Inch Cape Offshore Wind Farm

New Energy for Scotland

Offshore Environmental Statement:

VOLUME 2D

Appendix 12B: Contaminated Sediments Baseline Development Area

Inch Cape Offshore Wind Farm

Appendix 12B: Contaminated Sediment Baseline Development Area

AMEC Environment & Infrastructure UK Limited

January 2013

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2	Repsol Review	January 2013
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Inch Cape Offshore Wind Farm

Appendix 12B: Contaminated Sediment Baseline Development Area

AMEC Environment & Infrastructure
UK Limited

January 2013

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Executive Summary

This report presents the baseline conditions for contaminated sediment at the Development Area. Results from a sampling program undertaken at the Development Area and surrounding area are given and compared to Cefas Action Levels (AL), Canadian Sediment Quality Guidelines and Dutch Standards to ascertain the level of contamination in relation to biological effects. The spatial distribution of contaminants associated with sediments at the Development Area is also assessed with the aim of identifying any enhanced areas of contamination. Additional sampling campaigns, namely the Clean Seas Environmental Monitoring Program (CSEMP) and the monitoring of the disposal ground at Bell Rock, provide background levels to compare against the results seen at the Development Area. Comparison is used to gain an understanding of the conditions at the site in context with the local marine environment. This is particularly important at this site due to the history of sewage sludge disposal and thus the potential sink of contaminants being released upon disturbance during the construction of the works in the Development Area. Baseline information presented here will then be used to inform the Environmental Statement to assess the potential impact of contaminated sediments on benthic fauna and the wider marine environment.

Following a survey program agreed with Marine Scotland, during April and May 2012 triplicate sediment samples were taken from 20 stations positioned within the Development Area, tidal excursion and control area using a 0.1 m^2 day grab. Sediments in the day grab were assessed visually and sub-samples stored in acid washed containers. One sample from each site was immediately transported to the United Kingdom Accreditation Service (UKAS) accredited laboratory, the National Laborotory Service (NLS), for analysis and the remaining samples were frozen at -20 ^{o}C.

Analysis included particle size analysis (PSA), total organic content (TOC), sulphide, metals, poly-aromatic hydrocarbons (PAHs), poly-chlorinated biphenyls (PCBs) and organotin compounds. Following the initial results (A samples), the second replicate (B samples) from each station, in addition to a further two sites outside the Development Area boundary, were analysed for metals using both a full and partial digest extraction method to allow comparison with historical data sets and validate the A sample results.

PSA results showed that all samples had a low mud composition, with this sediment component constituting less than 10 per cent in the majority of samples. Samples were primarily sandy with fine and medium sand making up the largest proportion of most stations. However two stations had a finer composition, with very fine sand making up a larger percentage while coarser fractions, including large pebbles, were the main component at two stations. The sorting coefficient of the samples was variable with the full range of classes, very well sorted to very poorly sorted. TOC and sulphide was also low at all stations.

Analysis identified that PAHs, PCBs and organotins were low across the site, with results below Cefas ALs, Canadian Sediment Quality Guidelines and Dutch Standards. Metal analysis showed that levels were higher, relatively, than the PCB, PAH, and organotin levels, with arsenic, cadmium, chromium, copper and nickel exceeding Cefas AL1 at the same sites for both A and B samples. Cefas AL2 was only exceeded at five stations within the A sample results for nickel and cadmium but these values were not reached in the B samples, suggesting that these results are anomalous. Through consultation with MS it was agreed that these levels were anomalous and could therefore be removed from the impact assessments (Email correspondence 5 November 2012). Levels of all contaminants were spatially variable across the site and there are no identified areas of enhanced contamination, despite the presence of the historical disposal ground, Bell Rock.

Metal results from the partial digest extraction were comparable to those recorded in 2002 at the Bell Rock disposal ground which suggests stable levels over the last decade, and literature reviews showed no significant effects on the benthos as a result of the disposal activities. Results from the Development Area were comparable to CSEMP data, however levels (particularly for metal contaminants) were generally slightly higher at the Development Area than CSEMP monitoring stations.

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12B.1 Introduction

12B.1.1 The Development

Inch Cape Offshore Limited (ICOL) are developing a Wind Farm and associated Offshore Transmission Works (OfTW). Definitions for the Wind Farm, OfTW, Development Area and Export Cable Corridor are as follows:

- Offshore Wind Farm/Wind Farm: Includes WTGs, inter-array cables, meteorological masts and other associated and ancillary elements and works (such as metocean buoys). This includes all permanent and temporary works required.
- Offshore Transmission Works (OfTW): The Offshore Export Cable and Offshore Substation Platforms (OSPs). This includes all permanent and temporary works required.
- Development Area: The area which includes WTGs, inter-array cables, OSPs and initial part of the Offshore Export Cable and any other associated works (see Chapter 7 Figure 7.1).
- Offshore Export Cable Corridor/Export Cable Corridor: The area within which the Offshore Export Cables will be laid outside of the Development Area and up to Mean High Water Springs (see Chapter 7 Figure 7.1).

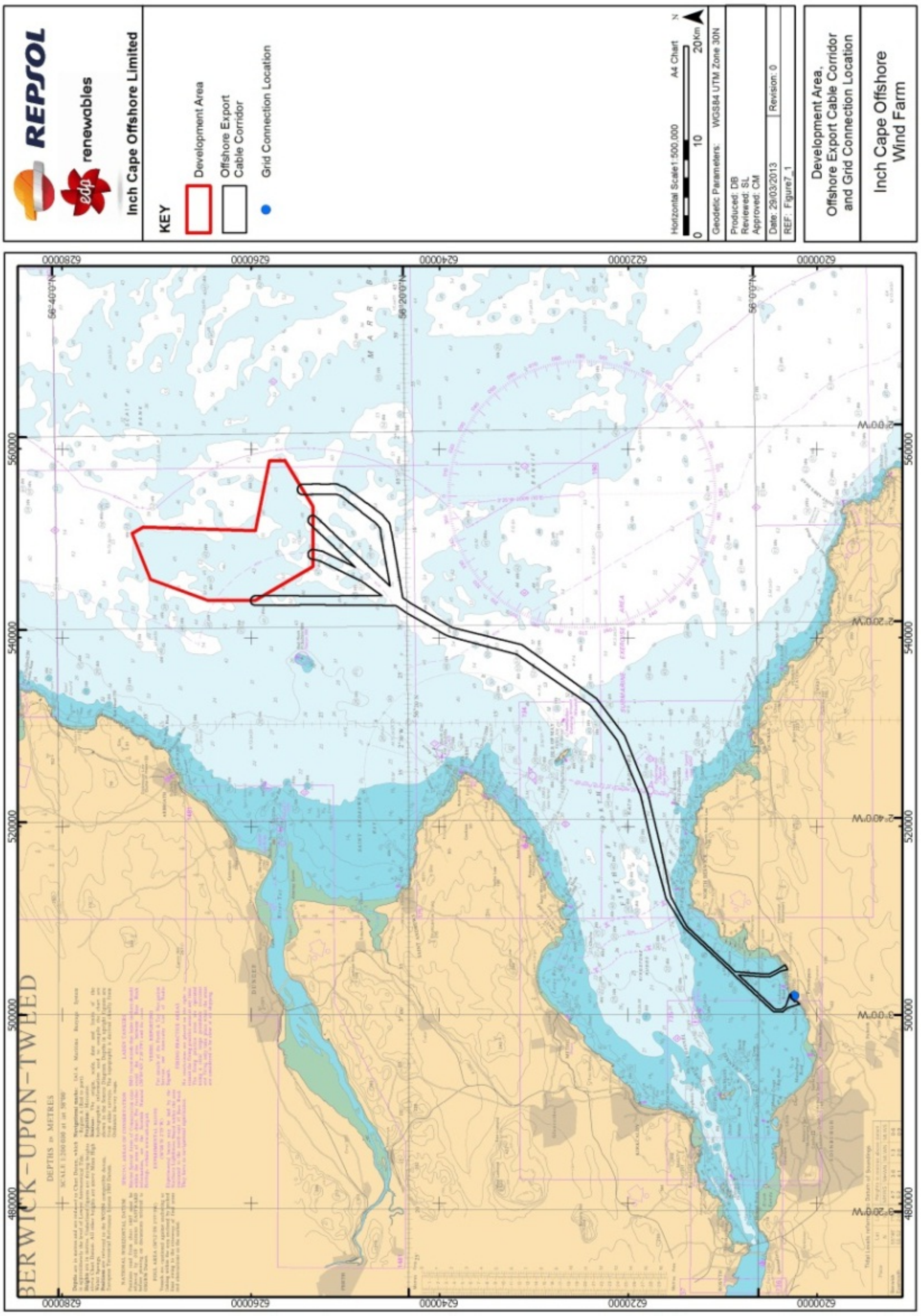
The Development Area and Offshore Export Cable Corridor and Regional Study Area can be seen in Figure 12B.1.

12B.1.2 Aims of this Study

The Environmental Impact Assessment (EIA) process for an offshore wind farm requires a full understanding of the environmental conditions of the area in which the introduction of the project may cause affects. This requires a full review of any existing contaminated sediment data as well as the targeted collection and analysis of sediment at the Development Area and adjacent areas. A separate study was commissioned for the Offshore Export Cable Corridor (see Appendix 12C Benthic Ecology Baseline Offshore Export Cable Corridor).Sample locations for this survey work were positioned to allow the assessment of the current level of sediment bound contaminants across the development site (i.e. within the Development Area), as well as to sample within the tidal excursion area and in a control area outside of the tidal influence. Sampling was particularly focused to collect data in and around a historical disposal ground (Bell Rock) which is found at the southern extent of the Development Area.

The primary aim of this study is to inform the EIA through analysis and mapping of the level of contaminants in the marine sediments at the Development Area. In the absence of statutory UK guidelines on threshold levels of contaminants in offshore sediments, the results of the survey were compared against Cefas Action Levels (ALs) which relate to contaminant levels in dredged sediments destined for disposal at sea. Where Cefas ALs do not exist for particular substances, Canadian Sediment Quality Guidelines and Dutch Standards are used instead to facilitate the analysis of the effects certain levels will have on the marine environment. Further comparisons are made against historical monitoring of contaminated sediments in the area undertaken as part of the Clean Seas Environmental Monitoring Programme (CSEMP) and sampling programs at the Bell Rock disposal ground. This study will support the impact assessment which is summarised in the ES Chapter 12: Benthic Ecology alongside information from Chapter 10 Metocean and Coastal Processes to ascertain the likelihood of any biological impact via mobilisation of contaminated sediments during the construction, operation and/or decommissioning phases of the project. In addition the study will inform the assessment in Chapter 13: Natural Fish and Shellfish.

Figure 12B.1 Development Area



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12B.1.3 Background Contamination Data

Chemicals released into the marine environment as a result of human activities can be persistent, toxic to flora and fauna, and can bio-accumulate up the food chain. The effects of chemical contaminants in the marine environment are well documented, resulting in sub-lethal or lethal effects which can act through a variety of pathways including endocrine disruption, as well as interfering with metabolic activity.

Large scale assessments of North Sea sediment contamination and water quality give some indication of the contamination status of the Development Area. Based on existing desk-based data, no specific areas of pollution in the vicinity of the Development Areaare identified (SEA 5, 2004). Typically, contamination studies are more widely available in coastal and estuarine habitats, with intermediate and offshore waters less well studied. However, Bell Rock disposal ground provides historical contamination data for the Development Area. This historical disposal ground, part of which sits within the Development Area, was used to dispose of sewage sludge from 1978 to 1998 (discussed further below). At this site, a series of monitoring studies, most recently reviewed by Hayes et al. in 2005, have taken place to determine the level of contaminants and assess any effects on the benthic biota. Results of this monitoring to date highlight no accumulation within sediments, which is likely to be as a result of the reported highly dispersive environment. Data from these studies, provided by Marine Scotland, shows that from 1991 to 2002 (the most recent sampling) the only contaminant to exceed Cefas AL1 was arsenic in 1993. Active coastal spoil grounds for dredged material are also found near to the Development Area at Montrose, Arbroath and in the Tay Estuary. Contamination records for these disposal sites show that in 2010 contaminant levels are generally low, with only four heavy metals exceeding Cefas AL1 at the Tay Estuary site. **Figure 12B.2** displays the disposal grounds in proximity to Development Area and their status.

Monitoring through CSEMP provides contaminant data for metals, poly-aromatic hydrocarbons (PAHs) and poly-chlorinated biphenyls (PCBs) in biota and sediments at a number of Scottish east coast sites between Arbroath and Montrose, and offshore at Montrose Bank. Data from 2010 shows levels to be generally low, with only chromium recorded above AL1 at the coastal Tay – Montrose Intermediate sites. These data can be used to compare the levels discovered in the targeted baseline survey to improve the spatial and temporal understanding of contamination within marine sediments at the Development Area. Available contamination data in the locality of Development Area is summarised in **Table 12B.1**.

Table 12B.1 Historical Data Sources

Source	Data Set	Analysis
Marine Scotland	Bell Rock Disposal Ground contamination data in 1991, 1993, 1995, 1998 and 2002, plus 2007	Arsenic, cadmium, chromium, copper, mercury, nickel, lead, zinc (1991 and 2007), PAH total (2002 and 2007) TBT, Total PCB and ICES 7[1] (2002).

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[1] Group of 7 PCB congeners known as the International Council for the Exploration of the Sea (ICES) set

Source	Data Set	Analysis
	data at Bell Rock.	
	Montrose disposal ground (1993, 2004 and 2007) contamination data.	Arsenic, cadmium, chromium, copper, mercury, nickel, Lead, Zinc (1993 and 2004), PAH total (2007) TBT (2004), Total PCB and ICES 7 (2004).
	Arbroath disposal ground (1993) contamination data.	Arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc.
	Tay (Middle Bank) disposal grounds (1998) contamination data.	Arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc.
CSEMP	Montrose Bank and coastal sites between Arbroath and Montrose. Dates variable, generally from 1999 to current.	Arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc. PCBs sum of ICES 7, acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, chrysene + triphenylene, dibenz[a,h]anthracene, fluoranthene, fluorine, naphthalene, phenanthrene, pyrene.

12A.1.1.1 Effects of Contamination in the Marine Environment

Major sources of contamination in the marine environment are terrestrial emissions and discharges, shipping, military activities and offshore industries (SEA 5, 2004). Harmful substances, including heavy metals, poly-aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and organotins, e.g. tributyltin (TBT) and dibutyltin (DBT), released into the marine environment through anthropogenic activity are persistent, toxic and have been found to bio-accumulate. Large scale contamination of the marine environment has been principally associated with industrial development since the 19th century (SEA 5, 2004) and the negative effects on the marine environment are well documented in the literature as detailed below.

Metals

Contamination of the marine environment with metals can have lethal and sub-lethal effects on fauna depending on concentrations present. Generally it is believed that heavy metals are associated with the smaller particle sizes, with relationships reported between fine-grained material and heavy metals in North Sea sediments (Thorne and Nickless, 1981). Excessive concentrations result in significant environmental effects (SEA 5, 2004); with cadmium, lead and mercury generally regarded to be of most concern (OSPAR, 2000). Some metals such as copper are known to be acutely toxic to invertebrate groups, e.g. crustaceans, and as such are used in anti-fouling paints replacing TBTs. Despite the known toxicity to marine species, some taxa such as the polychaete, *Capitella capitata*, and oligochaete, *Tubificoides benedii*, can show tolerance to metal contamination, and in some cases heritable tolerance has been demonstrated (Grant *et al.*, 1989).

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are persistent organic compounds which are both stable and toxic in the marine environment. PAHs are potential mutagens and carcinogens in marine organisms and humans. They can also bio-accumulate in marine organisms, particularly invertebrates such as bivalves which provide a prey source for fish, birds, marine mammals and humans. Fish can excrete PAH faster than other organisms such as bivalves, and as such do not bioaccumulate them in the same way (OSPAR, 2004a). However sub-lethal toxic effects have been observed such as growth reduction, chronic diseases and reproductive impairment (OSPAR, 2004a).

Poly Chlorinated Biphenyls (PCBs)

PCBs have been contaminants in the marine environment for over 60 years. Although the manufacture of materials containing PCBs was banned in 1986, they are persistent chemicals which occur in nearly all marine habitats and organisms and due to their persistence and lipid solubility they can bioaccumulate. Sources of PCBs to the marine environment during the height of their manufacture and use included aerial deposition, ocean dumping, wastewater discharge, vessel coatings, rainfall, and surface runoff (Parnell *et al.*, 2008). In the North Sea PCBs were used in transformer oils in electrical plants on platforms. Due to the hydrophobic nature of these compounds huge amounts have sedimented to the sea floor adsorbed to organic particles (Magnusson *et al.*, 2006). Marine sediments will therefore continue to serve as secondary sources of these contaminants, both to the benthic communities inhabiting them and to other organisms through food web transfer (Magnusson *et al.*, 2006). For PCBs entering the marine environment, bottom sediments are the ultimate repository where they may become a source for uptake by marine organisms through direct or indirect contact or, for filter-feeders, by ingestion.

PCBs act as endocrine disrupting chemicals in marine organisms and can cause disruption to reproduction and immunodeficiency in marine mammals. PCBs have been shown to be lethally toxic to fish in laboratory studies and can cause legions, reproductive problems and liver damage in humans (OSPAR, 2004 b). However, information about their impact on benthic species is relatively scarce (Danis *et al*., 2003).

Organotins

Organotins such as the biocide TBT were used to reduce fouling on marine structures and vessels. Their use was banned on vessels under 25m in 1987 and on all vessels in 2008. Restrictions on the use of TBT were enforced as the toxic effects it had on target organisms were beginning to be detected in non-target organisms. One of the effects of TBT is imposex, the development of male sex organs in female marine invertebrates. To date imposex due to TBTs has been reported in 150 species and toxicity can occur at very low concentrations (Smith *et al.*, 2006).

12A.1.1.2 Disposal Grounds

Due to the effects of contamination in the marine environment, monitoring is carried out by regulatory bodies to record levels, particularly at disposal grounds where contamination could enter the environment and accumulate. When reviewing this data, it is important to have threshold levels against which potential damage to marine flora and fauna can be assessed. Currently there are no statutory standards against which to assess the quality of marine sediments in the UK, however there are standards (Cefas Action Levels) relating to the upper limits of contaminant levels present in sediments which are allowed to be disposed of at sea (i.e. dredged sediments). To regulate the disposal of marine sediments at sea, levels of contamination within marine sediments are assessed against these Action Levels in order to help reduce any impacts (OSPAR, 2010). This pre-licensing assessment aims to prevent the disposal of highly contaminated sediments in the marine environment and avoid the occurrence of direct toxic effects on marine animals and plants.

Cefas Action Levels do not give definitive threshold values. Two action levels are defined and the response to different levels of contamination within their boundaries is given (**Table 12B.2**):

- **Action Level 1-** Contaminants in sediments below this level are generally of no concern and are unlikely to influence the licensing decision about sea disposal.
- **Action Levels 1 and 2-** Contamination in sediments between levels 1 and 2 requires further consideration and testing before a decision can be made about sea disposal.
- **Above Action Level 2-** Contamination above this level is generally considered unsuitable for sea disposal.

Table 12B.2 Cefas Action Levels for Metals, PAHs, Organotins and PCBs in Sediments (MM0, 2011)

Contaminant Group	Contaminant	Action Level 1 (mg kg^{-1})	Action Level 2 (mg kg^{-1}) kg^{-1})
Metals	Mercury	0.3	3
	Arsenic	20	100
	Cadmium	0.4	5
	Chromium	40	400
	Copper	40	400
	Lead	50	500
	Nickel	20	200
	Zinc	130	800
Polychlorinated biphenyls	PCBs sum of ICES 7	0.01	n/a
	PCBs sum of 25 congeners	0.02	0.2
Organotin's	TBT, DBT, MBT	0.1	1

Although not specific to the UK, the Canadian Sediment Quality Guidelines (CCME, 1999) and

Dutch Standards (ABPmer, 2010) are commonly used to assess sediment quality (**Table 12B.3**) and are approximate equivalents to UK Action Levels (in general Canadian Threshold Levels have the lowest value, followed by Cefas Action Level 1, then Dutch Standards, Canadian Probable Effect Levels, and the highest values are for Cefas Action Level 2, although the hierarchy does vary with different contaminants).

The potential effects which will occur at the Canadian Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) are as follows:

- Minimal effect range below the TEL where adverse biological effects occur rarely;
- Possible effect range between the TEL and PEL where adverse biological effects occur occasionally; and
- Probable effect range above the PEL where adverse biological effects occur.

Dutch Standard levels vary in their definition depending on the contaminant in question. The Zoute Bagger Toets or Saline Dredge Material Test requires that no more than two non-priority substances are allowed to exceed the action level with no more than 50 per cent per substance. Priority substances are tributyl tin, cadmium, mercury, nickel, lead, sum 10 PAHs, sum 7 PCBs, sum DDT/DDD/DDE and hexachlorobenzene (ABPmer, 2010).

Not all contaminants are assigned a Cefas Action Level (**Table 12B.2**), Canadian Threshold/Probable Effect Level or Dutch Standard (**Table 12B.3**), but using a combination of the two methods to classify and assess potential impacts from contaminated sediments gives a good indication of potential impacts and the appropriate action to be taken (Adnitt *et al.*, 2010).

Table 12B.3 Canadian Sediment Quality Guidelines and Dutch Standards

Contaminant Group	Contaminant	Canadian Threshold Level (mg kg^{-1})	Canadian Probable Effect Level (mg kg^{-1})	Dutch Standard (mg kg^{-1})
Metals	Mercury	0.13	0.7	0.13
	Arsenic	7.24	41.6	29
	Cadmium	0.7	4.2	4
	Chromium	52.3	160	120
	Copper	18.7	108	60
	Lead	30.2	112	110
	Nickel	15.9	42.8	45
	Zinc	124	271	365
PAHs	Total	n/a	n/a	8
	Acenaphthene	0.00671	0.0889	n/a
	Acenaphthylene	0.00587	0.128	n/a
	Anthracene	0.0469	0.245	n/a
	Benzo(a)anthracene	0.0748	0.693	n/a
	Benzo(a)pyrene	0.0888	0.763	n/a
	Benzo(b)fluoranthene	n/a	n/a	n/a
	Benzo(ghi)perylene	n/a	n/a	n/a
	Benzo(k)fluroanthene	n/a	n/a	n/a
	Chrysene	0.108	0.846	n/a
	Dibenzo(ah)anthracene	0.00622	0.135	n/a
	Fluroanthene	0.113	1.494	n/a
	Fluorene	0.0212	0.144	n/a
	Indeno(123cd)pyrene	n/a	n/a	n/a
	Naphthalene	0.0346	0.391	n/a
	Phenanthrene	0.0867	0.544	n/a
	Pyrene	0.153	1.398	n/a
PCBs	PCBs sum of ICES 7[2]	n/a	n/a	0.1
	PCBs sum of 25 congeners	0.0215	0.189	n/a
Organotins	TBT	n/a	n/a	0.115

na = Information Not Available.

Figure 12B.2 displays the historical and active disposal grounds in and surrounding the Development Area; those that are currently active are located at Arbroath and Montrose and the Middle Tay. For

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[2] Sum of ICES 7 PCB congeners (The 7 congeners are PCB 28, 52,101,118,138,153 and 180)

these sites, **Table 12B.4** displays the most recent contaminant records. **Table 12B.5** shows the volume of material that has been disposed of to date. Results show that levels of contamination are generally low with Action Level 1 only being exceeded at the Middle Tay in 1998 for Chromium, Mercury, Nickel and Lead.

