

An Offshore Wind Farm on the Kish and Bray Banks

Environmental Impact Statement

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Reviewed and Updated by

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SAORGUS | ENERGY LTD

Volume 3 of 5 - Appendix B Physical Environmental Impact Assessment

Geological Report on the Environmental Impact of the Proposed Kish & Bray Banks Wind Farm Development.

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Introduction

This report attempts to identify and quantify the sedimentological impacts of the proposed development of an offshore wind farm, potentially consisting of 145 turbines, on the Kish and Bray Banks (Figure 1). The proposed site is situated approximately 10km east of the Irish coastline, off the coasts of counties Dublin and Wicklow (Figure 2). The report deals only with the potential impact of the main site and does not address any of the impacts associated with the installation of the related cable needed to link the development into the onshore electricity grid.

Data used is derived from that presented in the published geological, marine and environmental impact literature for the area. Additional information was incorporated from a number of site surveys undertaken on behalf of Saorgus Energy Ltd.

The proposed site for the development exists in a region characterised by a series of coast-parallel northsouth trending offshore banks, and NNE-SSW trending sedimentary bedforms reflecting the control of the principal tidal current direction. These banks stand in shallow water and in places rise to within a few meters of the surface.

The banks occur in a punctuated line along the east coast of Ireland, with breaks maintained by strong current activity and sediment movement. The banks serve an important role in offering wave protection to the coast and controlling tidal flow. The overall bank structures are stable in nature, whereas surface sediments exist in dynamic equilibrium with tidal and current conditions.

Seabed surface sediment maps, published by the British Geological Survey (BGS) and the Geological Survey of Ireland (GSI), indicate the substrate as being composed of sand. This is corroborated by marine charts of the area (Admiralty chart No. 1468).

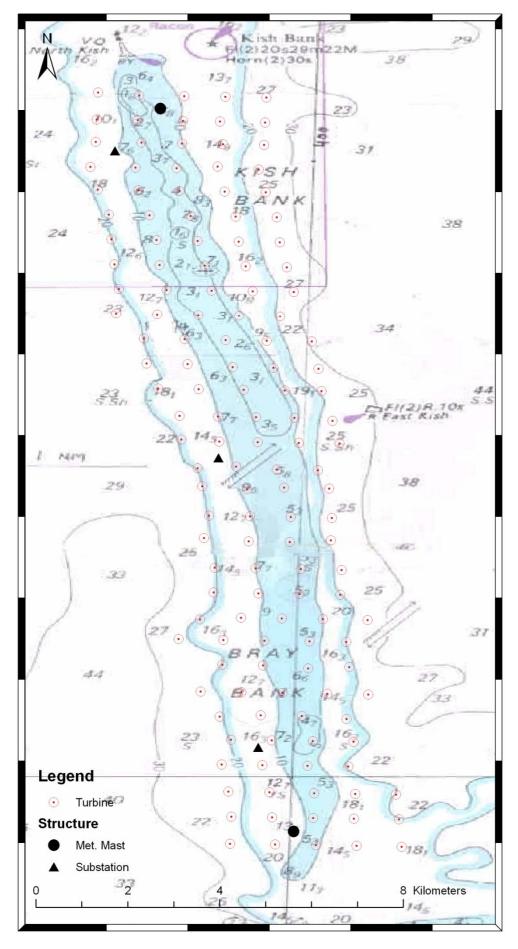


Figure 1: Turbine layout over the proposed development. Depths presented in meters.

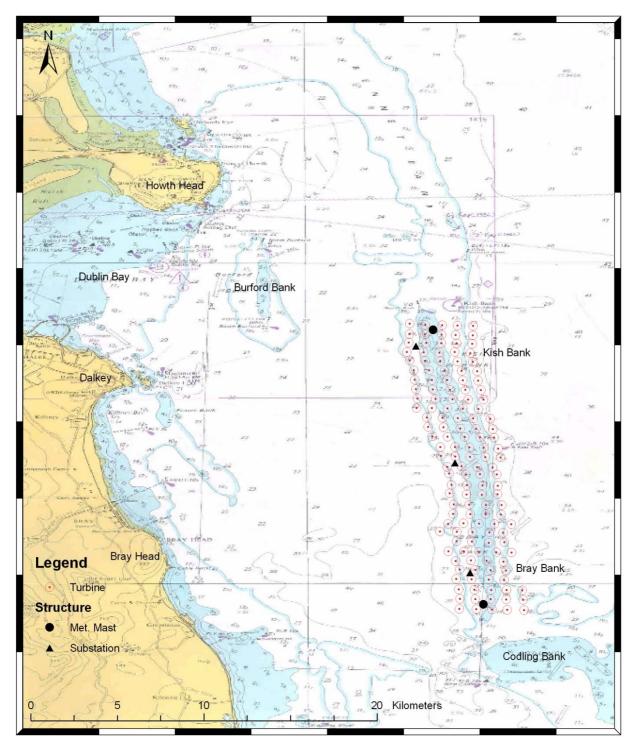


Figure 2: Site location in relation to surrounding region. Depths presented in meters.

Bathymetry

Existing bathymetric data is represented on Admiralty Chart No. 1468 and was acquired between 1843 and 1911, using traditional sounding (lead-line) and navigation systems. The published chart indicates waterdepths of 2-26m (Chart Datum) within the region of the proposed site. The planned site is located along a North-South section, with shallower (in places approximately 1m) depths being observed to the north of the site.

More recent bathymetric data for the region is presented in Wheeler *et al.* 2000. A series of profiles, with a mean line separation of 2kms, were acquired across the proposed site, using a single-beam echo-sounder for depth determination and Differential GPS for navigation. Line density from this study is greatest towards the north of the proposed site and reduces towards the south. The data acquired was reduced to chart datum through reference to onshore tide-gauges. A comparison of the data acquired and that presented on the Admiralty Chart for the area was performed, revealing a close correlation between the two datasets for the deeper isobaths on the Kish and Bray Banks, but less so in the shallower areas and towards the crests of the banks (Figure 3). This may suggest that there has been some migration of the banks in historical time; however the authors note that the markedly different technologies and techniques used in the generation of the datasets and formulation of isobaths limits their usefulness as "time-series".

In 2008, Saorgus Energy Ltd. commissioned a hydrographic and geophysical survey of the proposed site (Hydrographic Surveys Ltd., 2009). A key element of this work program was the acquisition of 115 preplanned bathymetric profiles crossing the Kish and Bray Banks, with a line spacing of 150m. This work was performed between 13th June and 11th September 2008 by using a digital single-beam echo-sounder, with positioning provided via Differential GPS and an onshore tide-gauge facilitating reduction to chart datum.

The improved sounding and track density provided by this survey has allowed accurate water-depths to be determined for each proposed turbine location and facilitated more detailed descriptions of the surface morphology of the proposed site. Additionally, as the data is available in digital format and is of sufficient sounding density, Digital Elevation Models (DEM's) are easily derived in addition to traditional chart products, easing visualisation and interpretation (Figure 4).

Immediately apparent from these digital representations is that the bank complex is more sinuous than the representation provided on the Admiralty Chart for the area. This observation is in agreement with the depiction of the 10m isobath in Figure 3.

Figure 5 presents the distributions of slopes over the proposed site. Towards the north of the proposed site, slopes are steepest on the western face of the banks. Going south, the slope on the western face of the banks reduces while that on the eastern face becomes more prominent. Further south, the slope of the eastern face decreases while that of the western face increases, leading to a more symmetrical appearance. In this region,

a broad shoal is evident in the 2008 acquired data, but is poorly reflected in the Admiralty Chart or Wheeler *et al.* (2000) isobaths. To the very south of the proposed site, the bank complex remains symmetrical but the crest narrows substantially.

No evidence of rock exposure is evident on the bathymetric data presented.

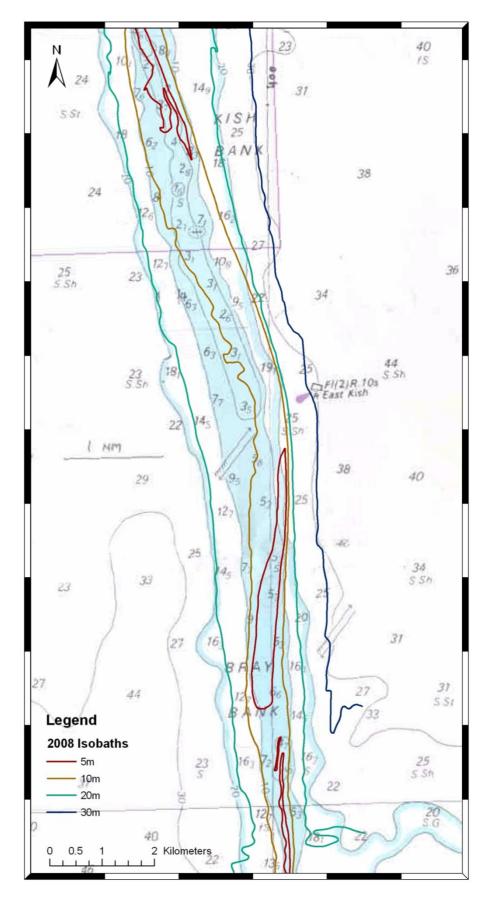


Figure 3: Comparison of recently acquired (2008) and historical bathymetric data [after Wheeler *et al.*, 2000]. Depths depicted in metres.

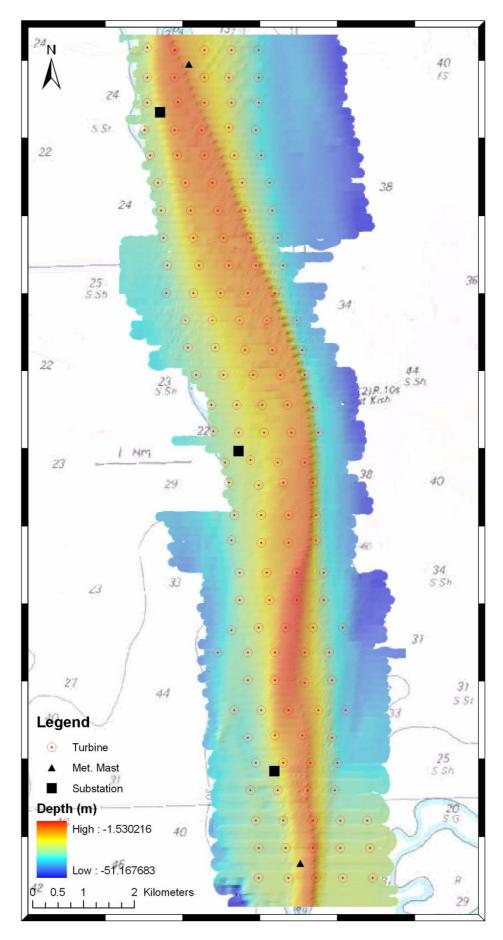


Figure 4: Digital Elevation Model derived from soundings collected during the 2008 survey of the proposed site. East-West trending lines represent minor tidal shifts, magnified by the griding algorithm. Depths depicted in metres.

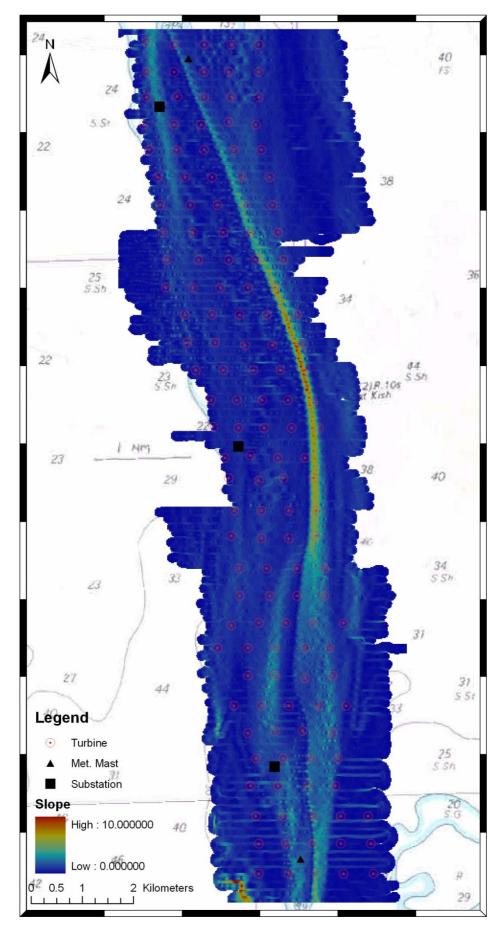


Figure 5: Slope distribution over the proposed site. Warm colours represent areas of steepest slope (10 degrees). East-West trending lines represent minor tidal shifts, magnified by the griding algorithm and slope computation.

Hydrography

Wave Environment

Wave data for the period 03rd May 2001 to 30th September 2004, was obtained through Met Eireann, for a nearby Marine Institute operated data-buoy (Data-buoy M2 - 53° 28.8'N 5°25.5'W). This data consisted of hourly wave height, period and wind direction readings. Summary statistics from this data set are presented in Figure 6.

In addition, the wind direction data has been used as a proxy for possible wave direction, with the resulting data being presented in the form of wave climate roses, indicating the frequency of waves coming from varying directions. Figure 8 represents all the data obtained in this format, while the second display represents a subset of the data – wave events with a height greater than 2.5m.

Additional data, previously presented (Natural Power, 2002), is also included for comparison. This data is derived from the UK Meteorological Office wave model. In contrast, this dataset covers a ten year period (1992 – 2001), but provides wind and wave data on a three hourly basis. Data was analysed for two points near the site (located at 53.00° N, 5.66° W and 53.25° N, 5.66° W). This data is also presented in the form of wave climate roses. Figure 9 shows the distribution of all waves during an average year for each point, while Figure 10 shows the orientation of those wave events with wave heights of greater than 2.5m.

The data indicates that the larger waves originate predominantly from the South to Southeast direction, with some input from the Northeast. This is consistent with the concept that waves arriving from the south are a result of channelling from the Atlantic, whereas those from other orientations are a result of the relatively short fetch of the Irish Sea.

Though wave conditions experienced closer to the proposed development are likely to be influenced by bathymetric and coastal factors, the close approximation between both datasets, suggests the data provides an accurate proxy for conditions experienced by the Kish and Bray Banks site.

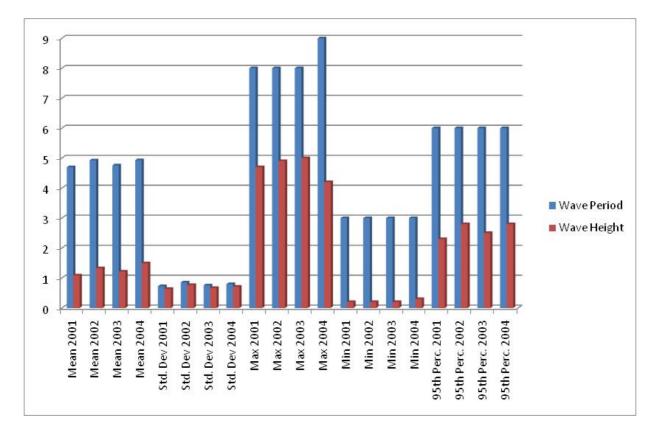


Figure 6: Summary statistics calculated from wave data recorded at M2 Data Buoy.



Figure 7: Location of M2 data-buoy [red] and UK Meteorological Office Wave Model data points [green].

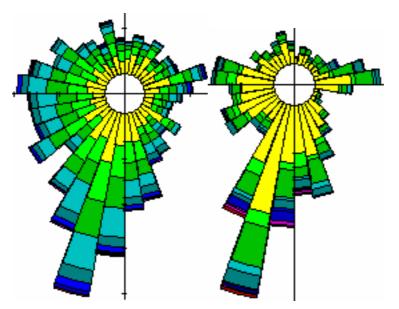


Figure 8: Rose diagram for all waves recorded at M2 data-buoy (left) and those with a wave height greater than 2.5m (right). Observed wind direction was used to infer wave orientation.

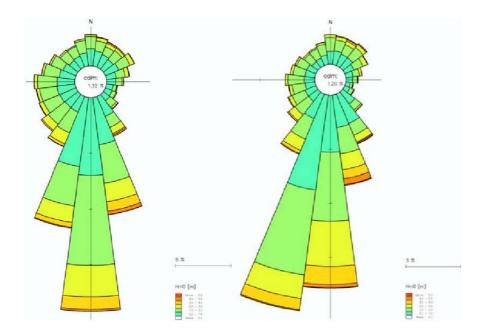


Figure 9: Annual average wave roses – North [left] and South [right] (Natural Power, 2002).

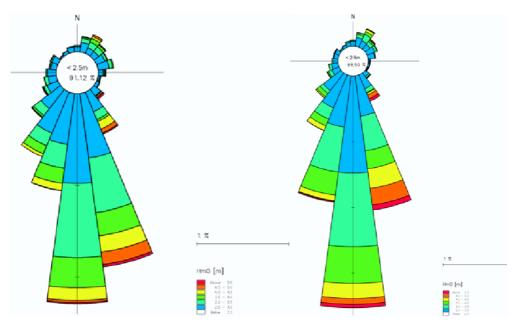


Figure 10: Annual wave roses for wave events with heights greater than 2.5m -- North [left] and South [right] (Natural Power, 2002).

Tidal Amplitude

The Admiralty chart for the area indicates a mean high water spring tide of 4.1m above chart datum. This correlates well with tidal data previously presented from Dublin, which indicated a 1 in 50 year return period extreme water level of 5.32m above chart datum (Natural Power 2002). This can be extended to the proposed site.

Tidal Flows

The proposed site experiences approximately southern flow during the Ebb tide and a northern flow direction during the Flood tide as shown on the Admiralty chart for the area. Data presented on the chart (Tidal Diamond C – $53^{\circ}19'3N$ 5°44'5W) indicates a maximum tidal velocity of 2.2 knots (1.13 m/s) with an approximately North – South flow orientation. Further tidal flow markers located along and adjacent to the Kish Bank indicate a more NNE – SSW orientation. Data previously published for the adjacent Codling Bank area, shows a maximum recorded current velocity of 1.67m/s, but also interpreted that the Kish Bank area would experience lower flow velocities than that of the Codling Bank (Natural Power, 2002). More detailed evidence of local flow conditions can be elucidated with reference to the geological bed-forms observable at the proposed site.

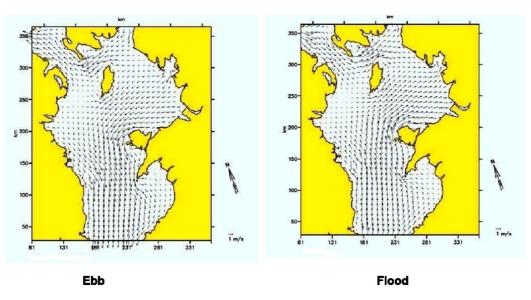


Figure 11: Representation of Ebb and Flood tidal flow in the Irish Sea (Natural Power, 2002).

Present Baseline Sedimentary Conditions

Overview

Current knowledge indicates that the overall bank structure exists in a stable state. Sedimentary bedforms observed both visually (Max *et al.*, 1976) and through the use of side-scan sonar (Wheeler *et al.*, 2000; Hydrographic Surveys Ltd., 2009) indicates that surficial sediment on the banks is actively mobile and migrating northwards. Sediment mapping, based on both sampling and sonar techniques indicate that the banks are composed of extensive thicknesses of sand to gravel sized material.

Bedform Distribution

The surficial sedimentary conditions of the proposed site are indicated primarily through available sidescan sonar records and sediment samples.

Wheeler *et al.* (2000) produced a regional interpretation covering the proposed development on the basis of a loose network of sidescan sonar profiles (Figure 12). They identified five echo-facies covering the proposed development, on the basis of echo intensity and bedform character:

- Stippled Bank Crest Facies Occurs in the north of the proposed development, on the crest of the Kish Bank. Represents a transition from sandwave dominated sediments on the bank margins, to environs dominated by planar beds with scattered patches of more highly reflective sediments interpreted to represent more gravel rich deposits. The morphology of sandwaves observed in this echo-facies was interpreted to indicate a northwardly transport direction.
- **Bank-crest Facies** This echo-facies occurs on the crest of the Bray Bank, as is described as being similar in character to the previously detailed unit, but lacking the patches of increased reflectivity.
- Stippled Sandwave Facies This unit occurs on the margins of the Kish Bank and represents areas dominated by sandwaves but also displaying areas of increased reflectivity, interpreted to represent more gravel rich deposits.
- Sandwave Facies This unit describes a highly mobile seafloor environment occurring on the margins of the bank complex. The facies is characterised by widespread sandwaves and other bedforms, with bedform development decreasing with distance from the bank complex. Bedform morphology implies a northerly net transport of sediment, with stronger tidal flows adjacent to the banks.
- Stable Seabed Facies The final facies is found at greater distances from the bank complex and represents regions where no bedforms were imaged. The unit is interpreted to represent a stable or non-mobile seafloor. While no bedforms were imaged, small scale ripples below the resolution of

the sonar instrument may exist. Ground-truthing of this facies type indicates a sandy to silty composition.

Further sidescan data was recently acquired on behalf of Saorgus Energy Ltd. within the same site survey as that detailed for the bathymetric data and employing the same line density (Hydrographic Surveys Ltd., 2009). In general, the data acquired shows a similar distribution of bedforms as reported above, though additional small scale bedforms are observed on the bank crests.

The bedform patterns described can be used to give an indication of the flow conditions experienced at the proposed site. Analogue modelling has determined the flow conditions necessary to generate a range of bedforms for sediments of a given size. Although the conditions experienced by the proposed site differ somewhat, from those used in experiments (experiments were carried out based on unidirectional flow; while the proposed site experiences bi-directional flow – sediments responding to both the Ebb and Flood tides and wave action), they still serve to provide an approximation of the conditions experienced, as the strongest ebb and flood flows follow differing pathways. For sediments with a grain size of approximately 0.5mm (medium sand), sand waves (dunes) are observed to form under flow velocities of approximately 0.6 m/s and gradually change to high-energy planar bed features at velocities above 1 m/s (Leeder, 1999). Under flow velocities of less than 0.6 m/s, such sediments are observed to form ripples.

As a result, the pattern of bedforms observed suggests that the strongest tidal flow conditions are found closest to the banks, due to the acceleration of tidal flows around the obstruction which the banks present.

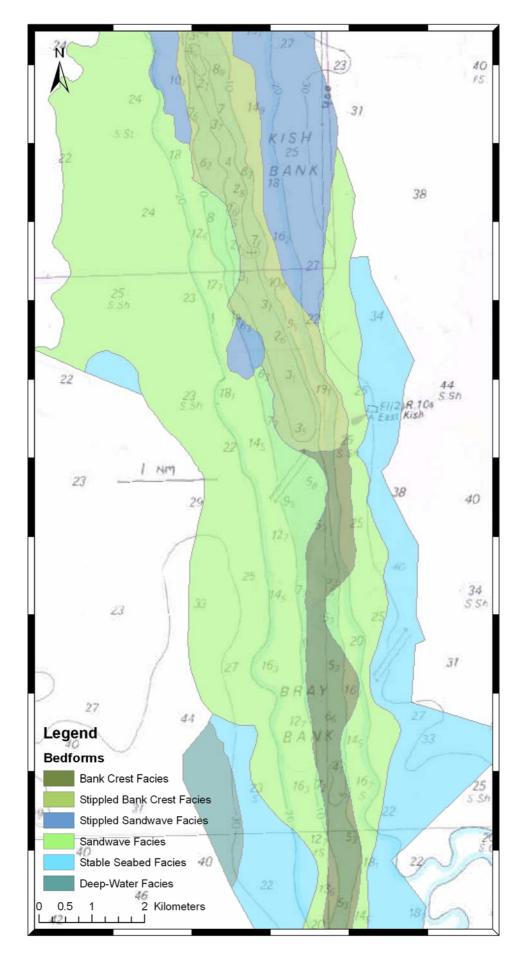


Figure 12: Seafloor facies distribution at proposed site (as mapped by Wheeler et al., 2000).

Sediment Distribution Patterns

Available sediment sampling data (Max *et al.*, 1976 & Wheeler *et al.*, 2000) indicates that the surficial sediments of the banks and surrounding area are composed primarily of sand-sized particles, with coarser gravely material concentrated on the bank crests. The limited number of sample stations suggests a degree of sediment fining towards the north.

Further information relating to the sediments of the area can be found in the biological report carried out as part of the development. A series of trawls were run over the site using a biological dredge fitted with a 1cm mesh bag, any sediment samples recovered were briefly described based on hand sample appearance. The report based on this work goes on to state:

"The survey showed that the shallower parts of the Kish and Bray banks consisted of fine sand with some shell. Along the western edge of the Kish Bank the seabed was predominantly coarse shell with sand, which graded into shell with pebbles, gravel and stones along the west of the Bray Bank and larger cobbles and stones at the southern end of the Bray Bank. The eastern side of the Kish Bank consisted of fine sand and coarse shell. It was likely that areas of hard substratum occurred at these sites due to the presence of Alcyonium digitatum in the samples. The substratum towards the south east of the Bray Bank consisted of pebbles, stones and mud" (EcoServe, 2008).

However, caution must be used when integrating this data with other sources. The samples obtained as part of this work contain an unknown "skew" in sediment size distribution due to the means used to acquire them. The 1cm mesh bag will allow quite large sediment particles to pass through, and the samples gathered are that portion of the seabed effectively trapped and retained by organic matter. In addition, the trawls were run over significant distances, as such, the sample may represent inputs from several bottom-types. A further potential source of error is the method used to describe the sample (visual estimation of grain size vs. granulometry as used by Wheeler *et al.*, 2000). With these caveats, locations for several of these shorter trawls are presented in Figure 13 along with accompanying details (Figure 14).

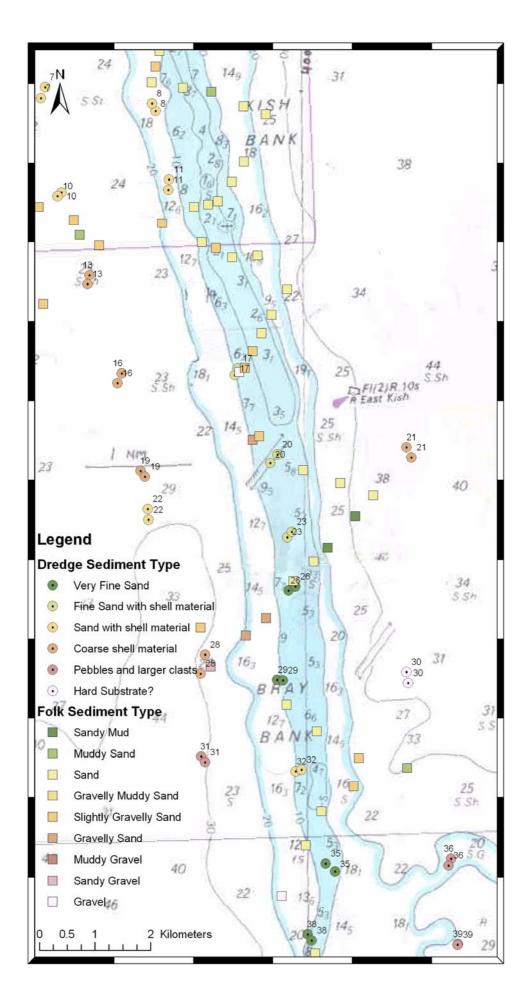


Figure 13: Locations of biological trawls traversing proposed development (geological description abbreviated to facilitate display) and samples presented in Wheeler *et al.* (2000).

Site no. Site name

Substratum

Distance (m)

l	North west of Kish Bank	Predominantly shell. Must also be rock as Alcyonium digitatum recorded.	180
	North of Kish Bank	Fine sand with some shell.	180
	North west of Kish Bank	Coarse shell with sand.	160
	On Kish Bank – northern half	Sand with some shell.	160
0	West of Kish Bank	Sand with coarse shell.	100
1	On Kish Bank – middle of Bank	Sand and broken shell.	180
3	West of Kish Bank	Coarse broken shell.	160
6	South west of Bank	Coarse shell.	190
7	On Kish Bank – south of Bank	Fine sand and broken shell.	130
9	North west of Bray Bank	Very coarse shell.	130
20	On Bray Bank – northern tip	Fine sand and broken shell.	210
1	North east of Bray Bank	Very coarse shell.	200
2	North west of Bray Bank	Coarse shell with sand. Mainly live Nucula sp.	190
3	On Bray Bank – northern half	Fine sand with some shell.	150
6	On Bray Bank – middle of Bank	Very fine sand.	150
8	West of Bray Bank	Very coarse shell.	130
9	On Bray Bank – middle of Bank	Very fine sand.	120
0	East of Bray Bank	Coarse shell but also must be rocky as Alcyonium digitatum recorded.	210
1	South west of Bray Bank	Stones, gravel, shell and sand.	120
2	On Bray Bank – southern half	Sand with broken shell and some pebbles.	110
5	On Bray Bank – southern half	Very fine sand.	220
6	South east of Bray Bank	Pebbles, stones and mud.	150
8	On Bray Bank – southern tip	Very fine sand.	130
9	South east of Bray Bank	Sandy mud with pebbles, shell and gravel.	13
1	South of Bray Bank	Pebbles and stones covered in bryozoan crusts with some sand.	170

Figure 14: Sediment descriptions from Short Biological Trawls

Subsurface Stratigraphy

The subsurface stratigraphy of the proposed site is detailed through reference to available borehole information, shallow seismic data acquired from the area and the established seismostratigraphic succession for the region.

Three boreholes were undertaken on behalf of Saorgus Energy Ltd. during 2008 (Glover Site Investigations Ltd., 2008). On the basis of sediment descriptions and geotechnical measurements provided, a sequence of 3 units can be determined:

- Unit 1: Seafloor to 3-6m Uppermost unit of loose silty fine to medium sands with traces of gravel and occasional shells.
- Unit 2: 3-6m to 12-15m Dense silty fine to medium sands with traces of fine gravel and occasional shells
- Unit 3: 12-15m to 20m Very dense silty fine to medium sands with occasional shells.

This succession correlates closely with data reported from a borehole in the vicinity of the Kish Lighthouse by Wheeler *et al.* (2000). They describe a sequence of 15m of fine sands overlying 11m of cohesive silts with some sand content. They note the existence of a layer of 'stiff clay' separating these units.

Wheeler *et al.* (2000) go on to define a working schema of echo-facies for the area on the basis of boomer seismic profiles, identifying three units and correlating these with the established regional nomenclature. Within this schema, echo-facies A seems to correlate with borehole Units 1 & 2, while echo-facies C potentially correlates with borehole Unit 3. Echo-facies B is depicted as a relatively thin unit, inferred to correlate with the 'stiff clay' described from the Kish Lighthouse borehole, but absent from the 2008 series of boreholes. Based on the regional stratigraphy, echo-facies C is inferred to be underlain by glacial till deposits.

Additional boomer profiles were acquired for Saorgus Energy Ltd. by Hydrographic Surveys Ltd., though at a reduced line density in comparison to bathymetric profiles (Figure 15). A similar sequence to that previously reported is observed on these profiles, though continuity of reflectors beneath the bank crests is not readily apparent. This is likely to be due to a combination of insufficient source energy, the density and thickness of the overlying sediments and the masking effect due to water-column multiples inherent in shallow-water surveys.

Echo-facies A has a mean thickness of approximately 20m over the survey area, but thins noticeably towards the south. Correlation of the available borehole information and the acoustic character of this unit suggest a predominantly sand based composition with minor silt and gravel content. Hyperbolic events in the near surface delineate localised patches of coarser sediment.

Towards the base of several profiles, reflections with an irregular profile / eroded appearance become apparent. Due to the density of the overlying media, it is difficult to determine if these reflections represent

bedrock or an eroded underlying till. However, considering the regional geology of the area, a glacial origin is suggested. None of the boreholes available intersect this unit. Towards the north of the site, these reflections are at sufficient depth to be of no concern, but may need to be taken into account during emplacement of foundations towards the south of the proposed development.

