

**Offshore Wind  
Programme Board**

**Overview of geophysical and geotechnical  
marine surveys for offshore wind  
transmission cables in the UK**

**September 2015**

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## CONTENTS

<b>1</b>	<b>Introduction and background .....</b>	<b>4</b>
1.1	Purpose and scope.....	4
1.2	Marine surveys in the context of offshore wind farm export cables .....	5
<b>2</b>	<b>Guidance common to different stages of marine survey .....</b>	<b>7</b>
2.1	Specification and procurement.....	7
2.2	Data management and deliverables.....	8
<b>3</b>	<b>Pre-installation .....</b>	<b>8</b>
3.1	Introduction .....	8
3.2	Desktop studies .....	10
3.3	Feasibility survey.....	11
3.4	Cable route survey.....	12
3.4.1	UXO.....	13
3.5	Near shore and landfall surveys .....	14
3.5.1	Near shore .....	14
3.5.2	Cable landfall .....	14
3.6	Pre-installation engineering.....	15
3.7	Environmental studies and surveys.....	16
<b>4</b>	<b>Installation phase .....</b>	<b>17</b>
4.1	Data collected immediately prior to installation .....	17
4.2	Data collected during burial .....	17
<b>5</b>	<b>Post-installation verification .....</b>	<b>18</b>
5.1	Purpose of post-installation surveys .....	18
5.2	'As-laid' survey.....	19
5.3	'As-built' or verification survey.....	20
<b>6</b>	<b>Summary of surveys typically requested at OFTO asset handover .....</b>	<b>21</b>
<b>7</b>	<b>Post-installation monitoring .....</b>	<b>22</b>
	Appendix A – Glossary .....	25
	Appendix B – Sources of further information .....	30
	B.1 Further information.....	30
	B.2 Other ongoing work.....	32
	B.3 Endnotes in report text.....	32

## 1 INTRODUCTION AND BACKGROUND

### 1.1 Purpose and scope

The offshore wind industry has been on a steep learning curve and lessons continue to be learnt from issues encountered on previous projects. Offshore cables are an area where the industry has experienced frequent cost overruns and information from insurance brokers and underwriters indicates that 80% of European offshore wind farm insurance claims have been cable-related.<sup>1</sup> Surveys are a key field in which a good process and targeted risk management can help to reduce the risks and costs associated with cable installation.

This document describes good practice in marine surveying processes for offshore wind farm transmission cables (export cables) in the UK. It provides an overview of the geophysical and geotechnical surveys<sup>1</sup> required for export cable installation and maintenance.

This document has been drafted by a working group of industry professionals, including developers, marine surveyors, consultants and installation contractors. In Autumn 2014, Ofgem held a workshop on key aspects of the OFTO regime. The working group that developed this document was established in late 2014 following on from the regulator's workshop. The working group was tasked with identifying existing good practice for marine survey activity and producing a high level resource which captured this in one place. The purpose of doing so is to share this good practice with a wider audience in order to de-risk future offshore transmission development and ultimately reduce costs. The Offshore Wind Programme Board Grid Group<sup>2</sup> agreed to publish the outputs from this working group in support of its aim to reduce the cost of offshore transmission associated with offshore wind power.

The working group participants brought with them a range of experiences that were discussed in the group and used to inform and shape this document. The report captures good practice and, in some areas, the different approaches that emerged from the group's experience. The group contributed information and collectively reviewed the resulting report, which is presented in the following sections: guidance common across survey stages; pre-, during and post- installation surveys; surveys typically requested at OFTO asset handover and post-installation monitoring.

This document will help to enhance communication and coordination of activities by providing a common understanding of the survey process and by consolidating the results of the learning curve to date. It reflects a typical current process based on experience to date and does not aim to be prescriptive, recognising that individual organisations and projects have variations on this process and that there will be further innovations in the future. Further, this document should not be taken as representing the views of any environmental, permitting or consenting organisation or authority, or interpreted as guidance of what is required to meet any environmental or planning

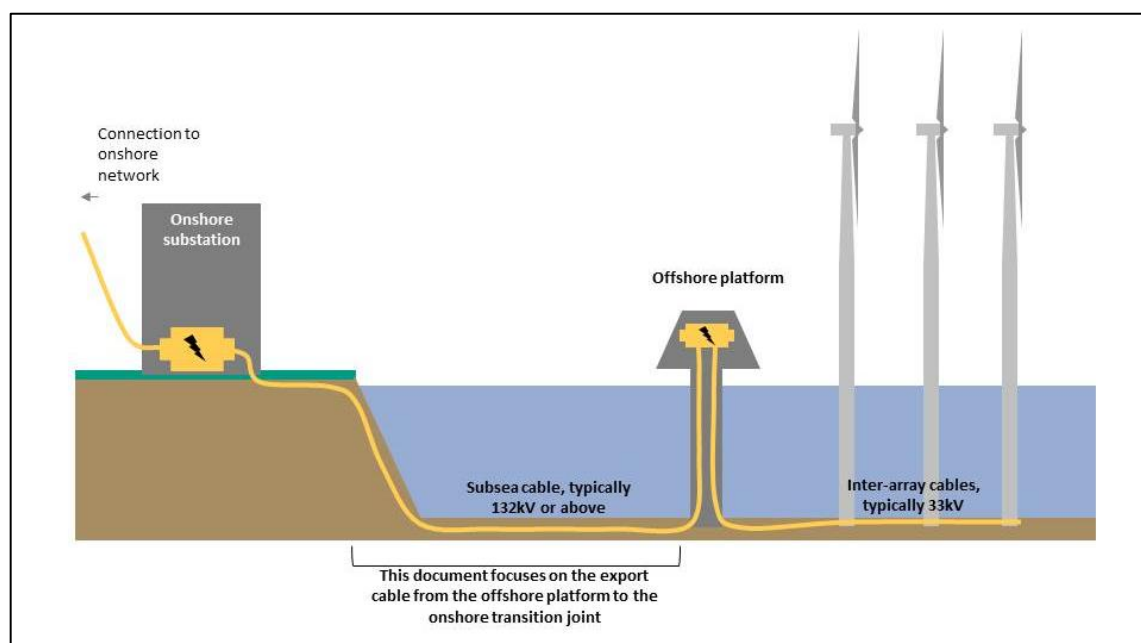
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<sup>1</sup> Definitions are provided in Appendix A.

<sup>2</sup> Offshore Wind Programme Board (OWPB) Grid Group. This group is working on areas with the potential to reduce costs in transmission connections, with a focus on design and construction.

legislation.

Figure 1 below shows the main transmission assets for a typical offshore wind farm. This document focuses on surveys relating to the subsea transmission cable between the offshore platform and the land cable. Whilst this overview does not extend to inter-array cables or interconnector cables, there are many common areas between these and export cables.