Table 12B.4 Contamination Records at Montrose, Arbroath and the Middle Tay

Site		**Montrose**			**Arbroath**	**Tay**
Year		**1993**	**2004**	**2007**	**1993**	**1998**
Contaminant	As (mg/kg)	5.34	6.69		7.14	15.24
	Cd (mg/kg)	0.20	0.00		0.20	0.25
	Cr (mg/kg)	10.49	14.94		7.30	42.79
	Cu (mg/kg)	10.36	4.01		7.92	24.77
	Hg (mg/kg)	0.03	0.00		0.02	0.66
	Ni (mg/kg)	9.82	11.43		10.38	25.65
	Pb (mg/kg)	11.61	8.35		13.76	61.07
	Zn (mg/kg)	29.42	26.05		24.70	119.01
	ICES7 (ug/kg)		0.79			
	Total CB (ug/kg)		1.44			
	TBT (ug/kg)		5.00			
	TOTAL PAH (46/47) (ug/kg)			119.62		

Values in red above CEFAS Action Level 1

Table 12B.5 Disposal Records at Montrose and Arbroath

	Disposal Of Material		
Site	**From**	**To**	**Quantity (Tonnes)**
Montrose	20-Jun-06	19-Jun-07	80870
	01-Apr-08	31-Mar-09	70210
	01-Jun-09	31-May-10	98463
	01-Apr-10	31-Mar-11	151289
	01-Nov-10	31-Oct-11	22700
	04-Apr-11	to date	186634
Arbroath	01-Jul-07	30-Jun-08	22232
	26-Oct-09	25-Oct-10	12401

Although now closed the Bell Rock disposal ground, used for the disposal of sewage sludge for over 20 years (stopping in 1998), is located partly within the Development Area, and historical contaminant sampling at this site helps to provide baseline contamination data within the Development Area. Levels of contaminants from a survey, undertaken in 2002, at the disposal ground at Bell Rock have been assessed against Cefas criteria and are reported by Hayes *et al*., 2005. PCB results show all values to be below Action Level 1. This is also true for PAH results which are also below Canadian thresholds. Analysis of heavy metals showed levels of Arsenic at Bell Rock above Action Level 1 in about 5 per cent of the samples collected, but all were below Action Level 2 and the Canadian PEL. All samples were below Action Level 1 for Chromium, Cadmium, Copper, Nickel, Lead and Zinc. Action Level 1 was exceeded by 3 per cent of samples for Mercury at Bell Rock but did not exceed Action Level 2. Hayes *et al*., 2005, found that no strong temporal variations of trace metals in surface sediments existed either during or post disposal operations, which indicates the highly dispersive nature of the area.

Table 12B.6 shows the heavy metal results, sources from Marine Scotland, at Bell Rock and Bell Rock disposal ground, partly within the Development Area. Only one record exceeds the Cefas action level 1, Arsenic in 1993.

Table 12B.6 Contamination Records at Bell Rock Disposal Ground

Site	Year	As (mg kg^{-1})	Cd (mg kg^{-1})	Cr (mg kg $^{-1}$)	Cu (mg kg^{-1})	Hg (mg kg^{-1})	Ni (mg kg^{-1})	Pb (mg kg^{-1})	Zn (mg kg^{-1})
Bell Rock disposal ground	1991	7.28	0.100	2.08	12.33	0.025	7.79	12.49	26.11
Bell Rock disposal ground	1993	79.05	0.050	2.31	8.71	0.010	6.82	12.08	26.08
Bell Rock disposal ground	1995	9.77	0.028	16.84	2.16	0.060	7.92	10.05	28.01
Bell Rock disposal ground	1998	10.07	0.029	16.96	2.05	0.073	7.83	9.68	25.75
Bell Rock disposal ground	2002	11.41	0.031	18.00	1.84	0.009	8.15	10.54	21.65
Bell Rock	2007	14.25	0.000	20.17	5.32	0.065	14.46	13.75	36.39

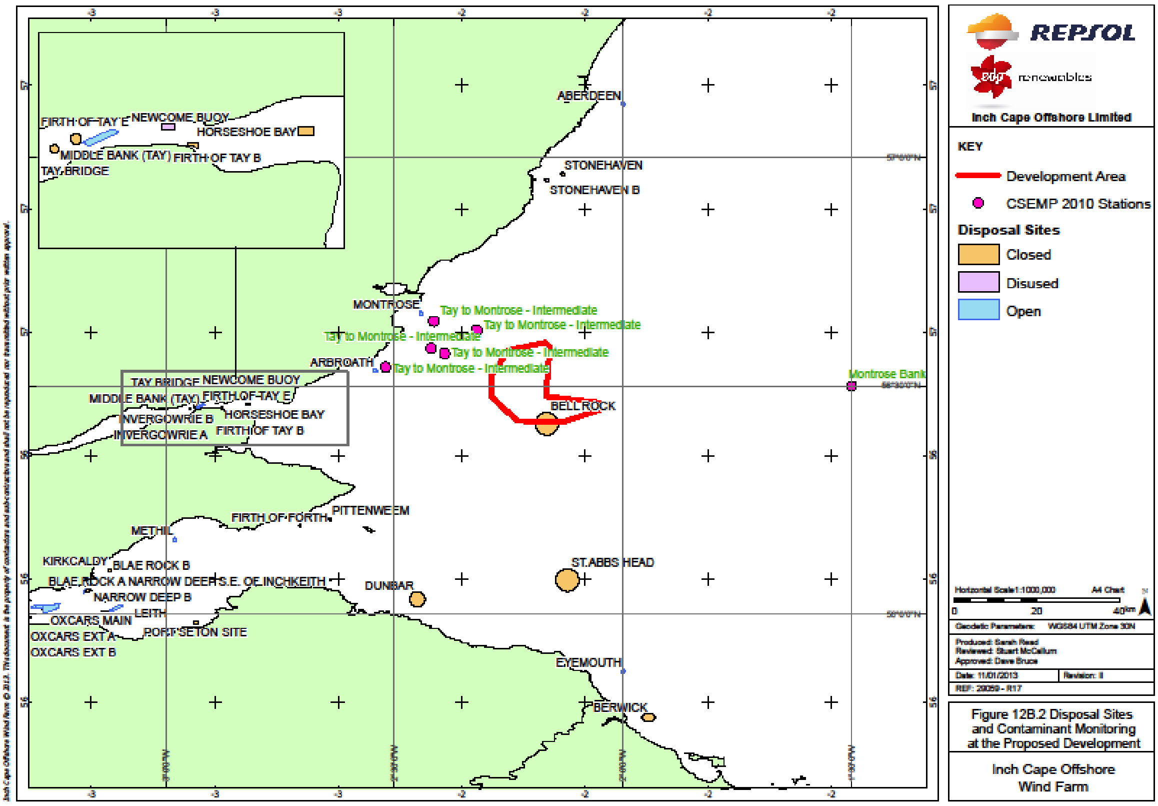
Values in red above CEFAS Action Level 1

12A.1.1.3 Historical Contamination in Proximity to the Development

In additional to direct disposal, contamination in the North Sea is largely accounted for by riverine and atmospheric transport (OSPAR, 2000). SEA 5, carried out in 2004, reviews the extent of large scale existing chemical contamination of the North Sea and is based on Cefas Aquatic Environmental Monitoring Reports (AERMS), reports from UUKOOA, Oslo and Paris Commission (OSPAR) reports as well as data acquired through National Monitoring Programs. The SEA 5 report found that the coastal and offshore area from Eyemouth to the Orkneys, encompassing the Development Area, is subject to lower historical and current inputs of hydrocarbons than adjacent areas, namely SEA 2 and SEA 3. Contamination concentrations within and offshore from the Tay Estuary are described (1998 data) within the SEA 5 report, and relevant areas to Development Area include stations within the Tay Estuary, two offshore, and one in the Firth of Forth. The stations offshore from the Tay showed levels of Cadmium below 0.05 mg l^{-1}, but higher values occurred in the Tay Estuary. Levels of Chromium were also higher within the studied estuaries than the intermediate and offshore sites, which had values below 0.5 mg l^{-1}. This distribution was also found to be true for Copper and Nickel, with the Tay estuary levels lower than the Forth. Zinc concentrations were again lower at intermediate and offshore sites, however the Tay estuary levels (2.9-5.3 mg l^{-1}) were higher than those at the Forth as well as historical data sets, indicating a potential contamination issue (SEA 5, 2004). PCBs, hexachlorbenzene (HCBs), DDT and dieldrin levels were generally found to be low in the SEA 5 region with the exception of the Forth Estuary which showed relatively higher levels for all the contaminants.

As harmful substances can be retained and accumulate within sediments for long periods of time, re-suspension and therefore redistribution of contaminated sediments can occur through the natural hydrodynamics of an area or through disturbance from human activities such as dredging, trawling and marine construction. The spread of contamination within marine sediments in the UK has been regularly monitored as part of the Clean Seas Environment Monitoring Program (CSEMP) which is a continuation of the National Monitoring Program that started in the late 1980’s, more recently known as the National Marine Monitoring Program. This monitoring activity for contaminants in marine sediments contributes to the requirements under the OSPAR convention. Contaminants listed in the OSPAR list of priority hazardous substances which are considered most harmful in marine sediments include metals, organotins, PAHs and PCBs. Of the sites sampled as part of this program the east coast of Scotland is represented; with sites along the coastline, as well as an offshore position at Montrose Bank **(Figure 12B.2**). Historical results give an indication into the level of contamination in the vicinity of the Development Area, and will allow comparisons to be made against data collected for the Development Area baseline.

Figure 12B.2 Disposal Sites and Contaminant Monitoring at the Development



For this study the CSEMP data has been accessed from the Marine Environment Monitoring and Assessment National database (MERMAN), collated and assessed to determine as far as possible the known level of contaminated sediments at and around the Development Area. Available data exists for metals, PAHs and PCBs within sediments, fish, shellfish and biota; sampling regimes have been variable and as such temporal data sets are site and substance dependant. The most recent sampling took place in 2010 and for some areas and substances data extends back to 1999.

In order to assess the level of contaminants found within sediments, CSEMP data is assessed against five main criteria:

- Background Assessment Concentration (BAC)
- Environmental Assessment Criteria (EAC)
- Effects Range Low (ERL)
- Effects Range Medium (ERM)
- European Commission food standard (EC)

The levels associated with these criteria are detailed in **Table 12B.7**.

BACs were developed by OSPAR for testing whether concentrations are near background levels. Mean concentrations significantly below the BAC are said to be near background. EACs were developed by OSPAR for assessing the ecological significance of sediment concentrations. Concentrations below the EAC should cause no chronic effects in marine species. ERLs and ERMs were developed by the United States Environmental Protection Agency (US EPA) for assessing the ecological significance of sediment concentrations. Concentrations below the ERL rarely cause adverse effects in marine organisms. Concentrations above the ERM will often cause adverse effects in some marine organisms. ECs have been used in the absence of other satisfactory criteria for assessing the ecological significance of biota concentrations. ECs are the maximum acceptable concentrations in food for the protection of public health.

Table 12B.7 Assessment Levels for CSEMP Contaminants

Hazardous Substance	**Assessment Criteria**				
	EC	**BAC**	**ERL**	**ERM**	**EAC**
PAHs in Sediment					
Naphthalene		8	160	2100	
Phenanthrene		32	240	1500	
Anthracene		5	85	1100	
Fluoranthene		39	600	5100	
Pyrene		24	665	2600	

Hazardous Substance	Assessment Criteria EC	BAC	ERL	ERM	EAC
Chrysene / Triphenylene		20	384	2800	
Benzo[a]pyrene		30	430	1600	
Benzo[ghi]perylene		80	85	330	
Indeno[123-cd]pyrene		103	240	950	
Metals in Sediment					
Arsenic		25	8.2	70	
Cadmium		0.31	1.2	9.6	
Chromium		81	81	370	
Copper		27	34	270	
Mercury		0.07	0.15	0.71	
Nickel		36	21	52	
Lead		38	47	218	
Zinc		122	150	410	
PCBs in Sediment					
CB28		0.22			1.7
CB52		0.12			2.7
CB101		0.14			3
CB118		0.17			0.6
CB138		0.15			7.9
CB153		0.19			40
CB180		0.1			12
PAHs in Shellfish					
Naphthalene					68
Phenanthrene		2.20			340
Anthracene					58
Fluoranthene		2.44			22
Pyrene		1.80			20
Benzo[a]anthracene		0.50			16
Chrysene / Triphenylene		1.62			
Benzo[a]pyrene		0.28			120
Benzo[ghi]perylene		0.50			22
Indeno[1,2,3-cd]pyrene		0.48			
PCBs in Shellfish					
CB28		0.15			0.64
CB52		0.15			1.08

Hazardous Substance	Assessment Criteria				
	EC	BAC	ERL	ERM	EAC
CB101		0.15			1.20
CB118		0.12			0.24
CB138		0.12			3.16
CB153		0.12			16.00
CB180		0.12			4.80
PCBs in Fish					
CB28		0.10			64
CB52		0.08			108
CB101		0.08			120
CB118		0.10			24
CB138		0.09			316
CB153		0.10			1600
CB180		0.11			480
Metals in Biota	**EC**	**BAC mussels**	**BAC oysters**	**BAC fish**	
Cadmium	1000	192	600	26	
Mercury	500	18	36	35	
Lead	1500	260	260	26	

Sites monitored by the CSEMP program in closest proximity to the Development Area (**Figure 12B.2**) are assessed in this study. Available data sets show that for metals, levels within sediments across the sites are generally below BAC. Although levels of arsenic, lead, mercury and cadmium have seen instances where they were recorded over BAC, by 2006 all are below BAC.

CSEMP monitoring of PAHs in sediments includes nine substances; namely naphthalene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene/triphenylene, benzo[a]pyrene, benzo[ghi]perylene and indeno[123-cd]pyrene. Results identify no significantly high levels of these contaminates at Montrose Bank and the coastal sites. A spatial trend exists to a degree, with Montrose bank and one coastal site being more commonly below BAC for all PAHs compared to the remaining coastal sites. However across all data sets for all sites and each individual PAH, where the BAC is exceeded levels of contamination are still below the ERL.

Seven PCB congeners are tested under the CSEMP monitoring program, and coastal sites show levels above the BAC. Although this suggests that levels are slightly elevated above background, five of the seven congeners displayed values below EAC for both the coastal and offshore sites, which should cause no chronic effects in marine species.

CSEMP monitoring also includes contamination levels in fish, shellfish and other biota. Fish contamination at Montrose Bank (data 2006-2009) shows mercury and lead levels below EC but Cadmium above EC. For two sites (Montrose Bank and St. Andrews), six of the seven PCB contaminants are below EAC. Results for contamination in shellfish are found at sites within the Tay estuary as well as coastal sites at Ferryden and St. Andrews. Mercury and Lead are below EAC, but Cadmium is above EC at Ferryden and Tayport. PCBs are generally high with all but one contaminant showing values above EAC at some of the sites. PAH levels are relatively low in comparison, with all sites below EAC. Results for contamination levels in biota are given for sites within the Tay estuary, Montrose Bank, Ferryden and St. Andrews. Lead and Mercury are below EAC and Cadmium levels are above EC at Montrose Bank, Ferryden and Tayport (data 2006-2009). There is no PAH data for Montrose Bank but the Tay Estuary and coastal sites at St.Andrews and Ferryport are below EAC. Levels of one PCB congener are reported to be over EAC for all estuary and coastal sites as well as Montrose Bank, and the majority of remaining congeners are above EAC at some sites. This data suggests that levels of Cadmium and PCBs are the contaminants most likely to cause adverse effects as a result of bioaccumulation.

The most recent (2010) contamination results, for Montrose Bank and the Scottish east coast sites (averaged), are displayed in **Table 12B.8** (site positions shown in **Figure 12B.2**), with results over Cefas Action Level 1 highlighted in red. Chromium is above Action Level 1 at the coastal sites, which has been the case since 2007. At Montrose Bank, arsenic was recorded over Action Level 1 in 1996, chromium above Action Level 1 in 2006 and cadmium and mercury above Action Level 1 in 2003. In 2010, no contaminants were recorded above Action Level 1 at Montrose Bank. Despite some metals exceeding Action Level 1 at some sites, these results indicate that the levels of contamination in the area are generally low.

Table 12B.8 CSEMP 2010 Contaminant Data

Site	Latitude	Longitude	Determinant	Result (mg kg^{-1})
Montrose Bank	56.499	-1.499	mercury	0.007
Tay to Montrose - Intermediate	56.57825	-2.412		0.021725
Montrose Bank	56.499	-1.499	arsenic	12.2
Tay to Montrose - Intermediate	56.57825	-2.412		8.675
Montrose Bank	56.499	-1.499	cadmium	0.07
Tay to Montrose - Intermediate	56.57825	-2.412		0.0825
Montrose Bank	56.499	-1.499	chromium	20.3
Tay to Montrose - Intermediate	56.57825	-2.412		47.375
Montrose Bank	56.499	-1.499	copper	2.33
Tay to Montrose - Intermediate	56.57825	-2.412		7.985
Montrose Bank	56.499	-1.499	lead	19.4
Tay to Montrose - Intermediate	56.57825	-2.412		20.35
Montrose Bank	56.499	-1.499	nickel	3.59

Site	Latitude	Longitude	Determinant	Result (mg kg^{-1})
Tay to Montrose - Intermediate	56.57825	-2.412		14.875
Montrose Bank	56.499	-1.499		16
Tay to Montrose - Intermediate	56.57825	-2.412	zinc	44.85
Montrose Bank	56.499	-1.499		0.0006
Tay to Montrose - Intermediate	56.59767	-2.408	PCBs sum of ICES 7	0.0006
Montrose Bank	56.499	-1.499		0.00004
Tay to Montrose - Intermediate	56.5908	-2.4124	acenaphthene	0.0005
Montrose Bank	56.499	-1.499	acenaphthylene	0.00004
Montrose Bank	56.499	-1.499		0.00004
Tay to Montrose - Intermediate	56.5908	-2.4124	anthracene	0.00154
Montrose Bank	56.499	-1.499		0.00014
Tay to Montrose - Intermediate	56.5908	-2.4124	benzo[a]anthracene	0.00452
Montrose Bank	56.499	-1.499		0.0003
Tay to Montrose - Intermediate	56.5908	-2.4124	benzo[a]pyrene	0.00602
Montrose Bank	56.499	-1.499		0.0003
Tay to Montrose - Intermediate	56.5908	-2.4124	chrysene + triphenylene	0.0057
Montrose Bank	56.499	-1.499		0.0002
Tay to Montrose - Intermediate	56.5908	-2.4124	dibenz[a,h]anthracene	0.00104
Montrose Bank	56.499	-1.499		0.0003
Tay to Montrose - Intermediate	56.5908	-2.4124	fluoranthene	0.0092
Montrose Bank	56.499	-1.499		0.00004
Tay to Montrose - Intermediate	56.5908	-2.4124	fluorene	0.0006
Montrose Bank	56.499	-1.499		0.0003
Tay to Montrose - Intermediate	56.5908	-2.4124	naphthalene	0.00116
Montrose Bank	56.499	-1.499		0.0003
Tay to Montrose - Intermediate	56.5908	-2.4124	phenanthrene	0.00588
Montrose Bank	56.499	-1.499		0.0002
Tay to Montrose - Intermediate	56.5908	-2.4124	pyrene	0.00872

Values in red above CEFAS Action Level 1

12A.1.1.4 Water Quality Assessments

A large percentage of urban waste water (90 per cent by volume) is discharged to marine waters in Scotland as most large population centres are located on the coast. Sewage disposal is associated with coastal communities along the east Scottish coastline (SEA5, 2004), with the majority of qualifying discharges upgraded to secondary treatment by 2001 to 2005 as required by the Urban Waste Water Treatment (UWWT) Directive (91/271/EEC). Secondary treatment works in closest proximity to the

Development Area are located at Montrose, Dundee and St. Andrews. SEPA conducts monitoring as part of the UWWT Directive and the Water Framework Directive (2000/60/EC); this includes monitoring seabed invertebrates, macroalgae, phytoplankton, nutrients, chlorophyll and dissolved oxygen in the vicinity of qualifying discharges to provide data for the four yearly sensitive area reviews. Under this scheme monitoring in the Tay Estuary has been undertaken since 1990 and assessments show the estuary not to be a problem area as a result of improvements to effluent treatment driven by the UWWT Directive (OSPAR eutrophication report, 2006). This report concludes that phytoplankton growth is not nutrient limited in the estuary so excess nutrients are exported to adjacent coastal waters; no obvious alterations to natural ecosystem function are occurring; the organic carbon content of the sediments is low; opportunistic green algal growth has not been observed and the waters are well oxygenated. SEPA monitoring under the WFD has also informed the Tay Area Management Plan (2009-2015) which reported in 2008 that the six coastal areas around the Tay Estuary, including Bell Rock, are in good ecological status. Under the Bathing Water Directive (76/160/EEC) monitoring by SEPA in 2003 for microbial indicators of faecal contamination at 40 sites in the SEA 5 area, encompassing the Development Area, were described as excellent or good and as such met the Directive’s mandatory quality standards (SEA5, 2004).

12B.2 Methods

12B.2.1 Rationale and Design

The survey methods were approved prior to use through consultation with Marine Scotland, after the submission of a detailed survey monitoring plan, which covered the benthic and contaminated sediment studies. These surveys were carried out simultaneously, with a sub sample of sediment taken for contaminated sediment analysis during the benthic survey (see Appendix 12A Benthic Ecology Baseline Development Area). A total of 20 sample stations were selected for contaminant analysis. The historical disposal ground at Bell Rock (partially within the Development Area) was mapped along with the ground types from acoustic mapping (Geophysical survey data IXSurvey, 2011). A total of 18 stations were chosen within the Development Area to ensure at least one sample was placed in each habitat identified through analysis of the geophysical survey data and that these sites gave a good spread of distances from the disposal ground, including the main direction of tidal transport across the Development Area. Two sites outside the Development Area boundary (T5 and C5), were also selected. T5 was selected because it is within the tidal influence (tidal excursion) and C5 as a control site outside the tidal influence. The combination of the sampling stations within the Development Area, and those outside (T5 and C5) is, from here on in, discussed as the survey area. Data from a drop down video (DDV) survey carried out prior to this grab sampling survey confirmed that ground conditions at all selected positions were suitable for a grab sample. **Table 12B.9** shows the coordinates and details of the sample positions and **Figure 12B.3** show the spatial distribution. Two additional stations (C2 and T3), sampled as part of the benthic survey programme, were tested for contaminants after initial testing identified potentially high levels of Nickel and Chromium in a number of samples. This is described further below in section 12B.2.3.1 Additional Testing

Table 12B.9 Proposed Sampling Stations

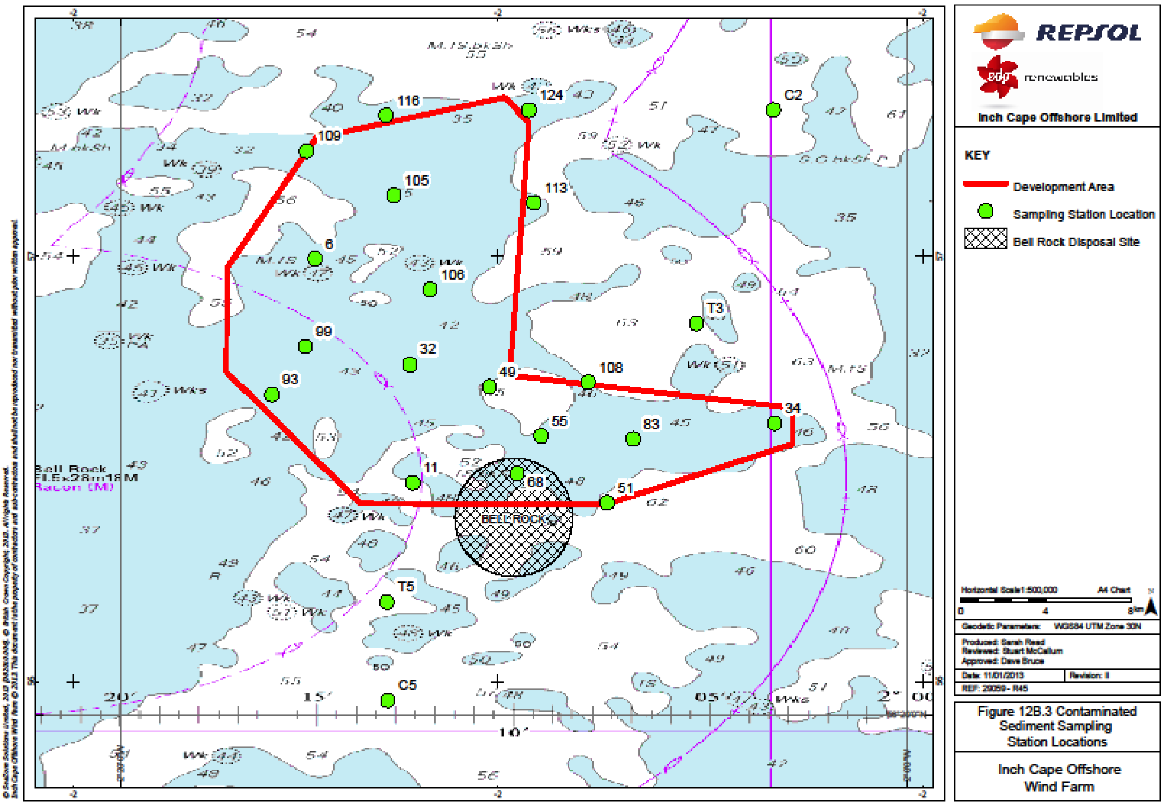
Station*	Latitude (WGS 84)	Longitude (WGS 84)	Ground Type	Description
6	56.52623	-2.25072	Strong Flat Deep	Development Area
11	56.4313	-2.20926	Strong Flat Deep	Development Area
116	56.58686	-2.2206	Weak Steep Shallow	Development Area
32	56.48147	-2.21068	Strong Flat Shallow	Development Area
34	56.45652	-2.05602	Strong Flat Shallow	Development Area
49	56.47202	-2.17696	Strong Mod Deep	Development Area
51	56.42299	-2.12691	Strong Mod Deep	Development Area
55	56.45119	-2.15499	Mod Flat Deep	Development Area
68	56.43534	-2.16511	Mod Flat Shallow	Development Area
83	56.44996	-2.11595	Mod Mod Shallow	Development Area

Station*	Latitude (WGS 84)	Longitude (WGS 84)	Ground Type	Description
93	56.46878	-2.26901	Weak Flat Shallow Rockhead	Development Area
99	56.48906	-2.25482	Strong Mod Shallow	Development Area
105	56.55311	-2.21726	Strong Mod Shallow	Development Area
106	56.51323	-2.20196	Strong Mod Shallow	Development Area
108	56.47396	-2.13494	Strong Mod Shallow	Development Area
109	56.57179	-2.25434	Strong Steep	Development Area
113	56.54986	-2.15798	Weak Flat Deep	Development Area
124	56.58905	-2.16008	Weak Steep Deep	Development Area
T5	56.38095	-2.22014	N/A	Within Tidal Excursion
C5	56.33934	-2.2199	N/A	Control Site
C2**	56.589205	-2.056368	N/A	Control site
T3**	56.498806	-2.089151	N/A	Within tidal excursion

*Position numbers reflect the Benthic Sample Positions as these surveys were completed alongside each other

**Additional sampling stations, tested after initial results showed five values above Cefas AL2 for nickel and chromium (see section 12B.2.3.1)

Figure 12B.3 Contaminated Sediment Sampling Station Locations



12B.2.2 Survey Methods

The contaminated sediment survey took place on board the research vessel the Arie Dirk (**Figure 12B.4**) operating out of Montrose Harbour between the 17 April 2012 and 2 May 2012 and was combined with the benthic survey (see Appendix 12A). A total of 20 sampling stations were used for the contaminated sediment survey. Surface samples were collected using a 0.1 m^2 day grab. Triplicate samples were taken at each sampling station with contaminants being analysed at one sample per station. (Additional samples were stored at -20 ^{o}C).

