Eyemouth Harbour Trust

Eyemouth Harbour Deepening

Support for Marine Licence Application

March 2019

Innovative Thinking - Sustainable Solutions

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1 Introduction

1.1 Background

Eyemouth Harbour was initially enlarged and deepened in 1998 to form the current Gunsgreen Basin. Maintenance dredging has since occurred within the Harbour at 2–3 year intervals to maintain safe navigation, predominantly from the entrance channel. However, the rate of dredging has not been sufficient to offset natural accretion, and there is now a requirement to restore the Harbour to the original depths of the 1998 deepening in order to meet current requirements for offshore industries in the area.

The current proposal is to remove accumulated sediment from three specific areas of the Harbour by means of a small backhoe dredger down to an advertised depth of 3 m below Chart Datum (CD). The dredged material is proposed to be deposited at an open licensed disposal site located about 3 nautical miles to the east of the Harbour entrance. It is proposed the dredge will be undertaken in phases throughout the length of a 3-year licence.

ITPEnergised, working on behalf of Eyemouth Harbour Trust, have already applied for and received a sediment contamination sampling plan from Marine Scotland's Licensing Operations Team (MS-LOT) and undertaken the sampling requested. Chemical analysis of samples taken from cores (down to 1 m) located at three different sites within the dredge area have indicated contamination, specifically of Polycyclic Aromatic Hydrocarbons (PAHs). These levels are considered by MS-LOT to be too high for a licence to be granted at present without further assessment or a management plan for the dredge material(s) being produced.

1.2 Project objectives

Eyemouth Harbour Trust has commissioned ABPmer to assist ITPEnergised and themselves in securing a Marine licence for the disposal of the dredged material at sea. ABPmer has therefore undertaken further analysis of the proposed dredging requirement with reference to the distribution of the volumes to be dredged, the range of material types and a more detailed appraisal of the contamination data. The aim of the work is twofold:

- To obtain a better understanding of the potential effect on the marine environment from potential disposal at the existing licenced disposal site (FO080); and
- Provide further information, appraisal and a dredge management plan to support a further submission to MS-LOT for re-consideration of the Marine Licence application for disposal of the sediment arisings from the proposed Eyemouth dredge.

This note presents the analysis and assessment as follows:

- Section 2 provides a spatial assessment of the existing material type throughout Eyemouth Harbour, and the potential causes for localised accretion. The section also assesses the levels of contamination (particularly the PAHs) found in the three existing core samples at three depths, against both the standard MS-LOT Action Level Guidelines and the Canadian Sediment Quality Guidelines (CSQG) (CCME, 1999). These cores are located in areas of different material characteristics to be dredged; each location representing different marine processes;
- Section 3 provides an overview of the proposed dredge methodology and quantities of material to be removed. Section 3 also provides an appraisal of the likely levels of contamination that would occur from disposal of then dredged material at the licenced

disposal site (FO080) and the direction of likely dispersal with respect to the local National and International designated areas. This environmental appraisal is assessed in terms of changes to water quality with respect to Water Framework Directive (WFD) Environmental Quality Standards (EQS) for the eight PAHs where PAH EQS Dossiers exist to derive Partition Coefficients for the uptake of the contaminant to the water column (European Commission, 2011). The total contaminant load is also assessed. The section also provides likely management mitigation that would reduce the overall PAH exposure at the disposal site;

- Section 4 provides potential amendments to the proposed dredge methodology (as set out in Section 3) to manage potential effects of contamination; and
- Section 5 provides a summary of the study conclusions.

1.3 Proposed dredging activity

Eyemouth Harbour Trust wishes to undertake the maintenance dredging in two stages. These are:

a) An initial removal of *circa* 1 m of material predominantly from the entrance channel (first year); and
b) Further removal of material in all areas to restore the Harbour design level of 3 m below CD over the 3-year period of a Marine Licence.

The dredge requirement at Eyemouth is spread over three areas as defined on Figure 1. In the first year the entrance channel (Inner and Outer) is proposed to be deepened by about 1 m from a current minimum depth of about 0.7 m below CD. Figure 1 and Table 1 along with the licence application indicate the proposed annual dredge rates in 'wet' tonnes, the likely equivalent *in situ* volume, the approximate total volume to be dredged to restore depths over the 3-years and the material type for each of the dredge areas.

Table 1. Dredge characteristics

Dredge Area	Approximate Existing Average Depth (m Below CD)	Approximate Volume to dredge to Restore to 3 m Below CD (m^3)	Licenced Annual Dredge/ Disposal Requirement (wet tonnes/ year)	Material Type	Assumed Approximate Average In Situ Density (kg/m^3)
A (Inner Entrance)	1.4	3,680	3,000	8 % clay/silt, 92 % sand	1,700
B (Gunsgreen Basin)	1.6	11,200	6,000	66 % clay/silt, 34 % sand	1,600
C (Outer Entrance)	0.7	6,900	6,000	2 % clay/silt, 98 % sand	1,700

Dredging will be undertaken by a small self-propelled hopper barge with backhoe bucket, e.g. MV Sandsend. The dredger will have a maximum carrying capacity of up to 400 tonnes of wet sediment in the hopper. Based on the assumed average density of the bed materials (Table 1) the maximum *in situ* volume removed each load will be about 250 m^3. This means that the annual disposal requirement would be equivalent to about 38 dredger loads. Assuming a bucket size of about 1.5 m^3

with an average 2 minute cycle time (allowing for vessel manoeuvring) the average loading time would be about 5.5 hours. The FO080 licenced deposit ground is *circa* 3 nautical miles from the Harbour entrance, therefore with a representative service speed of about 8 knots and time for disposal the overall cycle time will be of the order of 6.5 hours. Given the tidal range in the Harbour and the current depths in the entrance channel and the loaded draught of the vessel, dredging will be tidally restricted, particularly on spring tides. This means that realistically only one dredge load will be deposited per tide. To remove the full annual licenced volume would take about 19 days (assuming no weather delays). The maximum rate of disposal at FO080 would therefore be a single load of up to 250 m^3 of Harbour dredge material approximately every 12.5 hours for 19 consecutive days per year.

