CHAPTER 5: PROJECT DESCRIPTION

INTRODUCTION

5.1. As set out in Chapter 1 (Introduction), the original Seagreen Project (herein referred to as the originally consented Project) received development consents from Scottish Ministers in 2014. Seagreen is now applying for consents for an optimised project design (herein referred to as the optimised Seagreen Project), based on fewer, larger, higher capacity wind turbines that are becoming available since the 2014 consent decision, and inclusion of monopiles as a foundation option.

5.2. The Seagreen Project comprises the Seagreen Alpha Offshore Wind Farm (OWF) (herein referred to as 'Project Alpha'), Seagreen Bravo OWF (herein referred to as 'Project Bravo') and the Offshore Transmission Asset. It is noted that the Offshore Transmission Asset has been licensed separately, no changes are proposed and therefore this is not considered further within this assessment. A full description of the Offshore Transmission Asset project is provided in Chapter 5 (Project Description) of the 2012 Offshore ES.

5.3. The term of the site lease with The Crown Estate will be 50 years. The operational lifetime of the optimised Seagreen Project is expected to be 25 years. At the end of this period the OWFs could be life-extended, repowered or decommissioned. If the OWFs are repowered during the period of the site lease, this would be subject to a separate consent process.

5.4. This chapter of the EIA Report sets out the design parameters for the optimised design throughout the construction, operation and decommissioning phases of the Project. A full description of the physical components of the optimised Project Alpha and Project Bravo is provided and the details are summarised in Table 5.13 at the end of this chapter. The chapter describes the necessary site preparation and construction stages, the operation and maintenance (O&M) and the decommissioning of the Seagreen Project.

5.5. The content of this chapter forms the basis for the assessment of impacts presented in the technical chapters of this EIA Report (Chapters 8 to 15).

5.6. All figures supporting this chapter can be found in Volume II: Figures. All appendices referred to in this chapter can be found in ES Volume III: Appendices.

OUTLINE OF PROJECT COMPONENTS

5.7. The optimised Seagreen Project comprises:

- Project Alpha and Project Bravo OWFs with a maximum of 70 Wind Turbine Generators (WTGs) in each Project and a maximum of 120 WTGs in total across both sites.

5.8. The licensed offshore 'Transmission Asset Project' infrastructure, includes:

- Up to five OSPs (Note: The general term OSP is used for the structure that houses the electrical equipment transforming the WTG electrical output from distribution [low] voltage up to transmission [high] voltage and convertor platforms that convert from HVAC power to HVDC power);
- High Voltage (HV) (circa 220 kilovolts (kV) or above) subsea power cables providing inter connection between OSPs i.e. the interconnector cables;

- Up to six HV export cables laid in trenches up to Mean High Water Springs (MHWS);
- Cable landfall and connection to onshore infrastructure up to MHWS; and
- Scour protection and cable protection (where appropriate).

5.9. The onshore components of the Transmission Asset Project (from mean low water springs [MLWS]) include the onshore export cables and onshore converter/substation. The onshore Transmission Asset infrastructure received Planning Permission in Principle (PPP) from Angus Council in 2013. This was extended in 2016 following reapplication by Seagreen.

5.10. The Project Alpha and Project Bravo OWFs comprise of the following key components. WTGs comprising supporting tower structures, nacelles and rotors, with associated access arrangements:

- WTG foundations and substructures;
- Subsea array cables linking the WTGs to the OSPs;
- Scour protection and cable protection (where appropriate); and
- Wave buoys, Light Detective and Ranging Equipment (LiDAR) mounted to a WTG to obtain meteorological data and other supporting instrumentation.

5.11. Plate 5.1 provides an overview of project components (including those already consented) for context.

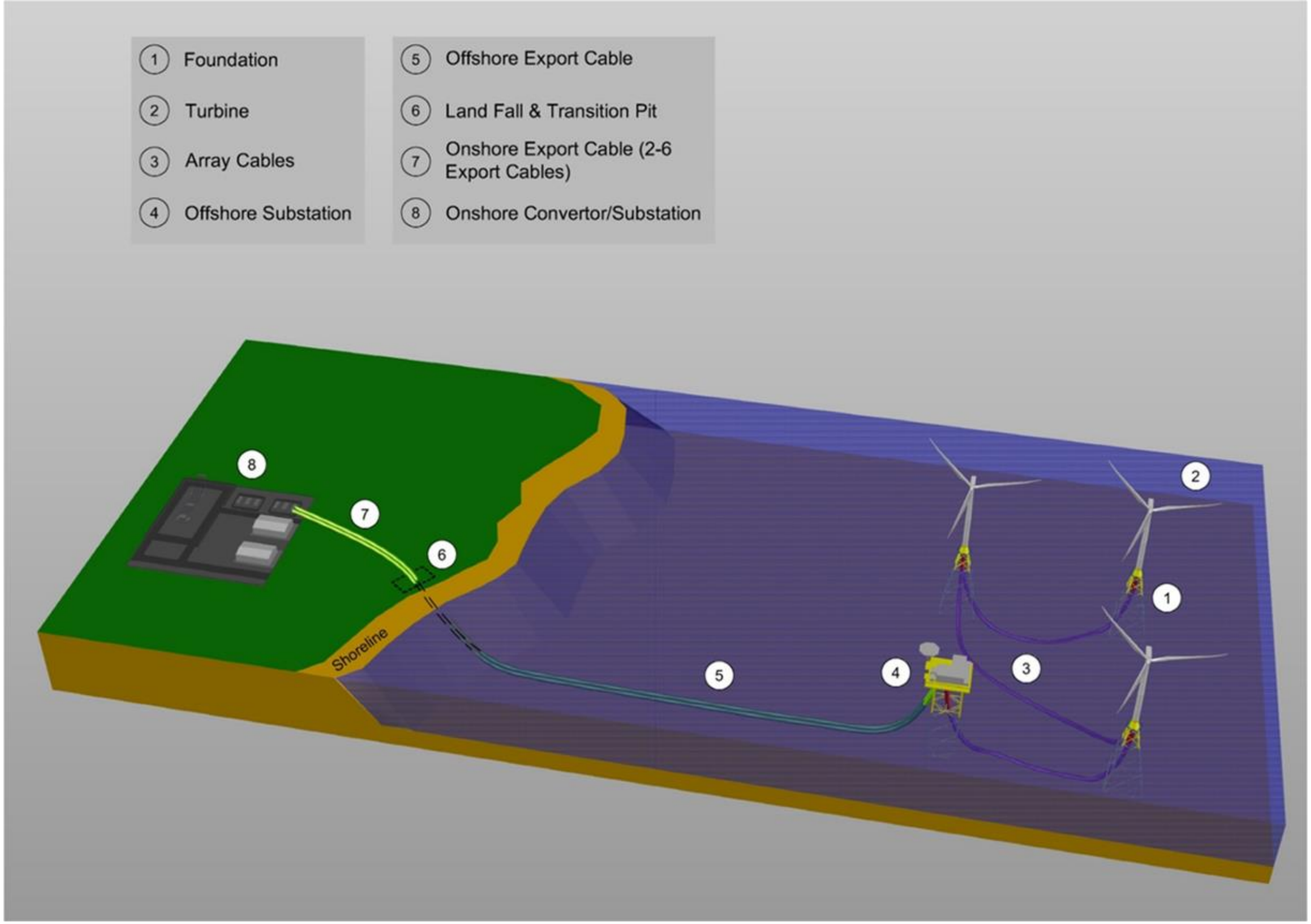
5.12. The optimised Seagreen Project comprises reduced infrastructure compared to the originally consented Project (2014) which included up to 75 WTGs in both Project Alpha and Project Bravo (up to 150 in total) and up to six meteorological masts.

5.13. The components of the Project Alpha and Project Bravo OWFs are summarised in Table 5.1.

Table 5.1 Description of Project Alpha and Project Bravo components

Project Alpha	Project Bravo	Combined
Up to 70 WTGs and supporting structures	Up to 70 WTGs and supporting structures	Up to 120WTG and supporting structures
Array cables connecting WTG strings to OSPs	Array cables connecting WTG strings to OSPs	Array cables connecting WTG strings to OSPs
Any necessary scour protection and cable protection	Any necessary scour protection and cable protection	Any necessary scour protection and cable protection
Up to three wave buoys with alternative of WTG mounted options. LiDAR mounted on WTG to obtain meteorological data.	Up to three wave buoys with alternative of WTG mounted options. LiDAR mounted on WTG to obtain meteorological data.	Up to six wave buoys with alternative of WTG mounted options. LiDAR mounted on WTG to obtain meteorological data.

Plate 5.1 Illustration of the Seagreen Project Components



THE PROJECT DESIGN ENVELOPE

5.14. The 'Design Envelope' approach (otherwise known as the 'Rochdale Envelope') was adopted in the original 2012 Offshore ES, whereby a range of potential design parameters including WTG and foundation types were considered and the Worst Case Scenario (WCS) was assessed for each topic. This approach is continued within this EIA Report.

5.15. Offshore wind farm projects are complex and it is not possible to define the final project design at the time an application for development consent is made. As a result, a number of options within the project design may remain under consideration until after consent is granted and further geotechnical investigations, detailed engineering design and procurement processes have taken place. To enable projects to accommodate these uncertainties, EIA can be based on the established principle of the 'Design Envelope'.

5.16. The assessment of a Design Envelope, for the purposes of EIA, requires that the WCS possible within that envelope are identified and assessed. The WCS identified and assessed is the most realistic scenario that would give rise to the greatest potential impact for the topic assessed. Any design parameter values less than the WCS assessed would therefore give rise to a reduced impact. The detailed design of the project can then vary within this envelope without rendering the ES findings inadequate.

5.17. With respect to the optimised Seagreen Project, the range of likely development scenarios and construction options, comprising the Design Envelope, are described in this chapter, with reference to the design optimisation updates and the originally consented Project to give a complete description of the optimised Seagreen project.

5.18. An explanation of the process by which the parameter ranges defined in the Design Envelope were determined is provided in Chapter 3 (Site Selection and Alternatives).

5.19. For a number of the project components, engineering decisions regarding preferred options and final design details have not yet been made. Retaining flexibility in the selection of preferred design options is a vital mitigation in the management of project risks and enables significant procurement commitments to be made at a more appropriate time later in the process after consent is secured.

5.20. Within the limits set by the project Design Envelope, flexibility is required in respect of the following:

- WTG layout including WTG positions and inter-array separation within OWF;
- Type of WTGs and their specification, for example the rotor diameter, blade tip height and clearance above the sea surface;
- The variation of detailed design and the use of different foundation types within an OWF array;
- The design and location of OSPs; and
- The location of wave buoys.

SITE DESCRIPTION AND CHARACTERISTICS

Project Location

5.21. The optimised Seagreen Project will be the first to be taken forward for development by Seagreen in the Firth of Forth Zone, herein referred to as the 'Zone'. At its closest point the Project lies approximately 27 kilometres (km) offshore, east of the Angus coastline in the North Sea, in the outer Firth of Forth and Firth of Tay region. The Project Alpha site area is 197km^2 and the Project Bravo site area is 194km^2. In total the Seagreen Project covers an area of approximately 391km^2.

5.22. The Project areas and site boundaries for the optimised Seagreen Project are the same as those considered within the 2012 Offshore ES for the originally consented Project. The location and boundaries of the Zone, Project Alpha and Project Bravo are shown in Figure 5.1.

5.23. The Project Alpha and Project Bravo OWF site boundaries have been delineated by the shallow waters (up to 40m deep) of the Scalp Bank to the west and the Zone boundary to the east and north. The southern boundary was defined by the extent of the original Phase 1 Development Area of the Zone.

5.24. The Scottish Territorial Waters (STW) OWF project Inch Cape lies approximately 9km west of Project Alpha and 12km west of Project Bravo. The STW OWF project Neart na Gaoithe lies approximately 27km south west of Project Alpha and 30km south west of Project Bravo.

Metocean, Seabed and Ground Conditions

5.25. A full oceanographic survey of the Zone was undertaken over December 2010 to August 2011 (Fugro GEOS, 2012; Intertek Metoc, 2012) to record wave, current and water level data, with further wave data available from an extended wave buoy deployment and additional inshore wave measurements. Long term wind and wave model data for the area was also purchased from the UK Meteorological Office.

5.26. Preliminary geophysical and geotechnical surveys of the Site and the export cable routes have been undertaken (GEMS, 2010, 2012a and 2012b and Osiris Projects, 2011). These informed initial engineering concept designs for foundations and substructures and established the initial ranges for the Design Envelope parameters described in the following paragraphs.

5.27. Further geophysical and geotechnical surveys of the Site are proposed for Spring/Summer 2018. Information from the geophysical and geotechnical surveys will be used to support the WTG foundation concept design. Survey licences have been obtained by Seagreen separate to the development consent for the optimised Project.

5.28. The project design parameters used for assessment within this EIA Report have utilised the data obtained to date in these investigations. Detailed description of the physical conditions of the optimised Seagreen Project area is provided, as relevant, in the technical chapters of this EIA Report (Chapters 8 to 15).

INDICATIVE OFFSHORE WIND FARM ARRAY LAYOUT

5.29. The initial, combined capacity for Project Alpha and Project Bravo was derived from a uniform distribution of regularly spaced WTGs across the project areas, identified at desk study stage. The 1,075MW connection agreement with National Grid established on this basis formed the upper capacity limit. To allow the flexibility for innovative WTG array design to optimise array efficiency, no preferred layout was defined in the 2012 offshore ES. Notwithstanding this, a minimum WTG spacing of five rotor diameters was defined, based on manufacturer recommendations and was to be applied to any preferred layout. During consent determination, however, Seagreen committed to a 1000m minimum WTG separation distance, to limit potential ornithology impacts.

5.30. Since the 2012 Offshore ES, further design review has taken place, however, final design refinement requires the results from geophysical and geotechnical surveys planned in Spring/Summer 2018. The indicative array layout for the optimised Seagreen Project presented in Figure 5.2 is based on a maximum of 120 WTGs across both Project sites. The overall 120 WTG limit is also scoped, in acknowledgement that a greater overall site capacity can be achieved using larger turbines.

5.31. Whilst the maximum number of turbines across both sites will be 120 WTG, up to 70 WTGs will be constructed in any one of the two project areas, dependent on the results of detailed ground condition investigations. Any limiting water depth and final array layouts for both projects will be defined following engineering refinement post consent including consideration of navigation requirements. Therefore, for example, a development scenario might comprise 70 WTGs in Alpha and 50 WTGs in Bravo, as shown in Figure 5.2, or vice versa, or any combination of WTG numbers up to 70 in each or 120 across both Projects. It should be noted that layouts presented are purely illustrative and that, as with other design parameters for which there is uncertainty, a realistic worst case layout has been assessed on a receptor by receptor basis within the impact assessments. These are presented in technical Chapters 8 to 15 of this EIA Report.

