River Carron Sea Locks Dredging
Best Practicable Environmental Option (BPEO) Report

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CONTROL SHEET

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1 INTRODUCTION

1.1 Background

Amco Giffen, acting on behalf of Scottish Canals have appointed EnviroCentre Ltd to complete a Marine Licence application for dredging at two sea lock sites where the Forth and Clyde Canal enters the River Carron near Falkirk. As part of the application, a Best Practicable Environmental Option (BPEO) assessment requires to be undertaken. This has been informed using sediment quality results from sampling undertaken in February 2023.

The material requiring to be dredged has accumulated around the sea lock gates. Anecdotal information from Scottish Canals personnel on site suggested that the accumulation of excess sediment around the lock gates is in part due to an extended period when the lock gates were not operated during the Covid-19 lockdowns of 2020. As such, this is considered to be a capital dredging project.

Dredging is to be undertaken at two separate areas, as shown in Drawing No. 776784-GIS003 and 776784-GIS004 in Appendix A. The Helix Sea Lock site is located at the end of the Forth and Clyde Canal, close to *The Kelpies*. The Grangemouth Sea Lock site is located at the end of the Queen Elizabeth II extension to the Forth & Clyde Canal, adjacent to Dalgrain Pumping Station.

The purpose of the samples analysis is to provide supporting information to Marine Scotland during the licensing process on sediment quality within the proposed dredge areas. This information can be used to inform potential disposal routes for the dredged material. The dredging and disposal activities are regulated by Marine Scotland under the Marine (Scotland) Act 2010. The licensing conditions require representative samples to be collected and the nature (i.e. physical composition), quality and contamination status to be determined.

1.2 Scope of Report

The following report details the sampling methodology, field and laboratory analysis and provides a summary of the sediment quality present within the proposed dredge areas.

The report will then use the available sediment analysis results to inform the identification of the best practicable environmental options (BPEO) from each of the available potential disposal options for the dredged materials. The options which are not considered to be practicable are rejected and the reasons for doing so are explained.

Those options which are practicable are examined in detail and assessed against the following considerations:

- Environmental;
- Strategic; and
- Cost.

The report then compares the practicable disposal options and draws a conclusion on the BPEO.

1.3 Action Levels – AL1 vs AL2

Two action levels are currently used to assess the suitability of sea-based disposal of dredged sediment material: Revised Action Level 1 (RAL1) and Revised Action Level 2 (RAL2).

Sediment with contaminant concentrations below RAL1 is generally considered to be below background levels for contamination and is suitable for disposal at sea.

For samples recording contaminant concentrations between RAL1 and RAL2, additional risk assessment may be required including further sampling and testing to fully identify pockets of contamination or implementation of bioassays to assess the materials suitability for sea disposal.

Material recording contaminant concentrations above RAL2 is generally considered to be unsuitable for disposal to sea. If the sea disposal route is to be pursued, further testing along the lines of bioassay accompanied by a robust justification for selecting sea disposal as the BPEO may be required. This would need to be supported further with additional information regarding any mitigation measures which could be put in place as part of these works. This would require further discussion and agreement with Marine Scotland.

1.4 Report Usage

The information and recommendations contained within this report have been prepared in the specific context stated above and should not be utilised in any other context without prior written permission from EnviroCentre.

If this report is to be submitted for regulatory approval more than 12 months following the report date, it is recommended that it is referred to EnviroCentre for review to ensure that any relevant changes in data, best practice, guidance or legislation in the intervening period are integrated into an updated version of the report.

2 SAMPLING LOCATIONS AND METHODOLOGY

Sediment sampling was undertaken on 21st and 22nd February 2023. The following section details the sampling methodology used to retrieve sediment samples. Works were undertaken in line with the Sampling Plan agreed with Marine Scotland Licencing Operations Team (EnviroCentre Document No. 13157, dated 22/12/2022),

2.1 Sample Locations

Three sample stations were located in each of the two dredge areas – i.e. Helix Sea Lock (HSL-1 to HSL-3) and Grangemouth Sea Lock (GSL-1 to GSL-3). Sample station locations are shown in Drawing No, 776784-GIS003 and 776784-GIS004 in Appendix A.

2.2 Sample Collection

Core samples were recovered using manual techniques as access for work boats is significantly constrained due to the presence of low bridges. This would result in insufficient clearance beneath the bridges at high tide. At low tide, there would be insufficient water depth to allow a vessel to safely navigate the channel.

All (but one) of the sample stations were accessed via an existing floating pontoon. Location GSL-3 was accessed on foot using a temporary access created using timber boards placed on the mud flat.

A 75mm wide by 3m long aluminium core tube, fitted with a sediment catcher, was driven into the sediment at the specified location by hand until refusal. Core barrels were retrieved by hand and a farm jack was used where required.

Once the tube was recovered, the recovery depth and sediment type at the base were noted. Cores were sub-sampled on the same day of collection.

All core samples were supplemented by a surface grab sample, to ensure there was sufficient surface sediment for analysis. Grab samples were obtained using a 0.045m^2 stainless steel Van Veen grab sampler. Grab samples were collected by hand from the survey vessel. Recovered material was emptied into a plastic bucket ready for sub-sampling. Where required, the grab was deployed multiple times to ensure enough sample was recovered for testing.

2.3 Field Information

The following field data was recorded for each sample obtained:

- A unique sample ID;
- Sample location;
- Sample coordinate in latitude and longitude in degrees, minutes and decimals of minutes;
- Date, time and depth of collection;
- Sampler's ID;
- Sediment description;
- Sample photographs; and,
- Details of any deviation from sampling protocol.

2.4 Sample Preparation

Cores were cut into subsections and extruded into a plastic core holder, spilt in half lengthways, photographed and logged prior to sub sampling. Grab samples were also photographed and logged prior to sub-sampling.

Samples for metals and particle sized analysis were sub-sampled using a plastic spoon and stored in plastic tubs. Samples for organic analysis were collected using stainless steel spoons and stored in amber glass jars.

Sampling equipment (spoons etc.) were cleaned with estuarine water between samples to minimise the risk of cross contamination.

Once samples had been placed within appropriate containers, they were labelled and placed immediately into cool boxes for dispatch to the project laboratory (Socotec).

2.5 Analysis Requirements

The laboratory analysis undertaken as part of this assessment was as follows:

- Metals - Arsenic, Chromium, Cadmium, Copper, Mercury, Nickel, Lead, Zinc;
- Organotins - Tributyl Tin & Dibutyl Tin (TBT);
- Polycyclic Aromatic Hydrocarbons (PAH USEPA 16);
- Polychlorinated Biphenyls (PCB ICES 7);
- Total Hydrocarbons (THC);
- Moisture Content;
- Particle Size Analysis (PSA);
- Total Organic Carbon (TOC); and
- Asbestos (presence/absence).

Samples were dispatched to Socotec's Marine Laboratory for analysis, which holds UKAS accreditation for analysis of marine sediment samples.

