Morlais Project
Environmental Statement

Chapter 4: Project Description

Volume III

Applicant: Menter Môn Morlais Limited

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Chapter 4: Project Description

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Morlais Project
Environmental Statement

Appendix 4.1: Front End Engineering and Design (FEED) Advice for Morlais (ITPE, 2019)

Volume III

Applicant: Menter Môn Morlais Limited

Document Reference: PB5034-ES-0041

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MORLAIS TECHNICAL FEASIBILITY

Front End Engineering and Design (FEED) Advice for Morlais

ITPE-D4

Document Information

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Abbreviations

AFL	Agreement for Lease
EIA	Environmental Impact Assessment
ES	Environmental Statement
HV	High Voltage (35kV to 230kV) – according to IEC 60038
ICPC	International Cable Protection Committee
km	Kilometres
km^2	Kilometres squared
kV	Kilovolts
LV	Low Voltage (less than ~1kV)
m	Metres
MFE	Mass Flow Excavator
m/s	Metres per second
MW	Megawatt
MV	Medium Voltage (1kV to 35kV) – according to IEC 60038
O&M	Operation and Maintenance
PDE	Project Design Envelope
POC	Point of Connection
RIB	Rigid Inflatable Boats
SAC	Special Area of Conservation
SCADA	Supervisory Control and Data Acquisition
TEC	Tidal Energy Converter
TRL	Technology Readiness Level
WGS	World Geodetic System

Glossary

Agreement for Lease	A contract in which the right to investigate the possibility of developing a wave or tidal energy project for a specific area, for a specific period of time, is granted by The Crown Estate; or by Menter Mon in the case of an Agreement for Sub Lease.
Array	A set of multiple devices connected to a common electrical grid connection.
Development Site	The area defined in the Morlais Head-lease off Holy Island, Anglesey
Device	One complete tidal stream unit including: Tidal Energy Converter(s) (TEC; i.e. rotors and nacelle) Foundations Support structure Surface piercing superstructure
Device Type	A characterised group of devices (e.g. surface piercing floating, piled tower, transverse axial).
Exclusion Zone	A zone established by a sanctioned body to prohibit specific activities in a specific geographical area.
Export cable	A cable that exports the power generated by a tidal energy converter(s) to the onshore substation.
Footprint	The area physically in contact with the seabed or ground.
Project Design Envelope	A range of maximum extents which can define a project. The detailed design of the scheme can then vary within this 'envelope' without invalidating the corresponding EIA.
STATCOM	static synchronous compensator - A regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. Usually installed to support electricity networks that have a poor power factor and often poor voltage regulation.
Technology Readiness Level	Measure of the maturity of evolving technologies. TRL 9 is representative of a fully matured technology. This is representative of multi-device demonstration of tidal energy converters.
Tidal Device	See Device
Tidal Energy Converter	The generation elements of a Tidal Device (combined rotor and nacelle).
Tidal Technology	A model of device (e.g. Triton, UFS, ARC1500)
Tidal Energy Converter	A device that generates electricity from the power of the tides

Table of Contents

1 Introduction

This report provides a summary of the key components of the project design envelope; covering onshore and offshore elements for both the Morlais and developer infrastructure and systems. This report contains sets of parameters for the project infrastructure together with descriptions to assist with their explanation and interpretation, this should not however, be taken as a Project Description.

The report is provided as a first draft for comment and discussion on the parameters provided. These will be refined and further detailed in collaboration Morlais, RHDHV and Marine Space for incorporation into subsequent drafts.

1.1 Morlais

The Morlais Project will seek to provide a consented tidal technology demonstration zone with communal infrastructure such as export cables and substations, for tidal technology developers to install arrays of tidal energy converters.

The Morlais Tidal demonstration zone (MDZ) is located in an approximately 35km^2 area to the west of Holy Island, Anglesey and will include grid connection via subsea cables as well as navigation aids and monitoring equipment.

The MDZ will have a maximum generating capacity of up to 180MW. Grid connection will be achieved in an area to the very east of Holy Island, or just across The Cob on Anglesey.

The project will consist of the following infrastructure and systems, all of which fall under the Project Design Envelope, and will be included under the current (single) EIA process:

Menter Môn component of the Morlais project:

- Landfall for up to 9 cables with short cable tails installed just offshore.
- Cable protection measures (where necessary) for these cable tails
- Landfall substation
- Grid connection and associated (inland) substation
- Cable circuits installed between landfall and grid connection substations
- Surface floating navigation buoys

Developer component of the Morlais project:

- Tidal devices, incorporating:
    - Foundation structures and associated support and access structures
    - Tidal Energy Convertors (TECs)
    - Seabed preparation measures for foundation installation (where necessary)
- Nine export cables to shore (1 per tidal array), that will connect to the 9 cable tails.
- Cable protection measures (where necessary)
- Electrical hubs or connectors as a means to allow multiple tidal devices to export power through a single export cable
- Inter-array cables within each array to connect tidal devices to one another and/or an electrical hub
- Tidal array specific marking and monitoring equipment (if applicable)

2 Onshore Elements

The Development Area,

The onshore Development Area, including the landfall and landfall substation search areas, preferred grid connection route and offshore cable corridor is shown in Figure 1.

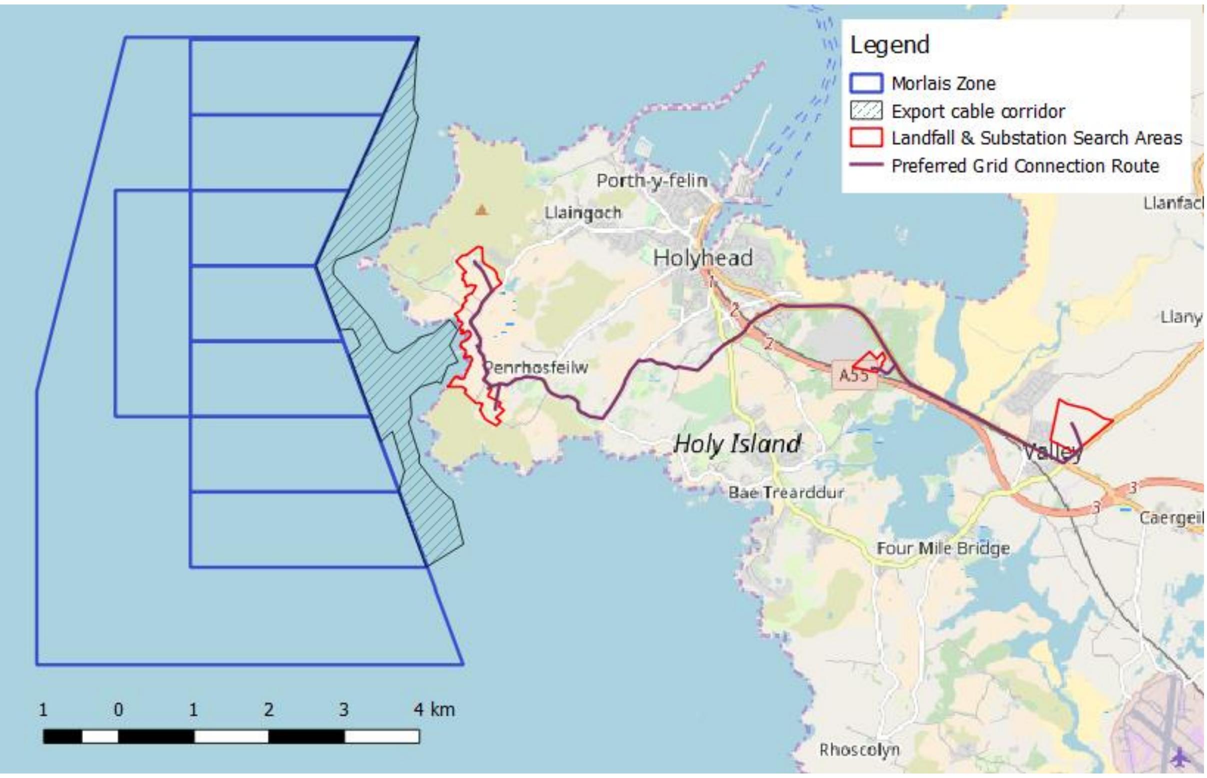


Figure 1: Map showing search areas and cable corridors

2.1 Substations

2.1.1 Landfall Substation

2.1.1.1 Overview

The substation at landfall will contain:

- Up to two 132kV cable circuits to the Inland Substation (at the grid connection point)
- A set of 132kV switchgear, associated measurement, protection and control equipment; although this may be eliminated at least in part.
- Likely a single 132/33kV ~180MVA transformer and associated earthing plant. two or more smaller transformers could also be used with a slightly larger footprint.
- A separate enclosed area (within a larger agricultural shed) or separate building containing:
  - Up to nine electrical plant rooms for developers to contain 33kV to LV step-up transformers, 33kV switchgear or 11kV switchgear as needed
  - Up to two 33kV switchrooms
  - Control / relay room
  - Low Voltage room
  - Battery room

  - Metering room
  - Developer offices
  - Toilet
  - Utility cupboard
  - Cable basement
- Other substation ancillary systems such as fire detection and suppression, communications, intruder alarms, etc.

The above assumes that:

- Any harmonic filtering is located at the inland substation.
- 132kV busbars, switchgear and hence redundancy is minimised.
- No reactive plant will need to be connected at 132kV and reactive power and voltage control requirements can be suitably addressed from the 33kV side.

This is to save space and reduce the footprint of the landfall substation as directed by Mentor Mon.

2.1.1.2 Dimensions

Dimensions of the landfall substation site would be up to 70m by 50m (or equivalent area) with a peak height of up to 18m. This is based on a single building (resembling an agricultural shed) will all plant indoor.

A design with outdoor plant would consist of a fenced compound up to 70m by 50m (or equivalent area). Within this would be two separate buildings approximately 55m x 10 x 7m high (or equivalent area) and 28m x 18m x 7m high (or equivalent area), as well as an outdoor transformer compound approximately 20m x 18m x 12m high (or equivalent area).

In addition, a temporary construction compound and laydown area will also be created, estimated up to 50 x 100m, or equivalent area.

2.1.1.3 Appearance

The preferred appearance from a technical perspective is for an agricultural shed-like structure (or structures) which will allow at least partial mitigation of noise and visual impact of outdoor equipment. The 'agricultural shed(s)' will have a steel structure and can be clad in timber or a profiled metal cladding to help blend into the landscape. The material and colour may be selected to suit planning requirements. The shed will likely feature low level ventilation louvers to bring in cooler outdoor air, and high-level exhaust cowls with ducted axial fans. These ventilation features would be visible from outside the building.

For the agricultural shed option, additional fencing would be optional and used for demarcation of the site and additional security if needed. As below this fencing may be wooden or substituted with a masonry wall.

Alternatively, the outdoor equipment may be placed outside with up to two separate substation buildings for indoor equipment. For this scenario, the substation perimeter will be protected by a wooden fence or masonry wall. The design of the fence or wall shall be such that it blends in with the local environment as far as possible. For additional security an internal palisade fence may be installed hidden from view within the external fence. Fencing would be minimum 2.4m tall.

The height of the building(s) could be reduced slightly, but at the expense of footprint and at increased cost.

It may be feasible to sink the foundations and floor level of the building and some outdoor plant slightly. This would be dependent on ground conditions and an assessment of ground water levels and flood risk; however, this is unlikely to be more than a meter or so based on expected ground conditions and to ensure there is sufficient space available for cable routing trenches below floor level.

The site will be constructed with all appropriate and legal measures taken to prevent trespassing and vandalism.

2.1.1.4 Screening

Native trees / vegetation or earth embankments may be strategically placed to suit planning requirements if applicable and if they do not interfere with access/egress, foundations, and drainage systems.

2.1.1.5 Access/egress

Main equipment access would be from South Stack Road or Lon Isallt.

Specific areas of the roads may need works to assist with turning radius or weight distribution for transport of low loader vehicles.

The entrance of the landfall substation is anticipated to be on the side facing the road. A permanent car park is to be located near the entrance, this may be within any perimeter fencing if applicable.

Access/egress to the site will be 24-hours.

Key areas of the landfall substation switchyards should be easily accessible in such a way that it is possible to easily remove and replace large items of plant, e.g. transformer or reactor. Ideally there will be a hard core or tarmac access road 5-7m wide from the road to any outdoor equipment compound or the plant access of the agricultural shed. Additional space for access around transformers should be allowed for. All enclosures or buildings should have a minimum of 1m gap between all sides and the site boundary for access.

2.1.1.6 Surfaces

Hard standing will be in the form of hard core or tarmac surfaces on or adjacent to the access roads within the substation. This pertains to the 5-7m wide perimeter access road, additional access areas around transformers and reactors, building entrances, and the main substation entrance and car park. Footpaths or pavement in and out of the substation building and areas commonly accessed may be of poured concrete instead of hard core or tarmac.

Outdoor areas within the compound will have a layer of crushed rock or gravel approximately 80mm to 150mm thick. This will be everywhere inside of the substation perimeter with the exception of the access roads, protruding equipment foundations, and buildings.

2.1.1.7 Foundations

Each item of outdoor and indoor electrical and non-electrical equipment will have a concrete slab foundation. Strip and pad foundations will be utilised if possible.

It may be necessary to utilise a piled foundation solution, using precast concrete piles or similar, if warranted depending on the underlying geological conditions (to be determined by the civils contractor). The transformer foundations will be bunded to contain any oil leakage from the transformer as will any other oil-filled plant.

2.1.1.8 Building materials

The interior of the landfall substation building, or agricultural shed will have fire barrier walls made of dry wall cladding. The main transformer room for the agricultural shed will have firewalls constructed out of concrete or concrete blocks. Other rooms may similarly utilise blockwork construction including the switchgear, battery and auxiliary power rooms.

2.1.1.9 Drainage systems

There will be several independent drainage systems for the landfall substation.

The foul drainage system is to take wastewater from personnel areas and connect into the local sewage system which requires approval from the authorities. This consists of foul drains with manhole covers at intervals. As a worst case this could require a foul pumping station. Alternatively, foul water could be handled with a local septic tank with an overflow into a local infiltration trench.

The surface water system collects run off from buildings and roads and may be run through oil interceptors and discharged using bund pumps so all contaminates are removed from the water. The drainage system should be designed to handle the worst-case water situation and with consideration of flood risk. The surface water may connect into a sewer system with approval from the authorities, discharge into a local watercourse if possible, or be discharged into a soakaway system constructed nearby.

An oil interceptor will be required to be installed to protect the surface water system from pollution. Such an interceptor capacity should be adequate to the area intercepted by the substation surface water drainage system.

2.1.1.10 Earthing

The earthing system is a mesh or grid of metal conductors which are installed on the substation site after earth works are completed and prior to installation of equipment or buildings.

The earthing grid is usually made of copper bars some 100mm^2 thick, placed about 250mm to 500mm below the surface in 3-7m squares. However, the earthing system should be designed in conformity to all the applicable standard and laws.

Earthing rods are large bars of solid copper or copper clad steel which penetrate deep into the earth (depth depending on required earthing resistance and ground conditions) and are linked to the earthing grid.

The earth grid should cover the entire site up to or including the fence perimeter, to which it should be solidly bonded.

Any other metal objects such as the building frame, cladding or metallic fencing may also be connected to this common earth grid or may have its own earth rod/grid system which is not coupled to the main substation earthing system.

Additionally, there may be an above-ground earthing ring where all metallic electrical plant is bonded together with earthing wires. If lightning towers are installed (e.g. for an HVDC substation), it would connect into this earthing ring.

All joints in the earthing grid and ring are bolted together rather than soldered or welded. The joint faces may be tinned to ensure a good electrical connection.

2.1.1.11 Lighting

A minimum of 110 lux directed lighting should be provided around the entry to the landfall substation which will only be turned on when needed, as well as equipped with motion sensors. Adequate lighting will be provided for any outdoor electrical plant areas in the form of compound floodlighting to facilitate any inspection or maintenance of electrical equipment at night. This would normally be 10lx along access paths and around major items of electrical plant. This may require columns to fix lighting to although electrical clearances should be followed to eliminate the possibility of a column falling across electrical equipment.

2.1.1.12 Electrical Supply

The power supply to the landfall substation should be drawn from two different sources for redundancy in case of a failure from the first source. Auxiliary power will be derived from auxiliary windings of the 33kV earthing transformers, or from separate dedicated auxiliary transformers within the substation. A backup power source may be taken from the nearest distribution system overhead lines. This would be extended to the site and lowered to the supply voltage via a pole-mounted or ground-mounted step-down transformer.

2.1.1.13 Telecoms

The required telecoms connections for the landfall substation will consist of phone lines and a secure connection to relevant Stakeholders such as to National Grid, the Morlais control centre, and/or developers.

Telecoms will be provided by renting a dedicated and secure line and tapping into the BT system.

2.1.1.14 Location of landfall substation

The location of the landfall substation, will be in one of 4 possible locations (as shown in Section 2.2). The location will be determined mainly by landowner agreement, although space available may also factor in as discussed in Section 2.1.1.3. This will then set the location of the landfall itself.

2.1.1.1 Summary

Table 1 below consists of a summary of the key parameters for the Landfall Substation.

Table 1: Key Parameters for the Landfall Substation

Parameter	Value (indoor plant)	Value (outdoor plant)
Footprint	50m x 70m (or equivalent area)	50m x 70m (or equivalent area)
Peak height	18m	12m
Appearance	Single building, resembling an agricultural shed. 5-7m wide perimeter access road.	Two buildings, resembling agricultural sheds [55m x 10 x 7m high (or equivalent area) and 28m x 18m x 7m high (or equivalent area)], plus outdoor transformer compound [20m x 18m x 12m, or equivalent] 5-7m wide perimeter access road.
Surfaces	Hard standing will hard core or tarmac surfaces. Outdoor areas within the compound; crushed rock or gravel.	Hard standing will hard core or tarmac surfaces. Outdoor areas within the compound; crushed rock or gravel.
Foundations	Concrete slab. Strip and pad where/if possible.	Concrete slab. Strip and pad where/if possible.
Materials	Steel structures clad in timber or a profiled metal cladding. Interior of buildings will have fire barrier walls of dry wall cladding, concrete or concrete blocks.	Steel structures clad in timber or a profiled metal cladding. Interior of buildings will have fire barrier walls of dry wall cladding, concrete or concrete blocks.
Lighting	Minimum of 110 lux directed lighting around entrance and electrical plant. Only be turned on when needed, as well as equipped with motion sensors.	Minimum of 110 lux directed lighting around entrance and electrical plant. Only be turned on when needed, as well as equipped with motion sensors.

2.1.2 Inland Substation

2.1.2.1 Overview

A separate substation will be required to achieve connection at the grid connection point.

This ‘Inland Substation’ at the grid connection point will contain:

- Up to seven 132kV circuit breaker bays.
- A space allocated for additional plant which could be utilised for:
    - Harmonic filters
    - Reactive compensation (e.g. shunt reactor) if needed

    - Dynamic reactive compensation and associated switchgear, transformer(s) and works if needed and not practical at 33kV at the landfall substation
- Control building possibly containing the following:
    - Control / relay room
    - LVAC room
    - Battery room
    - Metering room
    - Toilet
    - Utility cupboard
- Other substation ancillary systems such as fire detection and suppression, communications, intruder alarms, etc.

2.1.2.2 Dimensions

Dimensions of the inland substation site would be up to 110m by 95m with a peak height of 10.5m for plant and the building.

In addition, a temporary construction compound and laydown area will also be created, estimated up to 50 x 100m, or equivalent area.

2.1.2.3 Appearance

The equipment will be in an outdoor compound surrounded by 2.4m tall palisade fencing. This fencing may be shrouded with an additional external wooden fence or masonry wall to help visual impact. There will also be a substation building at the site to contain control and relay equipment. Alternatively, it may be possible to locate this in outdoor ground mounted cubicles. The site will be constructed with all appropriate and legal measures taken to prevent trespassing and vandalism.

2.1.2.4 Screening

Native trees or vegetation may be strategically placed to suit planning requirements as long as it does not interfere with access/egress, foundations, and drainage systems.

2.1.2.5 Access/egress

Main equipment access is to be confirmed pending confirmation of the grid connection point.

Specific areas of the roads may need works to assist with turning radius or weight distribution for transport of low loader vehicles.

The entrance of the inland substation is anticipated to be on the side facing the road. A car park is to be located near the entrance, this may be within any perimeter fencing if applicable.

Access/egress to the site will be 24-hours.

Key areas of the inland substation switchyards should be easily accessible in such a way that it is possible to easily remove and replace large items of plant, e.g. transformer or reactor. There will be a hard core or tarmac access road 5-7m wide from the road to any outdoor equipment compound and substation building. Additional space for access around transformers, reactors or similarly large plant should be allowed for. All enclosures or buildings should have a minimum of 1m gap between all sides and the site boundary for access.

2.1.2.6 Surfaces

Hard standing will be in the form of hard core or tarmac surfaces on the access roads within the inland substation. This pertains to the 5-7m wide perimeter access road, additional access areas around transformers and reactors, building entrances, and the main substation entrance and car park.

Footpaths or pavement in an out of the inland substation building and areas commonly accessed may be of poured concrete instead of hard core or tarmac.

Outdoor areas within the compound will have a layer of crushed rock or gravel approximately 80mm to 150mm thick. This will be everywhere inside of the substation perimeter with the exception of the access roads, protruding equipment foundations, and buildings.

2.1.2.7 Foundations

Each item of outdoor and indoor electrical and non-electrical equipment will have a concrete slab foundation. Strip and pad foundations will be utilised if possible. It may be necessary to utilise a piled foundation solution, using precast concrete piles or similar, if warranted depending on the underlying geological conditions (to be determined by the civils contractor). The transformer foundations will be bunded to contain any oil leakage from the transformer.

2.1.2.8 Building materials

The interior of the substation building will have fire barrier walls made of dry wall cladding. Other rooms may utilise blockwork construction such as switchgear, battery and auxiliary power rooms.

2.1.2.9 Drainage systems

There will be several independent drainage systems for the inland substation.

The foul drainage system is to take wastewater from personnel areas and connect into the local sewage system which requires approval from the authorities. This consists of foul drains with manhole covers at intervals. As a worst case this could require a foul pumping station. Alternatively, foul water could be handled with a local septic tank with an overflow into a local infiltration trench.

The surface water system collects run off from buildings and roads and may be run through oil interceptors and discharged using bund pumps, so all contaminates are removed from the water. The drainage system should be designed to handle the worst-case water situation and with consideration of flood risk. The surface water may connect into a sewer system with approval from the authorities, discharge into a local watercourse if possible, or be discharged into a soakaway system constructed nearby.

An oil interceptor will be required to be installed to protect the surface water system from pollution. Such an interceptor capacity should be adequate to the area intercepted by the substation surface water drainage system.

2.1.2.10 Earthing

The earthing system is a mesh or grid of metal conductors which are installed on the substation site after earth works are completed and prior to installation of equipment or buildings.

The earthing grid is usually made of copper bars some 100mm^2 thick, placed about 250mm to 500mm below the surface in 3-7m squares. However, the earthing system should be designed in conformity to all the applicable standard and laws.

Earthing rods are large bars of solid copper or copper clad steel which penetrate deep into the earth (depth depending on required earthing resistance and ground conditions) and are linked to the earthing grid. The earth grid should cover the entire site up to or including the fence perimeter, to which it should be solidly bonded.

Any other metal objects such as the building frame, cladding or metallic fencing may also be connected to this common earth grid or may have its own earth rod/grid system which is not coupled to the main substation earthing system.

Additionally, there may be an above-ground earthing ring where all metallic electrical plant is bonded together with earthing wires. If lightning towers are installed (e.g. for an HVDC substation), it would connect into this earthing ring.

All joints in the earthing grid and ring are bolted together rather than soldered or welded. The joint faces may be tinned to ensure a good electrical connection.

2.1.2.11 Lighting

A minimum of 110 lux lighting should be provided around the entry to the inland substation which will only be turned on when needed. Adequate lighting will be provided for any outdoor electrical plant areas in the form of compound floodlighting to facilitate any inspection or maintenance of electrical equipment at night. This would normally be 10lx along access paths and around major items of electrical plant. This may require columns to fix lighting to although electrical clearances should be followed to eliminate the possibility of a column falling across electrical equipment.

2.1.2.12 Electrical Supply

The power supply to the inland substation should be drawn from two different sources for redundancy in case of a failure from the first source. A power source may be taken from the nearest distribution system overhead lines. This would be extended to the site and lowered to the supply voltage via an auxiliary transformer. Backup supply could be provided by a diesel generator at site.

2.1.2.13 Telecoms

The required telecoms connections for the inland substation will consist of phone lines and a secure connection to relevant Stakeholders such as to National Grid, the Morlais control centre, and/or developers.

Telecoms will be provided by renting a dedicated and secure line and tapping into the BT system.

2.1.2.14 Location of Inland substation

The location of the inland substation, will be in one of 2 possible locations; either at the Orthios site (former Anglesey Aluminium works); or in a field just to the north east of Valley (as shown in Figure 2). The location will be determined by the grid connection agreement; either with National Grid or Orthios.

It is also possible that a smaller connection (for a first phase of the project); approximately 13.5MVA at 33kV, could be achieved at Parc Cybi. A connection of this size and nature could be achieved with considerably less infrastructure at the connection point.

Figure 2: Map showing the location of possible grid connection points and landfall substation

2.1.2.15 Summary

Table 1 below consists of a summary of the key parameters for the Inland Substation.

