Warrenpoint Port

Maintenance Dredging 2024-2027

Information to Inform a BPEO Assessment

November 2023

Project Nr

642

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Project:	Warrenpoint Port - Maintenance Dredging 2024-2027
Title:	Information to Inform a BPEO Assessment

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1 Introduction

1.1.1 Warrenpoint Harbour Authority, the operators of Warrenpoint Port, are seeking a new marine licence to dispose of dredged material arising from maintenance dredging within Warrenpoint Harbour and its Inner Approach Channel in the period 2024-2027. Maintenance dredging is required to conserve safe water depths for navigation and berthing in the port and its approaches.

1.1.2 The scope of the future maintenance dredging and disposal of dredged material in the period 2024-2027 is expected to be similar to that in the period 2020-2023. Accordingly, maintenance dredging is likely to be undertaken using a trailing suction hopper dredger (TSHD) supported by a bed leveller / plough dredger, and potentially a backhoe dredger supported by a self-propelled barge or a small grab hopper dredger and is likely to result in a maximum of 805,000 tonnes of dredged material (including gravel, sand, silt and clay) being deposited in the sea at the Warrenpoint B disposal site.

2 Waste Regulations (Northern Ireland) 2011 – BPEO Assessment

2.1.1 In accordance with Part 3 of the Waste Regulations (Northern Ireland) 2011 (as amended), in determining an application for a marine licence, DAERA must make an assessment of whether the proposed waste management option for the dredged material arising from maintenance dredging within Warrenpoint Harbour and its Inner Approach Channel achieves the best practicable environmental option (BPEO) taking into account the application of the waste hierarchy.

2.1.2 This report provides the relevant information to DAERA in order to progress Warrenpoint Harbour Authority's marine licence application. This report updates the information provided in 2015 and 2018 to support the previous marine licence applications to dispose of dredged material at sea. Minor changes have been made to incorporate new information, but the conclusions of this BPEO assessment are unchanged; that is, the proposed disposal at the Warrenpoint B disposal site is the best practicable environmental option for the dredged material arising from maintenance dredging within Warrenpoint Harbour and its Inner Approach Channel.

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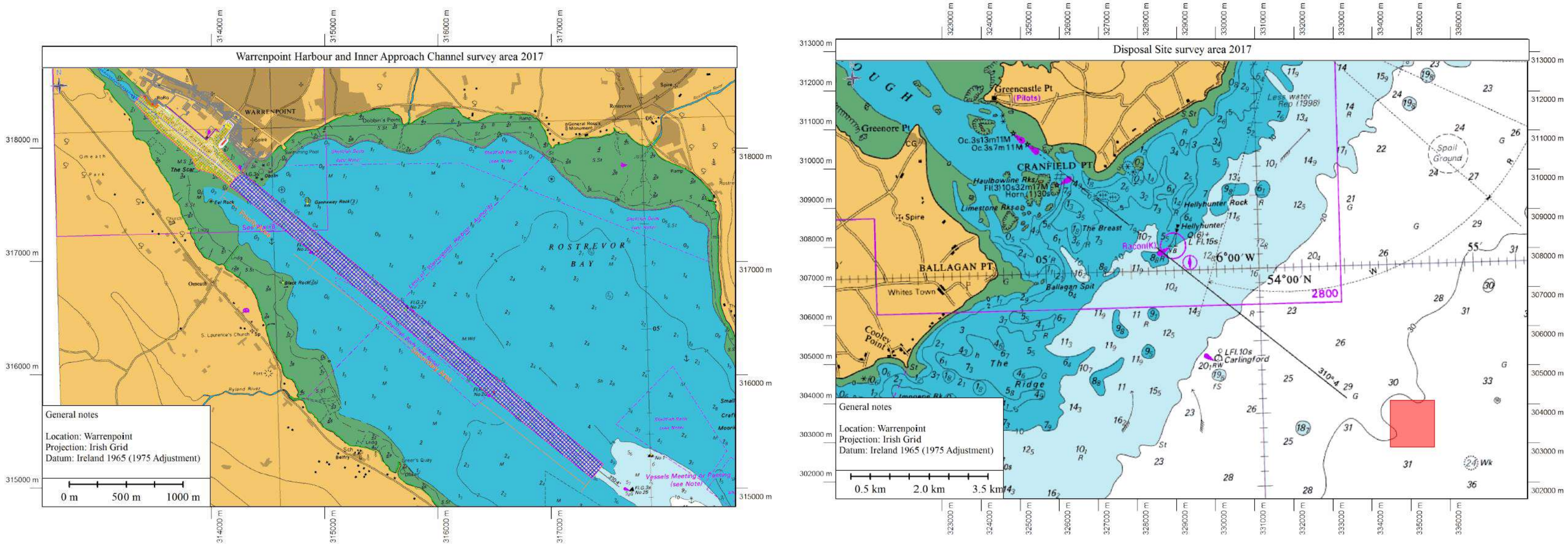
Name of project or plan	Warrenpoint Port maintenance dredging 2024-2027
Application number/reference	TBC
Brief description of the project or plan	Maintenance dredging will take place within the sub-tidal navigable channels and berths within the boundary of Warrenpoint Harbour and its Inner Approach Channel (**Figure 1, left**), and the disposal of dredged material will take place within the boundary of the Warrenpoint B disposal site (**Figure 1, right**). As for previous maintenance dredging campaigns, maintenance dredging from 2024 to 2027 will be undertaken using a TSHD supported by a plough dredger and, potentially, a mechanical dredger (e.g., backhoe dredger or grab dredger) supported by a self-propelled barge. As for previous maintenance dredging campaigns, the dredged material will be transported in a hopper inside a TSHD or a self-propelled barge and deposited at the Warrenpoint B disposal site. **Figure 1 Warrenpoint Harbour and Inner Approach Channel (left) and Warrenpoint B Disposal Site (right)** 

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Need for dredging	Regular bathymetric surveys estimate that Warrenpoint Port accumulates approximately 100,000m3 of sediment each year. Sediment accretion rates are influenced by river flow and tidal and weather systems, and tend to be higher in the harbour area and relatively lower in the approach channel (**Figure 1, left**). The strategy for maintenance dredging is complicated by the irregular distribution of sediment by manoeuvring vessels with limited under keel clearance. This action causes the deeper areas within the harbour area (particularly the deeper berth pockets and turning area) to be subject to the highest rates of sediment accretion and, therefore, the need for regular maintenance dredging campaigns to remove significantly more volumes of sediment than average accretion rates would suggest.
Previous dredging campaigns	Routine maintenance dredging has been carried out at Warrenpoint Port since 2005 with an increase in frequency in recent years to maintain the deeper navigation and berth depths required by larger commercial vessels. Typically, maintenance dredging has been undertaken by a small or medium sized trailing suction hopper dredger (TSHD) with the assistance of a plough vessel to assist with bed levelling. Occasionally capital dredging has been carried out to deepen areas within the harbour. Between 2005 and 2008 capital dredging was undertaken using a mechanical dredger because the bed material was too resistant to allow dredging using a TSHD. The volume of dredged material resulting from a dredging campaign in any given year may vary subject to weather, sea state and by area in which the work is required. In recent years, dredging campaigns have removed volumes ranging from approximately 5,000m^3 to approximately 400,000m^3. The previous dredging campaigns at Warrenpoint Port are summarised in the table below (**Table 1**).

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Table 1 Previous Dredging Campaigns at Warrenpoint Harbour and in the Approach Channel

Year	Dredging Works	Dredging Methodology	Approx. Dredged Material Volume
2022	Inner Harbour Area (maintenance works)	TSHD	62,300m^3
2020	Turning Circle (maintenance works)	TSHD	54,000m^3
2019	Inner Harbour Area (maintenance works)	TSHD	34,000m^3
2018	Deep Water Berth Pocket (maintenance works)	TSHD	20,300m^3
2017	Entire Harbour Area and Approaches (maintenance works)	TSHD	393,000m^3
2016	Deep Water Berth Pocket and Approaches (maintenance works)	TSHD	50,000m^3
2015	Turning Circle (maintenance works)	GHD	5,800m^3
2014	Deep Water Berth Pocket (maintenance works)	TSHD	30,000m^3
2011-2012	Entire Harbour Area and Approaches (maintenance works)	TSHD	390,000m^3
2008	Turning Circle (maintenance works)	TSHD	25,000m^3
2009	Breakwater, Container Ship Berths Pocket, Turning Circle (capital works)	Backhoe	127,000m^3
2006-2007	Ro-Ro Berth (capital works)	Backhoe	20,000m^3
2005	Town Dock Phase 2 (capital works)	Backhoe	41,000m^3
2005	Turning Circle and Approach Channel (maintenance works)	TSHD	268,000m^3
2004	Town Dock Phase 1 (capital works)	Backhoe	13,000m^3

Previous disposal of dredged material	All previously dredged material has been disposed of at the Warrenpoint B disposal site (**Figure 1, right**). The disposal site is situated some 26km from Warrenpoint Port and approximately 11km outside of Carlingford Lough, where water depths exceed 30m.
Sediment quality of dredged material	Between June and August 2023, the sediment samples within Warrenpoint Harbour and the Inner Approach Channel were collected by AFBI with DAERA in attendance and sent to Socotec's laboratory for testing and analysis to characterise its physical and chemical properties. Surface and core samples were taken from representative locations agreed in advance with DAERA within Warrenpoint Harbour and its Inner Approach Channel (see

