JP KENNY

SW WAVE HUB CABLE - SEABED SEDIMENT STUDY

Report No. 2057, REV 1

Issued 28 April 2009

Metoc plc
Exchange House
Liphook
Hants GU30 7DW
United Kingdom

Tel: +44 (0) 1428 727800
Fax: +44 (0) 1428 727122

E-mail: info@metoc.co.uk
Web Site: www.metoc.co.uk

DOCUMENT RELEASE FORM

Title:	SW WAVE HUB CABLE - SEABED SEDIMENT STUDY
Client:	JP KENNY
Metoc Document No:	2057
Date of Issue:	28 April 2009
Level of Issue:	REV 1

		Hard Copy	***Digital***
Distribution:	JP KENNY	No:	PDF
	Metoc plc	No:	PDF
Prepared By:	Brian D'Olier, Jung Daruvala		
File Reference:	TMAR51.DOC		
Project No:	P1209A		

Project Manager:	Authoriser:
	
Jung Daruvala	Nick Barcock

Rev No	***Date***	***Reason***	***Author***	***Checker***	***Authoriser***
Rev 0	14.4.09	Original	BdO,JFD	DS,JI	NWB
Rev 1	28.4.09	Approved by client	BdO,JFD	DS,JI	NWB

COPY NUMBER: (applies to hard copies only)

SUMMARY

Metoc prepared this report for JP Kenny who is managing the design and installation of the Wave Hub Export Cable for SWRDA. The present study is carried out under authorisation of Service Order No 6600-e dated 19 February 2009 and the terms of the existing General Agreement for Provision of Consultancy and Technical Services between JP Kenny and Metoc dated 9 August 2004.

The report describes the surface geology of the seabed along the cable's intended route and recommends a safe minimum burial depth to ensure the cable remains buried throughout its working life. Burial is planned from the landfall out to KP 3.3 km, being the limit of significant sediment cover on the seabed. Beyond this, the cable will be fixed in place by rock dumping.

The study has taken into consideration the available geophysical data collected by the Project including a route bathymetry survey and beach transects along and closely parallel to the proposed cable route. The bathymetry survey took place in July 2005 and is partly outdated as the proposed hub location has subsequently moved around two miles east. The beach survey was conducted at monthly intervals over the period Nov 2007 – Sep 2008. The study also takes account of extreme wave conditions, which Metoc has prepared in the metocean design basis (Metoc Report 2056, issued in parallel with the present study).

The overall recommendation is that the cable should be buried 1.5 m below the lowest profile seen in the survey data.

- On the beach, this means 1.5 m below the lowest minimum seen on any of the three transects
- Seaward of the beach, this means 1.5 m below the (summer) profile. [Should pre-lay survey show any substantial drop in the offshore seabed profile the burial depth should be lowered by an equal amount.] It is assumed that the amount of sediment cover will increase during winter, affording added protection when storm waves are expected to be more severe.

Given the presence and highly dynamic nature of deltaic shoal features to the east of the river channel, it is suggested that exposure of the buried cable is less likely if routed to the eastern limit of the proposed cable corridor, for the first 600m away from the landfall.

The study has not addressed the risk from anchoring or trawling activities, which are beyond the given scope of work.

CONTENTS

1 INTRODUCTION AND OBJECTIVES 1

1.1 PROJECT DESCRIPTION 1
1.2 REQUIREMENTS 1
1.3 LOCATION AND SETTING 1

2 GEOLOGY 4

2.1 SOLID / BEDROCK 4
2.2 QUATERNARY AND RECENT DEPOSITS 4
2.3 OFFSHORE GEOMORPHOLOGY 5
2.4 PRESENT DAY SEDIMENTARY ENVIRONMENT 6

3 CABLE BURIAL & PROTECTION 9

3.1 CABLE PROTECTION - LANDFALL TO APPROX KP 3 9
3.2 CABLE PROTECTION – KP 3 TO OUTER ST IVES BAY 11
3.3 CABLE PROTECTION - OUTER ST IVES BAY TO THE HUB SITE. 12
3.4 OLD HUB SITE 12
3.5 RECOMMENDATIONS 13

4 INSTALLATION & ROUTEING 15

5 REFERENCES 16

1 INTRODUCTION AND OBJECTIVES

1.1 PROJECT DESCRIPTION

JP Kenny, on behalf of the SW Regional Development Agency (SWRDA), is managing the design and installation of the subsea power cable that will export electricity ashore from a wave farm offshore of St Ives Bay.