Figure 12B.4 Arie Dirk Survey Vessel

After a visual assessment of the sediment was made, samples from the day grab were collected using a stainless steel scoop (washed with hexane between samples). Samples were taken from the surface of the sediment in the grab, avoiding the edges of the grab and any anoxic layer (a note of its depth was made). Samples were transferred to trace metal free (acid washed) containers. Samples were frozen as soon as possible after being taken and remained frozen until analysis.

Analysis on the contaminants listed in **Table 12B.10** was undertaken by the National Laboratory Service[3]. In line with Cefas guidance (MARG, 2010), analysis was performed on whole samples (rather than the lowest fraction) and the methods of analysis followed the procedures outlined in the Green Book (MARG, 2010). A sub-sample was also taken for particle size analysis (PSA) and total organic carbon (TOC) analysis. The PSA analysis was undertaken using laser diffraction, which involves a low power visible laser transmitter producing a parallel, monochromatic beam of light which illuminates the particles by use of an appropriate sample cell. The incident light is diffracted

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[3] United Kingdom Accreditation Service (UKAS) accredited laboratory for marine sediment analysis, hence all and all results will be UKAS accredited

by the particles illuminated to give a stationary diffraction pattern regardless of particle movement. By integrating over a suitable period a representative bulk sample of the particles contributes to the final measured diffraction pattern. Results were then grouped using Wentworth sediment classifications. For TOC analysis, organic carbon is oxidised to carbon dioxide in the dichromate method with a parallel reduction of hexavalent chromium (Cr6+) to trivalent chromium (Cr3+) and an accompanying colour change from orange to green. The intensity of the colour change, measured by spectrophotometer, is proportional to the trivalent chromium concentration which is related to the organic matter content in the soil or sludge. This colour change is compared to calibration curves to obtain the TOC concentrations of the samples.

Table 12B.10 Contaminants Tested within the Sediment Samples

Heavy metals	Organotins	Polynuclear Aromatic Hydrocarbons (PAH)	Polychlorinated Biphenyls (PCB)
Sulphide	Dibutyl Tin	Acenaphthene	PCB - 028
Mercury	Dioctyl Tin	Acenaphthylene	PCB - 052
Arsenic	Diphenyl Tin	Anthracene	PCB - 101
Cadmium	Tetrabutyl Tin	Benzo(a)anthracene	PCB - 118
Chromium	Tributyl Tin	Benzo(a)pyrene	PCB - 138
Copper	Triphenyl Tin	Benzo(b)fluoranthene	PCB - 153
Lead		Benzo(ghi)perylene	PCB - 180
Nickel		Benzo(k)fluoranthene	PCB : Total (28, 52, 101, 118, 138, 153, 180)
Tin		Chrysene	
Zinc		Dibenzo(ah)anthracene	
		Fluoranthene	
		Fluorene	
		Indeno(1,2,3-c,d)pyrene	
		Naphthalene	
		Phenanthrene	
		Pyrene	
		PAH : Total	

12B.2.3 Data Analysis

When reviewing contamination data, it is important to have threshold levels against which potential damage to marine flora and fauna can be assessed. As such, contamination levels in sediments were compared against Cefas ALs (**Table 12B.11**) where available, and the Canadian Sediment Quality Guidelines and Dutch Standards levels for substances without Cefas ALs (**Table 12B.12**).

With respect to these definitions, in general, contaminant levels below AL1 are not considered to be of concern and are, therefore, likely to be approved for disposal at sea. Material with contaminant levels above AL2 is generally considered to be unsuitable for disposal at sea. Dredged material with contaminant levels between AL1 and AL2 requires further consideration and testing before a decision can be made.

For the Canadian Sediment Quality Guidelines, TEL represents a concentration below which adverse biological effects are expected to occur only rarely (in some sensitive species for example). The higher level, the PEL, defines a concentration above which adverse effects may be expected in a wider range of organisms.

Contamination results from the survey area were also compared with historic data, Bell Rock disposal ground monitoring data and CSEMP data (see Introduction **Section 12B.1**) to assess whether levels of contaminants had increased, decreased or remained stable in the area of the Inch Cape Offshore Wind Farm.

Table 12B.11 Cefas Action Levels for Metals, PAHs, Organotins and PCBs in Sediments

Contaminant Group	Contaminant	Action Level 1 (mg kg^{-1})	Action Level 2 (mg kg^{-1})
Metals	Mercury	0.3	3
	Arsenic	20	100
	Cadmium	0.4	5
	Chromium	40	400
	Copper	40	400
	Lead	50	500
	Nickel	20	200
	Zinc	130	800
Polychlorinated biphenyls	PCBs sum of ICES 7	0.01	n/a
	PCBs sum of 25 congeners	0.02	0.2
Organotin's	TBT, DBT, MBT	0.1	1

Table 12B.12 Canadian Sediment Quality Guidelines and Dutch Standards

Contaminant Group	Contaminant	Canadian Threshold Level (mg kg^{-1})	Canadian Probable Effect Level (mg kg^{-1})	Dutch* Standard (mg kg^{-1})
PAHs	Total	n/a	n/a	8mg
	Acenaphthene	0.00671	0.0889	n/a
	Acenaphthylene	0.00587	0.128	n/a
	Anthracene	0.0469	0.245	n/a

Contaminant Group	**Contaminant**	**Canadian Threshold Level (mg kg^{-1})**	**Canadian Probable Effect Level (mg kg^{-1})**	**Dutch* Standard (mg kg^{-1})**
	Benzo(a)anthracene	0.0748	0.693	n/a
	Benzo(a)pyrene	0.0888	0.763	n/a
	Benzo(b)fluoranthene	n/a	n/a	n/a
	Benzo(ghi)perylene	n/a	n/a	n/a
	Benzo(k)fluroanthene	n/a	n/a	n/a
	Chrysene	0.108	0.846	n/a
	Dibenzo(ah)anthracene	0.00622	0.135	n/a
	Fluroanthene	0.113	1.494	n/a
	Fluorene	0.0212	0.144	n/a
	Indeno(123cd)pyrene	n/a	n/a	n/a
	Naphthalene	0.0346	0.391	n/a
	Phenanthrene	0.0867	0.544	n/a
	Pyrene	0.153	1.398	n/a
PCBs	PCBs sum of ICES 7[4]	n/a	n/a	0.1
	PCBs sum of 25 congeners	0.0215	0.189	n/a

n/a = Information Not Available.

12B.2.3.1 Additional Testing

Initial results showed five values above Cefas AL2 for nickel and chromium. To validate whether this result was a true representation of the contaminants at these sampling stations, the second replicate from all sampling stations was tested for all metals. In addition, replicates from control station 2(C2) and tidal station 3(T3) that were collected as part of the benthic survey were also tested. Metal results of both tests are presented and discussed together within this baseline report. In addition, to compare results against historical data, a partial digest extraction method was also applied to the second analysis. Within this report, the initial samples are referred to as A samples and the second replicate samples are referred to as B samples.

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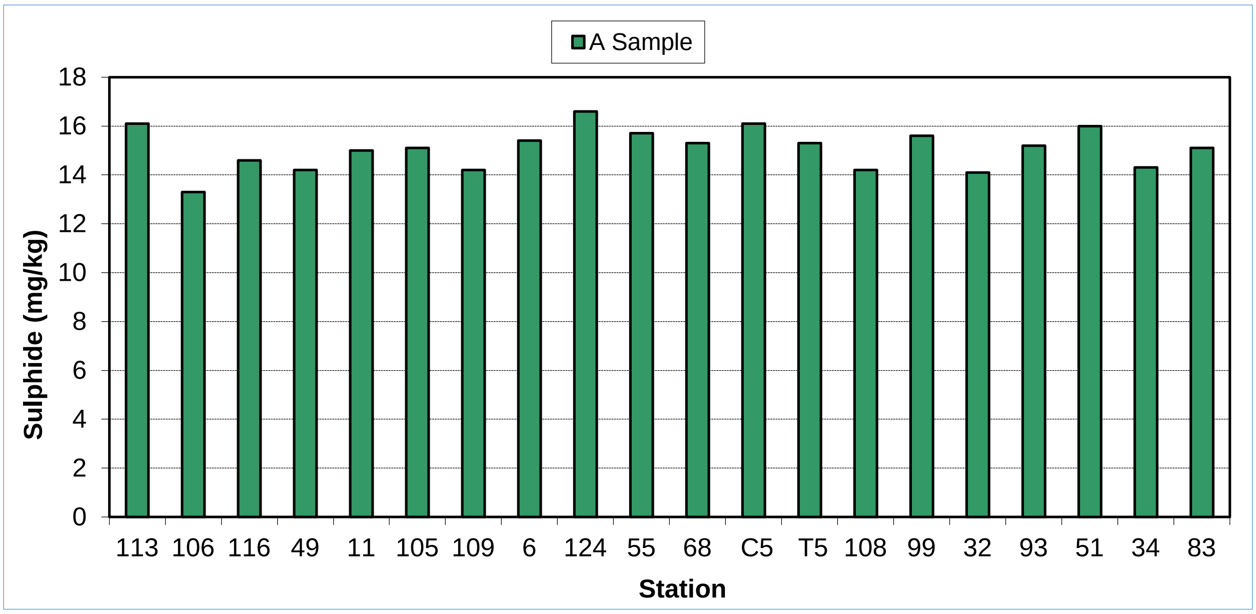
[4] Sum of ICES 7 PCB congeners (The 7 congeners are PCB 28, 52,101,118,138,153 and 180)

12B.3 Results

12B.3.1 Sulphide Results

Sulphide levels are found to be relatively consistent across all samples (**Figure 12B.5**), with values ranging from 13.3 to 16.6 mg kg^{-1}. There are no reference levels for Sulphide, although it would be expected that concentrations in offshore areas are higher than those found in coastal locations. The levels of sulphides at each sampling station are detailed in **Annex 12B.1**.

Figure 12B.5 Sulphide Levels at Sampling Stations



12B.3.2 Metal Results

Results for individual metals for both A and B samples are displayed in **Figures 12B.6** to **12B.14** with Cefas ALs (AL1, and AL2 where AL1 is exceeded) also plotted for reference where available. The levels of metal contamination recorded for A and B samples are given in **Annex 12B.1** and **Annex 12B.2** respectively.

