Authorisation

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Summary

The British Marine Aggregate Producers Association (BMAPA), a constituent body of the Quarry Products Association, have commissioned a research project to assess the impact of marine aggregate dredging upon benthic biological resources. The study investigates the biological impacts of suction trailer dredging techniques within an existing marine aggregate production licence, and considers the impact of dredged sediment deposited on the seabed through the screening process. Production Licence Area 408 (Coal Pit) which is situated 100km east of the Humber Estuary in the Southern North Sea, was chosen for the study site to avoid any possible influences from adjacent licences

To support the interpretation of the benthic results, BMAPA commissioned Coastline Surveys Europe Ltd (CSEL) to produce a seabed sediment report (this report) for the study area. The CSEL report has been prepared with reference to particle size information arising from the biological grab samples collected in August 2000, together with geophysical and geotechnical data collected during routine monitoring surveys that were carried out by the licensee, Hanson Aggregates Marine Ltd, in the summer of 2000. This report forms a standalone annex to the biological assessment.

These investigations demonstrate a close relationship between the seabed topography, morphology of the seabed sediments (bedforms) and the sediment grain size parameters.

- The southern sector of the licence, which is located in deep water, is dominated by fine to very fine sands that are well sorted; this sector coincides with an area of featureless sands and low profile long wavelength megaripple bedforms.

- The central and northern sectors of the licence lie in shallower water and the seabed sediments comprise a mixed suite of grain sizes that are poorly sorted and dominated by the coarser grain sizes. Interpretation of the sidescan data indicates that the seabed sediments comprise lag gravel with a discontinuous and thin sand cover of mobile sands, locally formed into linear ribbons.

A review of the Admiralty tidal data indicates that the direction of sand movement is in a south easterly direction, an assumption which is largely corroborated by bedform morphology. However, in the west of Area 408 a series of bedforms located on the margins of the Coal Pit depression suggests a reversal in transport direction. This localised sediment transport reversal is assumed to be due to the rapidly changing seabed topography affecting the capacity of the ebb and flood tidal streams to transport sediment.

Area 408 (Coal Pit) Seabed Sediment Report, 2001.

1 Introduction

The aim of this report is to describe the seabed sediments, their relationship to sedimentary bedforms and the hydrodynamic environment.

In Area 408 the underlying geology strongly influences the nature of the surface sediments so a brief review of the shallow geology will be included in this report. It will then discuss the interpretation of sonar data collected in August 2000 together with sedimentary data collected in 1999 and 2000 and infer the general direction of sediment transport within the licence area.

This report is based on:

- Geophysical seismic survey data (collected in 2000), covering the actively dredged zone during the period 1995 to 2000 and a buffer zone of 1000 metres surrounding this zone. Field Report No. 5497.2 details the survey operations completed by Gardline Surveys Ltd.

- Geotechnical site investigation (collected in 1999) comprising 18 vibrocore samples. These investigations were undertaken by Alluvial Mining Ltd., Field Report No. 96524-3(01).

- Benthic grab sampling data (collected in 2000), comprising some 219 samples collected from 185 sample locations in and around Area 408. These investigations were undertaken by Andrews Survey, Area 408 grab survey factual report, No. 028/408/Lab (01).

- Area 408 geological monitoring interpretative report, which reviewed the thickness of seabed sediments and specific licence conditions. The report was completed by Coastline Surveys Europe Ltd., Report No. 852

2 Location

Area 408 lies in water depths ranging from 23 to 32 metres below Chart Datum and is located at the northern end of the “Coal Pit” sea bed depression, approximately 100km due east from the entrance to the River Humber, in the Southern North Sea, Figure 1 & Table 2. The licence area measures approximately 13km x 8.5 km.

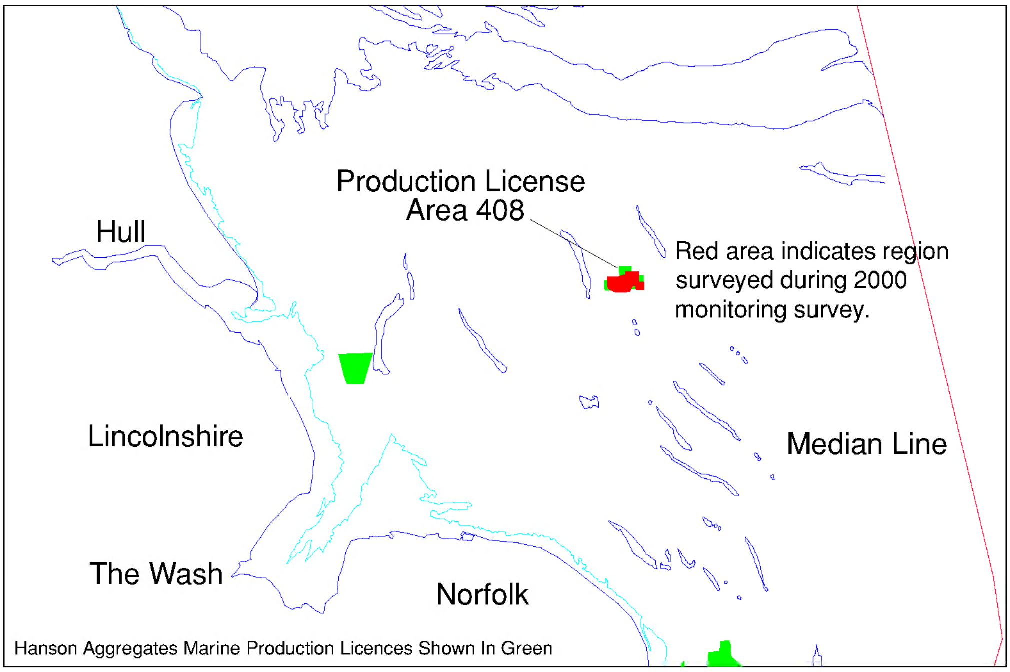


Figure 1 Area 408, “Coal Pit”, location map.

Area 408 Licence Co-ordinates (OSGB)				
	Latitude	Longitude	Easting	Northing
A	53 36' 00" N	001 38' 00" E	640369mE	417654mN
B	53 36' 00" N	001 42' 00" E	644778mE	417881mN
C	53 38' 00" N	001 42' 00" E	644585mE	421587mN
D	53 38' 00" N	001 45' 00" E	647889mE	421760mN
E	53 36' 30" N	001 45' 00" E	648036mE	418981mN
F	53 36' 30" N	001 48' 00" E	651341mE	419157mN
G	53 34' 30" N	001 48' 00" E	651539mE	415450mN
H	53 34' 30" N	001 38' 00" E	640511mE	414874mN

Table 1; Area 408, “Coal Pit”; marine aggregate production licence co-ordinates.

3 Bathymetry

The bathymetry of Area 408 is dominated by a “Y” shaped area of deep water that is the northerly extension of the Coal Pit seabed depression. Maximum water depths of 31 to 32 metres are found in the south, which shoal rapidly northwards. Two shoal patches lying at 22 to 23 metres are located in the centre of the surveyed area and to the north of these shoal patches there is a featureless plateau lying at 24 metres.

Detailed comparison of bathymetric change is outside the scope of this report. However from a review of Figures 2 & 3, bathymetry sets collected in 1995 and 2000 respectively, it can be seen that the significant seabed features have remained stable during this interval. The physical impact of aggregate extraction on the seabed topography can be observed in the vicinity of 644250mE 416750mN. Here the seabed has been lowered by up to 1.5 metres and minor bed-level changes also occur in the other intensively dredged regions. Analysis of bathymetric change indicates no apparent accretion surrounding the dredged areas.

The greatest bathymetric changes are located in the south west of the survey area and range from 5m erosion to 4m accretion. Sonargraph interpretation shows this region coincides with an area of sandwaves, where naturally occurring, localised changes in bathymetry are to be expected.

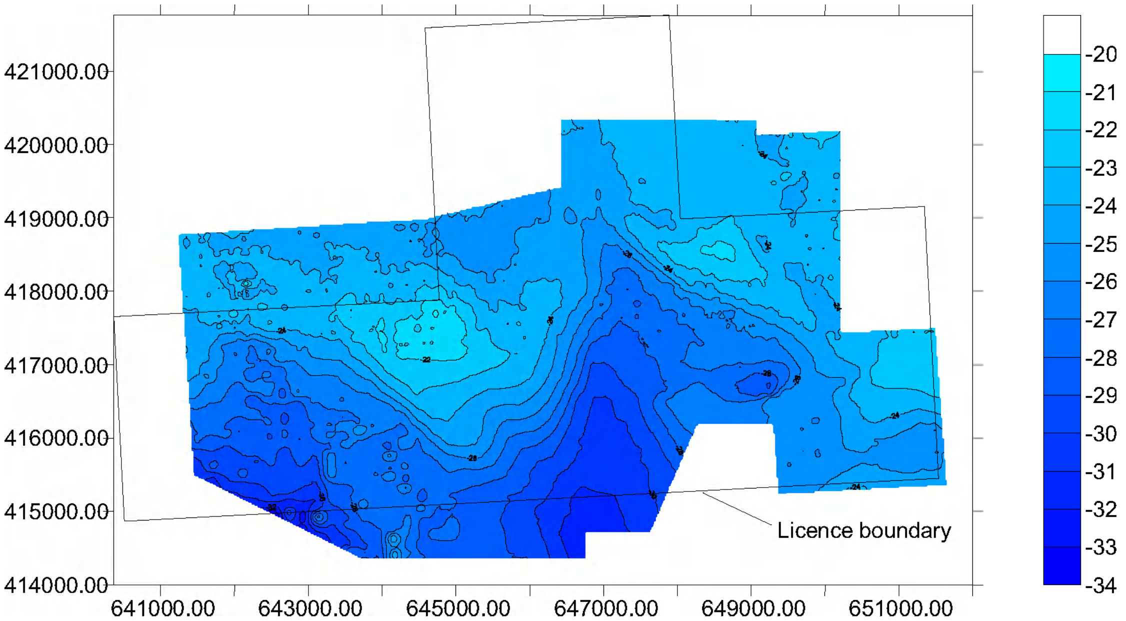


Figure 2 1995 bathymetry, pre-dredge baseline

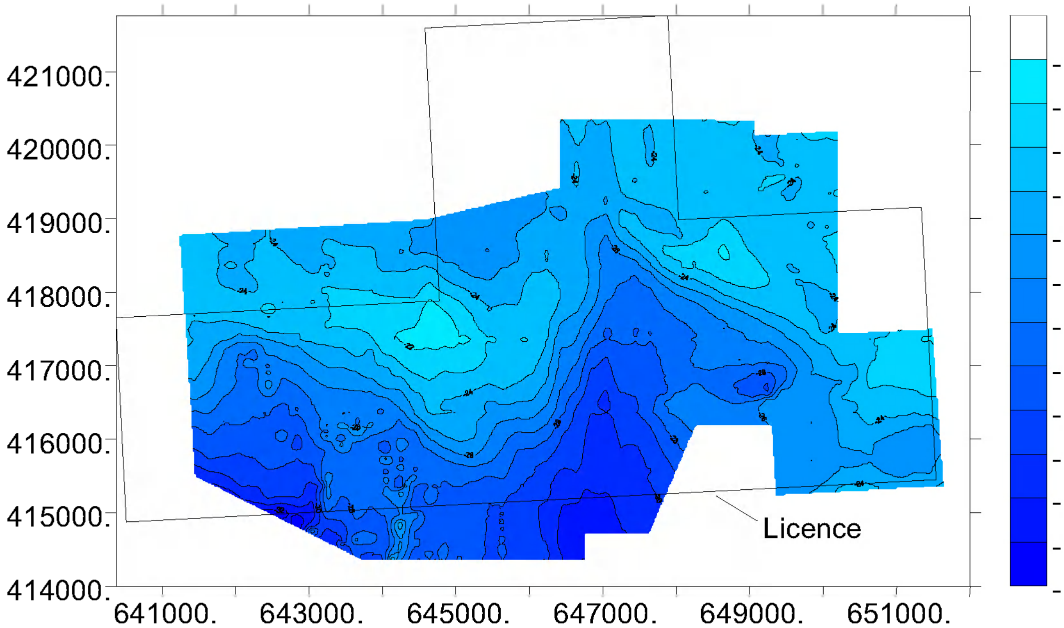
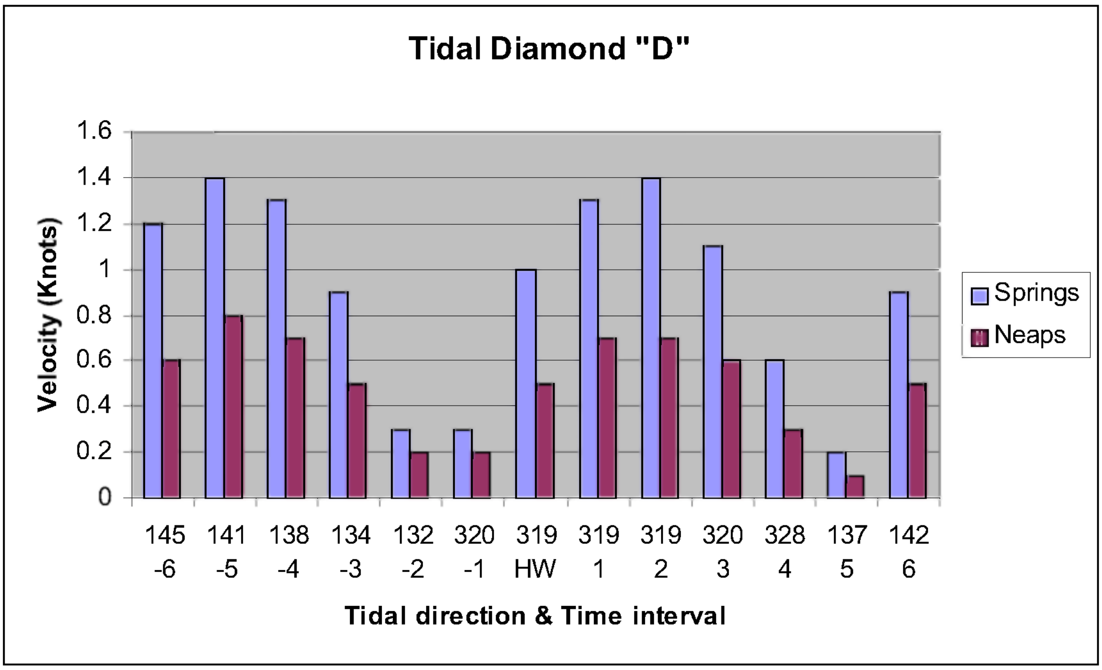
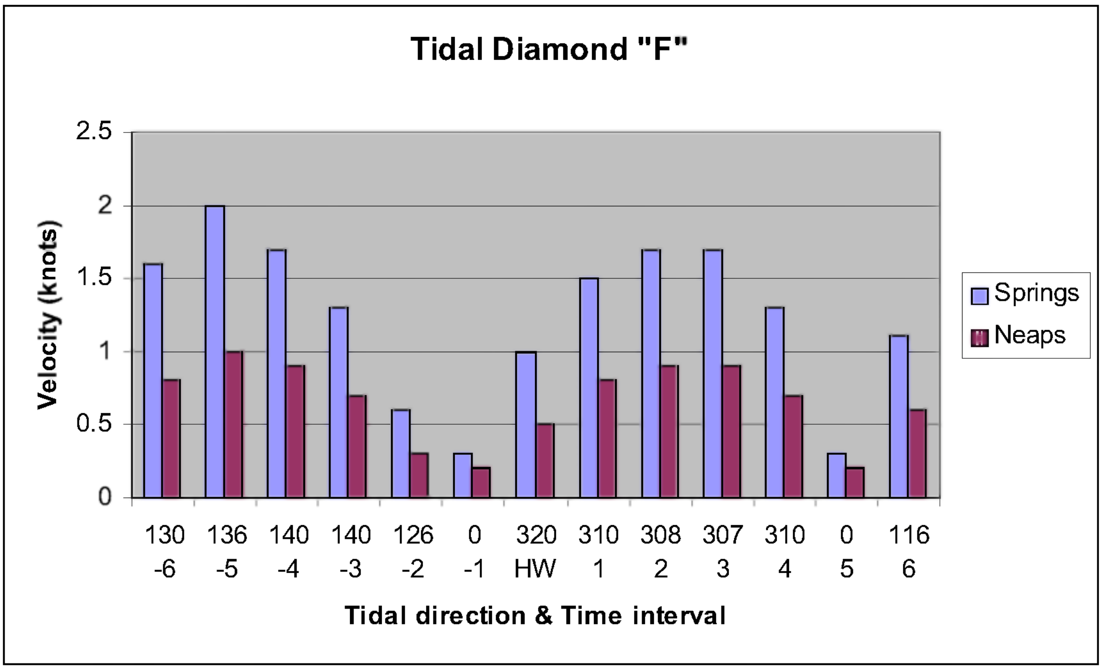