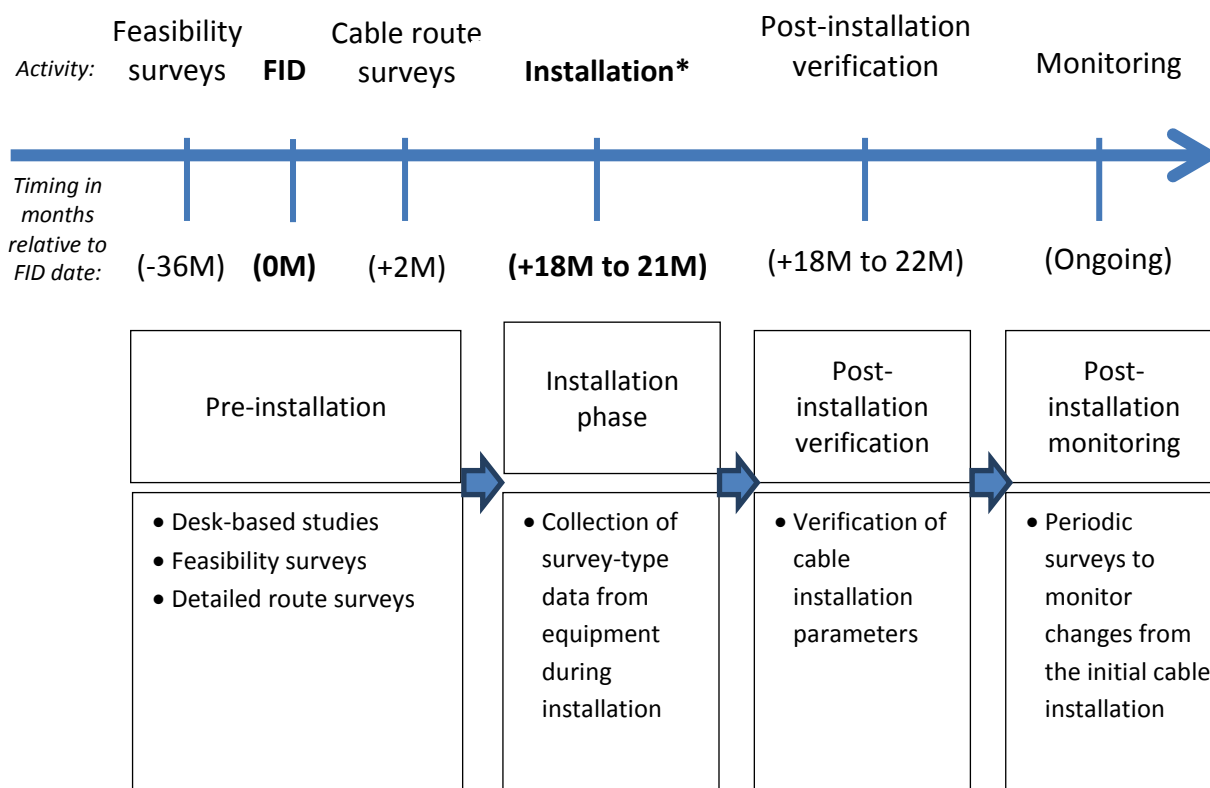
**Figure 1: Offshore wind transmission assets.**

## 1.2 Marine surveys in the context of offshore wind farm export cables

Marine survey data is used to inform cable routing, the methodology for laying and burying cables, and substation and landfall site selection. The choice of onshore substation site and landfall are not directly considered in this report, although these choices will affect decisions relating to the subsea cable.

A typical process is shown in Figure 2. The process timing is shown in months before and after the project's Final Investment Decision (FID). Timings are indicative and vary between projects. The surveying aspects of projects involving export cables have been broken down into four stages, as shown in Figure 2.

The pre-installation stage includes research and surveys to determine seabed conditions, which will inform cable routing and installation. During cable installation and burial, data is collected. Following cable lay and/or burial, post-installation verification surveys are often undertaken. Finally, surveys are required for ongoing monitoring of the seabed along the cable route, to ensure that the cable remains protected. Each phase, shown below, is explained in more detail through the course of this document.



\*Assumes single-season cable installation. Sometimes installation may be carried out across more than one season.

**Figure 2: Surveying phases in relation to key project dates.**

Developers have the challenge of balancing the benefits and risks of investment. Prior to FID, the appetite for investment is limited, as the project is not certain to proceed. Developers often seek to manage risk by minimising investment in the early project development phase. This limited funding affects investment in the initial surveys. However, experience of past installation issues serves to underline the importance of effective and early survey planning.

Areas with significant opportunity for risk mitigation are detailed below.

Permits and consents are sought early in the process, often prior to FID. The finance available for early pre-FID surveys is often limited. However, inadequately informed permits and consent plans can constrain the cable installation when it is subsequently designed based on more detailed survey information. These constraints increase the risk to the project and contractor, making installation contracts more complex and costly. Conducting surveys earlier in the process can help to mitigate these risks. In light of these considerations, best practice is to use a risk-based approach to target resource to areas where risk can be most easily mitigated.

Once the FID is made, detailed route engineering can be undertaken and the installation of the cable will typically take place after 18 months or more. Dialogue between all parties is critical to facilitate the process. For example, it is useful for cable installation contractors to speak to surveyors to ensure they receive the information they need. Involving installation contractors early, at the survey stage, will make the

information handover easier. It can also help to incorporate lessons learnt from previous installations in the specification of the planning and survey data collection phases. However, there are still some challenges to be resolved regarding the early involvement of installation contractors while maintaining a fair tendering process to all contractors.

## **2 GUIDANCE COMMON TO DIFFERENT STAGES OF MARINE SURVEY**

This section draws out considerations that apply to all the types of survey described in sections 3 to 7. It briefly covers: key specification and procurement documents and data management and deliverables.

Sections 3 to 6 refer to particular survey methods that are typical of each stage of the export cable installation process. The range of survey methods is illustrated in the glossary (Appendix A) of this report.

This report does not provide guidance on which method should be used, as this is specific to each project, due to the nature of the seabed, water depth, environmental constraints and the continual development of survey tools.

### **2.1 Specification and procurement**

It is strongly recommended that the key stakeholders who need to use the resulting survey data are consulted on their requirements, as surveys can often fulfil multiple purposes. This includes providing relevant information for export cable protection planning, environmental and marine consents. This is a key point – providing insufficient data to key stakeholders will lead to a greater number of assumptions, higher estimated costs and requests for additional surveys that could have been acquired more cost effectively at the initial stage.

A specification document should be produced to ensure that the survey requirements, in terms of the objectives, the equipment to be used and the operating parameters, are understood by all parties. It is also useful to engage with contractors, inviting them to make suggestions or offer alternatives in order to capture latest methodologies and equipment capabilities.

A scope of work document should be written, clearly stating the extent of each survey and any assets to be inspected. A clear scope of work, supported by a detailed desk study, will allow survey contractors to specify appropriate techniques for pre-installation surveys in order to meet the objectives.

An invitation to tender must be produced by the developer, which provides information to survey contractors on the work required. Interested contractors will tender a bid for the work. Each bid will then be subject to a technical and commercial evaluation to ensure it conforms to the scope of work and specification documents.

Sufficient time must be allowed to secure the requisite survey licences. Intrusive surveys on the seabed within Crown Estate demise require a separate licence from the

Crown Estate, in addition to any the relevant Marine Authority may grant.

## **2.2 Data management and deliverables**

Comprehensive reports should be produced detailing the results of the surveys. An experienced specialist third party representative should be on board the survey vessel to ensure that both the data acquisition and interpretation are accurate and give confidence in the survey results. This applies to all surveys to ensure consistency.

Site investigation and surveys will produce significant volumes of data, so it is critical that an appropriate data management system is in place to allow rapid interrogation and extraction of relevant data. Reports and results should be made available to all stakeholders in hard copy and common electronic formats (such as MS Word, MS Excel, GIS, DWG, PDF, AGS). Most survey contractors will normally produce survey reports in a PDF format.

With the prevalence of Geographical Information System (GIS) software, it is strongly recommended that the survey specification requires that all data be issued in a suitable electronic format. Two key standards for the dissemination of survey data are the Marine Environmental Data and Information Network (MEDIN) data standards<sup>ii</sup> and the Association of Geotechnical and Geoenvironmental Specialists (AGS)<sup>iii</sup> data transfer formats.

A key feature, often overlooked, is the specification of a fixed coordinate reference system (CRS) and datum level. Any appropriate CRS can be used, however, once selected, it is recommended that all stakeholders in the development are required to report all data against this CRS. Particular care is required at the interface between the shallow water zone and beach landing, where onshore (Ordnance Survey) and offshore coordinate systems will need to correctly interface. For example, where applicable, survey data may be referenced against Low Astronomical Tide by using the Vertical Offshore Reference Frames (VORF) model<sup>iv</sup>, which addresses both shore interfaces and different vertical datums.

