Montrose Port Authority

Maintenance Dredging BPEO

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Notice

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Executive Summary

The commercial viability of the Port of Montrose relies on maintenance dredging of the navigation channel and harbour. The marine licence requires renewal in 2018. This report provides a Waste Hierarchy Assessment (WHA) to determine the Best Practicable Environmental Option (BPEO) for use/disposal of the dredged material as required for the marine licence.

The WHA has not identified any practical, viable and cost effective immediate uses of the maintenance dredge material. However, the character of some of the material is suitable for use should a feasible, cost effective (to the port and the wider public) and environmentally sustainable option be identified. As such a continual review of the potential to use the dredge material is recommended. However, without any suitable uses available at the present time, disposal is the only option.

The current method of disposal in the marine environment at a licenced disposal ground has been concluded to remain the BPEO. No issues of note have been reported from the previous disposal operations at the existing licenced disposal site in Lunan Bay (Montrose FO010). This location is still considered to be the optimum location. Disposal to land would be very expensive, impractical, not environmentally sustainable, and therefore considered unviable.

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1 Introduction

1.1 Background

The Montrose Port Authority facilities are approximately 1.8 km from the open sea (North Sea), accessed by a dredged channel. The Port of Montrose handles all types of vessels up to about 25,000 tonnes deadweight. To accommodate these vessels the entrance channel was deepened to 5.5 m below Chart Datum (CD) and the quayside berth pockets to 8 m below CD to provide safe navigation. As a result, the depths in the navigation channel, the berths and turning area within the harbour need to be maintained by dredging as required, with campaigns nominally one to three times a year.

Freshwater flows from the River South Esk pass through a relatively shallow and muddy 9 km^2 intertidal basin (known as Montrose Basin) before passing through the harbour and navigation channel and exiting into the North Sea. The channel is bordered to the south by a rocky peninsula (Scurdie Ness) and to the north by the intertidal shallow spit system known as Annat Bank, which comprises an area of sand and gravel where tidal flows are predominantly to the south. This configuration is shown in Figure 1.

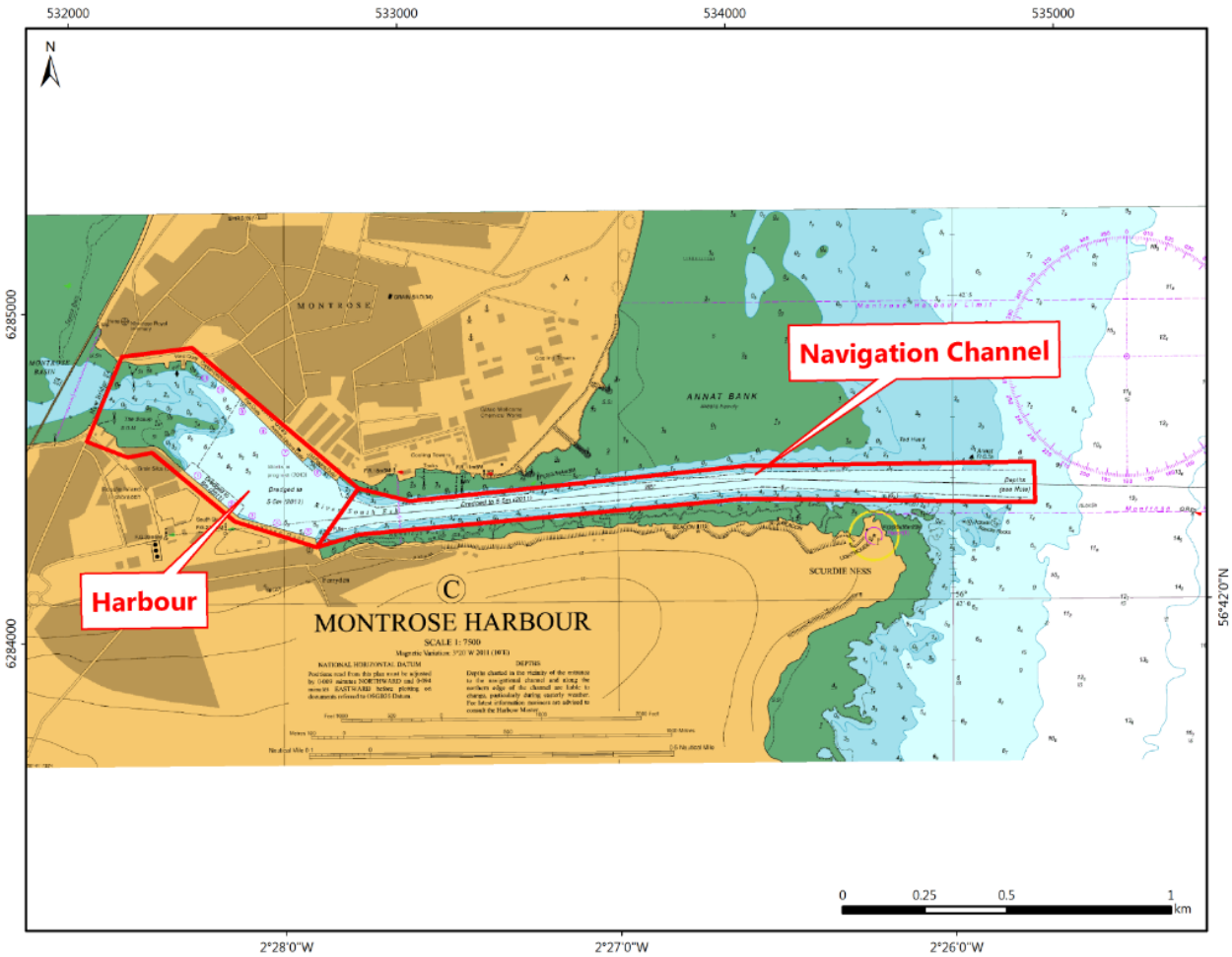


Figure 1. Configuration of Montrose Harbour and navigation channel showing dredge area

Sediment deposits in the Harbour and navigation channel predominantly from three mechanisms:

- Silt from the River Esk, predominantly in the Inner Harbour berths and on Scaup Bank which grows across the vessel manoeuvring area to and from the berths;
- Sand, predominantly moving southwards from and over Annat Bank in the strong flood flows particularly on large spring tides. This sand collects on the north side of the Outer Channel and then moves across the channel. Additional sand moves along the axis of the channel from the sea, with the strong flood flows distributing sandy sediments into the mid- channel and into the Inner Harbour;
- Storm disturbed sand and gravel, moved onshore to Annat Bank and then further disturbed into the channel.

These mechanisms for sedimentation create the continual requirement for maintenance dredging, with storm conditions creating the variation in magnitude and timing of the requirement. As a result, consent is required for the disposal of the maintenance dredge arisings managed via a Marine Disposal Licence.

This dredging and disposal is currently licenced by The Marine (Scotland) Act 2010, Part 4 marine licence reference 05450/16/0 until 29 April 2018. The licence currently allows up to 100,000 m^3 to be deposited by the method of vessel bottom disposal at the licenced deposit Area Montrose, FO010 (Figure 2). A renewal licence application is required to be submitted to the Marine Laboratory, Aberdeen (the licencing authority on behalf of the Scottish Minister) in early 2018 for which a new or updated BPEO will be required.

