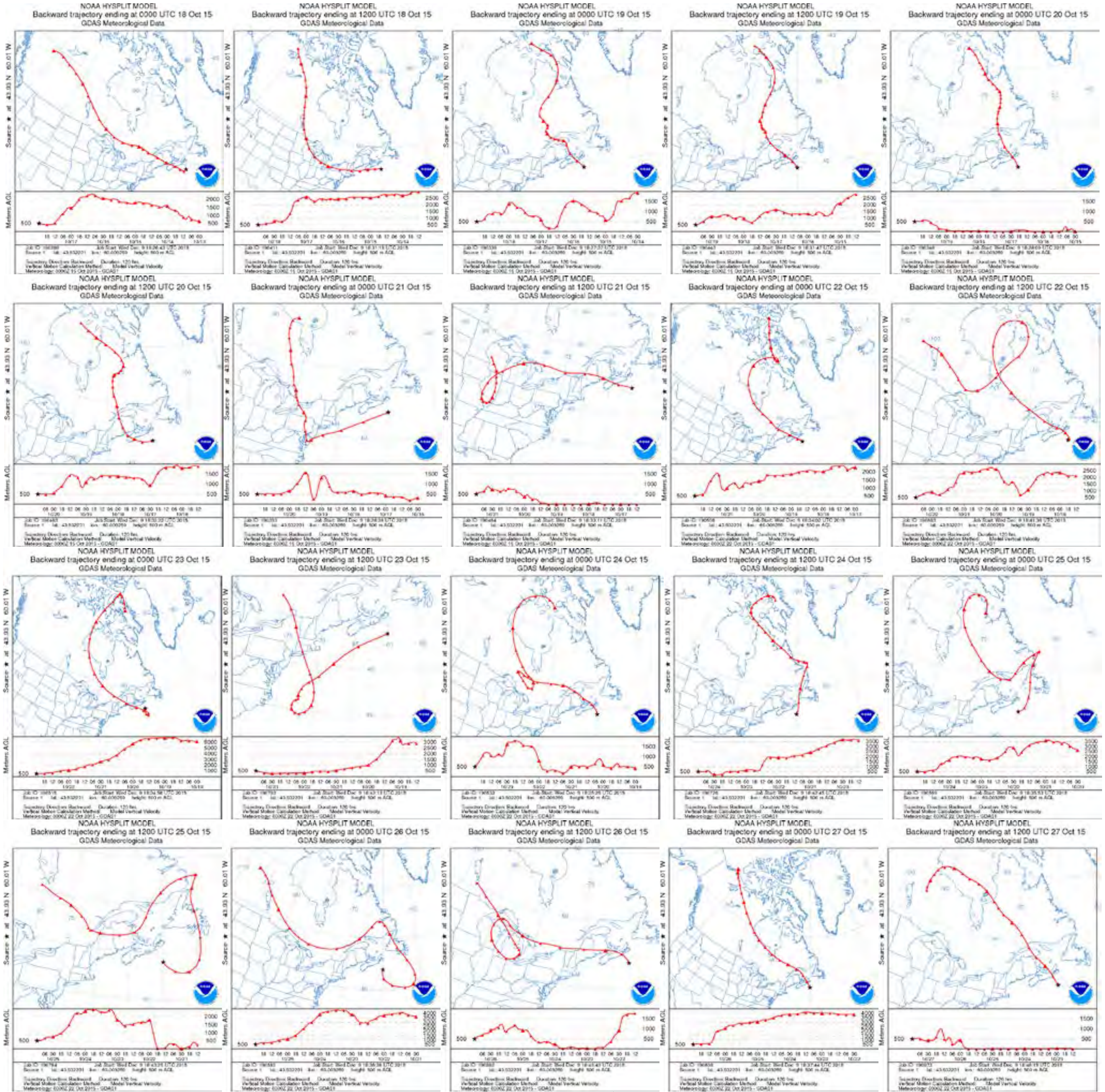
September 18th – 27th, 2015



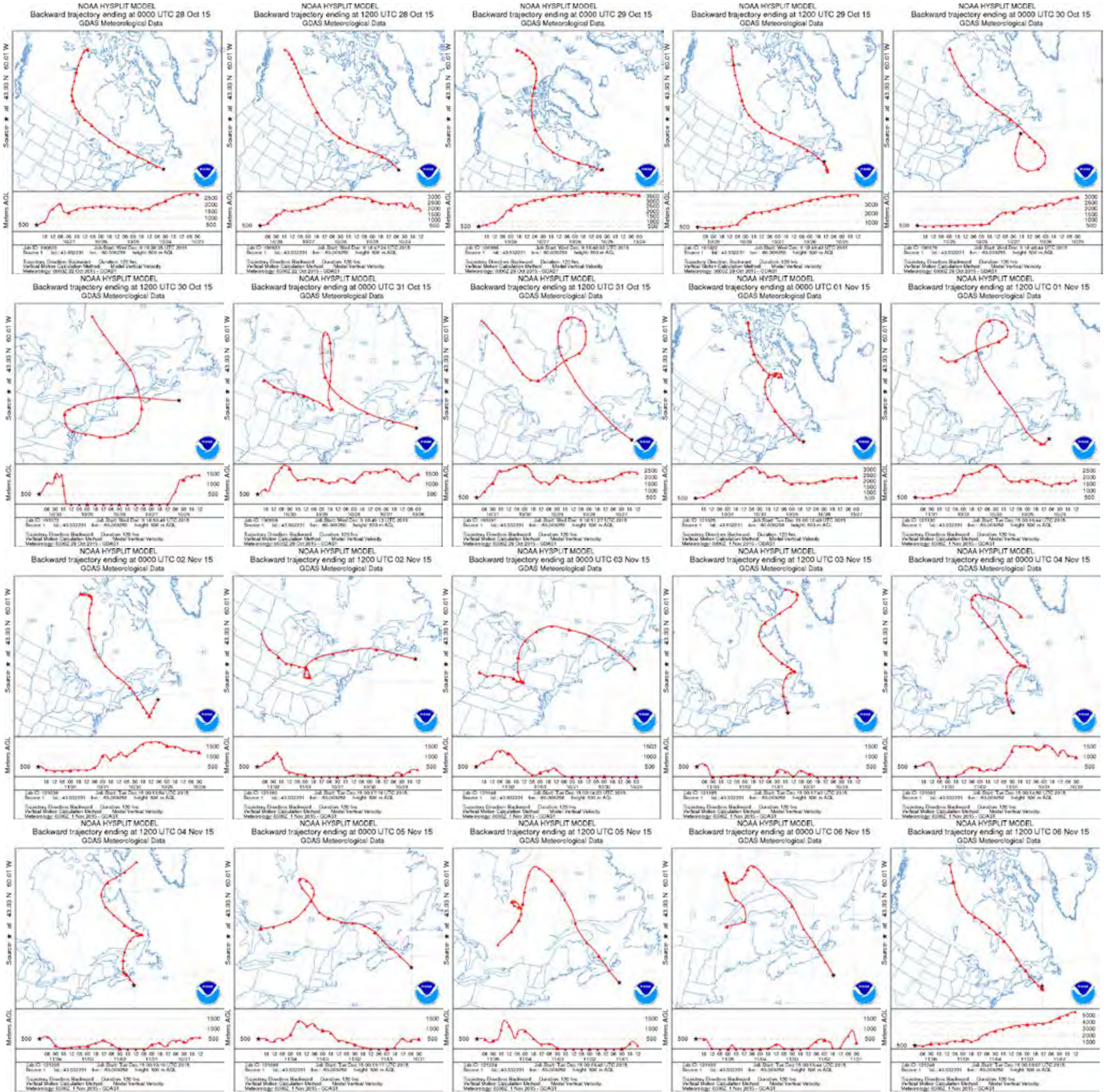
September 28th – October 07th, 2015



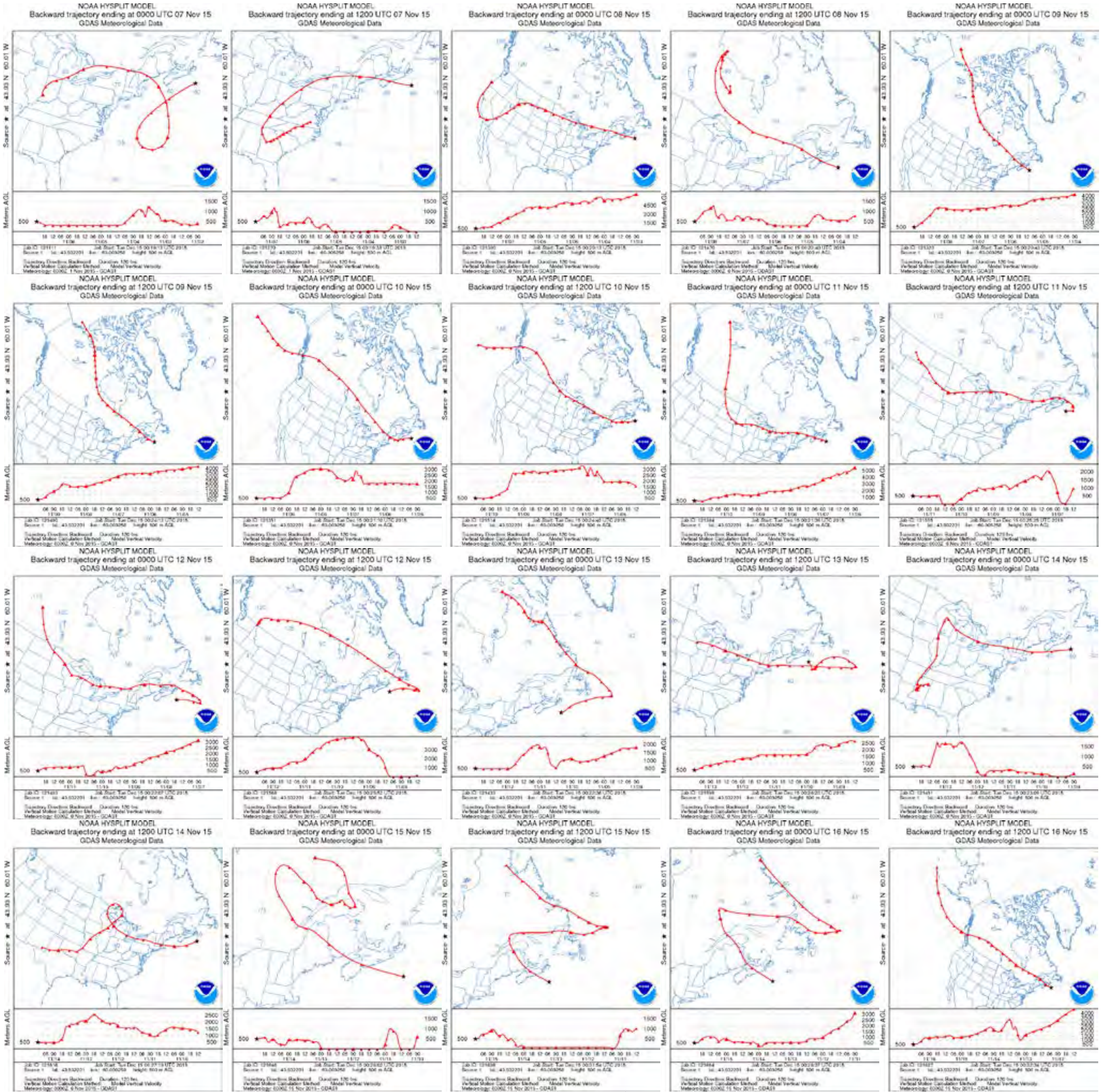
October 08th – 17th, 2015



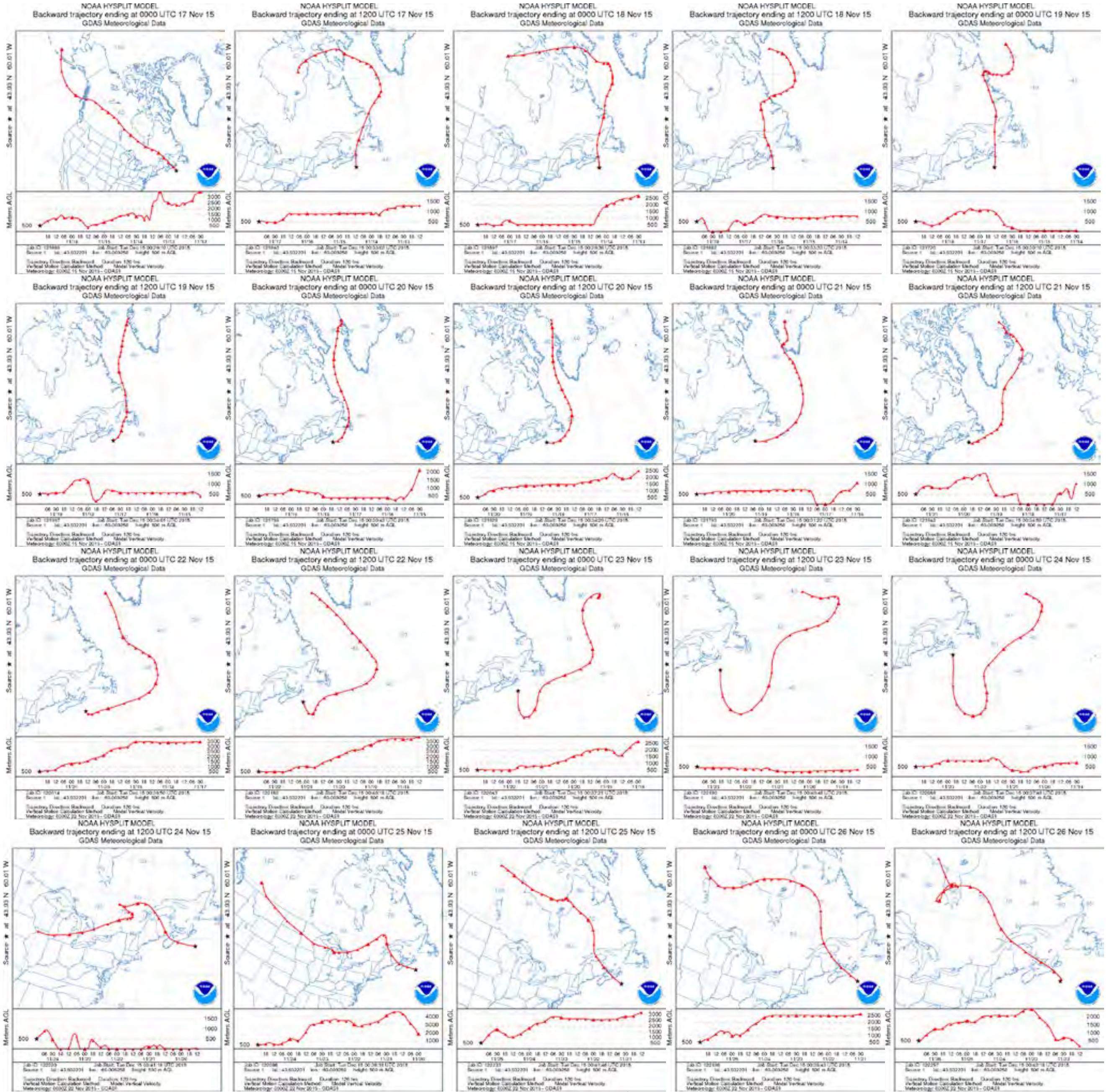