As for the CRS, the vertical datum and method for tidal correction should be specified and fixed for the project. This will allow better comparisons of different datasets. However, where possible, a fixed installation or seabed feature should also be surveyed during operations for a reference check.

## **3 PRE-INSTALLATION**

### **3.1 Introduction**

A pre-installation survey is an important pre-requisite to any export cable design or installation. Without a thorough understanding of the environmental and geological conditions and local sediment transport systems, it will not be possible to design a cable route that is both practical and economic to install.

A number of stakeholders, such as cable route engineers, installation contractors, cable burial contractors and consenting bodies, will use the pre-installation survey data for a

wide range of purposes during the development process.

Key uses of the data include to:

- Identify an area where the cable can be installed;
- Develop a baseline of the environmental conditions;
- Design a final cable route;
- Specify the cable protection requirements;
- Identify particular hazards along the cable route;
- Identify the installation methods that can be used;
- Predict performance of cable burial tools;
- Contribute to modelling potential sediment transport at site;
- Predict long-term changes to the seabed, such as moving sandwaves, that might need to be monitored.

Information is required on the morphology of the seabed; for example slopes, hollows, scarps, sand waves and sandbanks need to be mapped. Any debris, boulders and particularly unexploded ordnance (UXO) need to be identified. The properties of the shallow geology need to be identified to inform the planning of cable protection, which is typically achieved by cable burial.

The pre-installation surveys will comprise several phases of survey work, as shown in Figure 3. The approach needs to be one of gradually increasing detail and scope as the route corridor is narrowed to a finalised alignment.

For cable route engineering, a geophysical and geotechnical survey will be required. The amount of data collected at any stage will vary depending on the complexity of the site, the availability of historical data from nearby infrastructure and the resources of the developer.

The term pre-installation survey will have a different meaning to different stakeholders, according to their focus on different transmission assets (such as the cable or the turbine and substation foundations) and on different aspects of the development (such as environmental impact or cable route engineering).

This section focuses on surveys for route consenting and engineering, rather than those immediately prior to cables being laid. Typically, these surveys must be performed several years prior to installation. Export cables vary in length but typical survey durations last weeks rather than days, so adequate time needs to be allocated for them.

Figure 3 shows key phases of the marine surveys required to prepare for cable installation. The remainder of this section covers the four headings shown in blue in Figure 3, before describing how the survey data is applied to pre-installation engineering. Finally, it outlines the environmental surveying stages.

Desktop studies	Feasibility survey	Cable route survey	Near shore and landfall surveys
<ul style="list-style-type: none"> <li>○ Collect available data from public and client sources</li> <li>○ Generate 'ground model'</li> <li>○ Design specification for preliminary surveys</li> </ul> <p><b>Duration = three months</b></p>	<ul style="list-style-type: none"> <li>○ Bathymetry</li> <li>○ Side-scan sonar</li> <li>○ Sub-bottom profiling</li> <li>○ Possible UXO clearance for sampling locations</li> <li>○ Seabed sampling/CPT</li> <li>○ Magnetometer</li> <li>○ Environmental sampling and testing</li> <li>○ Laboratory analysis</li> <li>○ Update 'ground model' and propose scope of work for detailed survey</li> </ul> <p><b>Duration = three months</b></p>	<ul style="list-style-type: none"> <li>○ As for feasibility survey but focused on selected route</li> <li>○ Detailed UXO survey</li> <li>○ Detailed surveys of crossing points</li> <li>○ Update 'ground model'</li> </ul> <p><b>Duration = six months</b></p>	<ul style="list-style-type: none"> <li>○ Bathymetry</li> <li>○ Side-scan sonar</li> <li>○ Sub-bottom profiling</li> <li>○ Possible unexploded ordnance (UXO) clearance</li> <li>○ Seabed sampling/CPT and/or deeper boreholes for HDD design</li> <li>○ Environmental and geotechnical laboratory testing</li> <li>○ Update 'ground model'</li> </ul> <p><b>Duration = three months</b></p>

Figure 3: Pre-installation survey phases.

### 3.2 Desktop studies

The desktop studies aim to identify a corridor within which a suitable export route may be found, from the wind farm to the landfall, which can be put forward for consent. In addition, a desktop study will broadly identify viable route options and will help to target the first phase of the subsequent marine surveys. Planning and specification requires an understanding of the route and the possible hazards likely to exist on, or in, the seabed that could affect the proposed infrastructure. Desk studies are an extremely important aspect of any pre-installation work and are the lowest cost activity in any development. They can be used to significantly reduce the amount of field work required. Further sources of information may be found in Appendix B<sup>v</sup>.

The seabed around the UK has been mapped in detail by the British Geological Survey (BGS), numerous oil and gas companies and other infrastructure developers. The BGS has compiled borehole, geophysical and geotechnical datasets into a comprehensive set of maps and offshore regional geology guides. In addition, a number of consultancies specialising in offshore geotechnics maintain databases of survey information. Collaboration between developers in adjacent locations and sharing of information will also lead to improved knowledge to support decision-making at

desktop study stage. Irrespective of its source, any acquired data should be reviewed by experienced personnel to assess its validity with respect to a specific project.

If a cable is to be installed in a location where no previous survey has been undertaken and the publicly available data is inconclusive, the desktop study may specify an early regional scoping survey. This can be used to identify a suitable area to investigate further for cable routing.

From this initial phase, it is important to collate all relevant data to create a ground model, which is a repository for all seabed-related data, often using common geospatial references to facilitate comparison of different data sets. This will inform cable routing and installation, and identify data gaps to inform the scoping of future surveys. This model must be set up to enable data to be added and updates made throughout the cable route project.

Shipping and fishing normally represent the greatest risk to submarine cables. The desktop study will provide information on the intensity and type of fishing and the navigation risks to the cable. It is important that this data is carefully analysed to assess the impact the construction of the wind farm will have in changing shipping routes and fishing areas, particularly if this results in concentrating shipping across the export cable. In a risk-based approach, such risks will be considered in combination with seabed information to determine the minimum burial depth<sup>3</sup> required.

Ongoing stakeholder engagement and consultation is important, even at route design stage. Fishermen have extensive seabed knowledge and can provide valuable information to complement survey data. Refer to Appendix B for Guidance on Fisheries liaison.<sup>vi</sup>

### 3.3 Feasibility survey

The desktop study normally specifies an initial feasibility survey, which is used to fill in any gaps of knowledge that the desk study cannot answer. Sufficient information is required to identify a suitable route for initial planning and to secure the appropriate consents.

A preliminary route survey will be performed with the likely route contained in a wide corridor. Often up to 1km wide, this corridor must allow for deviation of the design route in order to avoid any identified hazards, while remaining within the surveyed area. However, narrower corridors are sometimes surveyed in shallow water, or as landfall is approached.

The feasibility survey will normally be dominated by geophysical methods to characterise the seabed, seabed mobility and shallow geology across the whole area. This will allow features and sedimentary units to be mapped.

The methodologies include:

- Bathymetry (ideally over a number of years);

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<sup>3</sup> Depth of burial is normally defined as the distance from the seabed level to the top of the cable.

- Side-scan sonar survey report;
- Echo sounder survey report;
- Acoustic sub-bottom profile survey;
- Magnetometer survey;
- Drop-down video.

Geotechnical methods are normally limited to drop cores or grab samples, depending on the seabed. Further information on different survey types is provided in Appendix A.

### 3.4 Cable route survey

The feasibility survey will have provided sufficient information to gain consent for the export route corridor, identify any large hazards to cable installation and provide an initial design route.