Table 2: Key Parameters for the Inland Substation

Parameter	**Value (outdoor plant)**
Footprint	110m x 95m
Peak height	12m
Appearance	Outdoor compound surrounded by 2.4m tall palisade fencing. Single building or ground mounted cubicles. 5-7m wide perimeter access road.
Screening	Possibly native vegetation
Surfaces	Hard standing will hard core or tarmac surfaces. Outdoor areas within the compound; crushed rock or gravel.
Foundations	Concrete slab. Strip and pad where/if possible.
Materials	Steel structures clad in timber or a profiled metal cladding. Interior of building will have fire barrier walls of dry wall cladding, concrete or concrete blocks.

Lighting	Minimum of 110 lux directed lighting around entrance and electrical plant. Only be turned on when needed, as well as equipped with motion sensors.

2.2 Landfall

Horizontal Directional Drilling (HDD) is the preferred option to achieve landfall (see Section 2.4). The use of ducts or J-tubes pinned to the cliff and/or laid in a shallow trench or slot will also be taken forward.

HDD landfall:

- Up to 9 cable tails at landfall.
- Up to 9 separate drills; each up to 550m long, nominally 450mm diameter.
- Separation of 10m between HDD entry points.
- Separation of 20m between HDD exit points.
- Temporary works area up to 120m x 70m (total area for HDD rig, site office and equipment plus laydown area).
- Total drill cuttings volume could be up to 900m^3 for HDD alone (total amount for all 9 drills).

Trenched Landfall:

- Up to 9 cable tails at landfall.
- Up to 9 separate shallow trenches (slots within the cliff face), each between 480m and 740m long.
- Individual trench width up to 600mm. Or single trench with all 9 cables laid within it of approx.. 10 width; 0.5 to 1.2m deep
- Total material removed could be up to 2,400m^3; however, the majority would be replaced to backfill the trench after the ducts / cables were installed.
- Duct or split pipe over 370m to 550m of each cable, up to 350mm external diameter.
- Temporary works area up to 100m x 50m (for site office and equipment plus laydown area).

In addition, there will be up to 9 transition pits, each up to 15m x 3m x 1.5m deep, equating to a footprint of 405m^2, distinct from the works area defined above. Within each pit, one submarine cable will be jointed and transitioned to three individual land cables.

An alternative for location Option 5a (possibly also Option 8a), would be to have the submarine cables terminated directly into the switchgear via the cable pit or basement of the substation however this would depend on the location and orientation of the substation with respect to the HDD entry and cable pulling area.

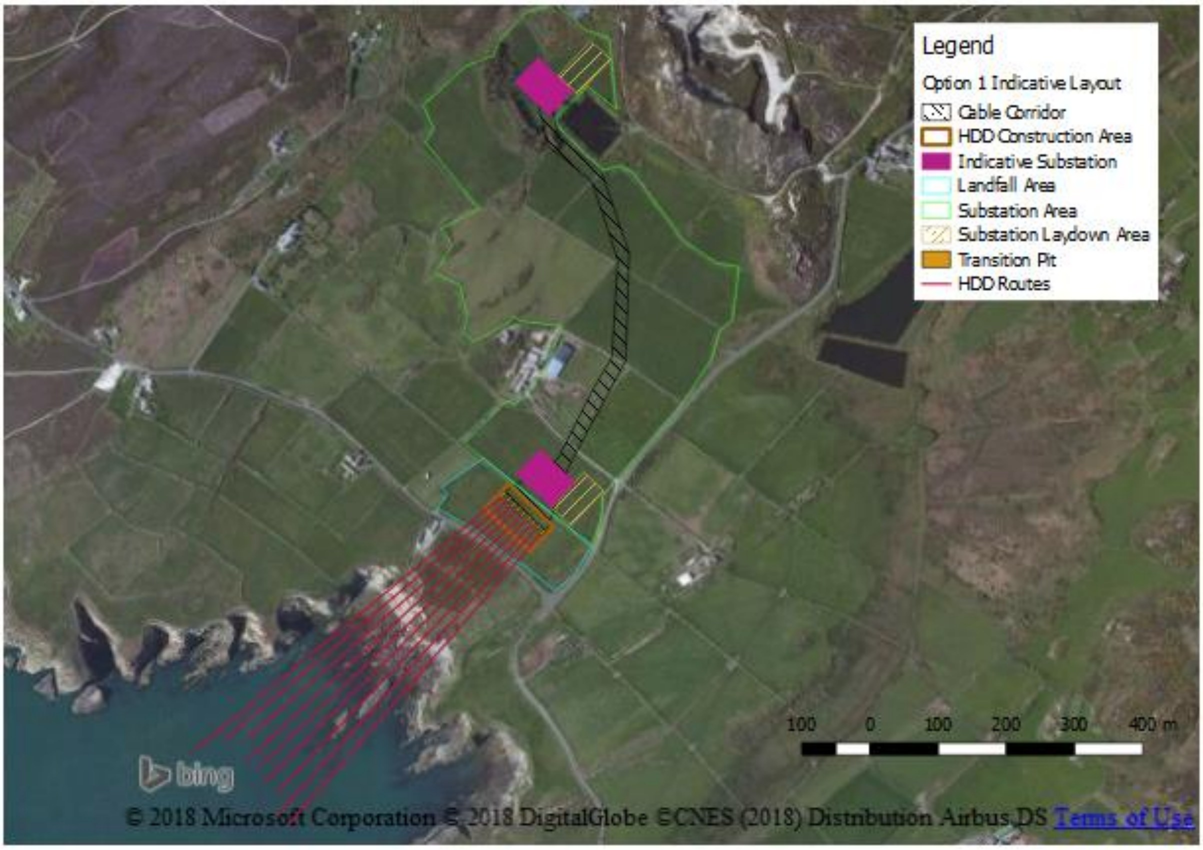


Figure 3: Possible outline layout for option 1 with HDD

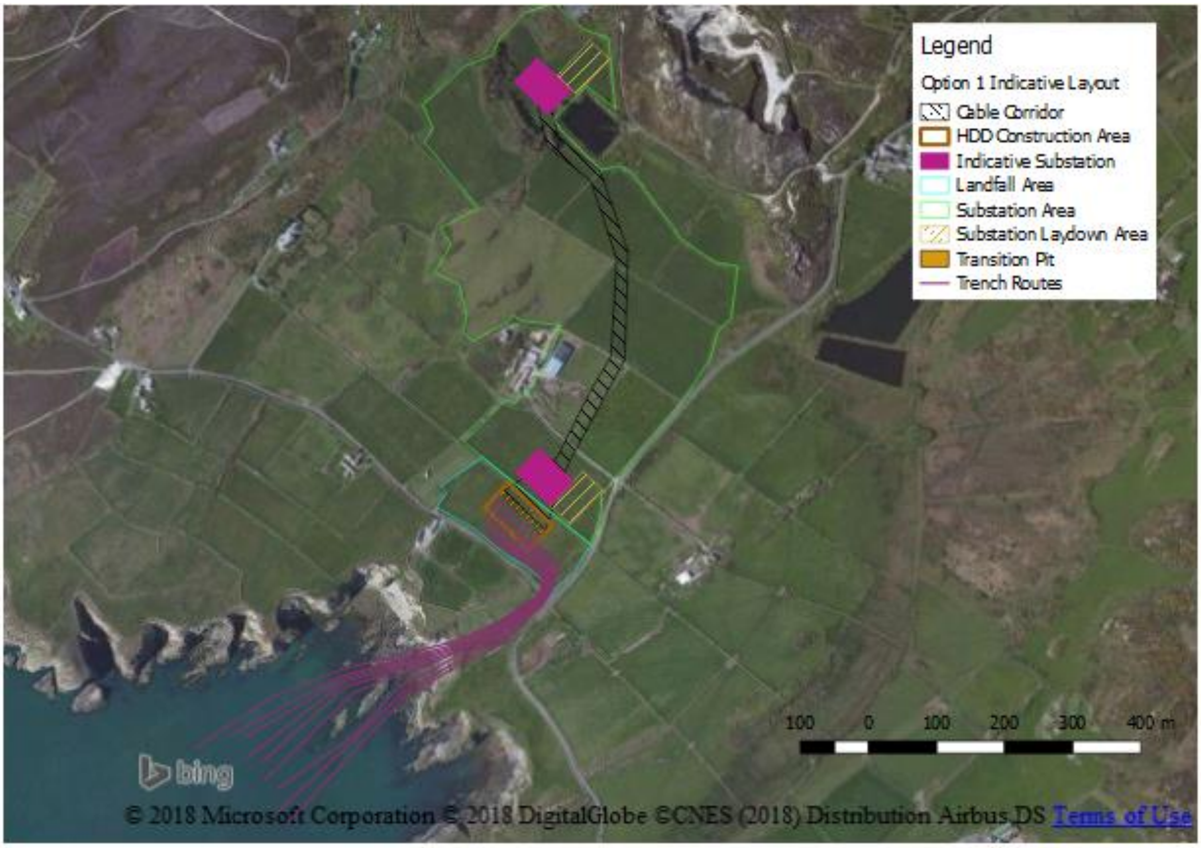


Figure 4: Possible outline layout for option 1 with trenched landfall

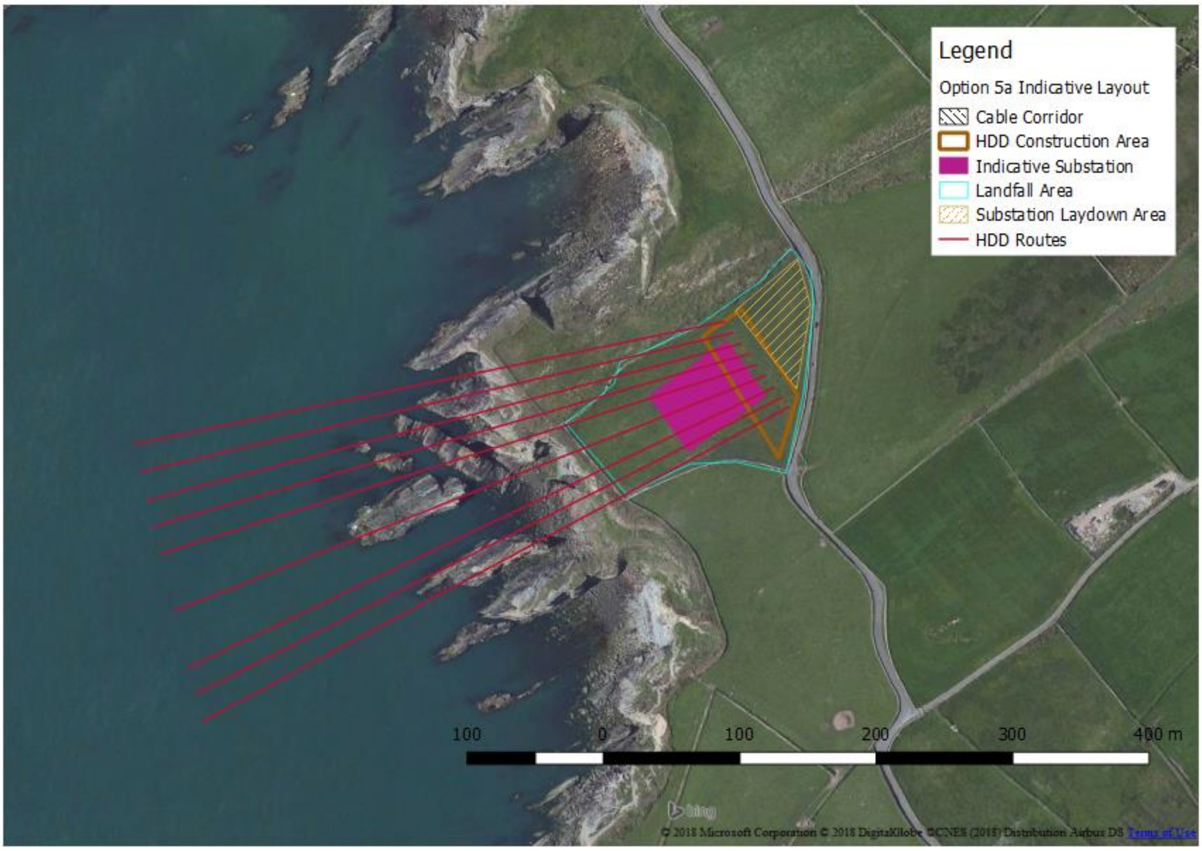


Figure 5: Possible Outline layout for Option 5a with HDD

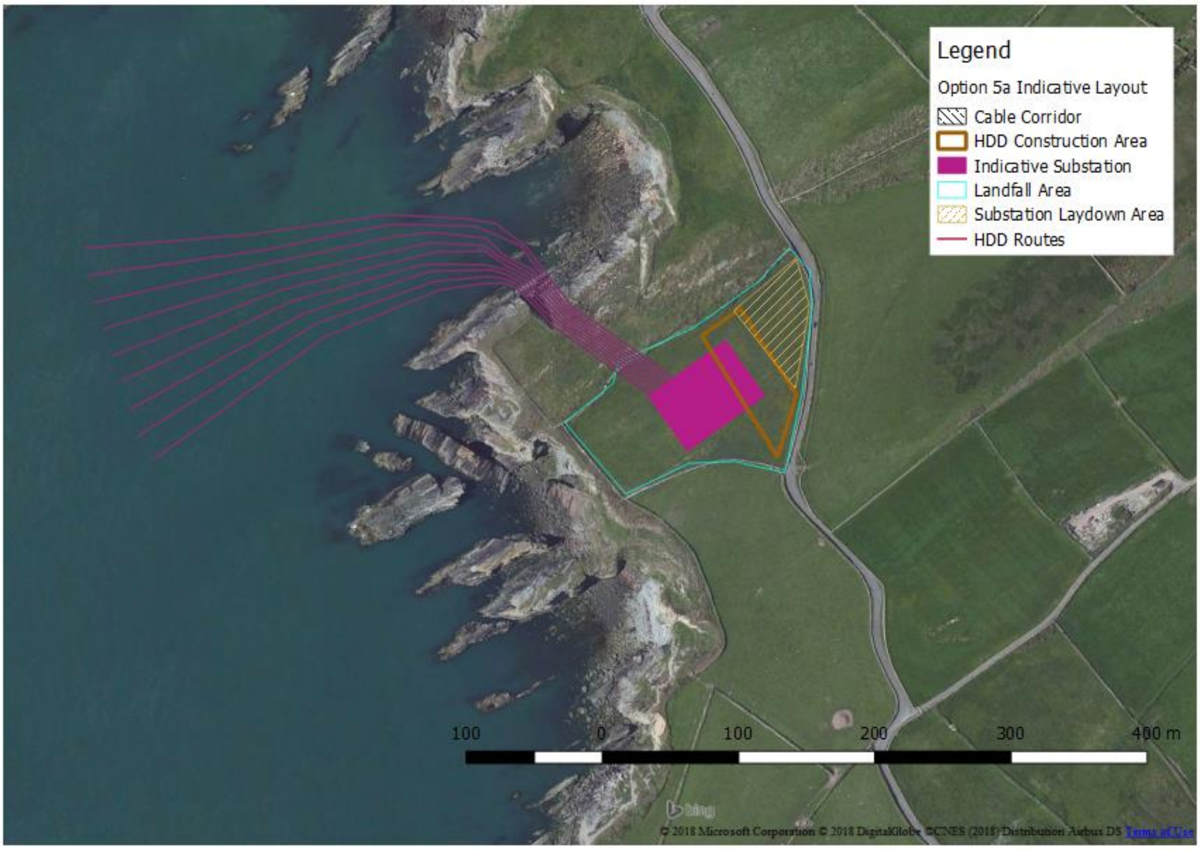


Figure 6: Possible outline layout for option 5a with trenched landfall

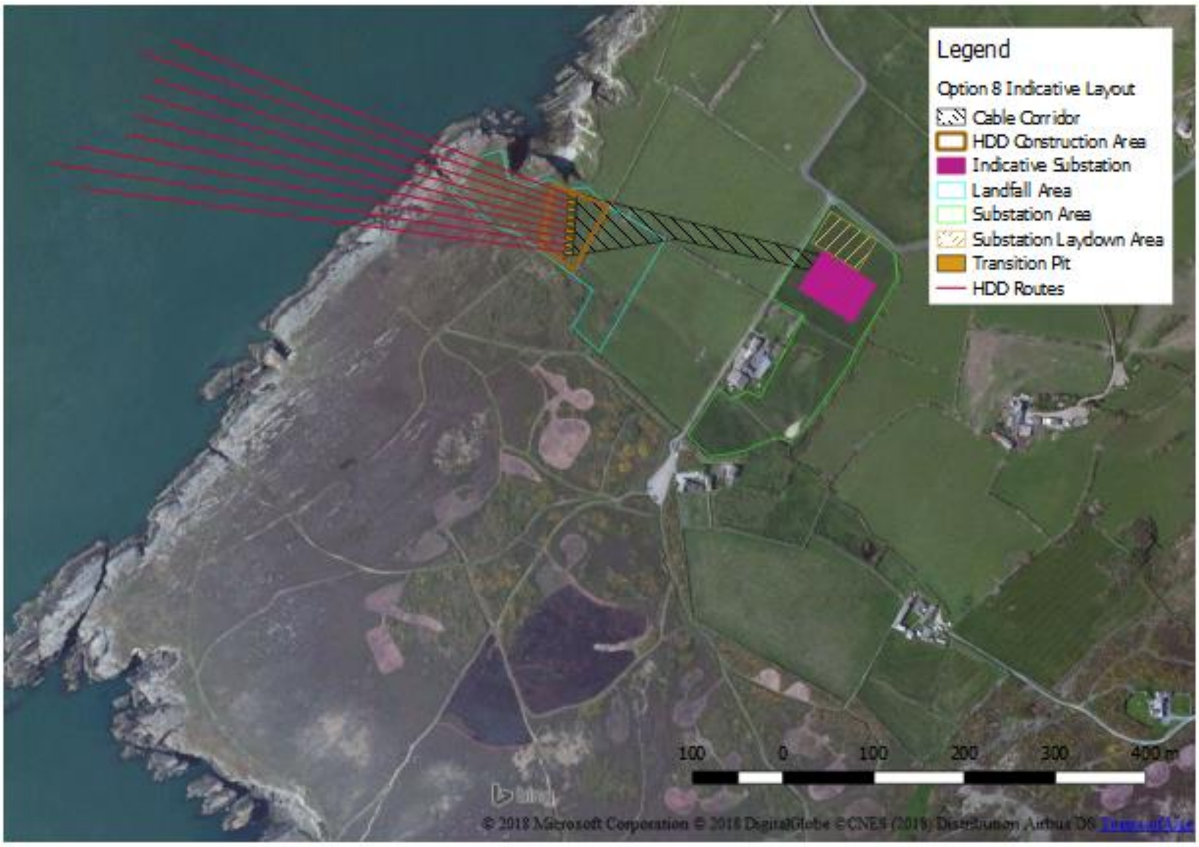


Figure 7: Possible outline layout for Option 8a with HDD

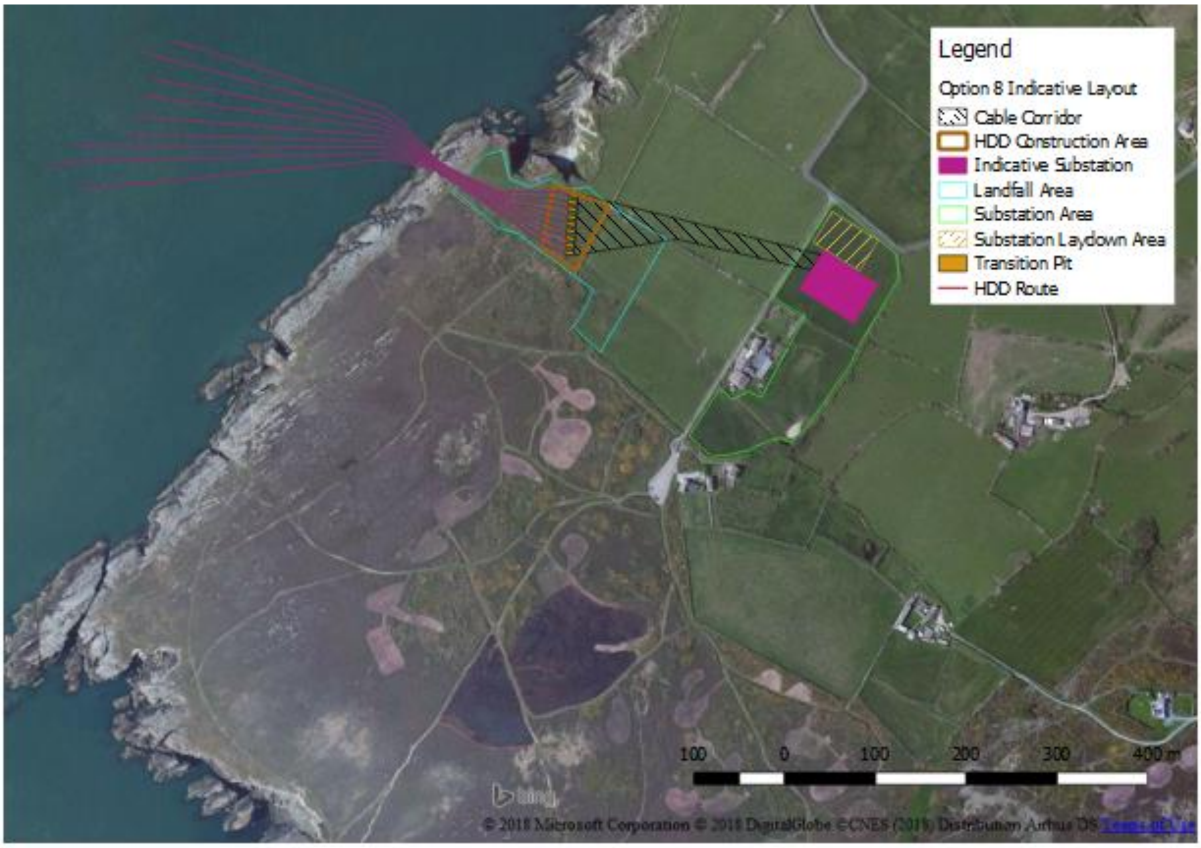


Figure 8: Possible outline layout for option 8a with trenched landfall

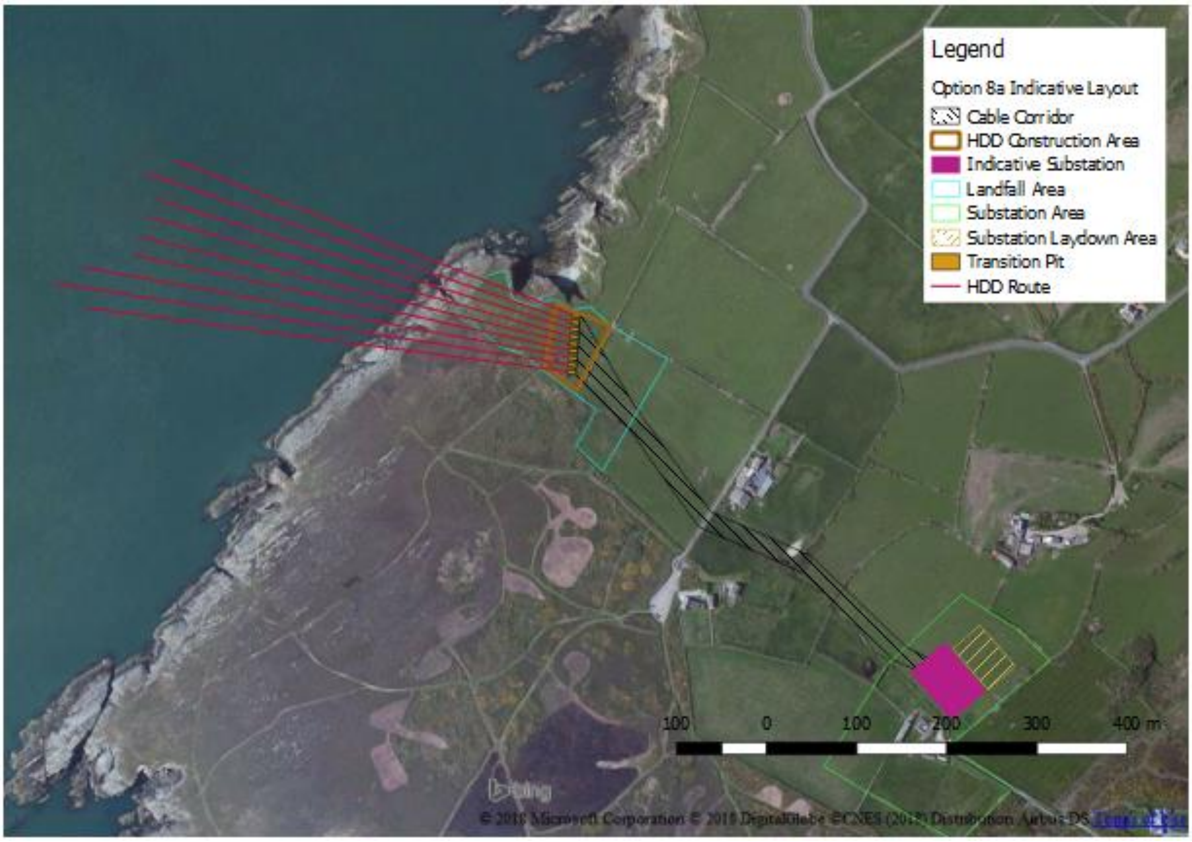


Figure 9: Possible outline layout for Option 8 with HDD

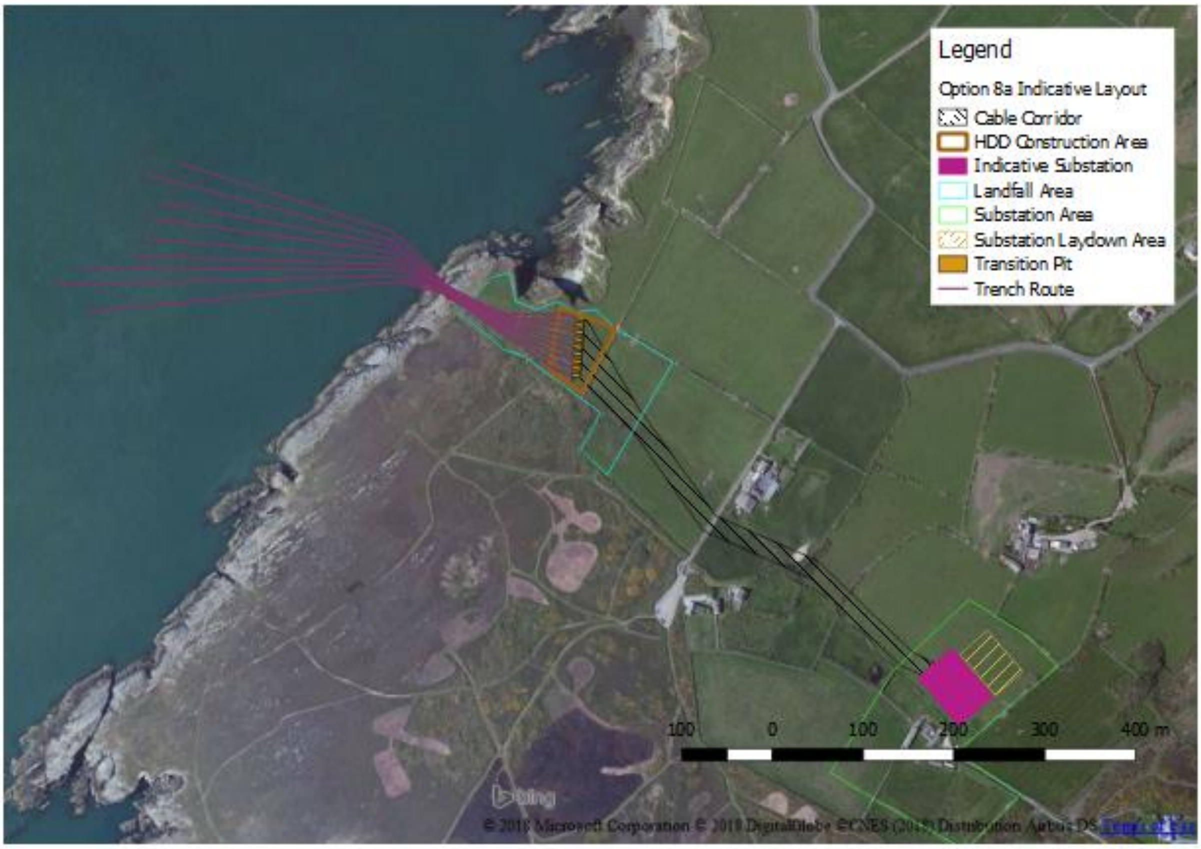


Figure 10: Possible outline layout for option 8 with trenched landfall

Further details on the above can be found in the report '260318 Morlais Cable Routing Report'.