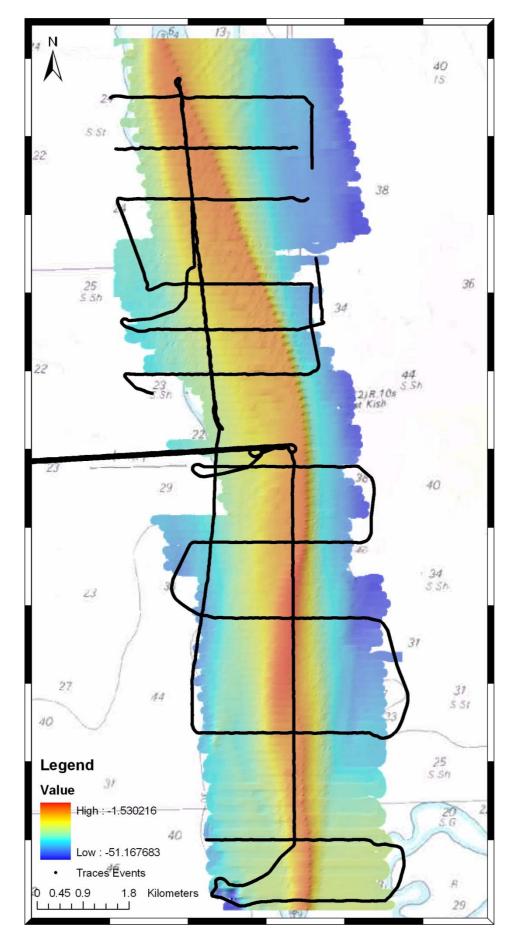


Figure 15: Trackplot of boomer profiles acquired in 2008, across the proposed development. Depths depicted in metres.

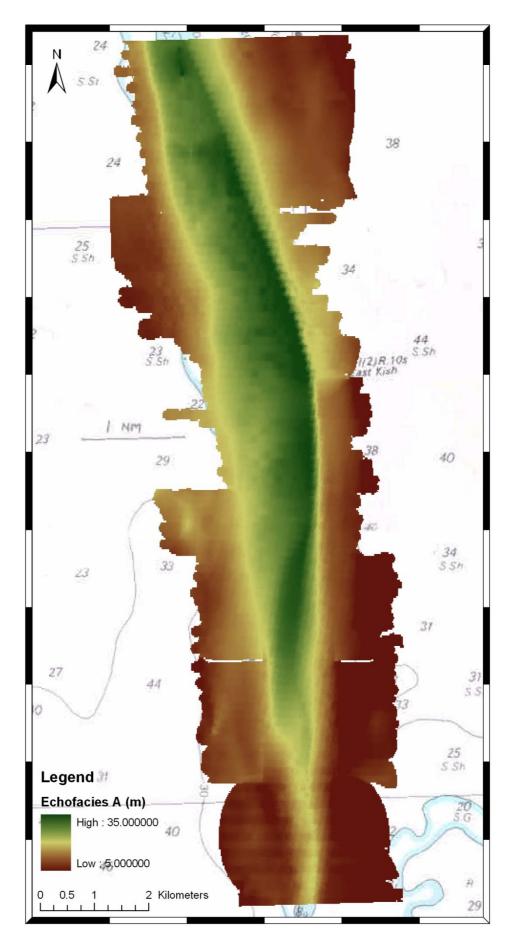


Figure 16: Estimated Sediment thickness to base of Echo-facies A in meters.

Flow, Wave and Scour Modelling

Various models have been derived to model the interaction of water depth, flow vectors, wave conditions and sediment transportation. These range from manual calculations based on a limited number of variables to complex computer simulations, which utilize a range of datasets, employ nesting of scenarios at varying scales to improve accuracy and prevent edge effects. All such models involve some degree of simplification of real-world conditions. As such, caution must be used when relying on their predictions.

Additionally, the quality of a model's predictions is controlled by the accuracy of the data on which it is based. In many respects, data for the offshore environment lags far behind that of the onshore environment in terms of both quantity and quality. This is partially due to inaccessibility and also the high cost of offshore activities. While dense echo sounding in shallow water can provide bathymetric data at a comparable resolution to that obtainable on land; sediment sample retrieval, borehole drilling and flow measurement remain costly and time-consuming endeavours. As a result, data collected from relatively sparse control points is extrapolated to a greater degree than would likely be performed for onshore activities. This has a potential impact on the accuracy and reliability of any models based on these variables.

It is considered in this case, that the erection of a numerical model is not justified in terms of the reliability of predictions that could be derived. However, it is interesting to note that where such numerical modelling has been carried out for other offshore wind farms, the models do not predict significant sedimentological impacts due to the construction and presence of turbine foundations (Natural Power, 2002; Seascape Energy Ltd., 2002).

Expected Environmental Impact of Proposed Development during Construction Phase

During the construction and decommissioning phases, it is expected that appropriate engineering plant and support vessels will operate at the proposed site for a relatively short period of time, to install and remove the various turbine foundations, support structures and other necessary infrastructure. The largest obstacle envisaged to be involved in this process is likely to be the turbine support structure, with a potential diameter of up to 5.5m if monopile foundations are used; if multi-pile or gravity based foundations are used this value is increased up to approximately 30 –35m.

Site Preparation

The extent of site preparation required, prior to foundation emplacement, is minimised if monopile foundations are used. In such a scenario, site preparations are likely to be limited to local levelling and removal of any large clasts, with minimal opportunity for sediment suspension. Where multi-pile or gravity based foundations are deployed, more intensive site preparation will be required, the magnitude and extent of which will be dependent on foundation design. In this scenario, the potential exists for greater quantities of sediment to be released into the water column. The likely usage of monopile foundations for the proposed development will lead to such ground preparations having no significant impact.

Foundation Emplacement

Dependent on the method used to install each turbine foundation, there is likely to be a requirement to drill or pile into the sediment. This will inevitably lead to the short-term release of small, localised volumes of sediment into the water column.

The potential worst-case scenario for this release of sediment would be through the utilisation of drilling or augering to emplace the foundation for a monopile turbine base. For example, a monopile foundation of 20m depth, 4m diameter and 0.1m wall thickness would require an excavation of approximately 250m³, rising to perhaps 20% above this to account for over-excavation.

However, a monopile foundation is hollow and if driven, sediment will occupy the interior of the structure. In the case of a driven pile, as is the expected method in these unconsolidated sediments, the displacement of sediment is relatively minor, on the order of $25m^3$.

Published data suggests that the volume of material released per foundation for a similar construction operation would be in the order of 700-800m³. Modelling carried out on the basis of these values suggests that the suspended sediment load only exceeds a background value (50mg/l) for short periods of time during augering in sand, and only then in close proximity (200m) to the foundation position (Natural Power, 2002). If augering encounters significant deposits of finer material, such as clay, this material is likely to remain in suspension for longer time periods and be dispersed over a larger area as a result.

The combination of the short-timescales and limited volumes of sediment involved in this process, provide minimal concern for elevated suspended sediment concentrations and the potential impacts associated with foundation emplacement are considered negligible.

Cable Laying

In addition to the turbines and their supporting structures, interconnecting cables between the turbines are required. These may potentially be buried beneath the seabed to ensure satisfactory protection against erosion and other activities that may compromise the integrity of the cables. Using modern ploughing techniques for cable burial, the seabed settles back in place over the cable as it is laid. However, during installation localised increases in suspended sediment concentrations may occur due to the release of finer fractions of the overlying sediment, but the extent of this is considered to be limited both spatially and temporally.

Alternatively, the cables may be left free-lying, assuming they are not at risk from trawling and other maritime activities. In such a scenario, the high-energy conditions experienced at the site are expected to lead to rapid burial of the cables, and a return to background sedimentological conditions.

Sediment released as a result of the above activities, is likely to result in only very thin deposits (apart from in the immediate vicinity of the installation sites). The natural high-energy conditions experienced at the site, will lead to these deposits being quickly reworked and integrated into the natural sedimentological regime.

In addition, the high costs of vessels & plant needed for cable laying and foundation installation suggests that foundation and cable laying activities will be staggered on a temporal basis with possibly one or two instances of such activities occurring at a given time. This "staggered" approach will facilitate a return to normal conditions and cause lesser impact than if a "blitz" approach was adopted.

As a result of these factors, installation of the turbines and associated infrastructure is likely to have a negligible impact on the sedimentary regime of the banks. In the immediate vicinity of foundation and cable installation activities, there will be a localised and limited change in conditions while installation activities are underway. This is not expected to alter the sedimentary regime of the site or the stability of the banks.

Expected Environmental Impact of Proposed Development during Operational Phase

During the operational phase it is anticipated that 145 turbines, ancillary cables and structures will be installed as part of the proposed development (Figure 1).

The impact of these structures on the sediment regime is considered in reference to:

- Potential for localised scour and sediment dispersal.
- The potential effect of the proposed development in changing local sedimentary conditions with consideration to the changes in the flow and hydrodynamic regimes.

Scour

All physical obstructions, whether naturally occurring or man-made, have the potential to initiate scour. Scour can be subdivided into general scour and local scour on the basis of temporal and spatial scale. General scour typically occurs over longer time scales and affects a larger area, whereas local scour results from the impact that an obstruction makes on its immediate surrounding area.

The presence of any structure (such as a turbine foundation) provides a local obstruction to flows, which would otherwise not occur. This results in an increase in local turbulence of the flow regime; the head-on flow slows down in front of the obstacle and then bifurcates to find an alternative path around it. As the bifurcated flow joins with adjacent flow at the sides of the obstacle, local velocity and turbulence (and the associated ability to potentially move sediments) increases (Figure 17). The separated flows rejoin in the wake of the structure and velocity decreases again.

Where this occurs in surface waters, the effects are expected to dissipate over short distances downstream of the structure. However, for flows on and just above the sediment surface, this local increase in velocity may exceed that required to mobilise sediment (dependent on sediment size and compaction) leading to the initiation of local scour. Due to bottom-friction, the changes to the flow regime due to an obstruction are expected to dissipate over short distances.

The following general relationships for scour can be expected:

1) Scour development is rapid in the initial phase following construction & then continues at a decreased rate until an equilibrium scour depth is reached.

- 2) The scour effects created by waves alone are generally small.
- 3) The typical shape of scour development is an inverted cone.

The principal concerns in relation to scour are the sediment plumes released due to the mobilisation of sediment and the potential for excessive scour to undermine the structural integrity of foundations. Where several structures exist in close proximity, the effect they have on flow conditions and scour may merge and lead to significant changes in the flow regime and general scour.

The magnitude of scour that occurs around an object is dependent on a number of conditions:

- Velocity of baseline flows.
- Local sediment conditions (grain size, compaction and other factors which affect its capacity for erosion).
- The footprint size and structure of the obstruction.

In general, monopile foundations will cause less scour due to their limited footprint size (4 to 5.5m). In contrast, multi-pile foundations would be expected to have a footprint of approximately 30-35m at the seabed and gravity foundations somewhere in the order of 20-25m (Figure 18).

Data observed in the North Sea, gives an indication of the approximate extent of local scour created due to the emplacement of a monopile structure. The placement of a 1.5m diameter structure, under similar sedimentary and slightly greater tidal flow velocities (average 1.4m/s), resulted in the formation of a scour pit with an equilibrium depth of 2.2m and a lateral extent of 14-20m (Noormets *et al.*, 2003).

Where necessary, scour protection can be deployed to minimize the effect of scour on the seabed, the design dependent on local geotechnical and engineering constraints. Scour protection can be implemented using a number of different means; these include, but are not limited, to the methods outlined below:

- Flow Energy Reduction Systems These consist of artificial seaweed and similar devices, which are placed on the seabed, in order to reduce flow velocity. Such a system is expected to be of limited use under the high-energy conditions experienced at the proposed development.
- Concrete Filled Geosynthetic Mattress Geosynthetic mattresses are much like large sandbags which are filled with concrete to form a flexible concrete mattress. While suitable for environments with a mild wave climate, this method of scour protection may prove difficult to deploy at the proposed site.
- Solid Apron or Collar This method consists of precast concrete blocks that are placed around the pile for instance, in the shape of two half moons.
- **Rock Armour** Rock armour consists of large rocks that are placed around the pile, with the goal of reducing flow velocities and shielding the softer sediments beneath. Rock armour can be deployed at three stages:
 - **Prior to piling** using this method the rock armour is placed on the seafloor prior to piling; the foundations are then driven through the rock armour and into the underlying seabed.

- **Piling followed by immediate placement of Rock Armour** This method involves placing the rock armour protection around the pile immediately after the pile has been driven into the seabed.
- Piling followed by placement of rock armour after the scour hole has been given some time to develop Using this method, the pile is put in place and the local scour hole allowed some time to develop around it; the rock armour is then deployed, some of it being placed within the scour hole. In a high-energy environment with sandy seabed conditions, it would be possible to place the rock armour in the scour hole developed after a few tides. This method has the advantage that the scour protection causes fewer disturbances to the hydrodynamic flow, as changes in the local topography of the seabed are minimised. This helps to reduce secondary scour effects. This is the method of scour protection that was deployed on the Arklow Bank Wind Farm.

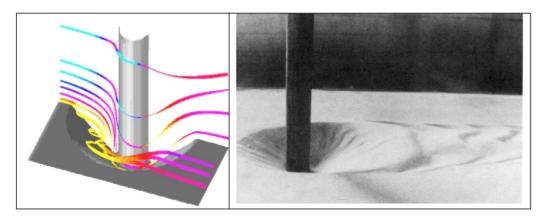


Figure 17: Flow modification and scour development around a vertical object (blue represents background flow velocity, whereas reds and yellows indicate areas of increased velocity) [from Cooper & Beiboer, 2002].

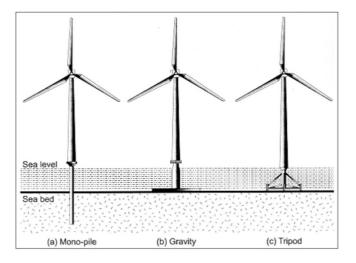


Figure 18: Various turbine foundation types.

Potential for Localised Scour around Structures at Proposed Site

A degree of localised scour is predicted to occur when any large artificial structure is placed on the seabed, but with appropriate management and foresight this can be limited and controlled.

The likely usage of monopile foundations (considered the most suitable for soft sediments in shallow water with actively mobile beds) as the preferred foundation type will limit the occurrence of scour due to the reduced obstruction they present to flows than other foundation types.

Scour rates are expected to be greatest in areas with highest flow rates; principally the crest of the Kish Bank; and the quantity of sediment removed before an equilibrium state is reached will be greater. The sedimentary bedforms observed in the area, indicate that flow rates are lower on the sides of the banks, implying that scour will occur to a lesser extent.

Scour protection will be designed and implemented to reduce and prevent this. This is likely to consist of a graded profile of rock fragments and coarse sediment placed around the base of the foundation, providing a shield to the underlying finer sediments, similar to the schemes outlined in the previous section. However the final design remains dependent on local engineering and geotechnical constraints.

In addition, the wide spacing of the turbine foundations in relation to their size – approximately 500m spacing between turbines with an expected diameter of about 5m – prevents the creation of cumulative effects due to the interaction of local scour from individual turbines.

In summary, local scour is likely to occur around the turbine foundations, but if appropriate measures are taken this can be prevented. The wide spacing planned between turbines is not envisaged to create a potential for global scour at the proposed site.

Impact of Proposed Development on Tidal Regimes and Wave Conditions

Each turbine foundation will form a local obstruction to tidal flows and wave patterns, leading to local modification of conditions. Tidal currents will accelerate around the obstacle, while waves will rebound from it.

However, the turbines themselves will occupy only a very small area of the proposed site, due to the large differences between their diameter and the spacing between individual turbines. Even in a worst-case scenario of gravity-based foundations (20 x 20m), the area of seabed occupied is under 1%. The 500m spacing between turbine sites is sufficient to allow flow conditions to return to a state approximate to their base level. This limits the opportunity for the effects from an individual turbine to interact and merge with those of its neighbours and lead to a widespread alteration in conditions.

As a result, the development will lead to localised and insignificant changes in flow and wave regime within the site area. In addition, the proposed development is not envisaged to lead to any regional changes in tidal and wave conditions. Immediately adjacent to the site, slight increases in tidal flow rates and decreases in wave height may be expected, but these are likely to return to background levels within a relatively short distance.

It is interesting to note that where numerical modelling has been carried out for similar developments (Natural Power, 2002; Seascape Energy Ltd., 2002), no change in tidal or wave conditions has been predicted for areas outside the planned site and its immediate vicinity. In addition, changes predicted within the area of the site have not been significant.

Impact of Proposed Development on Sedimentary Regime and Bank Stability

The localised changes in tidal flow and wave regime within the site of the proposed development will potentially lead to increased sediment mobility in the vicinity of individual turbines. However, assuming that appropriate scour protection is utilised, this will be limited in both extent and volume. Available evidence suggests that the sediments of the bank are presently quite mobile. As a result, any increased mobility due to the presence of the development is not viewed as being significant.

Outside the site and its immediate surroundings, very little change in sedimentary conditions is expected. Sedimentary pathways are expected to continue as before.

Bank stability is not expected to be altered due to the expected slight increase in sediment mobility. The large spacing between turbine sites and their relatively small footprint in comparison to the banks area, limits the extent of their effect. Even allowing for scour and increased sediment mobility adjacent to individual turbines, only a very small proportion of the bank can be affected. As a result, the proposed development is not viewed as posing a significant risk to bank stability.

Impact of Proposed Development on Coastal Stability and Erosion

Coastal erosion and instability on the east coast poses a major concern to planners both on a regional and national scale. The potential economic and social effects due to land and structure loss, disruption of transport networks and the potential for loss of lives make this a very serious issue.

As the proposed development is not envisaged to have a significant regional impact on either the wave, tidal or sedimentary regimes of the area, and is located several kilometres from shore, it is not expected to have any significant impact on coastal stability or erosion processes. Indeed, the minor obstruction the development poses to waves and the associated reduction in wind velocities might afford the coastline a very limited degree of protection.

Coastal erosion will continue regardless of the proposed development, with hydraulic forces such as waves continuing to erode and remove headlands such as Bray and Howth Head. An unknown and unquantifiable risk of change in the future exists due to the potential influence of global warming on climate conditions and sea level. The production of emissions-free electricity from the Kish and Bray Banks would ameliorate any such risk.

Impact of Proposed Development in Relation to Aggregate Extraction

The Kish and Bray Banks have long been recognised as a potential source of material for the aggregates industry. Their location (approximately 10km from the Dublin metropolitan areas) and the shallow depths prevalent around the banks make them ideal for this purpose. However, no plans for offshore aggregate extraction currently exist.

The utilisation of the banks as a site for offshore wind farms is not compatible with their usage for aggregate extraction, as this may lead to the potential destabilisation of turbine foundations. Following the working lifetime of the proposed wind farm development and any necessary restoration, the site will once again be available as a potential source of aggregates.

The environmental impact of the proposed wind farm development is considered to be far less than the potential impact of wholesale aggregate extraction.

Impact of Proposed Development in Relation to Petroleum Resources

Currently, no economic deposits of petroleum resources have been identified in the area of the development.

The proposed wind farm site is not envisaged to cause any significant obstruction in the future development and potential extraction of petroleum resources.

Impact of Proposed Development in Relation to Coal Extraction

The existence of coal bearing strata has been recognised in the Kish Bank Basin since the 1970's. Details of these resources and potential means for extracting them are contained in GSI Report Series 86/3. No plans exist, as yet, to further explore or begin extraction of this resource. Extraction using the methods outlined therein is unlikely to be economically viable in the current climate.

The proposed wind farm site is not envisaged to cause any significant obstruction in the future development and potential extraction of this resource. In addition, the environmental impact of the proposed wind farm site is considered to be significantly less than that likely to result from any future development of the Kish Bank Basin coal deposits (taking into account both the onshore and offshore impacts of the methods outlined in the aforementioned report and the impact of carbon and sulphur emissions resulting from the utilisation of material extracted).

Impact of Proposed Development in Relation to the Potential for Release of Sediment Trapped Contaminants

The installation of wind turbines at the proposed site will inevitably lead to the release and remobilisation of limited amounts of sediment during emplacement of the foundations. A small potential exists that some of the sediment disturbed may harbour potentially toxic compounds which may be released into the environment.

No studies for this have been carried out in the area. A potential source of such contaminants is the release of sewage and other material into Dublin Bay. Sediments closer to the source would be considered more at risk of containing such contaminants and the finer, low-energy sediments observed closer to shore are more likely to be suitable for harbouring such contaminants than the coarser sands and gravels of the banks. In addition, the high-energy conditions experienced at the proposed site, would be expected to lead to rapid dispersal of any contaminants prior to entrapment in the sediment.

As such, potential for the release of contaminants during installation at the proposed development is considered minimal.

Impact of Proposed Development in Relation to Earthquake Activity

Areas around the Irish Sea and the associated landmasses of Ireland and Wales, have historically experienced several minor earthquakes, though the epicentre of known events are all generally focused to the East of the planned site, closer to Wales. Historic earthquakes in the region have been of low magnitude and only caused relatively minor structural damage.

There are a series of N-S trending faults near the proposed site, which could potentially accommodate crustal movements associated with earthquakes. However, none of these are currently believed to be active or experiencing significant strain. Though this may change in the future, they are unlikely to become reactivated during the lifetime of the planned wind farm.

All the evidence suggests that the likelihood of earthquakes leading to a significant environmental impact at the proposed site is low.

Conclusions

- Installation of turbine foundations and associated infrastructure will lead to the release of small volumes of sediment into the surrounding environment. This will lead to local increases in suspended sediment concentrations. Such increases will be temporally and spatially limited. The high energy conditions experienced at the proposed site will lead to rapid reworking and dispersal of such sediment into the natural sedimentary regime of the banks. Installation of such structures will have minimal environmental impact with regard to sedimentation.
- Turbine foundations and any free lying cables will provide limited obstructions to tidal flows. This could lead to localised scouring around such structures, though this may be prevented through the deployment of scour protection measures. Spacing between structures is sufficient to prevent interaction of scour from individual foundations.
- The proposed wind farm will provide a limited obstruction to tidal flows, potentially leading to localised increases or decreases in flow rates. The small size of the turbine structures and the spacing between turbine locations imply that such changes will be limited in magnitude. The overall effect of the proposed development on tidal flows, apart from in the immediate vicinity of the site, is deemed insignificant.
- The proposed wind farm would provide a limited obstruction to waves, potentially leading to changes in height and orientation. The small size of the turbine structures and the large spacing between turbine locations imply that such changes will be very limited in magnitude. This conclusion is supported by modelling carried out for a number of adjacent wind farm developments. The overall effect of the proposed development on wave conditions, apart from in the immediate vicinity of the site, is deemed insignificant.
- The proposed wind farm development would have a limited impact on the sites natural sedimentary processes. The sites sediments exist in quite a high-energy state, and the development is not likely to obstruct or alter the banks sediment pathways. The slight local changes in flow conditions will cause some modification of sedimentary conditions, but the overall activities of the bank and its interaction with the shoreline are not likely to be significantly affected.
- The environmental impact of the proposed development is less than the expected impact of some other potential uses of the area.

Recommendations

- Further studies may be required in order to facilitate the design of optimal scour prevention measures.
- Subject to engineering constraints, monopile foundations should be used in preference to other foundation types, due to their reduced footprint and the reduced ground preparation required prior to emplacement
- Where feasible, driving should be used in preference to augering for the emplacement of monopile foundations, due to the smaller volumes of sediment potentially released.
- Monitoring following emplacement of the first turbines will allow the effectiveness of deployed scour prevention measures to be assessed and modified if required.
- Careful consideration is required regarding the methods used to protect the cable deployed during the proposed development.
 - Within the main turbine site, the seabed is characterised by highly mobile sands. It is expected, that following construction, this area will be noted on nautical charts and potentially excluded from trawling and non-emergency vessel anchoring, precluding the most common causes of cable failure. In such an environment the cable may be left free-lying or trenched.
 - If these cables are left free-lying, it is expected that they will be 'absorbed' into the background sedimentary patterns, becoming periodically buried and uncovered, dependent on sediment migration patterns. Cable design needs to be sufficiently armoured to resist the abrasive effects resulting from such sediment mobility.
 - Where trenching is employed, burial depth needs to be of sufficient magnitude to account for this sediment mobility. Planned and achieved burial depths should be measured from the troughs of identified sandwaves, rather than crests, due to the mobility of such features over time.
 - The proposed cable route represents more heterogenous sedimentary conditions. The offshore portion of this route appears to consist of sandy sediments with small-scale bedforms (ripples) whose magnitude increases landward. Closer to shore, coarser grained sediments become dominant. Along this route, cables are considered more likely to be impacted by fishing or vessel anchoring, than within the main development. As a result, entrenching the cables is suggested as the most suitable method. Again, planned and achieved burial depths should be measured from the troughs of sedimentary bedforms present in the area, allowing for the mobility of such features.

Consultation with experienced marine cable-laying contractors is recommended to further establish the particulars of cable-laying operations.

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Proposed Kish & Bray Banks Offshore windfarm

Preliminary site investigation

Report No: 08-0585



Client: Saorgus Energy Ltd

November 2008

Proposed Kish & Bray Banks offshore windfarm Preliminary site investigation

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Appendix B	Excerpts from geology maps
Appendix C	Borehole logs
Appendix D	Laboratory test results
Appendix E	Photographs of Jack-up platform

Document Control Sheet

Report No.: 08-0585

Project title: Proposed Kish & Bray Banks offshore windfarm Preliminary site investigation

Client: Saorgus Energy Ltd

Revision	Status	Report prepared by:	Report reviewed by:	Issue date
	Final		1 (12.2) (12.2)	L
		David Cameron	Gabriel Gallagher	
		BSc CEng MIEI	BSc (Hons) PhD CEng MICE MIHT	

The works were conducted in accordance with:

Specification and related documents for ground investigation in Ireland (Engineers Ireland, 2006)

British Standards Institute (1999) *BS 5930:1999, Code of practice for site investigations.* Incorporating Amendment No. 1 of December 2007

Methods of describing soils and rocks

Soil and rock descriptions are based on the guidance in Section 6 of BS 5930: 1999, *The Code of Practice for Site Investigation*, with the following exceptions:

- 1. The following terms are used in the description of fine-grained soils, where applicable:
 - soft to firm: fine-grained soil with consistency description close to the boundary between soft and firm soil (Table 13 of BS5930).
 - firm to stiff: fine-grained soil with consistency description close to the boundary between firm and stiff soil (Table 13 of BS5930).

Abbreviations	used on exploratory hole logs
U	Nominal 100mm diameter undisturbed open tube sample
Р	Nominal 100mm diameter undisturbed piston sample
В	Bulk disturbed sample
D / J	Small disturbed sample
W	Water sample
ES / EW	Soil sample for environmental testing / Water sample for environmental testing
SPT	Standard penetration test using a split spoon sampler (small disturbed sample obtained)
СРТ	Standard penetration test using 60 degree solid cone
X,X/X,X,X,X	Blows per increment during the standard penetration test. The initial two values relate to the seating drive (150mm) and the remaining four to the 75mm increments of the test length.
N=X	SPT blow count 'N' given by the summation of the blows 'X' required to drive the full test length (300mm)
X*/Y	Incomplete standard penetration test where the seating drive could not be completed. The blows 'X' represent the total blows for the given length of seating drive 'Y' (mm)
X/Z	Incomplete standard penetration test where the seating drive was achieved but the full test length was not. The blows 'X' represent the total blows for the given test length 'Z' (mm)
V	Shear vane test (borehole) Hand vane test (trial pit) Shear strength stated in kPa
VR	V: undisturbed vane shear strength VR: remoulded vane shear strength
<u>dd/mm/yy: 1.0</u> dd/mm/yy: dry	Date & water level at the borehole depth at the end of shift and the start of the following shift
Abbreviations	relating to rock core – reference Clause 44.4.4 of BS 5930: 1999
TCR (%)	Total Core Recovery : Ratio of rock/soil core recovered (both solid and non-intact) to the total length of core run.
SCR (%)	Solid Core Recovery : Ratio of <i>solid core</i> to the total length of core run. <i>Solid core</i> has a full diameter, uninterrupted by natural discontinuities, but not necessarily a full circumference and is measured along the core axis between natural fractures.
RQD (%)	Rock Quality Designation : Ratio of total length of <i>solid core</i> pieces greater than 100mm to the total length of core run.
FI	Fracture Index : Number of natural discontinuities per metre over an indicated length of core of similar intensity of fracturing.
NI	Non Intact : Used where the rock material was recovered fragmented, for example as fine to coarse gravel size particles.
DIF	Drilling induced fracture: A fracture of non-geological origin brought about by the rock coring.

Proposed Kish & Bray Banks offshore windfarm Preliminary site investigation

1 AUTHORITY

On the instructions of the Client Saorgus Energy Ltd, a ground investigation was undertaken at a site on and adjacent to Kish & Bray Banks to establish the ground conditions with regard to the proposed construction of an offshore windfarm.

2 SCOPE

The extent of the investigation was as directed by Glover Site Investigations Ltd and included boreholes, sampling, insitu and laboratory testing, and the preparation of a report on the findings, including recommendations for construction.

3 DESCRIPTION OF SITE

It is proposed to construct 145 wind turbines on and around Kish and Bray Banks off the coast of Co. Dublin and Co. Wicklow; location as shown on the plan in shown in Appendix A.

Bed levels at the location of the boreholes were in the range of 4.5-13.1m below Chart Datum.

4 SITE OPERATIONS

The Site Operations, conducted during the period 13 to 26 September 2008, comprised:

• three boreholes by cable percussion boring methods

The number and location of the exploratory holes were as instructed by the Engineer. Their locations are shown on the exploratory hole location plan in Appendix A.

4.1 Boreholes by light percussion methods

Three boreholes were sunk by means of a Dando 2000 rig using shell and auger techniques. The boreholes were bored in 200mm diameter using temporary casing and boring tools and extended to depths of 19.1-20.0m.

The boreholes were bored from a large jack-up capable of working in 28m of water. The jack-up was moved around the site by means of a large tug.

Disturbed (small bag and bulk bag) samples were taken, representative of the strata encountered.

Standard penetration tests were carried out at regular intervals, where appropriate. The borehole logs report whether the split spoon sampler (SPT) or solid cone (CPT) was used. The overall penetration is stated for those tests for which the full 450mm drive was not possible.

The borehole logs are provided in Appendix C.

5 LABORATORY WORK

Upon their receipt in the laboratory, all disturbed samples were carefully examined and accurately described and their descriptions incorporated into the preliminary borehole logs. The logs were revised, where necessary, based on the results of the laboratory tests.

Laboratory testing, conducted as scheduled by the Engineer, comprised the following:

- classification tests: particle size distribution by wet sieving.
- soil chemistry tests: pH and water soluble sulfate content.

The test results are presented in Appendix D. Unless noted otherwise, tests were conducted in accordance with BS 1377:1990, *Methods of test for soils for civil engineering purposes*. *Parts 1 to 9*.

6 GROUND CONDITIONS

6.1 General geology of the site

Appendix B presents excerpts of the 1:1,000,000 scale Solid and Quaternary geology maps of the area (British Geological Survey, 1991 and 1994) These show:

• Permian-Triassic rocks overlain by Quaternary glacial deposits.

The soil strata are of sand (>50% sand, <5% gravel) belonging to the Late Pleistocene to Early Holocene periods.

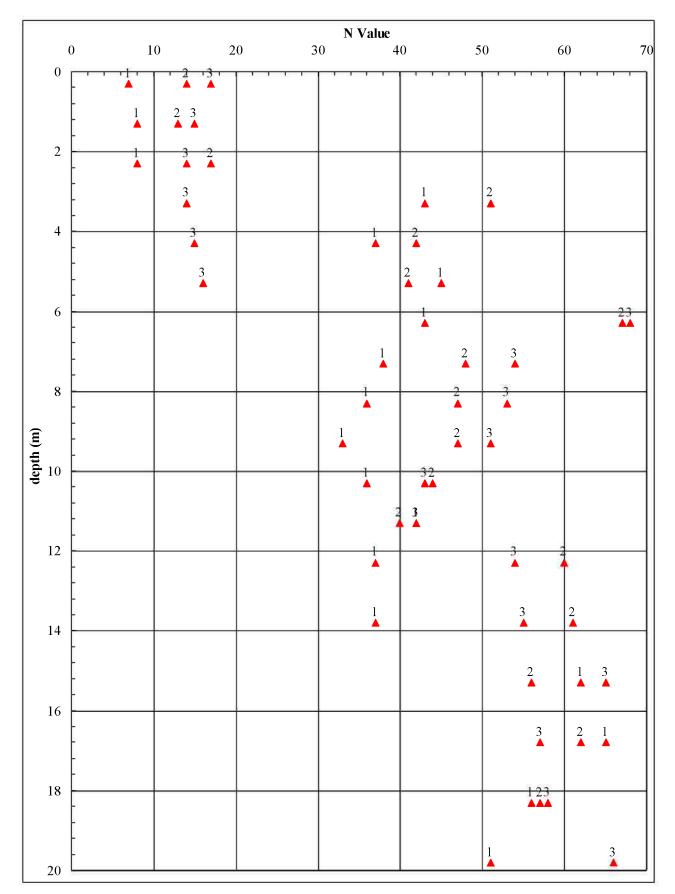
6.2 Ground types

The soils encountered in each of the three boreholes, to their maximum depth of 20m, were marine sand deposits, typically slightly silty – silty, predominantly fine to medium sand.