October 18th – 27th, 2015



October 28th – November 06th, 2015



November 07th – 16th, 2015



NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 17 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 17 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 18 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 18 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 19 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 19 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 20 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 20 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 21 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 21 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 22 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 22 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 23 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 23 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 24 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 24 Nov 15
GDAS Meteorological Data

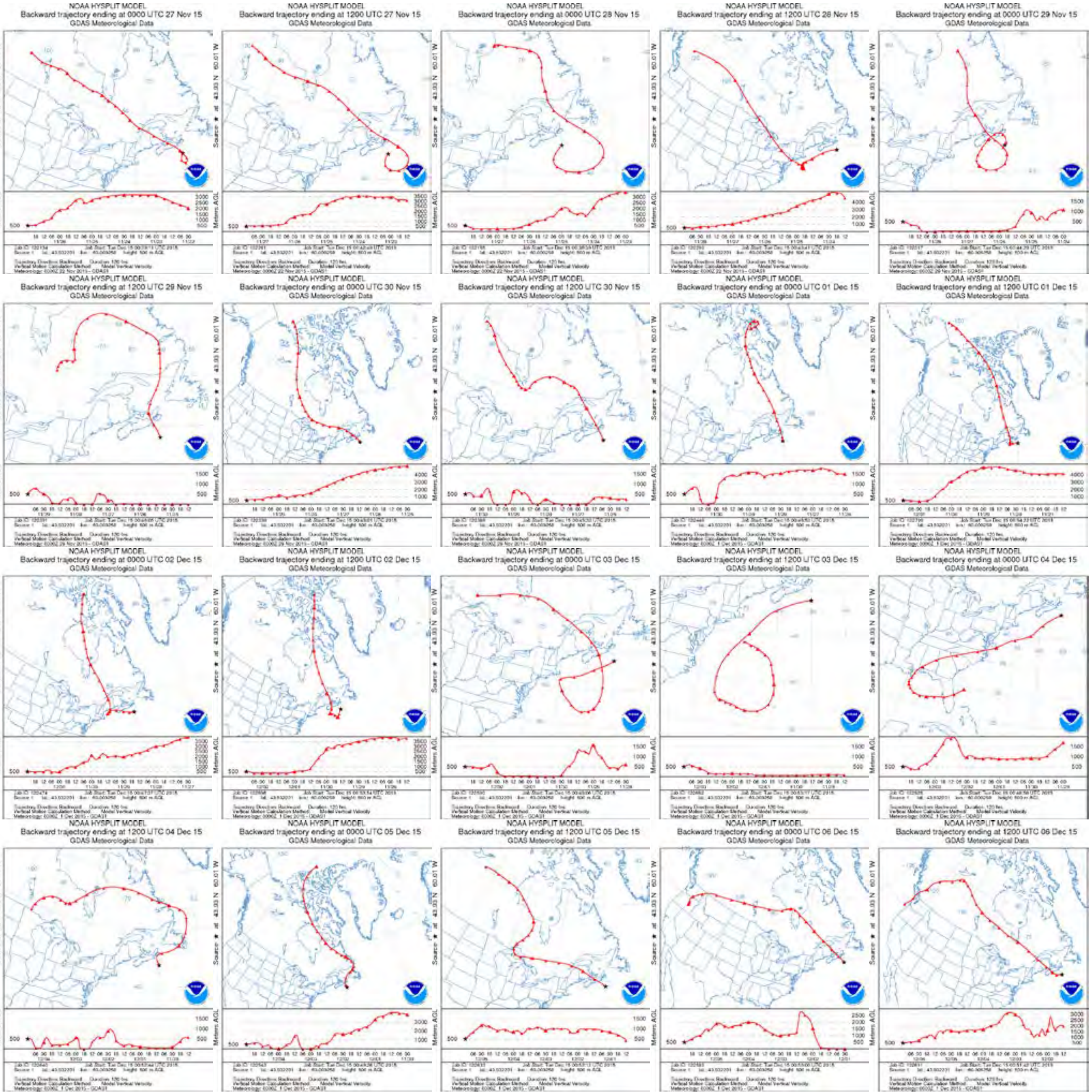
NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 25 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 25 Nov 15
