FOREWIND

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Offshore Project Boundary Selection Report

Dogger Bank Creyke Beck A & B
Dogger Bank Teesside A & B

Offshore Project Boundary Selection Report

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Overview:

This report justifies the selection of the first four of Forewind's offshore project boundaries to be developed in the Round 3 Dogger Bank Zone. The relevant environmental, engineering, commercial and consenting considerations that Forewind has taken into account in the selection of these project boundaries are explained

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1.1 Background

1.1.1 Forewind and the Dogger Bank Zone

1.1 In 2008, The Crown Estate (TCE) announced proposals for the third round (Round 3) of offshore wind farm leasing. Under the Round 3 process, TCE identified nine large areas of seabed around the UK which were considered the most suitable areas for development of wind farms (www.thecrownestate.co.uk/r3-site-selection). A competitive tender process was run which awarded these Round 3 zones to different wind farm developers.

1.2 Forewind is a consortium comprised of four leading international energy companies; RWE, SSE, Statoil and Statkraft. Forewind was awarded the development rights for the Dogger Bank Round 3 Zone in January 2010. This Zone comprises an area of 8660km^2 located in the North Sea between 125km and 290km off the coast of Yorkshire.

1.3 The delivery strategy of Forewind has been structured around the delivery of 9GW of offshore wind farm projects in the Dogger Bank Zone by 2023. At the time of award of the site by The Crown Estate in 2010, it was believed that a capacity of 13GW might be achievable if the Zone was found to be completely developable and with limited constraints. As this report goes on to discuss, a target capacity of 9.6 GW is now considered more likely in the light of information gathered over the course of the last two years. The 9.6 GW capacity will be achieved by a series of individual wind farm projects being developed in phases. These projects will be constructed by different parties over a phased period that is anticipated to commence in 2015.

1.4 The following project boundary selection process has utilised both desk-based and site specific survey data gathered both for environmental and engineering purposes. The environmental data have had the biggest effect on defining the overall developable area across the Dogger Bank Zone. The engineering and economic criteria have had a greater influence in defining the project boundaries within the identified developable area.

1.1.2 Zone Appraisal and Planning (ZAP)

1.5 The Zone is large enough to accommodate multiple wind farm projects and offers flexibility in space to select the most appropriate areas within the Zone to site these wind farms. A full detailed survey of the whole Zone has not been possible, although sufficient information has been obtained to provide the understanding of constraints necessary for project location decisions to be made. A phased approach has been taken to the development of the Zone. This allows Forewind to identify a number of technical, economic and environmental considerations to inform the identification of sites for offshore wind farm development. This commenced with individual Tranches being identified for survey purposes. The original intention was to identify four tranches within the Zone (A, B, C and D) with the capability of siting up to three wind farm projects in each. This process was part of the Forewind Zone Appraisal and Planning process (ZAP).

1.6 Forewind identified Tranche A in 2010 (Tranche A selection report, Forewind, October 2010[1]) and Tranche B in 2011 (Tranche B selection report, Forewind, May 2011[2]). These were the first and second areas respectively within the Dogger Bank Zone to be selected for offshore wind farm project development (Figure 1)

- **Tranche A** is approximately 2000km^2 in area, located in the South-West of the Zone, with the majority of water depths being less than 30m LAT (Lowest Astronomical tide).
- **Tranche B** has a total area of 1500km^2 and is located in the South-East of the Zone, with the majority of water depths being less than 35m LAT.

1.7 Selection of Tranche A and Tranche B was informed by information which was collated during ZAP and presented in the Zone Characterisation Document (ZoC, December 2011[3]). This identifies a number of activities and environmental considerations across the Dogger Bank Zone. The ZoC (now in its second edition) primarily provides a baseline understanding of the environment across the Zone. The information is continuously evolving and a further edition of the ZoC will be produced as Tranches C & D are identified. The ZoC is supplemented by the production of reports such as this which outline further steps in wind farm spatial planning across the Zone undertaken by Forewind.

[1] http://www.forewind.co.uk/uploads/files/tranche_a_selection_report.pdf

[2] http://www.forewind.co.uk/uploads/files/Tranche%20B%20Selection%20Report.pdf

[3] http://www.forewind.co.uk/uploads/files/Zonal%20characterisation%20document%20 (second%20version).pdf.

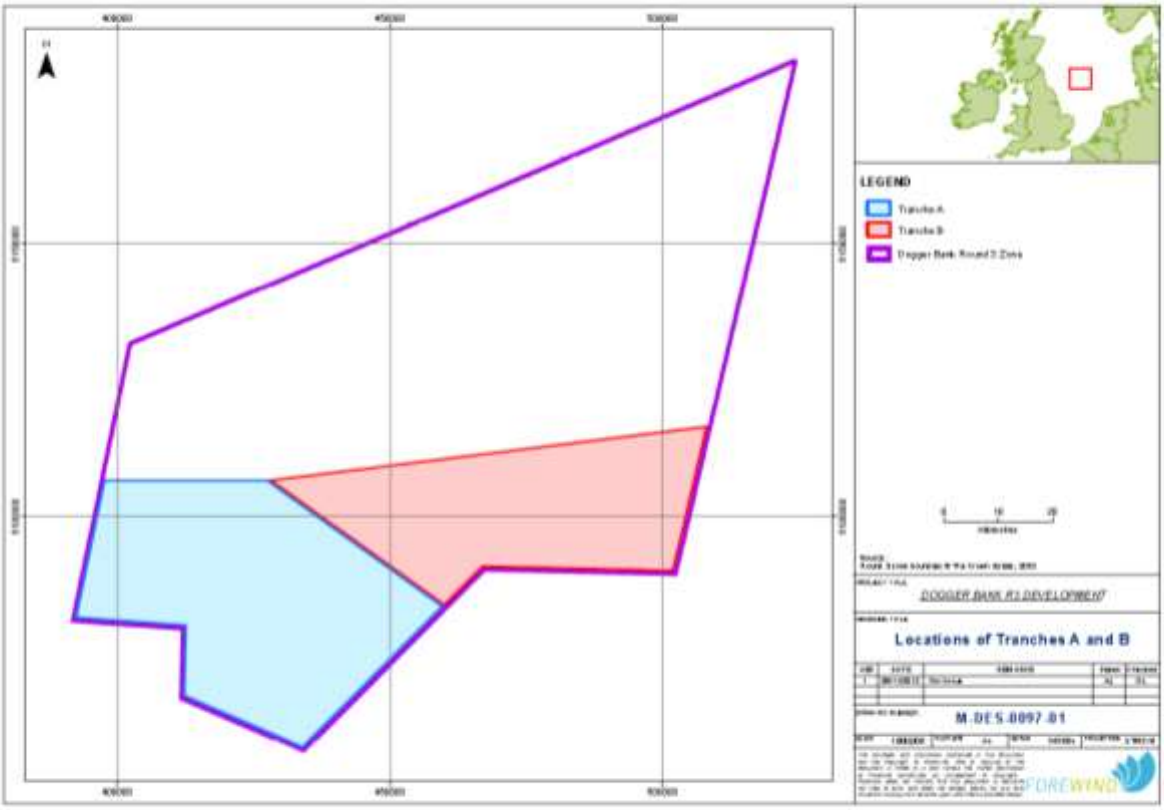

Figure 1 Dogger Bank Tranches

1.8 As part of the Zone Appraisal and Planning (ZAP) process a heat map was produced to provide a view of all known consenting considerations see Figure 2. This combined information from existing desk based assessment work, inputs from a series of stakeholder workshops held in 2010 and early zone wide data collected by Forewind. Simultaneously the Forewind engineering work stream produced a heat map evaluating the variation in cost of energy across the Zone, taking into consideration the cost of foundations, cost of export cables, strategic and health and safety implications as well as predicted variation in wind resource. The engineering heat map is presented in Figure 3. Both heat maps were based upon the best available information at the time.

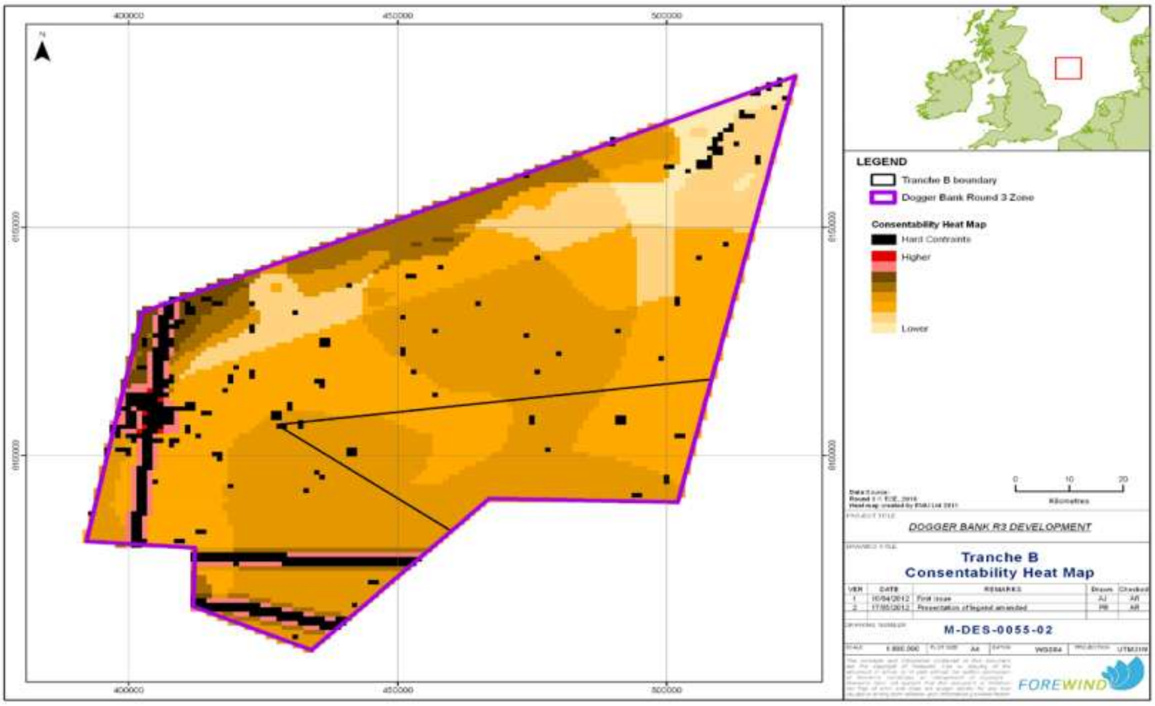

Figure 2 Consenting heat map showing Tranche B (May 2011)

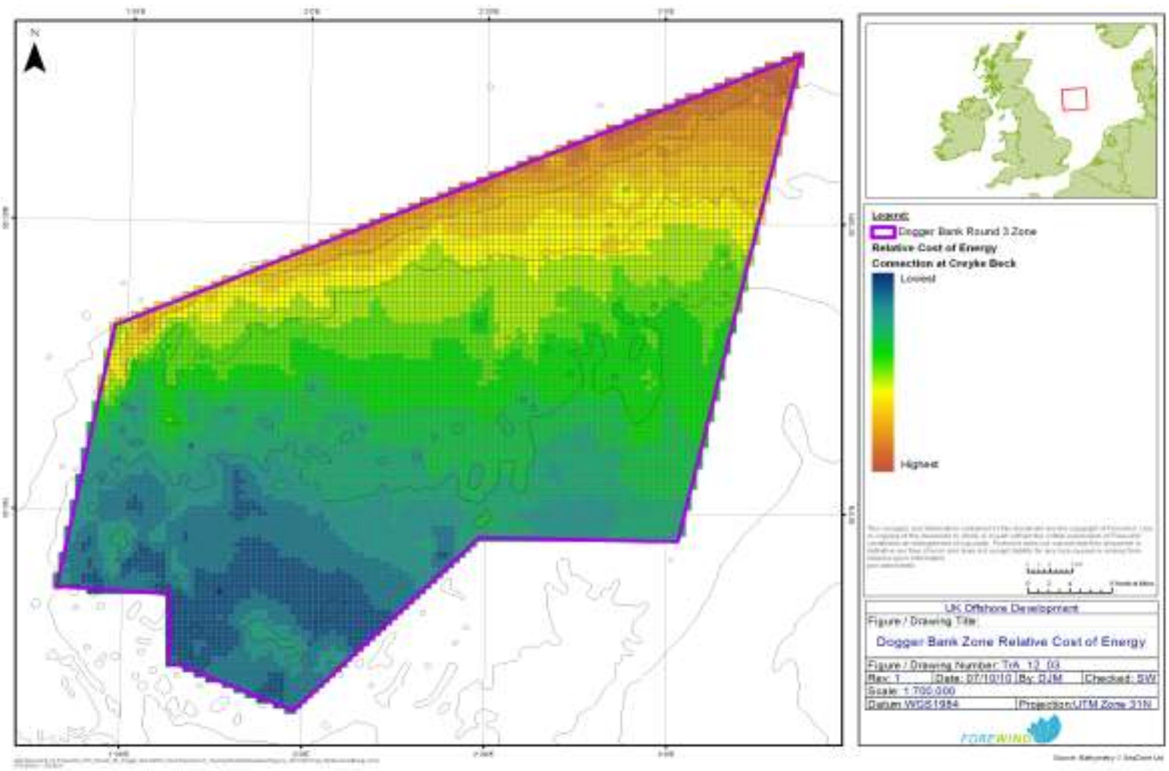

Figure 3 Dogger Bank Engineering Assessment Heat Map

1.1.3 Zonal development to date

1.9 This zone appraisal and planning approach has subsequently led to the identification of the following components associated with projects to be located in Tranches A and B.

Dogger Bank Creyke Beck Projects

1.10 Forewind has secured agreement with National Grid for 2GW of grid connection capacity at the Creyke Beck substation in the East Riding of Yorkshire, in the form of two 1GW connections. This onshore grid connection capacity of 2GW will be sufficient for two projects in the Dogger Bank Zone.

1.11 Following an initial Scoping exercise, Forewind identified a 2km wide offshore cable corridor from the southern section of Tranche A to a chosen landfall on the Holderness Coast. This cable corridor will connect the offshore components of the wind farm to the shore. A 32km long, 1km wide onshore cable corridor has also been identified to connect the landfall area to the National Grid substation. A study area for the onshore direct current to alternating current convertor stations has also been identified.

1.12 The rationale for selection of the above components is presented in the Dogger Bank Creyke Beck Preliminary Environmental Information 1 (PEI1) documents (Forewind, November 2011[4]) and will be updated in the draft Environmental Statement which Forewind will consult on in 2013.

Dogger Bank Teesside projects

1.13 Forewind has secured agreement with National Grid for grid connection capacity of 4GW at Teesside. This is enough for four projects in the Dogger Bank Zone to be connected to the national grid, although as this report goes on to describe only two of these connection will be accommodated within Tranche A and B and the other two will be located in the Zone area to the north of Tranche A and B.

1.14 Forewind sought to identify areas of the Teesside coastline between the Tees Estuary and Saltburn-by-the-Sea which could accommodate landfall for up to four export cable systems (up to 8 individual cables). The landfall has been identified between Redcar and Marske-by-the-Sea.

1.15 Forewind has undertaken an exercise to identify potential converter station sites within the industrial area to the south of the Tees Estuary at Teesside. A long list of sites that fitted Forewind's initial design criteria has subsequently been refined to a shortlist of six potential sites. Owing to the uncertainty of the precise landfall and the

[4] http://www.forewind.co.uk/uploads/files/20111122_CreykeBeck_PEI_20120.pdf

precise converter station sites, defining onshore cable corridors is still work in progress.

1.16 The rationale for selection of the above components was set out in the Dogger Bank Teesside Preliminary Environmental Information 1 (PEI1) documents (Forewind, May 2012[5]).