Figure 3, 2000 bathymetric monitoring survey.

The tidal data is reviewed from Admiralty Chart 1187, which shows two tidal diamonds located in the vicinity of Area 408, diamonds D and F. Diamond F is located at position 53 35.0' N 001 48.0' E on the eastern boundary of the licence area and Diamond D is located in position 53 37.5' N 001 38.2' E to the north east of the licence. Figure 4 shows the current rose and ellipse for spring tides at each station and displays the hourly current direction and speed as a series of vectors. The maximum tidal speed is 2 knots (1.02ms^{-1}) in a south easterly direction at station F and 1.4 knots (0.72ms^{-1}) at station D. From the diagram it can be seen that the tides are strongly rectilinear, trending north west / south east and have net residual current vectors of 123^{0} / 0.65 knots at station F and 147^{0} / 0.49 knots at station D.

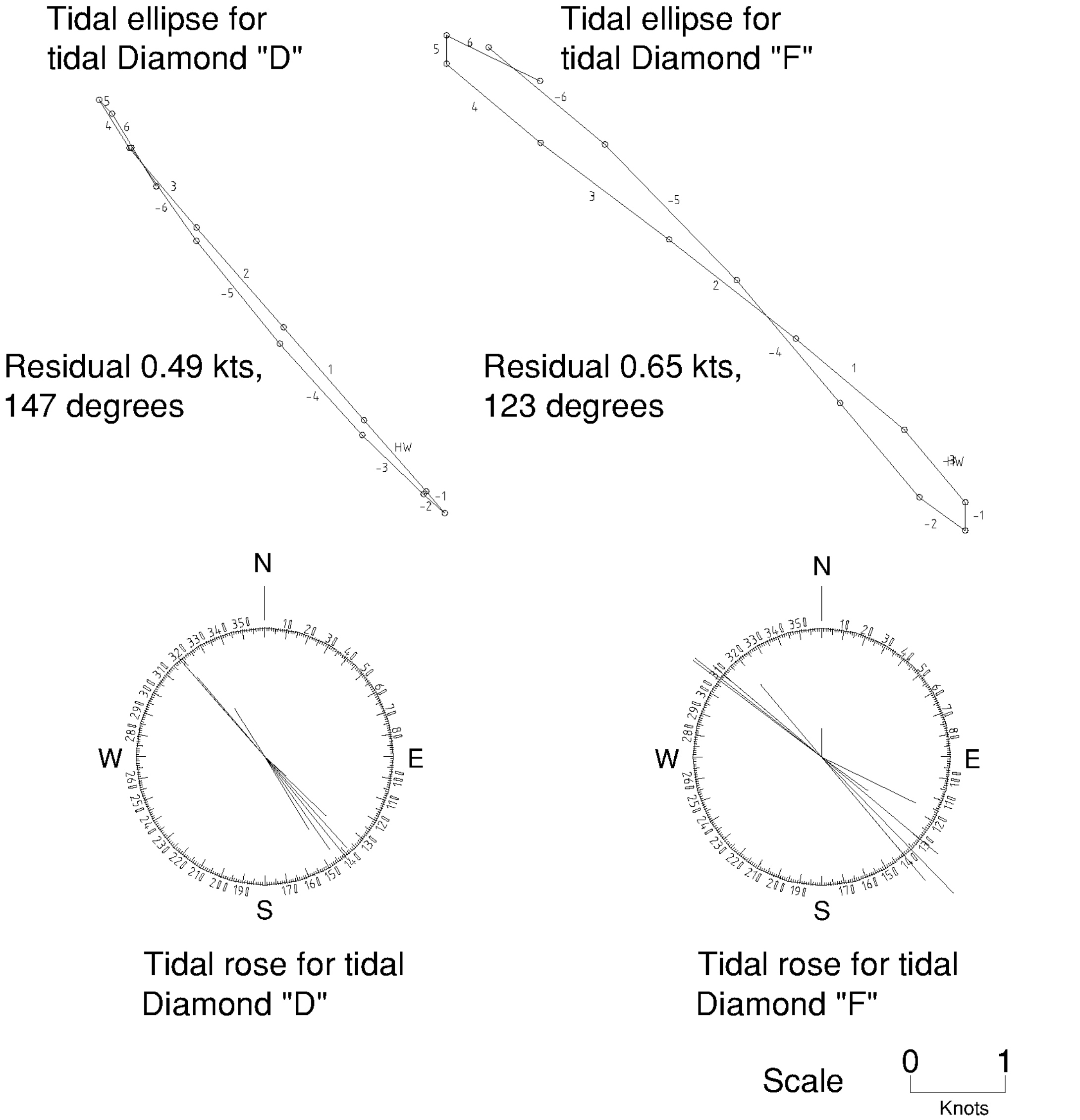
During neap tidal conditions the tidal velocities are just under half those experienced during spring tides, graph 1.





Graph 1, Graphical representation of Admiralty tidal diamond stations close to Area 408.

Figure 4. Tidal ellipse and tidal rose diagrams for Tidal Diamonds "D" & "F" located on Admiralty Chart 1187.



4 Quaternary Geology

The Pleistocene geology has a significant impact upon the nature of the Holocene (surface) sediments in the vicinity of Area 408 and a major change, that trends east-west through Area 408, occurs in the underlying Pleistocene units. These units comprise glacial and interglacial sediments that are generally thin, and form a complex association of sedimentary units comprising tabular diamicton sheets and infilled palaeovalleys.

The seabed geology in the north of Area 408 comprises extensive reddish to greyish brown, stiff diamicton sheets of subglacial and supraglacial till deposits which are generally less than 5 metres thick (Boulders Bank Formation). These sheets are generally well defined on geophysical records by significant seismic reflectors bounding units of chaotic to poorly ordered seismic reflectors. The Formation is locally exposed at the seabed but is generally covered by a veneer of sediment that is up to a few decimetres in thickness.

The southern sector of Area 408 partly overlies a series of deeply incised, infilled, palaeovalleys which trend in an east-west direction. It is inferred from the arrangement of seismic reflectors and acoustic characteristics of the palaeovalley infill seen on the geophysical records that the composition of channel fill is of fine grained sediment. These palaeovalleys have extensive shallow margins that either “pinch-out” against diamictons in the north and north west or inter-digitise with adjacent channels in the north east and south west. The seismic characteristics of the channel margins are predominantly reflector free with low acoustic backscatter, again indicating the presence of fine grained sediment.

The sediments infilling the palaeovalleys are usually, but not always, separated from the seabed by disordered seismic units comprising several layers, lenses and shallow channels. In the centre of the survey area, draped over the topographic high that trends east west, are two to three shallow lenses of sediment, some of which partially overlie each other. The configuration of reflectors combined with the variable acoustic nature of the lens, ranging from obliquely parallel prograding clinoforms with a high reflection amplitude, to reflector free acoustically transparent units, which indicate a varied sedimentological composition. As will be seen from Figures 8 to 14 it is in this region that the coarsest seabed sediments are located.

South of this region of coarser sediments and overlying the palaeovalley infill is a unit that is 1 to 3 metres thick. Seismically the unit is composed of parallel, continuous, flat lying reflectors, which are locally chaotic and irregular in configuration, it is inferred that the unit is composed of fine sandy sediments. The unit is overlain in places by several small sandwaves, circa 2 metres in amplitude, and have a clear basal reflector separating them from the underlying sediments. Figure 5, a north – south cross section through Area 408 illustrates these various units.

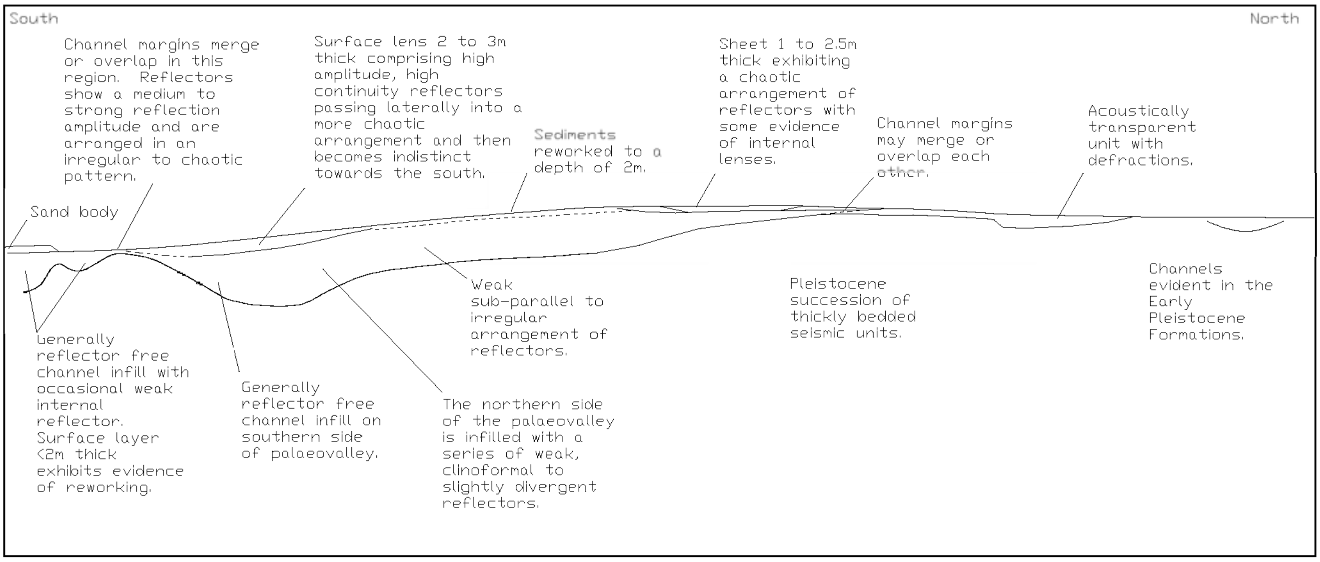


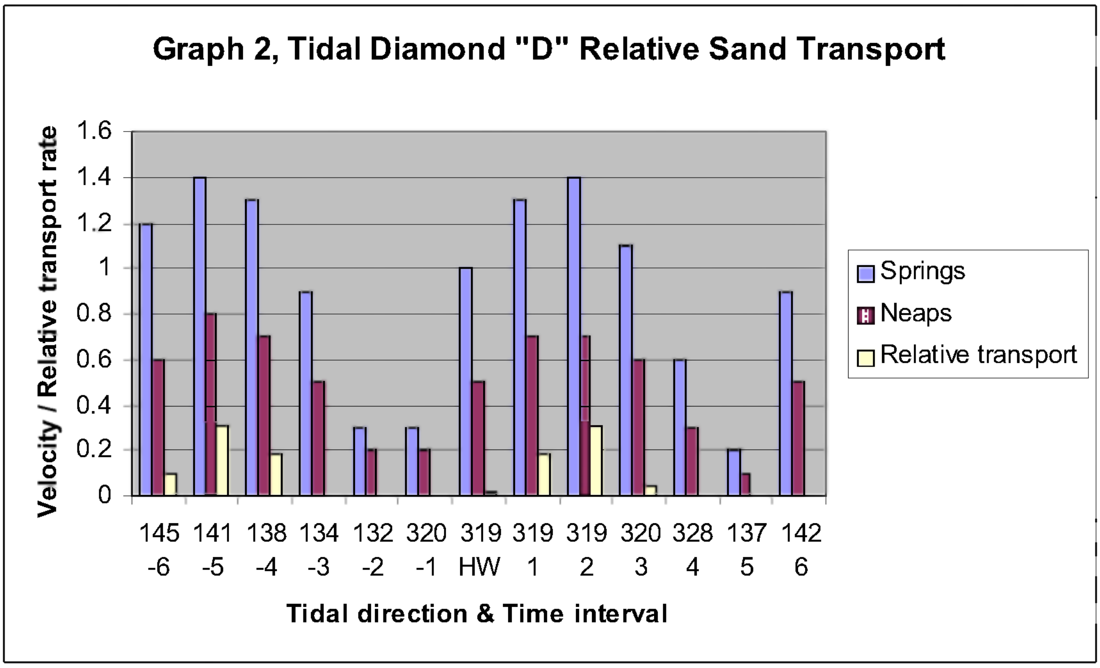
Figure 5: Schematic cross section showing the general arrangement of seismic units.