2 Review of Harbour Sediment Contamination

2.1 Introduction

Eyemouth Harbour receives fluvial discharge from the Eye Water, a small river draining a catchment of *circa* 120 km^2 catchment[1] that is channelled through the length of the Inner Harbour before being dispersed into either the Gunsgreen Basin and/or the entrance channel in the approximate area of Gunsgreen House. The Eye Water is therefore likely to be a potential source of silt and finer clays to these areas, particularly during times of peak discharge.

Coarser material (predominantly in the form of sand) is transported into Eyemouth Harbour from the North Sea due to wave activity. Waves will be modified by shoaling and refraction throughout Eyemouth Bay and funnelled into the Harbour Entrance, depositing the sediment across the Harbour entrance and channel. This is indicated by a shallow bar (generally ranging between 0.6 m below CD and 0.8 m below CD in depth) extending *circa* 140 m from the seaward end of the East Pier towards the Harbour and gradually deepening to *circa* 1.5 m below CD immediately off the southern end of the existing fuel jetty (Aspect, 2018). It is likely the rate of material supplied to this area will be enhanced either during extreme storm events or when wave activity enters Eyemouth Bay specifically from northerly directions. Furthermore, the extent the bar encroaches into the Inner Entrance is likely to be controlled by continued interactions between wave activity (entering the Eyemouth Bay) and river discharge (Eye Water), with short-term imbalances in either process resulting in positional shifts of the bar position and rate of sedimentation.

The shape of Gunsgreen Basin and its entrance location will protect the Basin from significant wave disturbance and tidal flows will be weak. The Basin is therefore predominantly a depositional environment for all sediment that can enter and potential tidal flushing will be limited. Any contamination that enters the Basin or is generated within will accumulate in the sediment. The bathymetry (Aspect, 2018) indicates the majority of sedimentation occurs in the north west corner of the Basin where current depths are *circa* 0.6 m below CD.

A sediment sampling programme was carried out during September 2016 for the Marine Scotland marine licence application process. Analysis of these data provides an indication of the dredge material physical characteristics and potential contamination level(s) throughout the proposed dredge area.

1 https://nrfa.ceh.ac.uk/data/station/meanflow/21016

Three sediment cores were taken to a total depth of 1 m below the existing bed. The location of the sampling sites is shown in Figure 1 with respect to the three different areas of the Harbour to be dredged and the annual dredge requirement for each expressed as wet tonnes.

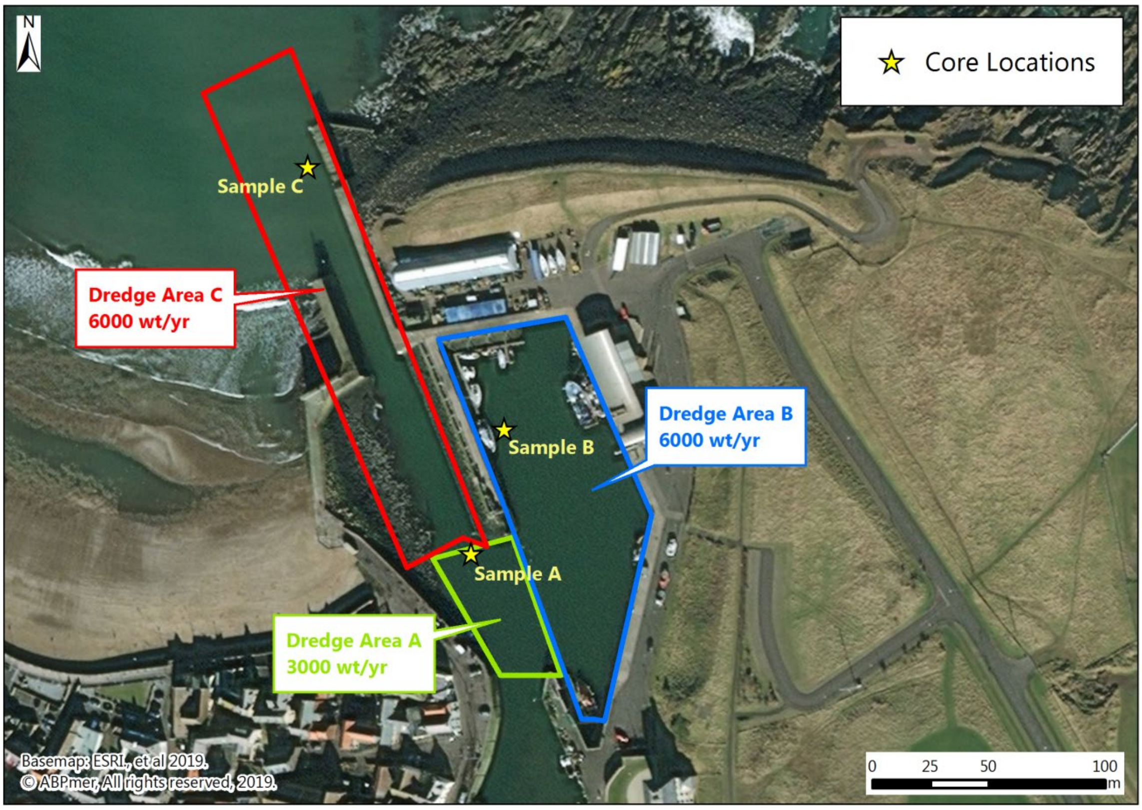

Figure 1. Proposed dredge areas and existing core sampling locations within Eyemouth Harbour during September 2016

Samples were collected from three depths in each core; 0-0.15 m, 0.15-0.5 m and 0.5-0.85 m below the surface. Each sample was analysed for the chemical content for the OSPAR (Oslo and Paris Convention) dredge management guidance range of contaminants. Physical parameters with respect to particle size and Total Organic Content (TOC) were also analysed. The following sub-section summarise these results in the context of the marine licensing requirements.

2.2 Sediment Analysis

2.2.1 Grain size and Total Organic Content (TOC)

For the purpose of the licensing process and assessment of the physical and chemical analysis, the material grain size is graded into three categories. These are:

- Silt – defined as <63 µm in size;
- Sand – defined as ranging between 63 µm and 2 mm; and
- Gravel – defined as > 2 mm in size.