1.17 The PEI1 documents mentioned above for the identified components of the Dogger Bank Creyke Beck and Dogger Bank Teesside projects can be found at www.forewind.co.uk.

1.2 Aims of this report

1.18 Offshore wind projects within the Dogger Bank Zone are classified as Nationally Significant Infrastructure projects (NSIPs) under the Planning Act 2008 as amended (the Planning Act).

1.19 This consent regime for NSIPs strongly encourages applicants to clearly explain all elements of the design of projects in the consent application. It also introduces a front loaded process where all consultation and important design decisions must be undertaken early in the development phase, before the application is submitted.

1.20 Identification of project boundaries is an important element of the site selection and design of the offshore wind farms. The individual project boundaries define the limits of where the offshore infrastructure (excluding export cables to shore) can be placed as well as any space between projects. These boundaries allow the full impact of the projects to be assessed in the Environmental Impact Assessments.

1.21 This report describes the selection of Forewind's **offshore** project boundaries of the first four offshore wind farm projects to be developed in the Round 3 Dogger Bank Zone, located within Tranches A and B (Figure 1). Cable Corridor selection processes are the subject of separate reports. The relevant environmental, engineering, commercial and consenting considerations that Forewind has taken into account in the selection of these project boundaries are explained.

1.22 A phased approach to the development of the first project boundaries has been necessary to ensure a robust process and selection due to the extent and complexity of the relevant considerations. Relevant engineering and consenting constraints were considered. The potential boundaries of future projects in the Zone as well as the first four projects were also considered in the context of economic viability of the whole Zone and for individual projects, however further future boundaries are not included in this report and will be presented following further Zone Appraisal work.

5 http://www.forewind.co.uk/uploads/files/Teesside/Teesside%20PEI1%20Non%20Technical%20Summary%20Lo%20Res.pdf

1.23 The area within each of the four project boundaries is considered necessary to accommodate the maximum number of wind turbines, collector and converter stations, inter array cables, meteorological masts and offshore operation hubs for each project, allowing for the necessary level of flexibility in the project design. The final project design will be determined after consent is granted as part of the final design process. The precise, final design of the offshore projects is therefore out of the scope of this report.

2 Key considerations for project identification

2.1 Introduction

2.1 Identification of the project boundaries for individual wind farms within the Zone is complicated by the lack of certainty on the precise technology and engineering solutions likely to be available at the time of construction. In addition the Zone is much further offshore and in deeper waters than the previous Round 1 and 2 wind farms. Together this results in higher development, construction and operational costs which present new challenges to meeting cost reduction targets and keeping the cost of energy low.

2.2 Low cost of energy is essential in order to ensure continued expansion and development in supply chains, encourage on going investment in the industry and to reduce costs to the consumer. The Dogger Bank Zone and the size and capacity of projects are much increased in scale compared to previous Round 2 offshore wind farm developments.

2.3 The economics and potential environmental effects of the whole Dogger Bank Zone development need to be considered when defining the boundaries of the individual projects. Therefore, that the impacts of the first projects to be developed will be considered in combination with impacts of projects developed later and vice versa.

2.4 This section explores the key engineering, commercial, health and safety and environmental considerations that the ZAP process has identified to date as having the potential to influence boundaries of projects located in Tranche A and B.

2.2 Engineering and Economic Considerations

2.2.1 Project Capacities and Overplanting

2.5 Each of the Dogger Bank projects has a secured grid connection capacity of 1GW each. However, the offshore generation capacity of each project may be up to 1.2GW. This allows the projects to be optimised for maximum efficiency taking into account electrical losses, turbine availability, and the natural variability of a wind farm’s output. This can be described as ‘overplanting’ (adding additional turbines to offset losses). The turbines will be curtailed such that the connection point in National Grid’s onshore substation does not receive more than 1GW at any point in time.

2.6 A more detailed explanation of overplanting and the identification of Zone capacity may be found in Section 3.

2.7 The maximum installed capacity offshore is therefore fixed, but the capacities, dimensions, and detailed design of many of the electrical components of the projects may vary. For this reason, Forewind has adopted the Rochdale envelope approach to describing the range of possible components and construction scenarios.

2.8 Given the considerable distance involved, the electricity generated will be transmitted to shore using High Voltage Direct Current (HVDC) technology. Over long distances this technology provides significant technical advantages over High Voltage Alternating Current (HVAC) technology, including lower power losses. HVDC technology also provides a number of environmental benefits in comparison to HVAC technology. HVDC transmission systems require smaller transmission cabling than equivalent HVAC transmission systems, reducing the impact on the site. This results in less overall copper required for the cabling system than HVAC technology, lowering both cost and environmental impact. HVDC technology requires a converter substation at each end of the export cable, to convert the power between AC and DC. Therefore, each project will include one offshore converter platform and one onshore converter substation

2.2.2 Offshore Project Description

2.9 The project boundaries identified for individual projects will need to accommodate a number of different offshore components that comprise the offshore wind farm. Each project will comprise the elements described below:

- Up to 300 wind turbine generators and their supporting tower structures per project. The wind turbine generators convert the kinetic energy in the wind into electrical energy. Each wind turbine will be mounted on a foundation to secure the structure vertically whilst withstanding loads from the wind and the marine environment.
- Up to four offshore collector stations and their associated foundations per project. The offshore collector stations receive power from the wind turbines and step up voltage for export to a HVDC converter station.
- A single offshore converter station per project and its associated foundations. The offshore convertor station converts alternating current (AC) to direct current (DC).
- Subsea inter-array cables will be installed within each project boundary. The subsea inter-array cabling transmits power between the wind turbines and the offshore collector platforms.
- Inter-platform cables will be installed within each project boundary. The inter-platform cabling transmits power between offshore collector stations and between offshore collector stations and the offshore converter station.
- Offshore export cable systems, carrying power from the offshore HVDC converter substation platform out of the project boundary to the landfall and possibly to other wind farm projects or offshore connection nodes.
- Up to five meteorological masts (met masts) may be installed within each project boundary. The data collected by these masts will be used to monitor the power

performances of projects. It should be noted that these project masts are in addition to two meteorological masts which are due to be installed in late 2012 within the Dogger Bank Zone. These will provide essential meteorological and oceanographic data, which will be utilised to optimise the design of the wind farms prior to installation.

- Up to ten pre-installed permanent vessel mooring buoys will be installed within each project boundary at intervals around the project area. The mooring buoys will allow vessels to moor at the project for a variety of reasons including at night, during lulls in work, to save fuel while station keeping, or in the event of machinery failures.
- If required, scour protection will be installed around the offshore structures. Scour protection can be achieved by a number of different methods, either individually or in combination, including but not limited to: rock placement, frond mats or concrete mattresses.
- Cable protection measures where necessary. Cable protection may be achieved by a number of different methods, either individually or in combination, including but not limited to: rock or gravel burial, bagged solutions, protective aprons, frond mats or concrete mattresses; and
- Up to two offshore accommodation or helicopter platforms and their associated foundations may be installed within each project. These will help facilitate operation and maintenance activities for the projects.

2.10 An indication of the numbers of the above components that are expected to be sited within individual project boundaries is given in Table 1.

Parameter	Quantity
Wind turbine generators and foundations	Up to 300
Collector substations	1 to 4
Converter substations	1
Meteorological masts	Up to 5
Mooring buoys	Up to 10
Accommodation/helicopter platforms	Up to 2

Table 1 Key Wind Farm Elements

2.11 The final offshore project design including the layout of the turbines, and other wind farm components, will depend on a number of factors including: stakeholder feedback, seabed obstructions, ground conditions, water depth, wind dynamics, economic factors, and the chosen wind turbine generator.

2.2.3 Wind Turbine Technology

2.12 The offshore wind industry is still in a developmental phase with new technologies and techniques continually emerging. Due to this rapid development it is necessary to maintain flexibility in the consent applications for the Dogger Bank projects. This will allow the final design, construction methodology, and operations and maintenance requirements to be optimised for the technologies available in the future.

2.13 In identifying project boundaries a key consideration is turbine dimensions. These dimensions have an impact of the spacing between turbines and consequently on the area required for a project. Offshore wind turbine technology is evolving rapidly and it is anticipated, in the time scales of the Dogger Bank projects, that turbines in the range of 4MW to 10MW will be available. Table 2 shows indicative dimensions and quantities of the turbines that may be built within a Dogger Bank project.

Turbine Parameter	Up to 4MW	6MW	10MW or greater
Maximum project total generating capacity (MW)	1200		
Max number of wind turbine generators per project	300	200	120
Max hub height (m) above highest astronomical tide (HAT)	115	130.5	154.5
Max upper blade tip (m) above HAT	183	214	262
Max rotor diameter (m)	136	167	215

Table 2 Indicative Turbine Dimensions

2.14 The spacing of turbines within wind farms is typically measured in number of rotor diameters.

2.15 Spacing must be carefully considered to avoid later developed projects being affected by 'wake effects' from earlier developed projects and vice versa. As well as understanding wind resource losses associated with large arrays, the cumulative effects of clustering wind farm projects close together in the Dogger Bank Zone needs to be considered.

2.2.4 Location of the Export Cables

2.16 An offshore cable corridor, 2km wide has been identified for the Dogger Bank Creyke Beck projects. This includes two exit points, from the southwest corner of Tranche A.

The southernmost exit point exceeds 2km width to form a cone shape at the edge Tranche A. This has been done to allow flexibility of cabling in the absence of known locations of the Dogger Bank Creyke Beck wind turbines. These exit points were considered in the selection of the project boundaries. The exit points are shown in Figure 4 below.

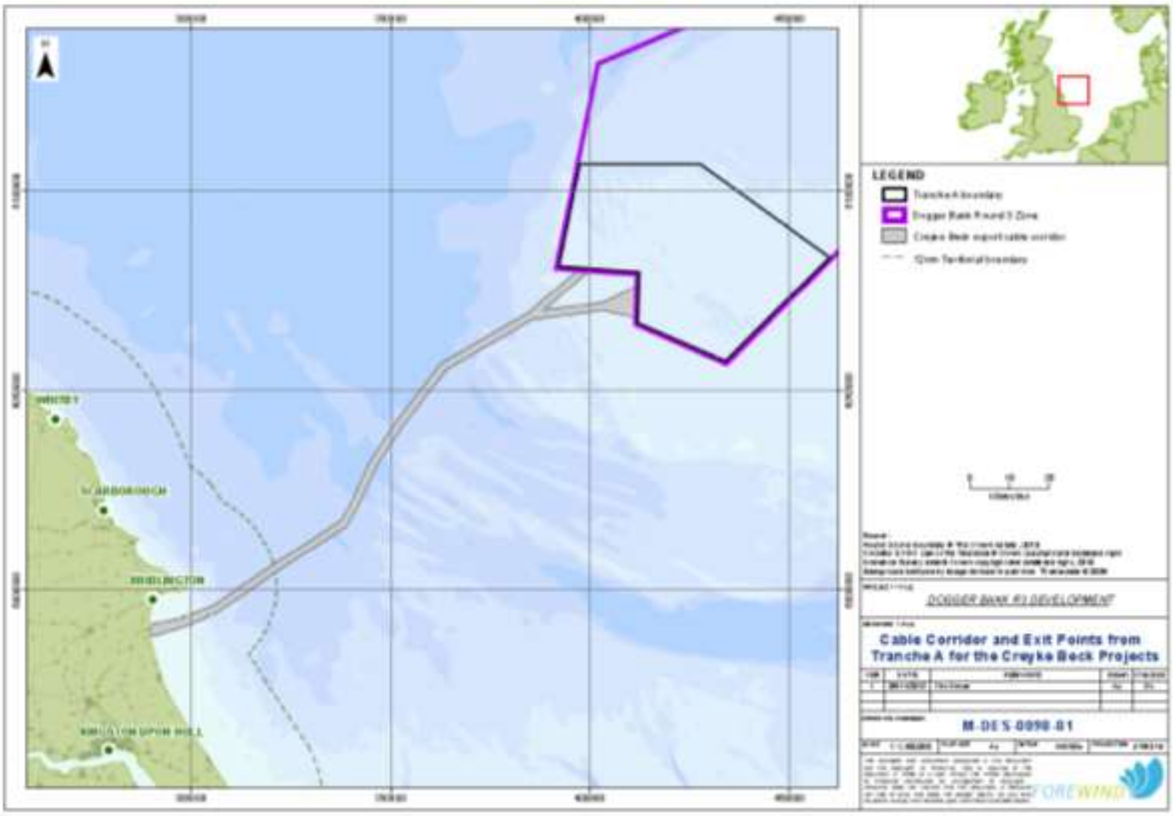

Figure 4 Dogger Bank Creyke Beck Cable Corridor

2.17 The location of Dogger Bank Teesside export cable corridors and the associated exit points from the Zone depends on the locations of the Dogger Bank Teesside project boundaries and the location of the landfall area. Figure 5 below presents the findings for an export cable corridor and exit points for the cable for Dogger Bank Teesside, the final report for which is due for imminent publication.

2.18 In identifying the first four project boundaries, Forewind has ensured that it does not limit options for the exit points and export cable routes for any future projects to be located outside of Tranches A and B.

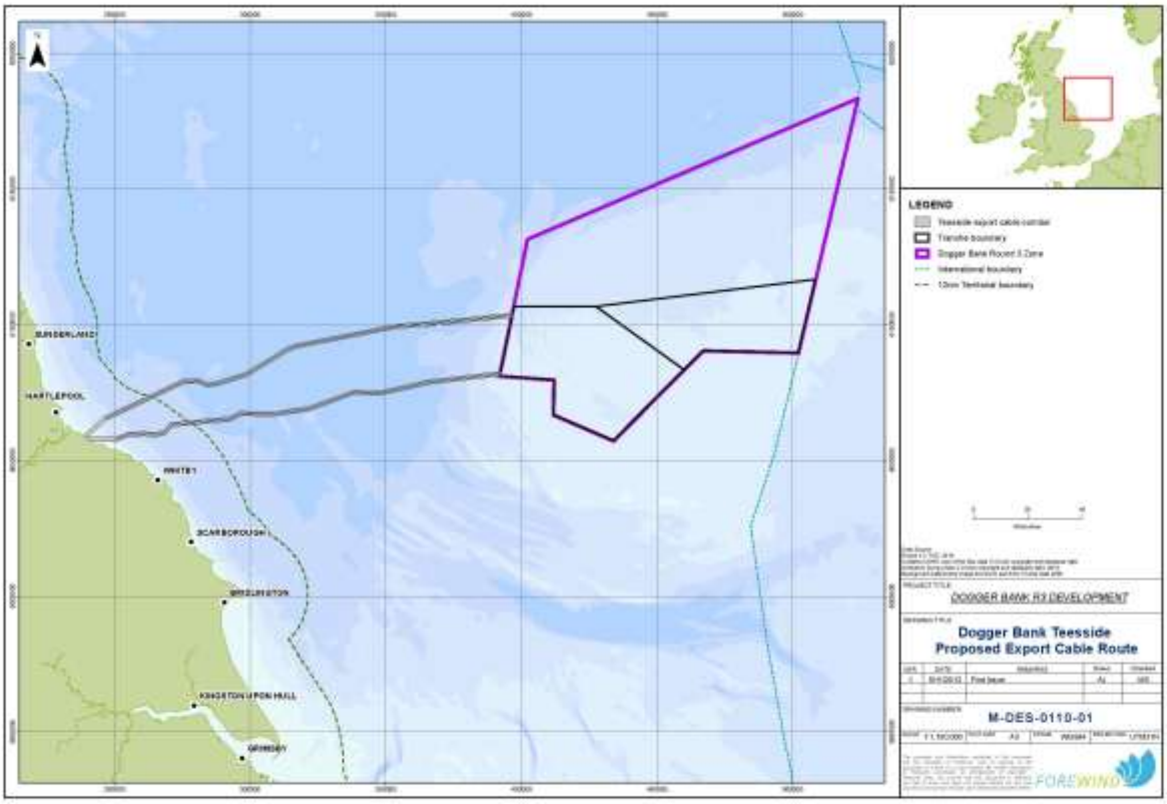

Figure 5 Dogger Bank Teesside Cable Corridor

2.2.5 Health and Safety Issues

2.19 There are numerous health and safety considerations in the design of project boundaries. Some of the key considerations are:

- Project boundaries need to incorporate collector and converter stations as well as helicopter and accommodation platforms. The boundary should allow these structures, so far as practicable, to be arranged in an easily understandable pattern with the wind turbines. This will help to minimise navigation risk.
- Project boundaries need to be designed to prevent turbines being positioned in a way that results in any asset being isolated outside of an array, as this could pose a hazard to navigation.
- Project boundaries need to incorporate a buffer of 250m for construction and operation purposes, and must allow enough flexibility for turbines to be moved to avoid features on the seabed; and
- Project boundaries must make allowance for safe operations and maintenance of existing assets (such as cables and pipelines) which are not part of the offshore wind project.