2.6 Deviations from the Sampling Plan

Sample station HSL-1 at the Helix Sea Lock was required to be re-located ~10 metres away from the location proposed on the Sampling Plan following six unsuccessful attempts in the vicinity of the proposed location. Little or no sediment was recovered in each of the six unsuccessful attempts. It is considered most likely that very soft fluid sediment was present above a small amount of coarse material that caused the sediment catcher to stay open, allowing the soft sediment to wash out of the barrel.

The surface (grab) sample collected at GSL-2 was damaged in transit to the laboratory. In order to avoid gaps in the analytical dataset, a repeat grab sample was collected from the same location and submitted for analysis on 10th March 2023.

A nominal depth of 1.5m was targeted at each of the sample locations at the outset. A maximum core depth of 1.15m was achieved (at HSL-3). All cores were progressed until refusal. Soft but cohesive clay was present at the bottom of each core.

3 RESULTS

Results of the sediment analysis are detailed in the following section. Summary tables highlighting exceedances above RALs are provided in Appendix C.

3.1 Physical Analysis

3.1.1 Particle Size Analysis (PSA)

Sediment comprises mainly sand (5.34% to 41.1%) and silt (58.9 to 94.66%) sized particles with no gravel content.

3.2 Chemical Analysis

3.2.1 Chemical Analysis Assessment Criteria

All chemical analytical results were assessed against Revised Action Levels (RAL) criteria as adopted by Marine Scotland. The results are summarised in sections 3.2 and 3.3. Summary reports detailing exceedances in the Marine Scotland format have been submitted along with the supporting information for the application.

Where contaminants have RALs as adopted by Marine Scotland, recorded exceedances above these criteria are summarised in Table 3-1.

All chemical data is reported and assessed on a dry weight basis.

Table 3-1: Exceedances of Revised Action Levels – Helix Sea Lock

Contaminant	No. of Exceedances (of 8 samples)	
	RAL 1	RAL 2
Arsenic	0	0
Cadmium	0	0
Copper	6	0
Chromium	6	0
Lead	5	0
Mercury	8	0
Nickel	5	0
Zinc	5	0
PAH (All Species)	8	-
PCBs	0	0
TBT	0	0
THC	8	-

Table 3-2: Exceedances of Revised Action Levels – Grangemouth Sea Lock

Contaminant	No. of Exceedances (of 8 samples)	
	RAL 1	RAL 2
Arsenic	0	0
Cadmium	0	0
Copper	7	0
Chromium	8	0
Lead	7	0
Mercury	8	0
Nickel	7	0
Zinc	6	0
PAH (All Species)	8	0
PCBs	0	0
TBT	0	0
THC	8	0

Sediment quality was fairly uniform at both sites with exceedances of the same group of metals and PAH species with levels recorded above Action Level 1. No exceedances above RAL2 were recorded.

3.3 Asbestos

Asbestos was not detected in any of the samples analysed.

4 DISCUSSION OF AVAILABLE DISPOSAL OPTIONS

The BPEO process is geared towards identifying a preferred overall strategy from the perspective of the environment as a whole, as opposed to detailed optimisation of any one selected scheme. It is a structured and systematic process to identify and compare strategic options in a transparent manner. Alternatives are evaluated in terms of their projected implications for the environment together with consideration of practicability, social and economic issues as well as within a wider strategic context.

The key stages of a BPEO are:

- Identification of options;
- Screening of options;
- Selection of assessment criteria;
- Analysis and evaluation of criteria; and
- Evaluation of BPEO.

Further details on methodology are provided within each section.

4.1 Identification and Screening of Available Disposal Options

A number of options are available for disposal of dredged sediments. The options considered are provided in Table 4-1 along with justification for screening out those options which have not been taken forward for further consideration.

Table 4-1: Initial Best Practicable Available Options

Location	Options	Screening Assessment	Carry forward?
Shoreline	Leave in situ	Not an option due to the requirement to clear sea lock gates (and the vicinity) of sediment to maintain/increase depth to allow safe passage of vessels entering/exiting the canal into the River Carron.	No
	Infilling of an existing dry dock/harbour facility (re-use)	No current or proposed dock/harbour infilling projects are known within a reasonable distance of the dredge site. The engineering properties of the material are unlikely to meet that of required engineered fill material which in these instances is typically required to be sand.	No
	Beach Nourishment	Given that the sediment comprises predominantly silt and clay sized particles, the material to be dredged is unlikely to be suitable for use as part of a beach nourishment project.	No
Land	Landfill Disposal	This is possible but it is unlikely that this option will offer a long-term solution due to lack of space at landfills, with other waste types likely to be prioritised. Landfill space is currently at a premium and does not offer a sustainable solution either financially or environmentally for the disposal of dredged arisings. Dredged material is likely to require treatment first in a dewatering facility to enable the handling of the material by trucks to landfill as landfills cannot accept material with high water content. Significant cost associated with set up of dewatering facility canal side plus transportation and additional costs associated with gaining the necessary permits and regulatory consents. One of the sites is a tourist attraction and would likely need to be closed during the works.	No
	Land Incineration	The dredged material consists of non-combustible material (silts, sands, gravels, shells) with a low combustible component.	No
	Application to Agricultural Land	The dredged material would need to be treated to reduce salt concentrations to acceptable levels. Would require detailed chemical analysis and assessment as well as a Waste Management License Exemption. Would require special precautions during spreading in relation to the risk of odour and watercourses / aquifers. Disposal of sediments in this manner would potentially have a detrimental effect on existing terrestrial habitats.	No
	Recycling	Material to be dredged predominantly comprises silt which is not typically suitable for recycling i.e. aggregate segregation typically requires sands and gravels.	No

Sea	Aquatic disposal direct to seabed.	The closest spoil ground is Bo'ness (FO004), approximately 6km north-east. Disposal at sea would require a dredging vessel with hopper to access the site. This may be challenging given the access restrictions on the River Carron given the presence of low bridges which are problematic at high tide; and limited water depth at low tide when barges are underload. The material would require to be dredged from land-based plant and transported by road to a dock facility for loading on to a bottom-emptying barge. This would result in several handling stages of material, including dewatering as per the landfill option outlined above, as well as significant additional cost. Due to the access constraints outlined this is	No
	Agitation Dredging/Water Injection Dredging/Plough Dredging	This method would see the sediment to be dredged injected with high-pressure water jets to dislodge it from the mud flats and into the River Carron channel on the ebb tide. The sediment would be removed from the area by a combination of river flow and tidal cycles. No double handling of material would be required with low environmental risk due to appropriate sediment quality screening measures applied during the licensing process. Road transportable/crane able units are available which would help navigate the access challenges presented by the presence of low road bridges etc. The site has previously been subjected to plough dredging which is another agitation dredging method.	Yes

4.2 Summary of Identified BPEO Options

Following review of the available options, the only viable option available is considered to be Water Injection Dredging due to the number of access constraints identified for the other available options.

As this is considered to be the only practicable option available, further comparative analysis has not been undertaken.

5 FURTHER ASSESSMENT

As detailed in Section 3, on the basis of the exceedances of Action Level 1, further assessment to ascertain the potential environmental risks associated to the dredging of the material for sea disposal is deemed a requirement.

