Galway Harbour Company

Galway Harbour Extension

Environmental Impact Statement

Chapter 6

Soils

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6.1 INTRODUCTION

The Galway Harbour Extension will involve the construction of Quay walls, land reclamation and dredging. In order to gain an understanding of the Engineering Geological conditions a Marine Drilling Investigation was conducted. A Desk Study of available documents relating to the site was also undertaken.

6.2 INFORMATION SOURCES

Information sources used in the compilation of this report include:

- Aerial Photography
- Geological Map and Memoir
- Admiralty Charts
- Coastal Site Walkover and geomorphology
- Bathymetric Survey [Survey of sea bed levels]
- Overwater Site Investigation [drilling conducted from raft]
- Laboratory testing
- Archaeological Report

6.3 SITE INVESTIGATIONS

6.3.1 Overwater Investigation

6.3.1.1 Intrusive Investigation

The investigation was carried out by Causeway Geotech Ltd in March 2012, using a C5 Combi-float jack up platform, 18x18m in plan fitted with four 17m long legs.
Test locations were marked out using a buoy and the jack was manoeuvred onto position using a work boat. The actual position of each investigation point was then surveyed using a GPS Trimble system.

The works were monitored on a full time basis by a Marine Mammal Observer.

Eight Shell and Auger Boreholes, three Rotary boreholes, twenty dynamic probes and seven CPTu tests were carried out at spacings of between 100m and 300m.

The extent of the investigation consisted of:

- Cable Percussive Boreholes
- In situ SPT testing and sampling
- In situ Vane testing
- Piezocone Penetration Tests
- Piston Sampling
- In situ dissipation tests
- Rotary Core Boreholes
- Dynamic Probes Super Heavy

The Borehole Layout is shown in Drawing 2139-2136-A and Figure 6.3.1 below. The Causeway Geotech Report is presented in Appendix 6.1.

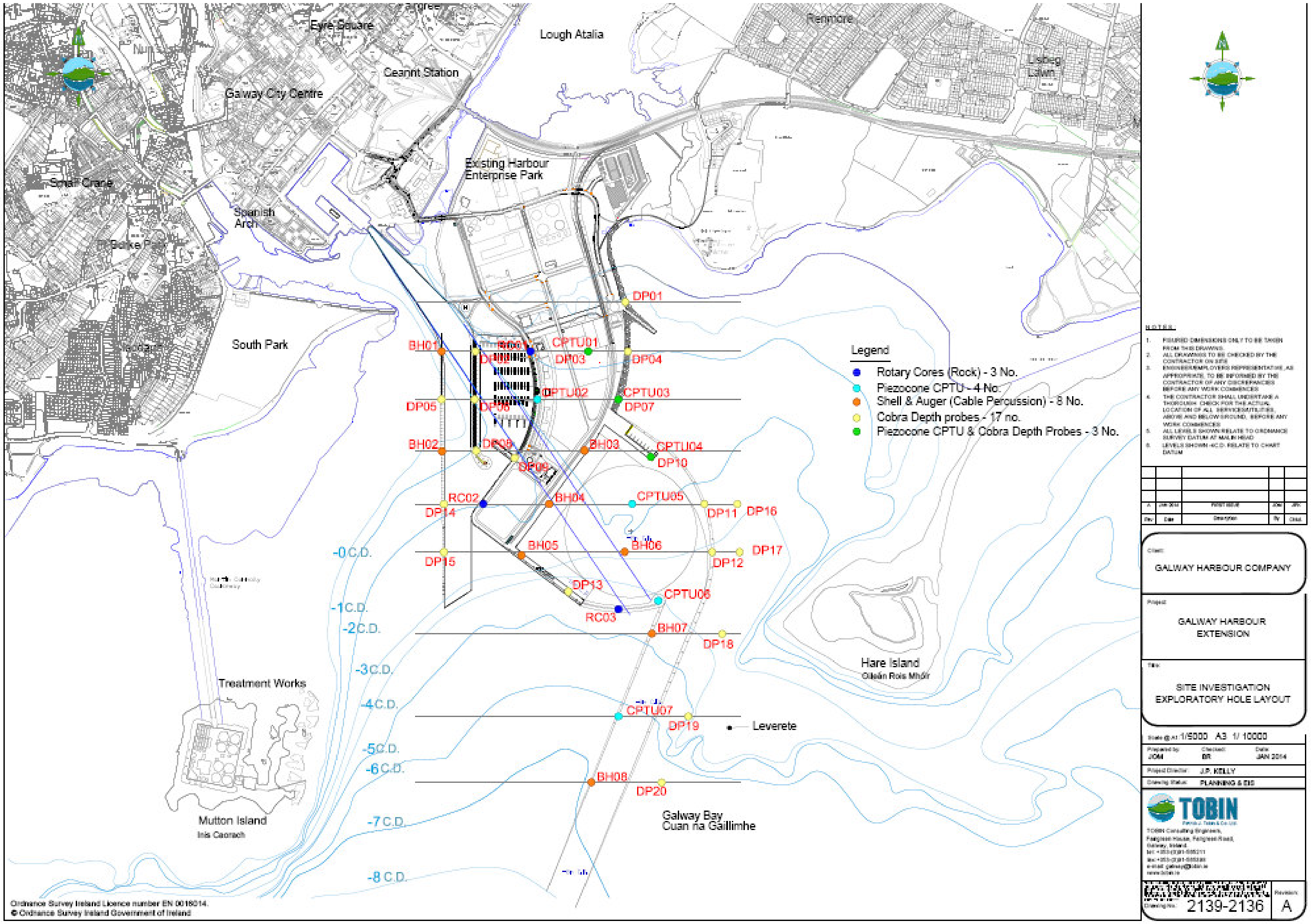

Figure 6.3.1 - Borehole Layout

6.3.1.2 Geotechnical Testing

Laboratory Test Schedules were prepared to provide design information on soil type, classification, strength and consolidation characteristics of the soils and the strength/mineralogy of the rocks. The tests scheduled and their purpose are summarised in Table 6.3.1

Geotechnical Testing		
Material	**Test**	**Purpose**
Overburden	Natural Moisture Content	Classification
	Atterburg Limits	Classification
	Particle Size Distribution	Classification
	Hydrometer / sedimentation	Classification
	Oedometer	Consolidation
	Remoulded Oedometer	Consolidation
	Undrained Triaxial	Shear Strength
	Consolidated Undrained Triaxial	Effective Strength
	pH/Sulphate	Soil Aggressiveness
	Organic Matter Content	Classification
Rock	Point Load Index	Strength
	Unconfined Compressive Strength	Strength
	Petrographic Analysis	Rock Type

Table 6.3.1- Geotechnical Testing

6.3.2 Lough Atalia Road Investigations

Two light cable percussion boreholes were bored to ‘refusal’. In situ testing consisted of Standard Penetration tests carried out at regular intervals. Disturbed bulk soil samples were also taken at each change in strata and were subsequently logged and tested in the laboratory.

Four rotary core boreholes were also undertaken to establish rockhead and to establish the nature and integrity of the underlying rock.