Figure 1.1 is a location map showing the cable route and the wave farm area. A selection of wave energy converters will connect to an underwater socket at the offshore end of the cable – the Wave Hub. JP Kenny has commissioned Metoc to perform this study to determine the appropriate cable burial depth. The study makes use of sedimentological information in the public domain and data collected by the Wave Hub Project including beach transects, offshore bathymetry and geophysical survey. It also takes into account the metocean design conditions, which Metoc has prepared under separate cover.

The work is carried out for JP Kenny under authorisation of their Service Order No 6600-e dated 19 February 2009 and the terms of the General Agreement for Provision of Consultancy and Technical Services between JP Kenny and Metoc dated 9 August 2004.

1.2 REQUIREMENTS

It is required that a review of available data is undertaken to assess likely variations in seabed profile due to sediment mobility and transport along the route of the power cable and at the Wave Hub site. This should include:

- Beach level changes at the landfall.
- Seabed mobility in the nearshore area
- General sediment transport in the Wave Hub area, particularly in respect of sediment dumping.

All of this should be related to two time scales:

  - The design life of the project – 25 years.
  - The installation period.

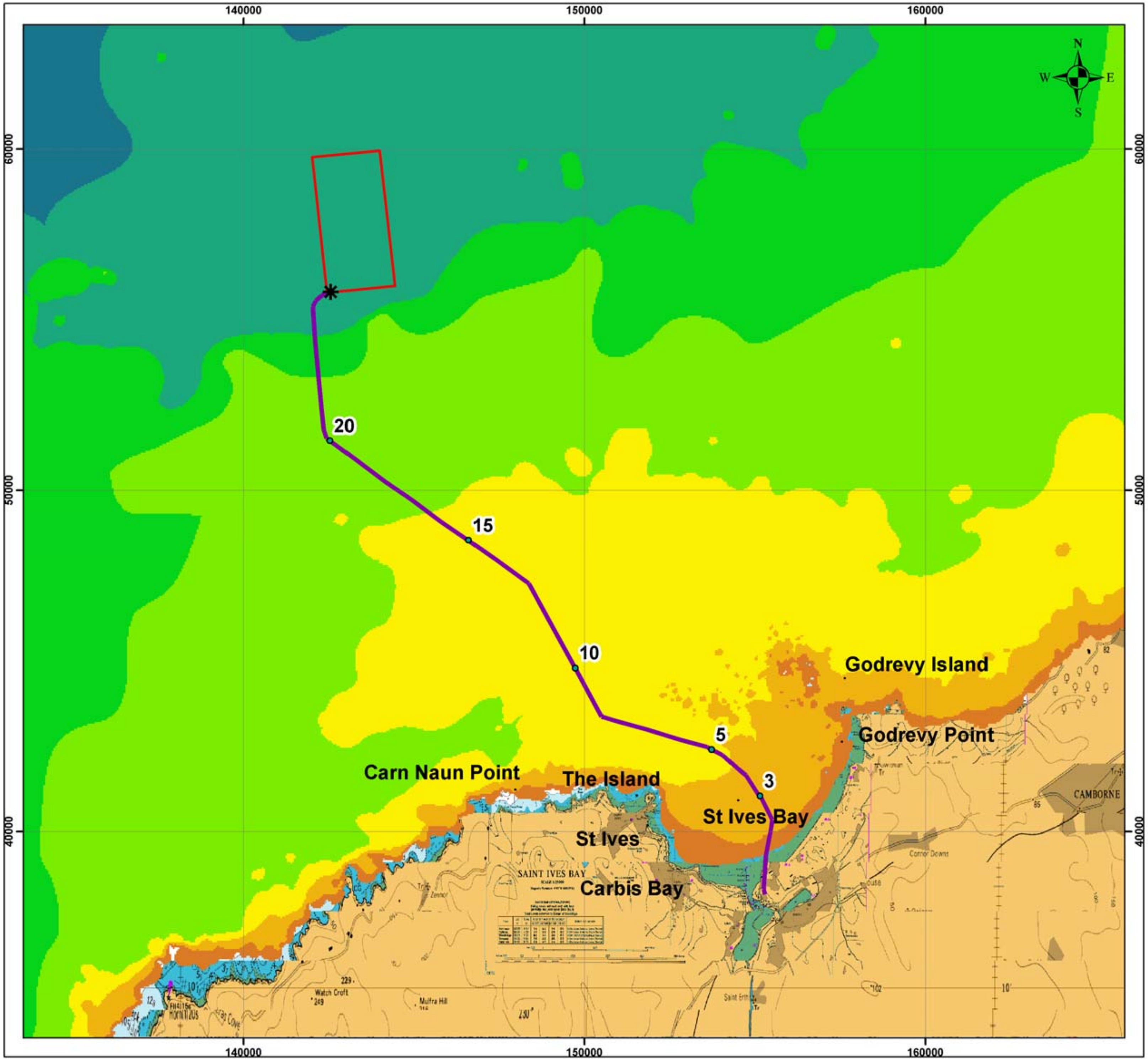
The burial depth must be designed to ensure against exposure during the design life period.

