Scour Hazard Assessment For Offshore Wind Developments - Lessons Learned From European Waters

HR Wallingford
Working with water

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Overview of scour issues

The drive for developing offshore wind has led to specific requirements for scour hazard assessment relating to the associated foundation structures and the cabling necessary for in-field transmission and power export. In the UK, offshore wind has been developed at large-scale as part of two rounds of commercial development. Scour hazard assessment is a key stage in the design process and can help:

- Ensure adequate foundation design and cable protection
- Identify appropriate scour monitoring and mitigation measures
- Minimize risk of interruption to power transmission
- Minimize operation and maintenance (O&M) costs.

Although general design approaches to scour assessment are well-established (DNV, 2007), recent advances as a result of our work include:

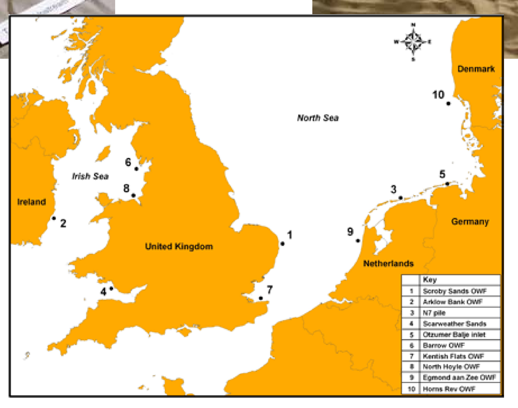
- Inclusion of subsea soil profiles
- New developments in time-series predictions.

These now allow more accurate prediction of scour around subsea structures in continuously varying wave and current fields.

Lessons learned

Important lessons have been learnt from the analysis of built foundations in European waters. Experience from European offshore wind projects, combined with industry-driven research by HR Wallingford, has improved understanding of scour processes at foundations and around subsea cables. This includes:

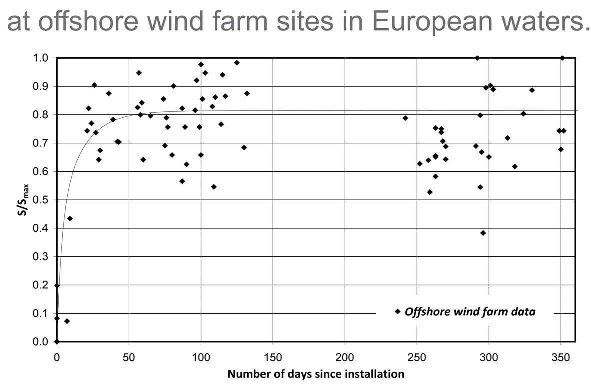
- Key findings from UK Government funded research on caisson founded wind farms supported by laboratory testing
- A synthesis of experience from built projects (DECC, 2008; COWRIE, 2010)



Time-scale of scour development

One of the outcomes from research (DECC, 2008) was the conclusion to start monitoring from the time of installation, in order to examine the range of scales of contribution to scour development. The monitoring would be carried out in parallel with measurement of environmental data. Multibeam echo sounder data would provide the overall scour pattern around the foundation and a permanently installed downwards looking echo sounder would provide information on the variation of scouring in time, for correlation with the environmental data.

The figure shows field data of scour development at monopile foundations from the date of installation from monitoring programmes at offshore wind farm sites in European waters.



Plot showing the exponential growth of scour depth with time from turbine foundation installation. S_{max} is the maximum recorded scour depth.

Scour evolution is explained by Whitehouse (1998). Recent studies by Harris et al. (2010b) suggest that the scour depths can vary continuously under combined current and wave conditions through time.

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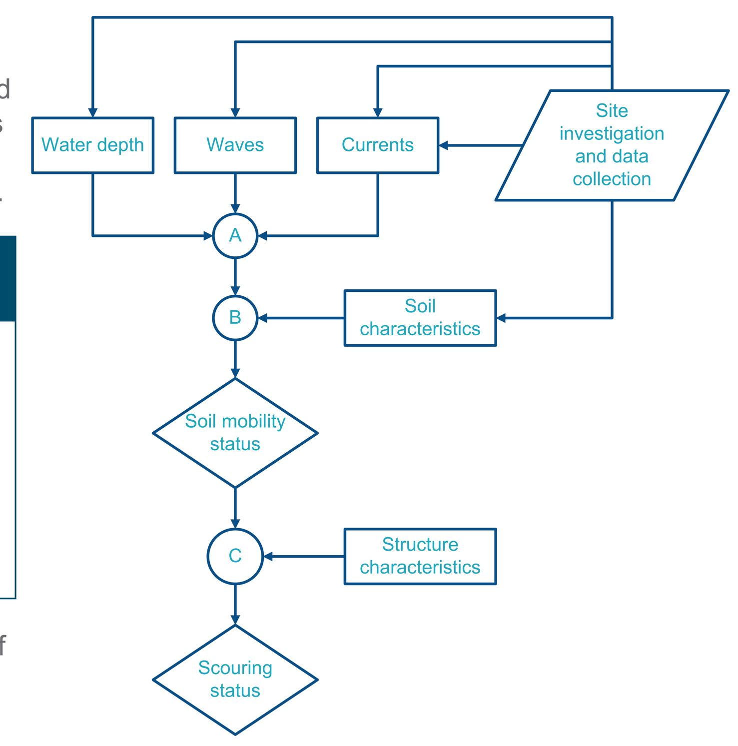
Scour Hazard Assessment

