5.3 Soils and Geology

This Chapter of the EIS describes and assesses the impact of the proposed development on soils, geology and hydrogeology within and immediately outside Dun Laoghaire Harbour.

Information has been provided in the following sequence:

- Maritime: 5.3.1, 5.3.2, and 5.3.3
- Landside: 5.3.4, 5.3.5, and 5.3.6

5.3.1 Introduction (Maritime)

Throughout its history the harbour has had many developments. Currently there are a number of berthing piers used primarily for merchant vessels such as the high speed ferry to Anglesey, (now discontinued). In addition there are two marina breakwaters both of which are located on the western side of the harbour and provide berthing for approximately 850 boats. The construction of these developments has successfully taken cognisance of the local soils and bedrock conditions.

Thus, the geotechnical regime of the harbour area has been established over many decades from the works undertaken. This information has been collated in the form of a desk study review of geological mapping records, previous ground investigations within the harbour and further afield within Dublin Bay as well as a recently commission ground investigation.

5.3.2 Methodology (Maritime)

5.3.2.1 Guidelines for Assessment

The Institute of Geologists of Ireland (IGI) put forward the view in 2002 that there was no formal methodology for assessing the extent and degree of impact that a project may have on geology and hydrogeology. This was due to the fact that 'geology' is not listed as an issue to be dealt with in the existing legislation (Second Schedule of the 1999 EC (EIA) Regulations (S.I. No. 93 of 1999) which identifies Human Beings, Flora, Fauna, Air; Climate, Landscape etc. Although 'Soil' is cited in the legislation, it was debatable if the scope extended to geology as such.

To address this IGI produced a document 'Geology in Environmental Impact Statements – A Guide, September 2002'. The IGI Guidelines deal mainly with terrestrial developments thus 'Soils' in a colloquial sense may cover a wide range of topics, as listed below:

- Mineral soils: Their name, texture, colour, geochemistry, setting etc which is essentially a description of 'top-soils'.
- Geology (superficial and bedrock): The regional and local setting, site investigation and geophysical details.
- Peat / Fens: Type of peatland, setting, stratigraphy, morphology, hydrology.
- Estuarine Sediments: Description should include, type, thickness, engineering characteristics.
- Vibration: Distance to residences, structures, animals from blasting activities (if any).
- Aquifers: Geometry, classification, annual recharge, water table fluctuations, physical parameters, flow directions, water quality, abstractions etc.

In 2013 the IGI published updated guidelines (Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements) in relation to the EU

Environmental Impact Assessment Directive to consider 'soils and water'. In the context of Irish State legislation the IGI 'Guidelines' define the requirement to assess the potential impact of a development on soil and water to be interpreted as an assessment of the soils, geological and hydrogeological environments.

A comparison between the 2002 'Guidelines and the 2013 'Guidelines' shows that not only are the latter twice the length but also differ in content to a considerable extent. One of the main additions to the new document was a recommended to use a four stage assessment process model that is broken down into 13 discrete steps. Guidance and issues to consider are given for each. This addition of a process model along with a more formal lexicon of impact and severity descriptors accounts for a significant proportion of the 2013 'Guidelines' document.

However, one significant portion of the 2002 'Guidelines' that has been removed was the categorisation of geology in the context of Project Type. Under this heading the 2002 'Guidelines' lists 33 categories of project that cover virtually every conceivable form of construction, land use or interaction with soils, rocks and groundwater. Of particular relevance to the Dun Laoghaire Harbour development is Project Type 10 - Ports and Marinas. An extract form the 'Guidelines' in reproduced in Table 5-1 below which provides a useful check list.

Table 5-1: IGI Guidance on Geological Issues to consider for Ports and Marinas (2002)

Project Type	Significance of Geology	Topics
Project Type 10 Ports Sea-water Marinas Fresh-water Marinas	**Impact on rock/soils** - Excavation - Stability - Erosion - Spoil deposition/removal - Erosion and siltation **Impact on groundwater** - Spillages - Seepage from storage areas	Soils Water

An analogous section in the 2013 'Guidelines' gives a set of generic activities such as: Earthworks, Storage / transmission of hazardous materials, Lowering groundwater levels, Discharges to ground, Excavations etc. However, there is no mention whatsoever of marine works. Thus in undertaking this assessment it was decided to draw upon elements of the 2002 'Guidelines' where useful to do so as well as taking cognisance of the extended 2013 'Guidelines'

5.3.2.2 The IGI Process Model

The 2013 'Guidelines' now includes a multi-stage process model. In making the assessment IGI recommend a systematic four stage approach and advocate the use of standardised phraseology and descriptions which are given in an Appendix to the 'Guidelines'.

However it is acknowledge that the method should not be taken as prescriptive to each and every project but rather as a guideline of how the process might usefully evolve from an initial desktop exercise to the information provided in the EIS. IGI note that frequently geologists work in conjunction with engineers. In particular engineering geologists and geotechnical engineers evaluate the natural conditions necessary for the safe construction and operation of many types of infrastructure and earthworks generally. Thus assessment of possible impacts associated durations and magnitude is may encompass multi-disciplinary professional judgement.

5.3.2.2.1 Initial Assessment

Initial Assessment is the first stage of the recommended process model. The first element of this is to 'Establish the Location, Type and Scale of the Proposed Development'. Within the EIS Chapters 3.3 and 3.5 are provided a very full description of location, type and scale of the project, thus reference should be made to that chapter. The narrative is divided into 'maritime' and 'landside' works and also by construction element such as dredging, scour protection, piling, quay construction and various ancillary work relation to access roads etc. These chapters include a description of the proposed methodologies for undertaking these works and consideration of their possible environmental impact and avoidance of same.

Chapter 3.6 also demonstrates that a number of alternative berthing configurations were considered and that the selected option is optimal in respect to minimising the volume of dredging and best from a navigational perspective. Within Section 5.3 Soils and Geology the above is extended to set the development in a historical context as well as a broader geographical and geological context.

The remaining steps in the Initial Assessment are associated with establishing baseline conditions with respect to the soil, geological and hydrogeological environment. Information gathering and investigation are pre-requisites to making informed assessments thus an extensive desk study was undertaken. This encompassed several sources of information: historical mapping, solid and drift geology for GSI, previous ground investigations that covered both the on-shore and off-shore environment, marine sediment sampling for particle size distribution and contaminant analysis, as well as recent and historical bathymetry data.

The findings of the desk study are presented in subsections that follow and on the basis of those studies an initial Conceptual Site Model (CSM) was developed. As described below this was refined on the basis of a ground investigation.

5.3.2.2.2 Direct and Indirect Site Investigations & Studies

The second stage of the IGI Process Model recommends site investigations and other studies. The desk study and the initial CSM informed the type of site investigations that were required to refine the ground model that would cover the full extent of the engineering works.

As anticipated within the 'Guidelines' sometimes there are constraints that limit the ideal scope – as was to prove the case due to some navigational restrictions. Subject to planning approval for the project, further ground investigations to inform engineering design localised to the berth will be undertaken.