The approach for this further assessment is outlined as follows:

- Provide an overview of the proposed dredge works and the identified disposal site including existing chemical monitoring data for the site where available; and
- Compare existing chemical data with other recognised sediment assessment criteria including those listed below. Summary tables are provided in Appendix B.

Background Assessment Concentration (BAC) - BACs were developed by the OSPAR Commission (OSPAR) for testing whether concentrations are near background levels. Mean concentrations significantly below the BAC are said to be near background. However, it should be noted that river catchments have their own unique geochemical finger prints and are also governed by the geology within the catchment, so in theory one set of background level values is not applicable to all situations;

Effects Range Low (ERL) - ERLs were developed by the United States Environmental Protection Agency (USEPA) for assessing the ecological significance of sediment concentrations. Concentrations below the ERL rarely cause adverse effects in marine organisms. Concentrations above the ERL will often cause adverse effects in some marine organisms;

Probable Effects Level (PEL) – PELs (Marine) have been adopted from the Canadian Environmental Quality Guidelines http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/) If a concentration is recorded above the PEL this is the probable effect range within which adverse effects frequently occur. The Threshold Effect levels (TELs) have been included in the summary table in Appendix B, but have not been used as part of the further assessment as they typically fall below the RAL1

Review of potential risks to the list of receptors identified in “Water Framework Directive Assessment: estuarine and coastal waters (https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters) to draw conclusions from available information and provide recommendation for proposed disposal routes.

5.1 Analytical Data Review

Existing analytical data for the proposed dredge sites are provided in Summary Table A in Appendix C. This data has been summarised against RAL 1 & 2, the BAC, ERL and PEL. As detailed previously, the data has not been reviewed against the Canadian TEL as these numbers are typically lower than RAL1.

While individual site results were compared against RAL1 and RAL2 in preceding sections, the further screening will be undertaken for all data and any specific issues identified for individual dredge areas.

A summary of the exceedances is detailed below:

5.1.1 Action Level 1

Exceedances of RAL1 can be summarised as follows:

- Arsenic –0 of 16 samples recorded arsenic levels above RAL1.
- Cadmium – 0 of 16 samples recorded cadmium levels above RAL1.
- Copper – 13 of 16 samples recorded copper levels above RAL1.
- Chromium –14 of 16 samples recorded chromium levels above RAL1.
- Lead –12 of 16 samples recorded lead levels above RAL1.
- Mercury – 16 of 16 samples recorded mercury levels above RAL1.
- Nickel – 13 of 16 samples recorded nickel levels above RAL1.
- Zinc –11 of 16 samples recorded zinc levels above RAL1.
- PAHs – 16 of 16 samples recorded at least one PAH species above RAL1; and
- THC – 16 of 16 samples recorded total hydrocarbons above RAL1.
- TBT 0 of 16 samples recorded total TBT above RAL1.
- PCBs 0 of 16 samples recorded PCBs above RAL1.

5.1.2 ERL & PEL Review

Exceedances of the ERL (where one is available) can be summarised as follows:

- Copper– 4 of 16 samples recorded copper levels above the ERL;
- Mercury – 16 of 16 samples recorded mercury levels above the ERL;
- Lead –14 of 16 samples recorded mercury levels above the ERL;
- Zinc – 1 of 16 samples recorded zinc levels above the ERL; and
- PAHs – 16 of 16 samples recorded at least one PAH species above the ERL.

Exceedances of the PEL (where one is available) can be summarised as follows:

- Fluorene and Dibenzo(a,h)anthracene – all samples at both sites

5.1.3 Action Level 2

There were no exceedances of RAL2 where one is available for review.

5.2 Averages

Review of the averaged data for each site has been undertaken i.e. considering the material as a single volume for disposal from each site. These data are provided in Tables B and C.

5.2.1 Helix Sea Lock

- RAL1 was exceeded for the following contaminants of concern, chromium, copper, mercury, nickel, lead, and zinc, various PAHs and THC;
- ERL was exceeded for mercury, lead and various PAHs;
- PEL was exceeded for various PAH species;
- There were no average concentrations recorded in exceedance of the RAL2 where one is available.

5.2.2 Grangemouth Sea Lock

- RAL1 was exceeded for the following contaminants of concern, chromium, copper, mercury, nickel, lead, and zinc, various PAHs and THC;
- ERL was exceeded for mercury, lead and various PAHs;
- PEL was exceeded for various PAH species;

- There were no average concentrations recorded in exceedance of the RAL2 where one is available.

5.3 Receiving Environment Sediment Quality

Typically sediment being removed from a dredge area is disposed of at a licensed disposal ground, or if being plough dredged, relocated to deeper water outside a harbour etc. In this instance, the dredge areas are essentially a continuation of the River Carron and not a confined area that would typically be encountered within a harbour type environment. The proposed method of water injection dredging will involve the use of hydrodynamic principals to mobilise the sediment from its current location to be carried away with the ebb tide/river flow for re distribution further downstream away from the site.

The other key point of consideration with these two sites is that there are no onsite sources of contamination which you would typically find within a harbour as they are access points to the canals. Considering these two points, the contaminant levels within the sediments are considered to be representative of the sediment within the wider catchment which are moved around naturally through tidal cycles. To provide further context, available sediment quality data from other dredge project in the Forth Catchment have been referenced with regards to additional sources of contaminant levels for further context. These are referenced below with average concentrations from these two data sources tabulated with averages of key contaminants of concern in Table 4-2 below:

- Data provided by Marine Scotland in 2018 from a Freedom of Information (FOI) request for Grangemouth;
- Data from application Port of Grangemouth - 00010017[1] can be summarise as follows for surface grab samples collected out with the various docks in the estuary and are referred to as 11 samples from the Bellmouth (G01-2022 to G11-2022)
    - RAL1 exceedances for chromium, copper, mercury, nickel, lead and zinc;
    - RAL1 exceedances of various PAH species in all samples
    - No RAL1 exceedances of TBT or PCBs

Table 4-2: Average Concentrations by site

Contaminant (All in mg/kg)	Helix Sea Lock Average	G'mouth Sea Lock Average	2018 Grangemouth Average	2022 Grangemouth (Bellmouth Average)
Chromium	55.2	58.5	75.2	55
Copper	31.9	32.1	48.9	29.4
Lead	53.2	55.0	65.2	50.2
Mercury	0.67	0.69	0.73	0.63
Zinc	135	137	165	125
Benzo(a)pyrene	0.22	0.24	0.45	0.20

Review of the average concentrations from the two sites for those contaminants with average concentration above RAL1, as well as other dredge sites in the Forth, would conclude that the contaminant levels are fairly uniform across all these sites. The data provided in 2018 is slightly elevated compared to the two sites being considered in this report and it is not clear where the samples were collected. Samples collected from the Bellmouth (approaches to the Grangemouth docks) in the estuary have very similar average concentrations when compared to the two sea locks.

[1] https://marine.gov.scot/sites/default/files/best_practicable_environmental_option_report.pdf

While the data set is not exhaustive, it further highlights that the sediment accumulation in-front of the sea locks is similar in nature to that in the wider estuary.