The results of the laboratory analysis indicate that:

- Core Location A is predominantly sand (90-92%) with a small contribution (7-9%) of silt. The Total Organic Contents (TOC) of the bed material is general high (13-14 %) down to *circa* 0.5 m. Beyond 0.5 m this is reduced to around 5 %. The total solid content of the sample increases with depth from 28 – 32 % with depth indicating increased consolidation, however, the sample 'holds' a significant volume of water, suggesting cohesive properties;
- Core Location B has a high contribution of silt (65-66 %) down to a depth of 0.5 m, before coarsening to predominantly sand (72 %) material at a depth of 0.85 m. The TOC content is consistent (4-5 %) throughout the depth of the core. The solid content in the samples is slightly higher 36-38 % than for Core Location A, despite the higher silt content. This suggests a lower energy environment possibly allowing increased consolidation of the bed; and.
- Core Location C is consistently sand (98 %) material with a small contribution of silt (<2 %) throughout the top 1 m of the bed. The TOC is consistently low (<0.5 %) throughout the top 1 m of the bed. This low silt and TOC content is reflected in the high total solid content (up to *circa* 78 %) indicating a free draining sediment.

2.3 Contamination levels

The results of chemical analysis of the samples collected from the three core locations within Eyemouth Harbour (see Figure 1) have been compared to the Marine Scotland chemical guideline Action Levels, administered by MS-LOT (Marine Scotland, 2017). Definitions of the respective Action Levels are provided below:

- **<Action Level 1 (AL1)** - In general, contaminant levels in dredged material below AL1 are likely to be acceptable for disposal at sea;
- **>Action Level 1 (AL1), <Action Level 2 (AL2)** - Dredged material with contaminant levels between AL1 and AL2 may require further consideration before a decision can be made; and
- **>Action Level 2 (AL2)** - Dredged material with contaminant levels above AL2 is generally considered unsuitable for disposal at sea.

2.3.1 Metals and organotins

Analysis of the trace metals and organotins (presented in Appendix A) showed that:

- At Core Location C, there was no contamination with all concentrations of the individual metals below AL1;
- At Core Location A, there was a marginal exceedance of AL1 for the near surface sample only, but only for Cadmium, Copper, Nickel and Lead. The maximum exceedance was about 6 % of the concentration interval between AL1 and AL2 for Copper;
- The most contamination was recorded at Core Location B within Gunsgreen Basin, where the sediment predominantly comprises silt. In this area, the contamination was homogeneous with depth. The exceedance of AL1 ranged from 6-35 % of the concentration interval between AL1 and AL2 for the respective metals. The higher percentage exceedance was for Tributyltin (TBT).

From experience elsewhere, such small levels and number of exceedances of AL1 are not usually a concern with respect to sea disposal, particularly when the small volumes to be disposed are considered (*circa* 6,000 wet tonnes/year). Moreover, MS-LOT's refusal of the marine licence was predominantly as a result of the high PAH concentrations. These are assessed further in the following section.

2.3.2 PAH concentrations

Firstly, it should be noted that the Marine Scotland Guideline Action Levels do not state an upper (i.e. AL2) concentration value for any specific PAH. Therefore, once AL1 has been exceeded, there is no upper concentration to place a quantitative perspective on the level of PAH contamination within a particular material.

Table 2 shows the PAH contamination levels for each sample tested with the exceedances of AL highlighted. These results show that in the sand material within the outer entrance channel (Core Location C) only Benz(a)anthracene, Chrysene, Dibenz(a)anthracene, Flouranthene and Pyrene exceed AL1. These exceedances are however, marginal and are restricted to the near surface (<0.15 m depth). All PAHs at depth are well below the AL1 threshold. This indicates that the sand to be dredged from the outer entrance and most of the channel is essentially uncontaminated.

In Gunsgreen Basin (Core Location B) the bed material is considerably finer (66 % clay and silt) and cohesive in nature. Here, the PAH contamination is for the most part higher (*circa* 1 – 10 times) than AL1, but not for all PAHs. Acenaphthene, Acenaphthylene and Napthalene remain below the AL1 threshold. PAH values are generally not consistent with depth in the core.

The PAH contamination is, however, considerably greater at Core Location A at the end of the Fuel Jetty. Here the bed material is silty sand (92 % sand). All samples from the core are higher than elsewhere and they appear to be 'layered', possibly suggesting variable rates of contamination over time. The highest concentrations are consistently in the layer 0.15 – 0.5 m below the surface. The lowest concentrations are generally nearer the surface, possibly suggesting the contamination source has reduced, more recently.

Overall these concentrations are very high and were the primary reason for the initial dredge disposal licence refusal. However, as noted above it is difficult to judge the scale of likely effect to the receiving environment because of the single Action Level threshold.

Table 2. PAH levels of collection samples against the Marine Scotland Guideline Action Levels

Sample	Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg Dry Weight)																							
	Bed Depth (m)	Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(e)pyrene	Benzo(ghi)perylene	Benzo(K)fluoranthene	C1-napthalenes	C1-phenanthrene	C2-napthalenes	C3-napthalenes	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Perylene	Phenanthrene	Pyrene	Total Hydrocarbon Content (THC)
A 1/1	0.00-0.15	47.23	100.54	581.21	1,329.54	995.24	797.21	775.16	522.50	859.17	322.81	1,974.27	460.56	527.33	1,307.41	147.96	2,835.32	132.97	513.30	188.97	248.31	1,525.93	2,430.08	610,111.71
A 1/2	0.15-0.50	533.38	1,014.18	2,718.37	3,247.25	2,262.98	1,658.86	1,700.72	1,301.58	1,764.32	15,478.61	8,444.57	10,702.23	7,606.32	3,147.49	314.08	6,843.10	2,260.06	952.47	4,543.03	526.44	9,008.31	6,141.11	1,595,817.31
A 1/3	0.50-0.85	174.57	199.48	723.30	1,630.71	1,356.35	1,214.51	1,099.91	823.86	1,235.83	569.94	1,775.62	740.83	925.09	1,774.07	202.16	4,674.78	375.12	829.78	189.78	384.04	3,473.98	3,493.58	558,379.63
B 2/1	0.00-0.15	18.06	23.84	206.33	370.59	306.58	413.05	327.89	259.14	299.83	116.44	521.92	191.24	188.38	491.88	61.92	640.53	133.84	282.43	46.06	131.06	191.24	926.57	3,380,176.21
B 2/2	0.15-0.50	30.09	20.82	122.21	351.07	334.53	396.15	325.52	304.70	301.60	223.89	830.52	437.68	944.68	418.73	62.91	647.97	95.64	304.57	62.77	165.10	327.50	655.08	2,684,687.33
B 2/3	0.50-0.85	32.17	19.00	129.66	287.97	272.34	352.94	265.29	242.94	267.27	185.01	1,012.91	418.95	1,040.54	393.64	56.08	541.75	103.35	238.43	62.26	147.74	313.80	659.88	2,343,671.15
C 3/1	0.00-0.15	3.69	7.14	32.31	110.20	87.88	60.94	63.18	42.50	67.43	8.17	96.06	12.42	25.02	103.94	12.57	174.64	10.23	42.58	5.71	19.13	41.96	168.19	19,794.45
C 3/2	0.15-0.50	<1	<1	2.23	6.72	6.85	7.04	6.90	5.18	6.39	9.47	8.75	9.93	9.69	7.64	1.18	10.63	1.07	4.74	3.47	1.59	6.94	10.14	7,548.33
C 3/3	0.50-0.85	3.13	1.98	11.30	26.72	24.06	19.24	18.15	13.74	19.83	28.59	24.27	22.61	19.27	26.57	3.62	50.18	4.39	13.98	13.20	6.34	29.05	42.44	10,002.92
Marine Scotland Guideline Action Levels (µg/kg Dry Weight)																								
AL1		100	100	100	100	100	100	100	100	100	100	100	100	100	100	10	100	100	100	100	100	100	100	-
AL2		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