The plot on the following page shows the variation of standard penetration test *N*-value with depth. The label above each data point is the borehole number.

The plot shows a trend of increasing *N*-value with depth with the soil and the following:

- loose to medium dense soil in the upper 2.5-6m
- becoming medium dense at greater depth
- and very dense below approximately 12m depth.



Variation of standard penetration test N-value with depth in the three boreholes

7 **DISCUSSION**

7.1 **Proposed construction**

It is proposed to construct 145 wind turbines on the Kish and Bray Banks.

The proposed tip height is 160m above mean sea level.

The recommendations for construction below should be read in conjunction with the non-intrusive geophysical surveys carried out by Hydrographic Surveys.

7.2 Recommendations for construction

7.2.1 Foundations to turbine tower

Expert opinion should be sought as to what depth of marine sands must be discounted due to the possibility of shifting sediment patterns.

The foundations for the turbines can be installed either as gravity foundations or using steel monopiles.

Gravity foundations, placed on the seabed and stabilised by sand or water, should be founded below the depth that could be affected by shifting ground and on dense sands, as encountered below 2.5-6m in the three boreholes. Adopting a design *N*-value of 40, and applying the method of Burland and Burbidge (1984) allows derivation of the following:

diameter of circular foundation (m)	allowable bearing pressure limiting settlements to 25mm (kPa)
10	350
15	275
20	225
25	200

Monopiles, formed by installation of hollow steel tubes by driving, drilling or vibration, should be designed in conjunction with specialist contractors. The method of pile installation and the resultant length of the pile is fundamental to the capacity of the pile.

Chemical tests (pH and water soluble sulfate contents) on soil samples indicate Design Sulfate Class DS-1 for the site and ACEC Class AC-1 – reference Table C1 of BRE Special Digest 1 (Building Research Establishment, 2005). The Digest indicates that no special measures are required in the mix design for underground concrete.

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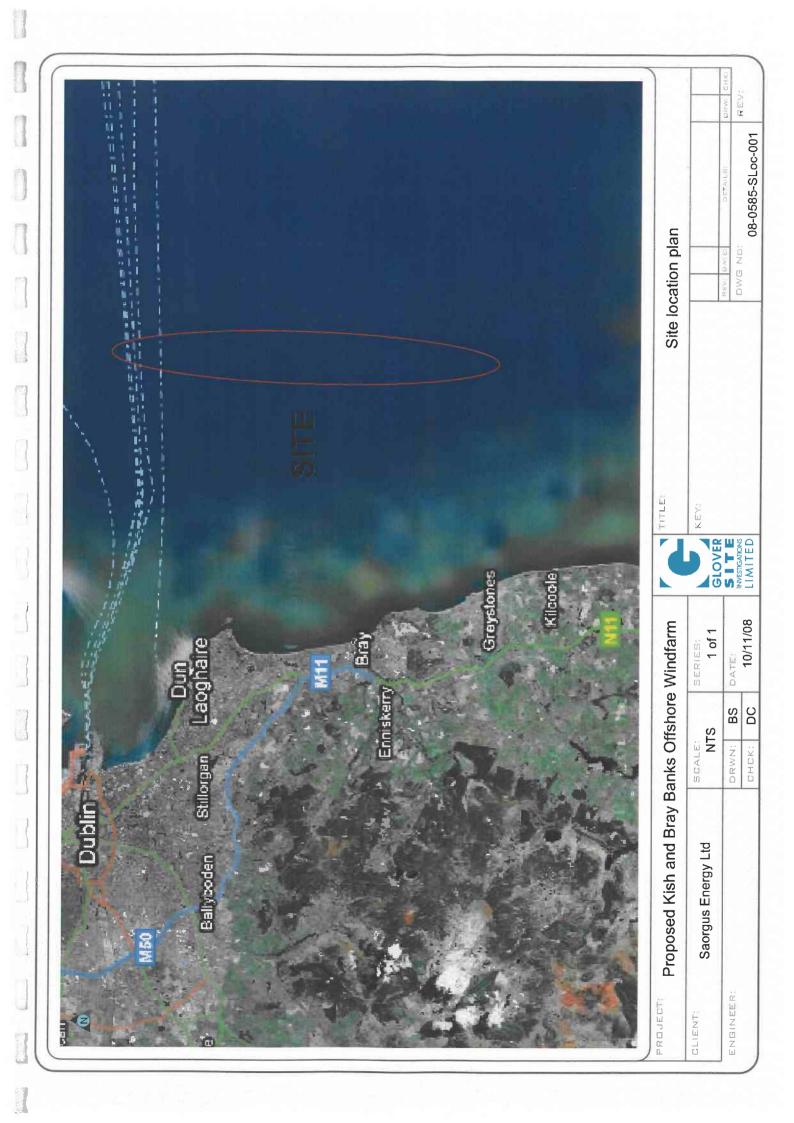
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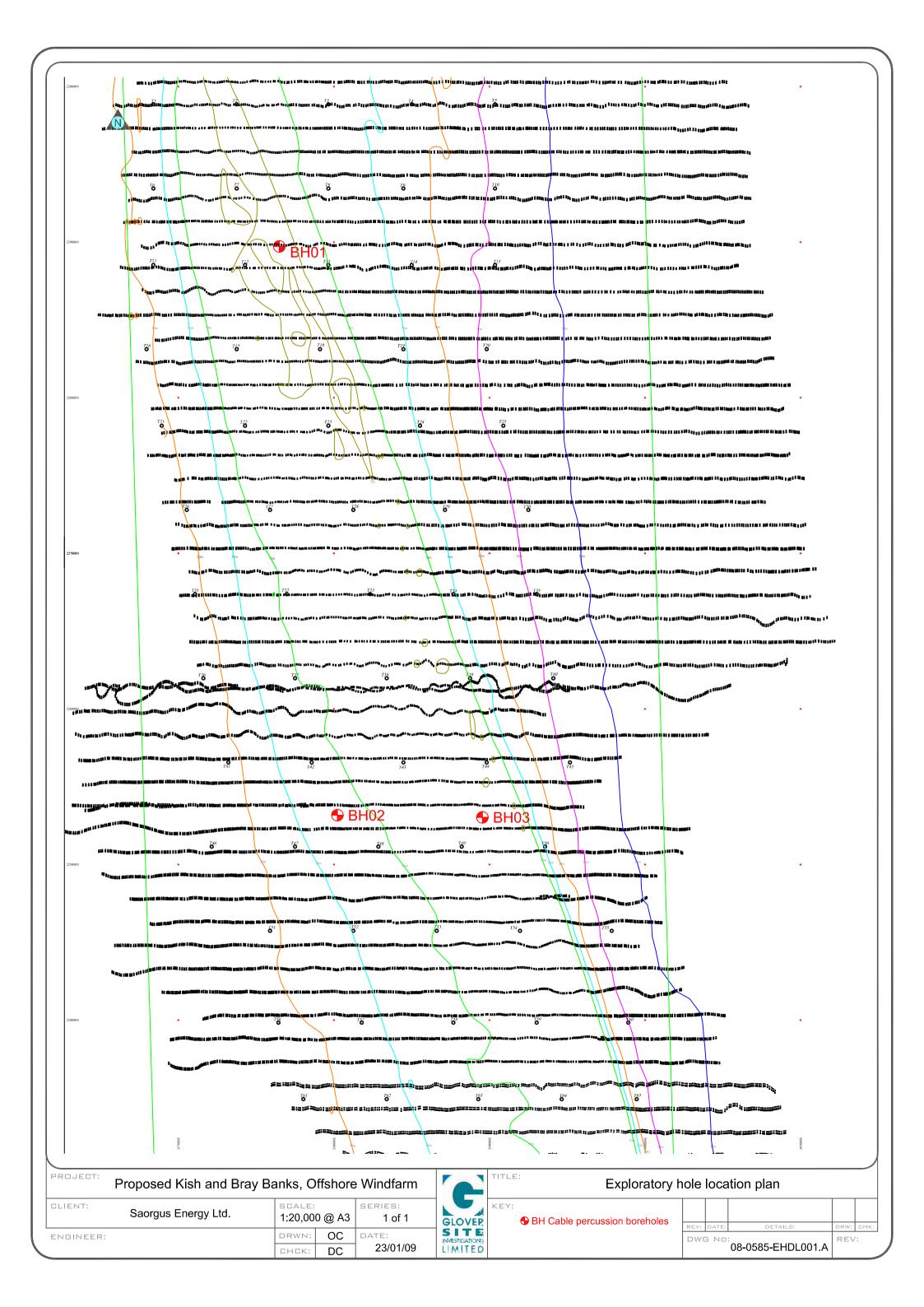
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Burland, JB and Burbidge, MC (1984), *Settlement of foundations on sand and gravel*, Proceedings of the Institution of Civil Engineers, Part 1, 1985, 78, Dec., 1325-1381.

Site and exploratory hole location plans

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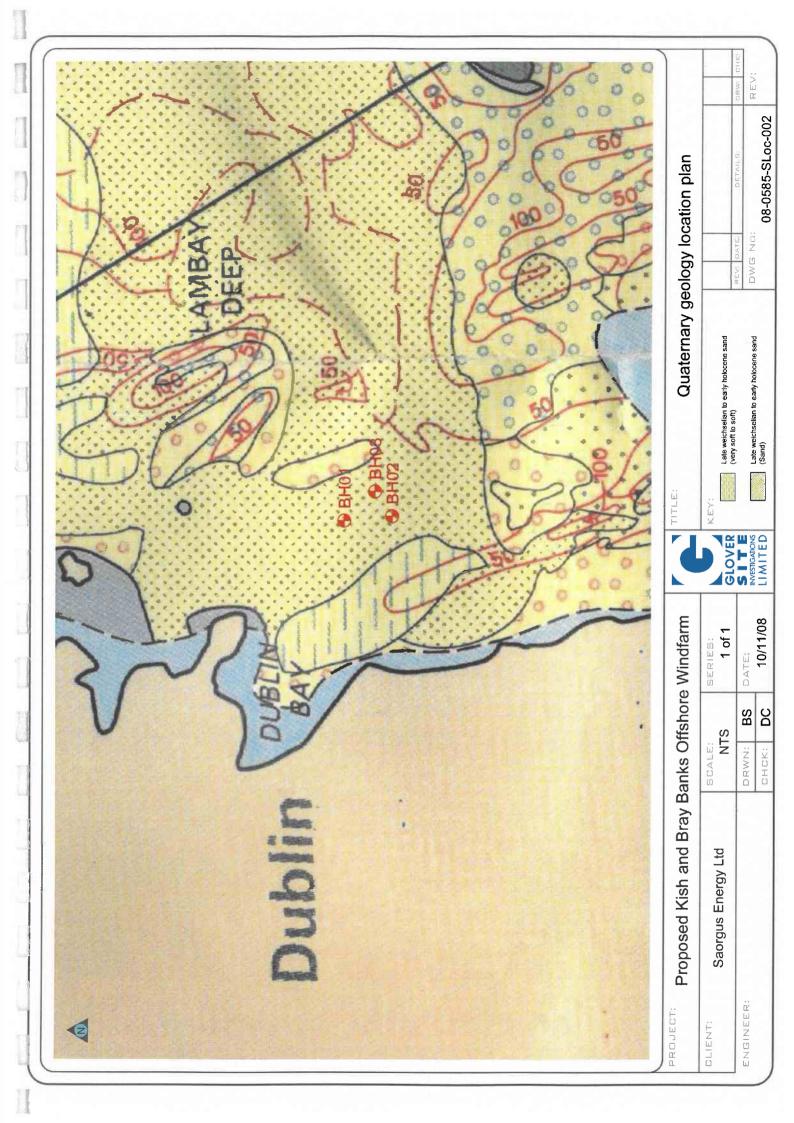


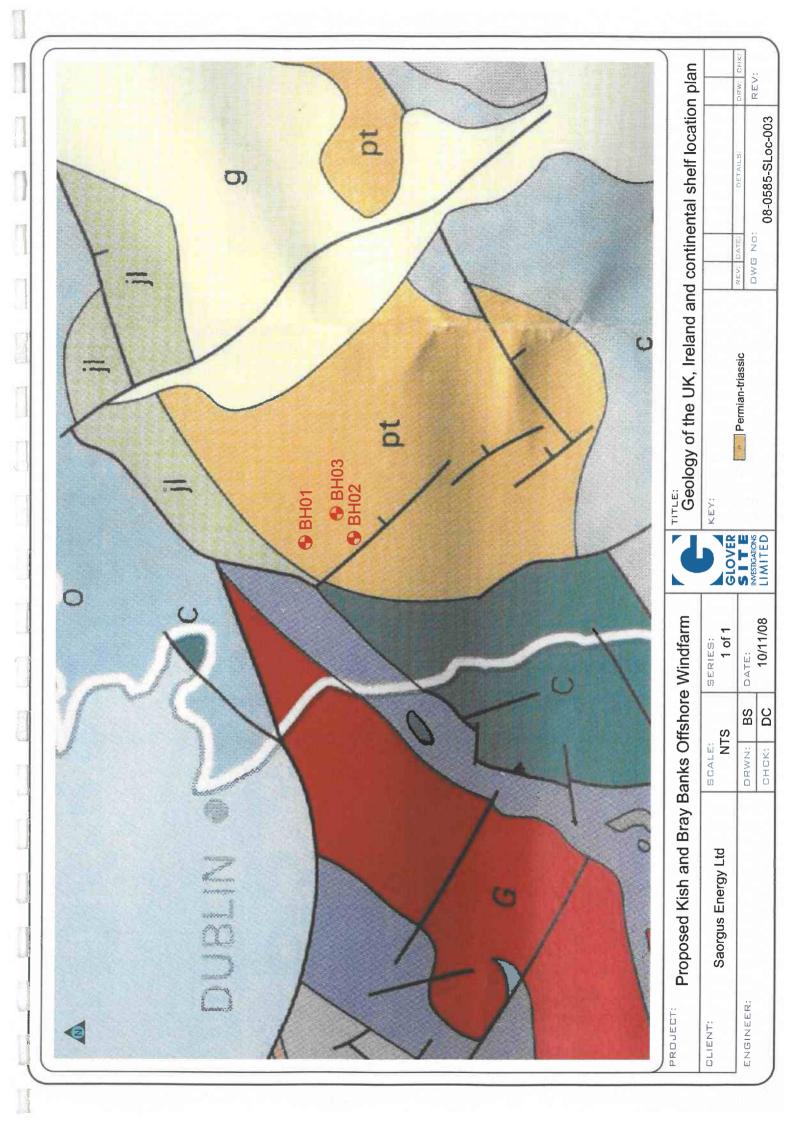
Appendix B

Excerpt of geology maps

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Appendix C

Borehole logs

Glo	over Sit	e Ir	ive	stigatio	ons	Ltd	Site Proposed Windfarm Kish & Bray Banks off Co Dublin and Co Wicklow	Boreh Numb BHC
Boring Method Cable Percussion		Casing Dlameter 200mm cased to 20.00m				Level (mCD) -4.50	Client Saorgus Energy Ltd	Job Numb 08-05
Depth		Location 337649.9 E 228972 N			Dates 13. 16.	/09/2008- /09/2008	Engineer	Sheet 1/2
Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mCD)	Depth (m) (Thickness)	Description	Legend
0.00	B SPT N=8			1,2/1,2,2,2			Loose grey silty fine to medium SAND with a trace of fine gravel and occasional shells	
2.00-2.45 2.00	SPT N=8 B			1,2/1,2,3,2				
	SPT N=43 B			5,6/9,10,12,12	-7.50	3.00	Dense grey silty fine to coarse SAND with a trace of fine to medium gravel and occasional shells	
4.00-4.45 4.00	SPT N=37 B			6,7/8,9,10,10				
5.00-5.45 5.00	SPT N=45 B			5,7/9,10,13,13				
6.00-6.45 6.00	SPT N=43 B			4,7/9,9,12,13		(7.00)		
7.00-7.45 7.00	SPT N=38 B			6,8/8,9,10,11				
8.00-8.45 8.00	SPT N=36 B			5,6/8,9,10,9				
9.00-9.45 9.00	SPT N=33 B		•	4,8/8,9,7,9				
10.00-10.45	SPT N=36			5,6/7,8,10,11	1100	-		XX X X
Remarks		L1			-14.50	<u> </u>	Scale (approx) Logge
							(approx 1:50) By dc/kl
							Figure	

Glo	ver Sit	e In	ve	stigatio	ons	Ltd	Site Proposed Windfarm Kish & Bray Banks off Co Dublin and Co Wicklow	Borehole Number BH01
Boring Method Cable Percussion			Diamete Omm cas	r ed to 20.00m		Level (mCD) -4.50	Client Saorgus Energy Ltd	Job Numbe 08-058
Death		Locatio 33		228972 N	Dates 13 16	/09/2008- /09/2008	Engineer	Sheet 2/2
Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mCD)	Depth (m) (Thickness)	Description	Legend
10.00 11.00-11.45 11.00	B SPT N=42 B			5,7/8.10,11,13		handaandanaa	Dense grey slightly silty fine to medium SAND with occasional shells	
12.00-12,45 12.00	SPT N=37 B			3,6/8,8,9,12		(5.00)		
13.50-13.95 13.50	SPT N=37 B			5,7/8,9,10,10				
15.00-15.45 15.00	SPT N=62 D			7,10/12,15,17,18	-19.50	15.00	Very dense grey slightly silty fine to medium SAND with occasional shells	
16.50-16.95 16.50	SPT N=65 D			8,11/12,16,18,19				
18.00-18.45 18.00	SPT N=56 D			7,10/12,13,15,16				
19.50-19.95 19.50	SPT N=51 D			8.9/10,13,14,14	-24.50		Complete at 20.00m	
Remarks					. <u></u>		Scale (approx	
							1:50 Figure	dc/kl No. 585.BH01

Glo	over Sit	e In	ve	stigatio	ons	Ltd	Site Proposed Windfarm Kish & Bray Banks off Co Dublin and Co Wicklow	Boreho Numbe BH0	
Boring Method Cable Percussion Depth (m) Sample / Test 0.00-0.45 SPT N=14 1.00-1.45 SPT N=13 2.00-2.45 SPT N=13 3.00-3.45 SPT N=17 3.00-3.45 SPT N=51 4.00-4.45 SPT N=42 5.00-5.45 SPT N=41 6.00-6.45 SPT N=67			Diamete Omm cas	r ed to 19.10m		Level (mCD) 13.10	Client Saorgus Energy Ltd	Job Number 08-0585	
		Locatio 33		225316.9 N		/09/2008- /09/2008	Engineer	Sheet 1/2	
Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mCD)	Depth (m) (Thickness)	Description	Legend	
0.00 1.00-1.45	B SPT N=13			1,2/3,3,3,5 2,2/3,2,4,4			Medium dense grey slightly silty fine to medium SAND with occasional cobbles		
	SPT N=17 B			3,4/3,5,4,5		(3.20)			
	SPT N=51 B			5,7/9,11,14,17	-16.30	3.20	Dense grey slightly silty fine to medium SAND with a trace of fine gravel and occasional shells		
4.00-4.45 4.00	SPT N=42 B			4,7/8,10,12,12					
	SPT N=41 B			5,6/8,10,11,12					
6.00-6.45 6.00	SPT N=67 B			7,8/11,15,18,23		(6.80)			
7.00-7.45 7.00	SPT N=48 B			6,8/10,12,12,14		(6.80)			
8.00-8.45 8.00	SPT N=47 B			7,9/10,12,13,12					
9.00-9.45 9.00	SPT N=47 B			6,8/10,13,12,12					
10.00-10.45	SPT N=44			6,7/10,11,12,11	-23.10	- - - 10.00 -		× · · · × · · · · · · · · · · · · · · ·	
Remarks		i	L.		<u> </u>		Scale (approx)	Logged By	
							1:50 Figure N	DC/KL	

Glo Boring Meth			Diamete	stigatio		Ltd	Site Proposed Windfarm Kish & Bray Banks off Co Dublin and Co Wicklow	Borehole Number BH02 Job	
Cable Percu	ssion	20	0mm cas	sed to 19.10m		-13.10	Saorgus Energy Ltd	Numbe 08-058	
		Locatio 33		225316.9 N	Dates 21/09/2008- 26/09/2008		Engineer	Sheet 2/2	
Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mCD)	Depth (m) (Thickness)	Description	Legend	
10.00	B SPT N=40			7,8/9,9,10,12		(2.00)	Dense grey slightly silty fine to medium SAND with occasional shells		
11.00 12.00-12.45 12.00	B SPT N=60 B			8,10/13,15,16,16	-25.10		Very dense grey slightly silty fine to medium SAND with occasional shells		
13.50-13.95 13.50	SPT N=61 B			10,13/14,15,16,16					
15.00-15.45 15.00	SPT N=56 B			8,11/12,12,16,16		-			
16.50-16.95 16.50	SPT N=62 B			7,10/13,15,16,18		(7.10)			
8.00-18.45 8.00	SPT N=57 B			9,11/12,14,15,16					
					-32.20	19.10 -	Complete at 19.10m		
Remarks					<u></u> E		Scale (approx)	Logged By	
							1:50	DC/KL	
							Figure N	lo. 85.BH02	

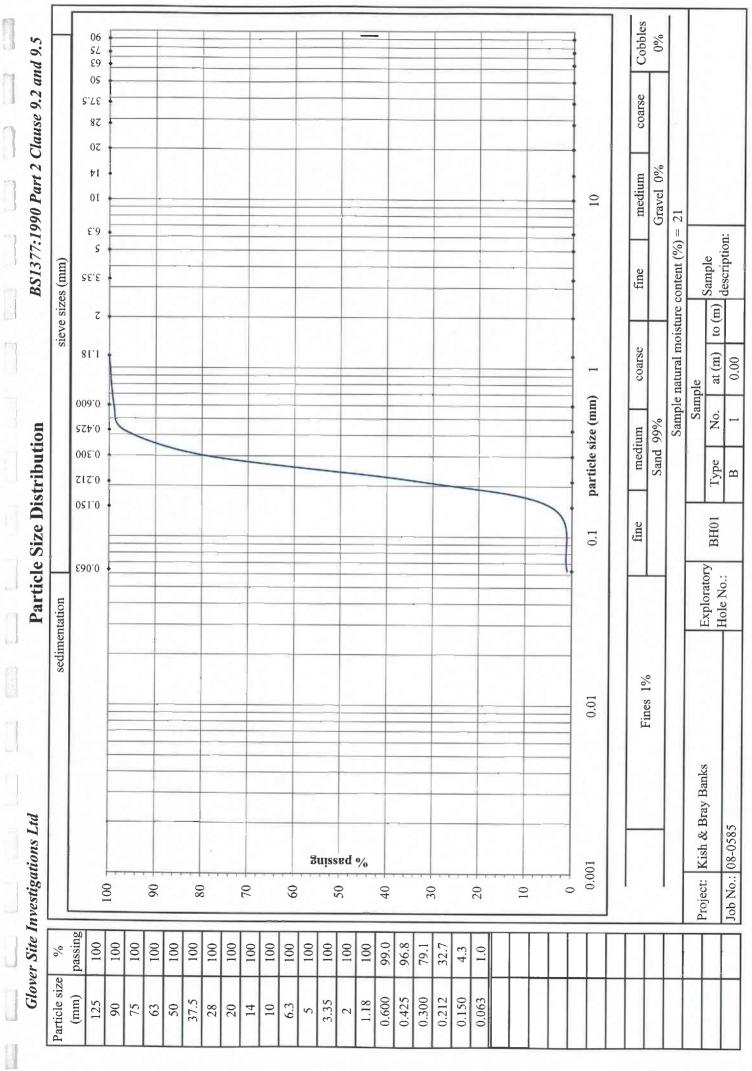
Glo	over Sit	e In	ve	stigatio	ons	Ltd	Site Proposed Windfarm Kish & Bray Banks off Co Dublin and Co Wicklow	Boreho Numbe BH0
		Casing Diameter 200mm cased to 20.00m				Level (mCD) -7.30	Client Saorgus Energy Ltd	Job Numbe 08-058
Glover Si Boring Method Cable Percussion Depth (m) Sample / Test 0.00-0.45 SPT N=17 0.00-1.45 SPT N=15 1.00-1.45 SPT N=14 2.00-2.45 SPT N=14 3.00-3.45 SPT N=14 3.00-3.45 SPT N=14 3.00-3.45 SPT N=14 5.00-5.45 SPT N=15 5.00-5.45 SPT N=16 6.00-6.45 SPT N=68		Locatio 33		225303.1 N	Dates 17 19	7/09/2008- 9/09/2008	Engineer	Sheet 1/2
Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mCD)	Depth (m) (Thickness)	Description	Legend
0.00 1.00-1.45	B SPT N=15			2,3/4,5,4,4 3,3/3,4,5,3			Medium dense grey silty fine to medium SAND with occasional shells	
2.00-2.45				2,3/3,3,4,4		(6.00)		
				2,2/3,4,3,4		(6.00)		
4.00-4.45 4.00				3,3/3,4,4,4				
5.00-5.45 5.00	SPT N=16 B			3,4/3,4,4,5		6.00		
6.00-6.45 6.00	SPT N=68 B			7,12/13,16,18,21	-13.30	6.00	Very dense grey slightly silty fine to medium SAND with occasional shells	
7.00-7.45 7.00	SPT N=54 B			8,10/11,13,15,15				
8.00-8.45 8.00	SPT N=53 B			9,10/11,13,13,16		(4.00)		
9.00-9.45 9.00	SPT N=51 B			8,11/10,10,13,18				
10.00-10.45 Remarks	SPT N=43			7,8/9,10,12,12	-17.30	10.00		
Remarks							Scale (approx)	Logged By
							1:50	DC/KL
							Figure 08-0	No. 585.BH03

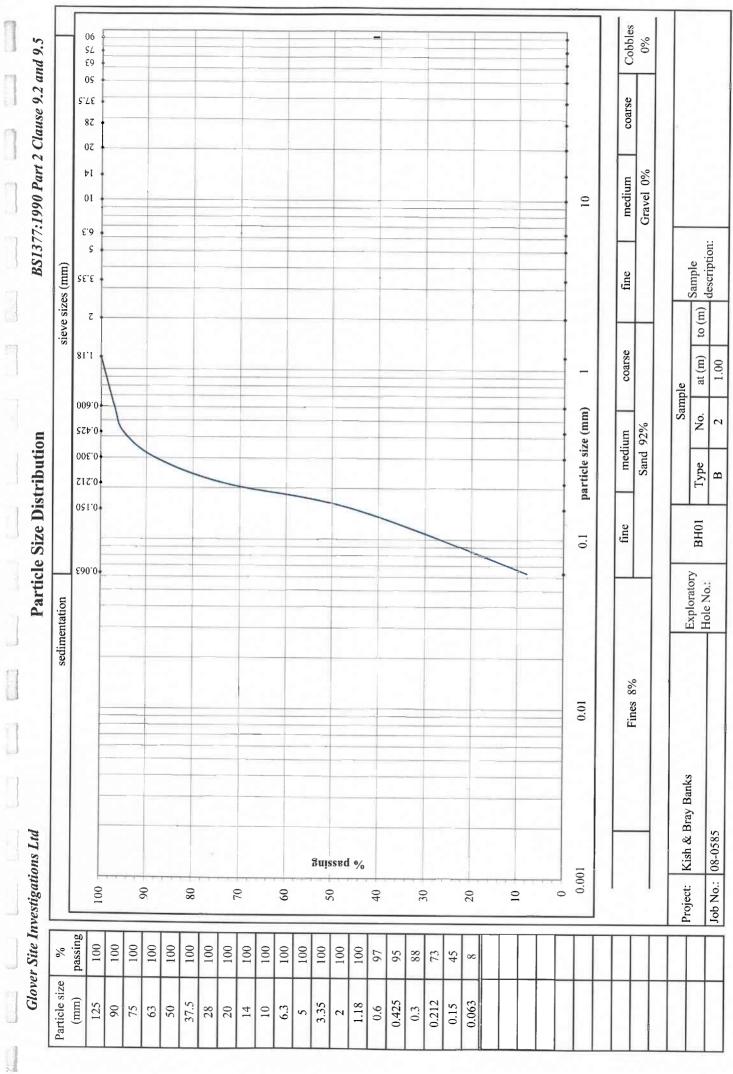
		-		stigatio			Site Proposed Windfarm Kish & Bray Banks off Co Dublin and Co Wicklow	Borehole Number BH03	
Boring Method Cable Percussion		Casing Diameter 200mm cased to 20.00m			Ground Level (mCD) -7.30		Client Saorgus Energy Ltd	Job Numbe 08-05	
		Locatio		225303.1 N	Dates	//09/2008-	Engineer	Sheet	
Depth (m)	Sample / Tests	Casing Water		Field Records	19/09/2008 Level Depth (mCD) (m) (Thickness)		Description	Legend	
10.00	В	-(m)	Depth (m)		(1105)			Legend	
11.00-11.45 11.00	SPT N=42 B			6,7/9,10,11,12		(2.30)	Dense grey slightly silty fine to medium SAND with occasional shells		
12.00-12.45 12.00	SPT N=54 B			3,4/5,15,16,18	-19.60		Very dense grey slightly silty fine to medium SAND with occasional shells		
13.50-13.95 13.50	SPT N=55 B			8,9/12,13,14,16					
15.00-15.45 15.00	SPT N=65 B			9,11/13,16,18,18					
16.50-16.95 16.50	SPT N=57 D			7,10/12,15,14,16					
18.00-18.45 18.00	SPT N=58 D			10,11/13,14,16,15					
9.50-19.95 9.50	SPT N=66 D			10,14/15,17,16,18	-27.30	20.00 -	Complete at 20.00m		
Remarks							Scale (approx)		
							1:50 Figure	DC/KL No. 585.BH03	