5.4 Chemical Assessment Conclusions

Multiple samples recorded exceedances of RAL1 for metals, TBT, PAHs and THC across both sites. There were no exceedances of RAL2 where one is available for review in any of the samples collected. All samples recorded contaminants at fairly uniform levels.

Comparison of contaminant concentration averages at the proposed dredge sites which exceeded RAL1 against other surface samples from other dredge sites in the Forth recorded very similar average concentrations and are considered to be representative of the wider sediment quality within the Firth of Forth Estuary.

5.5 Water Framework Directive Assessment

As outlined in the Water Framework Directive Assessment: estuarine and coastal waters, there are several key receptors which can be impacted upon including the following:

- Hydromorphology
- Biology – habitats
- Biology – fish
- Water quality
- Protected areas

Each of these points are considered in Table 4-3 below:

Table 4-3: Receptor Risk Assessment

Key Receptor[2]	Brief Summary of Potential Effects on Receptor	Further Consideration Required?	Comment
Hydromorphology (Source Area)	Morphological conditions, for example depth variation, the seabed and intertidal zone structure tidal patterns, for example dominant currents, freshwater flow and wave exposure	No	The areas proposed to be dredged are located within the Middle Forth Estuary which is classified as a Heavily Modified Waterbody. (ID:200436) with an overall status of moderate for morphology and hydromorphology.
Biology - habitats	Included to assess potential impacts to sensitive/high value habitats.	No	The dredge sites are located c. 2km away from the closet designated sites which includes the Firth of Forth, SSSI SPA and RAMSAR The Firth of Forth SSSI includes a variety of terrestrial and intertidal habitats. Those which have the potential to be impacted are the mudflats and saline lagoon and transitional grassland. However, The SPA and RAMSAR site are designated for a variety of bird species. Considering the distance between the proposed dredge sites and the intertidal habitats, the risks from the displacement of accumulated silts to the River Carron through water injection dredging are considered to be low.

[2] https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters

Key Receptor[2]	Brief Summary of Potential Effects on Receptor	Further Consideration Required?	Comment
Biology – fish	Consideration of fish both within the estuary and also potential effects on migratory fish in transit through the estuary	No	The Forth Estuary and its tributaries support populations of migratory fish including salmon and seatrout. The Middle Forth Estuary has a WFD status of good for fish. The proposed dredging works are considered likely to be undertaken over a relatively short period of time, so any effects are likely to be short lived. It is noted that under periods of exceptionally hot and dry weather the potential for oxygen related issues to arise: *i.e.* oxygen depletion and it is proposed that dredging works will be avoided as far as practicable during such times.
Water Quality	Consideration must be given to water quality when contaminants are present in exceedance of CEFAS RAL1.	Yes	The sites are located within the Middle Forth Estuary which with an over classification of Good. Overall chemistry and priority substances do not have a current classification, with the last recorded classification noted as pass in 2011. The water body records a pass for copper, chromium and unionised ammonia and physico-chemical status is recorded as good. Contaminants are noted to exceed CEFAS RAL1 within sediment samples. It is noted that sediments with comparable contaminant levels within other areas of the estuary based on available information.

Key Receptor[2]	Brief Summary of Potential Effects on Receptor	Further Consideration Required?	Comment
Protected Areas	If your activity is within 2km of any WFD protected area, include each identified area in your impact assessment. • special areas of conservation (SAC) • special protection areas (SPA) • shellfish waters • bathing waters • nutrient sensitive areas	No	The proposed dredging sites site are located within 2km of • Firth of Forth Ramsar Site • Firth of Forth Special Protection Area The SPA[3] and RAMSAR[4] sites qualifying features are for a variety of birds. The proposed dredging is not considered to present a significant risk to the features of the designated sites. The sites are not located within 2km of designated bathing waters or shellfish waters.

[3] https://sitelink.nature.scot/site/8499
[4] https://sitelink.nature.scot/site/8424

5.6 Potential Risk to Water Quality

The potential risks to water quality and fish at the dredge sites and disposal site are further considered as all other receptors have been screened out of the assessment.

The sites are located within the Middle Forth Estuary which has an over classification of Good.

Although there are contaminants of concern above the RAL1 within the sediment for dredging, it is considered that these levels will not contribute to an overall degradation of water quality at the disposal site and are similar in chemical composition to sediments in other areas of the Firth of Forth previously dredged. While any effects are considered to be both localised and temporary, the potential for both dilution and natural attenuation in the open waters beyond the dredge sites is considerable.

The key contaminants for impacting water quality are considered to be metals as these have the potential to dissolve or desorb from sorption sites within the sediment. However, the overall concentrations of metals are generally low and natural geochemical processes will limit their solubility. Given the large dilution potential it is not expected that there would be a long term impact on water quality.

PAHs and hydrocarbons are hydrophobic with low aqueous solubility and will naturally remain associated with organic sediment fractions, rather than become dissolved within the water column. On this basis, the risks associated with impact to water quality from chemical contaminants in sediment are considered to be low, with the associated dilution potential providing further mitigation.

The key risk to water quality is considered to be an increase in turbidity/suspended solids during the dredging works. Although this is likely to cause a localised increase in suspended solids, it is considered that this will be both local and temporary in nature and not have a long term impact.

The sediments at both sites comprise predominately largely finer grained sediments with the average across both sites noted as 17% sand and 83% silt.

The water injection dredging will fluidise the sediments and will be dispersed by the ebb tide for retention and redistribution within the wider estuary.

In summary, the associated risk with degradation of water quality directly associated with the proposed dredging methodology is considered to be Low i.e. unlikely to cause a change in status of the waterbodies in question.

5.7 Conclusions and Recommendations

Review of available information has highlighted that although several contaminants of concern exceed RAL1 in sediment samples, assessment of key receptors identified from the Water Framework Directive assessment for estuarine and coastal waters concluded that there is a low risk of the sediments impacting upon the overall ecological or chemical status. Additionally, the contaminants of concern levels recorded in the sediment are considered to be similar in nature to sediments sampled elsewhere in the estuary.

The water injection dredging option is considered to have no significant long-term impact on the marine environment and mirrors similar approaches historically undertaken using a plough dredge.

REFERENCES

Marine Scotland (2017). Pre-Dredge Sampling Guidance Version 2: Scottish Government.

Marine Scotland (2015). Guidance for Marine Licence Applicants Version 2: Scottish Government.