2.3 Environmental and other Consenting Considerations

2.20 The following broad categories were investigated initially to assist with identification of both Tranches A and B as described in the ZoC (2011), and then following more recent environmental information used to refine the developable area within the Zone. The developable area being key to then determining Project Boundaries within.

Environmental and other consenting considerations	
Geology and physical environment	Navigation and Shipping
Benthic Ecology	Commercial Fisheries
Fish resource and ecology	Oil and Gas
Birds	Military, aviation and radar
Marine mammals	Marine aggregates and disposal
Nature Conservation	Pipeline and cables
Archaeology and cultural Heritage	Other marine users

Table 3 Environmental and other consenting considerations

2.21 The ZAP process identified and analysed features within each of these categories, and this assessment influenced the selection of project boundaries. More detailed assessment of impacts on features within project boundaries will be undertaken during EIA for each project. Review of these features in the ZoC does not provide an assessment of likely impacts of project boundaries on the relevant features. Rather it serves to describe the implication of the feature to the project boundary, such as an increased consenting effort or risk; increased consultation effort or technical and financial challenges during installation and operation.

2.22 From the data collated in the ZoC and in the absence of a full EIA, the following consenting parameters were identified as having the potential to influence the project boundary selection within Tranches A and B:

- Geological and physical environment
- Pipelines and cables and other third party infrastructure
- Benthic ecology (including the cSAC)
- Commercial fisheries
- Fish ecology
- Marine mammals

- Birds
- Shipping and navigation
- Marine aggregates

2.23 Other factors not included in the list above, whilst will influence individual project impact assessments were not deemed to affect spatial project boundary selection.

2.3.2 Geological and Physical Environment

2.24 To introduce wind farms to the Dogger Bank Zone the depths of water, sediment types and seabed ecology and archaeology needs to be understood. Wind farms in deeper water result in higher costs, whilst different sediment types pose varying degrees of challenge for cable and foundation installation, resulting in higher costs in more challenging areas.

2.25 Forewind has undertaken extensive bathymetric, geophysical and geotechnical surveys of the Dogger Bank Zone to determine the depth of water (bathymetry), seabed ecology and archaeological features and to characterise the seabed and sub seabed sediments. Tranche A survey data has been interpreted. Interpretation of the Tranche B surveys is ongoing.

2.26 Bathymetry surveys have established that Tranche A has the majority of water depths of less than 30m LAT (Lowest Astronomical Tide) whilst Tranche B has the majority of water depths less than 35m LAT. Sidescan sonar surveys have been conducted within tranches A and B. This produces a black and white photograph-like (acoustic) image of the seabed. It is used to help characterise areas of sand ripples, sandwaves, gravels and cobles, wrecks and manmade infrastructure and used for ecology, seabed processes and archaeology assessments.

2.27 For the installation and burial of cables, suitable ground conditions need to be identified which extend below the seabed to a maximum depth of three metres. Shallow soils data from sub-bottom profiler data is used to identify areas of gravels & cobbles, boulders, sand units and clays etc. In addition to remote sensing (seismic data), ground truthing from grab samples, boreholes and Cone Penetrometer Tests has been undertaken at intervals throughout both Tranches A and B and has been used to help interpretation of the geophysical survey data.

2.28 Ultra high resolution (UHR) seismic data is used to evaluate the foundation zone. In general, the larger the turbine, the deeper (monopile) or wider (gravity base structures) the foundation type. To accommodate all types of foundations the survey data extends to more than 70m below seabed, which is much deeper than the data needed for installing cables.

2.29 So far, the survey findings have been significantly different to any other previous understandings of the Dogger Bank, and prove that Dogger Bank is predominantly a mound of clay, with thin sands over most of the surveyed area. It has however been found that within the shallower waters within Tranche A, towards the southeast and east of the Tranche there is a thicker layer of sandy sediments which may allow easier cable installation.

2.30 In the west of the Zone there is complex geology, which would require extensive drilling of boreholes to understand and characterise it fully. This region has extensive geological faults associated with it and is therefore considered a more challenging (expensive) area for the location of wind farm projects. Other than this area of complex geology, the remainder of Tranche A is considered suitable for wind farm development. There are however, areas less desirable than others due to the higher economics associated with installing turbine foundations and cables in certain sediment types.

2.31 During the boundary selection process there was continuous feedback between the Forewind engineering design team and geotechnical and geophysical expertise to improve the long term cost effectiveness of development and the categorising and defining of hazards for improved economic risk management associated with ground conditions. The avoidance of the area of complex geology was considered when selecting project boundaries as detailed below.

2.3.3 Pipelines, cables and other third party infrastructure

2.32 Operational pipelines and cables are considered hard constraints to wind farms. This is because wind farm structures cannot be sited on these structures. Buffer zones are provided to ensure the safety of the existing infrastructure during the construction operations associated with the wind farm. For example, anchor spreads or jack-up feet from vessels engaged in the construction of the wind farm will only be permitted to encroach up to a certain buffer from the cable or pipeline to ensure they do not damage the existing infrastructure. Additionally, during operation, buffers are required to ensure the safety of vessels working on repair or maintenance operations in close proximity to the surface wind farm structures and to ensure adequate space for the repair and maintenance of the cable or pipeline is provided.

2.33 Consultation has indicated that the buffers required for out of service cables and pipelines are either not necessary or significantly smaller than for operational assets. This is because the same level of maintenance and hence access to the cable or pipeline is not expected or required. However, where these are charted, note is still made of out of service cables and pipelines to ensure that consultation captures any concerns relating to these assets.

2.34 Early data collection from published sources and the output of conflict checks from The Crown Estate identified active and inactive cables and pipelines within proximity to the Dogger Bank Zone. The assets that could potentially influence project boundaries within Tranches A and B are shown in Table 4 and Figure 6.

Cable	Operator	Active or Inactive Cable/Pipeline	Interaction with Tranches
TATA North Europe	TATA	Active	Potential to influence projects located in the south of tranche A
UK – Germany 6	BT/Cable and Wireless	Active	Potential to influence projects located in the south of tranche A
SEAL	SHELL UK	Active	Potential to influence projects located in the west of tranche A
UK – Denmark 4	BT	Inactive	Proximity to Dogger Bank Creyke Beck B's NW corner but first 12nm of cable removed and the rest is left inactive

Table 4 Cable and Pipelines in proximity to Dogger Bank Zone

2.35 On-going dialogue between Forewind and the operators of these pipelines and cables has helped to inform the boundary design of projects to be located in Tranches A and B. A dialogue on crossing and proximity agreements is currently in progress with operators.

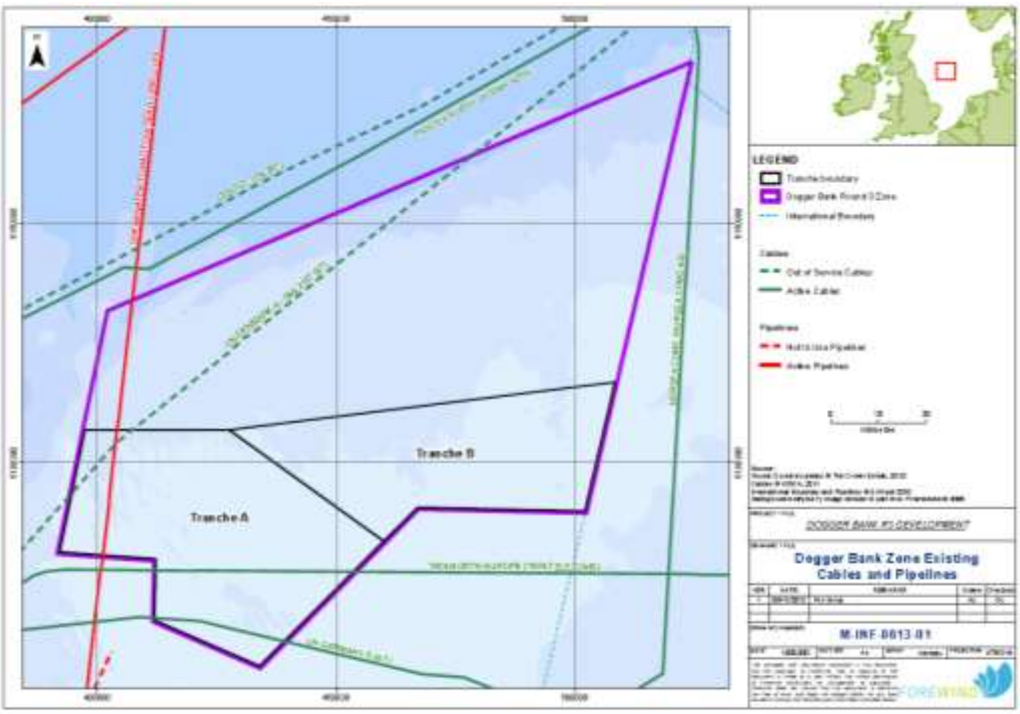

Figure 6 Dogger Bank Zone Existing Cables and Pipelines

2.36 There are no active oil or gas fields located within Tranche A and Tranche B. Numerous exploration wells have been drilled, but have been plugged and abandoned, or released as a dry holes.

2.37 There are seven oil and gas blocks currently licensed (as part of the existing or 26th licensing round) for oil and gas exploration and development that intersect with the south eastern boundary of Tranche A and the southern boundary of Tranche B, Figure 7.

Figure 7 Dogger Bank Oil and Gas Blocks

2.38 The close proximity of oil and gas operations to a wind farm could increase navigational risk and vessel collisions or have implications for helicopter access. Consultation with the oil and gas developers of any developments emerging from the 26th Licencing Round has suggested that any plans for any oil and gas discoveries made would not be known until 2015. Consideration of the presence of any known existing or planned structures should be considered when designing project boundaries. However, if locations of potential infrastructure are not yet known, these cannot be accounted for when designing project boundaries.

2.3.4 Benthic ecology

2.39 The Dogger Bank is a raised seabed that falls into Dutch, Danish, British and German areas of the North Sea. The UK section of the Dogger Bank qualifies under the European Council Directive for the conservation of habitats and wild fauna and flora (European Commission Habitats Directive 92/43/EEC). This is because it has 'sandbanks which are slightly covered by seawater all the time. This has resulted in this area being classified as a candidate Special Area of Conservation (cSAC) (JNCC, 2012[6]). This identified site overlaps with the whole of Tranches A and B of the Dogger Bank Zone and thus, as will be seen in the following benthic section, does not provide reason to differentiate project boundaries.

2.40 The procedure for the designation of Special Area of Conservation (SAC) begins with the identification of draft sites for Special Area of Conservation (dSAC). These are then considered by the UK government and renamed as possible Special Area of Conservation (pSAC). If accepted they are recommended to the European Commission (EC) as candidate Special Areas of Conservation (cSAC). The Dogger Bank Zone is currently at the cSAC stage. The submission of the cSAC to the EC occurred in August 2011.

2.41 Benthic ecology is the study of the ecology living on or just in the seabed. It includes the sediment surface level and the organisms living on and within the sediment. Installation of foundations, cables and other structures can cause direct physical loss and/or disturbance of the seabed. This, as well as any increase in suspended sediment in the water column from cable and foundation installation can impact benthic communities. The footprint of foundation and cable installation can lead to permanent loss of habitat.

2.42 Forewind commissioned an initial Zone wide coarse resolution geophysics survey followed by more detailed surveys of Tranche A and Tranche B. From the data collected and in conjunction with ZAP work the northern edge of the Zone was deemed more sensitive from a benthic perspective due to the presence of slope reef habitat.

2.43 Forewind further commissioned benthic ecology surveys to establish the benthic communities present within the Dogger Bank Zone. The aim of the surveys was to identify the baseline benthic communities, especially those of conservation interest and in particular those listed in Annex 1 of the Habitats Directive.

2.44 The Tranche A surveys were completed in November/December 2011. An indicative biotope map is given in Figure 8. The Tranche B surveys are currently taking place and awaiting data interpretation, although the Zone wide geophysics data collected in 2010, suggests similar assemblages of biotopes across the two Tranches. The surveys consisted of grab and video samples of the seabed. A proportion of the grab sample stations were also sampled for chemical analysis.

2.45 From the results and interpretations available at the time of identifying project boundaries, the majority of the habitats were generally tolerant to disturbance and

[6] http://jncc.defra.gov.uk/pdf/DoggerBank_ConservationObjectivesAdviceonOperations_6.0.pdf

showed high recoverability and thus did not merit highly in terms of being able to determine preference for one project area over another. The only exception to this is the less developable area identified to the north of the Zone.

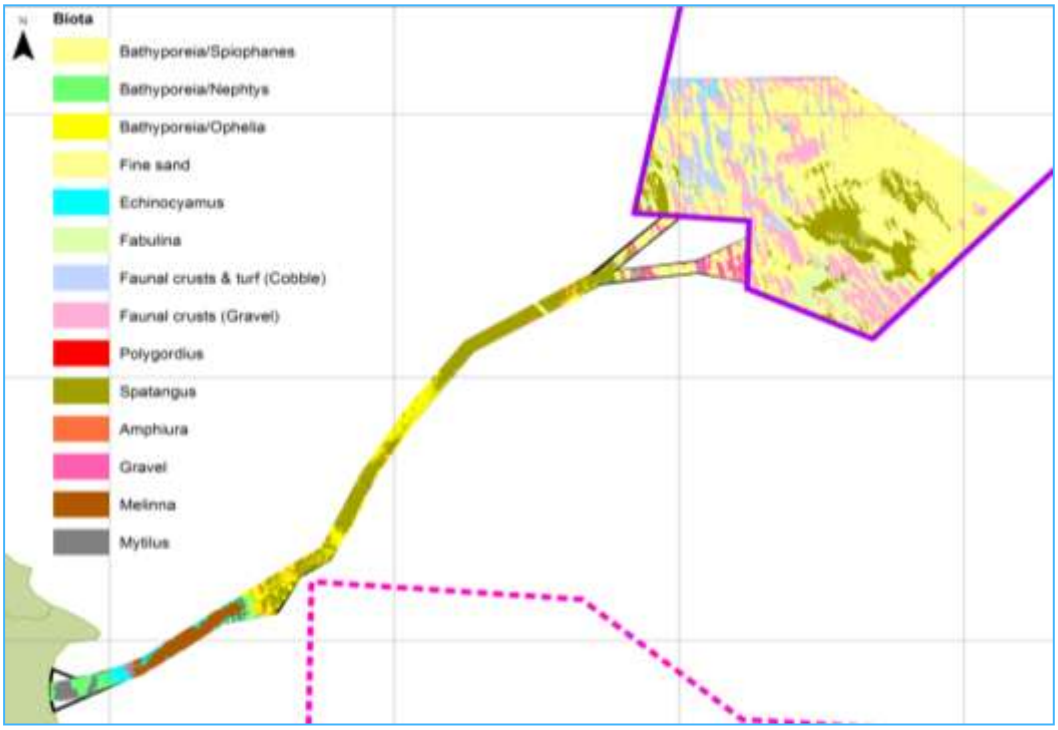

Figure 8 Tranche A and Dogger Bank Creyke Beck Cable corridor biotopes (as at November 2012 work in progress)

2.3.5 Commercial Fisheries

2.46 Forewind believes that commercial fisheries can co-exist with offshore wind farms. Since the award of the Zone to Forewind, consultation with the fishing community has been conducted to discuss how co-existence might be best achieved. It is acknowledged that the construction of an offshore wind farm could prevent fishing continuing within the wind farm should turbines be too close together for vessels to manoeuvre between them, or if structures present a significantly increased health and safety risk (i.e. risk of snagging on unprotected and unburied cables). Consultation has provided information on the types and levels of fishing occurring in the Dogger Bank Zone, and this information has been used to inform the identification of project boundaries. More specific work relating to the impacts of the proposed detailed parameters for each project will then form part of the EIAs for each project area.