Four trial pits were excavated and subsequently logged for observations on ground conditions, pit stability and water ingress. The trial pits also facilitated the exposure of the foundations of the Lough Atalia Bridge abutments. Foundation records were undertaken. Small and bulk disturbed soil samples were also recovered and returned to the laboratory for testing.

The Irish Drilling Report Site Investigation Report is presented in Appendix 6.2.

6.4 GEOLOGY

6.4.1 Soil and subsoils

The existing Galway Harbour Enterprise Park was constructed on partly reclaimed land south of Lough Atalia at Renmore.

The existing facilities there were founded on rockfill and other engineering fill materials placed directly onto the existing land or onto the alluvium. The reclaimed area is protected by extensive rock armour, comprising large boulders, particularly along its southern margin

The proposed Harbour Extension extends from the southern side of the existing facilities some 935m southwards into the Bay.

The soils immediately south of the rock armour comprise alluvium which consists of sand and interlayered silts and sands with localised clusters of large angular boulders.

The alluvium is underlain by Glacial Till and Fluvioglacial deposits. The Glacial tills are exposed along the shoreline east of the Enterprise Park and on Hare Island. They consist of stiff light brown gravelly clayey SILT/CLAY with some cobbles and boulders. The borehole records indicate that Glacial Till with gravel layers, ranging in thickness from 0.95m to 2.8m with some cobbles and possible boulders present beneath the Alluvium and above the bedrock.

In some areas thin impersistent layers of PEAT/ organic SILT are present between the glacial deposits and alluvium PEAT is exposed on the shoreline south of the Renmore Barracks.

6.4.2 Regional Bedrock Geology

The bedrock geology of the Galway region is described in detail in a Memoir (titled Geology of Galway Bay). An extract from the 1:100,000 scale Bedrock Geological Map Series Sheet 14 is presented in Figure 6.4.1 below. These map series are representative of the distribution of rock types exposed at the surface or under the cover of superficial soil deposits.

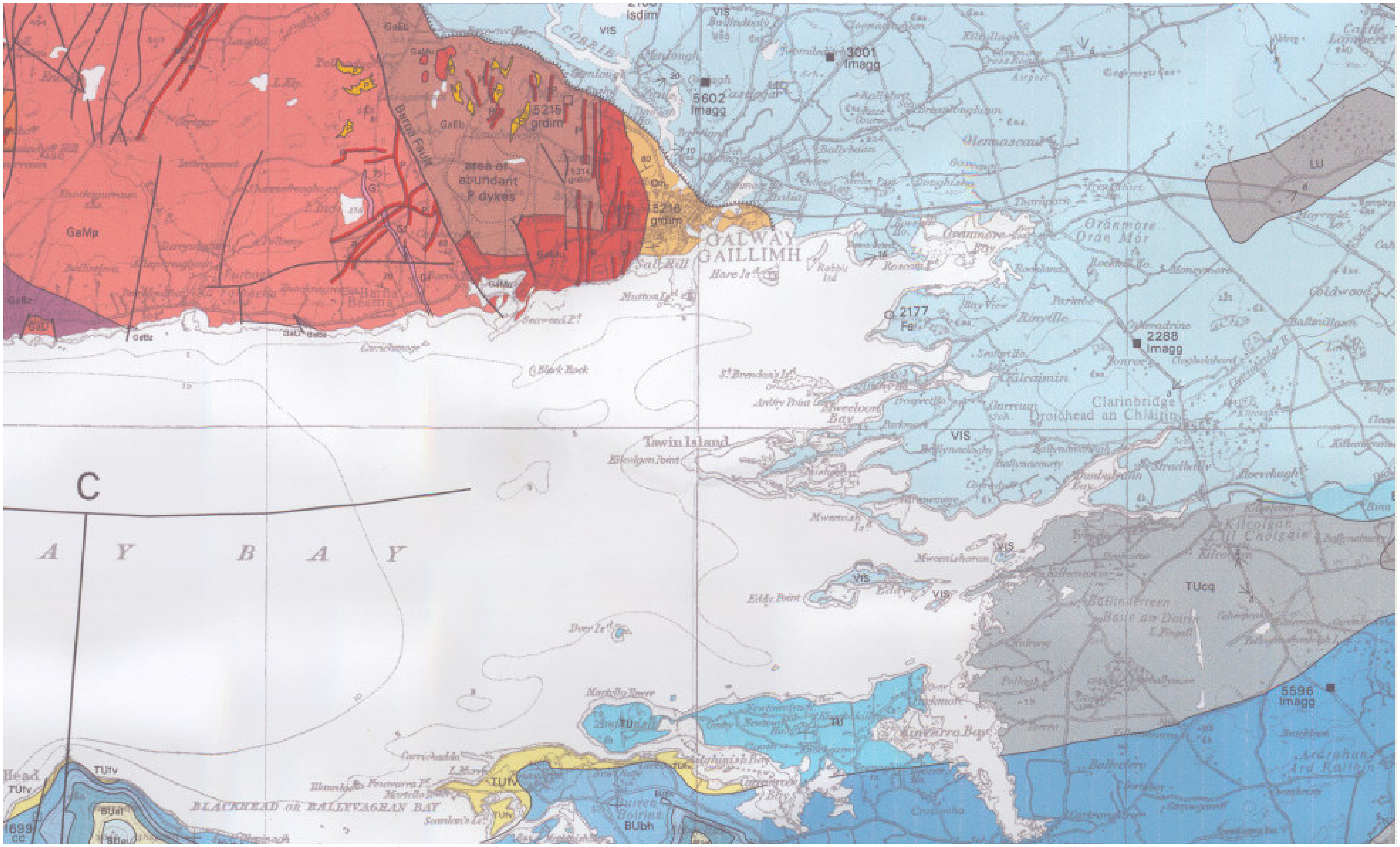

Figure 6.4.1 - Bedrock Geology – Extract from Geology of Galway Bay, Geological Survey of Ireland 2003

A portion of the geological map at larger scale in the vicinity of the proposed harbour is presented in Figure 6.4.2.