Figure 12B.6 Mercury Levels at Sampling Stations

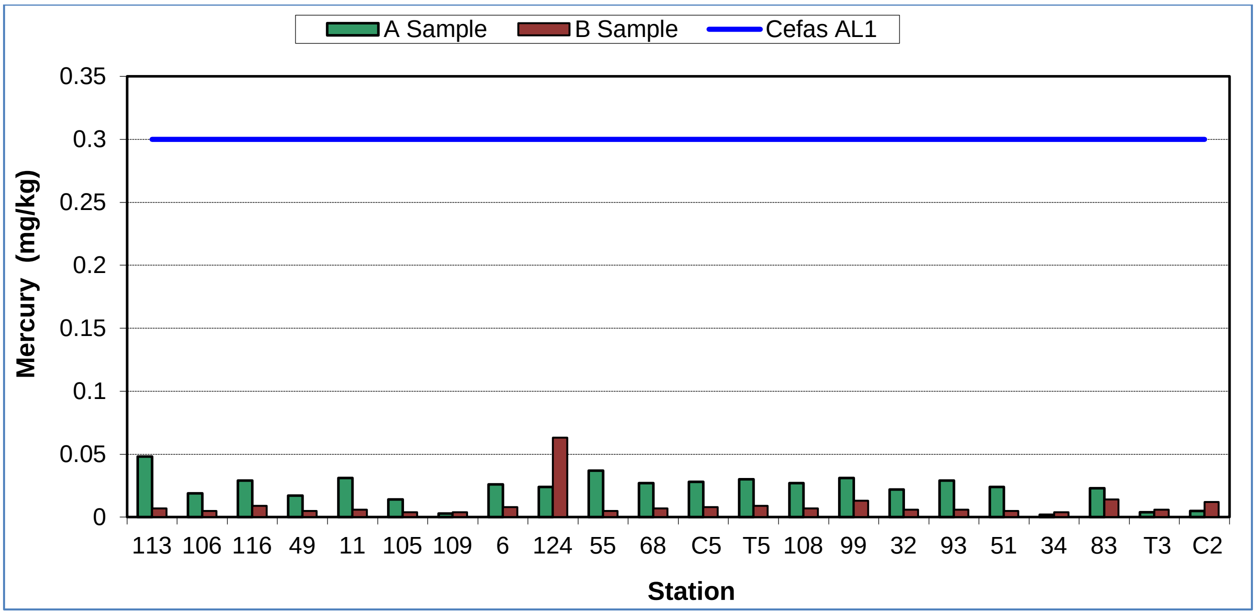


Figure 12B.7 Arsenic Levels at Sampling Stations

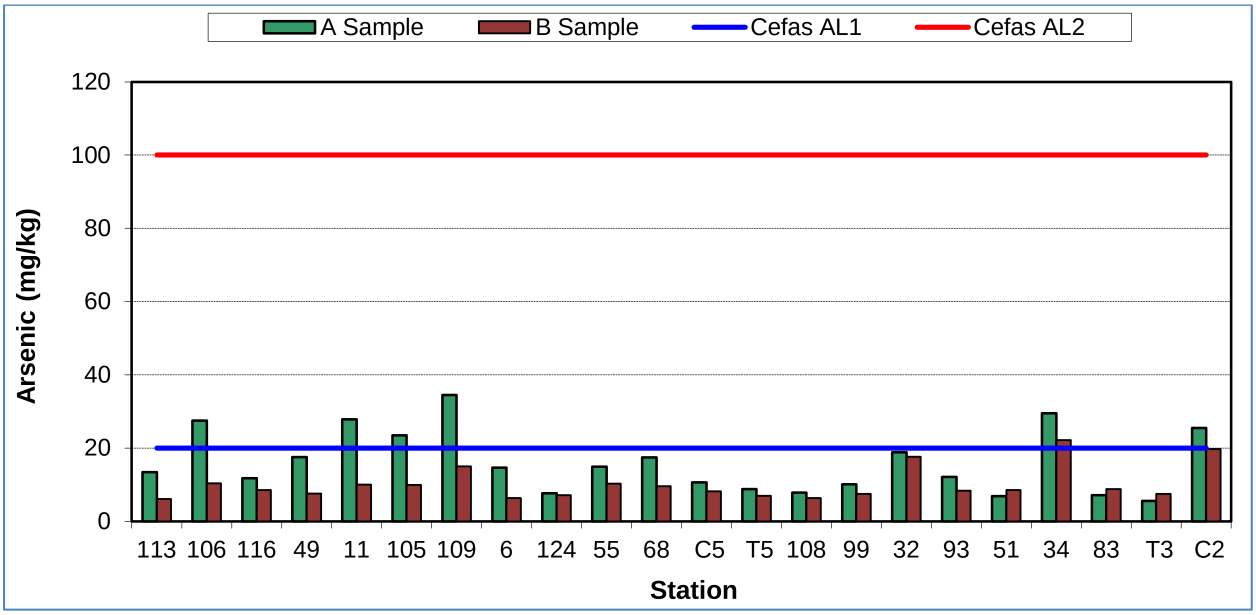


Figure 12B.8 Cadmium Levels at Sampling Stations

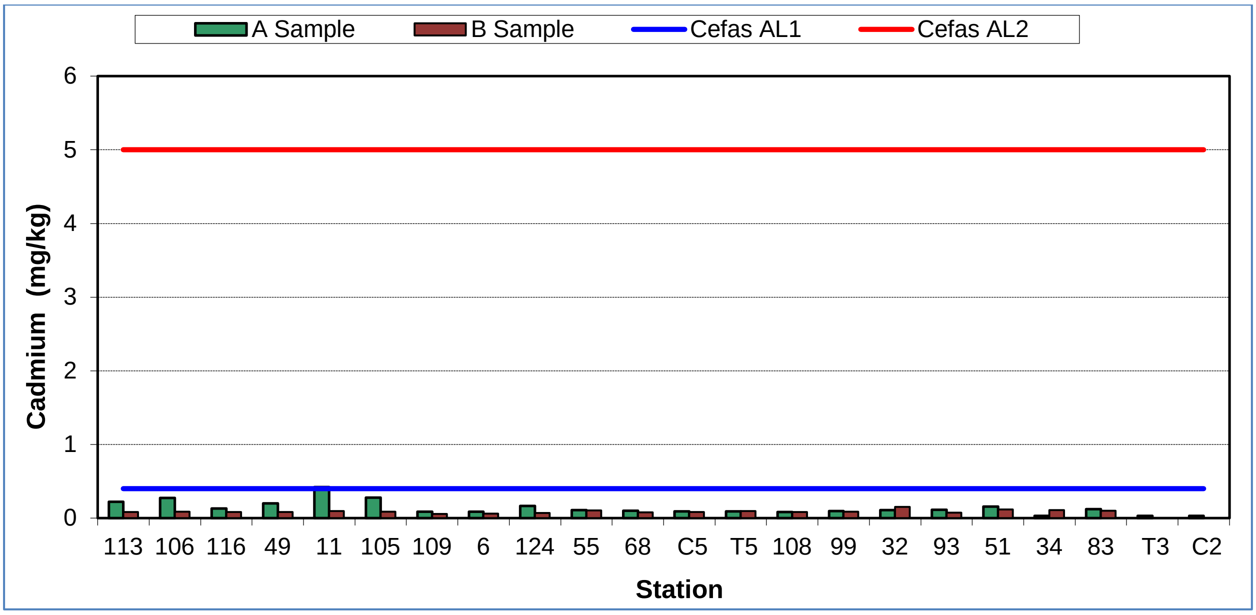


Figure 12B.9 Chromium Levels at Sampling Stations

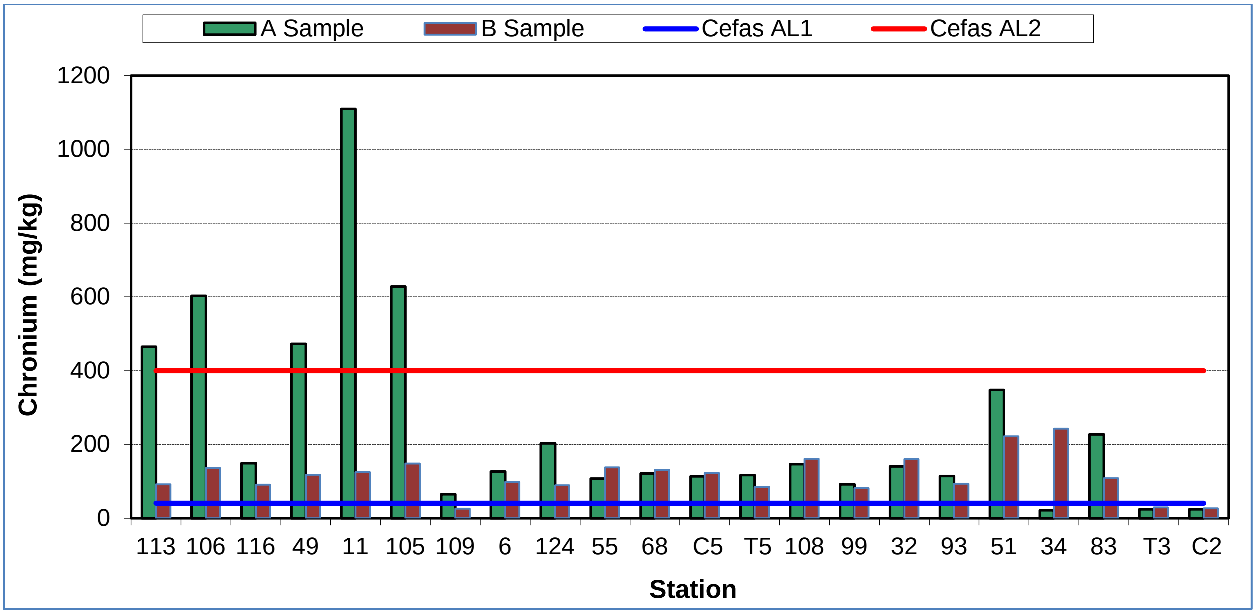


Figure 12B.10 Copper Levels at Sampling Stations

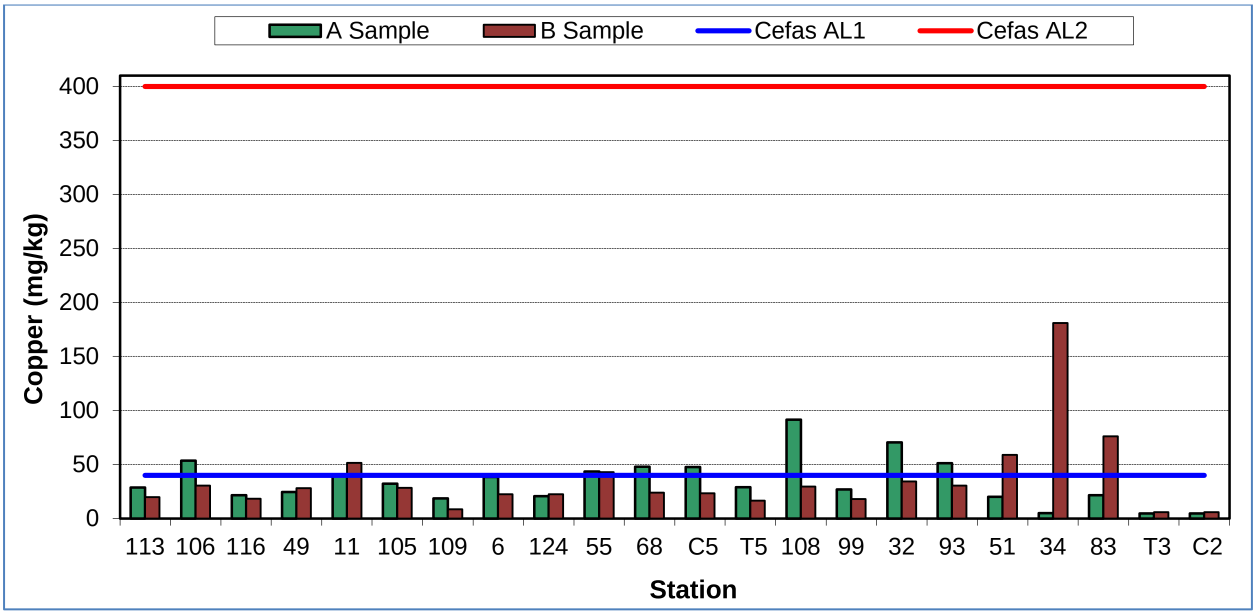


Figure 12B.11 Lead Levels at Sampling Stations

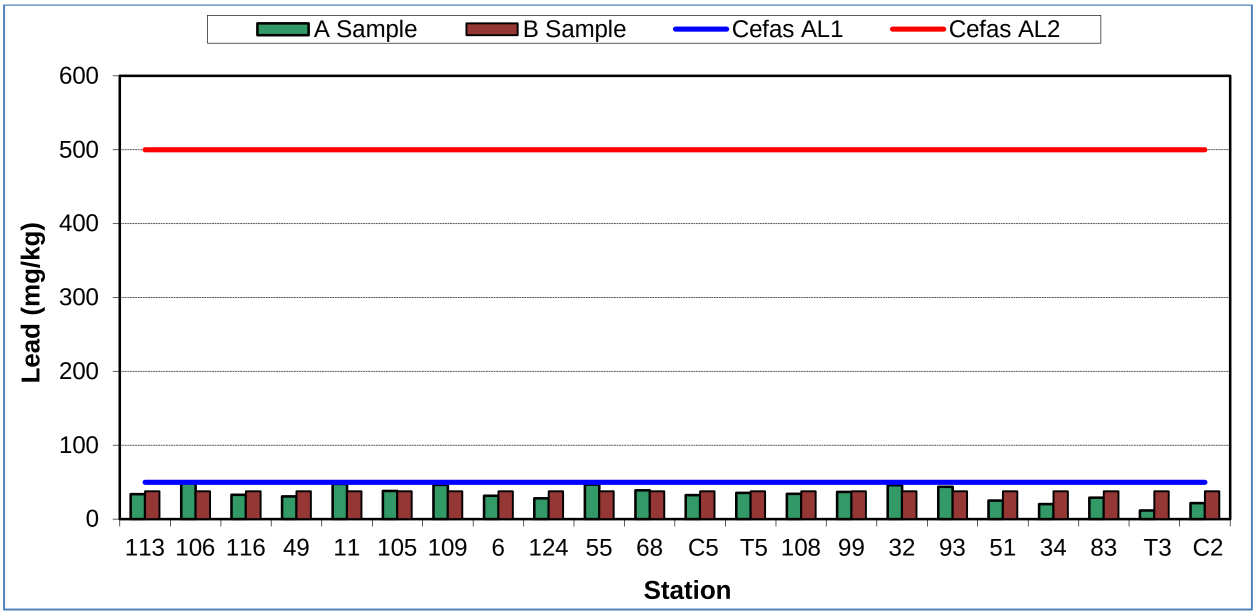


Figure 12B.12 Nickel Levels at Sampling Stations

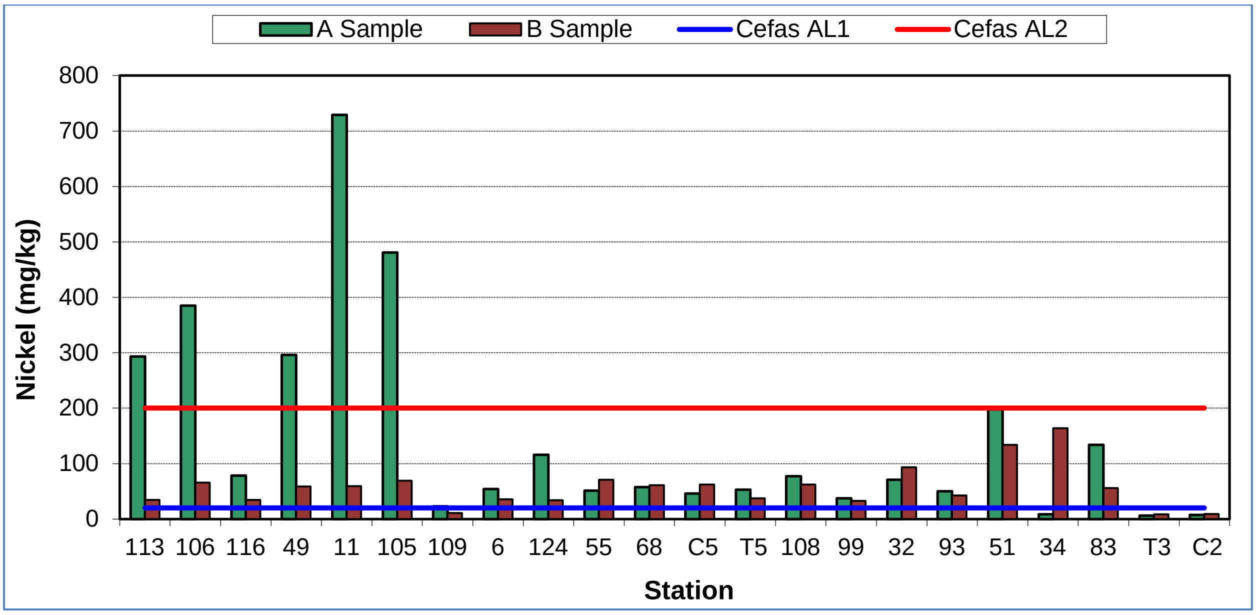


Figure 12B.13 Tin Levels at Sampling Stations

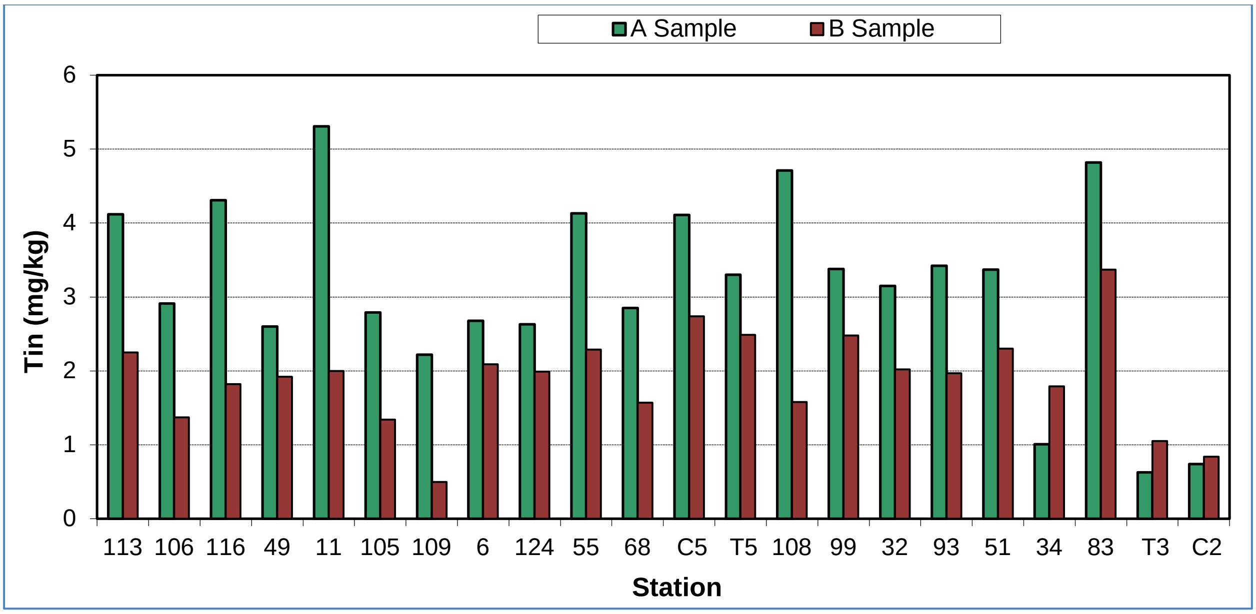
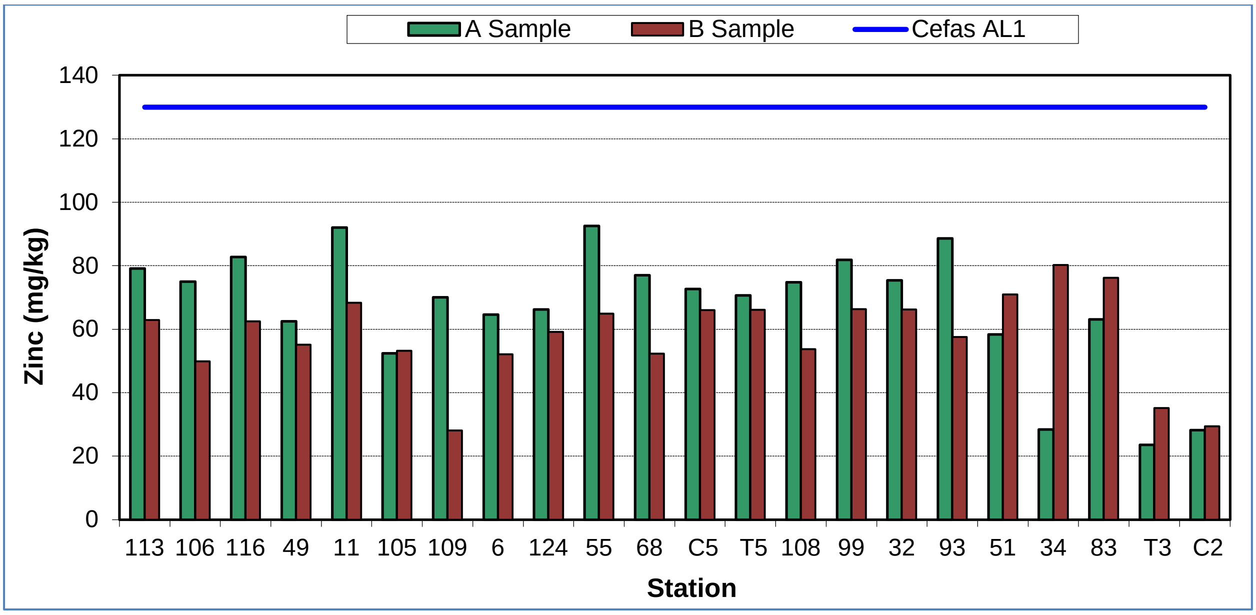


Figure 12B.14 Zinc Levels at Sampling Stations



Results show that within the A samples some metals at a number of stations, namely arsenic (six stations), cadmium (one station), chromium (19 stations), copper (seven stations) and nickel (19 stations) exceeded Cefas AL1, **Table 12B.13** Nickel and chromium also exceeded Cefas AL2 at five stations. In the B sample results, with arsenic exceeded at one station, chromium at 19 stations, copper at five stations and nickel at 19 stations. At no stations for any of the metals within the B samples is Cefas AL2 exceeded.

Table 12B.13 Summary of Metal Results in Comparison with Cefas Action Levels

Contaminant	A samples >Cefas Action Level 1	A samples >Cefas Action Level 2	B samples >Cefas Action Level 1	B samples >Cefas Action Level 2
Mercury	0/22	0/22	0/22	0/22
Arsenic	6/22	0/22	1/22	0/22
Cadmium	1/22	0/22	0/22	0/22
Chromium	19/22	5/22	19/22	0/22
Copper	7/22	0/22	5/22	0/22
Lead	0/22	0/22	0/22	0/22
Nickel	19/22	5/22	19/22	0/22
Zinc	0/22	0/22	0/22	0/22
Tin	N/A	N/A	N/A	N/A

12B.3.3 Poly-Aromatic Hydrocarbons (PAH) Results

Results of individual PAH results are displayed in **Figures 12B.15** to **12B.30** with the Canadian Threshold Effects Level (TEL) plotted where available. At no stations is the Canadian TEL exceeded. PAH levels from each sampling station are displayed in **Annex 12B.1.**