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	samples stations S1 to S19 in **Figure A2.1** and **Table 2.1** in **Appendix 2**). Socotec's laboratory participates in the QUASIMEME Scheme (Quality Assurance in Marine Environmental Monitoring in Europe). The analytical results are presented in **Appendix 2** and are summarised below. Physically, the sediment within Warrenpoint Harbour and its Inner Approach Channel was tested to determine its principal particle sizes and its organic matter content. The results indicate that the sediment is typically composed of organic silty clay comprising silt (typically >75 per cent), sand (typically <20 per cent) and, occasionally, gravel (typically <5 per cent), and organic matter (typically 1 to 3 per cent), as shown in Table A2.2 in Appendix 2. Chemically, the sediment within Warrenpoint Harbour and the Inner Approach Channel was tested to determine the concentrations of contaminants of concern (i.e., metals, organotin compounds, polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PBCs)). The results indicate that the sediment contains negligible and low levels of these contaminants when compared to relevant sediment quality standards; namely, the Action Levels used to characterise dredged material in Northern Ireland and the Republic of Ireland, and the Gorham-Test Effects Ranges used to characterise the potential for toxic effects on benthic ecological receptors (**Table A2.3** in **Appendix 2**). The Action Levels are used in Northern Ireland and the Republic of Ireland to determine the contaminant loading of dredged material and its suitability for disposal at sea (i.e., disposal onto the seabed of open water, marine environments). Sediment with contaminant loads below Action Level 1 is generally considered suitable for disposal at sea, while sediment with contaminant loads above Action Level 2 is generally considered unsuitable and precluded from disposal at sea. The Gorham-Test Effects Ranges are used to determine the contaminant loading of sediment in relation to toxic effects on benthic communities. Sediment with contaminant loads around Effects Range Low (ERL) is generally considered to have a low potential for toxic effects (10th percentile), while sediment with contaminant loads around Effects Range Median (ERM) is generally considered to have a moderate potential for toxic effects (50th percentile). In summary, the sediment is believed to contain negligible and low levels of contamination because: • The sediment within Warrenpoint Harbour and its Inner Approach Channel is characterised by contaminants generally present at concentrations that are below and slightly above the Action Level 1 used in Northern Ireland, as shown in **Tables A2.4, A2.5 and A2.6** in **Appendix 2**. • The sediment within Warrenpoint Harbour and its Inner Approach Channel is characterised by contaminants generally present at concentrations that are below and slightly above the Action Level 1 used in the Republic of Ireland, as shown in **Tables A2.7, A2.8 and A32.9** in **Appendix 2**. • The sediment within Warrenpoint Harbour and its Inner Approach Channel is characterised by contaminants generally present at concentrations that are below and slightly above the ERL used to indicate the potential for toxic effects on benthic ecological receptors, as shown in **Table A2.10** in **Appendix 2**.
BPEO considering the waste hierarchy	The waste hierarchy is applied in Northern Ireland for ranking waste management options according to what is the best option for the environment (**Figure 2**). In accordance with the waste hierarchy, for dredged material the most desirable option would be to prevent or reduce the amount of dredged material arising from maintenance dredging, while the least desirable option would be disposal at sea or on land.

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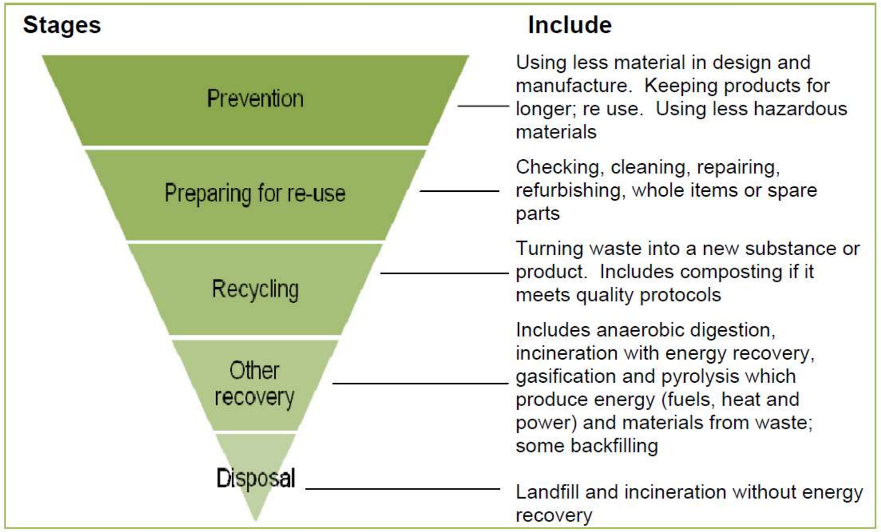
Figure 2 Waste Hierarchy (source: DOENI, 2011)



Stages	Include
Prevention	Using less material in design and manufacture. Keeping products for longer; re use. Using less hazardous materials
Preparing for re-use	Checking, cleaning, repairing, refurbishing, whole items or spare parts
Recycling	Turning waste into a new substance or product. Includes composting if it meets quality protocols
Other recovery	Includes anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waste; some backfilling
Disposal	Landfill and incineration without energy recovery

The following paragraphs review the options for dredged material from Warrenpoint Harbour and the Inner Approach Channel at each of the levels within the waste hierarchy in order to identify the BPEO in accordance with the provisions of the Waste Regulations (Northern Ireland) 2011 (as amended).

Prevention and reduction options

The best environmental option would be to prevent the need for dredging and, therefore, to prevent the generation of dredged material. Prevention options include cessation of maintenance dredging and/or introducing new infrastructure to prevent sedimentation.

If maintenance dredging were to stop at Warrenpoint Port, sedimentation would gradually reduce the water depths in the port's navigable areas and berths. The effect of sedimentation would be delayed temporarily due to scouring of the affected bed by the propeller action of the commercial vessels using the port; however, over time the ongoing sedimentation would eventually reduce water depths with the port such that navigation would not be safe or possible, which is not a practicable option.

Turbidity monitoring has shown that the majority of sedimentation at Warrenpoint Port is derived from estuarine / coastal sources, and transported and deposited on flood-dominated tidal currents. While infrastructure has been installed in some ports that directs tidal and river currents in such a way to prevent sedimentation in key areas (e.g., 'training' walls), the layout of the harbour and berths at Warrenpoint Port means that the installation of training walls is believed to not be a practicable option.

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	In the absence of a practicable option to prevent maintenance dredging and the generation of dredged material, the next best environmental option would be to reduce the amount of dredged material arising from maintenance dredging. One such option is already being undertaken at Warrenpoint Port such that maintenance dredging is only undertaken when absolutely necessary to allow safe navigation and berthing of commercial vessels. This option is based on a limited access procedure that restricts the size of commercial vessels that can navigate to the port and access the berths at times other than high water. No other practicable options have been identified or adopted. Given that the general trend in commercial shipping is towards the use of vessels with greater draught, any loss of water depth and navigability is certain to have an adverse effect on the port's commercial operations and opportunities. While no detailed study is made here, it is reasonable to suppose that the port's commercial viability would decline with the loss of water depth to the point where it ceased to be commercially competitive, which would eventually result in the port's closure. Warrenpoint Port is the second largest port in Northern Ireland with significant strategic importance serving a hinterland which includes the southern part of Northern Ireland and the northern part of the Republic of Ireland. The port is vital to the local economy, employing circa 70 people directly and indirectly contributes to more than 400 local jobs through customers and supply chain contributing more than £10m into the local economy.
Re-use and recycling options	Re-use and recycling options (as per **Figure 1**), which are also referred to as beneficial use options and alternative use options for dredged material, are options that include a direct or indirect use for dredged material (with or without some form of treatment) in a productive manner such that the dredged material is removed from the waste stream. Re-use and recycling options for dredged material include engineering uses, environmental uses and product uses. A review of the available information on the different use categories is provided at **Appendix 1** and is used to consider the options for dredged material arising from maintenance dredging for Warrenpoint Port. There are a number of key factors that influence the practicability of re-use options for dredged material arising from maintenance dredging of Warrenpoint Port. These matters include the volume of the dredged material, the nature of the dredged material (e.g., physical and chemical composition, including sediment type, water content, organic matter content, salinity, contamination, etc), the dredging methodology, dredged material transport and handling methodology (including the availability of quayside infrastructure to bring the dredged material ashore), the presence / absence of environmental sensitivities (e.g., protected habitats and species), the timing and frequency of maintenance dredging campaigns, consenting requirements (e.g., marine licensing, planning permission), and public perception. The following paragraphs consider the most practicable re-use options for dredged material arising from maintenance dredging of Warrenpoint. *Beach Nourishment* Beach nourishment uses dredged material to replace beach material that has been removed by storm events and other conditions. The dredged material must be a direct, like-for-like replacement of the beach material (i.e., fine sand must be replaced with fine sand). Beach nourishment can be used to simply restore a beach as a recreational area, but also to restore a beach's function as a flood and coastal erosion risk management measure.

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	Beach nourishment generally requires hydraulic dredgers, such as TSHDs, which are typically used for maintenance dredging of Warrenpoint Port. However, the additional plant required to transport and place the dredged material on a beach (e.g., pipelines and pumps) would increase the cost of the maintenance dredging campaign. Currently, there is no active beach nourishment occurring or proposed within Carlingford Lough and Warrenpoint Harbour Authority is not aware of any local beaches requiring nourishment to address erosion problems or improve recreational facilities. Sediment testing (**Appendix 2**) indicates that the dredged material from most maintenance dredging areas would generally comprise organic silty clay comprising silt (typically >75 per cent), sand (typically <20 per cent) and, occasionally, gravel (typically <5 per cent), and organic matter (typically 1 to 3 per cent). Given the dominant silt content, the dredged material is generally unsuitable for beach nourishment because nourishment material must have similar or slightly larger particle size density to the in situ beach material otherwise it would be eroded away quickly over time due to the local tides and currents. Also, the organic matter content could lead to a temporary odour impacts. On this basis, no suitable sites for beach nourishment are present within the vicinity of Warrenpoint Port. Given the above, beach nourishment is believed to not be a practicable option. *Land Reclamation / Improvement* Land reclamation is perhaps the best-known re-use of dredged material and involves creating new land from within a sea or estuary, while land improvement involves raising existing land to improve its situation for reasons such as flood risk reduction. Currently there is no active land reclamation or improvement occurring or proposed within Warrenpoint Port and Warrenpoint Harbour Authority is not aware of any requirement for land reclamation / improvement in Carlingford Lough given that there is ample residential and industrial space available for socio-economic development. In the past, Warrenpoint Harbour Authority has re-used granular dredged material arising from the turning circle to improve the composition of the land within the port's estate in advance of further development. However, with the exception of dredged material sourced from the turning circle, sediment testing (**Appendix 2**) indicates that the dredged material from most maintenance dredging areas would generally comprise organic silty clay. Given the dominant silt content, the dredged material is generally unsuitable for land reclamation / improvement because the construction material must have a sufficient load-bearing capacity for its end use. Given the above, land reclamation / improvement is believed to not be a practicable option. *Coastal Protection using Geotubes* Geotubes are large 'bags' made from a high tensile strength woven polypropylene geotextile. Geotubes are designed to receive and retain dredged material while allowing water to escape through the pores of the geotextile. Initially designed as a dredged material dewatering mechanism,

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geotubes filled with dewatered dredged material are increasingly used in the construction of marine structures (i.e., replacing quarried material) such as flood and coastal erosion risk management structures.