Table 3: Summary table for landfall parameters

Parameter	Value (HDD landfall)	Value (trenched landfall)
Number of cables	9	9
Max. length of drill / trench	550m	740m
Drill / trench dimensions	Nominally 450mm	Individual trench width up to 600mm. Or single trench approx. 10 width; 0.5 to 1.2m deep
Duct diameter	Nominally 300mm	Nominally 350mm
Material removed	Up to 900m^3	Up to 2,400m^3 (majority replaced)
Temporary works area	Up to 120m x 70m	up to 100m x 50m
Transition pits	Up to 9, each up to 15m x 3m x 1.5m deep	Up to 9, each up to 15m x 3m x 1.5m deep

2.3 Onshore Cables

The onshore cable route would feature up to two 132kV cable circuits. Each circuit would consist of three power cables plus a fibre optic cable. This results in up to six power cables and two fibre optic cables in total.

- Up to 17km total route length.
- Up to 110mm diameter cable for each circuit (up to 6 off in total).

The cables will be laid in trenches up to 1.5m wide by 1.7m deep. Joint bays will be required every 400m to 900m along the cable route. Each joint bay will be up to 15m by 3m by 1.5m in size and will be constructed with a concrete base and timber frame. Provision will be made for an earth link box of 1.5m by 1.5m within proximity to each joint bay. Up to 40 joint bays may be required.

Space for cable pulling of up to 20m by 7m should be allowed around each joint bay for hardstanding for cable pulling works.

See Appendix A for route maps.

See report '260318 Morlais Cable Routing Report' for further details.

2.3.1 Installation Method

The trench will typically be made by digging up ground along the route with a large excavator plus use of a rock breaker along some sections. For installation in fields, the trench will be backfilled with sand and/or stabilised material to ~300mm above the top of the cables. The native material that was removed during construction will be replaced on top of the stabilised material with any large and sharp stones removed. Finally, the trench will be topped up with a minimum of 300mm topsoil and the land restored as close as possible to its original conditions. Burial will typically be 1.1m from the surface to the top of the ducts. Up to 30m working width for plant access, lay down of equipment, top soil and spoil plus trench shoring.

Cable installation in the road or verge will be like that of the field though normally more time-consuming and space constrained. Instead of the works spreading out sideways, activities will tend to be sequenced and material removed from site rather stored alongside the trench. A trench will be cut through the road surface and excavated. Once the trench is prepared, the cables or ducts will be laid, and the road reinstated. A working area of approximately 6m width would suffice for installation in a single lane road.

Crossings of railway+A55 (Approximately 150m drill length) and waterway (up to 1,200m) via HDD. Up to 2 crossings, involving 6 drills each possible. Two site areas will be prepared for each HDD crossing; firstly the drill rig site where the HDD enters the ground (up to 50m x 50m, or equivalent area) and secondly the exit point on the other side of the crossing (up to 30m x 30m, or equivalent area).

When crossing underground services, it is likely that the cable trenches will pass underneath existing services, unless the service is extremely deep; determined through further surveys.

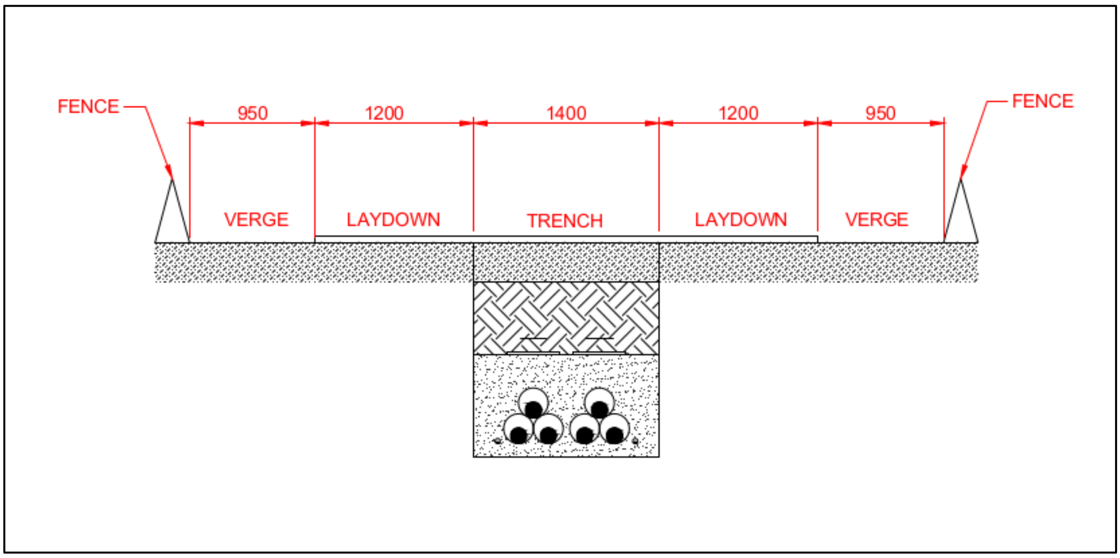


Figure 11: Cross-sectional diagram of example cable arrangement for installation in a single lane road

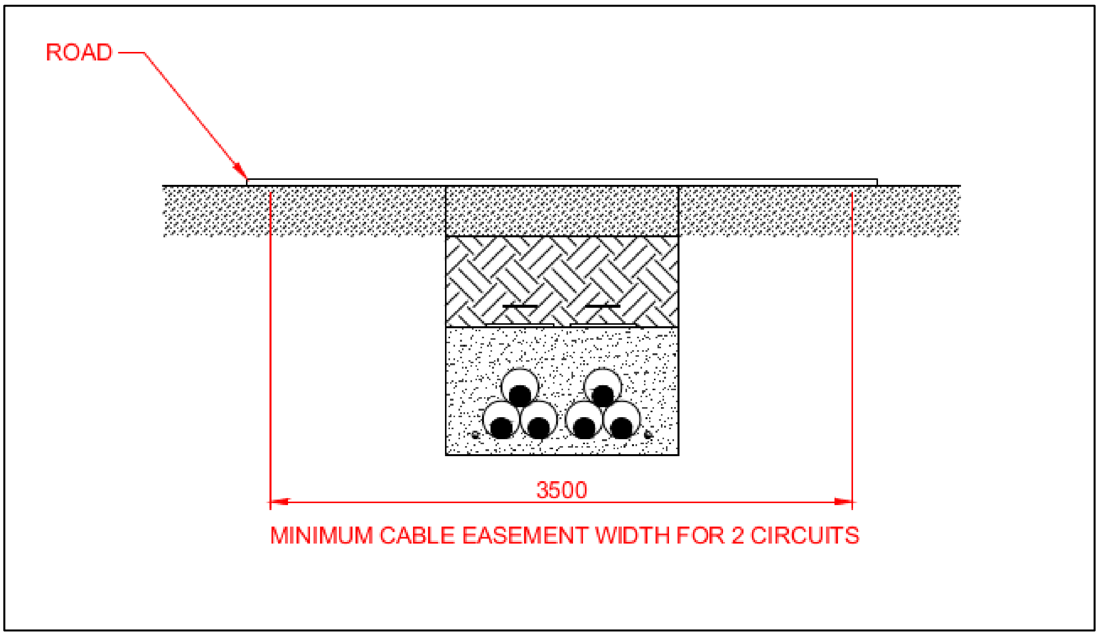


Figure 12: Cross-sectional diagram of example easement for trench installation

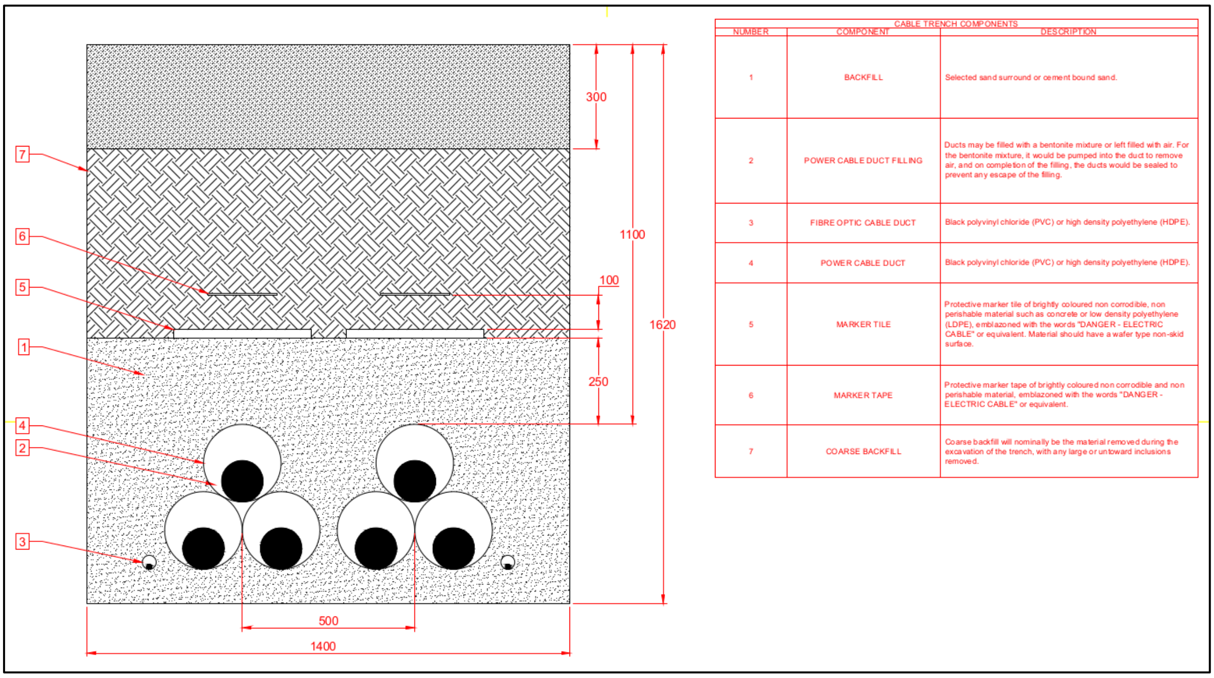


Figure 13: Cross-sectional diagram of an example trench with two 132kV cable circuits

See report '260318 Morlais Cable Routing Report' for more details

Table 4: Summary table for onshore cable parameters

Parameter	Value
Number of cables	6 power cables plus 2 fibre optic cables (2 circuits)
Cable diameter	Up to 110mm
Max. route length	17km
Trench dimensions	Up to 1.5m wide by 1.7m deep
Joint bays	Up to 40 (15m by 3m by 1.5m in size)
Temporary works area	6m up to 30m width. Space for cable pulling of up to 20m by 7m around each joint bay
HDD crossings	Up to 2 crossings, 6 drills each. Up to 50m x 50m temporary works area for drill rig; up to 30m x 30m temporary works area at exit point.

2.4 Construction

2.4.1 Construction Schedule

A likely build out schedule for the onshore and landfall infrastructure would be approximately 24 months (assuming all works carried out in parallel, not sequentially); consisting of the following:

- HDD at landfall – 4 to 6 months
- Substations (Landfall and Inland) - 24 months; first year enabling works and civils, second year electrical fit out and commissioning. Work mainly running in parallel, but some works staggered / phased between them.
- Offshore cable tail installation - 2 months
- Onshore cable circuit installation (including HDD for any crossings) -12 to 18 months

Working hours:

- 24/7 for HDD and offshore cable tail installation
- Daylight only / 6 days for all other works

Offshore works (for installation of tidal devices and associated cabling and infrastructure) would be phased over a period of several years, taking up to 15 days per device or hub and up to 1.5 day for each inter-array cable, and up to 20 days for each export cable; as detailed in Section 3.2.4 and Table 11.

2.4.2 Installation Method

Construction works will include the following principal activities:

- Enabling works at both the landfall and grid connection sites, including:
  - Surveying and measurement of sites
  - Reinforcement or alteration of access roads
  - Creation of construction compounds: temporary laydown/construction areas and site office (estimated up to 50 x 100m for both landfall and inland substations)
  - Provision of electricity supply to site and other services
  - Construction of temporary security site fencing/provisions
  - Possible tree and scrub clearance
  - Foundation excavation
- Landfall works.
  - HDD
  - Possible alternative works if HDD not found to be feasible: Consisting of cutting of shallow trenches with excavator / rock cutter; installation and pinning of ducting and/or subsea cable with split-pipe to cliff face, across foreshore region, all within trench where possible
- Creation of parking areas.
- Construction of foundations for substation buildings and plant.
- Construction of cable basements or cable pits.
- Construction of the landfall substation including building(s) and any outdoor compound(s).
- Construction of the inland substation including building(s) and any outdoor compound(s).
- Possible construction / installation of screening and/or landscaping measures, including embankments and/or stone walls.
- Construction of transition pits to joint marine and non-marine cables.
- Installation (pulling in) of subsea cable tails.
- Cable installation between submarine cables and inland substation.
- Cable installation between landfall and grid connection substations.
- HDD to enable crossings of watercourses/roads.
- Installation of transformers, switchgear and other electrical infrastructure within both substations.
- Termination of cables and wiring of electrical systems.

- Installation and termination of communications.
- Testing and commissioning activity.
- Reinstate access roads/public rights of way and affected ground.

2.4.3 Onshore traffic and staff

Estimates for the expected vehicle movements for the different stages of construction work are shown in Table 5 below.

Table 5: Vehicle trips and staffing requirements for onshore construction works

Item	TOTAL PERSON-DAYS	TOTAL HGV TRIPS	TOTAL LGV TRIPS
Cable Installation: 132kV double circuit in road to Valley	9,761	5,196	10,990
Landfall substation	4,240	1,575	3,645
Inland substation	7,425	3,609	8,353
HDD	4,500	480	540

Note that a trip has been defined as a return journey between vehicle origin (e.g. haulage depot, quarry, materials supplier) and the construction site (e.g. substation, cable installation site, construction compound).

2.4.4 Noise Emissions

A general and non-exhaustive list is included below for plant creating notable noise in relation to the onshore works. The plant list is relevant to construction.

Table 6: Noise emission figures for onshore construction plant

Vehicle / plant	A-weighted sound pressure level, *LAeq, T*, dB at 10 m	BS 5288-1:2009 Table Reference	Comments
Excavator	70 -79	Table C.2	Will be used at all points of the works
Bulldozer	75 - 81	Table C.2	Will be used at all points of the works
Dump Truck	76 - 81	Table C.2	Will be used at all points of the works
Rock breaker	82 - 93	Table C.1 C.5	May be relevant to substations and landfall works
Compressor	65 - 75	Table C.3 C.5	May be used at all points of the works
Generator	61 - 74	Table C.4	May be used at all points of the works
Pneumatic breaker mounted on excavator	72 - 95	Table C.1 C9	May be used at all points of the works
HGV Lorry	76 - 80	Table C.2 C.4	Will be used at all points of the works

HDD drill rig and power plant	77 - 82	Table C C.9	Likely needed at landfall and possibly the rail and road crossing along cable route if applicable
Pile driving (hammer)	77 - 89	Table C.3	If substation foundations need to be piled
Pile driving (sheet)	68 - 88	Table C.3	Possible for trenching works
Water pumps/motors and temp generators	62 - 65	Table C.2	May be needed at various locations depending on ground water conditions
Hand operated compactor	73 - 79	Table C.2	Will be used along cable routes and at substations
Driven compaction roller	78 - 80	Table C.2	May be used along cable routes and at substations
Concrete mixer lorry and pump	60 - 80	Table C.4	May be used at transition pits and substations
Cable pulling winch	73 -76	Table D.4	Various locations for cables
Tractor	79 - 80	Table C.4	May be used at various locations
Chain saw	86	Table D.2	Only if tree and bush clearance necessary
Angle grinder	80 - 91	Table C.4	Will be used at substations and various locations for cable works
Tarmac production plant	75 - 84	Table C.5	Used along cable route and at substations
Large mobile crane	71 - 82	Table C.4	Used at substations

Table 7: Summary table for onshore construction schedule parameters

Parameter	Value
HDD Schedule	4 to 6 months Working 24/7
Substations schedule (Landfall and Inland)	24 months Daylight only / 6 days
Offshore cable tail schedule	2 months Working 24/7
Onshore cable circuit schedule	12 to 18 months Daylight only / 6 days
Tidal device schedule	Up to 15 days per device or hub
Inter-array cable schedule	Up to 1.5 days for each
Export cable schedule	Up to 20 days for each

3 Offshore Infrastructure

3.1 Menter Môn Component of the Offshore Infrastructure

3.1.1 Offshore cable tails

Morlais will install up to 9 separate cable tails up to 620m long. It is anticipated that at least double armoured XLPE cables of up to 300mm^2 cross section may be used; resulting in a diameter of minimum 120mm. Developers will connect their own export cables to these.

Morlais cable tail installation will be achieved with the use of a specialist cable installation vessel, barge or multicat.

Cable landing onshore will be achieved through the use of a shore mounted winch which pulls the cable ashore through the ducts from the vessel. The installation vessel will then lay down a short length of cable tail and associated protection.

3.1.2 Cable tail installation

After HDD drilling, dive operations will be required to fit a seal/cap to the offshore end of each of the ducts. This would be carried out by a small dive support vessel/multicat and will take approx. 5 days.

Just before cable installation, dive operations will again be required to open the ducts and install pick-up lines for the cable laying vessel. If the HDD end is in an area of sediment then it may need to be exposed which will require diver excavation. This would also be carried out by a small dive support vessel/multicat and take approx. 5 days.

Installation of the Morlais Cable tails is likely to be undertaken by a cable vessel, barge or multicat (up to 140m by 6m draft), plus small support vessel(s).

The cable installation vessel is likely to be on site up to 10 days; Cable protection installation vessels may be on site for up to 2 days.

The cable vessel will be mobilised directly from manufacturing /supply port; likely to be Hartlepool, (Halden) Norway, Italy or Germany for cables.

Installation support ports are likely to be Holyhead, Mostyn, Liverpool or Birkenhead; although ports further afield may also be used.

It is anticipated that there will be a safety zone of 500m around all installation vessels during works.

Post cable install, if the HDD is to be bentonite filled then the offshore end will need to be vented which will require further dive operations. This would also be carried out by a small dive support vessel / multicat and take approx. 5 days.

See report '260318 Morlais Cable Routing Report' for further details.

3.1.3 Navigation and monitoring equipment

At a minimum, all boundaries of the zone will need to be marked with the appropriate IALA Cardinal mark. In addition, there may be additional cardinal markers or special mark buoys required, particularly along the western and eastern boundaries. The exact requirements for marking will be confirmed by appropriate regulators at consent.

A maximum of 6 marker buoys required for each array individual array has been assumed, totalling 48 buoys.

Cardinal buoys will be required to have flashing white lights with a visibility of not less than 5 nautical miles. Special Mark buoys to have flashing yellow lights with a visibility of not less than 5 nautical miles.

Each marker buoy is anticipated to have a body diameter of up to 3m, and a focal plane height for the light of 6m.

Marker buoys would typically be anchored by a gravity anchor (high density reinforced concrete or steel clump weight) no more than 3m in diameter, with a chain catenary in contact with the seabed of no more than 30m.

A number of Acoustic Doppler Current Profilers (ADCPs) will be deployed across the site to measure current flow speeds and directions. Each ADCP would most likely be a seabed mounted unit, deployed in a stainless steel seabed frame. Up to 40 units with a diameter of approximately 1.5m and a seabed footprint of approximately $7m^2$ each could be deployed across the site.

3.2 Developer Component of the Offshore Infrastructure

3.2.1 Export cable corridor

Indicative routes for 9 export cables, one to each tidal array have been estimated for each of the three preferred landfall sites.

These have been estimated without any detailed geophysical data and as the installation will be undertaken by the developers rather than Morlais; it is suggested that a cable corridor is put forward rather than the defined routes as they will require more detailed design and planning as well as coordination between developers. This is shown in Figure 14 below.

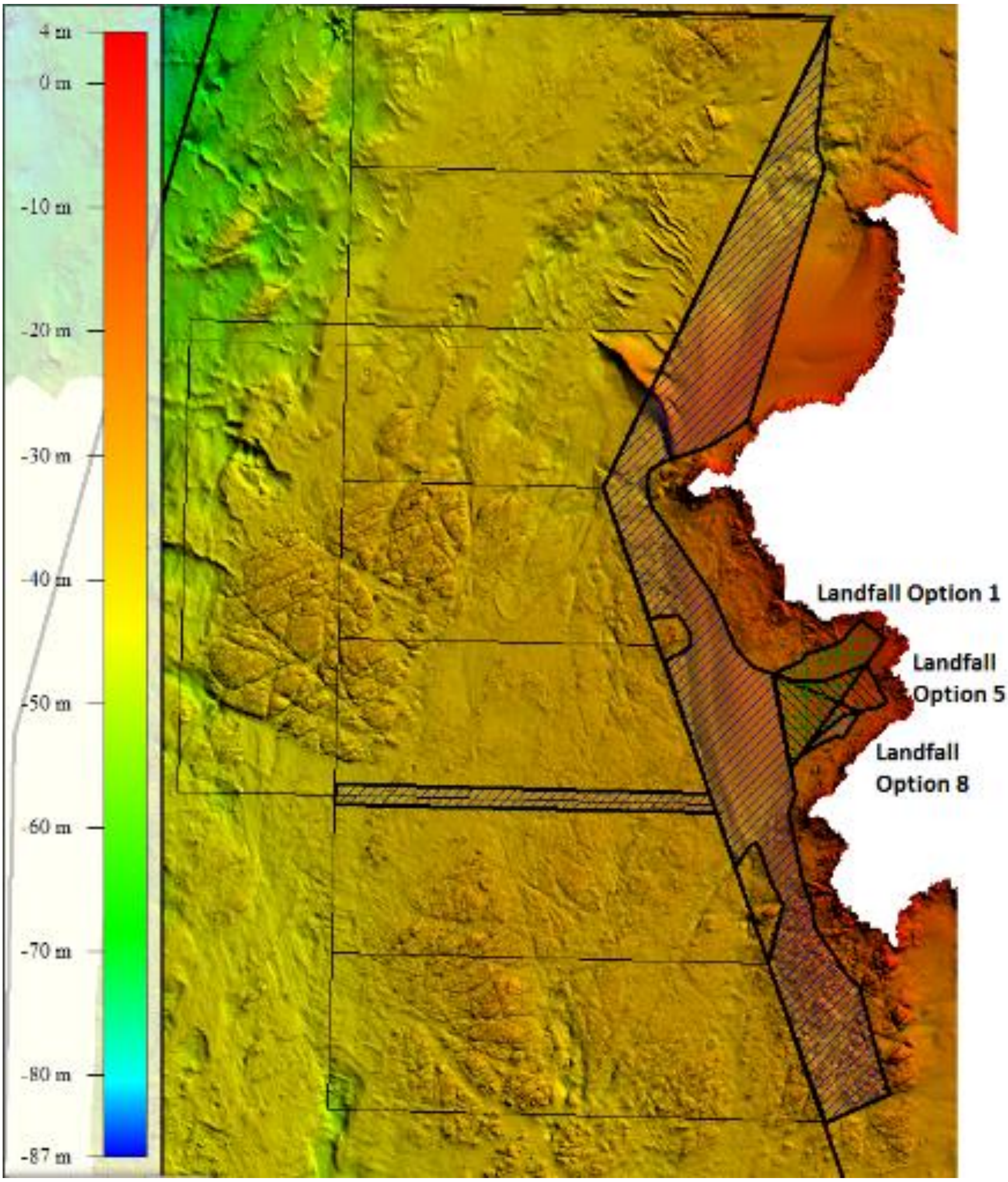


Figure 14: Morlais Export Cable Corridor

3.2.2 Indicative export cable routes

Indicative export cable routes only are shown in Figure 15, Figure 16 and Figure 17 below.