However, from the EIS perspective the geotechnical investigation provided site specific classification of the strata and a set of geotechnical and geochemical parameters obtained from both in-situ and laboratory measurements. To a large extent this confirmed the initial CSM but provided more detailed levels on changes in stratigraphy. Those findings are presented in subsequent sections where those aspects which are considered relevant and significant to this particular project are discussed in the context of the construction and operational time frames.

It should be noted that although the IGI Process Model advocates considering the activities associated with the proposed development under the Initial Assessment, the descriptions provided in Chapter 3 go beyond that and take full cognisance of both the desk study and subsequent ground investigation.

5.3.2.2.3 Mitigation Measures, Residual Impacts and Final Impact Assessment

The third stage of the IGI Process Model is to consider mitigation, residual impacts and a final assessment. Due to the nature of the project there are certain activities such as dredging and piling which unavoidably interact with the soils and geology.

Mitigation starts at the design stage and Chapter 3.6 describes how alternative berthing configurations were considered and that the selected option is optimal in respect to minimising the volume of dredged material. The information gained from the ground investigation shows that the material to be normal marine sands and silts which may be safely excavated by suction dredger for subsequent disposal on the Burford Bank. Any pockets of slightly elevated levels of contaminants within the harbour sediments arising from historical practices will be 'diluted' with the non-contaminated material.

Chapter 3.5 also describes the proposed piling using a caisson methodology that will allow removal of shallow marine deposits and then the very stiff boulder clay below. The piles may penetrate to rockhead. During construction the caisson will contain arising and good construction practice should minimise discharge to the harbour waters. The steel caissons will be left in place and reinforced concrete cast internally to form a solid 'plug'. Compared to the geographical extent of the marine sediments, boulder clay and granite the material extraction for piling is miniscule.

Thus the main measures in respect to mitigation are related to (a) minimisation of impact through strategic level decisions, (b) detailed design elements such as scour protection mattresses or selected technology, (c) good construction practices to reduce the risk of accidental pollution or (d) the 'dilution' effect of the mixing that will occur within the dredger hopper of isolated levels of higher concentrations of pollutants with other material.

These mitigation measures and residual impacts are described in the subsections that follow.

5.3.2.2.4 Completion of the Soils, Geological and Hydrogeological Sections of the EIS

The fourth and final stage of the IGI process Model represents completion of the EIS. The manner in which this EIS has been structured is such that this has been incorporated into the earlier stages. The assessment has been partitioned into Maritime and Landside activities and within each potential environmental risks and mitigations have been considered and any residual impacts discussed in context. Thus each activity such as dredging or piling has been dealt with in terms of the construction and operational phase therefore is nothing more in the sense of 'completion' to be added.

5.3.2.3 Desk Study

The desk study followed the normal pattern of assembling and reviewing the physical geography, geology and historical development of the site. The information was drawn from Admiralty charts, historical maps, a series of earlier ground investigations and geotechnical reports relating to Dun Laoghaire Harbour as well as a range of datasets from the Geological Survey of Ireland (GSI).

Some difficulties were encountered with the earlier material due to the absence of accurate spatial references or ambiguity as to the datum level that was being used. With respect to levels it should be noted that there are in effect three: (1) Chart Datum, which generally relates to the Lowest Astronomical Tide (LAT) local to the chart, (2) Poolbeg, which is the datum formally used by the Ordnance Survey of Ireland (OSi) up until 1970 and (3) Malin Head the current datum used by OSi. A number of these datasets were assembled with a GIS (Quantum), but care is required in terms of spatial transformations and datum.

5.3.2.3.1 Geographical Context

Dun Laoghaire Harbour, highlighted in Figure 5.1, is located 12 km southeast of Dublin city centre. The water surface area of the harbour is approximately 66ha and enclosed by the West and East Piers which have a combined length of 4.6km and were constructed in the period 1817 to 1859. The harbour entrance is orientated to the northeast between two roundheads with an opening of approximately 380m between the masonry faces.

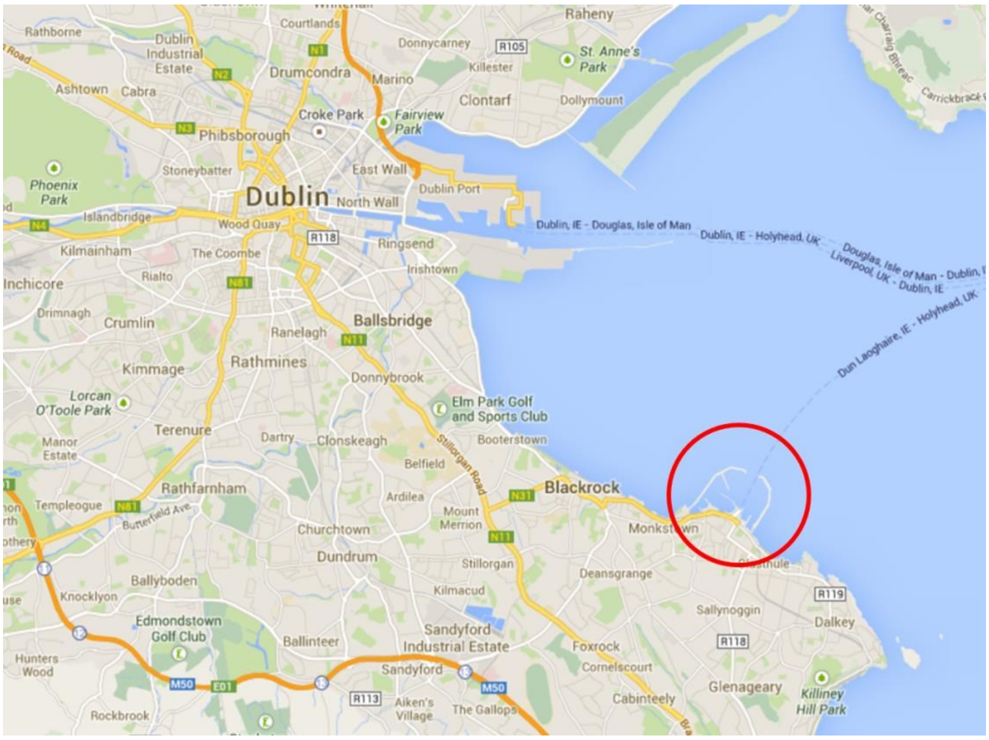

Figure 5.1: Location of Dun Laoghaire Harbour

Throughout its history the harbour has had a number of developments. A review of the historical maps and aerial photographs on-line at the Ordnance Survey of Ireland website (http://maps.osi.ie/publicviewer) was undertaken to assess changes within the harbour. A series of historical twenty-five inch scale (1890-1910), six inch scale (1832 -1842) and more recent aerial photography is available.

Figure 5.2: Ordnance Survey, Six inch, 1832-1842

An early map is shown in Figure 5.2 and dates from soon after the completion of the outer wall of what was then called Kingstown Harbour. With the exception of the 'Coal Pier' located at the 'Old Harbour' on the west there are no other projecting piers. The annotation along the shoreline in the centre of the harbour states 'Proposed Pier', and the main berthing area next to the 'Club Ho(use)' is termed 'New Wharf'.