5.32. Flexibility with respect to WTG location within the project boundaries is required to enable the WTG layout, and OSP locations and structural design to be optimised following consent and after detailed ground investigation has been undertaken. The final layout will be fixed following completion of the Preliminary Engineering Design work following the outcome of foundation feasibility studies combined with wind resource optimisation. The layout optimisation process will also inform the array cable arrangement and the locations of the consented OSPs and transmission cables.

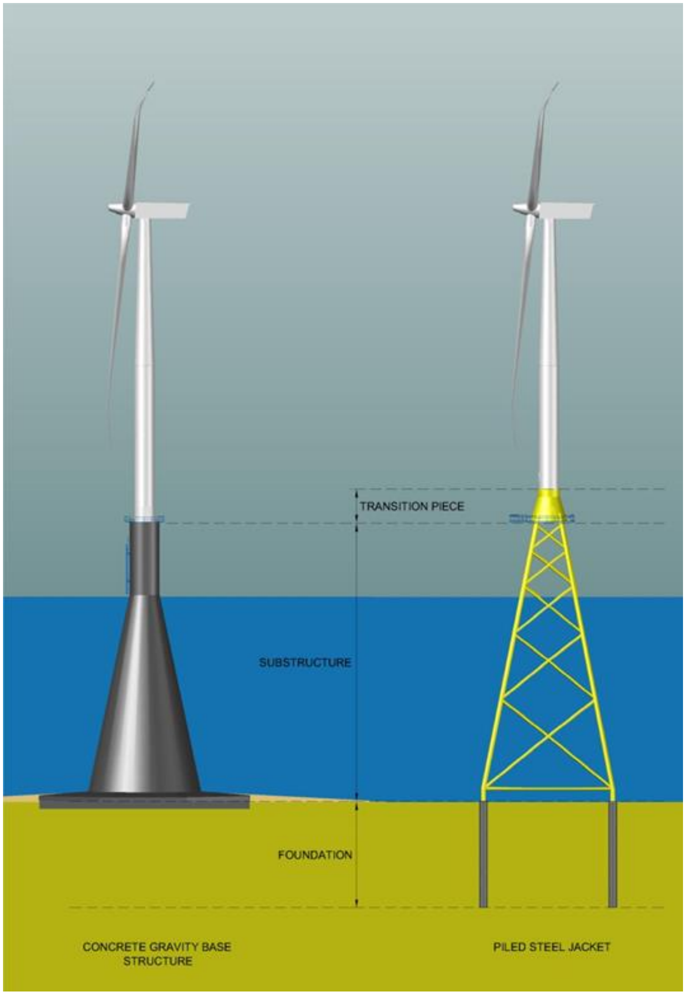
5.33. Project Alpha and Project Bravo may be built as separate OWFs or as a combined Project (the optimised Seagreen Project). The WTG array layout for the Development will be designed to best utilise the available wind resource, while seeking to reduce environmental effects and impacts on other marine users.

OFFSHORE PROJECT COMPONENTS

Wind Turbine Generators

5.34. This section provides a description of the WTG options under consideration for the optimised Seagreen Project and included within the Design Envelope for assessment. The WTG topside components are supported on a foundation and substructure as illustrated in Plate 5.2. The foundation connects the entire structure to the seabed and the substructure connects the WTG topside to the foundation.

Plate 5.2 Illustration of substructure and foundation definitions



5.35. The key WTG parameters for assessment are summarised in Table 5.2. Conventional three bladed, horizontal axis WTGs will be used, comprising the following main components and as illustrated in Plate 5.3:

- **Rotor** – comprised of the blades, hub and spinner;
- **Nacelle** – housing the electrical generator, the control electronics and the drive system; and
- **Structural support** – including the tower and nacelle yawing mechanism which allows the rotor and nacelle to turn and face into the wind. Note that this does not include the foundations or supporting substructure.

5.36. The maximum height of the WTGs is expected to be up to 280m from LAT to the blade tip in the vertical position. The rotor diameter is based on two times the individual blade length, plus the diameter of the rotor hub. The rotor hub height is determined from the blade length plus the blade tip clearance. The maximum and minimum rotor tip heights are based on the rotor diameter and the respective maximum or minimum blade clearance required above Lowest Astronomical Tide (LAT). These dimensions are illustrated in Plate 5.3.

5.37. The size of WTGs described above are consistent with current developments in WTG technology, however the final decision on the preferred WTG will not be made until all statutory consents are in place and the Development has secured a Contract for Difference (CfD).

5.38. For reference, the 2014 consented rotor diameter was 167m, the consented blade tip height 209.7m and the consented minimum blade tip clearance above sea level 29.8m LAT.

5.39. To avoid excessive turbulent wake effects, no WTG will be positioned closer than 1000m from any other WTG in any direction. WTG separation distance could be increased further, to comply with WTG manufacturers' load calculations and consequent warranty requirements. The final array layout design will be determined through consideration of a number of factors including energy output, maintenance requirements, electrical infrastructure design requirements, and geotechnical and environmental constraints. The maximum spacing allowed between WTG rows is 3000m to meet navigational safety requirements.

Table 5.2 WTG Parameters for Assessment

Parameter	Minimum/Maximum Parameter Limit
Capacity of Wind Turbine Generators (MW)	No max
Maximum rotor diameter (m)	220
Maximum blade chord (m)	7.5 – estimated in relation to nacelle dimension
Minimum blade tip clearance above sea level (Lowest Astronomical Tide (m) (LAT))	32.5
Maximum hub height (m) (LAT)	170
Maximum blade tip height (m) (LAT)	280
Nacelle Dimensions (estimated Length x Breadth x Height) (m)	25 x 10 x 12
Operating wind speed range (cut-in/cut-out) (m/s)	Cut in 4 Cut out 32
Operating speed range (revolutions per minute (rpm))	4 to 14
Rotor swept area (m^2)	38,014
Minimum spacing between WTGs (m)	1,000

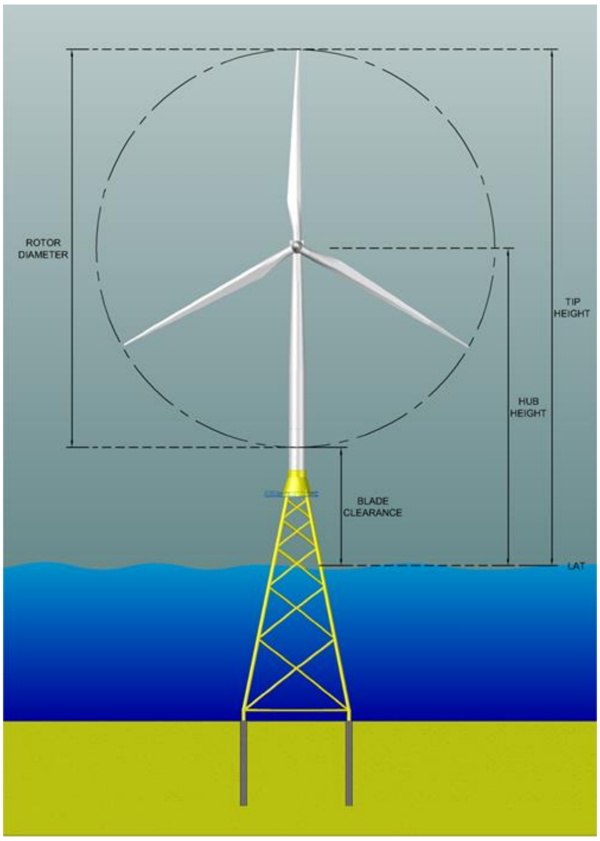
5.40. The WTG operating wind speed will be in the range 4 metres per second (m/s) to 32m/s. Below the generator cut-in speed of 4m/s when the rotor turns, insufficient energy can be captured for operation. Above the cut-out speed of 32m/s, the rotor is stopped to prevent damage to the WTG. The operating rotational speed between the cut-in and cut-out wind speeds is in the range five revolutions per minute (rpm) to 14rpm. The estimated monthly mean rotor speed, shown in Table 5.3 has been determined using a 20 year hindcast time series data set for predicted wind speeds at the project site, and available WTG operational data.

Table 5.3 Mean monthly WTG rotor speeds

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Speed (rpm)	10.6	10.4	9.7	8.9	8.5	8.3	8.0	8.3	9.1	10.0	10.3	10.3

Note Rotor speeds vary depending on the WTG technology. The above are representative of rotor speeds for rotor diameters at the lower end of the Design Envelope. Rotor speeds of larger WTG would be lower.

Plate 5.3 Illustration of WTG dimensions



5.41. The WTG nacelle will contain the power generation equipment, including the drive system, generator and brake. A WTG monitoring and control system is also housed in the nacelle. The range of parameters in WTG nacelle dimensions within the Design Envelope, are given in Table 5.3. A WTG transformer converts the electrical power output generated to the desired OWF distribution voltage. A cut away diagram of typical nacelle components is shown in Plate 5.4.

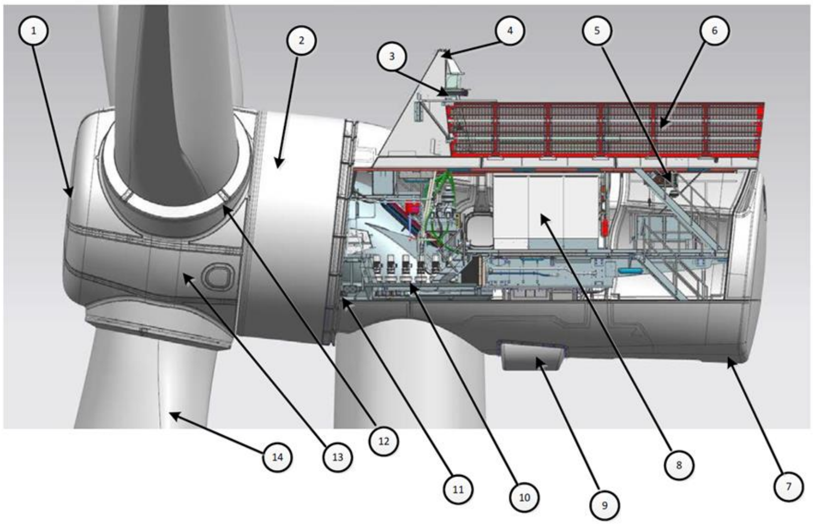
5.42. The nacelle is mounted on a yaw ring seated at the top of the WTG tower, to enable the rotor to respond to changes in wind direction (Plate 5.4).

5.43. The estimated weight for the combined rotor, hub and nacelle assembly for the larger WTGs is around 650 to 700 tonnes. However, there is no specific information on WTGs at this scale at present and therefore this is an estimate, based on known weights of existing machines.

5.44. The WTG tower will be a tubular steel column. Typical tower dimensions are between 6.5m and 10m base diameter. The transition piece connects the WTG tower to the substructure and can also house the WTG electrical and communication equipment. On a monopile the transition piece also assists in achieving vertical alignment of the WTG structure through the adjustment possible within the joint with the substructure.

5.45. The rotor, nacelle and upper tower sections will be painted in semi-matt pale grey colour. Either the transition piece or the lower tower section or substructure of each WTG, from approximately 15m above Highest Astronomical Tide (HAT) to 2m below LAT, will be painted with a high visibility yellow colour.

Plate 5.4 Illustration of WTG nacelle and rotor components



Source: Siemens Gamesa

Notes:

1 Spinner	8 Convertors (2pcs.)
2 Generator	9 Transformer
3 Wind instruments and Aviation Light	10 Yaw Gear
4 Passive Cooler and Active Cooling Fans	11 Bed Frame
5 Portable Nacelle Service Crane	12 Blade Bearing
6 Heli Hoist	13 Hub
7 Canopy	14 Blade

Substructures and Foundations

5.46. Substructure and foundation options are as already assessed in the 2012 Offshore ES and consented in 2014, with the additional consideration of monopiles as a substructure/ foundation option.

5.47. Initial design of the substructure and foundation combinations has considered viability in respect of the WTG size to be supported; the suitability of ground conditions for the foundation; the wind and wave loading on the structure and the vibration characteristics of the WTG. Due to the variation in water depth across the Project Alpha and Project Bravo sites, the substructure dimensions will be tailored to suit a specific depth range and a range of substructure heights will be installed across both OWF sites to ensure the hub height and minimum blade clearance height remain consistent across the WTGs.

5.48. Foundations and substructures under consideration for the optimised project include:

- Monopiles (substructure and foundation combined in one piece);
- Pin piled tubular jackets;
- Suction caisson jackets; and
- Gravity base structures (GBS).

5.49. Other substructure design variants may be considered, including a three leg steel jacket design and a tripod or quadropod design, supporting a monopile, with driven or suction pile foundations. A GBS hybrid design consisting of a gravity base slab with a steel jacket attached may also be considered. The parameters associated with these design variants are contained within the Design Envelope parameters described below for piled steel jackets and GBS.

5.50. Selection of the preferred foundation design will be based on a detailed assessment of ground conditions and other factors influencing design viability, including project economics, prior to construction.

5.51. The 2012 Offshore ES considered pin piled and suction caisson jacket foundations, and GBS foundations, and the potential associated impacts were assessed. Monopiles were not proposed in the original Design Envelope, as at the time they could not be installed at the water depths of the proposed OWFs. Due to advances in OWF monopile design they are now being considered as a viable foundation option for depths of water up to approximately 50m. However, it should be noted that due to limitations related to water depth, a maximum of 70 monopile foundations will be utilised across the combined sites, with the remainder of locations using one or more of the other foundation design options. For example, a maximum of 70 WTG could use monopile foundations with the remaining 50 WTG utilising jackets or GBS. In addition, due to site constraints of deeper water in Project Bravo, up to 70 monopile foundations could be used within Project Alpha alone, but the maximum possible monopile foundations that could be used within Project Bravo is 35.

5.52. The foundation and associated substructure options that define the extent of the Design Envelope parameters are summarised in Table 5.4. Further studies will be undertaken as part of the detailed design process to determine the final design selection. The following sections describe the key parameters for substructure and foundation options considered for the optimised Seagreen project. Installation of foundations and substructures is described in Section 'Offshore Wind Farm Construction' of this chapter.