2.47 Consultation with National and International fishing parties concerning commercial fishing in the Zone is on-going and commercial fish and fish ecology surveys have been informed by consultation with The Marine Management Organisation (MMO), The Centre for Environment, Fisheries and Aquaculture Science (Cefas), the Joint Nature Conservation Committee (JNCC) and Natural England.

2.48 The nationalities of fishing vessels operating across Dogger Bank are principally Danish, Dutch, Belgian, British, Swedish, Norwegian and French. There is a concentrated sand eel fishery focused on the western margins of the Dogger Bank Zone see Figure 9, which predominantly consists of Danish, Swedish and Norwegian vessels. This has been a key spatial differentiator across the Zone in influencing Project Boundary selection.

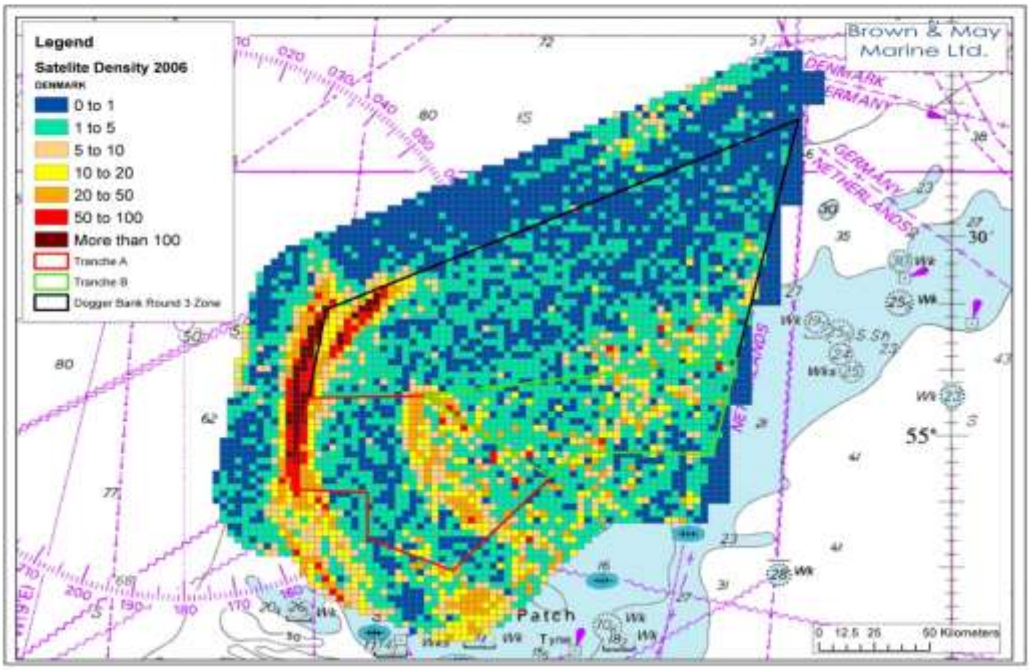

Figure 9 Dogger Bank Shipping Density indicating the predominant sand eel fishery to the west of the Zone

2.49 Shipping density surveys between April 2010 and December 2011 have been conducted, as well as desk based studies of existing data. This has included AIS (Automatic Identification System) and satellite tracking. Shipping surveys established that 44% of traffic in the Dogger Bank was due to commercial fishing.

2.50 Surveys have found that in addition to the sand eel fishery, fishing activity is dominated by beam trawling year round for plaice, lemon sole, turbot, skate and rays and Dover sole on a seasonal basis. Demersal seine fish netting and demersal trawling also occurs.

2.51 Overall Forewind believes, apart from on the west of the zone, the density of fishing across the Zone is relatively low. Data made available to Forewind in the lead up to selecting project boundaries suggest no reason to amend the boundaries in terms of any area having more significance over another in terms of fisheries. Forewind has recently received proposals from the Fishing Industry regarding co-existence of fishing and renewables and these will be discussed. It is not anticipated that this will lead to changes in the boundary, but will involve discussions on layouts within boundaries. Forewind is seeking to co-exist with the fishing community and remains committed to assessing the impacts of projects on commercial fisheries and maintaining active dialogue.

2.3.6 Fish Ecology

2.52 Noise and suspension of sediment in the water column caused by the installation of foundations and cables can potentially affect fish spawning or nursery grounds and lead to the displacement of fish resource in the Zone. The foundation and cable footprints will also lead to a small, but permanent loss of habitat, which could result in a change in the species composition around these structures. Although understood to be of limited project boundary selection significance, some species of fish are sensitive to electromagnetic fields. The HVDC technology that Forewind is considering using for the Dogger Bank projects is considered to have lower Electro Magnetic Field (EMF) emissions than alternative technologies.

2.53 To establish the numbers and species of fish present (including the presence of potential nursery and spawning grounds) Forewind commissioned a range of surveys in the Dogger Bank Zone covering spring, summer and autumn 2010, 2011 and 2012.

2.54 With the exception of the Sandeel fish populations on the western margin of the Zone, none of the fish ecology data to date with respect to nursery or spawning grounds provides key spatial evidence that would influence one project boundary over another. The triangle area between Dogger Bank Creyke Beck A and B and Dogger Bank Teesside B, may benefit from being undeveloped due to Sandeel densities being higher although not as high as the Western margin.

2.3.7 Marine Mammals

2.55 Wind farm construction activities such as foundation construction (particularly monopiling) activities can result in elevated noise levels through the water column. At its most severe it could impact marine mammal mortality, or irreparable harm, down to disturbance of the normal behaviour of the animal. This range of effects will be due to a number of variables including the size of the piling equipment, the substrate the foundation is being built in and the distance of the marine mammal from the noise source.

2.56 Vessel activity increases the risk of collisions with marine mammals, and turbine structures can cause barriers to marine mammal movement. Electromagnetic fields produced from export and inter-array cables can interfere with the navigation of some marine mammals. Key prey species for marine mammals in the Dogger Bank Zone include a number of flatfish and sand eel species. Any significant loss of these prey sources could result in indirect effects on marine mammals.

2.57 Prior to 2010 the Crown Estate carried out aerial surveys across the Round 3 Programme (including the Dogger Bank Zone) that captured data on both birds and marine mammals. After the Crown Estate's survey work finished in March 2010, Forewind commissioned HiDef Aerial Surveying Limited to perform aerial surveys and Gardline to perform boat based surveys starting in January 2010 (these coincided with the ornithology surveys). These surveys gathered information on the numbers of species and distribution of marine mammals present in the Dogger Bank Zone. Forewind has discussed methodology and preliminary findings with the JNCC and has presented its finds to a number of non-government organisations including The Whale and Dolphin Conservation Society, WWF and Greenpeace. Further dialogue will follow the impact assessment work on the first projects.

2.58 Bird and marine mammal surveys have covered the entire Dogger Bank Zone. Both the aerial and boat method followed a series of transect lines evenly spread out over the whole Zone. In January 2011 Forewind commenced a more intensive survey effort over Tranche A with more transect lines flown for the aerial survey and a priority given to the transects within the Tranche A area for the boat survey. The rest of the Zone was surveyed at a lesser effort. Tranche B was subsequently identified and from July 2011 an intensive 12 month survey effort commenced running on the same principles as Tranche A. Surveys have revealed that there are minke whale, white beaked dolphin, harbour porpoise and Grey seal present in the Dogger Bank Zone. Harbour porpoise, being the most commonly recorded, have been identified throughout the Zone. Other species have been recorded but at too low numbers to undertake sufficient density plots.

2.59 As previously discussed Tranches A and B are within a cSAC under the Habitats Directive due to having sandbanks which are slightly covered by sea water all the time. The JNCC considers harbour porpoise to be a generally ubiquitous and highly mobile species within the North Sea and therefore these mammals are not considered as a qualifying feature of the cSAC in the UK sector.

2.60 However, the Dogger Bank geological feature extends into Dutch, Danish and German waters. The Dutch Doggersbank pSCI and Klaverbank pSCI and German Dogger Bank SCI special conservation areas lie on the eastern borders of the Dogger Bank Zone. These non UK areas have included harbour porpoise and harbour seal and the Dutch sites also include grey seal within their qualifying features. Whilst this does not directly influence project boundary selection, projects nearer to these sites may be more influenced during the Impact Assessment phases

2.3.8 Birds

2.61 The introduction of an offshore wind farm poses a number of potential risks to birds. The primary risks on the Dogger Bank are thought to be from potential collision with turbine blades or other structures in the wind farm and displacement of seabirds from the area of a wind farm.

2.62 Turbines can be physical barriers to birds feeding within or migrating through the Dogger Bank Zone. Construction and operation phases bring increased noise and human presence. This has the potential to disturb and displace bird species and their prey and provide foraging opportunities for other opportunistic species of birds. This can result in competition and displacement of existing species in the Dogger Bank Zone. Other species could actively avoid the wind farm, displacing them to other locations where they would have to compete for prey resource or expend additional energy on feeding and could lead to increased mortality or a failure in their breeding success.

2.63 The Crown Estate initiated aerial and boat based ornithological surveys for the Round 3 Programme in 2009. Aerial surveys utilised high definition digital video camera technology, whilst boat based surveys rely on visual observation techniques counting and identifying species and geographically referencing the records. Aerial and boat based surveys of the Dogger Bank Zone have been continued by Forewind since 2010. Surveys have covered the entire Dogger Bank Zone. In January 2011 Forewind commenced a more intensive survey effort over Tranche A with more transect lines flown for the aerial survey and a priority given to the transects within the Tranche A area for the boat survey. The rest of the Zone was surveyed at a lesser effort. Tranche B was subsequently identified and from July 2011 an intensive 12 month survey effort was commenced running on the same principles as Tranche A.

2.64 Surveys have revealed high numbers of birds throughout the Dogger Bank Zone. Of particular significance is the recurring presence of high concentrations of some bird species on the western margins of the Zone, see Figure 10 below. This area also coincides with a commercial sand eel fishing ground (ref Figure 9), and is closest to the main breeding colonies along the east coast of England and Scotland.

2.65 Surveys have identified significant concentrations of species that may be affected by displacement such as guillemot, razorbill, little auk and puffin. The species considered to be the most sensitive to collisions in the Dogger Bank Zone are black-legged kittiwake, northern gannet, lesser black-backed gull, and great black-backed gull.

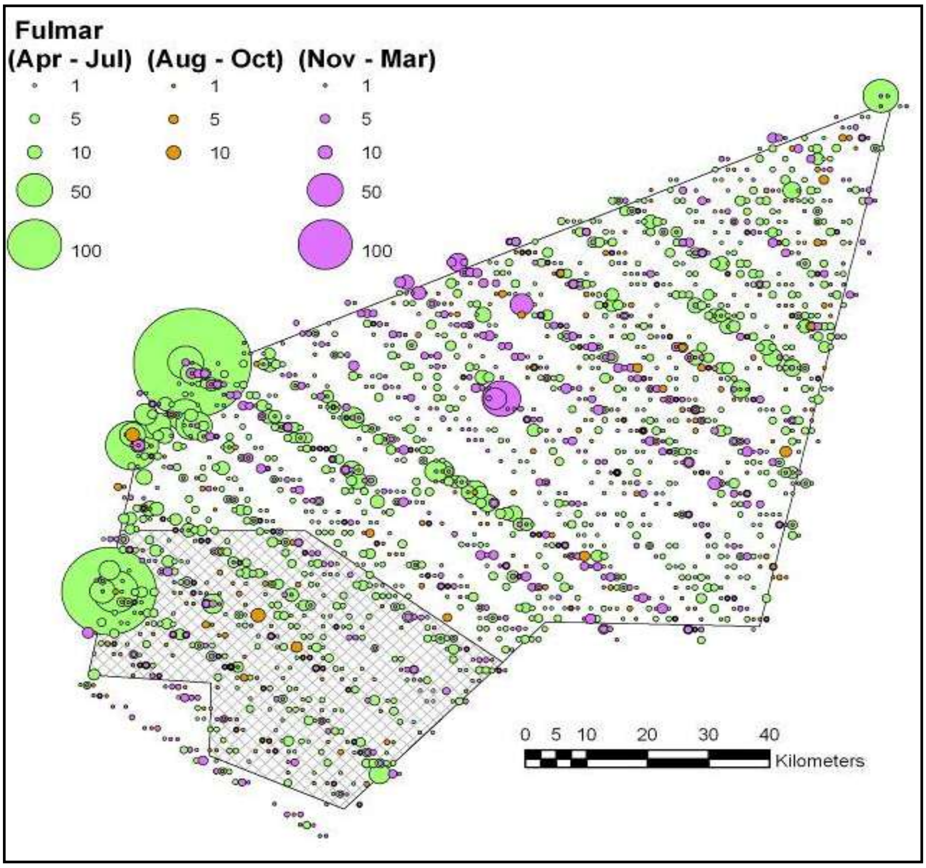

Figure 10 Dogger Bank Bird Surveys showing high densities on the western edge of the Zone (example shown Fulmar)

2.66 Recurring areas of higher densities to the western edge of the Zone have warranted a revision of the design of the developable area, see Figure 12.

2.67 In conclusion, birds are generally located across the whole zone; project boundaries will avoid high bird densities in the west of the zone through refinement of the developable area, see Figure 12 and; in the absence of other specific high density bird areas within the remaining developable area, birds are not a key factor in other boundary spatial decisions.

2.3.9 Shipping and Navigation

2.68 The introduction of an offshore wind farm to an area of sea currently devoid of offshore installations and structures can increase the navigational safety risk for mariners navigating through the area. The main hazard to mariners from the presence of offshore wind farms is an increased collision risk to both vessels and wind farm structures. This risk is created by transit deviations, structures creating visual confusion, structure presence impairing small vessel detection (visual or radar) systems, and the potential to impact emergency response capability. As a result, it is necessary to assess the baseline environment including the identification of navigational features, defining existing users such as fishing operators and determining historical commercial shipping routes (both regular operators and densely used routes).

2.69 Marine traffic data, charted information and consultation feedback were used to identify the baseline environment of the Dogger Bank Zone. The marine traffic survey data used for the baseline navigation review of the assessment area included two datasets of AIS data (21 days in Spring/Summer 2011 and 28 days in Autumn/Winter 2011/2012) and one dataset of Radar data (28 days in August, September and October 2010). These data were recorded from survey vessels working at the site during the given periods and form part of a large data set of over 500 days data collected by Forewind.

2.70 Navigation was considered as part of the Tranche B area selection, when a shipping channel through the Zone was being contemplated. However, since that time further discussions have taken place with the shipping community as well as the Maritime and Coastguard Agency (MCA) and Trinity House. Generally the majority of potentially affected ship operators have all stated that they would not have an issue with there NOT being a channel through the wind farm Zone and that there would be relatively little impact on their operations in the absence of such a channel.