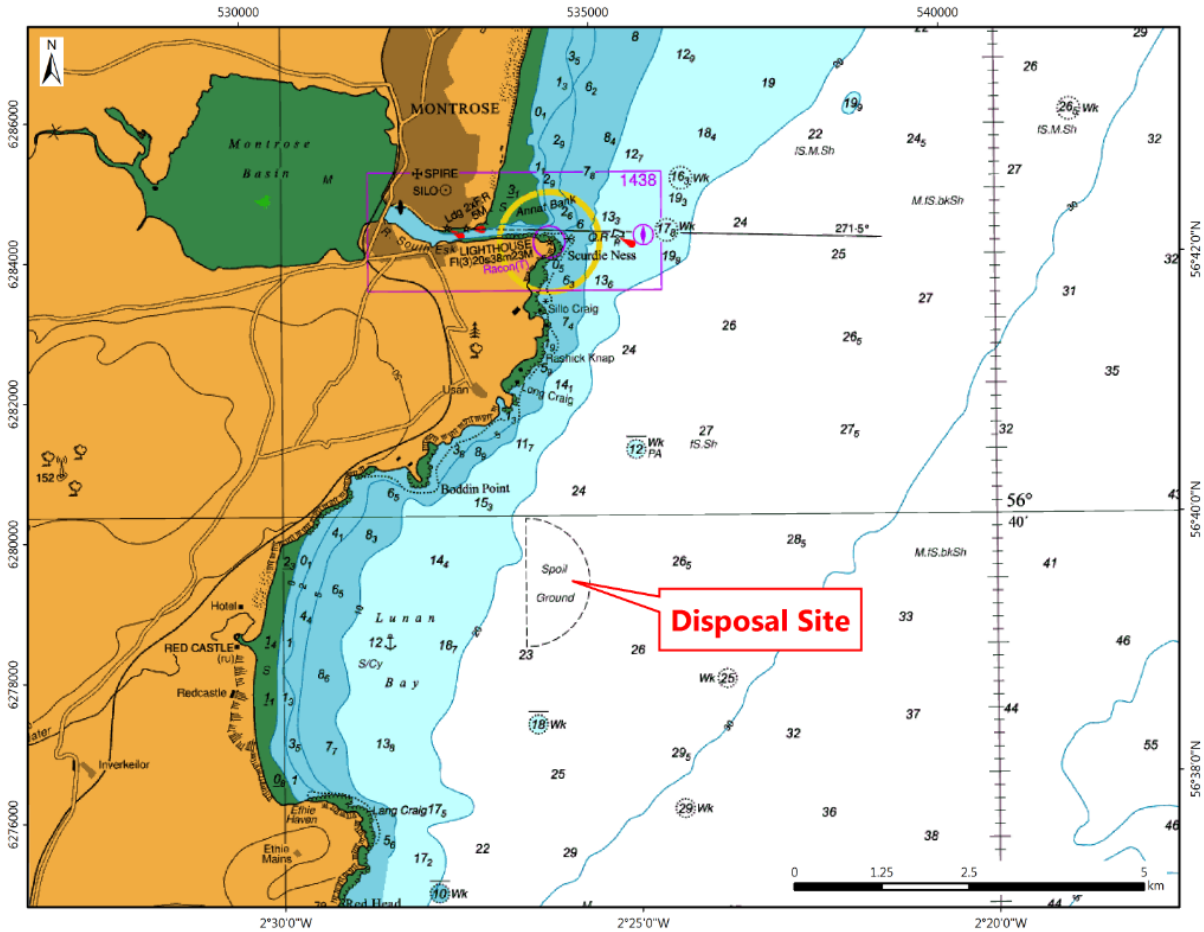


Figure 2. Licenced disposal site location (Montrose, FO010)

1.2 Report scope

This report provides a Waste Hierarchy Assessment (WHA) to determine the Best Practicable Environmental Option (BPEO) for the use/disposal of the dredged material that is required for a Marine Licence under Marine (Scotland) Act, 2010. The assessment t has considered:

- Previous BPEO assessments;
- Previous and on-going consultation with;
  - Scottish Natural Heritage (SNH);
  - The Crown Estate;
  - Marine Scotland Licencing and Operations Team (MSLOT);
  - Angus Council;
  - Scottish Environmental Protection Agency (SEPA); and
- Results of a Sediment Tracer Study, undertaken by Angus Council, (Partrac, 2016).

This information is assessed to determine the current BPEO considering the options for practicality, environmental implications and cost benefit.

The report is structured as follows:

Section 1: Introduction;
Section 2: Sets out the dredge Requirement;
Section 3: Provides a review of the policy;
Section 4: Outlines the dredge material characterisation;
Section 5: Describes the dredge options;
Section 6: Waste Hierarchy Assessment;
Section 7: Provides an operational cost comparison for potential options; and
Section 8: Presents the overall WHA and BPEO conclusion.

2 Dredge Requirement

Since 2010 the maintenance dredging requirement to maintain depths for a sufficient period to 5.5 m and 8 m below CD in the channel and berths respectively has averaged just under 60,000 m^3 per year, varying between no dredging in 2013 to over 108,000 m^3 in 2016. When dredging is required campaigns generally last between 4 and 7 days. Historically dredging has been required at a frequency of between 9 and 18 months but the greater requirement to maintain depths for longer periods as increased the frequency of dredging. The licenced dredge returns since 2010 are provided in Appendix A. The dredging is required to be undertaken by a small to medium size Trailing Suction Hopper Dredger (THSD), with a loaded draught of 5.6 m around, with maximum hopper capacity of about 2,300 – 2,900 m^3. However, given the material type ranging from silt to gravel, the *in situ* volume removed is likely to be highly variable and only be in the order of 1,000 m^3 on average per load.

On each campaign dredging normally commences in the navigation channel and then moves into the Inner Harbour and is generally confined to the period starting about 2 hours after LW to about 2 hours after HW, i.e. predominantly on the flood flows. Most dredging is undertaken on the neap tides, extending into mid tide ranges. Spring tide flow rates, however, prevent dredging. The dredger trails at an average speed of about 3 knots over the ground and the overall dredge cycle time (i.e. fill, sail to disposal site bottom dispose and return to dredge location takes on average 45 – 60 minutes.

3 Policy Review

Dredged material is classed as a waste material once removed and is strictly controlled as it enters the waste stream. Beneficial use and disposal of dredged material at sea are controlled Under the London Convention 1972, the 1996 Protocol, the OSPAR Convention 1992 and the revised EU Waste Framework Directive (2008/98/EC). Under the Marine (Scotland) Act 2010 alternatives to disposal of the dredged material are to be explored and documented in the form of a BPEO assessment. Should this assessment identify a practical alternative to disposal of dredged material, this option should be further considered before consent for disposal at sea (or land) is made. Any identified locations for use and/or disposal also need to take account of the UK Government Sustainable Development Strategy and the Marine Policy Statement (see Section 3.1).

3.1 Marine Policy Statement

The UK Government Sustainable Development Strategy sets out the need for all Government policy to be in line with the principles of sustainable development (HMG, 2005). These principles are expressed through the five high-level marine objectives which take forward the UK vision for the marine environment of "clean, healthy, safe, productive and biologically diverse oceans and seas". These high-level objectives are: (1) Achieving a sustainable marine economy; (2) Ensuring a strong healthy and just society; (3) Living within environmental limits; (4) Promoting good governance; and (5) Using sound science responsibly.

It is becoming increasingly important that space within the marine environment is utilised effectively to ensure activities can be undertaken in a sustainable manner with minimal conflict between users. The Marine Policy Statement (MPS) indicates that, “The Marine Plan should identify areas of constraint and locations where a range of activities may be accommodated. This will reduce real and potential conflict, maximise compatibility between marine activities and encourage co-existence of multiple uses” (Defra, 2011).

The Port of Montrose lies at the northern end of the regional Forth and Tay Marine Plan Area, whilst most of Montrose Bay is in the North East [Scotland] Marine Plan Area. Currently there is no specific Marine Plans for these two regional areas and therefore decisions in the interim must be made in accordance with the National Marine Plan (Scottish Government, 2015). Furthermore, compliance with the principles documented in the UK’s Sustainable Development Strategy should be guaranteed for any locations considered for re-use and/or disposal.

3.2 Waste Policy

Waste policy and, consequently, the WHA (and therefore the determination of the BPEO) are strongly governed by the waste hierarchy set out in Article 4 of the Waste Framework Directive. The waste hierarchy ranks waste management options according to what is best for the environment and comprises the following in order of most to least favoured (top to bottom):

- Prevention;
- Re-use;
- Recycle;
- Other recovery; and
- Disposal.