Generally, geotubes are only suitable for relatively sheltered marine locations. While there are sheltered areas along the shore of Carlingford Lough, these areas are not subject to significant flood risk or coastal erosion, and it is believed that no risk management works are planned.

Sediment testing (**Appendix 2**) indicates that the dredged material from most maintenance dredging areas would generally comprise organic silty clay. Given the dominant silt content, the dredged material is generally unsuitable for filled geotubes because the geotextiles are typically designed to retain coarser material (e.g., sand with grain sizes between 63micron and 2mm, and with an average grain size of approximately 300micron). Given the dominant silt content, the dredged material is generally unsuitable as a fill material for use in geotubes.

Given the above, the use of dredged material in geotubes is believed to not be a practicable option.

Landfill Cover / Liner Material and Quarry or Mine Cover / Fill Material

Dredged material may be used as landfill cover or liner material, or used to fill disused quarries and mines. The suitability of dredged material for this purpose depends on a number of factors including particle size, water content, salinity and contamination.

Sediment testing (**Appendix 2**) indicates that the dredged material from most maintenance dredging areas would generally comprise organic silty clay. Given the dominant silt content, the dredged material is generally unsuitable for use as a liner material because of its limited clay content, and its use as cover material may be limited by its salt content. Also, the sediment's water content would be very high due to the hydraulic dredging method associated with using a TSHD, which would require a significant dewatering effort on land prior to transport and use for any of these options, including the temporary set up and use of a dewatering lagoon and pipelines, and a significant number of lorry movements to transport the material by road.

The nearest landfill site is 10.5km away in Newry; however, this site already has a supply of daily cover material provided by construction and demolition waste, and demand is not expected to increase as no new landfill sites are planned locally. Other existing landfill sites are either too small in relation to quantities to be disposed, or are too remote from the site, and there are no redundant local quarries or mines in the area.

Given the above, the use of dredged material as a liner, cover or fill material for landfills and/or disused quarries and mines is believed to not be a practicable option.

Manufactured Topsoil

It is possible for dredged material in conjunction with household organic waste to be used for agricultural or horticultural purposes.

Sediment testing (**Appendix 2**) indicates that the dredged material from most maintenance dredging areas would generally comprise organic silty clay. Given the good organic content and organic retention characteristics due to the presence of a silt fraction, the dredged material may be suitable for manufacturing topsoil; however, as the dredged material is not well graded with low granular content which would cause very poor

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drainage characteristics, and the dredged material would has a saline content that would adversely affect seed germination; therefore, the dredged material would be unsuitable for use in topsoil without significant amelioration. Also, the pH of the dredged material is also likely to require costly adjustment with the use of aluminium sulphate or a similar product. Also, the sediment's water content would be very high due to the hydraulic dredging method associated with using a TSHD, which would require a significant dewatering effort on land prior to transport and use for this options, including the temporary set up and use of a dewatering lagoon and pipelines, and a significant number of lorry movements to transport the material by road.

The demand for manufactured topsoil in the local area is deemed to be limited.

Given the above, the use of dredged material for the manufacture of topsoil is believed to not be a practicable option.

Aggregate Material

Aggregates typically comprise coarse-grained, granular material including gravel and sand. Marine-derived aggregates are an attractive alternative to land-based sources of aggregates (i.e., quarried aggregates) since marine extraction and emission costs are less than 50 per cent of land extraction and emission costs. Currently, the dredged material from Warrenpoint is not used for aggregates and currently the Crown Estate does not licence any marine aggregate extraction sites in the territorial waters of Northern Ireland.

Sediment testing (**Appendix 2**) indicates that the dredged material from most maintenance dredging areas would generally comprise organic silty clay with a very low gravel and sand content. In general, therefore, the majority of the dredged material would be unsuitable for use as aggregates, while separation of the minor gravel and sand content would be unacceptably uneconomic.

Given the above, the use of dredged material as an aggregate material is believed to not be a practicable option.

Wetland Habitat Enhancement / Creation

Dredged material can be used to enhance (e.g., restore, rehabilitate) or create intertidal and shallow subtidal wetland (e.g., mudflats and saltmarshes) by stabilising, nourishing or expanding habitats, which can indirectly improve an area's conservation and/or recreation value.

Currently dredged material from Warrenpoint Port is not used for habitat enhancement, although it is used in other UK locations; for example, in the Stour and Orwell estuaries in England using dredged material arising from the ports of Harwich and Felixstowe.

While there are a number of intertidal and shallow subtidal habitats along the shore of Carlingford Lough, many of these habitats are designated for their inherent habitat value or for their supporting habitat value for certain species, and are present within conservation areas protected under various laws and policies, and are not currently noted to be in deterioration. The need for wetland enhancement or creation has not been identified in supporting policies and such an action would require potentially complex scientific assessment and licensing.

In the absence of a perceived demand within Carlingford Lough, and given the sensitivities of habitats within Carlingford Lough, the use of dredged material for habitat enhancement / creation is believed to not be a practicable option.

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	Sediment Cell Maintenance / Sustainable Relocation Dredged material can be returned to the aquatic system from which was removed to maintain and/or supplement sediment supply and, therefore, the natural sediment processes; potentially offsetting physical problems such as coastal erosion risk, flood risk and habitat loss. The return mechanism typically involves hydraulically pumping and discharging the dredged material using a pipeline. Sediment cell maintenance / sustainable relocation is unlikely to be required and likely to be counter-productive in Carlingford Lough given the proximity of shallow subtidal aquaculture areas and shoreline habitats that could be adversely affected by an increased sediment supply which could directly or indirectly smother habitats and species, or detrimentally affect filter feeding processes. Given the above, the recycling of dredged material for sustainable relocation is believed to not be a practicable option.
Disposal options	The principal disposal option for dredged material arising from Warrenpoint Port is disposal at sea at the Warrenpoint B disposal site. The disposal site is situated approximately 26km from Warrenpoint Port in depths exceeding 30m (**Figure 1 right**). This practice has been undertaken for many years including the dredging campaigns listed in **Table 1**. Impacts relating to disposal have been monitored at Warrenpoint B disposal site and no adverse impacts have been recorded by Warrenpoint Harbour Authority or by third parties. In the absence of suitable re-use and/or recycling options for the dredged material arising from Warrenpoint Port, disposal at the Warrenpoint B disposal site remains the only practicable option and, therefore, the best practicable environmental option and the best social, logistical and economic option available.
BPEO conclusion	After review, disposal at sea at the Warrenpoint B disposal site is considered to be the most appropriate and best practicable environmental option for dredged material arising from maintenance dredging campaigns at the Port of Warrenpoint.

APPENDIX 1: Re-use and Recycling Options for Dredged Material

Table A1.1 Advantages and Disadvantages of Various Re-use Options for Dredged Material: Engineering Options

Re-use Option	Description	Advantages (+) / Disadvantages (-)
Land improvement	Filling, raising and protecting a periodically submerged area and/or generally improve the quality of the land (e.g., public parks, replenishing agricultural soil, golf courses, sports fields, etc).	+ Provides a possibly cheaper and more environmentally conscious alternative to disposal. + Facilitates creation of land for port, industrial or agricultural use. + Potential profits to be made from land reclamation are substantial. — Not all dredged material may facilitate the basic requirements to sustain plant and animal life or support appreciable loads. — Consolidation and drainage may be slow, thus the strength achieved may be low. — May only be suitable for capital dredging projects. If long term development is not acceptable sporadic maintenance dredging spoil cannot be used. — Requires extensive impact studies of the local environment and ecology. — Waterbed depth must be adequately shallow. — Quality of the foundation material must be adequate for final design use. — Potential land ownership issues must be resolved.
Land reclamation	Raising a permanently submerged area to use for a specific motive.	
Beach nourishment	Replacement of the required quantities of sand and gravel material lost through the natural erosion of beaches and shorelines.	+ Provides a naturally occurring aquatic material to replace a shortfall in a similar material. + Process could potentially operate in tandem with maintenance dredged material collection. + Sea defences improved. + Tourism may be dramatically improved upon completion. + Value of surrounding land may increase. — Dredged material may be contaminated with material unsuitable for the beach environment. — Dredged material must be the same size or larger than in situ material. — Dredged material must be the same colour shade as the original material or slightly darker. — Dredged material quantity must be sufficient for both the visible portion of the beach and the submerged portion.
Offshore berms	Creation of submerged berms to moderate the inshore wave climate, thus, reducing the loss of beach material.	+ Using a wide range and collection of material from rock, sand and clay. + May be created by simple discharge of DM from hoppers. + Can protect areas of high land value (e.g., beaches) from erosion. — Identification of the most destructive wave direction is crucial. — Optimum placement area must be suitably located and be sufficiently shallow. — The height of the berm is critical in calculating the reduction in wave force. — Unless rock, useful life may be short due to erosion and dispersion.