A further survey stage is required to identify and refine the cable route and to provide installation contractors with the information they require to plan and cost the installation works. This cable route survey includes environmental, geophysical and geotechnical testing and sampling, including (but not limited to):

- High-resolution bathymetry;
- Side-scan sonar;
- Sub-bottom profiling;
- Cone penetration testing;
- Vibrocore sampling;
- Grab sampling;
- Drop-down video.

The geophysical survey techniques will be performed along a narrower corridor than the feasibility survey, in the range of  $\pm 200\text{m}$  to  $500\text{m}$  either side of the proposed route centreline. Higher resolution methods will be used to identify finer detail. Similarly to the feasibility survey, narrower corridors are sometimes surveyed in shallow water, or as landfall is approached.

The choice of geophysical survey methods and the frequency of sampling or line spacing depend on several factors. These include the expected geology, seabed variation, water depth and the purpose of the survey, whether for preliminary route selection or detailed alignment engineering.

The depth of the geotechnical survey data required will depend on the anticipated or prescribed burial depth of the cable. Typically, this has been up to  $3\text{m}$  below the seabed and so the depth of interest for the survey will be to approximately  $5\text{m}$  to  $10\text{m}$  below the seabed. However, a trend towards using risk-based methods and ongoing research on risks is leading to reduced burial depth requirements, meaning that geotechnical investigations along the cable route will usually not need to be deeper than  $5\text{m}$ . In the near shore area, where deep horizontal directional drilling (HDD) may be used, the depth of interest may increase.

Geotechnical sample spacing should be informed by the geophysical information. A targeted approach enables sampling frequency to be increased where concerns or changes in the seabed conditions have been observed in earlier surveys. Larger spacing between samples may be used in areas where the previous information indicates a homogeneous seabed.

Special attention must also be given to cable and pipeline crossings. A detailed survey will be needed to accurately locate the crossing point and this may require magnetometer and sub-bottom profiling if the cable or pipeline is buried. It is highly likely that a remotely operated underwater vehicle (ROV) survey using cable/pipe trackers will be required by existing and future asset owners. Although this may be carried out at a later date to support detailed crossing engineering.

Following the field work there is generally a programme of laboratory testing on the recovered geotechnical samples. This will determine seabed stability and strength and allow burial and back-fill assessments to be performed. In addition, thermal and electrical conductivity testing will be performed on the soil samples, which can be useful to model or interpret cable temperatures.

Samples taken from the seabed must either be analysed and tested offshore or returned to an accredited laboratory onshore. A specialist must conduct all testing in order to obtain the soil properties for burial assessment, backfill, settlement and scour. A typical lab test schedule may take six weeks from receipt by a lab to producing the report but may take up to twelve weeks, depending on the testing programme. Testing is performed to international standards. Refer to Appendix B for further information<sup>vii</sup>.

#### **3.4.1 UXO**

In some areas, there may be a risk of encountering unexploded ordnance (UXO) left by historical military activity, deposited from wrecks or uncovered by dynamic seabed activity. Prior to performing an expensive and lengthy field survey, a UXO desktop study threat and risk assessment should be undertaken by specialists to assess the level of risk, advise on any mitigation measures to reduce the threat, and also to identify the nature of the UXO and the likelihood that it is either lying on the seabed or buried. If the desk study identifies that the site, or part of it, may be a risk to safety during survey, installation or operations and maintenance (O&M), then a specific UXO survey should be performed. Any targets found during this survey should then be avoided or investigated further before being discounted or mitigated.

The UXO survey should be performed once the final route has been determined. A detailed UXO survey will require multiple magnetometers and will necessitate much closer line spacing than a conventional geophysical survey.

These are highly specialised surveys, which can require a significant amount of time for data analysis and processing. The output will normally be a list of suspect targets that then require further investigation by divers or ROV. The impact of UXO on route selection should not be underestimated, as this may influence installation works considerably.

Some contractors require a UXO clearance certificate prior to conducting geotechnical sampling. Others only require these certificates for sites where jack-up barges might be used.

### 3.5 Near shore and landfall surveys

Some past projects have encountered difficulties due to a lack of, or inadequate, near shore and landfall surveys. Both are key areas. Typically, an offshore survey vessel can survey from offshore to the 10m Lowest Astronomical Tide (LAT) contour, but in shallower water and at landfall a separate survey vessel or equipment is required. These shallow water/landfall survey methods are captured in a number of existing documents – refer to Appendix B for further information<sup>viii</sup>.

#### 3.5.1 Near shore

In the shallow water and/or inter-tidal zone, seabed surveys will be performed using shallow draught vessels. Airborne Lidar can also be an option for measuring the seabed topography, if water clarity is good enough, although it has limited applications for seabed topography in the UK due to visibility issues. Survey lines also need to be closer together to get full coverage of the seabed in shallow areas. Resistivity and refraction surveying techniques are used to obtain information on shallow geology in very shallow water environments where some sub-bottom profilers are not suitable.

For geotechnical sampling, it may be necessary to mobilise marine drilling equipment on a jack-up or floating barge to collect samples for the horizontal directional drilling (HDD) profile, as data down to approximately 30m below seabed may be required in some HDD projects. This can be expensive and so these types of survey tend to be done once the cable route is finalised and the most relevant location for drilling is known. Shallow sampling can be taken using shallow draught vessels and surveying during high water periods, or by land-based equipment traversing the beach at low tide.

#### 3.5.2 Cable landfall

Once the landfall point is selected an additional land-based geophysical survey and geotechnical investigation will be required. Land-based geophysical surveys can include seismic reflection or refraction surveys, as well as surveys to locate the presence of existing services in the vicinity of the works. The depth of investigation will depend upon the landfall installation method.

If HDD is the chosen installation method then it is likely that seismic refraction/reflection, geotechnical drilling and/or deep push cone penetration testing will be required. This is to allow the geology of the area and the implications on the ground conditions for HDD installation to be fully understood.

There may also be a requirement for land-based UXO magnetometry if a potential risk has been identified in the desktop UXO threat and risk assessment.

Landfall and inter-tidal areas can be environmentally sensitive and can require specific permitting, which requires planning and can sometimes restrict the time periods in which survey and cable installation work can be carried out.

### 3.6 Pre-installation engineering

Each stage of survey data will be used to refine the proposed cable route down to a final alignment, which may be further refined with input from the cable installation contractor.

Offshore wind farm export cables are routinely buried in order to protect them from third party damage (primarily from fishing and anchoring activities). Recent practice is for survey data to be used to inform a cable burial risk assessment to determine recommended burial depths and reduce any risk of cable damage to an acceptable level. A number of organisations have developed proprietary or published risk-based methods to design burial protection in relation to environment and third party risks in specific areas (e.g. taking account of the intensity of marine traffic along the proposed cable route). Further sources of information on risks assessments may be found in Appendix B.<sup>i</sup>

Typically, the installer will assess the specific conditions of the project, the seabed conditions and the required burial depths to propose the preferred approach and tools to be used for cable burial. The survey information enables appropriately specified equipment to be used from the start, saving time and money. Further information on cable installation can be found in the accompanying document, *'Overview of the offshore transmission cable installation process in the UK'*.

The amount and quality of the available seabed information is an important factor in the success of the cable installation, as this is used to plan operations, select installation tools and manage risks related to the cable route and seabed conditions. However, due to variations in seabed and soil conditions, and the discrete nature of geotechnical sampling, the information on seabed conditions can only provide a high level of confidence, not 100% certainty, about conditions along the entire cable route.

Each export cable is unique due to its location, so the installation solution must be unique to each cable. To determine the appropriate installation solution, consideration should be given to the specifics of the burial requirements and the cable protection technologies available for such a project (see Figure 4).