Scour is a physical process related to the movement of the seabed sediment as a result of the flow of water away from a structure. The soil conditions are described by geotechnical parameters. There are two levels; at its most simple (Level 0) the assessment is based on the presence or absence of certain features on the seabed.

Sand Indicators of mobility	Clay Indicators of erosion
Ripple marks	Longitudinal furrows or grooves
Megaripples	
Sand dunes	Obstacle marks - scour around rocks or wrecks and other debris on the seafloor
Obstacle marks - scour and deposition around rocks or wrecks and other debris on the seafloor	

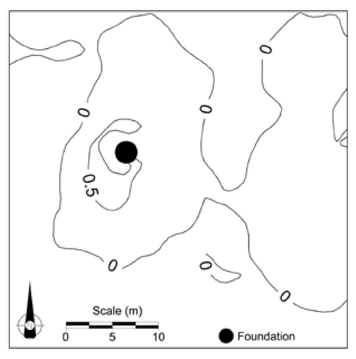
The second level of assessment, Level 1, makes use of known information of the wave and currents combined with knowledge of the soil to make an assessment of the soil mobility status and feeds directly into the scour screening methodology shown in the figure.



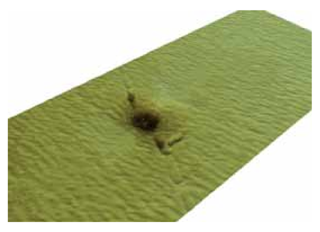
Level 1 Scour Screening Hazard Flow Chart (Whitehouse, 2006)

Seabed environments

Foundations are placed in a variety of seabed environments, each has its different challenges and scour response.



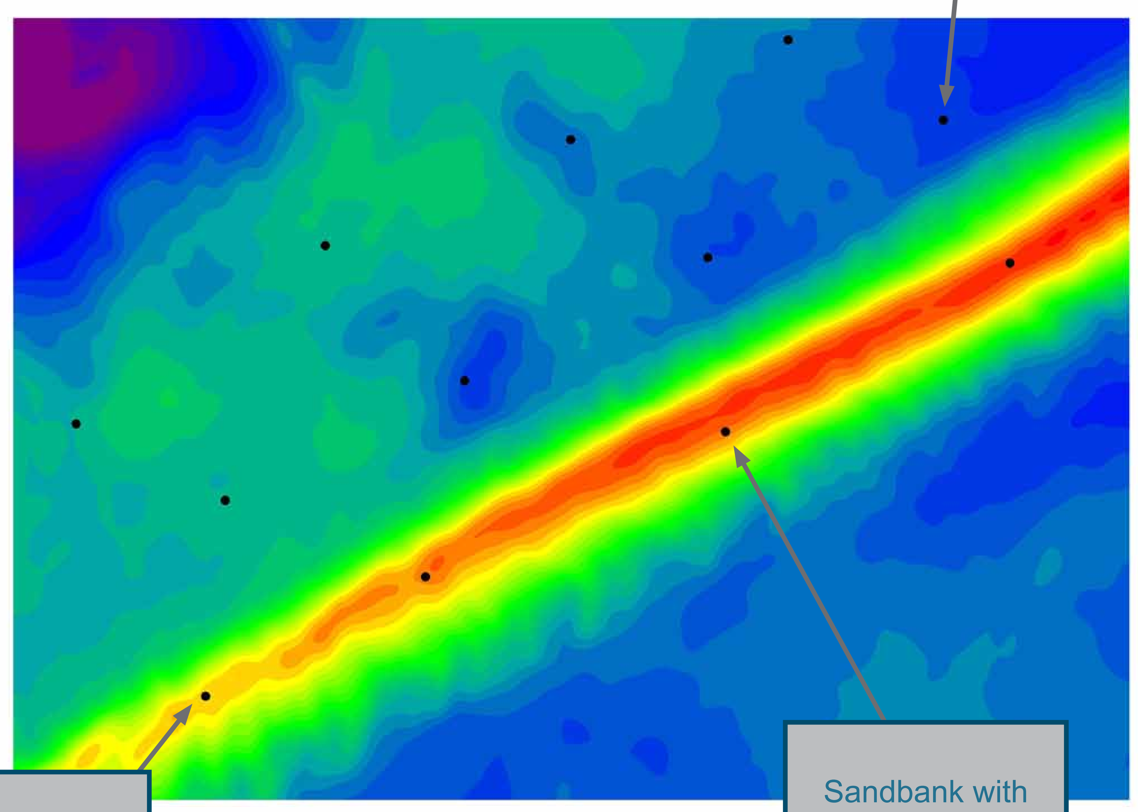
In open seabeds with veneer the scour is limited in the short term and accumulates over time in the underlying bedrock.