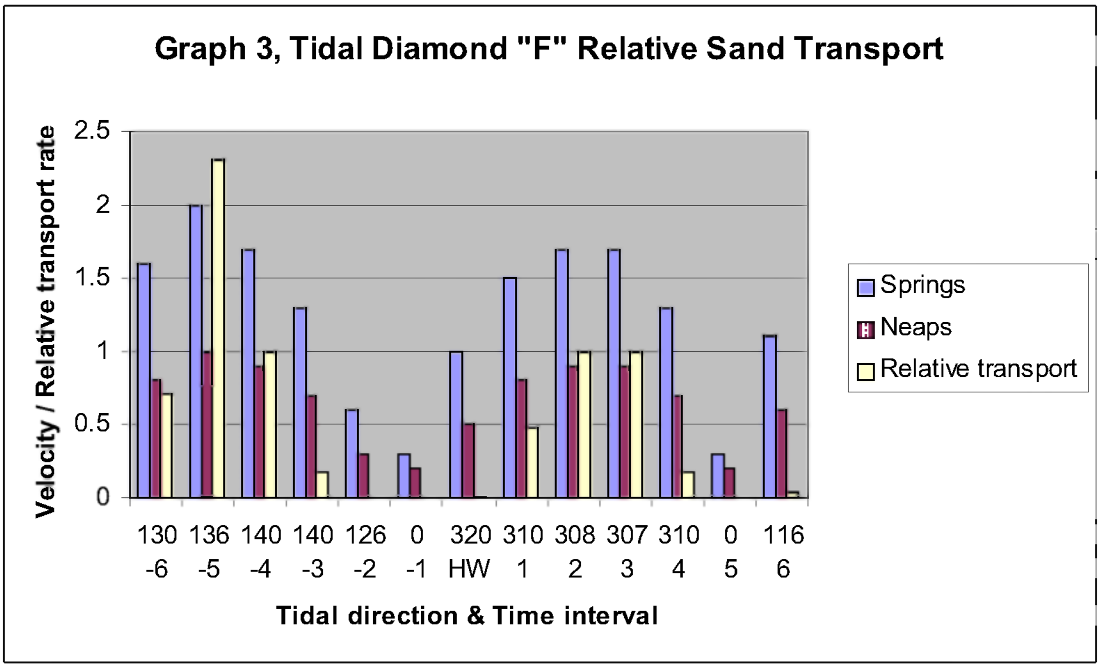
The Quaternary geological development of this area has resulted in the presence of stiff stony clays in the north of Area 408 and thick sequences of finer sandy sediment in the south. Overlying this framework, modern (Holocene) sediments comprising remnants of Early Holocene intertidal muds, silts and peats and Holocene sands and lag gravels that are in a process of achieving equilibrium with the present day hydrodynamic regime.

5 Seabed Configuration and Composition

The discussion on tidal regime in the vicinity of Area 408 indicates the net residual movement of water is in a south easterly direction and it is possible that the net sand transport direction is also in that direction. To confirm the direction of net sand transport the competency of the hourly tidal velocities in their ability to transport sand will now be considered and compared with the actual bedforms that have been developed on the seabed. Graphs 2 & 3 show the relative sand transport rates for spring tidal conditions at Admiralty tidal Diamonds “D” & “F”.

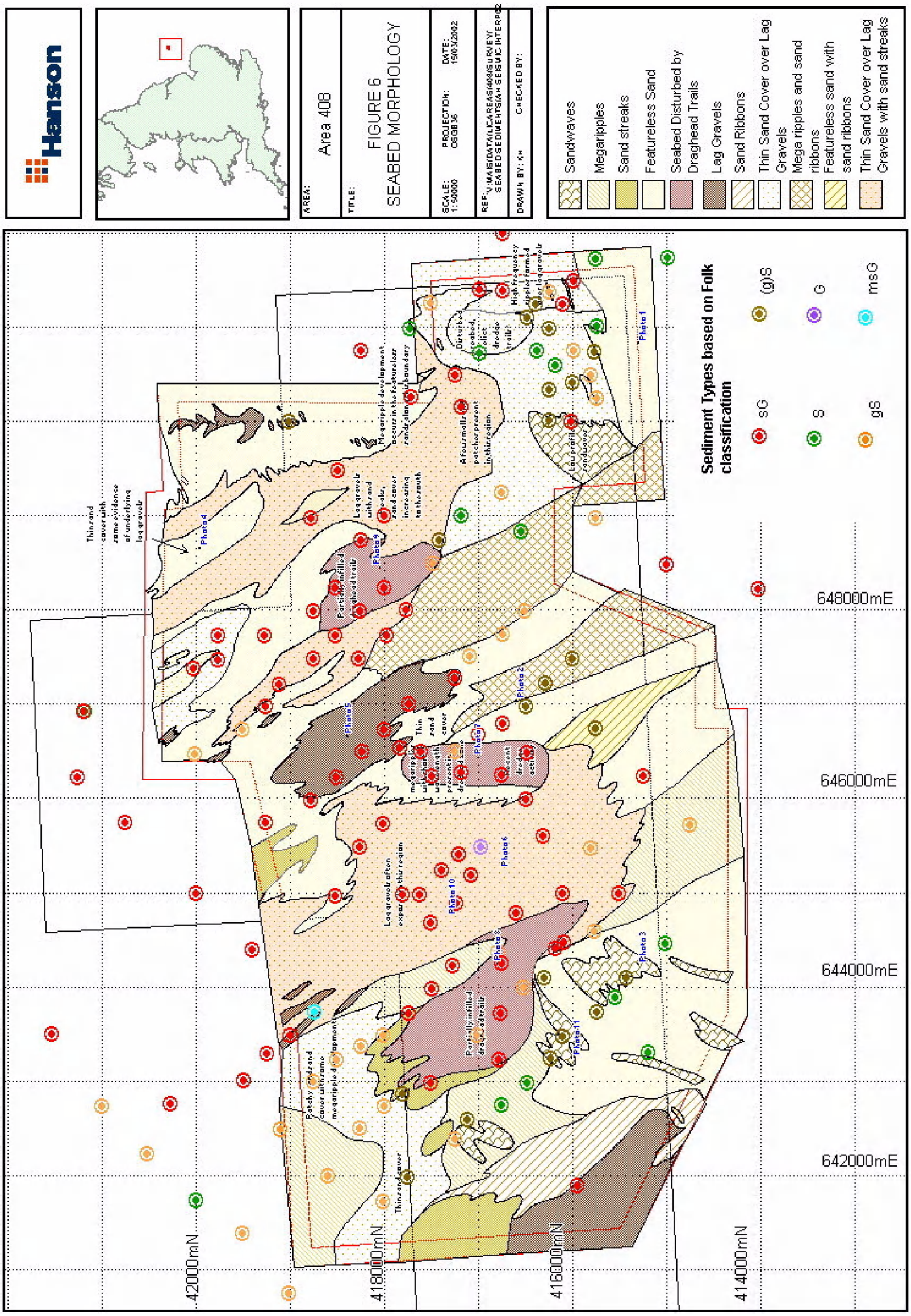
The graphs show that the flood tide, which flows to the south east has a greater competency to transport sand than the ebb tide; this inequality is approximately 7 % greater at station D and 37% greater at station F. It is unlikely that gravels will be transported due to tidal energy alone because current velocities do not exceed the threshold required to induce movement.





The tides and to a lesser extent wave action have reworked the seabed sediments into a distinctive series of bedforms which comprise a variable thickness of sand cover overlying lag gravels and Quaternary clays. Figure 6 shows an interpretation of the various bedform types identified from the sonargraphs, boundaries between the bedform types are for the most part gradational. Seabed sediments as identified in the grab and vibrocore samples have been characterised using the Folk sediment classification system and are presented as an overlay to Figure 6. The map shows the central and northern sectors of Area 408 to be dominated by sandy gravel sediments, with more sandy sediments present across the south eastern and south western regions. Extensive areas that have sandy gravel at sea bed are also found from sonar evidence to have a cover of sand ribbons, streaks or megaripples, but sand waves are found only in the areas with an extensive and thicker cover of sandy sediment. Figure 6 provides an indication of the natural variability and distribution of seabed sediments. The locations of photographs presented later in this section that illustrate the main bedform types identified are also shown on Figure 6.

The development of bedforms in Area 408 indicate that sand is naturally mobile in this region and is transported mainly due to the effects of tidal influence. The general pattern of bedforms present indicates that sand is naturally entering the area from the north east and is being transported in a south easterly direction, however, there are local variations which are discussed in the following section.


Hanson
AREA: Area 408
TITLE: FIGURE 6
SEABED MORPHOLOGY
SCALE: 1:50000
PROJECTION: OSGB36
DATE: 15/03/2002
DRAWN BY:
CHECKED BY:
Sandwaves
Megaripples
Sand streaks
Featureless Sand
Seabed Disturbed by Draghead Trails
Lag Gravels
Sand Ribbons
Thin Sand Cover over Lag Gravels
Mega ripples and sand ribbons
Featureless sand with sand ribbons
Thin Sand Cover over Lag Gravels with sand streaks
Sediment Types based on Folk classification
sG
(g)S
S
G
gS
msG
648000mE
646000mE
644000mE
642000mE
420000mN
418000mN
416000mN
414000mN

Seabed sediments, in the south of the surveyed area are composed of an almost continuous and relatively thick sand cover. It is probable that these sands were deposited in the Pleistocene or Early Holocene periods at the northern end of the Coal Pit seabed depression. To the east and west, these sands are featureless (Photo 1) compared to the central section where megaripple cover is more common (Photo 2). The sediments are fine grained and range from well sorted to moderately well sorted sands.

Two distinctive types of megaripple have been distinguished in the surveyed area:

- An extensive cover of megaripple bedforms that commonly have the following dimensions, wavelength 12.5m and height of <1m are frequent in the thick sand belt in the south of the licence area. Locally superimposed over some of the megaripple fields are current parallel, linear bedform features.

- Localised patches of well defined, short wavelength (1 to 2 metre) megaripples are commonly arranged in ribbons with their slightly sinuous megaripple crests orientated transverse to the dominant tidal flow. The avalanching face of these megaripples is orientated towards the south east, suggesting sediment transport in that direction. These patches occur thoughout the central and northern sectors of the survey area and have similar configurations to that seen in photo 10.

Three small sandwave fields occur in the south western section of the survey area, located on the north western flank of the Coal Pit seabed depression. The sandwaves have a height of between 1 and 3 metres; wavelengths of between 100 and 200m, and have their crest axes orientated northeast- southwest, (Photos 3 & 11). The sandwaves have an asymmetric cross sectional profile that would tend to suggest that the probable net direction of sediment movement in that area is towards the north west compared to the regions south easterly trend. This apparent anomaly may be related to localised changes in the currents competency to transport sediment on the flood and ebb tidal cycles caused by changing seabed topography. The southerly flowing currents pass over relatively shallow water and then flow into deeper water. As the tide passes into deeper water it may slow and so reduce its capacity to transport sediment. Conversely during the northerly flowing tide the current is restricted as it passes from deep water into shallower water so the flow increases along with its capacity to transport sediment.

A small area of very low profile sandwaves, which tend to have a symmetrical cross sectional profile are present in the south east of the surveyed area and also coincide with the north eastern flank of the Coal Pit depression. It is possible that the sandwaves are effectively trapped in their present location due to the local changes in inequality of the flood and ebb tidal cycles and were certainly present before the commencement of dredging operations.

Generally towards the margins of the large sand bodies in the south of the area and some of the sand patches, the coverage of sand becomes incomplete and patchy, typified by the bedform configuration seen in Photo 4. In these areas the underlying sediments are partly exposed at the seabed.

The thickness of sand cover thins towards the north and where the sand thickness ranges from veneer up to rarely more than a metre, the surface sands have been formed into a series of linear, ribbon like, features. These features are aligned with their elongated axis parallel with the dominant tidal current directions ($320/140^0$) and megaripple cover, if present, is generally poorly developed. They range in size from sand streaks overlying lag gravels, through sand ribbons to elongated sand patches.