There are no other significant features shown within the main body of the harbour, however the cartographic detail at the east and west abutments of the harbour walls are worthy of note. Both of these locations show bedrock. The eastern exposure has some outcrops a short distance out from the shoreline and the western area has a more extensive rock shelf.

From the perspective of dredging some comfort may be taken from the fact that no off-shore rocks / shoals are shown. However, when making comparisons between maps covering an extended period one has to allow for the different cartographic conventions that were employed and the degree of accuracy and technology available to the surveyors at the time.

Currently there are a number of berthing piers used primarily for merchant vessels such as the high speed ferry to Anglesey. In addition there are two marina breakwaters (Western and Eastern) both of which are actually located on the western side of the harbour and provide berthing for approximately 850 boats.

5.3.2.3.2 Bathymetry

The Mean Sea Level of the tide gauge at Malin Head, County Donegal was adopted as the national datum in 1970 from readings taken between January 1960 and December 1969. All heights on National Grid mapping since then are in metres above this datum. Earlier maps used the low water mark of the spring tide on the 8 April 1837 at Poolbeg Lighthouse, Dublin. Initially fixed for County Dublin, it was adopted as the national datum approximately five years later. Heights relative to this datum were originally given in feet. There is a significant difference between these references with Malin Head datum being approximately 2.7 m above the Poolbeg Lighthouse datum.

The navigational chart for the harbour shows depths ranging from 2.0m to a maximum of 11.2m. The deeper area is in general aligned with and in the vicinity of the RoRo terminal used by the high speed ferry. It is likely that this deeper pocket has been formed by scouring action induced by the ferry itself.

A number of hydrographic surveys were undertaken within the harbour area during the period 2010 to 2013 where the depths have been expressed to a chart datum. This sequence of surveys shows little change in bed level and consequently little deposition of sediment in the harbour. However, these more detailed surveys show that the scour hole associated with the high speed ferry berth actually has a depth of approximately 15.5m.

The GSI has been conducting detailed off-shore and near-shore seabed surveys for a number of years. This INFORMAR dataset is available (by downloading) and covers the harbour and offshore areas. For consistency, internal and external to the harbour, an extract of the GSI data has been used to generate the water depths, subsequently used in the ground investigation schedule. From information (verbal) received from GSI their depths are relative to LAT.

The GSI data shows that the ground investigation within the harbour area will be in mean water depths of between 4m and 11m, and outside the harbour the mean depths are in the range 7m to 10m.

5.3.2.3.3 Chemical Surveys

Part of the process of designing the 2014 ground investigation was to review previous chemical surveys. A summary of the relevant aspects of those findings is presented here.

Historically the turbidity levels in the harbour are generally low and there has been no requirement for routine dredging. However, a series of engineering works and one dredging contract have resulted in a series of sediment samples being taken over the last two decades.

The results from these surveys give a somewhat mixed picture, but also have to be seen in a spatial context as they relate to a variety of locations within the harbour.

A 1994 survey found elevated mercury levels in the Old and Coal Harbours. The 1998 survey found elevated Tri-Butyl-Tin (TBT) values in the Coal Harbour but an order of magnitude lower in the main harbour. This survey found mercury concentrations of 4mg/kg in sediments in the area between the Carlisle Pier and the East Pier.

In June 2002 and February 2003 sediment sampling, dynamic probing and archaeological investigations were undertaken in parts of the harbour where dredging was proposed. No substance in concentrations that would have prohibited or restricted the proposed dredging was encountered. A further series of sediment samples and chemical analysis was undertaken which were associated with various harbour developments and these are cited in the East Bight Marina Report, RPS, dated September 2008.

5.3.2.3.4 Application of the Desk Study

The findings of the desk study which also included a review of the geology (discussed later) enabled an initial Conceptual Site Model (CSM) to be developed. These findings were included in the documentation for the Dun Laoghaire Harbour Site Investigation contract. In addition to providing background information to contractor the bathymetry, superficial and bedrock information was used to develop the schedule of drilling and probing locations.

The purpose of the 2014 ground investigation contract was for sediment sampling, dynamic probing and drilling in order to gather soil and rock core samples to assess the conditions and material properties within the harbour for a preliminary assessment of a berthing structure and inform decisions on the approach channel which requires dredging.

5.3.2.4 Ground Investigation (2014)

The main ground investigation works comprised sediment grab sampling, dynamic probing and drilling to gather soil and rock core samples.

Soil samples recovered from the boreholes were taken to an approved testing laboratories by the contractor. In summary, the objective of the ground investigation works was to ascertain:

- the depth and the nature of soil horizons and bedrock;
- the engineering properties of the materials and provide information for the preliminary design of berthing facilities and the cut faces to the dredged channel;
- recording site and laboratory data in a factual report on the ground conditions.

The numbers, location and type of intrusive investigations scheduled took cognisance of information received from the client and other stakeholders who use the harbour. At the time the contract documentation was being prepared various constraints were imposed upon the locations and nature of activities that could be undertaken; in particular jack-up barges were not to be deployed within Fairway 1 and the investigations were not to extend beyond the seaward jurisdiction of Dun Laoghaire Harbour. These constraints constituted significant operational restrictions on the objectives and furthermore parts of the proposed dredging extended beyond the spatial limits.

Subsequent to the issue of the Invitation to Tender (ITT) there was some relaxation in relation to Fairway 1 with a narrower corridor being reserved for the high speed ferry access. This enabled some borehole positions to be repositioned closer to the area of interest and a revised scheduled to be prepared. The final ground investigation locations are shown in Figure 5.3 which gives sufficient coverage for the EIS but the intention is that, subject to the proposal receiving planning consent, addition ground investigation will be undertaken to inform the detailed engineering of the piles.

