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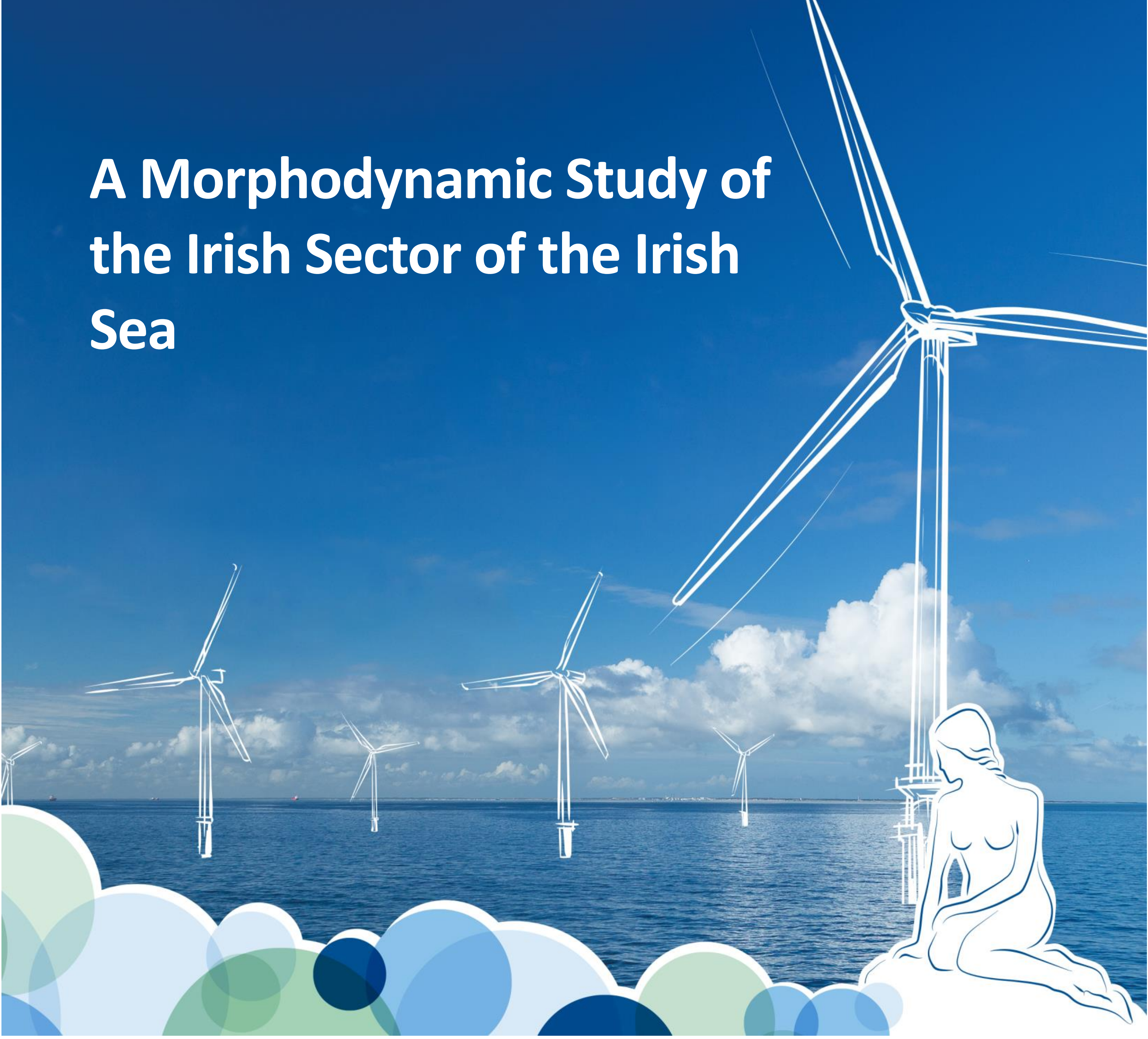
A Morphodynamic Study of the Irish Sector of the Irish Sea