Re-use Option	Description	Advantages (+) / Disadvantages (-)
Intertidal and/or subtidal habitat restoration, recreation, etc	Restoration or extension of habitats using fine grain sediments (e.g., mudflats, saltmarshes).	+ One of the few beneficial uses of clay and silt size sediment. + Improves or provides habitat for invertebrates. + Generally welcomed by environmental stakeholders. — Only applicable to areas within estuaries with quiescent hydrodynamic conditions. — Regeneration site needs to be reasonably local and accessible. — Some degree of temporary containment may be required during placement. — Potential for temporary increase in local water turbidity due to run-off.
Coastal protection	The use of geotubes to contain dredged material to aid in coastal erosion defence. Excavated rock can also be used as cover material.	+ Can prevent coastal flooding and erosion. + Use of geotubes retains and isolates contaminants. + Reduces quantity of quarried material required. — The size and weight of the rock is important in the design of coastal protection structures. — Hydraulic equipment (pumping) is required for geotubes.
Landfill cover	Landfill cover is used daily to minimise odour and vermin. Substantial material is also required for a permanent cap when areas of the landfill are at capacity.	+ Should be a vast improvement in the aesthetics of the area upon completion of project. + Subject to salinity, the regeneration of plant life will revitalise wildlife. + Possible amenity and recreation areas for locals can be created. + Value of surrounding lands increase as well as the developed land itself. — Desalination will be needed to stimulate plant growth. — Dewatering will be required in most cases and in all cases where hydraulic dredgers are used. — Contamination levels must be at a suitable level for the materials intended use. — Growth testing will have to be carried out to ensure that the material can support growth satisfactorily.
Capping material	Using clean dredged material as a cover to envelop contaminated DM disposed in open water or as covering in solid waste landfills.	+ Provides an effective method of controlling contaminated dredged material within the aquatic environment. + More economical than treatment of contaminated dredged material. + No additional costs than disposal at sea — Coarse or highly cohesive uncontaminated material necessary. — Water depth must be acceptable. — Accurate placement is essential. — Monitoring and maintenance may be required periodically. — Organic content should be low to deter organisms. — Placement should be carried out during low wave action at a low velocity with the potential use of a diffuser.

Table A1.2 Advantages and Disadvantages of Various Re-use Options for Dredged Material: Environmental Options

Re-use Option	Description	Advantages (+) / Disadvantages (-)
Upland creation enhancement	Creating or enhancing an upland habitat usually refers to a bird habitat. This area does not have to be in an elevated area but can be located by the water or even on an artificial island.	+ Almost any dredged material that is clean can be used. + Benefits to environment must be compared with the losses. + Possible creation of tourist attractions. — Transport costs can be excessive especially in rural areas. — Timing of the work may be hindered by feeding, breeding and migration patterns of certain species, including protected species. — Elevation, location and the topography of the area must be appropriate.
Wetland creation / enhancement	Dredged material is used to create / stabilise eroding natural wetland shorelines or nourish subsiding wetlands.	+ Project would improve the overall environmental conditions onsite. + Can drastically improve flood defence and erosion issues. + Provides a soft engineering solution which can be a cheaper and more attractive option than a concrete structure. — Contamination levels must be extremely low. — Material used must be silty in nature with good organic content. — Lengthy planning involved which may disrupt dredging project. — It is easier to enhance an area of wetland than to create a wetland. — May require various environmental assessments and/or consents. — Biological testing, which would include numerous bioassays, would be required.
Sediment cell maintenance (sustainable relocation)	The 'in estuary' placement of dredged material during beneficial use schemes, either by trickle charging or direct intertidal placement, ensures that perturbations to an estuary's cell maintenance during essential dredged is minimised. Also known as sustainable relocation. Applies exclusively to maintenance dredging.	+ May be supported by relevant Marine Plan policies. + Is a more environmentally friendly solution than disposal at sea. + Can prevent erosion on the down-drift side of the port / harbour. + No extra equipment is required. + Contamination levels normally will be low as the material concerned will be recently deposited sediment. + No requirements on type of dredged material. + Can be more economical than disposal at sea. — Impact on local wave environment must be assessed. — The time in the tidal cycle when the work is done must be optimised.

Table A1.3 Advantages and Disadvantages of Various Re-use Options for Dredged Material: Product Options

Re-use Option	Description	Advantages (+) / Disadvantages (-)
Products derived from the treatment of dredged material	Examples include topsoil material, fill material, landfill liner material, road sub-base material, lightweight aggregate, brick / ceramic manufacturing material.	+ Can offset costs of sourcing another material. + Price dependent on quality of material but generation of a profit is possible. + Some products will require no capital equipment. + Some products can lock in contaminants. + Regularly reduces disposal at sea costs. — Dewatering is essential and a prerequisite. — Saline content and levels of pH must be evaluated. — Grading of material must be appropriate. — May not be suitable for dredged material for some aspects of public use (i.e., parks) or agricultural use depending on contamination levels. — Relevant technical standards must be met and adjustment in chemistry of manufactured goods must be assessed. — Optimum mixes must be found and tested. — Time frame for the availability of material decisive in construction projects to avoid costly delays. — Considerable equipment required for processing. — Transport will have to be by road at delivery stage. — Constant supply of material may be necessary to make the project sustainable into the future. — Public prejudice against technologies/processes used to treat and manage sediments. — Intermittent, variable sediment characteristics associated with typical dredging projects. — Required development of market and acceptance of products produced from dredged sediments. — Resistance from labour groups to displacement of traditional products and associated jobs. — Long-term liability and legal responsibilities associated with produced products. — For most products, cost is prohibitive.

