Managing the issue of seabed sediment in offshore renewable energy projects

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ABSTRACT: The offshore renewable energy sector requires information about the types and behaviours of sediments at and below the seafloor for: structure foundations; inter-array and export cables corridors; scour and depositional processes post-construction. Identification of the so-called 'stable seafloor surface' is also required along with an indication of seabed sediment mobility. Challenges associated with these issues will be discussed in relation to wind farm projects from around UK coastal waters.

Lessons learned from these previous and ongoing investigations are helping to inform the situation with regard to the North Wales Tidal Energy and Coastal Protection Project. This is a proposed 2.5 GW energy generation project with a 30+km long seawall enclosing an impoundment with an area of ~157 km². It will be necessary to understand much more clearly the processes affecting sediment mobility off the North Wales Coast in order to manage sediment and related issues successfully.

1. INTRODUCTION

The offshore renewable energy sector requires information about the types and behaviours of sediments at and below the seafloor for: structure foundations; inter-array and export cables corridors; and scour and depositional processes post-construction. The nature of these materials affects the design and selection of foundation types (monopiles, piled jackets, gravity bases, caissons, *etc*.) and influences the choice of cable routing and subsequent cable installation methods. Understanding the susceptibility of sediments around structures to scour at the seabed or excessive deposition is critical to the ongoing performance of the installed facilities. Identification of the so-called 'stable seafloor surface' is also required in order to be able to determine the amplitudes and directions of movement of various types of seabed bedforms as well as to indicate the lowest possible level of scour. Challenges associated with these issues will be discussed in relation to wind farm projects from around UK coastal waters.

2. CONSIDERATIONS FOR SEABED SEDIMENT MOBILITY ANALYSES

When considering seabed sediment mobility, it is commonly assumed that the reference surface over which seafloor bedforms move is level and smooth. This is frequently not the case. There may be a palaeo-topography associated with a landscape that has been formed by late Pleistocene or earlier processes that has subsequently become submerged as sea level has risen since the last ice age. An example of this from the now-abandoned Rhiannon Offshore Wind Farm Project, Irish Sea Zone is shown in Figure 1. The seismic expression of former moraines or drumlin ridges can be seen poking through the contemporary seafloor on this extract from a seismic section. These features, which comprise over-consolidated glacial sands and clays, have a characteristic darker seismo-acoustic expression compared with that of overlying fluvio-glacial deposits that are normally-consolidated and which appear with a light, more open-texture, seismo-acoustic character.

With respect to contemporary seabed bedforms, a consideration is the source of sediments, whether from elsewhere in the Irish Sea or from erosion of the substrate.

3. SEABED SEDIMENT-SUBSTRATE RELATIONSHIPS

There is a growing body of evidence from detailed geophysical investigations associated with offshore wind farms to suggest that the base level of seafloor in parts of UK coastal waters is being deflated by erosion (Figure 2). This is in part apparently as a consequence of scour into sandy sub-members that contributes material towards bedform development. The role of reworked substrate sediments in the mass balance of mobile sediments within the |Irish Sea needs further consideration. There is also evidence that more cohesive components of the substrate, such as clay bands, can resist a degree of scour and can form a flatter surface across which sediments can be moved or/or winnowed relatively easily. As a consequence of this erosion of the seafloor, the seafloor surface can become more irregular in form. What is not understood is how this irregular topography can influence how sediment migrates across the seafloor and form different styles of bedforms, and affects current flow at a more localised scale to form secondary bedforms. There are clearly scale effects at play. How these can be included in seabed sediment mobility analyses is the subject of ongoing discussion.

4. NORTH WALES TIDAL ENERGY & COASTAL PROTECTION PROJECT

The maximum tidal range along the North Wales coast is one of the highest around the UK and outside of the Severn Estuary, with potential for substantial electricity generation. The North Wales coast has also suffered from major historical coastal flooding that has resulted, for example in 2010, in inundation of >10 km² of land, homes, businesses and vital infrastructure, costing more than £100 million in insured losses. As a result of the coastal flood risk, there has been a reluctance to invest in the region, where there are several areas of significant economic deprivation.

Over the last two years significant work has been undertaken by North Wales Tidal Energy & Coastal Protection Co. Ltd (NWTE) to develop the vision of a major tidal range power generation project off the North Wales coast with tripartite benefits: (a) predictable generation of clean electricity; (b) coastal flood protection; and (c) economic regeneration.

Nominally, the proposed power generation scheme will include:

- A 32+ km long sea wall providing protection from storm surges within the Irish Sea;
- An impounded area of around 157 km²;
- Up to 100 power turbines with a total installed capacity in excess of 2 GW, potentially generating more than 3 TWh per year;

Low-lying areas along the coast are increasingly at risk of flooding, the more so when sea level rise from changing climate is taken into account. Vital communications links, such as the strategically important North Wales Main Line railway that connects London and Holyhead on Anglesey, and the A55 North Wales Expressway, which forms part of the Trans-European Networks programme (Euro-route E22), will be defended.