Sand streaks appear on the sonargraphs as isolated lighter grey streaks overlying a generally speckled, darker grey substrate (Photo 5). Sand ribbons have a variable appearance depending upon the sand supply and range from narrow lineations with well defined lateral boundaries through to broader swathes of sand with defuse margins and parasitic megaripple cover, both types are interspersed by lag gravels (Photo 6).

In general the sand ribbons tend to broaden and merge in a south easterly direction, which suggests that the net sand transport direction is towards the south east.

Sidescan sonar evidence of recent (1999 / 2000) dredging activity is restricted to an area approximately 1500m by 500m, centred on position 646300mE 417100mN (Photo 7). The direct impact upon the seabed is a series of shallow trenches and attendant ridges, the size and shape of these features being influenced by seabed geology and type of dredging plant utilised. These recent dredge trails tend to conform to the “W” type of impression formed by a “Californian” type of draghead that has twin trailing articulated visors.

Two further sites have been directly impacted by concentrated dredge activity centred on positions 643700mE 416900mN and 648200mE 418200mN. Here the dredge trails are indistinct and tend to be partially to almost completely infilled by mobile sands encroaching over the micro topography formed by the draghead, Photos 8 & 9. Dredge monitoring data indicates that the bulk of dredging activity ceased in these areas at least 1 year prior to the collection of the sonar data.

Naturally the disturbed areas coincide with data gathered from electronic monitoring systems fitted to dredging vessels’ operating on Crown Estate marine aggregate licences, which is used to police the vessels activities. Figure 7 shows the spatial extent of dredging operations and it can be demonstrated that approximately 25 % of the Area 408 has been directly impacted to some extent by dredging operations during the past 5 years. However, the vast majority of dredging activity has been concentrated into three small areas comprising 6% of Area 408. In the areas indicated as being affected by a low to medium level dredging activity, very little direct evidence of seabed disturbance is discernible on the sonar records.

Sand that infills the dredge imprints is derived from three sources:

- Sand, naturally present in the north west, being moved in a south easterly direction under the influence of net sediment transport initiated by inequalities present in the tidal regime.
- Sand particles in the vicinity of the dredge imprint will oscillate with the flood and ebb tidal cycles gradually infilling the depression. From Graphs 2 and 3 not only can it be seen that the net or residual movement of sand is to the south east but also that the north westerly flowing tide is capable of transporting sand. Hence sand grains will follow an elliptical path whose centre migrates to the south east.
- Sand introduced to the system by dredging over spill and screening returns will enter the transport system, some of which will infill the dredge imprints and some to merge with the sediment transport pathway.

The fact that the dredge imprints are infilled indicates that sand transport is active in the region and is capable of completely removing all physical evidence of low intensity dredge activity relatively quickly.

Figure 7, Yearly dredging intensity plots.

No wrecks or significant wreckage were observed on the 2000 sidescan sonar records and no charted wrecks are indicated on Admiralty Chart No. 1187, Outer Silver Pit. However, two sub-sea well heads are known to be present within the licence area and currently have an aggregate extraction exclusion zone placed around them.

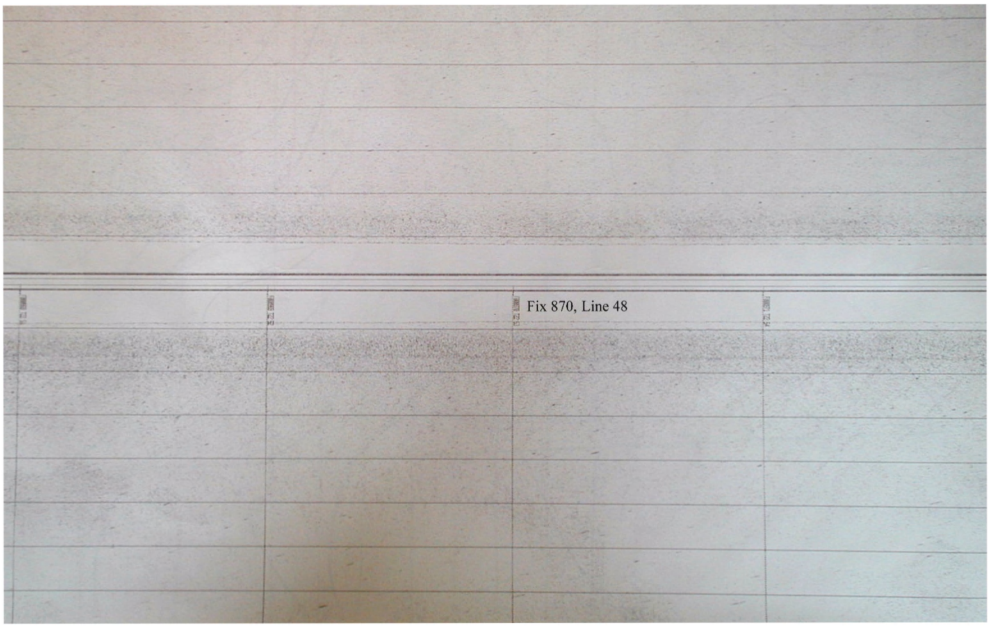


Photo 1 Featureless sandy seabed. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

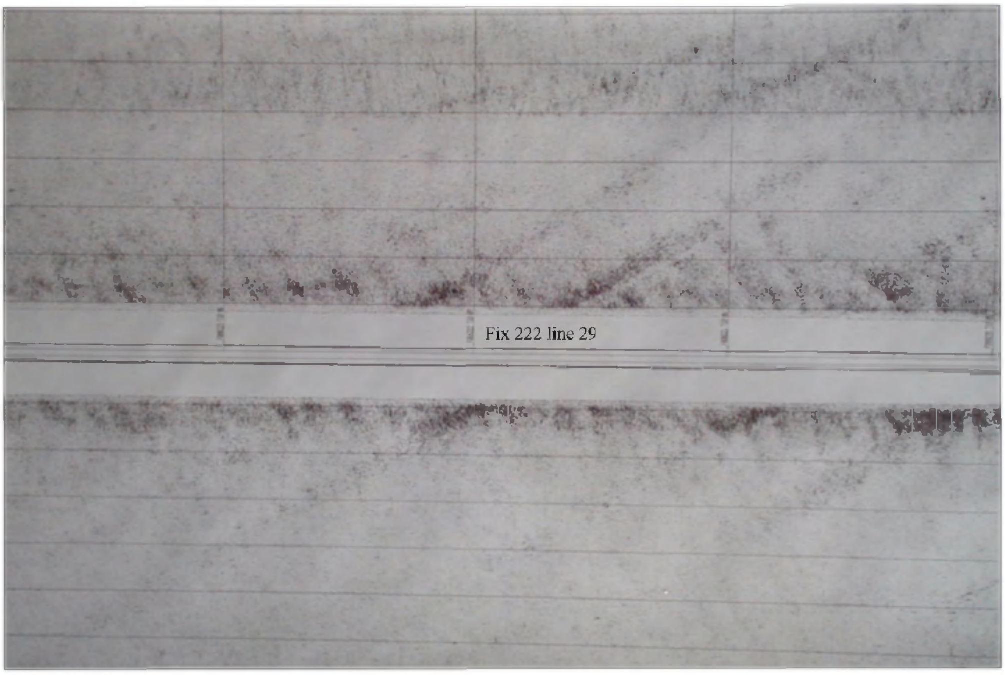


Photo 2 Sand cover with some megaripple development. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

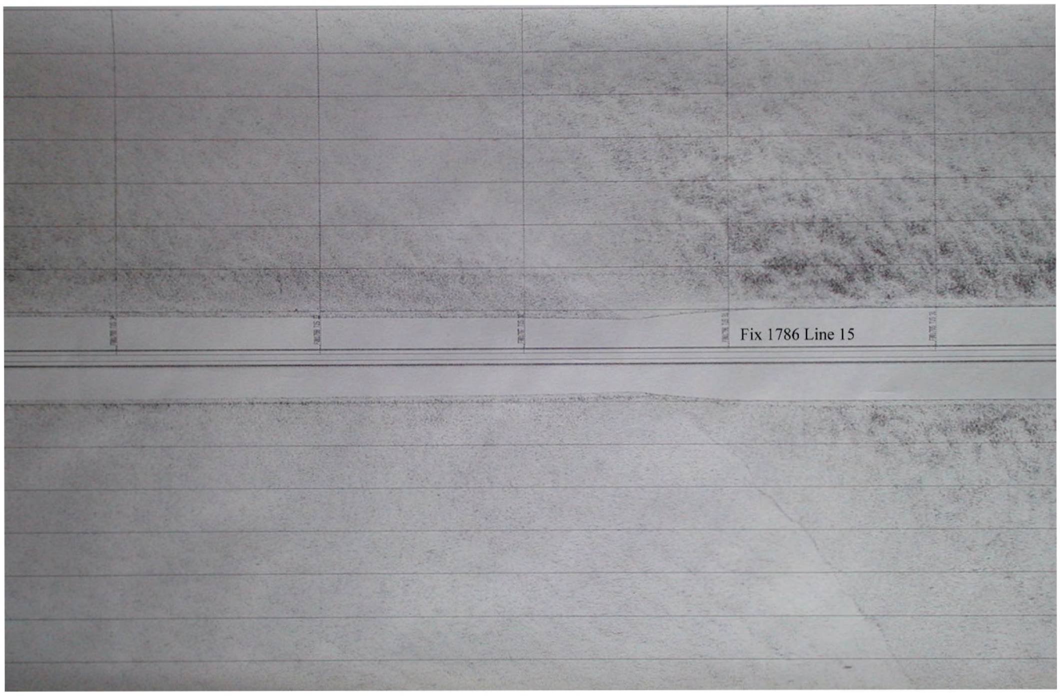


Photo 3 Sandwave field. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

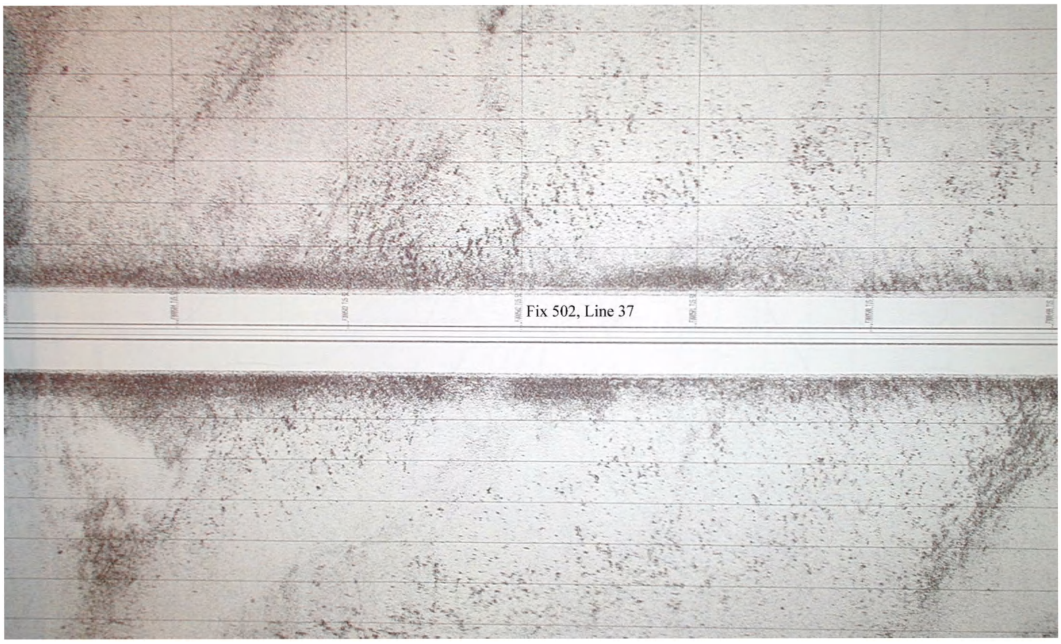


Photo 4 Thinning sand cover. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

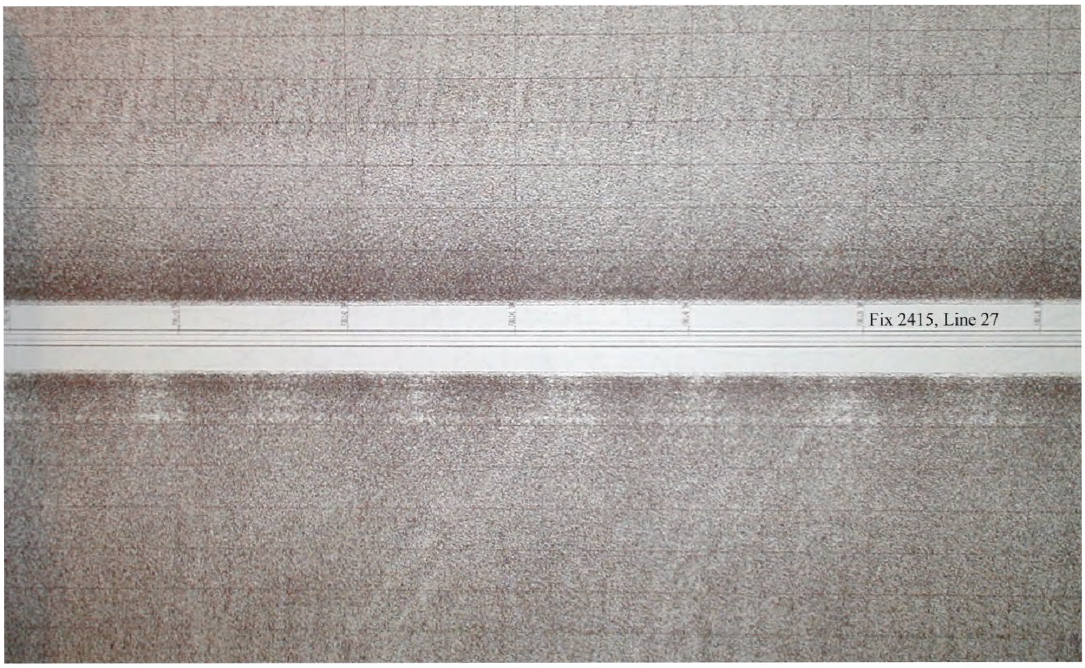


Photo 5 Lag gravels with sand streaks. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