1.3 LOCATION AND SETTING

The area in question lies within St Ives Bay and along a narrow cable corridor to the Wave Hub site some 25 km to the northwest. Water depths vary from zero at the shoreward end to between 50 and 60 metres at the Hub Site. Sediment cover is relatively thin, often less than one metre in thickness and of intermittent cover[i]. The seabed consists of layer of sands and gravels overlying bedrock except within the Bay where the sedimentary layer thickens markedly. This report is the result of the assessment of the available data and suggests a design burial depth for the export cable.

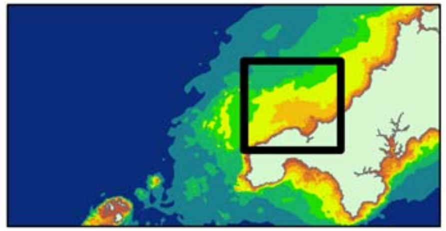
Wave conditions reflect the Hub's exposure to the Atlantic Ocean. At the Hub itself, significant wave height averages around 2 m and can exceed 10 m in storms (design 100-year extreme is nearly 14 m). These values reduce by about half in the more sheltered region where the cable is to be buried, i.e. the nearshore part of St Ives Bay.

The extreme cases assume that storm waves coincide with high tide and storm surge. Storm waves can produce significant wave orbital velocities up to around 2 m/s near the seabed over much of the route.



SW Wave Hub Cable

Figure 1.1: Location Map
Sediment Study



Legend

- ✱ Wave Hub
- Cable Route
- Wave Farm

CMAP Bathy: Depth in Meters

- < -70
- -60 to -70
- -50 to -60
- -40 to -50
- -30 to -40
- -20 to -30
- -10 to -20
- 0 to -10

Date	Friday, April 3, 2009 11:23:06	
Projection	British_National_Grid	
Spheroid	Airy_1830	
Datum	D_OSGB_1936	
Data Source	CMAP, DHI, JP Kenny, Metoc	
File Reference	J:\P1209\Mxd\Reports\ Report_Map.mxd	
Checked	Produced By	Harshal Galgale
	Reviewed By	Jung Daruvala

J P KENNY

METOC

0 0.5 1 2 3 4 5 6 Km

2 GEOLOGY

2.1 SOLID / BEDROCK

The bedrock comprises a deep-seated granite batholith that has not been reported as being exposed at the seabed along the projected route but is known to underlie at depth the whole of the planned route. Overlying the bedrock layer is a mixture of folded Middle (Gramscatho Group) and Upper (Mylor Slate Formation) Devonian sedimentary rocks consisting of sandstones, mudstones, occasional limestones and some igneous intrusions/extrusions that do outcrop at the seabed along the majority of the seabed route.

Folding of the rocks tends to be along a NE/SW axial trend and therefore across the line of the cable corridor. As such, rock exposure at the seabed will vary from low angle, relatively smooth rock bed surfaces to steeply dipping, angular rock bed ends. The differing strengths and thus the erosive capacity of each individual rock bed will have resulted in a locally variable, uneven rocky seabed. Faulting of these rocks has also occurred, principally along a NW/SE trend with, for instance, a major fault underlying and perhaps helping to determine the alignment of the Hayle River and its estuary.

At the shoreward end of the route, at the southwestern end of the Bay close to the locally exposed part of the St Ives/Lands End granite batholith, the Devonian Mylor Slates have been cleaved and altered by faulting, volcanism and the granite intrusion. This fracturing and alteration has made them more susceptible to marine, fluvial and periglacial erosion in the past. The substantial coastal embayment of St Ives Bay is to some extent the result of this later erosive activity around the eastern edge of the Lands End granite.

Underlying the relatively recently deposited sands and gravels within the Bay, the bedrock will have a locally variable, uneven surface much as it is further offshore.

2.2 QUATERNARY AND RECENT DEPOSITS

At times of low sea level, a situation that has occurred several times during the last 1.5 – 2.0 million years, the area under consideration for this project has been exposed to subaerial, fluvial and at times, periglacial erosion. The palaeo-River Hayle and its tributaries will have deposited sediment north and west of the area of the present coastline derived from their catchment areas within Cornwall. In addition it is believed that glacial activity during at least one period of lowered sea level extended across from the Celtic Sea reaching the Scilly Isles and almost reached the area of present day Cornwall. Under these near glacial–periglacial conditions all the rock strata of the area would have undergone deep frost-shattering, fracturing, weathering and hill slope solifluction thus subsequently providing easily transported sediment, for the rivers and later marine activity.