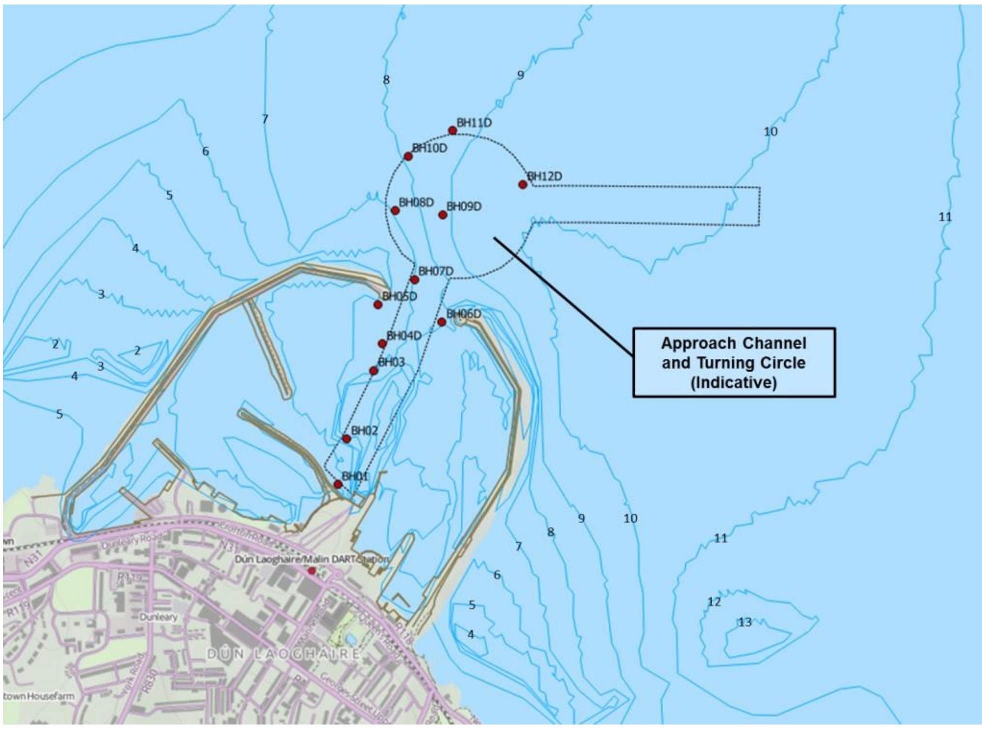

Figure 5.3: Ground Investigation (2014) Locations

5.3.3 Soils (Maritime)

In colloquial terms 'soils' are often taken to be both the superficial soils (termed drift) and the solid geology, however in the context of this project a distinction must be made. The descriptions of these horizons are drawn largely from the Geotechnical Factual Report produced by IGSL Ltd into the investigations undertaken during May and June 2014 in Dun Laoghaire Harbour (DLH).

This report (contained in Appendix 5.3.1, Volume 2 of this EIS) along with a summary of their findings presented below, plus the desk study information allowed the initial Conceptual Site Model to be updated and constitutes the best available description of the receiving environment.

5.3.3.1 <u>Receiving Environment</u>

5.3.3.1.1 <u>Solid Geology</u>

Although the on-shore area of the Dublin region has been extensively studied the bedrock geology of Dublin Bay itself is poorly defined. However, as part of the investigations into a long sea outfall from Ringsend Wastewater Treatment Works twenty-three off-shore boreholes were drilled along two trajectories extending eastwards into the bay.

The onshore geology of the Dublin area is shown in Figure 5.4, and is based on digital data available from Geological Survey of Ireland (GSI). There are two dominant bedrock types, limestone to the north and granite to the south. In more detail this comprises Lower Palaeozoic rocks (including the Bray Group), Leinster Granite and several Carboniferous formations. The central region is dominated by what is commonly referred to as 'Calp' limestone with two inliers of Lower Palaeozoic rocks at Balbriggan and Portrane. To the north are more Lower Palaeozoic rocks. A small fault-bounded inlier of Bray Group is also found on the Howth peninsula along with Waulsortian limestone.

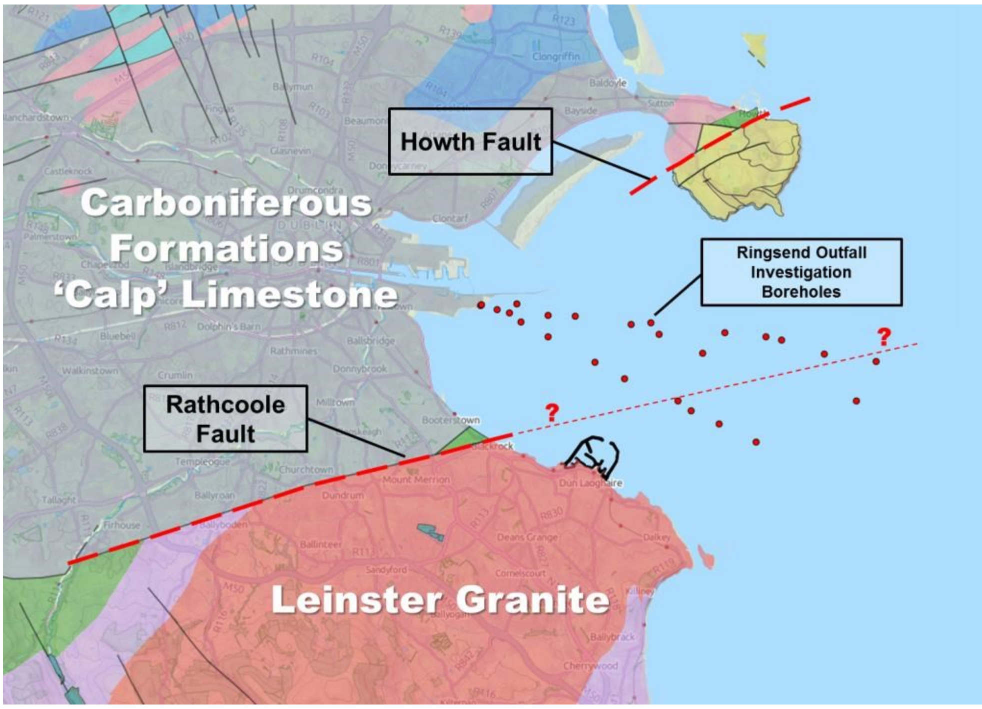

Figure 5.4: Solid (Bedrock) Geology of the Dublin Bay

The most notable faults are the Rathcoole Fault which bounds the Leinster granite and the Howth Fault which passes through Balscadden Bay on the Howth peninsula. The Rathcoole Fault, forms the southern margin of the Dublin Basin, where there is an unconformity between the Leinster Granite and Carboniferous rocks to the north. Its onshore trace is accurate and if the continuation of this structure eastwards into Dublin Bay has a similar trend, then it may be expected to pass through the line of Ringsend boreholes. However, in a review of these borehole logs by McDonnell (2013) no granite was encountered.

Although the bedrock mapping stops at the shoreline it is clear from the alignment of the geology that there is likely to be continuity off-shore at least as far as the area of interest in Dun Laoghaire Harbour. That being the case, the bedrock beneath the harbour is granite with microcline phenocrysts and this has been confirmed by the 1993 ground investigation for the RoRo ferry terminal. The depth to bedrock in the vicinity of St Michaels Pier is between 3–4m at landfall to 16-19m at the seaward end.

Due to the requirement for dredging to accommodate the large cruise vessels the area of interest extends well beyond the end of St Michaels Pier through the harbour entrance and several hundred meters beyond. No historical information relating to bedrock levels could be identified for this area.

It may be that the trend observed at St Michaels Pier continues seaward, but the evidence is sparse as the closest information relates to the Ringsend boreholes some 2.5km offshore where the depth to bedrock ranges from approximately 30m to 60m. The bedrock surface if interpolated from the Ringsend dataset to the shoreline within the harbour suggests the presence of a trough orientated to the northeast.

Although the above inference is based on sparse borehole data given the general depths to bedrock (and its virtual absence in the 2014 Ground Investigation discussed below), it is considered that the dredging depths for the proposed project would be very unlikely to reach bedrock.