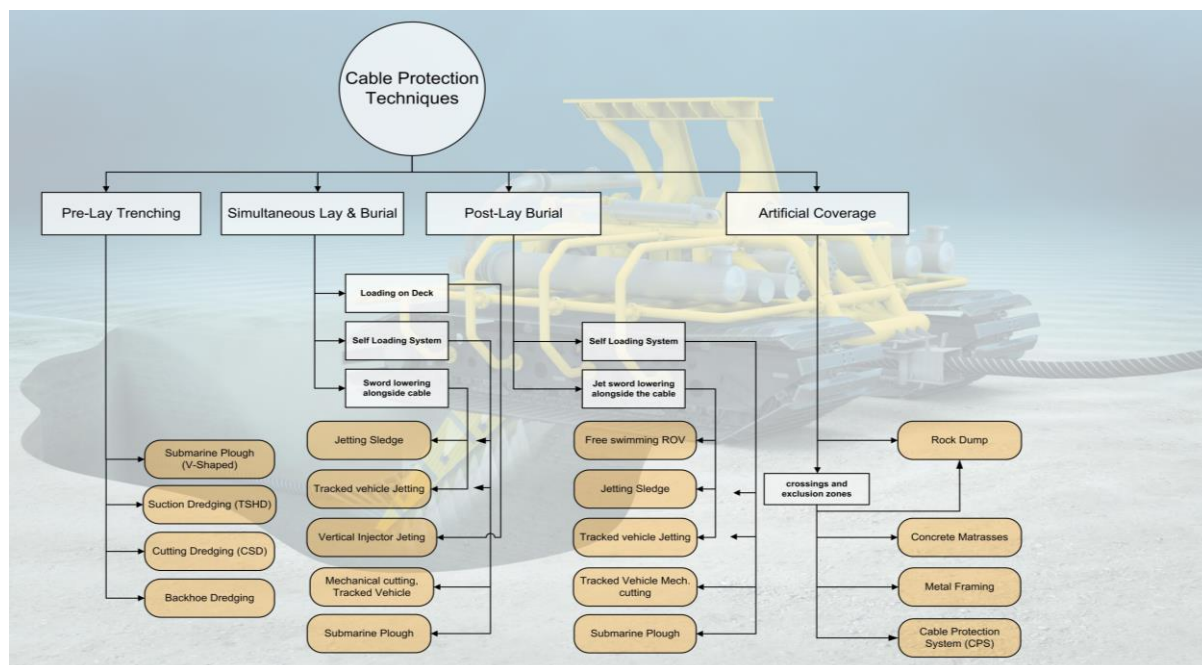


Figure 4: Cable protection techniques, courtesy of VBMS.

### 3.7 Environmental studies and surveys

There are some synergies between cable route engineering and environmental surveys, although these may not always be carried out together due to differences in the types of survey and timing required.

Environmental surveys tend to be completed at an early stage, with baseline data collected before any other operation is conducted on site. This is because environmental information is required for various consents. The information required for an environmental statement includes studies on noise, pollution, sediment movement, visual habitat surveys etc.

Pre-installation desktop studies and field sampling surveys are essential in understanding and assessing potential environmental impacts of cable installation as part of the statutory Environmental Impact Assessment (EIA). In addition, there may also be a requirement for archaeological surveys.

The results of these surveys are used to inform mitigation measures against any significant adverse effects. Typically, desktop studies will identify the extents and boundaries of any designated nature conservation areas, which may be affected directly (by cable installation) or indirectly (through the movement and deposition of sediment plumes).

Following the initial desktop review, and drawing upon the results of stakeholder consultation, sub-tidal and inter-tidal benthic ecology site surveys must be undertaken. These will 'ground-truth'<sup>4</sup> the geophysical data and collect information on the distribution of habitats, species and sediment chemistry in the cable corridor.

<sup>4</sup> Ground-truthing is the verification of seabed soil types.

The installation and operation of submarine cables can have certain consequences for marine, environmental, and heritage receptors, which must be considered and assessed as part of statutory consenting processes. These consequences are typically identified during initial stakeholder consultation and are used to inform the scope of pre-installation desktop studies and sampling campaigns. Guidance on the application of best environmental practice for cable laying and operation can be found in Appendix B<sup>ix</sup>.

## 4 INSTALLATION PHASE

As outlined in section 3.6, offshore wind farm export cables are routinely buried to protect them from third party damage. Typically, the installer will propose the approach and tools required for cable burial, having assessed the conditions specific to the project, informed by survey data.

A clear scope of work, supported by adequate route survey soils and geophysical data, is key to enabling installation contractors to cost and manage risks in a project. Good survey information on seabed conditions will help to reduce uncertainty and the risks associated with the installation bid and minimise the risk of subsequent cost overruns due to unforeseen ground conditions.

Further information on cable installation can be found in the accompanying document, *'Overview of the offshore transmission cable installation process in the UK'*, and its associated list of further sources of information.

Surveys are an integral part of any installation activity. Survey-type data can also be collected immediately prior to, and during, installation. This is outlined below.

### 4.1 Data collected immediately prior to installation

Pre-lay surveys are typically performed immediately prior to installation by the installer's survey contractor. Immediately prior to installation a pre-lay grapnel run or remotely operated underwater vehicle (ROV) visual survey may be completed to check for hazards. ROV-mounted sub-bottom profilers may also be used to check for shallow-buried boulders or obstructions. Pre-lay surveys should be performed by full-spec survey ROVs with multi-beam echo sounders (MBES) and cable trackers. Some equipment may have difficulty operating in shallow water, in which case pre-lay surveys for shallow water areas may rely on geophysical data.

### 4.2 Data collected during burial

Cable installation operations need to be supported by survey information to understand what the installation contractor has accomplished. Documentation needs to be produced to measure and communicate this information to the contractor and project developer.

Each installation approach, along with the chosen equipment, will have a specific set of measurements that must be collected during the installation phase:

- a) For pre-lay trenching, a survey of the trench will be needed, as the equipment used will not typically collect sufficient 'as-trenched' survey data. In most cases a high-resolution multi-beam survey will be carried out by a pre-lay trenching vessel or separate survey vessel. The processed output can be fed into the survey package for the cable lay vessel and will show the dimensions and position of the trench;
- b) During simultaneous lay and burial, the trenching equipment will (alongside operational data required for the actual burial) record position coordinates for the tool and cable (x,y data). Jetting sledges, vertical injectors and ploughs can also measure the depth (z component) of the cable's position. This data is logged and displayed on the survey screens of the installation vessel in real-time. Where jetting or mechanical cutting trenchers are used, the depth of burial cannot be measured during trenching and will need to be established post-installation. This can be achieved using cable tracking sensors on the trenching tool, or through a separate campaign using a vessel equipped with cable tracking sensors on a sledge or ROV;
- c) In the case of post-lay burial, the position coordinates (x,y data) of the cable, as well as cable slack information, will be available to the trenching operators in real-time to track and bury cable. For depth of burial measurement by various tools, the same applies as described under b);
- d) If the cable is protected by artificial coverage, such as concrete mattresses, a post-lay burial survey will be required in all cases. The combined data from laying operations and post-lay/burial multi-beam surveys can be processed to produce charts showing depth of burial and/or level of protection.

Other data collected during installation may include non-survey type data such as cable handling and tension data.

## 5 POST-INSTALLATION VERIFICATION

### 5.1 Purpose of post-installation surveys

Surveys are an integral part of installation activity and this extends to the post-installation phase of the project. To understand what the installation contractor has accomplished, documentation needs to be produced to measure, communicate and provide this information to the contractor and project developer.

Post-installation surveys are carried out to verify that the transmission cable is buried to the required depth, in the correct position and that there are no areas where the cable may be overstressed, exposed or present a snagging hazard. Often no additional environmental consents beyond those for the installation are required at this stage, if the operations fall within the consented period. Licences issued by the relevant Marine Authority may also require post-construction surveys.