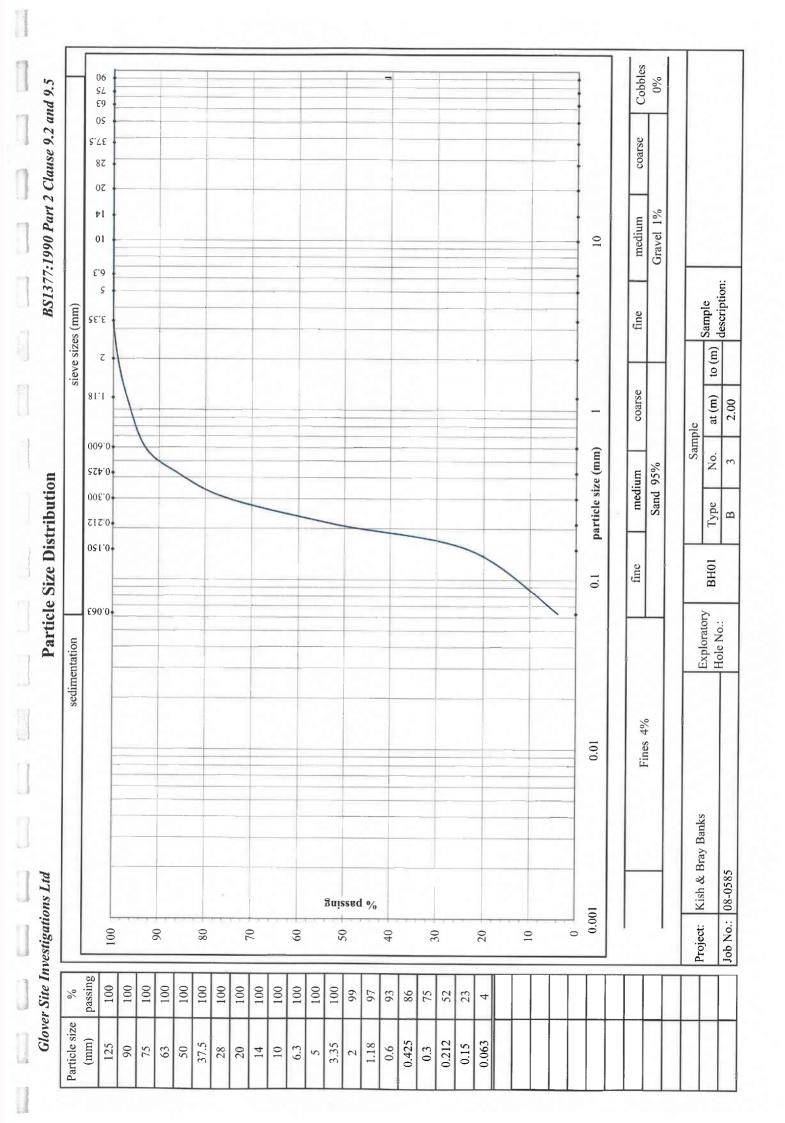
Appendix D

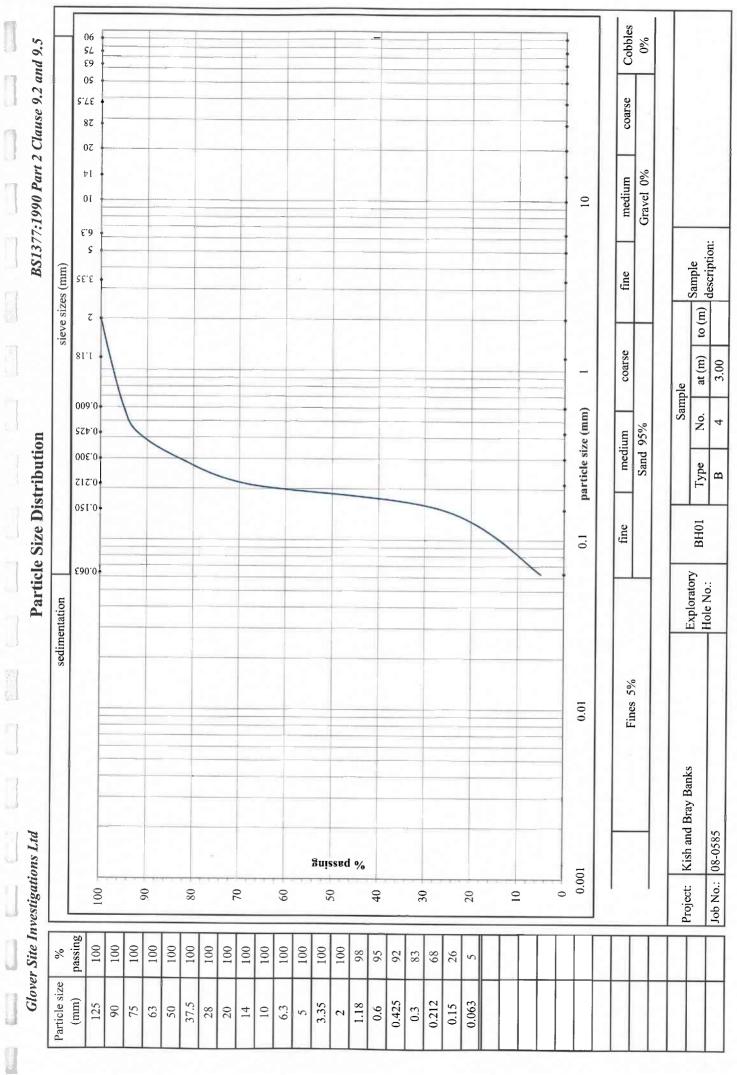
Laboratory test results

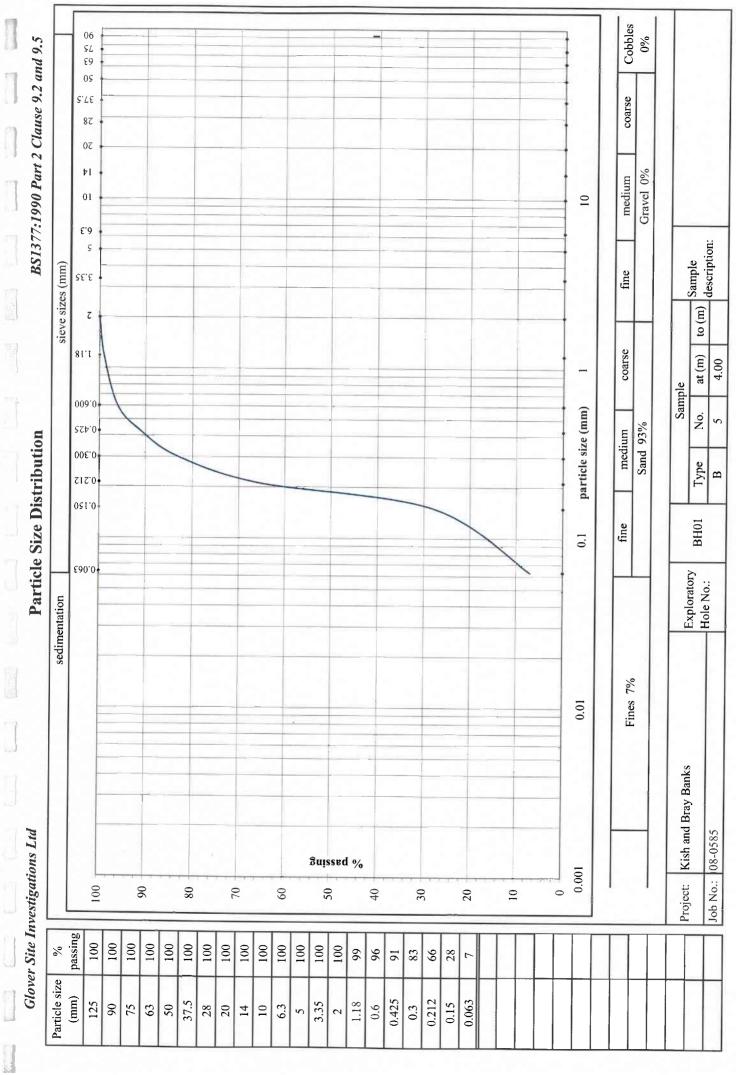
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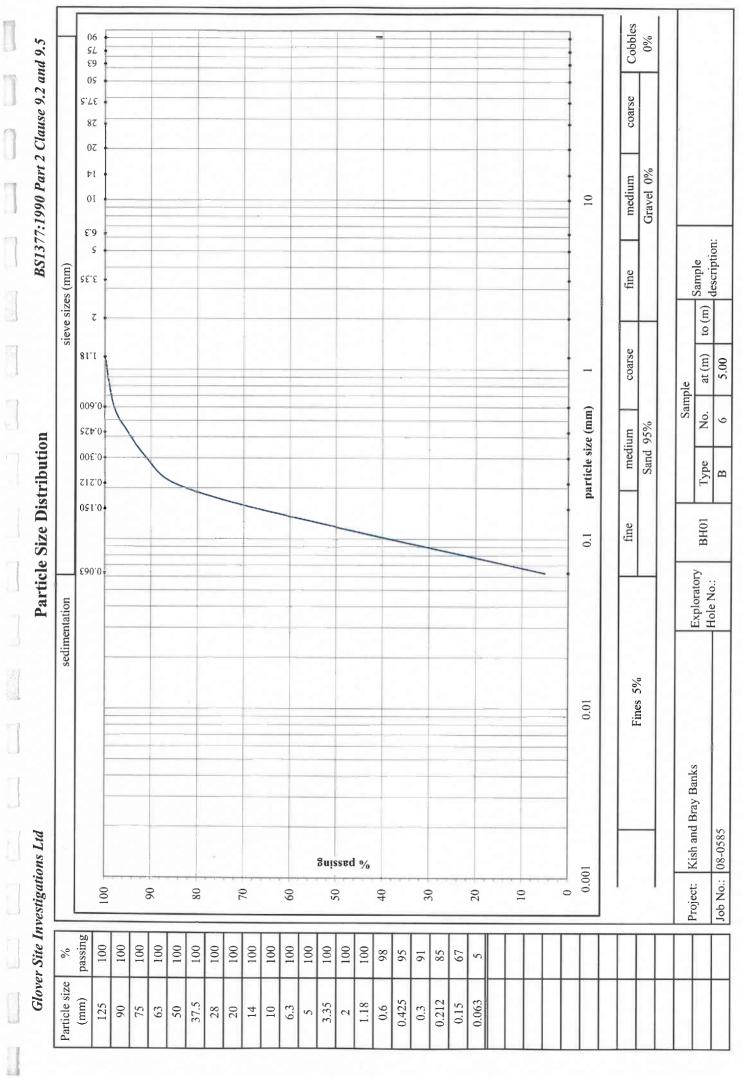


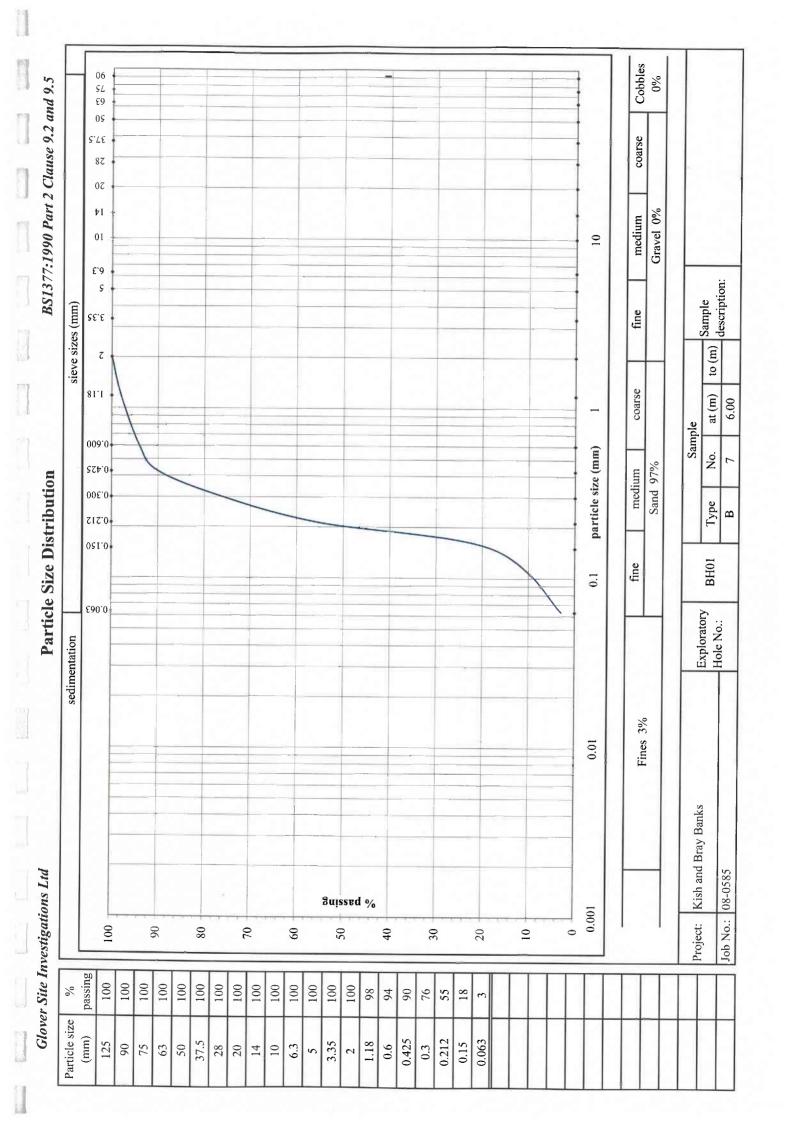


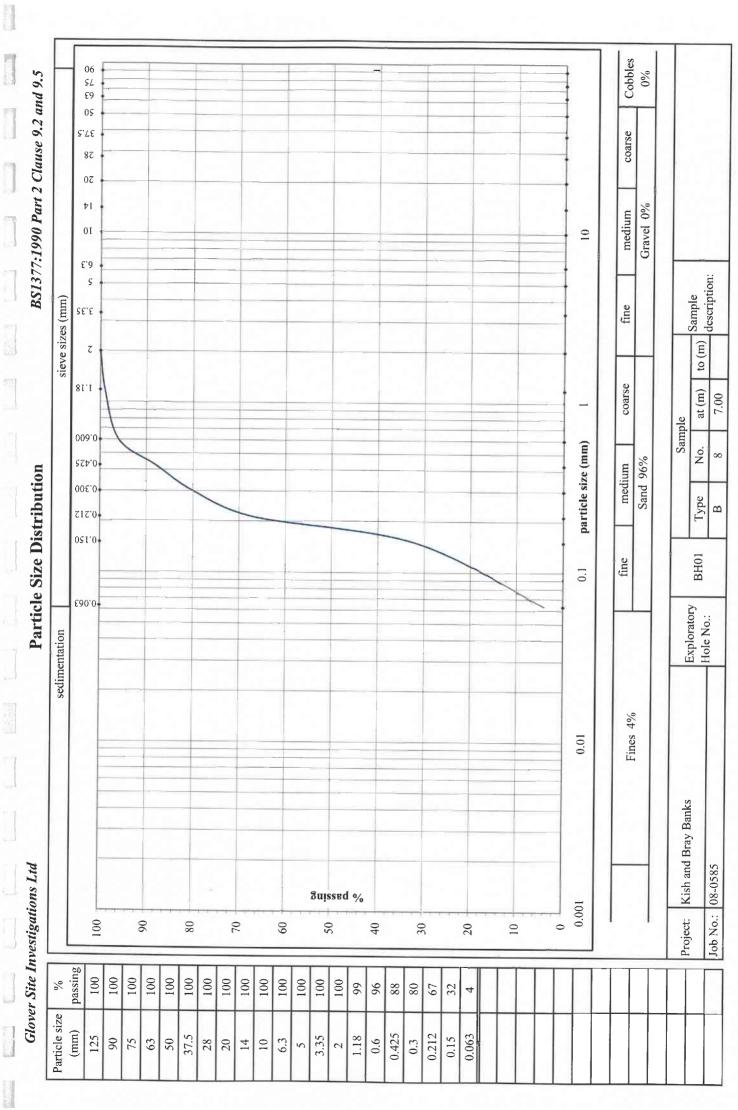


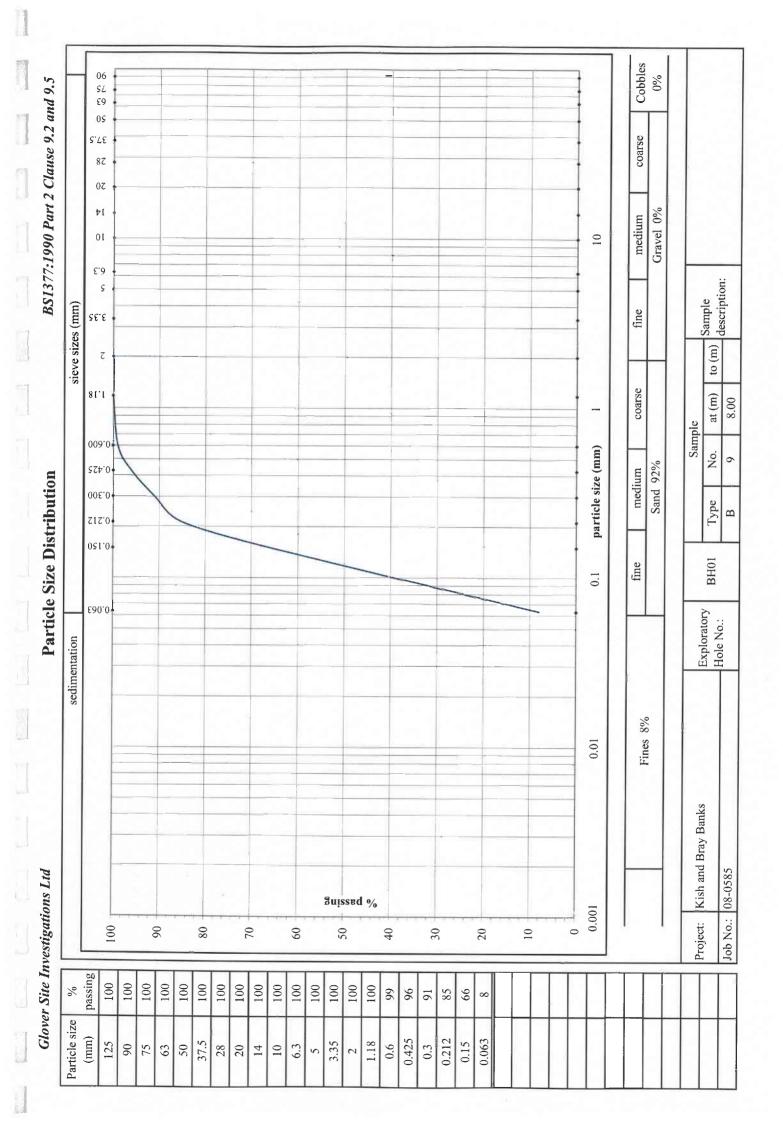


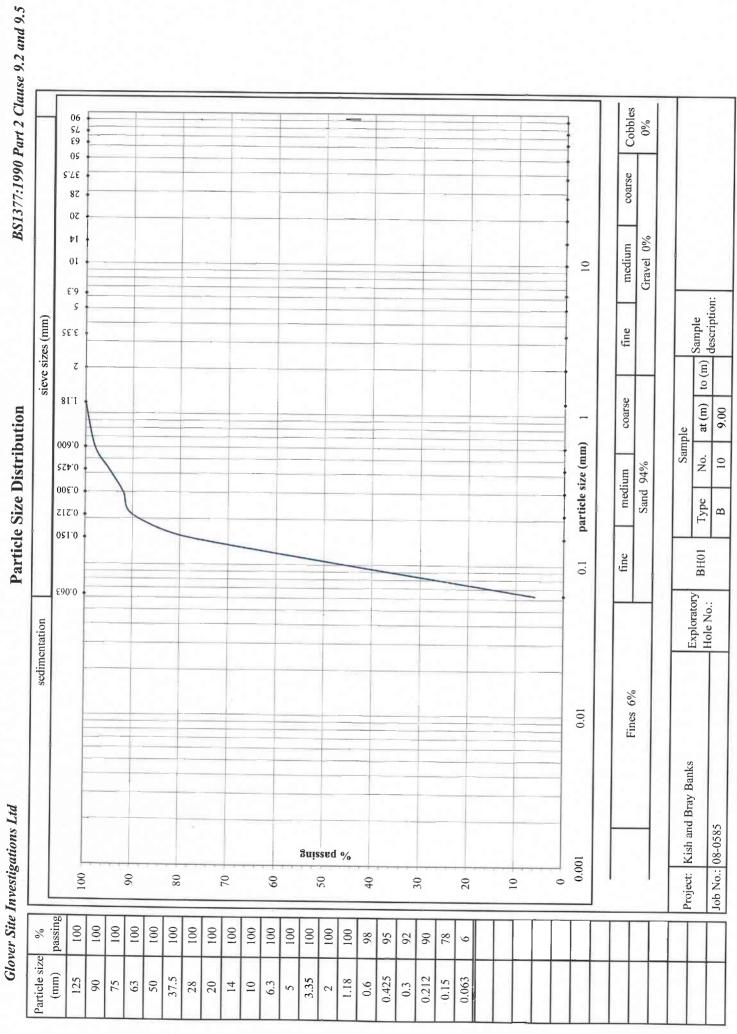










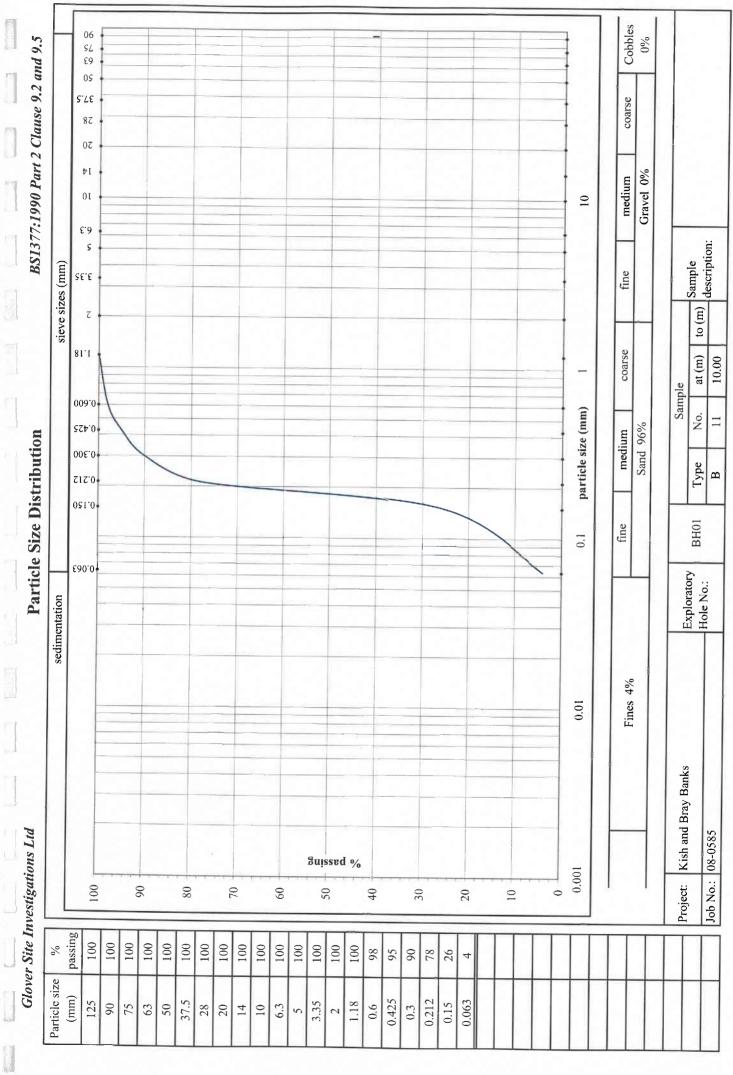


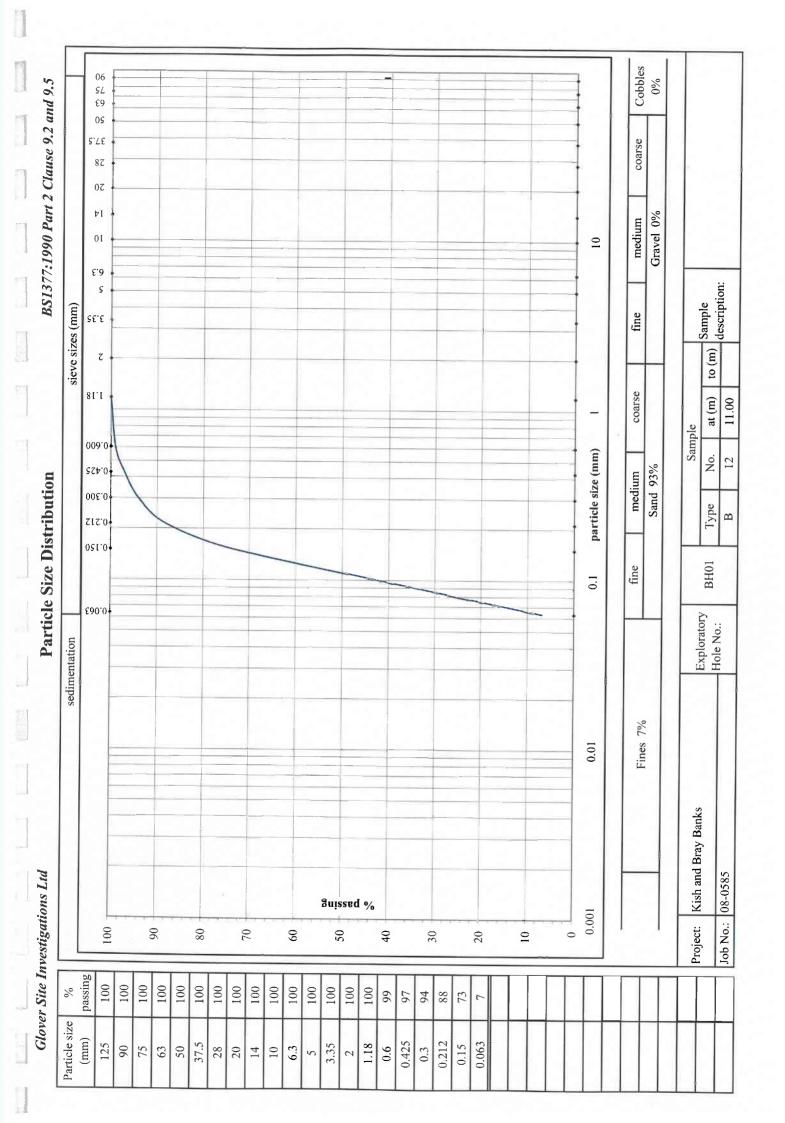
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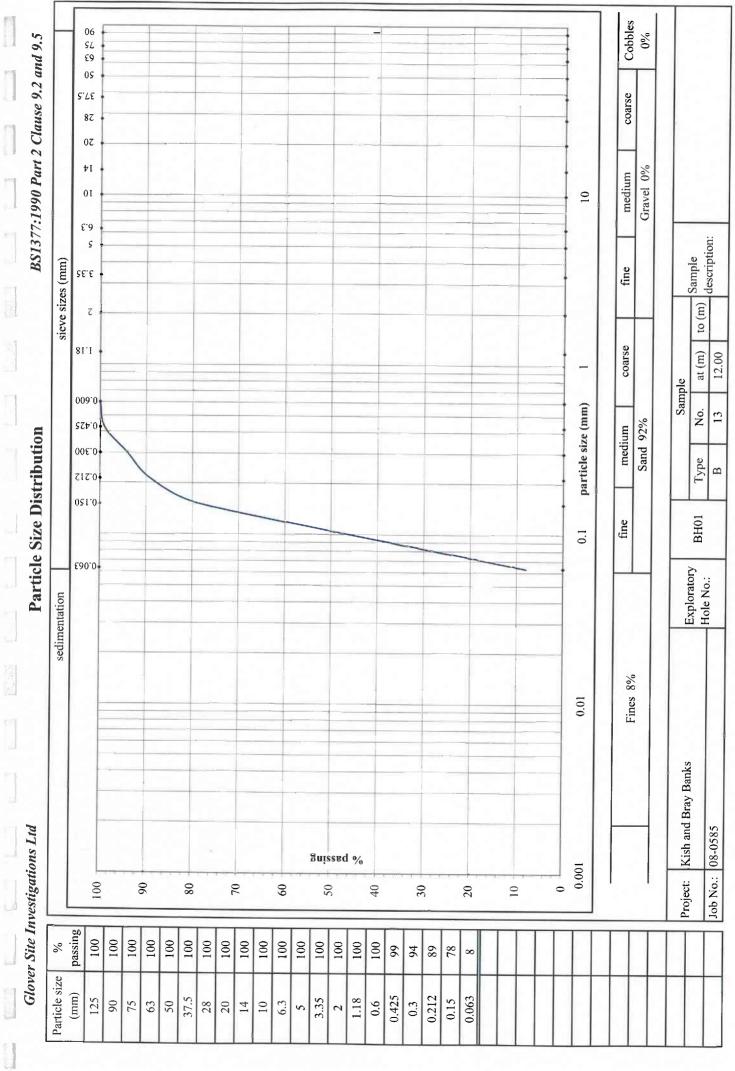
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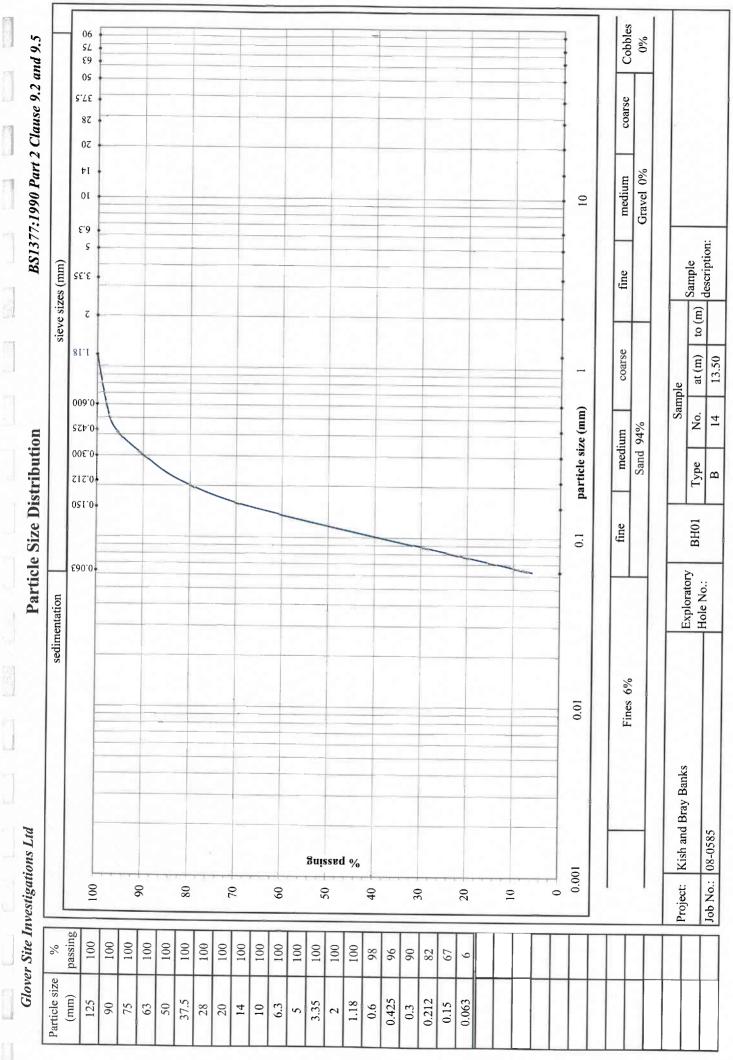
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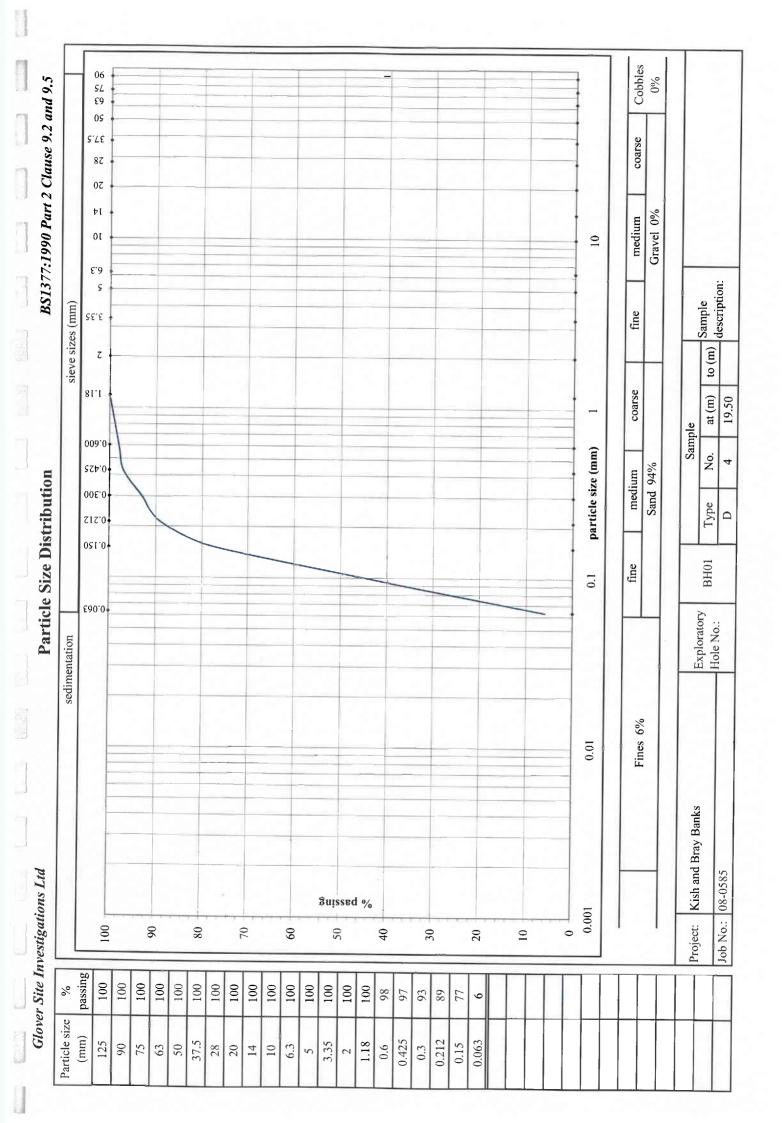
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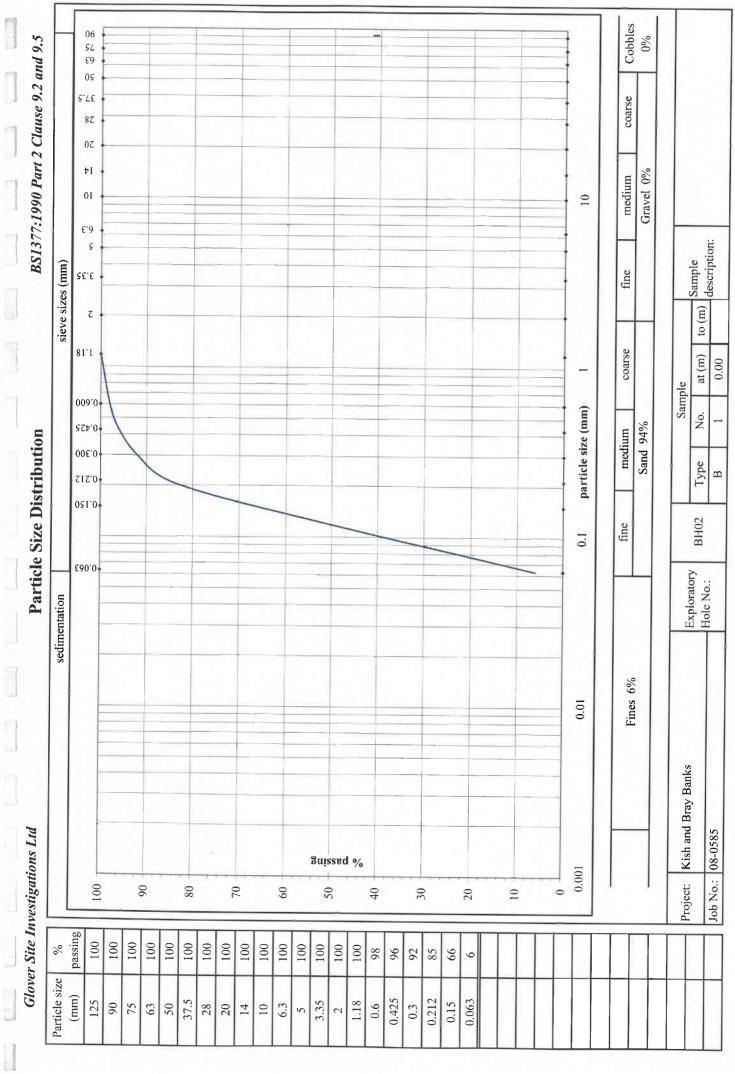