The design, construction and support of a tidal impoundment of the size and scale envisaged will be one of Wales' and the UK's largest infrastructure projects, providing employment for many years. Mitigation of the threat of coastal and fluvial flooding will help to reduce insurance premiums and flood-related blight to property values. It will also save local authorities and insurance companies from the costs of repairing flood damage that would most likely occur if the scheme does not proceed, estimated notionally in excess of £500 million over the next hundred years. The improved investment environment will also allow extensive business and property development in areas that are currently an insurance risk. Furthermore, by having such a major impoundment scheme in place it will provide a canvas on which new businesses can be developed to exploit the protected area of water (*e.g.* water sports activities and other visitor amenities), as well as associated enhanced support services within the coastal hinterland.

5. MANAGING SEDIMENT OFF THE NORTH WALES COAST

Before the specific design of the civil engineering structure and power generation units can be completed, there is a need to understand much more fully the hydro-dynamic processes in the southern part of the Irish Sea off the North Wales coast. At present it is evident that there is a generally-eastward migration of sediment along the shoreline, culminating in accretion at the Talacre sand dune system. However, what are unclear are the boundary processes that transport sediment between the coastline and several kilometres offshore. It is evident from satellite imagery of sediment plumes as well as from bathymetry information that there are possibly different scales of gyres operating. These may vary from gyres of the order of two hundred metres length rotating clockwise east of Colwyn Bay but counter-clockwise between Llandulas and Llandudno. These in turn may feed into and be related to three counter-clockwise gyres, of the order to 8 km long, orientated roughly WNW-ESE but south of the existing wind farms and the Constable Bank sand ridge. There are also questions as to why Constable Bank exists where it does with its particular orientation, which is parallel to that of other linear seabed features across the coastal offshore region.

There are questions perhaps of a more academic basis as to processes that might be related to deglaciation and isostatic rebound changing the base levels over millennia compared with the apparent lack of understanding of processes dominated by contemporary influences. The former, due to the very long time scale, may have little significance in relation to processes that impact offshore renewable energy projects with their short project durations in contrast to the latter that might have greater and more direct impact. It is important to be able to determine the sensitivities within the offshore marine environment in order to know how large engineering structures will impact on these processes and what their consequences will be and where.

6. CONCLUSIONS

It is clear from both the previous investigations undertaken as part of the Rhiannon Wind Farm Project and from other projects elsewhere in UK coastal waters that substrate appears to play a part in influencing bedform development and affecting local current flow. It is also apparent from initial work as part of the North Wales Tidal Energy and Coastal Protection Project that the interaction between large scale hydro-dynamic processes within the Irish Sea and the near-shore coastal environment is complex and very poorly understood. This has been identified as an important component of the research to be undertaken as part of the project’s Environmental Impact Assessment baseline studies.

7. ACKNOWLEDGEMENTS

Thanks are due to the RIL seismic team (Dr Lucy Catt, Dr Gwen Salaün and Ms Ana Branco Fernandes) for their work on the various offshore wind farm projects. Thanks are also due to colleagues in NWTE for their input to the early stages of the North Wales Tidal Energy and Coastal Protection Project.