Of the 12 boreholes in the 2014 Ground Investigation one (BH01) was taken to bedrock. This established granite at a depth of 19.50m below seabed level (-23.57m Chart Datum (CD)). The granite is classed as medium grained, crystalline and moderately weathered. Borehole BH01 is one of three boreholes in the approximate vicinity and orientation of the proposed cruise liner berth. Bedrock was not encountered in BH02 or BH03 which were terminated at depths of 25.20m (-31.37mCD) and 26.50m (-34.05mCD) respectively in grey / black boulder clay.

As illustrated in Figure 5.5 below, good core recovery was obtained in BH01. This provides an understanding of the rock quality and fracture state showing discontinuities are medium and closely spaced and surfaces range from smooth to rough and planar. The discontinuity surfaces contain clay smearing and dips are 45 to 60 degrees and locally sub-vertical.

Figure 5.5: Granite core recovery from BH01

Point load tests were conducted on sections of the recovered core which indicated a characteristic strength of 60,000 – 70,000kN/m^2; characteristic of strong rock.

5.3.3.1.2 Superficial Geology

On the basis of a 1993 ground investigation, the harbour bed is described as comprising loose / soft and clayey silts. These appear to represent normally consolidated marine deposits and range in depth from 1m to possibly 3m. This material was in places particularly soft and SPT rods sank 2 to 3 metres under self-weight.

The Quaternary material below the silts is heavily consolidated boulder clay with granular horizons characteristic of a fluvio-glacial deposition process. There was no obvious pattern to the distribution of the granular horizons. A large proportion of the boreholes encountered prominent boulders and cobbles typically in the 200mm x 150mm size range.

The superficial deposits in the Dun Laoghaire area consist of very heavily over-consolidated glacial till frequently concealed by made ground / fill (typically reworked glacial till). IGSL note that intra-glacial sand and gravel horizons are prevalent in the area on-shore and have given rise to issues with perched water and tunnelling works for Dun Laoghaire Main Drainage.

This generalised description largely draws upon on-shore ground investigations. An examination of the DLH borehole logs and material descriptions suggest that the over-consolidated glacial till continues off-shore to what is now the marine environment, but that these are overlain by more recent and softer marine sediments.

The upper deposits consist of grey sandy SILT and grey brown silty SAND containing shell fragments. The material exhibits a laminated structure, which can arise from storm events. The boreholes at the proposed berthing area showed these marine sediments to have a thickness of up to 8.50m with elevations of -12.60m to -14.70m Chart Datum (CD).

The particle size analysis on the marine sediments shows, on the whole, a high proportion to be in the 0.1mm to 0.5mm size range. Determination of the strength using Standard Penetration Tests (SPT) classified the fine sand as very loose in consistency while that of the silt to have a low shear strength. The materials encountered are as anticipated and characteristic estuarine and marine sediments.

Underlying the geologically recent marine sediments is a very heavily over-consolidated glacial till or 'boulder clay'. This material consists of grey brown and dark grey or black, slightly sandy gravelly CLAY / SILT with cobbles. Localized lenses of sand and gravel were encountered within this sequence and these are characteristic of lodgement till deposits and reflect the heterogeneity of the material, Figure 5.6. The glacial till is colloquially referred to as Dublin Boulder Clay and has a high matrix strength with prevalence of cobbles. Penetration with cable percussive boring techniques proved difficult and required the use of rotary drilling techniques.

Figure 5.6: Example of 'Dublin' Boulder Clay

In the borehole log descriptions IGSL differentiate between the upper and lower glacial till which is stated to occur approximately 15m below seabed level. Characterisation tests were undertaken on the glacial till and show it to have a low plasticity. SPT values for the lighter grey upper till classify this as having a very high strength (c. 150 – 300 kN/m^2) and that of the lower dark grey till as having extremely high strength (c. 300 – 600 kN/m^2). From an engineering geological perspective, the dark grey glacial till is deemed to have the inherent stiffness and strength of a very weak rock, such as a mudstone.

5.3.3.1.3 Made Ground

A comparison between the current configuration of Dun Laoghaire Harbour and the earliest mapping shows that there are significant areas of made ground due to a series of developments of piers and breakwaters that have successively moved the shoreline outwards.

With the exception of a small area where the new pier connects to the current infrastructure, some terminal buildings and road realignments the majority of the works will not be on made ground. None of the geotechnical investigations undertaken during 2014 were in made ground.

5.3.3.1.4 Sediments

The build-up of sediments within the marine environment is a natural process fed by the network of freshwater fluvial systems offloading sediments gathered from erosion and runoff from land. Once mobile within the oceans, sediments may be carried and deposited along shorelines or within sheltered areas such as harbours.

Contaminants entering the water courses may become adsorbed to sediments and the build-up of sediments over time can increase contaminant concentrations. Sources of contamination that can build up in marine sediments derive from processes such as industrial waste water, sewage effluent, agricultural runoff, marine transport and isolated pollutant incidents. As concentrations of contaminants potentially build up within sediments they can act as an ongoing source of contamination to the environment. Common contaminants within a marine environment are heavy metals as they do not readily disperse or dilute when mixed with saline water and instead collect within settled sediments and become immobile as marine sediments build up over time.

Due to these potential contaminative issues sediments should be tested prior to dredging to ascertain their quality and potential impact on the marine environment.

In view of this, samples of marine sediments were taken within an area to be dredged as part of development works for a new terminal and berthing facility within Dun Laoghaire Harbour. Samples were sent for chemical analysis including particle size analysis to National Laboratory

Services, Environment Agency for England and Wales. Sampling and laboratory chemical analysis were conducted in accordance with the Marine Institute Guidelines 2006. Sampling consisted of (A) 10No. surface 'grab' samples completed by Hydrographic surveys Ltd in November 2013, (B) 12No. boreholes extracting samples from between -13.08 to 14.96CD completed by IGSL Ltd between May and June 2014, and (C) 13 No. surface 'grab' samples completed by Hydrographic Surveys Ltd in January 2015. (refer reports in Appendices 5.3.2 and 5.3.3, Volume 2 of this EIS)

5.3.3.1.5 Sediment Quality

The laboratory results of the analysis were compared against Marine Institute Guidelines for the Assessment of Dredge Material for disposal in Irish Waters, to assess their suitability for disposal at sea. The Marine Guidelines state a lower and upper level of concentrations. All contaminants with concentrations below the lower level screening level (Class 1) are considered a low risk to the marine environment. Concentrations between the lower and upper level (Class 2) are considered marginally contaminated. Concentrations higher than the upper level (Class 3) are considered likely to cause harm to a marine environment.

No detectable traces of Organotin Compounds were observed in any of the sediment samples screened. Therefore all samples are classified as Class 1 in accordance with Marine Institute Guidelines.

DDT and PCB testing showed no detectable traces on all samples with the exception of a minor elevated DDT concentration at one location within the harbour area.