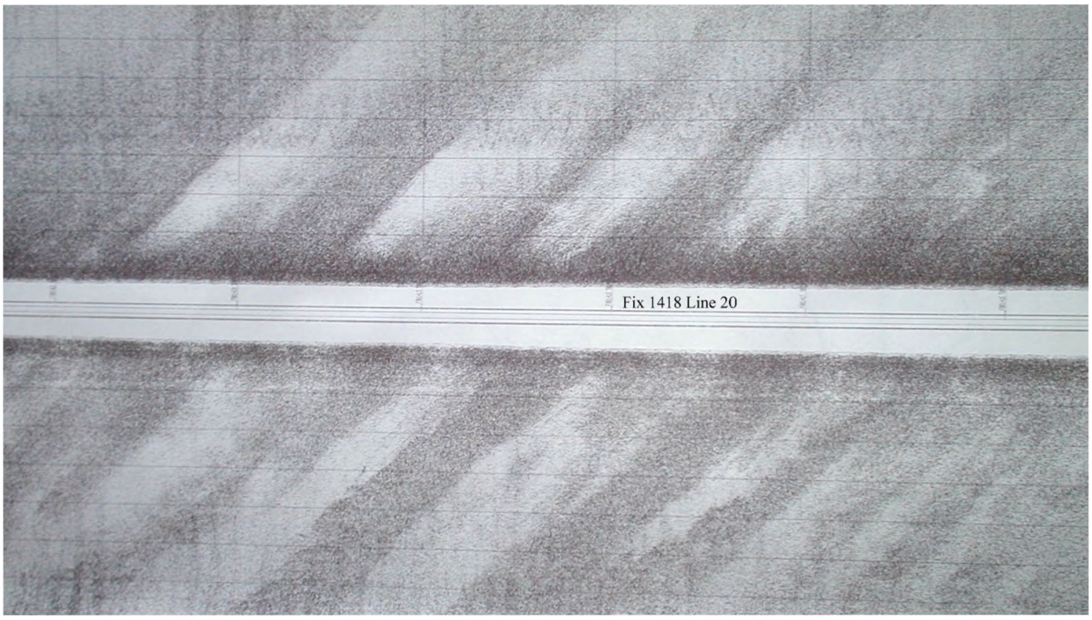


Photo 6 Sand ribbons. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

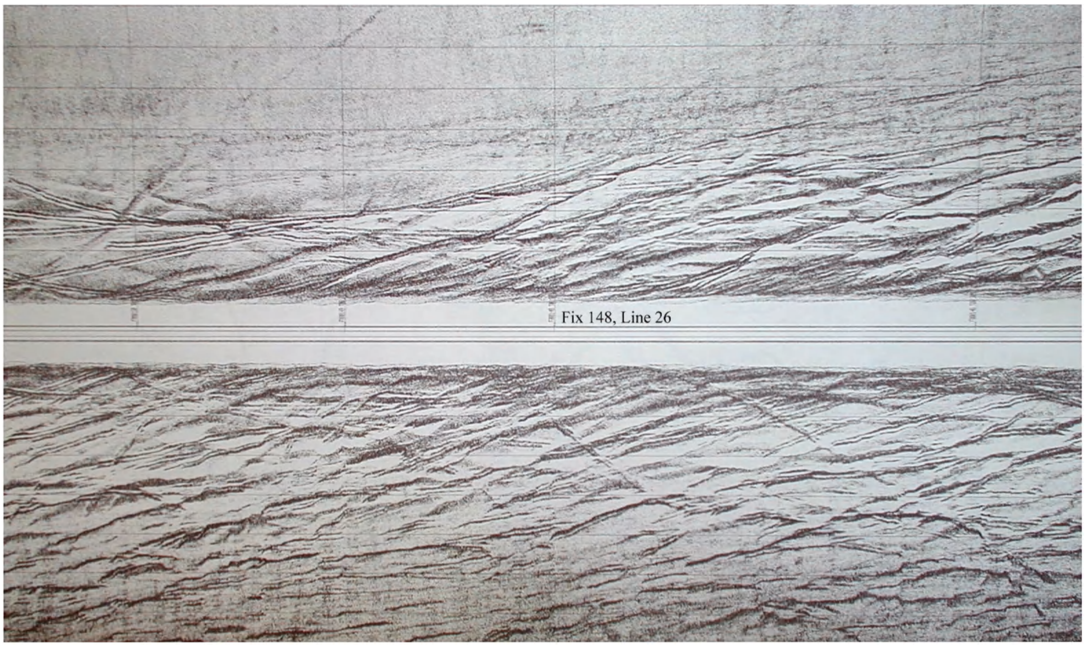


Photo 7 Fresh draghead trails in a heavily dredged area. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

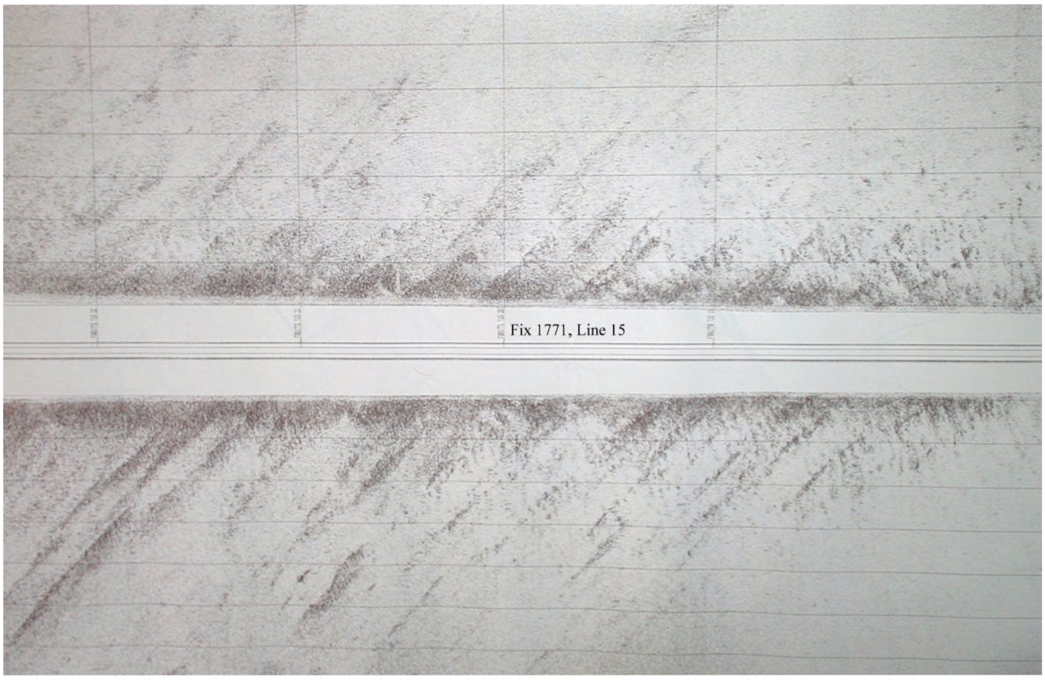


Photo 8 Partially infilled draghead trails. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

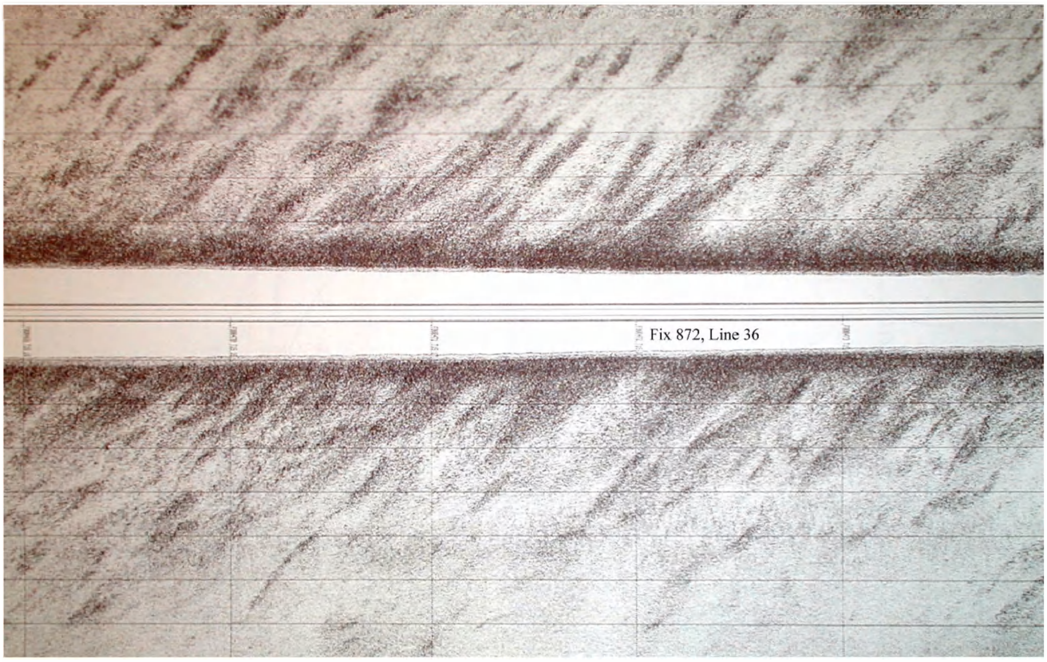


Photo 9 Partially infilled draghead trails. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

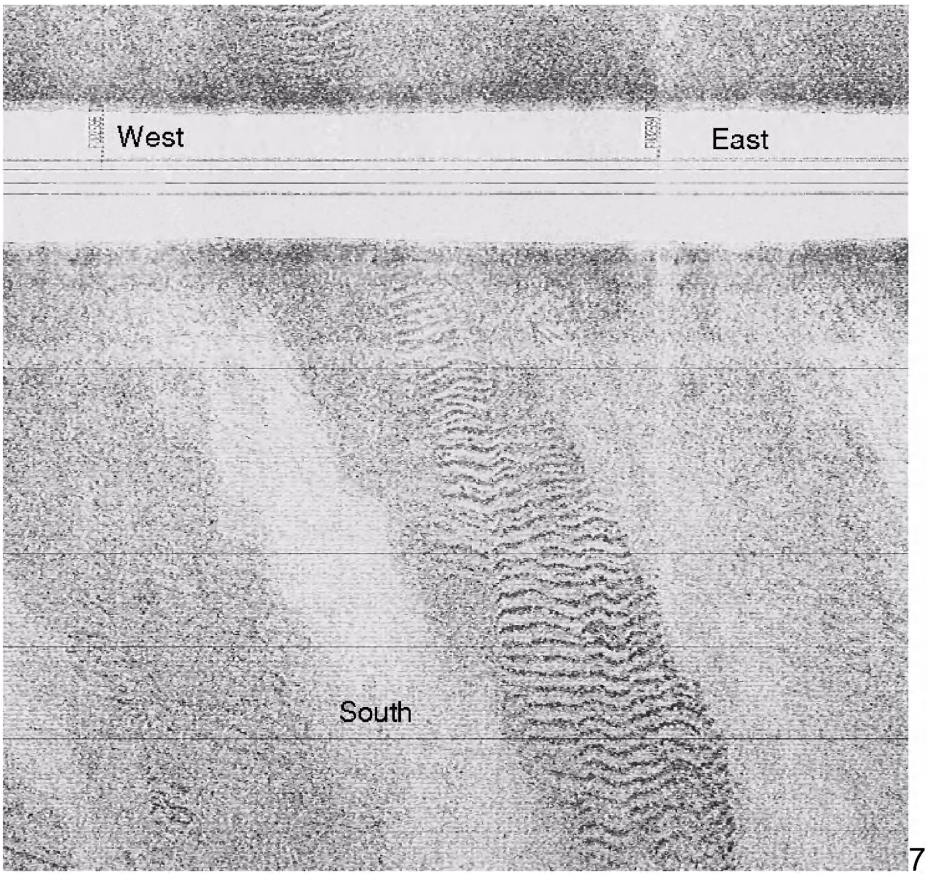


Photo 10 Ribbon of megaripples orientated with their avalanche face towards the south east. (Horizontal scale, 100m between vertical fix marks; vertical scale, 12.5m slant range between horizontal lines.)

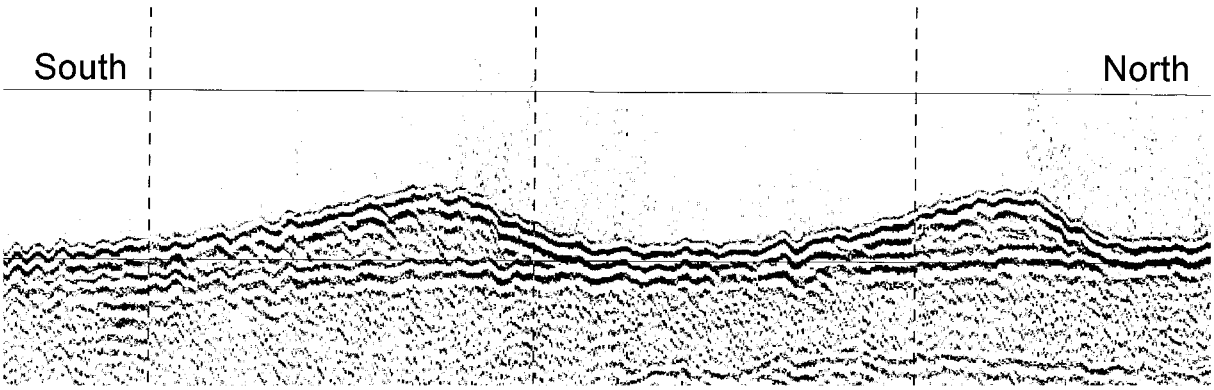


Photo 11 Sandwave asymmetry, avalanche face orientated towards the north west. (Horizontal scale, 100m between vertical fix marks; vertical scale, sandwaves 2 to 3m amplitude.)