2.71 Also discussions with the MCA in particular have focussed on how comparatively light the shipping activity is in the Dogger Bank Zone compared to elsewhere in the North Sea. Thus there is no evidence that “Areas to be avoided” or similar area restrictions would be required. Whilst Forewind is still carrying out impact assessment work in relations to Navigational Risk Assessment, we consider the biggest influence for the wind farms will be on layout and aids to navigation such as lighting and markings rather than the boundaries.

2.72 Data analysis has shown that the Dogger Bank Zone has relatively few, vessel transits through the Zone in relation to both its size and other North Sea Round 3 projects. Due to the Zone’s distance offshore, recreational sailing is also low. However, as discussed above, there is a strong commercial fishing presence within the Zone, in particular sand eel fishing to the western boundary of the Zone.

2.73 In order to address the cumulative issues arising from multiple large offshore wind farm developments in the Southern North Sea, Forewind joined the developers of the Hornsea and East Anglia zones in forming the Southern North Sea Offshore Wind Forum (SNSOWF). The group recognised that the cumulative impacts of all three zones should be accounted for when considering selection of suitable project areas and commissioned a report into the effects. Additionally consultation was also undertaken with UK and transboundary regulators.

2.74 The marine traffic survey identified only 10 main routes operating within 10nm of Tranches A and B. The majority of vessel types transiting on these routes were identified as tankers and cargo vessels. Fishing activity was recorded across both tranches with a high density of vessels to the west of Dogger Bank during the sand eel fishing season (April, May and June). The level of recreational vessel activity was noted as being very low.

2.75 Although vessels may be displaced by the presence of Dogger Bank wind farms, a maximum increase in transit time for any vessel would be about twenty two minutes, or 1.2% of total journey distance for the average route. This was calculated within the Navigational Risk Assessment (NRA). Consequently no areas of the Zone were identified at this stage as being unsuitable for wind farm development as a result of shipping activity and hence no areas were ruled out on this basis for the project boundary selection process. It was noted that site design, including presence of peripheral structures, lighting and marking, needed to be considered to ensure that the projects do not pose additional risk to shipping.

2.3.10 Marine Aggregates

2.76 Marine aggregate extraction is generally not possible within wind farms since anchoring of dredging vessels close to cables and dredging near to buried cables could result in damage to both vessels and cables.

2.77 At present there are no licensed areas within the Dogger Bank Zone itself. However, there is currently an application for an aggregate dredging ground approximately 600m northwest of Tranche A (see Figure 11). This will cover an area of 11.13km2. Consultation with the application holders has confirmed that a buffer zone of 2km is preferred between the proposed aggregates area and any wind farm structures. Currently this discrete area will be avoided and no other influence on project boundaries is anticipated other than consideration of the possible presence of vessels associated with this dredging site.

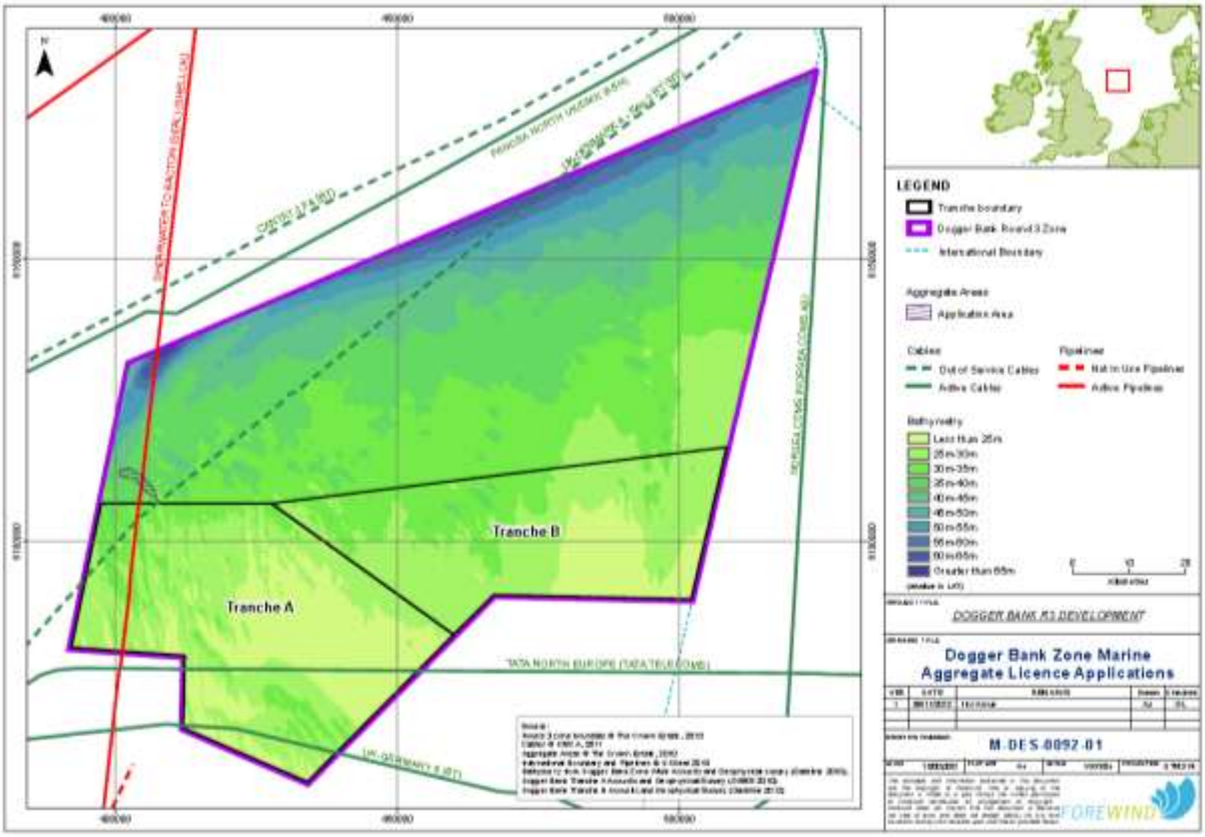

Figure 11 Dogger Bank Marine Aggregate Licence Applications

2.4 Summary of Environmental and other Consenting Considerations

2.78 Forewind's understanding of the environmental, consenting and spatial issues within the developable area and in the absence of the full results of any project specific Environmental Impact Assessment is as follows:

2.79 Based on available data, Dogger Bank Creyke Beck B is located near to an area identified as being potentially sensitive from an environmental perspective, particularly relevant to effects on the sand eel fishery and on birds. This sensitivity has been taken into account by moving the western edge of developable area and thus project boundary to the east of the SEAL pipeline. Further understanding of the bird collision risk and bird densities in this area will inform any further spatial requirements within each project boundary.

2.80 Whilst all Tranche A and B projects fall within the candidate Special Area of Conservation designated area for shallow sand bank habitats, there have been no exceptionally intolerant or sensitive habitats identified and as such all areas so far are currently deemed to be of low or negligible sensitivity. Consideration of the

Habitats Regulations and appropriate assessment requirements will be undertaken on a project basis in the context of potential cumulative issues for the first projects identified.

2.81 Harbour porpoise is considered (by JNCC) as being a generally ubiquitous species within the North Sea and as such is not identified as a primary qualifying feature of the Dogger Bank cSAC. The Dutch and German authorities have, however, included harbour porpoise within their Dogger Bank designations. Interpretation of data so far does not indicate any one area of the Zone as being at more risk than any other with respect to Harbour Porpoise.

2.82 From early consideration of the implications of the Habitats Directive on the Zone with respect to birds, habitats and marine mammals and with the exception of the removal of the western edge of the Zone from the developable area, the remaining areas across the Zone have relatively equal levels of constraint. As such the further selection of project boundaries has not had to be influenced directly by these factors other than removal of the western edge of the Zone.

2.83 Uncertainty of development activities within the newly licensed oil and gas blocks will remain until seismic surveys are undertaken and oil and gas developers determine any potential resource. Consultation with the oil and gas developers of these blocks has suggested that any plans for any discoveries made would be likely to be finalised in 2015. The renewable industry is investigating whether a compensation clause could be included in the agreement for lease with the Crown Estate in the event of a discovery being made. A watching brief will be maintained.

2.84 Whilst clarity on any MoD issues has not been forthcoming, there are currently no indications that there are any issues that would affect wind farm siting across the Zone.

2.85 The ‘triangular’ area between Dogger Bank Creyke Beck A, Dogger Bank Creyke Beck B and Dogger Bank Teesside B, see Figure 12, has been identified previously as an area for seine netting and thus avoiding development in this area may be beneficial to the fishery (as this gear type could not be used in a wind farm). It should be noted that European fishermen, if required to make a choice, have suggested so far that avoidance of the sand eel area would be their preference. However it should be noted that different countries have interests in the two types of fishing. Whilst this ‘triangle’ might not be ideal from a shipping and navigation perspective, the majority of shipping activity will be outside of the project boundaries.

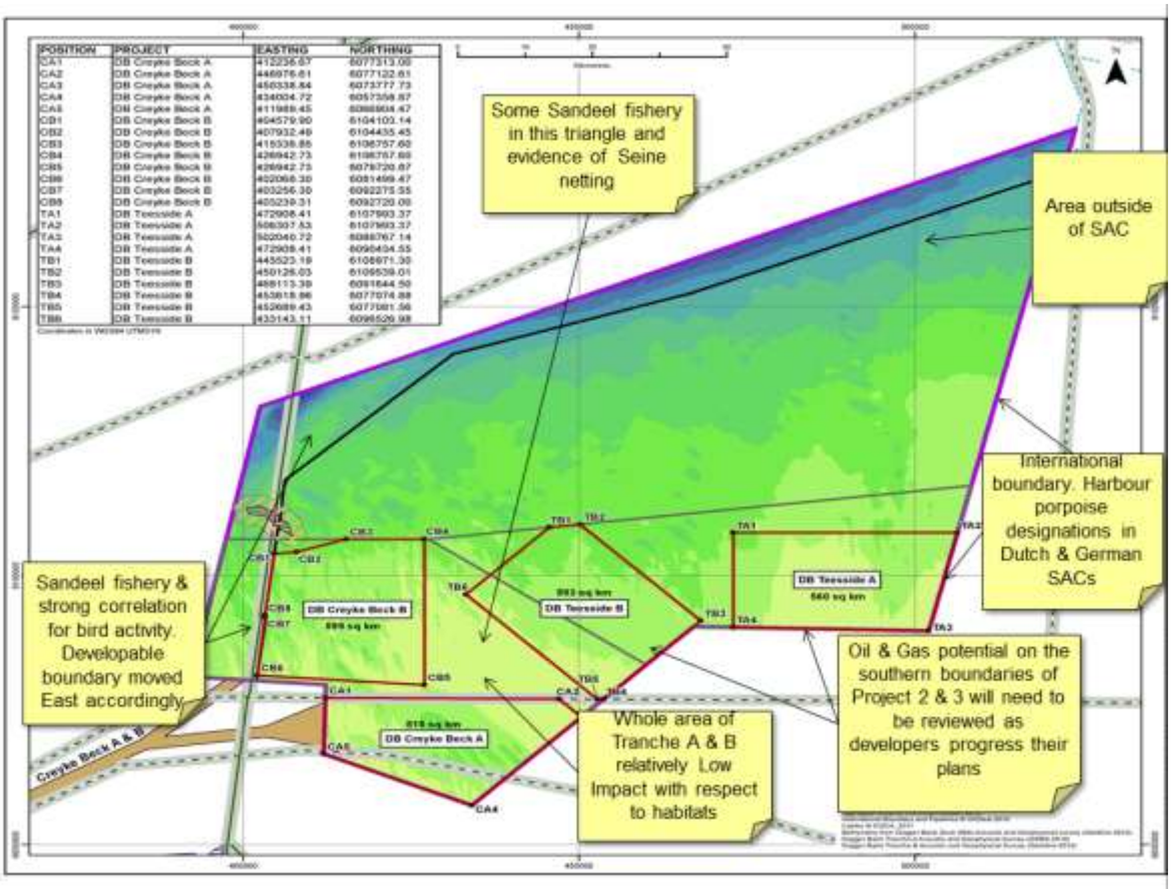

Figure 12 Summary of key consenting issues associated with Project Boundary selection

2.86 Overall Forewind believes the density of fishing across the Zone is relatively low. Forewind is seeking the goal of co-existence with the fishing community and remains committed to assessing the impacts of projects and maintaining active dialogue.

2.87 The majority of potentially affected ship operators have all stated there would be relatively little impact on their operations. Also discussions with the MCA in particular have focussed around how comparatively light the shipping activity is. The biggest influence for the wind farms will be on layout and aids to navigation such as lighting and markings rather than the boundaries.

3 Identification of Zone Capacity

3.1 Introduction

3.1 In order to be able to identify project boundaries, it is necessary to first understand the full potential capacity of the Zone for offshore wind. In order to do this there are four parameters that must be established:

i. Identification of developable area of the Zone.
ii. Determination of optimal project capacities
iii. Determination of optimal project areas
iv. Identification of optimal Zone capacity.

3.2 In addition to environmental considerations the economics of wind farm projects are an important factor in the determination of the developable area, size of the projects and Zone capacity. As such, Forewind has developed an analysis tool called the Forewind Cost Analysis Tool (FCAT). This analyses the impact that different project layouts and engineering designs have on the economics of the Dogger Bank Zone and the individual projects within the Zone.

3.3 The FCAT model tested the sensitivities of Zone and project economics to the following:

- Varying degrees of overplanting
- Varying project areas and turbine spacing
- Varying turbine arrays
- Varying project shapes and sizes
- Varying Zone capacities

3.4 Some assumptions were used on which to base the FCAT model:

- Construction costs based on 2012 prices.
- All projects assumed to be constructed and commissioned at the same time.
- A project lifetime of 25 years.
- All projects suffer from the wake effects of a fully developed Dogger Bank Zone.
- Income is based on predicted market value of energy generation.

- Costs for foundations, installation, operations and maintenance are adjusted for each specific turbine location in the Dogger Bank Zone.
- There may be interconnections between projects.
- 7MW turbines were treated as the base case turbine

3.5 FCAT acts as a modelling node accepting outputs from a number of other specialised models and then amalgamating them with FCATs own modelling criteria before undertaking a simulation. This allows Forewind to take a holistic approach to its analysis by incorporating many variables into one model.

3.6 The FCAT tool was used in the identification of the project capacities, project areas and Zone capacity.

3.2 Identification of a Dogger Bank Developable Area

3.7 Based on the analysis provided in section 2 above, and an exercise involving Forewind and guidance from parent organisations, a work stream which combined consenting, engineering and economic considerations to establish a developable area within the Dogger Bank Zone was undertaken. The developable area can be considered as the regions within the Dogger Bank Zone that projects may be located.