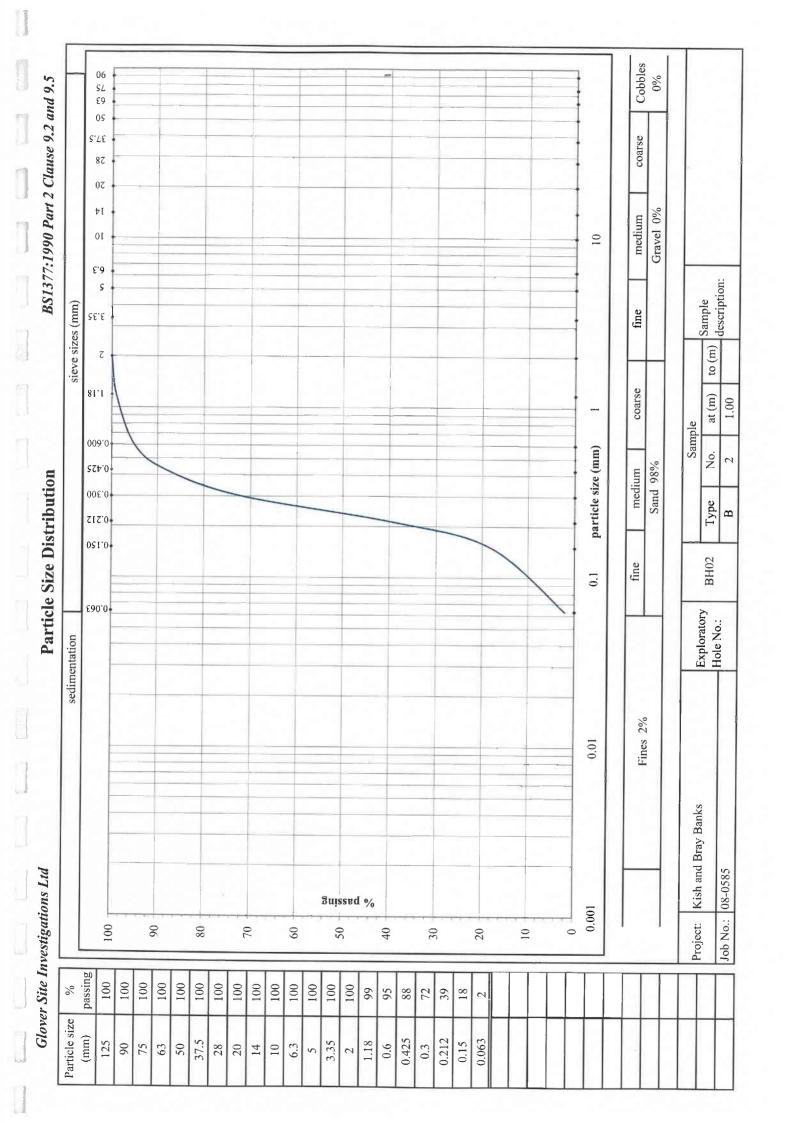


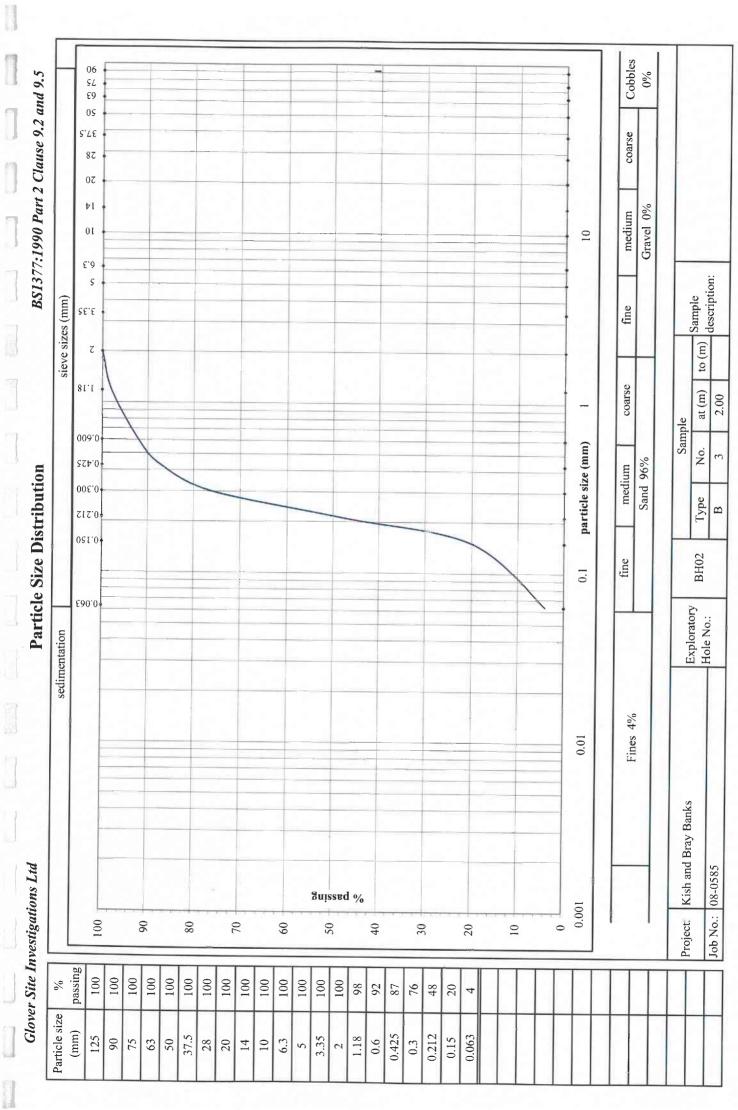


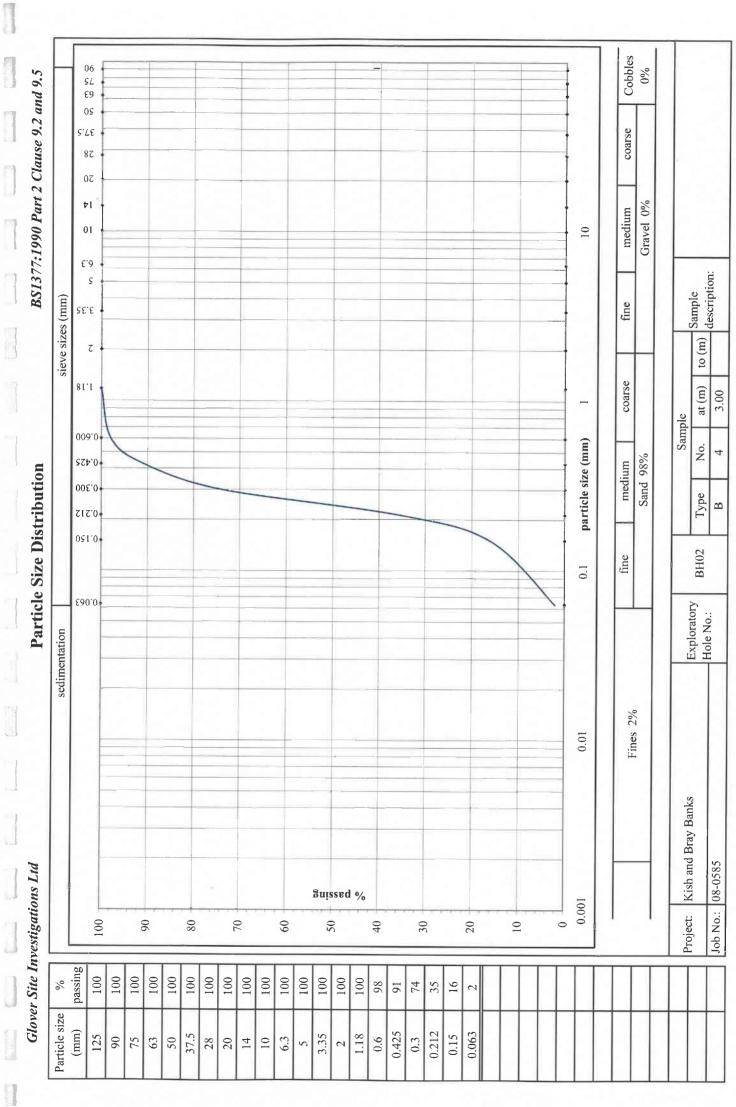


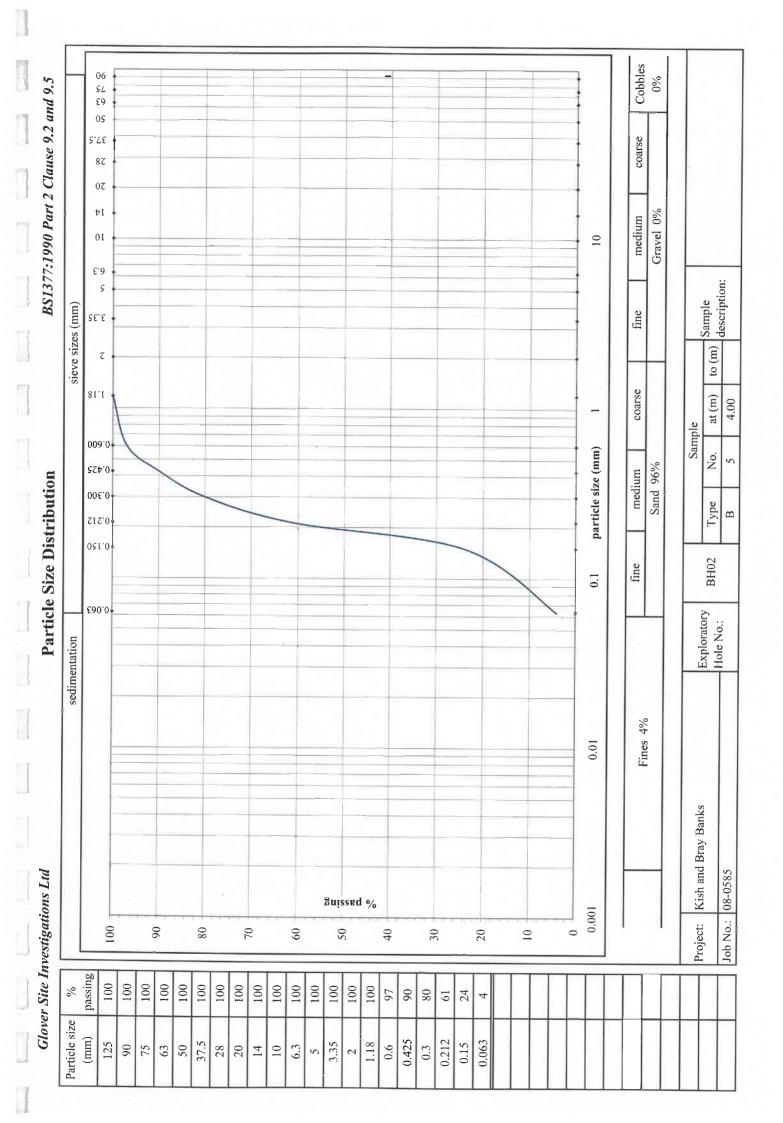


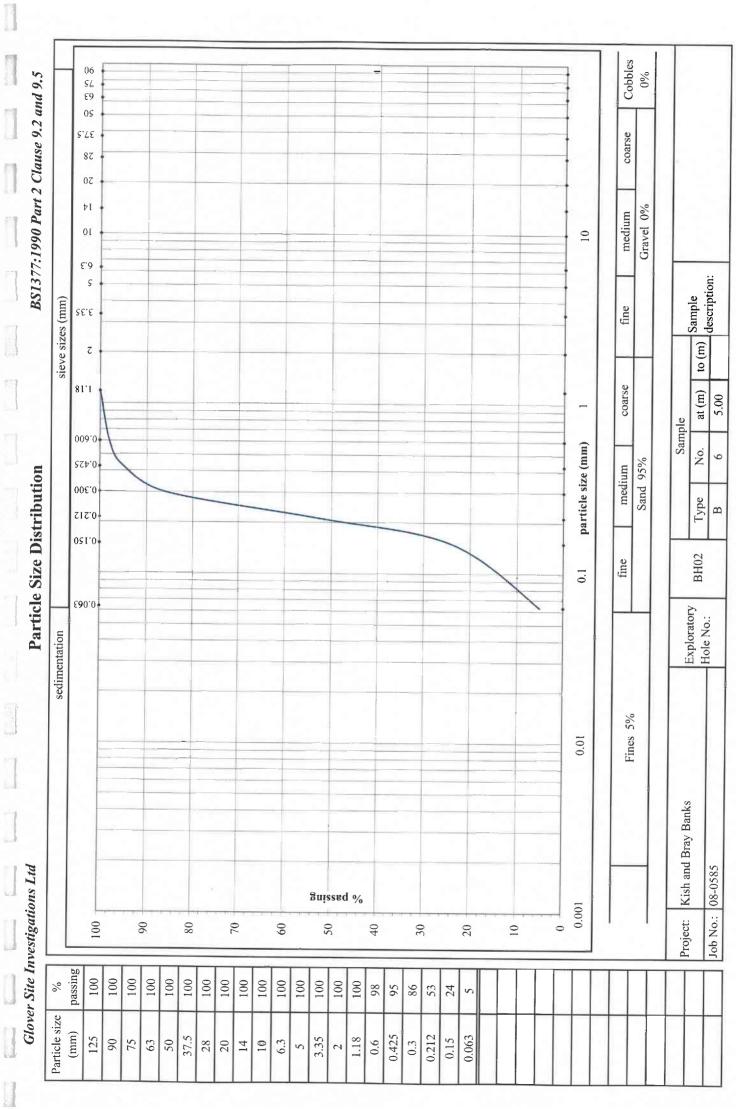


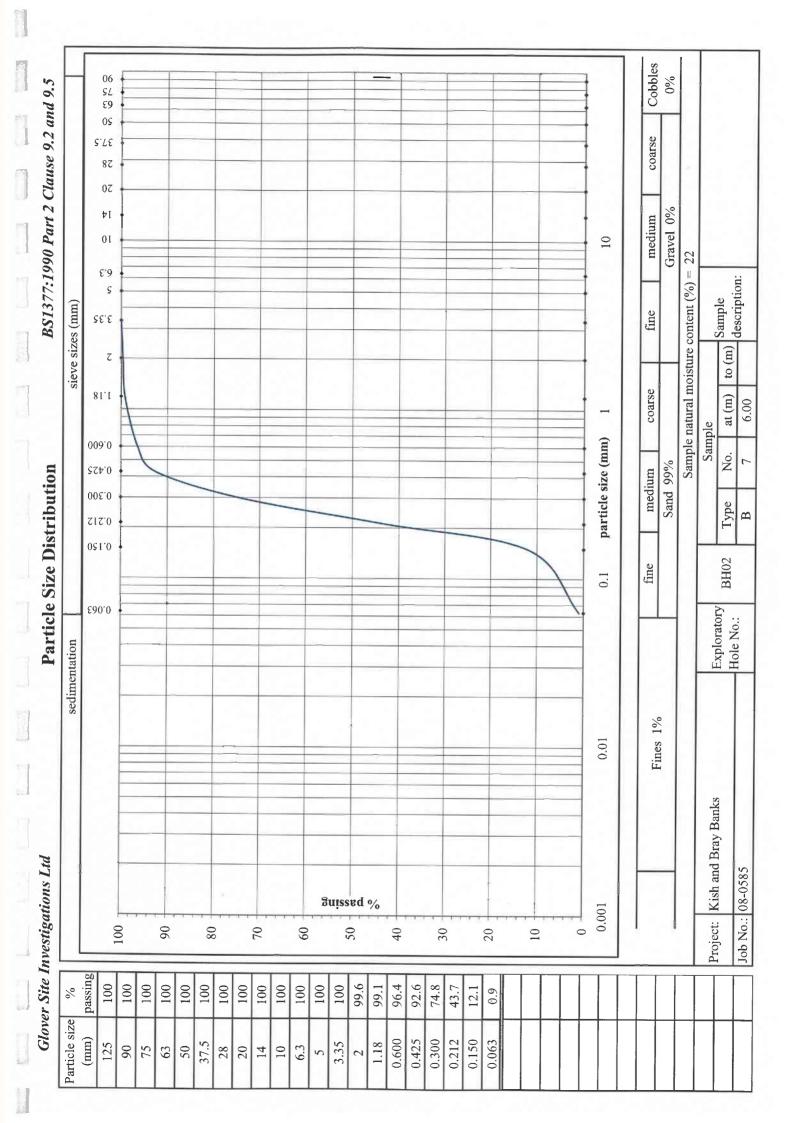


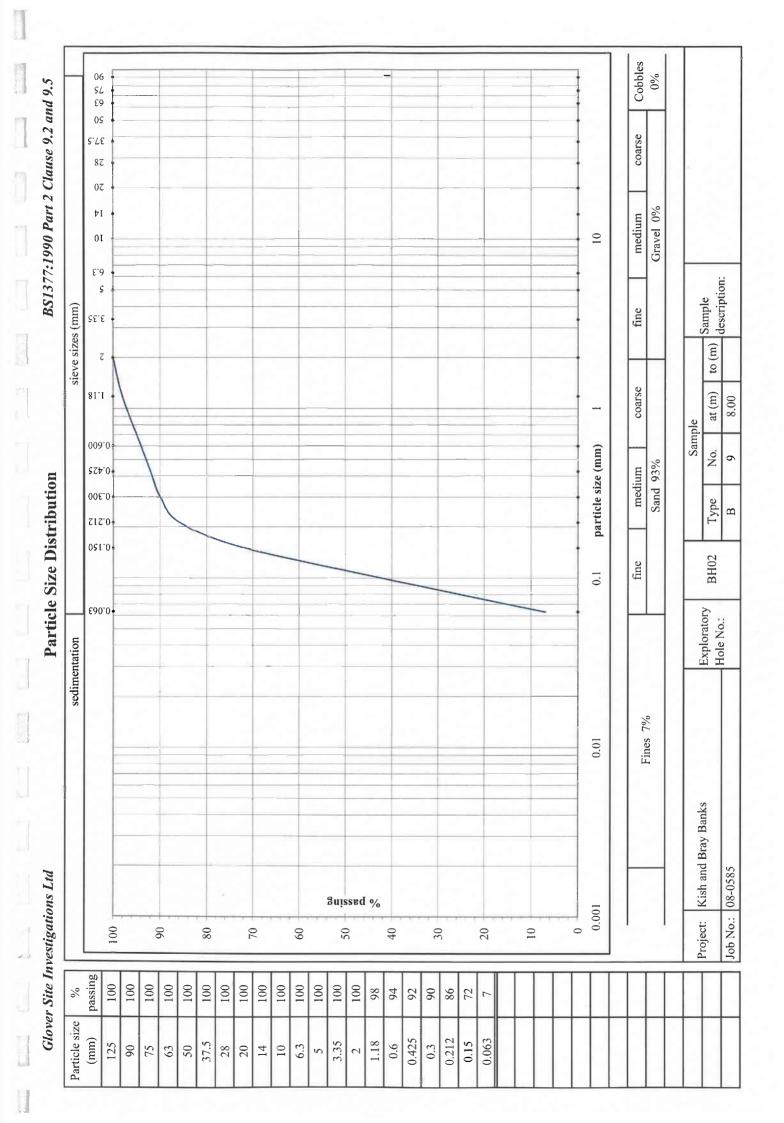


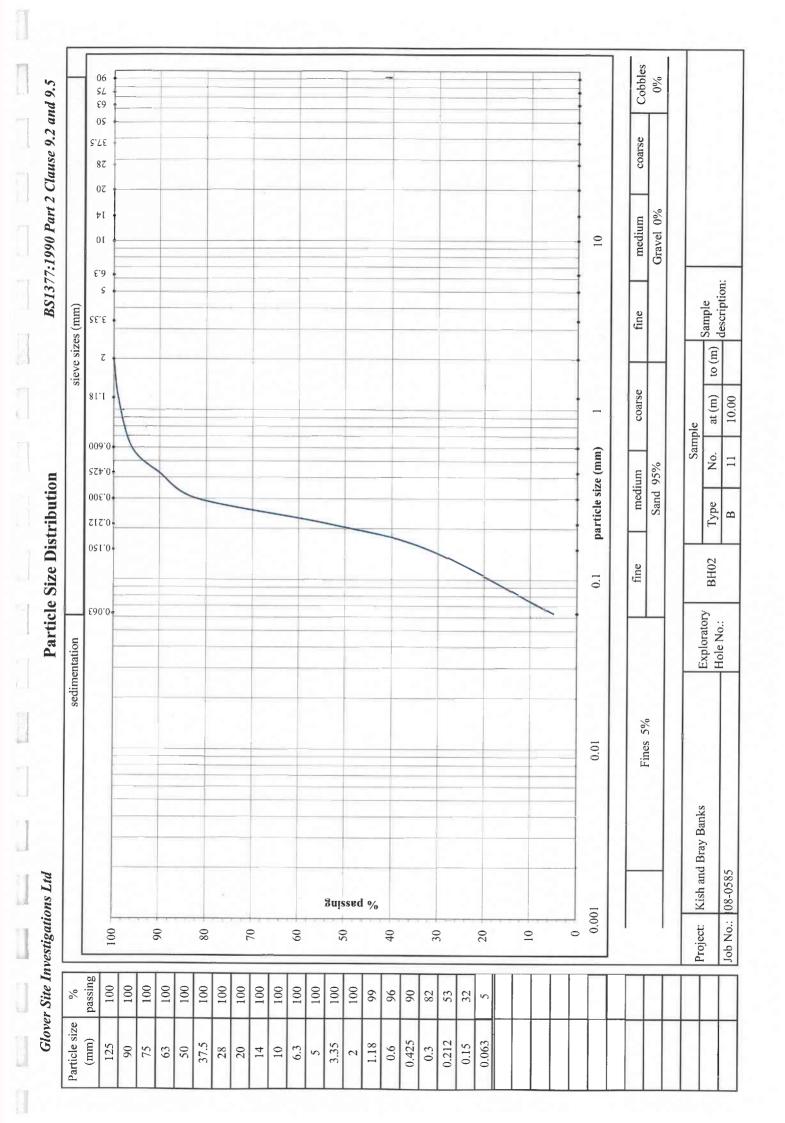


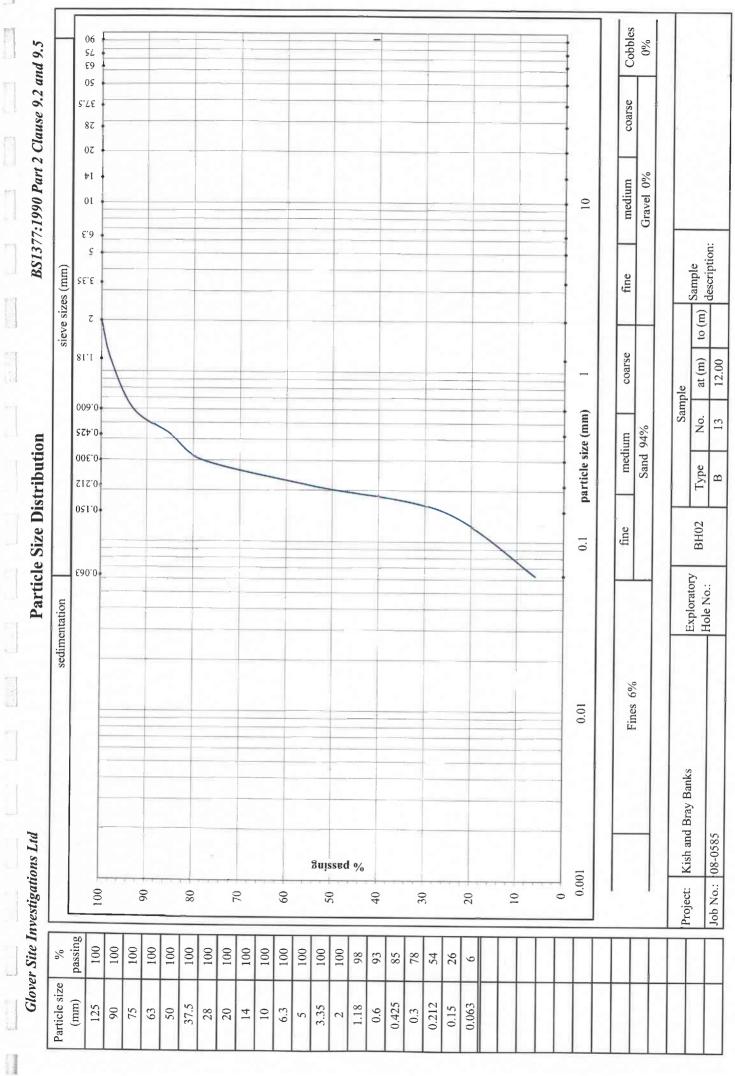


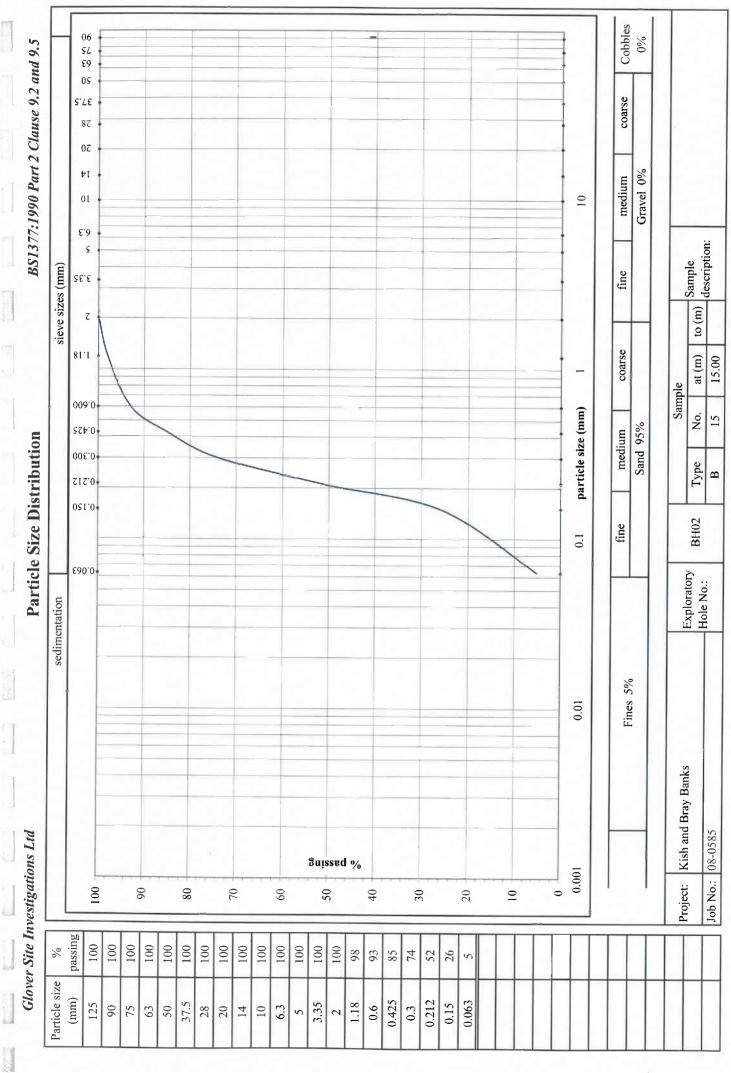


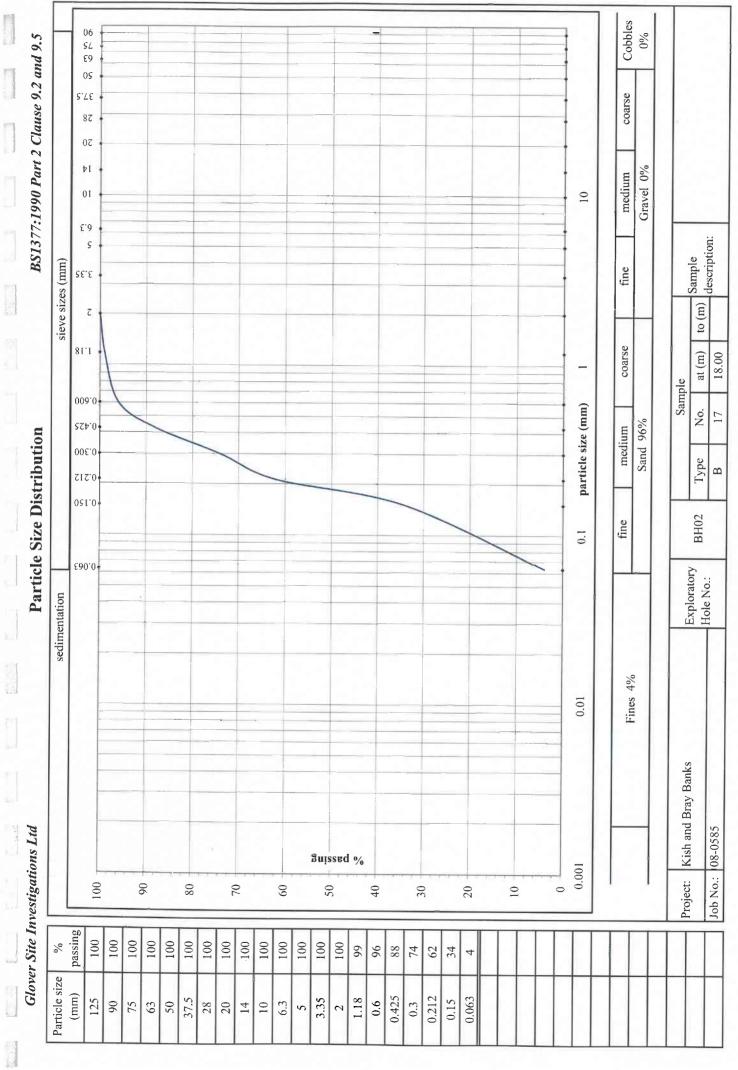


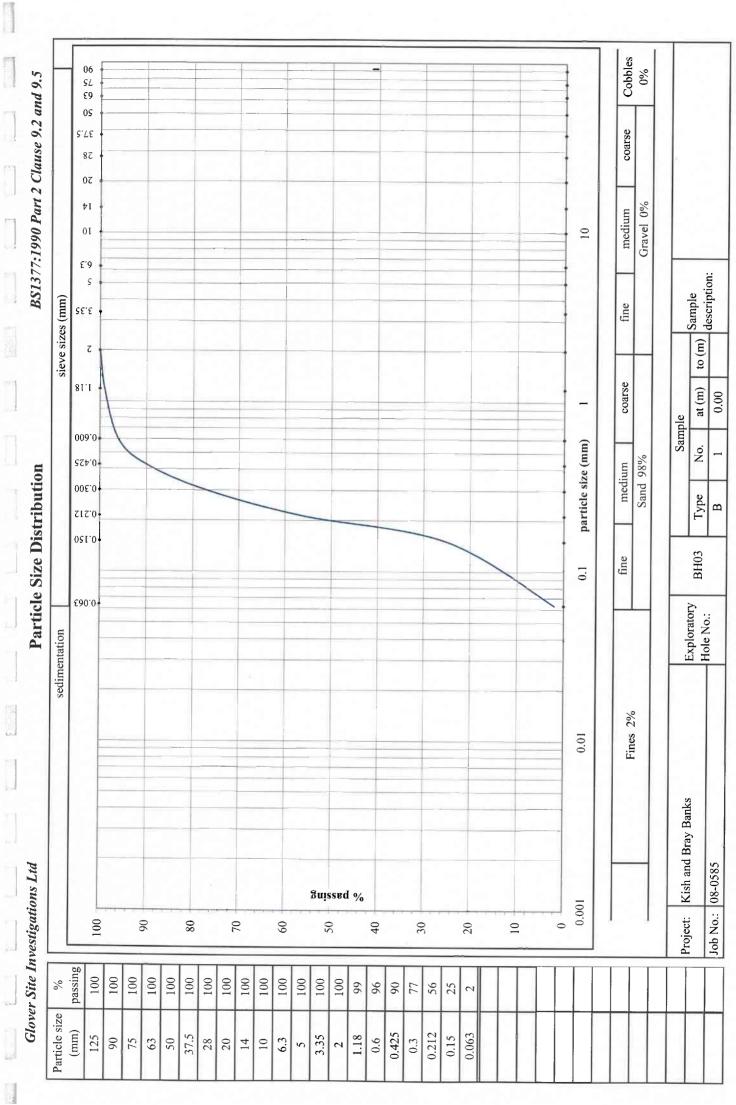