Wind turbine foundation - 3D image of surface contours, Princess Amalia Wind Farm (data provided by Van Oord).

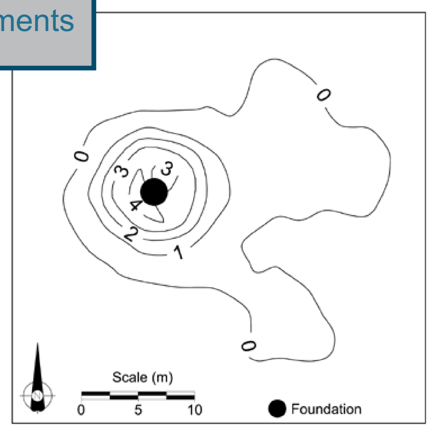
The scour profile around the foundation interacts with the cable runs.

Open seabed with deep sand or veneer over bedrock

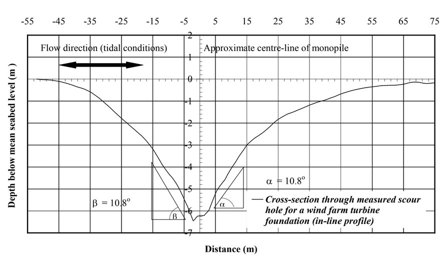


Sandbank with deep sand and mobile sediments

Sandbank with mobile crest



In open seabed environments in deeper water the scour is well developed but not as deep as in shallow water.



On the sandbank the scour varies with time and the scour profile can be quite extensive along the tidal ellipse.

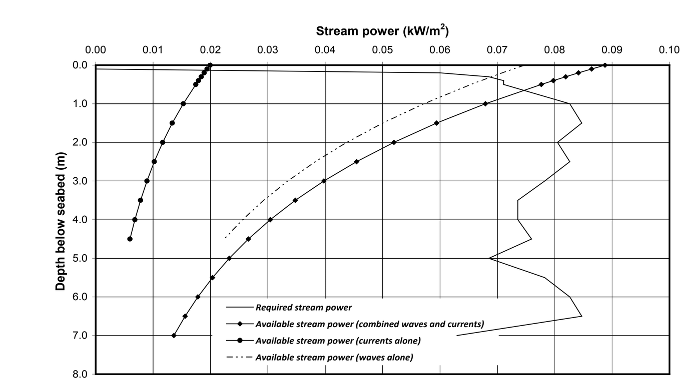
Detailed results of lessons learned are presented in Whitehouse et al (2010, 2011)

Using subsea soil data

For scour assessments in general, it is very important to know the characteristics of the subsea soil profile, and data analysis starting from 1m below the seabed or deeper in a foundation site investigation will not always be representative of the surface sediment properties required for a scour assessment. Knowledge of the sediment properties below this layer will become important though for predicting scour development with depth into the seabed should scouring extend beyond that sediment layer.

The Erodibility Index provides a measure of the in situ strength of the material, whilst the stream power P provides a measure of the rate of energy dissipation in the near-bed region due to hydrodynamic forces.

If P exceeds the erosion threshold then scouring will occur. The approach was originally developed for scouring of rock spillways, but the methodology applies equally to marine type soils (e.g. Annandale, 2006). Harris et al. (2010a) adapted the method developed by Annandale (2006) for marine soils.



Plot showing the application of the Erodibility Index method to predict scour depth with predominantly clay marine soils

Scour protection

Scour countermeasures have been applied at the Scroby Sands, Robin Rigg and Arklow Bank, as well as other sites. The scour protection that has been placed appears to be effective in preventing bed lowering adjacent to the foundations. The interaction of the placed scour protection with the surrounding seabed levels has been examined. Where material has been placed in the scour hole formed around the foundation and the top level of the protection is above the level of the surrounding seabed it is evident that the mound of protection material has produced a secondary scour response.

Model tests were performed in facilities at HR Wallingford to determine the magnitude of scour around unprotected monopiles, the potential level of damage to scour protection and to assess the extent of scouring around protected monopiles. Static and dynamic designs were tested as well as the impact of changes in general bed level due to sandwave migration.

The OPTI-PILE Design Tool has been developed by HR Wallingford to assist in the prediction of the depth / extent of scour and the design of scour protection around offshore monopiles (Den Boon et al, 2004). This provides a consistent methodology for scour protection analysis in conjunction with laboratory tests.

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