The waste hierarchy places emphasis on waste prevention or minimisation of waste, followed where possible by re-use of the material. For any dredging project, the *in situ* characteristics of the material (physical and chemical), the method and frequency of dredging (and any subsequent processing), determines its characteristics for consent through the waste hierarchy (Section 4). This understanding is central for consideration of management options and determination of the BPEO for dealing with the management of dredged material.

Where prevention of the dredging is not possible, then the volume to be dredged should be minimised, then options for re-use of the material, recycling and other methods of recovery must be considered in the first instance. In the context of dredge material this could include, for example:

- Engineering uses, such as:
  - Aggregate for the construction industry;
  - Land creation and improvement;
  - Beach nourishment;
  - Construction of offshore berms;
  - Capping material; and
  - Temporary disposal at sea (e.g. in an aggregate site) for future re-use.
- Agriculture and product uses:
  - Aquaculture; and
  - Construction material.
- Environmental enhancement:
  - Intertidal feeding/creation, e.g. islands for birds, mudflat and saltmarsh creation, fisheries habitat and wetland restoration.
- Post treatment of the dredge material to change its character prior to determining a potential use, for example:
  - Dewatering to create consolidated sediments;
  - Separation basins; to separate sediments into different size classes for different uses;
  - Soil manufacturing; and
  - Physio-chemical treatments of contaminated sediments.

Following such treatments, the material may be able to be used for example, as top soil or bricks etc.

Should no practical and cost-effective solutions be identified, final options for the disposal of the dredged material are considered. These include:

- Marine disposal in licenced deposit sites; and
- Land based disposal in terrestrial landfill (possibly after treatment such as incineration).

Each of the stages in the waste hierarchy has been considered in turn, where practical, for the management of the dredge arisings within this assessment. This has also taken into account the respective policies as outlined above.

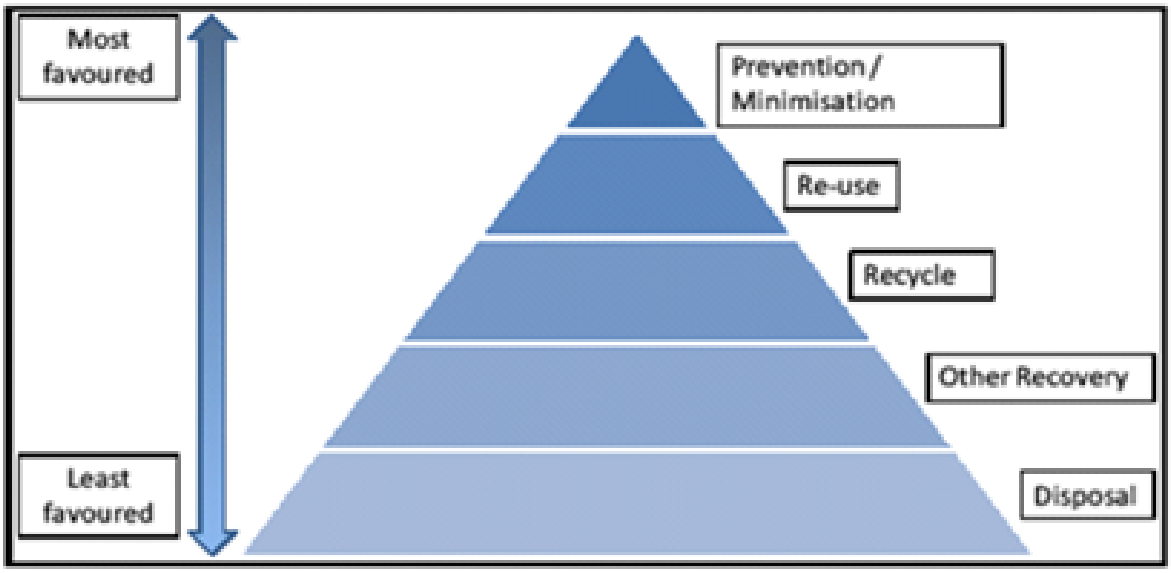


Figure 3. Waste framework hierarchy

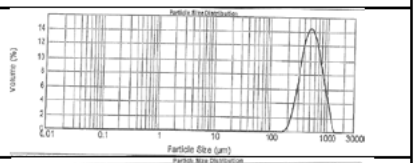
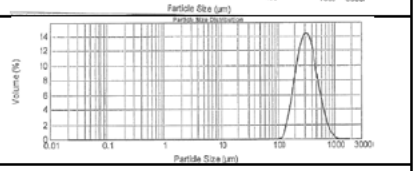
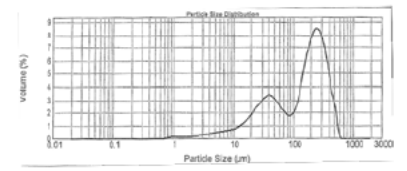
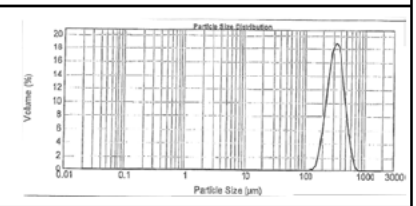
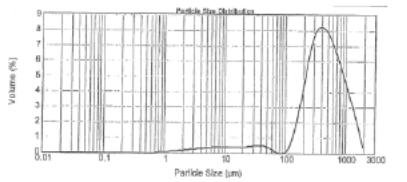
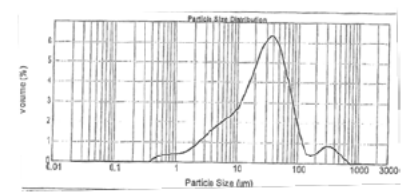
4 Dredge Material Characterisation

4.1 Physical

The material to be dredged is mixed comprising of mud (silt/clay), fine to coarse sand and a small proportion (*circa* 1%) of gravel. The relative mix varies both with location along the channel and harbour and with time. Larger proportions of finer sediments are associated with periods of heavy rainfall and snowmelt, particularly on spring tides, whereas the proportion of gravel is likely to be higher following storm events. The proportion of sand tends to be higher during 'normal' weather conditions. Historical analysis of survey depths indicates that each dredge campaign removes in general between 0.5 – 1 m of sediments.

Previous particle size analysis (PSA) has been undertaken on the sediments to be dredged in the channel and in the harbour. This grading is shown in Table 1.

Table 1 . Dredge sediment particle size

Sample Location	Particle Size (µm)			Comment	Distribution
	D10	D50	D90		
2012 Samples					
1 Main channel	315	525	884	Well sorted medium to coarse sand	
2 Inner harbour Channel	200	331	573	Well sorted medium sand	
3 Berths 1/2	19	168	375	Bimodal Mud (coarse silt (with clay) and predominantly fine sand	
2013 Samples					
1 Main channel	226	337	501	Well sorted medium and coarse sand	
2 Inner harbour Channel	140	418	511	Predominantly fine to coarse sand, small proportion of mud and gravel	
3 Berths 1/2	4	28	91	Predominantly Mud with small proportion of fine sand	

Information on current PSA needs adding when samples collected and analysed

4.2 Chemical

4.2.1 Historic contamination

Chemical analysis of surface bed samples is available for the same locations as for the PSA analysis (Table 1), collected in 2012 and 2013. Chemical sample analysis was also undertaken in 2013 and 2014 specifically in Berths 6/7 (with depth) and Berth 10 respectively. The chemical analysis test reports are provided in Montrose Port Authority (2015).

The surface samples from 2012 showed no individual contaminant concentrations that were greater than Action Level 1 (Scottish Government, 2017) for the prescribed suite of heavy metals, Tributyltin

(TBT), ICES 7 PCB's and the 16 PAH's. In 2013 a small amount of TBT was recorded within the berth sample along with the PAH Anthracene, but only marginally exceeded Action Level 1. The samples from Berth 10 indicated a small elevation in concentrations of hydrocarbons, but again only marginally exceeding Action Level 1, with no other contamination that would cause concern. The cores analysed for Berths 6 and 7 showed a marginal contamination (above Action Level 1) through significant depth for both heavy metals (mainly Lead and Zinc) and the Benzo derivative PAH's).