Depending on water depth and burial requirements, a variety of survey tools are

available. The surveys may be carried out by towed sensors, ROVs or divers.

There are two approaches to cable installation: either to lay it in one operation and to subsequently bury it, or to do both in a single operation. The former approach entails an additional ‘as-laid’ survey, outlined below, which is not required for ‘as-built’ installations.

‘As-laid’ (if appropriate)	‘As-built’
<ul style="list-style-type: none"> <li>Where the cable is laid and buried separately.</li> <li>Aims to identify the laying position and condition of the cable on the seabed.</li> </ul>	<ul style="list-style-type: none"> <li>After cable is laid and buried, whether by simultaneous lay and burial or separate operation.</li> <li>Aims to determine depth of burial.</li> </ul>

**Figure 5: Post-installation surveys.**

## 5.2 ‘As-laid’ survey

Where burial is carried out after the cable is laid (not simultaneously), an ‘as-laid’ survey is conducted after the cable is laid on the seabed. The as-laid survey is to ensure that the cable has been laid within the specified corridor and the cable is suitable for burial, where applicable, with no bights of cable or kinks that may interfere with the burial tool and potentially damage the cable.

Four methods of inspection may be used to verify the cable condition:

- Acoustic inspection using towed sensors (or vessel-mounted sensors for shallow water), typically side-scan sonar and/or a swathe bathymetry system.
- Acoustic inspection using 3D imaging sonar as the cable is laid in position.
- ROV inspection, where an ROV is deployed from the survey vessel and visually follows the cable over the seabed. An ROV system may have a cable tracker fitted to assist in poor visibility conditions.
- Diver inspection, where a diver is deployed to swim along the cable to both visually and physically inspect the cable on the seabed. This mode of inspection is constrained by water depth, currents, and tides and would normally be used only if necessary for visual inspection of areas that are inaccessible by ROV. Diving is generally not the first option considered as the alternatives may present lower health and safety risks.

The sensors, ROV and divers should all be tracked using an acoustic tracking system. This provides an accurate geographical position for the as-laid cable, except in shallow water work, where the sensors may be fitted directly to the survey vessel. The data acquired by these sensors can be plotted directly on charts and used during the trenching operation as the defined cable position.

The latest 3D imaging sonar systems and software can produce an image of the cable as it is being laid. This allows for continuous monitoring of the cable during the lay process. This data can be recorded and then used to produce the as-laid survey.

Therefore, there is sometimes an option to combine the installation monitoring and post-lay survey as the cable is laid. In certain oil and gas operations, this data is reviewed online and then recorded and accepted as the 'as-laid' survey positioning information. This method has started to be used by developers for inter-array cable installation. It is not yet the generally accepted process in the offshore wind industry, but it does have the potential to improve the efficiency and accuracy of the installation operation and, therefore, help to reduce costs.

### 5.3 'As-built' or verification survey

The as-built survey is carried out after the cable has been laid and buried. The purpose of the survey is to determine that the cable burial depth meets the specification defined by the developer. Depth of burial data may alternatively be determined directly by burial tool measurements. The depth from the seabed to the top of the cable should be specified in the detailed design and burial specification documents, which will have taken into account the environmental and engineering constraints.

It is important that this post-installation survey is carried out to a high standard and to a consistent datum. This will provide a baseline dataset, both of the position and the depth of burial, against which future surveys will be measured.

Information on cable routes and any sections of exposed cables should be communicated to fishing and/or shipping companies via the Kingfisher Information Systems - Offshore Renewables Cables Association<sup>x</sup> – and kept up-to-date.

The following methods may be used to determine the cable burial depth:

- a) Acoustic inspection using towed sensors (or vessel-mounted sensors for shallow water), typically a sub-bottom profiler or pinger. This equipment is deployed on survey lines perpendicular or angled to the cable lay direction. Survey line separation should be determined by the perceived risk of insufficient or shallow burial caused by variations in seabed relief or changes in substrate. Where the seabed has few features with minimal gradient, a separation of 50m may be appropriate. Where the cable crosses sand waves or depressions this separation can be reduced to identify burial depth at the sand wave crests and troughs. The materials used in the cable construction and the seabed substrate type will determine how suitable this method is. Deeper burial and coarser sediment types result in increased energy diffraction and reduced cable detection capability. Fine-tuning of the sub-bottom profiler/pinger may be required and different frequencies employed to get the best return from the cable.
- b) ROV fitted with electromagnetic, magnetometry or swath sub-bottom imaging equipment.
- c) Multi-beam echo sounder (MBES) survey. Where rock placement is used or mattresses are deployed over a surface laid cable then an MBES survey may be sufficient to determine the depth of burial.

- d) Diver inspection. A diver is deployed to swim to a given position along the cable route and pushes a probe into the seabed to detect the cable and determine depth of burial.

The resulting depth of burial information can help to quantify the risk of cable damage from fishing, anchoring or other third party activity.

Where the survey results indicate a cable has not been buried according to the required specification, further studies may be undertaken to determine the implications and associated risks. This may be increased scour risk, exposure to fishing activity, snagging etc. and will indicate whether remediation is required to further protect the cable.

Survey information is crucial to cable installation and problems in this field can result in significant costs. Historically, legal action has occurred on some projects as a result of survey data being withheld, insufficient detail being provided or from misunderstandings between contracting parties. In this regard an open, detailed and collaborative project tends to reduce risks in the long-term.

## 6 SUMMARY OF SURVEYS TYPICALLY REQUESTED AT OFTO ASSET HANDOVER

In Great Britain, under the regulatory regime's developer-build model, new offshore transmission assets are competitively tendered. The final owner and licence-holder is known as an Offshore Transmission Owner (OFTO).

The greater confidence the Offshore Transmission Owner (OFTO) has in the as-built verification survey, the more comfortable it will be in taking on the transmission cable. Verification that the cable is buried in-line with the burial specification will also provide the insurers with more confidence and enable risks to be managed and appropriate operations and maintenance plans specified.

In addition to the specific cable surveys described in this section, the following documents (data, figures, reports) are typically requested by the OFTO (or their delegated representative) to assess long-term burial and exposure risks:

- Desktop study reports describing the geology, morphology and history of the site;
- Meteorological and ocean data;
- Obstruction reports;
- UXO threat report;
- Geotechnical reports describing the properties of the materials in the route corridor in four dimensions;
- Bathymetry data (preferably over a number of years);
- Seabed mobility assessments;
- Coastal/landfall reports;

- Scour potential reports;
- Corridor route assessment reports ;
- Shipping and fishing activity reports;
- Cable strike/pull risk assessments;
- Cable burial reports;
- Any remediation proposals.

A risk-based assessment of the burial depth, likely mobility of the seabed and risks associated with human activities are likely to dictate the frequency and location of monitoring surveys during the operational period of the asset. In addition, these surveys can help to quantify operational and maintenance risks to the cable.

## **7 POST-INSTALLATION MONITORING**

The licence issued by the relevant Marine Authority may include post-installation survey requirements, typically in the first few years post-installation. Also, where the cable installation design cannot fully mitigate the risk of cable exposure, post-installation monitoring surveys may be carried out periodically after installation by the developer or the OFTO, according to the ownership at the time.

Where practical, Marine Authority requirements and other project or environmental monitoring requirements should be carried out in the same survey operation for efficiency.

The survey strategy should be planned with good consent liaison and management, and by using all relevant data (within a ground model) to identify areas of potential risk.