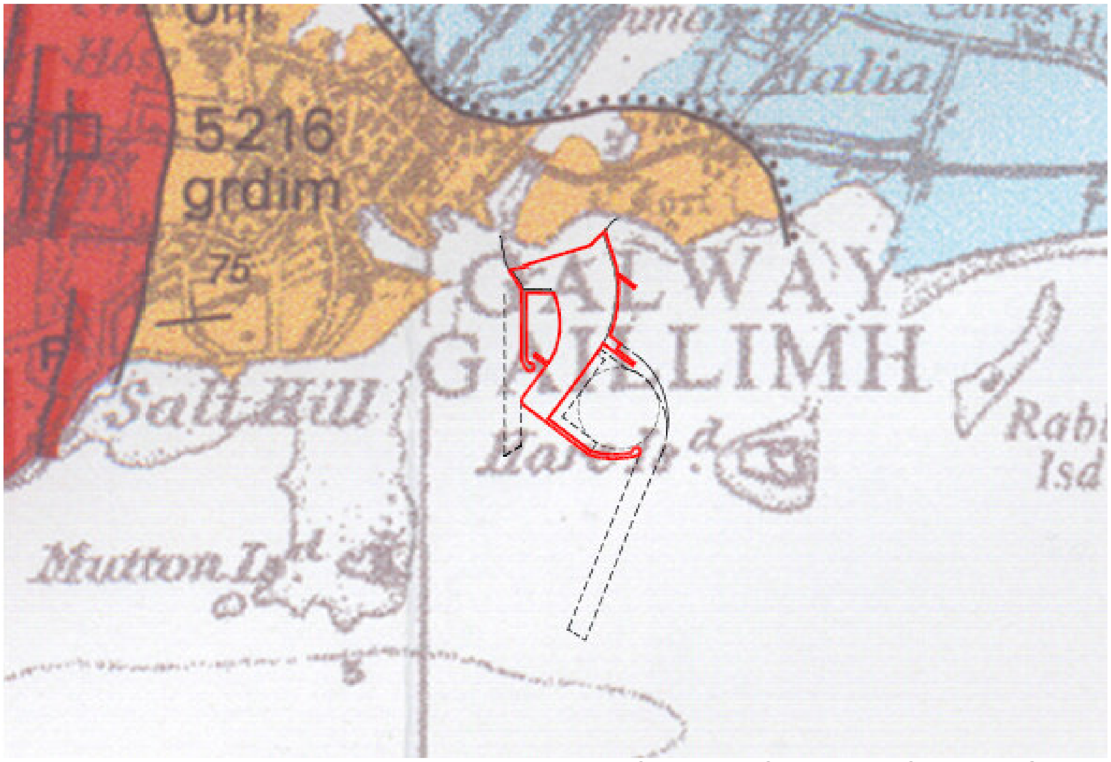

Figure 6.4.2 - Vicinity of Proposed Harbour - Extract from Geology of Galway Bay, Geological Survey of Ireland 2003

South of the existing Enterprise Park, bedrock with clusters of large angular boulders is exposed at low tide along the eastern and western sides of the proposed extension. Aerial Photographs indicate that the rock/boulders extend from the present shoreline due south about 250m into the Bay.

MetaGabbro outcrops are exposed along the shoreline east of the Enterprise Park. Very Strong GRANITE was encountered in the Boreholes drilled at Lough Atalia Bridge

For an aerial photograph see Figure 6.4.3 below. Drg 2139-2117 shows the Bathymetry (seabed levels) of the area in the vicinity of the proposed development.

Figure 6.4.3 - Aerial Photography at low water level showing existing features and outline of proposed development

The Bedrock Geology in the area is quite complicated with rocks from the Ordovician, Devonian and Carboniferous Ages present.

6.4.2.1 Ordovician Period

Beneath the existing docks and the Galway Harbour Enterprise Park are rocks of Ordovician age, which is 440 to 495 million years. These rocks are part of the Metagabbro and Orthogenesis suite. These metamorphosed rocks were intruded during arc magmatism which occurred in the Grampian Orogeny between about 461-475Ma ago. The metagabbros consist mainly of hornblende gabbros and hornblende gabbronorites. The orthogenesis rocks were metamorphosed during crystallisation and usually have a marked foliation. The more Granitic Gneisses are younger and have a weaker foliation. The composition of the orthogenesis varies from quartz diorite, tonalite, granodiorite and granite.

6.4.2.2 The Galway Granite Batholith [Devonian]

The Galway Granite is Devonian aged, from about 380 to 410 million years old, and is about 65km to 20km in area. The granite in the vicinity of the site is the Murvey Granite which is present immediately west of the existing harbour. The rocks are primarily fine grained felsic granites. It has a curved north-south contact with the Ordovician rocks to the east. Many of these rocks were hydrothermally altered with chloritisation of biotite, sericitisation of plagioclase and development of garnets which is the geological signature of the Galway Granites.

Dolerite Dykes have been recorded in the Galway Granite and in the Orthogenesis rocks.

6.4.2.3 Carboniferous Rocks

Carboniferous rocks are present east of the Harbour Enterprise Park and consist of undifferentiated Visean Limestones.

6.4.3 Impacts on Geology

The proposed development will contribute to the current understanding of the Quaternary and Bedrock Geology in the eastern end of Galway Bay. The nearest recorded mineral deposit is the Rinville Mine, where galena, pyrite and sphalerite were mined from Carboniferous Limestones until about 1849. Carboniferous rocks are not present beneath the proposed development

6.5 GROUND CONDITIONS

6.5.1 Made Ground

The existing Galway Harbour Enterprise Park was constructed using imported rockfill, recycled demolition material and selected Glacial till materials. The reclaimed area is protected by extensive rock armour, comprising individually placed large boulders.

6.5.2 Soils

Seabed level in the boreholes varies from –0.3mmCD in DP1 in the north to -7.8mCD in BH 8 some 1,300m south in the Bay (See Drg 2139-2136 for locations of referenced exploratory locations).

Grey slightly silty to silty SAND is present along the shoreline but was not encountered in the boreholes.

Very soft/loose dark grey and greenish grey slightly organic slightly clayey SILT with occasional shells was present in all of the boreholes. An upper layer, ranging in thickness from 1.60m to 3.30m, consisting of slightly sandy to sandy SILT was encountered in all boreholes with the exception of BH 8 The SILTs are interlaminated and interbedded with thin SAND and silty SAND layers. The depth of SILT ranged from 1.50m in DP1 to 12.50m in BH 4. The SILT is between 0.00m and 3.2m thick beneath Lagoons 1 to 5. Beneath Lagoon 6 its thickness varies from 5.2m to 7.1m. The thickest SILT is present beneath Lagoon 7 and varies from 9.0m in the South Western corner of the Lagoon to 12.5m in the east.

The CPTu tests indicate that the SILT is layered in situ. The silt gave off a slight odour of hydrogen sulphide during drilling. A gas pocket was encountered at 7.30m depth on BH 5

At the base of the silt, thin organic layers were encountered in BH's 6,7 ,8 and RC03 , about 0.2m thick, at between 6.60m and 8.60m depth. The layer consisted of firm brown PEAT or peaty SILT.

In BH RC01 a 0.4m thick layer of Oyster shells in an organic silt matrix, was encountered at 2.6m depth. These layers rest directly on the Glacial Deposits.

Glacial deposits are present beneath the Alluvium in all of the Boreholes The Glacial deposits consists of very stiff to stiff grey gravely clayey SILT/ CLAY with cobbles/boulders and with layers of very dense sandy silty GRAVEL with cobbles/boulders

6.5.3 Bedrock

Bedrock was encountered between 3.4m and 14.4m below seabed level which equates to –4.4 m CD and –16.6m CD. The Rockhead slopes generally at less than one degree from North to South.

The rock encountered in the Boreholes consisted of grey, pink and dark grey Granites, with some pale green chloritisation along discontinuities. The rocks are predominantly intact and moderately strong to strong which will therefore be difficult to remove, hence the design has minimised the requirement for rock removal.

6.6 GROUNDWATER

6.6.1 Soils

The overburden consists of interbedded silts and sands with some clays. These units are locally underlain by sandy gravels. Continuous pore water pressure measurements were undertaken at 7 locations. These show a steady increase in pore water pressure with depth. All these deposits are under lowest tidal water level and contain high volumes of saline groundwater.