Also the nearby, often floating ice sheet, as it melted, will have deposited glacial till and meltwater, muds, sands and gravels within the present day offshore area.

2.3 OFFSHORE GEOMORPHOLOGY

The recent sediments of the Cornish coast, where they exist, lie upon an uneven bedrock surface that slopes gently seaward. Offshore, this slope is interrupted by a series of three steeper, northwestward facing sections that have been interpreted as being submerged cliff lines from former sea level stands – the Upper, Medial and Lower. As far as it is possible to judge from the data available, in the study area the most pronounced of these is quite possibly the Medial Cliff Line that is present here lying at approximately the 40 metre isobath. There is also a short steep change of slope at approximately the 35 metre isobath. This might be the Upper Cliff line but could be solely due to locally variable rock competency.

Examination of the isobaths offshore of this northern section of the Cornish coast suggests that the deeper erosion of the bedrock underlying St Ives Bay around the St Ives/Lands End Granite (section 1. Solid Geology) continued around the northern side of the granite. Thus the 20, 30 and 40 metre isobaths lie only 4-5 km offshore along the coastline to the west of St Ives towards Carn Naun Point. As there is no definite sign of any palaeo-valleys from the geophysical surveys carried out for this project, the palaeo–Hayle River and possibly the palaeo – Red River probably followed the softer more easily erodible rocks immediately surrounding the Granite and its associated volcanic rocks.

During times of lowered sea level these rivers could have run to the southwest along this offshore, deep water, channel closely parallel to the present Cornish coast. Elsewhere around the southwest Peninsula, buried river valleys continue only as far as the 35 to 40 metre isobaths. These indents within the 20, 30 and 40 metre isobaths off the coast to the north and west of St Ives strongly suggest that this is the case here.

However more directly northwest of St Ives Bay the 20, 30 40 and 50-metre isobaths strike away markedly towards the north and northwest suggesting that at times of lower sea level a ‘Headland’ projected in a northwesterly direction at least as far as the Hub site. To the west of the Hub Site this ‘Headland’ curves round and projects further seaward thus affording the Hub site with some protection from deep swell wave induced currents from the west. This would allow some temporary/permanent sedimentation, depending on material grain size, of coarser sediment to take place within the Hub Site area. At the 40 m isobath, this ‘Headland’ has a steep face suggesting that here the Medial Cliff line crossed it. The Hub site lies at the foot of this cliff line.

Thus from the shore the cable route approximately follows the eastern/northern edge of the palaeo–Hayle River valley and its tributaries through St Ives Bay as far as about 50º14´N, 5º28´E. It then turns towards the northwest and crosses onto the marine planed surface of the ‘Headland’ where after extensive bedrock outcrop with patchy, sandy gravel veneer occurs. Towards the northern end of the ‘headland’ route, at the foot of and against the Medial Cliff Line, further sandy sediments have accumulated. Within the Hub site sand and sandy gravel predominates covering rough rock outcrops.

2.4 PRESENT DAY SEDIMENTARY ENVIRONMENT

2.4.1 Sedimentary 'Sinks'

During the most recent period of rising sea level - the late Devensian–Flandrian transgression - wave action will have reworked most if not all of these variously deposited sediments. In addition as the water deepened, tidal currents will have begun to operate redistributing the various sediments. The result is that the finer more mobile sediments will have either been moved offshore into deep water 'sinks' below the limit of wave activity or into inshore, shallow water 'sinks' where coastal headlands afford a sufficient sheltering effect. Consequently St Ives Bay contains predominantly a medium/coarse sand overlying some of the low sea level coarser 'lag' deposits.

Offshore due to strong wave activity and tidal action, the deposits become progressively thinner, coarser in size and more intermittent. Here are found gravely sand and sandy gravels, lying largely in hollows within the uneven bedrock surface. At approximately the 40 metre isobath, and below the effect of all except the most extreme wave/tidal conditions, sand within a deeper water 'sink' once more becomes the predominant sediment. Thus the Wave Hub site and the immediately adjacent section of the Cable Corridor do have an intermittent sand/sandy gravel cover overlying the low sea level, coarse 'lag' deposits.

2.4.2 Sedimentary Sources

At the present time new supplies of sediment into the project area are limited, being restricted to:

- Very small amounts derived by river action from their catchment areas.
- Small amounts of rock fragments derived from erosion by tidal/wave action upon the resistant rocks of the coastline and any exposed bedrock on the seabed.
- Small amounts derived from storm erosion of the raised beach deposits particularly at the northeastern end of the Bay at Godrevy Point.
- Very small amounts derived by biological activity upon the rocks (drilling/boring molluscs, sponges etc).
- Still relatively minor volumes but probably more substantial amounts than any other single source, derived from the shells and skeletal parts of present day marine fauna chiefly in the form of $CaCO_3$.