These contamination levels did not stop the issue of the current dredge licence, therefore this indicate the sediment to be dredged and disposed is likely to be considered 'safe' for disposal in the marine environment.

4.2.2 Present contamination

Results from current sampling, when collected and analysed, for this application (2017/2018) need to be added and discussed

5 Dredge Options

The composition of the sediment to be dredged, as described in Section 4 and the area over which it needs to be removed indicates the optimum method for dredging is to use a Trailer Suction Hopper Dredger (TSHD). This could be supported by a grab dredger (or backhoe dredger and barges) in the more confined areas of the berthing pockets. All dredge methods would allow vessel bottom disposal.

The TSHD uses suction to raise loosened material from the bed through a pipe connected to a centrifugal pump. Suction alone may not be sufficient to remove the sand. It is likely therefore the dredger draghead will include 'ripping teeth' and water jets to help loosen the sediments. The requirement, or not for water jetting, will depend on the length of time between maintenance campaigns in the approach channel. The TSHD is the most efficient method when working with fine substrates such as mud, silt, sand and loose gravel as the material can be easily remobilised into suspension. The TSHD also has the potential to pump out the sediment, either in the form of 'rainbowing' or through a pipe onto land or a beach. The size of the channel and harbour along with the tidal range restricts the dredger (particularly a TSHD) to the small/medium size. The dredgers currently used with loaded draught of 5.6 m are considered to be the optimum size as they are close to the maximum size that can work for the longest periods of the tidal cycle.

Other dredge methods that could be considered are:

- A cutter suction dredger (CSD), pumping through a pipe to nearby beach/disposal location or to a 'dewatering' confined area on land. Alternatively, it could load barges for disposal similar to a TSHD. This method has significant practical disadvantages compared to a TSHD. For mostly the dredger is essentially stationary, requiring 'spud legs' on the channel/ harbour bed and cables to anchors to allow movement along and across the channel. The CSD would therefore effectively block the channel to commercial navigation whilst dredging and would take significant time to move anchors, move away for vessels and then reset anchors to continue dredging. The dredge 'downtime' would therefore be substantial.

  Overall, while in theory sediment (the sand) could be pumped to the neighbouring beaches, the time taken to dredge the channel and the blockage to navigation makes the method impracticable;

- Water Injection Dredging (WID**)** could be an option for consideration, however, this method is primarily designed for mud and fine sediments. The coarseness of the sand will mean a high settling velocity, so the sediment flow created by the WID would quickly resettle down the channel. There is therefore the potential to create 'bars' or areas of shallower depth along the channel before the sand can be removed completely. Thus during the dredge operation, the Least Available Depth (LAD) of the channel/harbour would have significant potential to reduce further before the dredge is complete.

  The method also has little or no control on where the sediment would end up. Most is likely to settle near the end of the channel or moved onto Annat Bank. This would create an increased supply of sediment with the potential to quickly return to the channel, particularly during storms and spring tide flood flows. Under this scenario the method would also tend to increase the potential sedimentation rate. On this basis, the method would create a negative impact with repeat to future channel maintenance;

- Sediment could also be 'agitated 'into the water column on the outgoing tide. Again, such a method would only be effective on spring tide ebb flows. The effects of this method of dredging would be essentially the same as for WID, but with even less certainty of benefit in maintaining the channel.

This assessment of dredge methods, taking account of the location, extent of required dredging, the range of material types as well as the tide and flow restriction indicates that a TSHD is the optimum method for maintaining depths at the Port of Montrose, both currently and for the longer term. The method removes the sediment (sand and silts) out of the local sediment circulation cell that helps cause the sedimentation in the channel. The method of disposal does not directly increase the sediment supply to be brought back to the channel, which would occur from other dredge methods, even if they were proved to be practicable for the dredge phase of the maintenance operation, which is very unlikely.

6 Waste Hierarchy Assessment

As described in Section 3.2 the waste hierarchy ranks waste management options according to the best environmental practice. The following section discusses the options, with respect to the management of the sand and silt arising from maintenance dredging of the Port of Montrose and the navigation channel.

6.1 Prevention

There are three main alternatives for the prevention of generating waste material, including:

1) Do Nothing (i.e. do not undertake maintenance dredging);
2) Reduce the dredging requirement; and
3) Reduce the disposal requirement.

The main approach to avoiding the generation of waste would be to not undertake the proposed maintenance dredging. To cease all maintenance dredging would, however, ultimately restrict the maximum size of vessel that could safely navigate to the Port of Montrose and therefore limit the competitiveness of the Port, eliminates existing trades which provide 'just in time' goods to a wider hinterland. Maintenance dredging is therefore seen as essential for the ongoing operations of the

Port of Montrose which supports the employment of *circa* 400 people directly on the port estate and *circa* 4,800 jobs (hauliers, suppliers etc.) in the Montrose area and further into north east Scotland.

The maintenance dredging (and therefore disposal) requirement has been optimised/minimised to facilitate safe and efficient navigation of vessels up to *circa* 25,000 tonnes (deadweight), or vessel draughts up to about 8 m, albeit tidally restricted. This means a minimum depth required in the channel of 5.5 m below CD. Channel depths are monitored by pre-and post-dredge surveys, however the decision to 'call' for a dredge campaign is based on regular spot depth surveys at 2 – 3 month intervals (or following storms) at 10 strategic locations within the harbour and channel, where sedimentation tends to occur.

This method of monitoring means the dredger is only called when necessary. In recent years this has varied from 0 to 3 times per year. Additionally, the monitoring method along with the detailed pre- and post-dredge surveys allow specific areas of the Port to be 'targeted' to maximise efficiency and minimise the dredge volume (hence disposal quantity) required.

As discussed in Section 5, the use of WID has also been considered to minimise the need for a separate waste disposal activity. However, the coarse sediments to be removed are not conducive for use of the method and the sediment is likely to settle in areas which would create an increased supply of sediment to return to the channel. This would effectively increase the future maintenance requirement. The method is therefore not considered viable.

In summary, all measures to prevent and/or reduce the volume of waste generated by the project have been fully considered and the present dredge management provides the minimum dredge requirement for the existing trade through the Port.

6.2 Re-use, recycling and other recovery

Potential options have been identified for uses of the dredge arisings from the Port of Montrose. These include, for example, habitat creation, engineering projects (e.g. land reclamation), agricultural land improvement, land reclamation, beach replenishment and other forms of recovery, such as for aggregates or building materials (following treatment). These options are reviewed below with respect to the maintenance dredge arisings.

6.2.1 Re-use

Spreading on agricultural land

The dredge material comprises predominantly sand with a smaller quantity of silt, which may have a low contaminant content, predominantly hydrocarbons. The dredge arisings will also contain a considerable volume of saline water. In a de-watered state, the average volume of annual dredging would cover a 12 ha area to a depth of 0.5 m.

The Montrose area is surrounded by extremely fertile land and as the material would have a high water and saline content the expected dredge spoil is not suitable for soil conditioning or spreading on agricultural land without extensive treatment. The logistics moving the material to any site would be like that described for sacrificial land disposal, in Section 6.3.1, below. Consequentially, this option for re use of the dredge arisings is not practical even for a small proportion of the material and therefore can be discounted as a method for managing the maintenance dredge arisings.

Land reclamation

At present, there are no areas within the Port of Montrose or the local vicinity being developed which require dredged material for land reclamation purposes. This option is therefore discounted, however

the sand and gravels, particularly from the outer channel area would be suitable as engineering fill in the future should there be a local need and practicality of delivery on the timescale required for dredging.

6.2.2 Recycling

Beach nourishment/replenishment

The dredge material that deposits, particularly in the outer navigation channel (sand and gravel) is of a grade suitable for beach nourishment/replenishment, albeit it may be of a different particle size grading from the natural beach in Montrose Bay. The material from the harbour is unlikely to be suitable as the sand is mixed with fluvial derived silt and clay sediments that are likely to change the nature of the beach. Providing the dredged material did not contain a significant proportion of river mud, it is believed that there would be no objections to the material being used for beach replenishment. Scottish Natural Heritage (SNH) has previously advised that it considers this option as an acceptable alternative to disposal at sea, providing the material is similar in nature to that prevailing at the replenishment site.