Table 5.4 Foundation Options Summary

	Foundation Type			
	Pin piles	**Suction Caissons**	**GBS**	**Monopiles**
Potential substructure	Jacket	Jacket	Integral to GBS	Monopile
Potential topside components	WTG	WTG	WTG	WTG
Primary materials	Steel	Steel	Concrete and steel	Steel or concrete
Brief description of foundation	Tubular steel piles on each leg of jacket driven into the seabed.	Upturned bucket style design on each leg of jacket sunk into the seabed using vacuum pumps.	Cast structure that sits on flat sea bed and relies on the weight of the structure and ballast for stability.	Single steel/ concrete pile driven into seabed

5.53. The sections below describe the different substructure and foundation combinations in more detail.

Jacket Substructures and Associated Foundations

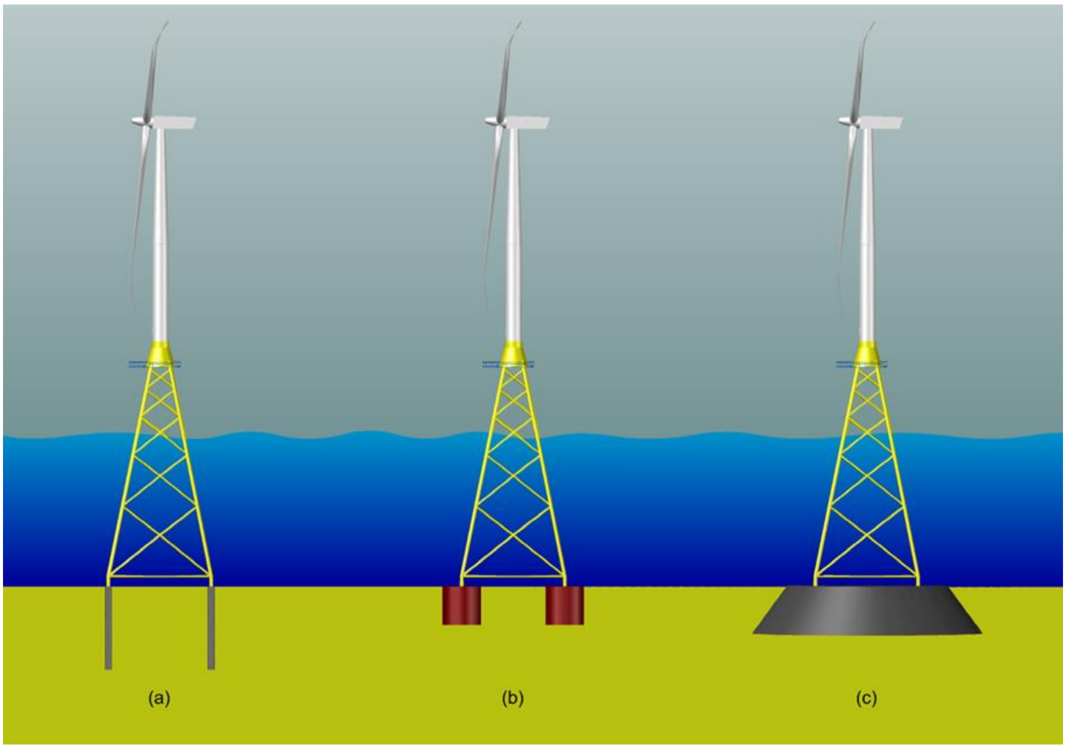
Jacket Substructures

5.54. A jacket substructure is typically a lattice design comprising primary sections of steel tubes that are braced by secondary sections of smaller diameter steel tubes, to form a strong, rigid frame. There are a wide range of potential geometries, including three or four leg designs and different leg angles. The jacket configuration considered in this EIA Report is a four leg structure.

5.55. Jackets can be combined with different foundation concepts (see Table 5.4). For the Project, tubular piles, suction caisson foundations and GBS are considered viable foundation options. Diagrams of these are shown in Plate 5.5. This configuration offers the lowest jacket mass, where the piles are pre-installed using a piling template (see Section 'Offshore Wind Farm Construction'). Pre-piled jackets are designed with spigots at the bottom of the legs which engage with the piles and are subsequently grouted in place. The main saving is in the removal of pile sleeves from the jacket structure and simplification in the load path direct from the legs to the piles. To connect jackets to the piles, the estimated volume of grout required will be approximately 45 cubic metres (m^3) per jacket. The maximum width of the jacket substructure at the water surface will be 30m.

5.56. The final design of the jacket will depend on a range of factors. These include water depth; the specific geological and seabed conditions at the location of each structure; the final size of the WTG; and also supply chain implications. It may also be the case that because of these factors more than one substructure design is required across the OWF sites. Jacket Design Envelope parameters are summarised in Table 5.5.

Plate 5.5 Tubular jacket with (a) tubular pin piles, (b) suction caisson piles and (c) possible GBS hybrid



Source: Garrad Hassan, 2011

Pin Piled Tubular Foundations

5.57. A tubular pin pile is a large steel tube that is driven into the seabed to the required depth by a piling hammer. For hard substrates drilling may also be required to achieve the desired depth of penetration. A jacket requires at least one tubular pin pile at each corner to secure it to the seabed. The size of tubular pin piles will depend on a number of factors, such as the loading on the structure and the ground conditions. The likely maximum WTG tubular pile diameter will be up to 2m and the likely maximum WTG tubular pile length will be up to 60m and the penetration depth 55m (Table 5.5). Installation of a tubular piled foundation is described in Section 'Offshore Wind Farm Construction'.

Suction Caisson Foundations

5.58. A suction caisson is similar to an upturned can, closed at the top and drawn into the seabed by water pressure. Water is pumped from within the foundation, to create suction such that it draws into the seabed and is secured (see Plate 5.5). A jacket requires at least one suction caisson at each corner to secure it to the seabed. Depending on seabed conditions and structural loading, the suction caisson diameters will be up to 14m and the penetration depth up to 23m (Table 5.5). Installation of a suction caisson foundation is described in Section 'Offshore Wind Farm Construction'.

Gravity Base Foundations and Substructures

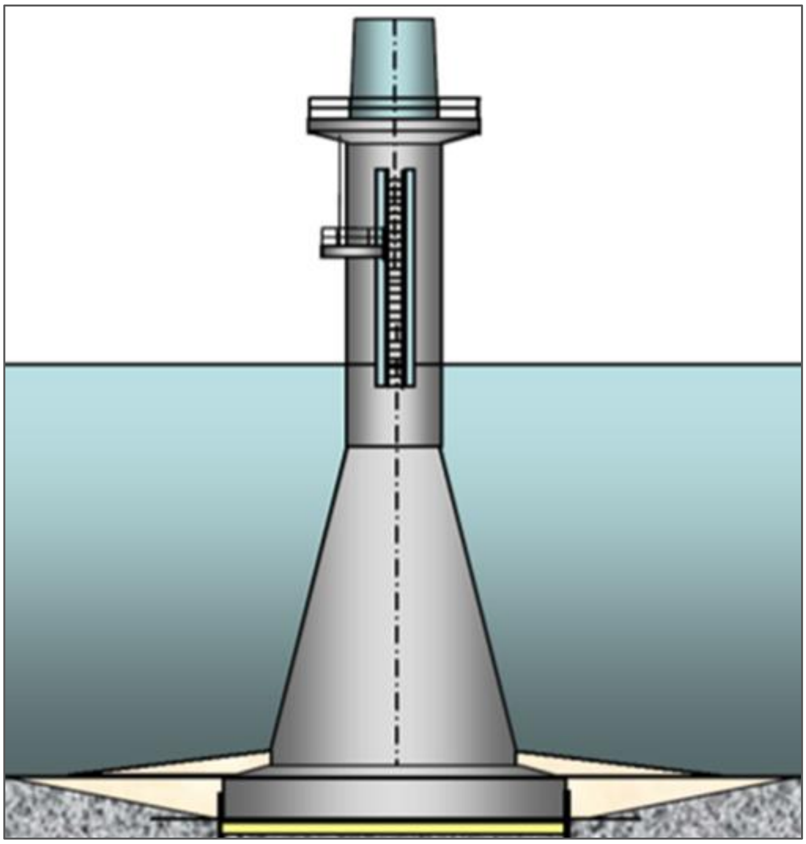
5.59. GBS provide structural stability through their self-weight and added ballast. The foundations must have a minimum base area, to achieve an acceptable distribution of the load on the seabed. The design proportions of the foundation are also affected by the water depth, the wind and wave loading and the substructure design. A conical GBS is illustrated in Plate 5.6. A GBS foundation would require some extent of scour protection.

5.60. GBS' are cast from concrete and steel and can also be combined with a jacket substructure. The likely GBS dimensions are given in Table 5.5. The maximum baseplate diameter will be 72m with a cone diameter at the base of up to 50m. GBS dimensions will be optimised for ground conditions at detailed design stage, once further ground conditions data is available. The GBS height will be up to 78m. Site selection for WTG foundations during detailed design will seek to maximise use of locations with good ground conditions if GBS foundations are selected.

5.61. GBS are filled with ballast in the form of sand or water on installation. Seagreen will investigate the potential to maximise reuse of arisings from ground preparation as ballast. Additional requirements for ballast may require imported material. It is anticipated that up to 37,500m^3 of ballast may be required per GBS.

5.62. A GBS has to be placed on flat and level ground, to ensure even distribution of weight and to ensure that the structure is vertical. Seabed preparation, involving some excavation to remove poor ground, may be required prior to installation. The preferred method is to place the GBS directly onto the seabed although ground preparation may allow smaller structures to be used. Levelling of the foundation may require grouting or the use of a gravel layer. Approximately 0.5m thickness of grout may be used across the footprint of the foundation. Installation of a GBS foundation is described in Section 'Offshore Wind Farm Construction'. GBS Design Envelope parameters are summarised in Table 5.5.

Plate 5.6 Conical GBS foundation with monotower



Source: Garrad Hassan, 2011

Monopiles

5.63. A monopile foundation comprises a large diameter steel or concrete tube (pile) driven vertically into the seabed. The dimensions of the pile depend on the size of the WTG, water depth, wind and wave loadings and the ground conditions at each location. The WTG tower can be connected to the foundation by bolting directly to a flange at the top of the monopile, or through the use of a transition piece. The transition piece is installed over or inside the monopile and is either secured by grouting, or directly bolted on top of the monopile.

5.64. Monopiles are driven into the seabed to the required depths using a piling hammer. For hard substrates drilling may also be required to achieve the desired depth of penetration. Monopile foundations have been deployed extensively at OWFs in the UK and across North West Europe.

5.65. For monopiles considered within the Seagreen Project, the tubular diameter may be up to 10m and the monopiles may be up to 95m in length with a maximum penetration of 45m below the seabed. Table 5.5 sets out the Design Envelope parameters for monopile foundations and Plate 5.7 presents an example monopile foundation, including the transition piece. Installation of a monopile foundation is described in the Section 'Offshore Wind Farm Construction' in this chapter.

Plate 5.7 Example of a single steel monopile together with the transition piece and scour protection

Source: Seagreen, 2018

Foundations: Scour Protection

5.66. Scour protection is required to ensure that erosion of the seabed around the foundation does not affect the stability, or integrity of the structure. Scour protection is provided by rock placement around the foundation. The installation of scour protection is described in the Section 'Offshore Wind Farm Construction' in this chapter.

5.67. Piled jacket foundations are assumed to not require scour protection and will be designed to accommodate local scour around the structure as well as global scour, the natural erosion of the seabed, where this occurs. Scour protection may be required for GBS, suction piles and monopiles. The final form and design of this scour protection will vary across the OWF sites and will be reviewed once detailed site data is available on the nature of the seabed. The total volume of scour protection required for the revised Design Envelope is estimated to be 900,000m^3 WCS (for GBS foundations). This is considerably smaller than the 1,734,000m^3 WCS calculated for the 2012 Offshore ES.

Foundation and Substructure Zones of Influence

5.68. The likely area of seabed over which foundation installation and operation may have an influence has been defined by identifying various zones of influence. Different combinations of substructure and foundation type will have different zones of influence depending on ground conditions and water depth. In line with the Scoping Opinion received from Marine Scotland Licensing Operations Team (MS-LOT) in November 2017, Physical Processes and Benthic Ecology have been scoped out of this EIA Report and further consideration of zones of influence is not required.

Summary of Foundation and Substructure Design Parameters

5.69. Table 5.5 below summarises the Design Envelope parameters for the foundation and substructure options.

Table 5.5 Foundation and Substructure Design Envelope Parameters

Parameter	Range or Maximum
Jacket Pin Pile Design Envelope parameters	
Maximum number of jacket legs per structure	4
Max no of pin piles per jacket	4 for 4 leg jacket structure
Max pile diameter (m)	2
Max pile length/penetration depth (m)	60 (pile length)/55 (penetration depth)
Max width of jacket substructure at water surface (m)	30
Scour protection	No scour protection anticipated.
Number of pin pile jacket locations	Max no. of jacket locations in Alpha = 70 Max no. of jacket locations in Bravo = 70 Max no. across both sites = 120
Jacket Suction Caisson Design Envelope parameters	
Number of suction caissons per jacket	Max 3 for 3 leg jacket structure
Max caisson diameter (m)	14
Max caisson penetration depth (m)	23
Max width of jacket substructure at water surface (m)	25
Max scour protection (m^3)	280,000 (up to 140,000m^3 in Alpha; up to 140,000m^3 in Bravo)
Number of jacket suction caisson locations	Max no. of jacket locations in Alpha = 70 Max no. of jacket locations in Bravo = 70 Max no. across both sites = 120
GBS Design Envelope parameters	
Max dimensions (m)	Base plate diameter 72 Cone diameter at base 50 Height 78
Max depth of ground preparation (m)	3
Estimated excavation volume (m^3)	16,000
Max ballast volume (m^3)	37,500
Max scour protection (m^3)	900,000 (up to 450,000m^3 in Alpha; up to 450,000m^3 in Bravo)
Number of GBS locations	Max no. of GBS locations in Alpha = 70 Max no. of GBS locations in Bravo = 70 Max no. across both sites = 120
Monopile Design Envelope parameters	
Max pile diameter (m)	10
Max pile length/penetration depth (m)	95 (pile length)/45m penetration depth
Max column diameter at waterline (m)	10
Max scour protection (m^3)	65,000 (up to 37,500m^3 in Alpha; up to 37,500m^3 in Bravo)
Number of monopile locations	Max no. of monopile locations in Alpha = 70 Max no. of monopile locations in Bravo = 35 Max no. across both sites = 70

Array Cables

5.70. The array cable network of an OWF collects the electrical power generated at the WTGs and connects to OSPs where the combined generated power can be converted to a higher voltage for transmission to shore and connection to the national electricity transmission grid (hereafter referred to as 'the Grid'). The array cables are included within the consent applications for the optimised Seagreen Project infrastructure. The OSPs and interconnector cables are included within the existing consent of the Transmission Asset Project infrastructure and are not considered further within this assessment.

5.71. The most commonly used OWF collection voltage in the UK is currently 33kV. Subsea cables at this voltage are available from a number of established manufacturers (Seagreen, 2011). A collection voltage of up to 66kV may be used for Project Alpha and Project Bravo.

5.72. The array cables will typically comprise three cores with copper or aluminium conductors and insulation/conductor screening. The three cores will be bound together and protected within a layer of steel armouring. The cable bundle will also include a fibre optic communications cable for OWF monitoring and control. A diagram of a typical 132kV submarine power cable is shown in Plate 5.8, although it should be noted that insulation thicknesses for a 33kV or 66kV equivalent would be less than that shown.