APPENDIX 2: SEDIMENT CONTAMINATION DATA AND COMPARISON TO QUALITY STANDARDS

Figure A2.1 Sample Identification: Sampling Station Location

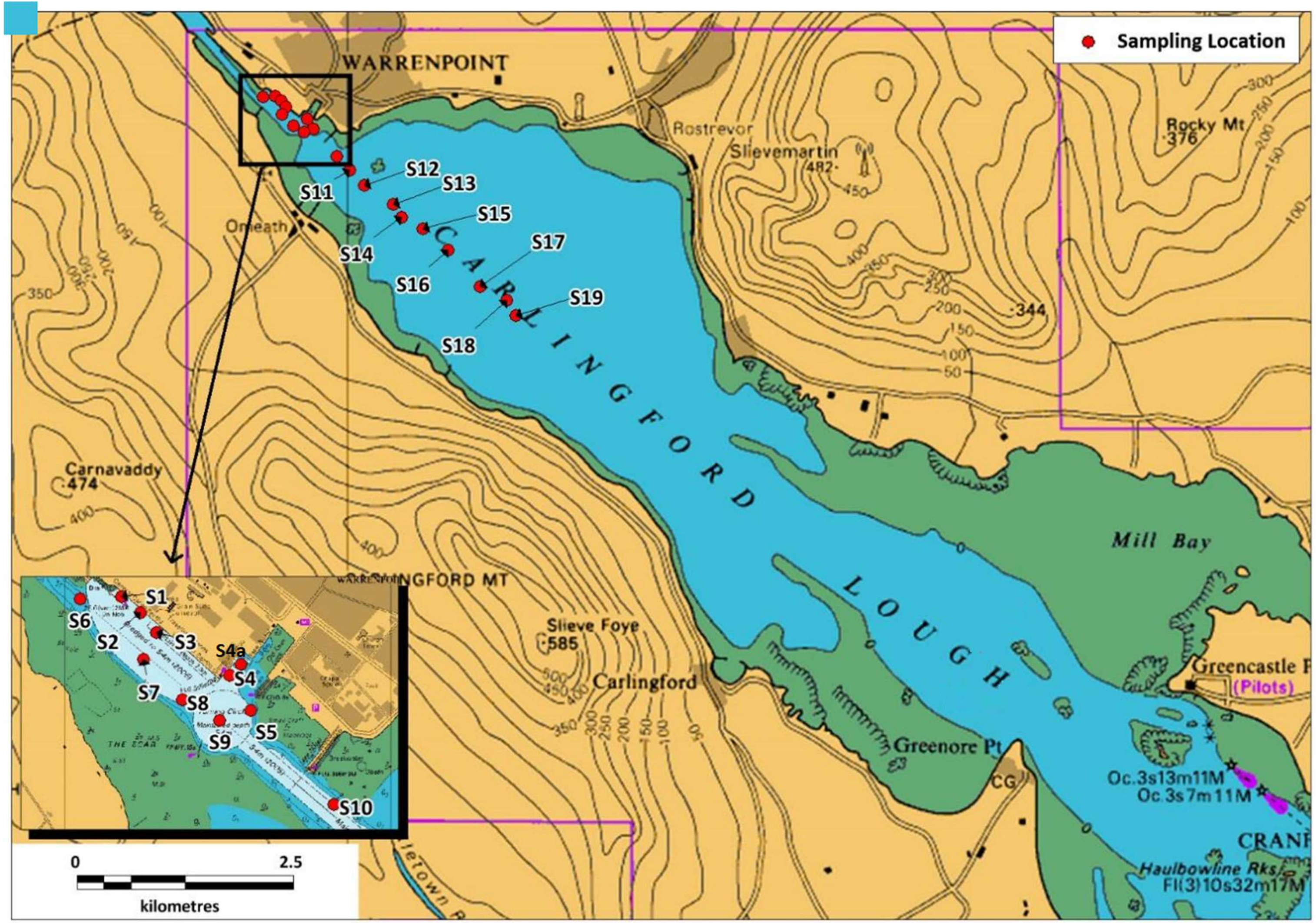

Table A2.1 Sediment Sample Identification, Depth and Position

Sample ID	Site Number	Sample Depth (m)	Irish Grid Easting	Irish Grid Northing	WGS84 Latitude	WGS84 Longitude
S1 0.0m	Site 1	Surface 0.0m	313620	318336	54° 6.098'	- 6° 15.830'
S2 0.0m	Site 2	Surface 0.0m	313686	318285	54° 6.070'	- 6° 15.771'
S3 0.0m	Site 3	Surface 0.0m	313742	318221	54° 6.034'	- 6° 15.721'
S4 0.0m	Site 4	Surface 0.0m	313990	318083	54° 5.957'	- 6° 15.497'
S4a 0.0m	Site 4a	Surface 0.0m	314032	318132	54° 5.974'	- 6° 15.399'
S5 0.0m	Site 5	Surface 0.0m	314062	317969	54° 5.894'	- 6° 15.433'
S6 0.0m	Site 6	Surface 0.0m	313482	318326	54° 6.094'	- 6° 15.957'
S7 0.0m	Site 7	Surface 0.0m	313699	318130	54° 5.986'	- 6° 15.762'
S8 0.0m	Site 8	Surface 0.0m	313834	317998	54° 5.913'	- 6° 15.642'
S9 0.0m	Site 9	Surface 0.0m	313961	317933	54° 5.876'	- 6° 15.527'
S10 0.0m	Site 10	Surface 0.0m	314349	317662	54° 5.725'	- 6° 15.177'
S11 0.0m	Site 11	Surface 0.0m	314501	317511	54° 5.642'	- 6° 15.041'
S12 0.0m	Site 12	Surface 0.0m	314671	317332	54° 5.543'	- 6° 14.889'
S13 0.0m	Site 13	Surface 0.0m	315010	317125	54° 5.427'	- 6° 14.583'
S14 0.0m	Site 14	Surface 0.0m	315107	316976	54° 5.345'	- 6° 14.498'
S15 0.0m	Site 15	Surface 0.0m	315360	316850	54° 5.274'	- 6° 14.269'
S16 0.0m	Site 16	Surface 0.0m	315651	316616	54° 5.144'	- 6° 14.008'
S17 0.0m	Site 17	Surface 0.0m	316031	316199	54° 4.914'	- 6° 13.669'
S18 0.0m	Site 18	Surface 0.0m	316342	316056	54° 4.833'	- 6° 13.387'
S19 0.0m	Site 19	Surface 0.0m	316456	315878	54° 4.736'	- 6° 13.287'
S4a 2.2m	Site 4a	2.2m	314032	318132	54° 5.974'	- 6° 15.399'
S4a-1.2m	Site 4a	1.2m	314032	318132	54° 5.974'	- 6° 15.399'
S4 2.2m	Site 4	2.2m	313990	318083	54° 5.957'	- 6° 15.497'
S4 1.2m	Site 4	1.2m	313990	318083	54° 5.957'	- 6° 15.497'
S3 1.7m	Site 3	1.7m	313742	318221	54° 6.034'	- 6° 15.721'
S1 1.8m	Site 1	1.8m	313620	318336	54° 6.098'	- 6° 15.830'
S10 1.3m	Site 10	1.3	314349	317662	54° 5.725'	- 6° 15.177'
S12 1.6m	Site 12	1.6m	314671	317332	54° 5.543'	- 6° 14.889'
S13 1.0m	Site 13	1.0m	315010	317125	54° 5.427'	- 6° 14.583'
S14 1.4m	Site 14	1.4m	315107	316976	54° 5.345'	- 6° 14.498'

Table A2.2 Sediment Composition

Sample ID	% Total Moisture	% Total Solids	% Gravel (>2mm)	% Sand (0.063-2mm)	% Silt (<0.063mm)	% Total Organic Carbon
S1 0.0m	67.8	32.2	0.00	11.92	88.08	1.70
S2 0.0m	68.4	31.6	2.96	13.96	83.07	2.42
S3 0.0m	66.7	33.3	0.00	13.96	86.04	2.50
S4 0.0m	66.9	33.1	0.00	12.76	87.24	2.42
S4a 0.0m	66.6	33.4	0.00	10.79	89.21	2.39
S5 0.0m	62.3	37.7	11.62	13.56	74.82	2.46
S6 0.0m	67.1	32.9	0.00	14.10	85.90	2.83
S7 0.0m	69.9	30.1	0.00	12.08	87.92	2.42
S8 0.0m	53.0	47.0	0.77	13.86	85.37	1.60
S9 0.0m	66.4	33.6	2.88	14.70	82.42	2.48
S10 0.0m	62.2	37.8	0.00	22.86	77.14	1.74
S11 0.0m	60.2	39.8	0.00	35.17	64.83	1.85
S12 0.0m	58.1	41.9	0.00	27.14	72.86	1.65
S13 0.0m	61.6	38.4	1.12	13.27	85.61	1.96
S14 0.0m	63.1	36.9	0.00	17.79	82.21	1.73
S15 0.0m	60.5	39.5	0.00	34.26	65.74	1.52
S16 0.0m	61.0	39.0	0.05	17.63	82.32	1.63
S17 0.0m	50.1	49.9	0.00	27.10	72.90	1.52
S18 0.0m	60.6	39.4	0.00	43.73	56.27	0.97
S19 0.0m	44.8	55.2	0.00	45.81	54.19	0.91
S4a 2.2m	61.3	38.7	0.00	12.75	87.25	2.44
S4a-1.2m	68.0	32.0	0.00	14.23	85.77	2.59
S4 2.2m	58.6	41.4	0.00	15.26	84.74	2.37
S4 1.2m	61.6	38.4	0.00	14.38	85.62	2.80
S3 1.7m	58.0	42.0	0.00	18.24	81.76	2.78
S1 1.8m	57.8	42.2	0.00	13.51	86.49	2.29
S10 1.3m	46.6	53.4	2.64	24.83	72.54	1.99
S12 1.6m	49.2	50.8	0.00	15.24	84.76	2.26
S13 1.0m	48.8	51.2	0.00	17.56	82.44	1.98
S14 1.4m	44.6	55.4	0.00	18.83	81.17	2.19

Table A2.3 Sediment Quality Standards

Contaminant	Units	Northern Ireland		Republic of Ireland		Gorham-Test Effects Range	
		Acton Level 1	Action Level 2	Acton Level 1	Action Level 2	Low	Medium
Arsenic	mg.kg^{-1} dry weight	20	100	20	70		
Cadmium	mg.kg^{-1} dry weight	0.4	5	0.7	4.2		
Chromium	mg.kg^{-1} dry weight	40	400	120	370		
Copper	mg.kg^{-1} dry weight	40	400	40	110		
Mercury	mg.kg^{-1} dry weight	0.3	3	0.2	0.7		
Nickel	mg.kg^{-1} dry weight	20	200	40	60		
Lead	mg.kg^{-1} dry weight	50	500	60	218		
Zinc	mg.kg^{-1} dry weight	130	800	160	410		
Organo-tins: TBT and DBT	mg.kg^{-1} dry weight	0.1	1	0.1	0.5		
PCBs: sum ICES 7	µg.kg^{-1} dry weight	10		7	1,260		
PCBs: sum 25 congeners	µg.kg^{-1} dry weight	20	200				
PAHs: individual	µg.kg^{-1} dry weight	100					
PAHs: acenaphthene	µg.kg^{-1} dry weight					44	640
PAHs: acenaphthylene	µg.kg^{-1} dry weight					16	500
PAHs: anthracene	µg.kg^{-1} dry weight					85	1,100
PAHs: benz[a]anthracene	µg.kg^{-1} dry weight					261	1,600
PAHs: chrysene	µg.kg^{-1} dry weight					384	2,800
PAHs: dibenz[a,h]anthracene	µg.kg^{-1} dry weight					63	260
PAHs: fluoranthene	µg.kg^{-1} dry weight					600	5,100
PAHs: fluorene	µg.kg^{-1} dry weight					19	540
PAHs: naphthalene	µg.kg^{-1} dry weight					160	2,100
PAHs: phenanthrene	µg.kg^{-1} dry weight					240	1,500
PAHs: pyrene	µg.kg^{-1} dry weight					665	2,600
PAHs: sum USEPA 16	µg.kg^{-1} dry weight			4,000			
DDT	µg.kg^{-1} dry weight	1					
Dieldrin	µg.kg^{-1} dry weight	5					
TEH	g.kg^{-1} dry weight			1			
γHCH	µg.kg^{-1} dry weight			0.3	1		
HCB	µg.kg^{-1} dry weight			0.3	1		

Key to Sediment Contaminant Data Comparison to Sediment Quality Standards

Indicator	Data Comparison to Sediment Quality Standards
🟩	Data is below Action Level 1 / Gorham-Test Effects Range Low
🟨	Data is above Action level 1 and below Action Level 2 / above Gorham-Test Effects Range Low and below Gorham-Test Effects Range Median
🟧	Data is above Action Level 2 / above Gorham-Test Effects Range Median
⬜	Not applicable as there is no Action Level / Gorham-Test Effects Range

Table A2.4 Sediment Contamination: Metals and Organo-tins (mg.kg^{-1} dry weight) compared to Northern Ireland Action Levels

Sample ID	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Dibutyltin	Tributyltin
S1 0.0m	11.7	0.26	69.8	21.6	27.6	<0.01	30.6	91.3	<0.005	<0.005
S2 0.0m	16.9	0.39	99.2	37.2	45.5	<0.01	47.5	187	<0.005	<0.005
S3 0.0m	18.4	0.51	102	35.8	47.4	<0.01	45.0	173	<0.005	<0.005
S4 0.0m	19.9	0.48	107	36.2	50.3	<0.01	47.3	176	<0.005	<0.005
S4a 0.0m	20.2	0.48	105	36.1	49.8	<0.01	48.0	177	<0.005	<0.005
S5 0.0m	16.0	0.39	92.5	30.1	42.6	<0.01	42.1	151	<0.005	<0.005
S6 0.0m	18.1	0.51	98.2	38.7	49.7	<0.01	44.6	185	<0.005	<0.005
S7 0.0m	25.6	0.65	140	51.2	69.1	0.03	62.8	243	<0.005	<0.005
S8 0.0m	14.8	0.39	90.5	28.6	42.5	<0.01	38.4	141	<0.005	<0.005
S9 0.0m	17.4	0.45	96.4	32.0	46.4	<0.01	43.1	160	<0.005	<0.005
S10 0.0m	15.2	0.38	86.2	26.0	41.2	<0.01	37.8	132	<0.005	<0.005
S11 0.0m	15.1	0.31	85.0	24.6	38.9	<0.01	37.4	127	<0.005	<0.005
S12 0.0m	14.9	0.30	87.9	24.8	37.0	<0.01	36.6	120	<0.005	<0.005
S13 0.0m	15.7	0.30	88.1	23.7	39.4	<0.01	37.6	128	<0.005	<0.005
S14 0.0m	16.0	0.30	86.6	24.8	39.0	<0.01	38.3	128	<0.005	<0.005
S15 0.0m	15.1	0.28	85.7	22.1	35.2	<0.01	38	114	<0.005	<0.005
S16 0.0m	16.5	0.28	89.9	23.7	39.2	<0.01	39.4	124	<0.005	<0.005
S17 0.0m	13.6	0.22	83.4	19.7	34.7	<0.01	35.7	109	<0.005	<0.005
S18 0.0m	11.1	0.15	65.7	13.9	27.2	<0.01	29.6	75.7	<0.005	<0.005
S19 0.0m	8.6	0.15	66.2	16.2	26.2	<0.01	25.3	64.8	<0.005	<0.005
S4a 2.2m	16.1	0.29	89.6	36.4	52.7	0.21	43.3	169	<0.005	<0.005
S4a-1.2m	17.8	0.33	87.2	36.6	54.8	0.20	42.0	177	<0.005	<0.005
S4 2.2m	18.6	0.27	81.6	33.0	52.9	0.22	39.2	159	<0.005	<0.005
S4 1.2m	18.5	0.36	82.9	35.7	54.4	0.17	41.6	168	<0.005	<0.005
S3 1.7m	18.5	0.33	81.6	34.3	54.0	0.17	40.1	164	<0.005	<0.005
S1 1.8m	15.9	0.35	80.0	37.4	51.0	0.15	41.8	156	<0.005	<0.005
S10 1.3m	14.0	0.29	71.1	25.8	43.9	0.12	34.4	133	<0.005	0.0165
S12 1.6m	16.5	0.26	78.4	27.9	49.2	0.14	37.8	144	<0.005	<0.005
S13 1.0m	16.2	0.30	81.7	29.0	56.5	0.21	38.9	155	<0.005	<0.005
S14 1.4m	17.9	0.29	85.1	28.8	52.0	0.13	41.3	153	<0.005	<0.005