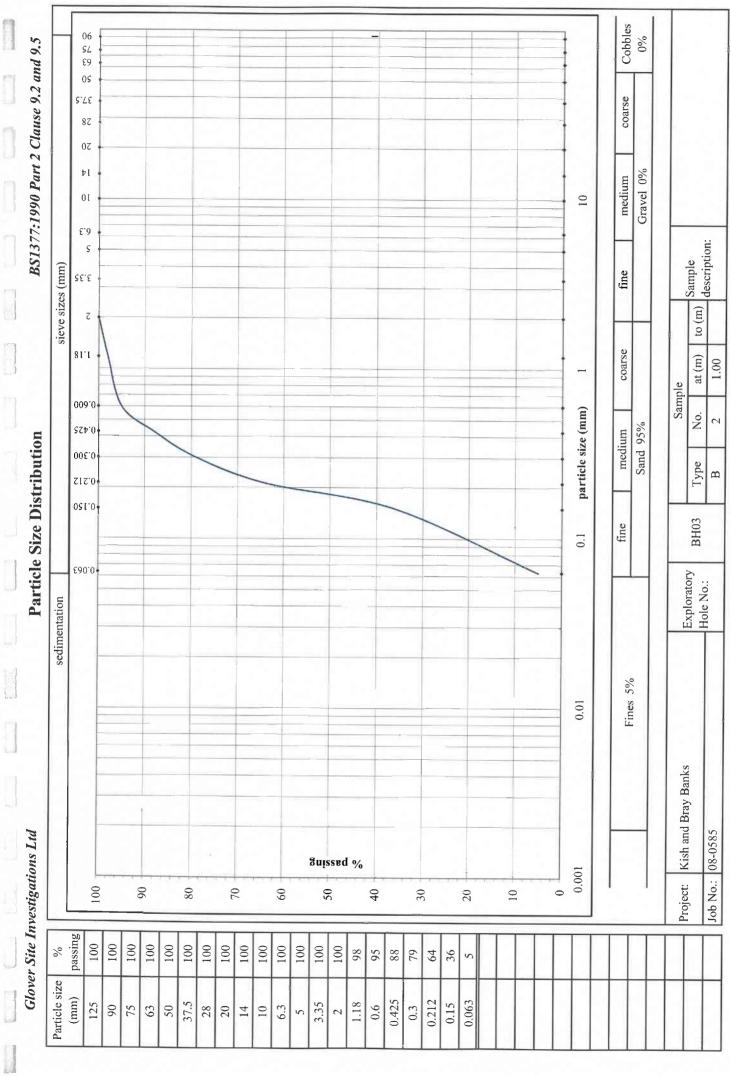


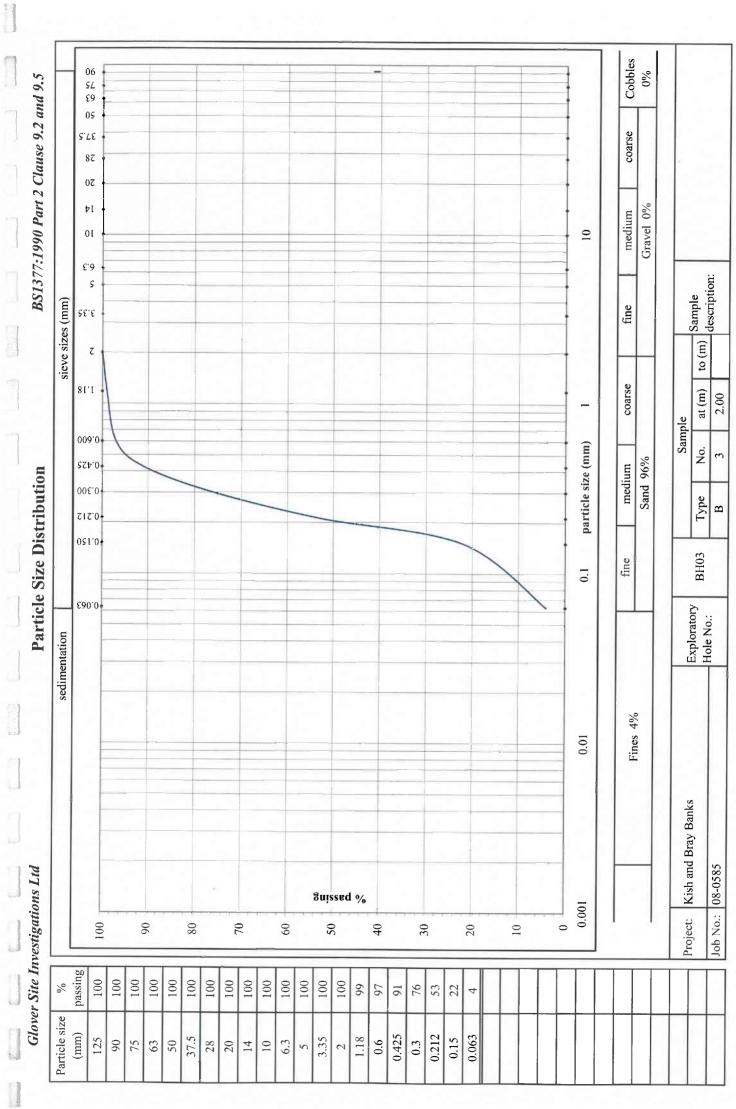


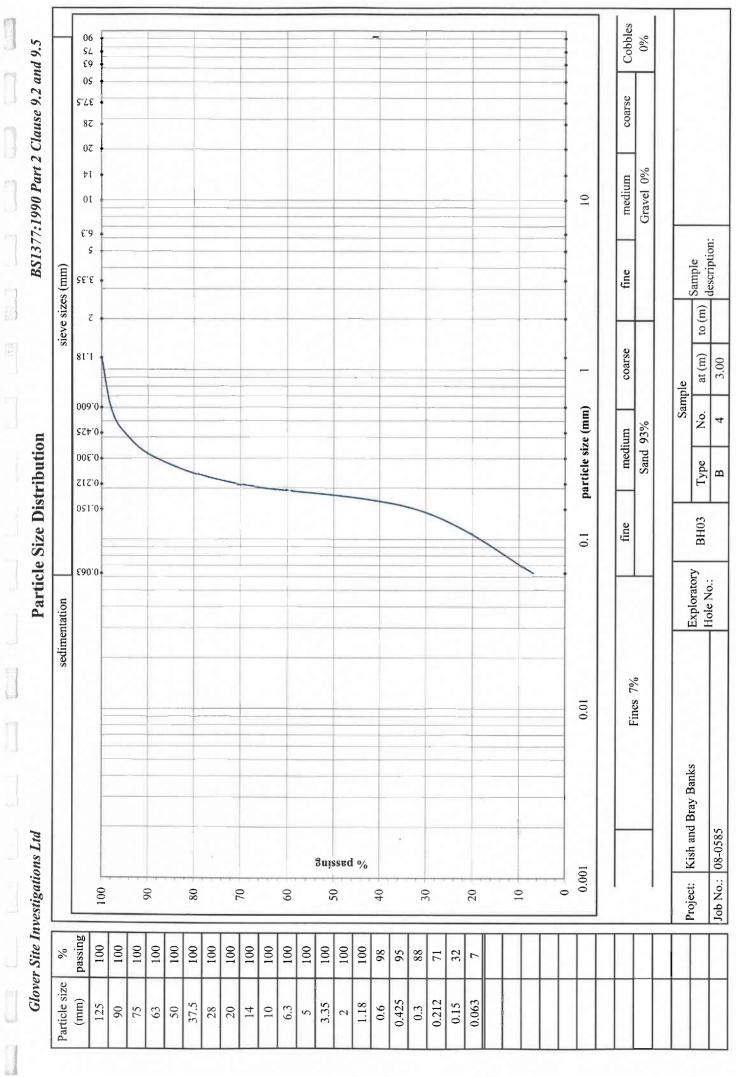


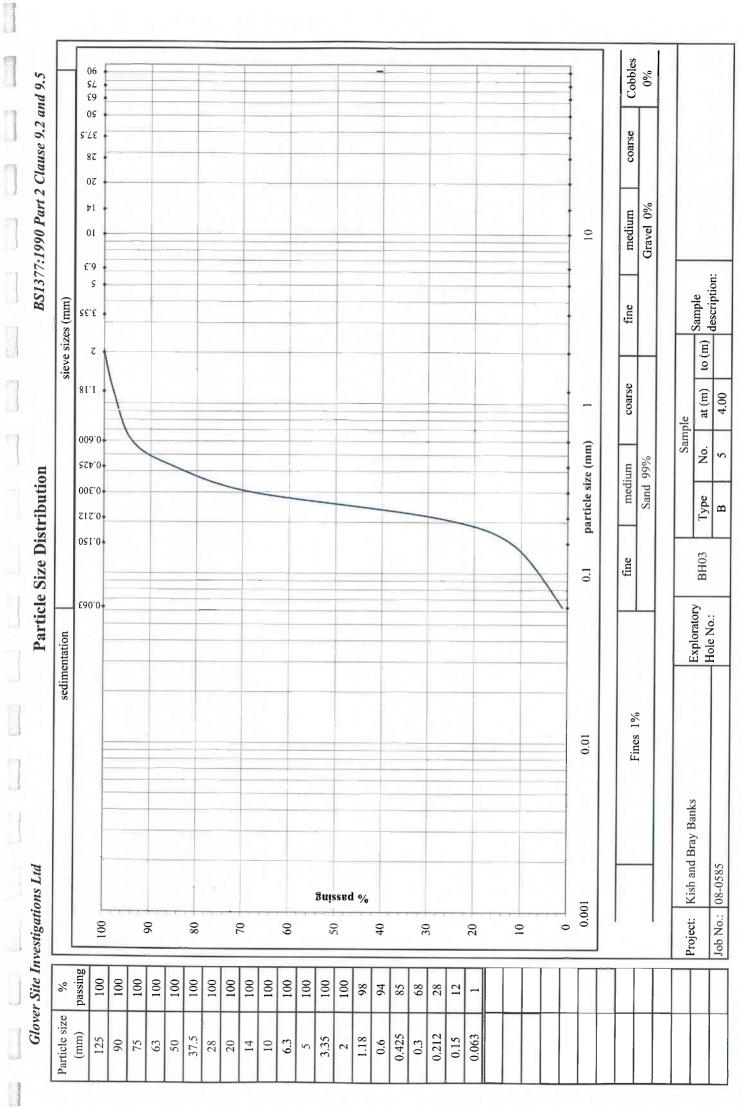


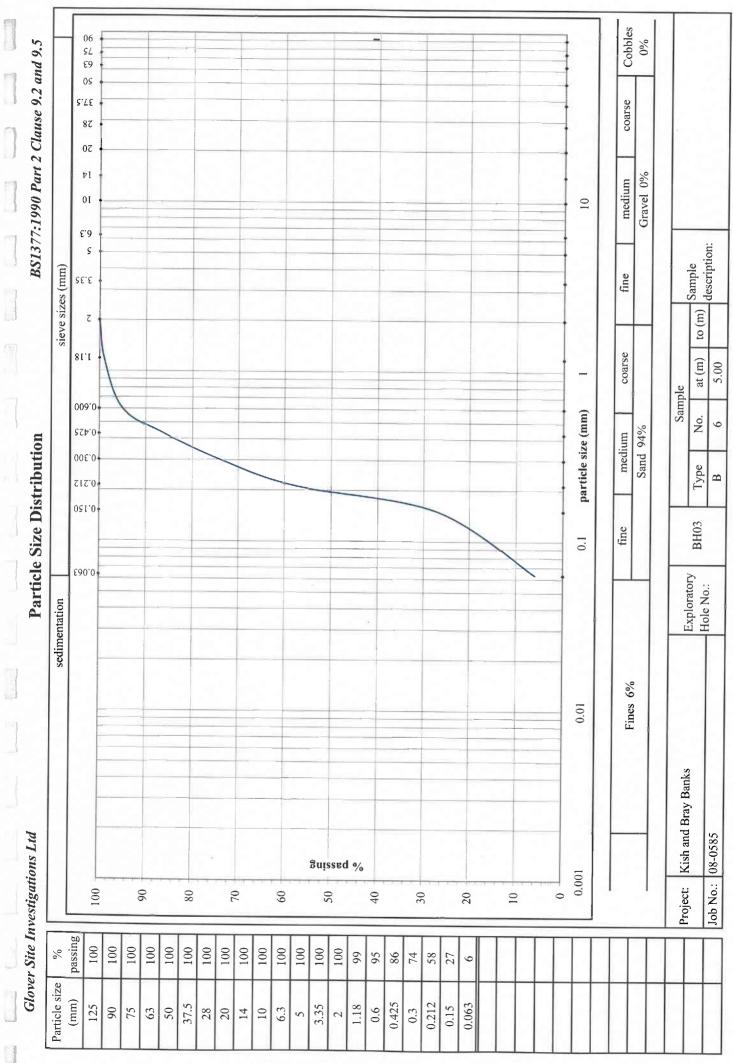




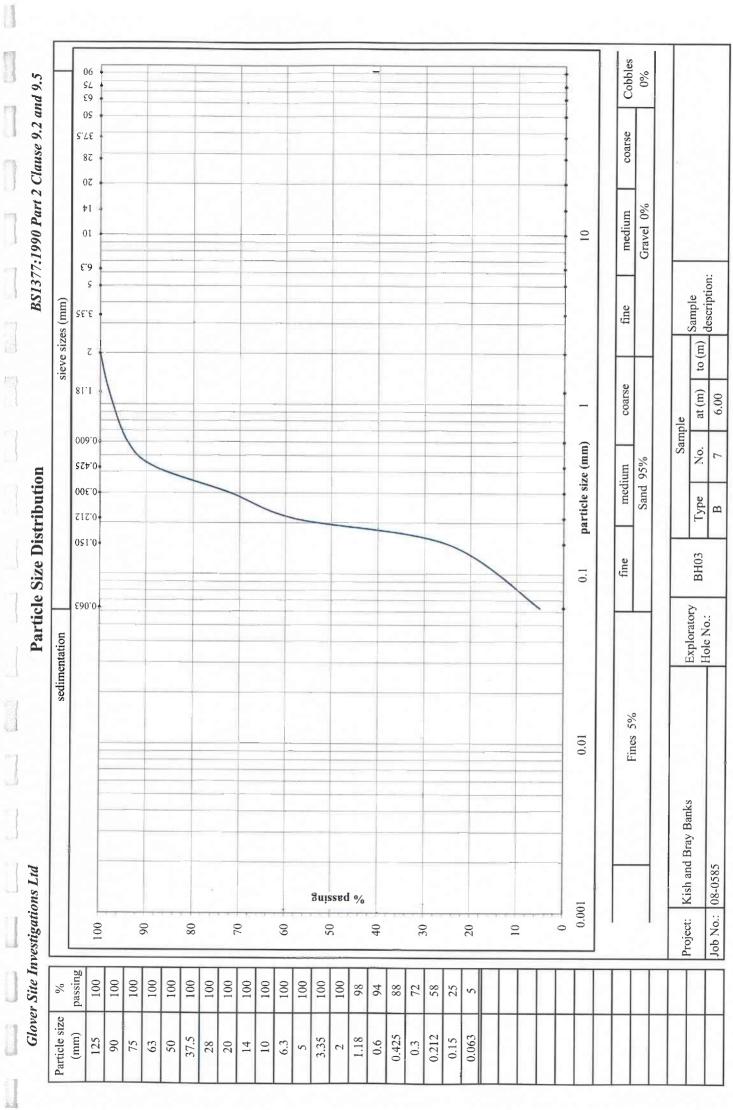


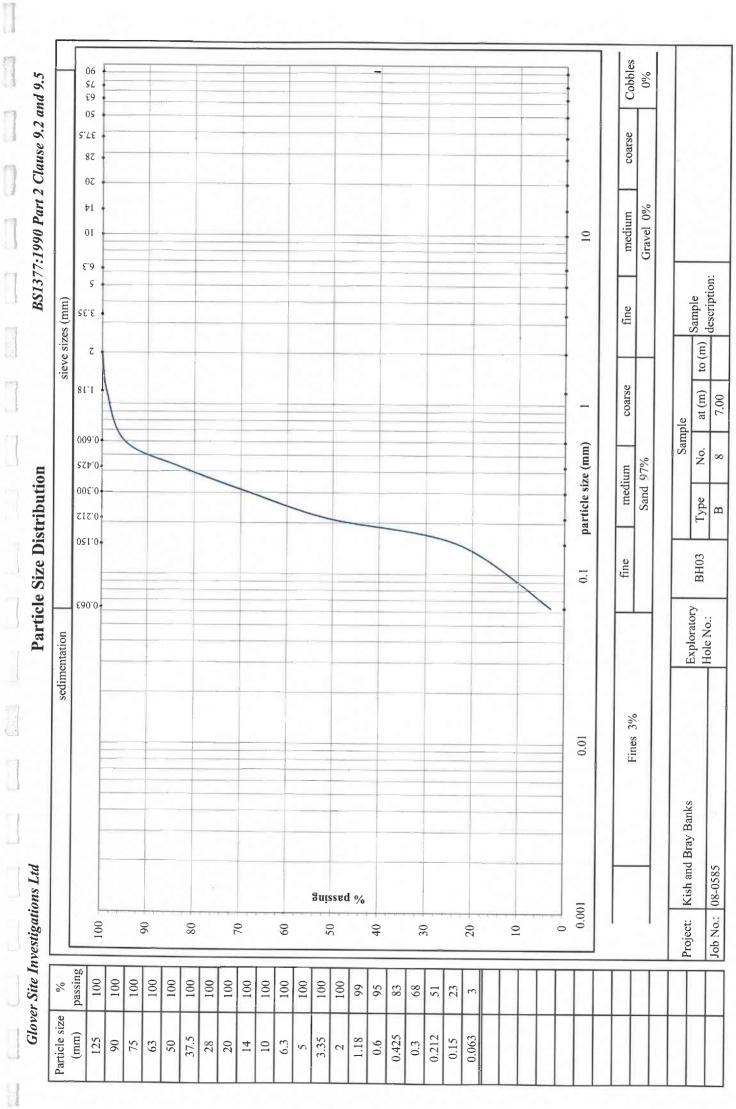


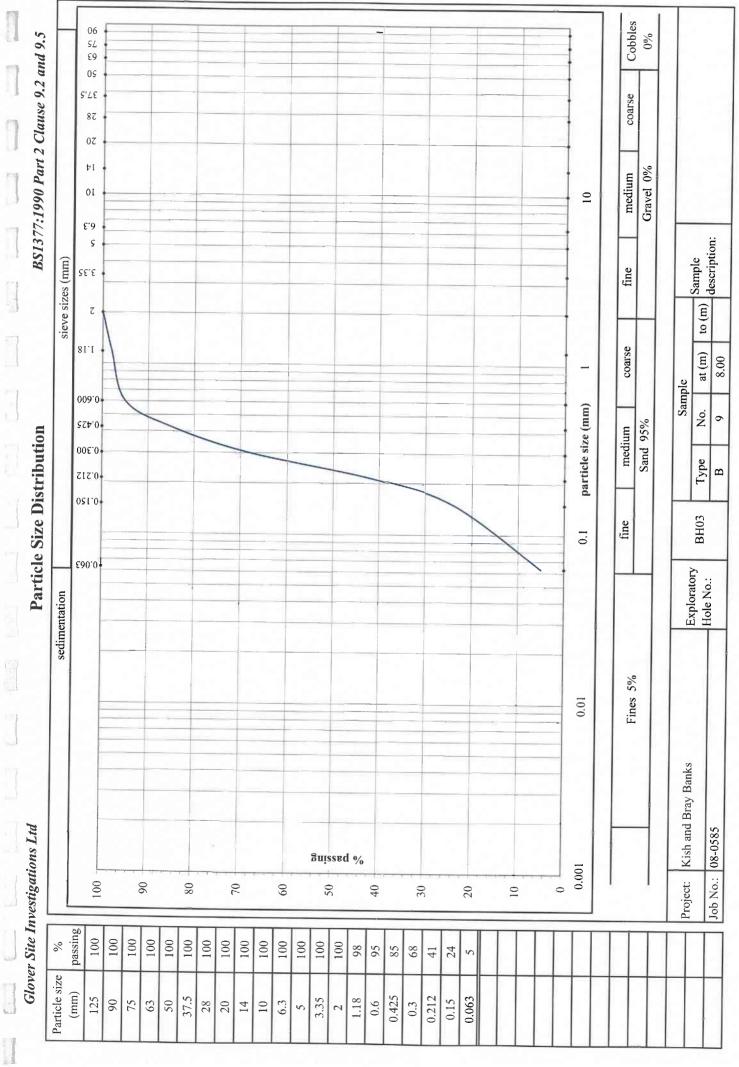


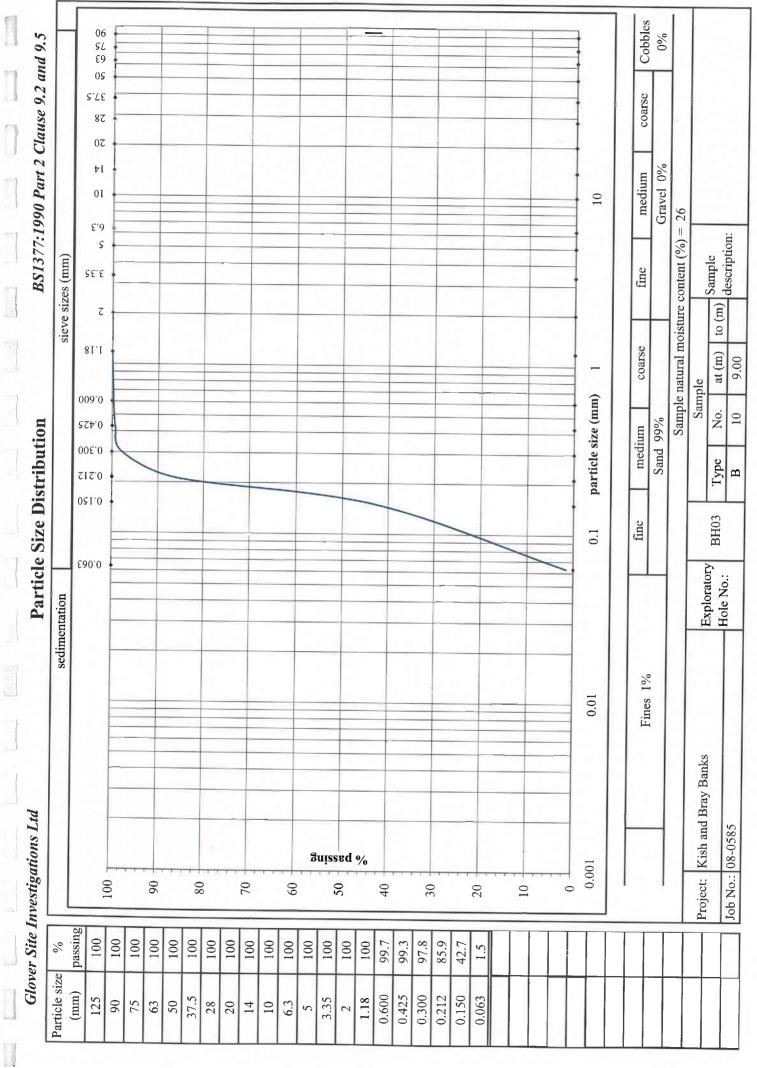


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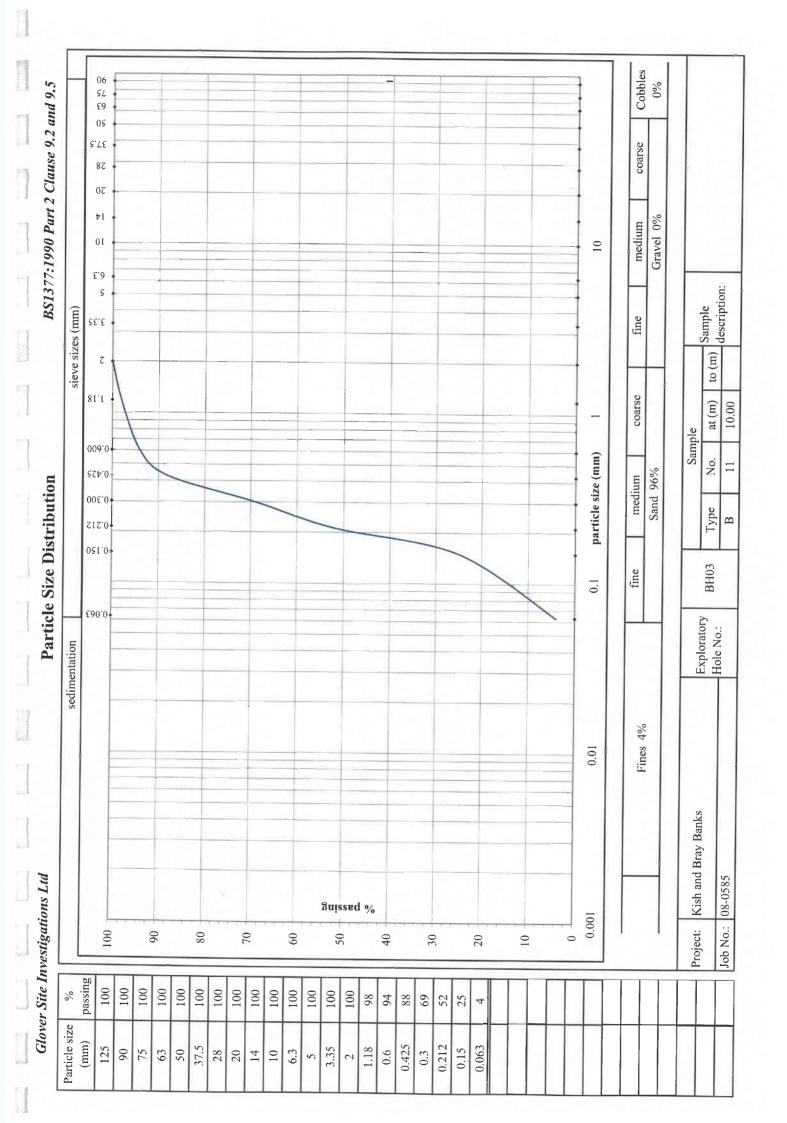