No samples analysed showed elevated concentrations of Total PAH when compared to the Marine Institute Guidelines. Therefore all samples are classified as Class 1.

The majority of sediment samples showed heavy metal concentrations below the lower level screening guideline value. The samples with the highest heavy metal concentrations were those at depth, samples taken at the surface showed much reduced concentrations suggesting the most heavily contaminated sediments had come from historic industrial activities. Although heavy metal concentrations were observed within the harbour area the highest concentrations were observed from locations beyond the harbour walls within Dublin Bay, again suggesting a historic source from local rivers and streams washing contaminated sediments from upstream.

Although there are some elevated concentrations of metals and DDT within the sediments at specific sampling locations these are not considered to be significant, considering the isolated occurrence of elevated results observed in sediments throughout the dredging area. In view of this and based on the current results the sediments from Dun Laoghaire harbour and Dublin Bay area are considered suitable for disposal at sea.

The results of the environmental laboratory testing carried out as part of the 2014 and 2015 sediment surveys were sent to the Marine Institute who found no objection, on the basis of sediment chemistry alone, to this material being dumped at sea – all subject to a later full EPA licence application.

5.3.3.2 Characteristics Of The Proposal

5.3.3.2.1 General

The proposal consists of the dredging of an approach channel, the construction of a piled quay, and associated landside works, all as described in detail in Chapters 3.3 and 3.5.

5.3.3.2.2 Piling

The preferred configuration for the jetty structure will have three main elements. Starting from on-shore there will be an 9.1m wide causeway which will lead to a 120m long by 20m wide quay structure positioned approximately mid-length of the ship. Extending from this quay to approximately 30m beyond the stern of the ship will be a 2m wide walkway linking breasting / mooring dolphins.

The access causeway, quay and walkway will be supported on large diameter piles which, where possible, will be taken down to bedrock. The mooring/breasting dolphin piles may be up to 3m in diameter, but others will typically be in the range of 750mm to 1000mm diameter.

On the basis of information currently available only one borehole (BH01) from the 2014 ground investigation encountered bedrock in the vicinity of the jetty, but it is intended to undertake further ground investigations to establish rockhead over a more extensive area to inform the detailed engineering design.

5.3.3.2.3 Dredging

Bathymetric surveys from 2007, 2010, 2011 and 2012 have been made available and these were supplemented by additional survey work in November 2013. Due to the low turbidity routine dredging has not been required and the last maintenance dredging within the harbour was undertaken in 2002. Water depths outside the roundheads are sufficient for all the current port traffic and hence no dredging has been undertaken external to the harbour.

Of interest, it should be noted that a significant scour pocket exists in the vicinity of the HSS ferry berth with the 2007 survey giving a maximum depth of approximately -14.5mCD. Subsequent surveys show depths in the range of -13.5mCD to -15.5mCD but the current Admiralty Chart (2012) gives a maximum depth of -11.2mCD. It is unclear if these variations reflect actual fluctuations in sediment deposition and scour or arise from the survey technique.

An examination of the bathymetry outside the harbour entrance shows that the 10.0mCD contour runs approximately north to south. Hence the shortest route into deep water is to turn the ship outside the harbour entrance and run the dredged channel approximately eastwest to open water and northeast southwest into the harbour.

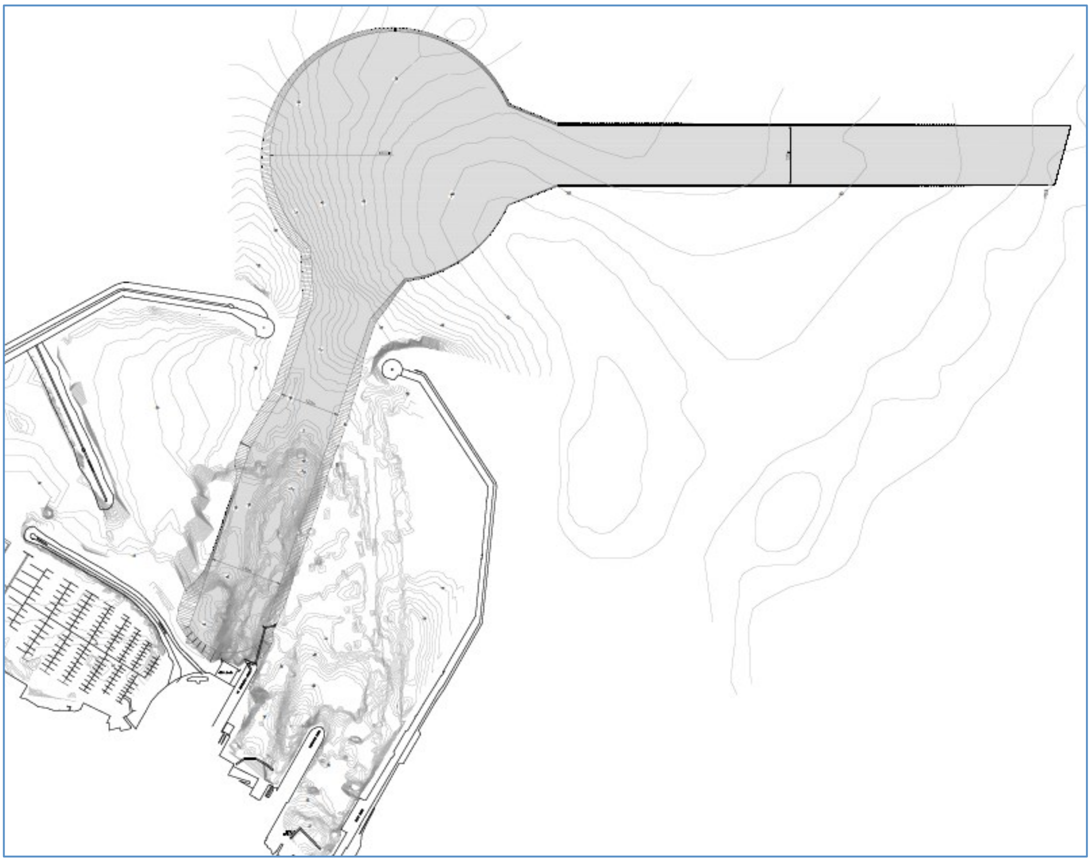

Figure 5.7: Turning Circle and Approach Channel (General Concept)

The position of the access channel has been selected to the west of the HSS pier as this provides an optimal navigation route into and out of the berth. This configuration also minimises the total volume of dredged material which will total approximately 710,000m^3.

5.3.3.3 Potential Impact of the Proposal

5.3.3.3.1 General

The potential impacts of the proposal may be considered within a temporal framework (construction and operational phases) and also by material type (resident materials and transient materials).

During the construction phase temporary impacts on water quality can occur from mobilised sediment arising from dredging or to a lesser extent from piling. A potential risk during both the construction and operational phases is that some suspended sediment may contain toxic contaminants (refer Table 5.2 below).