6.6.2 Bedrock

The bedrock beneath this part of the bay consists of very low permeability GRANITES with some metamorphic rocks. On land these rock units are classified as poor aquifers, which are generally unproductive except for local fracture zones. Where groundwater flow is encountered it is generally in localised systems with little continuity between systems. Examination of the rock core indicates that the rock is unfissured and typically has no visual porosity.

6.6.3 Impacts on Hydrogeology

The saline water contained within the soils is not considered a viable source of clean potable groundwater. It is expected that the bedrock will contain little or no groundwater.

6.7 ENGINEERING CHARATERISTICS OF SOILS

6.7.1 Sand

At low tide it is noted that grey silty to very silty SAND is present on the sea bed

6.7.2 Silt

These soils consist of dark grey and greenish grey slightly organic slightly sandy to sandy SILT underlain by SILT with occasional to some marine shells.

Its moisture content ranges from 25% to 82% with an average moisture content of about 54% based on 45 measurements. A plot of moisture content v depth for the SILT’s is presented in Figure 6.7.1.

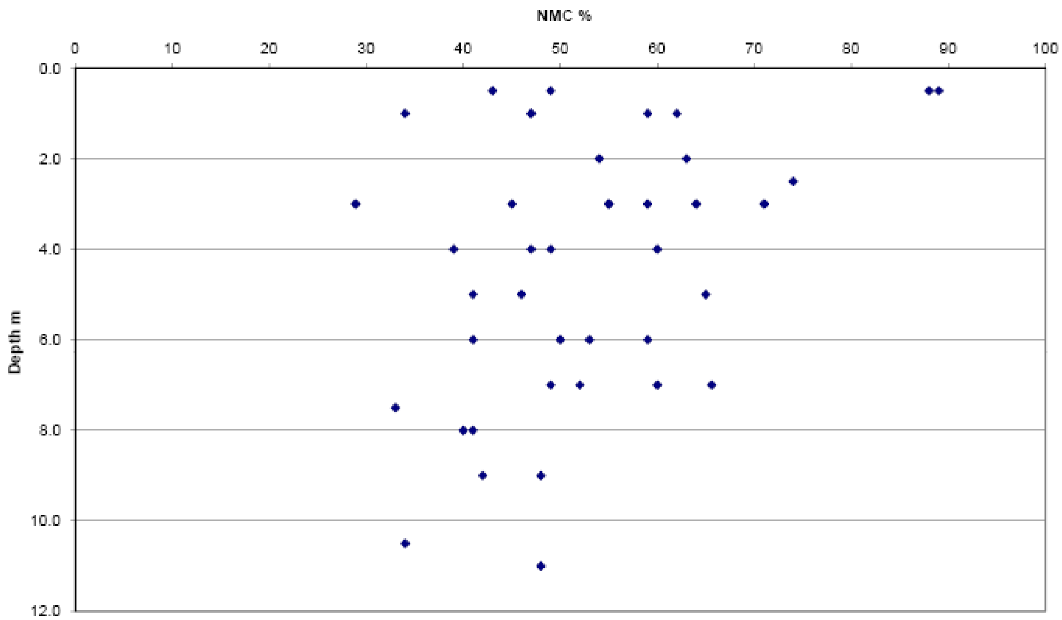

Figure 6.7.1 - Moisture Content Versus Depth

Grading analysis indicates that upper part of the alluvium is slightly sandy containing between 17% and 27% SAND

Particle size distribution tests show between 71% and 99% of the material is SILT. A plot of the SILT content, percentage retained between the 0.002mm and 0.06mm sieves v depth for the alluvium is presented in Figure 6.7.2. The silts contain between 1% and 10% clay.

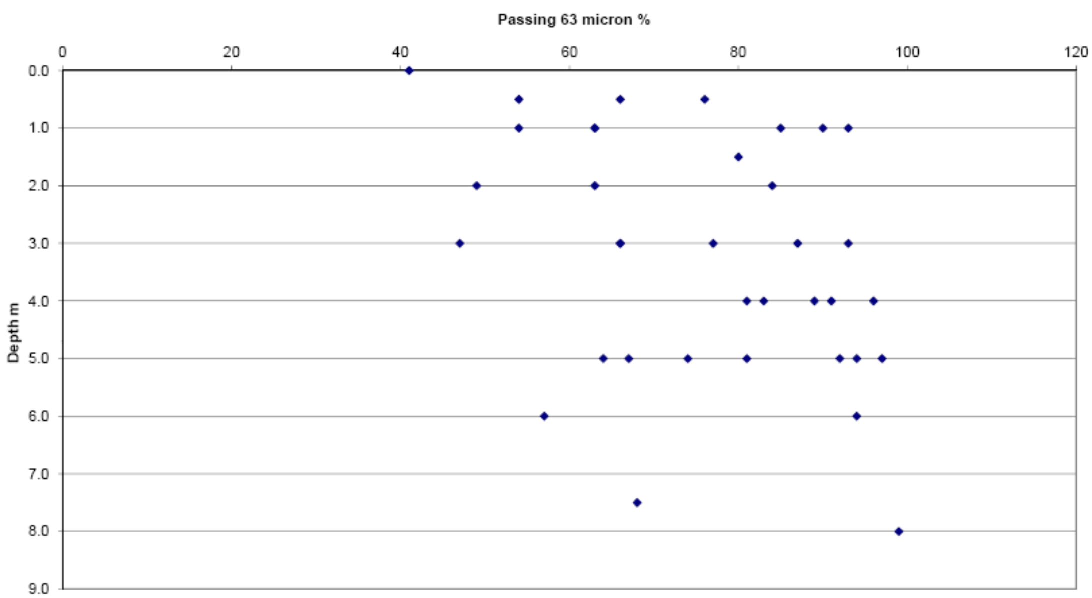

Figure 6.7.2 - Percentage Passing 63 micron sieve SILTS

The results of Atterberg limit tests indicate that the material is predominantly of intermediate plasticity with a liquid limit ranging from 36% to 46 %.

Cone penetration tests, SPT values and in situ VANE tests indicate that the silt is very loose/very soft in situ. Pore water dissipation tests were scheduled but pore water pressures did not rise above hydrostatic levels and the tests therefore could not be carried out.

The in situ Vane Shear Strength ranges from 5kN/m^2 to 10kN/m^2 with an average of 7kN/m^2 (very soft) from 13 tests. A plot of Vane Shear Strength against depth is presented in Figure 6.7.3.