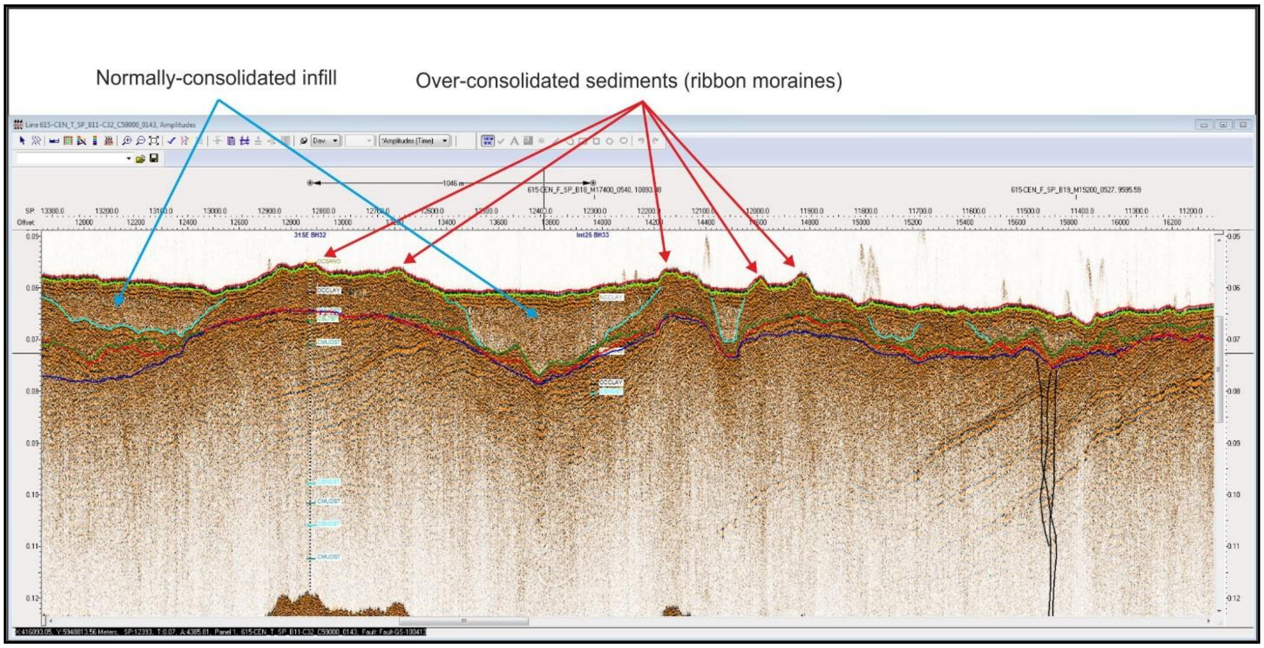

Figure 1. Example of seismic data from the Rhiannon Offshore Wind Farm, Irish Sea Zone, indicating protrusion of over-consolidated glacial sediments through the seabed.

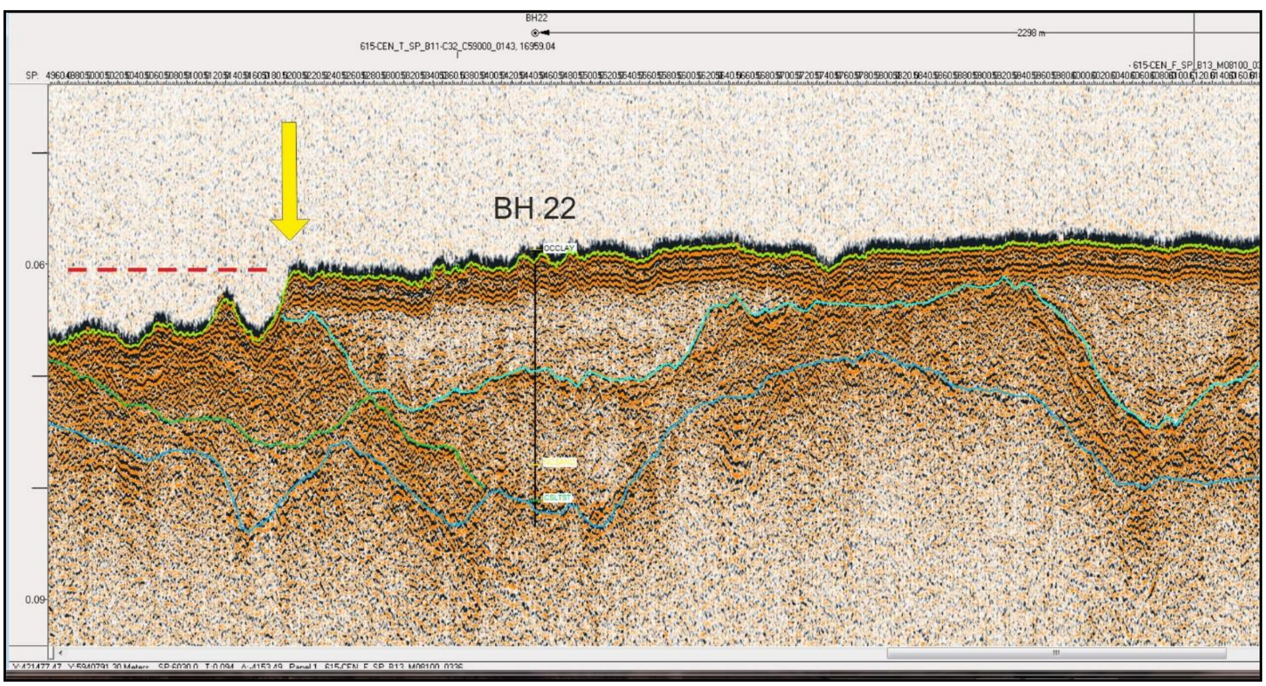

Figure 2. Example of seismic data from the Rhiannon Offshore Wind Farm, Irish Sea Zone, indicating erosion of normally-consolidated sediments and deflation (red dashed line) of the seabed left of the nick point highlighted by the yellow arrow.