Careful route planning will have to be undertaken to avoid the worst of the ground conditions; rocky outcrops, excessive slope angles, uneven ground (which may result in suspensions) and significant seabed features.

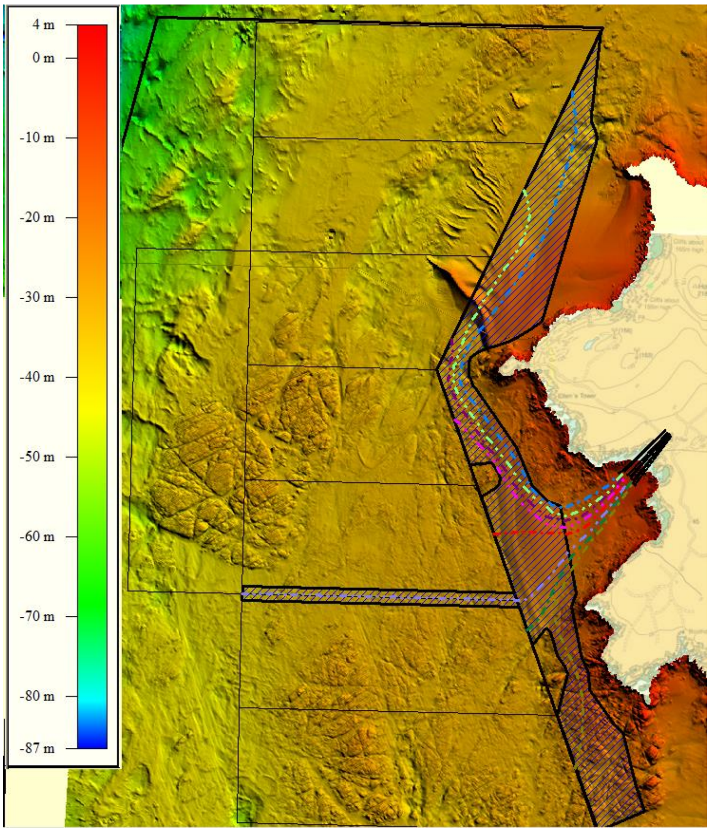


Figure 15: Indicative Routes to Landfall 1

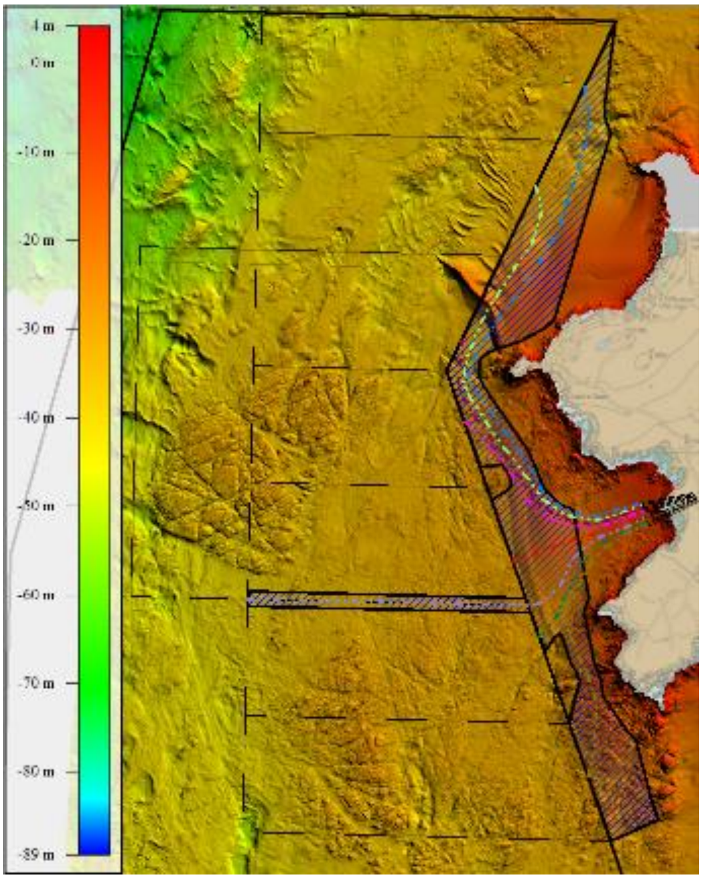


Figure 16: Indicative Routes to Landfall 5

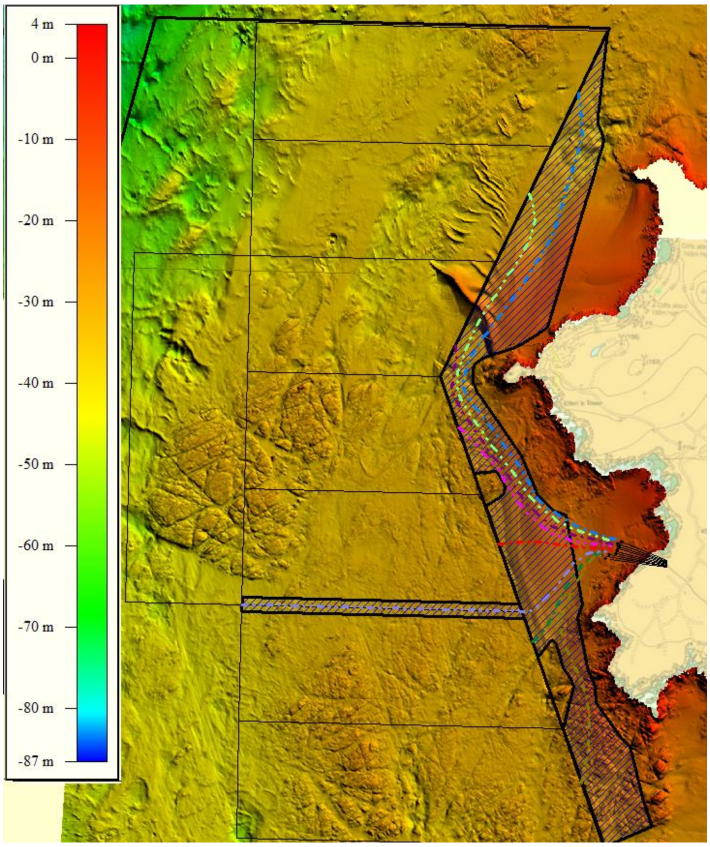


Figure 17: Indicative Routes to Landfall 8

3.2.3 Export cables

Up to 40.5km of export cables will be installed from 9 export cables (not including inter-array cables).

- Cable diameter, up to 120mm.
- With split pipe, up to 170mm diameter
- Individual cable routes 1.2km to 6km
- Total seabed footprint (cables + protection systems) could be up to 11,745m^2

Up to 160km of inter-array (turbine) cables may be installed on the seabed. Up to 30km of flexible umbilical cables mid-water column may also be used, for smaller floating or mid-water column devices, (See Table 13, Table 14 and Table 15 in Section 4.3 below).

3.2.4 Cable Protection and Installation

Cables will be free laid with strategic protection (rock bags, mattressing or split-pipe) at locations along the length. No trenching will be required, although it is possible that some post installation jetting may be needed to bury the cable in for the first 1 to 2km and other short sections if found necessary – see point immediately below.

There is a significant sandwave feature located in the northern half of the zone and export cable corridor. It is likely that cables will be installed over this and then carry out an as-laid survey to identify any areas where the cable is in suspension and then carry out any necessary targeted remedial work at that time. The sandwave can be reduced using a mass flow excavator or dredger. If the sandwave were to be removed completely and reduced to the surrounding seabed height a maximum of approximately 565,000 cubic metres of sediment will need to be removed.

Up to 270 individual rock bags or concrete mattresses (up to 18m^2 each) could be used on the export cables (excluding inter-array cables).

Developer export cables will be installed using specialist cable installation vessel, barge or multicat. The vessel will pick-up the Morlais cable end, connect their cable, and lay towards their tidal array. Following cable laying, protection systems (as above) will be installed and burial of the cable in the first 1 to 2 km may be attempted with multiple passes of a jet trenching ROV, or possibly diver burial techniques over shorter lengths in the shallow water.

Installation of export cables could require a medium sized cable installation vessel (up to 140m long and 6m draft), plus vessel for rockbags / matresses (30m long x 12m wide) with barge (could be up to 130m long, x 30m wide), with a small additional support vessel for each.

Cable installation vessels are likely to be on site up to 20 days each; protection installation vessels 12 days each. Up to 9 separate campaigns possible.

The cable vessels will be mobilised directly from manufacturing /supply port; likely to be Hartlepool, (Halden) Norway, Italy or Germany for cables.

Installation support ports are likely to be Holyhead, Mostyn, Liverpool or Birkenhead; although ports further afield may be used by some developers.

It is anticipated that there will be a safety zone of 500m around all installation vessels.

Connection to device arrays could include daisy-chained devices as well as connection via single and multiple hubs (submerged & surface piercing).

See report '260318 Morlais Cable Routing Report' for more details

3.2.5 Hubs

It is estimated up to 90 separate hubs may be required to aggregate output from multiple devices. See Table 13, Table 14 and Table 15 in Section 4.3 below. The following cases are envisioned:

- Up to 90 seabed mounted, fully submerged
- Up to 70 floating surface piercing
- Up to 8 seabed mounted, surface piercing

Hubs would typically connect and aggregate power from between 3 and 4 individual devices.

Hubs may be 'passive' - just a busbar joining multiple turbines together; or 'active' - containing a transformer, switchgear and possible control equipment (converters).

Seabed hubs are likely to be largely cylindrical structures, between 2 and 6m in diameter, up to 10m long. They may also have 'external', sealed transformers, that would fit into a similar footprint. Height of the structure off the seabed is likely to be approx. 5 - 8m. Keel clearance depends on the depth at the location. This clearance will be minimum 20m. They will largely be gravity bases of up to 600 tonnes.

Some hubs may also be on a surface piercing structure; a small jacket or monopile structure (2 - 6m diameter monopile, up to 18m above the sea surface at LAT). The electrical equipment could be within a larger diameter pile, or on a separate topside (up to 10m x 10m). Gravity base (up to 2,000 tonnes) or drilled piles (up to 6m diameter).

3.2.6 Operations and Maintenance of Export Cables

It is expected that once installed, the ongoing offshore operations for the export cables will be limited to inspection (through survey) and maintenance of the cables and ancillaries.

The inspection regime for the offshore cables is expected to consist of annual inspections for the first 2 or 3 years reducing to every 2 years thereafter depending on the results of the initial surveys.

The inspections will be performed by an offshore survey vessel using an ROV to assess the cables for any signs of damage or movement that has resulted in a free span. In the event of any cable movement to a position of concern, corrective action will either involve a (larger) work-class ROV to move that portion of the cable to a more stable location and/or the use of additional rock bags to lay over / under the cable in its new position.

As well as the scheduled maintenance operations it may be necessary to repair a subsea cable in the event of a failure or break. The most common cause of damage to a cable in offshore projects is from fishing trawl gear or anchor impact.

Repair of a cable will necessitate a vessel with suitable lifting and cable jointing equipment. The following process will be undertaken in this event:

- Isolation of the requisite cable(s).
- Location of the fault from onshore using suitable electrical techniques.
- Location and assessment of the fault offshore using an ROV.
- Cutting the cable subsea adjacent to the break on an area of 'good cable'.
- Lift the good end of the cable, check this part of the cable is undamaged;
- Once check is satisfactory, buoy off good end and return to water;
- Lift damaged section of the cable, cut out any damaged length;
- Splice on spare cable length;
- Return to previously buoyed off end and joint to spare cable;
- Return cable to the seabed;
- Complete testing from onshore;
- Re-energise system.

It is anticipated that up to 10 major cable repairs (5 days each) may be required throughout the project life. It is assumed that up to 750 m of cable will be subject to repair works per event (7,500m in total). These will involve the same type of seabed disturbance and potential exclusion of other marine users due to the presence of cable repair vessel, as experienced via the main cable installation phase. However, any such disturbance will be much more temporally and spatially limited.

Annual maintenance of navigational buoys and any environmental monitoring equipment will also be required. These works will be undertaken using a workboat with small crane. The buoys or ADCP frames will be lifted onto the vessel from which appropriate maintenance can be carried out, this will include cleaning to remove marine growth, bulb replacement for buoys; diagnostic tests and battery replacement for ADCPs.

Operations and maintenance requirements for Developer devices is described in Section 4.5.

3.3 Offshore Infrastructure Summary

Table 8: Summary table for offshore Infrastructure summary

Parameter	Value (Menter Môn Component)	Value (Developer Component)
Number of cables	9	9
Subsea export cable diameter	Nominally 120mm With split pipe, up to 170mm diameter	Nominally 120mm With split pipe, up to 170mm diameter
Subsea cable length	Up to 620m individual length Up to 5km total	Export cables: • Up to 6km individual length • Up to 40.5km total Inter-array cables: • Up to 2.5km individual length • Up to 160km total
Subsea cable + protection seabed footprint	Up to 120m^2	Export cables, up to 11,745m^2 Inter-array cables, up to 24,800m^2
Cable installation	Pulled through ducts from vessel using shore mounted winch	Surface laid with strategic protection. Post lay burial where possible.
Vessel days on site	10 days cable vessel 2 days cable protection vessel 15 days dive support	Up to 20 days for each export cable (180 total). Protection installation vessels 12 days each (108 days total) Up to 1.5 days for each inter-array cable including connection
Hubs	N/A	Up to 90 separate hubs. 70 surface piercing floating. 8 seabed mounted surface piercing **Seabed hubs** - between 2 and 6m in diameter, up to 10m long. **Surface piercing** - (2 - 6m diameter monopile, up to 18m above LAT). Equipment within pile, or on a separate topside (up to 10m x 10m).
Cable Repair		Up to 10 export cable repairs over lifetime of project. 5 days per repair. 750m length of cable affected per repair (x 10 repair events = 7,500m)

Navigation buoys	Up to 48 buoys, 3m diameter body, light at 6m heigh, visible at not less than 5 nautical miles. Anchored by a concrete weight no more than 2m in diameter, with a chain catenary in contact with the seabed of no more than 30m	N/A
Monitoring systems	N/A	Up to 40 seabed mounted ADCPs, with a diameter of approximately 1.5m and a seabed footprint of approximately 7m^2

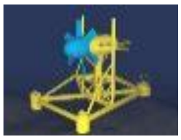
4 Developer Devices

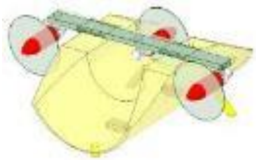
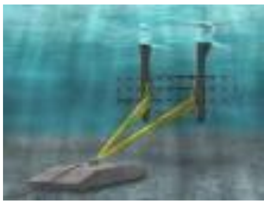
This section presents a summary of relevant parameters to define the Project Envelope for developer devices, presented by categories covering multiple devices, rather than by specific devices.

4.1 Device Categorisation

Table 9 below shows the initial suggested categorisation of devices for Project Envelope.

Table 9: Suggested categorisation of devices for Project Envelope

Category	Sub-Category Name	Device Name / Developer	Images
1 **Seabed Mounted Devices**	**(A) Seabed mounted single rotor**	Nova Sabella Atlantis Resources Corporation AR1500 Andritz Hydro Hammerfest	   
	(B) Ducted axial flow (seabed mounted)	Open Hydro	
	(G) 3 rotor seabed mounted platform.	Verdant	

	(I) Seabed mounted cross-flow	Repetitive Energy	
	(J) Seabed mounted multi-rotor	QED Naval Subhub	
2 Mind-water Column Devices	**(F) Multi rotor buoyant mid water.**	Renewable Devices Capricorn *(SME PLATO)*	 
3 Floating Devices	**(C) Multiple rotor buoyant platform**	TidalStream Triton Tocardo TFS	 
	(D) Twin rotor floating	Scotrenewables Magallenes	 
	(E) Cross-flow multi-rotor floating	Instream	
	(H) Spar Buoy	Aquantis	

The following categories have been excluded:

- Surface piercing, seabed mounted tower (e.g. Seagen S)
- Large seabed mounted cross flow, horizontally oriented (e.g. Kepler)
- Ducted cross-flow (e.g. Blue Energy)
- Other 'novel' designs (e.g. Minesto, Flumill, hydrofoils)

4.2 Array Layout

Three indicative layouts (each totalling 180MW), each with a different combination of device arrays (sub-categories) in different locations are shown in Figure 18, Figure 19 and Figure 20 below.

Note these are indicative only and show the variety of devices available, they are not intended to show actual layouts or locations of devices which will be determined by the developers themselves.

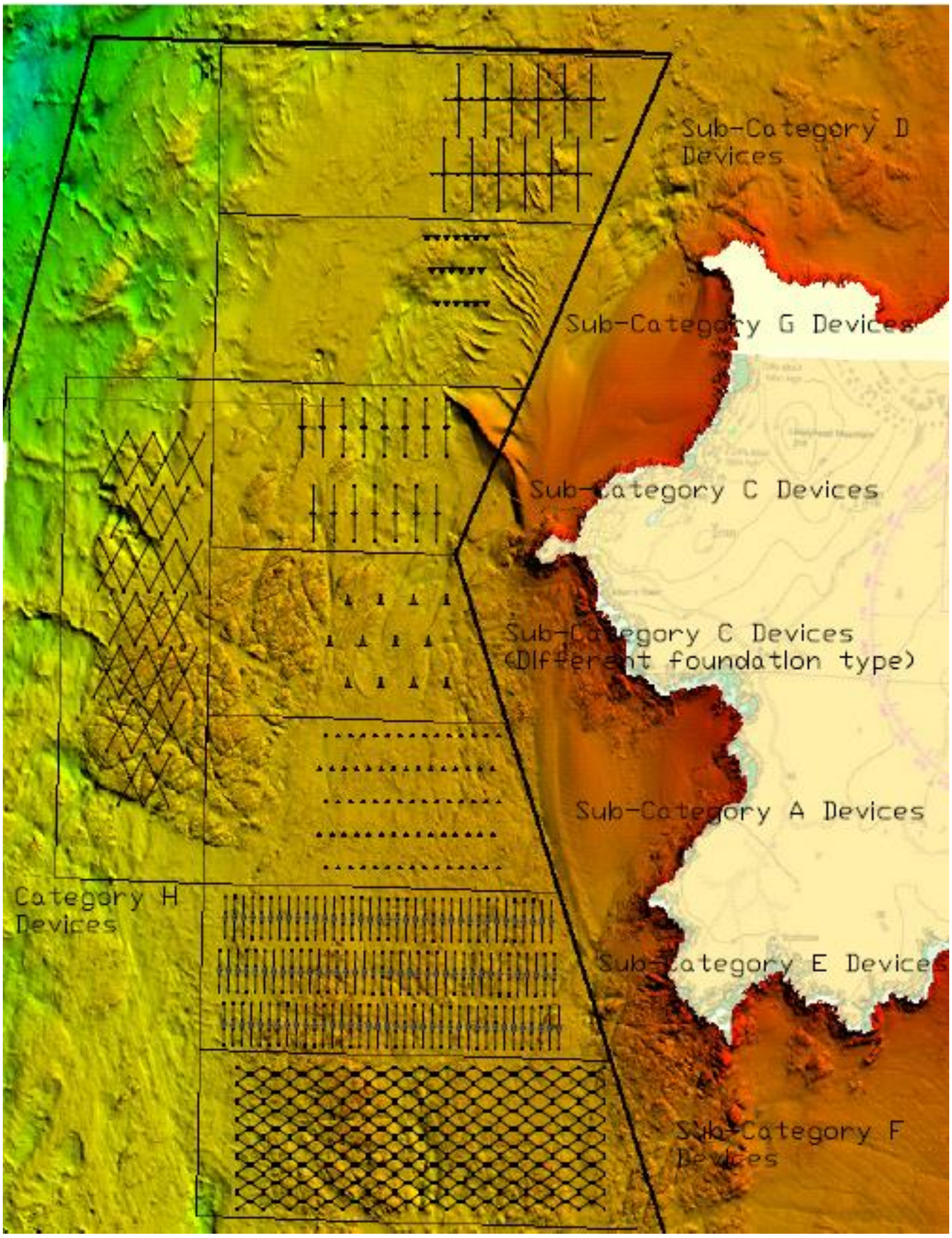


Figure 18: Indicative Layout Scenario1. Note these are indicative only and show the variety of devices available, they are not intended to show actual layouts or locations of devices which will be determined by the developers themselves.

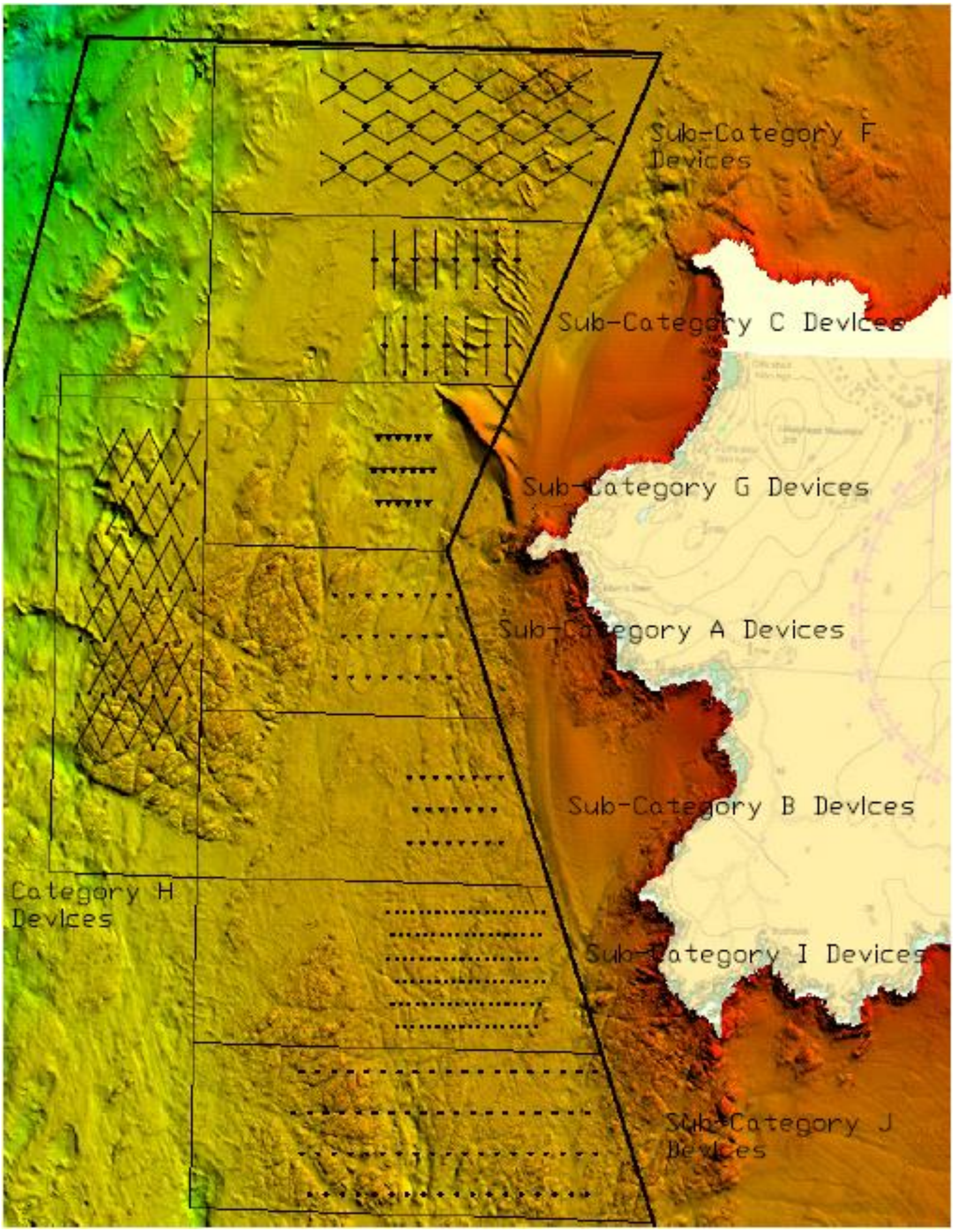


Figure 19: Indicative Layout Scenario 2. Note these are indicative only and show the variety of devices available, they are not intended to show actual layouts or locations of devices which will be determined by the developers themselves.