Figure 12B.15 Acenaphthene Levels at Sampling Stations

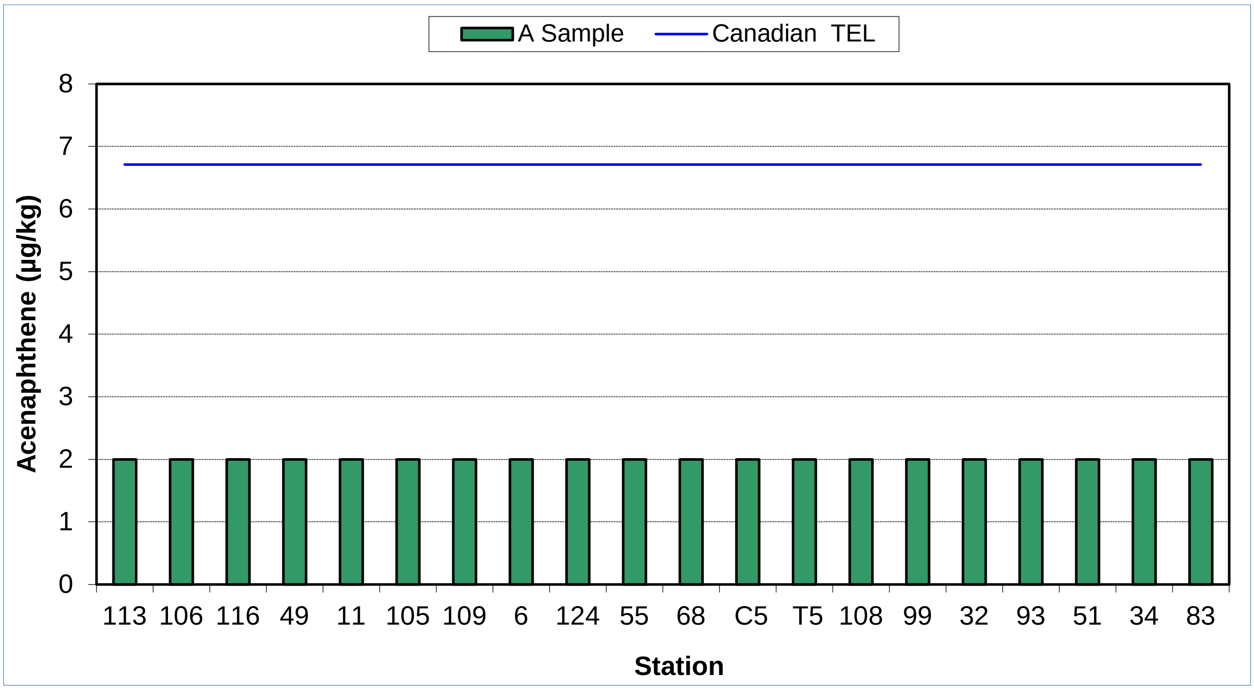


Figure 12B.16 Acenapthylene Levels at Sampling Stations

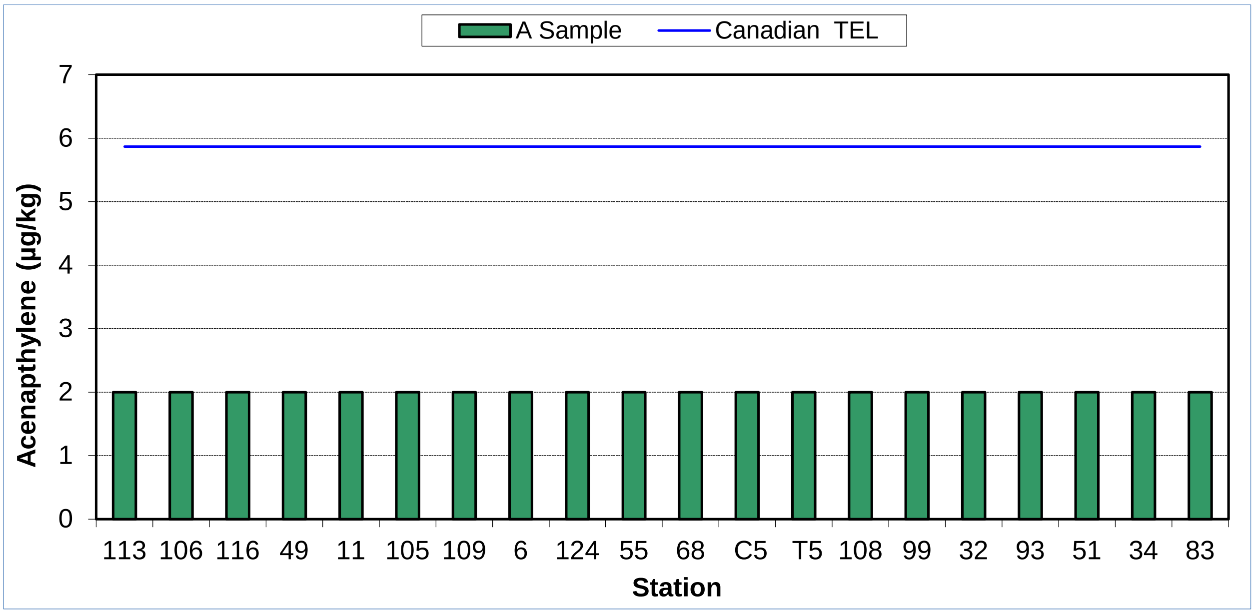


Figure 12B.17 Anthracene Levels at Sampling Stations

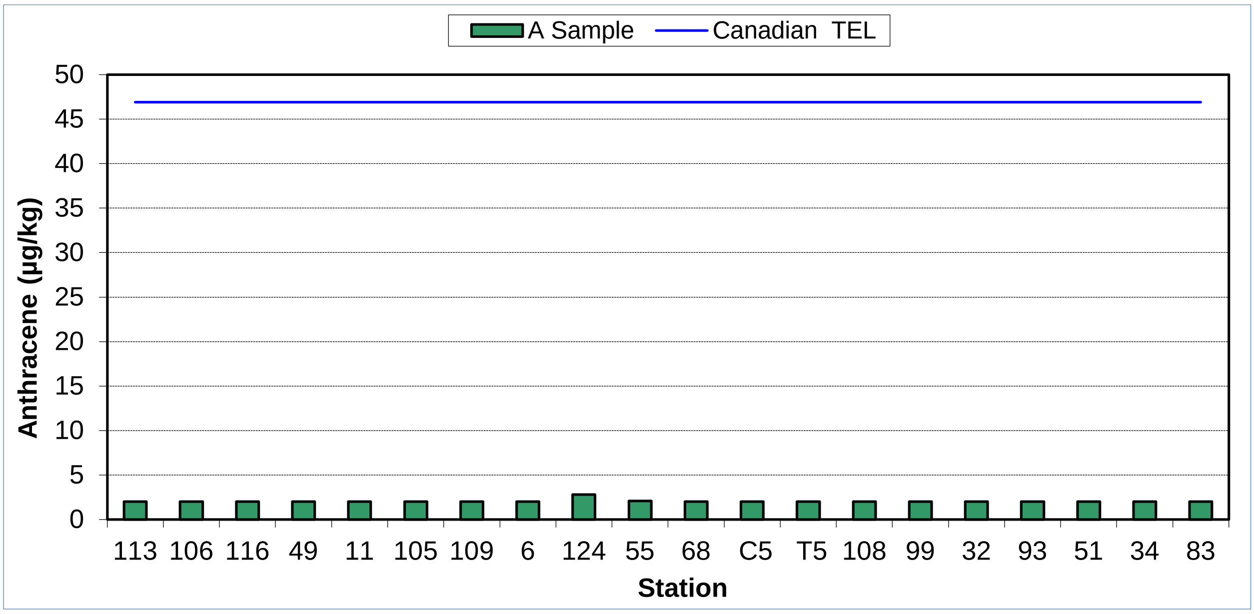


Figure 12B.18 Benzo(a)anthracene Levels at Sampling Stations

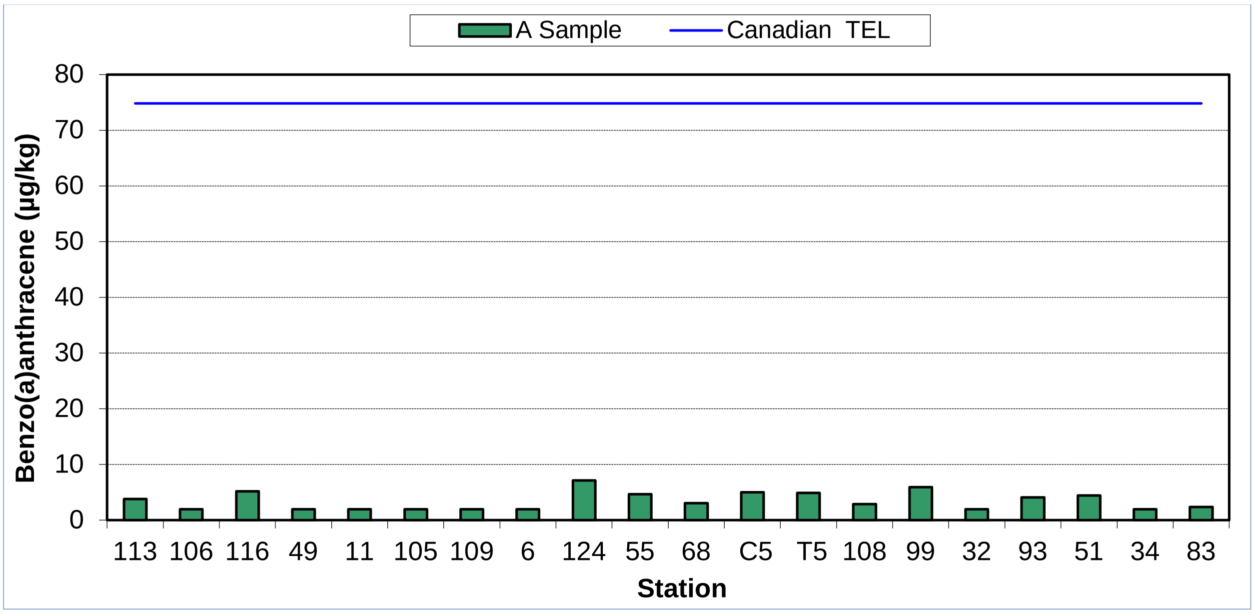


Figure 12B.19 Benzo(a)pyrene Levels at Sampling Stations

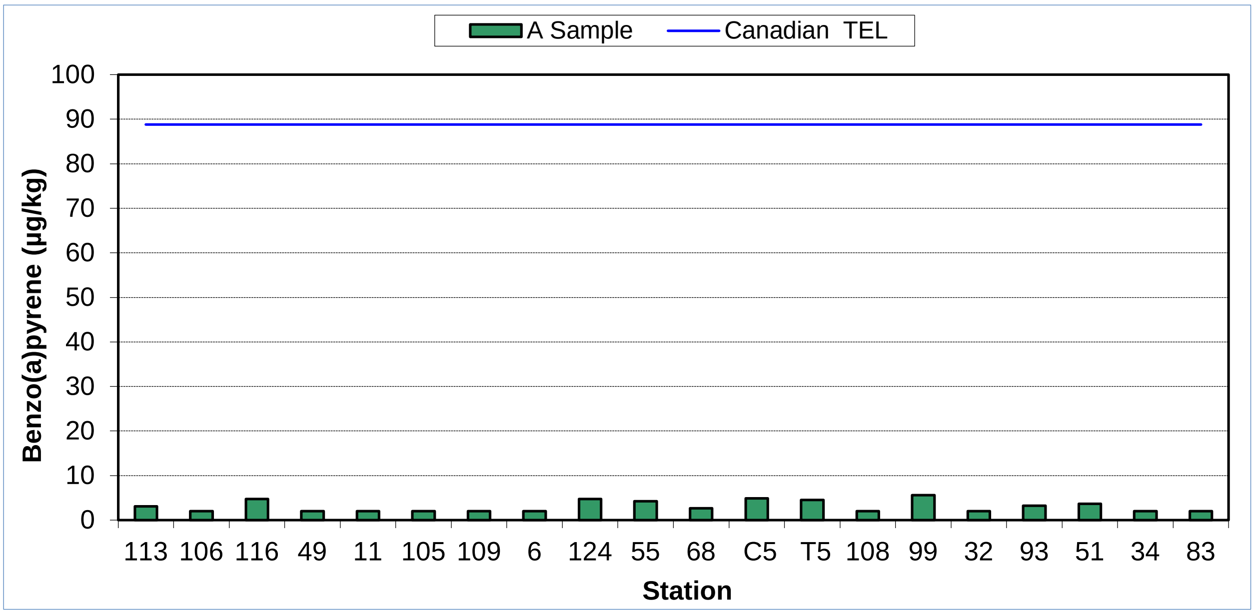


Figure 12B.20 Benzo(b)fluoranthene Levels at Sampling Stations

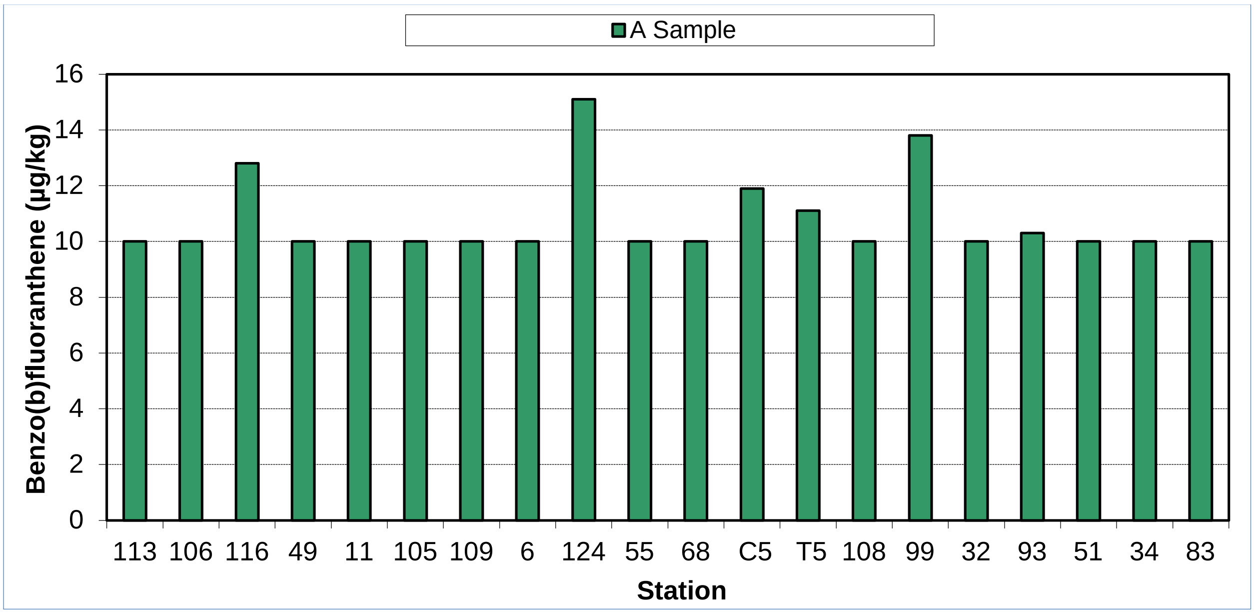


Figure 12B.21 Benzo(ghi)perylene Levels at Sampling Stations

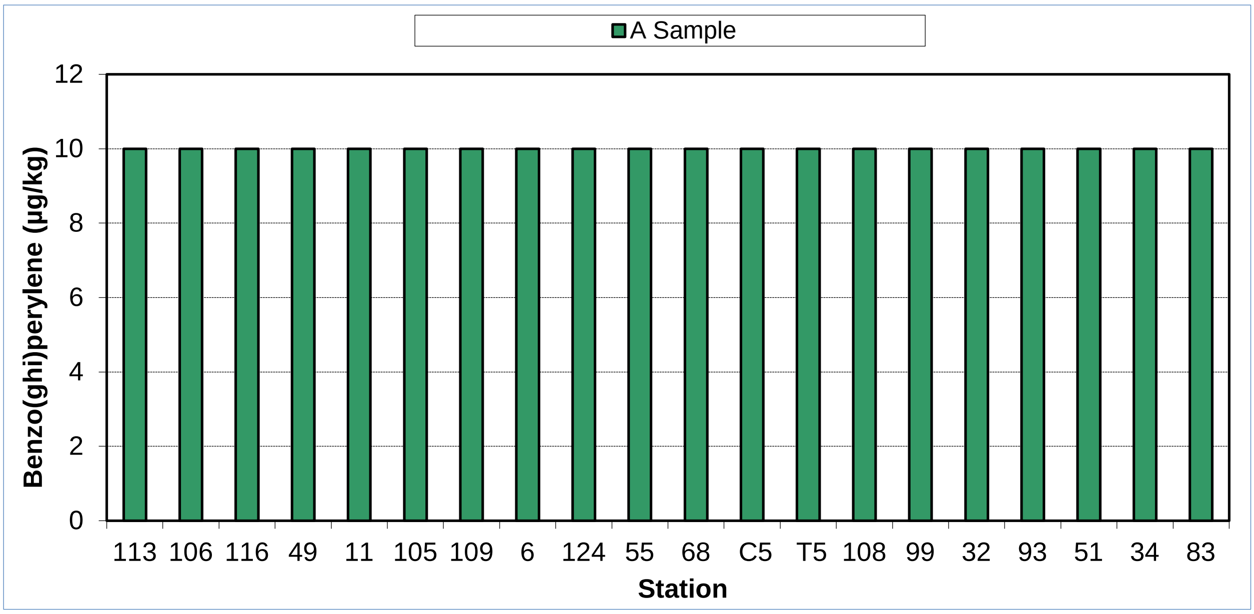


Figure 12B.22 Benzo(k)fluoranthene Levels at Sampling Stations

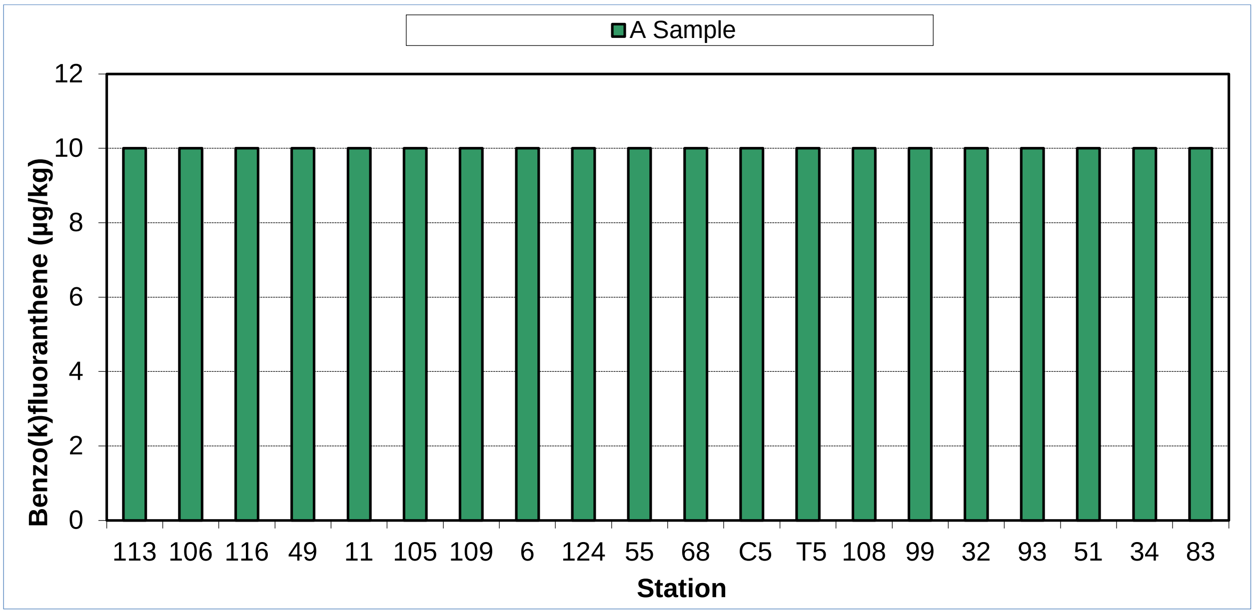


Figure 12B.23 Chrysene Levels at Sampling Stations

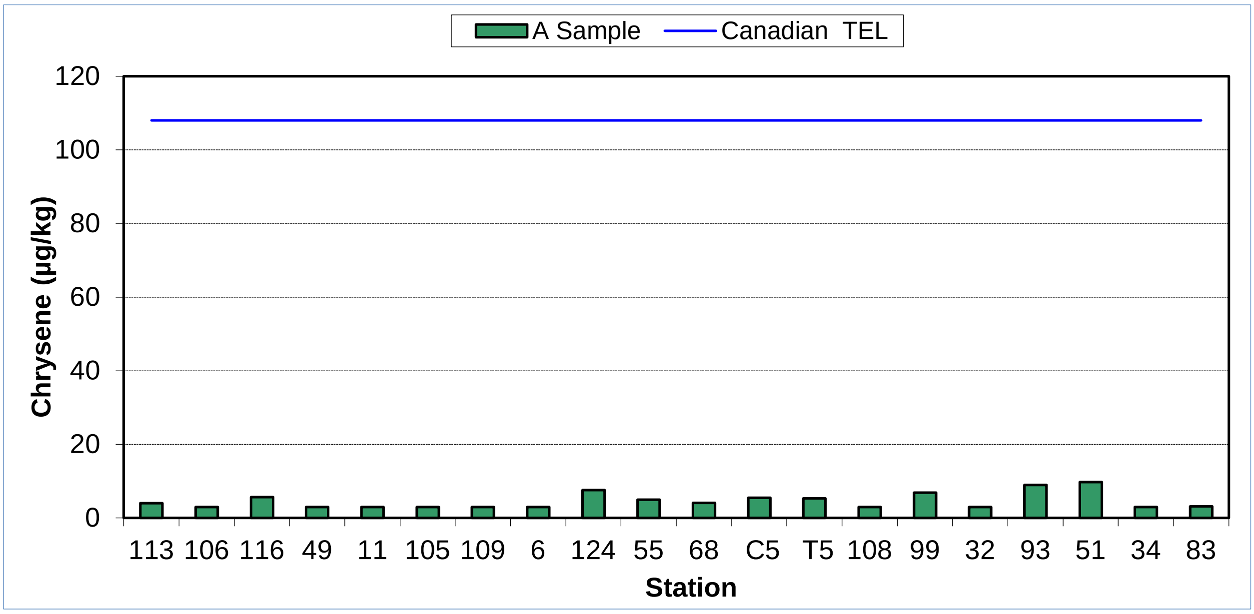


Figure 12B.24 Dibenzo(ah)anthracene Levels at Sampling Stations

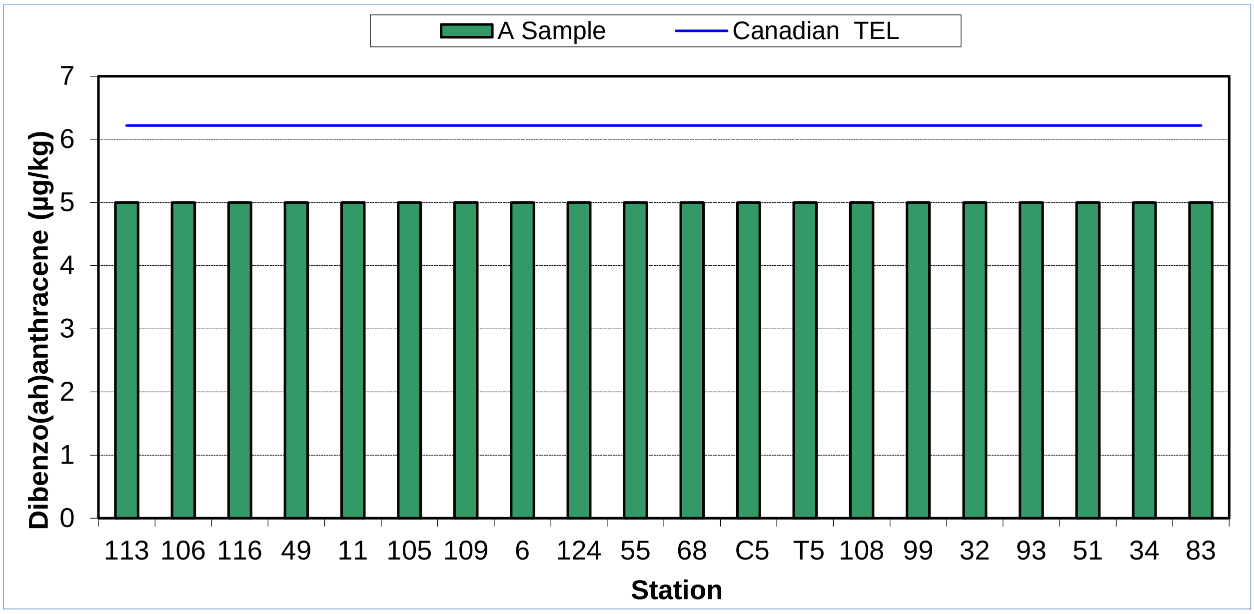


Figure 12B.25 Fluroathene Levels at Sampling Stations

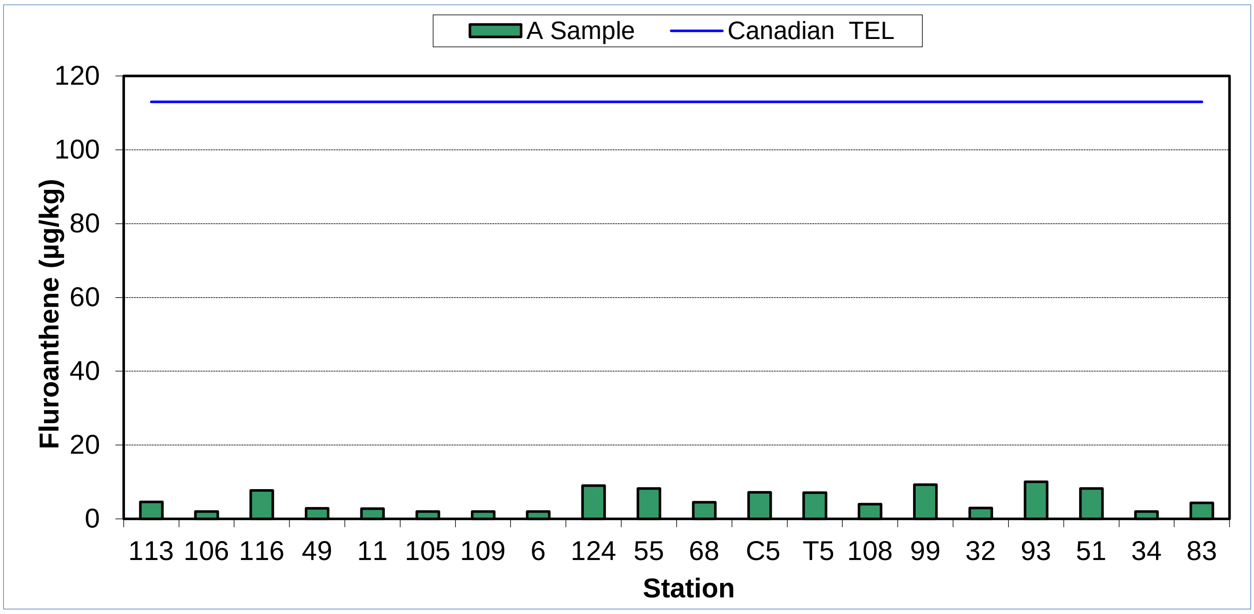


Figure 12B.26 Fluorene Levels at Sampling Stations

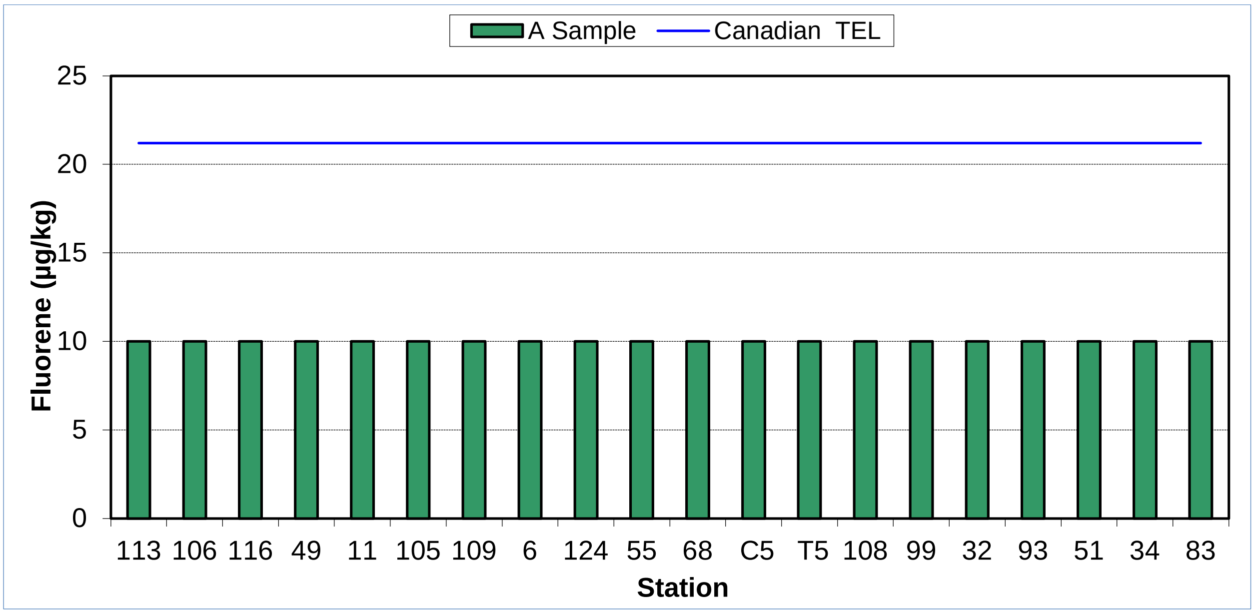


Figure 12B.27 Indeno(1,2,3-c,d)pyrene Levels at Sampling Stations

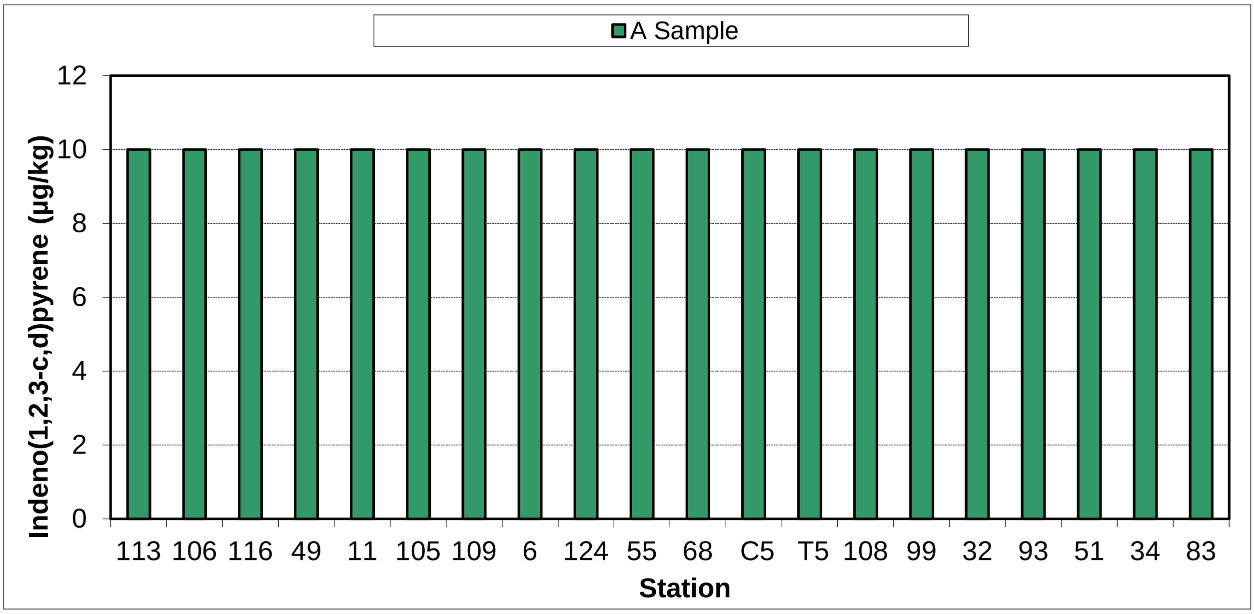


Figure 12B.28 Naphthalene Levels at Sampling Stations

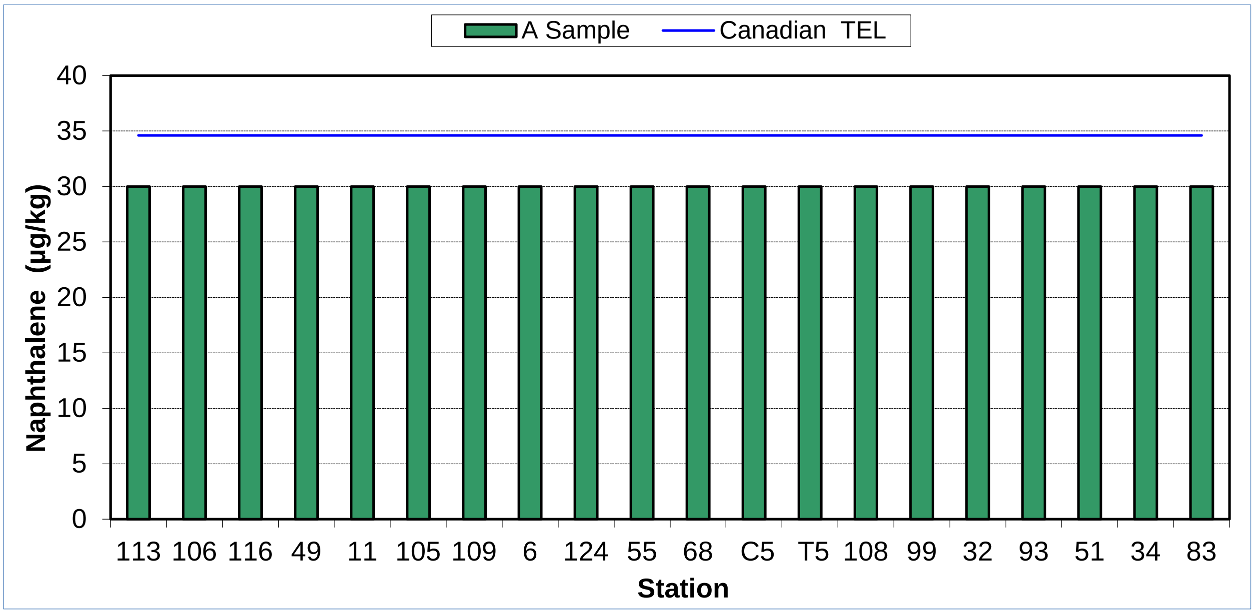


Figure 12B.29 Phenanthrene Levels at Sampling Stations

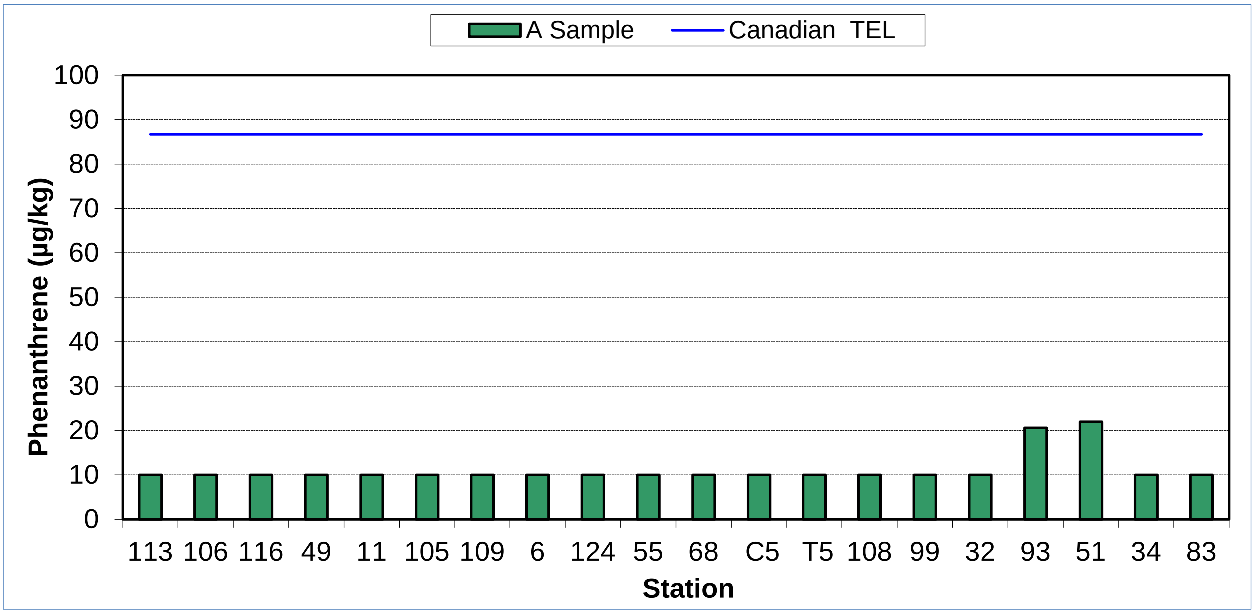
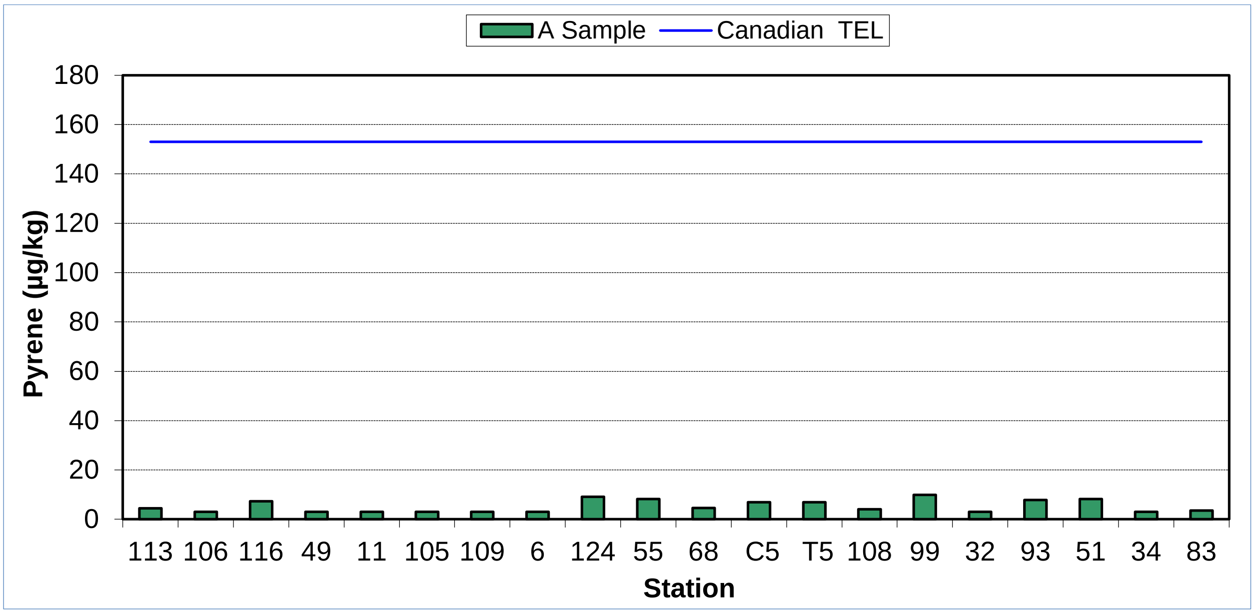
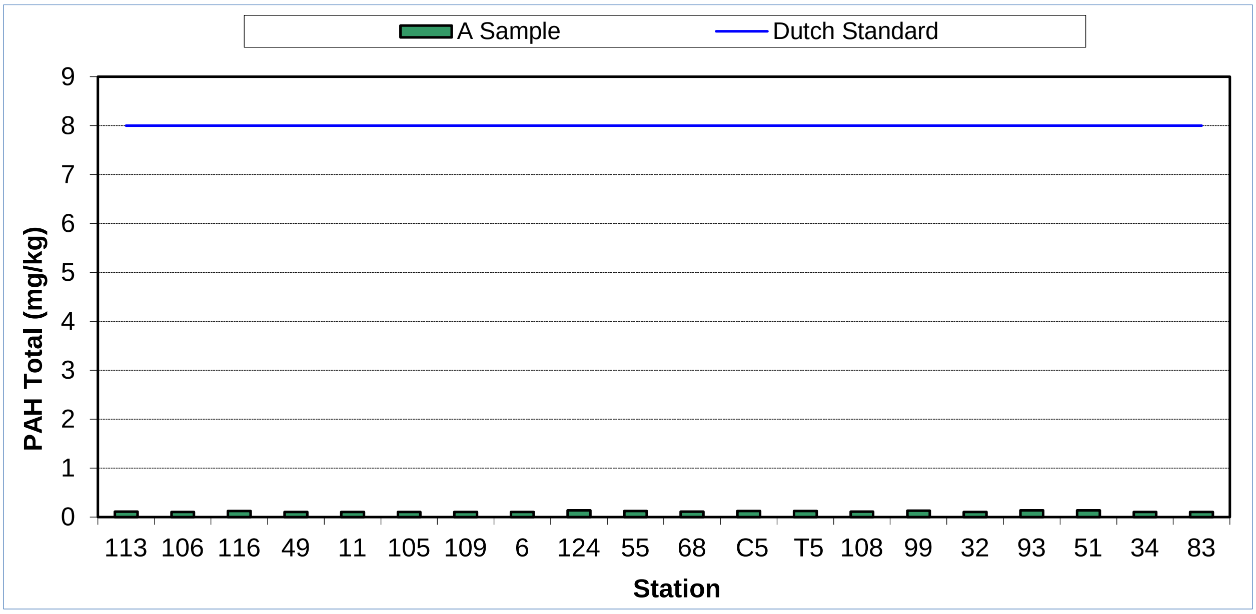


Figure 12B.30 Pyrene Levels at Sampling Stations



Total PAH results are presented for all stations in **Figure 12B.31** with the Dutch Standard for reference, highlighting that all stations are below this reference level.

Figure 12B.31 Total PAH Levels at Sampling Stations



12B.3.4 Poly-Chlorinated Biphenyl (PCB) and Organotin Results

All individual PCBs were below laboratory detection limits (0.1 µg kg^{-1}). Whilst there are no reference levels for individual PCB's, the total PCBs (ICES 7) can be compared against Cefas AL1. Results are displayed in **Figure 12B.32** which shows that all stations recorded PCB levels below AL1. PCB results for each sampling station are provided in **Annex 12B.1**.

All organotins were below the laboratory detection limits of 3 µg kg^{-1} which is below Cefas AL1, **Figure 12B.33**. Organotin levels for each sampling station are provided in **Annex 12B.1**.

Figure 12B.32 Total PCB Levels at Sampling Stations

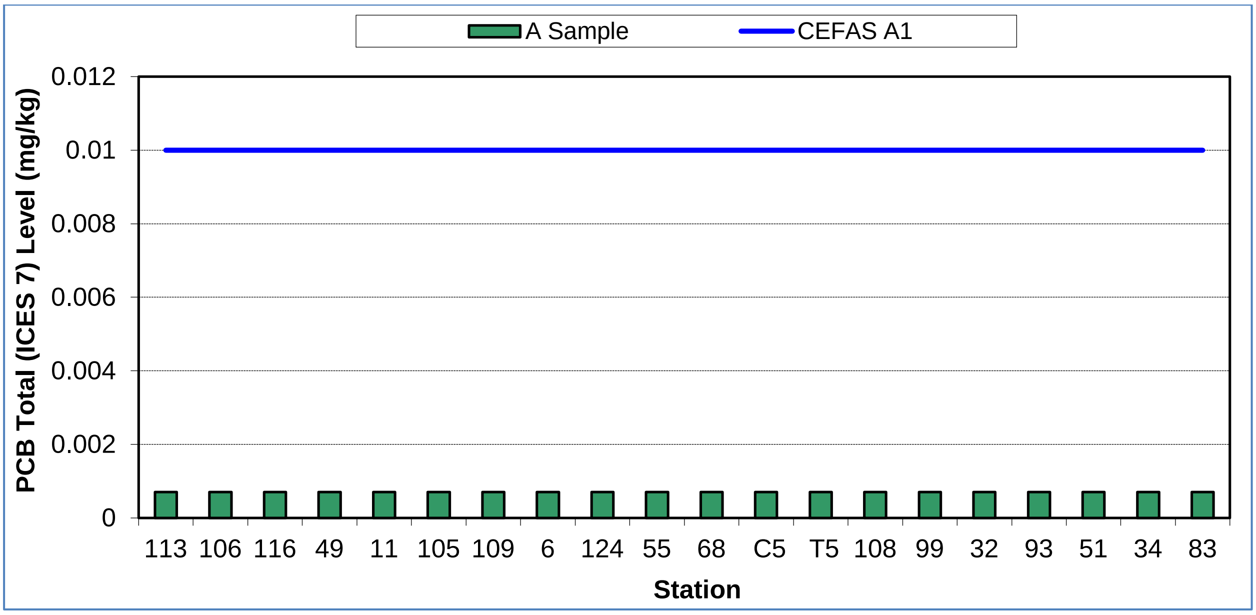
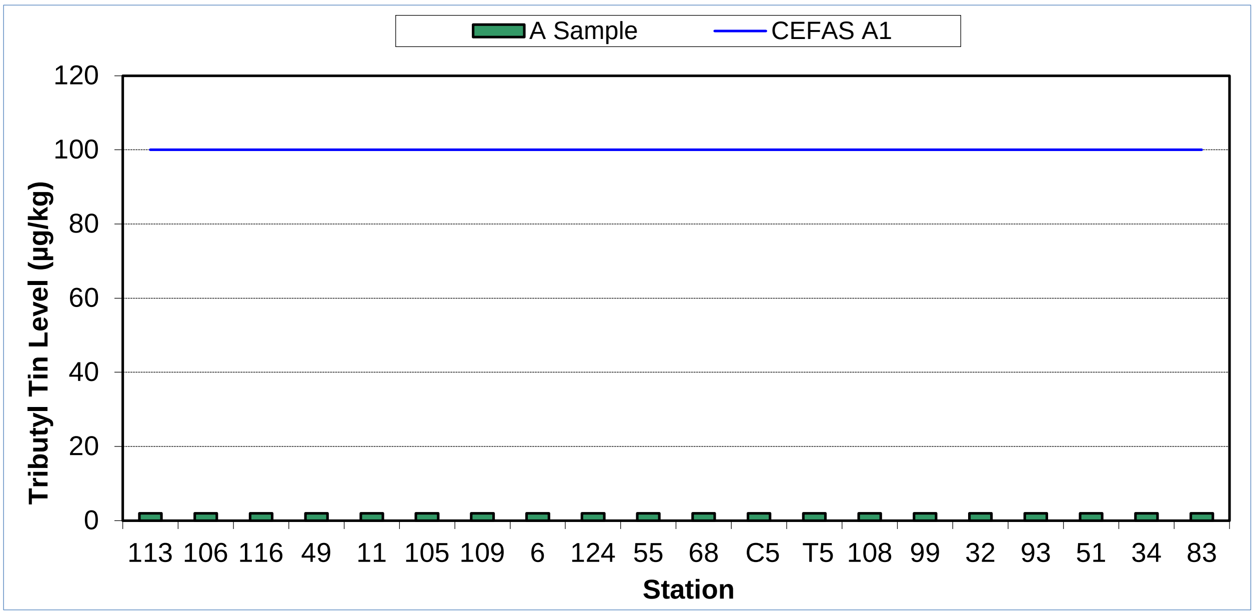


Figure 12B.33 Tributyl Tin Levels at Sampling Stations



12B.3.5 Total Organic Carbon and Particle Size Analysis

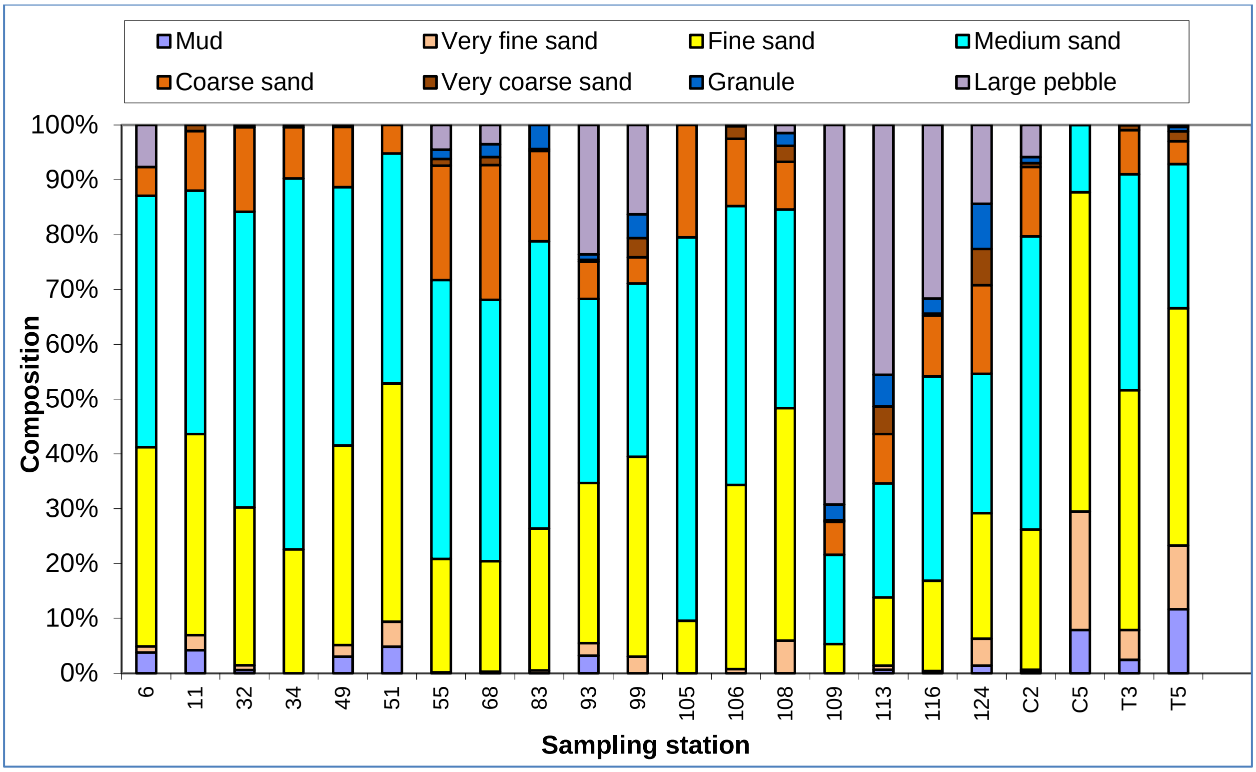
TOC results are displayed in **Table 12B.14** with low values at all sampling stations. The majority of samples (15/ 22) had levels below detection limits (0.4 per cent) with the remainder (7/ 22) never exceeding 0.9 per cent. TOC values for each sampling station are provided in **Annex 12B.3**.

Table 12B.14 TOC Results at Sampling Stations

Station	TOC (%)
113	0.767
106	<0.4
116	0.82
49	<0.4
11	<0.4
105	<0.4
109	0.414
6	<0.4
124	0.53
55	<0.4
68	<0.4
C5	<0.4
T5	0.416
108	0.45
99	0.63
32	<0.4
93	<0.4
51	<0.4
34	<0.4
83	<0.4
T3	<0.4
C2	<0.4

PSA results, using Wentworth classifications, show that all samples have a small mud component, with mud constituting less that 10 per cent in the majority of samples (**Figure 12B.34**). Samples are primarily sandy with fine and medium sand making up the largest proportion of 16 of 22 stations. Stations C5 and T5 are of finer composition, with mud and very fine sand making up a larger percentage. Coarser fractions were present at some stations with 109 and 113 notably coarser, with a large proportion (70 per cent and 40 per cent respectively) of the material consisting of large pebbles. A full PSA breakdown is provided in **Annex 12B.3**.

Figure 12B.34 PSA Results at Sampling Stations



The sorting coefficient at each station is presented in **Table 12B.15** and shows the variability between stations, with the sorting coefficient ranging from 0.46 (very well sorted) to 2.37 (very poorly sorted).

Table 12B.15 Sorting Coefficient Results at Sampling Stations

Station	Sorting Coefficient	Description
105	0.46	Very well sorted
34	0.51	Well sorted
32	0.65	Well sorted
T3	0.68	Well sorted
106	0.69	Well sorted
49	0.7	Well sorted
51	0.71	Well sorted
83	0.73	Well sorted
11	0.77	Moderately sorted
C5	0.97	Moderately sorted
108	1.12	Poorly sorted
68	1.18	Poorly sorted

Station	Sorting Coefficient	Description
C2	1.18	Poorly sorted
55	1.21	Poorly sorted
6	1.27	Poorly sorted
T5	1.38	Poorly sorted
109	1.96	Poorly sorted
113	2.13	Very poorly sorted
116	2.16	Very poorly sorted
124	2.24	Very poorly sorted
99	2.28	Very poorly sorted
93	2.37	Very poorly sorted

12B.4 Discussion

An assessment of the extent of sediment contamination needs to be made to allow the effects of the disturbance and mobilisation of contaminants from these sediments to be assessed within the Development Area EIA. This assessment will be achieved in this section through an overview of actual levels, spatial analysis of the contamination results and through the comparison with historical contamination records.

12B.4.1 Results Overview

12B.4.1.1 Particle Size Analysis and Total Organic Carbon

PSA and TOC play a large role in both the chemical and biological processes that occur within sediment. It is widely recognised that contaminants are more readily associated with fine particles due to a larger adsorption surface and TOC has a direct role in determining the redox potential in sediment, thus regulating the behaviour of other chemical species such as metals (Tukura *et al*., 2007). TOC and PSA are also linked because sediment carbon usually increases with a decreasing grain size. Despite these reported relationships the results across the survey area are variable with the highest percentages of TOC not seen at the sites with the lowest grain size (or within the disposal ground with a history of sewage sludge disposal) and the highest levels of contamination not found at the stations with the greatest percentages of fine sediments and TOC. This is likely a result of the low percentage values of both TOC and fine sediments found across the survey area, as well as the mobile nature of sediment in this area. The sorting coefficient for each station also shows that there is a considerable variability across the site with sediments ranging from very well sorted to very poorly sorted.

12B.4.1.2 Sulphide