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SUMMARY

Ireland's expansive marine resource has the potential to provide significant economic growth through the development of critical infrastructure such as offshore renewable energy installations. Offshore wind farm developments may affect the marine environment in a number of ways, including increasing turbidity, development of scour around turbine foundations, as well as erosion around electricity cables. This can have environmental implications, as well as impacts on the operation of the wind farm. For instance, erosion around the electricity cables can result in infrastructural damage leading to operational downtime for the wind farm. To fully understand the seabed response to an offshore windfarm development, a thorough understanding of the hydrodynamics and seabed morphodynamics processes is required. This project will conduct a morphodynamic study of designated areas in the Irish Sea and will involve a geological, geotechnical, sediment transport assessment of the seabed sediments. Repeat surveys will be conducted to assist in understanding seabed changes over time. Furthermore, predictive sediment transport modelling will be used to characterise future seabed changes and to quantify the risk for future potential offshore wind developments in the Irish Sea.

PROJECT OVERVIEW

1.1. OBJECTIVES

A detailed knowledge of seabed morphodynamics and sediment mobility is key to a number of end-users in both science and engineering as well as stakeholders in fisheries and navigation. Understanding and being able to monitor, or predict, morphodynamic change on the seabed is critical to safely deploying and maintaining offshore infrastructure like renewable energy installations as well as cable and pipleine deployment.

Whilst generally concerned with near-seabed hydrodynamics and morphodynamics, this project is primarily focussed on the issue of seabed mobility. In order to qualify and quantify the morphodynamics of the Irish Sea, this project will address the following central research questions:

- What is the range of seabed morphodynamics in the Irish Sea at present?
- What are the time-scales related to this range and the influencing parameters?

With this research questions in mind, we aim to:

1. Improve our understanding of seabed hydrodynamics, morphodynamics and scour development in the Irish Sea;
2. Identify areas prone to seabed changes, which may impact anthropogenic activities;
3. Quantify future morphodynamic change through predicitve modelling.

To achieve these aims, we set forth the following obectives:

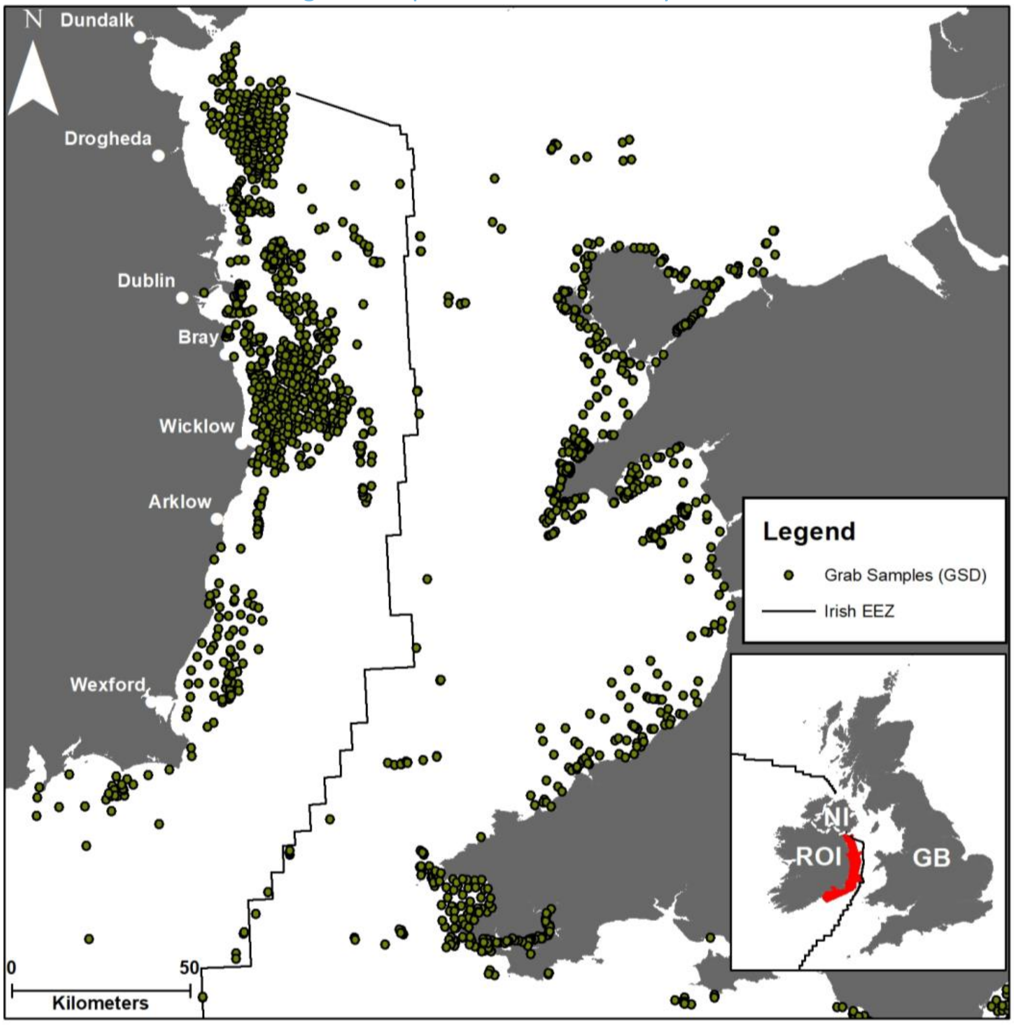
1. Review existing databases (including INFOMAR) for the Irish Sea and identify areas of historic seabed change and significant morphodynamic development;
2. Characterise selected sites using seabed mapping data such as multi-beam echosounder (MBES) and sub-bottom profiling;
3. Where possible, perform repeat surveys on selected sites to assess temporal changes in seabed morphodynamics;
4. Determine sediment mobility at selected sites based on integrated numerical modelling using the DHI-MIKE21 software;
5. Develop a risk register associated with quantified and predicted outputs.