2.3.3 Comparison against Canadian interim sediment quality guidelines

The Canadian Council of Ministers of the Environment (CCME) provides another method for chemical quality assessment. This method of assessment uses two threshold levels (as opposed to a single Action Level) allowing a more 'refined' assessment of the contamination levels. The CCME have defined the two levels as the Interim Sediment Quality Guideline (ISQG) and the Probable Effect Level (PEL). These thresholds define three ranges of material quality in terms of chemical concentrations (CCME, 1999). These are:

- **(<ISQG)** - Sediments lower than the ISQG are considered to be of acceptable quality. Management options at these sites would focus on the protection of existing sediment quality conditions;
- **(>ISQG, <PEL)** - Sediments between the ISQG and PEL are considered to represent potential hazards to exposed organisms. Although adverse biological effects are possible within this range of concentrations, their occurrence, nature, and severity are difficult to reliably predict on an a priori basis. Specific conditions at these sites are likely to control the expression of toxic effects; and
- **(>PEL)** - The PEL represents the lower limits of the range of chemical concentrations that are usually or always associated with adverse biological effects. Sediments greater than the PEL are considered to represent significant and immediate hazards to exposed organisms.

The same three sample cores have also been compared to the CCME standards in Table 3 (note only the PAH where there are Canadian sediment quality values are shown). It should be noted that 9 of the 12 stated ISQG values for PAHs in the CCME Guidelines are lower than and variable compared to the AL1 stated in the Marine Scotland Guidelines. The magnitude of exceedance above the stated ISQG value relative to the PEL can be used to provide greater information on the likely magnitude of effect on the marine environment. It is suggested that the ISQG and PEL thresholds could be used as corollaries for the Marine Scotland Action Level methodology. Consequently, it is suggested that PAH concentrations lying between the two standards might also be considered as suitable to be disposed at sea.

When comparing the sample PAH concentrations against the CCME Guidelines (Table 3), the overall sediment quality of the nine samples from the three core locations is highly variable. PAH values at Core Location A are higher than at other locations exceed both the ISQG and PEL threshold values throughout the depth of the core (i.e. down to 1 m). This is consistent with the Marine Scotland analysis.

Concentrations of PAHs at Core Location B are above the ISQG values, but none of the PEL thresholds are exceeded. Analysis of the concentration relative to the range in contamination between the individual PAH ISQG and PEL thresholds show that for the most part the measured concentrations are 45 – 60 % of the ranges.

The sand at Core Location C (Outer Entrance channel) is generally of good quality, with minor PAH exceedances of four ISQG thresholds at the surface (<0.15 m). No exceedances of PEL thresholds occur at any depth in the core.

Table 3. PAH levels of collected samples against the Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life

Sample	Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg Dry Weight)												
	Bed Depth (m)	Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Naphthalene	Phenanthrene	Pyrene
A 1/1	0.00-0.15	47.23	100.54	581.21	1,329.54	995.24	1,307.41	147.96	2,835.32	132.97	188.97	1,525.93	2,430.08
A 1/2	0.15-0.50	533.38	1,014.18	2,718.37	3,247.25	2,262.98	3,147.49	314.08	6,843.10	2,260.06	4,543.03	9,008.31	6,141.11
A 1/3	0.50-0.85	174.57	199.48	723.30	1,630.71	1,356.35	1,774.07	202.16	4,674.78	375.12	189.78	3,473.98	3,493.58
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B 2/2	0.15-0.50	30.09	20.82	122.21	351.07	334.53	418.73	62.91	647.97	95.64	62.77	327.50	655.08
B 2/3	0.50-0.85	32.17	19.00	129.66	287.97	272.34	393.64	56.08	541.75	103.35	62.26	313.80	659.88
C 3/1	0.00-0.15	3.69	7.14	32.31	110.20	87.88	103.94	12.57	174.64	10.23	5.71	41.96	168.19
C 3/2	0.15-0.50	<1	<1	2.23	6.72	6.85	7.64	1.18	10.63	1.07	3.47	6.94	10.14
C 3/3	0.50-0.85	3.13	1.98	11.30	26.72	24.06	26.57	3.62	50.18	4.39	13.20	29.05	42.44
Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (µg/kg Dry Weight)													
SQG		6.71	5.87	46.9	74.8	88.8	108	6.22	113	21.2	34.6	86.7	153.0
PEL		88.9	128	245	693	763	846	135	1,494	144	391	544	1,398

2.3.4 Spatial analysis

This analysis confirms that the sand in the outer entrance channel can be considered as clean. The PAH contamination throughout the depth at Core Location A (Inner Entrance channel) is contaminated to a level that will probably cause environmental effects if disposed at those concentrations, not accounting for dilution process during the dredging process.