The Institute of Geologists of Ireland 2013 'Guidelines' provides a series of expressions by which the impact assessment may be classified. These are in accordance to the EPA 202/3 terminology and is in four parts – Quality, Significance, Duration and Type, each of which has associated attributes. In addition the 'Guidelines provides the NRA 2008 lexicon which for the purposes of a marine project such as the proposed development are overly complex.

In this EIS the EPA style descriptors have been used to assess the impact of the various activities and this is shown in Table 5-4 later in this section. Prior to that tabular presentation, which forms a summarisation, there are narrative descriptions of the actions, mitigations and impacts. The latter are expressed in a single more colloquial expression that is intended to capture the dominant outcome to the four part tabular assessment, which may be more readily assimilated by the lay person.

5.3.3.3.2 Construction Phase (Geology)

As described above, the geology, in descending sequence, may be considered to comprise soft marine silty / sandy sediments, stiff boulder clays and granitic bedrock. The bedrock and boulder clays lie entirely below the dredging activity and will be minimally impacted by the piling alone.

There will be normal construction activity and plant related risks such as accidental spillages of fuels, hydraulic oils, 'wet' concrete or other substances, but pathways to link these incidents to the deeper geological strata are implausible. Furthermore, these risks should be controlled by good construction management practices.

The 'footprint' area of the piles in the context of the jetty and the harbour as a whole is very small and, as neither stratum has any special designation, the marginal impacts are not significant.

Given the location and bathymetry none of the geo-hazards listed in the IGI Guidelines, such as triggering of landslides, subsidence or contamination of aquifers are considered plausible. The dredged channel is sufficiently remote from the existing roundheads and at a higher level than the foundations to avoid any potential problems with undermining.

5.3.3.3.3 Construction Phase (Sediment)

Potential Impact of Dredging and Depositing of Sediments at Burford Bank

- Dredging and depositing of the sediment will result in a localised and temporary increase in suspended sediments whilst dredging and depositing is occurring;
- Suspended sediments may persist in suspension for a period after dredging/depositing;
- Re-suspended sediments will be deposited in the vicinity of the dredger or distributed wider;

- Depositing of sediments may result in uneven thicknesses of seabed at Burford Bank; and
- Depositing of sediments may result in contamination of the marine environment within the Burford Bank area.

Assessment of Potential Impacts

Impact of Dredging

The marine investigation conducted by ISGL Ltd in 2014 shows that the sediment material is almost entirely (approximately 90%) unconsolidated sands with a small volume of silt close to the HSS birth. These materials are designated as suitable for the proposed dredging method.

A detailed assessment of the impact of dredging of marine sediments within the Dun Laoghaire Harbour area has been completed by ABPMer Ltd in Report R.2307 October 2014 (refer Chapter 5.4 Coastal Processes, and EIS Appendix 5.4.1, Volume 2 of this EIS). In summary the assessment concluded that dredging of the sediments will likely result in a localised temporary increase of suspended sediments. Re-suspended sands will be deposited in the order of minutes and for silts hours from the end of dredging. Fines may persist in suspension in the order of hours up to a day within the harbour. Less of an impact will occur in Dublin Bay as any suspended sediment plumes are unlikely to affect more than a few tens of metres from the dredger. Therefore it is considered that the capital dredging scheme will have a negligible impact.

Impact of Disposal at Burford Bank

Depositing of the sediments is likely to result in a localised temporary increase of suspended sediments. The majority of the sediment load will likely fall directly to the seabed as a coherent unit or gravity flow, without entering suspension. Sandy sediments placed in suspension will settle out within 15 to 30 minutes from release; silty sediments will settle out within 7 to 12 hours from the time of release. Fines will likely remain in suspension in the order of days or weeks from the time of release dispersing to negligible levels. Therefore it is considered that the physical depositing of sediments will have a negligible impact.

Construction Phase Impacts

The construction project has been designed with mitigation to limit the impact on the receiving marine environment – refer EIS Chapters 3.3, 3.5, 3.6, and 5.2.

Impact of Sediment Contamination at Burford Bank

Chemical analysis on the sediment samples taken from within Dun Laoghaire Harbour and immediately outside the harbour within Dublin Bay identified elevated concentrations of heavy metals and DDT when compared to the Class 1-3 screening assessment as outlined in the Marine Institute Guidelines.

Due to the sampling density there are isolated peak elevated results. Owing to this fact and the likely effect of sediment mixing during the dredging process, the majority of these isolated elevated concentrations will become homogenised within the overall sediment matrix within the dredging vessel hopper and therefore the overall average concentration will become significantly reduced prior to depositing at sea, which will act further to combine the sediment matrix. For this reason, the contaminant concentrations from the varying sample locations and depths have been averaged for the purpose of highlighting this point and identifying the contaminants of concern. Table 5-2 below shows average contaminant concentrations for the Dun Laoghaire Harbour and Dublin Bay area, compared to Marine Institute Guideline levels.

Table 5.2 Average concentration of contaminants in Dun Laoghaire Dredged Channel

Contaminant	Level 1 / Level 2	Average Concentration mg/kg	Category / Class
Cadmium	0.7 / 4.2	0.17	Class 1
Mercury	0.2 / 0.7	0.04	Class 1
Arsenic	9 / 70	8.77	Class 1
Chromium	120 / 370	98.94	Class 1
Copper	40 / 110	15.58	Class 1
Lead	60 / 218	19.34	Class 1
Nickel	21 / 60	20.24	Class 1
Contaminant	Level 1 / Level 2	Average Concentration mg/kg	Category / Class
Zinc	160 / 410	79.49	Class 1
DDE	0.0022 / 0.027	0.00015	Class 1
DDT	0.0016 / 0.046	0.00198	Class 2

The average concentrations listed in Table 5-2 above show only a minor elevated concentration and a Class 2 classification for DDT. Therefore the sediments are considered suitable for disposal at sea. Owing to the Class 2 concentration being only slightly exceeded for the insecticide the overall environmental impact of the sediment within Burford Bank is likely to be minor.

The Marine Institute Guidelines 2006 specifies a single (Level 1) guideline value for Total PAH (sum of 16) of 4.0 mg/kg. While several samples showed a presence of PAH contamination (most notably sample M5 which contained 1.65 mg/kg), all results were shown to be safely below the Level 1 guideline value.

Sediments from within Dublin Port have been deposited at Burford Bank regularly in recent years under a dumping at sea licence as part of routine maintenance dredging. Contaminant analysis from sediment samples taken in 2006 have been averaged to offer a comparison of the sediment quality between those from the Dublin Port and those from the Dun Laoghaire channel. The results are presented in Table 5.3 below.

Table 5.3 Comparison of average contaminant levels in the Dublin Port navigation channel to those in the Dun Laoghaire navigation channel.