Coastal erosion, beach and sand dune recession has occurred throughout Montrose Bay in common with much of Eastern Scotland. The rate of erosion has increased since the early 1990's due to an increase in episodic erosion events, predominantly because of wave activity from the east and southeast, 'drawing' down beach sediment and taking it predominantly offshore, (ABPmer, 2017).

Suggestions have been made that the maintenance dredge material from the Port of Montrose could be used beneficially as beach nourishment/replenishment within Montrose Bay. A tracer study (Partrac, 2016) of the movement of sediment deposited nearshore within Montrose Bay indicated that for benefit to be gained the sand material would need to be deposited a further 600 m north of the trial deposit location to prevent short–term circulation of a proportion of the material back to the Port. Also of note was that only a relatively small proportion of the deposited sediment was monitored and very little at the dune/defence toe.

The trial deposit was placed as far inshore as possible by a smaller draught dredger than normally used for the maintenance campaigns. The study indicates that for any significant benefit the dredged material would need to be deposited well within the beach closure depth (i.e. further inshore than the trial), with the greatest effect if it can be deposited at the toe of the dunes/defence. The only way replenishment of this kind could be achieved would be to pump the material high up the beach and re-profile with excavators. This material would still only be sacrificial, slowing but not eliminating the current erosion rates.

TSHD dredging is the optimum method for maintaining the Port and its' navigation channel (see Section 5). However, the method mixes large volumes of water to 'transport' the sediment through the suction pipe to the vessel hopper. The proposed dredger also has the facility to pump out through a pipe to the shore, although this is a costly and time-consuming process in comparison to bottom disposal at a licenced deposit ground.

Pumping direct from the dredge location is not practical as the dredger would have to be connected to a pipe, either from a quay or a mooring point within the channel which would effectively block the channel during the pumping operation. Also, a pipe would need to be run along the foreshore for *circa* 2.5 km and would need to be deployed and removed each time the replenishment was required. A pump booster station may also be required to pump the sand efficiently over such distances. Intervention of this kind would significantly damage the existing beach and restrict recreational use far beyond the area of replenishment. The infrastructure required for the deployment would also be significant and costly to implement. The feasibility of running a pipeline directly to a suitable

replenishment site would therefore be unrealistic due to distance and logistics of maintaining system integrity in public areas with the inherent risk of leakage or damage.

The only viable method of shore transfer is therefore via pumping either direct from the dredger or from a mooring point offshore via a floating pipeline. The pipe outlet would be set as close as possible to the coast defence /dune toe, without allowing the transport water to erode the existing beach or dune. The sediment would then have to be profiled by land based mechanical plant. Again the pumping infrastructure, albeit shorter than for direct transfer would need to be deployed and removed at the time of each replenishment, or dredge campaign, at considerable additional cost (compared to sea disposal) and at reduced dredge efficiency.

In addition to the transport considerations, careful control of the disposal option would be required for beach replenishment and only sands and gravels could be deposited at the site. Any material contaminated with river mud, i.e. from the harbour area, would still require to be transported to the licenced disposal site (Lunan Bay) or used elsewhere, as separation of these material fractions would not be possible. Based on the area dredged, i.e. harbour area, the dredger crew would have to assess whether to deposit at the beach replenishment site or Lunan Bay. In addition, the dredging operation would have to be controlled sufficiently to ensure that mixed loads were not generated and to maximise the suitable material available for the beach replenishment site.

This method of beach replenishment has been used in the past (2006) when sand from Montrose was used at Aberdeen (86,000 m^3). Montrose Port Authority is alert to further enquiries of this nature arising and prepared to evaluate the merits of each in due course should such requirements arise.

For beach replenishment as described above to be considered the BPEO for management of the maintenance dredge material the following consents, and assessment are required:

- Consent of Marine Scotland is required for works in tidal waters under Marine (Scotland) Act 2010. An existing consent is currently in place for maintenance dredging works which prescribes bottom disposal at the Lunan Bay disposal site. An amendment to the consent would be required for beach replenishment to be consented;
- Consent to dispose of material to the foreshore or seabed from both Marine Scotland and Crown Estate. The Crown Estate, generally, may be happy to issue consent, providing all other statutory consents are in place and subject to negotiation of a disposal fee;
- Local acceptability of the use of the dredged material as beach replenishment;
- Assessment of the environmental implications of a beach recharge at the identified location and the potential effects of any dispersion on the Site of Special Scientific Interest (SSSI) at the mouth of the River Esk and the National Nature Reserve (NNR) to the north. As noted above the tracer study and physical process assessment has indicated that significant benefit to coastal management would only arise for the sand and gravel to be placed high in the tidal frame at the toe of the existing defence and circa a least 2.5 km north of the port to avoid potential for short term recirculation back to the navigation channel.

Any scheme would need in addition consultation with:

- Angus Council; and
- Beach Stakeholder Committee.

Taking all the above strategic, operational, environmental and commercial considerations into account, beach replenishment by pipeline from an offshore mooring point is discounted as the BPEO at the current time due to:

- Timescale issues relating to the efficiency of maintaining depths in the navigation channel taking account of tidal and operational restrictions. Dredging the same quantity (as presently required) would take considerably longer, therefore the dredging requirement is unlikely to be achieved over a neap tide campaign, therefore the maintained channel depth would reduce requiring further dredge campaigns and the length of the vessel access window for the larger ships would be reduced;
- Not all sediment could be used (for replenishment), so disposal at the existing deposit ground would still be required for the silt material and mixed sediments;
- Significant land based plant would be required during each replenishment to re-profile the sand once pumped ashore;
- Even with this form of replenishment the material would still be sacrificial to storm activity, thus only slowing the current coastal erosion rather than protecting the defence/dune face. The cost of the whole scheme to the Port and Angus Council (for the beach works) is considered to be highly expensive and impractical for the Port and the Council for the small benefit gained;
- Dredging costs will be significantly increased (see an approximate dredge cost comparison in Section 7).

Consideration of the available options for re-use, recycling and other forms of recovery of the maintenance dredge arisings from the Port of Montrose, have not indicated any viable practical and commercial alternatives for use of the dredged material that provide a significant cost benefit at the current time.

The BPEO is therefore considered to be disposal of the maintenance dredged sand, silt and gravel either to land or sea. These options are considered in Section 6.3.

6.3 Disposal

6.3.1 Sacrificial Landfill

The nature of the dredged material (a mixture of sand, silt and gravel) is unsuitable for sacrificial landfill without involving an extensive transport and treatment process. Disposal to landfill would involve a complicated material handling operation involving sea to land transfer, de-watering, loading to trucks and transport to site. In addition, there would need to be a change in dredger type, for example from a TSHD designed for maintenance dredging to one designed for aggregate recovery or a change to a mechanical form of dredger, unless a settling lagoon could be constructed.

Each existing dredger load would produce *circa* 1,000 m^3 of 'semi- wet' material after water has been 'weired-off' from the dredger or de-watered in a settling lagoon on land. This volume equates to *circa* 50-60 lorry loads of material produced at the quayside in a time of 1 – 2 hours to several hours depending on the method of de-watering the dredge arisings. Given the current maximum production rate of about 12,000 m^3 day (i.e. *circa* 12 vessel loads), the de-watering process and transfer to lorries would not be able to keep up with the production rate even with a 'conveyor belt like' fleet of lorries. Consequently, a temporary store on land (or within a settling lagoon) would be required in order not to reduce the dredge efficiency further, given that the production is already likely to be at least halved due to the unloading process compared to disposal at sea. This reduction in efficiency would have considerable consequence with respect to being able to maintain channel depths, given the existing tidal restrictions noted in Section 2.