The silt sediments in Gunsgreen Basin have PAH contamination which the Canadian Guidelines suggest would cause potential hazards to exposed organisms, but whether this would occur will depend on local conditions. This suggests the material from Gunsgreen Basin may be acceptable for disposal at sea, at small volumes ('dosages').

3 Environmental Appraisal (Disposal)

3.1 Introduction

This section provides an environmental appraisal of the dispersion of sediment and potential affects to water quality at the licenced disposal site (FO080) as a result of the proposed dredging works set out in Section 1.3.

The closest disposal site to Eyemouth Harbour is the licenced site FO080 approximately 3 nautical miles east of the Harbour entrance. This site is located beyond a shelving foreshore in an area where depths are 50 – 60 m. This site is located *circa* 2 km outside a EU designated coastal Special Area of Conservation (SAC), about 20 km south east of a Special Protection Area (SPA) for birds and 15 km north west of a nationally designated Marine Conservation Area. The relative locations are shown in Figure 2. Also shown is a 'rose' representation of the tidal and wave climates for the geographical co-ordinates of the licenced disposal site. The data have been extracted from ABPmer's SEASTATES database (ABPmer, 2013) and show the hourly depth-averaged tidal current speed, current direction, significant wave height (Hs) and mean wave direction over a 39-year hindcast period from 1979–2018.

The diagram shows that the tidal flows are approximately aligned NW - SE, approximately parallel to the coastline and the boundary of the SAC designated area. The maximum depth-average flows are of the order of 0.6 m/s on spring tides. Significant wave heights, based on the long-term analysis exceed 3 m and predominantly come from the sector north through east. This indicates that any sediment deposited will be moved slightly inshore of the disposal site by wave activity whilst the disposed material remains in the near surface layers of the water column.

The material will, however, be deposited *en-masse* from bottom opening doors/split hopper, therefore will descend rapidly to the bed, over the *circa* five minutes of the disposal operation. This means the sand, silt and clay will only be affected by wave activity for a short period. The dispersal plume will therefore be tidally dominated. This indicates that the dispersal plume will not move towards the shore and affect the SAC, Assuming the maximum flow speeds exist throughout the tide (an overestimate), the sediment does not completely settle to the bed (unlikely) and is deposited at HW or LW, the maximum distance the plume would travel is about 13 km. On this basis, the plume will not interact with any designated areas.

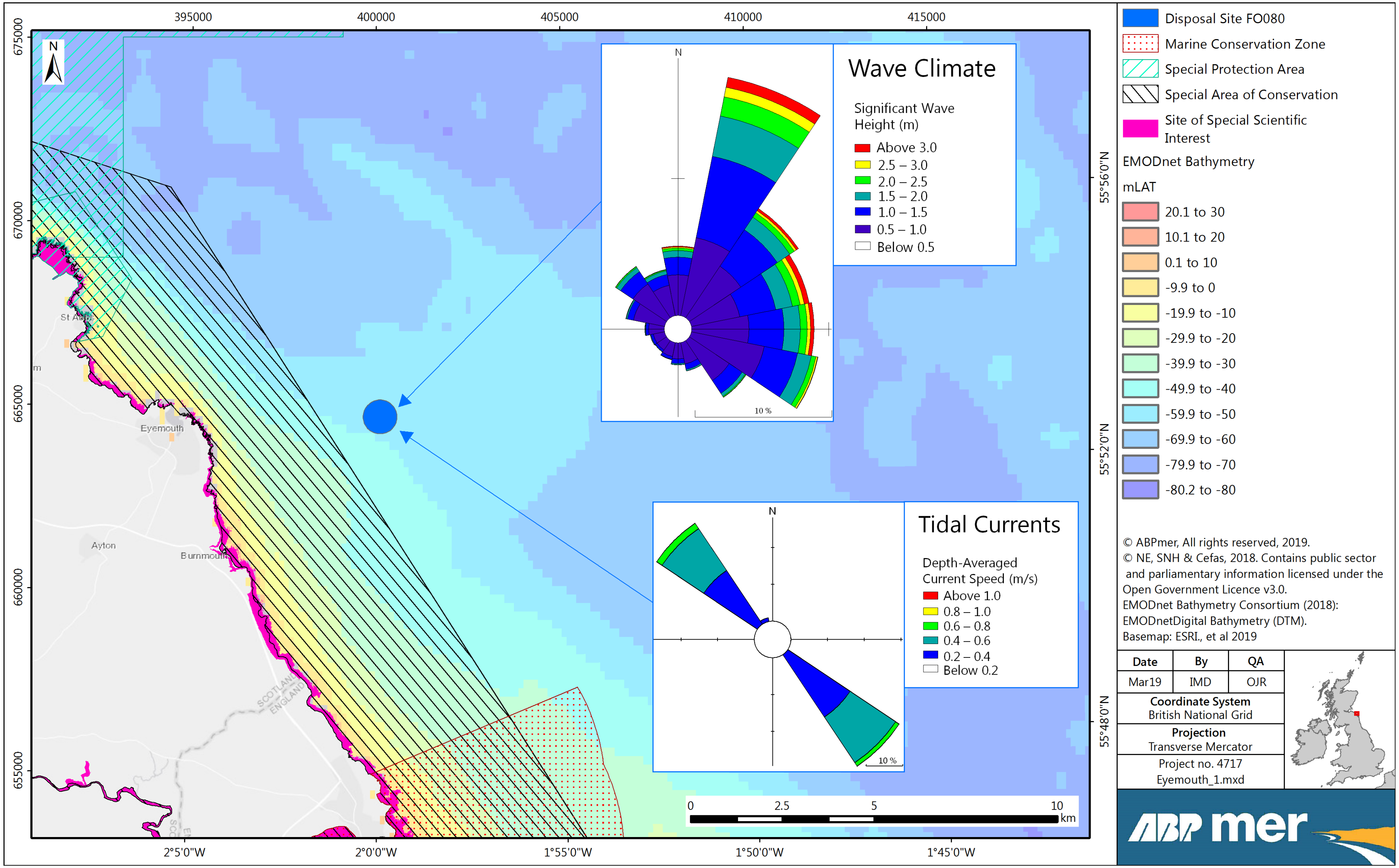

Figure 2. The licensed disposal site offshore of Eyemouth Harbour in relation to surrounding designated areas