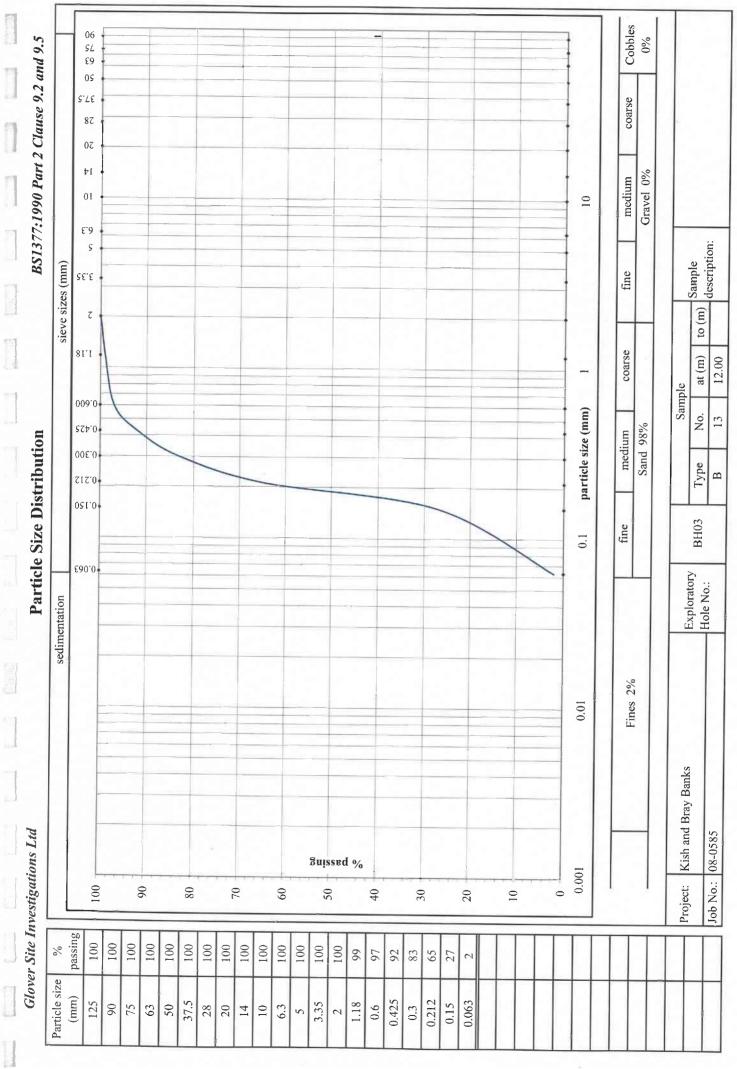


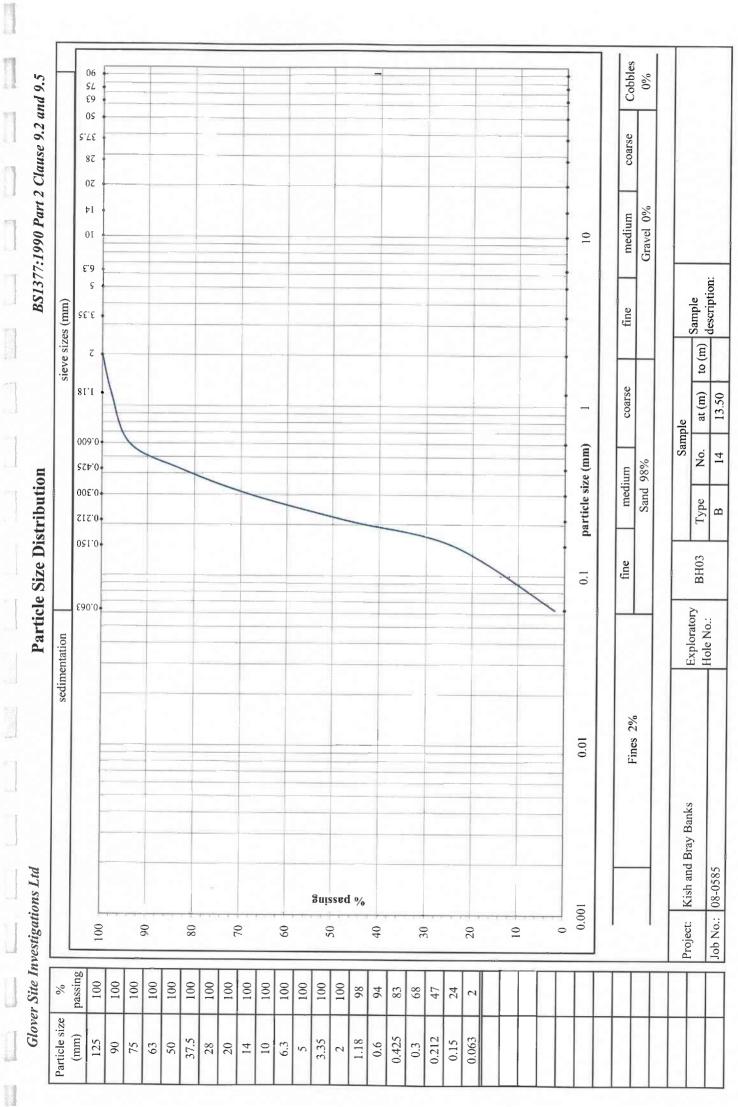




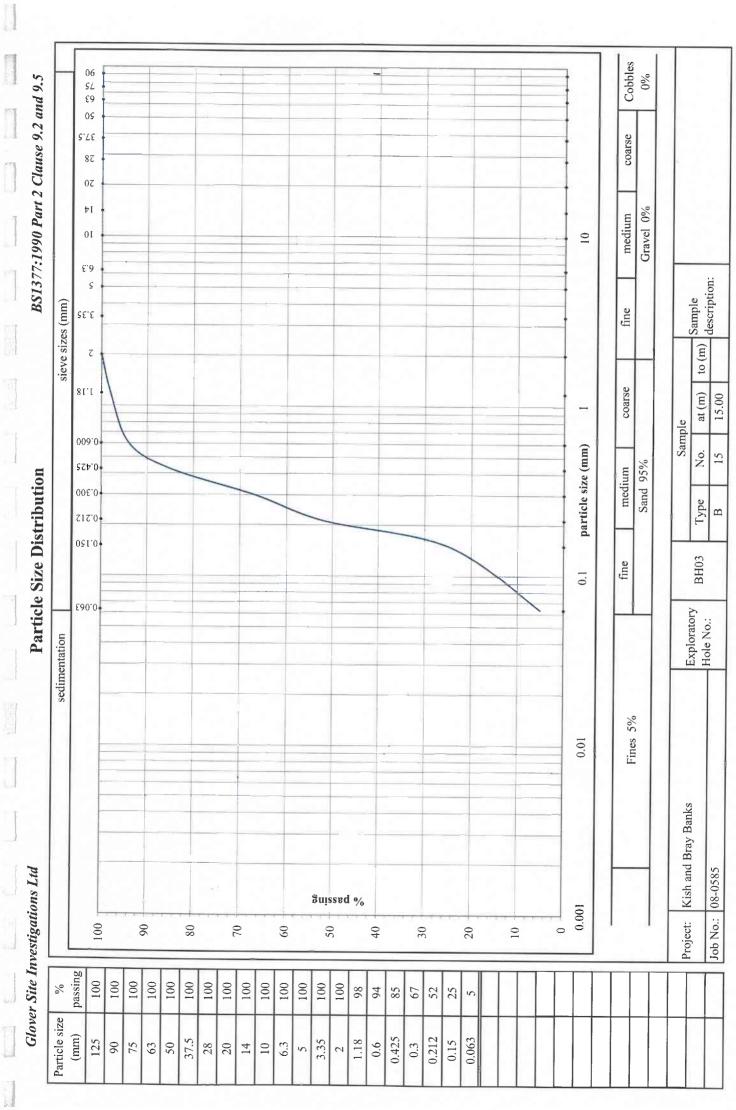
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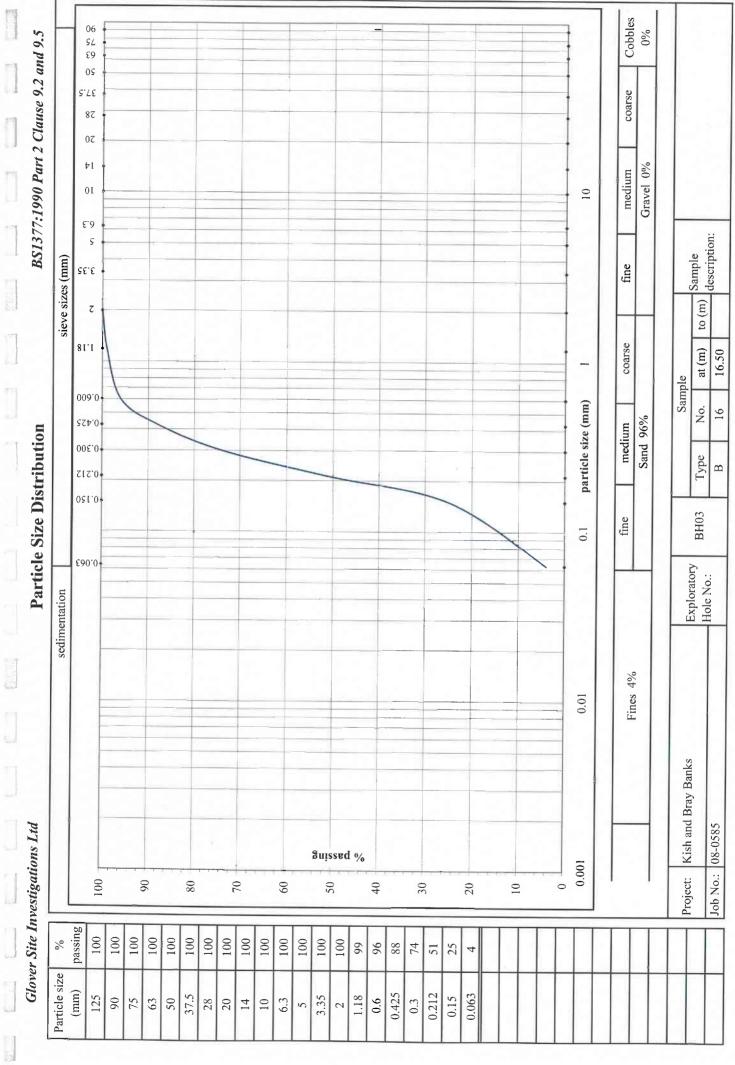


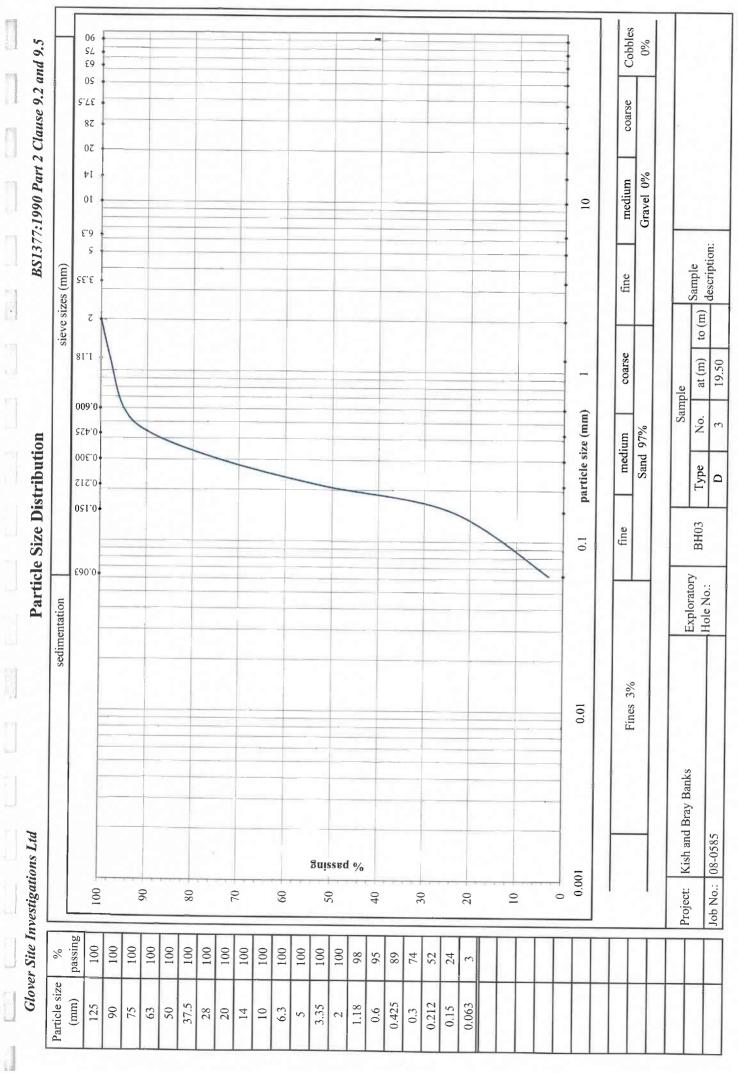




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Job No.: 08-0585

Contract: Kish and Bray Banks

CHEMICAL TESTS Tests 3, 4, 5 & 9 of BS 1377 : Part 3 : 1990

Sheet 1 of 1

EH	Sample		Sample Depth		Passing 2mm		Mass Loss on	Sulphate Content SO ₄ Soil/water Groundwate		pH Value
No.	Туре	No.	at (m)	to (m)	Sieve (%)	Content * (%)		extract \$ (mg/l)	r (mg/l)	a)
BH01	В	2	1.00			100		63	(112/1)	7.5
BH01	В	9	8.00			100		41		7.5
BH01	D	4	19.50			100		35		7
BH02	В	3	2.00		•	100		44		7.5
BH02	В	7	6.00			100		28		7
BH02	В	9	8.00			100		36		7.5
BH03	В	3	2.00			100		39		7.5
BH03	В	10	9.00			100		41		7.5
BH03	D	3	19.50			100		35		7.5
							_			-
										-

* Walkley and Black's dichromate method –Clause 3
Average of 3 specimens - Clause 4
\$ Water soluble SO₄ from 2:1 water - soil extract - Clause 5.5
@ Average of 2/3 specimens - Clause 9.5
Clause Nos. of BS 1377 : Part 3 : 1990

in the second

Appendix E

Photographs of Jack-up platform







Kish and Bray Banks

Proposed Turbine Location Feasibility Study

Hydrographic and Geophysical Report of Survey Volume 1 June – September 2008

PN 18/08

Prepared For:

Saorgus Energy Ltd Enterprise House Kerry Technology Park Listowel Road Tralee Co. Kerry

Prepared By:

Hydrographic Surveys Ltd The Cobbles Crosshaven Co. Cork

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2.2 Bathymetric Survey	5
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2.4 Geophysical Survey	6
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Drawings

HS 59-1/08 Bathymetric Survey	Scale 1:5000
HS 59-2/08 Bathymetric Survey	Scale 1:5000
HS 59-3/08 Bathymetric Survey	Scale 1:5000
HS 59-4/08 Bathymetric Survey	Scale 1:5000
HS 59-5/08 Bathymetric Survey	Scale 1:5000

HS 59D-1/08 Subbottom Cross-Sections

Horizontal Scale 1:5000 Vertical Scale 1:500

HS 59D-2/08 Subbottom Cross-Sections

Horizontal Scale 1:5000 Vertical Scale 1:500

1. Introduction

A bathymetric and geophysical survey was carried out on the Kish and Bray Banks as part of a Hydrographic and geophysical project commissioned by Saorgus Energy Ltd to determine locations for a total of 145 wind turbines.

Mobilisation for the bathymetric survey took place on the 13th June 2008. This element was finally completed on 18th September 2008 with demobilisation from site taking place on the 19th September.

The geophysical survey was carried out between the 11th and 15th September 2008. The following report outlines the methodologies employed during the survey and describes the results achieved.

2. Methodology

2.1 Horizontal Control and Grid

Horizontal control was provided by DGPS using satellite broadcast corrections. The navigation unit used was the Trimble AgDGPS 132 unit which provides submetre accuracy.

The DGPS position was interfaced and logged to Hypack Survey software to provide real-time line guidance and a continuous record of position. On-line transformation of WGS'84 latitude and longitude to Irish National Grid took place within the survey programme.

2.2 Bathymetric Survey

The ODOM Hydrotrac digital echosounder was used to record the seabed levels within the survey area. This echosounder has a resolution of .01meters. It also has an "all-in-one" recorder/digitizer providing data in both analogue and digital format.

The sounder was also interfaced into the Hypack 2008 survey software thereby providing a digital record with related position fixes.

The bar-check method was used both at the start and end of each day's survey for calibration of the echosounder.

Survey lines were planned at 150m centres in an East-west direction covering the total length of the Kish and Bray banks. A total of 115 bathymetric survey lines were run.

2.3 Vertical Datum

Tides were measured in Dun Laoghaire Harbour using a Valeport 740 model vented tide gauge. This was installed onto the pier at Dun Laoghaire and recorded tidal height every 5 minutes for the duration of the survey. The tidal height results were reduced to Chart datum, as requested by the clients, using a TBM of

+5.39m CD.

2.4 Geophysical Survey

The C-boom Low Voltage boomer was employed for recording the subsurface profiles over the banks.

The seismic parameters were set to allow for a penetration of approximately 90m below the seabed.

The C-boom system was towed astern. Layback from the antenna position was recorded and applied to all the results relating to the subbottom survey.

All the data was recorded in digital format. Navigation was interfaced into this system from the Trimble unit thereby providing a continuous record of position. Processing of all profiles was carried out using the Coda Octopus subbottom processing toolkit. A total of 12 east-west lines were run over the length of the banks.

3. Results

3.1 Bathymetric Survey Results

The results of the bathymetric survey are presented in the following charts:

HS:59-1/08 to **HS:59-5/08** Depths have been reduced to Chart Datum and contours are given at 5m intervals.

The general characteristics of the bathymetry within the survey area can be summarised as follows:

HS:59-1/08: At the Western limit contours are more closely spaced together than on the eastern side. This indicates that the bank has a steep west slope and slightly gentler eastern aspect. Least depths recorded over the top of the bank range from between 2.8m to 4.0m CD.

Sandwaves are a prominent feature over the bank. Progressing southwards the top of the bank would appear to be characterised by two prominent peaks.

The sandwaves seem to fade out towards the Eastern limit.

Table One

Depths at Proposed Turbine Locations

Turbine Number	Depth m CD	Turbine Number	Depth m CD
T1	17.7	T16	20.0
T2	3.7	T17	7.0
Т3	12.6	T18	5.5
T4	17.4	T19	14.6
Т5	26.7	T20	25.8
T6	17.6	T21	20.0
Τ7	5.0	T22	8.0

T8	12.1	T23	5.8
Т9	17.0	T24	15.3
T10	26.0	T25	26.1
T11	19.1	T26	20.0
T12	4.7	T27	8.0
T13	9.9	T28	6.2
T14	16.5	T29	16.6
T15	25.6	T30	26.5

HS:59-2/08: The eastern side of the bank is starting to display a very steep incline from the top of the bank. The western slope is gradually becoming more gentle.

The shallowest depths recorded over the top of the bank range from 3.9m to 4.9m. Heights of sandwaves vary between 0.5 to 1.3m.

Turbine Number	Depth m CD	Turbine Number	Depth m CD
T31	20.2	T48	11.2
T32	9.7	T49	8.1
T33	6.0	T50	14.4
T34	13.7	T51	20.8
T35	25.8	T52	14.5
T36	23.0	T53	10.0
T37	10.0	T54	7.5
T38	7.0	T55	26.5
T39	11.0	T56	22.0
T40	25.4	T57	16.5
T41	21.0	T58	11.0
T42	12.0	T59	8.0
T43	7.8	T60	26.0

Table twoDepths at Proposed Turbine Locations

T44	6.2	T61	21.3
T45	26.2	T62	17.0
T46	25.4	T63	11.0
T47	15.7	T64	8.8
		T65	22.0

HS:59-3/08: towards the southern limits of HS:59-3/08 the bathymetric depths become quite shallow with depths of 1.5m recorded in places. The bank is still characterised by a gently sloping western slope with a steep eastern slope.

Table ThreeDepths at Proposed Turbine Locations

Turbine Number	Depth m CD	Turbine Number	Depth m CD
T66	>20.0	T81	15.0
T67	17.0	T82	8.0
T68	11.0	T83	10.4
T69	9.0	T84	21.9
T70	23.1	T85	14.0
T71	>21.0	T86	7.0
T72	17.3	T87	16.0
T73	13.3	T88	23.3
T74	7.9	T89	14.0
T75	24.6	T90	7.5
T76	>20.0	T91	16.8
T77	16.1	T92	21.3
T78	11.2	T93	12.5
T79	4.8	T94	2.0
T80	21.0	T95	23.6

HS:59-4/08: Least depths over the bank range from 1.4m to 3.0m, south to Northing 217200N. South of 217200N there is a deepening ranging from 4.3m to 6m on average on the bank.

The asymmetrical nature of the bank seems to be tapering off slightly. From the spread of the contours the bank seems to be more symmetrical.

Sandwaves are still a feature, however the heights are not as prominent.

Table Four

Depths at Proposed Turbine Locations

Turbine Number	Depth m CD	Turbine Number	Depth m CD
T96	21.0	T112	8.3
Т97	12.5	T113	23.5
T98	2.0	T114	23.7
Т99	22.4	T115	19.0
T100	23.6	T116	5.0
T101	16.5	T117	14.0
T102	3.6	T118	28.7
T103	13.4	T119	24.3
T104	27.8	T120	11.8
T105	27.1	T121	5.8
T106	20.8	T122	23.2
T107	8.5	T123	23.4
T108	8.8	T124	12.0
T109	23.6	T125	8.4
T110	22.1	T126	26.4
T111	7.0		

HS:59-5/08: Depths recorded on top of the bank can be as shallow as 2.6-2.8m, this averages out to between 3-4m towards the southern extent of the survey area. The asymmetrical nature of the bank that was such a prominent feature at the northern limits does not appear to be as evident at this end of the Kish and Bray banks.

Turbine Number	Depth m CD	Turbine Number	Depth m CD
T127	23.1	T136	20.0
T128	18.2	T137	17.5
T129	5.6	T138	3.0
T130	23.8	T139	18.7
T131	21.3	T140	18.5
T132	17.8	T141	19.3
T133	7.4	T142	17.3
T134	20.8	T143	9.5
T135	20.5	T144	17.5
		T145	18.1

Table FiveDepths at Proposed Turbine Locations

3.2 Geophysical Survey Results

3.2.1 Background Information

The Kish and Bray banks are described as the largest sand bank found off the east coast of Ireland. It measures approximately 18km in length. The surface seabed sediments are largely composed of sand of medium to low acoustic reflectivity (Jackson, et al. 1995, Anglesey Sheet 1:250,000 series Seabed Sediments BGS and GSI).

The sequence of Quaternary sediments found covering the Kish and Bray banks can be classified under the Prograded facies of the Western Irish Sea Formation (Jackson et al 1995, Anglesey Sheet 1:250,000 Quaternary Sediments BGS and GSI The Geology of the Irish Sea). The main characteristics of the facies are largely composed of sand. Over the Kish and Bray banks this facies is typically overlain by the Surface Sands formation which is characterised by sands, slightly gravelly sands and some muddier sands.

According to Wheeler et al. (2001) a simple stratigraphy of the Kish and Bray banks consists of :

Unit A: an upper layer of sand with weak internal reflectors suggesting minimal density contrasts.

Unit B: Thin unit underlying Unit A with a strong acoustic response. This unit may contain clay, gravel layers and mud and silt. This in turn overlies Unit C.

Unit C: A poorly imaged unit with few internal reflectors which occasionally contains thin beds comparable with Unit B.

Wheeler et al. (2001) also indicate that over the Kish Bank the thickness of Unit A to Unit B can be over 38m and on the Bray Bank can be over 37m.

3.2.2 Subbottom Profiles

The results of the subbottom profiling survey carried out by HSL are presented as a series of 12 east-west orientated cross sections that run the length of the Kish and Bray banks. These are displayed on charts **HS:59D-1/08 and HS:59D-2/08**

Three boreholes were drilled on the Kish Bank by Glover Site Investigations under contract to Saorgus Energy. The results of BH1, BH2 and BH3 have been incorporated onto the appropriate sections.

The interpretations presented for this element of the survey are based on correlations between characteristics displayed on subbottom profiles, geotechnical information where available, background data and the authors experience. These are subject to change pending further ground-truthing. Two main horizons were identified within the seismic profiles. These were represented by a planar, almost continuous character.

From the existing borehole information and the background data it would appear most likely that these horizons are indicative of changes in the subsurface sediment texture and density. The principal composition of this sediment would be sand with densities ranging from medium to very dense with gravel layers and silt. There may also be a clay component.

The horizons that have been identified as possible rock/glacial till would seem to correlate with Unit C from Wheeler et al. 2001 who describe this unit as a poorly imaged strata that occasionally contains other thin beds comparable with those described above. Given the lack of information, if it is required to identify/clarify this unit, further ground-truthing would be advisable.

In lieu of any further information, at present based on the data resolved from the subbottom profiles it would appear that within the sections the range of material thickness can be summarised as follows.

Subbottom Section	Interpreted Material thickness
Section 1	5-33m
Section 2	24-42m
Section 3	15-38m
Section 4	10-20m
Section 5	greater than 27m
Section 6	greater than 20m
Section 7	greater than 20m
Section 8	10-30m
Section 9	at least 20m
Section 10	15-20m
Section 11	up to 22m
Section 12	at least 20m

Bibliography

Jackson, et al. 1995. United Kingdom Offshore regional report: The Geology of the Irish Sea. *London: HMSO for the British Geological Survey*.

Wheeler, et al. 2001. Seabed Mapping and Seafloor Processes in the Kish, Burford, Bray and Fraser Banks Area, South-Western Irish Sea. *Irish Geography, Volume* 34(2), 194-211

Maps

Anglesey Sheet 53°N – 06°W including part of Dublin 53°N – 08°W, British Geological Survey and Geological Survey Of Ireland, 1:250,000 **Seabed Sediments**

Anglesey Sheet $53^{\circ}N - 06^{\circ}W$ including part of Dublin $53^{\circ}N - 08^{\circ}W$, British Geological Survey and Geological Survey Of Ireland, 1:250,000 Quaternary Geology

Appendix One

Equipment List

Appendix One

Equipment List and Technical Specifications

Navigation: Trimble AgDGPS 132 Receiver This navigation unit provides sub-metre differential position accuracy in differential mode.

BathymetryODOM Hydrotrac digital echosounderHypack 2008 survey software.The navigation can be interfaced into this software package to providereal-time line guidance and continuous logging of position in bothLatitude and Longitude and Irish National Grid.



The ODOM Hydrotrac digital echosounder recorder set up onboard during survey.



Odom Hydrotrac featuring full waterproof cover. **Hydrotrac** was specifically designed to work on small survey boats and inflatable water craft in rugged conditions such as surf zones. while being compact and portable, it is fully waterproof during operation. Hydrotrac incorporates the thermal printer and advanced features of odom's established echotrac line of echo sounders and is competitively priced.

SPECIFICATIONS

Frequency

- 200 kHz (standard)
- 40 & 33 kHz (optional)

Output Power

• 500 Watts

Power Requirement

- 9-18 VDC (standard)
- 18-36 VDC or 110/220
- VAC (optional)

Ports

- 2 (RS232 or RS422)
 Resolution 0.1 feet or .01 meters
- (selectable)

CONTROLS

- Sensitivity
- Chart On/Off & Advance
- Event Mark
- Transmit Power (High/Med/Low)

TOUCH PAD SETTINGS

- Draft, Velocity & Tide Inputs
- Time & Date
- Scale Width & Center
- Blanking
- Calibration Gate
- Alarm Filter
- Fix Interval

Specifications for the ODOM Hydrotrac digital echosounder

Subbottom Profiling:

C-boom low voltage subbottom profiling system Coda Octopus Subbottom Processing Toolkit software. The subbottom system was deployed astern. The technical specifications for the C Boom system are discussed below.



Towed catamaran with seismic source for C-boom subbottom profiling system

C-Boom

Technical Specifications Model C-Boom LVB

C-Boom Catamaran

Comprising Frame, Plate and Electronics module Dimensions 950 x 1010 x 370mm Weight in Air 30Kg Energy discharge per pulse 100J Acoustic output (re 1uPa @ 1m) -200dB Dominant frequency 1760Hz Resolution better than 300mm Firing rate 6 per second max Working voltage 400 – 600 Volts DC Transducer diameter 370mm Power supply & trigger connector 6 pin Impulse (Via combined power & tow cable) Transducer Connection 4 Pin LVB Connector Tow frame 19mm Stainless 316 tube Tow Depth: 0 – 1000mm continuous

C-Boom Power Supply

Dimensions (Inc 19" mounting) 485 x 430 x 85mm Weight 18Kg Supply voltage 110 / 220 Volts ac, 50/60 Hz (Operator selected) Output voltage 400 – 600Volts dc (Operator adjustable) Connections Mains - IEC Catamaran - 12 Pin Cannon Trigger - BNC 50 Ω Power consumption 800W Power source 1.5 KVA generator Resolution 30cm or better Environmental Safe portable equipment Electrical isolation Fully isolated from mains input and trigger circuits

C-Boom

Technical Specifications Model C-Boom LVB **C-Boom Light Weight Tow Cable** Standard length 60m (Other lengths available on request) Weight in air 13Kg Weight in water 4Kg Diameter 14mm Composition Double polyurethane jacket Double screened Kevlar reinforced Cable baseling straig 700Kg

Cable breaking strain 700Kg Cable termination Termination shell is bonded on to the Aramide strain member with potting Appendix Two

Table of Proposed Turbine Locations

Turbine ID	Easting	Northing	Latitude (Modified Airy)	Longitude (Modified Airy)
T1	336839.3	229934.4	53 18 7.287 N	005 56 49.6296 W
T2	337375	229885.3	53 18 5.2009 N	005 56 20.7947 W
Т3	337964.3	229885.3	53 18 4.65 N	005 55 48.9911 W
T4	338500	229885.3	53 18 4.1472 N	005 55 20.0805 W
T5	339035.7	229885.3	53 18 3.6424 N	005 54 51.1701 W
T6	336839.3	229344.3	53 17 48.2093 N	005 56 50.5449 W
T7	337375	229344.3	53 17 47.7108 N	005 56 21.6369 W
T8	337964.3	229344.3	53 17 47.16 N	005 55 49.837 W
Т9	338446.4	229344.3	53 17 46.7076 N	005 55 23.822 W
T10	339035.7	229344.3	53 17 46.1525 N	005 54 52.0225 W
T11	336839.3	228852.5	53 17 32.3096 N	005 56 51.3073 W
T12	337437.5	228861.6	53 17 31.3651 N	005 55 56.6381 W
T13	337964.3	228852.5	53 17 31.2605 N	005 55 50.6014 W
T14	338500	228852.5	53 17 30.7578 N	005 55 21.7013 W
T15	339035.7	228852.5	53 17 30.2532 N	005 54 52.7972 W
T16	336785.7	228311.5	53 17 14.8692 N	005 56 55.0376 W
T17	337375	228311.5	53 17 14.3209 N	005 56 23.2442 W
T18	337910.8	228311.5	53 17 13.8204 N	005 55 54.3375 W
T19	338446.4	228360.7	53 17 14.9087 N	005 55 25.3646 W
T20	338982.2	228311.5	53 17 12.8138 N	005 54 56.5354 W
T21	336892.9	227819.7	53 16 58.87 N	005 56 50.0164 W
T22	337428.6	227819.7	53 16 58.3714 N	005 56 21.1179 W
T23	337964.3	227819.7	53 16 57.8709 N	005 55 52.2195 W
T24	338553.6	227819.7	53 16 57.3179 N	005 55 20.4299 W
T25	339089.3	227819.7	53 16 56.8134 N	005 54 51.532 W
T26	337053.6	227278.7	53 16 41.2303 N	005 56 42.1868 W
T27	337589.3	227278.7	53 16 40.7312 N	005 56 13.2915 W
T28	338125	227278.7	53 16 40.2302 N	005 55 44.3965 W
T29	338714.3	227278.7	53 16 39.6769 N	005 55 12.6055 W
T30	339250	227278.7	53 16 39.1718 N	005 54 43.7161 W
T31	337107.2	226737.7	53 16 23.6902 N	005 56 40.1351 W
T32	337696.4	226737.7	53 16 23.141 N	005 56 8.3577 W
T33	338232.2	226737.7	53 16 22.6396 N	005 55 39.4606 W
T34	338767.9	226737.7	53 16 22.1364 N	005 55 10.5691 W
T35	339303.6	226737.7	53 16 21.6312 N	005 54 41.6779 W
T36	337160.7	226196.7	53 16 6.1501 N	005 56 38.0892 W
T37	337750	226196.7	53 16 5.6008 N	005 56 6.31 W
T38	338339.3	226196.7	53 16 5.049 N	005 55 34.5312 W
T39	338875	226196.7	53 16 4.5456 N	005 55 5.643 W
T40	339410.7	226196.7	53 16 4.0399 N	005 54 36.7551 W
T41	337231.4	225655.7	53 15 48.5941 N	005 56 35.1162 W
T42	337857.1	225655.7	53 15 48.0105 N	005 56 1.378 W
T43	338446.4	225655.7	53 15 47.4585 N	005 55 29.6026 W
T44	338982.1	225655.7	53 15 46.9547 N	005 55 0.7181 W
T45	339517.9	225655.7	53 15 46.4487 N	005 54 31.828 W
T46	337214.3	225114.8	53 15 31.1229 N	005 56 36.8775 W
T47	337750	225114.8	53 15 30.6236 N	005 56 7.9954 W
T48	338285.7	225114.8	53 15 30.1224 N	005 55 39.1136 W
T49	338821.4	225114.8	53 15 29.6192 N	005 55 10.2319 W