Sediment samples taken by the British Geological Survey show that the sand of the surface sediments contains > 75% of calcium carbonate while the gravel fraction contains > 50%. This suggests that the more recent marine sedimentary activity is largely the result of the deposition of the carbonate rich, skeletal remains of the infauna. This additional sediment input is to some extent balanced by the loss of the finest particulate shell debris by suspension load on the ebb tides, by dissolution of the $CaCO_3$ in the increasingly acidic seawater, and by wind blow from the beach.

It is likely that the St Ives Bay sediment 'sink' is full and only rising sea level will allow any appreciable and steady increase in sediment input to take place. At the present time, sea level rise is calculated as being 5mm/year though 'global warming' might well increase that rate in the future.

2.4.3 Sediment Movement

The chief body of sediment in question here is that contained within the St Ives Bay sediment 'sink'. Some of this sand will be contained within the buried palaeo valley of the Hayle and its tributaries before they combined to run away westward. The rest lies on the bedrock surface within the protective headlands situated at either ends of the Bay.

Due to the strong wave action and tidal currents, any sand lying seaward of the protective shelter of Godrevy Island and Godrevy Point on the north side and The Island, St Ives and Carn Naun Point to the south will tend to be swept past the Bay.

At peak spring tidal flows, the currents are predominantly towards the WSW during ebb and towards ENE during flood with current magnitudes of 2 knots (1 m/s) being attained**.** Meteorologically-induced surge action may enhance the current velocities to exceed 3 knots (1.5 m/s). These extremes will be activated predominantly from the NW/W/SW sectors and are also accentuated by the channel-like submarine contours to the southwest of St. Ives that direct the flood tidal flow direction and by constriction can locally increase the near seabed flow speeds.

Immediately north of the Bay the form of the northwestward projecting 20 metre isobath will cause some of the flood flow to be diverted and refracted towards the Bay with any sand in transport being swept across the Bay towards the east and the shore. Once in the Bay these tidal currents, which set at approximately 110º at peak flood flows, weaken unless they are wave assisted. As the flows slow, sedimentation will occur. In addition a flood gyre is likely to operate in the eastern lee side of The Island, St Ives also causing any nearshore sediment in transport to be diverted into the Bay particularly around the Carbis Bay area.

On the ebb, because of the presence of Godrevy Point and Island and the projecting 10 metre isobath, tidal flows of up to 2 knots (1 m/s) tend to be diverted a little away from the coast though a weak ebb gyre will operate southwest of this projection. Within the Bay, ebb tidal currents are weak but are directed from east to west thus moving some finer sediment in that direction.

Wave action, however, is the dominant force in the shallow waters of St Ives Bay. The waves are predominantly from the west and are refracted into the Bay driving sediment eastwards and towards the shore. Inshore, particularly towards the Hayle estuary section of the route, the angle of approach of these refracted waves will cause a dominantly southwesterly longshore drift movement of sediment. Easterly winds also accentuate this direction of motion.

Under most conditions sand is largely trapped within, and moves in a dominantly clockwise motion around the confines of the Bay. One result of this motion is to deposit sand within the narrow entrance of the Hayle estuary. This sedimentation has necessitated considerable annual dredging to be carried out in the past, in order for larger boats to use the harbour. The normal flushing of the estuary by the ebbing tide is insufficient to complete this naturally, the remaining channel in that circumstance only allowing smaller boats to pass.

Within the bay, some sand is also lost from the beach on a temporary basis by Aeolian transport. This loss occurs both alongshore to the east or west into the estuary, but principally onshore into the coastal dunes. In the future the steadily increasing, perhaps accelerating, sea level rise will mean that erosion to the toe of the dunes could take place but it is unknown whether this loss to the dunes would be balanced by the wind blown depositional process driving the sand dunes further inland.

3 CABLE BURIAL & PROTECTION

3.1 CABLE PROTECTION - LANDFALL TO APPROX KP 3

During the winter storm season, high energy waves erode and transport sand from the upper beach profile towards the offshore, where it is deposited below the low water mark in the form of a sub tidal alongshore sand bar. The response of the beach to the storm conditions results in the "winter" beach profile and is characterized by a flattening of the upper beach face, with one or more long shore sand bars accumulating below the low water mark.

During the summer season, constructive swell waves transport much of the sand from the offshore sand bars back onto the beach above the low water mark, giving the beach a steeper more even "summer" profile.