Sulphide levels are low across the site, indicating that sediments are mobile, with no clear anoxic layer. Sulphide monitoring is important as an indicator of anoxic layers of sediment because oxygen depletion can lead to higher sulphide levels, due to the activity of some anaerobic bacteria. There is a potential interaction during re-suspension of contaminated sediments whereby mobilisation of metal contaminants into the dissolved phase is hindered by newly formed oxides of metals during their release from anoxic to oxic conditions. Van den Berg *et al*., (2001) and De Groote *et al*., (1998) (both cited in Eggleton & Thomas, 2004) observed low mobilisation of metal contaminants into the dissolved phase during dredging, which was thought to be due to the rapid scavenging of sulphide liberated metals by newly formed Fe and Mn oxides/hydroxides.

No standards are currently used for Sulphide within sediments and little information is available locally, however studies in America have shown levels to be between 2,000 – 5,000 mg kg^{-1} at outfall sites in Bellingham Bay, Washington (Blakely, 2004). Offshore sediments are not expected to be as high in Sulphide as those in inshore areas, and this is reflected in the results from this survey, with all stations showing low values below 20 mg/kg. Further evidence that the sediment is not anoxic is the physical description of each site which reports no evident anoxic layer. This gives a lower potential of scavenging of contaminants upon oxidation during disturbance such as dredging.

12B.4.1.3 Poly-Aromatic Hydrocarbons, Poly-Chlorinated Biphenyls and Organotins

The results of individual and total PAHs are low (all values below the Canadian TEL) and also comparable between stations. These findings highlight that background levels of PAHs are low within the Development Area and outside of the site at tidal and control stations, which suggests there are no active sources or historical sources being uncovered under current environmental conditions. This pattern is also seen for the individual PCBs. Total PCB and organotin results for all stations are below both laboratory detection limits and Cefas AL1. The fact that these contaminants are undetectable in the sediment again highlights the low levels of contamination in and around the Development Area.

12B.4.1.4 Metals

To establish and understand the level of metal contamination across the site, two samples (A and B replicate samples) from each station were analysed.

For some metals, namely mercury, lead and zinc, results are low across all stations for both A and B samples with results lower than Cefas AL1. Cadmium also shows relatively low levels, with Cefas AL only being exceeded in one A sample. Copper shows variable results with seven A samples and five B samples exceeding Cefas AL1, but no values above Cefas AL2. Results for nickel and chromium showed higher levels, with 19 stations exceeding Cefas AL1 for both A and B samples. The upper Cefas AL2 for both nickel and chromium was not exceeded in the B samples, while at five stations in the A samples AL2 was exceeded. Most remaining stations showed close comparability between A and B samples which suggests that these high levels recorded as above Cefas AL2, are not widespread or that the initial results were anomalous. While it is difficult to ascertain why these results were substantially higher than both their replicates, and other samples from the same batch, possible explanations could be the contamination of sample pots or samples during or post survey, for example stainless steel contains both nickel and chromium. Treatment and storage of samples post collection could also have caused an increase in extractable metals, for example a study of nickel and chromium levels in sewage sludge during aerobic combustion showed that concentrations of these metals increased in the order of 30 per cent over a 30 day period (Zheng *et al*., 2007).

Due to the physical-chemical processes involved in treatment, sewage sludge tends to concentrate heavy metals. The fact that sewage sludge was disposed at Bell Rock disposal ground, which is partially within the Development Area, could explain the elevated levels of metals in comparison to the PAH, PCB and organotin levels. The exact content of the disposed material is difficult to ascertain due to the likely irregular inputs of sources, both industrial and domestic. However, studies have been conducted to determine the typical levels of heavy metals in wastewater which have shown the general order of Cd <Cr ≤ Pb<Mn< Ni ≤ Cu< Zn < Fe (Karvelas *et al*., 2003). Karvelas *et al*. (2003) also reviews the solubilities of heavy metals in sewage and reports the follows the orders: Pb<Cu< Cd, and Cu< Pb< Cd< Zn. These results do not suggest that chromium and nickel would be expectantly high in wastewater and sewage sludge and thus at the Bell Rock disposal ground. In fact nickel is more soluble in water than other metals and is found primarily in the dissolved phase than the particulate phase (Karvelas *et al*., 2003). This further suggests that the five stations where chromium and nickel were above Cefas AL2 are not representative of the level of contamination at the Development Area, and more likely are anomalous results borne out of post sample contamination. Through consultation with Marine Scotland it was agreed that these levels were anomalous and could therefore be removed from the impact assessments (Email correspondence 5 November 2012).

12B.4.2 Spatial Analysis of Contamination

The low, and in most cases undetectable levels of PAH, PCB and organotins are consistent between all samples and therefore do not show any spatial trends across the survey area. The results for metals were more variable and to aid the understanding of background levels, the spatial distribution of contaminants results are displayed in **Figures 12B.35** to **12B.36,** and display both A and B samples.

Figure 12B.35 presents metals that were all below Cefas AL1, i.e. mercury, tin, zinc and lead. The spatial distribution of mercury, tin and zinc show that levels are variable across the site and are not seen to be at their highest in the disposal ground. Variability is found at a lesser degree for lead, with values relatively consistent across the survey area. In general for all these metals, the tidal and control sites to the south west of the Development Area have lower contaminant levels than those to the north east of the disposal site, although this is more likely due to the increased percentages of fine particles found at the south west sites than locality to the disposal ground.

Arsenic, cadmium and copper all showed results over Cefas AL1 for at least one sampling station, and the spatial distributions of these metals are set out in **Figure 12B.36**. Results are variable across the stations and although A and B samples are generally comparable, the stations that exceed AL1 are not constant between the two sets of samples despite being taken from the same location. This highlights the variability of the metal levels within and outside the Development Area at a small spatial scale (meters). The sampling station within the Bell Rock disposal ground does not show the highest levels of arsenic, cadmium, or copper, with Cefas AL1 only exceeded for copper. The lack of any clear spatial pattern in the distribution of these metals is most likely a result of the highly dispersive hydrodynamic nature of the area.