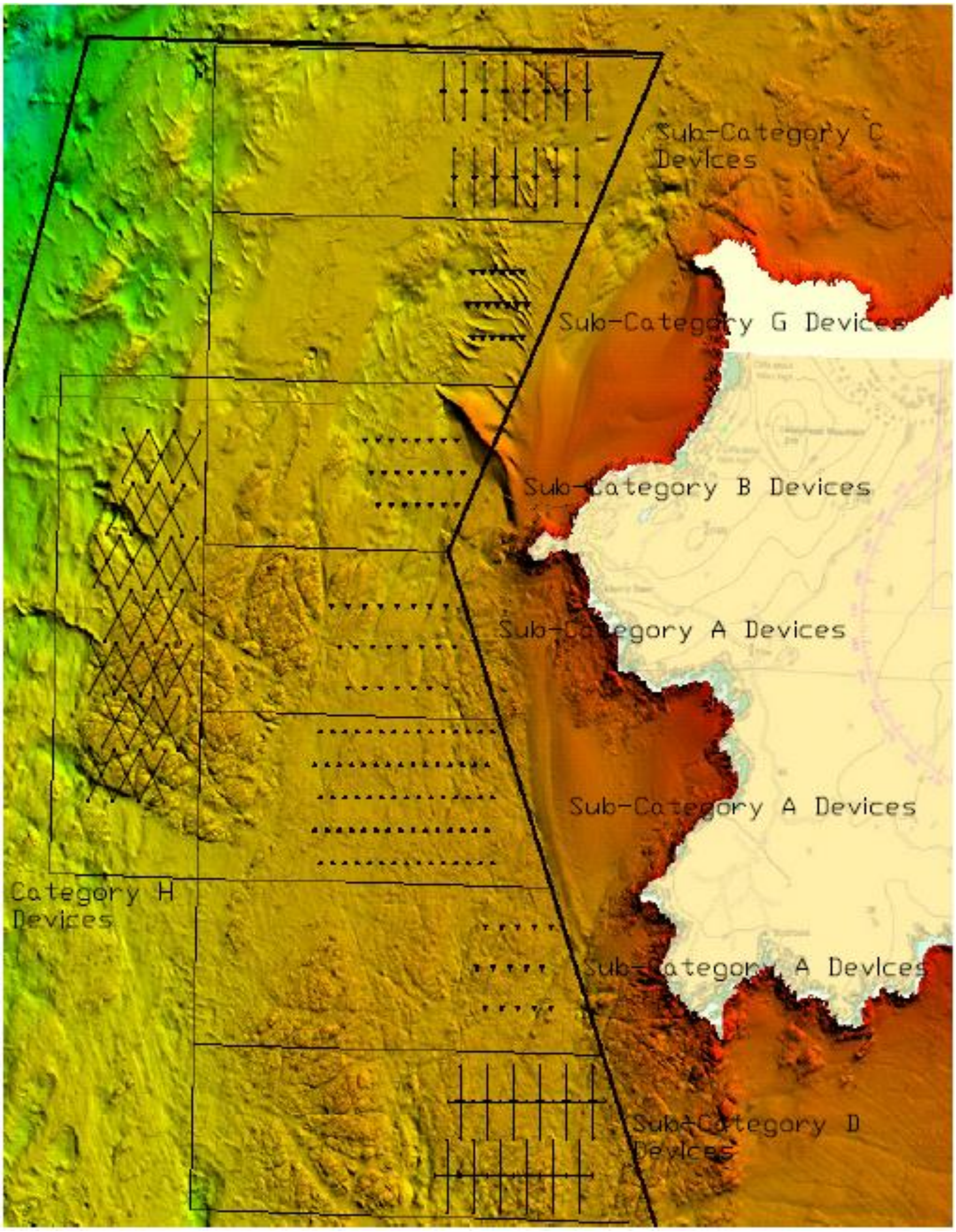


Figure 20: Indicative Layout Scenario 3. Note these are indicative only and show the variety of devices available, they are not intended to show actual layouts or locations of devices which will be determined by the developers themselves.

Given the number and spread of devices in a 180MW project (as shown in the images above), and the likelihood that inter-array cables for some of the floating and mid-water column devices may be suspended mid-water column, it is considered likely that the entire site may have to be an exclusion zone during the operational phase.

4.3 Device Parameters

Table 10 below summarises the typical as well as the 'extreme case' (maximum or minimum) for all the devices consulted (and categorised above). The 'device information' in this table is the same as from the RHDHV and MS PDE spreadsheet. Also see Table 11 to Table 15 for a breakdown of key parameters by category and array size.

Table 10: Device Parameters

DEVICE INFORMATION	Range or typical case for Project Envelope	Extreme case for Project Envelope
Location of devices	Seabed mounted, mid-water column, floating / surface piercing	
Nominal Output (MW) per device	Device output: 100kW to 2.5MW Individual turbine output: 50kW to 1.5MW	Up to 2.5MW for Multiple rotor buoyant platform (in Category 2). 1.5MW for largest single rotor system (in Category 1)
Under keel clearance under LAT (to closest point)	5m to 14m range of under keel clearance for fully submerged systems 1m to 6m for surface floating systems.	Minimum case for fully submerged (in Category 1) is 5m. Floating devices have no clearance at all/
Under keel clearance to rotor tip under LAT	Typically 5m to 14m range of under keel clearance for fully submerged systems 1m to 6m for surface floating systems.	Minimum for fully submerged (in Category 1) is 5m. Minimum for surface floating is (in Category 3) 1m.
Type/description of rotors or equivalent system	• Axial flow – Open rotor – Ducted • Cross flow Pitch control and fixed pitch blades	
No. of rotors (or equivalent for different systems)	Typically 1 to 4 per device. Up to 40 per device.	40 rotors for Multiple rotor buoyant platform (in Category 2). Up to 2,110 individual rotors total for the project (Deploying majority of small, multi-turbine devices)
No. of rotor blades (or equivalent for different systems)	Up to 10 (ducted turbine), or 6 open rotor. Typically 2 to 3, per rotor.	Up to 10 (ducted turbine), or 6 open rotor - per rotor. Up to 120 for a single device [Multiple rotor buoyant platform (in Category 2)] with 40 rotors. Up to 6,230 individual blades total for the project

Rotor diameter (m)	5m to 27m rotor diameter. Typically 10m to 16m diameter.	27m, open rotor, fully submerged, in Category 1
Area of leading edge of rotors	1.5 - 15 m^2 per rotor	Up to 15m^2 per rotor (for pitching blade) axial flow open rotor
Speed of turbine rotation	Nominally 11 - 15 rpm typical	Up to 60rpm (30m/s tip speed) for small rotors (less than 10m diameter), open rotor. Up to 15rpm (20m/s tip speed) for larger rotors (more than 11m diameter), open rotor.
Power conversion system	Typically each rotor would be coupled to a 3 stage planetary (helical) gearbox. This is then coupled to a standard asynchronous generator; most incorporate a hydraulically released parking brake. Most devices are variable speed, fixed pitch with frequency converters. About 50% of turbines yaw. Onboard step-up transformers are typical. 50kW to 1MW power trains will be most common.	Range could be 50kW to 1.5MW power trains per rotor. N.B: Can exclude hydraulic power transmissions.
Device structure	Typical seabed mounted axial flow turbines (in Category 1) have nacelles between 2m and 4m diameter, 15m to 30m long; mounted to towers/piles up to 50m long. Floating platforms between 22m long x 30m wide catamaran and 72m long x 4m diameter monohull.	• Largest structure would be Multiple rotor buoyant platform (in Category 2). Support structure weight - up to 1,100 tonnes, measuring 38m across ' wings', 30m high 'spar buoys' and tether arms 57m long – max 15 devices • Up to 180 surface piercing devices maximum: o Largest surface piercing element would be 72m x 4m diameter (Also 45m x 6m beam) for Twin rotor floating (in Category 2) – max 15 devices; or o 22m long x 30m wide (surface floating catamaran platform), in Category 2 – max 120 devices
Foundation type for devices	• Seabed mounted – Gravity bases (including tri-frame) – Multi-pile jackets (including tripod and quadrapod)	Largest could be a 'tri-frame' up to (30m x 30m), note area in direct contact with the seabed is significantly less, see below.

	– Monopiles • Floating with moorings & anchors – Mid-water column – Surface piercing Typically piles will be a single monopile, twin piles, tripods or quadrapods	Up to 4 piles or anchor blocks for some foundations. Up to 1,350 individual anchors / foundations including those for hubs.
Footprint of GBS foundations	The area in direct contact with seabed for a gravity base would typically be very small (<10m^2) as often gravity bases use 3 'feet' that penetrate the seabed (by up to 500mm). 'Swept Area' for floating systems (area that could be subject to chain drag) might typically be between 2,400m^2 (in Category 2) and 9,500 m^2 (in Category 2) per device.	Maximum case in direct contact with seabed, would be gravity anchors for floating systems (blocks of up to 13m x 6m [78m^2]), 4 per device (= 312m^2) - (in Category 2) 'Solid' bases (i.e without feet) would almost certainly only be used as anchors for floating systems, therefore levelling would not be important. In a few limited cases some clearing (or grouting) of the seabed might be necessary for foundations or drills if a sufficiently level area could not otherwise be found – this would be expensive in this depth of water though, so would not anticipate it being widespread. Total seabed footprint for gravity base foundations across the project could be up to 56,000m^2 'Catenary Swept Area' for floating systems (area that could be subject to chain drag) could be up to 9,500 m^2 per 2MW device maximum case - (in Category 2). Total 'Catenary Swept Area' across entire project could be up to 1,450,000 m^2
Footprint of piled foundations	18m x 23m tripod 'footprint' - typically 15m^2 of seabed actually drilled for piles (assumed using three 2.6m diameter sockets [2.2m diameter piles]). ~250m^3 of drill cuttings for same (3x2.6m diameter sockets 16m deep). (in Category 1)	Maximum across entire project assumed 180 devices plus 60 hubs using 4 drilled piles each (2.6m diameter sockets by 16m deep). Total volume of cuttings would amount to 244,650m^3. Disposal of material in-situ. The duration for each drill could be up to 3 days, for a total of 960 drills this would total 2,880 drilling days on site.
Device spacing and sea surface covered	Most seabed mounted devices would have a typical spacing of 70m to 100m between centres perpendicular to the flow, 180m to 250m parallel the flow.	Maximum case would be floating devices sharing moorings. Therefore up to 150m between structure centres perpendicular to the flow, 250m parallel to the flow (in Category 2). Each device could move by up to 80m (±40m) in the direction parallel to

	Although seabed conditions, could alter this considerably, and result in higher spacings.	the flow, and 60m (±30m) in the direction perpendicular to the flow. Overall surface area covered by device movement (including device yawing) is up to 4,800m^2 for a single floating device (in Category 2). Maximum area taken up by all arrays, including spaces between devices (i.e. not seabed footprint) could be up to 12,383,300m^2
Installation method including maximumseabed construction footprint (including anchors, jack up)	Wide range of installation strategies depending on the foundation / mooring approach: • Installation of foundations, then lower, ballast or pull the nacelles / turbines down onto the foundation. • Installation of foundation and turbine as a complete unit from a heavy lift (DP or moored barge) or bespoke vessel. • Installation of foundation and turbine as a complete unit towed to site and then ballasted into position (seabed or mid water column). • Use floating systems (towed to site) that remain on the surface (or partially so) attached to pre-installed anchors and mooring lines. Piled foundations would mainly be installed by a moored barge or DP vessel with sufficient cranage (250 - 400t). Monopile and pinpiles would most likely be installed through remote drilling using a subsea rig controlled from a DP vessel (up to 3 days per large pile drilled, or 1.5 days for pin-piles). Nacelle / powertrains together with rotors would then generally be installed separately using an appropriately sized DP vessel (likely to be the same as for the foundation installation) or a multicat. Typical time for complete installations is between 3 and 15 days per turbine, including foundation. Inter-array cables typically 1 to 1.5 days per cable including connection.	Fully deployed case would be pin-piled anchors requiring multiple drilling operations (in Category 1), could be up to 15 days per device. Total time on site installing developer devices and hubs could be up to 4,860 days Inter-array cable installation may take up to 1.5 days per cable to install and connect. For 775 inter-array cable total, this could total 1,162 days

	A moored barge suitable for installation would be approximately 100m x 30m and have 4 to 8 x 100 tonne gravity blocks (5m x 5m) or drag anchors (3m x 5m) with some anchor chain catenary, estimated at 400m to 500m length on seabed and 1m diameter. A typical mooring spread would consist of moorings on a 'radius' from the vessel centre of between 500 and 800m. Overall 'footprint' of mooring spread would be a rectangle of approximately 500 to 1,400m by 850 to 1,600m. This type of vessel will require one or two small support vessels (30m x 22m) to assist with positioning and anchor deployment. A DP vessel, would be of a similar size to the barge (155m x 30m) but would not disturb the sea bed and may not require any tugs.	
O&M	Wide range of O&M strategies, broadly falling into one of two categories: • Those with an intervention period of several years (generally between 2 and 5) • Those who intend to access their machines for maintenance (planned and unplanned) many times during each year However, unplanned maintenance, particularly in the early years, would likely require access to each device multiple times in a year, regardless of strategy. Access to machines for maintenance planned by developers in a manner broadly similar to their installation process: • All but the most major of maintenance activities carried out on-board devices whilst on site. • Removal of devices to an O&M port to carry out this work. • Modular approach so that certain systems can be removed from the device and taken to shore, leaving the rest of the device on site.	Access to each turbine could be up to 15 times per year. Maximum case would be requirements for moored barge or DP vessels for major operations (unplanned) / rebuilds; totalling 2 to 3 days per device.

	O&M vessels range from RIB, small work boat, through to large DP vessel. Surface piercing and floating technology would generally require RIBS or workboats for access for most operations. Larger jobs and fully submerged turbines generally require a DP vessel to lift / lower the nacelle and rotor onto the foundation for access. Work on these turbines will be carried out onshore. Turbine lifting operations would typically take only a few hours each.	
Materials	Turbine nacelles typically weight 100 - 200 tonnes - comprising mostly a steel structure, including main shaft, gearbox, generator, transformer and converter (large quantity of copper in the last 3 components). Rotors typically consist of 3 blades constructed from composite materials weighting between 1 and 4 tonnes each. The support structure for the nacelles are generally fabricated from approximately steel and range from 150t to over 600t. Piles fabricated from steel typically weight between 20 and 40 tonnes. Gravity foundations / anchors can weigh up to 1000t or more and are generally constructed from reinforced concrete.	Maximum case device would be large Multiple rotor buoyant platform (in Category 2) with gravity bases - 1,100 tonne steel platform, gravity base could be approximately 13x17x4m (2,000 tonnes) reinforced concrete Total for the entire site could be up to 145,000 tonnes of steel and up to 350,000 tonnes of concrete or rock.
Liquid inventory	Typically quantities of liquids will be less than: - 600l oil (gearboxes, transformers etc.) - 50l grease (bearings seals etc.) - 800l hydraulic fluid In each device	Maximum quantities across the entire site could be up to: - 180,000l oil (gearboxes, transformers etc.) - 9,000l grease (bearings seals etc.) - 140,000l hydraulic fluid
Antifouling system	Anti-fouling will typically be a dry coating of Antifouling – e.g. Intersleek 900; applied to local areas of concern. Would be applied before the first deployment. It would be reapplied where necessary during the subsequent removal of the device from the sea for maintenance.	

Coatings	Structures will typically be painted with modified epoxy or acrylic based paints suitable for subsea and splashzone, abrasion-Resistant; plus similar primer. e.g. International Protective Coatings - Interzone 954As or Resistex C137V2. Quantities generally less than 1,000 litres	Maximum across entire site could be up to 200,000 litres
Electrical systems	Most turbines will export grid compliant power at either 11kV (some 24kV or 33kV longer term) via converter, a step-up transformer from generator voltage (typically 690V), switchgear and a three-phase (wet or dry mate) connectors mounted in the nacelle of the turbine. Multi-turbine platforms generally aggregate output from all turbines (at generator voltage) and step up the voltage with a single transformer. Typical inter-array cabling would be approximately 9km to 17km in a (30MW) tidal array, **NB –** Inter-array cables for floating systems could be mid-water column umbilicals with buoyancy.	Maximum inter-array cabling could be up to ~28km per (30MW) tidal array; ~160km total. Total seabed footprint across the site for inter-array cables could be up to 24,800m^2 Up to 30km of flexible umbilical cables mid-water column may also be used, for smaller floating or mid-water column devices
Heating and cooling systems	Cooling in nearly all cases is achieved through passive heat sinks on the nacelle of the turbines, allowing heat to be dissipated into the surrounding water. In some cases, drivetrains (gearboxes and generators) are in direct contact with seawater, providing passive cooling that way.	Maximum case would be a device with a water abstraction/discharge system used for cooling.
Communication systems	Typically fibre optics through the power umbilical cable. Back-up with radio antenna or wifi	
Energy storage	Some devices may have some energy storage in the form of (lead-acid) batteries. These systems are generally small 2 - 7kWh	Maximum case would be technology with sufficient battery storage to power connection / disconnection systems (e.g. winches). These could be as high as 12 to 50kWh systems, these are unlikely to be lead-acid, more likely Li-ion, Ni-MH, etc.
Energy sink	Assuming 5% dissipation of energy as heat - between 10 and 125kW of heat per device will be sunk into the tidal flow during operation.	

Power requirements	Many turbines require auxiliary power to run winches, hydraulic and communication systems etc. Power will also be required to energise transformers and generators during start-up and stand-by. Supply of electrical power through additional (low voltage) cores within the export cable will be included. Generators will also produce reverse power flow through the main cores. 'Reverse' power flows would typically be between 20 and 150kW for each turbine.	Maximum power draw for the entire site could be up to 30MW
Hydraulic systems	Hydraulic systems are used in many turbines for access systems or locking system, as well as to maintain sufficient oil flow through gearboxes and bearings. Hydraulics also used to actuate brake to hold the rotor static when required. Typical quantities of hydraulic fluid onboard is likely to be less than 1,000 litres.	
Potential discharges to sea	There are no intentional emissions or discharges from devices. Marine pollution would be restricted to matters related to leakage of lubricants and the type of paint or coating that the subsurface structures would use to prevent excessive growth of marine organisms. Any leak is not likely to result in the discharge of more than 1,000 litres of oil based hydraulic fluid. Discharges from installation and O&M vessels may occur (such as cooling water) however, this will be restricted by maritime standards and regulations. Up to 6m^3 of cement based grout may be discharged into the water at the seabed. This is non-toxic and would either reside around the foundations of the device or gradually be removed by the tidal flows.	
Potential discharges to air	There are no anticipated gaseous discharges into the air environment by the devices during the installation, operational and decommissioning phases. There will be atmospheric discharges associated with the installation and O&M vessels however.	

4.4 Device Numbers

The following total device numbers can be expected across the Morlais zone:

- Up to 620 small (less than 300kW) devices
- Up to 180 large 1MW+ devices
- Up to 180 surface piercing devices (large or small)
- Max 30MW of any one device in an array (max 150 devices)

4.4.1 Phasing

Most respondents indicated that they would be looking to deploy the first phase of their projects as soon as Morlais is ready, in 2022. Based on the responses that were received and on the general development strategies within the industry; it is likely that most developers would be looking for an initial phase of between 3 to 5 MW, with a ~10MW phase following a few years afterwards; and an ultimate build out of up to 30MW per tidal array. Some of the developers of smaller systems stated that an initial phase of 1 to 2MW would be their aim.

Based on this position and to aid in evaluating impacts of different project sizes / phases, parameters for individual devices, as well as for a 5MW, 10MW and 30MW array are presented in Table 11 to Table 15 for the 'extreme case' for each category of device

Table 11: Device (Rotor and Structural) Parameters by Category

		Rated capacity of Device	Rotor diameter	Max. single TEC swept area (m^2)	Max. device swept area (m^2)*	Max tip speed (m/s)	Min. seabed clearance (m)	Min. surface clearance (LAT) (m)	Height of surface piercing structure (m)
Category 1	Seabed mounted single rotor	0.1 - 1.5MW	5 - 26m 1 rotor	530.9	530.9	19.7	4	5	N/A. But possible use of small marker buoys
	Ducted axial flow (seabed mounted)	1 - 2MW	12 - 16m 1 rotor	201.1	201.1	5.9	3	11	N/A. But possible use of small marker buoys
	3 rotor seabed mounted platform	1.2MW	10 - 16m 3 rotors	78.5	235.6	11.5	6	14	N/A. But possible use of small marker buoys
	Seabed mounted cross-flow	0.025 - 0.5MW	5 - 10m 1 rotor	50.0	50.0	22.0	2	21	N/A. But possible use of small marker buoys
	Seabed mounted multi-rotor	0.15 - 1.5MW (3MW)	5 - 16m 3 rotors	78.5	235.6	15.7	3	17	N/A. But possible use of small marker buoys
Category 2	Multi rotor buoyant mid water.	0.2 - 1.25MW	5 - 16m 2 to 4 rotors	201.1	402.1	12.6	8	6	N/A. But possible use of small marker buoys
Category 3	Multiple rotor buoyant platform	1.5 - 2MW	5 - 10m 5 to 40 rotors	75.4	785.4	30.0	8	3 (surface piercing)	Twin elements, each approx 9m x 3m x 3m. Antennas an additional ~2.5m
	Twin rotor floating	2MW	16 - 19m 2 rotors	283.5	567.1	15.9	11	5 (surface piercing)	72m long, 3.8m diameter (~2m above water) 45m long x 6m breadth, 4-5m high. Antennas an additional ~2.5m
	Cross-flow multi-rotor floating	0.2MW	5m 4 rotors	12.5	50.0	8.5	24	1 (surface piercing)	Twin hulls up to 22m long, 3m diameter (1.5m above water). Gantry and infrastructure up to another 2.5m heigh.
	Spar buoy	0.5 - 1MW	16 - 27m 1 rotor	415.5	415.5	13.6	11	6 (surface piercing)	Up to 4m diameter 6.5m heigh

* Includes rotor hub

Table 12: Device (Installation & Array) Parameters by Category

		Likely layout / spacing	Floating device movement (m)	Hubs	Seabed footprint of device (m^2)	Total device area (m^2)	Volume of drill arisings from pile install (m^3)
Category 1	Seabed mounted single rotor	~100 x 250m ~50 x 100m	N/A	Likely. 1 for every 3 to 6 devices. Could be surface piercing	25	400	300
	Ducted axial flow (seabed mounted)	~160 x 400m (80m x 200m)	N/A	Possibly. 1 for every 3 to 4 devices. unlikely surface piercing	21	420	N/A
	3 rotor seabed mounted platform	~60 x 200m	N/A	Possibly. 1 for every 4 devices. Could be surface piercing	10	650	N/A
	Seabed mounted cross-flow	~50 x 150m ~100 x 250m	N/A	Likely. 1 for every 4 devices. Could be surface piercing	144	144	N/A
	Seabed mounted multi-rotor	~100 x 250m	N/A	Unlikely. But could be 1 for every 3 to 4 devices. unlikely surface piercing	10	875	N/A
Category 2	Multi rotor buoyant mid water.	~150 x 300m ~120 x 120m	±35m parallel to flow. ±35m perpendicular to flow	Unlikely. But could be 1 for every 3 to 4 devices. Likely surface piercing	240	2000 (including moorings)	18
Category 3	Multiple rotor buoyant platform	~150 x 500m	±40m parallel to flow. ±30m perpendicular to flow	Unlikely	300	1600 (including moorings)	254
	Twin rotor floating	~200 x 450m ~150 x 200m	±40m parallel to flow. ±30m perpendicular to flow	Possibly. 1 for every 4 devices. Likely surface piercing	478	2,100m (including moorings)	340
	Cross-flow multi-rotor floating	~50 x 300m	±15m parallel to flow. ±10m perpendicular to flow	No	168	1300 (including moorings)	N/A
	Spar buoy	~180 x 340m ~100 x 250m	±20m parallel to flow. ±20m perpendicular to flow	Unlikely. But could be 1 for every 3 to 4 devices. Likely surface piercing	460	2000 (including moorings)	255

* Includes hub

Table 13: Parameters for 5MW Array by Category

		~5MW array									
		Number of devices	**Max array swept area (m^2)**	**Array seabed footprint (m^2)**	**Total array area (m^2) ***	**Seabed footprint electrical hubs (m^2)**	**Length of inter-array cabling (m)**	**Footprint of inter-array cabling (m^2)**	**Number inter-array cabling protection systems**	**Footprint inter-array cabling protection (m^2)**	**Volume drill arisings pile installation (m^3)**
Category 1	Seabed mounted single rotor	4 to 50	2,124	425	183,300	180	2,800	336	34	154	5,100
	Ducted axial flow (seabed mounted)	3 to 5	1,005	106	32,900	60	1,500	180	10	45	N/A
	3 rotor seabed mounted platform	5	1,178	50	29,200	80	2,800	336	10	45	N/A
	Seabed mounted cross-flow	10 to 200	1,250	3,600	136,400	80	3,700	444	50	226	N/A
	Seabed mounted multi-rotor	4 to 34	1,442	170	408,900	80	4,000	480	34	154	N/A
Category 2	Multi rotor buoyant mid water.	4 to 25	1,608	960	416,470	80	3,800	456	50	226	462
Category 3	Multiple rotor buoyant platform	3 to 4	2,356	1,200	149,700	N/A	2,600	312	8	36	1,017
	Twin rotor floating	3	1,701	1,433	185,080	60	2,000	240	9	41	1,019
	Cross-flow multi-rotor floating	25	1,250	4,200	373,200	N/A	2,500	300	50	226	N/A
	Spar Buoy	5 to 10	2,077	2,300	278,730	60	2,400	288	10	45	1,274