The purpose of a post-installation survey is multi-fold, and includes the following:

- To assess the burial status of the cable and determine cable exposure/ free-spanning or monitor existing exposures / spans;
- To identify cable damage;
- To assess the burial depth of the cable;
- To assess scour in the vicinity of the substation;
- To assess mobile sediment movement and sediment level changes (scour / erosion / accretion) from previous surveys;
- To update the ground model to review sediment level changes and trends;
- To assess the condition of existing remedial works;
- To identify hazards / potential hazards in the vicinity of the cable / offshore substation;
- To monitor any previously-identified sensitive habitats;
- To monitor any previously-identified areas of archaeological interest;
- To inform any maintenance works required;

- To provide seabed information in order to assess any third party compensation claims;
- To deliver consent compliance<sup>5</sup>;
- To deliver third party pipeline, cable or other crossing agreement compliance.

Survey frequency and methodology is site-specific and should be developed to ensure consent compliance and best monitor areas of perceived risk along the export cable and in the vicinity of the offshore substation. These may be on the basis of a regular inspection schedule or a variable schedule based on a perceived risk or threat. In the event of a risk-based programme the frequency of survey will vary depending on the risk factors. These may be landfall, shipping channels, fishing intensity, mobile seabed (as a result of strong currents and tides, or shallow water areas) and scour (for example occurring around the cable or edges of concrete mattress or rock installations). The monitoring programme should implement the knowledge and experience gained from previous marine and engineering surveys.

The ground model should be updated following data collection, with a re-assessment of risk and future survey strategy. It is also important that asset owners update fishing and shipping companies with any new information regarding cable routes or sections of exposed cables.

A post-installation geophysical survey will typically cover a corridor between 50m and 100m wide, centred on the export cable position, extending from the transition joint bay (onshore) to the offshore substation. Where cable pipeline crossings exist, the survey corridor may be increased, as required, to between 100m and 200m in width.

When planning a post-installation survey, reference should be made to the following information:

- Metocean data;
- Trenching report and burial depth;
- Existing ground model;
- Geological and geotechnical risk register;
- Existing cable risk assessment (if cable is changing ownership, via OFTO, it would be prudent to conduct an independent cable risk assessment, based on a review of the data provided);
- Documentation of existing remedial works;
- Time-varying bathymetric model (sediment mobility);
- Consent conditions and obligations.

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<sup>5</sup> Note: The requirement for a post-installation survey of the export cable routes is embedded in the marine licences for offshore wind farm projects. Survey requirements may also be detailed in the river works licence or harbour works licence, where a harbour or Port Authority has jurisdiction. Licence conditions may vary between projects, but typically require that bathymetric surveys are undertaken twice a year (six monthly intervals) for a period of three years following export cable installation and burial, the first survey being undertaken within six months of export cable installation and burial, and thereafter following a major storm event (defined as a one in ten wave event at the site). The consent requirements typically do not define the extent of survey coverage, which should be considered on a case-by-case basis. Typically, consents have not required monitoring over the lifetime of a project.

Surveys should be concentrated in areas where the perceived risk to the cable is high, with less emphasis in areas of low risk and stable seabed where the required depth of burial has been achieved. Previous surveys may have identified areas of relatively stable seabed and specific areas of potential risk to the export cable, including but not limited to:

- Areas of reduced sediment cover/scour;
- Cable exposure;
- Cable free-spanning;
- Hazards in vicinity of export cable/substation – debris, rock outcrop, boulders etc.

Areas of high wave action and strong tidal current regimes, mobile sediments and migrating bedforms are common in near shore environments in UK waters. Such areas present a potential risk to the cable of exposure and damage.

Monitoring surveys will generally be undertaken using MBES and high resolution side-scan sonar to identify sediment level changes, cable exposure and seabed obstructions. If significant sediment scour is identified, then follow-up ROV-based surveys may also be required. These will determine the depth of burial of the cable to inform remedial work requirements such as re-burial, rock placement or mattresses. If cable exposure is identified or damage suspected, then a follow-up visual inspection using ROV-mounted video may be undertaken.

Areas of cable exposure will be subject to increased risk of cable damage, primarily from anchoring and fishing activity. If towed fishing gear comes in to contact with a cable then this can cause potential risks to the safety of those on board, as well as damage to the cable and fishing gear. Therefore, fishing communities are especially concerned about possible cable exposure, which represents a fastening hazard.

The asset owner has a duty of care to notify interested parties, including the fishing community, of any identified seabed hazards via a Notice to Mariners.

## Appendix A – Glossary

Name	Definition
Acoustic positioning	An acoustic positioning system is used for the tracking and navigation of underwater vehicles or divers. It does this by using acoustic distance and/or direction measurements, and subsequent position triangulation. These compute the underwater position in relation to the vessel, which in turn is located by GPS.
Acoustic survey	Typically, a side-scan sonar system (SSS) is utilised to survey the seabed for features and obstructions. These surveys may be used to ensure the lay path is clear of obstructions or to verify the cable position on the seabed.
AUV	An autonomous underwater vehicle (AUV) is a robot that operates underwater without requiring input from an operator. AUVs vary in size and depth capability, and carry a set of sensors depending on the survey requirement. In terms of cable work they can be configured with MBES (multi-beam echo sounder), side-scan and in some cases SBP (sub-bottom profiler). An AUV may be used in areas that are inaccessible to vessels due to water depth – either too shallow for the vessel or too deep for towed sensors. They need recharging regularly and battery life varies from a few hours for smaller vehicles, to three days for large systems.
Bathymetric survey	A bathymetric survey is performed using an echo-sounder to determine the depth of water under the transducer. This measurement is based on the velocity of sound through water and the time from transmission to reception. The depth acquired needs to be corrected for tidal effects and is reduced to Lowest Astronomical Tide (LAT) as a standard. These surveys typically employ an MBES/swathe sounder – see definition.
Cable-crossing survey	This type of survey is carried out to determine the depth of a buried cable or pipeline. It may be carried out using an SBP, by crossing the cable perpendicular to the cable lay direction at regular intervals, or using an ROV with a cable tracker. This is in preparation for laying a cable across the detected cable/pipeline and to enable the crossing to be prepared using a bridge or mattresses.
Cable tracker	A cable tracker is a device that is typically fitted to an ROV to detect cables beneath the seabed. A frame is mounted to the front of the ROV to hold the sensors. The sensors detect either the magnetic signature of the cable or an audible tone, which can be injected into the cable to aid detection. In some cases the cable tracker can detect depth of burial, as well as position.
CPT	The cone penetrometer test (CPT), or cone penetration, is a method used to determine the geotechnical engineering properties of soils and delineating soil stratigraphy. The test method consists of pushing an instrumented cone into the ground at a controlled rate, with the tip facing down.
CVI	Close visual inspection (CVI) refers to a detailed visual

	inspection of cable or components and may involve cleaning the item and using magnetic particle inspection (MPI) or wall thickness checks.
Day grab	This spring-loaded device is used to take disturbed samples from the seabed. This helps with ground-truthing (verification of seabed soil types) when combined with SSS – see definition.
DGPS	Differential global positioning system (DGPS) is a higher accuracy system than standard GPS due to the incorporation of externally-provided differential corrections to the satellite data, which compensate for ionosphere-created observation errors. It is typically accurate to between 1-2m.
Drone	Drones are increasingly being used, both for aerial survey of landfall locations and for inspection of blades and offshore towers. These vary from purely visual systems through to Lidar-carrying systems for top surveys of landfalls (see definition for Lidar). Drones can be launched from vessels and they are being used increasingly to detect de-lamination of the tower and other defects on the tower and blades.
Drop-down camera	A drop down camera is typically an underwater camera, or group of underwater cameras, attached to a frame. This is typically used in environmental surveys of the seabed. In poor visibility situations, the sides may be glass and the frame filled with fresh water to provide better imaging.
Geophysical survey	Geophysical surveys are non-intrusive and consist mainly of bathymetric surveys, side-scan sonar and the use of a sub-bottom profiler to characterise the seabed, its mobility and the shallow geology. The side-scan is designed to detect any object that lies above the seabed level such as cables, debris or obstructions. It will also indicate the presence of pockmarks or depressions on the seabed. The SBP/pinger (see definition) is designed to look below the seabed at the strata, normally providing detail of the top 5-10 metres when used during cable installation or verification of burial depth.
Geotechnical sampling or surveys	The geotechnical survey will deliver information about the soil in the subsurface at a specific location. There are several methods for obtaining geotechnical information including cone penetration test (CPT), (see definition) vibrocore, boreholes, grab sampling and box coring. Depending on the chosen method, it will provide soil strength and soil type information. Sampling of the seabed soils is typically carried out with 'day grabs', 'gravity corers', 'vibrocorers' or a drilling rig for deep bore holes.
GI	General Inspection – an acoustic inspection using SSS (see definition) and bathymetry.
GNSS	Global navigation satellite system (GNSS) – this covers all satellite systems, such as GLONASS or NAVSTAR, which have global coverage.
GPS	Global Positioning System is a satellite positioning system for general use, typically accurate to 5-10m. See also RTK and DGPS.
GVI	A general visual inspection, normally using an ROV or diver to provide a visual inspection of cables or components.