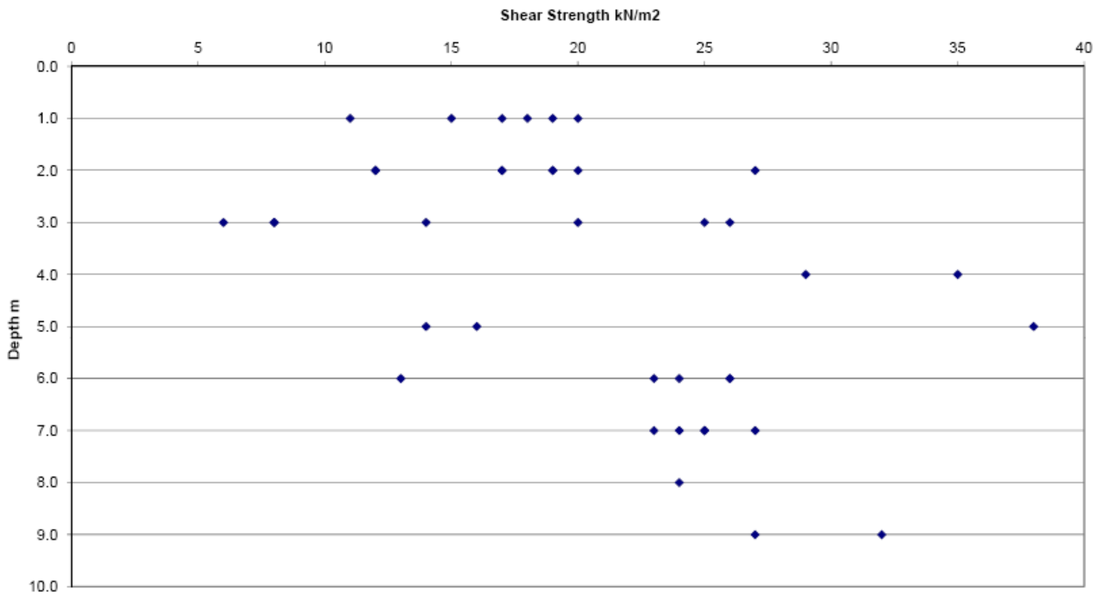

Figure 6.7.3 - Vane Shear Strength Versus Depth

The organic matter content ranged from 1.3% to 2.1%. One higher value of 4.8% was recorded in BH 1 at 3.0m depth representing a localised organic layer.

The Shear Strength measured on Undisturbed Samples ranges from 7kN/m^2 to 24kN/m^2 with an average of 14kN/m^2 (very soft to soft) from 7 tests.

Bulk density ranges from 1.50Mg/m^3 to 1.81Mg/m^3 showing a slight increase with depth with an average of 1.68Mg/m^3 from a total of 18 tests. A plot of the bulk density with depth is presented in Figure 6.7.4.

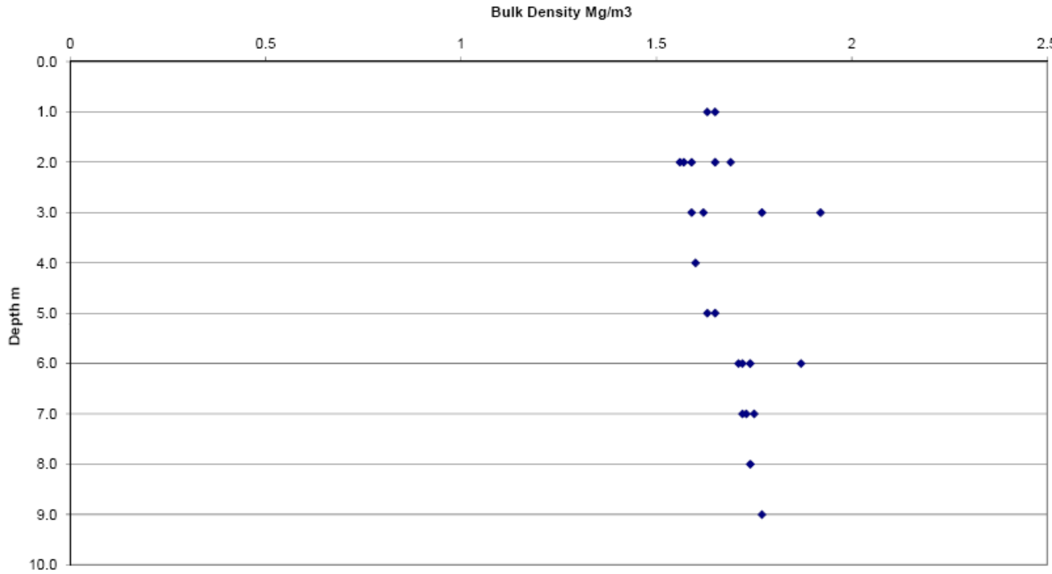

Figure 6.7.4 - Bulk Density Versus Depth

The SILT's are normally consolidated alluvial soils with high to very high compressibility. The Coefficient of Volume Compressibility (m_v) over the Effective Stress range of 50kPa to 100kPa varies from 0.94m^2/MN to 2.44m^2/MN. The Coefficient of Consolidation (c_v) over the same effective stress range varies from 0.29m^2/yr to 0.38m^2/yr.

From Remoulded Consolidation tests on the SILT's, the Coefficient of Volume Compressibility (m_v) over the Effective Stress range of 50kPa to 100kPa varies from 0.40m^2/MN to 1.64m^2/MN. The Coefficient of Consolidation (c_v) over the same effective stress range varies from 0.26m^2/yr to 0.58m^2/yr.

Consolidated Undrained Triaxial tests with pore water pressure measurements were conducted to assess the Effective Stress Parameters. The Effective Angles of Friction recorded were 34 and 38 degrees and Effective Cohesion is 0.Tests carried out to assess the aggressiveness of the soils to concrete indicate that the soils are slightly alkaline and the majority of soils classify as Design Sulfate Class DS-1 and ACEC (Aggressive Chemical Environment for Concrete) Class AC-1 in accordance with the recommendations of BRE Special Digest 1, Concrete in aggressive ground, (2005). ACEC classes vary from AC-1 being the least aggressive to AC-5 being the most aggressive. Construction materials suited to the DS and ACEC classifications of the soil will be used for the construction of quays, yards, breakwaters etc to control degradation and leaching to water.

The silts are primarily mineral. The organic content is typically less than 2%. The silts will lend themselves to soil consolidation and will benefit from surcharging and verti-drainage to expedite the consolidation required.

A diagrammatic section of the soils profile is shown in Figure 6.7.5.