APPENDICES

A FIGURES

290600

290700

682300

682200

N

56° 1.233081,
-3° 45.37772

HSL-2

HSL-1

56° 1.221427,
-3° 45.396754

56° 1.224107,
-3° 45.346746

HSL-3

56° 1.21116,
-3° 45.378406

Legend

- Sample Station
- Dredge Area Boundary Points
- Helix Sea Lock Dredge Area

Do not scale this map

Client
Amco Giffen

Project
Helix Sea Lock Pre-Dredge Sampling

Title
Sample Station Locations

Status
Final

Drawing No.	Revision	Date
776784-GIS003	-	06 Mar 2023
Drawn	**Checked**	**Approved**
FR	CCAS	CCAS

Scale
1:750 @A3
0 3.75 7.5 15 22.5 Metres

Rev	Date	Amendment	Initials
-	-	-	-

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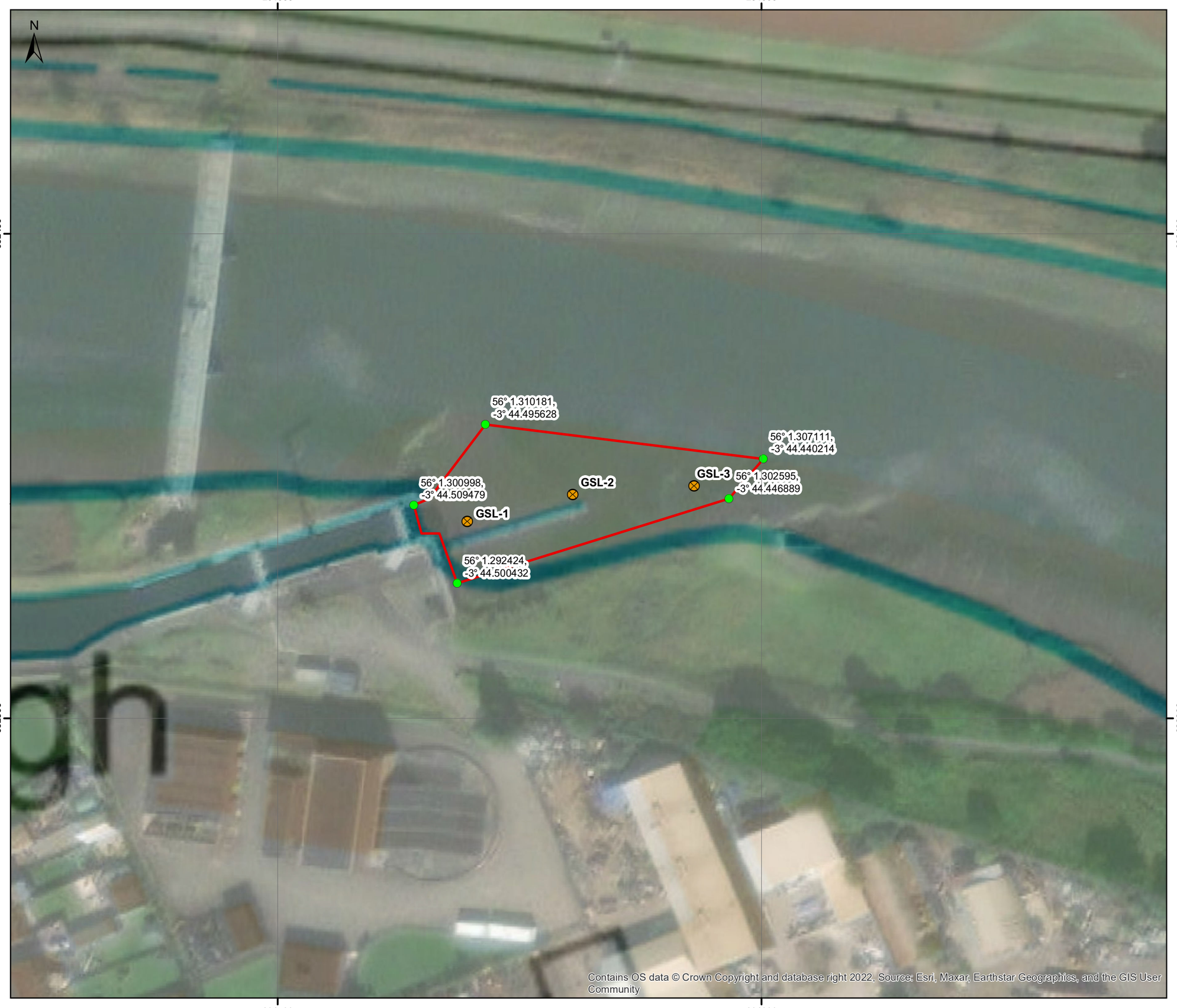

Legend

- Sample Station
- Dredge Area Boundary Points
- Grangemouth Sea Lock Dredge Area

Do not scale this map

Client
Amco Giffen

Project
Grangemouth Sea Lock Pre-Dredge Sampling

Title
Sample Station Locations

Status
Final

Drawing No.	Revision	Date
776784-GIS004	-	06 Mar 2023
Drawn	**Checked**	**Approved**
FR	CCAS	CCAS

Scale
1:750 @A3
0 3.75 7.5 15 22.5 Metres

Rev	Date	Amendment	Initials
-	-	-	-

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B SAMPLE LOGS

envirocentre 8 Eagle Street, Craighall Business Park, Glasgow, G4 9XA`	**Project Name**	Helix & Grangemouth Sediment Sampling	**Location ID**
	Project No.	776784	**HSL-1**
	Client	Amco Giffen	

SEDIMENT CORE LOG

Date/Time:	22/02/2023	**Latitude/Longitude:**	290615.7518 , 682221.9032
Dredge Area:	-	**Sampled/logged by:**	FR/AK
Method:	Van-Veen Grab & Manual Core	**Core Length (m):**	1.0m

Remarks:

0.0 - 0.15m
Very soft dark grey silt with frequent lenses of dark grey sticky clay.

0.15 – 0.5m
Soft dark grey very clayey silt.

0.5 – 0.8m
Soft dark grey very clayey silt.

0.8 – 1.0m
Soft dark grey silty sticky clay.

Biota: None noted.

Odours: None noted.

Anthropogenic Inputs: None noted.

Notes: Sample location moved mid-way along pontoon as multiple failed attempts were made due to hard (possibly gravel) base resulted in washouts.

envirocentre 8 Eagle Street, Craighall Business Park, Glasgow, G4 9XA`	**Project Name**	Helix & Grangemouth Sediment Sampling	**Location ID**
	Project No.	776784	**HSL-2**
	Client	Amco Giffen	

SEDIMENT CORE LOG

Date/Time:	22/02/2023	**Latitude/Longitude:**	290622.2506 , 682228.9506
Dredge Area:	-	**Sampled/logged by:**	FR/AK
Method:	Van-Veen Grab & Manual Core	**Core Length (m):**	0.7m

Remarks:

0.0 – 0.15m
Very soft dark very clayey silt.

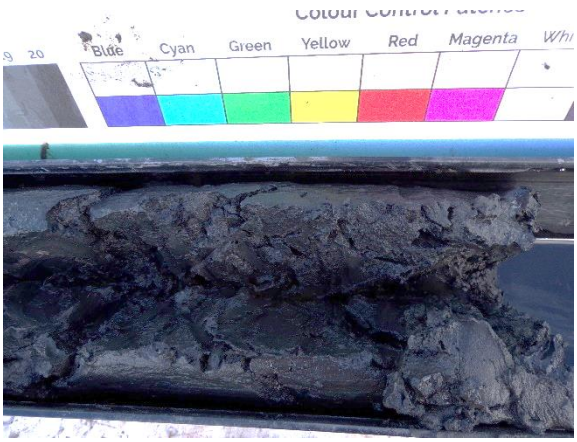
0.2 – 0.7m
Very soft dark very clayey silt with lenses of stiff grey clay at 0.2m and 0.4m (clay content increases with depth).