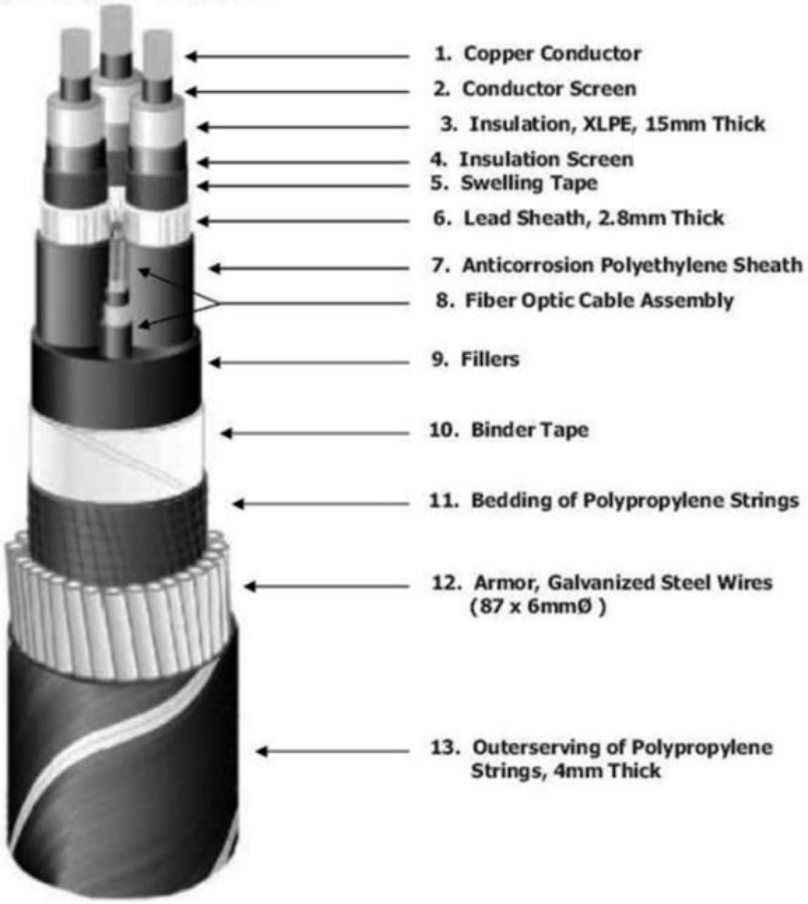
5.73. The cables will connect the WTGs together into 'strings'. The total length of array cables is estimated to be up to 325km for Project Alpha OWF and 325km for Project Bravo. To retain flexibility, the total array cable length is based on an estimate for regular array layouts with a range of WTG spacing, with an additional factor to allow for the potential adoption of irregular array layouts. The WTG array strings will then be connected to the OSPs.

5.74. The precise array cable layout will be defined during Front End Engineering Design (FEED). It will be driven by the WTG layout configuration, but it will also be influenced by ground conditions, electrical losses, installation limitations, environmental constraints and economic factors.

5.75. The array cables will be buried wherever feasible, in order to provide protection against damage. Based on currently available information it is considered possible that up to 90% burial could be achieved, to a minimum burial depth of 0.5m (Table 5.6). The temporary zone of influence on the seabed during cable laying operations will be a maximum of 10m width.

5.76. Where cable burial cannot be achieved protection measures will be required. A small section at either end of each length of array cable will also be unburied in order to allow connection to the WTG or OSP substructures. Cable protection will be achieved through rock armouring or placement of concrete mattresses. Cable installation is described in Section 'Offshore Wind Farm Construction' of this chapter.

Plate 5.8 Cut away illustration of a three core submarine cable



Source: Nexans

Table 5.6 Array Cable Parameters

Array Cables	Alpha		Bravo	
	Min	Max	Min	Max
Anticipated maximum array cable length (km)	-	325	-	325
Total trenched (plough or jet) cable length (km)	-	292.5	-	292.5
Estimated total rock or mattress protected length (km)	0	32.5	0	32.5
Estimated length of cable route clearance (km)	0	97.5	0	97.5
If trenched, estimated trench width (m)	-	3	-	3
If trenched, cable burial depth (m)	0.5	2.1	0.5	2.1
If trenched, width of temporary Zone of Influence (m)	-	10	-	10
If rock or mattress protected, max height (m)	-	1	-	1
If rock or mattress protected, max width (m)	-	7	-	7
Array cable voltage (kV)	33	66	33	66

5.77. Array cable lengths are determined by the WTG layout. An array cable options study (Seagreen, 2011) was completed using a number of potential layout configurations, including an unconventional layout that may require a greater total extent of array cabling in comparison to a standardised grid array. The maximum array cable lengths for assessment will not exceed that presented in Table 5.6. A minimum is not required for assessment and has not been defined.

Wind Measurement

5.78. Up to three permanent meteorological masts were consented in 2014 for installation at both the Project Alpha and Project Bravo sites. Rather than the installation of separate meteorological masts, for the optimised Seagreen project LiDAR are likely to be mounted directly onto certain WTGs.

5.79. Wind data from the LiDAR will be used to verify WTG performance and to support ongoing OWF operations. The data will also input to wind forecasting for resource predictions.

Wave Buoys

5.80. Up to six wave buoys will be deployed at a number of locations within the Site to measure wave height, period, direction and spreading angle. The wave data will be sent via satellite telemetry to the shore and recorded internally for Seagreen and will provide input for the development of a forecast model for the region. The wave buoys will be moored at each location and may be protected by guard buoys to protect the measuring equipment. Consultation will be undertaken with the local fishing interests prior to deployment and the standard marine notification requirements will be followed.

5.81. Each wave buoy will be marked with a flashing amber light to standard requirements and an additional radar reflector fitted to enhance radar visibility. Seagreen will seek a clearance of up to 350m at each wave buoy location. They will be serviced at approximately six month intervals. At the end of the deployment period each wave buoy and mooring will be fully recovered from the Site.

5.82. No change is proposed from the originally consented Project, compared with the optimised Seagreen Project, although a potential alternative to a conventional wave buoy involves a WTG mounted wave radar system. This would remove the requirement for wave buoys and associated clearance areas. The use of a radar mounted alternative will be decided at the detailed project design stage.

OFFSHORE WIND FARM CONSTRUCTION

5.83. Construction methods described in the 2012 Offshore ES and already consented, remain relevant to the larger WTGs included within the optimised Design Envelope and the installation of the WTG towers on monopile foundations.

5.84. Details of the construction aspects of the optimised Seagreen Project are indicative at this stage and may be subject to modification during detailed design for construction and commissioning. The information provided is based on best available information at the time of writing.

5.85. The indicative construction programme provided (Table 5.7) sets out a broad timescale and sequence for the required construction activities for the optimised Seagreen. Construction of each OWF project may be taken forward at the same time. Alternatively, construction of each project may take place sequentially.

Offshore Pre-Construction and Construction Key Activities

5.86. Construction of the optimised Seagreen Project will be completed in a number of stages as follows:

- Pre-construction surveys and seabed preparation activities;
- Transportation (structures floated or transported offshore on vessels);
- Offshore foundation installation;
- Offshore substructure installation;
- Array cable installation and protection;
- WTG installation; and
- Commissioning.

5.87. Offshore construction activities are likely to overlap, to provide the most efficient construction schedule. Installation of the consented offshore and onshore transmission works will be undertaken in parallel with the offshore construction works.

Outline Offshore Construction Programme

5.88. The offshore construction period for the optimised Seagreen Project is anticipated to take place over four years. The indicative programme is shown in Table 5.7.

Table 5.7 Optimised Seagreen Project: Indicative OWF Construction Programme

	Year 1	Year 2	Year 3	Year 4
Foundation/substructures				
Array cable installation				
WTG installation				
Commissioning				

5.89. The durations given assume that most of the construction work takes place between April and the end of September each year and the programme is therefore conservative. However, for the purposes of this EIA Report, allowance for construction activities to take place at any time of the year should be made, as vessel utilisation is important in maintaining schedule and reducing costs.

5.90. The minimum period of time for the substructure and foundation installation for the optimised Seagreen Project is anticipated to be 18 months with an expected maximum period of 24 months. Installation of the WTGs and the array cables is expected to take between 12 and 24 months.

5.91. The construction commencement date will be dependent on achieving consent and securing a CfD contract for the Development and the programme defined under the CfD contract. It is expected that construction and commissioning will be undertaken in a phased approach. It is in Seagreen's interest to plan and implement an efficient and effective construction programme. It is anticipated that construction activities will take place within the periods outlined, but are not expected to take the full duration shown against each activity.

5.92. Installation of a single project, i.e. Project Alpha or Project Bravo alone is anticipated to take approximately three years. Construction activities would take the same staggered approach as described for the optimised Seagreen Project.

5.93. A number of installation and construction options are under consideration for the optimised Seagreen Project. The final options selected will be determined by a range of factors. These include the type of foundations to be used; the extent of onshore assembly of infrastructure and the location of the manufacturing base(s), and the construction port base.

5.94. The availability of construction vessels of the capacity required for the installation of large structures in the water depths found across the Project area is also a key consideration. As the scale of the offshore wind industry develops it is likely that new innovations in large scale offshore installation methods will emerge to improve efficiency and safety of installation.

5.95. For the purposes of this EIA Report it has been assumed that there will be up to four construction vessels per Project each greater than 80m in length, servicing the construction stage at any given time.

5.96. Seagreen will endeavour to minimise impact or disruption to other users of the sea in planning the construction activities in detail. For example, a phased programme will be utilised to reduce safety zones while construction is in progress. Array cables will be jetted or trenched or protected by rock placement as soon as is practicable after being laid on the seabed to allow resumption of fishing activity. It is also proposed to maintain ongoing dialogue with the commercial fishing sector directly and through the existing Forth and Tay Commercial Fisheries Working Group (CFWG). This will enable direct communication to inform fishermen about planned activities and, where practicable, allow the commercial fishing sector to influence timing and sequence of activities such that any disruption is minimised. Table 5.8 summarises the spread of construction vessels likely to be used for the construction programme.

Table 5.8 Construction Vessel Requirements

Construction Aspect	Likely vessel requirements
Pre-construction geophysical survey	Dedicated geophysical survey vessel using side scan sonar, multibeam echosounder and magnetometer. Will survey OWF sites and Export Cable Route (ECR) corridor
Pre-construction geotechnical survey	Dedicated geotechnical survey vessel will take a number boreholes, core penetration tests (CPTs) and vibrocores within the OWF sites and ECR corridor
Cable Pre-Lay Grapnel Run (PLGR) and SCAR plough	Dedicated vessels with PLGR device and SCAR plough (or equivalent) and Remotely Operated Vehicle (ROV)
Plough trials	Cable installation vessel along selected installation equipment (plough, jetting ROV and or trencher)
WTG and OSP substructures/ foundations	Foundation installation Heavy Lift Vessel (HLV) or jack-up barge and possible foundation transportation vessel
Scour protection	Construction barge or dedicated rock placement vessel
Cable Mattress/Rock Placement	Construction barge or dedicated rock placement vessel
WTGs	HLV or jack-up barge
OSPs	HLV or jack-up barge, substation installation vessel
Cable lay	Cable lay barge/vessel

5.97. The objectives in developing the construction methods will be to:

- Minimise construction related health and safety risks to personnel;
- Minimise construction related environmental risks;
- Minimise cost risk;
- Minimise schedule risk; and
- Maximise production.

5.98. To meet the above objectives, the following approach will be adopted in engineering the construction methods:

- Address construction issues early in the design process, specifically including safety reviews;
- Minimise offshore construction;
- Maximise onshore assembly and pre-commissioning;
- Standardise design and components;
- Minimise interdependency of offshore operations; and
- Optimise timing of offshore construction.

Marine Control and Safety

5.99. An application for safety zones will be made to the Scottish Ministers under Section 95 of the Energy Act 2004 as amended by the Scotland Act 2016 (Section 62), and in line with the UK government Department of Business, Energy and Industrial Strategy (BEIS) Guidance Notes for Applying for Safety Zones around offshore renewable energy installations (OREIs) (BEIS, 2011), as adopted by the Scottish Ministers. It is intended that safety zones will be applied for during construction and during periods of major maintenance in the operational phase. A separate application may be made for the decommissioning phase at a later stage once requirements are known.

5.100. The purpose of the safety zones will be to manage the interaction between vessels associated with the OWFs and other users or developments in order to protect life, property and the environment. Only project associated vessels will be permitted to enter the safety zones, and third party vessels will therefore be kept at a safe distance from construction, commissioning, and major maintenance activities related to the Seagreen Project, in order to avoid incidents.

5.101. 'Rolling' safety zones of radius 500m (the maximum permissible under international law) will be applied for around any fixed wind farm structure where active construction or major maintenance is ongoing, as denoted by the presence of large construction or maintenance vessels at that structure. The application may also contain provision for 50m safety zones around any structures during the construction phase where work is not active.

5.102. Details of the safety zones will be promulgated including through Notice to Mariners in advance of implementation. The safety zones will be continually monitored whilst active, either by a dedicated guard vessel, or by another designated on-site vessel associated with construction/maintenance activities.

5.103. Temporary navigation lights may be fitted to structures during the construction stage. These detailed requirements have not yet been determined and confirmation will be sought from the appropriate bodies during development of the relevant Consent Plans required to discharge consent conditions.

Pre-Installation Activities

5.104. Prior to installation of any type of foundation or cable, a pre-installation seabed survey will be required, to confirm that no obstructions are present, such as unexploded ordnance (UXO), debris or large boulders. If obstructions are identified, the area may be prepared for the intended installation activity, for example using an ROV grab, a PLGR or SCAR plough, or the foundation may be microsited to avoid obstructions. In addition, there may be a need to microsite the foundations by up to approximately 50m, for example to avoid sensitive ecological or archaeological seabed features that may be identified.

Construction Methods for the Optimised Seagreen Project (Project Alpha and Project Bravo)

5.105. This section describes construction methods for all aspects of the optimised Seagreen Project, including construction of the range of foundation types and details on any associated seabed preparation. Construction methods are also applicable if either Project Alpha or Project Bravo are constructed separately.

Foundation and Substructure Installation

Jacket Installation with Driven and/or Drilled Tubular Pin Piles

5.106. Piled steel jackets have been widely deployed to support offshore oil and gas platforms and are currently being used for WTGs.

5.107. Typically, the piles are brought to the OWF site on transportation vessels or barges and installed using an installation vessel. On arrival at the OWF site, piles are lifted from the transport barge using the installation vessel's crane, moved to the vertical position and then lowered to the seabed for installation to commence. Piles are likely to be positioned on the seabed using a template or installation frame (see Plates 5.9 and 5.10). Piles do not normally require any seabed preparation, however obstacles such as boulders may be removed by ROV grab. The most efficient method of installing a pile is to drive it into the seabed using a hydraulic hammer.