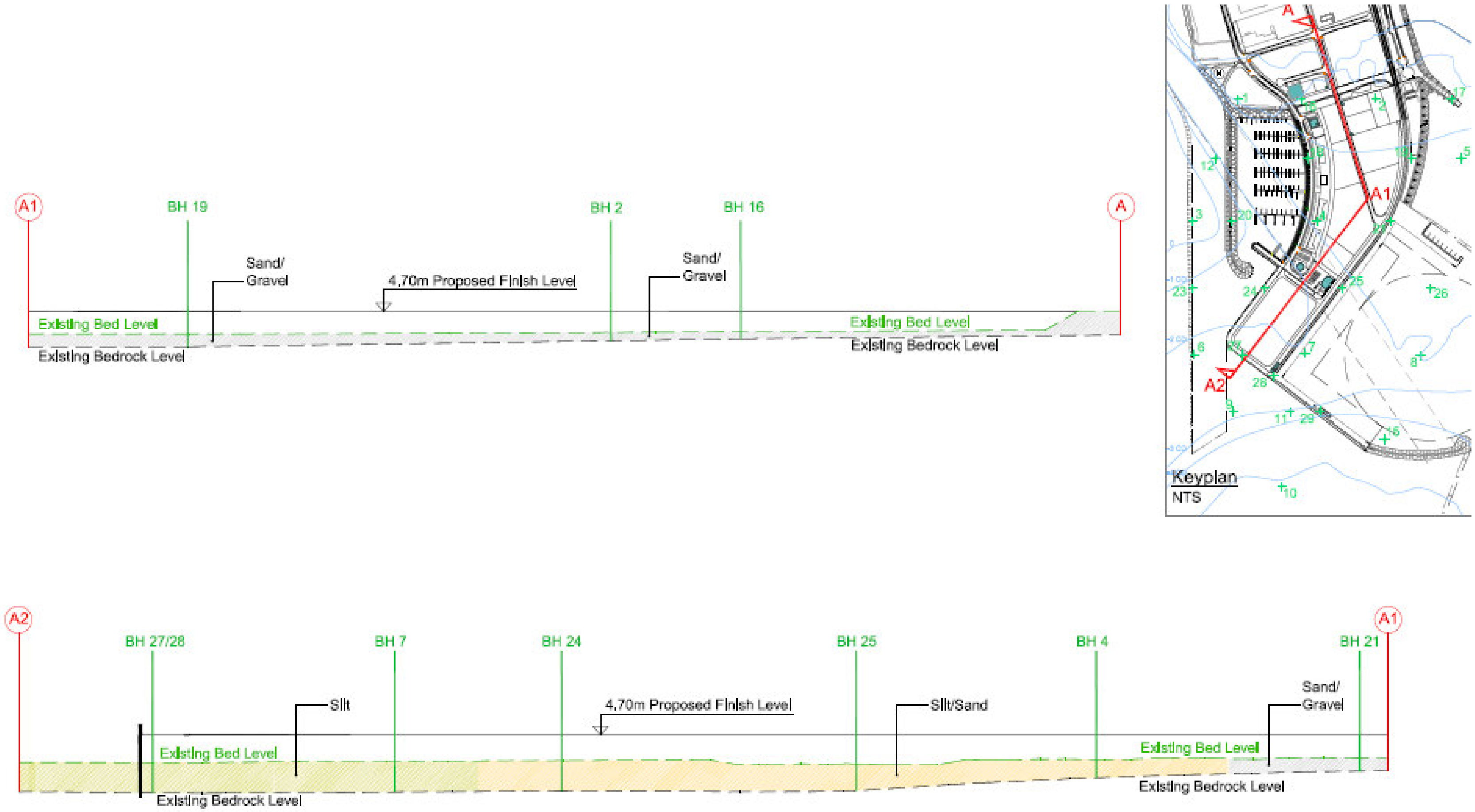

Figure 6.7.5 - Section through development showing typical seabed make-up

6.7.3 Post Glacial Peat

A thin layer, typically less than 0.2m thick of soft amorphous highly compressible peat occurs locally beneath the alluvial soils. The moisture content of the organic layer ranged from 81% to 113%. In situ Vane Shear Strengths of 14kN/m2 and 25kN/m2 were measured in two tests. The organic matter content of this layer ranged from 5% to 12% based on two Laboratory tests.

6.7.4 Glacial Deposits

The Glacial soils consist of stiff to very stiff grey gravely clayey SILT/CLAY with some cobbles and boulders. Above the CLAY, layers of sandy GRAVEL are present locally.

Its moisture content ranges from 10% to 38% with an average moisture content of about 18% based on 5 measurements.

Particle size distribution tests show between 33% and 72% of the material passes the 63 micron sieve. The gravel content ranges from 10% to 44% gravel.

The results of Atterberg limit tests indicate that the material is of a low plasticity CLAY with a liquid limit ranging from 15% to 34 %.

It is considered that the glacial till will behave predominantly as a cohesive material in situ. The N-values are typically greater than 50 which indicate that the Glacial soils are very dense/very stiff.

6.8 SEDIMENT QUALITY

6.8.1 Granulometry

Sections 7.5.3 & 7.5.4 of the EIS present a detailed analysis of the sediment granulometry.

With regard to sedimentation rates and build up of material, there will be only the same amount of sediment or less coming in from the river/sea, the rate will be at most the same as it is at present. With the Mutton Island causeway in place and the sewage pipes shut down both in the Corrib River, and off South Park, the sediment loadings will be somewhat less than in previous years. This in turn suggests a slower build-up of material within the proposed development area over time than is the case at present.

Information from the Harbour Master suggests that maintenance dredging occurs ca. every 10 years or when the channel has filled in to ca. +50 cm over the last dredging, which gives an annual build-up rate of 5 cm in one year or 0.015 cm per day. Other than the obvious fact that the dredging will deepen the sea bed around the proposed development site, the newly dredged area will have no significant impact on existing sea bed contours.

6.8.2 Sediment Chemistry

Sections 7.5.3 & 7.5.4 of the EIS present a detailed analysis of the sediment chemistry.

These results indicate that there are no reasons to suggest that mobilisation of deep sediments will impact on water or sediment quality during the dredging operations.

An Bord Pleanala, in their scoping document for the EIS recommended that sediment samples be collected off South Park which had served as a municipal dump some decades previously to determine any evidence of contaminants.

Marine sediment samples were collected at South Park for selected contaminant analysis to be carried out.

The analysis presented in Section 7.5.4 of the EIS does not indicate any long term or residual contaminant leakage or seepage from the historical municipal dump at Southpark.

6.9 ENGINEERING CHARACTERISTICS OF ROCK

The bedrock consists predominantly of very strong to extremely strong crystalline GRANITES with some Diorites, Dolerite Dykes and metamorphosed rocks

Total Core Recovery ranged from 81% to 100% in bedrock. The fracture state of the rocks can be assessed from the Rock Quality Designation (RQD) and the Fracture Index. The borehole logs indicate that the RQD values range from 30% to 86% with an average of 84% and the Fracture index ranged from 0 to 10. These parameters indicate that the rock mass is initially moderately fractured, becoming intact and competent with depth.

The Bulk Density of the rocks ranged from 2.51Mg/m^3 to 2.58Mg/m^3.10. Laboratory Point load tests recorded Is(50) strengths ranging from 3.23MPa to 7.24MPa. Three Unconfined Compressive Strength tests were carried out on the rock core. Recorded strengths ranged from 31.4MPa to 55.1MPa. The results of strength tests indicate that the rock material is generally moderately strong to strong.

Petrographic examination of the rocks confirmed that bedrock encountered in the Boreholes is igneous in origin and consists of GRANITES. The rock is composed of interlocking anhedral crystals of plagioclase and orthoclase feldspar, quartz, and chlorite and opaques. The rock matrix of the GRANITES classify as very strong to strong.

6.10 GEOTECHNICAL IMPLICATIONS

6.10.1 Bund Construction

The development will consist of 7 bunded lagoons. The walls of lagoons 1, 2 and 5 will be constructed by the loose tipping of selected granular Class 6A material directly into water. The lagoon walls will be lined internally with geomembrane to facilitate controlled drainage of the dredged fill. A layer of free draining stone fill will be placed over the geomemberane to protect it during main filling operations. The walls of lagoons 3, 4 and 6 will be of two types – walls formed using type of Class 6A material and walls formed by combiwall piles. The walls of lagoon 7 will be constructed using combiwall piles.