Contaminant	Level 1 / Level 2	Average Concentration of Sediment mg/kg^{-1} (Dublin Port 2006)	Average Concentration of Sediment mg/kg (Dun Laoghaire)
Cadmium	0.7 / 4.2	1.08	0.17
Mercury	0.2 / 0.7	0.233	0.04
Arsenic	9 / 70	13.52	8.77
Chromium	120 / 370	34.86	98.94
Copper	40 / 110	58.862	15.58
Lead	60 / 218	92.39	19.34
Nickel	21 / 60	29.11	20.24
Zinc	160 / 410	298.29	79.49

The table above highlights that sediments within the Dun Laoghaire area are significantly less contaminated than sediments dredged from Dublin Port and deposited at Burford Bank since 2009, therefore the impact of the Dun Laoghaire sediments being deposited at Burford Bank is considered minor.

5.3.3.3.4 Operational Phase (Geology)

With respect to the stiff boulder clay and granitic bedrock no operational impacts have been identified.

5.3.3.3.5 Operational Phase (Sediment)

On the basis of the deep 'pocket' observed at the berth for the HSS ferry, operational related scour of the loose sands and silts is considered as a possibility.

The location of these effects is most likely to occur in the immediate vicinity of the proposed quay structure due to the operation of the main propulsion units and the bow thrusters to bring the ship onto and off the berth. Over the long term these actions could potentially result in localised scour pockets at the landward end of the berth.

Should these scour effects occur the structures for which there would be most concern are the existing breakwater and the high speed ferry berth adjacent to the landward end of the new quay.

The existing roundheads at the entrance to the harbour will not be affected by scour from the cruise ships as:

- The cruise ships will be at least 50m away from the roundheads and will largely be operating with main engines, so the water jet from the propellers will be parallel with the line of the dredged channel.

- The roundheads are founded on competent soils/rock below the loose sands and silts, and at a lower level that the bottom of the dredged channel.

5.3.3.4 Avoidance, Remedial Or Reductive Measures

5.3.3.4.1 Geology

It is intended that scour protection mattresses will be incorporated into the design of the jetty where it joins the existing infrastructure. The flexible mattress will be placed on the inclined face and toe of the breakwater and adjacent quay. These measures will counteract any tendency for high velocity currents from the propulsion units to scour the harbour bed material.

As a beneficial impact, the existing scour hole which runs from -10.5CD to -15.5CD will be filled up to a level of -10.5CD. This will have two benefits:

- It will reduce the amount of dredged material taken to the Burford Bank Spoil Ground by approximately 20,000m^3.
- It will reduce the risk of instability in the existing harbour structures by eliminating the historic scour hole.

5.3.3.4.2 Sediment

Contaminated Sediments

To further determine the extent and distribution of sediments showing an elevated level of contaminants, further investigation, sampling and testing of the sands to be dredged will be undertaken prior to construction. This will enable areas of dredge to be classified as either Level 1 or Level 2 in accordance with the Marine Institute Guidelines. If appropriate the more contaminated materials will be dredged first and placed in the Burford Bank Spoil Ground, and then capped with the uncontaminated material. The use of the Burford Bank for this purpose is acknowledged as being the subject of a Dumping at Sea Licence from the EPA.

Construction Phase

The risk of water and sediment quality impacts associated with construction operations can be controlled by good management practice and adherence to environmental codes and practices. It is considered the impact will be negligible.

5.3.3.5 Predicted Impact Of The Proposal

Table 5-4 provides a summary of the impact assessments (allowing for mitigation) for the various elements of the project described in previoius sections.

The impact characteristics and associated descriptors that have been used are as given in the Institute of Geologists of Ireland 2013 'Guidelines' except for the term 'Do Nothing'. This expression may be confused with having done nothing; whereas it is intended to mean that the environmental status is as if nothing had been done. Thus the term 'Normalised' has been used to indicate conditions reverting to the previous norm.

5.3.3.5.1 Geology (Residual)

With the mitigation measures proposed there are no predicted long term impacts on the geology from the proposal.

5.3.3.5.2 Sediment (Residual)

As pertained to in Section 5.3.3.3 and within the ABP Mer modelling report the lasting impact of the capital dredging and construction works will be moderate but short term in respect of sediment dispersal.

However, following a more detailed assessment of sediments at locations identified as having minor elevated concentrations of metals and DDT there is a greater certainty of sediment mixing within the dredging vessel. Thus the isolated sediments with a greater contaminant concentration can be managed limiting the direct impact on the Burford Bank area thus ensuring the longer term overall impact is slight, if detectable at all compared to material already deposited there.

5.3.3.5.3 Worst Case

The worst case scenario would be in relation to the dredging works and the inadvertent release of sediment into the water column. This potentially could arise from uncontrolled or poorly controlled release of dredged material during loading, transport, or unloading to/ from the dredger vessel. This could cause temporary local increases in suspended sediment concentrations and potentially spread locally beyond the dredger work area.

There is a low chance of occurrence of loss of a total load. Current velocities recorded are low particularly within the Harbour walls thus limiting spread potential. The predominantly sandy nature of the sediment deposits will also limit spread through rapid deposition as has been reported in the Coastal Processes modelling report contained in Appendix 5.4.1 EIS Volume 2, and in Chapter 5.4. Overspill from, and overloading of, the dredgers must be actively avoided through application of good maritime construction practices. The Contractor shall therefore be mandated to document a suitable construction management plan containing avoidance measures stating the emergency actions to help limit spread. On that basis the impact would be local and temporary and slight.

Table 5.4 Impact Assessment Matrix

Phase	Activity	Quality	Significance	Duration	Type
CONSTRUCTION PHASE	**Scour**	**Neutral:**	**Imperceptible**	**Short Term**	**Cumulative**
		Scour is a cummulative effect and there will be some additional marine traffic during the construction phase but change arising from this, if any, is likely to be short term and impercetable.			
	Dredging	**Negative**	**Slight**	**Short Term**	**Normalised**
		During construction there will be slight negative consequences to turbidity. In the sense of a change to bathymetry the action is intended to be irreversable, but normal benthic conditions will re-establish.			
	Marine Disposal	**Neutral**	**Slight**	**Permanent**	**Residual**
		By definition the deposition of dredged material at Burford Bank is permanent and residual, but it is unlikly to change the exist quallity of that environmnet which already receives material from Dublin Port.			
	Piling	**Negative**	**Slight**	**Short Term**	**Normalised**
		During construction there may be slight negative consequences in local turbiudity. However this will be temporary and post construction the environment will revert to its previous state - 'Do Nothing' condition.			
	Scour Protection	**Positive**	**Moderate**	**Permanent**	**Residual**
		The infilling of the existing scour pocket from the HSS ferry is a moderate but positive change and placement of protective matresses is intended to provide a permanent positive benefit to the harbour environment.			
OPERATION PHASE	**Scour**	**Neutral**	**Imperceptible**	**Permamant**	**Cumulative**
		Potential causes of scour in the operation phase arise from normal harbour traffic and the large cruise ships. The navigation approach for cruise ships reduces risk to the roundheads. Propeller scour is catered for as below.			
	Scour Protection	**Positive**	**Slight**	**Permanent**	**Residual**
		It is recognised that currents from bow thrusters or main propulsion, if in the unlikly event of cruise ship berthed stern first, this this will impact upon infrastructure. Scour protection matresses will protect against this.			