Plate 5.9 Stanislav Yudin HLV with the pile installation frame on board

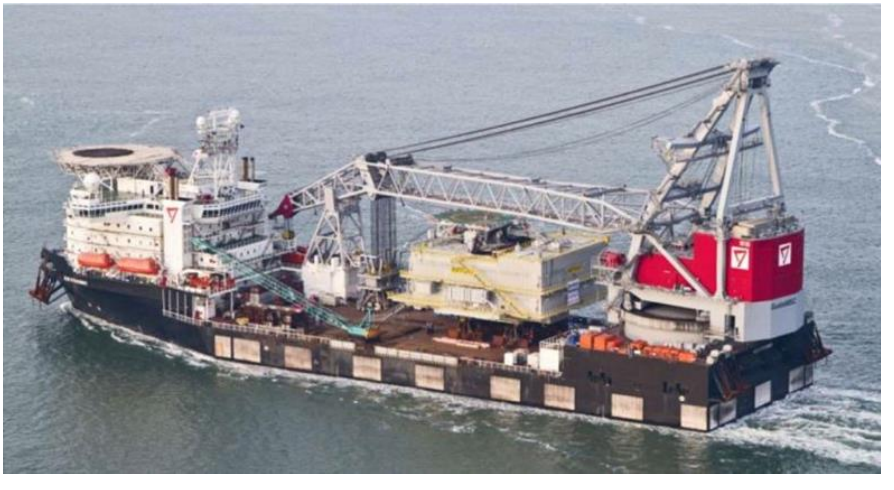
Source: Beatrice Offshore Windfarm Ltd (BOWL) 2017

Plate 5.10 Pile installation frame being deployed

Source: BOWL 2017

5.108. Alternatively, the installation vessel may pick up the piles directly from a port and transport them to the OWF site. The installation vessel could be a jack–up barge, a monohull crane vessel, or HLV as shown in Plate 5.11.

Plate 5.11 The Oleg Strashnov HLV



Source: BOWL 2017

5.109. A jack up barge or vessel will have up to six legs. The likely seabed coverage for each leg will be up to 8 to 10m diameter with a seabed penetration of up to 25m.

5.110. For pre-piled jackets, the piles are installed first by driving them through a re-usable template. Once the pile has been placed in position, the pile hammer is attached to the top and the pile is driven to the required depth. Once the template has been removed, the jacket is then lowered into place and the legs stabbed into the piles and grouted. Drilled piles may also require additional grouting to provide sufficient load capacity.

5.111. Using pre-piled jackets has the advantage of breaking the installation schedule dependency between the supply of piles and substructures, which improves the efficiency of pile and substructure installation. It is also a less weather sensitive method and can be carried out throughout the year with a suitable vessel, although there would be more weather down-time in the winter months compared to the summer.

5.112. The whole operation to install one pile takes approximately 13 hours, including positioning the installation vessel and the piling hammer, placing the template or substructure and aligning the pile. Within this overall period the pile driving activity takes place over approximately 2 hours, depending on ground conditions. The complete piling operation for a four leg jacket is expected to take approximately two days. For the purposes of assessment, a maximum duration of up to two years has been assumed for the completion of all piling operations.

5.113. Pile driveability studies were carried out based on soil profiles derived from geotechnical survey which informed the selection of piling scenarios for assessment within the EIA. A reasonable WCS has been determined, at a blow force of approximately 1,800kJ.

5.114. It is anticipated that this blow force will only be required where firmer seabed materials are encountered. Each tubular pile could warrant up to 6,075 hammer strikes, at a rate of approximately 45 blows per minute, to drive it to the required depth, dependent on pile size and ground conditions.

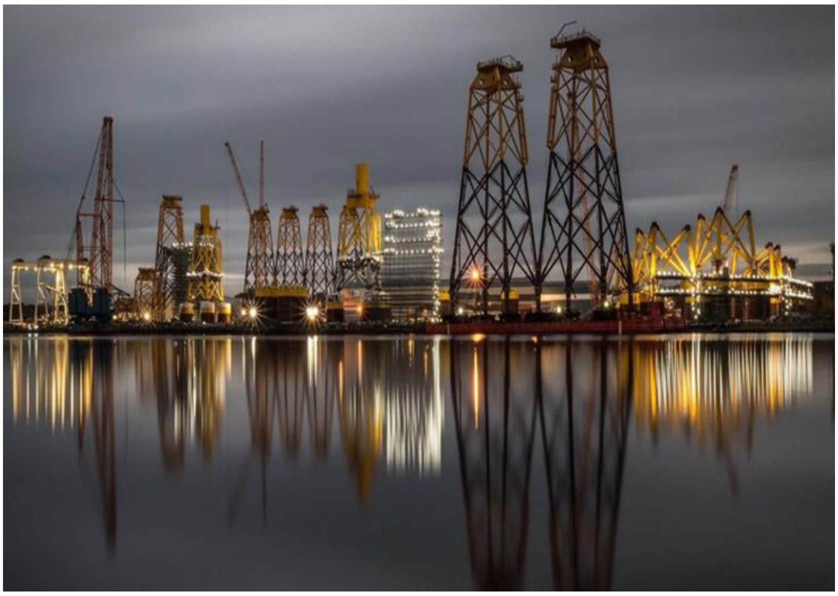
5.115. Table 5.9 summarises indicative pin pile installation details.

Table 5.9 Pin Pile – indicative installation details

Design Parameter	Optimised Design Envelope		
	Project Alpha	Project Bravo	Combined
Max hammer energy (kJ)	1800	1800	1800
Max minutes of piling per pin pile (min)	135	135	135
Max No. of pin piles installed in 24 hours	4	4	4
Assumed max no. of piling days (slow rate) (note split of WTG between projects is an example only)	140	140	240
Number of simultaneous piling events	May be simultaneous pin piling at Alpha and Bravo, or simultaneous monopile and pin piling at Alpha and Bravo		

5.116. Jackets are normally fully assembled at a quayside (see Plate 5.12) and loaded onto a large flat top transportation barge, either vertically or on their side, for transport to the OWF site. The transportation barge is towed out to the installation location and the jacket is then lifted and lowered into position on the pre-installed piles by an installation vessel (see Plate 5.13). (Note: Transition pieces are attached to the jacket substructures during manufacturing and will therefore not need to be fitted offshore). The jackets will then be grouted to the piles. The installation vessel may also be used for transportation.

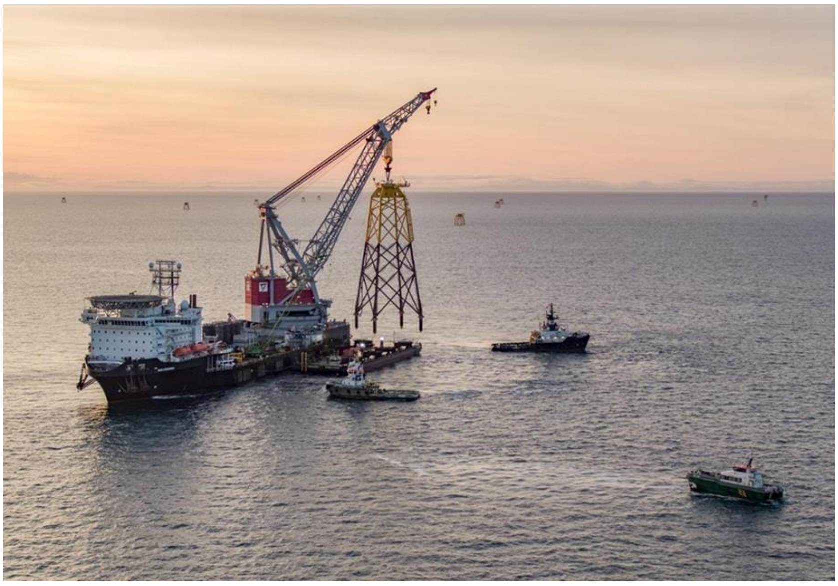
Plate 5.12 Jacket on Quayside ready for Transportation



Source: BOWL 2017

5.117. Placement of a steel jacket on pre-driven piles can be completed in under a day once any soil plug within the pile has been removed, if necessary, usually through jetting. The connection between the pile and the substructure is usually achieved by injecting cement grout into the annulus between the pile sleeve and the pile. This is likely to be done from the installation vessel and will take around one day per structure. Jacket installation can be carried out all year with a suitable vessel but the operation requires a longer weather window than pile driving alone (to allow grout to cure). Jacket installation is therefore more likely to take place in summer than in winter.

Plate 5.13 Jacket Installation from HLV Oleg Strashnov at Beatrice Offshore Wind Farm



Source: BOWL 2017

5.118. Few jack-up vessels are capable of working in the water depths found across the Project Area. Typically those that are capable will be larger vessels similar in scale to the Pacific Orca (130m in length, 38m beam), illustrated in Plate 5.14.

Plate 5.14 Jack up construction vessel Pacific Orca

Source: Swire Blue Ocean

Suction Caisson Installation

5.119. Suction caisson foundations will usually be integrated with the substructure during fabrication. Installation will then require a single operation which would normally be undertaken from a floating vessel (HLV or SSCV, see Plate 5.15) by use of Dynamic Positioning (DP) or jack-up vessel. Once placed onto the seabed and settled under its own weight, water would then be pumped out of the suction caisson. This creates a pressure differential, with the pressure inside the caisson piles lower than the pressure in the sea, which draws the caisson piles into the seabed. Suction caisson penetration typically takes about eight hours but the whole operation, including setting up and positioning would take approximately one day. There are also 'self-installing' suction pile concepts using a pontoon barge towed by an Anchor Handling Tug (AHT).

Plate 5.15 Installation of a tripod jacket on suction piles

Source: SPT Offshore

Gravity Base Structure Installation

5.120. The GBSs will be manufactured onshore. If GBS is being used for the foundation it may be integrated with the substructure during fabrication so that both components are transported to site as a single structure. Alternatively, the GBS foundation may be transported to site on its own and the substructure attached once the foundation is in place. The buoyancy of a hollow GBS base is an advantage during transportation and installation.

5.121. A GBS can be transported to site by a towed pontoon barge and then lifted into place on site by a separate vessel (HLV or SSCV). Alternatively, the lifting vessel can also provide transport to site. If the GBS is designed to be self-floating, it can be towed to site by an AHT and lowered to the seabed by controlled ballasting using seawater. This will be followed by the addition of suitable granular ballast material to resist the long term loading regime. Ballast material for the GBS is likely to consist of sand. The ballast can also be removed from the GBS, to allow decommissioning.

5.122. The maximum vessel requirement for installation of GBS and integrated substructures would be a tow to site by two AHTs and assisted placement.

Seabed Preparation for Gravity Base Structures

5.123. A GBS usually requires seabed preparation over the footprint area, to ensure a uniform load distribution and vertical alignment (Garrad Hassan, 2011). This typically involves dredging to remove superficial sediments followed by rock and/or gravel placement to form a level footing. Specialist dredgers and rock placement vessels will be used for these operations which would be monitored using ROVs. The dredging and ground preparation method adopted will be determined through the detailed ground investigations undertaken during detailed design.

5.124. Site selection will seek to minimise the extent of ground preparation required. For the majority of the site for average strength soils an average seabed preparation depth of up to 3m is assumed. If weaker strength soils are encountered greater seabed preparation depth may be required, however these locations will be avoided where possible.

5.125. The surplus material produced during the ground preparation and seabed levelling will be disposed of in-situ, either on the seabed adjacent to the substructure or re-used as a ballasting medium for the substructure. The materials likely to be produced from the seabed preparation for GBS' comprise deposits of sand and gravel with occasional potential for clay where present close to the surface. Seagreen will investigate the potential to maximise reuse of arisings from ground preparation as ballast.

5.126. Skirts around the perimeter of the GBS (to a depth of 5m) can be used to minimise or even remove the requirement for seabed preparation. These skirts also assist in the protection of the structure from scour. When skirts are used, grout is required to fill any gaps under the base slab.

Monopile Installation

5.127. The monopile foundations will be fabricated onshore at a manufacturing site that has yet to be identified. Once fabricated the monopiles will be transported to the OWFs by one of the following methods:

- Sealing the ends, floating, and towing them;
- Transportation on a cargo barge and/or vessel; or
- Transportation on the deck of an installation vessel.

5.128. Once on location at the OWFs, the monopiles will be lifted by a crane onto the installation vessel and held in place vertically using a pile gripper located on the deck of the vessel. As described above for pin piles, monopiles are driven into the seabed using a hydraulic hammer (powered by the installation vessel, or by a generator located on the deck).

5.129. Indicative installation parameters for the monopiles are given in Table 5.10. Monopiles generally require a higher hammer energy than pin piles due to their size. All installation activities and their durations are subject to weather and wave height constraints and installation vessel numbers and availability.

5.130. During installation, WTG monopile foundations will be installed one at a time. However, installation of a monopile may be carried out concurrently with a jacket pin pile, using separate installation vessels. Piling may occur at any time of day (vessel operations are 24 hours), though piling will not be constant for 24 hours per day. Between piling of individual monopiles, vessel movements and pile handling operations will need to occur with the result that one monopile would be installed per day. Therefore the estimated installation time for the maximum number of 70 monopiles is 70 days. This would not be undertaken in a continuous period.

5.131. It is expected that the piles will be driven by a hydraulic hammer using a maximum energy of 3,000kJ +/-2%. The hammer energy required to drive the monopiles will depend on seabed conditions at each location. Some locations may need a reduced level of hammer energy to achieve the required ground penetration. However, at some locations installation may stall, even if the full 3,000kJ hammer energy is used, due to denser areas of seabed such as gravel deposits, buried obstructions, such as boulders; and rock and/or bedrock. At these locations, pile driving activities will be paused, a drill used to 'drill out' the seabed within and underneath the monopile to allow it to move again, and then pile driving will resume.

Table 5.10 Monopile – Indicative installation details

Design Parameter	Optimised Design Envelope		
	Project Alpha	Project Bravo	Combined
Max no. monopile foundations (in water depths up to 50m)	70	35	0
Max hammer energy (kJ)	3000	3000	3000
Max hours of piling per monopile	4	4	4
No. of monopiles installed in 24 hours	1	1	1
Max no. of piling days (note split of WTG between projects is an example only)	70 (non-consecutive) – Dependent on piling scenario. Accounts for multiple vessels, weather downtime, breakdown etc.	35 (non-consecutive) – Dependent on piling scenario. Accounts for multiple vessels, weather downtime, breakdown etc.	70 (non-consecutive) – Dependent on piling scenario. Accounts for multiple vessels, weather downtime, breakdown etc.
Number of simultaneous piling events	No simultaneous piling of monopiles but potential simultaneous piling of 1 monopile and 1 jacket pin pile at Project Alpha and Project Bravo.		

5.132. A 'soft start' of 20 minutes, where the hammer energy would be around 400kJ, would be expected at all locations. After this 'soft start', piling energy will be slowly increased, in order to maintain a target number of blows per metre of penetration. The total number of blows over the four hours piling period may be around 8300, giving an average of 35 per minute.

Fitting the Transition Piece

5.133. The WTG tower can be connected to the foundation by bolting directly to a flange at the top of the monopile, or through the use of a transition piece. The transition piece (depicted in yellow in Plate 5.7) is installed over, or inside the monopile and is either secured by grouting, or directly bolted on top of the monopile. The transition pieces are brought to the project area either by barge, or on the installation vessel and lifted into place. If used, grout is pumped into the gap between the foundation central tubular and the transition piece and allowed to set. The turbine tower and wind turbine generator can then be installed onto the transition piece. The transition piece will include the boat landing, working platform and ancillary equipment (such as boat fenders, access ladders and lifting equipment). Transition pieces can extend from the bottom of the WTG tower to water level, or right down to the seabed, depending on the design.