No compaction is required where Class 6A material is used. Above tidal level fill materials will be spread and compacted by standard earthworks plant. The selected type of Class 6A Material will be clean rockfill 500mm to 50mm in size. This grading does not comply strictly with 6A which requires at least 15% passing 10mm sieve. The selecting out of material less than 50mm is proposed to curtail silt wash into water.

Where granular fill is placed onto the granular materials or bedrock the stability of the side slopes of the bunds will be satisfactory. Settlement in the gravels will be immediate, long term settlement of the glacial till will be nominal and there will be no ground settlement where the fill rests directly on bedrock. Where thin, less than 2.0m, of very soft/loose alluvium is present beneath the bund walls, it will be removed by dredging in advance of rockfill placement.

The site investigation information indicates that it is possible to construct a haul road as far south as CPT 3 without significant settlement or stability issues along the east side of lagoons 1, 2 and 5. See Section a-A of Drawing 2139-2142 for a typical construction detail.

Along the west side ground conditions are suitable for rock bund construction as far as at least RC01. South and South West of RC01 up to 7.1m of very soft fine grained soils are present.

Where these materials are removed by dredging in advance of rock bund construction it is feasible to construct a lagoon wall to the south of lagoon 4 with Class 6A material. See Drawing 2139-2142 which shows up to 5m of dredging required at the deepest location.

6.10.2 Marina and Quay Construction

The proposed construction method involves the driving of a double combi pile wall to create a cofferdam. The wall will consist of a combination of steel tubular piles, up to 1.5m in diameter, with intermediate sheet piles in groups of three. The Quay walls will act as a self supporting gravity structure. Its stability is dependent on the properties of the fill used to backfill within the walls and the type of soil/rock at foundation. Soft soils will be removed to reach an adequate foundation which will not be prone to settlement when rock fill is then placed over them.

Above the bedrock layers of very dense gravel and boulders are present. These layers would require very heavy driving to penetrate and would result in damage to some of the piles. It is proposed therefore to excavate/dredge this layer in advance of pile driving.

The bedrock consists of moderately strong to very strong GRANITEs with probable DOLERITES and metamorphosed rocks. The steel piles will not penetrate into bedrock without pre-treatment of the rock mass by fragmentation. Blasting will require the drilling of a series of closely spaced holes 3m into bedrock. The holes will be charged with explosives and stemmed. The maximum instantaneous charge will be limited to reduce the effect of any shock wave generated by the blast events. The vibration limits are stated in Chapter 10 of this Report.

Blasting will shatter the deeper rock but will only crack and loosen the upper layer of rock. Hence the upper approximate 1.0m layer will require to be removed by a back hoe excavator and possible rock breaker to allow piles to be driven into the lower better shattered rock.

Piles will be grouted into position as described in Construction Methods in Chapter 4 of the EIS.

The cofferdam will be backfilled with free draining fill materials to provide lateral stability and immediate solid quay base. This quay will then be able to receive back hoe dredged material from barges, for delivery to the lagoons 1 to 6.

6.10.3 Land Reclamation

Stage 1 will consist of lagoons designated 1 to 6. Lagoons 1, 2 and 3 will initially receive sediment being a mixture of silt or sand with occasional gravel dredged by a Trailer Suction Hopper Dredger. This material will be, in effect, fluidised, with moisture contents in the 100% plus range.

On completion of suction dredging Lagoons 1 to 6 will be filled with the stiffer material dredged using a backhoe excavator. These materials will be predominantly SILT with some sand, clay with occasional gravel and organic matter.

The sea bed beneath Lagoons 1, 2, 3 and 5 consist of free draining Sands and no pre-treatment of the sea bed is anticipated prior to placement of dredged materials.

Lagoon 4 is predominantly underlain by relatively free draining soils except in the vicinity of CPT 18 along the western side of the lagoon. Where low permeability silts are present the lagoon floor will be covered by a geomembrane, sand blanket or inverted granular filter as appropriate. The floor of lagoon 6 will benefit from such seabed pre-treatment.

The walls of the lagoons will be built using granular fill lined internally with a geomembrane to facilitate drainage of the dredged materials.

In Lagoons 1, 2, 3, 4 and 5 the foundation strata are predominantly granular soils and it is expected that these relatively free draining soils will consolidate during construction of lagoons. The dredged materials will comprise initially fluidised silts from the Suction Dredging, followed by excavated slightly denser cohesive soils placed on top. The lagoons will be filled in stages dependent on the availability of material from dredging operations. After placement these materials will continue to settle for years as the soils slowly drain and consolidate.

It is proposed to accelerate the rate of consolidation by installing prefabricated vertical band drains, surcharging and cambering the surface and by the placement of a permeable layer on top of the surcharge. The efficient use of band drains can result in significant reductions in the time required for consolidation of the soils. Band drains are proposed on a 1.5m triangular grid to give the required rate of settlement.

Where foundation material has an insitu silt of depth up to 10m (e.g. Lagoon 7), there will be settlement of the insitu soils and the placed material. Material will have to be placed in stages to allow soil stability to develop. It will require to be placed in a balanced fashion to allow wall structural stability to be generated and protected. As this material will derive from the stripping of the surcharge from Lagoons 1 to 6 by conventional earth works methods this work can be scheduled accordingly.

Some 1.4 million cu.m of insitu silts and sands will be stabilised in their existing position by the surcharging and verti-drainage method proposed.

6.10.4 Capital Dredging

The development will require extensive dredging and it is estimated that up to 1.815 million cu.m will removed from the sea bed and deposited in the lagoons.

Two types of Dredging will be utilised

- Trailer Suction Hopper Dredger(TSHD)
- Pontoon Mounted Backhoe Long arm Excavators

The first system is a self propelled vessel, fitted with suction pipes, suitable for use in very soft and soft soils and the dredged material will be hydraulically pumped into lagoons 1 to 3. The suction dredger can ensure minimal silt plume by removing a concise deep area of the softer material rather than wide shallow area.

The backhoe system will excavate the lower stiffer materials from the sea bed and load them onto barges. The back hoe will use a large volume laser directed closable bucket which will not shed its silt load when rising through the water. Once in the barge, mixing with free water will be eliminated. The pontoon will be towed onto position. The barges will transport the dredged soils to the initial section of commercial quay where materials can be loaded into dump trucks to allow placement in the lagoons as detailed in Section 4 of the EIS. The internal haul roads required for distribution of the materials into the bunds have been designed as the bund walls.

Dredging of material will inevitably result in some dispersion of the fine fraction into the water column. The appropriate use of suction dredger and backhoe excavator in proper weather conditions will avoid the need for silt curtains which would be most difficult to maintain.

6.10.5 Dredging Monitoring

An environmental monitoring program will be adhered to throughout the works. Monitoring of suspended substances concentration, effects of velocity and direction of water currents and measurements of turbidity, noise and vibration will be undertaken. Turbidity meters will be installed at dredge sites to record and indicate appropriate working conditions over water to ensure that dredging is controlled, as proposed.