GDAS Meteorological Data

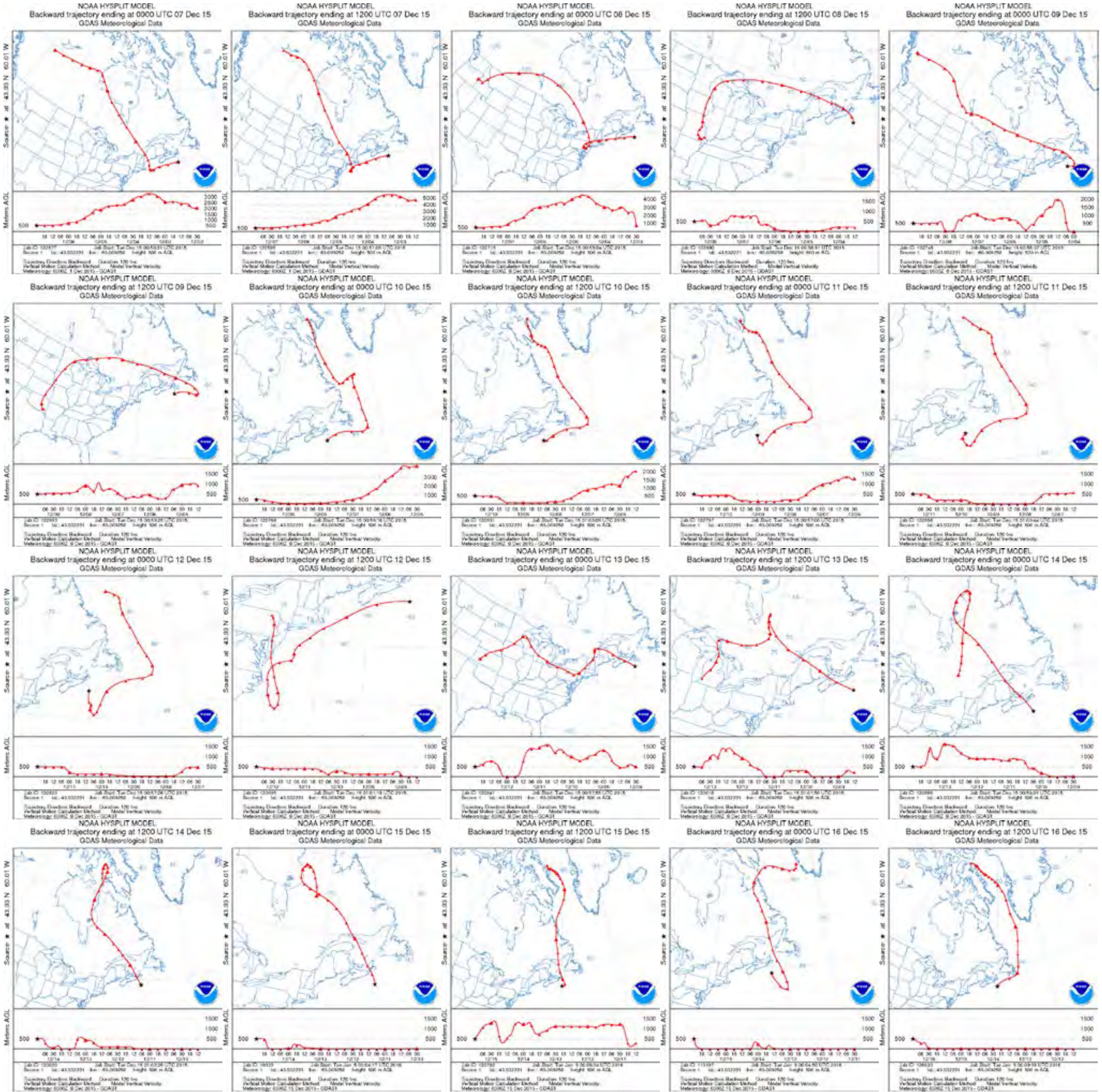
NOAA HYSPLIT MODEL
Backward trajectory ending at 0000 UTC 26 Nov 15
GDAS Meteorological Data

NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 26 Nov 15
GDAS Meteorological Data