Previous consideration has been given to the construction of bunded holding lagoons within the Harbour Area. These would need to be above MHWS. Two quays and associated back up areas would

also be required. This would result in the loss of valuable operational areas within the port for the duration of the dredging and transfer operations affecting the Port Authority both economically and commercially. This could lead to loss of both present and future trade.

Additionally, there is no single landfill site identified that would be able to take all the material produced from the dredging operations. The resulting dredged material would have to be distributed to various sites within the Angus area. Those sites identified would be accessed by lorries travelling from the Port on public roads through the towns of Montrose, Brechin and Forfar. The minimum estimated number of vehicle trips necessary to transport material to landfill would be in the order of 2,600 at a rate of up to *circa* 700 lorries per day whilst maintenance dredging occurs.

The number and availability of suitable vehicles to transport wet dredge material and transport by road is not known. However, inevitably such an operation would involve some spillage of the dredge material. This would not be acceptable to the public. In addition, the Local Authority and Police have indicated that they would consider any loss of dredge material from vehicles as a hazard to road safety for which the Port Authority could be held liable in the event of an accident/environmental incident.

Landfill space, generally is becoming more valuable because of increased demand and decreased availability. Owners and operators of sites are reluctant to sacrifice space for inert material thus shortening the life of their site and reducing capacity for industrial and domestic controlled wastes. This would place increased pressure to open further sites in the locality, which is unlikely to be favoured by either local authorities or the public.

In view of the reasons noted above, it is concluded that the transfer of the dredged material to landfill is not a practical option and therefore can be discounted as a method of managing the maintenance dredge arisings.

6.3.2 Sea

The maintenance dredged material has been disposed for many years at the licenced disposal area named Montrose FO010 in Lunan Bay to the south of the Port. The location is shown on Figure 2. The volume and material type dredged, along with contaminant levels have not changed, therefore continuation of the current practice remains a viable option.

As noted in Section 6.1 the current practice is managed to minimise the dredging requirement by the optimum dredge method (TSHD) for the current commercial trade, and this is considered not like to change in the near future.

Montrose Port Authority has had no adverse reports from previous disposal activity and it is understood that these operations have not appeared to have any significant adverse effect on the receiving environment in terms of contaminated load or on the benthic communities. This is even though:

- Disposal to the Deposit Ground will have a slight effect on other marine activities in the area during periods of transport and disposal of the dredged material. Currently disposal occurs for up to a total of 12 days per year, split between up to three separate campaigns;
- The sediment is disposed from bottom opening doors (i.e. at the draught of the dredger below the surface) is a mixture of sand, silt and gravel, the majority of which will settle quickly to the bed and will be dispersed over a longer period, probably initiated by wave disturbance;
- The finer sediment fractions do have the potential to contain some contamination, but at levels that currently are not considered to be a pollutant to cause a hazard risk to the

environment around the disposal location. Predominantly, however, the material disposed is inert, therefore there is unlikely to be a risk to commercial fishing interests, which operate in the local area. There is therefore minimal risk of contaminants entering the food chain and causing a threat to public health;
- The most significant environmental effect is due to smothering of the seabed, however this is only likely near to the designated disposal area. During the actual disposal, and for a short period thereafter no more than a few tides), there could be a marginal reduction in water quality, which is likely to be temporary and transient increase in suspended sediment concentrations, which reduce quickly away from the site.

The main effects of the disposal are all short term and transient in nature. It is therefore unreasonable to assume that the proposed dredging and disposal operations will have a long-term impact on the environment. Continuing the current disposal practice will not change (make any worse) the current minimal impacts on the uses and users, habitats and ecology of the disposal area. Moreover, there is anecdotal evidence from local fishermen suggesting that the disposal site becomes a rich feeding ground during sea disposal operations. It is thought that the discharge of material releases organisms, previously contained within the sea bed material at the dredge site, into the water column. Thus, the disposal site attracts increased feeding activity during such operations. In effect, this can be considered a small environmental benefit.

Overall, the current maintenance dredge practice:

- Is optimal for maintaining navigation to the Port for the current trade mix and the physical processes occurring which cause the sedimentation and affect the efficiency of the maintenance dredge operation;
- Has caused small temporary impacts near the disposal site, but has not caused a significant risk to the natural environment, or uses and users of the area; and
- The proposed future disposal volumes and material types are similar to those historically disposed.

Consequentially, disposal to sea at the current location remains a viable and practicable option.

7 Cost Implications

The above review of options for the management of dredged material from the Port of Montrose with respect to the WHA has indicated that there is no viable option to the disposal of the dredged sediment. The current method of dredging and disposal is considered near optimal as disposal to land is considered to be not operationally viable.

Beach replenishment was also considered and could provide local environmental benefit. However, the replenishment would require placement at the upper beach/dune toe to be effective and could not accommodate all the material types dredged. The practicalities of such placement for the limited potential benefit provided would compromise the current commercial operations.

For operational cost evaluation Table 2 compares an estimate of the relative operating costs of the current disposal method to using the material for beach replenishment. This comparison assumes all material could be used and the method of replenishment did not impact on the port operations, which the discussion above suggests is very likely to occur.

Table 2. Operating costs (£/m³)

Activity Description	Sea disposal at Montrose FO010 licenced disposal site	Beach Replenishment pumped from a dredger moored offshore
Dredging	£2.00/ m³ [1]	£2.50/ m³ [2]
Pump to upper beach at replenishment site	n/a	£6.00/ m³
Mooring and floating pipe infrastructure, deployment and removal	n/a	£0.50/ m³
Beach profiling	n/a	£2.00/ m³
Total	**£2.00/ m³**	**£11.00/ m³**

[1] Includes transport and bottom disposal
[2] Includes for increased dredge campaign requirement

The cost comparison in Table 2 would suggest that even if beach replenishment was considered practically feasible then the overall management cost would be *circa* 5 times greater than for the current sea disposal option. If the potential impact on the port operations could be put into cost terms it is likely that the difference could rise to near an order of magnitude increase in cost. Such costs would need to be borne by both the Port and Angus Council. Increases of this kind would not be viable for the Port.

8 Conclusion

The WHA has not identified any immediate uses of the maintenance dredge sands, silt and gravel or potential methods of recovery. However, the sands and gravel could potentially be used in the future, such as for land reclamation fill, aggregate (should there be a local demand) or for fully funded beach replenishment (to offset the increased operational costs to the Port). As such a continual review of the potential to use the dredge material should be undertaken. Without any suitable uses available at the present time, disposal is the only option.

Disposal to land would not be practicable or environmentally sound and would be very expensive and is therefore not a viable option. The current method of disposal in the marine environment at a licenced disposal ground is considered to remain the BPEO. No issues of note have been reported from the previous disposal operations at the existing licenced disposal site in Lunan Bay (Montrose FO010), therefore this location would still be considered as the optimum location.

9 References

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10 Abbreviations/Acronyms

AL	Action Level
AL1	Action Level 1
AL2	Action Level 2
DBT	Dibutyltin
BPEO	Best Practicable Environmental Option
CCME	Canadian Council of Ministers of the Environment
CD	Chart Datum
HW	High Water
ID	Identity
ISQGs	Interim Sediment Quality Guidelines
LAD	Least Available Depth
LW	Low Water
MHWS	Mean High Water Springs
MPS	Marine Policy Statement
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated Biphenyl
PEL	Probable Effect Level
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
TBT	Tributyltin
TEL	Threshold Effect Level
TSHD	Trailer Suction Hopper Dredging
UKAS	United Kingdom Accreditation Service
WHA	Waste Hierarchy Assessment
WID	Water Injection Dredging