Ultimately, this project will deliver a morphodynamic atlas of the Irish Sea along with a database of sediment hydrodynamic and morphodynamic parameters for designated areas. These will then be used by stakeholders and infrastructure developers as critical engineering and environmnetal baseline data for projects.

1.2. SEDIMENT MOBILITY IN THE IRISH SEA

Initially a database of surface sediment grab samples was compiled, based on grain-size distribution (GSD) analysis from various sources (INFOMAR ; [1]; [2]) (Figure 1).

Figure 1 Location of sediment grab samples used in this study



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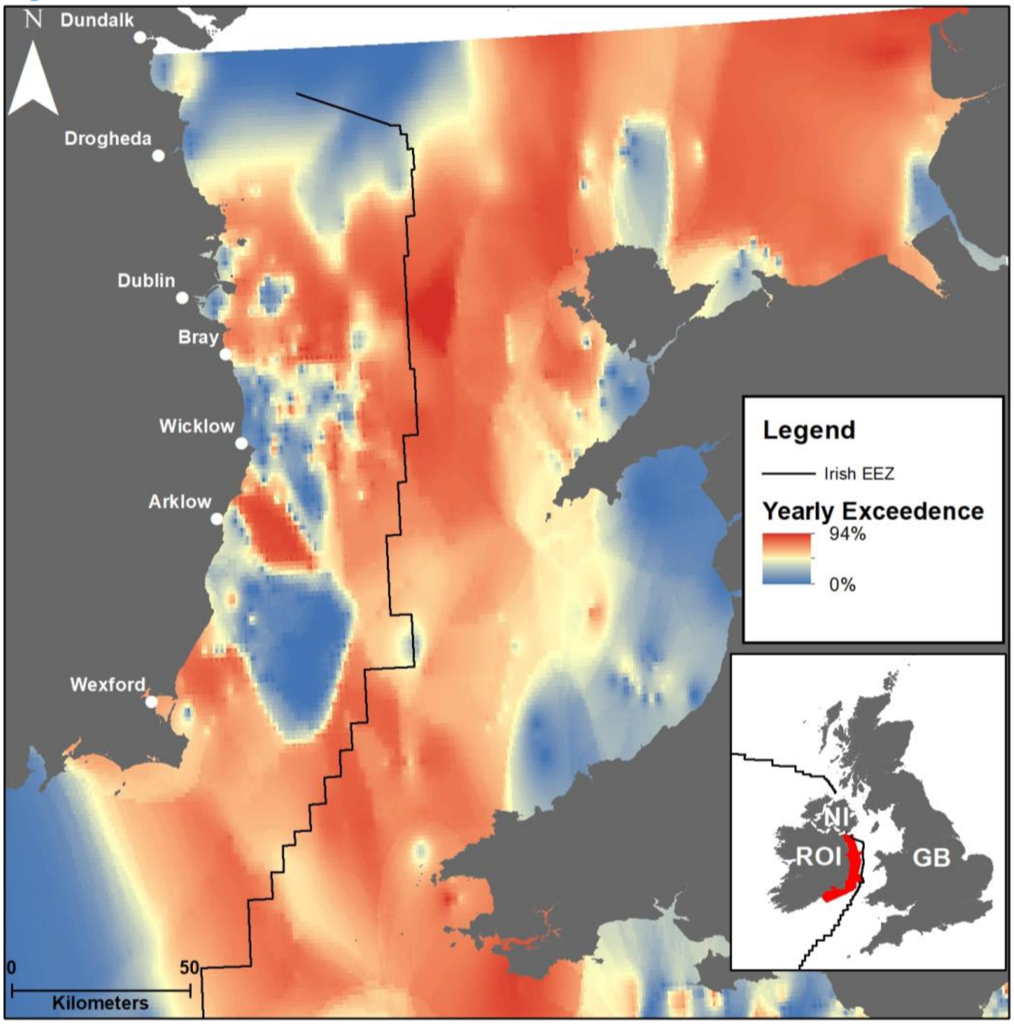
A map of bed-critical sediment thresholds were calculated using interpolated D50 values from this dataset (Figure 1), based on the approach of Van Rijn (1984) [3], across the area of interest. Bed-flow stress values were computed using the Marine Institute ROMS model output and compared to bed-critical values to calculate the percentage yearly exceedance of bed-critical for a specific reference year (i.e. 2018) and thus the time that the sediment is mobile (Figure 2).