Seabed Preparation for Monopiles

5.134. Seabed preparation for monopile foundations is likely to be minimal. Monopile locations will be selected using the results from geophysical and geotechnical surveys to identify locations avoiding obstructions and seabed slopes. Further pre-installation surveys may be required and if obstructions or seabed slopes are identified, WTGs will be micro-sited to avoid obstacles, or an ROV grab may be used to clear the location.

Drilling Monopiles and Pin Piles/Sediment Discharges

5.135. Installation of the monopiles and pin piles may also include drilling methods to assist the piling operations, where seabed conditions make driving difficult. Monopiles and pin piles may also be installed by vibropiling, which would significantly reduce the impulsive underwater noise generated at installation.

5.136. Drilling typically takes much longer than driving and requires careful control of drilling fluids and cement grout, as well as the disposal of the drilling arisings. Seagreen will seek to adopt best practice in this regard.

5.137. It is anticipated that some drilling may be required at some locations in Project Alpha and Project Bravo if monopile or pin piled foundations are selected. A combined drill and drive piling operation for a monopile could require up to 10 days. A combined drill and drive piling operation for a four leg jacket could require up to six days.

Noise Emissions from Piling: Monopile and Pin Piling Activities

5.138. It is well established that some construction noise sources, such as impact piling, generate high underwater noise levels. It is therefore important to consider and document the potential impact of the construction noise as part of the overall EIA process. If driven piles are selected for substructure installation, generated underwater noise has the potential to affect a range of sensitive receptors (such as marine mammals and some fish species). This is considered within Chapter 9 (Natural Fish and Shellfish Ecology) and Chapter 10 (Marine Mammals) of this EIA Report. The ground conditions and applied loadings to the substructures will determine the diameter and length of pile and hence the size of piling hammer, the energy force that must be applied to the hammer and the required duration of piling operations. In combination, these parameters will determine the extent of noise emissions during the construction period for the Project.

Grouting of Foundations

5.139. If grout is used, typically, high strength low shrinkage grout is required to withstand the significant compressive stress at joints. Grout is a strong inert cement mix and may be mixed on board the installation vessels, or mixed onshore and transported to the site. The final selection and mix design of the grout will be determined by the structural design, installation methodology and commercial factors. During any grouting operations, the grout is pumped to the required location whilst being carefully monitored and the flow is switched off once the required volumes are in place. Methods are adopted which are designed to minimise grout loss to the surrounding environment. Spillage of grout will be minimised using either inflatable or wiper seals located at the base of the transition piece. The indicative volume of grout required for a single 10m diameter monopile foundation is approximately 95m^3.

Installation of Scour Protection: All Foundations

5.140. Scouring of soft surficial sediments may occur around foundations where localised increases in the near bed currents occur, resulting in increased erosion, forming scour holes or scour tails. The pre-construction geophysical survey will ascertain the level of scour protection required for each location. Scour surveys will continue beyond the construction stage of the project and may form part of the ongoing inspection regime and monitoring for the OWFs.

5.141. If scour protection is required, this will be achieved by rock placement around the foundation and the base of the substructures after installation. Rock placement will infill any scour pit which may have developed after installation and will create a rock berm above seabed level. This will be designed to remain stable for the full lifetime of the structure and under all forms of predicted environmental loading. The time lag between GBS installation and scour protection installation would be kept to a minimum to reduce the risk of scour occurring around the structure.

5.142. The rock placement will be achieved using a fall pipe vessel (Plate 5.16) or a vessel with a side tipping system. On a fall pipe vessel, the rock is conveyed to the side of the ship and freefalls down a chain-mail pipe. An ROV positioned at the end of the pipe is used to adjust the delivery point relative to the ship. The combined movements of the ship and ROV are used to form the required design of scour protection. The fall pipe ROV is used to survey the position and shape of structures created, using acoustic profilers and other devices. Alternatively the rock could be placed using a grab device from a suitable vessel.

5.143. Following installation, the foundation area and the base of the structure will be resurveyed, to confirm that the required coverage and rock profile has been achieved.

Plate 5.16 Typical fall pipe vessel

Source: Xero Energy

WTG Installation

5.144. The most likely method of installing the larger WTG is a 'stick build' approach as described below. It is possible that that new innovations in large scale offshore installation methods will emerge, to improve WTG installation efficiency and safety.

Stick Build Installation

5.145. The stick build approach comprises the installation of individual WTG components during separate offshore lifts. This is currently the most common approach to constructing WTGs offshore and requires a jack-up vessel, to ensure appropriate stability of blades, rotor etc. while bolted flange connections are made up and takes longer than a single lift.

5.146. A nearby quayside facility may also be required for this method to allow delivery of WTG components throughout the year. The jack-up vessel could pick up components from this facility or from a floating barge. If there is sufficient storage capacity at the WTG manufacturer's facilities, it may be possible to deliver components directly from the manufacturer's facility to the installation vessel offshore.

Array Cable Installation

5.147. Array cables will generally be buried using trenching, jetting or ploughing techniques as dictated by the ground conditions. Array cable installation is unlikely to take place before installation of the WTG foundations and substructures.

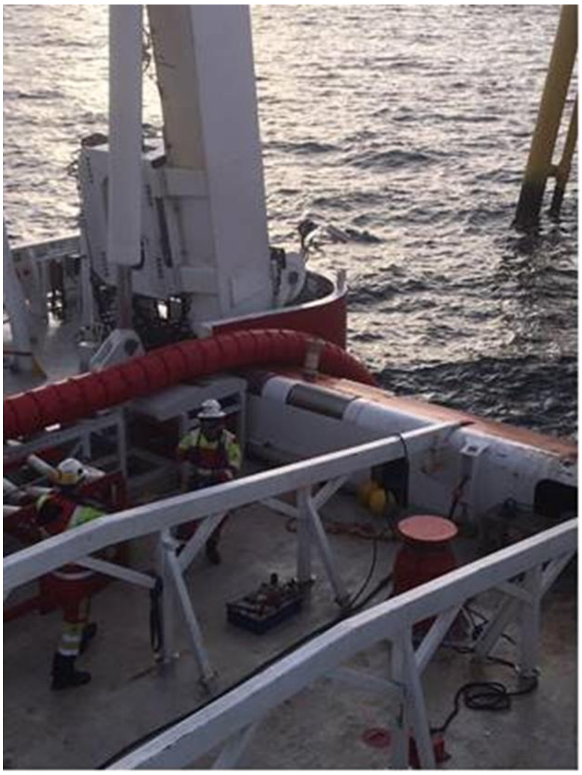
Array Cable Installation Procedure

5.148. A cable barge or a specialist cable installation vessel is likely to be required to install the cable into the seabed (see Plate 5.17). Cables will be supplied on reels or loaded onto the vessel in one continuous length. The vessel will then travel to site and take up a position adjacent to the start location, for example a WTG or OSP. The vessel will either hold station using DP, or set anchors in a stationary mooring pattern.

Plate 5.17 Typical cable installation vessel

Source: BOWL 2018

Plate 5.18 Cable being laid off installation vessel



Source: Seagreen 2018

5.149. One end of the array cable will then be floated from the cable reel towards the WTG substructure. The cable is then laid (see Plate 5.18) from the WTG towards the next WTG in the string, or the OSP. The cable installation vessel will either move under DP control, or by hauling on its anchors. If the second method is used, redeploying the anchors will be required.

5.150. Depending on the design of the WTG or OSP substructure, the cable will be sunk, then either lifted or pulled onto the substructure. Pull-in operations will be carried out using a small ROV or construction vessel. This will most likely take place after substructure installation. This operation can be carried out at any time of year, although there will be more weather downtime in winter than in summer.

Pre-installation Works

5.151. The preferred array cable routes will be surveyed during the pre-construction geophysical survey, to locate any obstacles that could obstruct cable laying, such as rocks, wrecks, metal objects, or debris and UXO. If an obstruction is located it will be assessed and an appropriate strategy will be established to remove or avoid the obstruction. Where a suspected UXO is identified specialist mitigation will be employed to either avoid, or make safe the obstruction.

5.152. The geophysical surveys will also serve to identify the location of sand waves along the cable routes so that an assessment can be made as to whether such features can be avoided or if not and to ascertain what level of seabed preparation (pre-lay sweeping) is required to ensure burial depth is achieved in stable (i.e. non mobile) seabed conditions. Prior to the cable installation, burial trials may be conducted in advance of the main installation programme. This will ensure that the chosen equipment is suitable for the ground conditions encountered and that burial depth can be achieved, in the absence of an established track record of successful installations. If undertaken, this could involve tests to bury sections of cable up to 1km in length in the soil types likely to be encountered. Following the trials the test piece will be removed from the seabed.

Array Cable Installation Methods

5.153. Different approaches and techniques are available for cable installation. These are:

- Simultaneous cable lay and burial, using a cable plough or a mechanical trencher; and
- Cable lay with subsequent burial using a jetting ROV or a mechanical trencher.

5.154. A combination of methods may be used for cable installations, depending on ground conditions. The preferred approach will be confirmed on completion of the pre-construction geotechnical site investigation surveys.

5.155. The rate at which cables can be installed is dependent on many factors, including:

- The target cable burial depth;
- The selected installation technique and approach;
- The type and properties of soils encountered; and
- Operational constraints (e.g. weather conditions).

5.156. Table 5.11 below provides some typical average cable installation rates for three trenching tools. However, these figures should be taken as indicative only at this stage, given that the selection of trenching tool will take place following geotechnical site investigation surveys at which point the appropriate installation approach will be confirmed.

Table 5.11 Typical cable installation rates

Trenching tool	Soil Description	Average Ranges of Trenching Speed (metres per hour [m/hr])
Cable Plough	Very soft to hard clay Loose to very dense sand	200 to 400 150 to 450
Jet Trencher	Very soft to stiff clay Very loose to very dense sand	60 to 250 80 to 560
Mechanical Cutter	Stiff to hard clay Loose Sand	200 to 400 500

Cable Burial by Ploughing

5.157. Cable burial ploughs cut through the seabed, lifting the soil from a trench into which the cable is laid (Plate 5.19). The plough is designed to cut a narrow trench, with a slot of material temporarily supported which then falls back over the cable. The advantage of this method is that burial can be achieved as the cable is laid, thus minimising risk to the cable. However, the number of vessels which can carry out this method and that have the required cable carrying capacity for heavy power cable is limited.

5.158. The performance of a plough and the depth of burial which can be achieved are a function of plough geometry and seabed conditions, with dense or stiff soils providing the greatest challenge. This operation is relatively slow and can be interrupted if weather conditions deteriorate.

Plate 5.19 Cable plough illustration

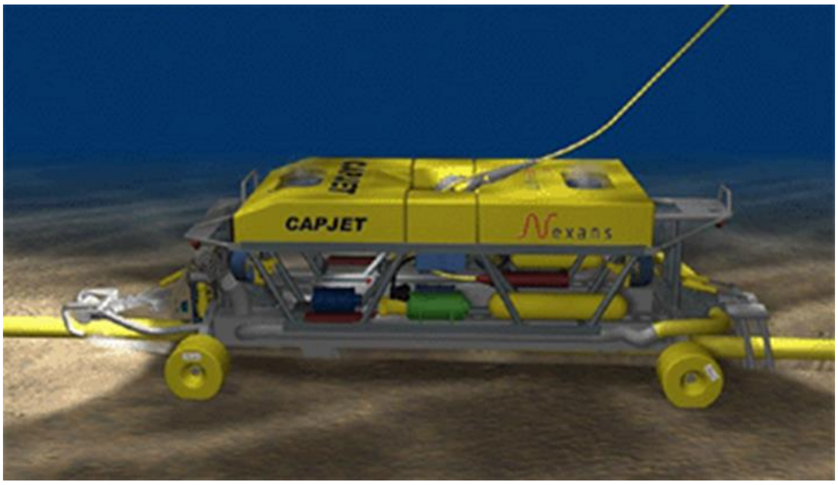
Source: Xero Energy

Cable Burial by Jetting

5.159. Where the seabed predominantly comprises soft sediments the array cables could be buried using a post-lay jetting technique, generally controlled from a DP vessel. The cable is laid on the seabed and a ROV fitted with high-pressure water jets is subsequently positioned above the cable (Plate 5.20). The jets fluidise a narrow trench into which the cable sinks under its own weight. The jetted sediments settle back into the trench and with typical tidal conditions the trench coverage is reinstated over several tidal cycles.

5.160. The advantage of this method is that the cable can be laid in a relatively rapid operation during suitable weather conditions. Cable burial can then be achieved separately with less concern over weather constraints disrupting operations. However, the performance of a jetting ROV is limited where sediments are more compacted.

Plate 5.20 A jetting ROV



Source: Nexans

Array Cable Burial Depths and Trench Widths

5.161. Cable burial depth will be determined by a detailed hazard identification survey, which will assess the different locations and the various shipping and dredging activities. The hazard identification survey will identify any areas where the cable burial depth may vary due to local features, such as:

- Sand waves;
- Erosion of the seabed;
- Intense dredge or trawl fishing activities; and
- Existing infrastructure or observed seabed obstacles.

5.162. The array cable burial depth will be a minimum of 0.5m, but could be down to 2.1m depending on ground conditions and the outcome of further burial risk assessments. Based on current understanding of ground conditions, it is expected that at least 90% of the array cable will be buried.

5.163. If buried, the estimated maximum trench width will be 3m and the maximum width of the temporary zone of influence, due to plough or ROV tracks, will be 10m.

Alternative Array Cable Protection

5.164. Achieving satisfactory array cable burial depths may not be possible in some areas and in close proximity to the WTGs and OSPs. Where burial is not possible, alternative measures will be utilised to ensure cable protection, these include:

- Placement of concrete mattresses over the cable;
- Rock placement to cover the cable on the seabed; or
- Placement of grout bags over the cables which are then inflated with structural grout. The grout cures to provide an effective over cover protection system for the cables.

Concrete Mattresses

5.165. Mattresses are generally made of concrete elements formed on a mesh of polypropylene rope, which will conform to changes in seabed morphology (Plate 5.21). Bevelled elements are used on the edges, to create a lower profile to encourage, for example, trawl gear to roll over the mattress. Where appropriate, mattresses fitted with polypropylene 'fronds' can be used to enhance the protection provided. The fronds encourage sediment deposition, in the best case creating a protective sand bank. Mattresses require placement either by divers or ROV, to ensure that they are positioned correctly; consequently this takes longer than other methods.