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendices





Innovative Thinking - Sustainable Solutions

ABP mer

A Dredge and Disposal Quantities 2010 to 2017

MPA Dredging Quantities 2010 to 2017

LICENSE VALIDITY DATES	START DATE	END DATE	DURATION (DAYS)	AMOUNT M^3	AMOUNT METRIC TONNES	VESSEL
01/04/2010 TO 31/03/2011	04/04/2010	10/04/2010	7	84,139	197,970	UKD MARLIN
04/04/2011 TO 03/04/2012	08/04/2011	14/04/2011	7	92,683	152,927	UKD MARLIN
15/05/2012 TO 14/05/2013	21/09/2012	26/09/2012	6	52,704	121,728	UKD MARLIN/MARGARETHE FIGHTER
28/04/2014 TO 27/04/2015	29/04/2014	03/05/2014	5	27,083	62,552	BOSKALIS WM DEO GLORIA
26/11/2014 TO 27/04/2015	05/03/2015	08/03/2015	4	1,540	2541	MV SHEARWATER
AS ABOVE	13/03/2015	17/03/2015	5	47,139	77,779	UKD MARLIN
04/04/2016 TO 29/04/2018	16/02/2016	21/02/2016	6	48,382	124,090	UKD MARLIN
30/04/2015 TO 29/04/2018	12/06/2016	15/06/2016	4	31,452	80,860	UKD MARLIN
AS ABOVE	08/11/2016	11/11/2016	4	28,557	52,130	UKD ORCA
""	20/03/2017	23/03/2017	4	47,228	103,200	UKD MARLIN

All figures are directly from dredger logs where available

Appendix B – Sediment Quality

Sediment samples from Montrose Harbour and navigation channel were collected in 2012, 2013 and 2014 from various locations. The individual chemical analysis results for heavy metals, PCB's, TBT and Polyaromatic Hydrocarbons (PAH) are compared with the Marine Scotland Action Levels (AL) in Tables B.3 to B.10 for the different years and locations. The Marine Scotland AL's are presented in Tables B.1. Additionally, Table B.2 sets out the Canadian Council of Ministers of the Environment (CCME) Interim Sediment Quality Guidelines (ISQG's) for PAH's which provide another level of analysis for hydrocarbons.

Table B.1.: Marine Scotland Action Levels

Contaminant	Marine Scotland Action Levels (mg/kg dry weight)	
	AL1	AL2
Arsenic	20	70
Cadmium	0.4	4
Chromium	50	370
Copper	30	300
Lead	50	400
Mercury	0.25	1.5
Nickel	30	150
Zinc	130	600
Organotins (Tributyltin, Dibutyltin, Monobutyltin)	0.1	0.5
Polychlorinated biphenyls (sum of ICES 7)	0.02	0.18

Table B.2: Canadian Interim Sediment Quality Guidelines

Contaminant	Marine Scotland AL1 (Note no upper level) (mg/kg dry weight)	Canadian Interim Sediment Quality Guidelines (mg/kg dry weight)	
	AL1	TEL	PEL
Acenaphthene	0.1	0.00671	0.0889
Acenaphthylene	0.1	0.00587	0.128
Anthracene	0.1	0.0469	0.245
Benzo(a)anthracene	0.1	0.0748	0.693
Benzo(a)pyrene	0.1	0.0888	0.763
Benzo(b)fluoranthene	0.1	No value	No value
Benzo(k)fluoranthene	0.1	No value	No value
Benzo(g,h,i)perylene	0.1	No value	No value
Chrysene	0.1	0.108	0.846
Dibenzo(a,h)anthracene	0.01	0.00622	0.135
Fluoranthene	0.1	0.113	1.494
Fluorene	0.1	0.0212	0.144
Ideno(1,2,3cd)pyrene	0.1	No value	No value
Naphthalene	0.1	0.0346	0.391
Phenanthrene	0.1	0.0867	0.544
Pyrene	0.1	0.153	1.398
Total Hydrocarbons	100	No value	No value

Table B.3: Sediment Samples – Metals (2012)

Contaminant	Sample Location ID		
	MPA 1 (2012) Main Channel	**MPA 2 (2012) Inner Harbour Channel**	**MPA 3 (2012) Berths 1/2**
Arsenic (mg/kg)	4.74	3.26	7.08
Cadmium (mg/kg)	<0.0009	<0.0009	0.0871
Chromium (mg/kg)	5.37	7.32	29.16
Copper (mg/kg)	1.71	2.94	18.24
Lead (mg/kg)	2.50	3.59	18.92
Mercury (mg/kg)	<0.01	<0.01	<0.01
Nickel (mg/kg)	5.50	9.09	23.26
Zinc (mg/kg)	9.97	16.38	60.00
Tributyltin (µg/kg)	<1	<1	10
PCB 28 (µg/kg)	<1	<1	<1
PCB 52 (µg/kg)	<1	<1	<1
PCB 101 (µg/kg)	<1	<1	<1
PCB 118 (µg/kg)	<1	<1	<1
PCB 153 (µg/kg)	<1	<1	<1
PCB 138 (µg/kg)	<1	<1	<1
PCB 180 (µg/kg)	<1	<1	<1
Key			
Below Marine Scotland Action Level 1			
Between Marine Scotland Action Level 1 and Action Level 2			
Above Marine Scotland Action Level 2			

Table B.4: Sediment Samples – PAHs (2012)

Contaminant	Sample Location ID		
	MPA 1 (2012) Main Channel	**MPA 2 (2012) Inner Harbour Channel**	**MPA 3 (2012) Berths 1/2**
Acenaphthene (µg/kg)	<0.01	<0.01	<0.01
Acenaphthylene (µg/kg)	<0.01	<0.01	<0.01
Anthracene (µg/kg)	<0.01	<0.01	<0.01
Benzo(a)anthracene (µg/kg)	<0.01	<0.01	0.01
Benzo(a)pyrene (µg/kg)	<0.01	<0.01	<0.01
Benzo (g,h,i)perylene (µg/kg)	<0.01	<0.01	<0.01
Benzo(b)fluoranthrene (µg/kg)	<0.01	<0.01	<0.01
Benzo(k) fluoranthrene (µg/kg)	<0.01	<0.01	<0.01
Chrysene (µg/kg)	<0.01	<0.01	0.01
Dibenzo(a,h)anthracene (µg/kg)	<0.01	<0.01	<0.01
Fluoranthene (µg/kg)	<0.01	<0.01	0.01
Fluorene (µg/kg)	<0.01	<0.01	<0.01
Indeno(1,2,3-cd)pyrene (µg/kg)	<0.01	<0.01	<0.01
Naphthalene (µg/kg)	<0.01	<0.01	<0.01
Phenanthrene (µg/kg)	<0.01	<0.01	<0.01
Pyrene (µg/kg)	<0.01	<0.01	0.01
Total 16 PAH's			
Key			
Below TEL			
Between TEL and PEL			
Above PEL			

Table B.5: Sediment Samples – Metals (2013)

Contaminant	Sample Location ID		
	MPA 1 (2013) Main Channel	**MPA 2 (2013) Inner Harbour Channel**	**MPA 3 (2013) Berths 1/2**
Arsenic (mg/kg)	5.33	11.06	13.75
Cadmium (mg/kg)	0.009	0.158	0.232
Chromium (mg/kg)	5.07	33.15	31.36
Copper (mg/kg)	1.86	15.53	14.26
Lead (mg/kg)	2.79	21.91	23.76
Mercury (mg/kg)	<0.02	0.09	0.10
Nickel (mg/kg)	5.68	22.47	23.79
Zinc (mg/kg)	10.39	68.79	75.06
Tributyltin (µg/kg)	<10	<10	158
PCB 28 (µg/kg)	<1	<1	<1
PCB 52 (µg/kg)	<1	<1	<1
PCB 101 (µg/kg)	<1	<1	<1
PCB 118 (µg/kg)	<1	<1	<1
PCB 153 (µg/kg)	<1	<1	<1
PCB 138 (µg/kg)	<1	<1	<1
PCB 180 (µg/kg)	<1	<1	<1
Key			
Below Marine Scotland Action Level 1			
Between Marine Scotland Action Level 1 and Action Level 2			
Above Marine Scotland Action Level 2			

Table B.6: Sediment Samples – PAHs (2013)