Biota: None noted.

Odours: None noted.

Anthropogenic Inputs: None noted.

Notes: Four attempts made off end of pontoon for suitable recovery. Sample undertaken at low tide, but with water still present.



envirocentre 8 Eagle Street, Craighall Business Park, Glasgow, G4 9XA`	**Project Name**	Helix & Grangemouth Sediment Sampling	**Location ID**
	Project No.	776784	**HSL-3**
	Client	Amco Giffen	

SEDIMENT CORE LOG

Date/Time:	21/02/2023	**Latitude/Longitude:**	290630.9521 , 682214.7197
Dredge Area:	-	**Sampled/logged by:**	FR/AK
Method:	Van-Veen Grab & Manual Core	**Core Length (m):**	1.15m

Remarks:

0.0 – 0.3m
Very soft dark grey slightly clayey silt.

0.3 – 0.7m
Soft Dark grey clayey silt.

0.7 – 1.15m
Soft sticky dark grey clay.

Biota: None noted.

Odours: None noted.

Anthropogenic Inputs: None noted.

Notes: -

envirocentre 8 Eagle Street, Craighall Business Park, Glasgow, G4 9XA`	**Project Name**	Helix & Grangemouth Sediment Sampling	**Location ID**
	Project No.	776784	**GSL-1**
	Client	Amco Giffen	

SEDIMENT CORE LOG

Date/Time:	22/02/2023	**Latitude/Longitude:**	291538.7092 , 682341.8765
Dredge Area:	-	**Sampled/logged by:**	FR/AK
Method:	Van-Veen Grab & Manual Core	**Core Length (m):**	1.05m

Remarks:

0.0 – 0.15m
Very soft/loose dark grey silt.

0.15 – 0.55m
Soft dark grey loose new silt.

0.55 – 1.05m
Soft dark grey silt.

Biota: None noted.

Odours: None noted.

Anthropogenic Inputs: None noted.

Notes: No water present at core location (dried out at low tide). Hydrocarbon bloom on surface of mudflat. Grab sample taken directly from mud flat.

envirocentre 8 Eagle Street, Craighall Business Park, Glasgow, G4 9XA`	**Project Name**	Helix & Grangemouth Sediment Sampling	**Location ID**
	Project No.	776784	**GSL-2**
	Client	Amco Giffen	

SEDIMENT CORE LOG

Date/Time:	21/02/2023	**Latitude/Longitude:**	291561.1989 , 682347.4328
Dredge Area:	-	**Sampled/logged by:**	FR/AK
Method:	Van-Veen Grab & Manual Core	**Core Length (m):**	1.0m

Remarks:

0.0 – 0.15m
Very soft dark grey (greyish-brown on surface) slightly clayey silt.

0.15 – 0.35m
Very soft dark grey very clayey silt.

0.35 – 1.0m
Soft dark grey clay.

Biota: None noted.

Odours: None noted.

Anthropogenic Inputs: None noted.

Notes: The Grab sample (0.0m – 0.15m) was damaged in transit to the laboratory. This this was re-sampled on 10/03/2022.

envirocentre 8 Eagle Street, Craighall Business Park, Glasgow, G4 9XA`	**Project Name**	Helix & Grangemouth Sediment Sampling	**Location ID**
	Project No.	776784	**GSL-3**
	Client	Amco Giffen	

SEDIMENT CORE LOG

Date/Time:	22/02/2023	**Latitude/Longitude:**	291586.0697 , 682347.9619
Dredge Area:	-	**Sampled/logged by:**	FR/AK
Method:	Van-Veen Grab & Manual Core	**Core Length (m):**	0.7m

Remarks:

0.0 – 0.15m
Soft grey/grey-brown clayey silt.

0.2 – 0.7m
Soft sticky grey very clayey silt.

Biota: None noted.

Odours: None noted.

Anthropogenic Inputs: None noted.

Notes: -

C DATA SUMMARY TABLES

Summary Table A1
Helix Sea Lock - Sampling Results Incorporated with BPEO Assessment (mg/kg)

						Helix Sea Lock													
	AL1	AL2	BAC	ERL	PEL	HSL-1 0.00-0.15m	HSL-1 0.15-0.50m	HSL-1 0.50-1.00m	HSL-2 0.00-0.15m	HSL-2 0.20-0.70m	HSL-3 0.00-0.15m	HSL-3 0.15-0.65m	HSL-3 0.65-1.15m	AVERAGE	No. Exceed RAL 1	No. Exceed RAL 2	No.Exceed BAC?	No. Exceed ERL	No. Exceed PEL?
Source			CSEMP	CSEMP	Canada														
Arsenic	20	70	25		41.6	9.7	11.4	12	14.5	13.4	14.2	14.7	14.8	13.1	0	0	0	-	0
Cadmium	0.4	4	0.31	1.2	4.2	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.0	0	0	0	0	0
Chromium	50	370	81	81	160	42.6	47.9	51.9	60.8	58.5	60.3	58.5	61.1	55.2	6	0	0	0	0
Copper	30	300	27	34	108	26.1	26.6	30.0	34.3	33.8	34.4	35.0	34.9	31.9	6	0	6	4	0
Mercury	0.25	1.5	0.07	0.15	0.7	0.5	0.59	0.66	0.69	0.72	0.74	0.75	0.73	0.7	8	0	8	8	4
Nickel	30	150	36	-	-	23.5	26.1	27.6	34.1	32.2	32.8	32.7	33.7	30.3	5	0	0	N/A	N/A
Lead	50	400	38	47	112	40	45.2	48.8	57	56.6	58.8	59.8	59.4	53.2	5	0	8	6	0
Zinc	130	600	122	150	271	106	116	120	149	142	146	149	150	134.8	5	0	5	0	0
Napthalene	0.1		0.08	0.16	0.391	0.041	0.052	0.069	0.040	0.057	0.048	0.042	0.052	0.05	0	-	0	0	0
Acenaphthylene	0.1				0.128	0.045	0.087	0.062	0.060	0.063	0.055	0.073	0.051	0.06	0	-	N/A	N/A	0
Acenaphthene	0.1				0.0889	0.128	0.156	0.209	0.122	0.173	0.148	0.150	0.150	0.15	8	-	N/A	N/A	0
Fluorene	0.1				0.144	0.229	0.328	0.333	0.228	0.258	0.278	0.309	0.305	0.28	8	-	N/A	N/A	8
Phenanthrene	0.1		0.032	0.24	0.544	0.246	0.348	0.381	0.262	0.273	0.322	0.345	0.327	0.31	8	-	8	8	0
Anthracene	0.1		0.05	0.085	0.245	0.263	0.369	0.401	0.285	0.302	0.346	0.378	0.370	0.34	8	-	8	8	0
Fluoranthene	0.1		0.039	0.6	1.494	0.205	0.295	0.327	0.239	0.254	0.278	0.311	0.319	0.28	8	-	8	0	0
Pyrene	0.1		0.024	0.665	1.398	0.257	0.341	0.378	0.292	0.275	0.316	0.341	0.334	0.32	8	-	8	0	0
Benzo(a)anthracene	0.1		0.016	0.261	0.693	0.273	0.385	0.393	0.261	0.268	0.320	0.353	0.329	0.32	8	-	8	7	0
Chrysene	0.1		0.02	0.384	0.846	0.027	0.047	0.047	0.035	0.038	0.043	0.052	0.047	0.04	0	-	8	0	0
Benzo(b)fluoranthene	0.1		-	-	-	0.460	0.620	0.671	0.407	0.498	0.514	0.573	0.549	0.54	8	-	N/A	N/A	N/A
Benzo(k)fluoranthene	0.1		-	-	-	0.083	0.121	0.131	0.083	0.111	0.101	0.105	0.106	0.11	6	-	N/A	N/A	N/A
Benzo(a)pyrene	0.1		0.03	0.384	0.763	0.152	0.217	0.256	0.172	0.200	0.227	0.255	0.252	0.22	8	-	8	0	0
Indeno(1,2,3cd)pyrene	0.1		0.103	0.24	-	0.186	0.232	0.256	0.161	0.186	0.199	0.209	0.207	0.20	8	-	8	1	N/A
Benzo(ghi)perylene	0.1		0.08	0.085	-	0.301	0.376	0.394	0.264	0.291	0.310	0.340	0.363	0.33	8	-	8	8	N/A
Dibenzo(a,h)anthracene	0.01		-	-	0.135	0.536	0.726	0.768	0.483	0.593	0.596	0.680	0.648	0.63	8	-	N/A	N/A	8
TPH	100		-	-	-	467	574	720	490	500	597	609	573	566	8	-	N/A	N/A	N/A
PCBs	0.02	0.18	-	-	0.189	0.00797	0.00796	0.00959	0.00677	0.0077	0.00826	0.00991	0.01183	0.009	0	0	N/A	N/A	0
TBT	0.1	0.5	-	-	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	0	N/A	N/A	N/A