The sonargraphs provide a continuous coverage of acoustic reflection properties of the surface sediments in Area 408, and from this data areas of similar acoustic properties (and inferred sediment properties) can be mapped out on a continuous basis for the whole of the survey area. This method has the advantage that the boundaries between differing sediments can be plotted with some accuracy. Grab sampling on the other hand provides data from discrete points and in areas of rapidly changing seabed sediment types i.e. sand ribbons overlying lag gravels, interpolated grain size parameter contour maps produced by modelling software may not resolve the fine detail. The following figures 8 to 14 show various grain size parameters derived from grab and vibrocore data collected in and around Area 408. They show the general trend of sediment parameters but lack the fine detail; however, there is a strong correlation between the changes in sediment parameters, the underlying geology and bathymetric contours.

Figures 8 & 9, mean and the median sediment parameters show that the coarser sediments lie in a band trending through the centre of the licence, just to the north of the Coal Pit sea bed depression. A comparison of the median and mean grain sizes shows that the centre of gravity of the frequency distribution generally tends towards the finer fractions present within the sample.

Figure 10, a contour plot of the Inclusive Graphic Sorting characteristics of the sediments show that in the southern region the sandy sediments range from being very well sorted to moderately well sorted. An apparent sorting anomaly occurs around sample number R149, which is very poorly sorted but lies within a well sorted region. The anomaly is due to the very high percentage of sediment finer than 63 microns in the sample. (Sorting depends to a certain extent on the grain size of the material and is likely to be better in sand than coarser material but deteriorates again in very fine sediments.) The sorting gradient rapidly increases away from the sandy areas in the south and is mainly very poorly sorted in the regions with higher gravel content.

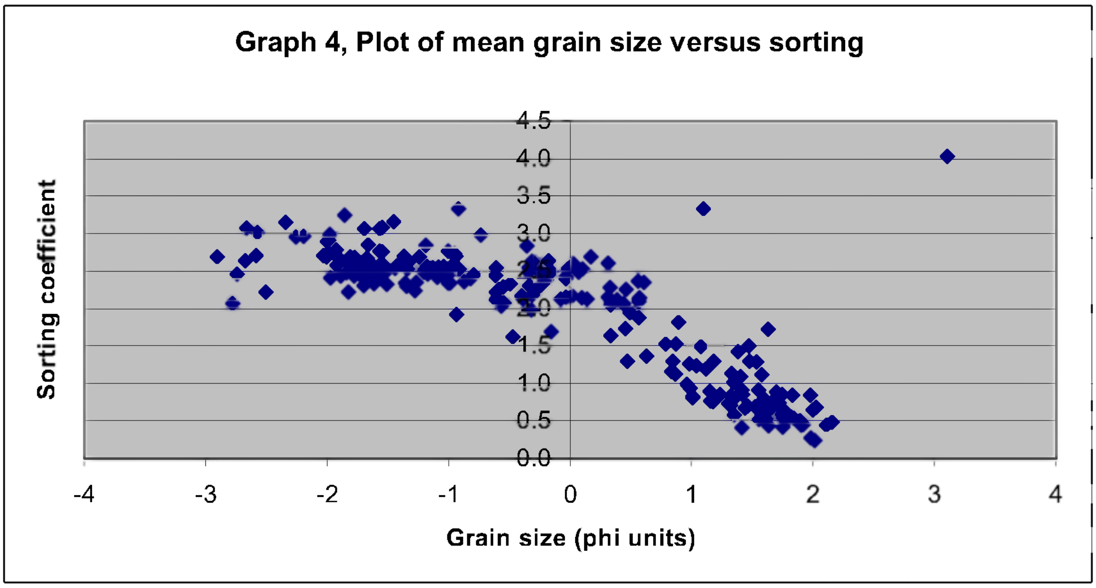
The Inclusive Graphic Skewness characteristics of the sediments are shown in Figure 11. The sandy sediments in the south tend to be strongly skewed towards the coarser particles within the tails of the grain size distribution; however, there are localised patches where the sediments are skewed towards the finer particles. The sediments of the central and northern sectors of the licence tend to be positively skewed and coincide with coarse seabed sediments.

The contour plot of Graphic Kurtosis, Figure 12, shows that in the south the sands have a very leptokurtic (peaked) grain size distribution indicating the dominance of a narrow range of particle sizes where as those in the central and northern sectors to range from very platykurtic to platykurtic (flat) indicating a broad range of particle sizes.

For comparison purposes contour plots 13 & 14 show the relative percentages of sand and gravel present within the seabed sediments using the Aggregate Industry's accepted grain size boundaries (> 5mm gravel, <5>63mm sand, <63mm silt). From these plots it can be seen that the highest concentration of coarser sediments are located along the ridge trending through the centre of the licence and also in the northern sector of the Area 408.

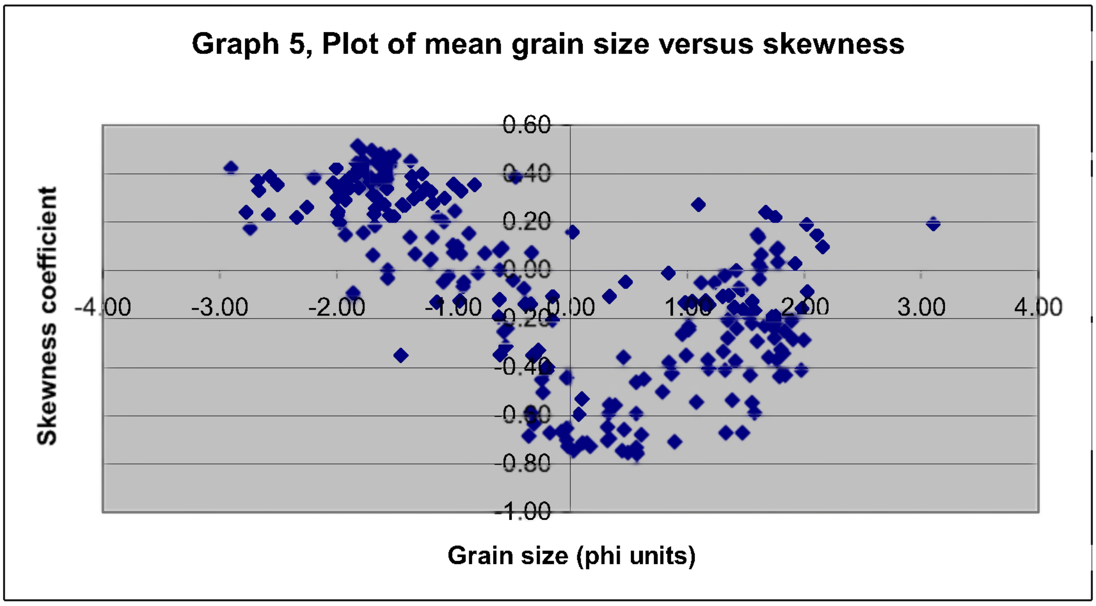
Silt / clay content is generally low <3% but north east of the licence (samples R16, R20 & R94) and in the north of Area 408 (samples 89 and 90), silt content is high. Silt content is also locally very high in the fine sand deposits to be found in the south peaking at 46.7% (sample R149). It is considered that the elevated silt / clay content is the result of sampling clay rich units from the underlying geology.

Graph 4 shows a plot of sorting against mean grain size for the grab and vibrocore samples. It shows a linear relationship with the coarser sediment being the worst sorted. It also suggests two different sediment populations from the clustering of data points with sorting values approximately greater than and less than 1.8 and a division of grain size about 0.5phi (0.75mm grain diameter- middle of the coarse sand grade). The cluster to the right of the Y axis tend to be located within the lag gravels whereas the cluster to the left is located in the sandier sediments in the south of Area 408.



An examination of a sub-set of samples located to the south of the lag gravels tentatively suggests that there are areas with slightly different grading characteristics associated with dredging areas (Evans 2002). Zones with a sorting coefficient of less than 0.5 are found to the south east of the two eastern dredged areas, and to the south west and west of the western dredged area. Net sand transport across the eastern part of the area is to the south east thus these areas lie down drift of the dredging areas, however, there may be a local reversal of transport direction in the western part of the area, which may explain the presence of better sorted sand to the west of the western dredged area.

A cross plot of mean grain size against skewness is shown in Graph 5. Here again there are two populations with a boundary between the two at about 0.5 phi; lag gravels and sand body. In the sandier sediments it was difficult to detect any change in skewness between the natural sandwave fields and the areas "down drift" of the dredged areas.



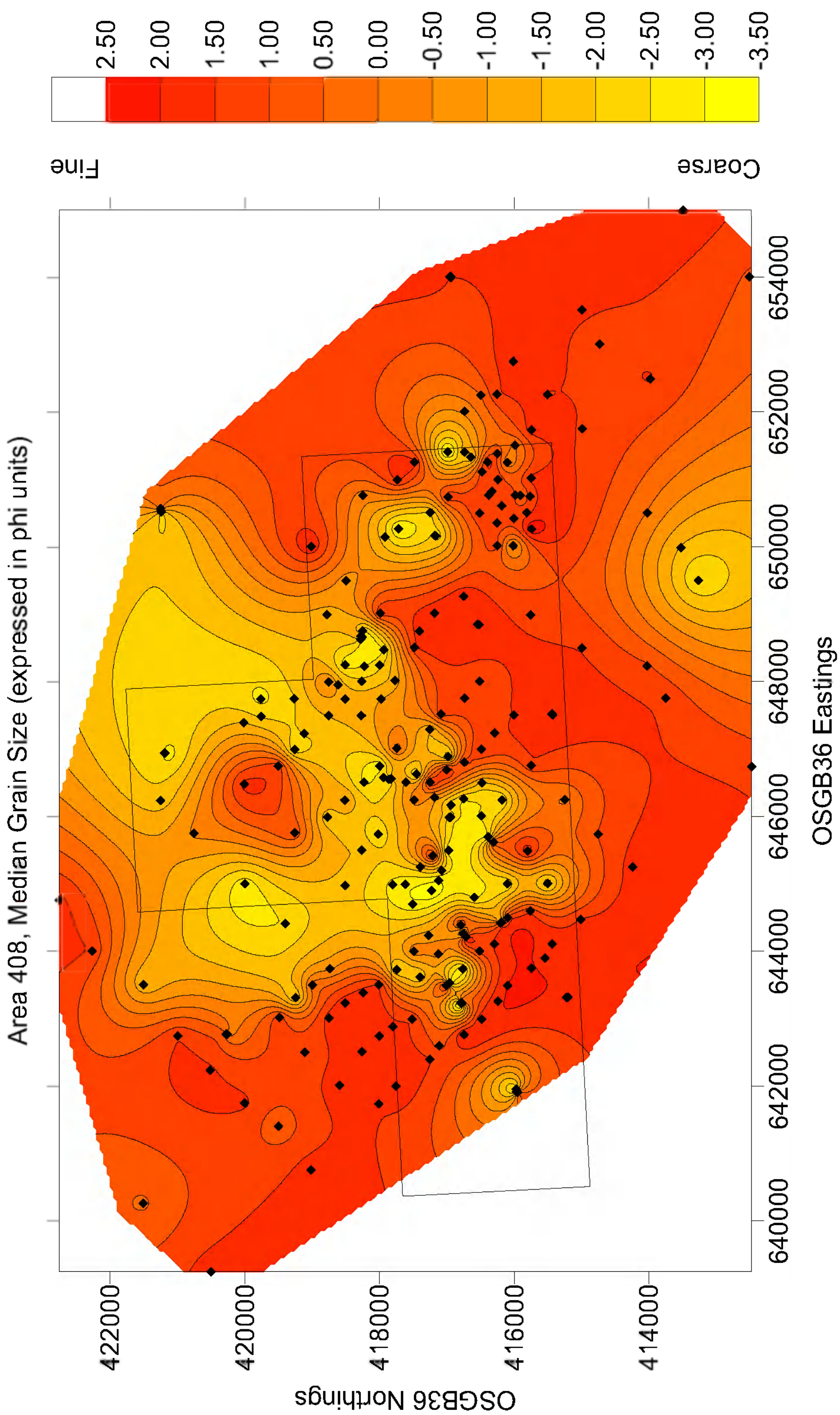

Area 408, Median Grain Size (expressed in phi units)
Fine
Coarse
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
640000
642000
644000
646000
648000
650000
652000
654000
OSGB36 Eastings
422000
420000
418000
416000
414000
OSGB36 Northings