3.2 Methodology

3.2.1 Appraisal assumptions

The appraisal is based upon the following assumptions:

- **Material type**- The estimated specific gravity for material within each dredge area (stated in Section 7 of the Marine Licence Application) are, from experience, considered to be higher than reality for maintenance dredge material when considering the nature of the material indicated by the laboratory analysis. For dredge areas A and C, comprising predominantly non-cohesive sand, the surface material which is subject to the wave and tidal influence is likely to have a bulk density of around 1,600 kg/m^3. This will increase with depth due to self-weight consolidation, possibly up to 1,800 kg/m^3. An average *in situ* bulk density is therefore assumed as 1,700 kg/m^3. Within Gunsgreen Basin, the area needing most dredging is predominantly clay and silt, which the physical characterisation suggests will have cohesive properties with the density increasing with depth. For this assessment, the average density of the material to be removed is estimated to be 1,600 kg/m^3;
- **Contaminant concentration**- The core sampling shows that the levels of PAH contaminants are either variable with depth, or consistent with depth, depending on the location. Furthermore, the depth of the cores only partially represents the level of material to be removed. For this assessment, an average value for each PAH has been calculated using the three depth values and applied uniformly to the whole core;
- **Dredger type**- Assuming no change from the information provided within Sections 6g and Section 10 of the Marine Licence Application, a backhoe dredger with a bucket volume of 1.5 m^3, a hopper capacity of 330 m^3 and a load draught of about 2.2 m will be carrying out the proposed dredging works. Considering the material type and vessel Deadweight Tonnage (DWT), it is suggested that any single dredge load will remove a maximum 250 m^3 *in situ*.

3.2.2 Contamination levels for appraisal

Based on the core samples being representative of the complete volume of each PAH to be dredged from each of the defined areas, Table 4 gives the total mass of contaminant that would be deposited at the FO080 disposal site for a single dredge load, for a 1 m lowering of the bed and for the complete removal down to the Harbour design level of 3 m below CD.

This, in general shows, that up to about twice the mass of each PAH contaminant will be removed from the Gunsgreen Entrance dredge area compared to the Basin (Dredge Area B) despite only approximately a third of the volume being removed.

Should marine disposal be granted the contaminant 'dosage' to the deposit ground will be an order of magnitude greater for material from Dredge Area A compared to Area B and 2 orders of magnitude greater than from the Entrance Channel (Dredge Area C).

Table 4. Approximate total masses of PAH contaminant removed from dredge areas

PAH	Total Removal Mass (kg)								
	Dredge Area A			Dredge Area B			Dredge Area C		
	Per Load	1 m Bed Lowering	3 mCD	Per Load	1 m Bed Lowering	3 mCD	Per Load	1 m Bed Lowering	3 mCD
Acenaphthene	0.069	0.636	1.018	0.006	0.201	0.281	0.001	0.011	0.026
Acenaphthylene	0.121	1.107	1.771	0.005	0.159	0.223	0.001	0.015	0.035
Anthracene	0.369	3.389	5.423	0.036	1.145	1.603	0.004	0.050	0.116
Benz(a)anthracene	0.569	5.230	8.367	0.079	2.523	3.533	0.013	0.158	0.364
Benzo(a)pyrene	0.423	3.888	6.220	0.071	2.283	3.196	0.011	0.131	0.301
Benzo(b)fluoranthene	0.337	3.092	4.948	0.091	2.905	4.066	0.008	0.096	0.221
Benzo(e)pyrene	0.328	3.012	4.820	0.072	2.296	3.215	0.008	0.097	0.223
Benzo(ghi)perylene	0.243	2.231	3.569	0.063	2.016	2.823	0.006	0.068	0.155
Benzo(K)fluoranthene	0.354	3.251	5.202	0.068	2.171	3.040	0.009	0.103	0.237
C1-naphthalenes	1.502	13.792	22.067	0.041	1.313	1.838	0.004	0.051	0.117
C1-phenanthrene	1.119	10.273	16.437	0.185	5.912	8.276	0.012	0.142	0.327
C2-naphthalenes	1.092	10.028	16.045	0.082	2.619	3.666	0.004	0.049	0.114
C3-naphthalenes	0.831	7.632	12.211	0.170	5.432	7.605	0.005	0.059	0.137
Chrysene	0.571	5.248	8.396	0.102	3.260	4.564	0.013	0.152	0.350
Diben(ah)anthracene	0.061	0.560	0.895	0.014	0.452	0.633	0.002	0.019	0.044
Fluoranthene	1.317	12.092	19.347	0.143	4.574	6.404	0.022	0.259	0.596
Fluorene	0.254	2.332	3.731	0.026	0.832	1.165	0.001	0.017	0.040
Indeno(1,2,3-cd)pyrene	0.211	1.934	3.094	0.065	2.063	2.888	0.006	0.067	0.155
Naphthalene	0.451	4.146	6.634	0.013	0.428	0.599	0.002	0.025	0.057
Perylene	0.106	0.976	1.562	0.035	1.109	1.553	0.002	0.030	0.069
Phenanthrene	1.285	11.801	18.882	0.065	2.081	2.913	0.007	0.086	0.197
Pyrene	1.107	10.164	16.262	0.175	5.602	7.843	0.020	0.243	0.559

3.3 Appraisal

The European Commission (2011) has produced a number of Environmental Quality Standard (EQS) dossiers, establishing EQS thresholds for dissolved contaminants in the water column. Eight of the PAHs have EQS values and associated Partitioning Coefficients for establishing the rate of dissolution of the chemical from sediment into the water. The Partitioning Coefficients have been used to determine the maximum dissolved PAH concentration that is likely to occur at the disposal site for the sediment contamination levels from the three dredged areas. These results are compared to the EQS values in Table 5. A colour code has been used to summarise the data. Green indicates that the maximum derived concentration is lower than the EQS, amber represent values close to the EQS and the red values substantially exceed the EQS.