Table A2.5 Sediment Contamination: PAHs (µg.kg^{-1} dry weight) compared to Northern Ireland Action Levels

Sample ID	Acenaphthene	Acenaphthylene	Anthracene	Benz[a]anthracene	Benzo[a]pyrene	Benzo[b]fluoranthene	Benzo[g,h,i]perylene	Benzo[k]fluoranthene
S1 0.0m	<5	<5	20.0	68.9	99.8	101	92.5	110
S2 0.0m	<5	<5	23.6	60.8	79.5	101	86.0	117
S3 0.0m	28.1	<5	29.4	57.7	77.5	109	81.7	101
S4 0.0m	<5	<5	19.8	73.6	88.6	124	97.8	107
S4a 0.0m	<5	<5	<5	57.3	76.6	102	75.5	86.1
S5 0.0m	<5	<5	19.2	66.6	91.0	108	89.5	104
S6 0.0m	<5	<5	26.2	105	140	159	135	164
S7 0.0m	<5	<5	21.4	84.4	95.4	116	98.2	108
S8 0.0m	<5	<5	14.6	45.2	51.4	79.6	60.5	66.4
S9 0.0m	<5	<5	15.0	88.7	138	148	132	141
S10 0.0m	<5	<5	22.2	90.3	89.5	113	89.4	105
S11 0.0m	<5	16.2	42.9	151	139	146	117	153
S12 0.0m	<5	<5	<5	48.3	58.3	67.1	55.4	66.1
S13 0.0m	<5	<5	<5	44.6	56.3	69.3	56.3	70.4
S14 0.0m	<5	<5	15.2	74.0	82.4	83.2	79.7	111
S15 0.0m	<5	<5	35.0	40.7	52.9	61.5	53.3	66.9
S16 0.0m	<5	<5	14.8	60.1	65.3	118	69.9	85.3
S17 0.0m	<5	<5	10.6	32.6	40.1	61.1	42.4	47.0
S18 0.0m	<5	<5	13.7	54.6	72.3	123	84.0	80.3
S19 0.0m	<5	<5	9.17	21.7	27.5	35.1	27.8	24.2
S4a 2.2m	9.17	11.6	35.9	124	155	170	143	204
S4a-1.2m	9.31	9.22	22.0	70.8	87.6	137	114	141
S4 2.2m	8.24	11.4	33.8	111	152	166	130	158
S4 1.2m	18.0	11.0	26.5	78.8	121	113	112	173
S3 1.7m	6.73	8.07	20.9	62.1	89.9	115	96.6	107
S1 1.8m	8.44	12.7	26.5	89.6	129	159	131	165
S10 1.3m	2.03	2.88	7.85	22.2	29.5	33.2	24.0	26.7
S12 1.6m	5.53	7.58	20.4	66.4	93.6	146	105	123
S13 1.0m	8.60	15.2	34.3	105	157	206	168	182
S14 1.4m	8.13	22.4	46.0	179	204	205	150	218

Table A2.5 continued Sediment Contamination: PAHs (µg.kg^{-1} dry weight) compared to Northern Ireland Action Levels

Sample ID	Chrysene	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno[1,2,3-c,d]pyrene	Naphthalene	Phenanthrene	Pyrene	Sum of USEPA 16
S1 0.0m	87.3	16.6	136	24.2	113	44.1	73.6	114	1,111.00
S2 0.0m	79.6	<5	143	26.2	94.9	34.1	68.2	121	<1,049.90
S3 0.0m	77.8	18.2	375	60.2	103	39.0	298	243	1,703.6
S4 0.0m	90.6	17.3	145	25.9	108	38.1	81.6	124	1,151.3
S4a 0.0m	72.0	13.1	101	15.1	91.6	28.1	57.1	97.9	888.40
S5 0.0m	84.2	18.1	120	22.4	93.0	34.1	64.0	113	1,037.10
S6 0.0m	120	19.2	167	27.6	147	42.2	73.8	167	1,503.0
S7 0.0m	106	18.5	154	26.4	117	35.2	87.7	139	1,217.2
S8 0.0m	51.5	<5	78.0	14.9	62.6	50.8	43.6	76.0	<710.10
S9 0.0m	105	17.7	143	23.5	147	40.5	69.4	136	1,354.80
S10 0.0m	98.6	14.6	169	23.6	98.3	32.0	77.6	147	1,180.1
S11 0.0m	159	24.1	339	21.8	136	41.2	117	267	1,875.2
S12 0.0m	56.8	<5	86.2	15.6	64.2	28.3	45.9	74.6	<686.80
S13 0.0m	53.0	<5	89.1	17.7	65.3	26.8	49.9	77.0	<695.70
S14 0.0m	84.8	<5	112	21.8	84.2	37.6	60.4	107	<968.3
S15 0.0m	52.4	<5	72.1	15.6	53.7	23.9	50.9	65.1	<281.3
S16 0.0m	74.1	<5	102	19.1	85.0	27.1	60.3	87.4	<381
S17 0.0m	37.2	<5	59.2	13.3	45.7	22.0	40.9	53.0	<520.1
S18 0.0m	69.2	13.5	97.7	16.7	81.9	30.3	53.4	95.7	896.3
S19 0.0m	28.3	<5	42.4	<5	29.8	16.1	32.8	39.8	<354.7
S4a 2.2m	144	30.1	240	33.2	160	48.2	121	211	1,840.17
S4a-1.2m	88.3	22.3	141	25.8	127	44.5	75.9	135	1,250.73
S4 2.2m	142	28.3	224	30.1	158	48.6	117	193	1,711.44
S4 1.2m	107	23.5	162	30.2	134	46.4	85.8	152	1,394.2
S3 1.7m	87.2	19.9	128	24.0	117	38.8	78.5	114	1,113.70
S1 1.8m	119	27.0	176	30.5	158	48.2	100	160	1,539.94
S10 1.3m	26.9	5.15	44.4	5.92	26.8	7.88	26.1	40.8	332.31
S12 1.6m	89.3	22.0	127	21.1	122	38.9	75.8	115	1,178.61
S13 1.0m	129	34.1	190	30.6	190	53.2	99.1	186	1,788.10
S14 1.4m	207	33.3	375	40.4	171	34.1	239	332	2,464.33

Table A2.6 Sediment Contamination: PCBs (μg.kg^{-1} dry weight) compared to Northern Ireland Action Levels

Sample ID	PCB28	PCB52	PCB101	PCB118	PCB138	PCB153	PCB180	Sum of ICES 7
S1 0.0m	0.20	0.25	0.15	0.29	0.10	0.23	0.10	1.32
S2 0.0m	0.30	0.33	0.13	0.24	0.17	0.19	0.11	1.47
S3 0.0m	0.18	0.22	0.14	0.30	0.09	0.18	<0.08	<1.19
S4 0.0m	0.36	0.65	0.71	1.00	0.62	0.76	0.53	4.63
S4a 0.0m	0.17	0.19	0.10	0.32	0.16	0.18	<0.08	1.20
S5 0.0m	0.16	0.14	0.09	0.18	0.15	0.14	0.09	0.95
S6 0.0m	0.19	0.22	<0.08	0.21	0.14	0.21	0.14	1.19
S7 0.0m	0.34	0.70	0.55	0.79	0.55	0.57	0.60	4.10
S8 0.0m	0.13	0.15	0.10	0.15	0.12	0.18	0.11	0.94
S9 0.0m	0.15	0.11	<0.08	0.28	0.21	0.19	<0.08	<1.10
S10 0.0m	0.10	0.09	<0.08	0.18	<0.08	0.11	<0.08	<0.72
S11 0.0m	0.11	0.10	<0.08	0.18	0.12	0.14	<0.08	<0.81
S12 0.0m	0.09	0.09	<0.08	0.08	0.08	0.12	<0.08	<0.62
S13 0.0m	0.15	0.13	<0.08	0.22	0.17	0.12	<0.08	<0.95
S14 0.0m	0.12	0.12	0.12	0.12	<0.08	0.15	0.08	<0.79
S15 0.0m	0.09	0.10	<0.08	0.09	0.10	0.11	<0.08	<0.65
S16 0.0m	0.10	0.11	0.16	0.31	0.24	0.23	0.08	<1.23
S17 0.0m	0.19	0.23	0.10	0.19	0.14	0.20	<0.08	<1.13
S18 0.0m	<0.08	<0.08	<0.08	0.09	<0.08	<0.08	<0.08	<0.49
S19 0.0m	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.56
S4a 2.2m	0.23	0.13	0.14	0.22	0.15	0.21	0.11	1.19
S4a-1.2m	0.21	0.10	0.12	0.21	0.20	0.17	<0.08	<1.09
S4 2.2m	0.18	0.12	0.15	0.15	0.26	0.29	0.15	1.30
S4 1.2m	0.19	0.10	0.10	0.23	0.21	0.30	<0.08	<1.21
S3 1.7m	0.23	0.11	0.13	0.22	0.15	0.19	0.09	1.12
S1 1.8m	0.58	0.44	0.38	0.44	0.33	0.54	0.35	3.06
S10 1.3m	0.17	0.09	0.10	0.14	0.19	0.25	<0.08	<1.02
S12 1.6m	0.22	0.15	0.12	0.19	0.25	0.30	0.08	1.31
S13 1.0m	0.21	0.14	0.19	0.22	0.19	0.31	<0.08	<1.34
S14 1.4m	0.21	0.12	0.13	0.22	0.22	0.26	<0.08	<1.24