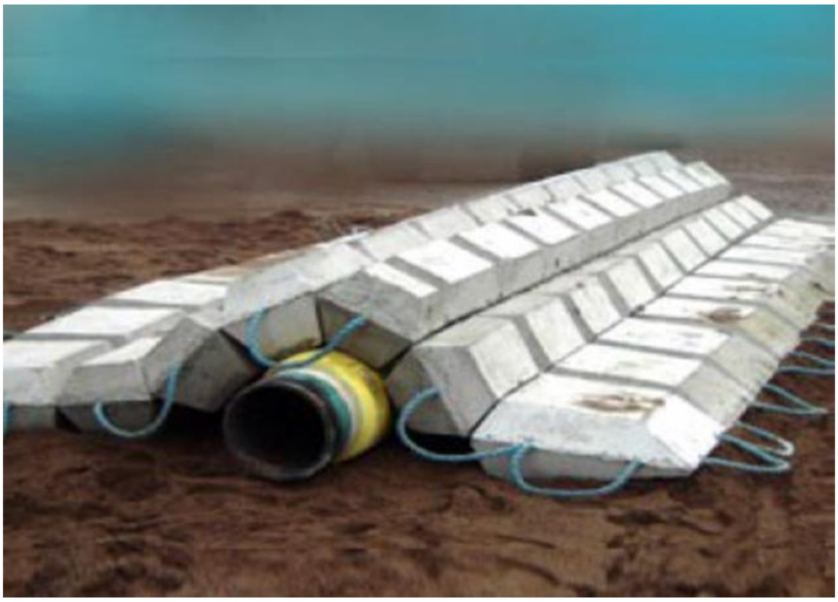
5.166. The maximum width of any mattressed array cable protection is expected to be 7m.

Rock Placement

5.167. Rock placement has long been established as a method for protecting cables. It is a relatively quick operation and is not as weather dependent as mattressing. The rock used is normally imported from land quarries, although sea aggregates can also be used, with grain sizes being tailored to achieve the necessary protection. Where water depth is not a limiting factor, rock is usually deposited by a fall pipe vessel, as this is the most efficient method of getting the material onto the seabed. This is further described in Section 'Installation of Scour Protection: all Foundations' and a typical fall pipe vessel is depicted in Plate 5.16.

5.168. The maximum width of any rock placement array cable protection is expected to be 7m.

Plate 5.21 Cable protection using concrete mattresses



Source: Xero Energy

OFFSHORE WIND FARM COMMISSIONING

5.169. Commissioning will generally comprise the following process, with procedures formalising the different, individual stages:

- A mechanical, visual and electrical continuity assessment;
- An energisation programme;
- Testing mechanical, electrical and control functions;
- Identification of faults;
- Rectification of faults;
- Re-testing; and
- Certification.

5.170. The commissioning of Project Alpha and Project Bravo, will be in accordance with approved commissioning procedures. This may be managed by the principal contractor(s) for construction of each project to the requirements of Seagreen, where applicable. All commissioning activities will be the subject of an approved safe system of work. Commissioning activities will include the WTGs performance and reliability testing and compliance with the Grid code standard.

OFFSHORE WIND FARMS OPERATION AND MAINTENANCE

5.171. This section describes the anticipated O&M activities for the OWFs. O&M for the Transmission Asset Project and the onshore infrastructure is excluded as these aspects are already consented.

5.172. The O&M information provided is based on best available information at the time of writing, as described in the Seagreen Operations EIA Input Report (Seagreen, 2012b). This is drawn from current operational knowledge in addition to reflecting regulatory requirements and industry best practice (Seagreen, 2012b). The information provided covers:

- Likely navigation requirements and markings for operations stage;
- Usual offshore operational lighting requirements;
- Likely WTGs access facilities;
- Pollution prevention;
- O&M outline strategy;
- Onshore O&M requirements;
- Onshore transport requirements;
- WTGs access by air; and
- O&M stage vessel movements.

5.173. The O&M port and onshore facilities may be shared by the operators of Project Alpha and Project Bravo. However, it is possible that separate facilities will be used. The description of O&M port facilities, onshore O&M requirements and onshore transport requirements are provided for information only. Consideration of these is out with the scope of this EIA (see Chapter 7 [Scope of EIA Report]).

5.174. Reliability and ease of maintenance are both design issues. Maintenance is required as a consequence of design, thus, it is crucial to address this at the early stages of the project. The primary objectives of the O&M activities will be to:

- Operate OWFs in a safe manner, causing minimal impact on the environment;
- Effectively convert wind energy to electricity and accurately measure and deliver electricity for sale;
- Maximise output while controlling operating expense;
- Safeguard the mechanical integrity of all facilities, substructures and installations;
- Maximise the use of appropriate technologies to improve the efficiency, safety and effectiveness of all operations, transport technology and maintenance activities; and
- Minimise manning and personnel transport to appropriate levels (as far as is reasonably practicable).

5.175. Once commissioned, the OWFs will operate automatically with each WTG operating independently. The operation and control of the OWFs will be managed by a Supervisory Control and Data Acquisition (SCADA) system, connecting each WTG to the onshore control room(s). The SCADA system will enable the remote control of individual WTGs, the OWFs in general, as well as remote interrogation, information transfer, storage and the shutdown/restart of any WTG if required.

Marine Control and Safety

5.176. The following description applies to both Project Alpha and to Project Bravo and the optimised Seagreen Project.

Lighting, Marking and Signage

5.177. The Northern Lighthouse Board (NLB) marine navigation requirements for WTG structures are covered in International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Requirement O-139 'The Marking of Man-Made Offshore Structures' (IALA, 2008). Aviation lighting requirements are provided in Civil Aviation Authority (CAA) Civil Aviation Publication (CAP) 393 and 764 (CAA, 2010 and CAA, 2012 respectively). Marine Guidance Note (MGN) 543 (Marine and Coastguard Agency [MCA], 2008) identifies the requirements for the design and construction of an OWF.

5.178. Lighting, markings and signage will comply with these requirements, or relevant requirements at the time of O&M activities.

5.179. WTGs will have Unique Identification Characters (UIC), including a numerical identification clearly visible from a vessel and from the air. UICs will be illuminated during the hours of darkness, if required. This lighting will be hooded or baffled to avoid confusion with navigation marks.

Anchorage and Safety Zones

5.180. It is likely that Seagreen will apply for an operational safety zone of 50m around each OWF structure in accordance with the relevant guidance. Through the application for consent, Seagreen will seek to extinguish the rights of navigation within these distances of each structure, in order to establish the desired safety zones.

5.181. During maintenance operations this will be extended to 500m (the maximum permissible under international law) around the relevant structures. Once the OWFs are operational, an Automatic Identification System (AIS) and closed circuit television (CCTV) from an onshore O&M Control Centre(s) will be in place to monitor vessel movements within the OWFs. The fundamental principle is that vessels will be kept at a safe distance from commissioning and operational activities related to the OWF in order to avoid collisions.

5.182. During the operational stage it is likely that a larger support vessel may be required for planned and unplanned maintenance activities. It is likely that several pre-determined areas will be identified and marked as temporary anchorage areas, such that before manoeuvring into final position, an initial mobilisation point is widely known. As detailed planning moves forward, it is possible that a mother vessel concept could be adopted whereby a larger vessel is semi-permanently positioned offshore and the day to day service activities are run from smaller daughter craft from the mother vessel saving transit time back and forth to a local port.

Marine Control Centre

5.183. A Marine Control Centre(s) for the OWFs will have AIS, video surveillance and radar coverage which will identify vessels with AIS facilities entering into the safety zone during O&M activities. This will be in addition to any visual observation made by personnel on O&M vessels or guard vessels working within and around the area. Any vessel identified or observed to stray in to the safety zone will be contacted by a designated member of the crew of the O&M vessels or guard vessels or from the Marine Control via multi-channel Very High Frequency (VHF) radio, including digital selective calling, and warned that they have encroached the safety zone. They will be instructed to divert their course out of the safety zone. Vessels which ignore this warning and are considered to be causing a potential danger will be further requested and then the details of the vessel reported to the MCA enforcement unit.

5.184. AIS and CCTV from Marine Control Centre(s) will be in place during operation of the OWFs, which will be used to monitor vessel movements within the Project Sites.

Access Strategy for Offshore Infrastructure

5.185. The WTGs will be designed to operate unmanned and are expected to be available to produce electricity for at least 95% of their installed life time. Planned outages for a WTG will be triggered primarily by routine maintenance requirements, but also occasionally at the request of the Maritime Rescue Co-ordination Centre (MRCC) in support of Search and Rescue (SAR) activities in the area. The WTGs will normally shut down during severe weather conditions when wind speeds exceed 32m/s to avoid damage to the WTG components. This will be controlled remotely.

5.186. Access strategies will be developed and may include both work boats and helicopters. The work boats will be used for routine maintenance operations and in weather conditions up to approximately 2m wave height. It is also expected that there will be provision for emergency accommodation on the OSPs for up to 12 personnel, with associated welfare facilities. Indicative work force numbers, vessel sizes and vessel movements are given in Table 5.12.

Table 5.12 O&M indicative parameters for Project Alpha and Project Bravo

O&M Range	Alpha		Bravo	
	Min	Max	Min	Max
Total number of offshore technicians	95	140	95	140
Number of service vessel required	6	8	6	8
Length of service vessels (m)	18	28	18	28
Number of vessel movements* per annum	1,320	1,760	1,320	1,760
Size of support vessel (m) (2x daughter craft)	70	90	70	90
Maximum number of wave buoys required	3	3	3	3

* One vessel movement is equal to one to- and from- OWF site trip.

5.187. In order to optimise site availability and generating capacity there may be a requirement to use helicopter access, to ensure site availability requirements, through personnel and material transfer via winching operations. The OSPs could be fitted with a helipad and helicopter refuelling capability (see CAP 748 'Aircraft Fuelling and Fuel Installation Management' [CAA, 2004]), this will maximise the helicopters operational potential as a base for internal transfers within the OWFs and refuelling.

5.188. Larger spares and equipment could also be delivered directly to the OWF sites from land based manufacturers by sea, using a crane ship or alternative suitable lift vessel.

5.189. Detailed evaluation will be undertaken to identify the best access strategies for the Seagreen Project. This will consider the experience and lessons learned from other constructed OWFs. The use of a 'mothership solution' will also be considered and modelled. Until this evaluation is complete it has been assumed that site access is likely to be a combination of the methods outlined below.

Access by Work Boat

5.190. Work boats, 18m to 28m in length, are typically used for daily transfer of personnel. Larger vessels are also now entering the market and will be considered (up to 50m in length). Personnel transfer to and from the WTG will be via a fender arrangement on the bow of the vessel.

Access from Mothership

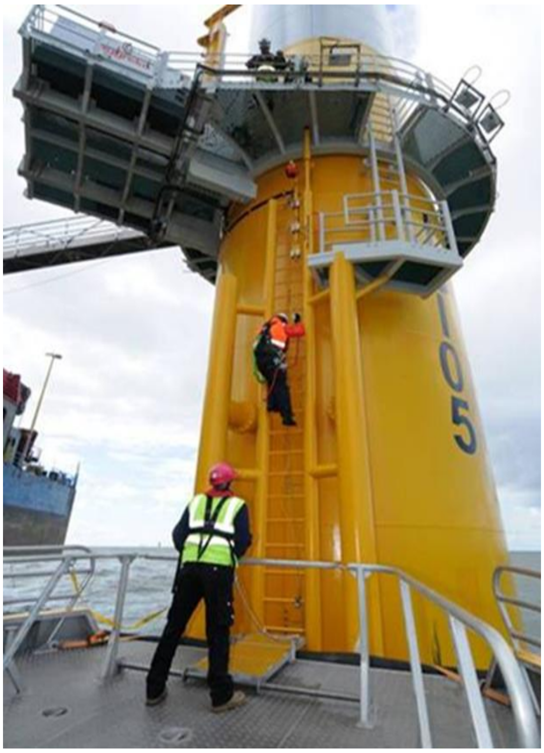
5.191. The mothership concept would operate from a larger port facility with personnel working a shift rota pattern. The mothership would be around 65m to 95m long and would accommodate the maintenance personnel, provide an on-board control room facility and provide the main stores location for the OWF sites. It would also be fitted out with a number of work boats and associated launch and recovery system, which would be the primary means of personnel transfer, supplemented by helicopter support when necessary. The mothership would be resupplied when alongside for crew changes.

Personnel and Access to WTGs

5.192. For maintenance purposes the WTGs are likely to be accessed primarily by work boats with helicopters providing a secondary means of access. The WTG substructure is likely to be equipped with one or more boat landings and ladders, dependant on a number of factors such as prevailing wave and tide conditions, acceptable foundation loadings and the potential use of helicopters as a secondary access method.

5.193. Plate 5.22 shows a workboat WTG landing operation at a monopile WTG tower design. This principle of access applies to all the WTG foundation options being considered by Seagreen.

Plate 5.22 A workboat landing operation at Greater Gabbard OWF



Source: Greater Gabbard OWF

Vessel and Helicopter Movements

5.194. For the daily transfer of personnel and materials from the onshore O&M base(s) to the OWF sites and back by work boat, a maximum potential of 1,760 vessel movements may be required per annum. This assumes vessels of the order of 24m for up to 30 personnel are used and assumes that a total of eight vessels are required to service each OWF site, based on accessibility of approximately 220 days per annum.

5.195. If a mothership is deployed, it is assumed that the vessel would undertake a crew change and resupply every two weeks.

5.196. If identified as appropriate for the project to supplement the workboat and mothership solution, helicopters may be used to transfer personnel and materials from the helipad at the O&M base or nearby airport. Based on current market data there is a conservative estimate that the WTGs will require an average of six visits per annum, it is assumed two of these visits will be by helicopter, however, this will need to be verified through modelling once the offshore layout is finalised.

5.197. A jack-up or crane barge will be required on an ad-hoc basis for potential maintenance of major components, such as replacement of a blade, gearbox or generator.

O&M Activities

5.198. O&M of the OWFs after commissioning will comprise of both scheduled and unscheduled events. Scheduled works on the WTGs and offshore electrical infrastructure will include annual or bi-annual maintenance, statutory inspection and routine inspection visits. When necessary, retrofitting and upgrading works may also take place. The scheduled works will normally be timetabled for the summer months, given the typically more settled weather and longer day light hours. Twenty-four hour working will also be evaluated, as this type of solution could be delivered from a mothership stationed offshore.

5.199. The number of required technicians is expected to be between 95 and 140, dependant on the WTGs selected. Exact maintenance requirements for larger capacity WTGs are not known at this stage. There will also be a core operations team of approximately 40 staff based at the onshore O&M Control Centre to manage and support all aspects of OWF operation.

5.200. The current technology of WTGs will require a major service every 12 months; they will also require periodic visits in the event the WTG experiences a fault which cannot be remotely reset. In addition some models of WTGs will require gearbox oil changes every five years. In certain circumstances large components such as gearboxes and blades may also need to be replaced. In this case a large crane vessel or jack-up, similar to that used for WTGs installation, will be used to carry out the necessary works.

5.201. Unscheduled repair activities will range from, attendance on location to deal with the resetting of false alarms, to major repairs. The frequency of unscheduled activities is expected to be highest in the early years of operation, when WTGs are first commissioned and require servicing.

5.202. At least two service personnel will be on an offshore structure during any visit for safety reasons. In order to achieve the maintenance programme, it is anticipated that O&M teams will be working simultaneously on several WTGs (and potentially also on the OSPs). It is therefore expected, that when access is being achieved by boat for O&M works, at least two vessels will be on-station within the OWF site at all times for safety reasons.