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Turbine ID	Easting	Northing	Latitude (Modified Airy)	Longitude (Modified Airy)
T50	339357.1	225114.8	53 15 29.114 N	005 54 41.3506 W
T51	337589.3	224573.8	53 15 13.2833 N	005 56 17.5009 W
T52	338125	224573.8	53 15 12.7828 N	005 55 48.6223 W
T53	338660.7	224573.8	53 15 12.2801 N	005 55 19.7439 W
T54	339196.4	224573.8	53 15 11.7757 N	005 54 50.8656 W
T55	339785.7	224573.8	53 15 11.2185 N	005 54 19.0982 W
T56	337642.9	224032.8	53 14 55.7431 N	005 56 15.453 W
T57	338178.6	224032.8	53 14 55.2423 N	005 55 46.5776 W
T58	338767.9	223983.6	53 14 53.0987 N	005 55 14.8905 W
T59	339303.6	223983.6	53 14 52.594 N	005 54 46.0159 W
T60	339892.9	223983.6	53 14 52.0364 N	005 54 14.2525 W
T61	337803.6	223491.8	53 14 38.1028 N	005 56 7.6331 W
T62	338339.3	223491.8	53 14 37.6015 N	005 55 38.761 W
T63	338928.6	223491.8	53 14 37.0479 N	005 55 7 W
T64	339464.3	223491.8	53 14 36.5427 N	005 54 38.1289 W
T65	339946.4	223491.8	53 14 36.0863 N	005 54 12.1464 W
T66	338107	222902	53 14 18.7513 N	005 55 52.2011 W
T67	338607	222902	53 14 18.2826 N	005 55 25.2565 W
T68	339107	222902	53 14 17.8123 N	005 54 58.3122 W
T69	339607	222902	53 14 17.3403 N	005 54 31.3681 W
T70	340107.1	222852.5	53 14 15.2661 N	005 54 4.4972 W
T71	338143	222386	53 14 02.0356 N	005 55 51.0659 W
T72	338642	222360	53 14 00.7273 N	005 55 24.2188 W
T73	339142.9	222360.7	53 14 0.2787 N	005 54 57.228 W
T74	339678.6	222360.7	53 13 59.7727 N	005 54 28.3633 W
T75	340214.3	222360.7	53 13 59.265 N	005 53 59.499 W
T76	338375	221770	53 13 41.9034 N	005 55 39.5271 W
T77	338875	221819.7	53 13 43.0407 N	005 55 39.5271 W
T78	339410.7	221770.5	53 13 40.9453 N	005 54 43.727 W
T79	339946.4	221770.5	53 13 40.4386 N	005 54 14.8661 W
T80	338446.4	221377.1	53 13 29.1341 N	005 55 36.2941 W
T81	339035.7	221327.9	53 13 26.99 N	005 55 4.6248 W
T82	339517.9	221377.1	53 13 28.1258 N	005 54 38.5709 W
T83	340107.1	221377.1	53 13 27.5681 N	005 54 6.8303 W
T84	338553.6	220737.7	53 13 8.3622 N	005 55 31.5185 W
T85	339089.3	220737.7	53 13 7.8587 N	005 55 2.6633 W
T86	339625	220737.7	53 13 7.3533 N	005 54 33.8085 W
T87	340160.7	220737.7	53 13 6.8461 N	005 54 4.9539 W
T88	338500	220737.7	53 12 52.5128 N	005 55 35.1737 W
T89	339089.3	220245.3	53 12 50.3686 N	005 55 3.512 W
T90	339624.9	220190.7	53 12 49.8634 N	005 54 34.6657 W
T90 T91	340160.7	220196.7	53 12 49.8034 N 53 12 50.9467 N	005 54 5.7312 W
T92	338660.7	220245.9	53 12 30.9407 N	005 55 27.5181 W
T92 T93	339196.4	219606.6	53 12 31.6939 N 53 12 31.1902 N	005 54 58.6698 W
			53 12 31.1902 N 53 12 30.6339 N	005 54 56.8698 W
T94	339785.7	219606.6		
T95	340321.4	219606.6	53 12 30.1262 N	005 53 58.0877 W
T96	338660.7	219065.6	53 12 14.2036 N	005 55 28.3635 W
T97	339250	219065.6	53 12 13.6495 N	005 54 56.6324 W
T98	339785.7	219065.6	53 12 13.1438 N	005 54 27.7878 W
T99	340321.4	219065.6	53 12 12.6361 N	005 53 58.9433 W

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Turbine ID	Easting	Northing	Latitude (Modified Airy)	Longitude (Modified Airy)
T100	338500	218475.4	53 11 55.2734 N	005 55 37.9375 W
T101	339035.7	218524.6	53 11 56.3611 N	005 55 9.0189 W
T102	339571.4	218524.6	53 11 55.8563 N	005 54 40.1775 W
T103	340107.1	218524.6	53 11 55.3495 N	005 54 11.3361 W
T104	340696.4	218524.6	53 11 54.7897 N	005 53 39.6093 W
T105	338232.1	218032.8	53 11 41.2149 N	005 55 53.0502 W
T106	338821.4	218032.8	53 11 40.6628 N	005 55 21.3258 W
T107	339357.1	218032.8	53 11 40.1589 N	005 54 52.4871 W
T108	339946.4	218032.8	53 11 39.6022 N	005 54 20.7632 W
T109	340428.6	218032.8	53 11 39.145 N	005 53 54.8051 W
T110	338821.4	217491.8	53 11 23.1725 N	005 55 22.1715 W
T111	339357.1	217491.8	53 11 22.6687 N	005 54 53.3361 W
T112	339946.4	217442.6	53 11 20.5215 N	005 54 21.6933 W
T113	340482.1	217491.8	53 11 21.6042 N	005 53 52.7809 W
T114	338553.6	216901.7	53 11 4.3459 N	005 55 37.5071 W
T115	339089.3	216901.7	53 11 3.843 N	005 55 8.6751 W
T116	339625	216901.7	53 11 3.3383 N	005 54 39.8433 W
T117	340214.3	216901.7	53 11 2.781 N	005 54 8.1271 W
T118	340750	216901.7	53 11 2.272 N	005 53 39.2958 W
T119	338821.4	216360.7	53 10 46.6046 N	005 55 23.9389 W
T120	339357.1	216409.8	53 10 47.6882 N	005 54 55.0333 W
T121	339892.9	216409.8	53 10 47.1825 N	005 54 26.1993 W
T122	340482.1	216360.7	53 10 45.0367 N	005 53 54.5694 W
T123	338982.1	215868.9	53 10 30.5538 N	005 55 16.06 W
T124	339517.9	215868.9	53 10 30.0495 N	005 54 47.2289 W
T125	340053.6	215868.9	53 10 29.5434 N	005 54 18.4036 W
T126	340589.3	215868.9	53 10 29.0354 N	005 53 49.5784 W
T127	338875	215327.9	53 10 13.1641 N	005 55 22.668 W
T128	339410.7	215327.9	53 10 12.6604 N	005 54 53.8457 W
T129	340000	215327.9	53 10 12.1041 N	005 54 22.1397 W
T130	340535.7	215327.9	53 10 11.5963 N	005 53 53.3177 W
T131	338982.1	214737.7	53 09 53.9826 N	005 55 17.8281 W
T132	339517.9	214737.7	53 09 53.4785 N	005 54 49 W
T133	340107.1	214737.7	53 09 52.922 N	005 54 17.3072 W
T134	340642.9	214737.7	53 09 52.4138 N	005 53 48.4835 W
T135	341178.6	214737.7	53 09 51.9037 N	005 53 19.6655 W
T136	339035.7	214196.7	53 09 36.4419 N	005 55 15.7901 W
T137	339571.4	214196.7	53 09 35.9377 N	005 54 46.9745 W
T138	340107.1	214196.7	53 09 35.4317 N	005 54 18.1593 W
T139	340642.9	214196.7	53 09 34.9237 N	005 53 49.3389 W
T140	341232.1	214196.7	53 09 34.3628 N	005 53 17.6464 W
T141	339035.7	213606.6	53 09 17.3641 N	005 55 16.7121 W
T142	339625	213606.6	53 09 16.8096 N	005 54 45.0174 W
T143	340160.7	213606.6	53 09 16.3035 N	005 54 16.2056 W
T144	340696.4	213606.6	53 09 15.7954 N	005 53 47.3942 W
T145	341285.7	213606.6	53 09 15.2342 N	005 53 15.7002 W

Survey Personnel

Project Manager:	Mike Haberlin
Field Surveyors:	Colin Johnston Joanna Andrewsksa

- **Geophysicist:** Claire M^cCarthy
- Autocad Technician: Gary Curtin

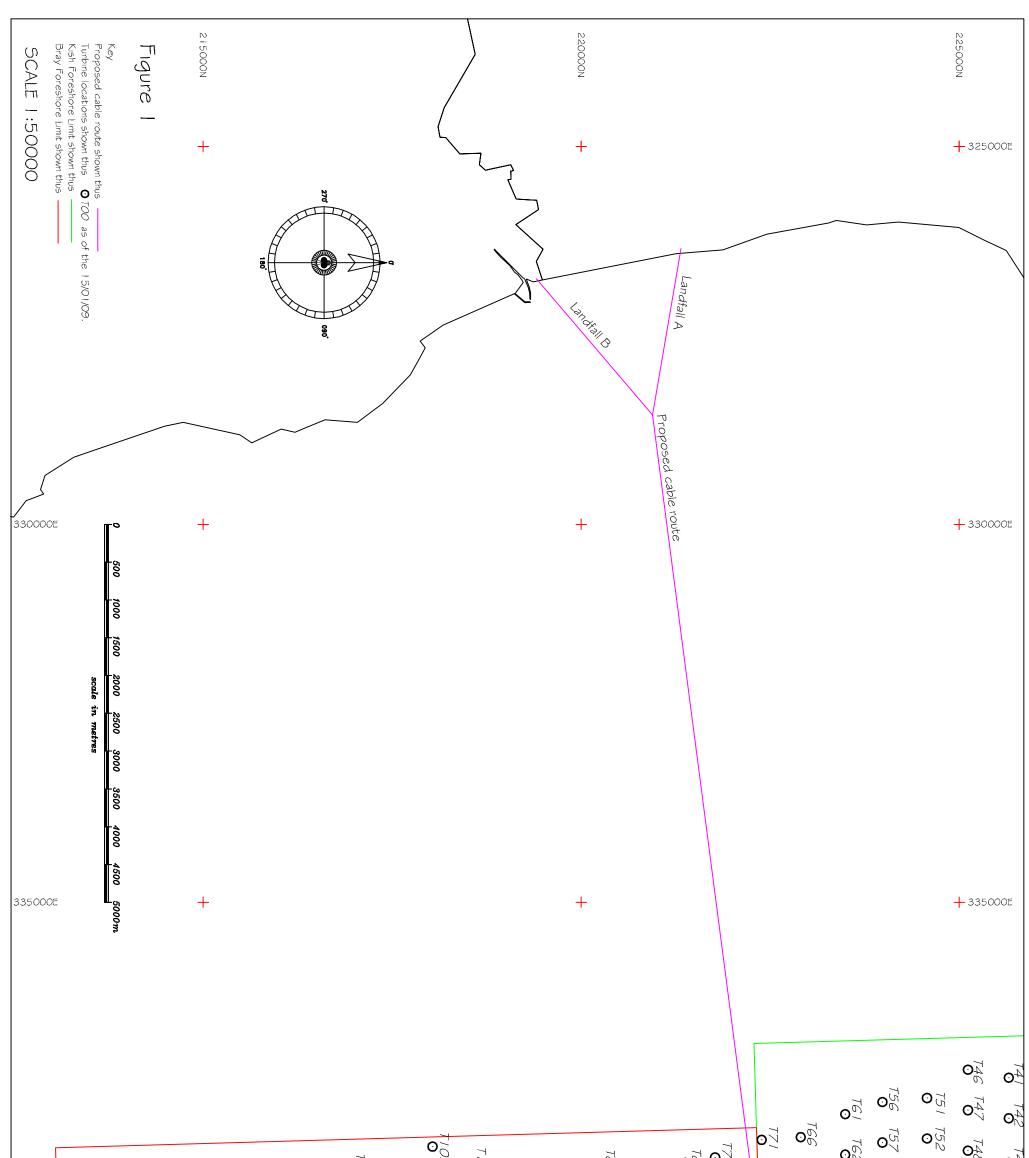
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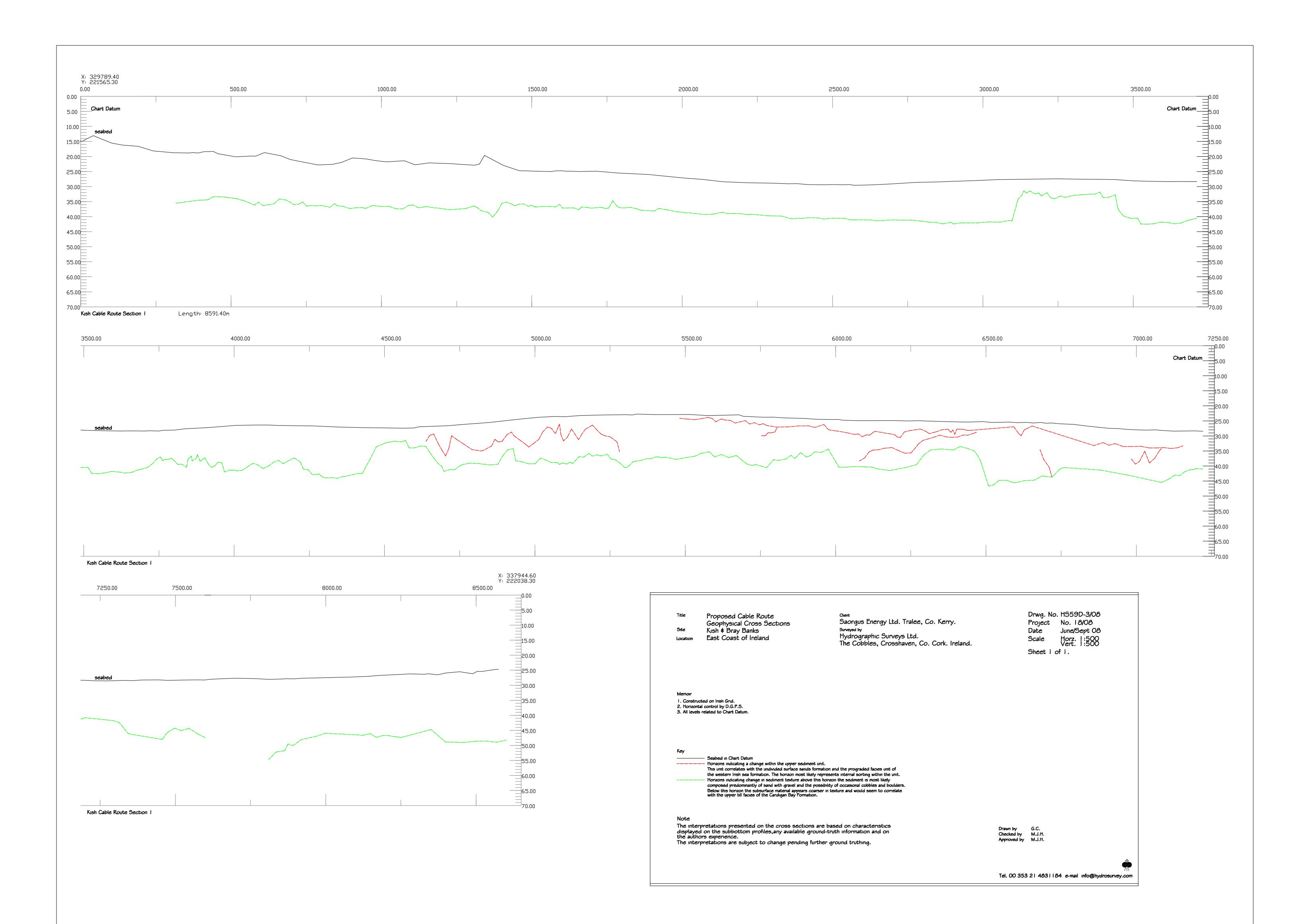
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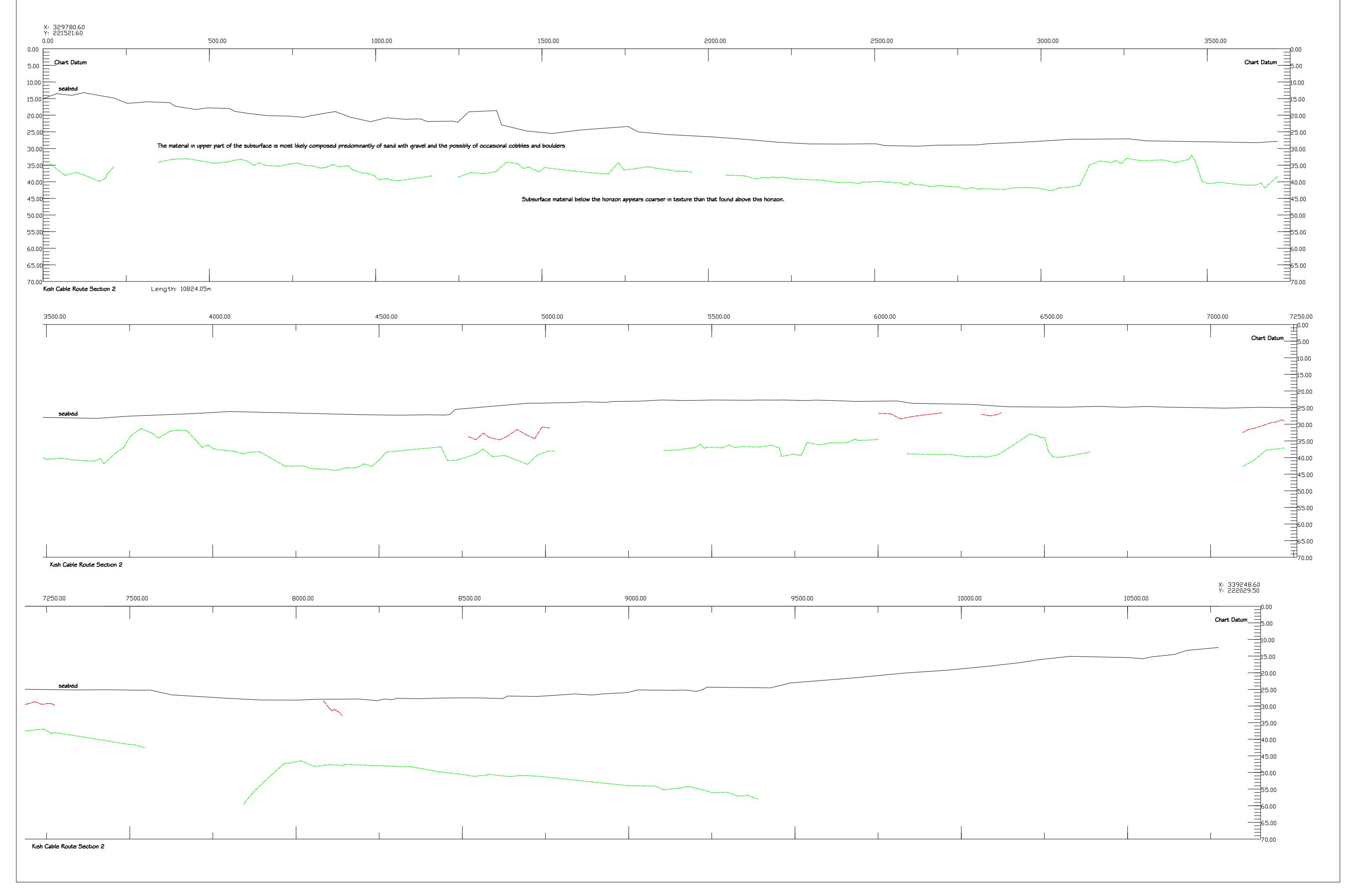
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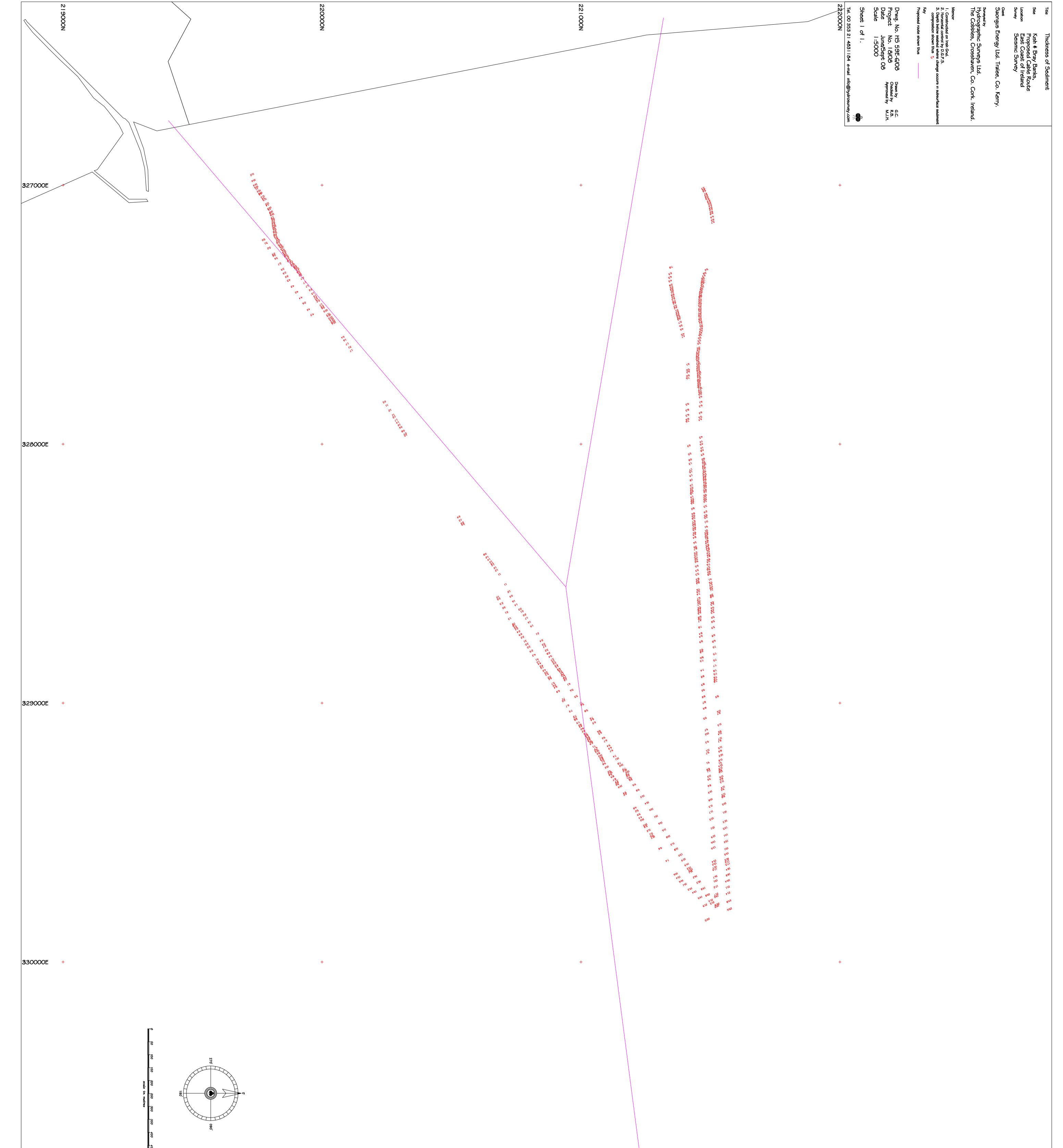
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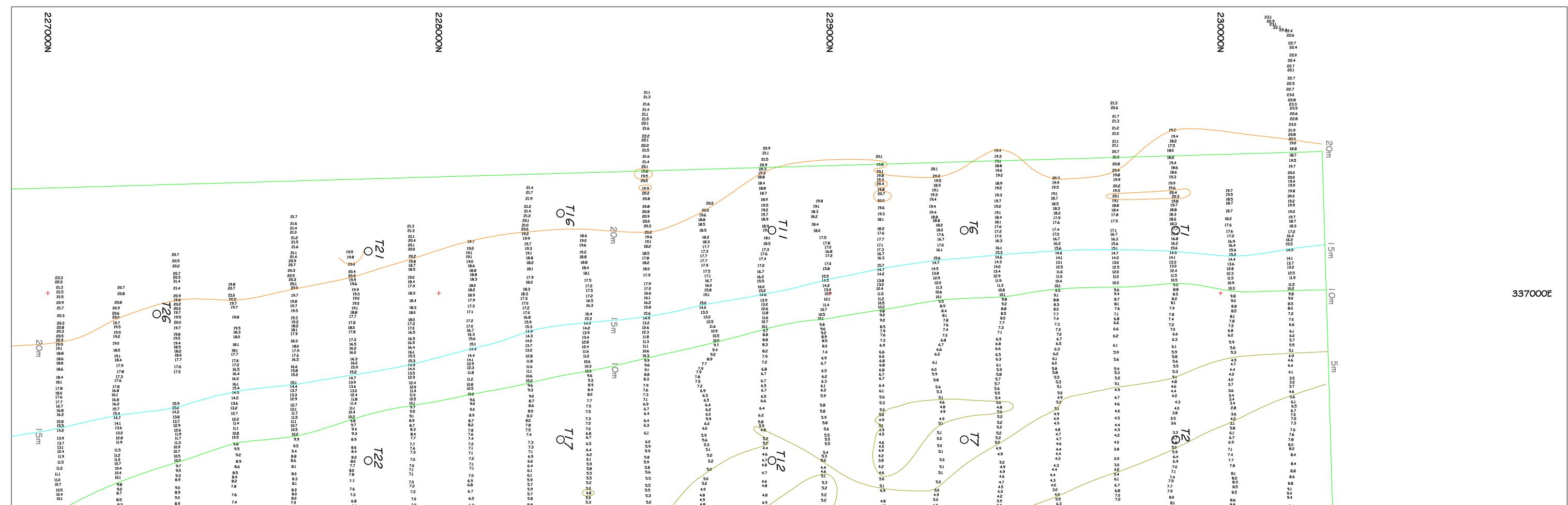
O O O O O O O 157 158 159 160 0 0 0 0 0 0 0 0 176 177 178 179 0 0 0 0 0 180 181 182 183 0 0 0 0 **O O O O O** 188 189 190 191 192 193 194 195 196 197 198 199 196 197 198 199 0 0 0 0 0 0 106 1107 11081109 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 185 186 187 0 0 0 0 172 173 174 175 167 168 169 170 0 143 144 145 0 0 0 T119 T120 T121 T122 **O O O O O O O** 0 0 0 0 0 0 0 1132 T133 T134 T135 0 0 0 0 0 **1**136 **1**137 **1**138 **1**139 **1**140 **0 0 0 0 0** 0 0 0 0 0 0 + 340000E 340000E 215000N 225000N 220000N







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227000			226000		scale in metres	0 100 100 100 100 100 0 00 100 100 100 100 0 00 00 00 00 00	Morthing Latitude Longitude 11 Sassars Sassars Sassars Sassars Sassars 12 337375 229865 3518 52009 005 5649 5226 13 337375 229865 3518 52009 005 5620 7047 14 336035 229344 351747 7108 005 5620 966 17 337375 229343 351747 7108 005 5620 966 171 336393 229344 351747 108 005 5620 987 171 336395 229344 351747 108 005 523822 W 171 338045 228961 5317 31746 108 5620 987 W 171 338045 228911 5317 146 1526 W 055 5500 14 W W 1565 517013 W W 105 <td>Key Froposed turne locations shown thus Bay Foreshore lumit shown thus Borehole locations shown thus Drwg. No. H5 59-1/08 Project No. 18/08 Date June/Sept 08 Scale 1:5000 Sheet 1 of 5. Tel. 00 353 21 4631164 e-mail info@hydrosurvey.com</td> <td>TitleProposed Turbine Locations SiteSiteKish & Bray Banks LocationLocationEast Coast of Ireland SurveyClientBathymetric SurveySaorgus Energy Ltd. Tralee, Co. Kerry.Surveyed by Hydrographic Surveys Ltd. The Cobbles, Crosshaven, Co. Cork. Ireland.MemorI. Constructed on Irsh Gnd. 2. Honzontal control by D.G.P.S. 3. Soundings in metres and decimetres reduced to Chart Datum.</td>	Key Froposed turne locations shown thus Bay Foreshore lumit shown thus Borehole locations shown thus Drwg. No. H5 59-1/08 Project No. 18/08 Date June/Sept 08 Scale 1:5000 Sheet 1 of 5. Tel. 00 353 21 4631164 e-mail info@hydrosurvey.com	TitleProposed Turbine Locations SiteSiteKish & Bray Banks LocationLocationEast Coast of Ireland SurveyClientBathymetric SurveySaorgus Energy Ltd. Tralee, Co. Kerry.Surveyed by Hydrographic Surveys Ltd. The Cobbles, Crosshaven, Co. Cork. Ireland.MemorI. Constructed on Irsh Gnd. 2. Honzontal control by D.G.P.S. 3. Soundings in metres and decimetres reduced to Chart Datum.

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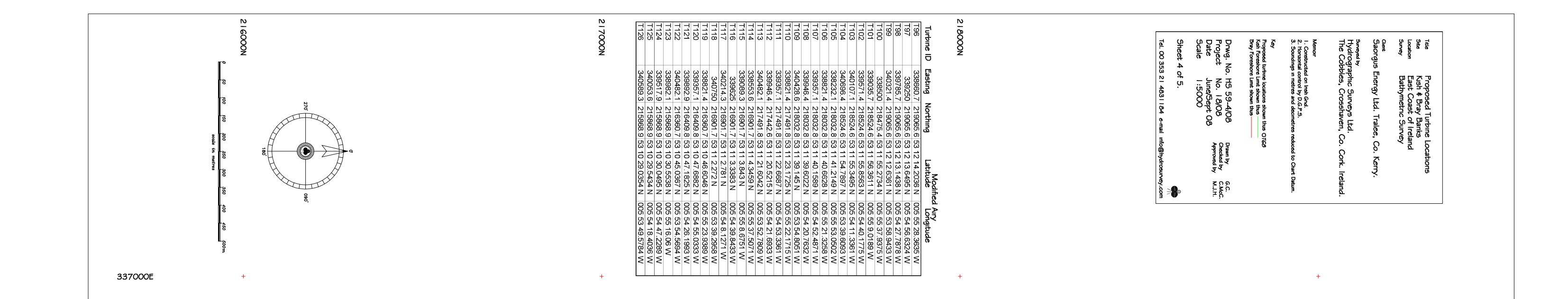
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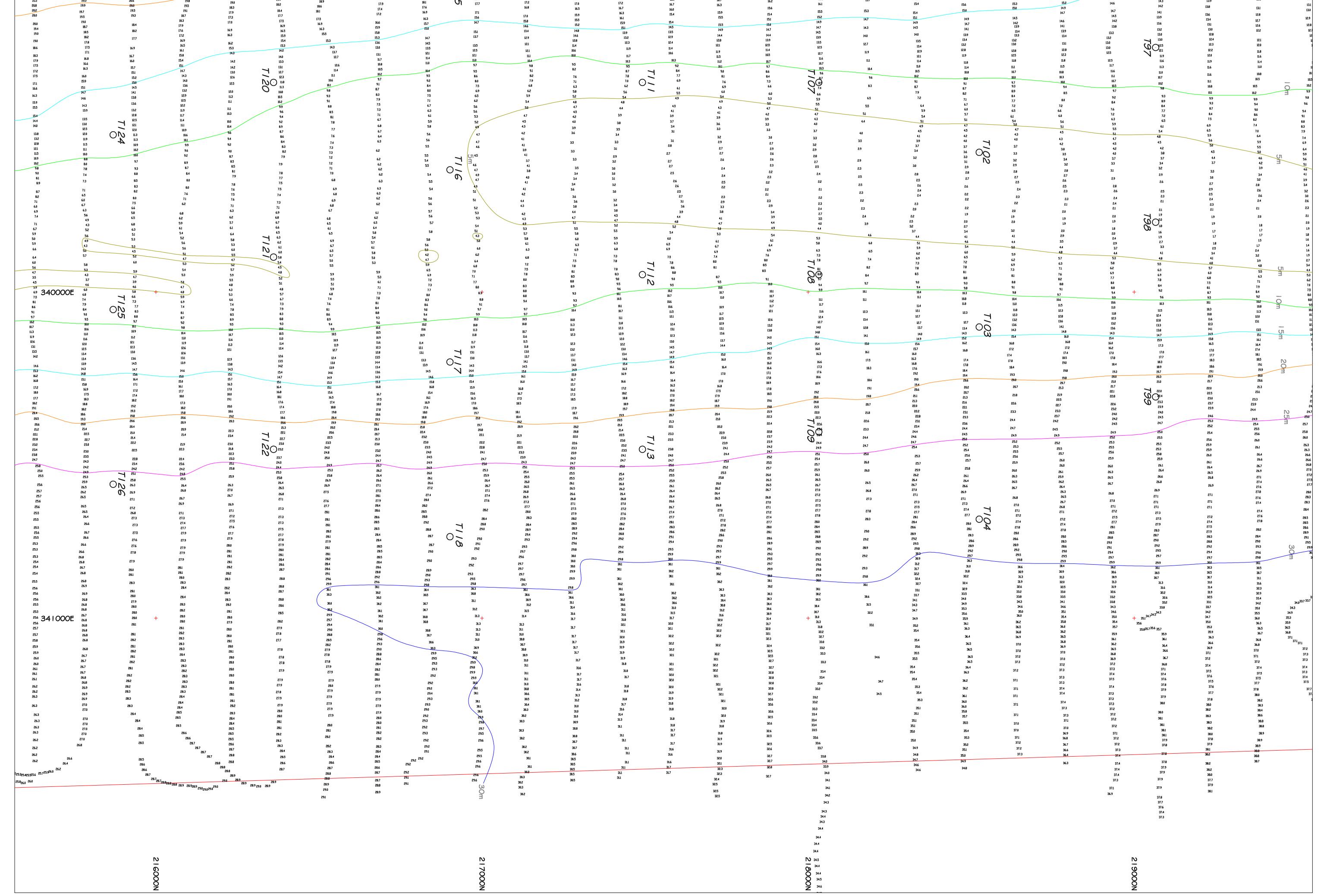
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