6.10.6 Construction Monitoring

Prior to commencement of construction instrumentation will be installed to monitor the response of the alluvium to the construction processes. Instrumentation will include piezometers, inclinometers and settlement plates. Instruments will be installed within the lagoons in a grid pattern and outside lagoon bunds prior to commencement of construction works. The measurements taken will facilitate the safe construction of the works and enable a comparison between design geotechnical parameters and the actual response of the soils to the works.

6.10.7 Maintenance Dredging

Maintenance Dredging will be required at the following locations:

i) The newly dredged channel to the old port.

The new channel to the old port will have the benefit of increased velocities at low tide which will help keep suspended solids from settling hence it will have a reduced maintenance dredging volume requirement when compared to the existing channel.

ii) The new channel to the new commercial port, turning circle, commercial berths and fishing pier berths

The new channel to the new commercial port will also have the benefit of increased velocities. The maintenance dredging required for the new turning circle, commercial berths and fishing pier berths will have short term serial localised negative Impacts similar to those that already occur, during maintenance dredging.

6.11 IMPACTS AND MITIGATION

6.11.1 Impact: Release of suspended solids into Galway Bay, with associated siltation on seabed. Release of Contaminants from Increased Suspended Sediment Concentrations during Dredging

Discussion and Mitigation:

Turbidity meters at dredge sites to record and control appropriate working over water to ensure that dredging is controlled.

Proposed Land reclamation works involving the construction of lagoon walls lined internally with geomembrane will act as fixed silt curtains and will contain the dispersion of suspended sediments when being pumped as land reclamation material within the marine environment.

Sediment Granulometry and Chemistry Analysis indicate that there are no reasons to suggest that mobilisation of deep sediments will impact the water or sediment quality during the dredging operations. Section 8 of the EIS includes the sedimentology study that has been undertaken for the proposed development.

6.11.2 Impact: Dust Emissions and Release of H_2S during land reclamation works

Discussion and Mitigation:

Section 9 of the EIS addresses the impact of the proposed development on air quality including airborne pollutants and dust emissions.

H_2S release will be controlled by alternating lagoons and damping down surfaces. On excavation of silts strong odours are given off by decomposing organic matter. These odours, although initially quite pungent, rapidly reduce as soil aerates. Discharge points for suction dredged materials will be established at a number of locations to facilitate the distribution of materials within the lagoons. Where suction dredged and excavated materials are deposited directly into water it is considered that odours generated will be limited. Above the tidal level materials will be placed in the dry and subject to evaporation and desiccation. To control dust the top surface of the materials will be sprayed to suppress the generation of dust and reduce odours.

An odour management plan will be implemented during the construction phase, using resident data, meteorological data and site operator knowledge to mitigate potential odour issues and implement remedial action using a developed common sense strategy. The management plan will include but not limited to odour monitoring proposals, odour control mechanisms and odour complaint procedures.

During construction of lagoons above tidal level, dust suppression will be accomplished by damping the deposition surface with seawater. This will also contribute to reducing any odours given off by the dredged materials. The top surface of the surcharge layer will be reprofiled and trimmed to facilitate surface runoff prior to the placement of the drainage layer/work platform for the vertical drains.

A site dust monitoring programme will be put in place during the construction phase with secure monitoring locations to ensure compliance with dust deposition limits. A dust management plan will be implemented during the construction phase, using resident data, meteorological data and site operator knowledge to investigate any dust complaints/potential dust complaints and implement remedial action using a developed common sense strategy.

6.11.3 Impact: Sediment suspension by Propeller Wash

Discussion and Mitigation:

The sediment re-suspension due to an increase in leisure craft during the operational phase will be a minimal impact as the great majority of these vessels are less than 20m. The larger commercial vessels will be operating in deeper water than they currently do as they will not have to enter the port and for this reason, it is considered that the propeller wash will not re-suspend the sea floor sediments as much as presently happens. For this reason the operational phase of the port is not seen as having any additional impact on sediment re-suspension. Section 8 of the EIS presents the hydrodynamic and sediment modelling for the proposed development.

6.11.4 Impact: Alteration to current directions at the proposed development site resulting in a shift of existing erosion and deposition sites

Discussion and Mitigation:

The current direction is not expected to be significantly altered resulting in low potential impact severity. Section 8 of the EIS details the hydrodynamic analysis that has been undertaken for the proposed development.

6.11.5 Impact: Sediment Re-suspension by Maintenance Dredging Operations

Discussion and Mitigation:

The sediment re-suspension due to maintenance dredging will be of a low impact severity. The dredging expected will not be of a significant quantity. It will be sediment which will have been deposited through tidal and hydrodynamic processes. The most recent maintenance dredging volume at the existing port was 65,000 m^3. As detailed in Section 8 of the EIS, there will only be the same amount of sediment or less coming in from the river/sea, the rate will be at most the same as it is at present. With the Mutton Island causeway in place and the sewage pipes shut down both in the Corrib River, and off South Park, the sediment loadings will be somewhat less than in previous years. This in turn suggests a slower build-up of material within the proposed development area over time than is the case at present.

The New Channel to the old port will be relatively self cleansing and the new channel to the new port is largely screened from river alluvium.

6.12 INTERACTIONS

Interactions were ongoing during the soil and geology studies for the proposed development: Studies which were interacted with include the following:

- Site Investigation
- Soil Surveys
- Layout Design
- Structural Design
- Construction Method Design
- Air, Noise and Water Studies
- Ecological Studies
- Archaeological Studies

Interactions with statutory and regulatory bodies were also factored into the compilation of this soils study.

Interaction with the Marine Institute, NPWS and the Local Authority in advance of the application for the requisite foreshore license for the proposed development, will ensure that the mitigations proposed within this soils study will be adequate and appropriate.

6.13 CONCLUSIONS

The proposed development has been designed to best suit the soil conditions pertaining rock, silt and sand.

The proposed design incorporates a beneficial use of dredged sediments for fill and surcharge. The design facilitates the re-use of all dredged soils for land reclamation purposes. Rock excavated within the site will be incorporated into the construction of lagoon walls, quays and haul roads.

The proposed design has been developed to satisfy the following requirements:

- Removal of soils from over rock to curtail soil disturbance from the drilling, blasting and removal of rock.
- Minimum rock dredge with appropriately controlled drilling, blasting and rock excavation as per the noise and vibration limits detailed in Section 9 of the EIS.
- Balance of sediment dredging and re-use as land reclamation.
- Minimum release of suspended sediments to sea by the implementation of suitable construction methods and practices thereby ensuring Minimum impact on the surrounding Galway Bay Environs.
- Practical phasing of development which best suits the methodology of construction regarding lagoons, dredging and quay construction.
- The working of soils as proposed will not have a significant impact on the waters where work will be undertaken.

6.14 REFERENCES

Geological Survey of Ireland (2003) *Geology of Galway Bay, Sheet 14, Scale 1:100,000*

British Standards Institute. BS1377:1990, *Methods of Test for soils for Civil Engineering Purposes. Parts 1 to 9*

British Standards Institute. BS8002:1994, *Code of Practice for Earth Retaining Structures*

British Standards Institute. BS5930:1999, *Code of Practice for Site Investigations*

Eurocode 7: Geotechnical Design

IGI (Irish Geotechnical Institute) Guidelines