Table 5. Maximum dissolved PAH concentrations of deposited material from each Dredge Area

PAH	Maximum Sediment Concentration (mg/kg)	Partitioning Coefficient (l/kg)	EQS (µg/l)	Maximum Dissolved Concentration (µg/l)
Dredge Area A				
Anthracene	1,340.963	793	0.1	1.691
Benzo(a)pyrene	1,538.194	20,795	0.027	0.074
Benzo[b]fluoranthene	1,223.526	20,795	0.017	0.059
Benzo(ghi)perylene	882.645	25,583	0.00082	0.035
Benzo[k]fluoranthene	1,286.441	19,859	0.017	0.065
Fluoranthene	4,784.399	2,444	0.12	1.958
Indeno(1,2,3-cd)pyrene	765.185	58,607	0.027	0.013
Naphthalene	1,640.595	35	130	46.874
Dredge Area B				
Anthracene	152.735	793	0.1	0.193
Benzo(a)pyrene	304.483	20,795	0.027	0.015
Benzo[b]fluoranthene	387.382	20,795	0.017	0.019
Benzo(ghi)perylene	268.928	25,583	0.00082	0.011
Benzo[k]fluoranthene	289.571	19,859	0.017	0.015
Fluoranthene	610.083	2,444	0.12	0.250
Indeno(1,2,3-cd)pyrene	275.144	58,607	0.027	0.005
Naphthalene	57.032	35	130	1.629
Dredge Area C				
Anthracene	15.278	793	0.1	0.019
Benzo(a)pyrene	39.599	20,795	0.027	0.002
Benzo[b]fluoranthene	29.073	20,795	0.017	0.001
Benzo(ghi)perylene	20.473	25,583	0.00082	0.001
Benzo[k]fluoranthene	31.216	19,859	0.017	0.002
Fluoranthene	78.482	2,444	0.12	0.032
Indeno(1,2,3-cd)pyrene	20.434	58,607	0.027	0.000
Naphthalene	7.460	35	130	0.213

As can be seen the sand from the entrance channel (Area C) would result in water quality values lower than the EQS. The silt, sand and clay from Area B gives rise to values either below or close to the EQS, with the exception of Benzo(ghi)perylene. Even with the significantly higher PAH concentrations from Area A (from those with Partitioning Coefficients), only Anthracene, Benzo(ghi)perylene and Fluoranthene give rise to maximum dissolved PAH concentrations above the water quality EQS. These data are considered a worst-case because they do not take account of the rate of input of sediment to the water column and the reduction in sediment concentration as the material falls through the water column and disperses.

When the volume of water passing under the disposal is taken into account (due to the ambient flow) the reduced suspended sediment concentration indicates that the partitioning of the highest sediment PAH concentrations would give rise to water concentrations below the EQS values.

3.4 Conclusions

This analysis, along with the initial Marine Scotland Action Level and Canadian Interim Sediment Quality standard assessment, indicates that disposal of the entrance channel sand (Dredge Area C) and Gunsgreen Basin (Dredge Area B) sand, silt and clay will have no (or negligible) effects on the marine environment; given the rate of dredging/disposal and frequency from the small dredger.

The smaller volume of sediment to be dredged from the entrance to Gunsgreen Basin (Dredge Area A) has been shown to have concentrations which would probably have effects on the marine environment from consideration of the sediment chemical analysis. The effects on water quality at the disposal site are likely to be higher than the EQS values for some, but not all PAHs, assuming still water conditions, however, taking account of sediment dilution in the flowing water causing a rapid reduction in water column suspended sediment concentrations the EQS are unlikely to be exceeded. When the distribution of sediment concentrations and dispersion is considered, little effect on the water quality is expected.

The physical environmental conditions at the disposal site also indicate the dispersal of sediment will not interact with the nearest designated areas as described in Section 3.1.

Taking the dredge as a whole, the overall mass of contaminant to be deposited at the disposal ground is considered small and is likely to have a negligible (unmeasurable effect) on the marine environment.

4 Dredge Management Plan Option

The analysis presented in the previous section suggests that disposal of all the proposed dredge material from Eyemouth Harbour is unlikely to have a significant effect on the marine environment. However, contamination from Dredge Area A does exceed the Action Level limits that would normally exclude the material being disposed at sea. The various areas to be dredged and volumes to be removed, however, do allow potential for dilution of the loads, with respect to chemical 'dosages' at the disposal site. The bathymetry indicates that approximately twice as much dredging is required from Dredge Area C compared to that for the Dredge Area A containing most of the PAH contamination.

Due to the nature of the dredge it would be possible to initially dredge a quarter of the *in situ* (bed) hopper volume as the dredger enters the Harbour from Dredge Area C, then half the hopper volume from Dredge Area A and complete the load from dredging Area C again, on the way to the way to the disposal site. As a consequence, the clean and contaminated material would be mixed thus reducing the overall contamination in the dredger load to be deposited at licenced disposal site FO080.

Table 6 provides a summary of the effect on the sediment contamination levels and water quality at the disposal ground as a result of this methodology. This shows that the sediment contamination will still exceed the Canadian PEL values by an average of about 200 % but the actual concentrations will be approximately halved. At the disposal site, the EQS values, not accounting for any sediment concentration dilution, still show some exceedances of the EQSs, but actual values are halved.

Table 6. PAH contamination levels at the disposal ground following dredge management plan

PAH	µg/kg Dry Weight	ISQG (µg/kg Dry Weight)	PEL (µg/kg Dry Weight)	% Above PEL	Partitioning Coefficient (l/kg)	EQS (µg/l)	Maximum Dissolved Concentration (µg/l)
Acenaphthene	128	6.71	88.9	143	793	0.1	0.161
Acenaphthylene	221	5.87	128	173			
Anthracene	678	46.9	245	277			
Benz(a)anthracene	1,059	74.8	693	153			
Benzo(a)pyrene	789	88.8	763	103	20,795	0.027	0.038
Benzo(b)fluoranthene	626				20,795	0.017	0.030
Benzo(ghi)perylene	452				25,583	0.00082	0.018
Benzo(K)fluoranthene	659				19,859	0.017	0.033
Chrysene	1,061	108	846	125			
Diben(ah)anthracene	114	6.22	135	84			
Fluoranthene	2,431	113	1,494	163	2,444	0.12	0.995
Fluorene	464	21.2	144	322			
Indeno(1,2,3-cd)pyrene	393				58,607	0.027	0.007
Naphthalene	824	34.6	391	211	35	130	23.544
Phenanthrene	2,348	86.7	544	432			
Pyrene	2,048	153	1,398	146			

Mixing the dredging locations on each load will therefore approximately halve the contamination 'dosage' at the disposal site, however, this will not reduce the actual sediment concentration to below the Canadian PEL limit or prevent some exceedance of the water quality EQS in a worst-case assessment. The total contaminant input over the 3-year period will remain the same, albeit noting this input will only occur for 2-3 weeks of each year. Overall, mixing the sediment from the dredge areas will approximately halve the potential for effect in the marine environment.