5.203. The Project Alpha and Project Bravo operators will have an O&M team in place for the day to day management and control of the OWF infrastructure. This is expected to be based in purpose built onshore O&M Control Centre facilities, ideally situated on the quayside at the chosen operations port location. If there is no local airport or heli-port available, this facility could also accommodate the helicopter hangar and heli-pad, if required.

5.204. In order to manage the post consent and ongoing site monitoring requirements it is likely that a combination of dive support vessels and ROVs will be used to undertake inspection of foundations, scour protection, cables and any other subsea infrastructure.

5.205. Transport of the WTG major components for replacement will normally take place by sea. It is expected that these will be shipped from the manufacturing base and loaded onto the vessel from larger ports for transport directly to the OWF sites. There will therefore be a need to use large vessel mounted cranes in order to replace defective components such as generators, gearboxes and blades. Detailed planning of the work and travelling time will be undertaken to keep transit as short as possible and maximise available durations for lifting operations and installation activities.

Pollution Prevention and Waste Management

5.206. Pollution prevention across the Projects would be controlled and mitigated from the design stage onwards. For example, the WTG nacelle frame typically will be designed and manufactured with a bund incorporated which can hold the full oil content of the gearbox (if required) in the event of a catastrophic failure. Additionally, if any oil filled transformers are used, the area will be bunded to contain any oil leaks.

5.207. The WTG maintenance personnel and any maintenance support vessel crew would be trained and equipped to use spill kits in the event of a break in containment occurring. This will be closely supported by a safe system of work which will be governed by a full risk assessment and method statement process. In the event of the safe system of work failing, or a catastrophic incident occurring, it is assumed that a spill response contract will be in place to control, manage, recover and dispose of any contaminants and dropped objects.

Waste Management

Construction

5.208. Most waste generated as a result of the Project would be during the installation of the offshore elements. An Environmental Management Plan (EMP) will be prepared prior to construction, as a consent condition requirement, and this will include waste management procedures for all relevant offshore activities. In accordance with regulation 10 of Annex V of MARPOL 73/78. Waste management procedures will:

- Describe and quantify each likely waste type and record how it will be disposed of, reused, recycled or recovered in other ways during the construction stage of project;
- Describe management arrangements for the different waste types and identify potential management facilities in the vicinity of the development. The available capacity of waste management facilities will be taken into account where applicable;
- Provide procedures for handling waste material. These will be managed to ensure they are strictly adhered to by site staff, contractors and visitors to the OWF sites and onshore O&M Control Centre(s); and
- Provide estimates for waste types arising from the construction of the offshore components.

Operation and Maintenance

5.209. The construction EMP, including waste management procedures will be updated for the O&M Phase of the Project.

5.210. During operations, each WTG will undergo a routine service every year. As part of this process, hydraulic fluids, gearbox oils and lubricants will be replaced and solid consumables such as filters will require disposal. If any components need replacing due to general wear and tear (these are likely to be WTGs and electrical parts at offshore substations), they will be removed and processed by licensed contractors.

5.211. Oils in the wind turbines would be biodegradable where possible. All wind turbines would have provision to retain all spilled fluids within the nacelle or tower. The volume of oil and fluids would vary depending on WTG design.

5.212. Any waste generated as a result of O&M activities will be managed in accordance with the waste management procedures and would be transported by a registered waste carrier to an appropriately licensed waste management facility for recycling or disposal onshore. All records of waste transfer notes will be kept. Only materials that cannot be recycled will be sent to landfill.

Weather and Sea Conditions Monitoring

5.213. Data from the on-site weather and sea conditions monitoring equipment will be used to support operations throughout the life of the OWFs. Aside from the normal requirement for wind and wave measurement devices, consideration will also be given to measuring tidal flow and direction and water temperature.

Port Facilities

5.214. This information is provided for information only as the consideration of O&M port facilities is out with the scope of this EIA (see Chapter 7 (Scope of EIA Report).

5.215. For the Seagreen Project a number of ports could offer all the necessary services to locate the onshore O&M Control Centre(s). A port study will be commissioned in 2018 to assist with determining the optimal location for the onshore O&M Control Centre(s) with the key factors in the choice being:

- Close location to the OWF sites, thus minimising the time spent travelling to and from the OWF sites;
- Protected harbour;
- Good tidal access and depth of mooring;
- Suitable and sufficient berthing for the service vessels; and
- Knowledgeable workforce, experienced in offshore activities.

5.216. A further requirement would be the availability of sufficient space for construction of a building to house a control room and office space along with stores, a workshop, and wet/dry room facilities. The selected onshore O&M Control Centre(s) location will also enable good infrastructure links, such as communication networks and transport links.

REPOWERING

5.217. The term of the site lease with The Crown Estate will be 50 years. The operational lifetime of Project Alpha and Project Bravo is expected to be 25 years. At the end of this period the OWF could be life-extended, repowered or decommissioned. If the OWF is repowered during the period of the site lease, this would be subject to a separate consent process.

DECOMMISSIONING

Background

5.218. The requirement to decommission is a condition of The Crown Estate lease and is also required through the provisions of Section 62 of the Scotland Act 2016. The Project operator(s) will be required to prepare detailed, costed decommissioning plans for approval by Scottish Ministers and to set aside funds for the purposes of decommissioning.

5.219. The decommissioning plan will consider the latest technological developments, legislation and environmental requirements at the time that the work is due to be carried out. For the purposes of the current consenting framework and as a basis for this EIA Report, a high level decommissioning programme based on the current technological and regulatory framework is outlined below.

Decommissioning of WTGs

5.220. The removal of the superstructure is expected to be the reverse of the installation procedure:

- Conduct assessment on potential hazards during the decommissioning work and pollutants to the environment that may result from the decommissioning work;
- Mobilise suitable vessels to the OWF sites;
- Remove any potentially polluting or hazardous fluids/materials from the WTGs (if identified in the risk assessment);
- Remove rotor blades;
- Remove nacelle;
- Remove tower sections; and
- Transport all components to an onshore site, where they will be processed for reuse/recycling/disposal.

Decommissioning of Substructures and Foundations

5.221. Removal of GBS foundations will require removal of the ballast and the GBS refloated. It will then be towed to an approved destination for re-use, recycling or disposal as appropriate.

5.222. Suction pile foundations may be lifted and removed using a HLV, reversing installation, or they may be cut below seabed level.

5.223. It may be preferable to leave any scour protection around the substructures bases or covering cables in-situ, in order to preserve the marine habitat that has been established over the life of the OWF (subject to discussions with regulators and advisors at that time).

5.224. It is currently envisaged that pin piled foundations will be cut below seabed level (using methods such as abrasive water jet cutter or diamond wire cutting) with the protruding section being removed. Complete removal of driven pin piles is not expected to be practical or desirable. The use of explosives in removing the piles is discounted due to the likely damage to the environment.

5.225. For decommissioning of monopile foundations, it is anticipated that, following WTG decommissioning and removal, the transition piece will be cut just above the grouted connection and removed by crane. The monopile will then be cut below the seabed level, to a depth that will ensure the remaining foundation is unlikely to become exposed. This is likely to be approximately one metre below seabed, although the exact depth will depend upon the sea-bed conditions and site characteristics at the time of decommissioning. The cutting process is likely to be via a mechanical or water jet cutter. Alternatively, if the soil conditions allow for it, the monopiles can be reverse vibrated out of the ground.

5.226. The sequence for removal of the monopile foundations and transition pieces is anticipated to be:

- Mobilise suitable vessel (likely to be a jack-up vessel or heavy-lift vessel);
- Cut the transition piece just above the grouted connection or unbolt the flange with the monopile and remove by crane;
- Deploy ROVs or divers to inspect the foundation and reinstate lifting attachment if required;
- Excavate outside and inside of monopile to approximately 0.5m below anticipated level of cutting (this will include removing any scour protection or debris around the base of the foundation);
- Cut the monopile using either a water jet cutter or a mechanical cutter approximately 1m below seabed level;
- Lift foundation onto transport vessel or the decommissioning vessel and transport to shore; and
- Parts will be processed for reuse, recycle or disposal.

5.227. Alternatively:

- Mobilise suitable vessel (likely to be a jack-up vessel or heavy-lift vessel);
- Cut the transition piece just above the grouted connection with the monopile and remove by crane;
- Instate lifting attachment and vibrator;
- Start vibration and lift the monopile out of the ground;
- Lift foundation onto transport vessel or the decommissioning vessel and transport to shore; and
- Parts will be reused, recycled or disposed.

Decommissioning of Offshore Cabling including Export Cabling

5.228. Discussions will be held with stakeholders and regulators to determine the exact locations where offshore cables should be removed. Cables may be left in situ if considered appropriate, or they may be wholly or partially removed. Throughout the project life-cycle, the burial depth will be closely monitored. A typical cable removal programme will include the following:

- Identify the location where cable removal is required;
- Removal of cables: Feasible methods include pulling the cable out of the seabed using a grapnel, pulling an under-runner using a steel cable to push the electrical cable from the seabed, or jetting the seabed material; and
- Transport cables to an onshore site where they will be processed for reuse/recycling/disposal.

SUMMARY OF OPTIMISED SEAGREEN PROJECT DESIGN

5.229. The Seagreen Project is comprised of two separate OWFs, Project Alpha and Project Bravo and the licenced Transmission Asset Project. The OWF projects may be built out independently, or in combination (the optimised Seagreen Project).

5.230. The proposed optimised design parameters for Project Alpha and Project Bravo are summarised in Table 5.13. Design parameters are provided for Project Alpha, Project Bravo and where relevant, for the wind farms combined (the optimised Seagreen Project). Those design parameters which have been optimised since the original consents are highlighted for ease of reference.

Table 5.13 Summary Optimised Design Parameters for Project Alpha and Project Bravo

Design Parameter	Optimised Design Envelope		
	Project Alpha	Project Bravo	Combined
Area (km^2)	197	194	391
Distance from shore (closest point) (km)	27	38	27
WTG			
Maximum number of Wind Turbine Generators (WTGs)	70	70	120
Maximum rotor diameter	220	220	220
Maximum hub height above lowest Astronomical Tide (LAT) (m)	170	170	170
Maximum blade tip height above LAT (m)	280	280	280
Minimum blade tip clearance above LAT (m)	32.5	32.5	32.5
Maximum blade chord (m)	7.5	7.5	7.5
Nacelle Dimensions (estimated Length x Breadth x Height) (m)	25 x 10 x 12	25 x 10 x 12	25 x 10 x 12
Operating wind speed range (cut-in/cut-out) (m/s)	Cut in 4 Cut out 32	Cut in 4 Cut out 32	Cut in 4 Cut out 32

Design Parameter	Optimised Design Envelope		
	Project Alpha	**Project Bravo**	**Combined**
Operating speed range (revolutions per minute [rpm])	4 to 14	4 to 14	4 to 14
Maximum rotor swept area (per WTG)	38,014	38,014	38,014
Minimum separation distance between turbines (m)	1000	1000	1000
Colour of WTG	Pale matt grey/off-white colour and will include aviation lighting		
Foundations			
Gravity Base Structures (GBS)			
Max no. of GBS locations	70	70	120
Max octagonal base plate width (m)	72	72	72
Max cone diameter at base (m)	50	50	50
Depth of ground preparation (m)	3	3	3
Estimated excavation volume per foundation (m^3)	16,000	16,000	16,000
Max height (m)	78	78	78
Max ballast volume per foundation (m^3)	37,500	37,500	37,500
Pin Piled Jacket Foundations			
Max no. of pin piled jacket foundations	70	70	120
Max no. of pin piles per jacket (4 legged)	4	4	4
Max pile diameter (m)	2	2	2
Max pile length (m)	60	60	60
Max penetration depth (m)	55	55	55
Max width of jacket substructure at the water surface (m)	30	30	30
Max hammer energy (kJ)	1800	1800	1800
Max minutes of piling per pin pile (min)	135	135	135
Max No. of pin piles installed in 24 hours	4	4	4
Assumed max no. of piling days (slow rate)	140	140	240
Number of simultaneous piling events	May be simultaneous pin piling at Alpha and Bravo, or simultaneous monopile and pin piling at Alpha and Bravo		
Suction Caisson Jacket Foundations			
Max no. of suction caisson jacket foundations	70	70	120
Max no. of suction caissons per jacket	3	3	3
Max caisson diameter (m)	14	14	14
Max caisson penetration depth (m)	23	23	-
Width of Jacket substructure at water surface	30	30	-

Design Parameter	Optimised Design Envelope		
	Project Alpha	Project Bravo	Combined
Monopile Foundations			
Max no. monopile foundations (in water depths up to 50 m)	70	35	70
Max pile diameter (m)	10	10	10
Max pile length (m)	95	95	95
Max penetration depth (m)	45	45	45
Max column diameter at waterline (m)	10	10	10
Max hammer energy (kJ)	3000	3000	3000
Max hours of piling per monopile	4	4	4
No. of monopiles installed in 24 hours	1	1	1
Max no. of piling days	70	35	70
Number of simultaneous piling events	No simultaneous piling of monopiles but potential simultaneous piling of 1 monopile and 1 jacket pin pile at Alpha and Bravo.		
Array Cables			
Anticipated maximum array cable length (km)	325	325	650
Estimated total trenched (plough or jet) cable length (km)	292.5	292.5	585
Cable route clearance (km)	97.5	97.5	195
Estimated total rock or mattress protected length (km)	32.5	32.5	65
If trenched, estimated max trench width (m)	3	3	3
If trenched, cable burial depth (m)	0.5 to 2.1	0.5 to 2.1	0.5 to 2.1
If trenched, width of temporary Zone of Influence (m)	10	10	10
If rock or mattress protected, max width (m)	7	7	7
Array cable voltage (kV)	33 to 66	33 to 66	33 to 66
O&M Range			
Number of service vessels required	6 to 8	6 to 8	12 to 16
Length of service vessels (m)	18 to 28	18 to 28	18 to 28
Number of vessel movements* per annum	1320 to 1760	1320 to 1760	2640 to 3520
Size of support vessel (m) (2x daughter craft)	70 to 90	70 to 90	70 to 90
Other			
Scour protection	Maximum volume of scour protection for the optimised project for GBS foundation option is 900,000m^3 (less than GBS WCS scenario assessed in the 2012 Offshore ES : 1,734,000m^3)		
Wave buoys	Up to six		

* One vessel movement is equal to one to- and from- OWF site trip.

5.231. As set out in Table 5.13 the Seagreen project has been optimised since the award of the original consents in 2014. The key design parameters that have been changed include:

- The maximum combined number of WTGs has reduced from 150 to 120;
- The 2014 consented rotor diameter was 167m and the proposed rotor diameter for the optimised Seagreen Project is up to 220m;
- The 2014 consented blade tip height was 209.7m and the proposed blade tip height for the optimised Seagreen Project is up to 280m;
- The 2014 consented minimum blade tip clearance was 29.8m and the proposed blade tip clearance for the optimised Seagreen Project is 32.5m; and
- The 2014 foundation options have been expanded to include the introduction of a monopile foundation option at up to 70 locations.

5.232. The above design parameters and information forms the basis of the assessment undertaken within this EIA Report.

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