Figure 2 Yearly exceedance (in %) of bed-critical sediment thresholds by bed-shear stress allowing sediment to be mobile



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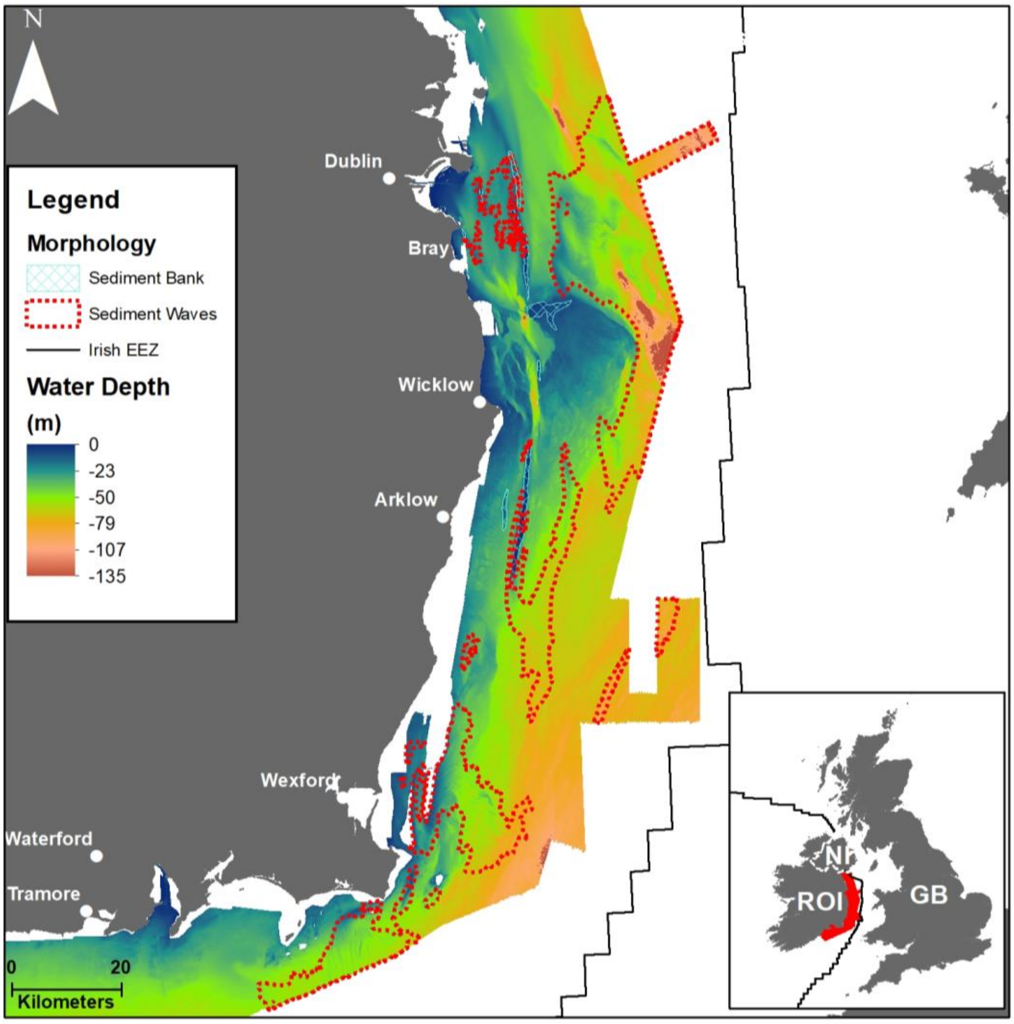
1.3. IRISH SEA MORPHOLOGY