*Including spaces between devices; but does not factor in seabed constraints; which could increase spacings considerably

Table 14: Parameters for 10MW Array by Category

		10MW array									
		Number of devices	**Max array swept area (m^2)**	**Array seabed footprint (m^2)**	**Total array area (m^2) ***	**Seabed footprint electrical hubs (m^2)**	**Length of inter-array cabling (m)**	**Footprint of inter-array cabling (m^2)**	**Number inter-array cabling protection systems**	**Footprint inter-array cabling protection (m^2)**	**Volume drill arisings pile installation (m^3)**
Category 1	Seabed mounted single rotor	7 to 100	3,717	825	436,200	360	5,600	672	74	335	10,200
	Ducted axial flow (seabed mounted)	5 to 10	2,011	212	113,900	120	3,000	360	24	109	N/A
	3 rotor seabed mounted platform	9	2,121	90	88,700	160	5,600	672	26	118	N/A
	Seabed mounted cross-flow	20 - 400	2,500	7,200	329,800	160	8,900	1,068	112	507	N/A
	Seabed mounted multi-rotor	7 to 67	2,799	330	662,500	160	9,500	1,140	74	335	N/A
Category 2	Multi rotor buoyant mid water.	8 to 50	3,217	1,920	952,700	160	8,500	1,020	100	452	924
Category 3	Multiple rotor buoyant platform	5 to 7	3,927	2,100	347,300	N/A	5,200	624	15	68	2,034
	Twin rotor floating	5	2,835	2,389	404,800	120	3,900	468	15	68	2,039
	Cross-flow multi-rotor floating	50	2,500	8,400	823,090	N/A	5,000	600	100	452	N/A
	Spar Buoy	10 to 20	4,155	4,600	544,300	120	4,800	576	26	118	2,548

* Including spaces between devices; but does not factor in seabed constraints; which could increase spacings considerably

Table 15: Parameters for 30MW Array by Category

		30MW array									
		Number of devices	**Max array swept area (m^2)**	**Array seabed footprint (m^2)**	**Total array area (m^2)***	**Seabed footprint electrical hubs (m^2)**	**Length of inter-array cabling (m)**	**Footprint of inter-array cabling (m^2)**	**Number inter-array cabling protection systems**	**Footprint inter-array cabling protection (m^2)**	**Volume drill arisings from pile installation (m^3)**
Category 1	Seabed mounted single rotor	20 to 300	10,619	2,500	1,241,800	1080	16,800	2,016	220	528	30,600
	Ducted axial flow (seabed mounted)	15 to 30	6,032	636	345,800	360	9,000	1,080	72	326	N/A
	3 rotor seabed mounted platform	26	6,126	260	246,900	480	16,800	2,016	76	344	N/A
	Seabed mounted cross-flow	60 to 1,200	7,500	21,600	949,300	480	26,700	3,204	330	1493	N/A
	Seabed mounted multi-rotor	20 to 200	8,482	1,000	1,838,600	480	28,500	3,420	230	1040	N/A
Category 2	Multi rotor buoyant mid water.	24 to 150	9,651	5,760	2,159,800	480	15,600	1,872	300	1357	2,771
Category 3	Multiple rotor buoyant platform	15 to 20	11,781	6,000	1,065,500	N/A	15,600	1,872	50	226	6,101
	Twin rotor floating	15	8,506	7,167	1,155,100	360	11,700	1,404	40	181	6,116
	Cross-flow multi-rotor floating	120	6,000	20,160	2,070,400	N/A	9,200	1,104	240	1086	N/A
	Spar Buoy	30 to 60	12,464	13,800	1,773,200	360	14,400	1,728	72	326	7,645

* Including spaces between devices; but does not factor in seabed constraints; which could increase spacings considerably

4.5 Operations and Maintenance of Developer Devices

Developers are expected to visit each tidal device up to 15 times annually for both planned and unplanned maintenance activities. Many developers plan to undertake at least monthly routine inspection / maintenance using small vessels. A worst case scenario of one five hour visit to each device on site per month may be foreseeable.

During maintenance activities a safety zone will apply around the O&M vessels. Offshore maintenance activities should be made available through Notices to Mariners

Typical maintenance jobs may include: diagnostic tests, oil changes and lubrication, replacement of control cards and sensors, removal of biofouling, overhaul or replacement of systems (gearboxes, generators, switchgear etc.). Major operations such as retrieval and repair following structural failures would require similar vessels and procedures as installation works.

Maintenance procedures vary with device types with some tidal technologies having built in mechanisms to raise the devices to the water surface minimising the requirement for large maintenance vessels. Examples are as follows:

- Buoyant nacelle (remotely) released to surface and towed by a Multicat or workboat to maintenance port. All work will be carried out onshore.
- Device designed for minimal interventions and high reliability (most critical systems are off the device), no gearbox or lubrication systems. Nacelle lifted with bespoke lifting frame via guide chains attached to the foundation. Turbine disconnected from cable and taken to shore for work.
- Each turbine nacelle can be independently lifted from / lowered onto a seabed frame using a DP vessel or crane barge with moderate lifting capacity. Work on the turbines will be carried out onshore. Lifting operations would typically take only a few hours each.
- Floating device is designed so that it can be accessed at sea so that a large proportion of the maintenance can be carried out without removing the turbine from its moorings. The device can, however, be towed by a small vessel to a nearby port for any major maintenance works.
- Surface piercing, floating platform is designed to be stable enough to carry out all but the largest of maintenance operations at sea. Access can be gained for some operations through surface piercing elements (transformers, control equipment etc.). Platform is raised (through variable buoyancy) for access to turbines. These can then be separately removed to shore for major work as necessary. Vessels for O&M would mainly be a workboat or Multicat. For removal of turbines, a large Multicat or possibly offshore DP vessel may be required.

For electrical hubs, requirements will vary depending on supplier and nature of the hub. Likely to require access several times a year. Fur fully submerged systems, the hub and foundation would either be lifted in its entirety or a buoyant hub may be remotely released, and accessed by a much smaller vessel on the surface. Surface piercing hubs could be access using smaller vessels on site and/ or be towed to shore for more major operations. A wide variety of DP vessels, heavy lift vessel, Multicat, workboats and ROVs may be used.

5 Vessels

Vessel Type	**Cable installation**
Use	Installation of subsea cables
Typical examples	CS Sovereign
Description	These vessels transport the spool of subsea electrical cable to the offshore site and allow the cable to be reeled off the spool and layed on the sea bed as the vessel tracks along the intended cable route.
Dimensions	Length 130.7m, Beam 21 m.
Draught	7.0 m
Gross tonnage	11,242 te
Propulsion	10,200 kW, 2 x Stork-Wärtsilä, including DP2 capbility (2 x 1MW bow thrusters, 2 stern azimuth thrusters)
Lifting capacity	7 small cranes with capacity < 5te. Max capacity of 5,200 te of cable
Other comments	Typically used to also deploy a cable plough/trencher but this is not likely to be the case at the Morlais site. An ROV may be employed during the cable lay to ensure the cable is free from snags/boulders etc
Anticipated vessel movements during construction	Up to 20 days for Morlais cable tails, and up to 20 days for each export cable. 10 days each for decommissioning of same cables. Up to 1.5 days per inter-array cable.
Anticipated vessel movements during O&M	Up to 4 events (5 days each) throughout project life for cable breaks

Figure 21: DP2 cable lay vessel (CLV) - C.S Sovereign (Image Source: Global Marine)

Figure 22: Cable Enterprise, cable lay barge (Image Source 4COffshore)

Vessel Type	**Small DP OSV**
Use	Installation / O&M
Typical examples	Kingdom of Fife
Description	Small and medium sized DP offshore vessels are often used for drill support, anchor handling, cable retrieval.
Dimensions	Length 61.20m, Beam 13.5m, Deck Space 300 m2
Draught	6.0m
Gross tonnage	1,459 te
Propulsion	2 x 2 MW Caterpillar C286-6, plus 392kW bow thruster
Lifting capacity	2 cranes each with capacity < 20te. Deck cargo capacity 500te,
Other comments	Bollard pull 75 te.
Anticipated vessel movements during construction	Up to 7 days installation per device and foundation.
Anticipated vessel movements during O&M	Up to 20 days per device per year (2 days per visit [1 day pickup on day dropoff], 10 visits)

Figure 23: Kingdom of Fife DP vessel (Image Source: 4COffshore)

Figure 24: The Severn Sea (Image Source: KML)

Vessel Type	**Offshore DP**
Use	Installation / O&M
Typical examples	North Sea Giant
Description	Multi Purpose Offshore Construction Vessel with sufficient deck space and cranage to accommodate most moderate offshore infrastructure lifts.
Dimensions	Length 160.9m, Beam 30.0m, Deck Space 2900 m^2
Draught	7.0m
Gross tonnage	18,151 te
Propulsion	21 MW Power. Konsberg DP III. 5 Voith-Schneider Units
Lifting capacity	1x 400 t Crane, 1x 50 t Crane
Other comments	DP3 capability with 3 stern thrusters and 3 bow thrusters. Dayrate: £100k-£150k/day
Anticipated vessel movements during construction	Up to 15 days installation per device and foundation (based on 4 x seabed drills).
Anticipated vessel movements during O&M	Up to 20 days per device per year (2 days per visit [1 day pickup on day dropoff], 10 visits)

Figure 25: North Sea Giant DP Vessel (Image source: North Sea)

Vessel Type	**Crane Vessel/Barge (Moored)**
Use	Installation/O&M
Typical examples	KML BD6074
Description	These relatively simple vessels offer moderate lifting capabilities and deck space but are well suited to installing tidal turbine nacelles. Typically they may be self propelled but offer no DP capabilities and so have to be positioned by tugs to deploy anchors to allow them to hold station.
Dimensions	Length 42.0m, Beam 22.0m, Deck Space 400m2
Draught	2.5m
Gross tonnage	1,246 te
Propulsion	N/A
Lifting capacity	150 te at 20m radius
Other comments	This vessel has a mooring system comprising 6 point, heavy duty Skagit/Smatco>350m 42 mm wire. A typical mooring spread would consist of 4 or 6 moorings on a 'radius' from the vessel centre of between 500 and 800m. Overall 'footprint' of mooring spread would be a rectangle of approximately 500 to 1,400m by 850 to 1,600m. Maximum theoretical impacted area for a large vessel is up to approximately 380,000m^2 (based on the maximum possible extend of vessel movement with a single anchor set-up). In reality it is highly unlikely that an installation would require quite so much movement from the vessel without moving anchors. Based on installing 5 machines in a row from a single anchor set-up, one might expect an impacted area of around 160,000m^2. It would be possible to achieve the same with a much smaller area, but that would require bigger anchors and hence bigger vessels to install them. Each anchor weight would be approximately 5 to 8m in diameter.

Anticipated vessel movements during construction	Up to 7-15 days installation per device and foundation.
Anticipated vessel movements during O&M	Unlikely to be used

Figure 26: Moored crane barge (Image Source: KML)

Vessel Type	**Multicat**
Use	Installation / O&M
Typical examples	Whalsa Lass
Description	As the name implies these are multiple use vessels that are frequently used to transport personnel, deliver small loads to site, towing floating devices. Their stability and speed, provided by the catermeran hulls can provide an advantage over tugs or other single hull, general purpose vessels. Anchor/mooring handling is another key role for these vessels
Dimensions	Length 26.0m, Beam 11.5m, Deck Space 160m2
Draught	3.5m
Gross tonnage	225 te
Propulsion	3 x Caterpillar C32 TTA, with three props, giving a total power of 1,902kW
Lifting capacity	2 x 10 te cranes (@16.5m), Bollard pull 37.2 te
Other comments	Some vessels have DP1/2 capability, but generally moored.
Anticipated vessel movements during construction	Up to 7 days installation per device.
Anticipated vessel movements during O&M	Up to 10 days per device per year (1 day per visit, 10 visits)

Figure 27: Multicat vessel – Green Isle (Image Source: Green marine)

Vessel Type	**Tug**
Use	Installation / O&M
Typical examples	Orkney Harbours – M.T. Harald
Description	Another multipurpose vessel capable of engaging in a wide variety of activities. Typically used to tow floating objects to site, keep barges/vessels on station whilst they are mooring. Their good visibility from the bridge and maneuverability means they are useful for operations where agility is required. Deck space and cranage allows the transport of equipment to site
Dimensions	Length 32.0m, Beam 10.0m,
Draught	4.6m
Gross tonnage	410 te
Propulsion	2 x azimuth Aquamaster units provide a total of 2,983 kW power
Lifting capacity	Lifting < 10 te (if crane fitted), Typical bollard pull 50 - 100 te
Other comments	The tug is equipped with towing equipment capable of loads in excess of 120 tonnes
Anticipated vessel movements during construction	Up to 5 days installation per device.
Anticipated vessel movements during O&M	Up to 10 days per device per year (1 day per visit, 10 visits)

Figure 28: Tug Boat (Image Source 4COffshore)

Vessel Type	**Workboat**
Use	O&M
Typical examples	MV LINE (CT Offshore)
Description	Similarly to multicats and tugs, workboats may be purposed for a range of tasks. These may include personnel transfer, surveying, the transport and deployment of equipment at site and diving/ROV support.
Dimensions	Length 26.0m, Beam 6.0m, Deck Space 40m2
Draught	2.1m
Gross tonnage	108 te
Propulsion	2 x 932kW engines
Lifting capacity	4te @ 4.5m, 1.6te @ 10m
Other comments	Often not with DP capability
Anticipated vessel movements during construction	Up to 5 days installation per device.
Anticipated vessel movements during O&M	Up to 10 days per device per year (1 day per visit, 10 visits)

Figure 29: Typical work boat (Image source: CT Offshroe)

Vessel Type	**RIB**
Use	O&M
Typical examples	Not named
Description	Typically used for crew transfe,r either from shore if close to port or from a larger vessel, onto a floating device or static structure
Dimensions	Typical length 6m-13m, beam 2-3m
Draught	<1.0m
Gross tonnage	< 2 te
Propulsion	100 - 300kW outboard
Lifting capacity	None
Other comments	
Anticipated vessel movements during construction	Crew transfer, up to 5 days per device
Anticipated vessel movements during O&M	Up to 10 days per device per year (1 day per visit, 10 visits)

Figure 30: RIB servicing an offshore installation

Vessel Type	Technology specific / Bespoke
Use	Installation / O&M
Typical examples	OpenHydro Installer / Triskell
Description	Some technology developers have opted to construct their own bespoke installation vessel. These are designed for the sole purpose of transporting the device to site and installing or retrieving it. Often these vessels are not self propelled and so rely on other devices to tow them.
Dimensions	Length 32.8m, Beam 23.3m
Draught	
Gross tonnage	
Propulsion	N/A
Lifting capacity	Cable drum winches on the barge have a minimum cable length per winch of 105m, and a working lifting capacity of 120 tonnes.
Other comments	
Anticipated vessel movements during construction	Up to 5 days installation per device.
Anticipated vessel movements during O&M	Up to 20 days per device per year (2 days per visit [1 day pickup on day dropoff], 10 visits)

Figure 31: Open Hydro bespoke installation vesse (Image Source: Open Hydro)l

Vessel Type	ROV
Use	Installation / O&M
Typical examples	Seaeye Cougar-XT
Description	ROVs are used throughout the lifecycle of an offshore project such as Morlais. These are safer (and often cheaper) than using divers in fast tidal flows at depth and allow the operator to observe underwater activities, undertake visual surveys/inspections and to carry out work such as controlling the positioning of subsea objects
Dimensions	Length 1.5m, Beam 1.0m
Draught	Height 0.8m
Gross tonnage	0.35 te

Propulsion	6 electric motors (4 vectored horizontals & 2 verticals)
Lifting capacity	Payload of 80kg
Other comments	May be launched and operated from many different vessels depending on the activity being undertaken.
Anticipated vessel movements during construction	Up to 5 days installation per device.
Anticipated vessel movements during O&M	Up to 5 days per device per year (1 day per visit, 5 visits)

Figure 32: Work Class ROV (Image Source: SMD)