There is an ample depth of sand along the cable route within the Bay for this seasonal sedimentary process over approximately the first 3 kilometres from the Landfall point (155158E 38383N). The depth of sand underlying the beach along the cable route is at least 11 metres at a point 700 metres from the Landfall. This thickness increases further towards the landfall but decreases to seaward. At:

- 1.0 kilometre it is 7 metres thick
- 2.0 kilometres it is 3.5 metres
- 2.5 kilometres it is 3 metres
- 3.0 kilometres it is 2.5 metres
- 3.5 kilometres it is patchy.

3.1.1 Cable Protection – Sediment Mobility

Of importance for this project is the need to find a level below which even the greatest storm wave beach drawdown will not result in exposure for the cable. Previous anecdotal evidence suggested that a change in beach elevation of at least 1.8 metres could occur and subsequent beach monitoring has borne this out.

3.1.2 Beach Monitoring - Methodology

Beach monitoring was carried out each month during the year starting November/December 2007 through to August/September 2008 over the upper 620 metres of the beach from the Landfall. It is noted that the survey may not have captured the morphodynamics of the beach under extreme storm conditions.

Three separate sections were measured, the central one being along the centre line of the cable route the other two being at 50 metres spacing each side of the centre line. The three sections comprised a total of 95 points at 20 m intervals.

3.1.3 Beach Monitoring - Findings

The resulting beach profiles taken between November 2007 and September 2008 along the three transects showed the characteristic “summer” to “winter” beach profile features as described in section 3.1, with a lowering of the upper beach during winter and a corresponding increase in sediment towards the offshore below the low water mark. Upper beach elevations between 60m and 100m away from the backshore showed a reduction of 1.1m and 0.79m at the centre and right hand transect respectively. The lower beach profiles between 160m and 400m offshore showed a cyclic pattern of erosion and accretion from winter to summer at each monitoring point with a maximum elevation reduction of 1.45m 140m along the centre transect, and a maximum elevation reduction of 1.15m occurring 360m along the right hand transect away from the landfall. The lower beach between 500m and 600m, revealed a maximum beach level reduction of 1.23m at the centre transect and 1.07m to the right of centre. Notably, the beach profiles taken along the right hand transect exhibited the least dynamic variability over the monitoring period.

The transect to the left of the centre line of the cable route was aligned parallel to the Hayle River. The beach profiles taken along this line showed a distinct erosional feature between 260m and 480m, with a reduction in elevation from March/April to September 2008 of 2.71m at its lowest level. The upper beach, 20m away from the landfall also showed a large elevation reduction from winter to summer of 2.37m. Level elevations on the mid and lower beach profile outside the erosional feature varied between 0.92m and 1.35m in the vertical over the measurement period.

Aerial images of the Hayle River as it flows into St Ives Bay show deposition of sediment either side of the river mouth channel and the presence of deltaic like shoal features to the east of the river channel. These features are persistent, and have been shaped by the combination of tidal currents, waves and riverine discharge, and will vary seasonally in position and elevation. Notably, the beach area immediately to the left and right of the Hayle river mouth, is highly dynamic. The transect line to the left of the centre burial line traverses across these shoal like features and is evidenced in the beach profile by a sharp reduction in beach level for a distance of 200m towards the offshore.

In summary, ninety five separate elevations were taken along the three sections, and these showed the following range changes;

- fifty seven showed changes < 1 metre,
- twenty eight were > 1 metre and,
- ten showed more than 2 metres change.

Along the left hand transect to the centre cable line at 360 metres from Landfall, an elevation range of 2.71 metres occurred. It was also notable that the range varied, sometimes markedly, over the 100 metre measured swathe of beach that separated the 3 measured sections; for instance at 400 metres there was a range of elevation variation of 1.59 metres between the three measurements.

Within three measured longitudinal sections along the cable route, the minimum level (mODN) or lowest beach level at any one monitoring point within a particular section of 100 metres measured from the Landfall point was noted. The following minimum beach elevations are the result.

- 0 – 100 metres 0.88 metres ODN
- 100 – 200 metres 0.14 metres ODN
- 200 – 300 metres -1.38 metres ODN
- 300 – 400 metres -2.10 metres ODN
- 400 – 500 metres -2.07 metres ODN
- 500 – 620 metres -2.16 metres ODN

These readings were obtained without any note of especially abnormal conditions during 2007/2008. However under extreme conditions of water level, of wave heights, wave orbital velocities and tidal currents, localised rip currents and thus beach profile scouring effects are likely to be magnified.

3.1.4 Beach Monitoring - Conclusions

The changes in profile levels illustrate the very variable longitudinal and lateral beach level changes that can occur from winter to summer. This variability might be due to localised rip currents that occur during high water levels at times of severe storms when significant wave orbital velocities within the Bay can exceed 1.8 m/s. Velocities of this magnitude are more than sufficient to mobilize any of the sand found typically within the upper layers of this sand beach and offshore in the Bay (instantaneous values associated with the largest individual waves will be around twice as large). Additionally, alongshore currents also increase when wave heights at breaking increase, allowing for greater amounts of sediment to be carried along the beach.