Since 2003, the Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR) programme, a joint venture between the Geological Survey of Ireland (GSI) and the Irish Marine Institute of Ireland (MI), has been collecting seabed mapping and bathymetric data in the Irish Sea. This high-resolution and spatially extensive dataset allows for a regional assessment of seabed conditions in order to identify seabed morphological conditions that could positively or adversely impact offshore infrastructure. In particular, sediment banks are considered favourable due to their shallow water depths and composition. Sediment waves can adversely impact structures if they are highly mobile by burying cables for example or scouring the base of foundations creating instability (Figure 3).

Figure 3 Bathymetry (water depth) in the Irish Sea with delineated morphological features relevant to this study. Namely, sediment banks and sediment waves.



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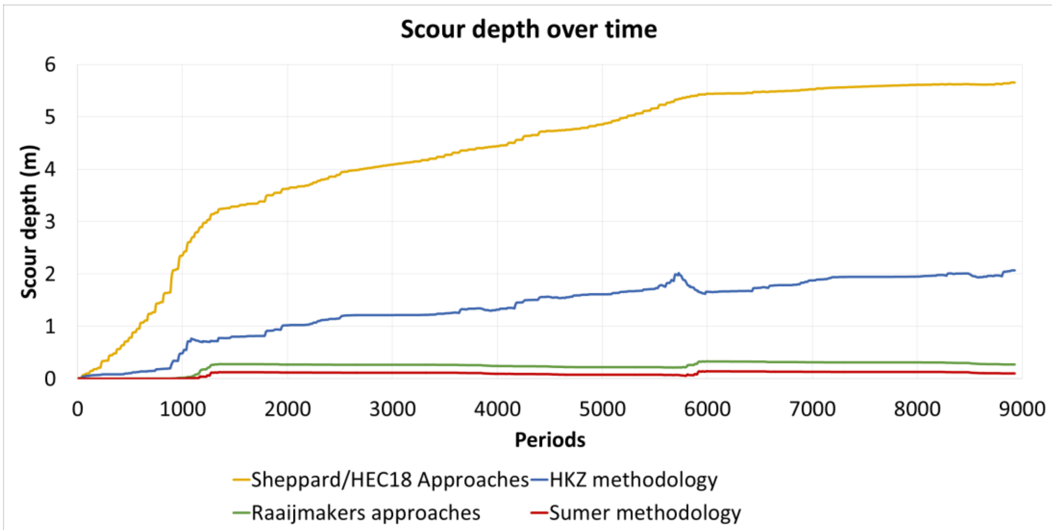
1.4. EMPIRICAL SCOUR MODEL

Experience from the Arklow Bank windfarm highlights infrastructural instability caused by scour which in turn affects the operation and cost of the windfarm [4]. In addition to numerical efforts, this study is also developing empirical based tools with which to qualify and quantity scour around structures. A number of approaches were applied to a common metocean dataset[1] to assess the applicability of each one. In this study the following approaches were considered (Figure 4):

- Sheppard and Miller (2006) [5]/HEC18 (2012) [6];
- Deltares (2017) [7];
- Raaijmakers and Rudolph (2008)[8];
- Sumer and Fredsoe (2002) [9].