Note: Underlined Values are < LOD
PEL Data Source: http://ceqg-rcqe.ccme.ca/en/index.html#void

Summary Table A2
Grangemouth Sea Lock - Sampling Results Incorporated with BPEO Assessment (mg/kg)

						Grangemouth Sea Lock													
	AL1	AL2	BAC	ERL	PEL	GSL-1 0.00-0.15m	GSL-1 0.15-0.55m	GSL-1 0.55-1.05m	GSL-2 0.00-0.15m	GSL-2 0.15-0.50m	GSL-2 0.50-1.00m	GSL-3 0.00-0.15m	GSL-3 0.20-0.70m	AVERAGE	No. Exceed RAL 1	No. Exceed RAL 2	No.Exceed BAC?	No. Exceed ERL	No. Exceed PEL?
Source			CSEMP	CSEMP	Canada														
Arsenic	20	70	25		41.6	16.5	15.4	14.1	15.6	14.1	12.7	13.6	14.0	14.5	0	0	0	-	0
Cadmium	0.4	4	0.31	1.2	4.2	0.04	0.06	0.1	0.04	0.06	0.05	0.04	0.1	0.06	0	0	0	0	0
Chromium	50	370	81	81	160	62.3	59.9	57.8	62.4	58.3	53.3	56.7	61.0	59.0	8	0	0	0	0
Copper	30	300	27	34	108	33.9	33.5	31.8	32.7	31.7	29.8	30.2	33.8	32.2	7	0	8	0	0
Mercury	0.25	1.5	0.07	0.15	0.7	0.72	0.71	0.68	0.69	0.67	0.63	0.66	0.75	0.7	8	0	8	8	3
Nickel	30	150	36	-	-	34.3	32.6	31.3	34.0	31.6	30.0	31.4	32.8	32.3	8	0	0	N/A	N/A
Lead	50	400	38	47	112	60.8	57.2	53.9	59.7	54.8	49.7	52	56.5	55.6	7	0	8	8	0
Zinc	130	600	122	150	271	154	144	135	144	136	125	128	138	138.0	6	0	8	1	0
Napthalene	0.1		0.08	0.16	0.391	0.048	0.048	0.048	0.086	0.047	0.043	0.043	0.043	0.05	0	-	1	0	0
Acenaphthylene	0.1				0.128	0.096	0.066	0.052	0.062	0.050	0.051	0.066	0.053	0.06	0	-	N/A	N/A	0
Acenaphthene	0.1				0.0889	0.163	0.147	0.183	0.228	0.174	0.137	0.153	0.154	0.17	8	-	N/A	N/A	0
Fluorene	0.1				0.144	0.296	0.290	0.341	0.495	0.316	0.268	0.296	0.283	0.32	8	-	N/A	N/A	8
Phenanthrene	0.1		0.032	0.24	0.544	0.351	0.305	0.385	0.579	0.344	0.309	0.345	0.315	0.37	8	-	8	8	1
Anthracene	0.1		0.05	0.085	0.245	0.377	0.348	0.405	0.516	0.372	0.337	0.375	0.357	0.39	8	-	8	8	0
Fluoranthene	0.1		0.039	0.6	1.494	0.299	0.283	0.335	0.446	0.293	0.282	0.310	0.306	0.32	8	-	8	0	0
Pyrene	0.1		0.024	0.665	1.398	0.347	0.351	0.368	0.517	0.318	0.289	0.322	0.336	0.36	8	-	8	0	0
Benzo(a)anthracene	0.1		0.016	0.261	0.693	0.369	0.321	0.370	0.542	0.345	0.298	0.343	0.306	0.36	8	-	8	8	0
Chrysene	0.1		0.02	0.384	0.846	0.049	0.044	0.054	0.077	0.053	0.042	0.047	0.050	0.05	0	-	8	0	0
Benzo(b)fluoranthene	0.1		-	-	-	0.543	0.501	0.619	1.090	0.564	0.468	0.581	0.485	0.61	8	-	N/A	N/A	N/A
Benzo(k)fluoranthene	0.1		-	-	-	0.121	0.109	0.100	0.124	0.094	0.097	0.109	0.107	0.11	5	-	N/A	N/A	N/A
Benzo(a)pyrene	0.1		0.03	0.384	0.763	0.249	0.220	0.276	0.400	0.230	0.232	0.250	0.245	0.26	8	-	8	1	0
Indeno(1,2,3cd)pyrene	0.1		0.103	0.24	-	0.197	0.207	0.190	0.231	0.192	0.192	0.203	0.213	0.20	8	-	8	0	N/A
Benzo(ghi)perylene	0.1		0.08	0.085	-	0.344	0.323	0.367	0.605	0.361	0.299	0.382	0.304	0.37	8	-	8	8	N/A
Dibenzo(a,h)anthracene	0.01		-	-	0.135	0.622	0.602	0.702	1.090	0.658	0.573	0.671	0.605	0.69	8	-	N/A	N/A	8
TPH	100		-	-	-	670	669	671	602	572	499	528	646	607	8	-	N/A	N/A	N/A
PCBs	0.02	0.18	-	-	0.189	0.00795	0.00774	0.00779	0.00579	0.00848	0.00951	0.00816	0.00879	0.008	0	0	N/A	N/A	0
TBT	0.1	0.5	-	-	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	0	N/A	N/A	N/A