Table A2.7 Sediment Contamination: Metals and Organo-tins (mg.kg^{-1} dry weight) compared to Republic of Ireland Action Levels

Sample ID	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Dibutyltin	Tributyltin
S1 0.0m	11.7	0.26	69.8	21.6	27.6	<0.01	30.6	91.3	<0.005	<0.005
S2 0.0m	16.9	0.39	99.2	37.2	45.5	<0.01	47.5	187	<0.005	<0.005
S3 0.0m	18.4	0.51	102	35.8	47.4	<0.01	45.0	173	<0.005	<0.005
S4 0.0m	19.9	0.48	107	36.2	50.3	<0.01	47.3	176	<0.005	<0.005
S4a 0.0m	20.2	0.48	105	36.1	49.8	<0.01	48.0	177	<0.005	<0.005
S5 0.0m	16.0	0.39	92.5	30.1	42.6	<0.01	42.1	151	<0.005	<0.005
S6 0.0m	18.1	0.51	98.2	38.7	49.7	<0.01	44.6	185	<0.005	<0.005
S7 0.0m	25.6	0.65	140	51.2	69.1	0.03	62.8	243	<0.005	<0.005
S8 0.0m	14.8	0.39	90.5	28.6	42.5	<0.01	38.4	141	<0.005	<0.005
S9 0.0m	17.4	0.45	96.4	32.0	46.4	<0.01	43.1	160	<0.005	<0.005
S10 0.0m	15.2	0.38	86.2	26.0	41.2	<0.01	37.8	132	<0.005	<0.005
S11 0.0m	15.1	0.31	85.0	24.6	38.9	<0.01	37.4	127	<0.005	<0.005
S12 0.0m	14.9	0.30	87.9	24.8	37.0	<0.01	36.6	120	<0.005	<0.005
S13 0.0m	15.7	0.30	88.1	23.7	39.4	<0.01	37.6	128	<0.005	<0.005
S14 0.0m	16.0	0.30	86.6	24.8	39.0	<0.01	38.3	128	<0.005	<0.005
S15 0.0m	15.1	0.28	85.7	22.1	35.2	<0.01	38	114	<0.005	<0.005
S16 0.0m	16.5	0.28	89.9	23.7	39.2	<0.01	39.4	124	<0.005	<0.005
S17 0.0m	13.6	0.22	83.4	19.7	34.7	<0.01	35.7	109	<0.005	<0.005
S18 0.0m	11.1	0.15	65.7	13.9	27.2	<0.01	29.6	75.7	<0.005	<0.005
S19 0.0m	8.6	0.15	66.2	16.2	26.2	<0.01	25.3	64.8	<0.005	<0.005
S4a 2.2m	16.1	0.29	89.6	36.4	52.7	0.21	43.3	169	<0.005	<0.005
S4a-1.2m	17.8	0.33	87.2	36.6	54.8	0.20	42.0	177	<0.005	<0.005
S4 2.2m	18.6	0.27	81.6	33.0	52.9	0.22	39.2	159	<0.005	<0.005
S4 1.2m	18.5	0.36	82.9	35.7	54.4	0.17	41.6	168	<0.005	<0.005
S3 1.7m	18.5	0.33	81.6	34.3	54.0	0.17	40.1	164	<0.005	<0.005
S1 1.8m	15.9	0.35	80.0	37.4	51.0	0.15	41.8	156	<0.005	<0.005
S10 1.3m	14.0	0.29	71.1	25.8	43.9	0.12	34.4	133	<0.005	0.0165
S12 1.6m	16.5	0.26	78.4	27.9	49.2	0.14	37.8	144	<0.005	<0.005
S13 1.0m	16.2	0.30	81.7	29.0	56.5	0.21	38.9	155	<0.005	<0.005
S14 1.4m	17.9	0.29	85.1	28.8	52.0	0.13	41.3	153	<0.005	<0.005

Table A2.8 Sediment Contamination: PAHs (μg.kg^{-1} dry weight) compared to Republic of Ireland Action Levels

Sample ID	Acenaphthene	Acenaphthylene	Anthracene	Benz[a]anthracene	Benzo[a]pyrene	Benzo[b]fluoranthene	Benzo[g,h,i]perylene	Benzo[k]fluoranthene
S1 0.0m	<5	<5	20.0	68.9	99.8	101	92.5	110
S2 0.0m	<5	<5	23.6	60.8	79.5	101	86.0	117
S3 0.0m	28.1	<5	29.4	57.7	77.5	109	81.7	101
S4 0.0m	<5	<5	19.8	73.6	88.6	124	97.8	107
S4a 0.0m	<5	<5	<5	57.3	76.6	102	75.5	86.1
S5 0.0m	<5	<5	19.2	66.6	91.0	108	89.5	104
S6 0.0m	<5	<5	26.2	105	140	159	135	164
S7 0.0m	<5	<5	21.4	84.4	95.4	116	98.2	108
S8 0.0m	<5	<5	14.6	45.2	51.4	79.6	60.5	66.4
S9 0.0m	<5	<5	15.0	88.7	138	148	132	141
S10 0.0m	<5	<5	22.2	90.3	89.5	113	89.4	105
S11 0.0m	<5	16.2	42.9	151	139	146	117	153
S12 0.0m	<5	<5	<5	48.3	58.3	67.1	55.4	66.1
S13 0.0m	<5	<5	<5	44.6	56.3	69.3	56.3	70.4
S14 0.0m	<5	<5	15.2	74.0	82.4	83.2	79.7	111
S15 0.0m	<5	<5	35.0	40.7	52.9	61.5	53.3	66.9
S16 0.0m	<5	<5	14.8	60.1	65.3	118	69.9	85.3
S17 0.0m	<5	<5	10.6	32.6	40.1	61.1	42.4	47.0
S18 0.0m	<5	<5	13.7	54.6	72.3	123	84.0	80.3
S19 0.0m	<5	<5	9.17	21.7	27.5	35.1	27.8	24.2
S4a 2.2m	9.17	11.6	35.9	124	155	170	143	204
S4a-1.2m	9.31	9.22	22.0	70.8	87.6	137	114	141
S4 2.2m	8.24	11.4	33.8	111	152	166	130	158
S4 1.2m	18.0	11.0	26.5	78.8	121	113	112	173
S3 1.7m	6.73	8.07	20.9	62.1	89.9	115	96.6	107
S1 1.8m	8.44	12.7	26.5	89.6	129	159	131	165
S10 1.3m	2.03	2.88	7.85	22.2	29.5	33.2	24.0	26.7
S12 1.6m	5.53	7.58	20.4	66.4	93.6	146	105	123
S13 1.0m	8.60	15.2	34.3	105	157	206	168	182
S14 1.4m	8.13	22.4	46.0	179	204	205	150	218

Table A2.8 continued Sediment Contamination: PAHs (µg.kg^{-1} dry weight) compared to Republic of Ireland Action Levels

Sample ID	Chrysene	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno[1,2,3-c,d]pyrene	Naphthalene	Phenanthrene	Pyrene	Sum of USEPA 16
S1 0.0m	87.3	16.6	136	24.2	113	44.1	73.6	114	1,111.00
S2 0.0m	79.6	<5	143	26.2	94.9	34.1	68.2	121	<1,049.90
S3 0.0m	77.8	18.2	375	60.2	103	39.0	298	243	1,703.6
S4 0.0m	90.6	17.3	145	25.9	108	38.1	81.6	124	1,151.3
S4a 0.0m	72.0	13.1	101	15.1	91.6	28.1	57.1	97.9	888.40
S5 0.0m	84.2	18.1	120	22.4	93.0	34.1	64.0	113	1,037.10
S6 0.0m	120	19.2	167	27.6	147	42.2	73.8	167	1,503.0
S7 0.0m	106	18.5	154	26.4	117	35.2	87.7	139	1,217.2
S8 0.0m	51.5	<5	78.0	14.9	62.6	50.8	43.6	76.0	<710.10
S9 0.0m	105	17.7	143	23.5	147	40.5	69.4	136	1,354.80
S10 0.0m	98.6	14.6	169	23.6	98.3	32.0	77.6	147	1,180.1
S11 0.0m	159	24.1	339	21.8	136	41.2	117	267	1,875.2
S12 0.0m	56.8	<5	86.2	15.6	64.2	28.3	45.9	74.6	<686.80
S13 0.0m	53.0	<5	89.1	17.7	65.3	26.8	49.9	77.0	<695.70
S14 0.0m	84.8	<5	112	21.8	84.2	37.6	60.4	107	<968.3
S15 0.0m	52.4	<5	72.1	15.6	53.7	23.9	50.9	65.1	<281.3
S16 0.0m	74.1	<5	102	19.1	85.0	27.1	60.3	87.4	<381
S17 0.0m	37.2	<5	59.2	13.3	45.7	22.0	40.9	53.0	<520.1
S18 0.0m	69.2	13.5	97.7	16.7	81.9	30.3	53.4	95.7	896.3
S19 0.0m	28.3	<5	42.4	<5	29.8	16.1	32.8	39.8	<354.7
S4a 2.2m	144	30.1	240	33.2	160	48.2	121	211	1,840.17
S4a-1.2m	88.3	22.3	141	25.8	127	44.5	75.9	135	1,250.73
S4 2.2m	142	28.3	224	30.1	158	48.6	117	193	1,711.44
S4 1.2m	107	23.5	162	30.2	134	46.4	85.8	152	1,394.2
S3 1.7m	87.2	19.9	128	24.0	117	38.8	78.5	114	1,113.70
S1 1.8m	119	27.0	176	30.5	158	48.2	100	160	1,539.94
S10 1.3m	26.9	5.15	44.4	5.92	26.8	7.88	26.1	40.8	332.31
S12 1.6m	89.3	22.0	127	21.1	122	38.9	75.8	115	1,178.61
S13 1.0m	129	34.1	190	30.6	190	53.2	99.1	186	1,788.10
S14 1.4m	207	33.3	375	40.4	171	34.1	239	332	2,464.33