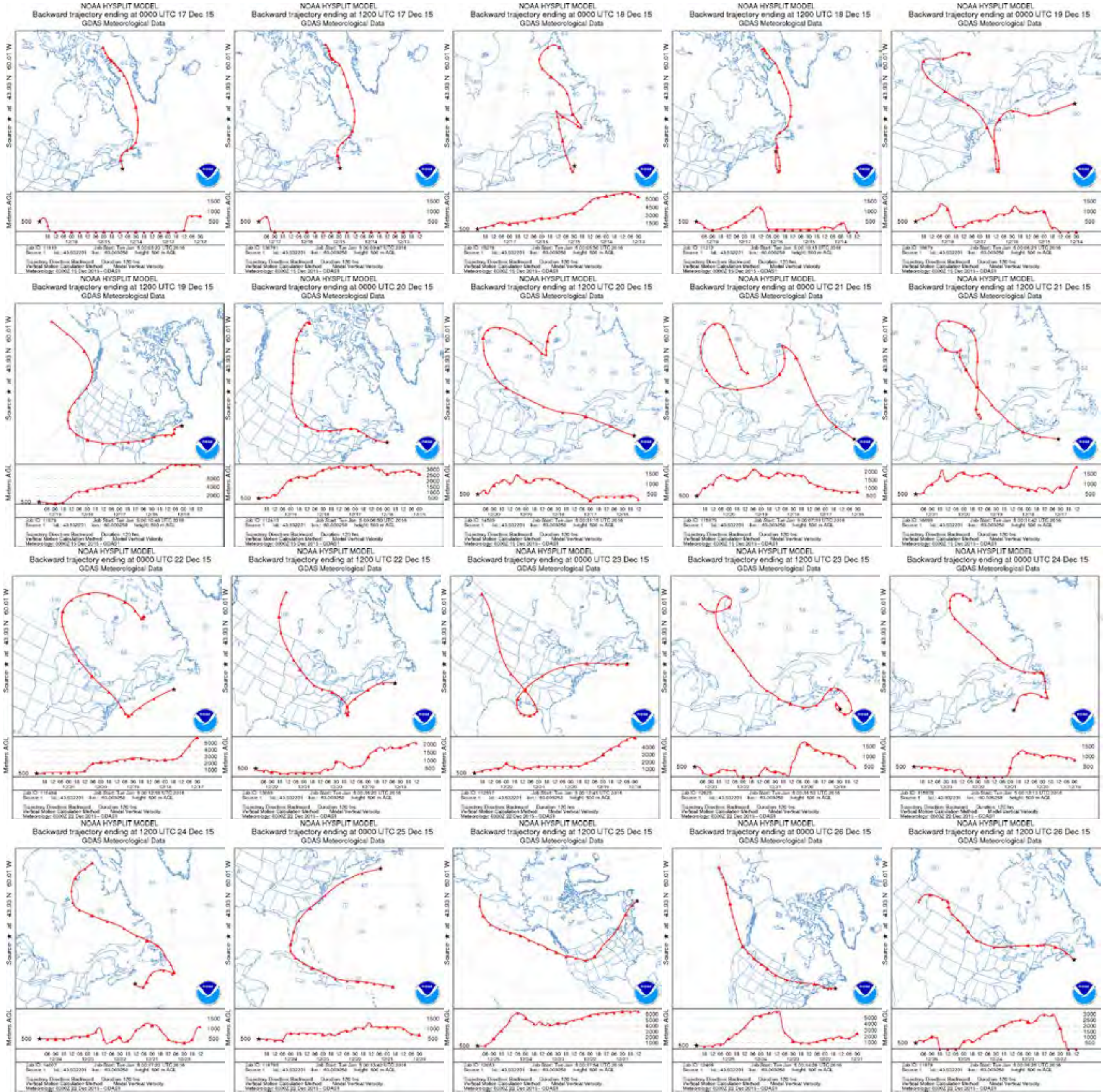
November 17th – 26th, 2015



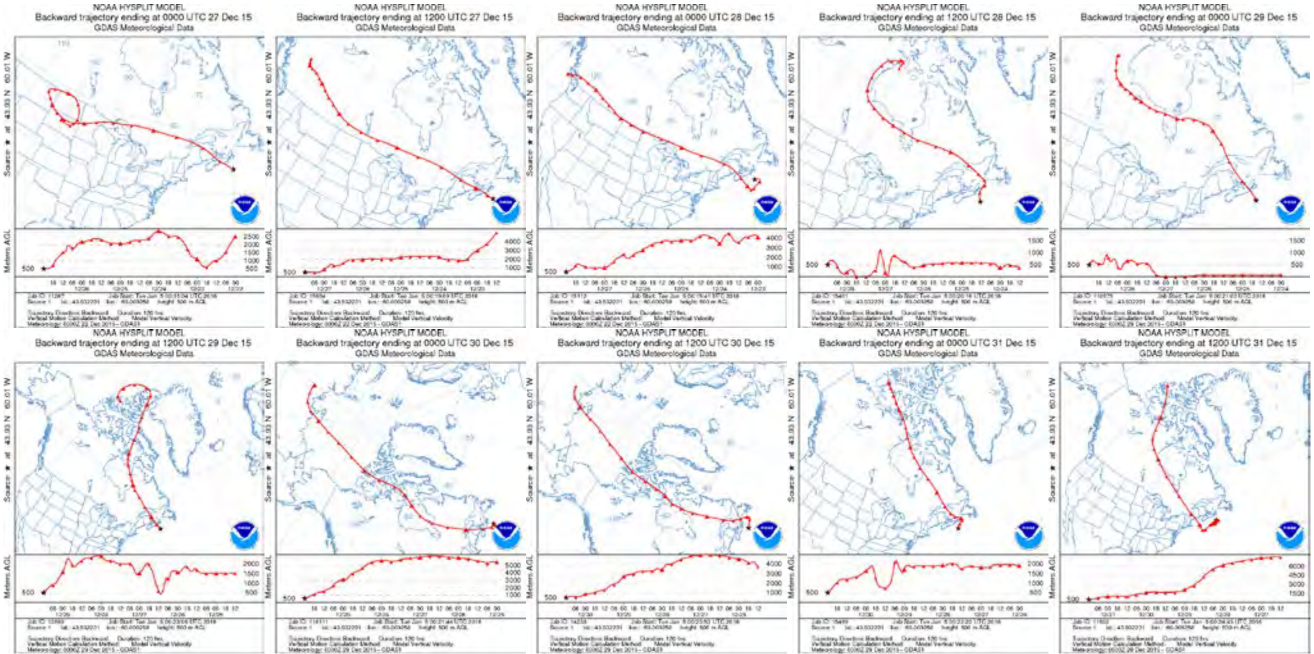
November 27th – December 06th, 2015



December 07th – 16th, 2015



December 17th – 26th, 2015



December 27th – 31st, 2015