5 Study Conclusions

Detailed analysis of the level of contamination in material proposed for dredging (particularly PAHs) within Eyemouth Harbour has been undertaken with reference to both the Marine Scotland Sediment Action Level Guidance and the Canadian Interim Sediment Quality Guidelines. The analysis has also taken account of the location of contamination and distribution with depth, the physical character of the material, the volume, rate and method of dredging for each dredge area. Consideration has also been made to the likely effects on water quality at the existing FO080 disposal site, should the material be licensed for disposal.

The results of the study indicate that:

- All sand to be dredged from the majority of the entrance channel (about 6,900 m^3, 30 % of the total) is clear of contamination and will not cause a hazard from disposal in the marine environment;

- The sand, silt and clay from Gunsgreen Basin (about 11,200 m^3, 50 % of the total) can be described as moderately contaminated; however, when assessed against the Canadian Interim Sediment Quality Guidelines they do not exceed the Probable Effects Level, a corollary for Action Level 2 in the Marine Scotland Guidance. The contamination level of PAHs averages about half way between the ISQG and PEL thresholds. Experience from other locations suggests this material could be deposited in the marine environment, particularly accounting for the small total volume and dredger loads, with a maximum of one load being able to be deposited on a tide;

- The silty sand to be dredged from Area A at the entrance to Gunsgreen Basin (about 3,700 m^3, 20 % of the total) has PAH contamination levels that substantially exceed the Canadian Probable Effects Level. The location of the core samples is representative of one end of the area and it is not certain this is representative of all the sediment to be dredged from this area. If deposited at the disposal ground, the effect on water quality with respect to the EQS varies for the different PAHs that can be analysed. Two are well below the respective EQS, three are close to the EQS (but above) and three can be considered to be well above the EQS for a worst-case scenario, which does not account for the effects of sediment dispersion within the water column. When this is taken into account the effect on water quality is significantly reduced;

- Due to the distribution of the clean and contaminated sediments and the relative volumes of each a dredge management strategy could be implemented, whereby the clean and contaminated material could be mixed in the dredger. This would approximately halve the maximum PAH contamination levels that would be deposited at the disposal site. The actual levels would still be in excess of the Canadian PEL values (average 200 % above) but the 'dosage' to the disposal site would be significantly lower, also halving the potential effect on water quality.

Given the small volumes to be dredged per annum and the total over 3-years, the maximum rate of disposal, equivalent to 250 m^3 per tide for a maximum of 2–3 weeks per year and that only 20 % is considered to be significantly contaminated it is unlikely disposal at licenced site FO080 would significantly cause a hazard to the marine environment. The site is also deep, with a significant flow so dispersal of the sediment is likely to be widespread causing significant and rapid dilution of the input suspended sediment concentration. The flow characteristics of the site indicate the dispersion of this material will not reach the national and international designated areas. The absolute contamination levels can be halved by implementing a dredge management plan, whereby sediment from two dredge areas can be mixed, i.e. the clean sand from Dredge Area C can be mixed in each load with the contaminated material from Dredge Area A.

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7 Abbreviations/Acronyms

ABP	Associated British Ports
AL	Action Level
CCME	Canadian Council of Ministers of the Environment
CSQG	Canadian Sediment Quality Guidelines
DWT	Deadweight Tonnage
EQS	Environmental Quality Standards
EU	European Union
Hs	Significant Wave Height
HW	High Water
ISQG	Interim Sediment Quality Guideline
LW	Low Water
mCD	metres relative to Chart Datum
MLWN	Mean Low Water Neap
MS-LOT	Marine Scotland Licensing Operations Team
PAH	Polycyclic Aromatic Hydrocarbon
PEL	Probable Effect Level
SAC	Special Area of Conservation
SPA	Special Protection Area
SQG	Sediment Quality Guidelines
TBT	Tributyltin
TOC	Total Organic Content
TOC	Total Organic Content
WFD	Water Framework Directive

Cardinal points/directions are used unless otherwise stated.
SI units are used unless otherwise stated.

Appendix





Innovative Thinking - Sustainable Solutions

A Trace Metal/Organotin Analysis

Sample	Bed Depth (m)	Dry Weight (mg/kg)									
		Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)	Dibutyltin (DBT)	Tributyltin (TBT)
A 1/1	0.00-0.15	13.2	0.42	45.5	49.6	0.13	30.2	63.4	128.4	<0.01447	0.0326
A 1/2	0.15-0.50	10.3	0.36	34.1	26.1	0.11	17.4	34.8	75.5	<0.01064	0.0192
A 1/3	0.50-0.85	8.0	0.18	37.3	27.2	0.09	17.4	22.6	58.4	<0.00713	0.0099
B 2/1	0.00-0.15	12.9	0.40	82.5	100.9	0.17	40.2	61.5	232.0	<0.00505	0.2390
B 2/2	0.15-0.50	16.6	0.59	86.6	79.3	0.18	39.1	48.9	238.1	<0.00514	0.3600
B 2/3	0.50-0.85	16.2	0.53	88.9	75.1	0.20	40.9	50.4	195.4	<0.00524	0.2750
C 3/1	0.00-0.15	16.4	0.09	31.3	10.2	0.05	14.5	13.7	31.6	<0.00500	<0.0020
C 3/2	0.15-0.50	15.1	0.09	30.5	10.1	0.04	14.3	14.6	32.6	<0.00500	<0.0020
C 3/3	0.50-0.85	15.6	0.07	31.5	11.2	0.04	14.2	14.6	32.1	<0.00500	<0.0020
Marine Scotland Guideline Action Levels (mg/kg Dry Weight)											
AL 1		20.0	0.40	40.0	40.0	0.30	20.0	50.0	130.0	0.10000	0.10000
AL 2		100.0	5.00	400.0	400.0	3.00	200.0	500.0	800.0	1.00000	1.00000

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