Appendix A: Onshore Cable Route Maps

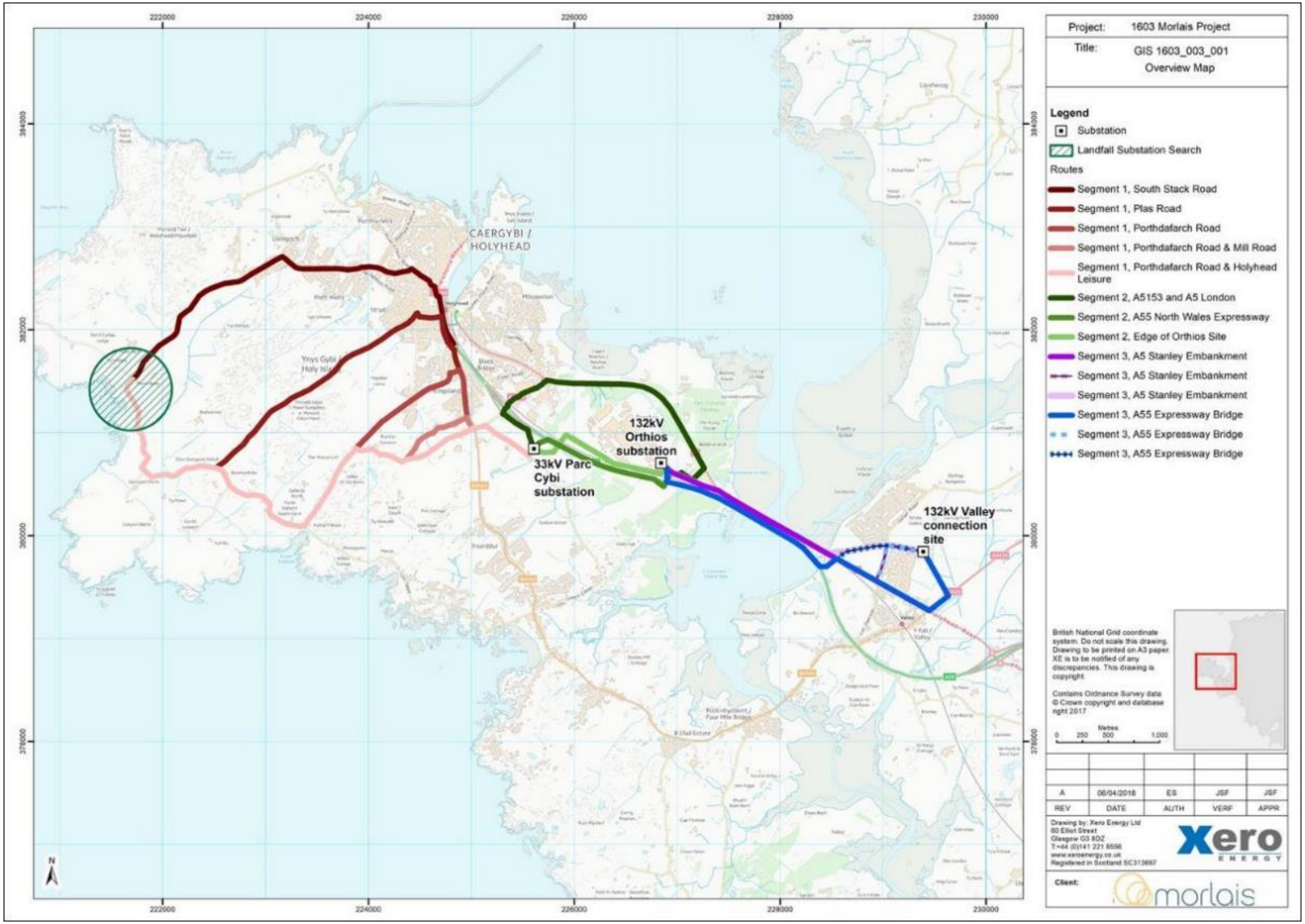


Figure 33: Onshore cable route options overview map

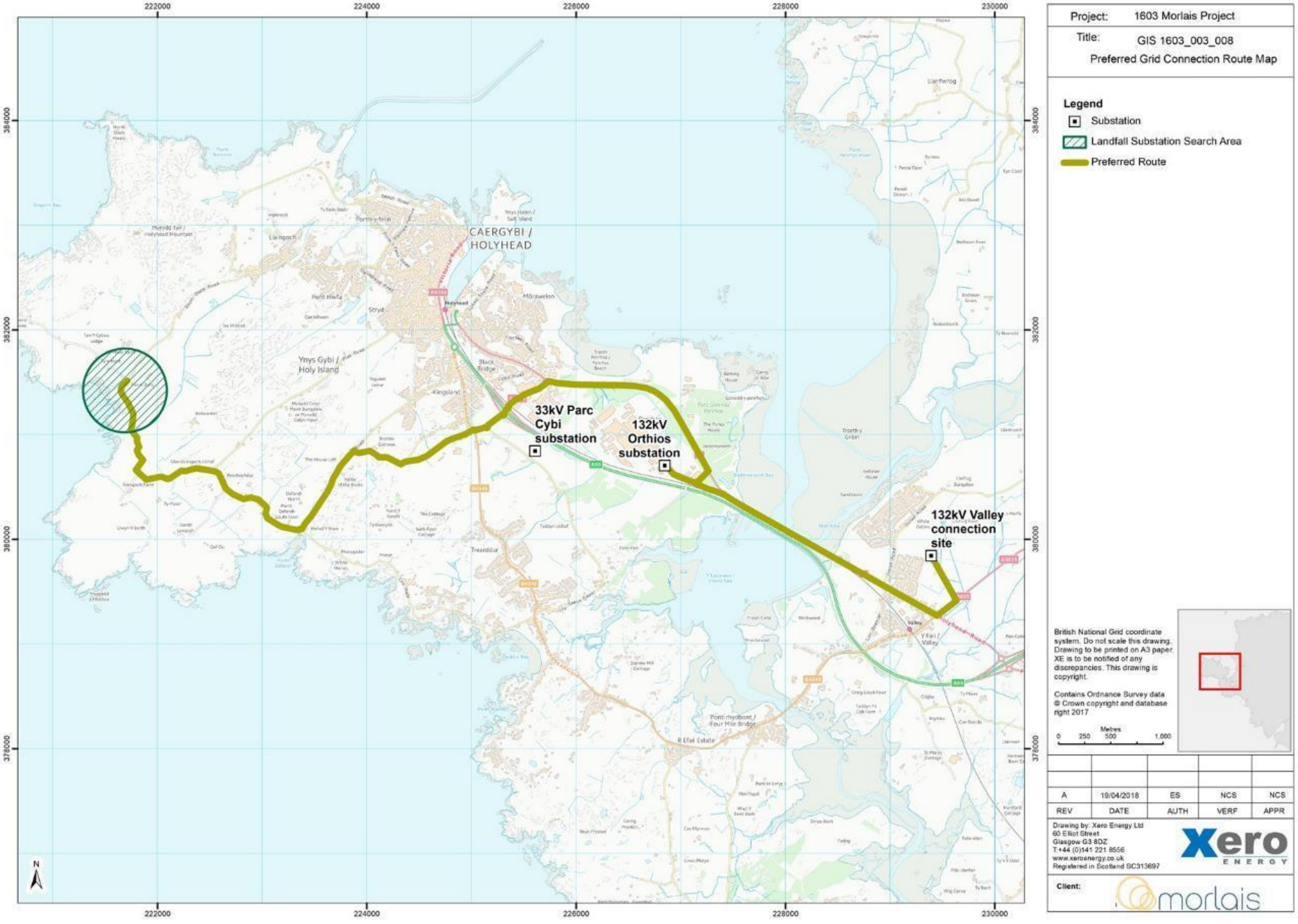


Figure 34: Preferred Grid Connection Cable Route

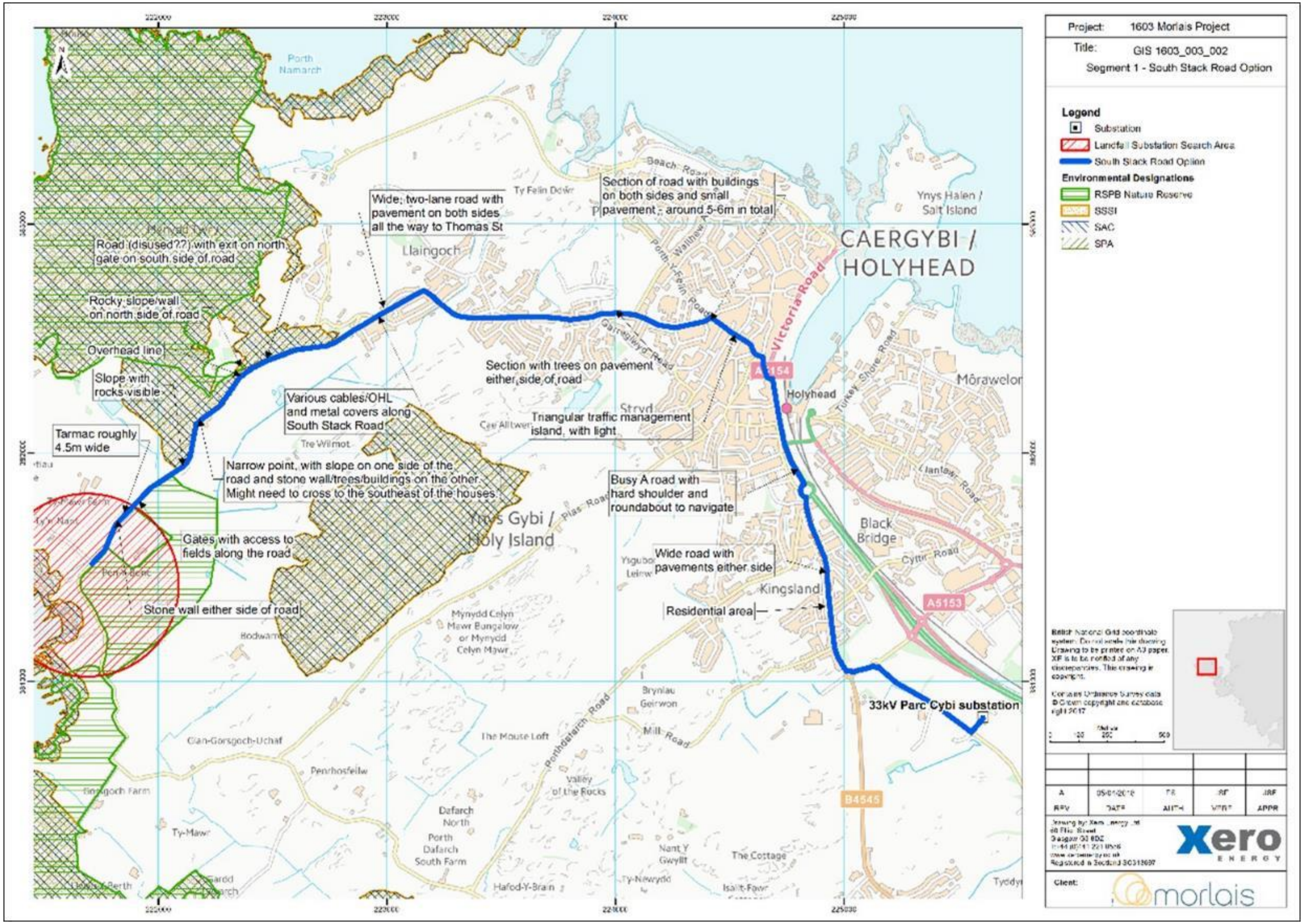


Figure 35: Onshore Cable Route Segment 1 – South Stack Road Option Notes

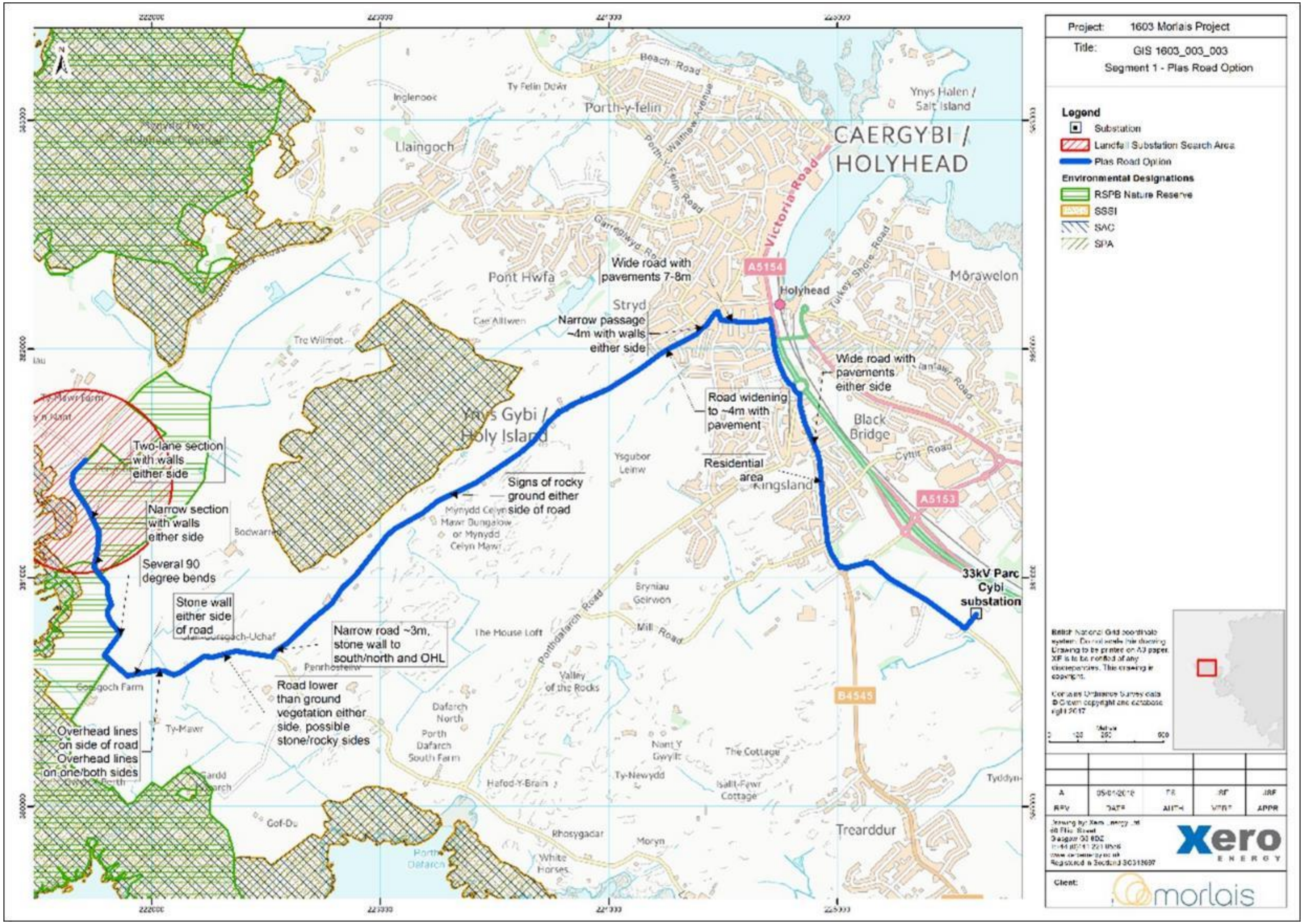


Figure 36: Onshore Cable Route Segment 1 – Plas Road Option Notes

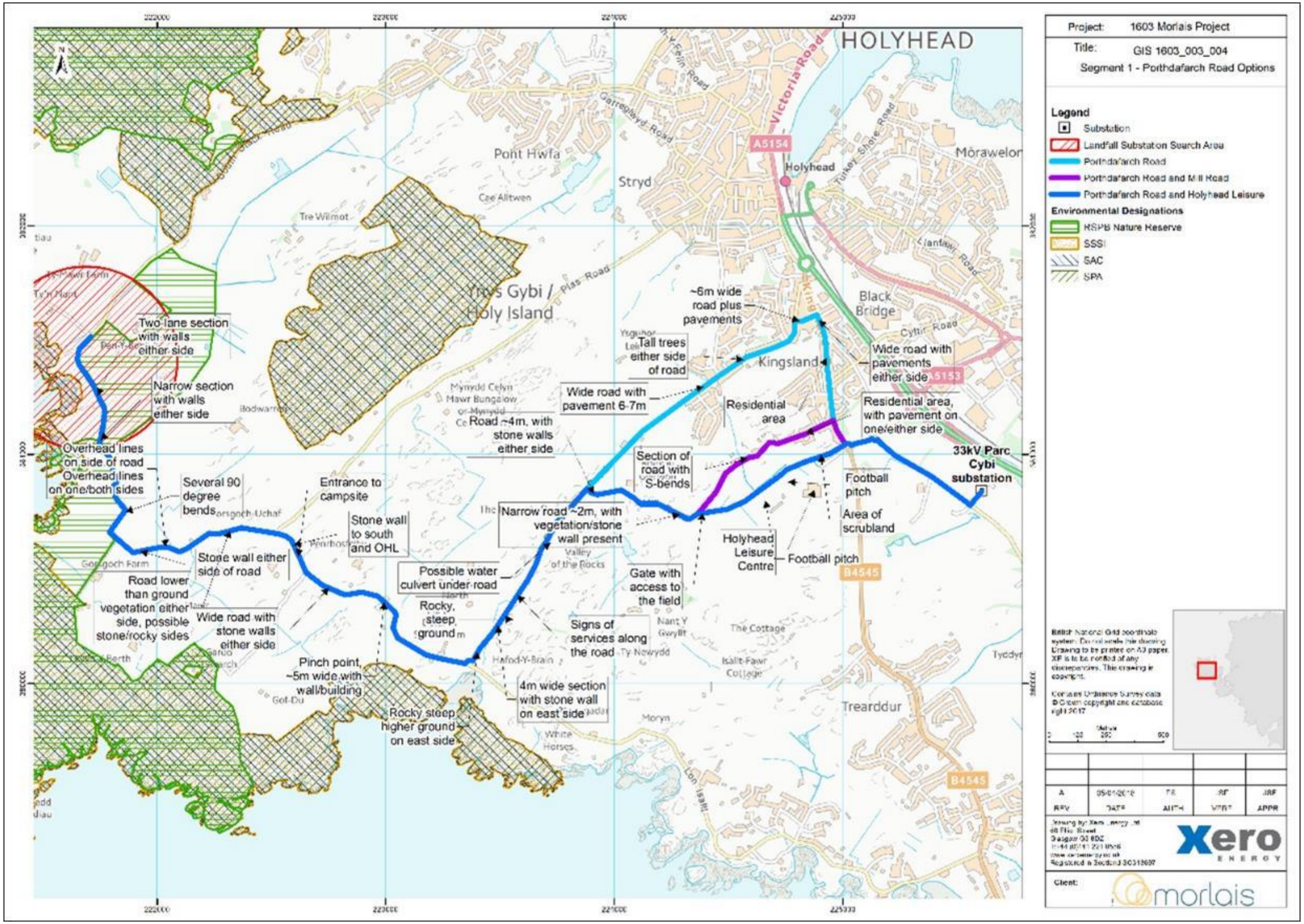


Figure 37: Onshore Cable Route Segment 1 - Porthdafarch Road Option Notes

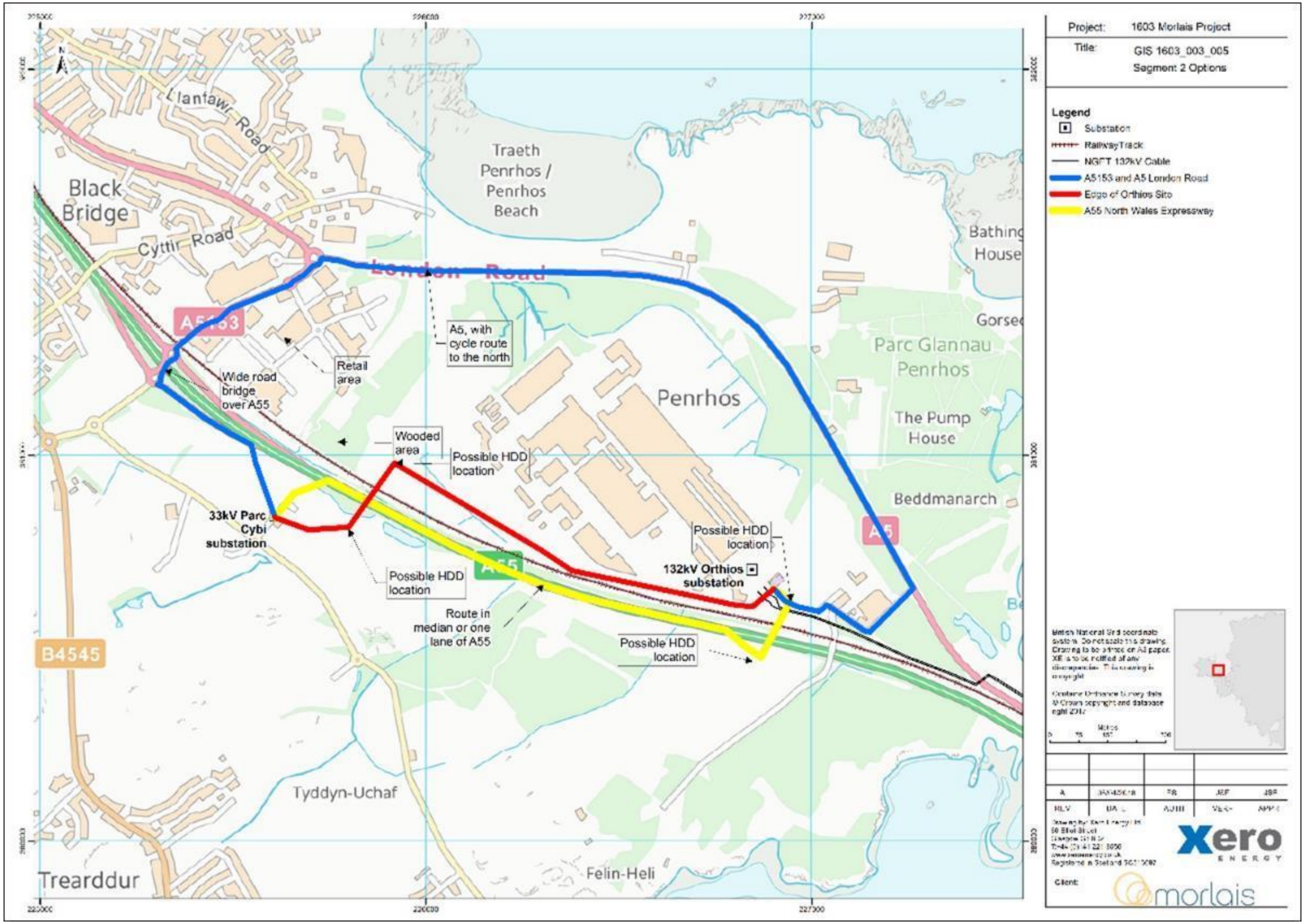


Figure 38: Onshore Cable Route Segment 2 Options Notes

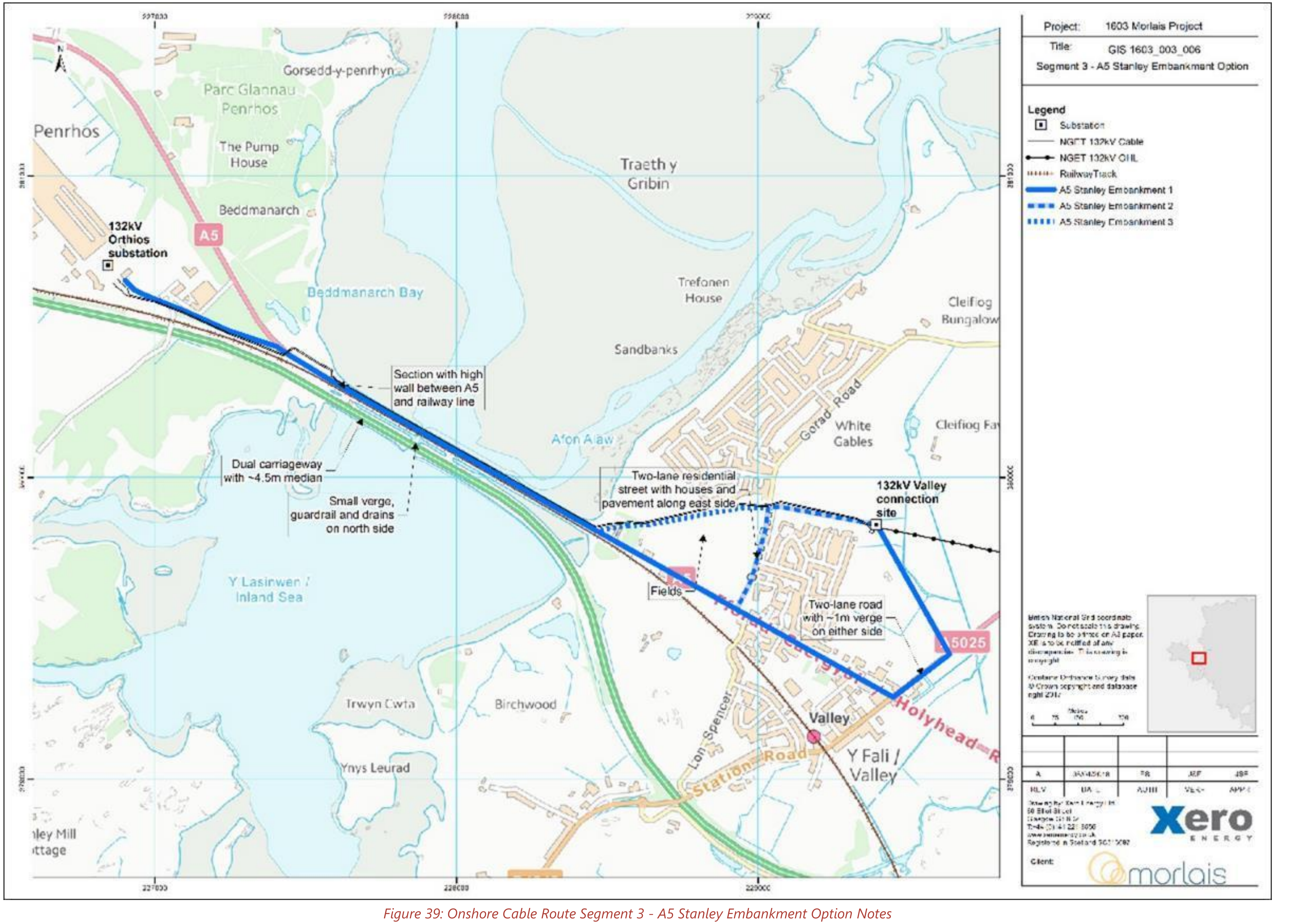


Figure 39: Onshore Cable Route Segment 3 - A5 Stanley Embankment Option Notes

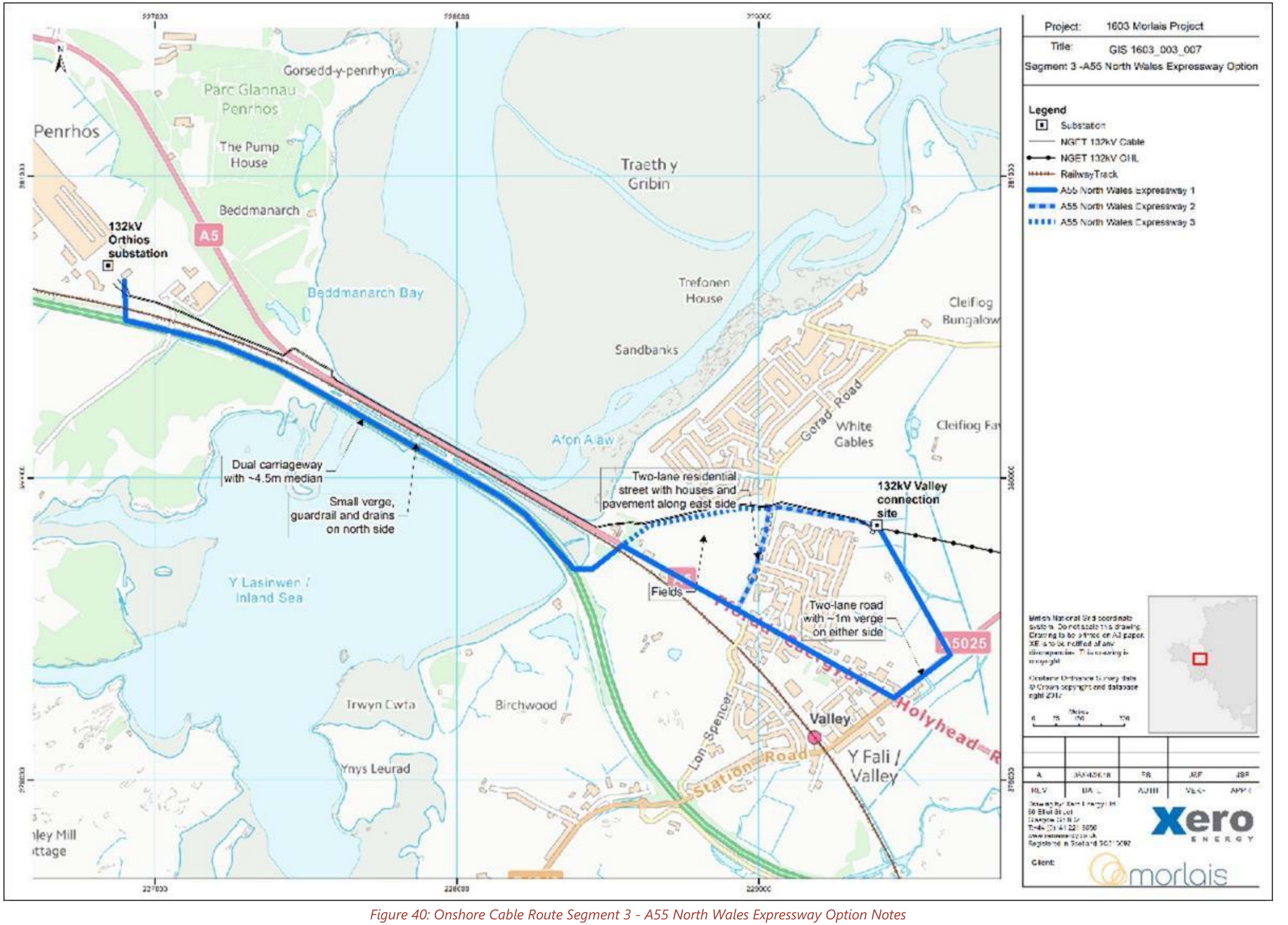


Figure 40: Onshore Cable Route Segment 3 - A55 North Wales Expressway Option Notes

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Morlais Project
Environmental Statement

Appendix 4.2: Morlais Feed Advice Report Addendum - 240MW offshore parameters update (ITPE, 2019)

Volume III

Applicant: Menter Môn Morlais Limited

Document Reference: PB5034-ES-0042

Chapter 4: Project Description

Appendix 4.2: Morlais Feed Advice Report Addendum - 240MW offshore parameters update

Morlais Document No.:	Status:	Version No:	Date:
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MORLAIS TECHNICAL FEASIBILITY

Morlais Feed Advice Report Addendum - 240MW offshore parameters update

morlais
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Table of Contents

1 Introduction

This addendum report provides an update to the Morlais Project Design Envelope Definition. It updates the developer device parameters for a 240MW project and provides a basis for their derivation to assist with their explanation and interpretation for use in the Project Description and in impact analyses.

The parameters presented in this report cover the following:

- Tidal devices, incorporating:
  - Foundation structures and associated support and access structures
  - Tidal Energy Convertors (TECs) being the generation elements of a tidal device (combined rotor and nacelle).
- Inter-array cables within each array to connect tidal devices to one another and/or an electrical hub
- Installation and O&M activities and durations

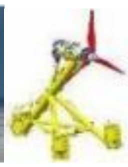
The following offshore infrastructure is not covered and refences should be made to the relevant sections in the original Project Design Envelope Definition report:

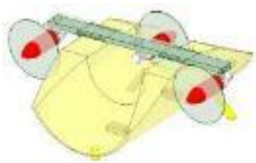
- Export cables to shore that will connect to the cable tails.
- Export cable protection measures and systems
- Electrical hubs or connectors as a means to allow multiple tidal devices to export power through a single export cable
- Tidal array specific marking and monitoring equipment

2 Technologies

Table 1 below shows the different categories of devices used to develop the Project Envelope, together with examples of the different sort of devices under each category.

Table 1: Categorisation of Devices for Project Envelope

Category	Sub-Category Name	Device Name / Developer Example	Images
1 Seabed Mounted Devices	**(A) Seabed mounted single rotor**	• Nova • Sabella • Atlantis Resources Corporation AR1500 • Andritz Hydro Hammerfest	   
	(G) 3 rotor seabed mounted platform.	Verdant	

	(I) Seabed mounted cross-flow	Repetitive Energy	
	(J) Seabed mounted multi-rotor	QED Naval Subhub	
2 Mind-water Column Devices	**(F) Multi rotor buoyant mid water.**	SME PLATO Renewable Devices Capricorn	
3 Floating Devices	**(C) Multiple rotor buoyant platform**	TidalStream Triton Tocardo TFS	
	(D) Twin rotor floating	• Orbital • Magallenes	
	(E) Cross-flow multi-rotor floating	Instream	
	(H) Spar Buoy	Aquantis	

The following categories have been excluded:

- Ducted axial flow, seabed mounted (e.g. Open Hydro)
- Surface piercing, seabed mounted tower (e.g. Seagen S)
- Large seabed mounted cross flow, horizontally oriented (e.g. Kepler)
- Ducted cross-flow (e.g. Blue Energy)
- Other 'novel' designs (e.g. Minesto, Flumill, hydrofoils)

3 Device Parameters

The following total device numbers can be expected across the Morlais zone:

- Up to 620 small (less than 300kW) devices
- Up to 240 large 1MW+ devices
- Up to 180 surface piercing devices (large or small)
- Max 30MW of any one device in an array (max 150 devices)

Table 2 below summarises the 'extreme case' (maximum or minimum) parameters for the devices categorised above.

The 'worst' or 'extreme case' figures presented are based on different scenarios across the entire site for each parameter. Each scenario was developed based on the maximum number of devices that represented a 'worst case' for that particular parameter, whilst assuming no more than 30MW of any one technology. E.g. for each parameter, the figures were calculated taking 30MW of a technology that represented the 'worst case' impact, then 30MW of the technology with the second 'worst', 30MW of 3rd 'worst; etc until the full potential across the site was reached. The figures for each technology were based on those provided by developers during the developer consultation exercise.