Figure 8

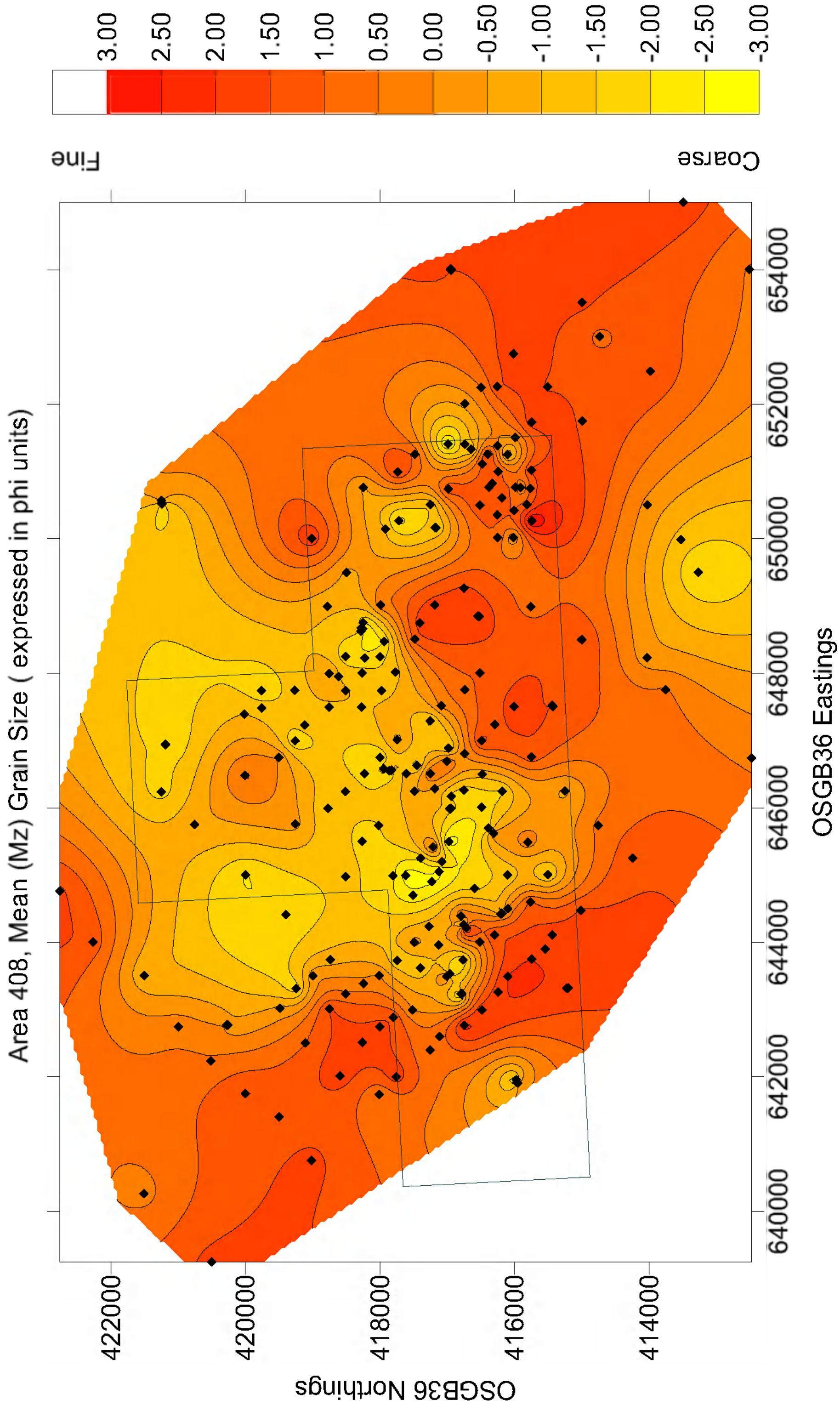

Area 408, Mean (Mz) Grain Size (expressed in phi units)
Fine
Coarse
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
OSGB36 Eastings
640000
642000
644000
646000
648000
650000
652000
654000
OSGB36 Northings
422000
420000
418000
416000
414000

Figure 9

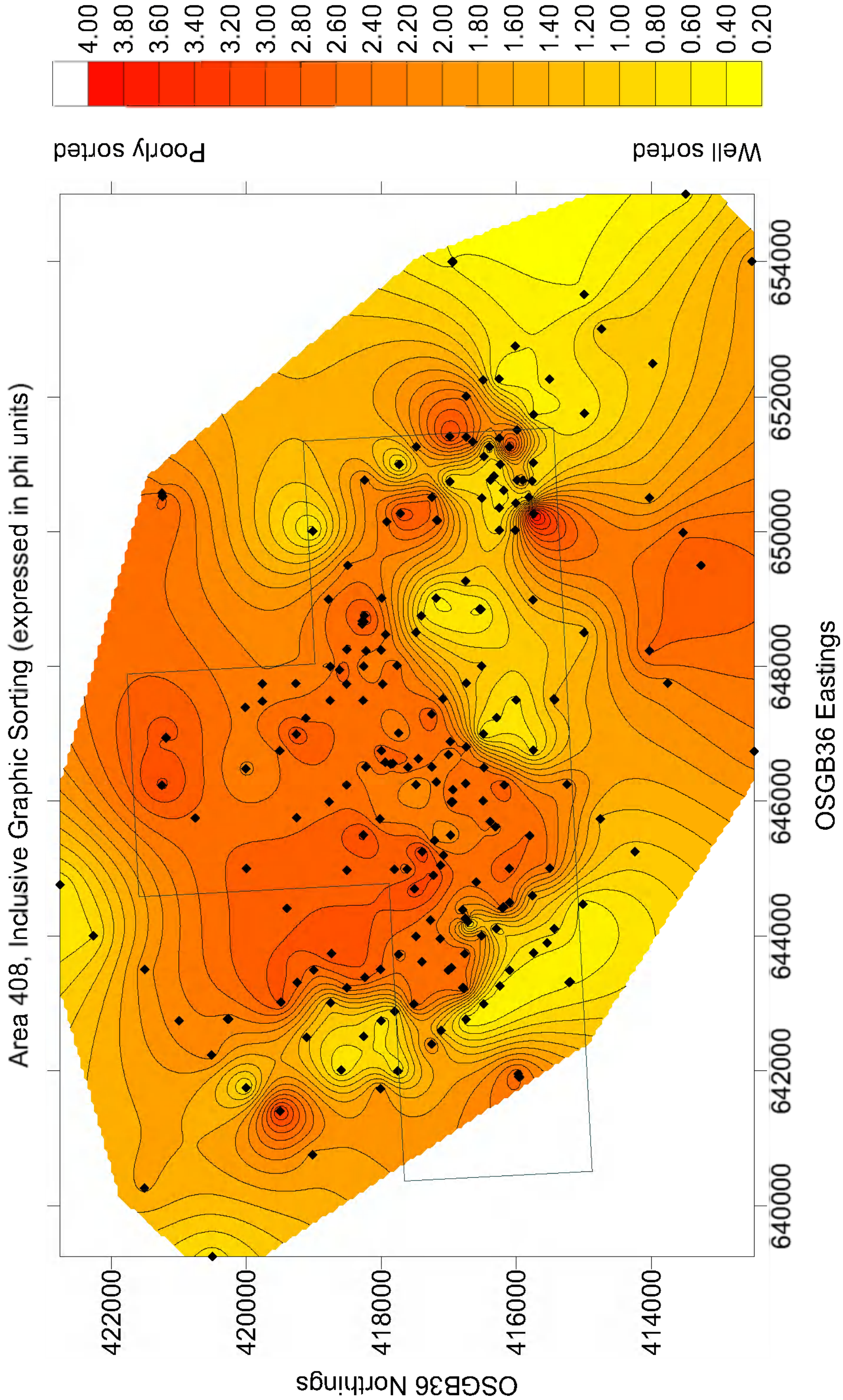

Area 408, Inclusive Graphic Sorting (expressed in phi units)
Poorly sorted
Well sorted
4.00
3.80
3.60
3.40
3.20
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
OSGB36 Eastings
640000
642000
644000
646000
648000
650000
652000
654000
OSGB36 Northings
422000
420000
418000
416000
414000

Figure 10

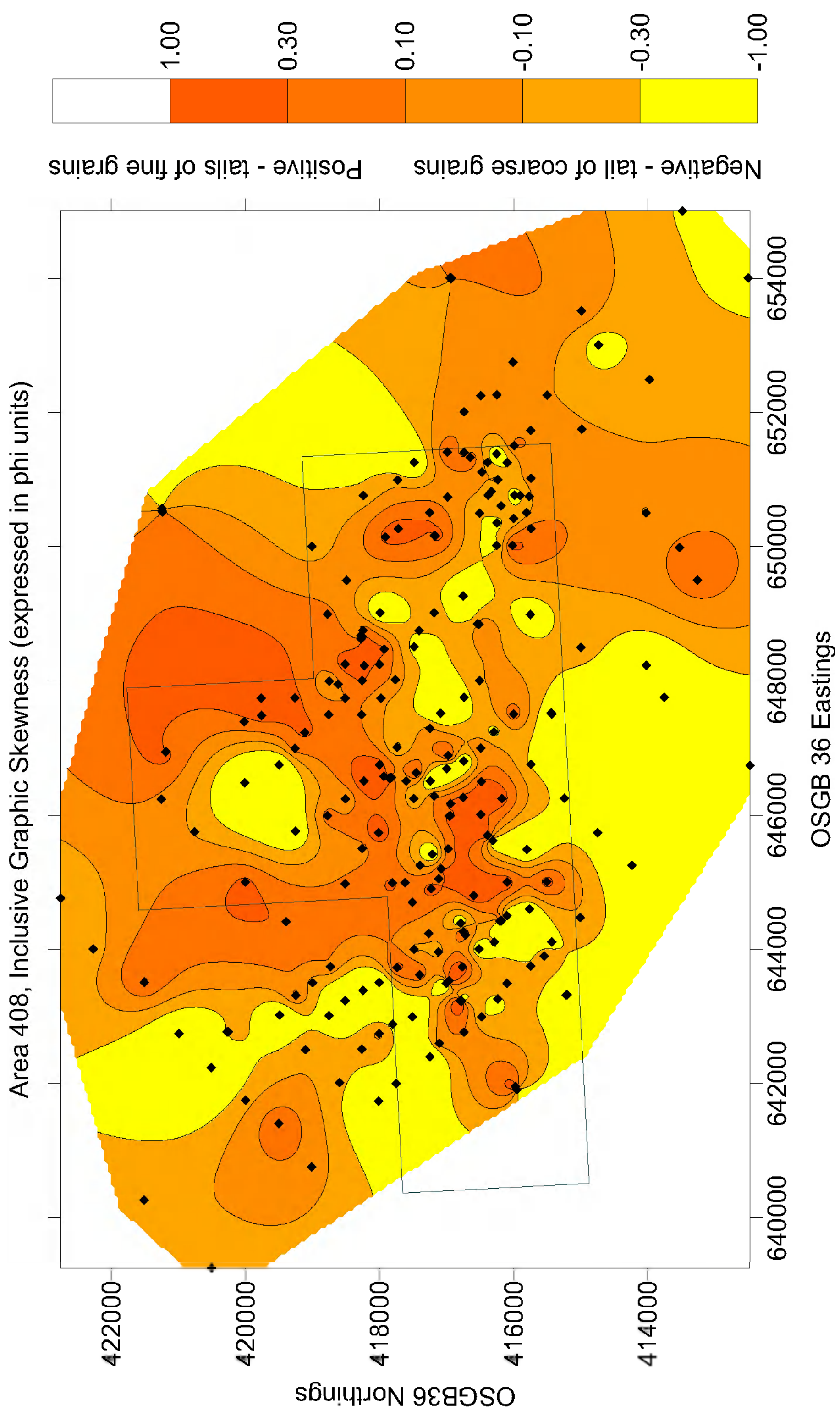

Area 408, Inclusive Graphic Skewness (expressed in phi units)
1.00
0.30
0.10
-0.10
-0.30
-1.00
Positive - tails of fine grains
Negative - tail of coarse grains
640000
642000
644000
646000
648000
650000
652000
654000
OSGB 36 Eastings
422000
420000
418000
416000
414000
OSGB36 Northings