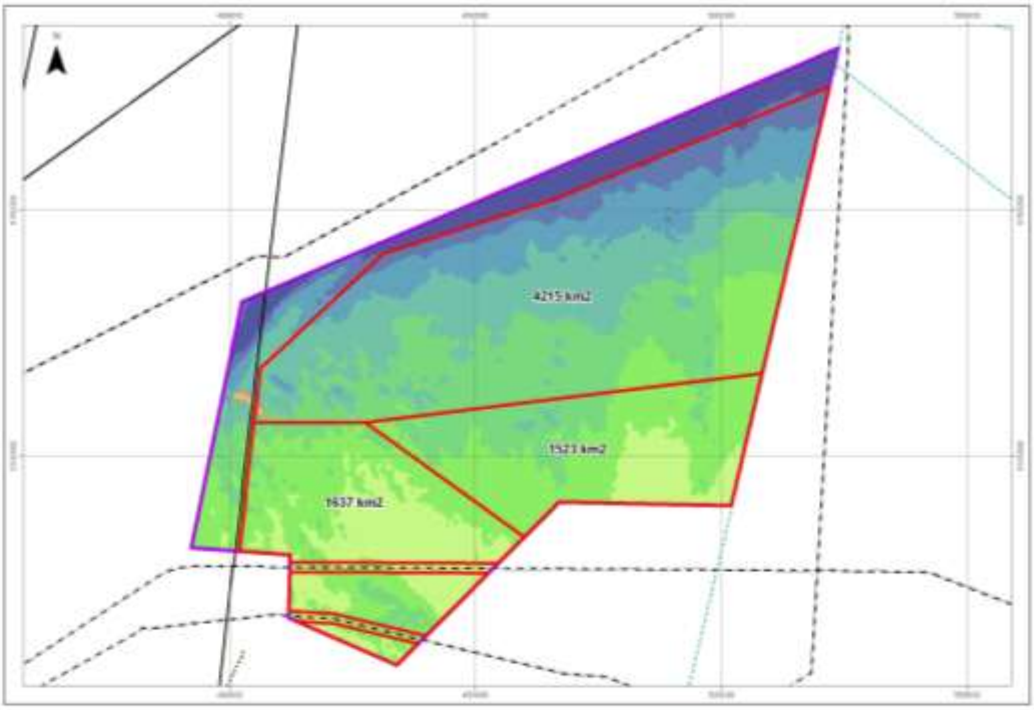

Figure 13 Dogger Bank Developable Area

3.8 Figure 13 shows the developable area within the Dogger Bank Zone. All areas outside the red line boundary were eliminated from the potential project development area prior to designing any project boundaries.

3.9 The area in the west of the Zone was eliminated despite its relatively shallow waters, good wind resource and being closest to the grid connection points. Due to these features this area had some of the some of the strongest technical and economic cases in favour of its inclusion in the developable area. However, Forewind opted to exclude the western region from the developable area due to the fishing activity, particularly for sand eel, and high numbers of key species of birds.

3.10 The removal of this area, whilst forgoing an area well suited for wind farm development, will reduce the impact on important environmental receptors. The exclusion of the western margin of the Dogger Bank Zone will help to create separation between some fishing activities and wind farm activities. This could reduce vessel traffic in the area, and reduce any potential for health and safety impacts that fishing activity within a wind farm could cause such as damage to equipment, collisions and uncovering of buried cables. The avoidance of placing wind farm projects in this western area could help to reduce potential displacement and lower collision rates of birds with turbines.

3.11 The northern and north western area of the Dogger Bank Zone has been excluded due to the depth of water and the presence of slope habitat species which are less tolerant to disturbance. Water depths in excess of 50m would pose a significant technical challenge to any projects being constructed in them. As the majority of the Zone would allow technology types suitable for shallower water the northern edges would require the development of different technical solutions to the rest of the Dogger Bank Zone. This would place greater commercial challenges on projects in the deeper waters. These factors combined lead to the exclusion of northern areas of the Dogger Bank Zone.

3.12 Whilst any points within the red line boundaries of Figure 13 are currently considered as developable area it should be noted this may be altered in the future as further studies and investigations proceed. Consultation through the Environmental Impact Assessment may identify other constraints which alter the developable area of the Dogger Bank Zone.

3.3 Determination of Project Capacities

3.13 Forewind undertook a series of exercises to determine if “overplanting” would be a viable option for projects within the Dogger Bank developable area. Overplanting means that the installed generation capacity exceeds the grid connection capacity.

3.14 For conventional power plants, the grid connection will equal the installed generation capacity of the project. Energy generation from offshore wind is dependent on a fluctuating wind climate, resulting in lower energy generation when lower wind speeds occur. Reduced energy generation is also normal when individual turbines are switched off expectedly or unexpectedly due to operations and maintenance activities. For conventional power plants the entire generation capacity can be lost during operations and maintenance activities. A wind farm may only lose a small proportion of generation capacity during operations and maintenance activities.

3.15 Electrical losses occur through the inter array and export cables, with longer cables resulting in larger losses. Overplanting turbines can counteract these losses, by exceeding the grid connection capacity onshore, therefore optimizing daily production of the wind farm.

3.16 The use of overplanting allows the projects to be optimised for maximum efficiency taking into account electrical losses, availability, and the natural variability of a wind farm's output. In the event of the overplanted full capacity being achieved, turbines can selectively be turned off to equal the grid capacity.

To determine the optimal level of overplanting Forewind conducted a series of modelling exercises. These exercises were based upon the benefits of overplanting turbines on a 1GW project, with a base case consisting of 143 7MW turbines. A number of different variables were factored into the modelling to explore their effects on overplanting:

- Using different turbine types
- HVDC loses (from the export cable);
- Inter array loses (electrical losses from the inter array cables);
- Wake losses (caused by loss of wind resource to a turbine in the wake of another turbine influenced by spacing between the turbines);
- Grid connection downtime; and
- Total cost for the turbines, including cost of construction, operation and maintenance.

3.17 Figure 14 and Figure 15 shows the results from Forewind's analysis. Figure 14 shows, as would be expected, increased energy output as additional wind turbines are added. As would also be expected, the gradient decreases as more turbines are added. This is due to the additional turbines being unable to export all their energy output as the other turbines are at full output. In effect the grid connection can be viewed as being "maxed out" more often and curtailment is necessary more often.

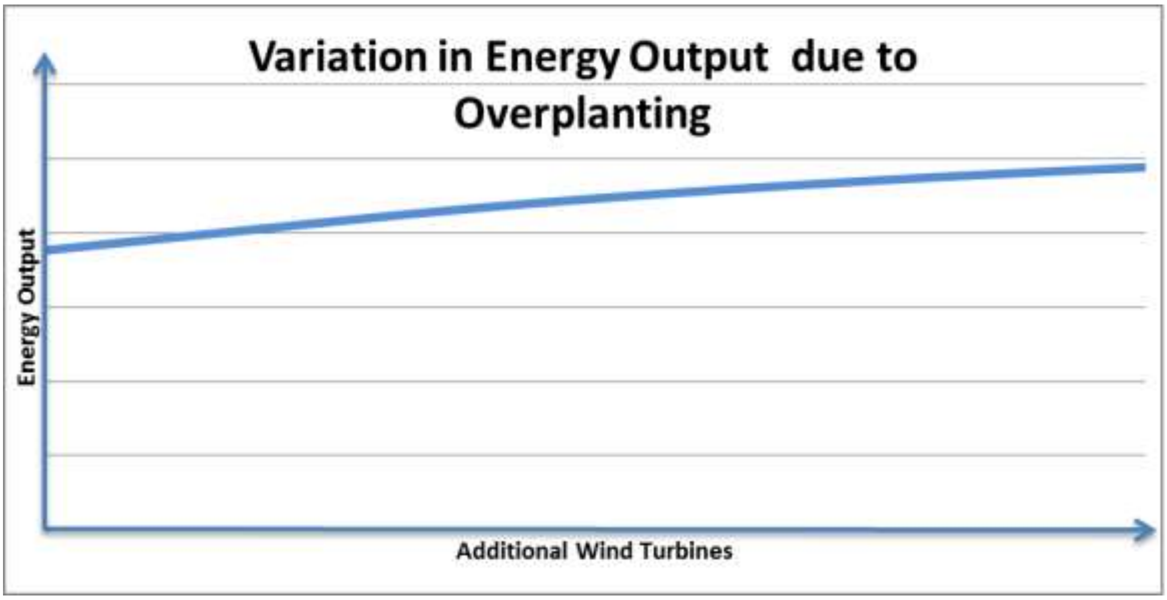

Figure 14 Variation in energy output due to overplanting

3.18 Figure 15 shows the economic return rate for overplanting. It shows that adding additional turbines does provide a financial benefit to the projects. However, as can clearly be seen in the figure the addition of too many turbines reduces this financial benefit. Where too many additional turbines are added they are not able to export their full energy output and as such produce a poorer economic return.

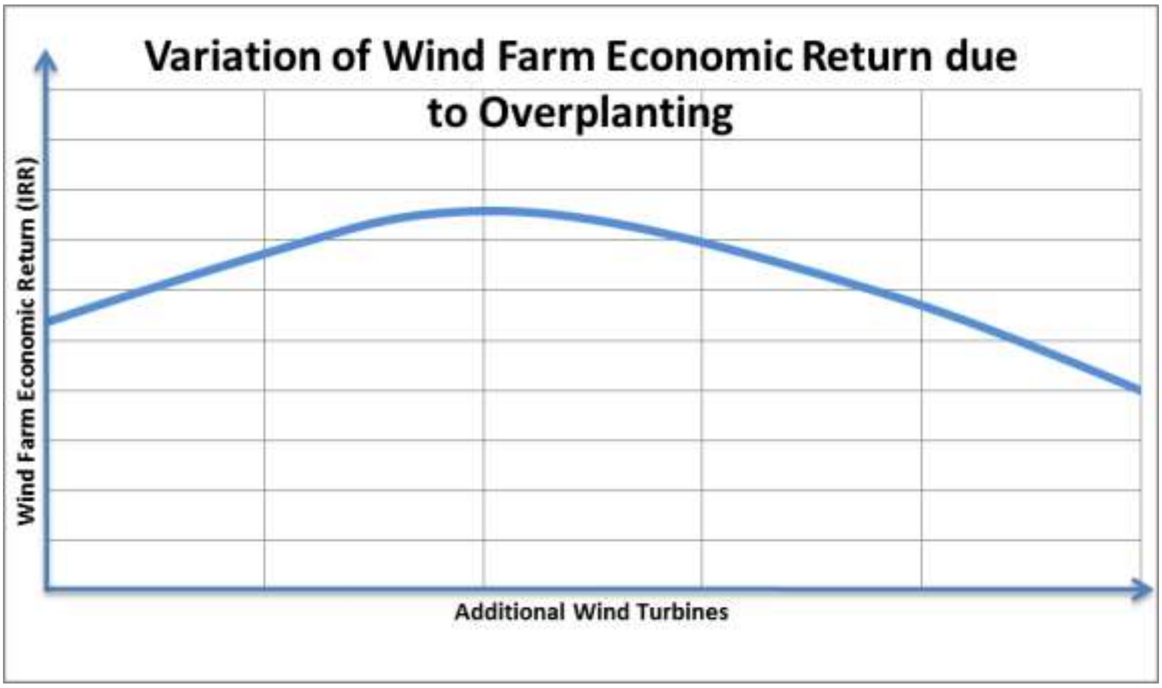

Figure 15 Variation in economic return due to overplanting

3.19 The principal drivers for the level of overplanting are the capital expenditure (capex) for the additional turbines, operations and maintenance availability and the degree of project interconnections within the Dogger Bank Zone. The exact level of overplanting will be dependent on the unique characteristics of each project and can only be determined once specific wind turbines have been selected for the site and the exact, site-specific wind regime is understood. The optimal level of overplanting is a careful balance of the increased construction and operation and maintenance costs offset against the additional revenue that can be generated.

3.20 Forewind determined that an offshore installed capacity of up 1.2GW per project would assist in optimising the 1GW grid connections that have been secured.

3.4 Determination of Project Areas

3.4.1 Array Design

3.21 Wind turbines extract energy from the wind and this process creates a wake downstream from the turbine where wind speed is reduced and flow is more turbulent. As the flow proceeds downstream the wake spreads out and the energy is recovered from the surrounding air, thus the wake decreases with distance. The reduction in energy is commonly referred to as wake loss. The size of the wake loss is proportional to the rotor diameter, with larger wind turbines requiring greater separation, allowing a minimum spacing between turbines to be established.

3.22 The impact each turbine has on the production capacity of other turbines within a project and neighbouring projects needs to be taken into account when designing optimum project boundaries. The array design needs to result in the highest possible energy capture, whilst balancing the associated higher costs of inter array cables that increased turbine spacing causes.

3.4.2 Turbine Spacing

3.23 As part of the modelling work undertaken by Forewind scenarios were run exploring the sensitivities of spacing between turbines. This modelling was based upon 7MW turbines which were spaced between 7 and 14 rotor diameters apart. 1 rotor diameter (1D) of a 7MW turbine is 164m. By increasing the spacing the energy capture is improved for each turbine. The results of which can be seen in Figure 16.

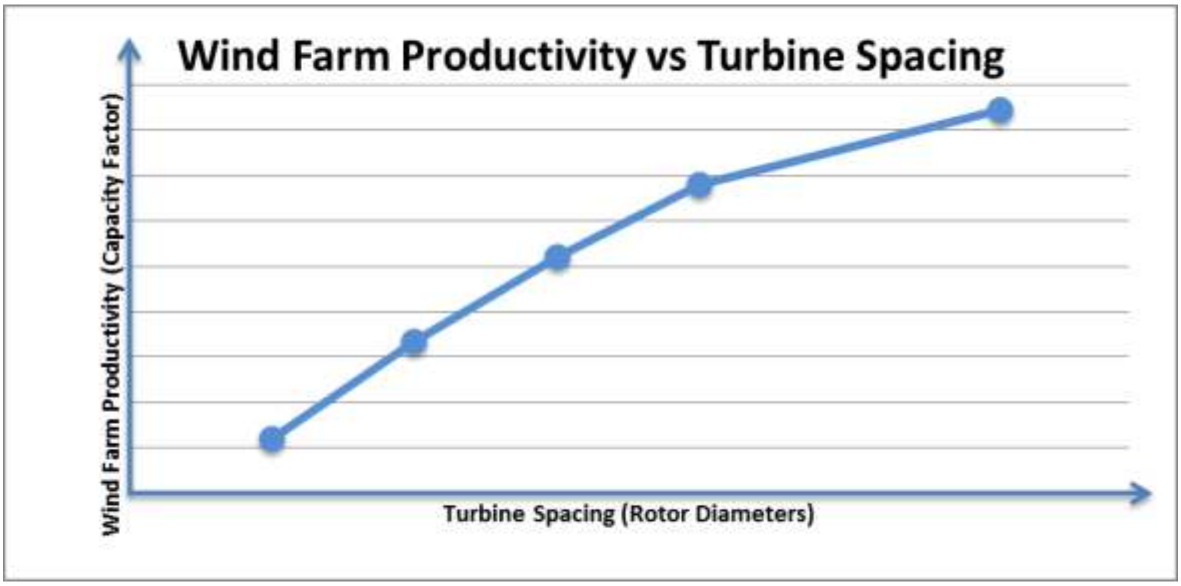

Figure 16 Wind farm productivity vs. turbine spacing

3.24 These results would imply that the optimal is to space the turbines as far apart as physically possible. However this improvement in wind farm productivity is counter balanced by the associated higher costs of inter-array cables that increased turbine spacing causes. Figure 17 shows the results for economic return against increased turbine spacing.