Both chromium and nickel exceed Cefas AL1 and AL2 at a number of stations, although AL2 is only exceeded in five stations within the A sample results. The difference between the A and B samples for these five sites in particular suggest that these results are anomalous. Nevertheless the majority of samples are above Cefas AL1 suggesting levels of chromium and nickel are relatively high. The results of these two metals follow a similar spatial pattern across the stations and no identifiable spread of contamination (**Figure 12B.37**). Control and tidal sites show values reflective of those seen within the Development Area, again with the sampling stations to the south west recording higher contaminant levels than those to the north east. As with the other metals the highest levels are not seen within the Bell Rock disposal ground.

Figure 12B.35 Mercury, Tin, Zinc, and Lead Levels for A and B Samples

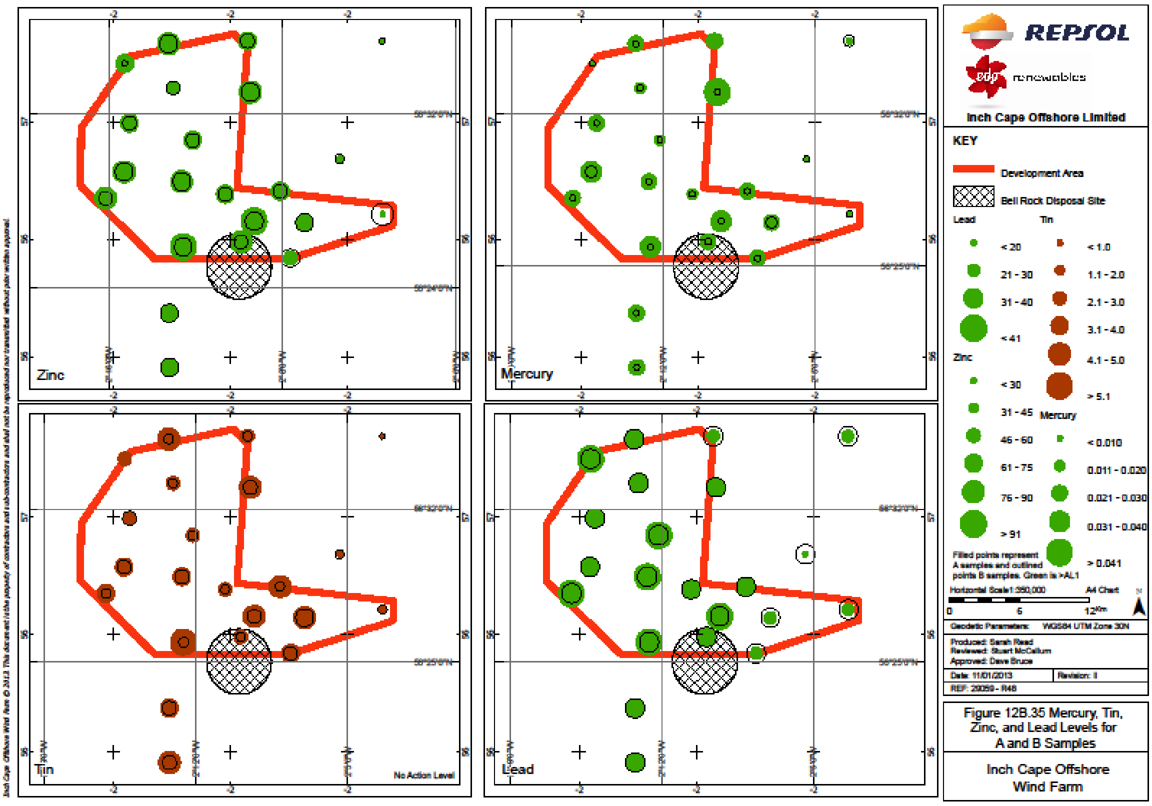
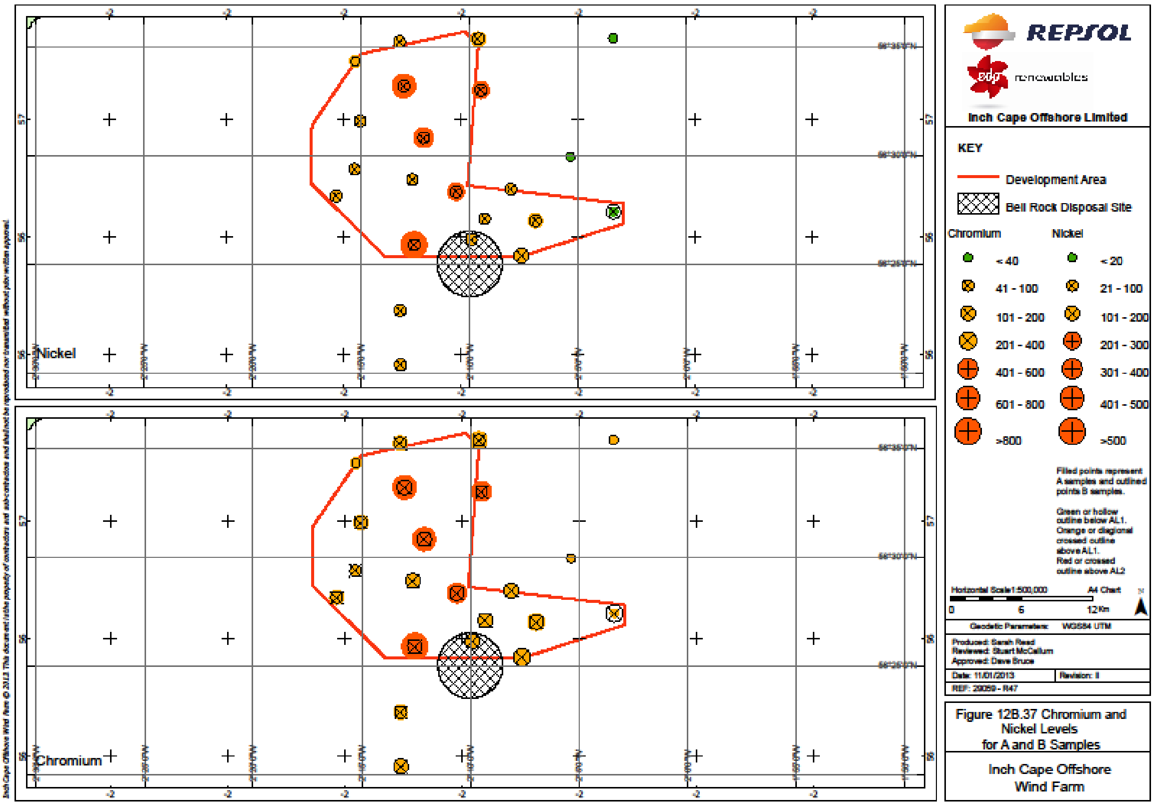


Figure 12B.36 Arsenic, Cadmium, and Copper Levels for A and B Samples

Figure 12B.37 Chromium and Nickel Levels for A and B Samples



12B.4.3 Comparison to Historical Records

Sampling at Bell Rock disposal ground has taken place from to 1991 to 2002, and the most recent results, supplied by Marine Scotland, are compared against the survey area results. Partial digest of metals (B samples only) was used to allow comparison and the average of all 2002 Bell Rock and 2012 site specific contaminated sediment survey results are displayed in **Figure 12B.38**. Results are comparable or lower in the samples from this site specific survey, suggesting there has been little change in contaminant levels over the last decade. Although it must be noted that while some samples overlap spatially, the samples across the survey area were taken over a wider area than the Bell Rock data. There is little evidence of any influence of the disposal ground on the spread of contamination across the survey area, with combined results for nickel and chromium plotted spatially in **Figure 12B.39**.

Figure 12B.38 Average Metals Levels at the Survey Area and Bell Rock Disposal Ground

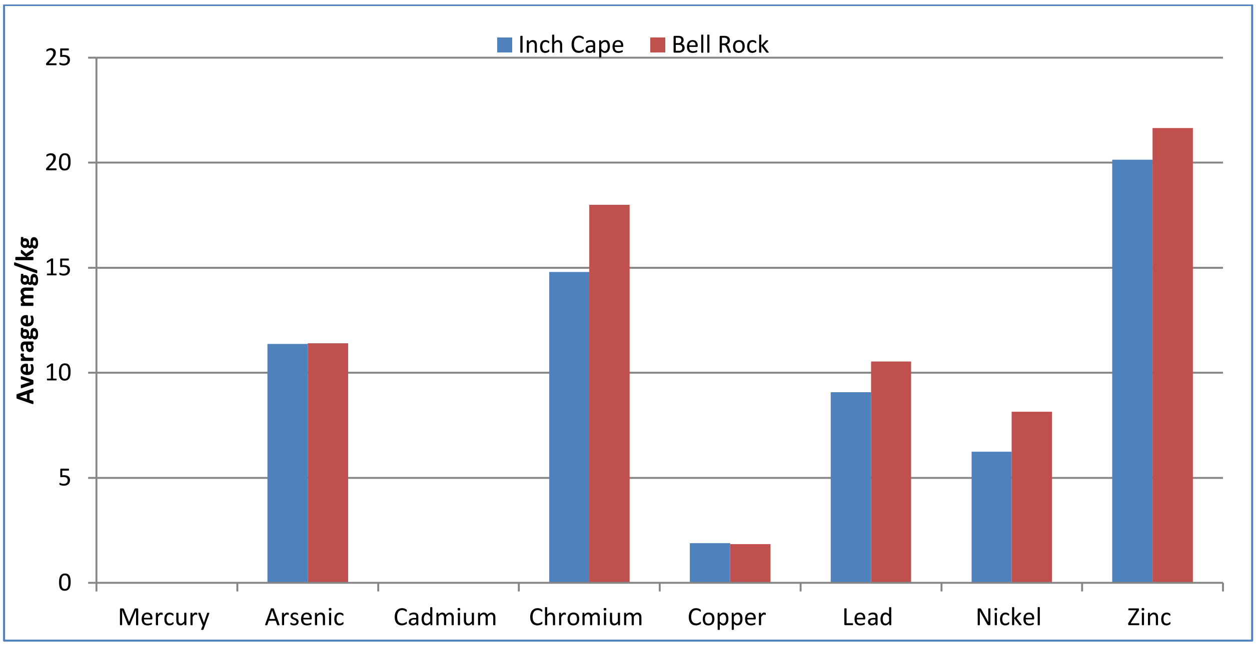
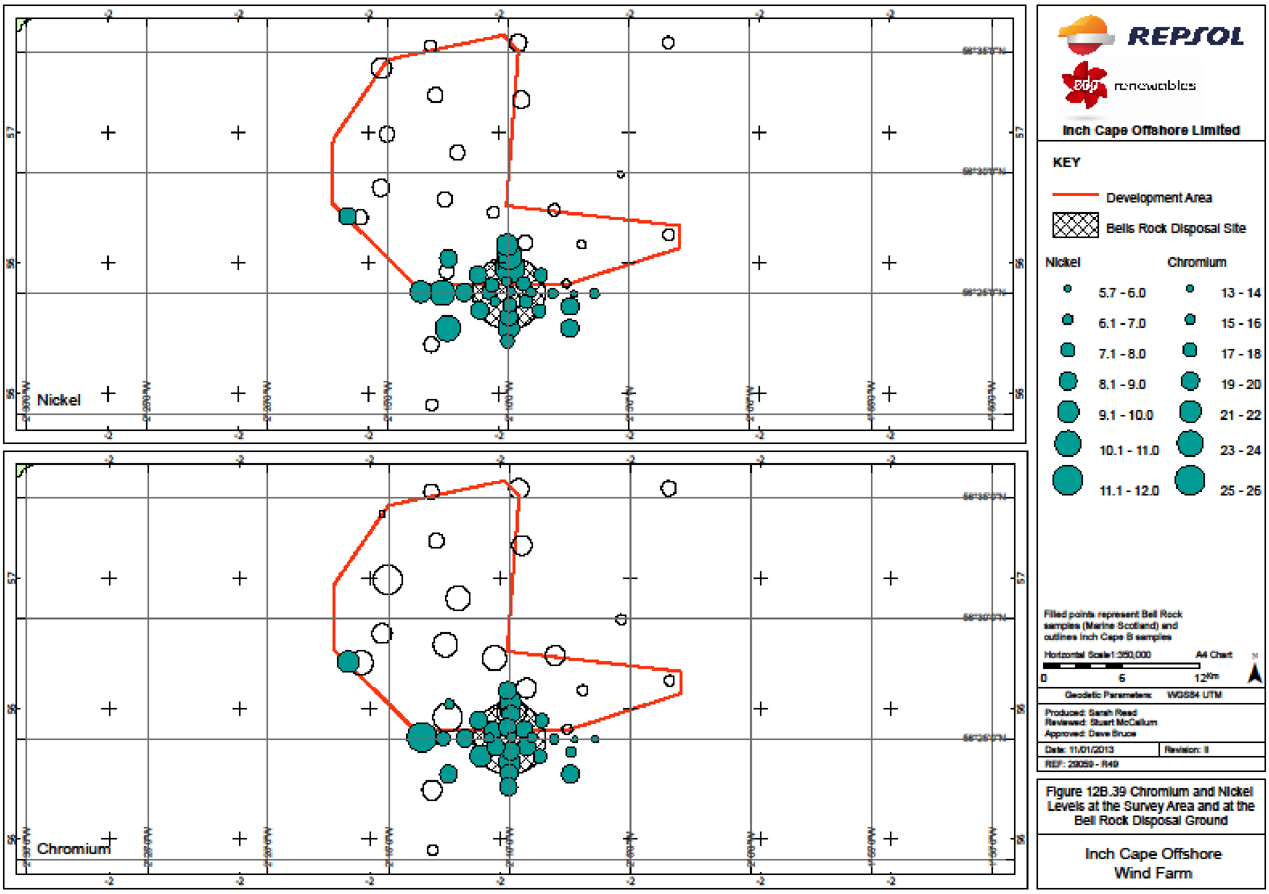


Figure 12B.39 Chromium and Nickel Levels at the Survey Area and at the Bell Rock Disposal Ground



Within the Marine Scotland data set from Bell Rock, contaminant levels are fairly stable from 1991 to 2002, with the changes between 1993 and 1995 attributable to methodology variance (Hayes *et al.,* 2005). Monitoring at Bell Rock disposal ground has shown no effects on the biota that can be attributed to the disposal activities (Hayes *et al.*, 2005). **Table 12B.16** displays the results from this study averaged across the survey area, with comparable Bell Rock disposal ground data. The similarity between this 2012 survey data and the Bell Rock disposal ground 2002 data particularly highlights the stability of levels over the last decade.

Results are also seen to be lower than samples taken in 2007 at Bell Rock Lighthouse, which is approximately 12km from the site and where there is no history of disposal. This suggests that the contaminant levels across the Development Area are not higher than those in the wider area.

Table 12B.16 Bell Rock Disposal Site Data and Survey Area Metal Levels

		Average Metal Contamination							
Site	**Year**	**As (mg kg^{-1})**	**Cd (mg kg^{-1})**	**Cr (mg kg^{-1})**	**Cu (mg kg^{-1})**	**Hg (mg kg^{-1})**	**Ni (mg kg^{-1})**	**Pb (mg kg^{-1})**	**Zn (mg kg^{-1})**
Bell Rock disposal ground	1991	7.28	0.100	2.08	12.33	0.025	7.79	12.49	26.11
Bell Rock disposal ground	1993	79.05	0.050	2.31	8.71	0.010	6.82	12.08	26.08
Bell Rock disposal ground	1995	9.77	0.028	16.84	2.16	0.060	7.92	10.05	28.01
Bell Rock disposal ground	1998	10.07	0.029	16.96	2.05	0.073	7.83	9.68	25.75
Bell Rock disposal ground	2002	11.41	0.031	18.00	1.84	0.009	8.15	10.54	21.65
Bell Rock Lighthouse	2007	14.25	0.000	20.17	5.32	0.065	14.46	13.75	36.39
Survey Area	2012	11.298	0.018	14.576	1.87	0.006	6.105	9.026	19.836

Note: Values in red above Cefas AL1

Partial digest results have also been compared to active disposal ground data which shows, levels across the survey area are lower than those recorded at the active disposal ground in the vicinity (**Table 12B.17**; **Figure 12B.2**).

Table 12B.17 Disposal Ground and Survey Area Contaminant Levels (Partial Digest)

Site		Montrose		Arbroath	Tay	Survey Area
Year		**1993**	**2004**	**1993**	**1998**	**2012**
Contaminant	As (mg kg^{-1})	5.34	6.69	7.14	15.24	11.30
	Cd (mg kg^{-1})	0.20	<0.10	0.20	0.25	0.018
	Cr (mg kg^{-1})	10.49	14.94	7.30	42.79	14.58
	Cu (mg kg^{-1})	10.36	4.01	7.92	24.77	1.87
	Hg (mg kg^{-1})	0.03	<0.01	0.02	0.66	0.006
	Ni (mg kg^{-1})	9.82	11.43	10.38	25.65	6.11
	Pb (mg kg^{-1})	11.61	8.35	13.76	61.07	9.03
	Zn (mg kg^{-1})	29.42	26.05	24.70	119.01	19.83

Note: Values in red above Cefas AL1

CSEMP data from 2010 shows that the sites at Montrose Bank, and those along the Tay to Montrose coastline (averaged), positions displayed in **Figure 12B.2**, display similarly low levels of PAHs as to those seen across the survey area (**Table 12B.18**). In 2010 the total PCB level at these same costal sites was 0.0006 mg kg^{-1}, a level which is comparable to the level of <0.0007 mg kg^{-1} seen across all samples. Average metal results are generally higher at the survey area than at CSEMP coastal locations, and the offshore location at Montrose Bank. This is as expected as CSEMP sites are not located within disposal ground thus typically less impacted by anthropogenic sources.

Table 12B.18 CSEMP Data (2010) and Survey Area Contaminant Levels

	Average Site Result (mg kg^{-1})			
Determinant	**Montrose Bank**	**Tay to Montrose - Intermediate**	**A Samples**	**B Samples**
PCBs sum of ICES 7	0.00060	0.00060	<0.0007	N/A
acenaphthene	0.00004	0.00050	0.00200	N/A
acenaphthylene	0.00004	0.00012	0.00200	N/A
anthracene	0.00004	0.00154	0.00204	N/A
benzo[a]anthracene	0.00014	0.00452	0.00348	N/A
benzo[a]pyrene	0.00030	0.00602	0.00306	N/A
chrysene + triphenylene	0.00030	0.00570	0.00464	N/A
dibenz[a,h]anthracene	0.00020	0.00104	0.00500	N/A
fluoranthene	0.00030	0.00920	0.00513	N/A
fluorene	0.00004	0.00060	<0.01	N/A
naphthalene	0.00030	0.00116	<0.03	N/A
phenanthrene	0.00030	0.00588	0.01113	N/A
pyrene	0.00020	0.00872	0.00525	N/A
mercury	0.00700	0.02170	0.02273	0.14638

arsenic	12.20000	8.67500	16.06045	14.26958
cadmium	0.07000	0.08250	0.13818	0.30279
chromium	20.30000	47.37500	246.12273	123.41667
copper	2.33000	7.98500	33.69318	50.63042
lead	19.40000	20.35000	34.61818	57.38333
nickel	3.59000	14.87500	147.85227	60.63542
zinc	16.00000	44.85000	67.26364	91.92917

Note: Values in red above Cefas AL1

12B.5 Conclusions

The degree of contamination within the sediments across the survey area are low for PAHs, PCBs and organotins, with results under the Canadian TEL, Dutch Standard and Cefas AL1 respectively. Consistency between all 22 samples suggests that the Development Area does not contain enhanced areas of contamination for these components.

Results from metal testing identified that levels are relatively high with arsenic, cadmium, chromium, copper and nickel exceeding Cefas AL1 at the majority of sites. The initial analysis on A samples also contained levels above Cefas AL2 at five stations for nickel and chromium due to the irregularity of these samples in comparison to the remainder, a second replicate was analysed (B samples). This re-analysis recorded no stations with levels above Cefas AL2 for nickel or chromium. As all but the five sites that exceeded AL2 showed comparability it is likely that these results are anomalous. Through consultation with MS it was subsequently agreed that these levels were anomalous and could therefore be removed from the impact assessments. (Email correspondence 5 November 2012). Nevertheless the majority of samples are above Cefas AL1 suggesting levels of chromium and nickel are relatively high.

Results also showed that TOC and sulphide levels were also low at all stations. PSA results show that all samples have a low mud composition, with this constituting less that 10 per cent in the majority of samples. Samples are primarily sandy with fine and medium sand making up the largest proportion of most stations. The sorting of samples is variable with the full range of classes represented, ranging from very well sorted to very poorly sorted.

The presence of a historical disposal ground partially within the Development Area, Bell Rock, gives the Development Area potential for contamination accumulation. However, contamination results are spatially variable across the entire survey area and there are no identified areas of enhanced contamination, despite the presence of the disposal ground. The lack of a spatial pattern within the results is likely to reflect the highly dispersive nature of the local environment and that disposal stopped in 1998. Partial digest testing of metals within the sediment samples allows the comparison with historical data. Contamination results are comparable to those recorded at the Bell rock disposal ground (provided by Marine Scotland) in 2002 which suggests levels have remained stable over the last decade. While no direct impacts of the disposal ground are clear, the fact that metals are found to be relatively high could be attributed to the disposal ground as heavy metals are common in sewage sludge, which was disposed at this site for around 20 years. However, literature reviews of the monitoring at the disposal ground do not identify significant effects on the benthos as a result of the disposal activity. CSEMP data is also comparable to results from the survey area, however levels (particularly for metal contaminants) are generally higher across the survey area than at the CSEMP monitoring stations.