The beach profiles taken along the left hand transect (beach station 1) showed the presence of a 200 m wide erosional feature, where marked erosion occurred between March and September 2008. It is evidenced from aerial photographs, that this erosional feature is in fact the cross section of one of the persistent deltaic shoals that are present to the east of the river channel. These shoal features were not displayed in the other two transect profiles because the transects ran perpendicular to the beach cross section, in line with the cable route, and did not cut across the shoal features.

In assessing the appropriate depth of burial for the cable, in the first instance the minimum levels (m ODN) reached throughout the beach monitoring period are most relevant.

3.2 Cable Protection – KP 3 to Outer St Ives Bay

From the geophysical and borehole evidence there is sufficient depth of the medium/coarse sand extending from the landfall at 155158E 38383N (Halcrow Geophysics 2005) seaward as far as approximately 3.2 km (154850E 41400N) to allow cable burial without encountering rockhead.

Beyond KP 3.2 the cable will begin to approach the bedrock surface and the sand overlying the bedrock soon thins to less than a metre, with sand becoming patchy beyond 3.5 km (154700E 41650N).

This point lies just beyond the protective line of the headlands - Godrevy Island/Point and The Island, St Ives. Also at this same locality, the rockhead surface that has remained at approximately -20.5 metres ODN since a point 2.0 km from Landfall, falls sharply to -25 metres ODN.

The area where the rockhead surface sharply declines also defines the very edge of the St Ives Bay sediment body. This is where sand is likely to be entering and leaving the sediment body. The cable will need rock dumping from approximately 3.2kilometres as sand levels at this extreme edge of the sediment body are likely to be variable so close to the more vigorous offshore influences.

3.3 CABLE PROTECTION - OUTER ST IVES BAY TO THE HUB SITE.

This section crosses the submarine 'headland', a largely sediment free, exposed bedrock surface, except for thin sandy gravel patches, at water depths varying from -11 m ODN to approximately -40 m ODN at the Medial Cliff line. It is likely that the vigorous wave and tidal action, which maintains this area largely free of sediment, would be sufficient to cause the cable to be moved.

The cable will need to be trenched into the rock surface or very securely weighted by rock dump or anchors. It is understood that rock dumping is planned.

3.4 OLD HUB SITE

Close to the originally planned Hub site at the base of the Medial Cliff line at approximately 139500E 53700N some sand/gravel up to 1.5 metres in thickness can be found. This sediment is largely located in the relative shelter of the northern edge of the deeper parts of the 'Headland' as it curves and extends further seaward.

The area is affected by tidal/wave generated currents, as small megaripples are reported. These are between 0.2 – 0.3 m in height with a wavelength of 1.5 and 2.5 metres. No asymmetry of form and thus direction of movement are noted. Also elongate scours or gravel ridges within the sediment, indicative of high velocity near seabed, current flows greater than 1.5m/sec, are reported. These could be due to surge induced/tidal flows being locally constricted between the Medial Cliff line and a steep Cliff line rock outlier (former low sea level island) at 138600E 54700N and around the outlier itself. Another similar patch of sand/gravel is also found on the northern side of the outlier while there are other small patches within the Hub Site area.

The area of the Hub site is therefore subject to intermittent, strong flows most possibly due to a combination of tidal activity coupled with storm surge generated currents. These are likely to be strongest from a westerly direction though there is a reasonably long fetch from the northeast that could enhance the tidal ebb flows.