Lidar	<p>Lidar (also written LIDAR, LiDAR or LADAR) is generally recognised as an acronym of ‘light detection and ranging’. It is a remote sensing technology that measures distance by illuminating a target with a laser and analysing the reflected light. Lidar surveys are typically used for water that is too shallow for vessels, inter-tidal zones or land surveys, and provides topographic/bathymetric data in a similar way to MBES systems. (See definition.)</p> <p>The Lidar systems are typically fitted to light aircraft or helicopters to cover large areas quickly. Larger drones are now available with smaller Lidar systems.</p>
Magnetometer/gradiometer	<p>Magnetometers are used to provide data on ferrous objects on or below the seabed (e.g. wrecks, UXO, cables, pipelines), and potentially the cable position and depth of burial. They are measurement instruments used for two general purposes: to measure the magnetisation of a magnetic material, like a Ferro magnet, and to measure the strength (and in some cases the direction) of a magnetic field at a point in space. A gradiometer is typically two or more magnetometers together on a frame to provide greater sensitivity and directional information.</p>
MBES/swathe sounder	<p>Multi-beam echo sounders (MBES), also known as ‘swathe’ systems, have multiple sensors to survey a wide sweep of the seabed in a single run. The width may be two or three times the water depth or more. These are typically used for route surveys and regional bathymetric surveys of the seabed providing detail on water depths and information on seabed topography, cable burial status/exposure and debris. Different systems use a different number of beams and frequencies, so they vary in their levels of accuracy and width of coverage. The selected system should be appropriate to the specific requirements of the survey.</p>
ROV	<p>A remotely-operated vehicle (ROV) is a tethered underwater vehicle linked to the vessel by either a neutrally buoyant tether or tether management system (TMS). The TMS is normally a garage-like device that contains the ROV while it is lowered through the splash zone. Additional equipment is commonly added to expand the vehicle’s capabilities. These may include sonars, magnetometers, still cameras, cable trackers, a manipulator or cutting arm, water samplers, and instruments that measure water clarity.</p>
RTK	<p>Real-time kinematic (RTK) refers to a highly accurate form of GPS. With RTK systems a local reference station is configured on an established point and corrections to the computed GPS position are generated and transmitted for use by mobile receivers. These corrections can allow precise measurements to be made, to the centimetre, depending on system parameters. Accuracy is typically better than 10cm in position and better than 50cm in elevation.</p>
Side-scan sonar (SSS)	<p>Side-scan sonar provides detailed seabed textural information pertaining to sediment type/ rock outcrop and information on seabed topography, cable exposure and debris. These systems use acoustic beams that are directed sideways from the device,</p>

	<p>which is normally towed behind a survey vessel. In this way it looks across the seafloor each side of the device, producing an image. Side-scan sonar imagery is commonly used to detect debris items and other obstructions on the seafloor that may be hazardous to shipping. It is also utilised to determine the status of pipelines and cables on the seafloor.</p> <p>SSS systems are available with different frequencies, which provide different levels of accuracy as a trade-off against range. For regional surveys, lower frequency systems, e.g. 100kHz, are used, which might achieve a 200m range. For environmental or detailed cable surveys, 400kHz or 900kHz systems (or higher) are used, which achieve ranges in the region of 70m and 40-50m respectively.</p>
Side-scan survey	<p>Prior to installing infrastructure, cables etc. on the seabed, a side-scan survey will be carried out. This will determine if there are any existing infrastructure, debris or seabed obstructions in the vicinity. A series of parallel lines are run, typically, 50-100m apart, to cover the area.</p>
Sub-bottom profiler (SBP)/pinger/boomer)	<p>A sub-bottom profiler (SBP) – also known as a pinger or chirp sonar – is used to determine the shallow soil strata below seabed level. An SBP provides detail on the properties of the sediment and depth to rock head, information on debris, and potentially the cable location and depth of burial.</p> <p>A low power, high-resolution sub-bottom profiler system will provide detailed information on the shallow sub-seabed down to approximately 5m, as well as cable location.</p> <p>An SBP will typically be used to determine the interface of various soil formations below the seabed and allows an assessment of the ability of burial tools to penetrate the seabed. Areas where a harder formation will reduce the burial depth can be identified. The SBP/pinger is also used to determine the depth of burial when carrying out cable-crossing surveys (see separate definition). Different frequencies and power outputs are available and the selection should be appropriate for the requirements.</p> <p>In parts of the UK with hard ground conditions, SBP/chirp systems are not suitable and other systems such as boomers are required.</p>
Topographic survey	<p>A topographic survey – or TOPO – is a survey of the land and provides height information at discrete points. It will also provide details of any buildings or other infrastructure at the landfall location. This survey may be carried out using theodolites, GPS or laser scanning systems and is typically used for landfalls and on-shore cable routing.</p>
USBL	<p>Ultra-short-baseline (USBL) and the related super-short-baseline (SSBL) systems rely on a small, tightly-integrated transducer array. This is typically mounted on the bottom end of a strong, rigid transducer pole, which is installed either on the side, or in some cases on the bottom, of a vessel. A combination of distance and direction fixes the position of the tracked target relative to the surface vessel.</p>
UXO survey	<p>Prior to installing infrastructure, cables etc on the seabed, a</p>

	survey will be carried out to determine if any unexploded ordnance (UXO) is present. A magnetometer or gradiometer will be used to detect buried items with ferrous content. A series of parallel lines are run to cover the area.
Vibrocorer	A vibrocorer has a core barrel that penetrates the seabed – typically a 6m core barrel is attached – and recovers a sample plug from the soils. The vibrocorer is generally better at recovering a core than a gravity corer, which is essentially the same device but the vibrocorer has an oscillating motor to help drive the barrel into the soils, whereas a gravity corer depends purely on its weight to acquire a sample.
3D imaging sonar	3D imaging sonar, also known as echoscopes, are a specific type of multi-beam sonar that transmit a broader swathe to enable 3D imaging of dynamic operations, such as touch down monitoring. Data can also be recorded and exported for ‘as laid’ surveys.

## Appendix B – Sources of further information

The documents listed below give further guidance on surveys for export cables, divided into:

- B.1 Further information,
- B.2 Other ongoing work, and
- B.3 References in report text.

### B.1 Further information

Allan, P.G. *‘Geotechnical aspects of submarine cables [presented at Subsea Geotechnics, Aberdeen, November 1998]’*, 1998

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## B.3 Endnotes in report text

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<sup>iii</sup> Association of Geotechnical and Geoenvironmental Specialists (AGS). AGS Data Format. Available at: <http://ags.org.uk/data-format/>

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