[1] https://offshorewind.rvo.nl/windwaterzh

Figure 4 Scour depth over time for four different approaches



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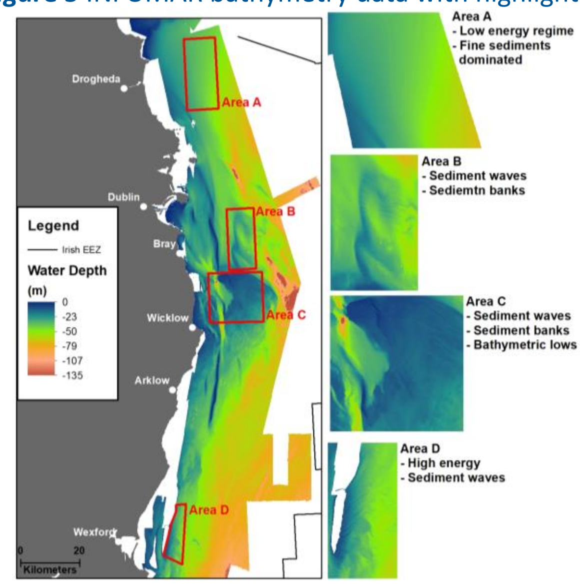
The next intended step is calculating scour shape and width in different directions by using Nielsen formulas. This will be followed by numerical modelling in then do Scilab and/or Matlab.

1.5. REPEAT DATA & MORPHODYNAMIC CHANGE

The project is in the process of securing vessel time in order to carry out repeat seabed mapping at selected sites (Figure 5). This repeat data will be used as qualitative validation for morphodynamic change, ascertained by comparing cumulative change over successive surveys.

Figure 5 INFOMAR bathymetry data with highlighted areas for future modelling



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1.6. MODEL SET-UP

The DHI-MIKE21 suite of tools allows simulation of the interaction of tide and wave generated currents and their effect on local sediment transport in marine environments. The objective of the model is to investigate the hydrodynamics and resulting seabed morphodynamics on areas of potential windfarm development in the Irish Sea. The modelling task consists of two stages: the hydrodynamics model will be set up and calibrated/validated and then, during the second stage, coupled to a sediment transport module.

The model set-up is made of two open boundaries spanning between Northern Ireland and Scotland (northern boundary) and between Ireland and Wales (southern boundary). Water level boundary conditions will be generated applying state of the art tidal constituent analyses accounting for variation in water level along the open boundaries at each time step, whereas wave boundary conditions will be derived from the ECMWF-ERA5 dataset.

Wind forcing condition will be imposed over the whole computational domain taking into account wind speed and atmospheric pressure leading to variation in water level and flow speed due to atmospheric effect (i.e. storm surge). Similar to wave data, the wind forcing data will be obtained from ECMWF-ERA5 dataset.

The model will be calibrated and validated for water level against several tide gauges along the Irish and British coasts belonging to the Marine Institute and the British Oceanographic Data Centre (BODC) and against offshore ADCP measurements for current and water level. The hydrodynamics will be first calibrated with respect to astronomical tides only and then further validated with inclusion of storm surge.

The capability of the model to accurately reproduce the Irish Sea wave climate will be tested against measured data from the M2 and M5 buoys belonging to the Marine Institute buoy network.

The hydrodynamic model thus calibrated/validated will then be coupled to the sediment transport model. The sediment transport model will make use of the sediment characteristics derived from the surveys and compute the transport rate of the non-cohesive sediment based on the flow conditions found in the hydrodynamic calculations. This will enable the computation of bed level change in the areas of interest.

The model also allows for inclusion of structures such as monopiles which have the effect of altering the local hydrodynamics through flow-structure interaction and, in turn, impacting on the local morphodynamics. In this regard an additional output may be represented by the assessment of the scour at the wind turbine monopile foundations.

ACKNOWLEDEMENTS

This project (Grant-Aid Agreement No. IND/18/18) is carried out with the support of the Marine Institute under the Marine Research Programme 2014-2020, co-financed under the European Regional Development Fund. This paper contains Irish Public Sector Data (INFOMAR) licensed under a Creative Commons Attribution 4.0 International (CC BY 4.0) licence.

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