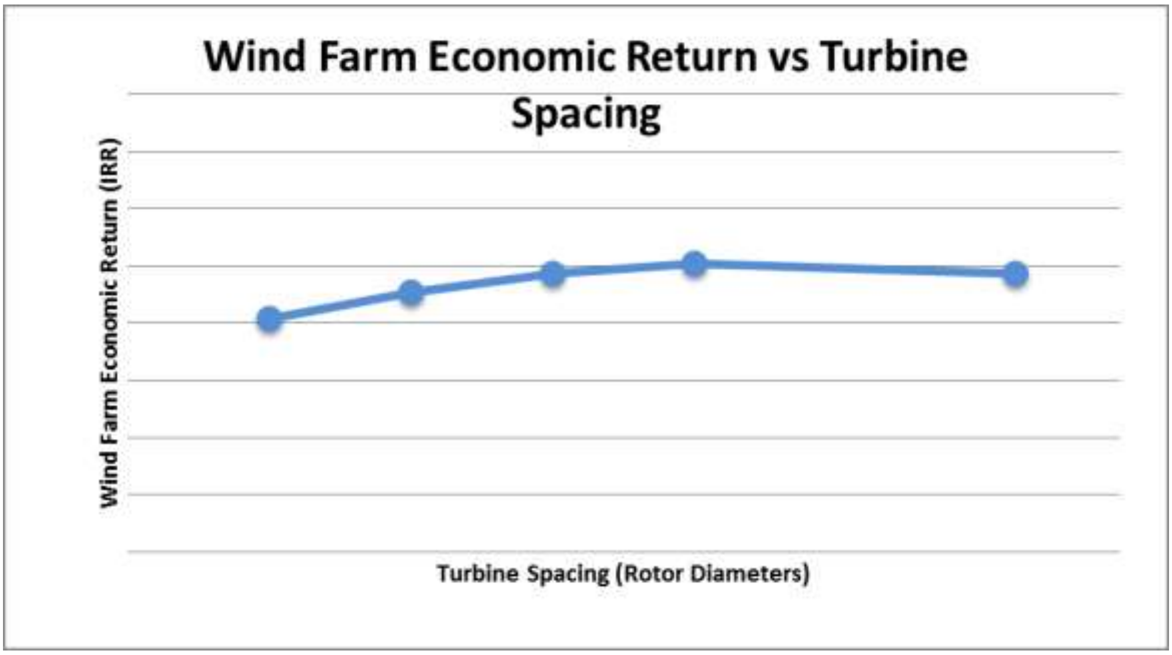

Figure 17 Economic return vs. turbine spacing

3.25 The analysis undertaken by Forewind identified that the highest economic return occurs in the region of 11D spacing between turbines.

3.26 However, this conclusion is dependent on number of assumptions, most notably the costs of inter-array cables. An increase or decrease in these costs would change this optimal spacing. For the Dogger Bank Creyke Beck and Teesside projects Forewind has opted to use 11D spacing as the basis for project area calculations where possible.

3.4.3 Project Area

3.27 Using 11D spacing between turbines Forewind has determined that an area of 558km^2 is the most desirable for each 1.2GW project within the Dogger Bank Zone. This assumes that each turbine within a project can be treated as if it was centred in a square with sides 11D long, an illustration of this can be seen in Figure 18**Error! eference source not found.** From the centre of a turbine to the centre of a neighbouring turbine is a distance of 11D. From the centre of a turbine to the boundary of its neighbour is a distance of 5.5D.

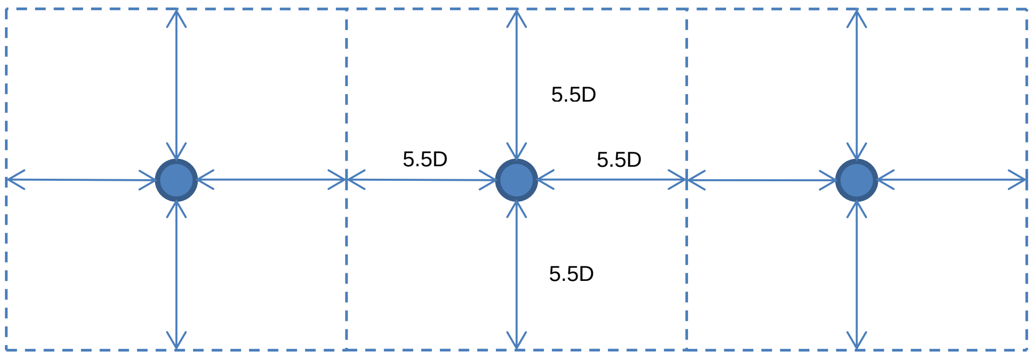

Figure 18 Turbine Spacing

3.28 In addition to considering energy capture there are a number of factors that should also be taken into account when considering project area:

- Project shape – The shapes of the projects themselves may not lend themselves conveniently being filled with squares. For example, the southernmost project is constrained by developable area boundaries into a triangular shape.
- Project consentability - In addition to improve consentability of the projects Forewind's development team has made a number of recommendations on turbine positioning. For example, turbines should not be positioned in a way that results in an isolated turbine outside of a straight array as this could pose a hazard to navigation.
- Boundary buffer – Whilst a buffer of 5.5D is not required between the turbine and the project boundary a buffer of some type will be required for construction and operation purposes.

- Local site Issues – Localised features on the seabed may require that turbines are positioned in new locations. For example the presence of a former river bed in the middle of a string may require some turbines to be moved resulting in empty spaces within the arrays.

3.29 In addition to the factors listed above each project should be able to encompass a number of other components that may be required by an offshore wind farm, such as:

- Up to four collector platforms;
- 1 converter platform;
- Up to two accommodation/helicopter platforms;
- Up to five meteorological masts; and
- Up to ten mooring buoys.

3.30 As a baseline an area of 558km^2 is sufficient for all turbines and provides the ability to compensate for the factors and components listed above. This baseline may be altered for individual projects depending on their specific criteria.

3.5 Identification of Zone Capacity

3.31 Using the FCAT tool Forewind undertook a range of modelling exercises to explore the total capacity that may reasonably be installed within the developable area. This was based upon a wide range of hypothetical scenarios ranging from covering the entire area in a single continuous grid with 15GW (an exaggerated maximum) of turbine capacity to populating the area with projects using star shaped arrays. The scenarios also allowed further comparison between projects with and without overplanting.

3.32 These modelling activities found that regardless of the scenario whilst it was possible to install large capacities (in excess of 10GW) within the developable zone, the reduction in energy output due to wake losses reduced the economic return of the projects. This trend can be seen in Figure 19, below, which shows how the economic return decreases with overutilization of developable area.

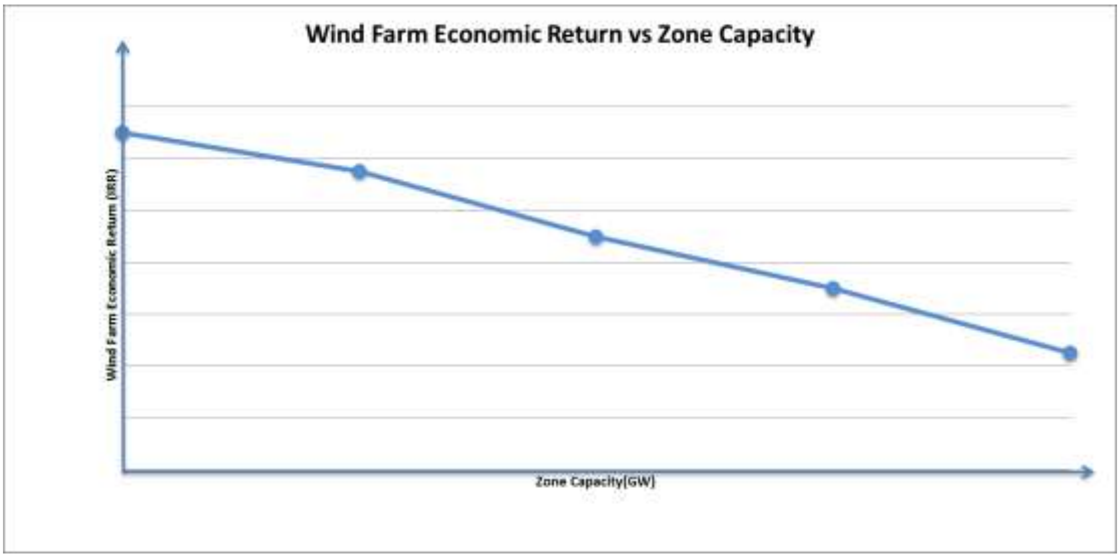

Figure 19 Economic return vs. Zone capacity

3.33 In addition to the benefits in terms of project economics of reducing the Dogger Bank Zone potential capacity from the 13GW communicated in 2010, it is considered that having fewer turbines and foundations installed in the Zone will have a number of other benefits:

- A reduction in environmental effects due to turbines.
- Fewer disturbances to seabed habitats.
- There should be more space for bird populations displaced to recover.
- Environmental impact on birds would be reduced.
- More space will be available for other marine users such as fishermen.
- Lower risk of health and safety issues. For example collisions between vessels and wind farm components due to navigational incidents and uncovering of buried cables due to trawling activity.
- Less noise from installing fewer foundations is favorable to marine mammals such as harbour porpoise.
- Fewer cumulative wake effects from clustering wind farms too close together, such as unforeseen wake effect.

3.34 Based upon the results from the Forewind modelling scenarios it has been concluded, using overplanted projects of 1.2GW each, that a capacity of approximately 9.6GW should be the maximum for the Dogger Bank Zone.

4 Identification of Project Boundaries

4.1 Overview

4.1 Using the project capacities, project area and Zone capacity outlined in Sections 3.3 to 3.5 Forewind undertook a series of modelling exercises to identify the project boundaries. The aim of these modelling exercises was to identify the optimal project boundaries for the Dogger Bank Zone taking into account engineering, commercial, health and safety and environmental considerations. The modelling exercises were undertaking in the FCAT tool described previously in Section 3.1.

4.2 The modelling process undertaken was iterative, with results from earlier layouts used to inform the later modelling results. Forewind modelled Zone layouts with different combinations of project boundaries within them. Over 100 potential Zone layouts have been modelled in FCAT to date. It should be noted that a number of these modelled layouts were used in the assessment of the project capacities, project area and Zone capacity discussed previously. Figure 20 shows an example of a modelled Zone layout.

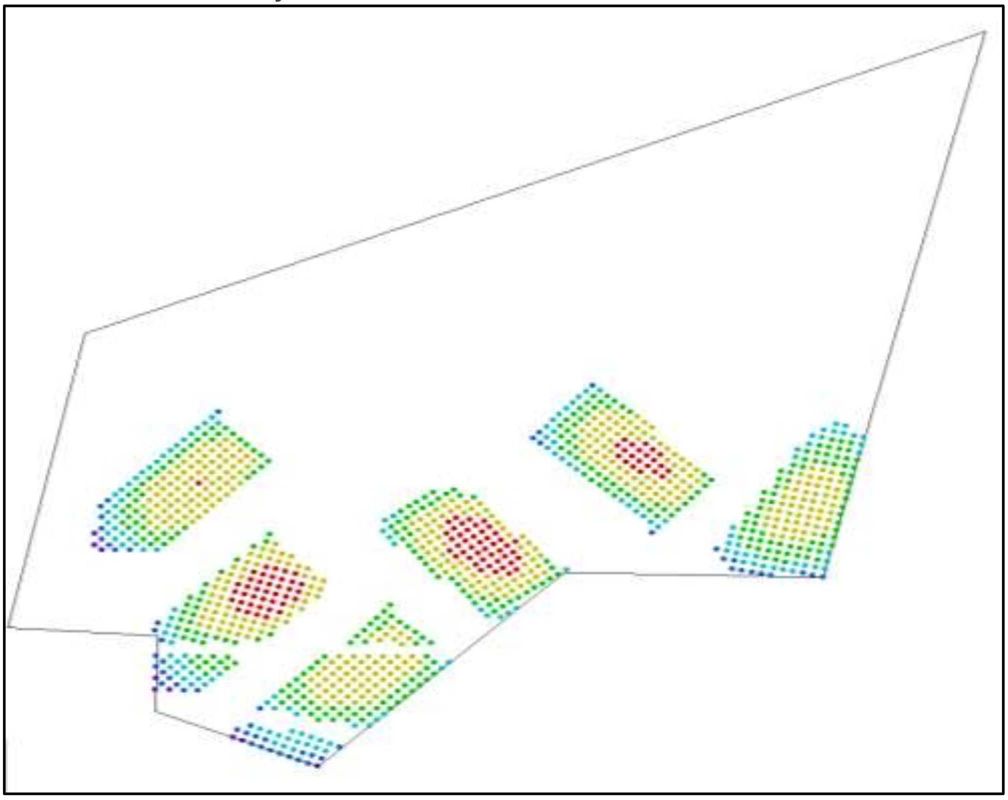

Figure 20 Example of modelled Zone layout – please note this is not the proposed solution but indicates the differences in output for a particular scenario

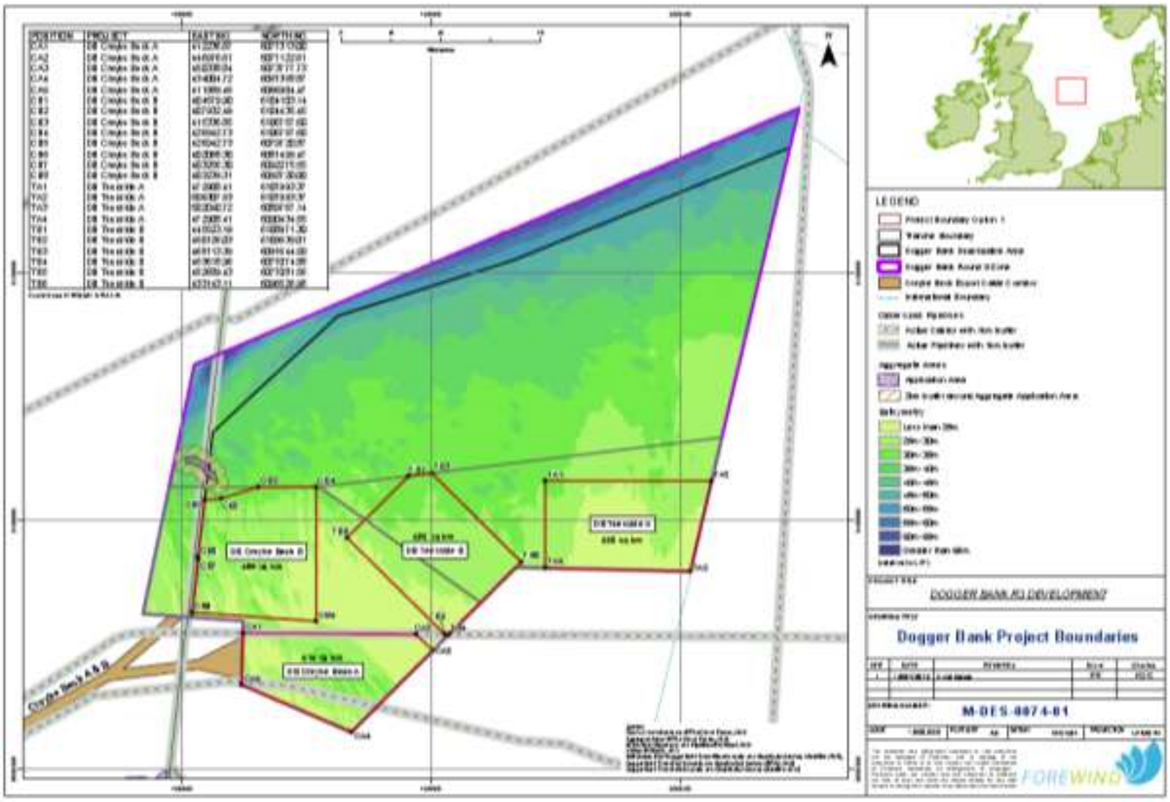

Figure 21 Project Boundaries

4.3 The modelling activities focused on producing optimised project boundaries for Dogger Bank Creyke Beck A & B and Dogger Bank Teesside A & B as they would be the first projects to enter the consent application process. Shown in Figure 21 are the project boundaries for Dogger Bank Creyke Beck A & B and Dogger Bank Teesside A & B which will be used further in the EIA process. It should be noted that the remaining 2GW connections to Teesside and further 2 GW connections yet to be determined will need to be located in the developable area to the north of Tranche A and B and will be subject to further Zone appraisal in the future.

4.4 These project boundaries and their corresponding areas are described in more detail in the following sections.

4.2 Dogger Bank Creyke Beck A

4.5 Dogger Bank Creyke Beck A is located within the southern portion of the Dogger Bank Zone in Tranche A. The key characteristics are listed in **Error! Reference ource not found.**.