3.5 RECOMMENDATIONS

3.5.1 Burial depth

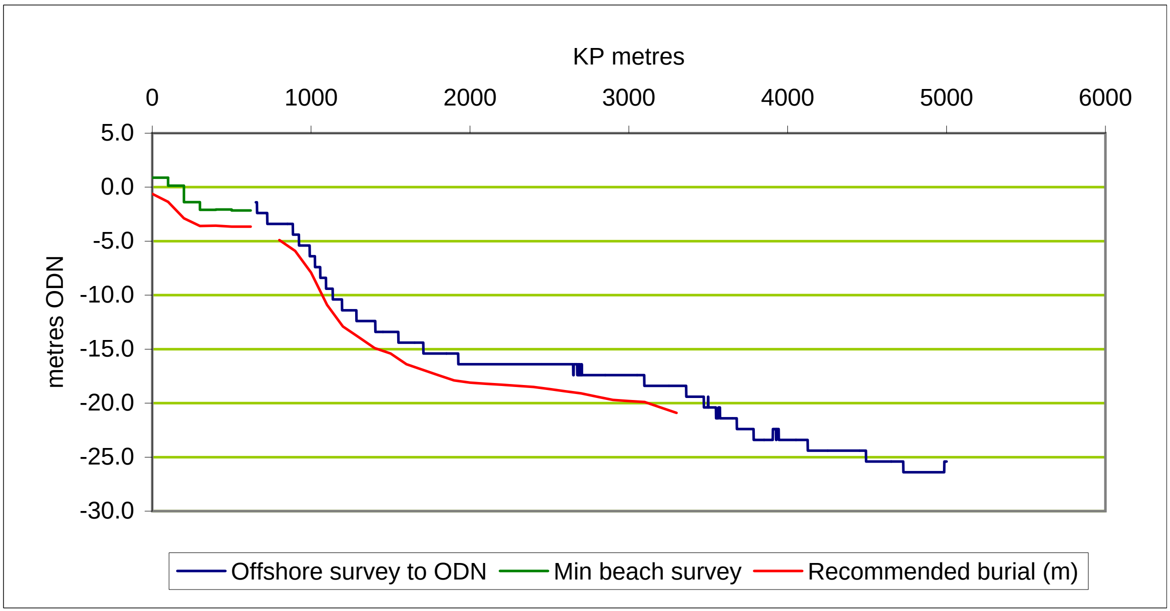
Table 3.1 presents the recommended burial depth profile from the shore end to 3300 m, being the limit of sediment cover suitable for burial. Based on the limited (9 months) observations from the beach profile monitoring study, it is recommended that cable burial should be approximately 1.5 metres below the minimum beach levels recorded during the beach monitoring process.

Further to seaward, the cable burial depths would be 1.5 m below the seabed levels obtained during the geophysical survey of July 2005. If the pre-installation survey detects any substantial drop in the profile relative to the 2005 survey, then the burial depth should be lowered by an equivalent amount.

Given the presence and highly dynamic nature of the deltaic shoal features to the east of the river channel, as evidenced in the left hand transect beach profiles (beach station 1), it is suggested that exposure of the buried cable is less likely if routed to the eastern limit of the proposed cable corridor, for the first 600m away from the landfall.

3.5.2 Beach monitoring

Given the variability the beach profile elevations along the three transects, and in particular the presence of deltaic like shoal features to the east of the river channel as evidenced from aerial photographs, it would be beneficial if more beach profile data could be collected to increase the database to two winter/summer cycles. This would enhance understanding of the beach morphodynamics in response to the changing wave, current and meteorological conditions.



KP (m)	Min beach survey
0	0.88
100	0.88
100	0.14
200	0.14
200	-1.38
300	-1.38
300	-2.1
400	-2.1
400	-2.07
500	-2.07
500	-2.16
620	-2.16

All elevations are metres OD(N)

Beach survey - 2007/2008
Offshore survey - 2005

KP	Recommended burial (m)
0	-0.62
100	-1.36
200	-2.88
300	-3.6
400	-3.57
500	-3.66
620	-3.66
800	-4.9
900	-5.9
1000	-7.9
1100	-10.9
1200	-12.9
1300	-13.9
1400	-14.9
1500	-15.4
1600	-16.4
1700	-16.9
1800	-17.4
1900	-17.9
2000	-18.1
2100	-18.2
2200	-18.3
2300	-18.4
2400	-18.5
2500	-18.7
2600	-18.9
2700	-19.1
2800	-19.4
2900	-19.7
3000	-19.8
3100	-19.9
3200	-20.4
3300	-20.9

Table 3.1 Survey Elevation and Recommended Burial Depth Profile

4 INSTALLATION & ROUTEING

During installation sand will be in motion within the site. However if this work is carried out within the calmer, summer period this movement is likely to be at a minimum. Any movement will be chiefly shoreward and then from east to west. The spoil could either be dumped on the eastern side of the trench during the installation period so that the trench shuttering can retain material. It will then be readily available to refill the trench.

If there is likely to be a lengthy installation period then it might be dumped on the western side where it will be slowly dispersed across the beach. Thus no major impediment to normal sand movement will be discernible to the general public. Later as the sand of the beach is relatively homogeneous, it can be scraped from a relatively wide area around the cable route in order to refill the trench.

5 REFERENCES

1) British Geological Survey. 1987. Land's End Sheet 50°N 06°W – Seabed Sediments & Quaternary Geology

2) Metoc plc, 2009. SW Wave Hub Cable – Metocean Design Basis. Metoc Report 2056.

Plus a selection of client-owned materials:

1) Wave Hub Geophysical Survey (2005) Final Report

2) Drawings (bathymetry, seabed features, alignment sheets)

3) Halcrow Report – Coastal Processes study

4) Shoreline Management Plan