Note: Underlined Values are < LOD

PEL Data Source: http://ceqg-rcqe.ccme.ca/en/index.html#void

Summary Table B

Helix Sea Lock Average Concentrations

All units in mg/kg

	AL1	AL2	BAC	<ERL	PEL	Dredge Average	Exceed AL1?	Exceed AL2?	Exceed BAC?	Exceed ERL ?	Exceed PEL?
Source			CSEMP	CSEMP	Canada						
Arsenic	20	70	25	-	41.6	13.1	No	No	No	N/A	No
Cadmium	0.4	4	0.31	1.2	4.2	0.0	No	No	No	No	No
Chromium	50	370	81	81	160	55.2	**Yes**	No	No	No	No
Copper	30	300	27	34	108	31.9	**Yes**	No	**Yes**	No	No
Mercury	0.25	1.5	0.07	0.15	0.7	0.67	**Yes**	No	**Yes**	**Yes**	No
Nickel	30	150	36	-	-	30.3	**Yes**	No	No	N/A	N/A
Lead	50	400	38	47	112	53.2	**Yes**	No	**Yes**	**Yes**	No
Zinc	130	600	122	150	271	134.8	**Yes**	No	**Yes**	No	No
					-						
Napthalene	0.1	-	0.08	0.16	0.319	0.05	No	N/A	No	No	No
Acenaphthylene	0.1	-	-	-	0.128	0.06	No	N/A	N/A	N/A	No
Acenaphthene	0.1	-	-	-	0.0889	0.15	**Yes**	N/A	N/A	N/A	**Yes**
Fluorene	0.1	-	-	-	0.144	0.28	**Yes**	N/A	N/A	N/A	**Yes**
Phenanthrene	0.1	-	0.032	0.24	0.544	0.31	**Yes**	N/A	**Yes**	**Yes**	No
Anthracene	0.1	-	0.05	0.085	0.245	0.34	**Yes**	N/A	**Yes**	**Yes**	**Yes**
Fluoranthene	0.1	-	0.039	0.6	1.494	0.28	**Yes**	N/A	**Yes**	No	No
Pyrene	0.1	-	0.024	0.665	1.398	0.32	**Yes**	N/A	**Yes**	No	No
Benzo(a)anthracene	0.1	-	0.016	0.261	0.693	0.32	**Yes**	N/A	**Yes**	**Yes**	No
Chrysene	0.1	-	0.02	0.384	0.846	0.04	No	N/A	**Yes**	No	No
Benzo(b)fluoranthene	0.1	-	-	-	-	0.54	**Yes**	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	0.1	-	-	-	-	0.11	**Yes**	N/A	N/A	N/A	N/A
Benzo(a)pyrene	0.1	-	0.03	0.384	0.763	0.22	**Yes**	N/A	**Yes**	No	No
Indeno(1,2,3cd)pyrene	0.1	-	0.103	0.24	-	0.20	**Yes**	N/A	**Yes**	No	N/A
Benzo(ghi)perylene	0.1	-	0.08	0.085	-	0.33	**Yes**	N/A	**Yes**	**Yes**	N/A
Dibenzo(a,h)anthracene	0.01	-	-	-	0.135	0.63	**Yes**	N/A	N/A	N/A	**Yes**
THC	0.1	-	-	-		566.3	**Yes**	N/A	N/A	N/A	N/A
PCBs	0.02	0.18	-	-	0.189	0.009	No	No	N/A	N/A	No
TBT	0.1	0.5	-	-	-	0.005	No	No	N/A	N/A	N/A

Summary Table C

Gramgemouth Sea Lock Average Concentrations

All units in mg/kg

	AL1	AL2	BAC	<ERL	PEL	Dredge Average	Exceed AL1?	Exceed AL2?	Exceed BAC?	Exceed ERL ?	Exceed PEL?
Source			CSEMP	CSEMP	Canada						
Arsenic	20	70	25	-	41.6	14.5	No	No	No	N/A	No
Cadmium	0.4	4	0.31	1.2	4.2	0.1	No	No	No	No	No
Chromium	50	370	81	81	160	59.0	**Yes**	No	No	No	No
Copper	30	300	27	34	108	32.2	**Yes**	No	**Yes**	No	No
Mercury	0.25	1.5	0.07	0.15	0.7	0.69	**Yes**	No	**Yes**	**Yes**	No
Nickel	30	150	36	-	-	32.3	**Yes**	No	No	N/A	N/A
Lead	50	400	38	47	112	55.6	**Yes**	No	**Yes**	**Yes**	No
Zinc	130	600	122	150	271	138.0	**Yes**	No	**Yes**	No	No
					-						
Napthalene	0.1	-	0.08	0.16	0.319	0.05	No	N/A	No	No	No
Acenaphthylene	0.1	-	-	-	0.128	0.06	No	N/A	N/A	N/A	No
Acenaphthene	0.1	-	-	-	0.0889	0.17	**Yes**	N/A	N/A	N/A	**Yes**
Fluorene	0.1	-	-	-	0.144	0.32	**Yes**	N/A	N/A	N/A	**Yes**
Phenanthrene	0.1	-	0.032	0.24	0.544	0.37	**Yes**	N/A	**Yes**	**Yes**	No
Anthracene	0.1	-	0.05	0.085	0.245	0.39	**Yes**	N/A	**Yes**	**Yes**	**Yes**
Fluoranthene	0.1	-	0.039	0.6	1.494	0.32	**Yes**	N/A	**Yes**	No	No
Pyrene	0.1	-	0.024	0.665	1.398	0.36	**Yes**	N/A	**Yes**	No	No
Benzo(a)anthracene	0.1	-	0.016	0.261	0.693	0.36	**Yes**	N/A	**Yes**	**Yes**	No
Chrysene	0.1	-	0.02	0.384	0.846	0.05	No	N/A	**Yes**	No	No
Benzo(b)fluoranthene	0.1	-	-	-	-	0.61	**Yes**	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	0.1	-	-	-	-	0.11	**Yes**	N/A	N/A	N/A	N/A
Benzo(a)pyrene	0.1	-	0.03	0.384	0.763	0.26	**Yes**	N/A	**Yes**	No	No
Indeno(1,2,3cd)pyrene	0.1	-	0.103	0.24	-	0.20	**Yes**	N/A	**Yes**	No	N/A
Benzo(ghi)perylene	0.1	-	0.08	0.085	-	0.37	**Yes**	N/A	**Yes**	**Yes**	N/A
Dibenzo(a,h)anthracene	0.01	-	-	-	0.135	0.69	**Yes**	N/A	N/A	N/A	**Yes**
THC	0.1	-	-	-	-	607.1	**Yes**	N/A	N/A	N/A	N/A
PCBs	0.02	0.18	-	-	0.189	0.008	No	No	N/A	N/A	No
TBT	0.1	0.5	-	-	-	0.0050	No	No	N/A	N/A	N/A