Table 2: Device Parameters

Device Information / parameter	Extreme Case for Project Envelope	Basis for Figures
Maximum rated output per device	2 MW	Largest device currently in advanced development
Minimum rated output per device	0.2 MW	Smallest device size given from developer consultation responses
No. of TECs (or equivalent for different systems)	1,648	Based on ~30MW arrays of each of the following and no more than 620 devices max.: - 480 Category 1A (e.g. Schottel TECs on SME PLATO) - 480 Category 3E (e.g. Instream TECs) - 300 Category 1J (e.g. Schottel TECs on QED Naval) - 150 Category 1A (e.g. Nova TECs) - 100 Category 3C (e.g. Tocardo TECs on UFS) - 78 Category 2F (e.g. Verdant TECs on Triframes) - 30 Category 3H (e.g. Aquantis TECs) - 30 Category 1A (e.g. Sabella TECs)
No. of blades	4,750	Based on ~30MW arrays of each of the following and no more than 620 devices max.: - 480 Category 1A (e.g. Schottel TECs on SME PLATO [3 blades]) - 480 Category 3E (e.g. Instream TECs [3 blades]) - 300 Category 1J (e.g. Schottel TECs on QED Naval [3 blades]) - 150 Category 1A (e.g. Nova TECs [2 blades]) - 100 Category 3C (e.g. Tocardo TECs on UFS [2 blades]) - 78 Category 2F (e.g. Verdant TECs on Triframes [3 blades]) - 30 Category 3H (e.g. Aquantis TECs [2 blades]) - 30 Category 1A (e.g. Sabella TECs [6 blades])
Rotor diameter	27 m	Open rotor, fully submerged (in Category 1) Largest figure given in developer consultation responses response.
Area of leading edge of rotors	3,744 m^2	Based on 240 x 1MW, 3 bladed TEC's (Category A device)

Max (AVERAGE) speed of turbine rotation	26.7 rpm	Averaged from figures supplied in developer consultation
Max device swept area	84,500 m^2	Based on ~30MW arrays of each of the following and no more than 620 devices max.: - 480 Category 1A (e.g. Schottel TECs on SME PLATO) - 480 Category 3E (e.g. Instream TECs) - 300 Category 1J (e.g. Schottel TECs on QED Naval) - 150 Category 1A (e.g. Nova TECs) - 100 Category 3C (e.g. Tocardo TECs on UFS) - 78 Category 2F (e.g. Verdant TECs on Triframes) - 30 Category 3H (e.g. Aquantis TECs) - 30 Category 1A (e.g. Sabella TECs)
Max tip speed	30 m/s	For small rotors (less than 10m diameter), open rotor. Highest figure from relevant developer consultation responses
	20 m/s	For larger rotors (more than 11m diameter), open rotor Highest figure from relevant developer consultation responses
Floating device movement	Each device could move by up to 80m (±40m) in the direction parallel to the flow, and 60m (±30m) in the direction perpendicular to the flow. Overall surface area covered by device movement (including device yawing) is up to 4,800m^2 for a single floating device (in Category 2). Also see Table 3 below. Highest figure from developer consultation responses.	
Minimum under keel clearance (UKC)	0 m under LAT	Floating devices have no under keel clearance at all = 0m. However, actual TEC component will have a minimum clearance of at least 5m. From developer consultation responses.
	8 m under LAT	Minimum case for fully submerged (in Category 1) is 8m From developer consultation responses.
Subsea Device Parameters (width)	36 m	Multiple rotor buoyant platform (Category 3C) in direction perpendicular to flow. Highest figure from developer consultation responses.
Subsea Device Parameters (height)	27 m	Multiple rotor buoyant platform (Category 3C) (including ~3m above water) Highest figure from developer consultation responses.
Subsea Device Parameters (length)	30 m	Multiple rotor buoyant platform (Category 1J) in direction parallel to flow. Highest figure from developer consultation responses.
Floating Device Parameters (width)	30 m	Surface floating catamaran platform (22m long x 30m wide), Category 3E in direction perpendicular to flow. Highest figure from developer consultation responses.
Floating Device Parameters (height)	40m (6.5 m above sea surface)	Spar Buoy, Category 3H From developer consultation responses. (Estimated height of element that is above water).
Floating Device Parameters (length)	72m	Twin Rotor Floating, Category 3D, in direction parallel to flow. Highest figure from developer consultation responses.

<table>
<tr><td>Total array area (sea surface covered)</td><td>12,459,500 m^2</td><td>Based on ~30MW of each of the following:

- Category 1A (e.g. Nova)
- Category 2F (e.g. SME PLAT-O)
- Category 3C (e.g. Tocardo UFS)
- Category 3D (e.g. Orbital)
- Category 3E (e.g. Instream)
- Category 3H (e.g. Aquantis)
- Category 1J (e.g. QED Naval)
- Category 3D (e.g. Magallanes)

Maximum area taken up by all arrays, including spaces between devices, measured from CAD drawings of indicative layouts.</td></tr>
<tr><td>Total Days Installation</td><td>6,106 days</td><td>Based on ~30MW of each of the following plus 120 hubs

- 120 devices @ 9days each Category 2F (e.g. SME PLATO)
- 120 devices @ 7days each Category 3E (e.g. Instream)
- 30 devices @ 15days each Category 1A (e.g. Atlantis with piles)
- 30 devices @ 15days each Category 3H (e.g. Aquantis with piles)
- 100 devices @ 4days each Category 1J (e.g. QED Naval)
- 150 devices @ 5days each Category 1A (e.g. Nova)
- 20 Devices @ 9 days each Category 3C (e.g. Tocardo UFS)
- 26 devices @ 6 days each Category 1G (e.g. Verdant)
- 120 hubs @ 15days each

Totalling 596 devices (and 120 hubs)</td></tr>
<tr><td>Power conversion system</td><td colspan="2">Typically each rotor would be coupled to a 3 stage planetary (helical) gearbox. This is then coupled to a standard asynchronous generator; most incorporate a hydraulically released parking brake. Most devices are variable speed, fixed pitch with frequency converters. About 50% of turbines yaw. Onboard step-up transformers are typical.

50kW to 1MW power trains will be most common. Range could be 50kW to 1.5MW power trains per rotor.

Hydraulic power transmissions unlikely.</td></tr>
<tr><td>Device spacing</td><td colspan="2">See Table 3

Most seabed mounted devices (in Category 1) would have a typical spacing of 70m to 100m between centres perpendicular to the flow, 180m to 250m parallel the flow.

Floating devices sharing moorings could be up to 150m between structure centres perpendicular to the flow, 250m parallel to the flow (in Category 3).

In all cases, seabed conditions, could alter these figures considerably, and result in higher spacings.</td></tr>
<tr><td>Material Quantities - Steel</td><td>207,950</td><td>Based on ~30MW of each of the following plus 120 hubs:

- 120 devices @ 170t each Category 2F (e.g. SME PLATO)
- 120 devices @ 170t each Category 3E (e.g. Instream)
- 15 devices @ 750t each Category 3D (e.g. Magallanes)
- 20 devices @ 800t each Category 3C (e.g. Tocardo UFS)
- 100 devices @ 500t each Category 1J (e.g. QED Naval)
- 150 devices @ 200t each Category 1A (e.g. Nova)
- 30 devices @ 650t each Category 1A (e.g. Sabella)
- 26 devices @ 400t each Category 1G (e.g. Verdant)
- 120 hubs @ 250t each

Totalling 581 devices and 120 hubs</td></tr>
<tr><td>Material Quantities - Concrete</td><td>463,700</td><td>Based on ~30MW of each of the following plus 120 hubs:

- 120 devices @ 430t each Category 2F (e.g. SME PLATO)
- 120 devices @ 430t each Category 3E (e.g. Instream)
- 15 devices @ 1,200t each Category 3D (e.g. Magallanes)
- 20 devices @ 1,500t each Category 3C (e.g. Tocardo UFS)
- 100 devices @ 400t each Category 1J (e.g. QED Naval)
- 150 devices @ 250t each Category 1A (e.g. Nova)
- 30 devices @ 400t each Category 1A (e.g. Sabella)</td></tr>
</table>

		- 26 devices @ 500t each Category 1G (e.g. Verdant) - 120 hubs @ 1,000t each Totalling 581 devices and 120 hubs
Liquid inventory	Typically quantities of liquids will be less than: - 600l oil (gearboxes, transformers etc.) - 50l grease (bearings seals etc.) - 800l hydraulic fluid In each device	
Oil (gearboxes, transformers etc.)	240,000 Litres	Based on 240 x 1MW drivetrains
Grease (beraing, seals etc.)	12,000 Litres	Based on 240 x 1MW drivetrains
Hydraulic fluid	192,000 Litres	Based on 240 x 1MW drivetrains
Coatings	270,000 Litres	Based on 240 1MW turbines with gravity bases Structures will typically be painted with modified epoxy or acrylic based paints suitable for subsea and splashzone, abrasion-Resistant; plus similar primer. e.g. International Protective Coatings - Interzone 954As or Resistex C137V2. Quantities generally less than 1,000 litres per device
Antifouling system	Anti-fouling will typically be a dry coating of Antifouling – e.g. Intersleek 900; applied to local areas of concern. Would be applied before the first deployment. It would be reapplied where necessary during the subsequent removal of the device from the sea for maintenance.	
Electrical systems	Most turbines are likely to export grid compliant power at either 11kV (some 24kV or 33kV longer term) via converter, a step-up transformer from generator voltage (typically 690V), switchgear and a three-phase (wet or dry mate) connectors mounted in the nacelle of the turbine.	
Heating and cooling systems	Cooling in most cases is achieved through passive heat sinks on the nacelle of the turbines, allowing heat to be dissipated into the surrounding water. In some cases, drivetrains (gearboxes and generators) are in direct contact with seawater, providing passive cooling that way. Maximum case would be a device with a water abstraction/discharge system used for cooling.	
Communication systems	Typically fibre optics through the power umbilical cable. Back-up with radio antenna or wifi	
Energy storage	Some devices may have some energy storage in the form of batteries (lead-acid, Li Ion, Ni-MH). These systems are generally small 2 - 7kWh. Maximum case would be technology with sufficient battery storage to power connection / disconnection systems (e.g. winches). These could be as high as 12 to 50kWh systems.	
Energy sink	Assuming 5% dissipation of energy as heat - between 10 and 125kW of heat per device will be sunk into the tidal flow during operation.	
Power requirements	Many turbines require auxiliary power to run winches, hydraulic and communication systems etc. Power will also be required to energise transformers and generators during start-up and stand-by. Supply of electrical power through additional (low voltage) cores within the export cable will be included. Generators will also produce reverse power flow through the main cores. 'Reverse' power flows would typically be between 20 and 150kW for each turbine. Maximum power draw for the entire site could be up to 30MW	

Potential discharges to sea	There will be no intentional emissions or discharges from devices. Marine pollution would be restricted to matters related to leakage of lubricants and the type of paint or coating that the subsurface structures would use to prevent excessive growth of marine organisms. Any leak is not likely to result in the discharge of more than 1,000 litres of oil based hydraulic fluid. Discharges from installation and O&M vessels may occur (such as cooling water) however, this will be restricted by maritime standards and regulations. Up to 6m^3 of cement based grout may be discharged into the water at the seabed. This is non-toxic and would either reside around the foundations of the device or gradually be removed by the tidal flows.
Potential discharges to air	There are no anticipated gaseous discharges into the air environment by the devices during the installation, operational and decommissioning phases. There will be atmospheric discharges associated with the installation and O&M vessels however.

Table 3 below shows device parameters foe each device category as summarised in Table 1.

Table 3: Individual Device Category Parameters

Sub-Category	Technology Example	Indicative Spacing	Floating Device Movement	Deployment water depth constraints	Device parameters (vertical) re: Under Keel Clearnace
1A Seabed mounted single rotor	Sabella	~100 x 250m	NA	Minimum = 25m Median = 37.5m Maximum = 50m	Up to 20m from seabed to blade tip
1A Seabed mounted single rotor	ARC	~100 x 250m	NA	Minimum = 35m Median = 42.5m Maximum = 50m	Up to 26m from seabed to blade tip
1A Seabed mounted single rotor	Andritz	~100 x 250m	NA	Minimum = 37m Median = 43m Maximum = 50m	Up to 29m from seabed to blade tip
1A Seabed mounted single rotor	Nova	~50 x 100m	NA	Minimum = 20m Median = 27.5m Maximum = 35m	14m from seabed to blade tip
1G Three-rotor seabed mounted	Verdant	~60 x 200m	NA	Minimum = 20m Median = 27.5m Maximum = 35m	14m from seabed to blade tip
1I Seabed mounted cross Flow	Repetitive Energy	~50 x 100m	NA	Minimum = 10m Median = 20m Maximum = 30m	10m from seabed to blade tip
1J Seabed Mounted multi-Rotor	QED Naval Subhub	~50 x 100m	NA	Minimum = 15m Median = 22.5m Maximum = 30m	15m from seabed to blade tip
2F Multiple rotor buoyant platform	Schottell SME PLAT-O	~120 x 120m	± 30m parallel to flow ± 20m perpendicular to flow	Minimum = 20m Median = 30m Maximum = 50m	20m from seabed to blade tip
3C Multiple rotor buoyant platform	Tocado UFS system	~150 x 500m	± 80m parallel to flow ± 60m perpendicular to flow	Minimum = 30m Median = 40m Maximum = 50m	NA - floating devices

3D Twin-Rotor Floating	Orbital	200 x 450m	± 80m parallel to flow ± 60m perpendicular to flow	Minimum = 35m Median = 42.5m Maximum = 50m	NA - floating device
3D Twin-Rotor Floating	Magellanes	200 x 450m	± 80m parallel to flow ± 60m perpendicular to flow	Minimum = 30m Median = 40m Maximum = 50m	NA - floating device
3E Cross-flow multi-rotor floating	Instream	~60 x 300m	± 30m parallel to flow ± 30m perpendicular to flow	Minimum = 5m Median = 22.5m Maximum = 50m	NA - floating device
3H Spar buoy	Aquantis	~180 x 340m	± 80m parallel to flow ± 60m perpendicular to flow	Minimum = 40m Median = 45m Maximum = 50m	NA - floating devices

Actual Under Keel Clearance will be a function of water depth at location of deployment

4 Foundations

Table 4 below shows maximum value parameters for the device foundations across entire 240MW project.

Table 4: Device Foundation Parameters for full 240MW Project

Device Information / parameter	Total parameter for 240MW opf devices	Basis for Parameter
Gravity Base Structures (GBS)	74,790 m^2	Based on ~30MW of each of the following plus 120 hubs: - 120 devices @ 4x36m^2 each Category 2F (e.g. SME PLATO), - 120 devices @ 2x60m^2 each Category 3E (e.g. Instream) - 15 devices @ 4x78m^2 each Category 3D (e.g. Magallanes) - 20 devices @ 2x78m^2 each Category 3C (e.g. Tocardo UFS) - 15 devices @ 4x78m^2 each Category 3D (e.g. Orbital) - 150 devices @ 1x9m^2 each Category 1A (e.g.Nova) - 30 devices @ 4x78m^2 each Category 3H (e.g. Aquantis) - 120 devices @ 1x36m^2 each Category 1I (e.g. Repetitive) - 60 hubs @ 4x40m^2 each - 60 hubs @ 1x100m^2 each Totalling 590 devices and 120 hubs:
Piled foundations (devices)	3,675 m^2	Based on: - 21m^2 per device (4 drills of 2.6m diameter each) x 80 devices - 4.5m^2 per device (4 drills of 1.2m diameter each) x 120 devices - 15.9m^2 per device (3 drills of 2.6m diameter each) x 90 devices
Piled foundations (hubs)	2,214 m^2	Based on: - 15.9m^2 per hub (3 drills of 2.6m diameter each) x 60 hubs - 21m^2 per hub (4 drills of 2.6m diameter each) x 60 hubs
Drill arisings	117,780 m^3	Based on drill areas calculated for 'Piled foundations (devices)' and 'Piled foundations (hubs)' above, each 20m deep
Duration of drilling	3,990 days	Total of 1,490 drills (based on same assumptions above), 1.2m diameter drill taking 2 days each, larger ones taking 3 days each

Swept Area of Catenary Cables	2,055,000 m^2	Based on: – 30 devices having swept area of 9,500m^2 (measured on CAD using maximum excursion criteria) - large floating devices, Category 3D (e.g. Orbital, Magallanes) – 140 devices having swept area of 7,500m^2 (measured on CAD using maximum excursion criteria) - medium floating devices, Categories 3C, 3H (e.g. Tocardo UFS, Aquantis) & hubs – 240 devices having swept area of 3,000m^2 (measured on CAD using maximum excursion criteria) - small floating devices Categories 3E, 2F (e.g. Instream, SME PLATO)

5 Inter-Array Cables

Table 5 below shows the parameters of the inter-array cables expected across the project, both surface laid on the seabed and floating umbilical cables.

Table 5: Inter-Array Cable Parameters

Information / parameter	Parameter	Basis for Parameter
Number of inter-array cables	740	Max value across entire 240MW project. Based on max number of devices (620) and hubs (120), as defined in Section 3
Total cable length	204.5 km	Max value across entire 240MW project. Based on ~30MW of each of the following plus 120 hubs (measured from CAD drawings of indicative layouts): - 120 devices @ 21.84km total Category 2F (e.g. SME Plato), - 26 devices @ 23.52km total Category 1G (e.g. Verdant) - 15 devices @ 16.38km total Category 3D (e.g. Magallanes) - 20 devices @ 21.84km total Category 3C (e.g. Tocardo UFS) - 100 devices @ 39.9km total Category 1J (e.g. QED Naval) - 150 devices @ 23.52km total Category 1A (e.g. Nova) - 30 devices @ 20.16km total Category 3H (e.g. Aquantis) - 120 devices @ 37.38km total Category 1I (e.g. Repetitive) Totalling 590 devices together with 120 hubs
Minimum cable length	100 m	Based on minimum spacing between devices plus extra for repairs & contingency
Maximum cable length	2.5 km	Based on maximum use of berth and radial connection approach with hub(s) near site boundary, plus extra for repairs & contingency
Cable diameter	120mm max	With split pipe, up to 170mm diameter. Based on largest conductor cross section for lowest likely voltage for 30MW and /or smaller sub- arrays
Cable system footprint	30,040 m^2	Total seabed footprint (cables and protection systems). Max value across entire 240MW project. Based on assumptions from 'Total Cable Length' and 'Cable Diameter' above, plus rock bags on max 100m intervals.
Installation duration	1,110 days	Max value across entire 240MW project. Based on 1.5 days installation per cable including protection systems - Surface laid with strategic protection. Post lay burial where possible.
Total umbilical cable length	**25 km**	Flexible, mid-water cables from device to seabed/hub. Max value across entire 240MW project. Based on 120 Category 3E (e.g. Instream) and 120 Category 2F (e.g. SME PLATO) devices
Minimum umbilical cable length	**30 m**	Based on minimum likely spacing between floating devices plus extra for repairs & contingency

Maximum umbilical cable length	**250 m**	Based on maximum likely spacing between floating devices plus extra for repairs & contingency. Any longer would be surface laid on the seabed.
Umbilical cable diameter	90mm max excluding floatation Up to 500mm diameter including floatation systems	

6 Installation

A wide range of installation strategies are likely, depending on the foundation / mooring approach:

- Installation of foundation, then lower, ballast or pull TEC(s) down onto the foundation.
- Installation of foundation and TEC as a complete unit from a heavy lift vessel (DP vessel or moored barge) or bespoke vessel.
- Installation of foundation and TEC as a complete unit towed to site and then ballasted into position (seabed or mid water column).
- Use of floating systems (towed to site) that remain on the surface (or partially so) attached to pre-installed anchors and mooring lines.

Piled foundations would mainly be installed by a moored barge or DP vessel with sufficient cranage (250 - 400t) and drill rig. Monopiles and pin-piles would most likely be installed through remote drilling using a subsea rig controlled from a DP vessel (up to 3 days per large pile drilled, or 1.5 days for pin-piles).

Nacelle / powertrains together with rotors would then generally be installed separately using an appropriately sized DP vessel (likely to be the same as for the foundation installation) or a multicat vessel.

Typical time for complete installations is between 3 and 15 days per turbine, including foundation.

Inter-array cables typically 1 to 1.5 days per cable including connection.

A moored barge suitable for installation would be approximately 100m x 30m and have 4 to 8 x 100 tonne gravity blocks (5m x 5m) or drag anchors (3m x 5m) with some anchor chain catenary, estimated at 400m to 500m length on seabed and 1m diameter. A typical mooring spread would consist of moorings on a 'radius' from the vessel centre of between 500 and 800m. Overall 'footprint' of mooring spread would be a rectangle of approximately 500 to 1,400m by 850 to 1,600m. This type of vessel will require one or two small support vessels (30m x 22m) to assist with positioning and anchor deployment.

A DP vessel, would be of a similar size to the barge (155m x 30m) but would not disturb the sea bed and may not require any tugs.

Table 6 below summarises the expected installation durations for the full 240MW project.

Table 6: Installation durations for full 240MW project

Parameter	Parameter for 240MW	Basis for Parameters
Export Cable Vessel Days	Up to 180 days	Based on 9 x blocks of 20 days, with each block continuous, but the 9 blocks spread across a nominal 5 year period (may be much longer, but not shorter) build out to 240MW.
Export Cable Protection	Up to 108 days	Based on 9 x blocks of 12 days, to begin up to 1 month after commencement of export cable laying (above)

Inter Array Cable Vessel Days	1,110 days	Based on 1.5 days per cable, as in Table 5. Minimum 10 year period build out, 8 arrays, and no more than 2 arrays built in parallel at any time.
Hub Installation Vessel Days	1,800 days	Based on 15 days per hub for 120 hubs Assume hubs and arrays will be built in parallel
Device Installation Vessel Days	4,306 days	Max value across entire 240MW project. Based on ~30MW of each of the following: Based on 596 devices - 120 devices @ 9days each Category 2F (e.g. SME PLATO) - 120 devices @ 7days each Category 3E (e.g. Instream) - 30 devices @ 15days each Category 1A (e.g. Atlantis with piles) - 30 devices @ 15days each Category 3H (e.g. Aquantis with piles) - 100 devices @ 4days each Category 1J (e.g. QED Naval) - 150 devices @ 5days each Category 1A (e.g. Nova) - 20 Devices @ 9 days each Category 3C (e.g. Tocardo UFS) - 26 devices @ 6 days each Category 1G (e.g. Verdant) Totalling 596 devices.

Note: Entire installation period (days) is not the sum of all these values - many installation operations will take place in parallel

Table 7 below shows the anticipated number of vessel days over the full 10 year construction period for the project.

Table 7: Vessel days over construction period

Parameter	Predicted Number of Vessels on site	Indicative Vessel Activity on Site (10yr build-out)				Basis / Assumptions
Construction Element		**Days over 10yr period**	**Days Per Year**	**Days Per Year per Sub-Zone**	**% of time vessel on site / year**	
Export Cable Installation	Up to 3	180	20	Each 20 day block of export cable installation per year predicted to be spread across each of the 8 sub-zones	5.48	Assumed to be 9 blocks of 20 days over 10yr period. Worst-case assumes that one 20 day block of activity occurs per year, for 9yrs of the 10yr build-out period 3 vessels = (1) cable installation vessel; (2) support vessels x2
Export Cable Protection Installation	3	108	12	Each 12 day block of export cable protection installation per year predicted to be spread across each of the 8 sub-zones	3.29	Assumed to be 9 x blocks of 12 days following each block of export cable installation. Worst-case assumes that one 12 day block of activity occurs per year, for 9 yrs of the 10yr build-out period 3 vessels = (1) cable tail installation vessel; (2) cable tail installation support vessel; (3) dive support vessel.
Inter-Array Cable Installation	2	1,110	110	13.75	30.14	Assumes a 10 year period build out of all 8 arrays, and no more than 2 arrays built in parallel at any time. So 1,110 days over the 3,650 days (10 years) assuming 2 arrays in parallel. 2 vessels = (1) cable installation vessel; (2) support vessel
Hub Installation Vessel Days	2	1,800	180	22.50	49.32	Assumes 15 days per (120 hubs) 2 vessels = (1) hub installation vessel; (2) support vessel Assume total hub installation vessel days will be spread equally across the 8 sub-zones, with 22.5 days/yr per sub-zone.

Device Installation Days	2	4,306	431	53.88	118.08	118% of year that device installation vessel will be on site reflects fact that there will be at least one vessel spread (1 x construction vessel plus 1 x support vessel) on site every day of the year (100%), and for 18% of the year, there will be 2 vessel spreads(4 vessels in total). These total vessel days will be spread across the 8 sub-zones, with a predicted total of 53.88 days of device installation vessel activity per sub-zone per year.
Total vessel days		**7,524**				

7 Operations and Maintenance

Developers are expected to visit each tidal device up to 15 times annually for both planned and unplanned maintenance activities. Many developers plan to undertake at least monthly routine inspection / maintenance using small vessels, as described in Section 4.5 of the Morlais Project Design Envelope Definition report. A worst case scenario of one five hour visit to each device on site per month may be foreseeable.

Table 8 below shows the umber of visits and duration for expected O&M activities fpor both devices and cables across the project.

Table 8: Number of visits and duration for expected O&M activities

Parameter	Offshore Export Cables	Devices	Basis / Assumptions
Inspection Regime	Annual inspections for the first 2 or 3 years, reducing to every 2 years thereafter.	Up to 15 times annually (for both planned and unplanned maintenance activities)	Inspection / maintenance – x 15 single day events per year. Assume that 10 are late spring, summer, early autumn. Other 5 are across rest of year.
Cable Repairs	Up to 10 major cable repairs (5 days each) may be required throughout the project life. It is assumed that up to 750m of cable will be subject to repair works per event (**7,500m** in total).		Cable repairs – 10 x 5 days or 50 days across life of project. Assume project operation life is 25 - 35 years, then one event every 2.5 to 3.5 years

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