Figure 11

COASTLINEUROPE

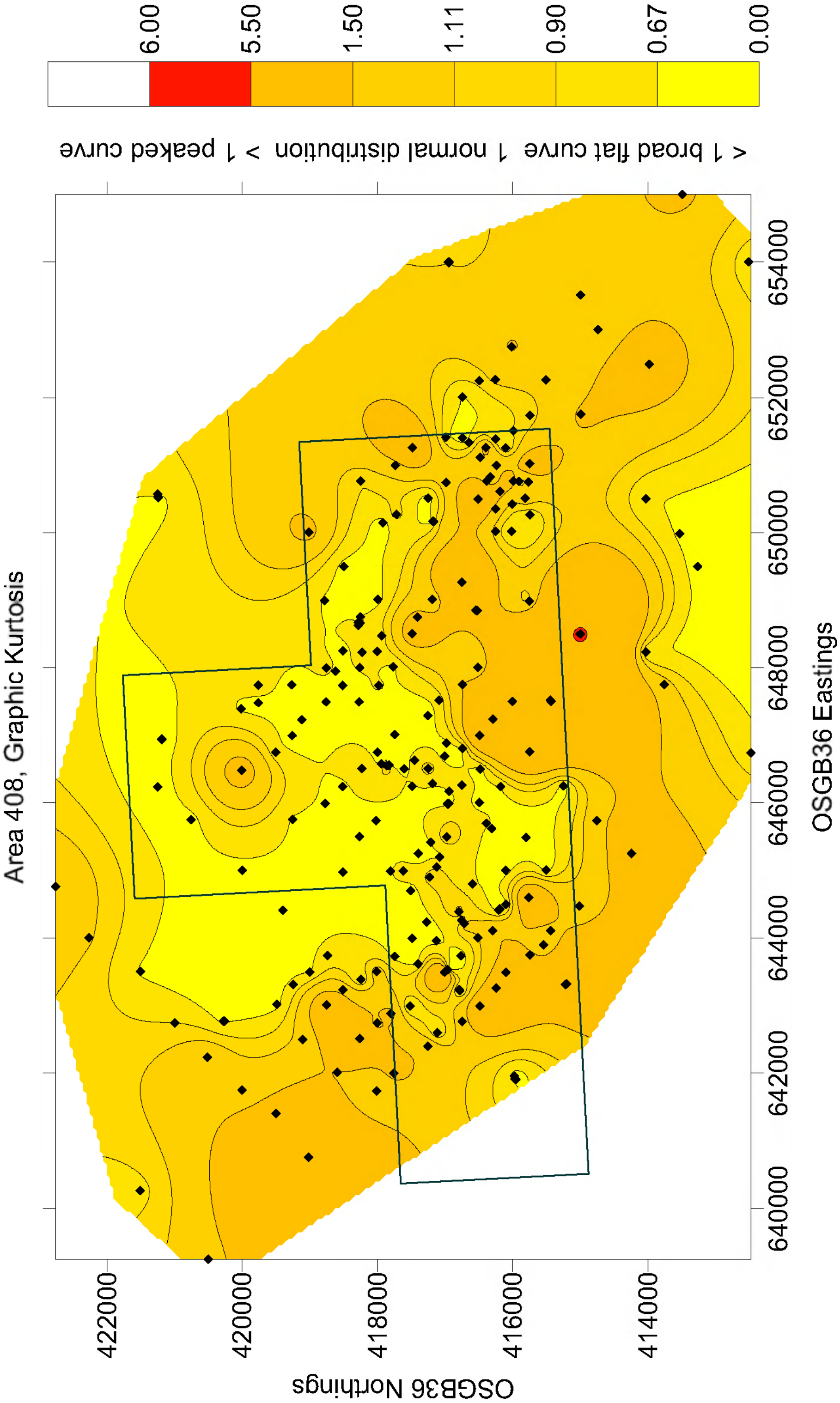


Figure 12

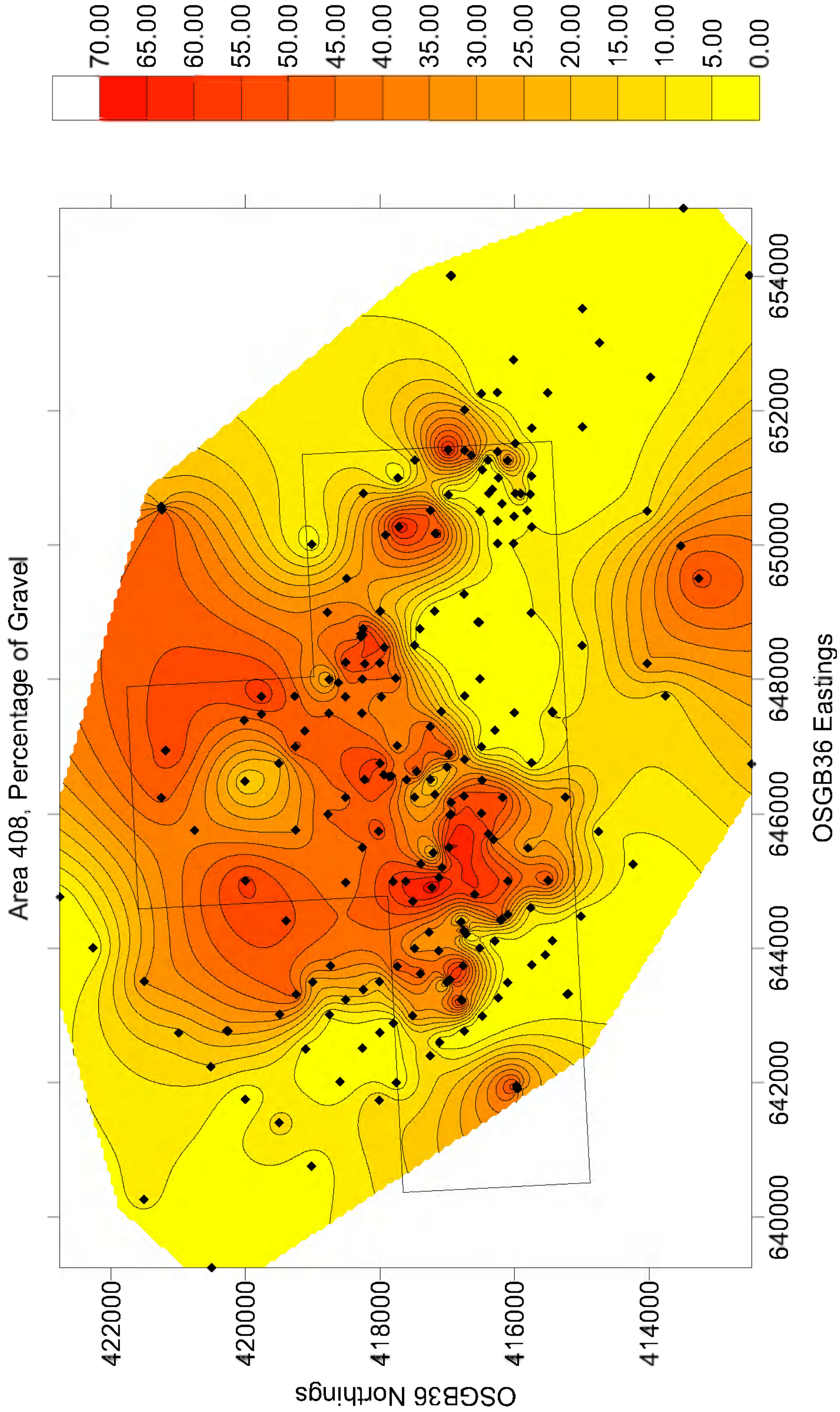

Area 408, Percentage of Gravel
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
654000
652000
650000
648000
646000
644000
642000
640000
OSGB36 Eastings
422000
420000
418000
416000
414000
OSGB36 Northings

Figure 13

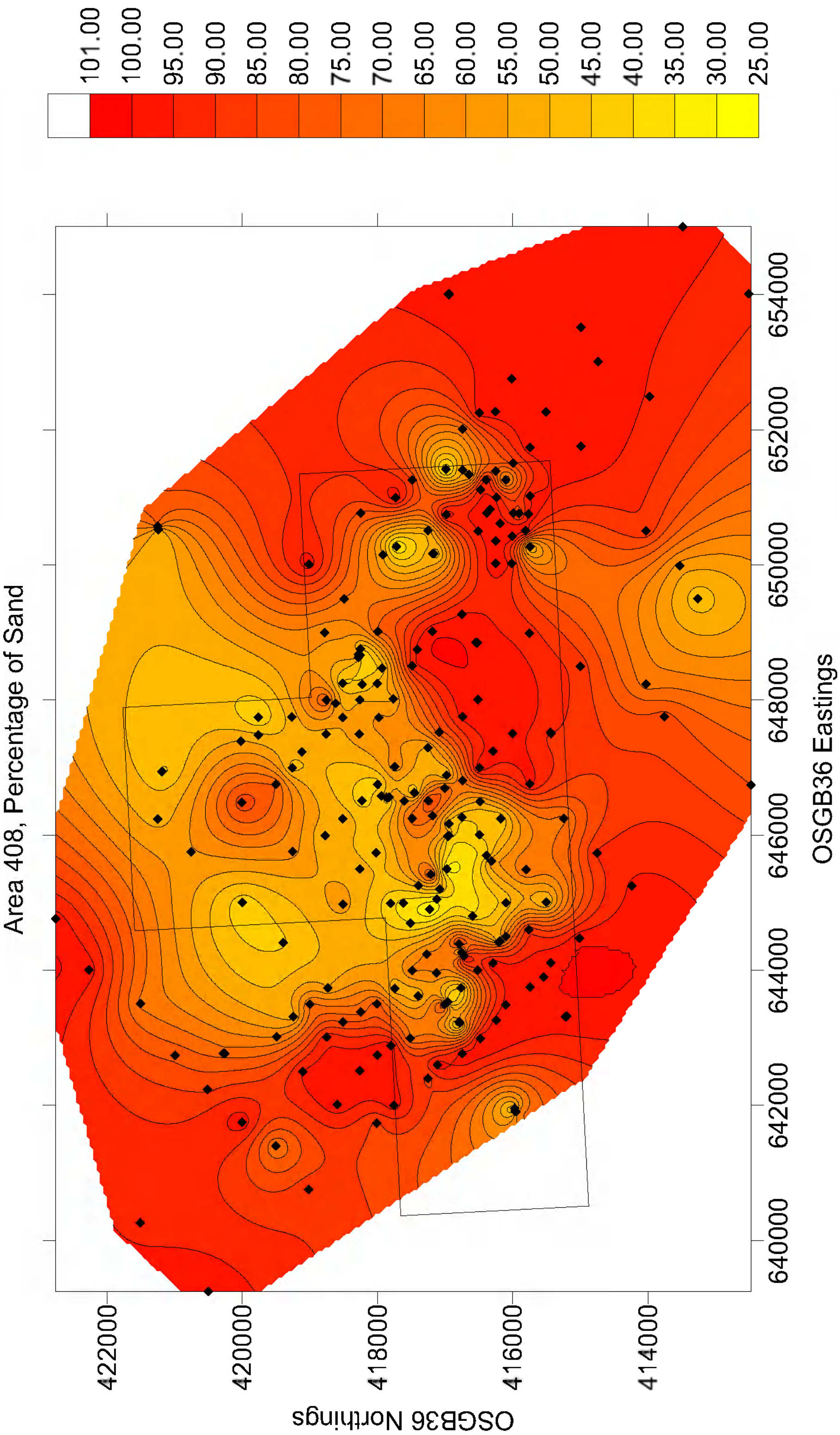

101.00
100.00
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
Area 408, Percentage of Sand
654000
652000
650000
648000
646000
644000
642000
640000
OSGB36 Eastings
422000
420000
418000
416000
414000
OSGB36 Northings

Figure 14

6 Conclusions

- Area 408 straddles a zone of rapidly changing bathymetry and geology that have had a major influence upon the natural composition of the seabed sediments.

- Actively dredged areas can be identified from a comparison of the pre dredge bathymetry and the 2000 bathymetric data sets. In these regions the seabed has been lowered by up to 1.5 metres, however, it has not been possible to discriminate any accretion surrounding dredged areas that may be attributable to the build up of over spill sediment returned to the environment through the dredging process.

- The tidal regime in Area 408 can be described as relatively weak, rectilinear currents, orientated north west – south east and have a net residual current flowing to the south east. There may be localised variations along the margins of the Coal Pit seabed depression.

- The seabed sediments are underlain by stiff and compacted glacial tills in the north and fine grained palaeovalley infill to the south; these sediments strongly influence the nature of the surface sediments.

- The bedforms show a recognisable trend of development ranging from sand free lag gravels, in shallower waters through to a well developed sand sheet with mobile bedforms in deeper water. The longitudinal and transverse axes of these bedforms are consistent with the main direction of residual tidal currents.

- Bedform orientation suggests that the general net sand transport direction is towards the south east.

- Sandwaves located in the south west may indicate a localised reversal in net sand transport direction.

- Grain size parameter trends of the seabed sediments strongly reflect the underlying geology and two different sediment populations can be identified that are related to the nature of the underlying sediments.

- The data very tentatively suggests that there are regions of well sorted medium sand that are different from the natural sand in Area 408. These areas tend to be associated with dredged areas and are located on the down drift side of the local sediment transport pathway.

7 References

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8 Method & Approach Adopted

The data supplied by HAML in connection with this project comprised:

- Area 408 July and August 2000 field survey report
- Sidescan sonar and continuous seismic profiling data from the 2000 survey
- Bathymetric isobaths based on the 2000 survey
- Report on vibrocore sampling operations undertaken in July 1999
- Bathymetric isobaths based on the 1995 pre-dredge baseline monitoring survey
- Crown Estate Dredging Intensity Plots 1995-1999 derived from automated dredge recording Electronic Monitoring System (EMS) data.
- Area 408 benthic grab survey, July / August 2000.

The seabed morphology and shallow geological configuration are based on a standard marine aggregate resource interpretation of sidescan sonar and continuous sub-bottom profiling data. This process involves;

- In the case of sidescan sonar, mapping areas of similar acoustic response, and
- In the case of profiling data, developing a seismic stratigraphical model from the inter-relationships between seismic reflectors, their geometry and comparative acoustic response of seismic units. The model is then used to predict the composition of sedimentary units lying below the sea floor.
- Correlation of the seismic models with the available sample data.

The description of sedimentary characteristics used for each resource block follows the conventions laid down in BS 5930.

The parameters used in the discussion of grain size distribution are based on the percentage of particle sizes passing the following set of sieve intervals:

Sieve size Millimetres	phi units phi = mm $\log_2$	Sieve size Millimetres	phi units phi = mm $\log_2$
75.0000	-6.2288	1.1800	-0.2388
50.0000	-5.6439	0.6000	0.7370
37.5000	-5.2288	0.4250	1.2345
20.0000	-4.3219	0.3000	1.7370
10.0000	-3.3219	0.2120	2.2379
5.0000	-2.3219	0.1500	2.7370
2.0000	-1.0000	0.0630	3.9885

Table 2 PSD Sieve Size Intervals

The grading curves were re-calculated with the class interval transformed into phi units and the grain size distribution indicating that percentage of the sample which is coarser than the class interval. From this data the sediment size relating to seven significant percentiles (5, 16, 25, 50, 75, 84 & 95 %) were extracted and used to describe the sediment in terms of various qualities, including the mean, median, sorting, skewness and kurtosis. These parameters have been calculated using the formulas suggested by Folk and Ward.

The distribution of the percentage of gravel (>5mm), sand (<5>0.063mm) and silt (<0.063mm), as commonly defined within the aggregate industry, together with the statistical measures that describe the distribution have been contoured and are presented as a series of figures indicating the spatial variations.