12B.6 References

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Annex 12B.1 A Sample Contamination Results

		Station								
		113	**106**	**116**	**49**	**11**	**105**	**109**	**6**	**124**
Analyte	*Units*									
Sulphide : Dry Wt	mg/kg	16.1	13.3	14.6	14.2	15	15.1	14.2	15.4	16.6
PAH : Total : Dry Wt	mg/kg	<0.111	<0.103	<0.125	<0.104	<0.104	<0.103	<0.103	<0.103	<0.134
PCB : Total (28, 52, 101, 118, 138, 153, 180)	mg/kg	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007
Mercury : Dry Wt	mg/kg	0.048	0.019	0.029	0.017	0.031	0.014	0.003	0.026	0.024
Arsenic, HF Digest : Dry Wt	mg/kg	13.4	27.5	11.8	17.5	27.8	23.5	34.5	14.6	7.65
Cadmium, HF Digest : Dry Wt	mg/kg	0.222	0.274	0.132	0.201	0.422	0.279	0.089	0.088	0.166
Chromium, HF Digest : Dry Wt	mg/kg	465	603	149	473	1110	628	64.5	126	203
Copper, HF Digest : Dry Wt	mg/kg	28.7	53.6	21.6	24.4	39.8	32.2	18.6	38.4	20.6
Lead, HF Digest : Dry Wt	mg/kg	33.7	49.5	33.1	30.6	47.5	38.3	46.3	31.5	28.3
Nickel, HF Digest : Dry Wt	mg/kg	293	385	78.3	296	729	481	23.1	53.9	116
Tin, HF Digest : Dry Wt	mg/kg	4.12	2.91	4.31	2.6	5.31	2.79	2.22	2.68	2.63
Zinc : HF Digest : Dry Wt	mg/kg	79.1	75	82.8	62.5	92	52.4	70	64.6	66.2
Acenaphthene : Dry Wt	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2
Acenaphthylene : Dry Wt	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2
Anthracene : Dry Wt	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	2.81
Benzo(a)anthracene : Dry Wt	ug/kg	3.82	<2	5.21	<2	<2	<2	<2	<2	7.16
Benzo(a)pyrene : Dry Wt	ug/kg	3.08	<2	4.72	<2	<2	<2	<2	<2	4.72
Benzo(b)fluoranthene : Dry Wt	ug/kg	<10	<10	12.8	<10	<10	<10	<10	<10	15.1
Benzo(ghi)perylene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10
Benzo(k)fluoranthene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10
Chrysene : Dry Wt	ug/kg	3.98	<3	5.69	<3	<3	<3	<3	<3	7.56
Dibenzo(ah)anthracene : Dry Wt	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoranthene : Dry Wt	ug/kg	4.62	<2	7.74	2.82	2.74	<2	<2	<2	8.96
Fluorene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10

		Station								
		113	**106**	**116**	**49**	**11**	**105**	**109**	**6**	**124**
Analyte	*Units*									
Indeno(1,2,3-c,d)pyrene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10
Naphthalene : Dry Wt	ug/kg	<30	<30	<30	<30	<30	<30	<30	<30	<30
Phenanthrene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pyrene : Dry Wt	ug/kg	4.42	<3	7.34	<3	<3	<3	<3	<3	9.1
PCB - 028 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 052 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 101 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 118 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 138 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 153 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 180 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dibutyl Tin : Dry Wt as Cation	ug/kg	<3	<3	<3	<3	<3	<3	<3	<3	<3
Dioctyl Tin : Dry Wt as Cation	ug/kg	<3	<3	<3	<3	<3	<3	<3	<3	<3
Diphenyl Tin : Dry Wt as Cation	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2
Tetrabutyl Tin : Dry Wt as Cation	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2
Tributyl Tin : Dry Wt as Cation	ug/kg	<3	<3	<3	<3	<3	<3	<3	<3	<3
Triphenyl Tin : Dry Wt as Cation	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2

		Station										
		55	**68**	**C5**	**T5**	**108**	**99**	**32**	**93**	**51**	**34**	**83**
Analyte	*Units*											
Sulphide : Dry Wt	mg/kg	15.7	15.3	16.1	15.3	14.2	15.6	14.1	15.2	16	14.3	15.1
PAH : Total : Dry Wt	mg/kg	<0.121	<0.110	<0.122	<0.121	<0.107	<0.132	<0.104	<0.136	<0.137	<0.103	<0.106
PCB : Total (28, 52, 101, 118, 138, 153, 180)	mg/kg	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007
Mercury : Dry Wt	mg/kg	0.037	0.027	0.028	0.03	0.027	0.031	0.022	0.029	0.024	<0.002	0.023
Arsenic, HF Digest : Dry Wt	mg/kg	14.9	17.4	10.6	8.79	7.8	10.1	18.8	12.1	6.87	29.5	7.15
Cadmium, HF Digest : Dry Wt	mg/kg	0.112	0.1	0.091	0.091	0.082	0.097	0.109	0.116	0.156	<0.03	0.123
Chromium, HF Digest : Dry Wt	mg/kg	107	121	113	117	146	91.7	140	114	348	20.9	227
Copper, HF Digest : Dry Wt	mg/kg	43.4	47.8	47.7	28.9	91.5	26.7	70.5	51.1	20.1	4.92	21.5
Lead, HF Digest : Dry Wt	mg/kg	46.6	39.1	32.6	35.6	34.2	37	46.1	43.9	25.2	20.3	28.9
Nickel, HF Digest : Dry Wt	mg/kg	51.2	57.5	45.8	53.1	77	37.4	71	50.1	198	8.65	134
Tin, HF Digest : Dry Wt	mg/kg	4.13	2.85	4.11	3.3	4.71	3.38	3.15	3.42	3.37	1.01	4.82
Zinc : HF Digest : Dry Wt	mg/kg	92.5	77	72.7	70.7	74.8	81.9	75.4	88.6	58.3	28.4	63.1
Acenaphthene : Dry Wt	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Acenaphthylene : Dry Wt	ug/kg	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Anthracene : Dry Wt	ug/kg	2.07	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzo(a)anthracene : Dry Wt	ug/kg	4.69	3.09	5	4.92	2.88	5.94	<2	4.12	4.43	<2	2.4
Benzo(a)pyrene : Dry Wt	ug/kg	4.2	2.63	4.86	4.54	<2	5.61	<2	3.25	3.63	<2	<2
Benzo(b)fluoranthene : Dry Wt	ug/kg	<10	<10	11.9	11.1	<10	13.8	<10	10.3	<10	<10	<10
Benzo(ghi)perylene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Benzo(k)fluoranthene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

		Station										
		55	**68**	**C5**	**T5**	**108**	**99**	**32**	**93**	**51**	**34**	**83**
Analyte	*Units*											
Chrysene : Dry Wt	ug/kg	4.96	4.12	5.45	5.3	<3	6.87	<3	8.99	9.74	<3	3.1
Dibenzo(ah)anthracene : Dry Wt	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoranthene : Dry Wt	ug/kg	8.18	4.5	7.22	7.09	3.97	9.27	2.96	<10	8.18	<2	4.3
Fluorene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Indeno(1,2,3-c,d)pyrene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Naphthalene : Dry Wt	ug/kg	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Phenanthrene : Dry Wt	ug/kg	<10	<10	<10	<10	<10	<10	<10	20.6	22	<10	<10
Pyrene : Dry Wt	ug/kg	8.28	4.54	6.96	6.91	4.03	9.86	<3	7.86	8.17	<3	3.5
PCB - 028 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 052 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 101 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 118 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 138 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 153 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PCB - 180 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dibutyl Tin : Dry Wt as Cation	ug/kg	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Dioctyl Tin : Dry Wt as Cation	ug/kg	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Diphenyl Tin : Dry Wt as Cation	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Tetrabutyl Tin : Dry Wt as Cation	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Tributyl Tin : Dry Wt as Cation	ug/kg	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Triphenyl Tin : Dry Wt as Cation	ug/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Annex 12B.2 B Sample Contamination Results

		Station								
Analyte	**Unit**	**113**	**106**	**116**	**49**	**11**	**105**	**109**	**6**	**124**
Mercury : Dry Wt	mg/kg	0.014	0.004	0.008	0.004	0.004	0.003	0.004	0.006	0.011
Arsenic : Dry Wt	mg/kg	8.38	22.8	7.58	14.5	7.63	16.7	7.41	10.5	4.54
Cadmium : Dry Wt	mg/kg	0.024	0.015	0.023	0.014	0.013	0.014	0.018	0.014	0.034
Chromium : Dry Wt	mg/kg	14.8	17.2	12.7	16.3	20	13.5	9.47	18.8	14.4
Copper : Dry Wt	mg/kg	2.33	1.81	2.61	1.51	1.66	1.8	2.41	2.07	2.61
Lead : Dry Wt	mg/kg	7.59	12.9	8	11.9	8.51	8.85	6.26	9.87	7.43
Lithium : Dry Wt	mg/kg	6.25	5.15	7.35	4.88	6.34	4.78	5.76	6	6.67
Manganese : Dry Wt	mg/kg	159	443	215	363	160	339	249	198	153
Nickel : Dry Wt	mg/kg	7.12	6.9	5.98	5.88	6.34	6.55	8.14	6.13	7.07
Vanadium : Dry Wt	mg/kg	25.1	53.1	24.5	38.7	27.8	39	21.2	35.2	19.3
Zinc : Dry Wt	mg/kg	20.1	20.6	18.3	20.3	24.5	16.2	16.9	24.5	20.2
Mercury : Dry Wt	mg/kg	0.007	0.005	0.009	0.005	0.006	0.004	0.004	0.008	0.063
Arsenic, HF Digest : Dry Wt	mg/kg	6.07	10.4	8.56	7.57	10	9.96	15	6.36	7.11
Cadmium, HF Digest : Dry Wt	mg/kg	0.083	0.089	0.083	0.082	0.095	0.088	0.056	0.061	0.069
Chromium, HF Digest : Dry Wt	mg/kg	91.5	136	91	118	125	148	25.7	98.4	89.3
Copper, HF Digest : Dry Wt	mg/kg	19.6	30.3	18.3	27.9	51.5	28.3	8.35	22.5	22.3
Lead, HF Digest : Dry Wt	mg/kg	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6
Nickel, HF Digest : Dry Wt	mg/kg	34.7	65.7	34.7	58.7	59.2	68.9	10.9	35.5	33.9
Tin, HF Digest : Dry Wt	mg/kg	2.25	1.37	1.82	1.92	2	1.34	0.5	2.09	1.99
Zinc : HF Digest : Dry Wt	mg/kg	62.9	49.9	62.5	55.1	68.3	53.2	28.1	52.1	59.2

		Station												
Analyte	**Unit**	**55**	**68**	**C5**	**T5**	**108**	**99**	**32**	**93**	**51**	**34**	**83**	**T3**	**C2**
Mercury : Dry Wt	mg/kg	0.005	0.005	0.007	0.01	0.009	0.012	0.003	0.006	0.004	0.004	0.006	0.004	0.005
Arsenic : Dry Wt	mg/kg	21.7	27.5	3.12	3.97	4.03	5.91	26.3	7.31	3.55	15.6	8.54	3.39	17.6
Cadmium : Dry Wt	mg/kg	0.016	0.021	0.025	0.022	0.013	0.025	0.017	0.013	0.011	0.011	0.022	0.016	0.018
Chromium : Dry Wt	mg/kg	16	18.8	11.6	15.5	14.6	14.7	16.3	16.3	11.9	11.2	11.8	11.3	13.5
Copper : Dry Wt	mg/kg	1.75	1.96	1.69	2.25	1.63	2.46	1.57	1.48	1.07	1.41	1.65	1.59	1.82
Lead : Dry Wt	mg/kg	13	14	9.1	5.39	6.75	8.74	13.5	8.95	4.24	7.47	9.11	4.91	12.1
Lithium : Dry Wt	mg/kg	4.78	6.46	4.97	5.77	4.67	6.45	4.52	4.71	4.19	3.85	4.49	4.37	4.17
Manganese : Dry Wt	mg/kg	289	398	92.2	129	127	233	366	214	89	231	146	91.7	220
Nickel : Dry Wt	mg/kg	6.14	7.94	5.13	6.25	5.08	7.56	6.09	6.06	4.28	5.8	4.49	4.27	5.11
Vanadium : Dry Wt	mg/kg	47.7	59.7	11.5	16.7	18.7	21.3	53.9	25.7	12.3	34.6	24.1	13.2	41.3
Zinc : Dry Wt	mg/kg	20	27.1	20.8	23.5	17.4	24.2	19.7	20.9	15.9	14.6	17	15.9	17.8
Mercury : Dry Wt	mg/kg	0.005	0.007	0.008	0.009	0.007	0.013	0.006	0.006	0.005	0.004	0.014	0.006	0.012
Arsenic, HF Digest : Dry Wt	mg/kg	10.3	9.58	8.15	6.94	6.33	7.44	17.6	8.38	8.53	22.2	8.79	7.5	19.7
Cadmium, HF Digest : Dry Wt	mg/kg	0.106	0.081	0.083	0.099	0.082	0.086	0.152	0.074	0.118	0.111	0.102	0.036	0.031
Chromium, HF Digest : Dry Wt	mg/kg	138	131	122	84.5	161	81.2	160	93.3	222	243	108	28.9	26.2
Copper, HF Digest : Dry Wt	mg/kg	42.8	23.9	23.3	16.6	29.5	17.9	34.1	30.4	58.9	181	76.1	5.83	5.75
Lead, HF Digest : Dry Wt	mg/kg	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6
Nickel, HF Digest : Dry Wt	mg/kg	70.7	61.3	62	37.5	62.1	32.5	93.5	42.4	134	164	55.6	8.53	8.92
Tin, HF Digest : Dry Wt	mg/kg	2.29	1.57	2.74	2.49	1.58	2.48	2.02	1.97	2.3	1.79	3.37	1.05	0.84
Zinc : HF Digest : Dry Wt	mg/kg	64.9	52.3	66	66.1	53.7	66.3	66.2	57.5	71	80.2	76.2	35.2	29.4

Annex 12B.3 Particle Size Analysis and Total Organic Carbon Results

	Station											
Analyte	**Units**	**113**	**109**	**105**	**116**	**106**	**99**	**93**	**32**	**6**	**124**	**11**
Grain Size Fraction : < -6 phi	%	0	0	0	0	0	0	0	0	0	0	0
Grain Size Fraction : -6 to -5 phi	%	0	68.4	0	0	0	0	0	0	6.95	0	0
Grain Size Fraction : -5 to -4 phi	%	0	0	0	10.6	0	0	21.2	0	0	0	0
Grain Size Fraction : -4 to -3 phi	%	39.9	0	0	18.8	0	14.5	2.09	0	0.65	11.9	0
Grain Size Fraction : -3 to -2 phi	%	12	1.2	0	7.13	0	9.6	1.21	0	0.12	16.4	0
Grain Size Fraction : -2 to -1 phi	%	5.05	2.82	0	2.56	0.19	3.85	1.02	0	0.03	6.85	0
Grain Size Fraction : -1 to 0 phi	%	4.41	0.3	0	0.33	2.29	3.12	0.32	0.39	0	5.46	1.06
Grain Size Fraction : 0 to 1 phi	%	7.87	5.92	20.5	10.3	12.3	4.28	6.7	15.4	5.26	13.4	10.9
Grain Size Fraction : 1 to 2 phi	%	18.2	16.1	69.9	34.6	50.9	28.2	33.2	53.9	45.8	21.1	44.4
Grain Size Fraction : 2 to 3 phi	%	10.9	5.24	9.57	15.3	33.6	32.5	28.9	28.8	36.3	19	36.7
Grain Size Fraction : 3 to 4 phi	%	0.68	0	0	0.1	0.72	2.67	2.24	0.86	1.11	4.07	2.77
Grain Size Fraction : 4 to 5 phi	%	0.1	0	0	0	0	0	0.39	0.58	0.61	0.56	0.84
Grain Size Fraction : 5 to 6 phi	%	0.44	0	0	0	0	0	0.84	0.09	1	0.42	0.87
Grain Size Fraction : 6 to 7 phi	%	0.01	0	0	0.14	0	0	0.77	0	0.87	0.15	0.98
Grain Size Fraction : 7 to 8 phi	%	0	0	0	0.12	0	0	0.87	0	0.98	0	1.1
Grain Size Fraction : 8 to 9 phi	%	0	0	0	0	0	0	0.28	0	0.28	0	0.37
Grain Size Fraction : 9 to 10 phi	%	0	0	0	0	0	0	0	0	0	0	0
Grain Size Fraction : > 10 phi	%	0	0	0	0	0	0	0	0	0	0	0
Grain Size Fraction : <3.9 microns	%	0	0	0	0	0	0	0.28	0	0.28	0	0.37
Grain Size Fraction : 3.9 - 7.79 microns	%	0	0	0	0.12	0	0	0.87	0	0.98	0	1.09
Grain Size Fraction : 7.8 - 15.59 microns	%	0.01	0	0	0.14	0	0	0.77	0	0.87	0.15	0.98
Grain Size Fraction : 15.6 - 31.99 microns	%	0.45	0	0	0	0	0	0.88	0.11	1.05	0.44	0.9
Grain Size Fraction : < 20 microns	%	0.15	0	0	0.26	0	0	2.16	0.11	2.38	0.3	2.74
Grain Size Fraction : 32 - 62.9 microns	%	0.08	0	0	0	0	0	0.35	0.57	0.56	0.57	0.82
Grain Size Fraction : < 63 microns	%	0.54	0	0	0.26	0	0	3.15	0.57	3.74	1.16	4.16
Grain Size Fraction : 63 to 125 microns	%	0.68	0	0	0.1	0.72	2.67	2.24	0.85	1.11	4.04	2.76
Grain Size Fraction : 125 to 249 microns	%	10.9	5.24	9.57	15.3	33.6	32.5	28.9	28.8	36.3	19	36.7
Grain Size Fraction : 250 to 499 microns	%	18.2	16.1	69.9	34.6	50.9	28.2	33.2	53.9	45.8	21.1	44.4
Grain Size Fraction : 500 to 999 microns	%	7.86	5.92	20.5	10.3	12.3	4.28	6.7	15.4	5.26	13.4	10.9

	Station											
Analyte	**Units**	**113**	**109**	**105**	**116**	**106**	**99**	**93**	**32**	**6**	**124**	**11**
Grain Size Fraction : 1000 to 1999 microns	%	4.41	0.3	0	0.33	2.29	3.12	0.32	0.39	0	5.46	1.06
Grain Size Fraction : 2000 to 3999 microns	%	5.05	2.82	0	2.56	0.19	3.85	1.02	0	0.03	6.85	0
Grain Size : 4000 to 7999 microns	%	12	1.2	0	7.13	0	9.6	1.21	0	0.12	16.4	0
Grain Size Fraction : > 8000 microns	%	39.9	68.4	0	29.4	0	14.5	23.3	0	7.6	11.9	0
Grain Size : 8000 to 15999 microns	%	39.9	0	0	18.8	0	14.5	2.09	0	0.65	11.9	0
Grain Size Fraction : 16000 - 31999 microns	%	0	0	0	10.6	0	0	21.2	0	0	0	0
Grain Size Fraction : 32000 - 62999 microns	%	0	68.4	0	0	0	0	0	0	6.95	0	0
Grain Size Fraction : > 63000 microns	%	0	0	0	0	0	0	0	0	0	0	0
Grain Size Inclusive Kurtosis	mm	0.697	0.551	0.514	0.712	0.454	0.669	0.629	0.514	0.15	0.66	0.467
Grain Size Inclusive Mean	mm	2.35	3.2	0.382	1.07	0.304	0.768	0.801	0.316	0.279	0.946	0.274
Inclusive Graphic Skewness :- {SKI}	Unitless	-0.63	-0.94	0.01	0.51	0.13	0.66	0.6	-0.01	0.33	0.32	-0.04
Kurtosis	Unitless	-1.78	-1.45	0.55	-1.03	15.4	5.29	0.19	2.27	15.1	-0.22	8.34
Particle Diameter : Mean	mm	4.77	6.15	0.401	3.31	0.359	2.37	2.45	0.35	0.857	2.62	0.311
Particle Diameter : Median	mm	4.8	8.69	0.38	0.545	0.298	0.319	0.332	0.318	0.276	0.604	0.272
Sorting Coefficient	Unitless	2.13	1.96	0.46	2.16	0.69	2.28	2.37	0.65	1.27	2.24	0.77
Total Organic Carbon	%	0.767	0.414	<0.4	0.82	<0.4	0.63	<0.4	<0.4	<0.4	0.53	<0.4

	Station											
Analyte	**Units**	**55**	**T5A**	**C5 A**	**T3A**	**C2 A**	**108**	**49**	**83**	**51**	**68**	**34**
Grain Size Fraction : < -6 phi	%	0	0	0	0	0	0	0	0	0	0	0
Grain Size Fraction : -6 to -5 phi	%	0	0	0	0	2.97	0	0	0	0	0	0
Grain Size Fraction : -5 to -4 phi	%	2.67	0	0	0	0	0	0	0	0	0	0
Grain Size Fraction : -4 to -3 phi	%	1.78	0	0	0	1.63	1.41	0	0	0	0	0
Grain Size Fraction : -3 to -2 phi	%	0.88	0	0	0	0.85	1.87	0	0.14	0	0	0
Grain Size Fraction : -2 to -1 phi	%	1.66	0.16	0	0	1	2.25	0	4.38	0	0	0
Grain Size Fraction : -1 to 0 phi	%	1.21	1.45	0	0.69	0.36	2.88	0.31	0.33	0	1.47	0.36
Grain Size Fraction : 0 to 1 phi	%	20.8	4.49	0	5.05	15.1	8.46	11	16.5	5.17	24.3	9.37
Grain Size Fraction : 1 to 2 phi	%	50.6	28.1	9.02	37.4	54.3	35.2	47.2	52.3	42	47.1	67.7
Grain Size Fraction : 2 to 3 phi	%	20.5	41.7	59.3	47.7	23.8	41.3	36.4	25.9	43.5	19.9	22.6
Grain Size Fraction : 3 to 4 phi	%	0.14	12	21.7	6.01	0.09	5.75	2.12	0.49	4.53	0.26	0
Grain Size Fraction : 4 to 5 phi	%	0	1.81	0.03	0.25	0	0	0.73	0	0.44	0	0
Grain Size Fraction : 5 to 6 phi	%	0	2.21	2.27	1.29	0	0	0.71	0	1.4	0	0
Grain Size Fraction : 6 to 7 phi	%	0	3.76	2.27	0.61	0	0	0.61	0	1.11	0	0
Grain Size Fraction : 7 to 8 phi	%	0	2.82	2.07	0.79	0	0	0.8	0	1.3	0	0
Grain Size Fraction : 8 to 9 phi	%	0	1.24	1.11	0.2	0	0	0.18	0	0.57	0	0
Grain Size Fraction : 9 to 10 phi	%	0	0.28	0.11	0	0	0	0	0	0	0	0
Grain Size Fraction : > 10 phi	%	0	0	0	0	0	0	0	0	0	0	0
Grain Size Fraction : <3.9 microns	%	0	1.51	1.22	0.2	0	0	0.18	0	0.57	0	0
Grain Size Fraction : 3.9 - 7.79 microns	%	0	2.81	2.07	0.79	0	0	0.8	0	1.3	0	0
Grain Size Fraction : 7.8 - 15.59 microns	%	0	3.76	2.27	0.61	0	0	0.61	0	1.11	0	0
Grain Size Fraction : 15.6 - 31.99 microns	%	0	2.26	2.28	1.34	0	0	0.74	0	1.46	0	0
Grain Size Fraction : < 20 microns	%	0	9.15	6.57	1.95	0	0	1.78	0	2.83	0	0
Grain Size Fraction : 32 - 62.9 microns	%	0	1.78	0.03	0.2	0	0	0.7	0	0.39	0	0
Grain Size Fraction : < 63 microns	%	0	12.1	7.87	3.14	0	0	3.03	0	4.84	0	0
Grain Size Fraction : 63 to 125 microns	%	0.14	12	21.7	6.01	0.09	5.75	2.12	0.49	4.52	0.26	0
Grain Size Fraction : 125 to 249 microns	%	20.5	41.7	59.3	47.7	23.8	41.3	36.4	25.9	43.5	19.9	22.6
Grain Size Fraction : 250 to 499 microns	%	50.5	28.1	11.2	37.4	54.3	35.2	47.2	52.4	42	47.1	67.7
Grain Size Fraction : 500 to 999 microns	%	20.7	4.49	0	5.04	15.1	8.46	11	16.5	5.17	24.3	9.37

	Station											
Analyte	**Units**	**55**	**T5A**	**C5A**	**T3A**	**C2A**	**108**	**49**	**83**	**51**	**68**	**34**
Grain Size Fraction : 1000 to 1999 microns	%	1.21	1.45	0	0.69	0.36	2.88	0.31	0.33	0	1.47	0.36
Grain Size Fraction : 2000 to 3999 microns	%	1.66	0.16	0	0	1	2.25	0	4.38	0	2.29	0
Grain Size : 4000 to 7999 microns	%	0.88	0	0	0	0.85	1.87	0	0.14	0	1.26	0
Grain Size Fraction : > 8000 microns	%	4.45	0	0	0	4.6	1.41	0	0	0	3.46	0
Grain Size : 8000 to 15999 microns	%	1.78	0	0	0	1.63	1.41	0	0	0	1.08	0
Grain Size Fraction : 16000 - 31999 microns	%	2.67	0	0	0	0	0	0	0	0	2.38	0
Grain Size Fraction : 32000 - 62999 microns	%	0	0	0	0	2.97	0	0	0	0	0	0
Grain Size Fraction : > 63000 microns	%	0	0	0	0	0	0	0	0	0	0	0
Grain Size Inclusive Kurtosis	mm	0.213	0.243	0.206	0.486	0.178	0.293	0.507	0.47	0.463	0.261	0.444
Grain Size Inclusive Mean	mm	0.384	0.187	0.154	0.232	0.351	0.285	0.279	0.342	0.24	0.398	0.319
Inclusive Graphic Skewness :- {SKI}	Unitless	0.34	-0.31	-0.33	0.02	0.34	0.36	-0.01	0.09	-0.09	0.31	0.07
Kurtosis	Unitless	17.7	25.2	0.55	17.5	19.4	22.8	3.06	22.6	1.03	20.4	4.88
Particle Diameter : Mean	mm	0.873	0.238	0.161	0.263	0.824	0.699	0.31	0.461	0.261	0.826	0.35
Particle Diameter : Median	mm	0.373	0.196	0.157	0.231	0.345	0.26	0.278	0.338	0.242	0.389	0.319
Sorting Coefficient	Unitless	1.21	1.38	0.97	0.68	1.18	1.12	0.7	0.73	0.71	1.18	0.51
Total Organic Carbon	%	<0.4	0.416	<0.4	<0.4	<0.4	0.45	<0.4	<0.4	<0.4	<0.4	<0.4