Contaminant	Sample Location ID		
	MPA 1 (2013) Main Channel	MPA 2 (2013) Inner Harbour Channel	MPA 3 (2013) Berths 1/2
Acenaphthene (µg/kg)	<1	1	5
Acenaphthylene (µg/kg)	<1	<1	2
Anthracene (µg/kg)	53	<1	153
Benzo(a)anthracene (µg/kg)	<1	2	31
Benzo(a)pyrene (µg/kg)	<1	2	48
Benzo (g,h,i)perylene (µg/kg)	<1	<1	59
Benzo(b)fluoranthrene (µg/kg)	1	4	55
Benzo(k) fluoranthrene (µg/kg)	1	5	47
Chrysene (µg/kg)	1	1	42
Dibenzo(a,h)anthracene (µg/kg)	<1	<1	12
Fluoranthene (µg/kg)	1	5	58
Fluorene (µg/kg)	<1	<1	7
Indeno(1,2,3-cd)pyrene (µg/kg)	<1	2	47
Naphthalene (µg/kg)	<1	<1	9
Phenanthrene (µg/kg)	<1	<1	35
Pyrene (µg/kg)	1	4	47
Total 16 PAH's	58	31	657
Key			
Below TEL			
Between TEL and PEL			
Above PEL			

Table B.7: Sediment Samples Berth 10 – Metals (2014)

Contaminant	Berth 10 Sample Location ID		
	Sample 1 (2014)	Sample 2 (2014)	Sample 3 (2014)
	56° 42.386N 02° 28.245W	56° 42.370N 02° 28.199W	58° 42.349N ?
Arsenic (mg/kg)	12.3	12.1	13.2
Cadmium (mg/kg)	0.13	0.11	0.11
Chromium (mg/kg)	31.9	32.4	34.5
Copper (mg/kg)	11.7	11.8	11.5
Lead (mg/kg)	17.3	18.02	20.4
Mercury (mg/kg)	0.05	0.04	0.05
Nickel (mg/kg)	20.2	20.5	21.6
Zinc (mg/kg)	61.4	57.6	60.6
Tributyltin (µg/kg)	<50	<50	<50
PCB 28 (µg/kg)	<1	<1	<1
PCB 52 (µg/kg)	<1	<1	<1
PCB 101 (µg/kg)	<1	<1	<1
PCB 118 (µg/kg)	<1	<1	<1
PCB 153 (µg/kg)	<1	<1	<1
PCB 138 (µg/kg)	<1	<1	<1
PCB 180 (µg/kg)	<1	<1	<1
Key			
Below Marine Scotland Action Level 1			
Between Marine Scotland Action Level 1 and Action Level 2			
Above Marine Scotland Action Level 2			

Table B.8: Sediment Samples Berth 10 – PAHs (2014)

Contaminant	Berth 10 Sample Location ID		
	Sample 1 (2014)	Sample 2 (2014)	Sample 3 (2014)
	56° 42.386N 02° 28.245W	56° 42.370N 02° 28.199W	58° 42.349N ?
Acenaphthene (µg/kg)	14	6	4
Acenaphthylene (µg/kg)	3	2	<1
Anthracene (µg/kg)	24	11	10
Benzo(a)anthracene (µg/kg)	73	42	26
Benzo(a)pyrene (µg/kg)	188	107	69
Benzo (g,h,i)perylene (µg/kg)	200	126	80
Benzo(b)fluoranthrene (µg/kg)	222	143	82
Benzo(k) fluoranthrene (µg/kg)	86	54	33
Chrysene (µg/kg)	194	108	76
Dibenzo(a,h)anthracene (µg/kg)	<1	<1	<1
Fluoranthene (µg/kg)	167	84	60
Fluorene (µg/kg)	18	10	13
Indeno(1,2,3-cd)pyrene (µg/kg)	95	76	27
Naphthalene (µg/kg)	27	15	55
Phenanthrene (µg/kg)	105	47	50
Pyrene (µg/kg)	132	72	47
Total 16 PAH's	1547	903	633
Key			
Below TEL			
Between TEL and PEL			
Above PEL			

Table B.9.: Sediment samples from Boreholes at Berths 6 and 7 – Metals (2013)

Contaminant	Berth 6 and 7 Borehole Location ID											
	Borehole 1 (2013)		Borehole 2 (2013)		Borehole 3A (2013)		Borehole 4 (2013)			Borehole 5 (2013)		
	1 m	3 m	1 m	3 m	0.2 m	3 m	2 m	6 m	9 m	1 m	4 m	10 m
Arsenic (mg/kg)	14.5	21.9	17.4	12.8	15.9	19.0	14.3	15.4	10.4	15.2	16.4	16.1
Cadmium (mg/kg)	0.12	0.12	0.12	0.08	0.25	0.11	0.09	0.15	0.07	0.41	0.46	0.12
Chromium (mg/kg)	71.3	72.9	55.1	49.8	62.0	72.3	53.5	42.4	58.7	51.5	56.9	58.3
Copper (mg/kg)	46.5	54.2	25.4	32.8	42.9	49.0	22.6	128.6	21.4	60.1	95.5	26.3
Lead (mg/kg)	19.6	21.0	19.8	12.1	24.2	17.9	28.0	349.2	32.6	256.5	246.5	18.5
Mercury (mg/kg)	0.04	0.03	0.02	<0.02	0.03	<0.02	0.05	0.27	0.04	0.10	0.13	<0.02
Nickel (mg/kg)	64.2	68.9	50.6	43.5	47.5	66.3	40.6	34.5	35.8	35.6	34.5	38.2
Zinc (mg/kg)	105.7	104.2	90.0	70.1	98.3	118.0	146.0	146.5	152.9	244.2	319.8	127.2
Tributyltin (µg/kg)	24	18	39	1	159	<1	<1	7	1	3	4	<1

Key	
Below Marine Scotland Action Level 1	
Between Marine Scotland Action Level 1 and Action Level 2	
Above Marine Scotland Action Level 2	

Table B.10.: Sediment samples from boreholes at Berths 6 and 7 – PAH (2013)

Contaminant	Berth 6 and 7 Borehole Location ID											
	Borehole 1 (2013)		<Borehole 2 (2013)		Borehole 3A (2013)		Borehole 4 (2013)			Borehole 5 (2013)		
	1 m	3 m	1 m	3 m	0.2 m	3 m	2 m	6 m	9 m	1 m	4 m	10 m
Acenaphthene (µg/kg)	<1	<1	<1	<1	6	1	2	4	1	4	3	<1
Acenaphthylene (µg/kg)	<1	<1	<1	<1	<1	<1	<1	1	<1	1	1	<1
Anthracene (µg/kg)	3	7	<1	3	6	7	2	16	<1	12	7	3
Benzo(a)anthracene (µg/kg)	<1	<1	<1	1	94	<1	17	106	2	99	57	<1
Benzo(a)pyrene (µg/kg)	<1	5	<1	<1	100	2	21	115	2	182	125	<1
Benzo (g,h,i)perylene (µg/kg)	<1	<1	<1	<1	43	<1	9	47	<1	142	77	<1
Benzo(b)fluoranthrene (µg/kg)	<1	<1	<1	<1	282	<1	48	267	3	422	293	<1
Benzo(k) fluoranthrene (µg/kg)	<1	<1	<1	<1	81	<1	13	76	1	121	84	<1
Chrysene (µg/kg)	<1	1	<1	2	82	1	19	90	3	100	62	<1
Dibenzo(a,h)anthracene (µg/kg)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluoranthene (µg/kg)	1	1	<1	3	82	2	22	120	6	107	77	<1
Fluorene (µg/kg)	2	3	<1	4	6	1	4	9	2	5	5	<1
Indeno(1,2,3-cd)pyrene (µg/kg)	<1	<1	<1	<1	47	<1	2	53	<1	155	92	<1
Naphthalene (µg/kg)	13	17	8	12	18	15	13	21	2	73	32	7
Phenanthrene (µg/kg)	2	5	<1	10	37	1	27	66	8	67	51	1
Pyrene (µg/kg)	<1	1	<1	4	73	2	24	128	7	108	81	<1
Total 16 PAH's	20	39	8	38	955	31	223	1119	37	1599	1044	11
Key												
Below TEL												
Between TEL and PEL												
Above PEL												

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