Table A2.9 Sediment Contamination: PCBs (μg.kg^{-1} dry weight) compared to Republic of Ireland Action Levels

Sample ID	PCB28	PCB52	PCB101	PCB118	PCB138	PCB153	PCB180	Sum of ICES 7
S1 0.0m	0.20	0.25	0.15	0.29	0.10	0.23	0.10	1.32
S2 0.0m	0.30	0.33	0.13	0.24	0.17	0.19	0.11	1.47
S3 0.0m	0.18	0.22	0.14	0.30	0.09	0.18	<0.08	<1.19
S4 0.0m	0.36	0.65	0.71	1.00	0.62	0.76	0.53	4.63
S4a 0.0m	0.17	0.19	0.10	0.32	0.16	0.18	<0.08	1.20
S5 0.0m	0.16	0.14	0.09	0.18	0.15	0.14	0.09	0.95
S6 0.0m	0.19	0.22	<0.08	0.21	0.14	0.21	0.14	1.19
S7 0.0m	0.34	0.70	0.55	0.79	0.55	0.57	0.60	4.10
S8 0.0m	0.13	0.15	0.10	0.15	0.12	0.18	0.11	0.94
S9 0.0m	0.15	0.11	<0.08	0.28	0.21	0.19	<0.08	<1.10
S10 0.0m	0.10	0.09	<0.08	0.18	<0.08	0.11	<0.08	<0.72
S11 0.0m	0.11	0.10	<0.08	0.18	0.12	0.14	<0.08	<0.81
S12 0.0m	0.09	0.09	<0.08	0.08	0.08	0.12	<0.08	<0.62
S13 0.0m	0.15	0.13	<0.08	0.22	0.17	0.12	<0.08	<0.95
S14 0.0m	0.12	0.12	0.12	0.12	<0.08	0.15	0.08	<0.79
S15 0.0m	0.09	0.10	<0.08	0.09	0.10	0.11	<0.08	<0.65
S16 0.0m	0.10	0.11	0.16	0.31	0.24	0.23	0.08	<1.23
S17 0.0m	0.19	0.23	0.10	0.19	0.14	0.20	<0.08	<1.13
S18 0.0m	<0.08	<0.08	<0.08	0.09	<0.08	<0.08	<0.08	<0.49
S19 0.0m	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.56
S4a 2.2m	0.23	0.13	0.14	0.22	0.15	0.21	0.11	1.19
S4a-1.2m	0.21	0.10	0.12	0.21	0.20	0.17	<0.08	<1.09
S4 2.2m	0.18	0.12	0.15	0.15	0.26	0.29	0.15	1.30
S4 1.2m	0.19	0.10	0.10	0.23	0.21	0.30	<0.08	<1.21
S3 1.7m	0.23	0.11	0.13	0.22	0.15	0.19	0.09	1.12
S1 1.8m	0.58	0.44	0.38	0.44	0.33	0.54	0.35	3.06
S10 1.3m	0.17	0.09	0.10	0.14	0.19	0.25	<0.08	<1.02
S12 1.6m	0.22	0.15	0.12	0.19	0.25	0.30	0.08	1.31
S13 1.0m	0.21	0.14	0.19	0.22	0.19	0.31	<0.08	<1.34
S14 1.4m	0.21	0.12	0.13	0.22	0.22	0.26	<0.08	<1.24

Table A2.10 Sediment Contamination: PAHs (μg.kg^{-1} dry weight) compared to Gorham-Test Effects Ranges

Sample ID	Acenaphthene	Acenaphthylene	Anthracene	Benz[a]anthracene	Benzo[a]pyrene	Benzo[b]fluoranthene	Benzo[g,h,i]perylene	Benzo[k]fluoranthene
S1 0.0m	<5	<5	20.0	68.9	99.8	101	92.5	110
S2 0.0m	<5	<5	23.6	60.8	79.5	101	86.0	117
S3 0.0m	28.1	<5	29.4	57.7	77.5	109	81.7	101
S4 0.0m	<5	<5	19.8	73.6	88.6	124	97.8	107
S4a 0.0m	<5	<5	<5	57.3	76.6	102	75.5	86.1
S5 0.0m	<5	<5	19.2	66.6	91.0	108	89.5	104
S6 0.0m	<5	<5	26.2	105	140	159	135	164
S7 0.0m	<5	<5	21.4	84.4	95.4	116	98.2	108
S8 0.0m	<5	<5	14.6	45.2	51.4	79.6	60.5	66.4
S9 0.0m	<5	<5	15.0	88.7	138	148	132	141
S10 0.0m	<5	<5	22.2	90.3	89.5	113	89.4	105
S11 0.0m	<5	16.2	42.9	151	139	146	117	153
S12 0.0m	<5	<5	<5	48.3	58.3	67.1	55.4	66.1
S13 0.0m	<5	<5	<5	44.6	56.3	69.3	56.3	70.4
S14 0.0m	<5	<5	15.2	74.0	82.4	83.2	79.7	111
S15 0.0m	<5	<5	35.0	40.7	52.9	61.5	53.3	66.9
S16 0.0m	<5	<5	14.8	60.1	65.3	118	69.9	85.3
S17 0.0m	<5	<5	10.6	32.6	40.1	61.1	42.4	47.0
S18 0.0m	<5	<5	13.7	54.6	72.3	123	84.0	80.3
S19 0.0m	<5	<5	9.17	21.7	27.5	35.1	27.8	24.2
S4a 2.2m	9.17	11.6	35.9	124	155	170	143	204
S4a-1.2m	9.31	9.22	22.0	70.8	87.6	137	114	141
S4 2.2m	8.24	11.4	33.8	111	152	166	130	158
S4 1.2m	18.0	11.0	26.5	78.8	121	113	112	173
S3 1.7m	6.73	8.07	20.9	62.1	89.9	115	96.6	107
S1 1.8m	8.44	12.7	26.5	89.6	129	159	131	165
S10 1.3m	2.03	2.88	7.85	22.2	29.5	33.2	24.0	26.7
S12 1.6m	5.53	7.58	20.4	66.4	93.6	146	105	123
S13 1.0m	8.60	15.2	34.3	105	157	206	168	182
S14 1.4m	8.13	22.4	46.0	179	204	205	150	218

Table A2.10 continued Sediment Contamination: PAHs (µg.kg^{-1} dry weight) compared to Gorham-Test Effects Ranges

Sample ID	Chrysene	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno[1,2,3-c,d]pyrene	Naphthalene	Phenanthrene	Pyrene	Sum of USEPA 16
S1 0.0m	87.3	16.6	136	24.2	113	44.1	73.6	114	1,111.00
S2 0.0m	79.6	<5	143	26.2	94.9	34.1	68.2	121	<1,049.90
S3 0.0m	77.8	18.2	375	60.2	103	39.0	298	243	1,703.6
S4 0.0m	90.6	17.3	145	25.9	108	38.1	81.6	124	1,151.3
S4a 0.0m	72.0	13.1	101	15.1	91.6	28.1	57.1	97.9	888.40
S5 0.0m	84.2	18.1	120	22.4	93.0	34.1	64.0	113	1,037.10
S6 0.0m	120	19.2	167	27.6	147	42.2	73.8	167	1,503.0
S7 0.0m	106	18.5	154	26.4	117	35.2	87.7	139	1,217.2
S8 0.0m	51.5	<5	78.0	14.9	62.6	50.8	43.6	76.0	<710.10
S9 0.0m	105	17.7	143	23.5	147	40.5	69.4	136	1,354.80
S10 0.0m	98.6	14.6	169	23.6	98.3	32.0	77.6	147	1,180.1
S11 0.0m	159	24.1	339	21.8	136	41.2	117	267	1,875.2
S12 0.0m	56.8	<5	86.2	15.6	64.2	28.3	45.9	74.6	<686.80
S13 0.0m	53.0	<5	89.1	17.7	65.3	26.8	49.9	77.0	<695.70
S14 0.0m	84.8	<5	112	21.8	84.2	37.6	60.4	107	<968.3
S15 0.0m	52.4	<5	72.1	15.6	53.7	23.9	50.9	65.1	<281.3
S16 0.0m	74.1	<5	102	19.1	85.0	27.1	60.3	87.4	<381
S17 0.0m	37.2	<5	59.2	13.3	45.7	22.0	40.9	53.0	<520.1
S18 0.0m	69.2	13.5	97.7	16.7	81.9	30.3	53.4	95.7	896.3
S19 0.0m	28.3	<5	42.4	<5	29.8	16.1	32.8	39.8	<354.7
S4a 2.2m	144	30.1	240	33.2	160	48.2	121	211	1,840.17
S4a-1.2m	88.3	22.3	141	25.8	127	44.5	75.9	135	1,250.73
S4 2.2m	142	28.3	224	30.1	158	48.6	117	193	1,711.44
S4 1.2m	107	23.5	162	30.2	134	46.4	85.8	152	1,394.2
S3 1.7m	87.2	19.9	128	24.0	117	38.8	78.5	114	1,113.70
S1 1.8m	119	27.0	176	30.5	158	48.2	100	160	1,539.94
S10 1.3m	26.9	5.15	44.4	5.92	26.8	7.88	26.1	40.8	332.31
S12 1.6m	89.3	22.0	127	21.1	122	38.9	75.8	115	1,178.61
S13 1.0m	129	34.1	190	30.6	190	53.2	99.1	186	1,788.10
S14 1.4m	207	33.3	375	40.4	171	34.1	239	332	2,464.33