Parameter	Value
Project size	515km^2 / 199 sq. miles
Project Capacity	Up to 1200MW
Grid Connection Point	Creyke Beck
Distance from shore (closest point)	131km
Predominant water depth range	20 to 35m below LAT

Table 5 Dogger Bank Creyke Beck A key project characteristics

4.6 The area for Dogger Bank Creyke Beck A is 515km^2, which is less than the baseline area identified previously in Section 3.4.3. The reduction in area is primarily due the presence the TATA North Europe telecommunications cable. To enlarge the Dogger Bank Creyke Beck A area beyond 515km^2 a number of cable crossings would be required over the telecommunication cable. These would incur additional costs to the project and pose greater engineering and consenting challenges. The smaller project area of Dogger Bank Creyke Beck A would normally impose a financial penalty due to wake effects of turbines reducing energy capture. However, this is counterbalanced by the good wind resource that is present in this region of the Dogger Bank Zone and the shallow water depths.

	Easting	Northing	Latitude	Longitude
1	412236.67	6077313.00	54° 44.501' N	1° 37.973' E
2	446976.61	6077122.61	54° 50.114' N	1° 38.014' E
3	450338.84	6073777.73	54° 50.305' N	2° 10.464' E
4	434004.72	6057358.87	54° 48.522' N	2° 13.640' E
5	411989.45	6066904.47	54° 39.557' N	1° 58.617' E

Table 6 Dogger Bank Creyke Beck A boundary coordinates

4.7 It should be noted that there is a degree of uncertainly of development activities within the newly licenced oil and gas blocks south of the Dogger Bank Zone. This may require additional area to be added to the project at a later date.The relative coordinates of the Dogger Bank Creyke Beck A are shown in Table 6

4.3 Dogger Bank Creyke Beck B

Parameter	Value
Project size	599km^2 / 231 sq. miles
Project Capacity	Up to 1200MW
Grid Connection Point	Dogger Bank Creyke Beck
Distance from shore (closest point)	131km
Predominant water depth range	20 to 35m below LAT

Table 7 Dogger Bank Creyke Beck B key project characteristics

4.8 Dogger Bank Creyke Beck B is located within the western portion of the developable area in Tranche A. The key characteristics are listed in Table 7.

Parameter	Value
Project size	599km^2 / 231 sq. miles
Project Capacity	Up to 1200MW
Grid Connection Point	Dogger Bank Creyke Beck
Distance from shore (closest point)	131km
Predominant water depth range	20 to 35m below LAT

Table 8 Dogger Bank Creyke Beck B key project characteristics

4.9 The area for Dogger Bank Creyke Beck B is 599km^2 which is greater than the baseline area identified previously in Section 3.4.3. The additional area is to provide the project with greater flexibility for environmental and engineering issues. The project economics of Dogger Bank Creyke Beck B are improved by locating it in as westerly position as possible. However, due to the presence of birds, marine aggregates and fishing activities, discussed previously in Section 2.3, on the western most margin of the Dogger Bank Zone there are a number of possible consenting issues. Appropriate positioning of turbines and other offshore assets may help to mitigate these issues. In addition, this area of Dogger Bank has been identified as being more geotechnically complex, which will have an impact on turbine positioning.

4.10 Additional project area will give flexibility to reposition turbines and other offshore assets.

	Easting	Northing	Latitude	Longitude
1	404579.90	6104103.14	55° 4.471' N	1° 30.330' E
2	407932.49	6104435.45	55° 4.688' N	1° 33.473' E
3	415336.85	6106757.60	55° 6.018' N	1° 40.388' E
4	426942.73	6106757.60	55° 6.129' N	1° 51.299' E
5	426942.73	6079720.87	54° 51.554' N	1° 51.712' E
6	402068.30	6081499.47	54° 52.258' N	1° 28.434' E
7	403256.30	6092275.55	54° 58.080' N	1° 29.327' E
8	403239.31	6092720.00	54° 58.319' N	1° 29.302' E

Table 9 Dogger Bank Creyke Beck B boundary coordinates

4.11 The relative coordinates of the Dogger Bank Creyke Beck B are shown in Table 9.

4.4 Dogger Bank Teesside A

Parameter	Value
Project size	560km^2 / 216sq. miles
Project Capacity	Up to 1200MW
Grid Connection Point	Lackenby
Distance from shore (closest point)	196km
Predominant water depth range	22 to 32m below LAT

Table 10 Dogger Bank Teesside A key project characteristics

4.12 Dogger Bank Teesside A is located within the eastern portion of the developable area in Tranche B. The key characteristics are listed in Table 10.

4.13 The area for Dogger Bank Teesside A is 560km^2 which is slightly greater than the baseline area identified previously in Section 3.4.3. It is envisaged that this area will be sufficient for Dogger Bank Teesside A. However, it should be noted that there is a degree of uncertainty of development activities within the newly licenced oil and gas blocks south of the Dogger Bank Zone. This may require additional area to be added to the project at a later date.

	Easting	Northing	Latitude	Longitude
1	472908.41	6107993.37	55° 7.074' N	2° 34.514' E
2	506307.53	6107993.37	55° 7.116' N	3° 5.934' E
3	506002.84	6106691.82	55° 6.414' N	3° 5.645' E
4	505580.86	6104889.29	55° 5.443' N	3° 5.246' E
5	505158.89	6103086.77	55° 4.471' N	3° 4.848' E
6	504736.91	6101284.24	55° 3.499' N	3° 4.449' E
7	504314.93	6099481.72	55° 2.528' N	3° 4.051' E
8	503892.96	6097679.19	55° 1.556' N	3° 3.654' E
9	503470.98	6095876.67	55° 0.584' N	3° 3.256' E
10	503083.60	6094221.93	54° 59.692' N	3° 2.892' E
11	502644.70	6092347.11	54° 58.682' N	3° 2.479' E
12	502627.03	6092271.62	54° 58.641' N	3° 2.463' E
13	502205.05	6090469.09	54° 57.669' N	3° 2.066' E
14	502040.72	6089767.14	54° 57.291' N	3° 1.912' E
15	500892.28	6089795.09	54° 57.306' N	3° 0.836' E
16	498624.07	6089846.94	54° 57.334' N	2° 58.711' E
17	498367.08	6089852.81	54° 57.337' N	2° 58.470' E
18	472908.41	6090434.55	54° 57.607' N	2° 34.614' E

Table 11 Dogger Bank Teesside A boundary coordinates

4.14 The relative coordinates of the Dogger Bank Teesside A are shown in Table 11.

4.5 Dogger Bank Teesside B

Parameter	Value
Project size	593km^2 / 229sq. miles
Project Capacity	Up to 1200MW
Grid Connection Point	Lackenby
Distance from shore (closest point)	165km
Predominant water depth range	23 to 35m below LAT

Table 12 Dogger Bank Teesside B key project characteristics

4.15 Dogger Bank Teesside B crosses the border between Tranche A and Tranche B, with the majority of the project located in Tranche B. The key characteristics are listed in Table 12.

	Easting	Northing	Latitude	Longitude
1	445523.19	6108971.30	55° 7.466' N	2° 8.743' E
2	450126.03	6109539.01	55° 7.801' N	2° 13.068' E
3	468113.39	6091644.50	54° 58.242' N	2° 30.113' E
4	467043.01	6090568.58	54° 57.658' N	2° 29.117' E
5	453618.96	6077074.88	54° 50.319' N	2° 16.670' E
6	452689.43	6077081.56	54° 50.317' N	2° 15.801' E
7	433143.11	6096526.98	55° 0.666' N	1° 57.272' E

Table 13 Dogger Bank Teesside B boundary coordinates

4.16 The area for Dogger Bank Teesside B is 593km^2 which is greater than the baseline area identified previously in Section 3.4.3. The additional area is due to the potential for the export cable from Dogger Bank Teesside A to be located along the south-eastern margin of the Dogger Bank Zone. This would require Dogger Bank Teesside A to be located further from the Dogger Bank Zone edge to provide adequate space for the export cable. However, this would otherwise reduce the project energy capture. By consenting a larger area allows a greater level of project flexibility dependent on the cable route. The relative coordinates of the Dogger Bank Teesside B are shown in Table 13.

5 Conclusion

5.1 The project boundary selection process has utilised both desk-based and site specific survey data gathered both for environmental and engineering purposes. The environmental data have had the biggest effect on defining the overall developable area across the Dogger Bank Zone. The engineering and economic criteria have had a greater influence in defining the project boundaries within the identified developable area.

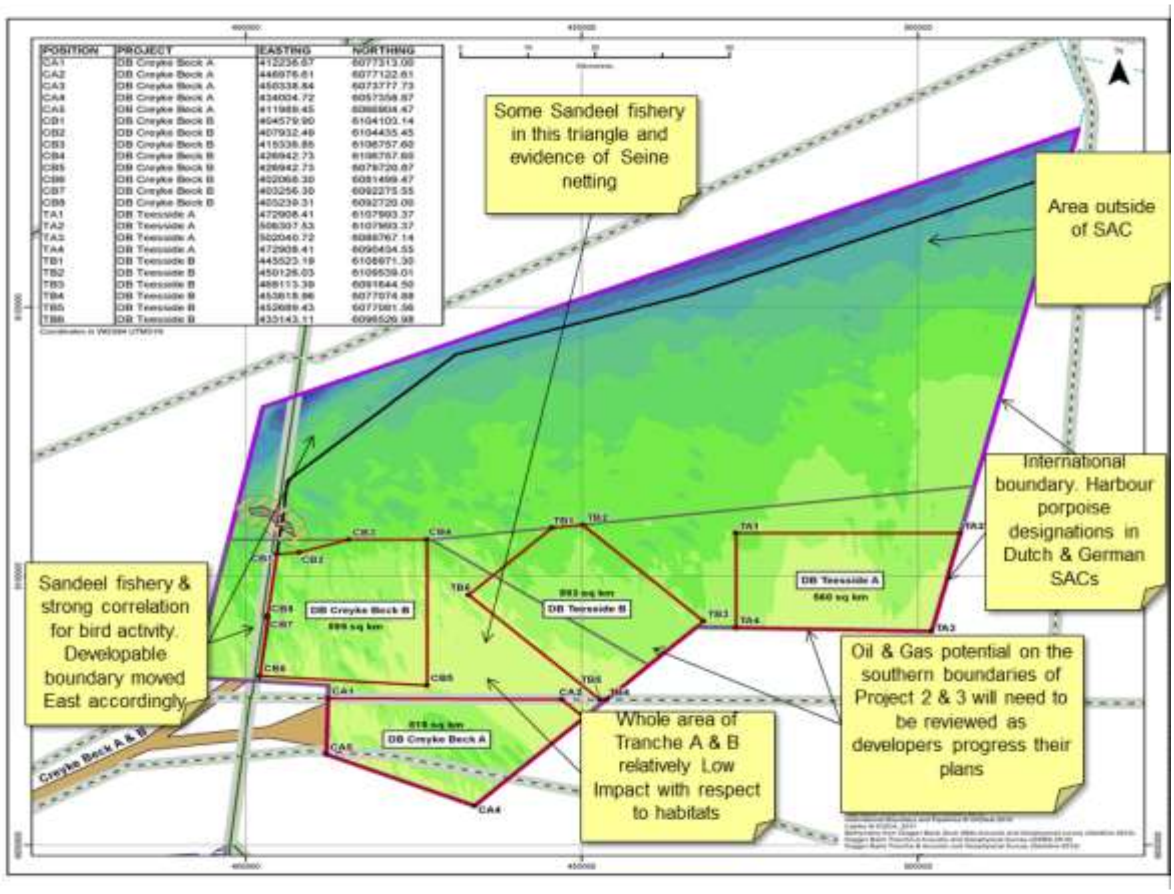

Figure 22 Summary of key consenting issues associated with Project Boundary selection

5.2 The removal of the western edge of the Zone whilst yielding potentially ideal wind farm area from an economic perspective, takes account of a key sandeel area that is used by the fishing industry as well as being a feeding ground for key bird species on the Zone.

5.3 It is considered that the project areas are broad enough to locate the offshore components required by each project and allow a degree of flexibility in the final project design. It is considered that the space between the projects is sufficient enough to reduce cumulative wake effects and allow wind recovery.

5.4 In summary over the course of the last three years Forewind has defined two Tranches, A and B. Forewind has re-evaluated the developable area on the basis of information gathered and has modified the developable area of the Zone. Further detailed work presented within this report has led to the selection of four project boundaries, for the first Dogger Bank projects. These project boundaries will now be used within the Environmental Impact Assessments (EIAs) whereupon further site specific data will be used to optimise turbine and project asset layouts and minimise environmental impacts wherever possible. It should be noted that full consultation and dialogue will continue for these EIAs as they progress. Further work will also continue to evaluate the optimum boundaries for the remaining projects 5, 6, 7 and 8 to the north of Tranches A and B.

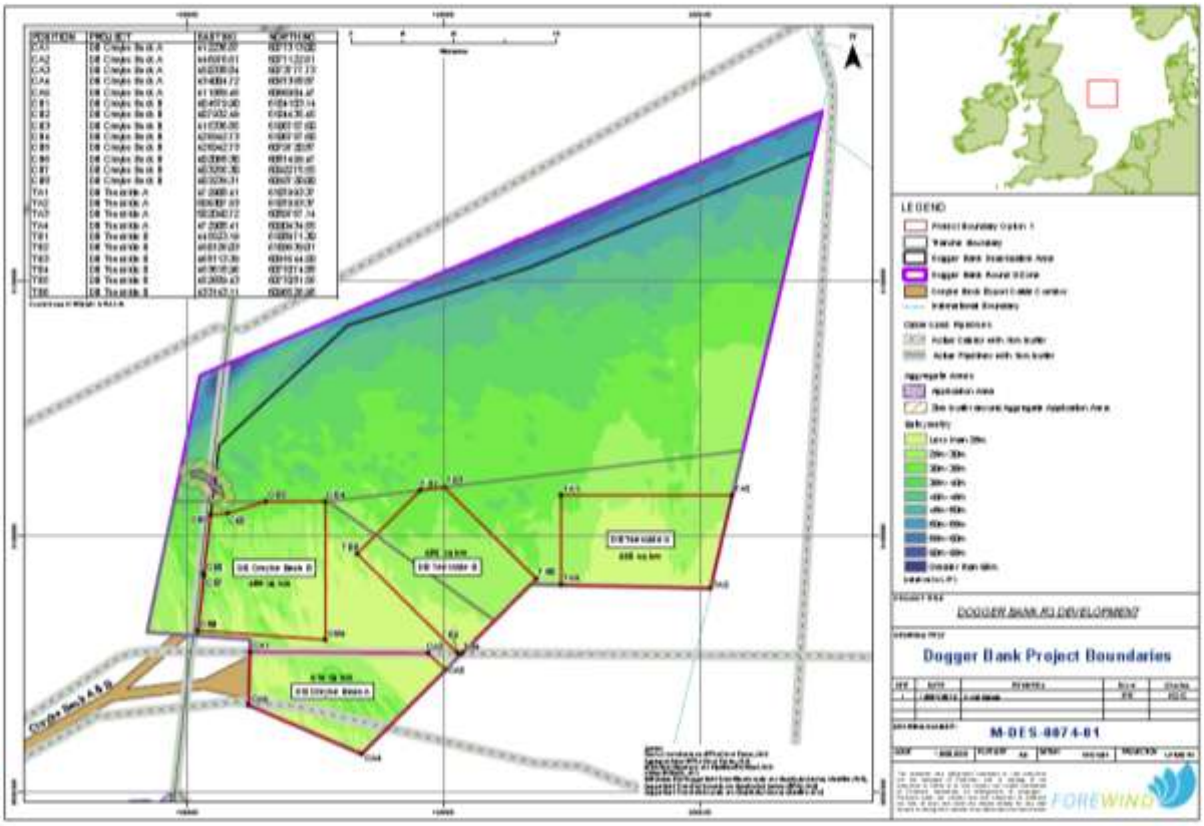

Figure 23 Project Boundaries taken forward to EIA

For more information

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